European Commission DG TREN

Preparatory Studies for Eco-design Requirements of EuPs

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Lot 12

Commercial refrigerators and freezers

Final Report

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Bio Intelligence Service - Scaling sustainable development
Industrial ecology - Nutritional health

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Content

PREFACE

Commercial refrigerators and freezers cover a large variety of products and they are used in diverse environments such as supermarkets, grocery stores, service stations, restaurants, hotels, pubs, and cafés. These products, often complex in nature, are estimated to consume an important portion of electricity consumption in the EU. Moreover, they have other negative environmental impacts during their life-cycle due to their material content such as the refrigerant and the insulating agents.

These products have been studied in the past with a special emphasis on the energy efficiency aspects. However, not much attention has been paid to the overall environmental impacts during their life cycle.

Different stakeholders have different approaches concerning the design, manufacturing, use, and end-of-life treatment of these products.

The manufacturers tend to focus their design on the energy requirement for the main application and on the choice of the refrigerating agent in order to reduce the impacts related to climate change and global warming (e.g. HFC replaced by natural agents). Many such actions may derive from national and international regulations, financial incentives (e.g. market transformation), and their personal commitment towards environmental issues.

On the other hand, the end-user (distributor and/or retailer) is conscious of the energy performance of these products (because they affect directly his electricity bills) but rarely of the environmental impacts. The key issues influencing the choice of a retailer are price, aesthetics, visible area of foodstuffs, and energy consumption.

In this context, a preparatory study was conceived for eco-design requirement for commercial refrigerators and freezers[1] in the framework of the EuP Directive. This study attempts to analyse the products falling in this category and to propose the approaches and means to improve their environmental and energy performance.

[1] Sometimes commercial refrigerators or freezers are used in a domestic environment but the focus of the present study is the products “designed” for commercial use.

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1. TASK 1: DEFINITION

Commercial refrigerators and freezers cover a large variety of products and they are used in diverse environments such as supermarkets, grocery stores, service stations, restaurants, hotels, pubs, and cafés. These products, often complex in nature, are estimated to consume an important portion of electricity consumption in the EU. Moreover, they have other negative environmental impacts during their life-cycle due to their material content such as the refrigerant and the insulating agents.

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The objective of this document on task 1 is to present and discuss definition and scope issues (Task 1.1) within the EuP preparatory study for the lot 12. It consists of:

- Categorisation of products,
- Description of product definitions - all the definitions being based on the main design criteria that characterize the products also named “cabinets”,
- Scope definition,

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- Identification of functional and technical parameters to be used for the selection of relevant products for detailed analysis and assessment during the next steps of the study.

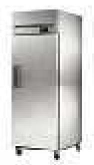
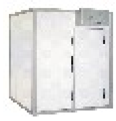
It also presents the available test standards and legislations relevant to these products.

1.1. PRODUCT DEFINITIONS

1.1.1 INTRODUCTION

There is a wide spectrum of products that could qualify for the product group “Commercial refrigerators and freezers” such as presented in Table 1-1.

Table 1-1: Products belonging to the group “commercial refrigerators and freezers”

1. Refrigerated display cabinets	
2. Refrigerated service cabinets	
3. Vending machines	
4. Wine cellars	
5. Ice cream freezers	
6. Walk-in cool rooms	

7. Chillers	
8. Ice makers	
9. Ice cream and milk-shake machines	
10. Minibars	

Starting with a general definition, different classifications of products are described in order to better identify the types of products. To clarify the product category dealt with in lot 12 study, some important restrictions to the scope of this study were made, which are explained below.

1.1.2 GENERAL DEFINITION

A **refrigerator** is a mechanical appliance for the storage and preservation of perishable food, where **food** is defined as "*any substance, whether processed, semi-processed or raw, which is intended for human consumption, and includes drink, chewing gum and any substance which has been used in the manufacture, preparation or treatment of food but does not include cosmetics or tobacco or substances used only as drugs*"[2].

According to the inside temperature, the refrigerated equipment can be classified into a **refrigerator** (temperature >0℃) or a **freezer** (temperature <0℃).

The United States Department of Energy (Office of Energy Efficiency and Renewable Energy) describes commercial refrigeration equipment as following:

The term commercial refrigerator, freezer and refrigerator-freezer mean refrigeration equipment that:

1. *is not a consumer product,*
2. *is not designed and marketed exclusively for medical, scientific, or research purposes,*

[2] Source of the food definition: The Codex Alimentarius Commission.

3. *operates at a chilled, frozen, combination chilled and frozen, or variable temperature,*
4. *displays or stores merchandise and other perishable materials horizontally, semi-vertically, or vertically,*
5. *has transparent or solid doors, sliding or hinged doors, a combination of hinged, sliding, transparent, or solid doors, or no doors,*
6. *is designed for pull-down temperature applications or holding temperature applications,*
7. *is connected to a self-contained condensing unit or to a remote condensing unit.*

The state of Washington provides the following definition for commercial refrigerators and freezers[3]:

(5)(a) "Commercial refrigerators and freezers" means refrigerators, freezers, or refrigerator-freezers designed for use by commercial or institutional facilities for the purpose of storing or merchandising food products, beverages, or ice at specified temperatures that: (i) Incorporate most components involved in the vapor-compression cycle and the refrigerated compartment in a single cabinet; and (ii) may be configured with either solid or transparent doors as a reach-in cabinet[4], pass-through cabinet[5], roll-in cabinet[6], or roll-through cabinet.

(b) "Commercial refrigerators and freezers" does not include: (i) Products with 85 cubic feet or more of internal volume; (ii) walk-in refrigerators or freezers; (iii) consumer products that are federally regulated pursuant to 42 U.S.C. Sec. 6291 et seq.; (iv) products without doors; or (v) freezers specifically designed for ice cream.

1.1.3 PRODUCT CLASSIFICATIONS

In order to better identify the types of equipments that can be considered as "commercial refrigerators and freezers", some existing product classifications were identified such as PRODCOM and CUSTOMS.

1.1.3.1 THE PRODCOM CLASSIFICATION

The PRODCOM[7] classifies commercial refrigerators and freezers in the category NACE 29.23 – "Manufacture of non-domestic cooling and

[3] Revised Code of Washington, chapter 19, section 260.010 (January 2007)

[4] The regulation also provides a definition for a reach in cabinet: *(13) "Reach-in cabinet" means a commercial refrigerator or freezer with hinged or sliding doors or lids, but does not include roll-in or roll-through cabinets or pass-through cabinets.*

[5] The regulation also provides a definition for a pass through cabinet: *"Pass-through cabinet" means a commercial refrigerator or freezer with hinged or sliding doors on both the front and rear of the unit.*

[6] The regulation also provides a definition for these cabinets: *(14)(a) "Roll-in cabinet" means a commercial refrigerator or freezer with hinged or sliding doors that allow wheeled racks of product to be rolled into the unit.*
(b) "Roll-through cabinet" means a commercial refrigerator or freezer with hinged or sliding doors on two sides of the cabinet that allow wheeled racks of product to be rolled through the unit.

[7] PRODCOM Classification: List of PRODucts of the European COMmunity.

ventilation equipment". In the subcategories different types of refrigerating furniture can be found:

29.23.13	Refrigerating and freezing equipment and heat pumps, except household type equipment
29.23.13.33	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage
29.23.13.35	Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator (except for frozen food storage)
29.23.13.40	Deep-freezing refrigerating furniture (except for chest freezers of a capacity <= 800 litres, upright freezers of a capacity <= 900 litres)
29.23.13.50	Refrigerating furniture (except for deep-freezing, show-cases and counters incorporating a refrigerating unit or evaporator)

It can be observed that commercial refrigerators and freezers explicitly appear in this classification. But, except the capacity and the temperature, few criteria are used to identify the different types of products.

1.1.3.2 The European CUSTOMS classification

The European customs classification[8] ranks the refrigerating equipments in the section XVI, Chapter 84, subchapter 8418:

Section XVI:	Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.
Chapter 84:	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof
8418	**Refrigerators, freezers** and **other refrigerating or freezing equipment**, electric or other; heat pumps other than air-conditioning machines of heading (8415)

For the details, please see the Annex 1- 1.

As for the previous one, this classification does not help to distinguish the different types of equipments.

1.1.3.3 Classification according to design criteria

Both previous classifications (PRODCOM and Customs) take into account some of those criteria such as:

[8] CUSTOMS Classification: The category defining the tariff to be applied to an imported good.

- The capacity of the equipment (volume)
- The level of temperature:
  - Refrigerator for temperature >0℃ (chilled)
  - Freezer for temperature <0℃ (frozen)
  - Refrigerator-freezer for a combined equipment with different compartments where the temperature is positive or negative,
- The orientation: vertical (upright), horizontal (chest) or combined
- The location of compressor/condensing unit: plug in or remote
- The presence and type of doors: with or without doors, in case with doors, transparent or solid and hinged or sliding

For the purpose of this study, the key design criteria used for distinguishing the products are following:

1. **Remote versus plug in product**
2. **Chilled versus frozen product**
3. **Vertical, horizontal or combined product**
4. **Without doors versus with doors product**
   Sub criterion: glass doors (transparent) versus solid doors

Other important design parameters could be "lit or unlit shelves", "the number of shelves", "multi-deck or not", etc. but they of secondary importance.

These definitions are based on recognised definitions found in the documents and reports from different sources viz. EUROVENT-Cecomaf[9], British Market Transformation Program, Energy Star Program requirements, US Department of Energy, and California Code of Regulations.

Criterion 1: Remote versus plug in equipment

Equipment with the remote condensing unit

According to the British Market Transformation Program[10], a product with a remote condensing unit means:

- A remote condensing system for direct expansion refrigeration, or
- A close coupled condensing system for direct expansion refrigeration, or
- A remote refrigerating system for secondary refrigerant circulation

It also means a factory-made assembly of refrigerating components designed to compress and liquefy a specific refrigerant that is remotely located from the refrigerated equipment and consists of one or more refrigerant compressors, refrigerant condensers, condenser fans and motors, and factory supplied accessories.

Another complementary aspect could be an appliance that:

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[9] EUROVENT-Cecomaf: the European Committee of Air Handling and Refrigeration Equipment Manufacturers

[10] Note BNCR08: "Energy Efficiency test specification for refrigerated display cabinets"

- receives refrigerant fluid from a condensing unit located externally to its equipment assembly;and
- is capable of being purchased and installed with different types of compressor or condenser, so that its efficiency depends on the type of compressor or condenser applied by the purchaser, installer, or user.

This type of equipment is typically designed for a specific end-user.

In the Intergovernmental Panel on Climate Change "Special Report on Safeguarding the Ozone Layer and the Global Climate System" published in April 2005[11], the commercial refrigeration systems using remote condensing units sector is divided in 4 categories:

- Small condensing units, used in small commercial equipment. They comprise one or two compressor and a condenser which are usually located outside the sales area. The cooling equipment includes one or two display cabinets. This type of system is often installed in specialized shops (e.g. bakeries, butchers, convenience stores).
- Centralized direct systems (direct expansion), used in supermarkets. They consist of one central plant in the form of a series of compressors and condensers located in a machinery room or an outside location. The refrigerant is piped directly into each display cabinet where it is expanded and evaporated to produce cooling. The resulting refrigerant vapour is pumped back to the central plant.
- Centralized indirect systems (secondary loop), their description is the same as above except that they use an indirect expansion system. The refrigeration of the display cabinets is provided by a secondary fluid which is pumped between the central plant and the refrigerated display cases.
- Distributed systems, used in supermarkets. They consist of smaller condensers and compressors close to the display cabinets so that many sets of compressor/condensers units are distributed around the store (up to 50 units in a large supermarket). This category includes the close coupled systems.

Equipment with the plug in condensing unit

Other ways to describe the same parameter: self-contained or integral.

[11] http://arch.rivm.nl/env/int/ipcc/pages_media/SROC-final/SpecialReportSROC.html

According to the British Market Transformation Program, a product with a plug in or self-contained condensing unit means "a refrigerated product designed to be supplied with an incorporated condensing unit which has internal condensate disposal and is connected to a single phase electrical supply."

This type of equipment is typically mass produced rather than designed for a specific end-user. It could be considered as standard equipment.

Criterion 2: Chilled versus frozen equipment

Chilled equipment

It means that the inside temperature is positive, above 0℃. The product is then named a refrigerator and defined in that way by the California Code of Regulations[12]: "a product that is designed for the refrigerated storage of food, including but not limited to solid food and wine, beer, and other beverages, at temperatures above 32℉ (0℃), and th at has a source of refrigeration requiring an energy input."

The temperature levels depend on the type of stored food: meats (+2℃), dairy products (+5℃), fresh vegetables (+7℃) [13].

Note: At the moment there is no real consensus on the maximum inside temperature. The Energy Star Program Requirements for Commercial Solid Door Refrigerators and Freezers (version 1.0, applicable from 01/09/2001), for example, requests a temperature below 40℉ (4.4 4℃) for commercial refrigerators.

Frozen equipment

It means that the inside temperature is negative, below 0℃. The equipment is then named a freezer and defined in that way by the California Code of Regulations: a freezer means a equipment that is designed as a unit for the freezing and storage of food, beverages, or ice at temperatures of 0℉ (-18℃) or below and that has a source of refrigerati on requiring an energy input.

Criterion 3: Vertical versus horizontal equipment

Vertical equipment

Another way to describe the same shape is "upright". According to the California Code of Regulations, an upright equipment (refrigerator or freezer) means a equipment to which access can be gained through a side-opening door (in case of existing doors).

Horizontal equipment

Another way to describe the same shape is "chest". According to the California Code of Regulations, a chest equipment (refrigerator or freezer)

[12] California Code of Regulations: These Appliance Efficiency Regulations, (California Code of Regulations, Title 20, Sections 1601 through 1608) dated January 2006, were adopted by the California Energy Commission on October 19, 2005, and approved by the California Office of Administrative Law on December 30, 2005.

[13] Data coming from UNICLIMA.

means a equipment to which access can be gained through a top-opening door (in case of existing doors). One can sometimes talk about "serve counter product" for certain configurations.

Criterion 4: Without doors versus with doors

Equipment without doors (open equipment)

It means that the product is completely open and that displayed food is easily accessible.

Equipment with doors (closed equipment)

It means that the product is closed by doors and that food is accessible after the opening of the doors which can be:

- sliding doors: Doors of furniture sliding parallel to their own level on a rail or in a groove made in the framework.
  or
- hinged doors: Doors with hinges for the articulation permitting the rotation of the doors around their axis.

Sub criterion: glass doors versus solid doors

Glass doors

It means that the product is equipped with side-opening and glass or transparent doors. Foodstuffs contained can be visible from outside.

Solid doors

It means that the product is equipped with side-opening and opaque doors. Foodstuffs contained cannot be visible from outside.

In the Annex 1- 2, the different configurations according to these four criteria are presented.

For each of them with their design characteristics, one can find the name of each type of product in order to classify such products and some indication concerning the locations where these products can be mostly found as well.

The following products can be found in the classification:

- Refrigerated display cabinets,
- Refrigerated service cabinets,
- Vending machines,
- Wine cellars,
- Ice cream freezers,
- Walk-in cool rooms,
- Minibars

But chillers, ice markers and ice cream and milk-shake machines are out of this classification. The next section will explain this exclusion from the classification.

1.2. SCOPE OF THE STUDY

As discussed in the previous sections a variety of products could fall under the scope of this study. For example, PRODCOM groups "refrigerating and freezing equipment and heat pumps (except household type equipment)" without taking account of the location of the condensing unit or of the temperature range (chilled or frozen).

Given the limited time available for this study, and in order to perform a through and detailed evaluation of the products, it is necessary to determine the precise scope of the study by of products to be analysed and therefore identify the products to be excluded and included.

1.2.1 CRITERIA FOR DEFINING THE SCOPE

According to the general definition and the classifications, three key aspects have been considered to define the scope of the study:

- Functionality,
- End-use (commercial/industrial),
- Availability of test standards

1.2.1.1 FUNCTIONALITY

For a coherent analysis and facilitate the comparison it is suggested to analyse the products having similar functionality.

The functionality of a refrigerator or a freezer being "**to cool or freeze food and store it at the proper temperatures**", some other products, which could have been considered as well, can be excluded because of a different functionality such as to "produce chilled water (chillers), to freeze water into ice (ice makers) or to make ice cream (ice cream and milk-shake machines).

It had been previously noticed that these products were also out of the classification based on design criteria.

1.2.1.2 END-USE

This study focuses on the products designed for commercial use and the products designed for industrial and/or domestic use shall be excluded, for example cold rooms.

1.2.1.3 AVAILABILITY OF TEST STANDARDS

The products normally tested with standards for commercial cabinets only could be considered and this leads to the exclusion of products tested with standards for household/industrial appliances such as wine cellars.

1.2.2 PRODUCTS EXCLUDED FROM THE SCOPE OF LOT 12

It is proposed to exclude following products from the scope of the present study.

1.2.2.1 On the basis of functionality

- Chillers

  According to the US Department of Energy, chiller is a type of cooling equipment that "**produces chilled water to cool air"**. The chilled water is distributed throughout the building by pipes.

  The two major categories of chillers are water-cooled and air-cooled:

  - **The water-cooled chillers** use water to transport away the heat rejected in their condensers. The water, called condenser water, is cooled in a cooling tower.

  - **The air-cooled chillers** have condensers that are cooled with ambient air.

- Ice maker

  An ice marker is a machine that "**freezes water into ice cubes"**. It is also called ice machine.

- Ice cream and milk-shake machine

  An **ice cream maker** is a machine used to "**make homemade ice cream"**. There are both manual and electric types of machine.

  An ice cream maker has to do two things; the mixture has to be cooled, and during this cooling process, the mixture has to be constantly churned to break up ice crystals that form and introduce some air to the mixture so that the resultant ice cream will have a smooth, creamy texture.

1.2.2.2 ON THE BASIS OF END-USE

- Walk-in cool room

  It can be considered more as an industrial product than a commercial one because it can be also found in cold stores, industries.

  Moreover the cool room is concerned by the "Building Directive[14]" (2002/91/EC), not by the "Machinery Directive[15]" (89/392/EEC) such as for the other refrigerated products.

  Finally, the cool room is not a standard product. It is tailor-made with several kinds of components, parameters meeting customers' requirements (different configurations of cool rooms). It would be time-consuming and not efficient to propose improvement measures by studying a chosen base case which does not reflect the real market.

1.2.2.3 ON THE BASIS OF TEST STANDARDS

- Refrigerated service cabinet (as catering equipment)
- Wine cellar
- Minibar

  It seems that the energy efficiency of these types of cabinets are rather tested with the standard EN 153 (1996)[16] for household refrigerators than with the standard EN 441 for refrigerated display cabinets.

  Moreover the wine cellars can rather be considered as domestic appliances (the market ratio for domestic use is probably more important than for the commercial use).

  Finally these types of cabinets represent a less important market share compared to the refrigerated display cabinets.

1.2.3 PRODUCTS TO BE CONSIDERED IN THE SCOPE

The following products can be included in the scope for further steps:

- Refrigerated display cabinet (remote and plug in)
- Vending machines

Each of these product categories contains a wide variety of products and configurations. For the purpose of choosing 1-2 base cases in the task 5, different scenarios are possible such as:

1. **Plug in display cabinet** (including the ice cream freezers) and **remote display cabinet without the refrigeration system**

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[14] Building Directive 2002/91/EC: The Directive applies to almost all buildings, residential and non-residential, both new and existing. Member States are allowed to exempt certain categories of buildings, such as buildings of historical or architectural importance, religious buildings and buildings of low occupancy or size.

[15] Machinery Directive 89/392/EEC: the term "machinery" covers any equipment, whether for domestic, commercial or industrial applications, that has parts actuated by a power source other than manual effort.

[16] Standard EN 153 (1996) : Methods of measuring the energy consumption of electric mains operated household refrigerators, frozen food storage cabinets, food freezers and their combinations, together with associated characteristics

This choice to only measure the cabinet is based on the fact that one cabinet may be connected to wholly different condensing units or compressor racks. The compressor energy consumption will then depend on the compressor choice and a wide variety of configurations exist for the refrigeration system whereas display cabinets are more standardised products, It can be useful to address the efficiency of display cabinets as a first step and studying the system with an assumed average refrigeration system.

2. **Complete remote system** (display cabinet + condensing unit + refrigerant circuit).

3. **Plug in display cabinet** and **vending machine**

According to the experts points of view and data found in some publications, the following arguments can be provided to support the inclusion/exclusion of some products:

- They represent the major market share,
- They are important from the environmental impact and energy consumption point of view,
- Levers of environmental improvement can be found (around 45% for the remote refrigerated display cabinets, for example), in terms of energy efficiency but also environmental impacts,
- Their manufacturers are willing to collaborate for the study

Based on the subsequent tasks, especially Task 2 (market analysis), a final choice will be made for base cases in consultation with the European Commission. Further, the products excluded from the present study will be mentioned with arguments for their exclusion and suggestion for their analysis later in separate studies.

1.3. TEST STANDARDS AND PRODUCT TESTING PROCEDURES

A “test standard” is a standard that sets out a test method, but that does not indicate what result is required when performing that test. Therefore, strictly speaking, a test standard is different from a “technical standard”. Namely, in technical use, a standard is a concrete example of an item or a specification against which all others may be measured or tested. Often it indicates the required performance.

However, “test standards” are also (but not exclusively) defined in the “technical standard” itself. For example, an ISO standard for a certain product or process gives the detailed technical specifications, which are required in order to conform to this standard. It also defines test standards (or rather methods) to be followed for validating any such conformity. A standard can be either product or sector specific, and it can concern different stages of a product’s life cycle. Thus, for each standard presented below, the scope (product and/or sector specific) and the life cycle stages which the standard deals with (manufacturing/distribution/use/end of life) are given.

EN/CENELEC internal regulations define a standard as a document, established by consensus and approved by a recognized body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context. Standards should be based on consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits. The European EN standards are documents that have been ratified by one of the three European standards organizations, CEN15, CENELEC16 or ETSI17.

1.3.1 EUROPEAN EN TEST STANDARDS

The "New Approach", defined in the European Council (EC) Resolution of May 1985, introduced, among other things, a clear separation of responsibilities between the EC legislator and the European standards bodies (CEN, CENELEC, ETS) in the legal framework allowing for the free movement of goods[17]:

- EC directives define the "essential requirements", e.g., protection of health and safety, which goods must meet when they are placed on the market.
- The European standards bodies have the task of drawing up the corresponding technical specifications meeting the essential requirements of the directives; compliance with the standard will provide a presumption of conformity with requirements of the directive. Such specifications are referred to as "harmonised standards".

European Standard adopted by CEN, CENELEC or ETSI, implies an obligation of implementation as an identical national standard and withdrawal of conflicting national standards[18]. Standards discussed in the following sections are summarised in Box 1-1.

Box 1-1: List of relevant standards and product testing procedures

TYPE	STANDARD
European Standards	
Safety	EN 378(1999): refrigerating systems and heat pumps - safety and environmental requirements
International Standards	
Safety	ISO 5149:1993(2004): mechanical refrigerating systems used for cooling and heating – safety requirements
	IEC 60335(2005): household and similar electrical appliances – safety – part 2-75: particular requirements for commercial dispensing appliances and vending machines – part 2-89: particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor

[17] http://ec.europa.eu/comm/enterprise/newapproach/standardization/harmstds/index_en.html

[18] http://www.cenorm.be/cenorm/index.htm

Energy Use	ISO 23953(2005): refrigerated display cabinet – part 2: classification, requirements and test conditions
Product specific test standards in Other Countries	
Safety	**U.S.A.**
	ANSI/ASHRAE 34(2001): designation and safety classification of refrigerants
Energy Use	**Canada**
	CAN/CSA-C827-98: "Energy Performance Standard for Food Service Refrigerators and Freezers"
	CAN/C657-04: "energy performance standard for commercial refrigerated display cabinets and merchandisers".
	CAN/CSA-C804:96**:** "energy performance of vending machines".
	U.S.A.
	ANSI/ASHRAE 72(1998): method of testing open refrigerators
	ANSI/ASHRAE 117(2002): method of testing closed refrigerators
	ANSI/ASHRAE 32.1(2004): method of testing of rating vending machines for bottled, canned and other sealed beverages
	Japan
	JRA 4032 (1993): commercial refrigerators, refrigerator-freezers and freezers
	South Africa
	SANS 60335-2-89(2003): part 2-89: household and similar electrical appliances – safety – particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor

1.3.1.1 European Test Standards on Safety

Standards on safety are indirectly linked to the study as they could introduce some requirements that affect the design of the product, especially for the choice of the refrigerant fluid.

Refrigerant fluids might be toxic, inflammable or having a low potential of recycling thus refrigerating systems are the concern of many safety standards which imply material choice and construction requirements for the designer of the refrigerating system.

Only one standard is presented here, other complementary safety standards are provided in Annex 1- 3.

- **EN 378(1999)**

The EN "refrigerating systems and heat pumps – safety and environmental requirements" standard is an answer to the European Directive on pressure equipment (97/23/EC) and to the European Directive on machinery (95/16/EC modified by 2006/42/EC). This standard was prepared by European Committee for Standardization/Technical Committee CEN/TC 182 (Refrigerating systems, safety and environmental requirements).

Scope: Refrigerating systems and heat pumps.

This standard applies to any refrigerant, toxic, inflammable or not.

The life cycle phase which is the concern of the standard: Conception phase.

The standard relates to the choice of the refrigerant fluids and gives procedures for the pressure system test. The aim is to reduce the number of hazards to persons, property and the environment, caused by refrigerating systems and refrigerants.

The second part of this standard defines testing and acceptance procedures.

The third part is about installation site and personal protection, and the last one is the concern of operation, maintenance, repair and recovery.

The environmental aspect of the product that can be impacted by the standard: Material content.

This standard does not allow European industries to accede to international markets because the international standard ISO 5149 is very far from the EN 378 standard. To comply with non European markets, the ISO TC 86 SC1 working group is managing the EN 378 evolution[19].

- **Other European standards on refrigerating systems**

There are many other European test standards on safety of refrigerating systems. Details for other relevant standards are provided in Annex 1- 3.

1.3.1.2 European Test Standards on Energy Use

The former EN 441 standard for energy consumption measurement of refrigerated display cabinet is now replaced by the international standard ISO 23953 which is described in section 4.2.2.1.

In Germany, two applicable standards exist:

DIN 18872-1: "Equipment for commercial kitchens – Refrigeration technology equipment - Part 1: Refrigerators and refrigerated counters, Requirements and testing"

DIN 18872-3: "Equipment for commercial kitchens – Refrigeration technology equipment – Part 3: Refrigerated display cases for food distribution, Requirement and testing" which include a section on the energy consumption (chapter 7).

[19] http://www.uniclima.org

1.3.2 INTERNATIONAL TEST STANDARDS

An international standard is a document established by consensus, and approved by a recognized body, that provides, for common and repeated use, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context.

1.3.2.1 INTERNATIONAL TEST STANDARDS ON SAFETY

The following international test standards on safety concern refrigerating systems and refrigerant fluids.

- **ISO 5149:1993(2004) – "mechanical refrigerating systems used for cooling and heating – safety requirements"**

Scope: Appliances with a charge greater than 150 g of flammable refrigerant in each refrigerant circuit and for the installation.

It applies to all types of refrigerating systems in which the refrigerant is evaporated and condensed in a closed circuit, including heat pumps and absorption systems, except for systems using water or air as the refrigerant. It is applicable to new refrigerating systems, extensions and modifications of already existing systems, and for used systems.

The life cycle phase which is the concern of the standard: Design and use phase.

This standard specifies the requirements relating to the safety of persons and property for the design, construction, installation and operation of refrigerating systems. It gives a classification of the refrigerating systems.

The environmental aspect of the product that can be impacted by the standard: Material choice.

- **IEC 60335(2005) – "household and similar electrical appliances – safety "**

Scope: Household and similar electrical appliances, including commercial dispensing appliances and vending machines.

This standard is divided in many parts two of which are more scope specific.

Part 2-75: (Edition 2.1-2005) – "Particular requirements for commercial dispensing appliances and vending machines"

This part of the standard deals with safety and hygiene aspects.

Part 2-89: (Edition 1.1-2005) – "Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor"

Appliances with a charge of more than 150g of flammable refrigerant in each separate refrigerant circuit are not covered by this standard.

1.3.2.2 INTERNATIONAL TEST STANDARDS ON ENERGY USE

Only one international standard was identified for energy consumption testing of commercial refrigerators.

■ **ISO 23953(2005) – "refrigerated display cabinets"**

The standard ISO 23953(2005) replaces the previous ISO 1992:1974 standard and replaces the European standard EN 441.

Scope: Commercial display cabinets for sale and display.

It is not applicable to refrigerated vending machines or cabinets intended for use in catering or similar non-retail applications.

The first part of this standard provides a classification of the refrigerated display cabinets. The classification provided in the ISO 23953 is provided in Annex 1- 4.

The life cycle phase which is the concern of the standard: Design phase.

The second part of this standard (ISO 23953-2) specifies requirements for the construction, characteristics and performance of refrigerated display cabinets used in the sale and display of foodstuffs.

It also sets classifications of the test room climates and of the M-package temperature. These two classifications are provided in Annex 1- 5.

The standards describes test conditions and tests methods for checking that the requirements have been satisfied, including water evaporation measurement, temperature measurement, energy consumption measurement, etc. A summary of the energy consumption measurement method is provided in the Box 1-3. The definition of the relevant parameters used in the calculation of the Total electrical Energy Consumption of refrigerated display cabinet is provided in the Box 1-2.

Box 1-2: Definition of the parameters used in the calculation of the Total electric Energy Consumption – EN ISO 23953

Definitions general

t_{deft}	defrost time, time during defrost within 24 h compressor is not running (or solenoid valve is closed) or secondary refrigerant is generally not circulating, but this time is not considered as stopping time
t_{run}	running time, time during which compressor is running (or solenoid valve is open) or during which secondary refrigerant is circulating (or solenoid valve is open) within 24 h
DEC	direct electrical energy consumption in kWh/24h
REC_{RC}	refrigeration electrical energy consumption in kWh/24h for remote cabinet for compression type refrigerating system
REC_{RI}	refrigeration electrical energy consumption in kWh/24h for remote cabinet for indirect refrigerating system
TEC	total energy consumption in kWh/24h

Definitions for compression-type refrigeration systems

θ_{mrun}	arithmetic average of the evaporator saturated temperature obtained from the pressure p_7 by referring to the table of saturation properties for the refrigerant in use, during t_{run} in degrees Celsius

$T_{mrun} = \theta_{mrun} + 273.18$

Definitions for indirect refrigeration-type systems

θ_i	secondary refrigerant temperature at cabinet inlet in degrees Celsius
θ_{mrun}	arithmetic average of the secondary refrigerant median temperature (θ) during t_{run} in degrees Celsius

q_{mrun}	arithmetic average of the secondary refrigerant mass flow during t_{run} in kilograms per second
c_i	specific heat of the secondary refrigerant in kilojoules per kilogram per degree Celsius at cabinet inlet
c_o	specific heat of the secondary refrigerant in kilojoules per kilogram per degree Celsius at cabinet outlet
p_{irun}-p_{orun}	the pressure drop between the inlet and the outlet of the cabinet during t_{run} in Newton per square metre
PEC	pumping electrical energy consumption
v	specific volume of the secondary refrigerant in cubic metre per kilogram; simplification: v = const. = 0,001 m3/kg
$\Phi_{24\text{-deft}}$	heat extraction rate for calculating the energy consumption of a cabinet, in laboratory conditions, reported in kilowatts.
τ	running time of the pump in hours per day.

Box 1-3: Total electrical Energy Consumption– EN ISO 23953

Refrigeration electrical energy consumption, calculation of REC

Cabinets fitted with incorporated condensing unit

REC=0

Cabinets with remote condensing unit

Cabinets intended for compression type refrigerating system:

$$REC_{RC} = (24h - t_{deft}).\Phi_{24-deft}.\frac{T_c - T_{mrun}}{0.34T_{mrun}}$$

T_c = 308,15 K (35 °C, but calculation in K).

Cabinets intended for indirect type refrigerating system

$T_{mrun} = \theta_i - 3K$

$$PEC = v\tau.\frac{2.5q_{mrun}(p_{irun} - p_{orun})}{0.5}$$

$$REC_{RI} = PEC + (24h - t_{deft})(\Phi_{24-deft} + 0.5PEC)\frac{(T_C - T_{mrun})}{(0.34T_{mrun})}$$

T_c = 308,15 K (35 °C).

Direct electrical energy consumption, calculation of DEC

Cabinets fitted with incorporated condensing unit

DEC is reported in kWh/24h, the compressor switching on/off frequency and the relative running time (ratio of running time to overall duration of a measurement cycle excluding defrost time) shall be measured (that is with all fitted electrical power-using components switched on).

Cabinets with remote condensing unit

The direct electrical energy consumption (DEC) of the cabinet only shall be measured (that is with all fitted electrical power-using components switched on).

Total energy consumption, calculation of TEC

TEC = DEC + REC

The environmental aspect of the product that can be impacted by the standard: Material choice and energy performance.

1.3.3 PRODUCT SPECIFIC TEST STANDARDS IN OTHER COUNTRIES

1.3.3.1 THIRD COUNTRY TEST STANDARDS ON SAFETY

- **U.S.A.**

ANSI/ASHRAE 34(2001): "designation and safety classification of refrigerants" [20]

The first part of this standard gives the numbering of the refrigerants. Each refrigerant is identified by a number made up of a prefix (letters) and a suffix (digits) (e.g. R22).

- Prefix: It is composed of the letter R for refrigerant.
- Suffix: e.g. 123: The units digit is the number of fluorine atoms, the tens unit is the number of hydrogen atoms and the hundreds digit is the number of carbon atoms minus one.

The second part provides a classification regarding two safety aspects: toxicity and flammability. This classification consists in two alphanumeric characters (e.g. A2); the capital letter corresponds to toxicity and the digit to flammability.

- Toxicity classification: refrigerants are divided into two groups according to toxicity:
  - Class A signifies refrigerants for which toxicity has not been identified at concentrations less than or equal to 400 ppm[21]
  - Class B signifies refrigerants for which there is evidence of toxicity at concentrations below 400 ppm.
- Flammability classification: refrigerants are divided into three groups according to flammability:

  - Class 1 indicates refrigerants that do not show flame propagation when tested in air at 21℃ and 101 kPa

  - Class 2 indicates refrigerants having a lower flammability limit of more than 0.10 kg/m3 at 21℃ and 101 kPa and a heat of c ombustion of less than 19 kJ/kg

  - Class 3 indicates refrigerants that are highly flammable as defined by a lower flammability limit of less than or equal to 0.10 kg/m3 at 21℃ and 101 kPa or a heat of combustion greater than or equal to 19 kJ/kg.

The Table 1-2 provides a classification of some refrigerants.

[20] http://www.iifiir.org/en/doc/1027.pdf

[21] ppm: parts per million

Table 1-2: Classification of some refrigerants

classification	denomination	composition or chemical formula (mass percentage)	safety classification
INORGANIC COMPOUND			
R717	ammonia	NH_3	B2
R718	Water	H_2O	A1
R744	carbon dioxide	CO_2	A1
ORGANIC COMPOUND			
Hydrocarbons			
R170	Ethane	CH_3CH_3	A3
R290	Propane	$CH_3CH_2CH_3$	A3
R600a	Isobutene	$CH(CH_3)_2CH_3$	A3
R1270	Propene (propylene)	-	-
Halocarbons			
Chlorofluorocarbons (CFCs) and Bromofluorocarbons (BFCs)			
R11	Trichlorofluoromethane	CCl_3F	A1
R12	dichlorodifluoromethane	CCl_2F_2	A1
Hydrochlorofluorocarbures (HCFC)			
R22	chlorodifluoromethane	$CHClF_2$	A1
R141b	1,1-dichloro-1-fluoroethane	CH_3CCl_2F	A2
R142b	1-chloro-1,1-difluoroethane	CH_3CClF_2	A2
Hydrofluorocarbons (HFCs)			
R32	difluoromethane	CH_2F_2	A2
R125	pentafluoroethane	CHF_2CF_3	A1
R134a	1,1,1,2-tetrafluoroethane	CH_2FCF_3	A1
R143a	1,1,1-trifluoroethane	CH_3CF_3	A2
R152a	1,1-difluoroethane	CH_3CHF_2	A2
Azeotropic mixtures			
R502		R22/R115 (48.4/51/2)	A1
R507		R125/R143a (50/50)	A1
Zeotropic mixtures			
R404A		R125/R143a/R134a (44/52/4)	A1
R407C		R32/R125/R134a (23/25/52)	A1
R410A		R32/R125 (50/50)	A1

UL 471: “safety standard for commercial refrigerators and freezers”

This standard is developed by Underwriters Laboratories[22] (UL).

[22] Underwriter Laboratories is an independent, not-for-profit product-safety testing and certification organisation.

These safety requirements cover commercial refrigerators and freezers intended for connection to alternating-current circuits rated not greater than 600 volts.

This standard applies to unitary and remote commercial refrigerators and freezers, including equipments such as display cases, reach-in cabinets, meat cases, frozen food and merchandising cabinets, beverage coolers, beverage cooler-dispensers, food service carts, ice cream cabinets, soda fountain units, door panel assemblies and processing water coolers.

UL 541: "safety standard for refrigerated vending machines"

These safety requirements cover self-contained, refrigerated vending machines intended for connection to alternating-current circuits rated 600 volts or less and which incorporate refrigeration systems of the air-cooled or water-cooled type employing hermetic refrigerant motor-compressors.

This standard does not cover vending machines incorporating universal motors rated at more than 250 volts, nor vending machines which have a principal function other than storage and dispensing of refrigerated products; nor to vending stations, that is, freestanding stationary structures for outdoor use.

- **South Africa**

SANS 60335-2-89(2003) Part 2-89: "household and similar electrical appliances – safety – particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor"

This standard is related to IEC 60335-2-89 (see 1.3.2.1). It specifies safety requirements for electrically operated commercial refrigerating appliances that have an incorporated compressor or that are supplied in two units for assembly as a single appliance in accordance with the manufacturer's instructions (split system).

1.3.3.2 THIRD COUNTRY TEST STANDARDS ON ENERGY USE

- **Canada**

Canadian Standard Association (CSA) developed many test standards which also provide mandatory Minimum Efficiency Performance Standard (MEPS), thus these standards are also part of the country legislation.

Details on the standards listed below are provided in the section dealing with legislation (section 1.4.2.1).

CAN/CSA-C827-98: "energy performance standard for food service refrigerators and freezers"

CAN/C657-04: "energy performance standard for commercial refrigerated display cabinets and merchandisers".

CAN/CSA-C804:96 "energy performance of vending machines".

- **U.S.A.**

The following American test standards are developed by the American National Standard Institute (ANSI) together with the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE).

ANSI/ASHRAE 72(1998): "method of testing open refrigerators"

It prescribes a uniform method of testing for rating of open refrigerators for food stores so that comparative evaluations can be made of energy consumption, product temperature performance, refrigeration load, required suction pressures and other performance factors.

ANSI/ASHRAE 117(2002): "method of testing closed refrigerators"

ANSI/ASHRAE 32.1(2004): "method of testing of rating vending machines for bottled, canned and other sealed beverages"

California State

The State of California sometimes uses modified American standards.

For appliances like self-contained commercial refrigerators, refrigerator-freezers, or freezers, with doors, California uses the ANSI/ASHRAE 117(1992) energy measurement standard except that the loading doors shall remain closed and the food temperature used during the test shall be adjusted to new values[23] (see Table 1-3).

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[23] California Energy Commission(2006) – Appliance Efficiency Regulations http://www.energy.ca.gov/2006publications/CEC-400-2006-002/CEC-400-2006-002-REV2.PDF

Table 1-3: Commercial refrigeration equipment test methods

Appliance	Test Method	
refrigerated bottled or canned beverage vending machines	ANSI/ASHRAE 32.1-2004 Volume of multi-package units shall be measured using ASI/AHAM HRF1-1979	
refrigerated buffet and preparation tables	ANSI/ASTM F2143-01	
other self-contained commercial refrigerators, refrigerator-freezers, and freezers, with doors	Volume shall be measured using ANSI/AHAM HRF1-1979. Energy consumption shall be measured using ANSI/ASHRAE 117-1992 except that the back (loading) doors of pass-through and roll-through refrigerators and freezers shall remain closed throughout the test and except that the controls of all appliances shall be adjusted to obtain the following product temperatures	
	Type	integrated average product temperature in °F
	refrigerator compartment	38±2
	freezer compartment	0 ±2
	wine chiller	45 ±2
	ice cream cabinet	-5 ±2
other self-contained commercial refrigerators, refrigerator-freezers and freezers without doors	Volume measured using ANSI/AHAM HRF1-1979 Energy consumption measured using ANSI/ASHRAE 72-1998, with the controls adjusted to obtain the following product temperatures	
	Type	integrated average product temperature in °F
	refrigerator compartment	38±2
	freezer compartment	0 ±2
	wine chiller	45 ±2
	ice cream cabinet	-5 ±2

- **Japan**

JRA 4032(1993): “commercial refrigerators, refrigerator-freezers and freezers”. The information about this standard is available only in Japanese.

1.3.4 OTHER TEST STANDARDS AND TESTING PROCEDURES

- **Related to the entire cabinet**

EN 153(1994): “household refrigerator”

This Test Standards provides methods of measuring the energy consumption of electric mains operated household refrigerators, frozen food storage cabinets, food freezers and their combinations, together with associated characteristics.

- **Scope:** Household refrigerators.

This standard it also used for testing of service cabinets and mini-bars.

- **The life cycle phase which is the concern of the standard:** Use phase.

The standard is dedicated to methods of measuring the energy consumption during the use phase of household refrigerators.

- **The environmental aspect of the product that can be impacted by the standard:** Energy consumption.

■ **Related to the lighting system**

EN 50294: "Measurement Method of Total Input Power of Ballast-Lamp Circuits"

The standard is primarily aimed at measuring the efficacy of both fluorescent lamps and/or ballast combinations. It uses the total input power method for ballast-lamp circuits together with light output (or lamp power input for low frequency systems). Test ballasts are operated with an appropriate reference lamp and the total circuit light output and input power are compared to a reference ballast and reference lamp circuit operated in parallel. The total circuit power and lamp lumen output (or lamp input power) is normalized back to standardized levels for comparison purposes. This standard was specifically developed by CELMA (European Lighting Manufacturer's Association) and subsequently adopted by CENELEC for use as the test method to determine the ballast energy efficiency under CELMA' s voluntary energy labelling program. The scope of the standard covers double and single capped fluorescent lamps and their ballasts.

1.3.5 CONCLUSIONS

Considering the product category of commercial refrigerators and freezers, there is no EN or ISO standards covering the whole range of products except ISO 29353 which address only refrigerated display cabinets. Therefore, a need is identified for defining test standards for other type of products. However, a precise recommendation will be possible only at the end of this preparatory study when the priority products will be identified through detailed analysis of environmental impacts.

The identified safety standards are mainly the concern of the lighting system, the refrigerating system and refrigerant fluids, as this part of the refrigeration products is more critical regarding safety and recycling aspects.

1.4. EXISTING LEGISLATION

1.4.1 EUROPEAN LEGISLATION

There is no specific legislation for commercial refrigerators in Europe. These appliances are electrical products, containing a refrigerant fluid (and potentially ozone depleting substances) and many European Directives apply to these products. They can be classified into two categories: environmental legislations and legislations related to safety.

The more relevant ones are listed in the Box 1-4.

Box 1-4: List of relevant European legislations

SCOPE	LEGISLATION
Environmental Legislations	
Entire product	Waste Electrical and Electronic Equipment Directive 2002/96/EC (vending machine)
	Restriction of the use of certain Hazardous Substances in electric and electronic equipment Directive 2002/95/EC (vending machine)
Refrigerating Fluids	Ozone Depleting Substances Regulation 2037/2000
	Fluorinated Greenhouse Gases Regulation 842/2006
Energy Legislations	Energy efficiency requirements for ballasts for fluorescent lighting- Directive 2000/55/EC of the European Parliament and of the Council
Legislations related to Safety	
Entire product	Machinery Directive 95/16/EC
	General Product Safety Directive 2001/95/EC
	Low Voltage Equipment Directive 73/23/EEC
Refrigeration Systems	Pressure Equipment Directive 97/23/CE

1.4.1.1 Environmental Legislations

- **Legislations applicable at product level**

The following European environmental legislations apply at the product level.

European directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE)

Effective 13 August 2005, the Directive requires separate collection, treatment and recovery of electrical and electronic waste. The Directive applies to the categories of electrical and electronic equipment which are dependent on electric currents or electromagnetic fields in order to work properly. It also covers equipments for the generation, transfer and measurement of such currents and fields falling under the categories set out in Annexes IA and IB of the Directive and designed for use with a voltage rating not exceeding 1000 Volt for alternating current and 1500 Volt for direct current.

According to the product categories provided Annex IA of the Directive, it covers vending machines.

European Directive 2002/95/EC on the Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS)

This Directive requires the substitution of various heavy metals (lead, mercury, cadmium, and hexavalent chromium) and brominated flame retardants (polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE)) in new electrical and electronic equipment put on the market from 1 July 2006.

The Directive applies to the categories of electrical and electronic equipment that are covered by the WEEE directive except medical devices and monitoring and control instruments. This Directive covers assemblies or subassemblies of products.

According to the product categories provided in Annex IA of the WEEE Directive, the RoHS Directive covers vending machines.

Legislations related to the Refrigerant Fluids

The following environmental European legislations are related to chemicals used as refrigerant fluid.

European Regulation N°2037/2000 on Ozone Depleting Substances (ODS)

This regulation covers production, importation, exportation, placing on the market, use, recovery, recycling and destruction of chlorofluorocarbons, other fully halogenated chlorofluorocarbons, halons, carbon tetrachloride, 1,1,1-trichloroethane, methyl bromide, hydrobromofluorocarbons and hydrochlorofluorocarbons. The regulation also imposes the reporting of information on these substances.

This regulation also applies to importation, production, placing on the market, use of substances enumerated in Annex I of the regulation.

It also set a schedule for the elimination of the substance listed in Annex I of the regulation. It indicates the interdiction of CFC molecules and the future interdiction of HCFC (total interdiction planned for 2010-2015). This regulation doesn't concern HFC.

European Regulation N° 842/2006 on certain fluorinated greenhouse gases

This regulation entered into force on 4th July 2006 and applies from 4th July 2007.

The objective of this Regulation is to "contain, prevent and thereby reduce emissions of the fluorinated greenhouse gases covered by the Kyoto Protocol. It shall apply to the fluorinated greenhouse gases listed in Annex A to that Protocol".

This Regulation addresses:

- the containment, the use, the recovery and the destruction of the fluorinated greenhouse gases listed in Annex I of the regulation
- the labelling and disposal of products and equipment containing those gases; the reporting of information on those gases
- the control of uses referred to in Article 8 of the regulation
- the placing on the market prohibitions of the products and equipment referred to in Article 9 and Annex II of the regulation
- the training and certification of personnel and companies involved in activities provided for by this regulation

The schedule of prohibition of placing on the market of products and equipments containing fluorinated greenhouse gases listed in the Annex I of the regulation is provided in Annex 1- 6 of this document.

Danish Statutory order 552[24]

This Danish legislation bans the use of HFC in foams and refrigeration systems except with charges between 10 kg and 250 kg. This Order applies to hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphurhexafluoride (SF_6) and sets a general ban on new products containing these substances from June 1st 2006. There are some exemptions from this general ban. For instance, the ban on HFCs will come into force for cooling equipment with HFC charges > 10 kg from 01.01.07 and the use of HFC for service purposes is exempted from the Order.

1.4.1.2 LEGISLATIONS RELATED TO ENERGY EFFICIENCY

Legislation related to the lighting system

The European Parliament and the Council of the European Union has issued a Directive 2000/55/EC of the European Parliament and of the Council on energy efficiency requirements for ballasts for fluorescent lighting put on the EU market. This directive shall apply to electric mains-operated ballasts for fluorescent lighting sources as defined in European Standard EN 50294.

The objective of Directive 2000/55/EC is to remove the least efficient products from the European market and thereby to contribute to EU climate change policy targets by reducing emissions from electricity generation, through the implementation of energy efficiency minimum performance standards.

1.4.1.3 LEGISLATIONS RELATED TO SAFETY

Legislations related to the entire Product

The following legislations apply either to the product as an entity or to different stages of the manufacture process.

European Directive 95/16/EC on Machinery, amended by 2006/42/EC

The Directive applies to machinery, defined as “an assembly, fitted with or intended to be fitted with a drive system other than directly applied human or animal effort, consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application”.

This Directive addresses essential health and safety requirements relating to the design and construction of machinery. These requirements are provided in the Annex IA of the Directive.

Effective 29 June 2006, this Directive has to be transposed at the member state level before 29 June 2008.

European Directive 2001/95/EC on General Product Safety

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[24] http://glwww.mst.dk/rules/Ministerial%20Orders%20in%20force/Chemicals%20in%20force/02034000.doc

This Directive covers all the products "which are intended for consumers or likely, under reasonably foreseeable conditions, to be used by consumers even if not intended for them, and are supplied or made available in the course of a commercial activity, and whether new, used or reconditioned".

The Directive requires producers to place only safe products on the market, and to inform about risks. A safe product is defined as one which, "under normal or reasonably foreseeable conditions of use including duration … does not present any risk or only the minimum risks compatible with the product's use, considered to be acceptable and consistent with a high level of protection for the safety and health of persons …". It obliges Member States to survey products on the market.

This Directive is effective on 15/01/2004.

European Directive 73/23/EEC on Low Voltage Equipments (LVD)

According to the Directive, electrical equipment are defined as "any equipment designed for use with a voltage rating of between 50 and 1 000 v for alternating current and between 75 and 1 500 v for direct current, other than the equipment and phenomena listed in Annex II" of the Directive.

The Directive covers all risks arising from the use of electrical equipment, including not just electrical ones but also mechanical, chemical (such as, in particular, emission of aggressive substances), health aspects of noise and vibrations, and ergonomic aspects as far as ergonomic requirements are necessary to protect against hazards in the sense of the Directive. The LVD lays down eleven "safety objectives", which represent the essential requirements of this Directive.

This Directive was amended by the Directive 93/68/EEC which adds that before being placed on the market, the electrical equipment referred to in Article 1 must have affixed to it the CE marking provided for in Article 10 attesting to its conformity to the provisions of this Directive, including the conformity assessment procedure described in Annex IV of the Directive.

Legislations related to the Refrigeration System Safety

European Directive 97/23/CE on Pressure Equipment

The Directive applies to the design, manufacture and conformity assessment of pressure equipment and assemblies of pressure equipment with maximum allowable pressure greater than 0.5 bar above atmospheric pressure (i.e. 1.5 bar of absolute pressure).

"The term pressure equipment includes vessels, piping, safety accessories and pressure accessories. Where applicable, pressure equipment includes elements attached to pressurised parts, such as flanges, nozzles, couplings, supports, lifting lugs etc".

Its purpose is to harmonise national laws of Member States regarding the design, manufacture and testing and conformity assessment of pressure equipment and assemblies of pressure equipments by setting:

- A classification of the equipments
- Essential safety requirements impacting on material choice, conception and manufacturing
- Conformity evaluation procedures

1.4.1.4 EUROPEAN LEGISLATION RELATED TO ENERGY USE

No European legislation on energy efficiency for commercial refrigerators and freezers has been identified. However, there exist legislations on energy efficiency for domestic appliances.

1.4.2 THIRD COUNTRY LEGISLATIONS ON ENERGY USE

Most of the third country identified legislations are mandatory Minimum Efficiency Performance Standards (MEPS). The aim of MEPS is to remove the least efficient appliances from sale. Specific test standard for energy consumption measurement is sometimes imposed in these MEPS.

1.4.2.1 CANADA

CAN/CSA-C827-98: "energy performance standard for food service refrigerators and freezers"

This standard applies to self-contained commercial refrigerators, refrigerator-freezers, and freezer cabinets that are intended for storage or holding food products and other perishable merchandise.

The CSA standard contains minimum performance criteria for annual energy consumption that vary with the volume of the refrigerator or freezer.

The standard is voluntary in all jurisdictions in Canada, except in:

- Ontario, where these criteria are regulated by the Province of Ontario's Energy Efficiency Act (Ontario Regulation 82/95, amended to O. Reg 18/02), and apply to products manufactured, sold, or leased after April 1, 2003.
- New Brunswick, where these criteria are regulated in Regulation 95-70 of the New Brunswick Energy Efficiency Act (O.C. 95-555), and apply to products manufactured, sold, or leased after August 31, 2004.

It prescribes a minimum energy performance standard and test methodology, with reference to ASHRAE testing methods (ANSI/ASHRAE Standard 72 for open cabinets and ANSI/ASHRAE Standard 117 for closed refrigerators).

Products must meet the energy performance standards denoted as "Standard Efficiency" in the following tables.

The second performance level "High Efficiency", defines products which can claim to be high efficiency units. All products are required to be clearly labelled with the average energy consumption of the unit achieved under specified test conditions, and whether it claims to be a standard or high efficiency unit.

This standard sets the maximum annual energy consumption for products, as shown in the following tables[25] (Table 1-4 to Table 1-8):

[25] Mark Ellis & Associates. *Minimum Energy Performance Standards for Commercial Refrigeration Cabinets*. Energy Efficiency and Conservation Authority (June 2003).

Table 1-4: Maximum annual energy consumption: refrigerators – solid doors

Type	Annual Energy Consumption (AEC_{max}), kWh/y	
	Standard efficiency	**High efficiency**
Reach-in	59 V + 1010	54 V + 470
Reach-in Wine Cooler	51 V + 300	47 V + 10
Milk or beverage type	31 V + 450	28 V + 260
Worktop table/undercounter	87 V + 780	79 V + 210

Note: V is the refrigerator volume, measured in ft^3

Table 1-5: Maximum annual energy consumption: refrigerators – glass doors

Type	Annual Energy Consumption (AEC_{max}), kWh/y	
	Standard efficiency	**High efficiency**
Reach-in	118 V + 2020	108 V + 940
Reach-in Wine Cooler	102 V + 600	94 V + 20
Milk or beverage type	62 V + 900	56 V + 520
Worktop table/undercounter	174 V + 1560	158 V + 520

Note: V is the refrigerator volume, measured in ft^3

Table 1-6: Maximum annual energy consumption: freezers – solid doors

Type	Annual Energy Consumption (AEC_{max}), kWh/y	
	Standard efficiency	**High efficiency**
Reach-in	172 V + 930	156 V + 1270
Ice cream cabinet	86 V + 1270	78 V + 755
Worktop table/undercounter	367 V + 2200	334 V + 400

Note: V is the refrigerator volume, measured in ft^3

Table 1-7: Maximum annual energy consumption: freezers – glass doors

Type	Annual Energy Consumption (AECmax), kWh/y	
	Standard efficiency	**High efficiency**
Reach-in	334 V + 1860	312 V + 2540
Ice cream cabinet	172 V + 2540	156 V + 1510
Worktop table/undercounter	734 V + 4400	668 V + 800

Note: V is the refrigerator volume, measured in ft^3

Table 1-8: Maximum annual energy consumption: refrigerator-freezers – solid doors

Type	Annual Energy Consumption (AECmax), kWh/y	
	Standard efficiency	**High efficiency**
Reach-in	92 AV + 1900	84 AV + 1160

Note: AV=Adjusted Volume = refrigerator volume plus 1.63 times the freezer volume (in ft^3).

CAN/C657-04: "energy performance standard for commercial refrigerated display cabinets and merchandisers".

This standard applies to open and closed refrigerated display cabinets that are intended for displaying and merchandising food products including canned and bottled beverages, ice (intended for human consumption), and other perishable merchandise (e.g. cut flowers). This standard applies to remote condensing commercial equipment with and without doors, and plug in commercial equipment with and without doors, except as covered by CSA C82798. Commercial refrigerators and commercial freezers with doors (including commercial ice cream freezers) are covered in CSA C82798.

It prescribes a minimum energy performance standard and test methodology, with reference to ASHRAE testing methods (ANSI/ASHRAE Standard 72 for open cabinets and ANSI/ASHRAE Standard 117). This Standard provides definitions, classifications, and a method for determining specific daily energy consumption (SDEC) values (see Box 1-5) and states minimum energy efficiency requirements for refrigerated display cabinets (see Table 1-9).

Box 1-5: Definitions and SDEC computation for CAN/C657-04 standard

SDEC	Specific Daily Energy Consumption
E_C	Daily energy consumption of the display cabinet
E_{RRS}	Daily energy consumption of the remote refrigeration system.
Q	Total refrigeration load per unit length of refrigerated display cabinet (a value obtained by the tests), (Btu/h)/m ((Btu/h)/ft)
EER	Energy Efficiency Ratio Btu/(Wh) – see Table 1-10.

SDEC = E_C + E_{RRS}. (kWh/m)/day)
E_{RRS} = (Q/EER) x (24/1000) (kWh/m)/day

Cabinet categorisation:

Class 1: low temperature multi deck, two or more air curtains, length of air curtain 1.0-1.3m

Class 2: medium temperature mult deck, single air curtain, length of air curtain 1.0-1.5m. Cabinet height 1.9-2.1m and depth 0.8-1.2m.

Class 3: medium temperature multi deck, single air curtain, length of air curtain 0.8-1.0m. Cabinet height 1.0-1.4m and depth 1.0-1.2m.

Class 4: low or medium temperature closed multi deck, single air curtain behind glass door. Cabinet height 2.0-2.1m and depth 1.0-1.2m.

Class 5: low temperature, well type self service cabinet, open or closed, with horizontal air curtain, length of air curtain 0.75-0.85m or 1.0-1.2m. Product loading depth 0.3-0.45m

Class 6: medium temperature single deck self service cabinet with single air curtain, length of air curtain 0.75-0.9m. Cabinet height 0.8-1.01m at the back and 0.7-0.9m at the front. Depth 1.0-1.2m.

Class 7: medium temperature single deck wall or island type self service cabinet with a perforated product shelf. Class 7 cabinets are dividing into three subclasses on the basis of the width of the display area:
a. narrow: 0.75-1.02m
b. medium: 1.03-1.27m
c. wide: 1.28-1.65m

Class 8: low or medium temperature cabinet with a flat or curved front glass and a sliding door service access to the rear. Height 1.25-1.4m, depth 0.95-1.2m. Class 8

cabinets are dividing into two subclasses on the basis of their evaporator coil arrangements: a. fan coil. b. gravity coil.

Table 1-9: Maximum SDEC ratings for C657-04 standard[26]

Class	Product Temperature °C	Temperature	Open/ Closed	Deck	Number of Air Curtains	Angle of Air Curtain from Vertical	MEPS 2004 SDEC [(kWh/m)/ day]
1	5.0	medium	open	single/ multi	1	0-30°	13.12
2	5.0	medium	open	single/ multi	1	30-60°	9.51
3	5.0	medium	open	single/ multi	1	60-90°	5.24
4	-17.8	low	open	multi	2 or 3	0-30°	30.84
5	-17.8	low	either	single	1	60-90°	15.10
6a	5.0	low/medium	closed	multi	single vent with glass		7.55
6b	-17.8	Same as 6a					20.01
7a	5.0	medium	closed	single/ multi	glass	n/a	8.53
7b	5.0	Same as 7a, except with only a gravity coil (no fan coil)					3.28

Table 1-10: EER values for R-404a[27]

Evaporating Temperature °C	EER Value Btu/(Wh)
-40.0	5.2
-35.0	5.9
-30.0	6.7
-25.0	7.6
-20.0	8.7
-15.0	9.9
-10.0	11.4
-5.0	13.3
0.0	15.6

CAN/CSA-C804:96 "energy performance of vending machines"

This standard specifies energy performance requirements for self-contained vending machines that actively cool or heat, or both, the product to be vended. It includes uniform procedures for measuring energy consumption and maximum daily energy consumption levels. This Standard applies to vending machines that dispense:

- refrigerated post-mix soft drinks

[26] Mark Ellis & Associates. *Minimum Energy Performance Standards for Commercial Refrigeration Cabinets*. New Zealand Energy Efficiency and Conservation Authority (June 2003).http://eeca.govt.nz/eeca-library/products/standards/report/meps-for-commercial-refridgeration-cabinets-03.pdf

See also http://www.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/cre_tsd_chapter3.pdf

[27] R-404a is a class A refrigerant and a zeotropic mixture of CHF_2CF_3, CH_3CF_3, CH_2FCF_3 (see classification according to ASHRAE 34 in the previous section).

- refrigerated packaged (e.g. canned and bottled) beverages
- hot products that have been stored in a cooled space
- cold products that have been stored in a cooled space
- bulk (i.e., non-pre packaged) hot beverages
- other types of vending machines.

The minimum energy performance standard is shown in Table 1-11.

Table 1-11: Energy performance standard for vending machines

Class	Description	Max. Daily consumption (E_{dmax}) kWh	Internal Temperature (°C)
A	Packaged beverage	$E_{dmax} < 8.66 + (0.009 \times C)$	1 ± 1
B	Post-mix beverage	8.0	1 ± 1
C	Chilled non-perishable food	14.0	16 ± 2
D	Cold perishable food		
	Gross volume < 300 L	10.5	4 ± 1
	Gross volume > 300 L	14.0	4 ± 1
E	Frozen food	14.0	-19 ± 1
F	Hot food that is stored cold	17.0	-9 ± 1
G	Frozen food or snack	12.0	-19 ± 1
H	Cold beverage or snack	8.0	1 ± 1
J	Cold perishable food/snack	10.5	4 ± 1
K	Hot beverage		
	< 10 L	4.5	94.5 ± 2
	> 10 L	6.0	94.5 ± 2

Note: C is the machine capacity in number of cans

Energy efficiency regulation (amendment 9 – 2006)[28]

This regulation is set by the Canadian Office of Energy Efficiency (OEE) and provides energy requirements as well as test methods.

- Self-contained, commercial refrigerators and freezers

  The following MEPS (see Table 1-12) set Maximum Daily Energy Consumption (MDEC) in kWh. The Canadian levels are based on the California levels rather than on CSA C827-98 levels because the CSA standard does not contain enough data to specify performance levels for some of the more common types of reach-in refrigerators and freezers; these units would therefore fall outside the regulations.

  Reach-in cabinets include: buffet tables, ice cream cabinets, milk, beverage and ice cream cabinets, milk or beverage cabinets, preparation tables, undercounter cabinets, wine chillers, and worktop tables.

[28] http://oee.nrcan.gc.ca/regulations/amendment9_part1.cfm?text=N&printview=N

Table 1-12: Maximum daily energy consumption for commercial refrigerators[29]

Product	Type of cabinet doors	Date	MDEC (kWh/day)
Reach-in cabinets, pass-through cabinets and roll-in or roll-through cabinets that are refrigerators, and wine chillers that are not consumer products	Opaque	January 1, 2007 to December 31, 2007	0.00441 V + 4.22
		January 1,2008	0.00441 V + 2.76
	Transparent	January 1, 2007 to December 31, 2007	0.00607 V + 5.78
		January 1,2008	0.00607 V + 4.77
Reach-in cabinets without doors where the cabinet is specifically designed for display and sale of bottled or canned beverages	No doors	January 1, 2007	0.00607V + 4.77
Reach-in cabinets, pass-through cabinets and roll-in or roll-through cabinets that are freezers	Opaque	January 1, 2007 to December 31, 2007	0.0141 V + 2.83
		January 1,2008	0.0141 V + 2.28
	Transparent	January 1,2007	0.0332 V + 5.10
Reach-in cabinets that are refrigerator-freezers	Opaque	January 1, 2007 to December 31, 2007	0.00964 AV + 2.63
		January 1,2008	0.00964 AV + 1.65

V = is the refrigerator volume measured in litres

AV = (adjusted volume, in litres) is equal to the refrigerator volume plus 1.63 times the freezer volume

- Refrigerated beverage vending machines

The following MEPS (see Table 1-13) set Maximum Daily Energy Consumption (MDEC) in kWh. The Canadian levels are based on the California levels rather than on the CSA C804-96 levels because the market data available to National Resources Canada (NRCan) indicate that regulating to the CSA standard would have little effect on the market, since the major manufacturers are already working toward the more stringent California standard.

29 http://oee.nrcan.gc.ca/regulations/reach-in-refrigerators-apr05.cfm?text=N&printview=N

Table 1-13: Maximum daily energy consumption for cold beverage vending machines

	Date	MDEC (kWh)	Ambient-air test temperature
Solid/opaque-door beverage vending machine	June 1, 2006 to December 31, 2007	0.55 x (8.66 + 0.009 C)	32.2℃
	January 1, 2008	0.45 x (8.66 + 0.009 C)	32.2℃
Multi-package vending machines	June 1, 2006	0.55 x (8.66 + 0.009 C)	23.9℃
Snack and refrigerated beverage vending machines	January 1, 2007	0.55 x (8.66 + 0.009 C)	23.9℃

C is the maximum quantity of product that is recommended by the manufacturer to be dispensed from one full loading of the machine.

1.4.2.2 CALIFORNIA[30]

The Table 1-14 provides standards that are exclusively California standards. They are applicable as state law to the sale or offering for sale of appliances in California. No appliance may be sold or offered for sale in California unless the appliance complies with the applicable standard as determined using the applicable test method listed in the section 1.3.3.2.

[30] California Energy Commission(2006) – Appliance Efficiency Regulations

Table 1-14: Standards for different commercial refrigeration equipment

Appliance	Doors	Maximum Daily Energy Consumption (kWh)			
		March 1, 2003	**August 1, 2004**	**January 1, 2006**	**January 1, 2007**
Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are refrigerators; and wine chillers that are not consumer products	solid	0.125 V+4.22	0.125 V+2.76	0.10 V+2.04	0.10 V+2.04
	transparent	0.172 V+5.78	0.172 V+4.77	0.172 V+4.77	0.12 V+3.34
Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are freezers (except ice cream freezers)	solid	0.398 V+2.83	0.398 V+2.28	0.40 V+1.38	0.40 V+1.38
	transparent	0.940 V+5.10	0.940 V+5.10	0.940 V+5.10	0.75 V+4.10
Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are freezers that are ice cream freezers	solid	0.398 V+2.83	0.398 V+2.28	0.398 V+2.28	0.39 V+0.82
	transparent	0.940 V+5.10	0.940 V+5.10	0.940 V+5.10	0.88 V+0.33
Reach-in cabinets that are refrigerator-freezers and that have and adjusted volume (AV) of 5.19ft3 or greater	solid	0.273 AV+2.63	0.273 AV+1.65	0.273 AV+1.65	0.27 AV-0.71
Reach-in cabinets that are refrigerator-freezers and that have and adjusted volume (AV) less than 5.19ft3	solid or transparent			0.70	0.70
Refrigerated canned and bottled beverage vending machines when tested at 90°F ambient temperature except multi-package units	Not applicable			0.55(8.66+0.009x C)	0.55(8.66+0.009x C)
Refrigerated canned and bottled beverage vending machines when tested at 75°F ambient temperature	Not applicable			0.55(8.66+0.009x C)	0.55(8.66+0.009x C)

V=total volume (ft^3)

AV=Adjusted Volume = 1.63xfrezzer volume (ft^3)+refrigerator volume(ft^3)

C = rated capacity (number of 12 ounce cans)

1.4.2.3 WASHINGTON STATE

The state of Washington recently issued a regulation comprising minimum efficiency standards[31] (January 2007). To verify the accordance of the appliances with these requirements, the products are tested with the California Energy Commission testing method as described in section 1.3.3.2.

The scope of this regulation for commercial refrigerators and freezers excludes all appliances without doors, walk in cabinets and ice cream freezers[32]. For products included in the scope[33], the requirements which

[31] http://apps.leg.wa.gov/RCW/default.aspx?cite=19.260.040

[32] See section 1.1.2

apply are the same as in California except for one category of appliance (Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are "pulldown" refrigerators – transparent door - 0.126V+ 3.51 maximum daily consumption in kWh/d) which does not figure in the Californian standard.

1.4.2.4 U.S.A.[34]

The Energy Policy Act of 2005 (EPACT 2005) prescribes new and amended energy conservation standards and test procedures that apply to commercial refrigeration equipment, and directs the Department of Energy (US DOE) to undertake rulemakings to promulgates such requirements no later than January 1st, 2009. In this context, the US DOE[35] published a notice of proposed rulemaking to adopt test procedures for measuring energy efficiency and related definitions for commercial refrigeration equipment including:

- ice cream freezers
- self-contained commercial refrigerators, freezers, and refrigerator-freezers without doors
- remote condensing commercial refrigerators, freezers, and refrigerator-freezers

The energy conservation standards developed will apply to commercial refrigeration equipment manufactured on or after January 1st, 2012.

The test procedure under consideration is the Air-Conditioning and Refrigeration Institute (ARI) Standard 1200, "Performance Rating of Commercial Refrigerated Display Merchandisers and Storage cabinets" (see section 1.5.1.2).

The scope of this rulemaking (*Energy Conservation Standard Rulemaking*) is defined by the three categories of products listed above. However, for remote cabinets, secondary coolant applications might not be covered (the discussion is ongoing). This is consistent with the ARI 1200 standard which explicitly excludes secondary coolant applications (i.e. remote display cabinets attached to secondary-loop refrigeration systems as defined in section 1.1.3.3).

The proposed product classes are defined based on the ARI 1200 standard (see Figure 1-2) but have been narrowed down to excluded the categories of products for which the EPACT 2005 prescribed standards (Figure 1-1).

The following standards for commercial refrigeration equipment fitted with doors are already prescribed by EPACT 2005 (Table 1-15):

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[33] Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are refrigerators, Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are freezers, Reach-in cabinets that are refrigerator-freezers

[34] http://www.eere.energy.gov/buildings/appliance_standards/commercial/refrigeration_equipment.html

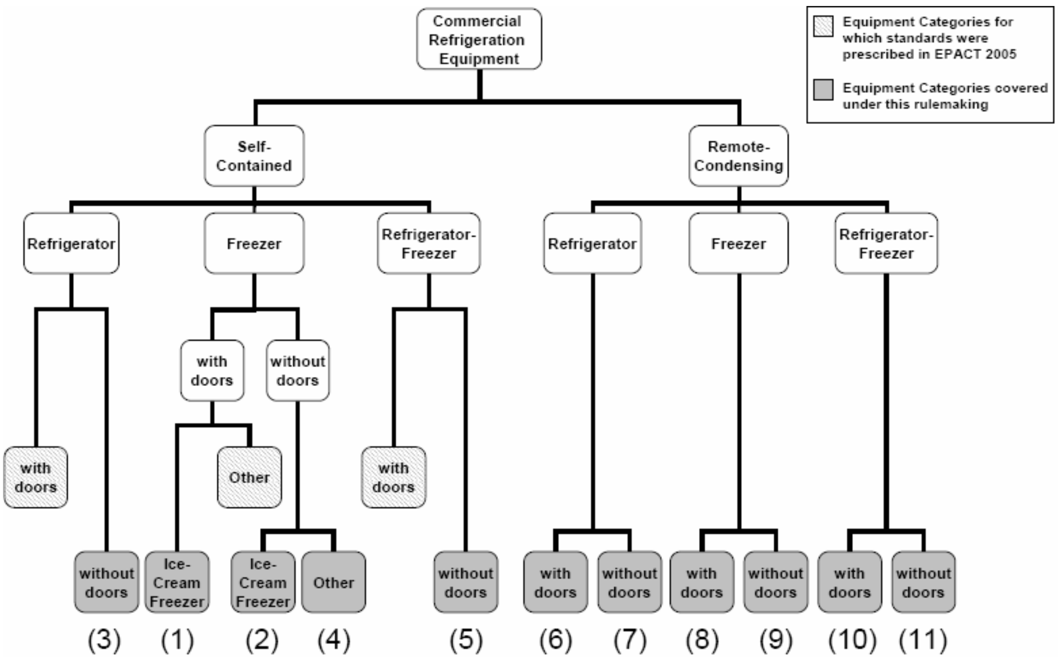
[35] US DOE Appliance and Commercial Equipment standards Program, of the Office of Energy Efficiency and renewable Energy's (EERE's) Building Technologies Program (BT)

Table 1-15: Standards prescribed by EPACT 2005[36]

Product category (commercial equipment)	Maximum daily energy consumption (kWh/day)
Refrigerators with solid doors	0.10 V + 2.04
Refrigerators with transparent doors	0.12 V + 3.34
Freezers with solid doors	0.40 V + 1.38
Freezers with transparent doors	0.75 V + 4.10
Refrigerators/Freezers with solid doors	0.27 AV – 0.71 or 0.70
V=total volume (ft^3) AV=Adjusted Volume = 1.63xfrezzer volume (ft^3)+refrigerator volume(ft^3)	

The other categories of product will be covered by the ongoing rulemaking.

Figure 1-1: Proposed categories covered by the rulemaking[37]



1.4.2.5 AUSTRALIA[38]

AS-1731(2003) + amendment 1(2005): "energy tests and minimum energy performance requirements"

The standard applies to both remote and self-contained refrigerated display cabinets primarily used in commercial applications for the storage of frozen and unfrozen food. This standard does not apply to refrigerated vending machines or cabinets intended for use in catering and similar non-retail applications.

[36] http://www.eere.energy.gov/buildings/appliance_standards/pdfs/epact2005_appliance_stds.pdf

[37] http://www.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/refrig_meeting_slides.pdf

[38] http://www.energyrating.gov.au

Part 14 of the standard determines the energy performance requirements.

Parts 1 to 13 of the standard establish the test methodology.

The test methods used to determine compliance with MEPS are based on the International Standard EN ISO 23953-2:2005, which have been substantially incorporated into the AS 1731 series of Standards. These standards are not equivalent. Regulatory authorities intend to continue to align the Australian Standard as far as possible with the ISO Standard.

Annex 1- 7 shows the MEPS and High Efficiency levels contained. Annex 1-8 provides the classification used by this standard.

These mandatory MEPS came into force on 1st October 2004.

1.4.2.6 South Africa

SABS 1406:1999: "commercial refrigerated food display cabinets"

This standard provides a test methodology and a minimum energy performance standard, based on the gross capacity of the cabinet.

The standard specifies requirements for three types and two climate classes of commercial refrigerated display cabinet for the storage, for sale, of frozen and fresh foods, and liquids in containers, and intended for operation on a three-phase 440 V power supply or on a single-phase power supply not exceeding 250 V phase to neutral.

The energy requirements of this standard cover energy consumption, test conditions and energy consumption test.

1.4.3 Other Legislations

1.4.3.1 Denmark

Since January 2006, a standard for the "Demanufacture of Refrigeration Equipment" was implemented in Danish law[39]. The RAL quality mark GZ-728 is the European standard for the demanufacture of refrigeration devices.

Scope

Refrigerating equipments containing CFCs.

These quality assurance and test specifications apply to the demanufacture of waste refrigeration equipment containing CFCs. The specifications cover the collection, storage and processing of such equipment and the handling of the materials recovered prior to re-use or disposal.

1.4.4 Conclusions

European directives and legislations covers many aspects of the products and influence refrigerant choice, refrigerating system manufacture, maintenance of the product, safety during the manufacture, maintenance and use phase whereas identified third country legislations mainly consist in

[39] http://www.ral-online.org/html_engl/detail.php?id=185

mandatory Minimum Efficiency Performance Standards (MEPS). These MEPS are sometimes provided with a specific test method to ensure that the MEPS are achieved.

1.5. Label and Voluntary Agreements

1.5.1 Certification programs and voluntary agreements

1.5.1.1 Eurovent Certification Program for Refrigerated Display Cabinets

Scope

This voluntary program concerns all product families of refrigerated display cabinets.

The purpose of Eurovent Certification Program is to create a common set of criteria for rating products. Through specification of certified products, the engineer's tasks are made easier, since there is no need for carrying out detailed comparison and performance qualification testing.

Certification program

The following dimensional and performance characteristics shall be certified:

- M-package temperature classification according to EN ISO23953:2004
- Refrigeration electrical energy consumption (REC) according to Eurovent/Cecomaf recommendation REC-05[40]
- Direct electrical energy consumption (DEC) according to EN ISO23953:2004
- Total display area (TDA) according to Eurovent/Cecomaf recommendation REC 05

Certified products or ranges are listed in the Eurovent Directories, specification sheets and literature and, where appropriate, advertising display the Eurovent Certification Logo. The Certification Logo guarantees that products have been submitted to independent checking and that they have been accurately rated.

Measurement recommendation REC-05

This documentation is a recommendation for energy consumption evaluation of remote refrigerated display cabinets regarding the standard EN 441 (ISO 23953).

These measurement methods are summarized in Box 1-6 and Box 1-7.

[40] REC-05(97): This Eurovent recommendation provides tools for the evaluation of Total Energy Consumption (TEC) and Total Display Area (TDA). It is available at http://www.eurovent-cecomaf.org/web/eurovent/web/Recommendations/REC05.pdf

Box 1-6: Total Energy Consumption measurement

Definitions

$P_{V,H,D,L,A}$	respectively fan, heaters, defrost heaters, lighting and accessories power (W)
$T_{V,H,D,L,A}$	respectively fan, heaters, defrost heaters, lighting and accessories running time within 24h
t_R	24h minus defrost period in h
T_C	conventional condensing temperature
T_0	refrigerant evaporating temperature (based on test with 24h lighting)
Φ_0	heat extraction rate in kW (based on test with 24h lighting)

Direct electrical Energy Consumption (DEC) calculation

$DEC= [(P_V.t_V)+ (P_H.t_H)+ (P_D.t_D)+ (P_L.t_L)+ (P_A.t_A)]$

Refrigeration electrical Energy Consumption (REC) calculation

$REC = t_R.\Phi_0;(T_c-T_0)/(0.34.T_0)$

Total Energy Consumption (TEC) calculation

TEC = DEC+REC in kWh/24h

Box 1-7: Total Display Area measurement method for remote cabinets

Definitions

h	horizontal projection, m
V	vertical projection, m
o	open surface
g	glazing surface
$T_{gh, vh}$	light transmission through the glazing surface for horizontal (resp. vertical) projection
L	cabinet length, m
$L_{oh, ov}$	horizontal (resp. vertical) open length
$L_{gh, gv}$	horizontal (resp. vertical) glazing length

Total Display Area (TDA) calculation

$TDA= (H_o.L_{oh})+ (H_g.T_{gh}.L_{gh})+ (V_o.L_{ov})+ (V_g.T_{gv}.L_{gv})$

For plug in refrigerated display cabinets, the TEC simply equals the DEC.

Benefits from certification

The Eurovent Certification provides clear benefits for selection of products and their performance.

The end users may have confidence that equipment will operate in accordance with design specifications, the energy cost will be correctly predicted and therefore the supplied product will correspond to the initial investment.

For manufacturers, the Eurovent Certification program creates a common platform for competition on equal terms based on comparable data.

Finally the image and integrity of the all industry is improved and a better confidence between manufacturers and certifiers is established.

1.5.1.2 ARI CERTIFICATION

With the development of ARI Standard 1200[41], Commercial Refrigerator Manufacturers Division members have agreed to establish a certification program for commercial refrigerator and freezer equipment. The certification program will verify a manufacturer's performance ratings through third party testing. The certification program, starting in January 2008 for remote refrigerated display cabinets, will be based on ARI Standard 1200 and will provide national and international recognition on the performance of commercial refrigerator equipment. The program has already been launched for plug in equipment (April 2007).

ARI[42] 1200(2006): "performance rating of commercial refrigerated display merchandisers and storage cabinets"

This standard describes a method for assessing the performance rating of commercial refrigerated display merchandisers and storage cabinets. The conformance with this standard is voluntary. This program will be launched in April 2007.

- The scope of this standard applies to:
  - Self-contained and remote commercial and refrigerated display merchandisers and storage cabinets
  - Open and closed commercial refrigerated display merchandisers
  - Service and self-service commercial refrigerated display merchandisers

  And excludes:
  - Commercial refrigerated display merchandisers forming the front wall of a refrigerated storage room backed up to a walk-in cooler
  - Miter transition display merchandisers used as a corner section between two refrigerated display merchandisers
  - Floral merchandisers
  - Refrigerated vending machines
  - Ice makers
  - Ice cream dipping cabinets
  - Soft serve extruders
  - Secondary coolant applications

The three categories of products included in the scope are further defined by six Basic Model Groups (BMG). BMG are models families that relate to each other either through similar characteristics. The six BMG and the related sub-categories are presented in Figure 1-2.

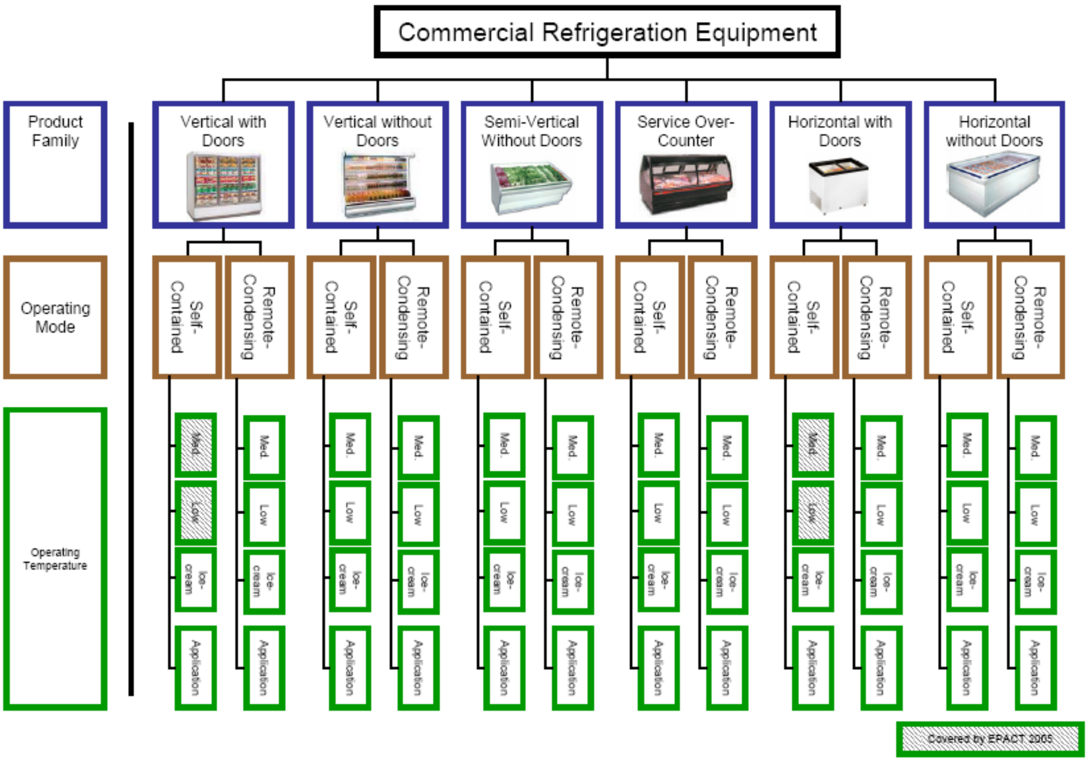
A more detailed definition of the commercial refrigeration products included in the scope is presented in Annex 1- 9.

[41] http://www.ari.org/NR/rdonlyres/6D7B6F89-7602-4729-A1E2-7A5688F9E8C6/0/12002006.pdf

[42] ARI : Air-conditioning and Refrigeration Institute is a trade association in USA

Figure 1-2: ARI 1200 Basic Model Groups

Source: ARI DRAFT CRMD Certification Program Operations Manual



- **Test requirements**

  The tests required for this standard shall be conducted in accordance with the ANSI/ASHRAE standard 72.

- **Definitions**

  Box 1-8 provides the definitions of the different parameters used in the ARI 1200 standard.

Box 1-8: Definitions and unit of the measured parameters for ARI 1200 standard

A_e =	Projected area from visible product through end walls, ft^2 [m^2]
A_r =	Gross refrigerated area, ft^2 [m^2]
AEC =	Anti-condensate energy consumption, kW·h/ft [kW·h/m] per day
CDEC =	Calculated Daily Energy Consumption, kW·h/ft [kW·h/m] per day
CEC =	Compressor Energy Consumption, kW·h/ft [kW·h/m] per day
COP =	Coefficient of Performance
DEC =	Defrost Energy Consumption, kW·h/ft [kW·h/m] per day
D_h =	Dimension of projected visible product, ft [m]
E_t =	Total energy measured or calculated for 24 hour period, kW·h [kW·h] per day
EER =	Energy Efficiency Ratio
FEC =	Fan Energy Consumption, kW·h/ft [kW·h/m] per day
IU =	International Units
LEC =	Light Energy Consumption, kW·h/ft [kW·h/m] per day
LECR =	Revised Light Energy Consumption, kW·h/ft [kW·h/m] per day
L =	Length of unit, ft [m]
n =	Number of fan motors
P_{ai} =	Power anti-condensate heater input, W [W]
P_c =	Power condensate evaporator pan heater input, W [W]
P_d =	Power defrost heater input, W [W]
P_f =	Power fan, W [W]
P_{fi} =	Power fan input, W [W]
P_{fo} =	Power fan output found on part nameplate, W [W]
P_{li} =	Power light input, W [W]
PEC =	Condensate Evaporator Pan Energy Consumption, kW·h/ft [kW·h/m] per day
Qrt =	Commercial refrigerated display merchandiser or storage cabinet load, Btu/h [W]
t =	Time unit is tested in 24 h period, h [h]
ta =	Time anti-condensate heaters are on in 24 hour period, h [h]
tc =	Time condensate evaporator pan heaters are on in 24 hour period, h [h]
td =	Time defrost heaters are on in 24 hour period, h [h]
tdt =	Time unit is in defrost, h [h]
tf =	Time fans are on in 24 hour period, h [h]
tl =	Time lights are on in 24 hour period, h [h]
TDA =	Total Display Area, ft^2 [m^2]/Unit of Length, ft [m]
TDEC =	Total Daily Energy Consumption, kW•h/ft [kW•h/m] per day
Vr =	Refrigerated Volume, ft^3 [m^3]
ηm =	Motor efficiency

- **Rating requirements**

Box 1-9 and Box 1-10 provide the details of the calculation of the Calculated Daily Energy Consumption (CDEC) and of the Total Daily Energy Consumption (TDEC).

Box 1-9: Performance rating for remote commercial refrigerated display merchandisers and storage cabinets

CDEC calculation

CDEC=CEC+FEC+LEC+AEC+DEC+PEC

Calculation of CEC $CEC = [(Q_{rt}/L).(t-t_{dt})]/(EER.1000)$ (if IU) $CEC = [(Q_{rt}/L).(t-t_{dt})]/(COP.1000)$

Calculation of FEC $FEC = (P_f.t_f)/(L.1000)$

$P_f = P_{fi}$ (if measured)

$P_f = (P_{fo}.n)/\eta_m$ (if calculated)

Calculation of LEC $LEC = (P_{li}.t_l)/(L.1000)$

Calculation of AEC $AEC = (P_{ai}.t_a)/(L.1000)$

Calculation of DEC $DEC = (P_d.t_d)/(L.1000)$

Calculation of PEC $PEC = (P_c.t_c)/(L.1000)$

Other parameters calculation

Refrigerated volume $V_r = A_r.L$

Total display area $TDA = (D_h.L)+A_e$

Presentation of the data

Item Number	Informational Item	Data
1	Commercial Refrigerated Display Merchandiser or Storage Cabinet Model Number	
2	Adjusted Dew Point, °F [°C]	
3	Load Capacity, Btu/h [kW]	
4	Refrigerated Volume, ft³ [m³]/Unit of Length, ft [m]	
5	Total Display Area, ft² [m²]/Unit of Length, ft [m]	
6	Commercial Refrigerated Display Merchandiser or Storage Cabinet Test Voltage, V	
7	Commercial Refrigerated Display Merchandiser or Storage Cabinet Evaporator Dew Point Temperature, °F [°C]	
8	Integrated Average Temperature of Product Simulators, °F [°C]	
9	CEC, kW·h/ft [kW·h/m] per day	
10	FEC, kW·h/ft [kW·h/m] per day	
11	LEC, kW·h/ft [kW·h/m] per day	
12	PEC, kW·h/ft [kW·h/m] per day	
13	AEC, kW·h/ft [kW·h/m] per day	
14	DEC, kW·h/ft [kW·h/m] per day	
15	CDEC, kW·h/ft [kW·h/m] per day	
16	Other Loads, Notes:	

Box 1-10: Performance rating for self-contained commercial refrigerated display merchandisers and storage cabinets

TDEC calculation

$TDEC = E_t/L$

Other parameters calculation

Refrigerated volume $V_r = A_r.L$

Total display area $TDA = (D_h.L)+A_e$

Presentation of the data

Item Number	Informational Item	Data
1	Commercial Refrigerated Display Merchandiser or Storage Cabinet Model Number	
2	Refrigerated Volume, $ft^3[m^3]$/Unit of Length, ft [m]	
3	Total Display Area, $ft^2[m^2]$/Unit of Length, ft [m]	
4	Commercial Refrigerated Display Merchandiser or Storage Cabinet Test Voltage, V	
5	Integrated Average Temperature of Product Simulators, °F [°C]	
6	TDEC, kW·h/ft [kW·h/m] per day	
7	Other Loads, Notes:	

1.5.1.3 EVA-EMP

The European Vending Association (EVA) developed a voluntary protocol to measure the energy consumption of vending machines which was updated in May 2006. The EVA-EMP (EVA- Energy Measurement Protocol) is based on two existing standards:

- CAN/CSA-C804-96 Energy Performance of Vending Machines

  Published in December 1996 by Canadian Standards Association

- Proposed Standard 32.1P

  Methods of Testing for Rating Bottled and Canned Beverage Vending Machines. Working Draft 97/2 by the American Society of Heating, Refrigerating and air-conditioning Engineers (ASHRAE). Published in March 1997

The EVA-EMP is designed to cover all food and drink machines. For all machines the energy consumption is measured in stand-by situation and vending situation. For the cooled machines the energy consumption after reloading the machine is also measured (pull down phase).

The protocol covers (but is not limited to) the following products relevant to Lot 12:

- Can & bottle machines
- Refrigerated confectionery & snack machines
- Refrigerated food machines
- Ice cream & frozen food machines

The electricity consumption is measured in the following conditions:

Table 1-16 : EVA-EMP ambient condition requirements

LOCATION	Temperature (^oC +/- 2)	Relative Humidity (% +/-5).
Specified as suitable for outdoor use	32	65
Specified for use indoors only	25	60

and following three test phases reproducing the machine normal operation:

- Machine idle phase.
- Machine vending phase.
- Machine re-loading & pull down phase.

Unlike the energy star program, the EVA-EMP is not yet a standard but a test protocol. As such it provides a tool that can be used and performed by any laboratory/end-user/manufacturer but does not provide a certification label.

1.5.2 LABEL ON ENERGY EFFICIENCY

If many efficiency labels or voluntary program to assess the energy efficiency of domestic appliances exist, only few programs exist for commercial refrigerant appliances.

In 1995 the European Union refused the introduction of mandatory energy labelling on refrigerated display cabinets.

For commercial refrigerated cabinets, there appears to be a good spread of performance in most categories however the impact of energy labels may be limited. For remote cabinets, most supermarkets select products on aesthetic and size criteria, and it is unlikely that performance labels will alter purchasing patterns[43].

1.5.2.1 EUROPEAN ENERGY STAR LABEL

Until now, the European Energy Star Label covers only office equipments[44].

1.5.2.2 US ENERGY STAR LABEL

This label is a voluntary agreement based on Minimum Energy Performance Standard (MEPS).

- **Program Requirements for Commercial Solid Door Refrigerators and Freezers – Eligibility Criteria[45]**

This program is effective on September 1, 2001.

Scope

The study-specific appliances covered by this program are:

- Commercial refrigerator, freezer and refrigerator-freezer
- Commercial refrigeration cabinet
- Self-contained refrigeration cabinet.

Energy specification

The qualifying products must meet the criteria listed in Table 1-17.

[43] Mark Ellis & Associates. *Minimum Energy Performance Standards for Commercial Refrigeration Cabinets* –Energy Efficiency and Conservation Authority (June 2003).
[44] http://www.eu-energystar.org/en/index.html
[45] http://www.energystar.gov/ia/partners/product_specs/eligibility/commer_refrig_elig.pdf

Table 1-17: Specifications for Energy Star qualified commercial solid door refrigerators and freezers

Product Type	Energy consumption under test conditions
refrigerators	<0.10 V + 2.04 kWh/day
freezers	<0.40 V + 1.38 kWh/day
refrigerator-freezers	<0.27 AV - 0.71 kWh/day
ice cream freezers	<0.39 V + 0.82 kWh/day
Note:	V=internal volume in ft^3
	AV=Adjusted volume =(1.63xfreezer volume in ft^3+refrigerator volume in ft^3
	Products tested to ASHRAE standard 117-1992

In performing these tests, manufacturers must use ASHRAE Standard 117-1992, "Method of Testing Closed Refrigerators," to measure the daily energy consumption of commercial solid door refrigerators and freezers with the following temperature specifications (see Box 1-11):

Box 1-11: Temperature specifications for Energy Star measurement

Product Type	Integrated average product temperature
Commercial solid-door refrigerator	38 ± 2 ℉
Commercial solid-door freezer	0 ± 2 ℉
Commercial ice cream cabinet	– 5 ± 2 ℉

Program Requirements for Refrigerated Beverage Vending Machines – Eligibility Criteria – Version 2.0

Scope

This program specially covers indoor and outdoor refrigerated beverage vending machines.

This program defines refrigerated beverage vending machine as "a self-contained system designed to accept consumer payments and dispense bottled, canned, and other sealed beverages at appropriate temperatures without on-site labour intervention".

All the products in the scope of the program must meet all the criteria described below to be identified as Energy Star.

Energy-efficiency specifications[46]

The specification includes requirements for the active mode as well as for the low power mode.

- Active mode consumption:

  Qualifying models shall consume equal to or less energy in a 24-hr period than the values obtained from the equations, shown below

  Tier I : Y = 0.55 [8.66 + (0.009 x C)]

  Tier II : Y = 0.45 [8.66 + (0.009 x C)]

[46] http://www.energystar.gov/ia/partners/product_specs/eligibility/vending_elig.pdf

Where: - Y is the 24 hr energy consumption (kWh/day) after the machine has stabilized

- C is the vendible capacity (the maximum quantity of standard product that can be dispensed from one full loading of the vending machine without further reload operations when used as recommended by the manufacturer).

- Low power mode consumption:

  In addition to meeting the 24-hour energy consumption requirements above, qualifying models shall come equipped with hard wired controls and/or software capable of placing the machine into a low power mode during periods of extended inactivity while still connected to its power source to facilitate the saving of additional energy, where appropriate. The machine shall be capable of operating in at least one of the low power mode states described below:

  Mode 1: Lighting low power state – lights off for an extended period of time.

  Mode 2: Refrigeration low power state – the average beverage temperature is allowed to rise to 40°F or higher for an extended period of time.

  Mode 3: Whole machine low power state – the lights are off and the refrigeration operates in its low power state.

- Test Criteria:

  Energy Star Partners are required to perform tests, according to the requirements included in this program specification, and then submit qualifying model information to the US Environmental Protection Agency (EPA) for approval.

  The measure a model's daily energy consumption has to be done according to ASHRAE Standard 32.1-2004, Methods of Testing for Rating Vending Machines for Bottled, Canned, and Other Sealed Beverages, using the test conditions provided in Section 6 of the standard:

  Machines marked "For Indoor Use Only":

  They must be tested at 75±2 °F (23.9±1 °C); 45±5% relative humidity; and 36±1 °F (2.2±0.5 °C) average beverage temperature throughout the test.

  Machines marked "Suitable for Outdoor Use" or "Suitable For Protected Locations":

  They must be tested at 90±2 °F (32.2±1 °C); 65±5% relative humidity; and 36±1 °F (2.2±0.5 °C) average beverage temperature throughout the test.

- Effective Date:

  The date that manufacturers may begin to qualify machines as Energy Star will be defined as the effective date of the agreement.

  Tier I: The first phase, Tier I, shall go into effect on April 1, 2004 and conclude on June 30, 2007.

Tier II: The second phase of this specification, Tier II, shall commence on July 1, 2007.

All products, including models originally qualified under Tier I, with a date of manufacture or rebuild on or after July 1, 2007, must meet Tier II requirements in order to bear the Energy Star on the product or in product literature.

1.5.3 VOLUNTARY AGREEMENTS

1.5.3.1 EUROPEAN COMPETITION PROJECT PROCOOL[47]

Context

Supported by the European Commission within the "Life" framework, the aim of the project is to support the development and market introduction of energy-efficient, eco-friendly commercial refrigeration appliances, being centred on an innovation.

Scope

Five categories of product can take part to the competition.

The definitions of product categories are given according to the standard EN 23953-1:

- refrigerator, closed, with a glass door, vertical, net volume 250-600litres
- refrigerated cabinets, open, vertical, Total Display Area 1.5-4.5m²
- refrigerator, open, horizontal, for packaged convenience food, Total Display Area 0.5-2m^2
- no cooling counters for unpackaged foodstuffs, freezer, closed with a glass lid, horizontal, net volume 150-350 litre
- no appliances with "Flip-Flop" lids, freezer, closed with a glass lid, horizontal, net volume>350 to 850 litre.

Products criteria

The criteria the appliances have to comply with are either mandatory or voluntary.

Details of the criteria are provided in Annex 1- 10 but the most study-relevant are:

- Energy consumption (Mandatory)
- Refrigerant composition: HFC free is obligatory (Mandatory)
- Noise emissions (Mandatory)
- Energy for cooling (Voluntary)
- Product design geared toward repair and recycling (Voluntary)

Stimulus expected from the competition

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[47] http://www.procool.info/

A specialist for cold appliance stated that he would like to see the introduction of an energy classification for commercial cooling similar to that of the label for domestic appliances.

1.5.3.2 MEMBER STATES VOLUNTARY AGREEMENTS

- **United Kingdom**

- **Enhanced Capital Allowance Scheme**[48]

Scope

Electrical appliances including refrigeration appliances (evaporative condensers, liquid pressure amplification, automatic air purges, controls, curtains, blinds and transparent covers, automatic leak detection).

Content

The Chancellor of the Exchequer, Gordon Brown, announced in the November 1999 Pre-Budget Report, support for business investment in low carbon technologies under the climate change levy package. This allowed for the introduction of a 100% first year Enhanced Capital Allowance (ECA) scheme, and a £50 million fund for energy efficiency and renewable.

The ECA scheme follows a number of representations from business proposing that the Government should introduce tax incentives to encourage firms to make energy saving investments. In designing the scheme for enhanced capital allowances, the Government drew on the model operating in the Netherlands.

Energy Technology List

This list is divided into 2 parts:

- The Energy Technology Criteria List which contains details of the energy-saving criteria that must be met for each of the technology classes
- The Energy Technology Product List which contains a list of products that have been certified as meeting those standards.

For refrigerated display cabinets, the energy technology criteria list is provided in Annex 1- 11. Annex 1- 11 also provides the thresholds for eligibility of these products. Different criteria exist depending of the type of appliance: remote or plug in; and depending of the operating temperature range (i.e. different threshold for a refrigerator and for a freezer). However, open or fitted with doors appliances are not differentiated in this scheme.

- **Market Transformation Program**[49]

Background

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48 www.eca.gov.uk
49 MTP(2006) – Sustainable Products 2006: Policy Analysis and Projections

The Market Transformation Programme was launched following a consultation paper[50] issued by the Environment & Business Division, in October 1997.

The Market Transformation Programme (MTP) supports the development and implementation of UK Government policy on sustainable products. MTP's aim is to reduce the environmental impact of products across the product life cycle by[51]:

- Collecting information.
- Building evidence of future environmental impacts.
- Working with industry and other stakeholders.

The approach is to communicate and interpret Government policy objectives as a set of specific action plans, or road maps, looking ahead at least ten years, and to get buy-in from policy-makers and industry at UK, EU and international levels. MTP also supports policy delivery, in particular, by developing corresponding product eco-design information (labels) and performance requirements (standards) to encourage innovation and competition.

Scope

Domestic or commercial appliances including commercial refrigeration (liquid chillers, refrigerated display cases, service cabinets, cold rooms, cellar cooling equipment, ice-making machines and refrigerated vending machines).

Identification of saving potentials for commercial refrigeration

In the 2006 report, MTP develops three standard scenarios to illustrate the potential impacts of the associate market transformation strategies:

- Reference scenario: without policy intervention
- Earliest Best Practice scenario: what would happen if everyone started buying the best available products
- Policy scenario: estimate of the likely effects of a program of policy measures

Comparing these scenarios, savings potential for energy use of commercial refrigeration has been identified. The development of minimum energy performance standards covering full and part load could help to access a significant proportion of the identified savings potential.

There is also great potential for savings through better service/maintenance and optimisation of present equipment and systems.

Moreover refrigerants used have an additional impact due to their direct carbon emissions through leakages and disposal. The development of refrigerants with no ozone-depleting potential and little, or no, global warming potential offers the possibility of reducing direct carbon

[50] Energy Efficient Consumer Products: A 'Market Transformation' Strategy for More Sustainable Consumption - 1997

[51] http://www.mtprog.com

emissions. In the case of more efficient refrigerants, it will reduce energy consumption and hence indirect carbon emissions as well.

Proposed actions

The proposed actions for commercial refrigeration are:

- Revise performance criteria and expand the product range for the Enhance Capital Allowance (ECA) Scheme to include display and service cabinets and reverse cycle liquid chillers (>100 kW).
- Engage trade groups and key buyers in green procurement initiatives.
- Develop standard and performance benchmarks for part-load operation of liquid chillers. Part-load testing and seasonal efficiency ratings would be more representative of the real-life situation. They need to be considered as a potential criterion for ECA.
- Development of criteria/thresholds and implementation of the EuP Directive for display cabinets, liquid chillers and vending machines.

1.6. CONCLUSIONS

The discussion presented in sections 1.1 and 1.2 outlined the key issues and parameters related to the products relevant to the lot 12. Further, it defines the scope of the study which is restricted to refrigerated display cabinets and cold vending machines.

The identification of the relevant legislation worldwide reveals that Canada, Australia and California have already developed obligatory standards.

Voluntary programs exist in Europe but their purpose is to provide a tool of comparison between competing products and they do not set any energy efficiency requirements. For refrigerated display cabinets these voluntary programs are based on the ISO 23953 standard and are well know from the manufacturers. Those procedures could possibly be adopted in Europe for the measurement of energy efficiency performance of display cabinets.

ANNEXES

Annex 1- 1: Customs Classification

The customs classification ranks the refrigerating equipments in the section XVI, Chapter 84, subchapter 8418:

Section XVI: Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.

Chapter 84: Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof

8418 **Refrigerators, freezers** and **other refrigerating or freezing equipment**, electric or other; heat pumps other than air-conditioning machines of heading (8415)

- **841810** **Combined refrigerator-freezers**, fitted with separate external doors
  - 84181020 Of a capacity exceeding 340 litres
  - 84181080 Other
- **841830** **Freezers** of the chest type, not exceeding 800 litres capacity
  - 84183020 Of a capacity not exceeding 400 litres
  - 84183080 Of a capacity exceeding 400 litres but not exceeding 800 litres
- **841840** **Freezers** of the upright type, not exceeding 900 litres capacity
  - 84184020 Of a capacity not exceeding 250 litres
  - 84184080 Of a capacity exceeding 250 litres but not exceeding 900 litres
- **841850** **Other refrigerating or freezing chests**, **cabinets**, **display counters**, **showcases** and similar refrigerating or freezing furniture
  - a. Refrigerated showcases and counters (incorporating a refrigerating unit or evaporator)
    - 84185011 For frozen food storage
    - 84185019 Other
  - o Other refrigerating furniture
    - 84185091 For deep-freezing, other than that of subheadings 841830 and 841840
    - 8418 50 99 Other

Annex 1- 2: Classification and description of the 24 types of equipments according to the chosen design criteria

- Remote versus plug in product
- Chilled versus frozen product
- Vertical, horizontal or combined product
- Without doors versus with doors product
- Glass doors (transparent) versus solid doors

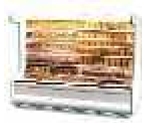
Equipment 1: Product with a **remote condensing unit**, **chilled**, **vertical** and **without doors**

Criterion1: "Remote condensing unit"

Criterion 2: "Chilled"

Criterion 3: "Vertical"

Criterion 4: "Without doors"



Type of equipment:

Remote refrigerated display cabinet for chilled food.

In this category one can find **semi-vertical cabinets.**

Potential locations: Mostly in supermarkets, grocery stores and service stations.

Equipment 2: Product with a **remote condensing unit**, **chilled**, **vertical** and **with solid doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Vertical"

Criterion 4: "With doors"

- Solid doors

Type of equipment:

Remote refrigerated service cabinet for chilled food or **refrigerated catering cabinet** for chilled food.

Potential locations: Probably in the restaurants' kitchens, in cold storages …

Equipment 3: Product with a **remote condensing unit**, **chilled**, **vertical** and **with glass doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Vertical"

Criterion 4: "With doors"

- Glass doors

Type of equipment:

Remote refrigerated display cabinet for chilled food.

Potential locations: Mostly in supermarkets, grocery stores and service stations.

- Equipment 4: Product with a **remote condensing unit**, **chilled**, **horizontal** and **without doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Horizontal"

Criterion 4: "Without doors"

Type of equipment:

Remote refrigerated display cabinet for chilled food.

It can be found as "islands" or "wall site" type.

Potential locations: Mostly in supermarkets, grocery stores and service stations.

- Equipment 5: Product with a **remote condensing unit**, **chilled**, **horizontal** and **with solid doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Horizontal"

Criterion 4: "With doors"

- Solid doors

Type of equipment:

Remote refrigerated service cabinet for chilled food.

Potential locations: Probably in the restaurants' kitchens, in cold storages…

- Equipment 6: Product with a **remote condensing unit**, **chilled**, **horizontal** and **with glass doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Horizontal"

Criterion 4: "With doors"

- Glass doors

Type of equipment:

Remote refrigerated display cabinet for chilled food.

Potential locations: Mostly in supermarkets, grocery stores and service stations.

- Equipment 7: Product with a **remote condensing unit**, **frozen**, **vertical** and **without doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Vertical"

Criterion 4: "Without doors"

Type of equipment:

Remote refrigerated display cabinet for frozen food.

Potential locations: Mostly in supermarkets, grocery stores and service stations.

- Equipment 8: Product with a **remote condensing unit**, **frozen**, **vertical** and **with solid doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "vertical"

Criterion 4: "With doors"

- Solid doors

Type of equipment:

Remote refrigerated service cabinet for frozen food.

Potential locations: Probably in the restaurants' kitchens, in cold storages…

- Equipment 9: Product with a **remote condensing unit**, **frozen**, **vertical** and **with glass doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Vertical"

Criterion 4: "With doors"

- Glass doors

Type of equipment:

Remote refrigerated display cabinet for frozen food.

Potential locations: Mostly in supermarkets, grocery stores and service stations.

- Equipment 10: Product with a **remote condensing unit**, **frozen**, **horizontal** and **without doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Horizontal"

Criterion 4: "Without doors"

Type of equipment:

Remote refrigerated display cabinet for frozen food.

It can be found as "islands" or "wall site" type.

Potential locations: Mostly in supermarkets, grocery stores and service stations.

- Equipment 11: Product with a **remote condensing unit**, **frozen**, **horizontal** and **with solid doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Horizontal"

Criterion 4: "With doors"

- Solid doors

Type of equipment:

Remote refrigerated service cabinet for frozen food.

Potential locations: Probably in the restaurants' kitchens, in cold storages…

- Equipment 12: Product with a **remote condensing unit**, **frozen**, **horizontal** and **with glass doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Horizontal"

Criterion 4: "With doors"

- Glass doors

Type of equipment:

Remote refrigerated display cabinet for frozen food.

Potential locations: Mostly in supermarkets, grocery stores and service stations.

- Equipment 13: Product with a **plug in condensing unit**, **chilled**, **vertical** and **without doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Vertical"

Criterion 4: "Without doors"

Type of equipment:

Plug in refrigerated display cabinet for chilled food.

In this category one can find **semi-vertical cabinets.**

Potential locations: Generally plug in refrigerated equipments will be found in corner stores, service stations, take-away food outlets, bottle shops, hotels, restaurants, pubs …. Self-contained units may also be used in supermarkets to supplement remote refrigerated equipments, particularly where equipments are to used in walkways.

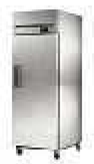
- Equipment 14: Product with a **plug in condensing unit**, **chilled**, **vertical** and **with solid doors**

Criterion 1: “Plug in Condensing Unit”

Criterion 2: “Chilled”

Criterion 3: “Vertical”

Criterion 4: “With doors”



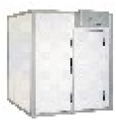
- Solid doors

Types of equipments:

Plug in refrigerated service cabinet for chilled food.

In this category one can find as well:

- The **walk-in cool room**: it is defined as “**a room designed for low temperature storage and generally comprising insulated walls and door sealing to maintain temperatures.**”



And four types of cabinets defined by the Energy Star program requirements for commercial refrigerators with solid doors:

- The **reach-in cabinet**: it is defined as “an upright commercial, self-contained refrigeration cabinet with hinged, solid doors but excluding undercounter, roll-in, roll-through, or pass-through equipments.”
- The **undercounter cabinet**: it is defined as “an upright commercial, self-contained refrigeration cabinet without a worktop surface, with hinged, solid doors and which are intended for installation under a counter.”
- The **roll-in or roll-through cabinet**: it is defined as “an upright, self-contained commercial refrigeration cabinet with hinged, solid doors that allow wheeled racks of product to be rolled into or through the refrigerator or freezer.”

- The **pass-through cabinet**: it is defined as "an upright commercial, self-contained refrigeration cabinet with hinged, solid doors on both the front and rear of the refrigerator or freezer."

Potential locations: Generally in corner stores, hotels, restaurants (kitchens), pubs …. Can also be used in supermarkets where cabinets are to used in walkways (cold storages).

- Equipment 15: Product with a **plug in condensing unit**, **chilled**, **vertical** and **with glass doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Vertical"

Criterion 4: "With doors"

- Glass doors

Types of equipments:

Plug in refrigerated display cabinet for chilled food.

In this category one can find the following equipments:

- The **wine cellar**, defined as a equipment which keeps wine at proper temperature. The bottles should be stored on their sides.

And the special equipment:

- The **vending machine** (specially for beverages), defined, by the US Energy Star Program on "Refrigerated Beverage Vending Machines", as "**a self-contained system designed to accept consumer payments and dispense bottled, canned and other sealed beverages at appropriate temperatures without on-site labor intervention.**"

  The particularity of this equipment is that it is completely closed: it is only opened for filling it. The customers do not need to open it to access the beverages.

  Two main types of vending machines can be distinguished:

  - **The indoor vending machine**: A machine intended for placement inside a building and not subjected to the effects of weathering. This machine is marked "For Indoor Use Only" in accordance with UL Standard 541 "*Refrigerated Vending Machines*."
  - **The outdoor vending machine**: A machine intended for placement outdoors and subjected to the full effects of weathering. This machine is marked "Suitable for Outdoor Use" or "Suitable for Protected Locations" in accordance with UL Standard 541 "*Refrigerated Vending Machines*."

Potential locations: Generally in corner stores, service stations, take-away food outlets, bottle shops, hotels, restaurants, pubs …. Can also be used for some of them in supermarkets to supplement remote refrigerated equipments, particularly where equipments are to used in walkways.

- Equipment 16: Product with a **plug in condensing unit**, **chilled**, **horizontal** and **without doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Horizontal"

Criterion 4: "Without doors"

Type of equipment:

Plug in refrigerated display cabinet for chilled food.

It can be found as "islands" or "wall site" type.

Potential locations: Generally plug in refrigerated cabinets will be found in corner stores, service stations, take-away food outlets, bottle shops, hotels, restaurants, pubs …. They may also be used in supermarkets to supplement remote refrigerated cabinets, particularly where cabinets are to used in walkways.

- Equipment 17: Product with **a plug in condensing unit**, **chilled**, **horizontal** and **with solid doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Horizontal"

Criterion 4: "With doors"

- Solid doors

Type of equipment:

Plug in refrigerated service cabinet for chilled food.

Potential locations: Generally in corner stores, hotels, restaurants (kitchens), pubs …. Can also be used in supermarkets where cabinets are to used in walkways (cold storages).

- Equipment 18: Product with a **plug in condensing unit**, **chilled**, **horizontal** and **with glass doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Horizontal"

Criterion 4: "With doors"

- Glass doors

Type of equipment:

Plug in refrigerated display cabinet for chilled food.

Potential locations: Generally plug in refrigerated cabinets will be found in corner stores, service stations, take-away food outlets, bottle shops, hotels, restaurants, pubs …. They may also be used in supermarkets to supplement remote refrigerated cabinets, particularly where cabinets are to used in walkways.

- Equipment 19: Product with a **plug in condensing unit**, **frozen**, **vertical** and **without doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Vertical"

Criterion 4: "Without doors"

Type of equipment:

Plug in refrigerated display cabinet for frozen food.

Potential locations: Generally plug in refrigerated equipments will be found in corner stores, service stations, take-away food outlets, bottle shops, hotels, restaurants, pubs …. They may also be used in supermarkets to supplement remote refrigerated cabinets, particularly where cabinets are to used in walkways.

- Equipment 20: Product with a **plug in condensing unit**, **frozen**, **vertical** and **with solid doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Vertical"

Criterion 4: "With doors"

- Solid doors

Type of equipment:

Plug in refrigerated service cabinet for frozen food.

As for the remote equipments, one can find in this category:

- The **walk-in cool room**
- The **reach-in cabinet**
- The **undercounter cabinet**
- The **roll-in or roll-through cabinet**
- The **pass-through cabinet**

Potential locations: Generally in corner stores, hotels, restaurants (kitchens), pubs …. Can also be used in supermarkets where cabinets are to used in walkways (cold storages).

- Equipment 21: Product with a **plug in condensing unit**, **frozen**, **vertical** and **with glass doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Vertical"

Criterion 4: "With doors"

- Glass doors

Type of equipment:

Plug in refrigerated display cabinet for frozen food.

Potential locations: Generally plug in refrigerated cabinets will be found in corner stores, service stations, take-away food outlets, bottle shops, hotels, restaurants, pubs …. They may also be used in supermarkets to supplement remote refrigerated cabinets, particularly where cabinets are to used in walkways.

- Equipment 22: Product with a **plug in condensing unit**, **frozen**, **horizontal** and **without doors**

Criterion 1: “Plug in Condensing Unit”

Criterion 2: “Frozen”

Criterion 3: “Horizontal”

Criterion 4: “Without doors”

Type of equipment:

Plug in refrigerated display cabinet for frozen food.

In this category one can find a special cabinet: the **ice cream freezer** defined, by the US Department of Energy, as “a commercial freezer that is designed to operate at or below –5°F (–21°C) and th at manufacturer designs, markets, or intends for the storing, displaying, or dispensing of ice cream.

Potential locations: Generally plug in refrigerated cabinets will be found in corner stores, service stations, take-away food outlets, bottle shops, hotels, restaurants, pubs …. They may also be used in supermarkets to supplement remote refrigerated equipments, particularly where cabinets are to used in walkways.

- Equipment 23: Product with a **plug in condensing unit**, **frozen**, **horizontal** and **with solid doors**

Criterion 1: “Plug in Condensing Unit”

Criterion 2: “Frozen”

Criterion 3: “Horizontal”

Criterion 4: “With doors”

- Solid doors

Type of equipment:

Plug in refrigerated service cabinet for frozen food.

Potential locations: Generally in corner stores, hotels, restaurants (kitchens), pubs …. Can also be used in supermarkets where cabinets are to used in walkways (cold storages).

- Equipment 24: Product with a **plug in condensing unit**, **frozen**, **horizontal** and with **glass doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Horizontal"

Criterion 4: "With doors"

- Glass doors

Type of equipment:

Plug in refrigerated display cabinet for frozen food.

In this category one can also find a special cabinet: the **ice cream freezer.**

Potential locations: Generally plug in refrigerated cabinets will be found in corner stores, service stations, take-away food outlets, bottle shops, hotels, restaurants, pubs …. They may also be used in supermarkets to supplement remote refrigerated equipments, particularly where cabinets are to used in walkways.

- Equipment 25: Product with a **remote condensing unit**, **chilled**, **combined** and with **glass doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Combined"

Criterion 4: "With doors"

- Glass doors

- Equipment 26: Product with a **remote condensing unit**, **chilled**, **combined** and with **solid doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Combined"

Criterion 4: "With doors"

- Solid doors

■ Equipment 27: Product with a **remote condensing unit**, **chilled**, **combined** and **without doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Combined"

Criterion 4: "Without doors"

■ Equipment 28: Product with a **Remote condensing unit**, **frozen**, **combined** and with **glass doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Combined"

Criterion 4: "With doors"

- Glass doors

■ Equipment 29: Product with a **Remote condensing unit**, **frozen**, **combined** and with **solid doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Combined"

Criterion 4: "With doors"

- Solid doors

■ Equipment 30: Product with a **remote condensing unit**, **frozen**, **combined** and with **without doors**

Criterion 1: "Remote Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Combined"

Criterion 4: "Without doors"

Commonly, manufacturers call "combi freezers" open (without doors) when the bottom part (horizontal) is open. Top parts (vertical) are typically fitted with doors.

■ Equipment 31: Product with a **plug in condensing unit**, **chilled**, **combined** and with **glass doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Combined"

Criterion 4: "With doors"

- Glass doors

- Equipment 32: Product with a **plug in condensing unit**, **chilled**, **combined** and with **solid doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Combined"

Criterion 4: "With doors"

- Solid doors

- Equipment 33: Product with a **plug in condensing unit**, **chilled**, **combined** and with **without doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Chilled"

Criterion 3: "Combined"

Criterion 4: "Without doors"

- Equipment 34: Product with a **plug in condensing unit**, **frozen**, **combined** and with **glass doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Combined"

Criterion 4: "With doors"

- Glass doors

- Equipment 35: Product with a **plug in condensing unit**, **frozen**, **combined** and with **solid doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Combined"

Criterion 4: "With doors"

- Solid doors

- Equipment 36: Product with a **plug in condensing unit**, **frozen**, **combined** and **without doors**

Criterion 1: "Plug in Condensing Unit"

Criterion 2: "Frozen"

Criterion 3: "Combined"

Criterion 4: "Without doors"

Annex 1- 3: Other less relevant European Standards on refrigerating systems

Reference	Title
EN 14276-1:2006	Pressure equipment for refrigerating systems and heat pumps - Part 1: Vessels - General requirements
EN 13313:2001	Refrigerating systems and heat pumps - Competence of personnel
EN 12178:2003	Refrigerating systems and heat pumps - Liquid level indicating devices - Requirements, testing and marking
EN 13136:2001	Refrigerating systems and heat pumps - Pressure relief devices and their associated piping - Methods for calculation
EN 1861:1998	Refrigerating systems and heat pumps - System flow diagrams and piping and instrument diagrams - Layout and symbols
EN 12284:2003	Refrigerating systems and heat pumps - Valves - Requirements, testing and marking
EN 12900:2005	Refrigerant compressors - Rating conditions, tolerances and presentation of manufacturer's performance data

Annex 1- 4: Classification of Refrigerated Display Cabinets according to EN ISO 23953

<table>
<tr><th>application</th><th colspan="2">positive temperature</th><th colspan="2">negative temperature</th></tr>
<tr><th>to be used for</th><th colspan="2">chilled foodstuffs</th><th colspan="2">frozen, quick frozen foodstuffs and ice cream</th></tr>
<tr><td rowspan="8">horizontal</td><td>chilled, serve-over counter open service access</td><td>HC1</td><td>frozen, serve-over counter open service access</td><td>HF1</td></tr>
<tr><td>chilled, serve-over counter with integrated storage open service access</td><td>HC2</td><td></td><td></td></tr>
<tr><td>chilled, open, wall site</td><td>HC3</td><td>frozen, open, wall site</td><td>HF3</td></tr>
<tr><td>chilled, open, island</td><td>HC4</td><td>frozen, open, island</td><td>HF4</td></tr>
<tr><td>chilled, glass lid, wall site</td><td>HC5</td><td>frozen, glass lid, wall site</td><td>HF5</td></tr>
<tr><td>chilled, glass lid, island</td><td>HC6</td><td>frozen, glass lid, island</td><td>HF6</td></tr>
<tr><td>chilled, serve-over counter closed service access</td><td>HC7</td><td>frozen, serve-over counter closed service access</td><td>HF7</td></tr>
<tr><td>chilled, serve-over counter with integrated storage closed service access</td><td>HC8</td><td></td><td></td></tr>
<tr><td rowspan="4">vertical</td><td>chilled, semi-vertical</td><td>VC1</td><td>frozen, semi-vertical</td><td>VF1</td></tr>
<tr><td>chilled, multi-deck</td><td>VC2</td><td>frozen, multi-deck</td><td>VF2</td></tr>
<tr><td>chilled, roll-in</td><td>VC3</td><td></td><td></td></tr>
<tr><td>chilled, glass door</td><td>VC4</td><td>frozen, glass door</td><td>VF4</td></tr>
<tr><td rowspan="8">combined</td><td>chilled, open top, open bottom</td><td>YC1</td><td>frozen, open top, open bottom</td><td>YF1</td></tr>
<tr><td>chilled, open top, glass lid bottom</td><td>YC2</td><td>frozen, open top, glass lid bottom</td><td>YF2</td></tr>
<tr><td>chilled, glass door top, open bottom</td><td>YC3</td><td>frozen, glass door top, open bottom</td><td>YF3</td></tr>
<tr><td>chilled, glass door top, glass lid bottom</td><td>YC4</td><td>frozen, glass door top, glass lid bottom</td><td>YF4</td></tr>
<tr><td colspan="3">multi-temperature, open top, open bottom</td><td>YM5</td></tr>
<tr><td colspan="3">multi-temperature, open top, glass lid bottom</td><td>YM6</td></tr>
<tr><td colspan="3">multi-temperature, glass door top, open bottom</td><td>YM7</td></tr>
<tr><td colspan="3">multi-temperature, glass door top, glass lid bottom</td><td>YM8</td></tr>
<tr><td colspan="5">codification

R remote condensing unit
H horizontal
I incorporated condensing unit
V vertical
A assisted service

Y combined
S self service
C chilled
F frozen
M multi-temperature</td></tr>
</table>

The general classification can be used as follows: HC1, VF1, YM5 …

When necessary, the classification can be more precise as follows: RHC1A, IVF1S…

Annex 1- 5: Classification of test room climate and of M-package temperature according to EN ISO 23953

Classification of test room climate class

test room climate class	dry bulb temperature ℃	relative humidity %	Dew point ℃	water vapour mass in dry air g/kg
0	20	50	9.3	7.3
1	16	80	12.6	9.1
2	22	65	15.2	10.8
3	25	60	16.7	12
4	30	55	20	14.8
6	27	70	21.1	15.8
5	40	40	23.9	18.8
7	35	75	30	27.3
8	23.9	55	14.3	10.2

Classification of M-package temperature

Class	the highest temperature of the warmest M-package equal to or lower than	the lowest temperature of the coldest M-package equal to or higher than	the lowest temperature of the warmest M-package equal to or lower than
	℃	℃	℃
L1	-15	-	-18
L2	-12	-	-18
L3	-12	-	-15
M1	5	-1	-
M2	7	-1	-
H1	10	1	-
H2	10	-1	-
S	special classification		

Annex 1- 6: Schedule of prohibition of fluorinated greenhouse gases containing equipment placing on the market

fluorinated greenhouse gases	products and equipment	date of prohibition
fluorinated greenhouse gases	non-refillable containers	4 July 2007
hydrofluorocarbons and perfluorocarbons	non-confined direct-evaporation systems containing refrigerants	4 July 2007
perfluorocarbons	fire protection systems and fire extinguishers	4 July 2007
fluorinated greenhouse gases	windows for domestic use	4 July 2007
fluorinated greenhouse gases	other windows	4 July 2008
fluorinated greenhouse gases	footwear	4 July 2006
fluorinated greenhouse gases	tyres	4 July 2007
fluorinated greenhouse gases	one component foams except when required to meet national safety standards	4 July 2008
Hydrofluorocarbons	Novelty aerosols	4 July 2009

Annex 1- 7: Australian MEPS –Cabinets MEPS and High Efficiency Levels AS1731[52]

Remote commercial refrigerated cabinets (tests conducted under climate Class 3)

Type	MEPS Maximum energy consumption TEC/TDA (kWh/day/m2)	High Efficiency Level Maximum energy consumption TEC/TDA (kWh/day/m2)
RS 1 - Unlit shelves	12.55	8.37
RS 1 - Lit shelves	17.76	10.66
RS 2 - Unlit shelves	12.73	8.49
RS 2 - Lit shelves	16.98	11.32
RS 3 - Unlit shelves	14.84	10.32
RS 3 - Lit shelves	18.39	12.26
RS 4 - Solid door	no value	no value
RS 4 - Glass door	9.73	6.77
RS 5 - Solid door	no value	no value
RS 5 - Glass door	no value	no value
RS 6 - Gravity coil	14.21	9.88
RS 6 - Fan coil	14.16	9.85
RS 7 - Gravity coil	no value	no value
RS 7 - Fan coil	14.79	9.86
RS 8 - Gravity coil	12.25	8.52
RS 8 - Fan coil	13.19	9.17
RS 9 - Gravity coil	no value	no value
RS 9 - Fan coil	12.09	8.06
RS 10 - High	no value	no value
RS 10 - Medium	no value	no value
RS 10 - Low	18.67	12.99
RS 11	38.13	26.52
RS 12	66.33	46.14
RS 13 - Solid sided	19.48	12.99
RS 13 - Glass sided	19.58	13.62
RS 14 - Solid sided	15.49	11.45
RS 14 - Glass sided	37.08	12.86
RS 15 - Solid door	no value	no value
RS 15 - Glass door	37.08	27.41
RS 16 - Solid door	no value	no value
RS 16 - Glass door	40.56	29.98
RS 17 - Solid door	no value	no value
RS 17 - Glass door	no value	no value
RS 18	48.58	39.75
RS 19	36.15	29.57
RS 20	no value	no value

[52] http://www.energyrating.gov.au/commrefrig2.html

Plug in refrigerated display cabinets (tests conducted under climate Class 3)

Maximum energy consumption TEC/TDA (kWh/day/m2)					
Type	**M-package temperature classes (See AS1731.6 Clause 5)**		**Type**	**M-package temperature classes (See AS1731.6 Clause 5)**	
	M1	**M2**		**L1**	**L2**
HC1	11.5	11.5	HF1	no value	no value
HC2	no value	no value	HF2	no value	no value
HC3	no value	no value	HF3	no value	no value
HC4	15.5	15.5	HF4	26.5	26.5
HC5	no value	no value	HF5	no value	no value
HC6	no value	no value	HF6	8	8
VC1	37.5	28	VF1	no value	no value
VC2	27	25.5	VF2	no value	no value
VC3	no value	no value	VF3	no value	no value
VC4 (a) Solid door (b) Glass door	 17 17	 17.5 17.5	VF4 (a) Solid door (b) Glass door	 44 44	 39 39
YC1	no value	no value	YF1	no value	no value
YC2	no value	no value	YF2	no value	no value
YC3	no value	no value	YF3	no value	no value
YC4	no value	no value	YF4	no value	no value

"High efficiency" plug in refrigerated display cabinets (tests conducted under climate Class 3)

Maximum energy consumption TEC/TDA (kWh/day/m2)					
Type	**M-package temperature classes (See AS1731.6 Clause 5)**		**Type**	**M-package temperature classes (See AS1731.6 Clause 5)**	
	M1	**M2**		**L1**	**L2**
HC1	8.5	8.5	HF1	no value	no value
HC2	no value	no value	HF2	no value	no value
HC3	no value	no value	HF3	no value	no value
HC4	11.4	11.4	HF4	19.5	19.5
HC5	no value	no value	HF5	no value	no value
HC6	no value	no value	HF6	5.9	5.9
VC1	27.6	20.6	VF1	no value	no value
VC2	19.9	18.8	VF2	no value	no value
VC3	no value	no value	VF3	no value	no value
VC4 (a) Solid door (b) Glass door	 7.30 10.7	 7.30 10.7	VF4 (a) Solid door (b) Glass door	 32.40 32.40	 28.70 28.70
YC1	no value	no value	YF1	no value	no value
YC2	no value	no value	YF2	no value	no value
YC3	no value	no value	YF3	no value	no value
YC4	no value	no value	YF4	no value	no value

Annex 1- 8: Classification of Refrigerated Cabinets: AS1731

Classification of remote refrigerated cabinets (Medium Temp)

Name	Australian Class	Definition	Subclass	
high open multi deck	RS1	Medium temperature multideck, single air curtain, length of air curtain 1.5-1.9m. Cabinet height 2.2-2.5m and depth 0.6-1.2m.	lit shelves	unlit shelves
medium open multi deck	RS2	Medium temperature multideck, single air curtain, length of air curtain 1.0-1.5m. Cabinet height 1.8-2.19m and depth 0.6-1.2m.	lit shelves	unlit shelves
low open multi deck	RS3	Medium temperature multideck, single air curtain, length of air curtain 0.8-1.2m. Cabinet height 0-1.79m and depth 0.6-1.2m.	lit shelves	unlit shelves
self service and storage closed cabinet	RS4		solid door	glass door
self service and storage closed cabinet-undercounter	RS5		solid door	glass door
flat glass fronted - single deck	RS6	Medium temperature single tier cabinet with a flat front glass and a sliding door service access to the rear. Cabinet height 1.25-1.4m, depth 0.8-1.2m. Cabinets are dividing into two subclasses on the basis of their evaporator coil arrangements.	gravity coil	fan coil
flat glass fronted - 2 tier or more	RS7	Medium temperature two or more tier cabinet with a flat front glass and a sliding door service access to the rear. Cabinet height 1.25-1.4m, depth 0.8-1.2m. Cabinets are dividing into two subclasses on the basis of their evaporator coil arrangements.	gravity coil	fan coil
curved glass fronted - single deck	RS8	Medium temperature single tier cabinet with a curved front glass and a sliding door service access to the rear. Cabinet height 1.25-1.4m, depth 0.8-1.2m. Cabinets are dividing into two subclasses on the basis of their evaporator coil arrangement	gravity coil	fan coil
curved glass fronted - 2 tier or more	RS9	Medium temperature two or more tier cabinet with a curved front glass and a sliding door service access to the rear. Cabinet height 1.25-1.4m, depth 0.8-1.2m. Cabinets are dividing into two subclasses on the basis of their evaporator coil arrangements.	gravity coil	fan coil
island/walk around merchandiser	RS10	High, Cabinet height 2.2-2.5m Medium, Cabinet height 1.8-2.19m Low, Cabinet height 1.0-1.79m	High /medium /low	

Classification of remote refrigerated cabinets (Low Temp)

Name	Australian Class	Definition	Subclass	
medium open multi deck	RS11	Low temperature multideck, length of air curtain 1.0-1.5m. Cabinet height 1.8-2.19m and depth 0.6-1.2m.	N/A	
low open multi deck	RS12	Low temperature multideck, length of air curtain 0.6-1.0m. Cabinet height 1.0-1.79m and depth 0.6-1.2m.	N/A	
well-type, single width cabinet	RS14	Low temperature, well type self service cabinet, open with horizontal air curtain, length of air curtain 0.75-0.85m.	solid door	glass door
well-type double width cabinet	RS15	Low Temp, Cabinet height 2.2-2.8m depth 0.6-1.2m	solid door	glass door
high self service and storage closed cabinet	RS16	Low Temp, Cabinet height 1.8-2.19m depth 0.6-1.2m	solid door	glass door
medium self service and storage closed cabinet	RS17	Low temp, Cabinet height 0-1.79m and depth 0.6-1.2m	solid door	glass door
low self service and storage closed cabinet	RS18	N/A	solid door	glass door
combination glass door over and well under	RS19	N/A	N/A	
high self service island closed cabinet	RS20	Low Temp, Cabinet height 2.2-2.8m depth 1.9-2.1m. Glass Door	N/A	
medium self service island closed cabinet	RS21	Low Temp, Cabinet height 1.8-2.19m depth 1.9-2.1m. Glass door	N/A	

Annex 1- 9 : ARI Certification related Basic Model Groups and definitions[53]

The ARI 1200 program defines 6 Basic Model Groups or Product categories from which the manufacturer (participant) must chose from when certifying one of his products:

- Vertical Multi-Deck, Display or Storage
- Vertical Multi-Deck with Doors, Display or Storage
- Semi-Vertical Multi-Deck, Display or Storage
- Service Over Counter, Display or Storage
- Horizontal, Display or Storage
- Horizontal with Doors, Display or Storage

Definition of Vertical Multi-Deck, Display or Storage Product Family.

Vertical multi-deck Product Family are defined as refrigerated display merchandisers or storage cabinets with multiple levels or shelves stacked vertically for the display or storage of food product.

Definition of Vertical Multi-Deck with Doors, Display or Storage Product Family.

Vertical multi-deck with doors Product Family is defined as refrigerated display merchandisers or storage cabinets with solid or transparent doors and multiple levels or shelves stacked vertically for the display or storage of food product.

Definition of Semi-Vertical Multi-Deck, Display or Storage Product Family.

Semi-vertical multi-deck Product Family is defined as refrigerated display merchandisers or storage cabinets with multiple cascading levels or shelves stacked vertically for a cascading presentation or storage of food product.

Definition of Service Over Counter, Display or Storage Product Family.

Service over counter Product Family are defined as refrigerated display merchandisers or storage cabinets that are enclosed with one or multiple levels or shelves and have access openings or doors in the rear. The display merchandisers and storage cabinets in this Product Family provide a visual presentation of food product from the front of the unit, and require another person to access the food product from the rear.

Definition of Horizontal, Display or Storage Product Family.

Horizontal Product Family is defined as refrigerated display merchandisers or storage cabinets with a single level or bin area for the display or storage of food product.

Definition of Horizontal with Doors, Display or Storage Product Family.

[53] Source: *Commercial Refrigerated Display Merchandisers and Storage Cabinets Certification Program Operation Manual.* Air-Conditioning and Refrigeration Institute (March 2006)

Horizontal with doors Product Family is defined as refrigerated display merchandisers or storage cabinets with solid or transparent doors with a single level or bin area for the display or storage of food product.

Each member of a Product Family consists of a specific product model, operating mode and operating temperature.

Product Model Operating Mode

The participant must define the product model operating modes for each specific product model (unit) submitted for certification. The product model operating mode must be defined when selecting a participant's unit for annual random testing and evaluation. The following are the defined product model operating modes covered within the scope of this program.

- Remote
- Self-Contained

Definitions of Product Model Operating Modes.

Remote

Remote is defined as the mode in which a refrigerated unit operates with a condensing unit or refrigeration system not mounted in or on the unit.

Self-Contained

Self-contained is defined as the mode in which a refrigerated unit operates with a condensing unit or refrigeration system mounted in or on the unit.

Product Model Operating Temperature.

The participant must define the product model operating temperature for each unit submitted for certification. The product model operating temperature must be defined when selecting a participant's unit for annual random testing and evaluation. The following are the defined product model operating temperatures covered within the scope of this program.

- Medium Temperature
- Low Temperature
- Ice Cream Temperature
- Application Temperature

Definitions of Product Model Operating Temperatures within a Model Group.

Medium Temperature

Medium temperature is defined as the operating temperature of a refrigerated unit that maintains an integrated average product temperature as defined in ARI 1200 for medium temperature applications.

Low Temperature.

Low temperature is defined as the operating temperature of a refrigerated unit that maintains an integrated average product temperature as defined in ARI 1200 for low temperature applications.

Ice Cream Temperature.

Ice Cream temperature is defined as the operating temperature of a refrigerated unit that maintains an integrated average product temperature as defined in ARI 1200 for ice cream temperature applications.

Application Temperature.

Application temperature is defined as the operating temperature of a refrigerated unit that maintains an integrated average product temperature as defined in ARI 1200 for application product temperature.

Annex 1- 10: Mandatory criteria for the ProCool competition

	Mandatory criteria	Definition		
M1	appliance category	**the plug in appliance must belong to one of the following categories:**		
		AC1 refrigerator with glass door, vertical (IVC4 according to EN 23953-1)		
			climate class	3 or 4
			temperature class	H1
			net volume	250-600 litres
		AC2 refrigerated cabinets (shelves), vertical (IVC2 according to EN 23953-1)		
			climate class	3
			temperature class	M2
			total display area	1.5 - 4m2, ratio of TDA to net volume must be between 3.3 and 4.5
		AC3 refrigerators, open, horizontal for packaged convenience-food (IHC3/IHC4 according to EN 23953-1) no counter for unpackaged food		
			climate class	3
			temperature class	M1
			total display area	0.5-2m2, ratio of TDA to net volume must be between 3.3 and 4.5
		AC4 freezer with glass lid, closed, horizontal, no flip-flop-lids (IHF5/IHF6 according to EN 23953-1)		
			climate class	3 or 4
			temperature class	L1
			net volume	150-350 litres
		AC5 freezer with glass lid, closed, horizontal (IHF5/IHF6 according to EN 23953-1)		
			climate class	3
			temperature class	L1
			net volume	>350-800 litres
		total display area (TDA) and temperature classes are defined according to prEN ISO 23953		
M2	energy consumption	**Energy consumption of appliances must not exceed the following threshold values per 24 hours**		
		AC1	0.45kWh/100lx24h, reference temperature +5°C	
		AC2	7kWh/m2 TDAx24h, reference temperature +5°C	
		AC3	4.5kWh/m2 TDAx24h, reference temperature +3°C	
		AC4	0.55kWh/100lx24h, reference temperature -18°C	
		AC5	0.8kWh/100lx24h, reference temperature -18°C	
M3	HFC-free	**Refrigerants, insulation foaming agents and lubricants must be free of HFCs (GWP100<20)**		
M4	lighting	**Electronic ballasts must be used (or LED)**		
M5	temperature-display	**Easily visible temperature display, tolerance ±0.5°C**		
M6	noise emission	**Noise emissions (acoustic pressure) must not be higher than 50dB**		
		Measuring point		
		wall site appliances:	1.5m above ground. Distance from appliance 1m from the middle of the front side	
		Island appliances	Measurement on all 4 sides and calculation of average value. 1.5m above ground. Distance from appliance 1m from the middle of all 4 sites	
M7	functionality and display of food	The appliance must be designed for a proper presentation of food in the commercial sector. There must be no condensation in the closed appliance categories		
M8	operating instructions	operating instructions must contain information about ecofriendly use, setup and maintenance of the appliance		
M9	availability on the market	The appliance must be available on the market after the competition. It can be ordered from February 2006 onwards and can be delivered until September 2006 the latest. The appliance must not be available on the market before the end of the competition (30th November 2005). This means that only newly developed products are accepted for submission.		

Annex 1- 11: ECA technology criteria list – Performance threshold for refrigerated display cabinets[54]

TEC=Total Energy Consumption in kWh/day
TDA=Total Display Area in square meters
“<=” means “less than or equal to”

Note: All classes are as per EN441, except M0, which is based upon recommendations from the British Refrigeration Association

Table 10-1: Cabinet temperature classes. Maximum temperatures must not be exceeded, even in periods of defrost

Class	the highest temperature of the warmest M-package equal to or lower than	the lowest temperature of the coldest M-package equal to or higher than	the lowest temperature of the warmest M-package equal to or lower than
	℃	℃	℃
L1	-15	-	-18
L2	-12	-	-18
L3	-12	-	-15
M0	4	-1	-
M1	5	-1	-
M2	7	-1	-
H1	10	1	-
H2	10	-1	-
S	special classification		

Table 10-2: Performance thresholds for integral cabinets

temperature class	performance threshold
L1	(TEC)/(TDA)≤19.10 kWh/day/m^2
M0	(TEC)/(TDA) ≤14.70 kWh/day/m^2
M2	(TEC)/(TDA) ≤12.70 kWh/day/m^2
H2	(TEC)/(TDA) ≤9.2 kWh/day/m^2

Table 10-3: Performance thresholds for remote cabinets

temperature class	performance threshold
L1	(TEC) / (TDA) ≤23.50 kWh/day/m^2
L3	(TEC) / (TDA) ≤21.00 kWh/day/m^2
M0	(TEC) / (TDA) ≤11.75 kWh/day/m^2
M1	(TEC) / (TDA) ≤11.75 kWh/day/m^2
M2	(TEC) / (TDA) ≤10.85 kWh/day/m^2
H1	(TEC) / (TDA) ≤8.00 kWh/day/m^2
H2	(TEC) / (TDA) ≤9.20 kWh/day/m^2

[54] Energy Technology Criteria List(2006) http://www.eca.gov.uk/etl/download/ETCL%202006%20(final%20Copy)%20for%20DEFRA.pdf

2. ECONOMIC AND MARKET ANALYSIS

This document is the task 2 report of the lot 12 EuP preparatory study on commercial refrigerators and freezers. The purpose of this task is first to assess general consumption and trade figures, using the PRODCOM data. In second instance, it provides market and cost inputs for the EU-25 wide environmental impact analysis of this product group. Thirdly it aims at providing insights to the market trends in order to identify the market structure in relation with the trends in product design. Such trends will be an input for the subsequent tasks such as improvement potential (tasks 6 and 7). Finally, practical data on consumer prices and rates is provided to be used later in the study in Life Cycle Cost (LCC) calculations.

2.1. GENERIC AND ECONOMIC DATA

The Eurostat database[1] contains market data:

- per number of units and per value (€)
- for the EU-25 or per country
- per year since 1995

The products listed in Eurostat are based on the PRODCOM classification. Following are the PRODCOM product categories which could be relevant to the lot 12:

29.23.13.33: Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage

29.23.13.35: Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator (excluding for frozen food storage)

29.23.13.40: Deep-freezing refrigerating furniture (excluding chest freezers of a capacity <= 800 litres, upright freezers of a capacity <= 900 litres)

29.23.13.50: Refrigerating furniture (excluding for deep-freezing show-cases and counters incorporating a refrigerating unit or evaporator)

The PRODCOM statistics have the advantage of being the official EU-source that is also used and referenced in other EU policy documents regarding trade and economic policy, guaranteeing EU consistency. However, it can be seen that this classification is not detailed enough and may not cover all the products identified in task 1.

In the MEEuP Methodology report[2] reservations about the reliability of the PRODCOM data were already expressed and the significance of these results should not be overrated.

[1] Data retrieved on the Eurostat website at http://epp.Eurostat.ec.Europa.eu on 2006/12/12

Table 2-1 gives an overview of the production, imports, and exports for the four identified categories in units and million Euros for the EU-25.

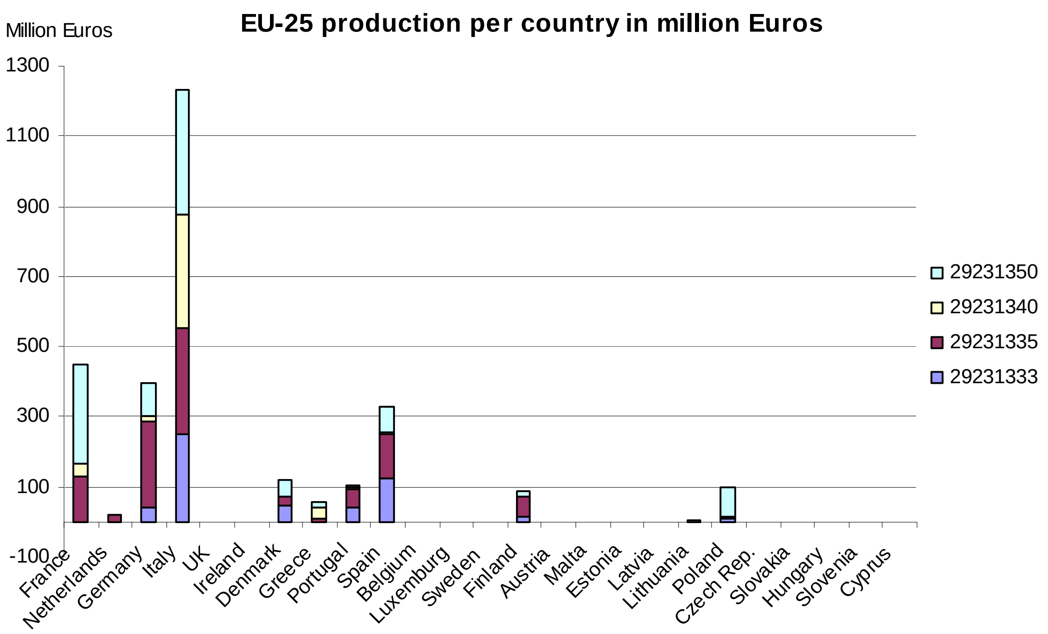
Table 2-1: Overview of the main Eurostat results - Generic economic data

PRODCOM	29231333		29231335		29231340		29231350	
EU-25, 2005	M. unit	M. Euro	M. unit	M. Euro	M. unit	M. Euro	M. unit	M. Euro
Production	0.47	611.96	0.74	1,207.53	0.61	433.57	1.04	1,076.69
Imports	0.05	20.75	0.42	155.29	0.05	8.73	1.72	79.55
Exports	0.16	82.50	0.78	412.95	0.05	25.84	0.32	187.08
App. Cons.	0.36	550	0.38	950	0.6	416	2.44	970

2.1.1 EU PRODUCTION

Annex 2-1 provides PRODCOM data for the EU-25 production of the 4 categories of refrigerators and freezers mentioned above for the year 2005. The most recent year for which data is available is 2005. It is also the year presenting the less blanks, confidential, estimated, or suppressed data. The aggregated estimates for the whole EU-15 and EU-25 are also from the PRODCOM database.

Figure 2-1 : Commercial refrigeration equipment EU-25 production (2005)



The production volume in EU-25 for the combined 4 categories is 2.9 million units corresponding to a total production value of € 3,330 million. Figure 2-1

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[2] Reference: VHK. *Methodology Study Eco-Design of Energy Using Products.* For the European Commission Directorate General of Energy and Transport. (2005) Available at http://ec.europa.eu/enterprise/eco_design/finalreport1.pdf

gives the distribution per countries. The PRODCOM data is not complete and some countries appear to have no production activity although it is not the case.

2.1.2 EU TRADE

2.1.2.1 EU IMPORTS AND EXPORTS

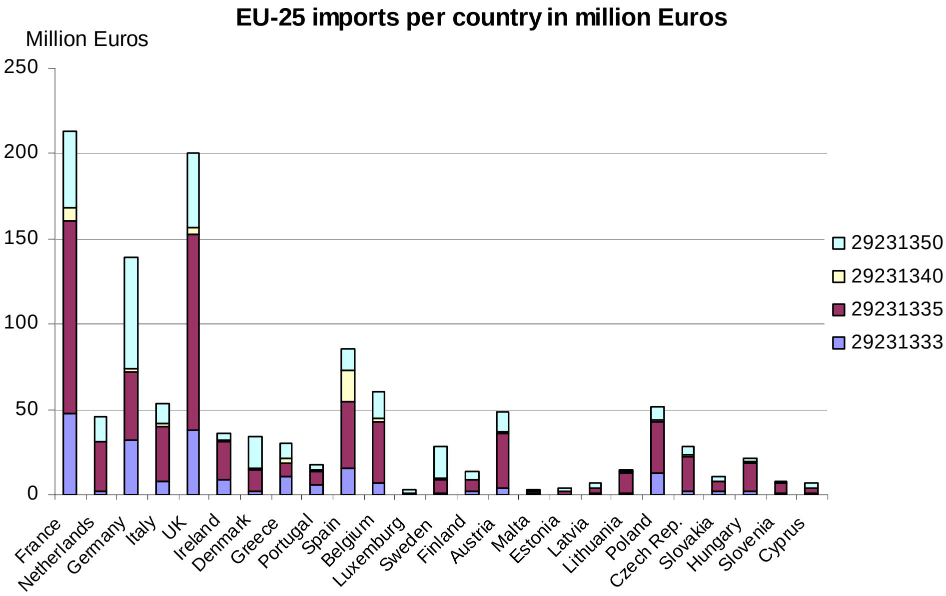
Annex 2-2 and Annex 2-3 present the Eurostat PRODCOM data on intra- and extra- EU-25 imports and exports for the 4 identified categories of products (29.23.13.33. 29.23.13.35. 29.23.13.40. 29.23.13.50[3]) per country and for the EU-25 as a whole.

Annex 2-2 shows that the total 2005 EU-25 imports of commercial refrigeration equipment amounted € 264.3 million which represents 27 % of the total import/export and 8 % of EU 2005 production value. The total EU-25 exports amounted € 708.4 million which represents 73 % of the total import/export and 21.3% of EU 2005 production value (Annex 2-3).

Figure 2-2 and Figure 2-3 present the imports and exports distribution per country in thousand units.

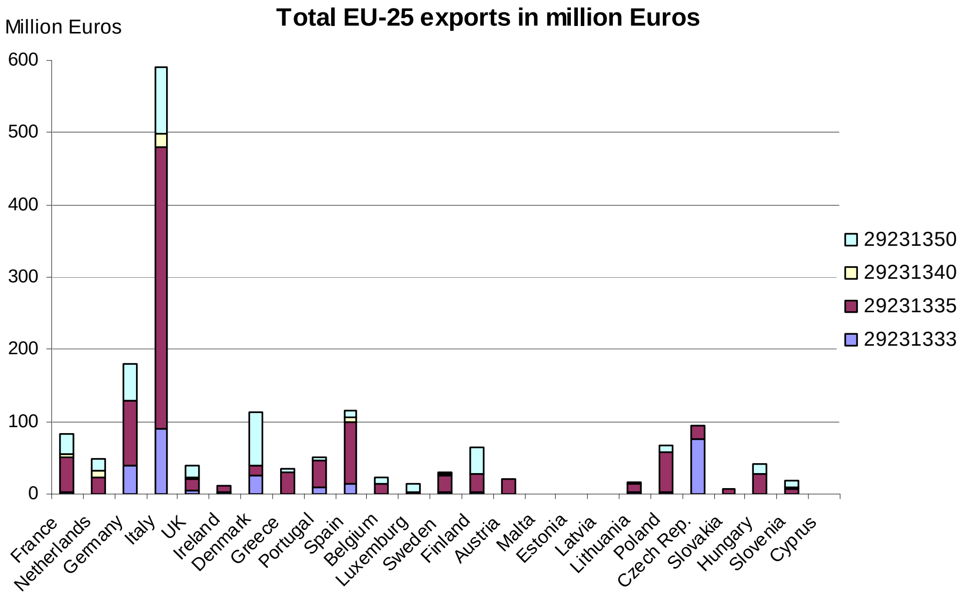
[3] 29.23.13.33: Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage
29.23.13.35: Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator (excluding for frozen food storage)
29.23.13.40: Deep-freezing refrigerating furniture (excluding chest freezers of a capacity <= 800 litres, upright freezers of a capacity <= 900 litres)
29.23.13.50: Refrigerating furniture (excluding for deep-freezing show-cases and counters incorporating a refrigerating unit or evaporator)

Figure 2-2: Commercial refrigeration equipment EU-25 imports[4] (2005)



[4] 29.23.13.33: Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage
29.23.13.35: Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator (excluding for frozen food storage)
29.23.13.40: Deep-freezing refrigerating furniture (excluding chest freezers of a capacity <= 800 litres, upright freezers of a capacity <= 900 litres)
29.23.13.50: Refrigerating furniture (excluding for deep-freezing show-cases and counters incorporating a refrigerating unit or evaporator)

Figure 2-3: Commercial refrigeration equipment EU-25 Exports (2005)



2.1.2.2 EU EXTRA-TRADE

On the Eurostat database, the breakdown of the imports and exports into intra and extra EU-25 data is given according to the Harmonised System (HS) classification or according to the Combined Nomenclature (CN). Table 2-2 gives the equivalence between the PRODCOM, the HS and CN classifications.

Table 2-2: Equivalence between the PRODCOM, HS, and CN classifications

<table>
<tr><th>PRODCOM</th><th>Designation</th><th>HS</th><th>CN</th></tr>
<tr><td>29.23.13.33</td><td>Refrigerated showcases and counters incorporating a refrigerating unit or evaporator for frozen food storage</td><td rowspan="4">8418.50</td><td>8418.50.11</td></tr>
<tr><td>29.23.13.35</td><td>Refrigerated showcases and counters incorporating a refrigerating unit or evaporator (excluding for frozen food storage)</td><td>8418.50.19</td></tr>
<tr><td>29.23.13.40</td><td>Deep-freezing refrigerating furniture (excluding chest freezers of a capacity ˜ 800 litres. upright freezers of a capacity ˜ 900 litres)</td><td>8418.50.91</td></tr>
<tr><td>29.23.13.50</td><td>Refrigerating furniture (excluding for deep freezing showcases and counters incorporating a refrigerating unit or evaporator)</td><td>8418.50.99</td></tr>
</table>

Annex 2-4 and, Annex 2-5 present breakdown of the extra EU-25 imports and exports by country of destination and of provenance according to the Eurostat Combined Nomenclature (CN) data.

The total extra EU-25 imports and extra EU-25 exports for 2005 for the 4 CN categories amounted respectively € 135.7 million (51% of the total intra and extra EU-25 imports) and € 520.8 million (73 % of the total intra and extra EU-25 exports).

The main countries of origin of imported commercial refrigeration equipment in EU-25 are China, Turkey, Romania and the US (see Figure 2-4). The main countries of destinations for exported EU-25 commercial refrigeration equipment are Russia, Switzerland, Norway and the US (see Figure 2-5).

Figure 2-4: Extra-EU imports per major country of provenance (2005)

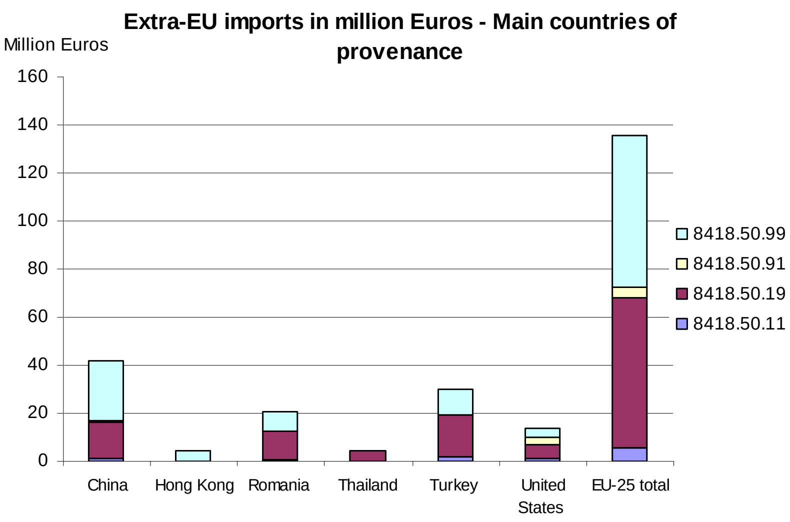
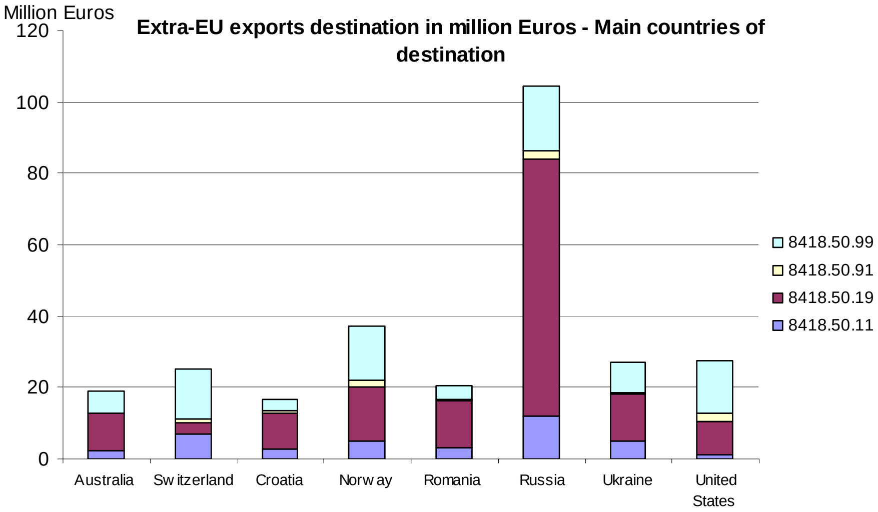


Figure 2-5: Extra-EU exports per major country of destination (2005)[5]



[5] 8418.50.11: Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator for frozen food storage
8418.50.19: Refrigerated show-cases and counters incorporating a refrigerating unit or evaporator (excluding for frozen food storage)
8418.50.91: Deep-freezing refrigerating furniture (excluding chest freezers of a capacity <= 800 litres, upright freezers of a capacity <= 900 litres)
8418.50.99: Refrigerating furniture (excluding for deep-freezing show-cases and counters incorporating a refrigerating unit or evaporator)

2.1.3 APPARENT EU CONSUMPTION

Annex 2-6 shows the apparent consumption (defined as production + imports - exports) of commercial refrigerators and freezers as calculated from the official Eurostat data. The total EU-25 apparent consumption for the year 2005 is estimated to € 2,890 million.

However, the poor quality of these data can be observed here, for example, many countries show negative consumption, which is not realistic. Hence, these datasets will not be used for lot 12 and instead the stock data will be calculated using sales data from manufacturers, as presented in the next section.

2.2. MARKET AND STOCK DATA

In order to arrive at more reliable data, the Eurostat data has to be supplemented by market analysis of specialised market research firms and data from sector specific databases as supplied by stakeholders.

2.2.1 STOCK DATA

2.2.1.1 CURRENT STOCK

An overview of the current EU-25 stock of commercial refrigerators and freezers is given in Table 2-3. **Erreur ! Source du renvoi introuvable.** gives the share of each category of products (in units).

Table 2-3: EU-25 stock of products covered in the scope of the Lot 12

Product category	Stock (units)
Remote refrigerated display cabinets (for year 2006)	2,150,000
Plug in refrigerated display cabinets – supermarket segment (for year 2006)	1,900,000
Beverage coolers – Food and beverage segment (for year 2006)	6,320,000
Ice cream freezers – Food and beverage segment (for year 2006)	2,710,000
Cold vending machines (for year 2004)	1,160,000

- **Remote refrigerated display cabinets**

Most of the data for the remote refrigerated display cabinets are the result of a survey among 5 members of EUROVENT (5 major remote refrigerated display cabinet manufacturers, referred to as the “EUROVENT survey” in the rest of the study).

More than 2 million units are currently in use in the EU-25.

The number of remote refrigerated display cabinets in operation in EU-25 according to the EUROVENT survey for the years 2004 to 2006 is presented in the following table (Table 2-4).

Table 2-4: Remote refrigerated display cabinets in operation in EU-25 per year

Year	Stock (000 unit)
2004	2,033
2005	2,083
2006	2,152

According to EUROVENT, the shares of the different categories of product belonging to the remote display cabinet family sold in EU-25 for the year 2006 are given in Table 2-5. The open vertical chilled cabinets (semi-vertical. multi-deck and roll-in) represent the most important market segment in the remote cabinet family.

Table 2-5 : EUROVENT estimation of the share of each product category

Product category	Eurovent classification	% of units sold belonging to this product category (2006)
Multi-decks & semi-verticals	RVC1/RVC2/RVC3	61
Counters: service & self service	RHC1/RHC2/RHC7/RHC8/RHF1/RHF7	16
Frozen food islands	RHC3 to RHC6 & RHF3 to RHF6	13
Glass doors & frozen multi-decks/SV	RVF4 & RVC4 + VF1 & VF2	4
Combis	RYC1 to RYC4 & RYF1 to RYF4	6
Total		100

More specifically, open RCV2 (vertical chilled open multi decks) were estimated to represent about 55 % of the remote refrigeration appliances on the market. RHF4 were identified as being the second most common product group totalling almost 13 % of the installed remote appliances in EU.

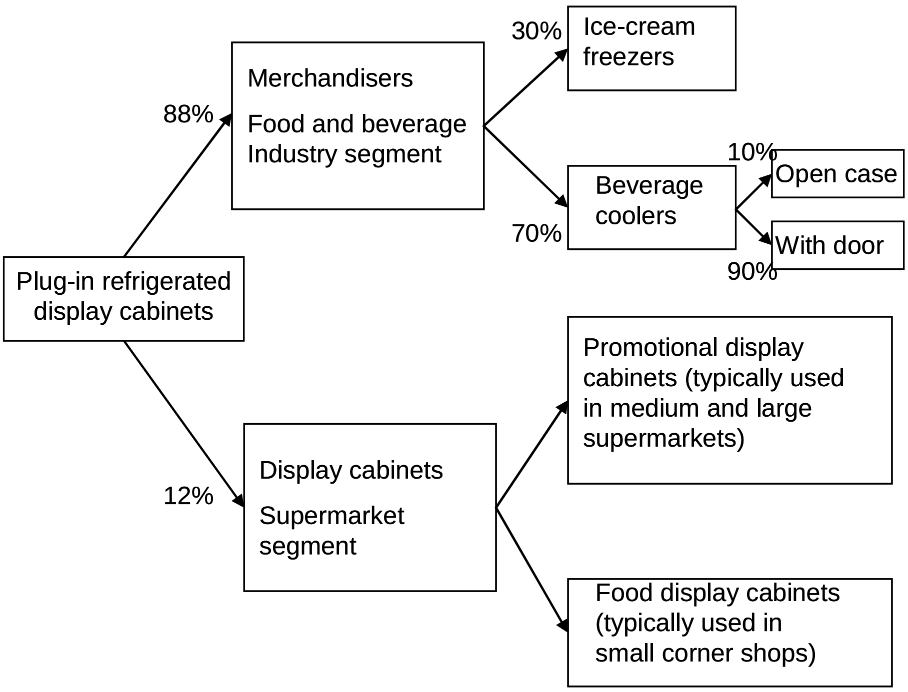
- **Plug in refrigerated display cabinets**

The plug in refrigerated display cabinet segment is highly fragmented and there is a large variety of products produced by manufacturers from very different market application e.g. for the supermarket segment, for beverage and ice cream companies, for small bars/restaurants.

Further, the plug in segment includes various products such as refrigerated food display cabinets (similar to remote display cabinets except the refrigeration unit is self-contained) and glass door merchandisers (also known as beverage coolers or ice cold merchandisers) which are commonly used in convenience stores, aisle locations in supermarkets, and some retail stores and small foodservice establishments. Beverage coolers represent the largest proportion of the plug in refrigerated display cabinets.

This diversity of manufacturers and products make it difficult to constitute a global market data for these products. Figure 2-6 shows the main actors in the plug in display cabinet market. The organisation of the market is linked to the different business segments: the food and beverage industries on one side and the retailers on the other (supermarket segment, non branded equipment).

Figure 2-6: Market fragmentation for the plug in segment



Using estimates of the sales for the beverage cooler segment from manufacturers (cf. section 2.2.2.1.) and an average lifespan of 8 years, the stock for the year 2006 is estimated to 6.3 million units. 10 % of the stock is represented by open beverage coolers and 90 % by beverage coolers with glass door(s).

These estimations seem realistic as another source[6] which estimates the number of "Hermetic group in stand alone equipment[7]" to 6,400,700 units for Europe in 2002 (EU 15).

Estimates evaluate the share of the beverage coolers to about two thirds of the plug in of the food and beverage segment and the number of ice cream freezers in stock can be estimated to about 2.7 million units in 2006.

The supermarket segment represents a smaller portion of the plug in appliances. Approximately 1.9 million units were in operation in 2006[8]. The supermarket segment can be defined by retailers including: hypermarkets,

[6] Reference: United Nation Environment Programme (UNEP). *Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee (RTOC).* (2002)

[7] Stand-alone equipment consists of systems where all the components are integrated: wine coolers, beer machines, ice cream machines, beverage vending machines, and all kind of stand-alone display cases.

[8] Figure based on estimates from multiple manufacturers

supermarkets, small supermarket, convenience stores and petrol stations. It mostly includes IVC2 and open IHF4[9] type cabinets.

Cold vending machines

The stock of vending machines has been determined for thirteen European countries (Table 2-6). According to the European Vending Association these thirteen European countries represent about 90 % of the total EU market. Italy, France, The United Kingdom, Germany, Spain and The Netherlands covering more than 80 % of the European market by themselves.

Based on this estimation, the total EU-25 stock is estimated to 3.3 million units for EU-25 in 2004. Furthermore, the share of refrigerated and frozen vending machines is estimated to 35 %[10]. With such estimation, the stock of cold vending machines can be assumed to be 1,156,620 units in Europe for 2004. This data seems in-line with similar data from other sources[11].

Table 2-6: Total vending machines stock per country[12]

Country / Year	1998	1999	2000	2001	2002	2003	2004
Austria						67,550	76,080
Czech Rep.						6,206	12,000
France	438,000		533,000		580,000	593,000	593,000
Germany					441,000	477,000	502,000
Netherlands				168,663			200,000
Hungary				13,138		29,000	33,000
Italy			611,063				613,650
Poland							7,000
Portugal							50,650
Slovakia							7,070
Spain							278,800
Sweden					81,310	84,700	88,000
Switzerland				81,500		84,400	81,500
UK	418,537	448,801	471,633	494,777	501,637	510,911	510,911*
Total estimated							3,055,665
No data for Belgium & Denmark							

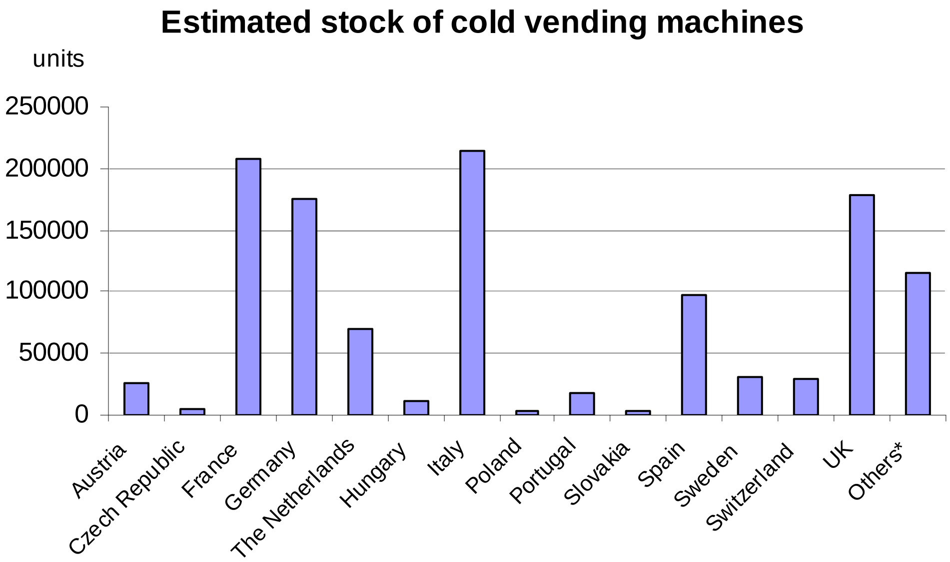
[9] Respectively a chilled multi deck and a horizontal chest freezer according to the Eurovent classification

[10] Reference: EVA

[11] Estimation is similar to the one figuring in the UNEP 2002 report by the Refrigeration, Air Conditioning and Heat Pumps Option Committee where the total stock of cold vending machines in Europe in 2002 (EU 15) was evaluated to 1,189,000 units

[12] Source: European Vending Association http://www.eva.be/main.html. It includes vending machines for hot beverages, Cans & Bottles, and Snack & food.

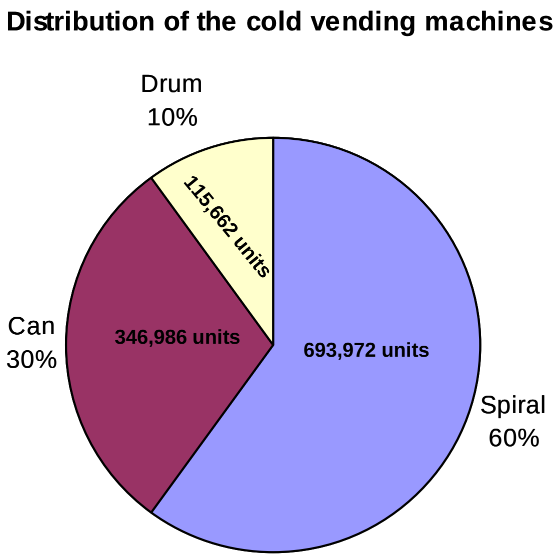
Figure 2-7: Estimated stock of cold vending machines per country (2004)



* Denmark, Greece, Belgium, Luxembourg, Finland, Malta, Estonia, Latvia, Lithuania, Slovenia, Cyprus

The cold vending machines segment is distributed as following: 55-60 % of the cold vending machines are spiral machines (for snacks and drinks), 30 % are bottled and canned beverage machines and 10-15 % are drum machines. A more precise description of the different types of vending machines is presented in task 4. For the inputs of the EcoReport Tool, the values in Figure 2-8 will be assumed.

Figure 2-8: Cold vending machine distribution per type (2004)



2.2.1.2 PAST AND FUTURE STOCK

- **Remote refrigerated display cabinets**

The data for 2006 and 2007 are an average of the estimations given by the industry. The data for the years 2008 to 2010 were calculated using the sales data in Table 2-15 and an estimated lifespan of 9 years for this category of products[13].

The future estimations of the stock of remote cabinets in operation in EU-25 show that it will increase as presented in Figure 2-9.

Figure 2-9: Estimated future stock of remote refrigerated display cabinets

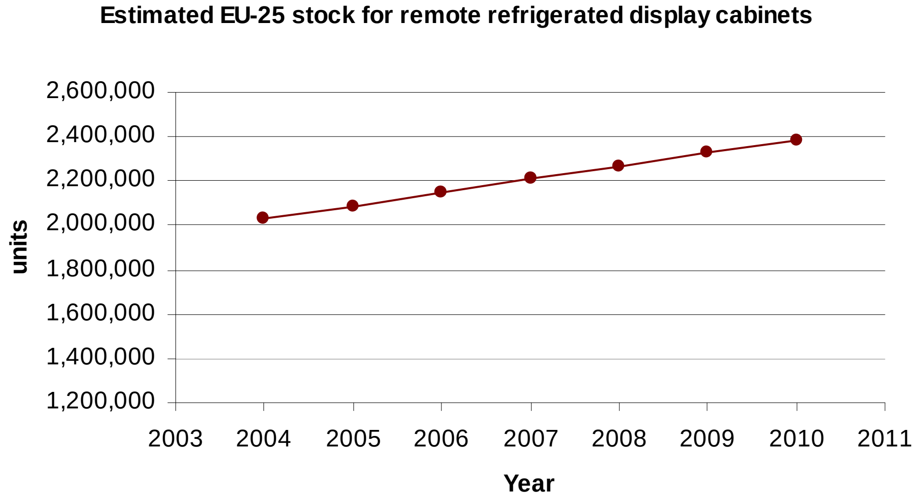


Table 2-7: Estimated future stock of remote refrigerated display cabinets

Year	EU-25 Stock (000 unit)
2006	2,152
2007	2,207
2008	2,267
2009	2,326
2010	2,385

- **Plug in refrigerated display cabinets**

The stock data of beverage coolers (Table 2-8) were calculated using the sales data in Table 2-16 and an estimated lifespan of 8 years for this category of products.

The future estimations of the stock of beverage coolers in operation in EU-25 show that it will increase as presented in Figure 2-3.

[13] Reference: EUROVENT Survey

Figure 2-10 : Estimated future stock of beverage coolers in EU-25

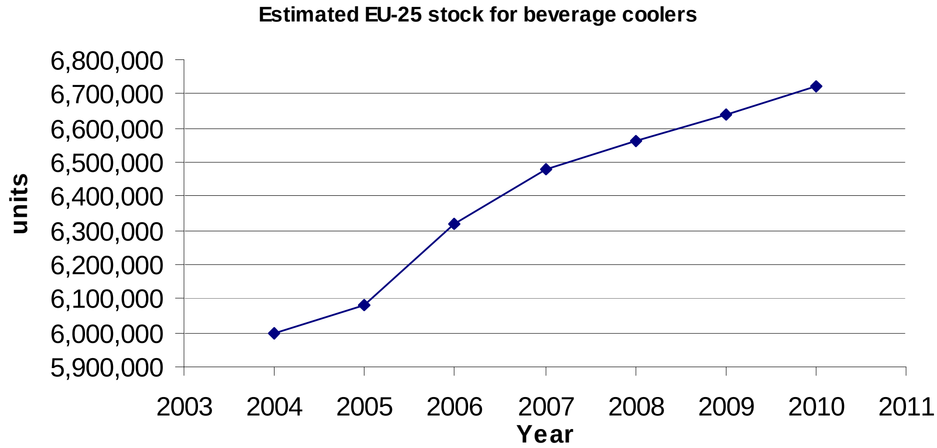


Table 2-8 : Estimated future stock of beverage coolers in EU-25

Year	EU-25 Stock (000 unit)
2004	6,000
2005	6,080
2006	6,320
2007	6,480
2008	6,560
2009	6,640
2010	6,720

For ice cream freezers, no specific data was available and it was estimated that the stock of ice cream merchandisers is equivalent to approximately half of the stock of beverage coolers (ratio is 7/3 as in Figure 2-6**).**

In the supermarket segment, based on consultation with manufacturers, the estimates of the stock of plug in appliances for the supermarket segment (excluding branded equipment of the food and beverage industry) lead to the following figures (Table 2-1):

Table 2-9: Estimated future stock of plug in appliances (supermarket segment)

Year	EU-25 Stock (000 unit)
2004	1,107
2005	1,146
2006	1,190
2007	1,235
2008	1,282
2009	1,331
2010	1,382

- **Cold vending machines**

Based on the sales data (see Table 2-17) and on the stock data for the year 2004, the stock of cold vending machines in the EU-25 were calculated (Table

2-10) for the years 2004-2010 using the assumption that the replacement rate is 10 %[14]:

Table 2-10: Estimated future stock of cold vending machines in EU-25

Year	EU-25 Stock (000 unit)
2005	1.266
2006	1.379
2007	1.497
2008	1.619
2009	1.746
2010	1.878

2.2.2 SALES

2.2.2.1 CURRENT SALES

An overview of the current commercial refrigerators and freezers sales is summarised in the following table (Table 2-11)

Table 2-11 : Overview of the current sales of commercial refrigeration equipments

Product category	Sales (000 unit)	Sales (€ M.)
Remote refrigerated display cabinets (for year 2006)	240	900
Plug in refrigerated display cabinets for the supermarket segment (for year 2006)	150	300
Beverage coolers (for year 2006)	790	660
Ice cream freezers	339	271
Cold vending machines (for year 2006)	126	365

- **Remote refrigerated display cabinets**

For remote refrigerated display cabinets, the European sales data is estimated to € 900 million in 2001 and in 2003 and € 860 million in 2004 and 2005[15].

An average of the EU-25 total sales (units delivered and installed) was evaluated to 240,000 units in 2006[16]. Using an average price calculated from Table 2-22 for remote refrigerated display cabinets, the total sales in EU-25 reach € 899 million in 2006.

- **Plug in display cabinets**

The sales data for plug in refrigerated display cabinets are given per market segment.

[14] Stock (n) = Stock (n-1) + sales (n) – (Replacement Rate) x Sales (n)

[15] Source: Eurovent

[16] Reference: EUROVENT Survey

The beverage coolers represent a large proportion of the plug in refrigerated display cabinets in the food and beverage market segment. For 2006, data from manufacturers of bottle merchandisers estimate the total EU-25 sales to 790,000 units for the beverage cooler segment.

Using an average price of € 830 (see section 2.4.1.2) the total sales reach € 660 million in 2006.

For ice cream merchandisers based on the results from Figure 2-6**,** it was estimated that the total EU-25 sales for 2006 was 338,571 units.

Plug in appliances of the supermarket segment total 150,000 unit sold in 2006 amounting to approximately € 300 million in 2006.

- **Cold vending machines**

Based on estimations from EVA[17], the total sales for 2004 are estimated to 116,614 units sold in EU-25. With an estimated annual sales growth rate of 3.9 %[18] (cf. section 2.2.2.2) the sales may amount 126,000 units in 2006 which represents € 365 million (Table 2-23) and will reach over 200,000 units sold in 2019.

2.2.2.2 ANNUAL SALES GROWTH RATE

World demand (also called sales) for commercial refrigeration equipment is projected to rise 5.3% per year (including price increase) through 2008 to US$ 25.8 billion, showing a improvement over the 1998-2003 period and reflecting the accelerating economic growth in Eastern Europe and developing regions[19]. Table 2-12 shows the expected increase in the worldwide demand for commercial refrigeration equipments and Table 2-13 provides the projections for different geographic zones. Table 2-14 presents the worldwide demand for commercial refrigeration equipment per type of product for various years from 1989 to 2009 (historical and estimated data).

Freezers and display cases are posting the fastest gains.

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[17] Table 2-17 and estimates that the share of the 13 EU countries represented in this table is 90 % of the total EU-25 and that 35 % of the sales are cold vending machines

[18] It is assumed that the sales growth rate remains the same

[19] Freedonia Study # 1367. *World Commercial Refrigeration Equipment to 2004*. (January 2001).
Freedonia Study # 1616. *World Commercial Refrigeration Equipment to 2006.* (December 2002).
Freedonia Study # 1895. *World Commercial Refrigeration Equipment to 2008.* (January 2005)
These studies consider commercial refrigeration equipment as consisting of reach-in and walk-in coolers/freezers, display cases, refrigerated vending machines, ice-making machines, and “parts and other goods” (including components. beverage refrigeration units. cryogenic equipment. liquid chillers. etc.). The last two categories as well as walk-in coolers/freezers are out of the scope of the lot 12 but still, the results of these studies give an overview of the refrigeration market situation.

This information is based on several research studies[20] on the commercial refrigeration equipment market published by the Freedonia Group Inc.

Table 2-12: Worldwide refrigeration equipment annual growth rates[21]

Period	1989-1994	1994-1999	1999-2004	2005-2008
Growth rate	4.6 %	5.6 %	6.2 %	5.3 %

Table 2-13: Commercial refrigeration equipment demand per country

	Region share (%)				Annual growth rate (%)	
Period	1994	1999	2004*	2009*	1994-1999	1999 - 2004*
United-States	23	28	27	26	9.3	5.2
Canada & Mexico	3	3	3	3	7.5	6.4
Latin America	3	3	4	4	6.4	9.4
Western Europe	**25**	**25**	**23**	**21**	**5.1**	**4.5**
Eastern Europe	**4**	**4**	**4**	**4**	**2.7**	**6.9**
Africa / Mid-East	4	4	4	4	6.2	7.8
China	4	5	8	10	14.9	13.7
Japan	22	17	15	14	0.6	3.8
Other Asia / Pacific	12	11	13	14	4.2	9.2
Total US$ (million)	14,166	18,638	25,120	33,175	**5.6**	**6.2**
*estimated in 2001						

Table 2-14 : Worldwide commercial refrigeration equipment demand per products

	Product share (%)					Annual growth rate (%)			
Year	1989	1994	1999	2004	2009	1989-1994	1994-1999	1999-2004	2004-2009
Display cases	**18**	**17**	**16**	**16**	**17**	**3.6**	**4.6**	**6.4**	**6.8**
Reach-ins & Walk-ins	**24**	**26**	**27**	**27**	**28**	**6.8**	**5.8**	**6.8**	**5.9**
Vending Machines	**12**	**12**	**14**	**14**	**13**	**4.6**	**7.7**	**6.4**	**5.0**
Ice machines	7	7	7	7	7	4.6	5.3	5.8	5.8
Parts & others	39	37	36	35	35	3.6	5.3	5.5	5.4
Total US$ (million)	**11,315**	**14,166**	**18,638**	**25,120**	**33,175**	**4.6**	**5.6**	**6.2**	**5.7**

Retailers are expanding in East and Central European countries such as Poland, Hungary and the Czech Republic. Since the refrigeration market is tightly linked to fast developing sectors such as food, beverage and retail, the demand for refrigeration equipment is expected to increase at a faster rate than on the Western side[22]. These new entrants from East and Central Europe are expected to succeed in the market by achieving low prices, which is made

[20] Freedonia Studies # 1367 # 1616. # 1895 as mentioned in footnote 10

[21] The results for the 1989-1994 and 1994-1999 periods are based on historical data, the results for 1999-2004 are a forecast found in the Freedonia #1616 study published in 2002 and the rate for the 2005-2008 period is a forecast found in the Freedonia #1895 study published in 2005.

[22] Reference: Frost and Sullivan. Central and East European Refrigeration Systems Market. (June 2003)

easier by the cheap labour available in these regions, increasing competitiveness and price pressure. In Western Europe, the market is more mature and less dynamic and there is a robust used equipment market.

In Europe, the refrigerated display cabinet market trends are mainly driven by the expansion of discounters (e.g. Aldi, Lidl), by the increase of frozen food consumption (more available space for new products in frozen segment with approximately 12% of new frozen food products every 2 years), and by customer expansion (emerging markets).

The sales for remote products in EU-25 are projected to globally increase during the 2004-2010 period[23]. Data from 5 major manufacturers show that for the 2004-2007 period, the total of remote units sold within the EU-25 will reach 245,000 units at an annual sales growth rate of 2.8 %. In the EUROVENT survey, only 2 manufacturers predicted the sales until 2010. Data are missing from the other manufacturers but a linear extrapolation enables to project the average EU-25 sales until 2010. Considering this assumption, the EU-25 total sales for remote products are predicted to reach 265,000 units in 2010 at an annual growth rate of 2.7% over the 2005-2010 period.

Figure 2-11 : Estimated total EU-25 remote equipment annual sales

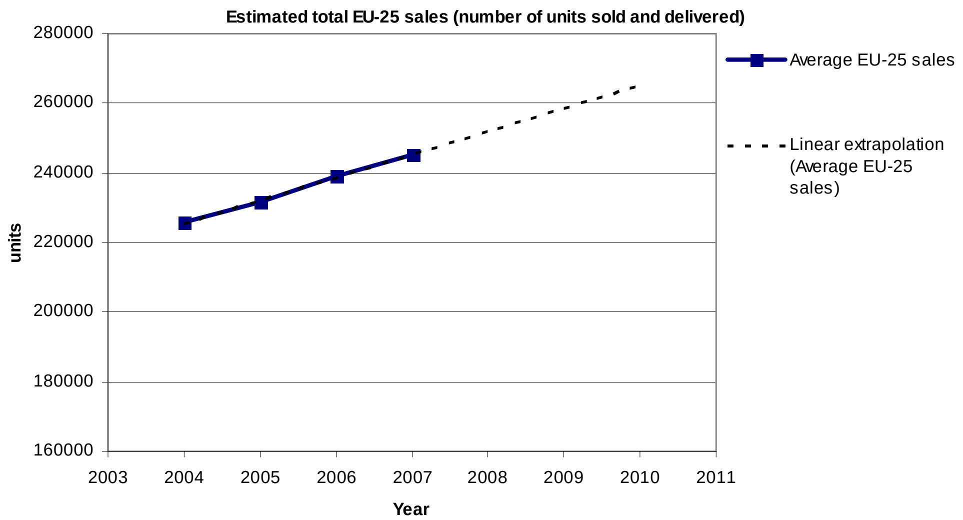


Table 2-15: Estimated EU-25 sales for remote refrigerated display cabinets

Year	Estimated EU-25 sales (units)
2004	226,000
2005	231,000
2006	240,000
2007	245,000
2008	252,000
2009	258,000
2010	265,000

23 Reference: EUROVENT Survey

Plug in refrigerated display cabinets

For the beverage cooler segment in EU-25, estimates from manufacturers project the sales to reach 840,000 units by 2010 at an annual sales growth rate of 2 %. Table 2-20 gives the estimated sales data for the 2004 – 2010 period.

Figure 2-12: Estimated total EU-25 beverage coolers annual sales in units

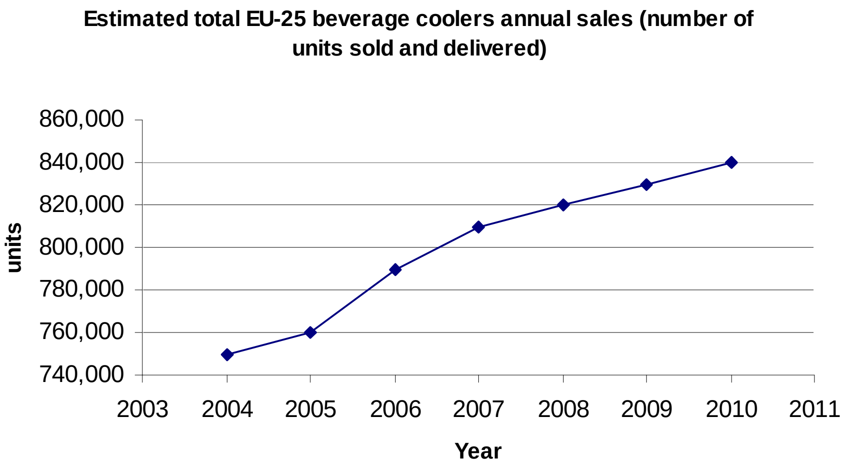


Table 2-16 : Estimated EU-25 sales for beverage coolers

Year	Estimated EU-25 sales (units)
2004	750,000
2005	760,000
2006	790,000
2007	810,000
2008	820,000
2009	830,000
2010	840,000

These estimates are similar to those produced by the UK Government[24] for refrigerated retail display cabinets where annual growth from 1985 to 1995 was recorded at over 25 % in the UK, and is predicted to fall to 2 % by 2010.

Cold vending machines

The market growth of refrigerated vending machines is still very significant, in particular in Europe[25]. Table 2-17 shows the annual sales growth rate for vending machines (Hot beverages + Cans & Bottles + Snack & food) in thirteen European countries. Based on EVA data, it is calculated to 3.9 % for the thirteen countries considered. The growth rate for the 2001-2004 period ranges from

[24] Reference: Tait. *Overview of Commercial Refrigeration in the United Kingdom. A sector review paper on Projected Energy Consumption*. UK Department of the Environment, Transport and the Regions (2000).

[25] Reference: United Nation Environment Programme (UNEP). *Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee (RTOC).* (2002)

negatives values in western European countries (France, UK, Germany) to figures over 10 % in Eastern Europe (Hungary, Czech republic, Slovakia).

Table 2-17 : Total vending machines units sold per year[26]

Country / Year	1998	1999	2000	2001	2002	2003	2004	Annual growth rate (%) 2001-2004
Austria	7,306	7,557	6,987	8,406	7,157	6,256	9,225	3.1
Czech Rep.				1,399	2,396	2,149	2,425	20.1
France	37,719	38,974	42,676	43,491	37,737	32,696	34,776	-7.2
Germany	28,730	33,447	33,491	39,276	32,143	30,633	35,956	-2.9
Netherlands	20,296	23,750	25,508	24,062	22,853	25,151	25,273	1.7
Hungary	2,534	5,449	2,445	588	807	984	2,211	55.5
Italy	39,971	48,385	51,893	47,132	48,225	66,855	78,599	18.6
Poland				1,280	2,815	2,778	2,328	22.1
Portugal				3,585	5,918	5,656	8,623	34.0
Slovakia				890	901	723	1,273	12.7
Spain				29,049	28,996	29,470	34,148	5.5
Sweden	5,843	6,596	8,945	7,757	8,568	9,674	11,130	12.8
UK + Ireland	46,964	43,623	40,725	47,511	45,523	44,213	42,718	-3.5
Total estimated				**267,620**	**253,484**	**266,494**	**299,865**	**3.9**
no data for Belgium & Denmark								

Based on the estimations that the thirteen countries are representative of 90 % of the total EU-25 market, the EU-25 annual sales growth rate for 2001-2004 is estimated to 3.9 %.

2.2.2.3 Replacement sales

More than half of the demand for commercial refrigeration equipment is for replacement units.

- **Remote refrigerated display cabinets**

The EUROVENT survey results for remote refrigerated display cabinets give the following results for the 2004-2010 period.

Most of the sales in the remote segment are replacement sales in EU-25. This is even more significant in Western Europe compared to East and Central Europe where major end-users such as retailers are still expanding.

[26] Reference: European Vending Association http://www.eva.be/main.html

Table 2-18: Share of replacement sales in EU-25 for remote equipment

Year	Remote refrigerated display cabinet share of replacement sales (%)
2005	79
2006	71
2007	77
2008	76
2009	77
2010	78

- **Plug in refrigerated display cabinets**

Most of the sales (70-90 %) are replacement sales for beverage coolers in EU-25. The same result is estimated for ice cream freezers.

Table 2-19 : Share of replacement sales in EU-25 for beverage coolers

Year	Beverage coolers share of replacement sales (%)
2005	89
2006	68
2007	79
2008	90
2009	90
2010	90

- **Cold vending machines**

Replacement rate for cold vending machines is estimated to 10 % with large discrepancies among the different EU-25 countries. Most of the replaced machines are then used in minor importance sites or sold in Eastern European countries (second life).

2.2.3 AVERAGE PRODUCT LIFE

- **Remote refrigerated display cabinets**

The average product life of remote refrigerated display cabinets is estimated to be 9 years and many manufacturers agree with such estimation. This estimate is in line with other similar estimates e.g. one used by the California Energy Commission [27](CEC). The CEC estimates the lifespan of commercial refrigerators and freezers to 9 years for those with doors and 10 years for open cabinets (remote and plug in).

- **Plug in refrigerated display cabinets**

[27] Reference: Holland J. and al. *Update of Appliance Efficiency Regulations*. California Energy Commission Staff Report. (November 2004). http://www.energy.ca.gov/reports/2004-11-30_400-04-007F.PDF . Here the lifetime is estimated to 9 years.

Plug in display cabinets have an average product life estimated to 9 - 10 years.

The results from manufacturers of beverage merchandisers show an average life of 6.5 years with standard deviation of 2 years. Considering estimations from other studies[28] an average lifespan of 8 years can be assumed for the beverage cooler segment and for ice cream freezers.

- **Cold vending machines**

For the whole cold vending machine segment, the average lifespan is estimated to range between 5 and 10 years.

The typical lifespan of a canned beverage vending machine is 7 to 10 years according to US Department of Energy.

The following lifetimes will be assumed for the purpose of task 5:

Table 2-20 : Average product life of commercial refrigeration equipment

Product	Lifespan (years)	Lifespan (years) for EcoReport
Remote refrigerated display cabinet	9	9
Plug in display cabinet	9 – 10	8
Beverage cooler	8	8
Cold Vending machine	7 – 10	8.5

2.3. MARKET TRENDS

2.3.1 MARKET AND PRODUCTION STRUCTURE

2.3.1.1 DISTRIBUTION

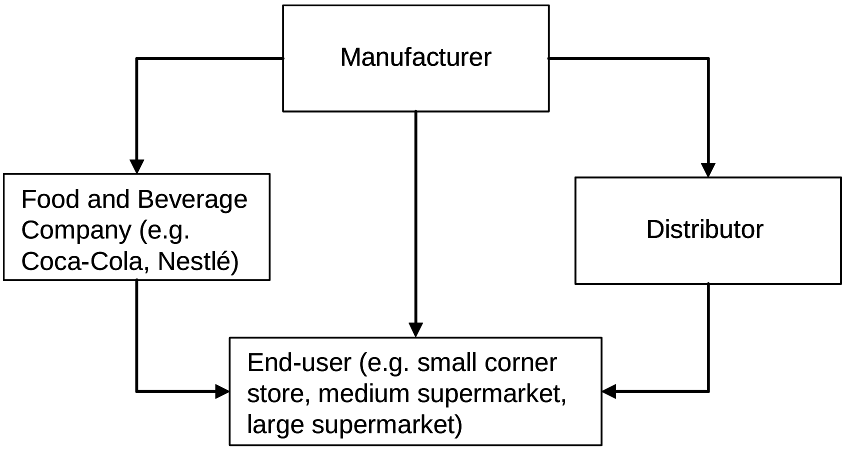
Typically, commercial refrigeration equipments are distributed in three different ways (Figure 2-13). By utilising the manufacturer's own sales staff to sell directly to the end-user, by working through regional sales offices or manufacturers' representatives to sell equipment to independent wholesalers (equipment dealers, distributors, agents, brokers, etc.) or by selling to large food and beverage companies who then give their appliances for free or rent them to end-users who in return will sell their products.

Because of the highly fragmented industry and diverse factors affecting end-user's needs, the most common distribution channel is from manufacturer to distributor to end-user. The distributor is the interface between the manufacturer and with food service operators on the commercial side and with food service consultants on the non-commercial side (colleges, hospitals, hotels). However,

[28] Reference: Arthur D. Little. *Energy Savings Potential for Commercial Refrigeration Equipment*. US Department of Energy. (1996). http://www.eere.energy.gov/buildings/info/documents/pdfs/comm_refridg_equip.pdf
Here the lifetime is estimated to 7 – 10 years

large chains often employ an architect or an engineer to specify their needs and buy equipment directly to the manufacturers[29].

Figure 2-13: Distribution of commercial refrigeration equipment



Remote refrigerated display cabinets are mostly sold directly to the end users (68%). 31 % is sold through a distributor and the rest to the food and beverage industry.

More than 95 % of the beverage coolers are sold to the food and beverage industry.

For cold vending machines, only 10 % of the products are sold directly to the end-users.

2.3.1.2 MARKET STRUCTURE

- **Refrigerated display cabinets**

For remote refrigerated display cabinets, it is estimated that 67 % of the market was detained by 5 major manufacturers in 2004 and 62 % in 2006.

Compared to the remote segment, the plug in segment is relatively fragmented, with over 50 plug in manufacturers in the EU-25[30].

2.3.1.3 PRODUCTION STRUCTURE

- **Refrigerated display cabinets**

Commercial refrigeration equipment is produced mainly in Japan, Western Europe and the US. However, these developed regions comprise mature

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[29] Reference: American Council for Energy Efficient Economy. *Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers*, ACEEE 2002

[30] Reference: Procool

markets for commercial refrigeration equipment. The fastest growth in production will be in industrializing areas of the world due to the rising number of supermarkets, grocery stores and other retailers (e.g. in China).

The manufacturing process for remote and plug in refrigerated display cabinets is relatively different and the major players in these two segments differ. Remote cabinet manufacturing processes require heavier machinery and foaming moulds, different material handling, etc. and many remote display cabinet producers also manufacture plug ins as well but not vice-versa.

In Europe, the major manufacturers for refrigerated cabinets are located in 2-3 countries as shown in Table 2-21. They are entirely different manufacturers, only a few companies manufacturing the two types of products.

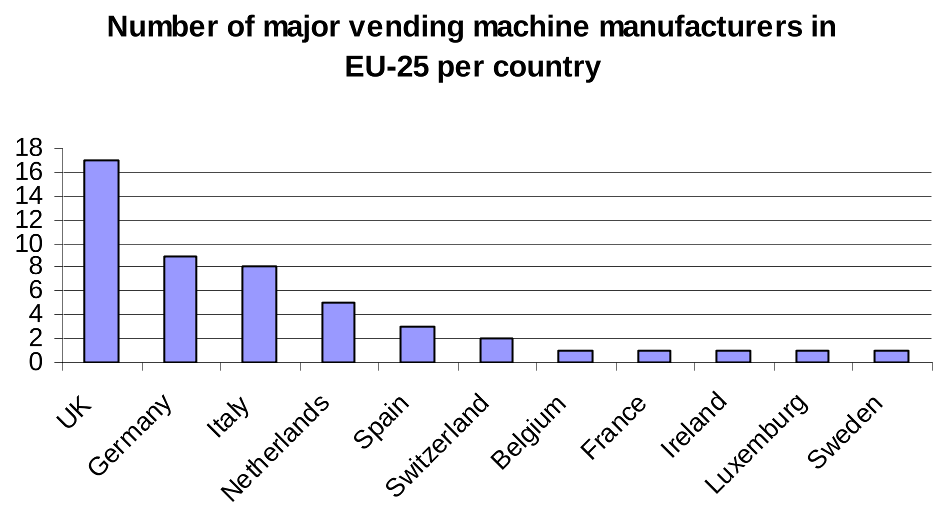
Table 2-21: Main EU locations of refrigerated display cabinet manufacturers[31]

Remote refrigerated display cabinets	Plug in refrigerated display cabinets
Italy France Germany Czech Rep. Hungary	Italy Germany France Sweden Spain

- **Cold vending machines**

The main countries of origin for vending machines in EU-25 are the UK, Germany and Italy[32].

Figure 2-14 : Location of the vending machine manufacturers



[31] Reference: Manufacturer's estimates

[32] Reference: EVA

2.3.2 GENERAL TRENDS IN PRODUCT DESIGN AND PRODUCT FEATURES

The main drivers of the changes in product-design and features in commercial refrigeration equipment are the following:

- Regulatory considerations
- Technological innovations
- Economy driven trends

2.3.2.1 REGULATORY CONSIDERATIONS

- **Alternative refrigerants**

Commercial refrigeration manufacturers are affected by the legal and regulatory actions in different countries as well as by international policy initiatives (e.g. UNEP).

Following to the Montreal Protocol, the European Union implemented the Regulation EC No. 2037/2000 on substances that deplete the ozone layer. It specifies an accelerated HCFC (Hydro chlorofluorocarbon) phase out schedule, compulsory recovery of CFCs (Chlorofluorocarbon) and HCFCs or ban of use, and leak control. The European schedule for the phase out of the ozone depleting refrigerants is stricter than the one established by the Montreal Protocol (and chosen by the US). This triggered a transition in the choice of refrigerants used in the commercial refrigeration industry.

During 2000-2002, the use of CFCs, the production of CFCs and the production of equipment using such refrigerant were banned.

Since January 2001, the use of HCFCs in new systems in Europe for all type of refrigeration equipment is forbidden. Concerning HCFCs production, placing on the market and use for the next coming years the regulation adopted the following provisions:

- **01/01/2008** Reduction of placing on the market by 85% with respect to 2001, Lowering of production by 65% with respect to 1997
- **01/01/2010 Prohibiting of placing on the market of virgin HCFCs**
- **01/01/2010 Prohibiting of the use of virgin HCFCs in the maintenance and servicing of all equipment**
- **01/01/2014** Lowering of production by 80% with respect to 1997
- **01/01/2015 Prohibiting of the use of recycled HCFCs in the maintenance and servicing of all equipment**
- **01/01/2020** Lowering of production by 85% with respect to 1997
- **01/01/2025 Prohibiting of production**

HCFCs are also part of the family of greenhouse gases, as well as HFCs (Hydro fluorocarbons), another type of common refrigerant. As such, these two refrigerants are submitted to the Kyoto protocol provisions but since these refrigerants show low TEWI (Total Equivalent Warming Impact[33]) the Kyoto protocol is not a trend setter in refrigeration equipment design.

In accordance with the Montreal Protocol and the related European regulation, the refrigeration industry has been challenged to find new replacement refrigerants. HFCs are emerging as the preferred replacement because of their low toxicity and non-flammability and their ability to reduce energy consumption[34].

In Europe, refrigeration equipment has been switching from HCFCs (mostly HCFC-22) to HFCs: R-404A and R-507A for low and medium temperature level whereas R-134a is chosen for medium temperature low capacity systems. All HFC have higher evaporator pressures than the refrigerants they are replacing and require manufacturer of refrigeration components to adapt their product.

A number of HCs (Hydrocarbons), ammonia and CO2 systems of different refrigeration capacities have also been installed in various countries in the last 5 years[35].

This refrigerant transition has caused the industry to adapt to the new properties of these replacement refrigerants and to work on system redesign to develop products that can operate with R-404A, R-507A, R-134a but also with HCs and CO_2.

Such a shift in use of alternative refrigerant has an influence on the overall product design and related energy and environment impacts. A trend of such change can be observed through Procool competition which gives an insight of the current drivers in products design for refrigerated display cabinets. The 5 products winners of the 2006 competition operated with R-600a (Isobutane, family of HCs) or natural refrigerants such as R-290 (Propane) and R-744 (CO_2).

Energy Efficiency

[33] The TEWI is a measure of the impact of the direct GWP (global warming potential) due to refrigerant leakage and of the indirect global warming impact due to the energy consumption of the whole refrigeration system. Higher energy efficiency of some refrigerants can offset a higher GWP by reducing the energy consumption.

[34] Arthur D. Little Inc. *Global Comparative Analysis of Global Comparative Analysis of HFC and Alternative Technologies for Refrigeration, Air Conditioning, Foam, Solvent, Aerosol Propellant, and Fire Protection Applications*. Final Report to the Alliance for Responsible Atmospheric Policy (March 21st 2002).

[35] *UNEP 2002 report by the Refrigeration, Air Conditioning and Heat Pumps Option Committee* (2002). This report also states that the choices for replacement refrigerants are different in Europe, Japan and the US. In Japan, voluntary policy is undertaken and more than one third of the new equipment uses HFCs. R-404A is preferred for low temperature and R-407C is used for medium temperatures. In the US, HCFC-22 is still in use, even in new equipment but more and more systems use R-404A.

In Europe, voluntary programs such as the EUROVENT certification program require manufacturers to claim the energy consumption of their products which encourages the industry to produce more efficient equipment.

The UK ECA scheme, the Australian MEPS energy consumption requirements, the Energy star programs, the California Energy Commission Program in the US for commercial solid doors refrigerators and freezers and for vending machines can be identified as trends setters toward an improved efficiency of these products.

2.3.2.2 TECHNOLOGY DRIVEN TRENDS

New components compatible with CO_2 refrigerants have been developed and their use is expected to increase in the near future. For example, Coca-Cola announced they are progressively switching to vending machines with CO_2 rotary compressors enabling 17 % energy savings and double door beverage coolers and vending machines with CO_2 reciprocating compressors which proved to be efficient technologies (15-35% reduction in electricity consumption). According to them, the use of CO_2 which is a natural refrigerant also reduces the total equivalent warming impact (TEWI) compared to HFCs. Further discussion on CO_2 based refrigeration will be developed in task 6.

2.3.2.3 ECONOMY DRIVEN TREND

- **End-user requirements**

Because of requirements from end-users related to the necessity of having a higher visibility of the foodstuff commercial refrigeration equipment tend to have an increased display volume for same footprint. More and more display cabinets, specifically in the low temperature range have heights over 2 m.

Manufacturers also offer more and more attractive display merchandisers and flexible and customised concepts to exactly meet its client with cases matching the store's design and offering a built-in lighted canopy option that retailers can use to advertise products or for signage.

To meet customer's energy concerns, electronic controls are also integrated in new display cabinets such as defrost controls. Roll-up night curtains that cannot be seen when not in use are more commonly integrated in open display cases. There is also focus on better condensation control on the exteriors of display cases. In cabinets with doors, anti-fog coating applied to the interior of a reach-in door allows shoppers to leave frozen food doors open for minutes at a time without fogging.

Although it is not a major trend, with the increase of the supermarkets' opening hours, and the decrease of the possibility to use night covers, some end-users have been demanding more and more commercial refrigeration equipment fitted with transparent doors (chilled multi decks).

2.4. CONSUMER EXPENDITURE BASE DATA

2.4.1 AVERAGE CONSUMER PRICES

2.4.1.1 REMOTE REFRIGERATED DISPLAY CABINETS

The averages prices in 2006 for remote refrigerated cabinets per product category in Europe are presented in Table 2-22. The average price for a remote display cabinets ranges between € 3,000 and € 7,000 depending of the size and the model.

Table 2-22: Average EU-25 prices for remote refrigerated cabinets (2006)

Product category	Eurovent classification	Average EU-25 Selling price (In €. ex-works. including factory & sales margin)	% of units sold belonging to this product category
Multidecks & semi-verticals	RVC1/RVC2/RVC3	3440	61
Counters: service & self service	RHC1/RHC2/RHC7/RHC8/RHF1/RHF7	3020	16
Frozen food islands	RHC3 to RHC6 & RHF3 to RHF6	3970	13
Glass doors & frozen multidecks/SV	RVF4 & RVC4 + VF1 & VF2	5940	4
Combis	RYC1 to RYC4 & RYF1 to RYF4	6780	6
Remote refrigerated display cabinet		3760	100

2.4.1.2 PLUG IN REFRIGERATED DISPLAY CABINETS

The typical price range for a beverage cooler is between € 200 and € 2,000 depending of the size and the design (single, double or triple door units). Beverage coolers without doors (open front or open top units) are generally more expensive (between € 600 and € 2,000). Estimates from manufacturers give an average unit price of € 830 for a beverage cooler excluding VAT (with a standard deviation of € 360) and € 800 for an ice cream freezer.

2.4.1.3 COLD VENDING MACHINES

The typical price of a cold vending machine ranges between € 1,300 and € 3,600 depending of the type of equipment (e.g. drum, spiral) and on the number of machines bought. An average unit price is estimated to € 3,500.

The average product prices estimates that will be used in task 5 and 7 are summarised in the following table:

Table 2-23: Average product price

Product	Product price (€)
Remote refrigerated display cabinet	3,760
Plug in display cabinet (supermarket segment)	2,000
Beverage cooler	830
Ice cream freezer	800
Cold Vending machine	3,500

2.4.2 RATES FOR RUNNING COSTS AND DISPOSAL

2.4.2.1 RUNNING COSTS

The significant running costs of commercial refrigeration equipment are the electricity costs, the repair and maintenance costs, and the installation costs.

- **Electricity costs**

Electricity prices in Member States, as of July 1 2005, are presented in Table 2-24. These rates will be used in a Life Cycle Cost (LCC) calculation at the later stage of the study (task 5).

The end-users for commercial refrigeration equipment range from small retail store to large supermarkets. Depending of the annual energy consumption, different electricity rates apply.

For medium and large supermarkets, the annual electricity use ranges from about 100,000 kWh per year for the smaller stores or more to over 1.5 million kWh per year for the largest[36] ones.

Beverage coolers and vending machines are used in all types of locations (offices, universities, public transportation stations, small corner stores, etc…). The electricity price will be assumed to an average of 10.5 €/ 100 kWh (with taxes).

[36]Reference: International Energy Agency. *IEA Annex 26: Advanced Supermarket Refrigeration/Heat Recovery Systems.* (2003)

Table 2-24 : **Electricity prices for industry depending of the annual consumption**

Electricity cost €/100kW with taxes	Standard consumer Ib 50 MWh.	Standard consumer Ic 160 MWh.	Standard consumer Id 1,250 MWh.	Standard consumer Ie 2,000 MWh.	Standard consumer If 10,000 MWh.
Austria	13.81	12.06	10.27	9.64	8.25
Belgium	15.22	14.01	11.53	10.14	9.62
Cyprus	23.38	18.22	12.79	11.47	11.47
Czech Rep.	9.34	8.68	7.89	6.93	5.96
Denmark	12.01	11.44	11.27	10.99	
Estonia	6.63	6.4	6.12	5.55	5.04
Finland	8.38	8.11	7.27	6.69	6.75
France	10.93	10.05	8.08	6.91	6.91
Germany	19.39	15.4	12.34	10.81	10.65
Greece	10.33	9.54	7.67	7.03	7.03
Hungary	14.06	15.12	11.9	9.51	8.52
Ireland	17.91	14.97	12.38	10.56	10.21
Italy	15.91	13.81	12.78	12.36	11.36
Latvia	7.57	5.42	4.9	4.82	3.9
Lithuania	8.84	7.7	6.16	5.88	5.87
Luxembourg	13.5	11.26	10	9.02	5.36
Malta	10.66	8.04	7.83	7.46	6.24
Poland	11.54	9.95	7.2	6.64	6.48
Portugal	11.44	9.56	8.39	7.72	7.7
Slovakia	11.32	10.42	8.92	8.28	8.15
Slovenia	12.64	9.25	8.09	7.34	7.09
Spain	12.09	8.48	7.21	6.64	6.25
Sweden	7.12	6.46	6.09	5.44	5.04
Netherlands	16.95	14.43	11.69	10.71	8.86
UK	12.01	10.35	8.48	7.81	6.83
EU-25	13.89	11.74	9.83	8.9	8.4

- **Repair and maintenance cost**

In the Energy star LCC calculation tool, the maintenance cost for commercial refrigeration appliances is negligible and fixed to zero.

First estimation of the maintenance cost during the whole product life is of about 7 % of the Life Cycle Cost for refrigerated cabinets (remotes and plug in appliances).

- **Installation costs**

There is no significant installation cost for plug in refrigerated display cabinets and cold vending machines as they are plug in appliances. Remote refrigerated display cabinets however need to be linked to a refrigeration system which supplies the cabinet with refrigerant. The installation costs only consider the labour costs implied, all material cost involved during installation being part of the refrigeration system costs will not be included. It is estimated to 10 % of the cabinet cost.

2.4.2.2 DISPOSAL COST

Most of the refrigeration equipment, including vending machines, is renewed before reaching the end-of-life and is sold in the second-hand market (exported to Africa, Asia, or Eastern Europe) implying a positive cost. If the product is not suitable for re-used it is typically sold to scrap metal dealers, also implying a positive cost.

A small fraction of the products however (mostly plug ins) are treated like household refrigerators in fridge recycling plants. Less than 1 % of the appliances found in these plants are commercial equipment. When disposed in refrigerator recycling plants, the disposal costs depend on the weight and the volume of the commercial refrigeration equipment. In EU-25 countries, this disposal cost varies between € 60 and € 250 per ton of equipment depending of many local factors such as the electricity rates, the employees' wages[37].

The recovering of 500 g of refrigerant liquid in commercial equipment costs approximately € 4 and recycling plants typically try to recycle the other material such as metal (e.g. steel, copper, aluminium).

The disposal cost in the Life Cycle Cost (LCC) calculation can be assumed to zero.

2.4.3 INTEREST AND INFLATION RATES

The following table shows national inflation and interest rates for the EU-25 as published by Eurostat and the European Central Bank (ECB).

Table 2-25: Interest and inflation rates for EU-25

Member State	Inflation rate [(a)] (%)	Interest rate [(b)] (%)
Austria	1.6	3.4
Belgium	2.8	3.4
Cyprus	1.4	5.2
Czech Republic	1.9	:
Denmark	2.2	3.4
Estonia	3.6	-
Finland	1.1	3.4
France	1.8	3.4
Germany	2.1	3.4
Greece	3.5	3.6
Hungary	3.3	6.6

[37] Reference : Interview with Mr. Christoph Becker – RAL Quality Assurance Association for the Demanufacture of Refrigeration Equipment Containing CFCs

Ireland	2.2	3.3
Italy	2.1	3.6
Latvia	7.1	3.5
Lithuania	3.0	3.7
Luxembourg	3.4	:
Malta	3.4	4.6
Poland	0.8	5.2
Portugal	2.5	3.4
Slovak Republic	3.9	3.5
Slovenia	2.4	3.8
Spain	3.7	3.4
Sweden	1.3	3.4
The Netherlands	2.1	3.4
United Kingdom	2.0	4.5
EU-15 Average	2.2 [c]	3.42 [c]
EU-25 Average	2.1	3.9

[a] Annual Inflation (%) in Dec 2005 Eurostat "Euro-Indicators", 7/2006 - 19 January 2006

[b] ECB long-term interest rates; 10-year government bond yields, secondary market. Annual average (%), 2005

[c] Euro zone

2.5. CONCLUSIONS

Establishing the stock of commercial refrigerators and freezers through existing data sources proved to be a daunting task. In the absence of a single source for comprehensive market data, current sales and stock of commercial refrigerators and freezers were derived from different sources.

The accuracy of these figures can be challenged but they clearly show that the yearly sales of the products are higher than the 200 000 unit threshold set in the EuP Directive (much higher for remote and plug in display cabinets).

The data presented in task 2 will form the basis of not only selecting the representative products and eventually formulating the base case(s). Further, product price and life time are also key input data for the analysis using EcoReport in tasks 5 and 7.

ANNEXES

Annex 2-1: Eurostat EU-25 production of lot 12 relevant products (2005)

PRODCOM	29231333		29231335		29231340		29231350	
2005 Production	000 unit	M. Euro	000 unit	M. Euro	000 unit	M. Euro	000 unit	M. Euro
France			42.49	128.87	14.65	35.43	81.20	282.63
Netherlands				20.88	0	0		
Germany	2.79	39.95	41.28	245.65	5.54	15.52	43.75	97.36
Italy	134.71	250.11	106.08	301.40	523.79	325.91	396.90	355.57
UK								
Ireland							0.00	0.00
Denmark	178.29	47.46	69.43	24.04	0.46	1.54	103.69	47.80
Greece	0.67	0.82	7.73	7.47	42.64	30.88	30.16	15.19
Portugal	37.32	38.87	64.63	54.62	5.32	2.91	17.66	8.68
Spain	53.01	126.85	147.67	120.86	5.94	7.09	141.81	71.86
Belgium							0	0
Luxemburg	0	0	0	0	0	0	0	0
Sweden					0	0		
Finland	14.52	16.63	65.15	55.41	0	0	12.51	18.36
Austria	0	0			0	0		
Malta	0	0	0	0	0	0	0	0
Estonia			0	0	0	0		
Latvia	0	0	0	0	0	0		
Lithuania	0	0	0	0	0	0	15.14	4.04
Poland	10.07	8.01	6.97	6.23		2.66	104.22	79.22
Czech Rep.								
Slovakia					0	0	0	0
Hungary					0	0	0	0
Slovenia			0	0			0	0
Cyprus	0	0	0	0	0	0	0	0
EU15			675.42	1141.16				
EU25	469.95	611.96	735.29	1207.53	610.94	433.57	1039.67	1076.69

Annex 2-2: Eurostat EU-25 Imports of lot 12 relevant products (2005)

PRODCOM	**29231333**		**29231335**		**29231340**		**29231350**	
2005 Imports	000 unit	M. Euro	000 unit	M. Euro	000 unit	M. Euro	000 unit	M. Euro
France	35.79	47.76	125.44	112.29	10.03	8.72	149.25	44.61
Netherlands	2.80	1.77	49.28	29.12	2.92	0.60	103.10	14.70
Germany	35.47	32.24	49.28	39.28	2.23	2.42	247.87	64.92
Italy	5.31	7.85	105.75	31.88	4.13	2.19	561.34	11.33
UK	48.63	38.29	117.36	114.23	6.46	3.84	886.57	43.60
Ireland	5.44	9.00	23.12	22.26	1.68	0.44	10.92	4.08
Denmark	1.07	2.40	14.39	12.32	0.71	0.51	86.22	18.78
Greece	37.63	10.97	113.08	7.71	5.85	2.42	83.56	9.36
Portugal	2.47	5.71	8.13	8.25	2.33	0.54	8.40	3.35
Spain	44.77	15.48	74.97	38.92	12.83	18.96	58.90	11.77
Belgium	7.31	6.85	40.94	35.85	0.53	1.75	32.41	16.23
Luxemburg	0.30	0.14	28.53	1.20	0.41	0.09	7.11	1.73
Sweden	1.89	1.38	14.38	7.56	0.52	0.54	50.02	18.30
Finland	2.14	2.25	3.33	6.25	0.26	0.35	11.49	4.87
Austria	2.80	3.75	29.17	32.48	0.87	0.67	16.59	11.37
Malta	0.52	0.80	6.22	1.54	0.02	0.12	3.69	0.78
Estonia	0.08	0.08	3.04	2.30	0.03	0.04	3.13	1.24
Latvia	1.78	0.66	3.19	3.40	0.02	0.01	2.61	2.33
Lithuania	2.63	0.90	10.70	12.18	0.14	0.26	1.98	1.64
Poland	31.12	12.16	35.23	30.81	0.20	0.42	8.93	8.26
Czech Rep.	13.09	2.39	54.47	20.28	1.39	0.82	11.53	4.37
Slovakia	1.47	1.80	5.89	5.97	1.01	0.36	2.92	2.42
Hungary	3.13	2.27	16.61	15.92	1.84	1.05	14.10	2.12
Slovenia	0.83	0.78	7.93	5.85	0.03	0.18	0.84	0.80
Cyprus	0.97	0.88	3.79	3.28	0.23	0.11	2.01	2.14
EU25	45.78	20.75	423.40	155.29	47.24	8.73	1718.09	79.55

Annex 2-3: Eurostat EU-25 Exports of lot 12 relevant products (2005)

PRODCOM	29231333		29231335		29231340		29231350	
2005 Exports	000 unit	M. Euro	000 unit	M. Euro	000 unit	M. Euro	000 unit	M. Euro
France	0.90	2.26	18.61	49.35	2.63	3.33	41.20	28.81
Netherlands	0.17	0.05	42.44	22.06	3.71	10.67	70.66	15.60
Germany	14.71	39.14	45.66	89.42	0.72	1.66	101.02	49.76
Italy	126.94	89.49	267.26	391.21	50.79	18.15	101.61	92.37
UK	3.76	5.48	53.47	15.02	6.37	2.39	48.80	15.33
Ireland	3.74	1.21	16.76	10.02	0.00	0.00	0.00	0.00
Denmark	80.16	25.65	331.96	13.39	1.07	1.22	177.36	73.52
Greece	0.51	0.01	50.38	30.44	0.17	0.12	17.45	4.72
Portugal	9.17	9.67	44.99	36.41	0.12	0.07	3.89	4.46
Spain	6.43	13.40	94.29	86.91	8.96	6.38	25.41	7.81
Belgium	0.35	0.40	20.23	13.07	0.11	0.06	19.96	8.67
Luxemburg	0.11	0.47	0.56	1.06	0.00	0.01	11.38	11.97
Sweden	1.29	3.43	10.79	21.47	1.24	2.39	10.15	3.69
Finland	1.88	1.31	49.37	25.40	0.08	0.20	20.42	37.41
Austria	0.00	0.00	6.32	20.25	0.62	0.42	0.00	0.00
Malta	0.00	0.00	0.05	0.03	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.05	0.03	0.00	0.00	0.30	0.04
Latvia	0.09	0.06	0.43	0.84	0.00	0.00	0.08	0.07
Lithuania	1.13	1.47	20.21	12.95	0.05	0.03	0.78	0.67
Poland	4.38	2.50	82.37	55.09	0.23	0.25	10.40	8.29
Czech Rep.	31.88	77.30	117.95	17.17	0.06	0.25	0.66	0.41
Slovakia	0.05	0.12	4.92	6.31	0.00	0.00	0.09	0.04
Hungary	0.74	1.02	38.07	25.92	0.03	0.02	40.16	14.69
Slovenia	0.39	0.61	7.46	6.90	3.32	2.72	13.97	7.85
Cyprus	0.00	0.00	0.24	0.10	0.00	0.00	0.00	0.00
EU25	155.19	82.50	784.17	412.95	54.36	25.84	322.72	187.08

Annex 2-4: Extra EU Imports 2005 per major countries of provenance

CN Code : 2005 Extra-Imports	8418.50.11 M. Euros	8418.50.19 M. Euros	8418.50.91 M. Euros	8418.50.99 M. Euros	Total M. Euros
China	1.56	14.43	0.84	25.00	41.83
Hong Kong	0.12	0.05	0.00	4.22	4.40
Romania	0.83	11.87	0.02	7.64	20.36
Thailand		4.10		0.33	
Turkey	1.58	17.74	0.33	10.50	30.15
United States	1.03	5.97	3.00	3.87	13.88
Others (Total< 3M.)					20.67
EU-25 Total	5.53	62.76	4.51	62.93	135.73

Annex 2-5: Extra-EU Exports 2005 by major country of destination

CN Code : 2005 Extra-EU Exports	8418.50.11 M. Euros	8418.50.19 M. Euros	8418.50.91 M. Euros	8418.50.99 M. Euros	Total M. Euros
United Arab Emirates	1.71	6.70	0.47	4.38	13.26
Australia	2.14	10.46	0.21	6.16	18.97
Bosnia and Herzegovina	0.86	2.19	0.04	0.35	3.43
Bulgaria	0.52	5.47	0.07	1.19	7.26
Belarus	0.41	2.44	0.09	0.23	3.16
Canada	0.52	3.65	0.53	1.72	6.41
Switzerland	7.00	3.24	0.85	14.20	45.29
Chile	1.65	1.90	0.44	0.29	4.28
China	0.17	2.70	0.10	2.61	5.58
Serbia and Montenegro	2.76	1.29	0.05	1.40	5.51
Algeria	0.41	0.90	0.39	1.30	3.00
Egypt	0.10	1.50	0.22	1.38	3.20
Hong Kong	1.13	1.37	0.10	2.25	4.85
Croatia	2.67	10.16	0.60	3.09	16.53
Israel	2.10	5.20	0.27	1.77	9.33
Japan	0.36	1.37	1.47	2.25	5.45
Korea (South)	0.32	1.49	0.27	1.91	3.99
Kuwait	0.36	2.24	0.16	1.87	4.63
Kazakhstan	0.13	4.94	0.13	0.39	5.59
Morocco	0.31	4.09	0.06	2.83	7.29
Mexico	0.61	3.66	1.26	3.12	8.65
Nigeria	0.01	0.26	0.02	2.98	3.27
Norway	5.12	15.08	1.85	15.04	37.09
New Zealand	0.16	2.50	0.01	1.36	4.03
Romania	3.21	13.24	0.19	3.97	20.61
Russia	12.10	71.75	2.49	18.34	104.68
Saudi Arabia	1.48	7.17	1.71	4.18	14.55
Thailand	0.22	1.47	0.36	2.09	4.14
Turkey	2.22	3.31	1.52	6.25	13.29
Ukraine	5.13	13.05	0.23	8.60	27.01
United States	1.30	9.26	2.04	14.95	27.55
Serbia	0.96	2.66	0.10	0.73	4.45
South Africa	0.32	1.72	0.59	1.07	3.70
Others (Total< 3M.)					72.30
EU-25 total	64.28	265.43	22.25	168.82	520.78

Annex 2-6: Eurostat EU-25 apparent consumption for year 2005

PRODCOM	29231333		29231335		29231340		29231350	
2005 App Cons	unit	M. Euro	unit	M. Euro	unit	M. Euro	unit	M. Euro
France			149.32	191.81	22.04	40.82	189.25	298.43
Netherlands				27.95	-0.80	-10.07		
Germany	23.55	33.05	44.90	195.51	7.04	16.28	190.60	112.52
Italy	13.09	168.46	-55.44	-57.92	477.13	309.94	856.63	274.53
UK								
Ireland							10.92	4.08
Denmark	99.19	24.21	-248.14	22.98	0.10	0.83	12.55	-6.93
Greece	37.79	11.78	70.43	-15.26	48.32	33.19	96.28	19.82
Portugal	30.62	34.91	27.77	26.46	7.52	3.38	22.16	7.56
Spain	91.35	128.93	128.34	72.87	9.81	19.67	175.30	75.82
Belgium							12.45	7.56
Luxemburg	0.18	-0.33	27.97	0.15	0.41	0.09	-4.27	-10.24
Sweden					-0.72	-1.85		
Finland	14.78	17.57	19.10	36.27	0.19	0.15	3.58	-14.18
Austria	2.80	3.75			0.25	0.25		
Malta	0.52	0.80	6.18	1.51	0.02	0.12	3.69	0.78
Estonia			2.99	2.27	0.03	0.04		
Latvia	1.68	0.60	2.76	2.55	0.02	0.01		
Lithuania	1.49	-0.57	-9.50	-0.77	0.10	0.23	16.34	5.01
Poland	36.81	17.67	-40.17	-18.05	-0.03	2.83	102.75	79.19
Czech Rep.								
Slovakia					1.01	0.36	2.83	2.38
Hungary					1.81	1.03	-26.07	-12.56
Slovenia			0.47	-1.05			-13.13	-7.05
Cyprus	0.97	0.88	3.55	3.18	0.23	0.11	2.01	2.14
EU25	360.54	550.21	374.52	949.86	603.82	416.47	2,435.04	969.16

3. CONSUMER BEHAVIOUR AND LOCAL INFRASTRUCTURE

Product-design may influence the consumer behaviour to some extent which consequently will influence the environmental impacts and the energy efficiency associated with the product during its use phase. However, consumer behaviour has a significant direct effect on the use of commercial refrigerators and freezers during their lifetime. The aim of this section is to explore the consumer behaviour and local infra-structure aspects for the lot 12 products and their influence on the energy and environmental performance of these appliances.

Looking at the consumer behaviour and real life situation will provide a more accurate picture of the real energy use.

First, the focus will be on the real life efficiency of commercial refrigeration equipment. Consumer behaviour is an important input for the assessment of the environmental impact and the life cycle cost of the products, and the relevant parameters will be quantified for the purpose of later analysis. Important parameters include practices in maintenance during the use phase. Further, consumer behaviour related to end-of-life aspects will be discussed. Requirements for local infra-structure will be presented and finally the restrictions to possible eco-design measures, due to social and cultural factors will be described in the last sub-section.

3.1. REAL LIFE EFFICIENCY

3.1.1 KEY ACTORS AND USAGE PATTERN

3.1.1.1 REMOTE AND PLUG IN REFRIGERATED DISPLAY CABINETS

Major end-users include small end-users such as corner stores, service stations, convenience stores, and medium and large supermarkets.

Medium and large supermarkets typically use remote display cabinets and a few plug in for merchandising purposes. Smaller end-users typically use plug in equipment.

Remote and plug in refrigerated display cabinets are typically used 24 hours a day, without interruption even during the weekends.

3.1.1.2 COLD VENDING MACHINES

There are several actors in the use phase of a vending machine. Firstly, the vending operators source and site the machines generally under contract providing a service/maintenance for cleaning, filling and cash collecting as well as any necessary maintenance if required. Machine manufacturers normally sell only to vending operators or distributors but some do sell direct to vending users. Product Suppliers also supply machines (e.g. snack, drinks manufacturers) with their products. These are generally run on a do-it-yourself basis with the individual site owner taking responsibility for machine filling and cleaning. Maintenance is normally organised by the product supplier.

Vending machines located outdoors are typically in operation 24 hours a day. Vending machines located indoors (e.g. office buildings, college, schools, public transportation) often have timer and switch off during after hours and switch back on before opening hours. The switch off time can be different depending on the location and a range of 4 to 12 hours has been observed.

3.1.2 LOAD EFFICIENCY

The way refrigeration equipment is loaded can influence its efficiency.

- Overloading

Overloaded displays decrease product quality and increase energy use by as much as 10 to 20 % per unit[1] by disturbing the air flow.

Most end-users fill their cabinets with too much foodstuff despite the "load limits" indications on the cabinets (load limit shows the maximum filling of the cabinet). Cabinet overloading is commonly used in all EU 25 countries in medium/large size Stores with highest Consumers affluence especially in horizontal chilled serve over counters, horizontal frozen open chest and semi-vertical chilled cabinets. However in the south of Europe load conditions are not often respected. The situation is better in the north. Also bigger supermarket usually respect the prescriptions more, due to stricter control from national Health Departments and overloading is typically more observed in small convenience stores.

- Foodstuff temperature

The temperature at which the foodstuff is loaded also influences the performance of the equipment. The cold chain shouldn't be interrupted. However, this is often the case for non-perishable items such as drinks. They are loaded at ambient temperature in the beverage cooler or the cold vending machines implying an increase in energy consumption to pull down their temperature.

- Loading duration

For closed equipment (display cabinets with doors and vending machines) the time taken to load the foodstuff during which the doors are open, allowing bigger heat infiltration from the ambient warm air also influences the energy consumption.

- Foodstuff management

Food and beverage companies provide display (typically beverage coolers) and vending units to retailers to promote a particular brand of product. These "free" fridges and freezers are installed in retail outlets across Europe and many stores have several of these units. There is little incentive from

[1] Reference: Sacramento Utility District (http://www.smud.org/)

equipment owners to provide more efficient ones as they are not responsible for the energy consumption costs (see section 3.4.6). In addition, there is usually a requirement that the supplied equipment is only used to display the supplier's products (i.e. one brand, and sometimes only one type of product). This implies that more refrigeration equipment is used than necessary, increasing the total energy costs.

3.1.3 TEMPERATURE SETTINGS

For commercial refrigeration equipments, two levels of temperature exist: medium temperature (1 °C to 4° C) for preservation of fresh food and low temperature (-18 °C to -25 °C) for preservation of frozen food. There are some deviations, for example, beverage coolers and cold vending machines operate between 3 and 12°C.

Differences between the recommended temperature (fixed by food and safety regulations) and the real working temperatures can sometimes be observed.

These differences can happen when the cabinet thermostat is set on food safety temperatures values and not on manufacturer's recommended values due to the position of the control temperature probes inside the cabinet: the displayed working temperature of the cabinet (thermometer) could be slightly different from the real temperature inside the refrigerated volume of the cabinet (higher or lower depending from the probe position). In this situation Manufacturer give the right information regarding the correlation between the displayed temperature (set by the thermostat) and the real cabinet working temperature.

3.1.4 LIGHTING SETTINGS

Lights are commonly switched on 12 hours a day. Except in beverage coolers and vending machines for which lights are commonly used 24 hours a day.

In the past lighting problems over refrigerated display cabinets were more frequent than today and end-users typically follow the manufacturers instructions concerning this point. Also, it seems that less and less customers ask for cabinets with shelf lights (for multi decks and semi vertical). But glass door cabinets are equipped with lights inside. Lighting systems that are installed too close to the foodstuff can lead to much higher refrigeration energy consumption, especially in open horizontal cabinets.

3.1.5 OTHER CHARACTERISTICS OF USE

Other characteristics of use can influence the energy consumption of commercial refrigeration equipment.

- The location of the appliance

Locating the display cabinet or vending machine in a cool non-dusty area and not in direct sunlight will keep energy consumption low. Cabinets near natural lighting have worse performances due to radiation and cabinets near doors to external environment have worse performance due to higher temperature and humidity.

Manufacturers recommend that plug in display cabinets should be located in well ventilated areas (with air conditioning) to provide good ventilation of the condenser coils and fans. However, plug in appliances are typically used in small stores often without any air-conditioning systems.

Also, merchandising cabinets are often located near the store's exits and cashers where optimal conditions are not always met. Also air conditioning inlets can interfere with the air curtain of some open refrigerated cabinets and impair their performance.

Remote refrigerated display cases are usually located in the same area in a store ("cold section"), away from heat sources (e.g. delicatessen's kitchens, condensing units) and protected from outdoor air infiltration.

- Anti-sweat heaters

Anti-sweat heaters are often used on display cabinets with glass doors, either remote or plug ins to reduce condensation and prevent foggy glass doors. They commonly stay on at full load 24 hours a day.

3.1.6 BEST PRACTICES IN SUSTAINABLE USE OF REFRIGERATED DISPLAY CABINETS

A number of governmental agencies and organisations[2] give recommendations for smart use of commercial refrigeration equipment and "energy-saving tips" to end-users of such products. Such strategies to reduce the energy use aim at reducing the amount of cooling needed which can be achieved through better equipment settings and through the reduction of heat losses and gains.

Refrigerated display cabinets require constant refrigeration energy intake to offset heat gains and losses mainly due to:

- Heat gains due to openings of the cabinet (convection)
- Heat gains through isolated surfaces of the equipment (conduction)
- Heat gains through the radiation from surrounding surfaces (e.g. store ceiling for display cabinets)
- Heat gains due to the components implemented inside the furniture (lighting, fans, defrost system, warm foodstuff, …)[3]

Figure 3-1 provides a first estimation of the major sources of heat gains: infiltration inside the cabinets through the openings is the primary source of refrigeration power losses.

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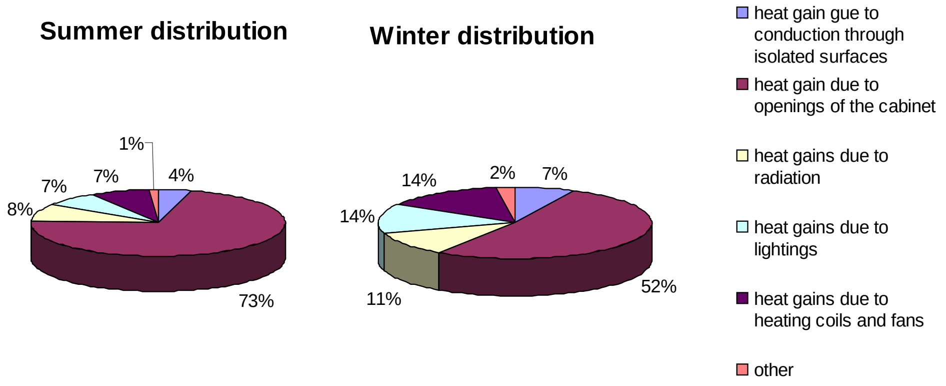
[2] Such as the Government of South Australia Department of Transport, Energy and Infrastructure, Energy Smart Initiative (Australia)

[3] Heat losses and gains will be further developed in task 4, section 4.4.

Figure 3-1: Heat gains from chilled refrigeration equipment in supermarkets[4]



Best practices to reduce the amount of refrigeration energy are discussed in following sub-sections.

3.1.6.1 EFFICIENT PRODUCT LOADING

Pulling down the temperature of foodstuff from the ambient temperature to the refrigerated temperature increases the energy demand. Storing goods in a cool area and loading the products when cool saves energy. For equipment with doors, quick loading of items reduces the heat transfer.

Also, the display cabinet should not be overloaded and used as permanent storage equipment. The stocking should be managed so that the refrigeration equipment is not overloaded.

Refrigeration requirement management can reduce the amount of cooling space needed. In the food distribution business, proper identification of the products that sell can allow to only display items that meet the demand and use less refrigeration - one fridge with a good turnover making more sense than two which are half full or loaded with slow-moving items.

3.1.6.2 REVIEW OF THE THERMOSTAT SETTINGS

Unnecessarily low temperatures waste energy and do not provide any benefit. For maximum energy savings, the temperatures should be set and kept at the maximum authorised temperature. Often, temperatures are set lower than necessary.

A regular check of the temperatures (which should be set to the maximum suitable temperature for the foodstuff) helps saving energy consumption.

[4] Reference: ENERTECH. *Diagnostic électrique d'un supermarché de moyenne surface.* Avril 2001 (ADEME Picardie)

3.1.6.3 LIGHTING CONTROL

Use of lower wattage light bulbs helps in reducing the amount of heat released and thus saving equivalent refrigeration energy. Switching off lights when unnecessary (e.g. during lunch hours) may result in overall reduction of energy consumption.

3.1.6.4 ANTI-SWEAT HEATERS AND HEATING COILS CONTROL

Anti-sweat heaters and heating coils ensure that no condensation occurs on the parts of the refrigeration furniture which are exposed to the ambient humid air. The power of these devices is normally constant and adds up to the refrigeration load. They are typically used 23 hours per day in low temperature cabinets (frozen) and 12 hours a day in chilled refrigeration equipment[5]. However, energy savings can be achieved by reducing the use of such heaters when the ambient air is colder and has a lower humidity.

The use of anti-sweat heaters can be controlled by switches responding to local dew point or humidity conditions. Appropriately placed sensors can measure dew point and allow the heater to switch off when not required.

Heating coils could also be replaced by a hot gas line running from the compressor to the door frame (for plug ins only).

3.1.6.5 LOCATING THE REFRIGERATION EQUIPMENT IN A COOL ENVIRONMENT

Avoiding direct sunlight, dusty areas, avoiding placing the display cabinet near a heated unit and providing good ventilation around the condenser and fans (in the case of plug ins and vending machines) result in higher energy efficiency of commercial refrigeration products.

3.1.6.6 MAINTAINING DOOR SEALS

Regular checks to verify that the door seals are providing sufficient insulation can also result in saving energy by preventing heat leakages.

3.1.6.7 NIGHT BLINDS AND INSULATING COVERS

Primary sources of heat gains in refrigerated display cabinets are ambient air infiltration inside the cabinet and radiation of heat toward the display case.

In open cabinets, one solution to reduce the radiative and convective heat transfer into the case is the utilisation of aluminium shields to cover the front opening of the display case during after hours.

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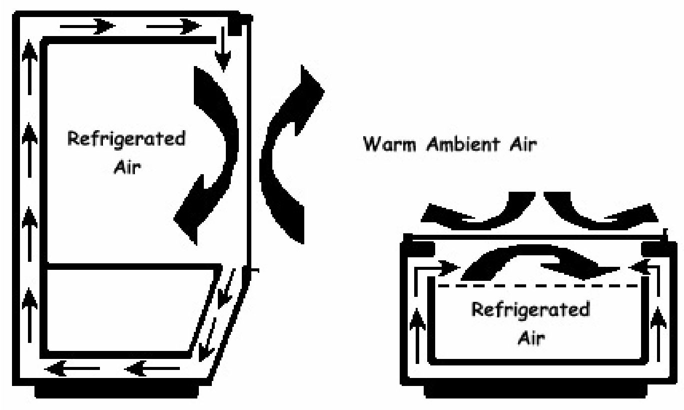
[5] Reference: Arthur D. Little, Inc., *Energy Savings Potential for Commercial Refrigeration Equipment Final Report*, Building Equipment Division Office of Building Technologies U.S. Department of Energy, June 1996.

http://www.eere.energy.gov/buildings/info/documents/pdfs/comm_refridg_equip.pdf

Figure 3-2: Air flow diagram for display cabinets with night cover on[6]



This type of night cover is widely used. In the case of vertical open cabinets, it ideally consists of a woven aluminium fabric which is pulled down in front of the opening either manually or automatically. The woven pattern of night curtains disperses radiated heat in many directions which is more effective than thermal blinds with smooth surfaces, which only reflect heat in the perpendicular direction. Refrigeration covers are not visible during business hours. The night curtain fabric normally rolls up and is stored in the top casing of upright refrigeration display cases, out of sight. The material used for such cover must be of high quality to ensure no condensation which could alter the quality of the foodstuff. The curtain is made of a food safe and perforated material which allows condensation to evaporate and prevent mildew from forming.

[6] Source : http://www.econofrost.com/products_covers.html

Figure 3-3: Display cases with night covers on[7]

The refrigeration load of supermarkets is reduced by 35 % in summer and 28% in winter when night covers are used for an average of 15.5 hours per day[8]. Many manufacturers claim that night covers can block up to 70 % of the ambient heat that normally enters the cabinet. Night covers can also be used for cabinets with glass doors to improve the insulation.

3.1.7 BEST PRACTICES IN SUSTAINABLE USE OF COLD VENDING MACHINES

The two major energy-consuming systems in cold vending machines are lighting and refrigeration. Lighting can account to 30 - 40 % of the total energy use[9] especially in the case of vending machines. Often very bright lighting is needed to illuminate logos and other advertising material. Lights are generally left on continuously, even during off-peak periods such as nights and weekends. The advertising value is of some interest for machines located outdoors but it is likely to be minimal for vending machines located inside buildings. Low cost technologies such as timers or motion detectors could easily be employed to reduce the time for which the lights are on and electricity consumption could be saved.

A typical motion detector operates in the following way: if no one is near the vending machine for 15 minutes and the compressor is not running, a control device shuts off the vending machine. If someone walks by the machine, the motion sensor will sense the movement and send power back to the machine (lights turn on). The internal thermostat of the vending machine then decides if the compressor needs to be restarted. The motion detector is also combined to a sensor which measures ambient room temperature. If the room is very warm, the control device will more often send power to the machine than if the machine is in a cold room. The machine turns on every 1-3 hours to ensure the beverages stay cool, even if nobody walks by the vending machine for many hours.

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[7] Source: Southern California EDISON, Refrigeration Energy Test Center

[8] Reference: ENERTECH. *Diagnostic électrique d'un supermarché de moyenne surface.* Avril 2001 (ADEME Picardie)

[9] Reference: American Council for an Energy-Efficient Economy. *Commercial Packaged Refrigeration: An Untapped Lode for Energy Efficiency*. (May 2002)

3.2. END-OF-LIFE BEHAVIOUR

3.2.1 ECONOMICAL PRODUCT LIFE

The economical products life in the case of commercial refrigeration products is much less than their technical life. Most of the remote and display cabinets are replaced even if they are still functioning properly. This can be either because of advertising and marketing reasons; many beverage companies replace the plug in display cabinets with the launch of a new product and many supermarkets replace the remote display cabinets to give a new look and to attract customers. Sometimes, they are also replaced because of hygiene reasons even if the technical components are functioning properly. That's why many of these display cabinets are exported (to Asia, Africa, etc.) and rarely reach their end-of-life within Europe.

In the case of vending machines, however, longer product lives are observed with some regular maintenance and repairs.

Table 3-1 provided average product life for these products but a reduced economical life will be used in LCC calculation during tasks 5 and 7.

Table 3-1: Average product life of commercial refrigeration equipment category

Product	Economical product life
Remote refrigerated display cabinet	9 years[10]
Plug in refrigerated display cabinet	6 - 10 years
Cold vending machines	7 - 10 years

The lifespan of plug in display cabinets is estimated to an average of 7 years. This covers various equipment lifetimes such as display cases (6 years) and beverage merchandisers (7 - 10 years) [11].

According to the UK Market transformation program, average lifespan of a vending machine is 10 years[12] often with refurbished and repaired parts.

3.2.2 REPAIR PRACTICES

When remote refrigerated display cabinets are washed with water-jets, the water could damage the evaporator fans. For plug in refrigerated display cabinets and cold vending machines, breakdowns seldom occur.

[10] Source: EUROVENT survey

[11] Reference: Mark Ellis and Associates. *Self-contained Commercial Refrigeration.* (March 2000)

[12] Reference: UK Market Transformation Program. *BNCR33 : Automatic vending machines* (18/05/2006) Available at http://www.mtprog.org

3.2.3 MAINTENANCE PRACTICES

3.2.3.1 REMOTE REFRIGERATED DISPLAY CABINETS

Regular basic maintenance on remote refrigerated display cabinets includes the following practices[13]:

- **Evaporator cleaning**

Cleaning the evaporator coils monthly and keeping them unobstructed can improve the efficiency. Blocking or partial blocking of the fin coils, and oil logging (oil coming from the compressor) will drop the evaporator temperature which reduces the cooling capacity and the desired cooling temperature might not be reached. A 1 °C drop in evaporating temperature increases the refrigeration electricity use by between 2 % and 4 %.

- **Evaporator defrost**

Remote display cabinets are mostly used in grocery stores and supermarket where the average humidity amounts to about 60 %. The high humidity rate is a result of the water coming from outside air intakes, shopper respiration and from the water used to clean the store. When in contact with the evaporator, the water condenses and freezes and a layer of frost forms on the outside of the evaporator acting as an insulator and hindering the heat exchange with the air that needs to be cooled. This results in poor energy efficiency.
Regular defrost prevents ice build-up. Different types of defrost methods exist: defrost through compressor shutdown, electric defrost and hot or cool gas defrost.

In the case of defrost through compressor shutdown the flow of refrigerant liquid in circulation inside the evaporator is temporarily stopped but the ventilators are kept in operation. The evaporator heats up melting the ice and the water resulting from the defrost is drained and collected in the defrost water tray. The water from defrosting is then either evaporated within the cabinet's volume (using an evaporator pan) or drained externally (drain line).
During the operation, the temperature rises above the set-point temperature and the food products' temperature rises as well. Therefore the duration of the defrost is limited to ensure that the foodstuff is kept under good storage conditions. Typically[14], the defrost cycles are set automatically and stop when the temperature reaches 12 °C , temperature above which no frost could subsist. The evaporator is then fed with refrigerant liquid and the vapour compression cycle can restart.

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[13] Reference: Mitchell, N. Annual Systems Inspections Reduce Electric Energy Consumption. (2000) Available at www.afce.asso.fr/stock_images/mcpid/pdf/asercomNMitchell2000.pdf (5/01/07)

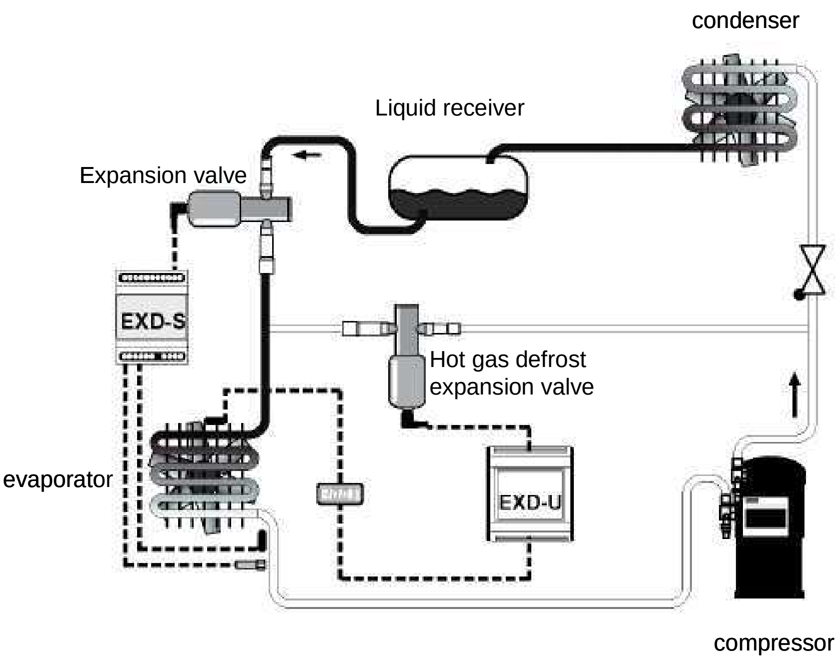
[14] The defrost operation can be automatic (no end-user action is required to initiate and stop the defrost), semi-automatic (automatic defrost with manual removal of the defrost water, or defrost initiated by the end-user which then stops automatically), or manual (the defrost is initiated and stopped by the end-user).

However, this defrost method is only acceptable for chilled refrigerated display cabinets and cannot be operated in the case of commercial freezers because it would require the refrigeration cycle to stop for a long time and this would impair the food preservation.

In cabinets operating below 0 °C, one common defros t method used to reduce the duration of the ice melting is the electric defrost through the use of defrost heaters. They consist of high power resistances that are fixed near the evaporator (defrost coil which is integrated to the evaporator coil) and that are switched on to accelerate the defrost. During this process the refrigerant supply is switched off and the ventilators are kept in operation to blow the warmed air on to the evaporator. A few minutes is then needed to achieve the complete melting of the ice and electric defrost is also very simple to use. However, higher electricity consumption is needed for the resistances and defrosting brings a mount of heat to the remote refrigerated display cabinet that needs to be taken out. In the ADEME study, they show that in typical supermarket frozen display cases, less than 20 % of the electricity used by the defrost heaters is actually used to melt the ice build up. The rest heats the air flow blown in the display case, heating up the equipment which will require to be cooled down after the defrost. The total duration of the electric defrost per day is estimated to 30 minutes in low temperature (frozen) display cabinets in a typical supermarket.

Hot or cool gas defrost are potentially efficient methods although they require additional piping (implying higher risks of refrigerant leakages) and maintenance. Hot gas defrost uses the hot discharge (high pressure) gas directly from the compressor piped to the evaporator, and the cool gas defrost involves the circulation of gas from the liquid receiver with a control valve to begin and end the defrost cycle. The cool or hot gas condenses in the evaporator, releasing heat which melts the ice from the evaporator coils. The merits claimed for cool gas defrost are that there is less temperature shock to the piping and evaporators compared to hot gas defrost. During this operation, the fans are switched off to prevent water carry-over from the coils. The refrigerant leaving the evaporator is piped back to the liquid manifold of the compressor pack for distribution to other display case circuit (Figure 3-4). In supermarkets, refrigeration systems can supply refrigerant liquid to a number of display cases which are piped in parallel. For this reason, the number of display cabinets which can be defrosted at the same time is restricted to avoid starvation of the compressor and system shut-down due to low suction pressure.

Figure 3-4: Hot gas defrost typical setting in a refrigeration system[15]



In a typical supermarket, the electric and hot or cool gas defrost is normally controlled by a preset time cycle with most display cabinets timed to defrost every 6 hours for a duration of 10 minutes[16].

Defrosting involves the introduction of heat inside the display case and this penalises the refrigeration system performance due to the fact that process energy is used while producing no useful cooling. Furthermore, during the defrost, the temperature inside the cabinet rises above the set limit for normal operation. Energy efficiency and better temperature control can be helped by initiating defrost operations only when it is required (and not through a timer), through control systems detecting lack of performance and by stopping the defrost cycle as soon as the evaporator is clear of ice.

A number of defrost control strategies have been applied over the years which include: measuring the air pressure drop across the evaporator, sensing the temperature difference between the air and the evaporator surface, fan power sensing, variable time defrost based on relative humidity and air differential across the coil. Most recent methods include measuring the ice thickness through monitoring the resonant frequency of an acoustic oscillator installed on the evaporator, measuring the thermal conductivity of the ice, using photo optical systems and fibre optic sensors to measure the presence of frost.

[15] Source: Copeland Alco control catalogue 2006

[16] Datta, D. and Tassou, S.A. *Frost Prediction on evaporator coils of supermarket display cabinets using artificial neural networks.* Department of Mechanical Engineering, Brunel University Uxbridge, UK

However, cost and the simplicity of use is an important factor for end-users since the number of cabinets in a modern supermarket may range from 40 to 150 units and electric defrost remains the most typically used method.

3.2.3.2 PLUG IN REFRIGERATED CABINETS

- **Evaporator cleaning**

Specially formulated cleaning solutions are available to clean the type of sediment that can collect over time in evaporators. Cleaning the evaporator annually can prevent the sediment collection and increase efficiency. The cleaning requires the power to be shut off and the drain tube to be disconnected. The bottom pan of the evaporator coil can then be unscrewed and removed.

- **Evaporator defrost**

The most common defrost methods are defrost through compressor shutdown, electric defrost and hot gas defrost as described in section 3.2.3.1

- **Condenser cleaning**

The cleanliness of the surface of the air-cooled condenser is very important. Even if the condenser is located in a ventilated area, if the air cannot directly contact the heat transfer surface because of dust and dirt then the condensing temperature will rise. Keeping the condenser coils clean will help reducing the electricity consumption. Manufacturers recommend the condenser to be cleaned at least twice a year in the case of beverage merchandisers.

Cleaning the condenser fan blades also ensures increased energy efficiency.

If condenser coils get too dirty, the compressor discharge pressures can get high enough to break the compressor in a short period of time. A regular check on this component can prevent reaching high discharge pressures resulting in higher efficiency.

3.2.3.3 COLD VENDING MACHINES

Vending machines are sealed appliances. The only maintenance practice is the cleaning of the condenser and the replacement of lamps when necessary.

3.2.4 REUSE, RECYCLING AND DISPOSAL

3.2.4.1 REFRIGERATED DISPLAY CABINETS

In European fridge recycling facilities, less than 1 % of the appliances are commercial equipments. Commercial refrigeration equipment can be frequently renewed (every 1 - 10 years depending of the supermarket chain) in medium supermarkets and large supermarkets for aesthetic and marketing reasons although it is still operational. Most of the commercial refrigeration equipment is then refurbished and introduced in the second-hand market. The used equipment is generally sold in East and Central Europe or in African/Asian countries.

Other practices also exist: when the equipment is not suitable for second hand use, some retailers sell the old equipment to scrap metal dealers. Valuable materials such as copper, aluminium and steel are recovered from these refrigerated display cabinets.

However, for cold beverage merchandiser, since almost all units in this market segment are branded-equipment, there is no significant used equipment market for beverage merchandisers. Bottling companies do not want their brand identity to be misused. After a 7 - 10 product life, the beverage company either: scrap the unit for parts, sell the unit overseas or refurbish the unit for continued use in same or different location.

Some plug in manufacturers comply with the WEEE directive, but their position varies depending of the country. The requirements are the same as for cold vending machines below (section 3.2.4.2.).

3.2.4.2 COLD VENDING MACHINE

Cold vending machines fall under the scope of the WEEE directive (category 10) which puts the responsibility on the producer and states that:

"*the rate of recovery shall be increased to a minimum of 80 % by an average weight per appliance, and component, material and substance reuse and recycling shall be increased to a minimum of 75 % by an average weight per appliance*;"

In UK (Market transformation program) at eventual end-of-life, it is assumed that the machine is purchased by a recycling broker who then breaks the product down, recovers the refrigerant and sells the separated metallic components for scrap. Very few of the products are buried in landfill sites and many of the recovered components can and are reused for spares within other products except for materials which cannot be reused easily such as the plastic branding, damaged seals and plastics. In the UK, very few vending machines do not make it to recycling indicating extremely high recovery rates for such products. According to the industry both refurbishing and cannibalisation (component reuse) of components is a common practice. It is considered that on average, 50 % of the machines are reused (in total or single parts) at the end of their lives.

3.3. LOCAL INFRA-STRUCTURE

A number of eco-design measures represent additional complexity for the refrigeration system and its control (e.g. lacks of know-how in the field of new refrigerants, in demand defrost control…). Most technicians providing service for remote refrigerated display cabinets would have difficulties in properly maintaining systems with such controls. A training effort would be required in order to enhance the understanding of these technologies and to convince technicians that equipment with such controls will work reliably.

Also for vending machines, the fact that end-users, who are the ones paying the electricity bills, are not the ones operating the machines adds a barrier to the implementation of system control. An end-user who wants to install a motion detector on a vending machine will need to educate and inform whoever is in charge of adding, replacing and moving vending machines to ensure that the motion sensors and the vending misers are mounted permanently into the wall or ceiling. Also turn over rates of employees in charge of the vending machine maintenance and loading may be high and each new delivery person has to be informed which adds an effort of coordination.

Interviews with various manufacturers and refrigeration equipment certification agencies (EUROVENT and ARI) have confirmed that in the case of remote refrigerated display cabinets, the installation of the refrigeration system and the maintenance of the whole system are the two major parameters influencing the energy consumption.

3.4. Possible barriers for eco-design

The following barriers to eco-design have been identified[17].

3.4.1 Focus on first cost

Purchase decisions for refrigerated display cabinets are generally not made on life cycle cost or payback considerations. Equipment buyers, either they are small end-users, medium end-users or large supermarket normally select the equipment that meets specifications at the lowest cost.

For medium-sized end-users and large supermarkets, the people in charge of selecting the equipment do not focus on energy efficiency as choice criteria because they are generally not the ones in charge of operating it or the ones paying the final electricity bill.

3.4.2 Limited information

End-users are often not aware of the difference of energy efficiency among competing products (i.e. no use of energy efficiency labels). Some end-users also lack information on the cost to power their equipment (typically small end-users and cold vending-machines users, accordingly the demand from energy efficient appliances is not very strong from their side).

[17] Reference: Data from manufacturers and from Arthur D. Little, Inc. *Application of Best Industry Practices to the Design of Commercial Refrigerators, Development of a High Efficiency Reach-in Refrigerator*. Final report to the National Energy Technology Laboratory, US Department of Energy. (June 2002). Available at <http://www.cee1.org/com/com-ref/doe-rep02.pdf >

This lack of resources among end-users for confident and accurate assessment of either the available technology options and related energy saving potentials adds up to the fact that in many cases the new equipment is purchased when the old equipment fails and there is no time to analyse in details the purchase decision (more specifically for small end-users).

The PROCOOL project related to plug in refrigerated display cabinets gave manufacturers the opportunity to present themselves as developers of innovative, environmentally friendly appliances.

3.4.3 PREFERENCE FOR STABILISED TECHNOLOGIES

Technologies diverging from current practice take time to be introduced into a significant portion of the market. Indeed, some end-users estimate that the switch for natural refrigerants on remote equipments requires technicians knowing how to install and operate refrigeration systems with such "new" refrigerants. Therefore, training technicians is a preliminary condition.

3.4.4 IMPORTANCE OF MERCHANDISING

Energy costs are often small compared to the food products sales revenue. In beverage coolers and cold vending machines, the energy cost typically represents an average of 3 - 4 %[18] of the sales revenue. Although they are not completely insignificant, the energy costs do not represent a large part of the sales revenue and this increases the tendency to disregard energy issues in evaluating sales-boosting design changes such as an increase in lighting intensity. Also for beverage coolers and cold vending machines, an increase of the insulation thickness is undesirable. This would result in a decrease in storage volume which would reduce sales capacity of a given unit.

Other issues related to merchandising advantages exist such as the necessity to keep the foodstuff at the reach of shoppers which implies that most of the display cabinets have no doors, although doors would prevent warm ambient air infiltration in the cooled cases. In display cabinets also lightings systems of high intensity are used to provide a clear presentation of the product.

3.4.5 LACK OF FINANCIAL INCENTIVES

The Dutch STIMECK scheme (http://www.mep.tno.nl) and the UK capital allowance (http://www.eca.gov.uk/) facility are the only programs identified which provide financial incentives for investment in energy efficient commercial refrigeration equipment.

The Dutch subsidy scheme is not operational anymore. But was a regionally administered scheme which provided subsidy on the basis of tons of CO_2 saved

[18] Arthur D. Little, Inc. *Energy Saving Potential for Commercial Refrigeration Equipment*. Final report to the Building Equipment Division, US Department of Energy. (June 1996)

per year to supermarket operating with energy efficient supermarket refrigeration equipment according to the STIMECK list of efficient products.

In the UK, end-users can benefit from tax concessions when they choose to buy energy-efficient products. The full list of complying products is available on their website (http://www.eca.gov.uk/etl/find/_14.htm). They include display cabinets, night covers, refrigeration control systems, etc.

3.4.6 END-USER VS. EQUIPMENT OWNER

For some type of equipment such as branded-ice cream chest freezers, beverage merchandisers, and cold vending machines, the end-user is not the owner of the equipment. Instead, most of this equipment is owned by the food and beverage companies who do not pay utility bills for the building where the units are located which eliminates any incentive of the machine owners to select equipment with more efficient measures available at higher purchase cost.

However some beverage companies engaged in environmental improvement provide new HFC free equipment to its clients.

3.5. CONCLUSIONS

The end-user behaviour has a significant impact on the electricity consumption of remote and plug in refrigerated display cabinets and cold vending machines. Improving simple operational and maintenance practices can reduce energy consumption of 15 % or more[19]. Many barriers to eco-design related to the end-user have been identified and will be taken into account when focusing on improvement potential (task 7).

[19] Reference : Australia Energy Smart Initiative

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4. TECHNICAL ANALYSIS OF EXISTING PRODUCTS

This document is the task 4 report of the lot 12 EuP preparatory study on commercial refrigerators and freezers.

Task 4 comprises of a general technical analysis of the existing products on the EU-market. For each category of product defined in task 1, an item representing the average current product on the European market will be analysed (identification in task 2). This analysis will serve as input for defining base cases (task 5).

4.1. PRODUCTION PHASE

4.1.1 REMOTE REFRIGERATED DISPLAY CABINETS

4.1.1.1 EQUIPMENT DESCRIPTION

A remote refrigerated display cabinet comprises an insulated storage space where the foodstuff is loaded. A thermally insulated envelope is built on the external side of the storage space. Cold air circulates between the outside of the storage space and the inside the insulating envelope to maintain a low temperature. Fans, located at the bottom of the unit circulate the air (Figure 4-1).

Air is blown through an evaporator to cool its temperature. A remote refrigerated display cabinet is a cabinet designed to be attached to a separate means of refrigeration. The refrigerant being evaporated in the evaporator flows in and out of the cabinet's refrigerant coils back to a remote refrigeration system (e.g. condensing unit).

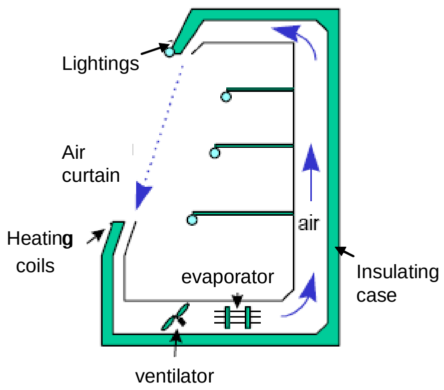
The case insulation is typically 37 – 50 mm thick and normally provided by blown polyurethane foam. Most common blowing agents include carbon dioxide, HFC 245fa, R 134a and Cyclopentane.

Evaporator fans circulate case air. The air flow in open cases (e.g. open vertical multi decks, open horizontal freezers) is blown over the open section of the cabinet creating a cold air curtain which separates food from the warmer ambient air, reducing cold spillage. The air is blown from the top of the case (discharge air grill) and directed into a laminar flow towards a return air grill leading to the evaporator where it is cooled down (Figure 4-1). Multiple fans are required for most cases.

Low temperature and some medium temperature evaporator require to be periodically defrosted to remove the frost that freezes on their surface (frozen cabinet evaporating temperature is near -35 °C). This can be achieve through electric defrost, hot or cold gas defrost. The former involves electric resistance heaters, the latter involves piping and valves which send hot compressor discharge gas or cold gas from the liquid receiver to the evaporator (defrost is further discussed in task 3)

The cabinets comprise shelves where the food products are displayed and also relatively strong lightings systems, typically fluorescent, to ensure a good visibility of the products for merchandising. Part of the cold surfaces of the cabinet are exposed to the ambient air and the risk of condensation can occur. Heating coils can are used to control the condensation and raise the temperature of the exposed surfaces above the dew point. Anti-sweat heaters are used on glass doors to prevent moisture from forming and impairing the visibility of the foodstuff. Efficient doors consisting of two or three glass layers enclosing a film of insulating gas also exist and do not require glass heaters.

Figure 4-1: Typical vertical multi deck display cabinet[1]



High pressure liquid and suction refrigerant piping must be connected to the case. Additional connections are electrical power supply and the drain lines for the condensate (from the defrost operation).

[1] Source: ADEME Picardie and ENERTECH. *Diagnostic électrique d'un supermarché de moyenne surface. (*April 2001). Available at < http://sidler.club.fr/RSuperm.PDF > (01/11/2007)

Figure 4-2: Remote glass door reach in display cabinet[2]

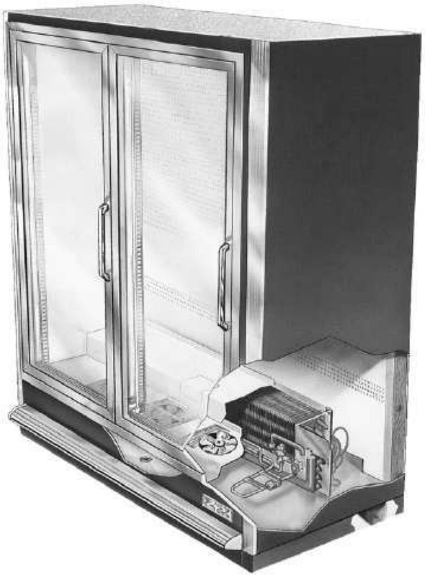


Figure 4-3: Remote open frozen island

4.1.1.2 BILL OF MATERIALS

The overall weight of remote refrigerated display cabinets depends primarily on the total display area and of the family of cabinet it belongs.

With the help of major manufacturers of remote refrigerated display cabinets, two major appliances have been identified as real life products that are typically used in EU-25:

1- Open Vertical Chilled Multi Deck (RCV2)

2- Open Frozen Island (RHF4)

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[2] Source: Arthur D. Little, Inc., *Energy Savings Potential for Commercial Refrigeration Equipment Final Report*, Building Equipment Division Office of Building Technologies U.S. Department of Energy, June 1996.

http://www.eere.energy.gov/buildings/info/documents/pdfs/comm_refridg_equip.pdf>

For each of these families of products, the bill of materials (BOM) of existing products (further referred to as the product cases) have been collected among manufacturers.

- **Open Vertical Chilled Multi Deck (RCV2)**

The BOM of 4 standard open vertical chilled multi decks have been collected (RCV2_1, RCV2_2, RCV2_3, RCV2_4) among four major European manufacturers.

The chosen category of multi deck for which the BOMs were collected presents the following characteristics (Table 4-1):

Table 4-1: Characteristics of a typical remote open vertical multi deck

Temperature class	3M2 (for dairy application)
Number of shelves	4
Length (m)	~3.75
Height (m)	~2.0
Front height (mm)	~ 400
Lighting system	unlit shelves standard canopy with magnetic ballast
Night curtains	No night curtains
Defrost heater	No defrost heaters – uses electronic temperature control to start the natural defrost (circulation of the refrigerant is stopped)
Expansion valve	Standard thermostatic expansion valve

These features were decided together with major remote refrigerated display cabinets. It was estimated that they represent the best picture of the products in stock in EU-25.

All remote vertical chilled multi decks are vertical cabinets with no doors as shown in Figure 4-1**.** Depending of the manufacturer, the design is slightly different and the configuration of the lighting system and of the evaporator fans is different. The lighting system comprises 2 to 3 fluorescent tubes of 36 W up to 54 W. The number of evaporator fans can vary between 4 and 6, with an output power of 10 W or 24 W (Table 4-2).

Table 4-2: Configuration of the RCV2 product cases

Configuration	RCV2_1	RCV2_2	RCV2_3	RCV2_4
Fans	6 x 10 W	4 x 24 W	5 x 10 W	4 x 10 W
Lights	3 x 36 W	2 x 36 W	3 x 54 W	3 x 36 W

Despite these differences, all four cabinets are fitted with the same type of components in terms of material composition and distribution. They run on R 404A and have a total display area ranging from approximately 6.2 m^2 to 7.2 m^2. The temperature range of these cabinets is M2 as defined in the ISO 23953: (-1 ℃) to (+7 ℃).

When providing the BOMs, refrigerated display cabinets were not always able to specify the material composition or the weight of the components included in their product. Where manufacturer's data was not available, assumptions were made together with the industry and with refrigeration component manufacturers to fill the gaps and to identify the typical components in RVC2s.

- Material composition of the fans/fan motors

Depending on the output range the total mass of the fan motor varies but the distribution of the materials remains the same.

For the evaporator and fans' motors, the identified components show the following characteristics for a fan connected to a 10 W output motor: the overall weight of the fan module3 is 1,710 g (1,200g for the motor). The fan is made with an aluminium blade and is connected to a shaded pole motor. The input power of the motor is estimated to 36 W (output power if of 10 W) and the material composition is as presented in Table 4-3. It mostly comprises iron (24-Ferrite) and copper (28- Cu winding wire) from the motor and iron from the fan grid (25 – Stainless 18/8 coil). In some cabinets, the blade of the evaporator fans can also be made of plastic. However the typical fan was identified as fitted with aluminium blades.

Table 4-3: Material composition of a typical fan and fan motor of 10W output

Po nr	MATERIALS Extraction & Produc Description of component	Weight in g	Category Click &select	Material or Process select Category first !	Mass %
1	**Fan Motor**				
2	Aluminium	120.0	4-Non-ferro	**27-Al diecast**	10.0%
3	Iron	780.0	3-Ferro	**24-Ferrite**	65.0%
4	Copper	240.0	4-Non-ferro	**28-Cu winding wire**	20.0%
5	PVC	60.0	1-BlkPlastics	**8-PVC**	5.0%
6	**Fan Blade**				
7	Aluminium	120.0	4-Non-ferro	**26-Al sheet/extrusion**	100.0%
8	**Fan Grid**				
9	Iron	390.0	3-Ferro	**25-Stainless 18/8 coil**	100.0%
10					
11	TOTAL WEIGHT	1710.0			

The same distribution of the materials can be applied for a fan connected to a 24 W output power shaded pole motor. However, the total weight differs.

- Lighting system

The lighting system consists of standard magnetic ballast connected to fluorescent tubes of 36 W or 54 W. It was assumed that the lamps were made of glass only. The material composition of the magnetic ballasts was not investigated as these products are already covered by a European directive (DIRECTIVE 2005/55/EC) and only their weight was taken into consideration.

- Electronic temperature control

It was assumed that the electronic temperature control device weights about 600 g. The material composition is given in Table 4-4.

[3] includes the fan blade, fan grid and fan motor

Table 4-4: Electronic temperature control material composition

Po nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	**Electronic temperature control**			
2	LED screen	100.0	6-Electronics	**48-SMD/ LED's avg.**
3	Housing	400.0	1-BlkPlastics	**10-ABS**
4	Sensor	50.0	3-Ferro	**22-St tube/profile**
5	Integrated circuit	50	6-Electronics	**47-IC's avg., 1% Si**
6	TOTAL WEIGHT	600		

- Other

In cooperation with the different manufacturers the weight and material composition of missing parts of the BOM were evaluated based on "expert guesses" (e.g. cables…). For some data missing in one BOM we used the average of the other BOMs.

The BOMs were completed based on the assumptions presented above in order to obtain the best available estimations of the material inventory of each remote refrigerated display cabinet. The end walls of the cabinets (side panels) were not considered in the BOM as this type of cabinet is usually sold without end walls and fitted in a line of similar cabinets. In Table 4-5, the gross weight includes the packaging and the cabinet with the end walls (representing approximately 30 kg); the weight from the BOM data only includes the packaging and the cabinet without the end walls.

This resulted in BOMs with 84 to 91 % of the material data (including the packaging) (Table 4-5).

Table 4-5: RCV2 product specifications for the 4 product cases

	RCV2_1	RCV2_2	RCV2_3	RCV2_4
Gross weight (total mass – catalogue data) (g)	685,000	N/A	680,000	640,000
Weight from BOM data (g)	622,440	594,024	573,845	539,076
% of data missing	9.13%	N/A	15.61%	15.77%
TDA (m^2)	6.77	6.27	7.13	6.18

To allow useful comparison the material data was normalised by adjusting up or down to a total display area (TDA) of 7 m^2. All material data was normalised to a 7 m^2 TDA cabinet, except for some specific components that are assumed to remain the same, such as the electronic temperature control device.

The total display area of the cabinet was chosen as the reference to normalise the data because it is the major parameter both influencing the BOM (TDA is linked to the dimension of the cabinet) and the electrical energy consumption. Indeed, the heat infiltrations thought the cabinet opening into the refrigerated space highly influence the refrigeration load and thus the energy consumption (further developed in 4.4.1.1).

The total normalised masses of the considered refrigerated cabinets differ from 10 kg to 80 kg. This is due to the different amounts of missing data and in the difference in the design of the cabinet, specifically in the cabinet housing and shelves (both in stainless steel).

The detailed BOMs for the four remote open vertical chilled multi decks are not presented to preserve confidentiality. The mass proportion of the different material used is given instead for each product case (Table 4-6).

Table 4-6: Total mass proportion per category of material

Materials	RCV2_1	RCV2_2	RCV2_3	RCV2_4
Bulk Plastic	2.25%	0.65%	6.43%	3.54%
Tec Plastics	5.08%	4.64%	0.00%	3.28%
Ferro	79.68%	80.15%	78.81%	65.80%
Non-ferro	8.53%	7.52%	6.17%	9.66%
Coating	1.39%	3.22%	1.78%	7.94%
Electronics	0.02%	0.03%	0.03%	0.03%
Misc. (Blowing agent)	0.05%	0.24%	0.24%	0.08%
Misc. (Glass)	0.08%	0.08%	0.05%	0.11%
Misc. (Ballast)	0.19%	0.32%	0.05%	0.22%
Misc. (Cardboard)	0.00%	0.70%	0.17%	0.00%
Misc. (Paper)	0.00%	0.35%	0.17%	0.15%
Misc. (Wood)	2.72%	2.11%	6.10%	9.20%

As shown in Table 4-6, the most significant materials in open multi decks are:

- The ferro-metal mostly used for the panels of the housing (21-St sheet galv.)
- The non-ferro metal used for the evaporator and the pipes
- The technical plastics used for the insulation (in RCV2_3 the plastic used for the insulation is bulk plastic)
- The wood used for the packaging.

The differences in the mass proportion predominantly come from the difference in the panels and the shelves used in the four cabinets. In order to proceed to a more detailed analysis and to identify the component groups being the most environmentally impacting, the BOMs were split into seven modules (see description below). The choice of this modular approach will be further developed in task 5.

Table 4-7: Total mass proportion per module

Modules	RCV2_1	RCV2_2	RCV2_3	RCV2_4
Housing	83.61%	88.24%	84.06%	83.29%
Evaporation Module	7.55%	5.87%	6.51%	3.84%
Expansion valve module	0.05%	0.07%	0.07%	0.07%
Anti sweat heater module	0.06%	0.00%	0.00%	0.00%
Electric Assembly	2.12%	0.63%	0.98%	1.09%
Packaging	4.20%	3.16%	6.49%	9.45%
Miscellaneous	2.41%	2.04%	1.90%	2.26%

The mass proportion per module is given in Table 4-7. This table shows that the housing of the multi deck represents the biggest mass of materials of the cabinet (~ 85 %), followed by the evaporation module (~ 6 %) and the packaging (~ 6 %).

The next paragraphs give a short description of the seven modules. In order to provide a more detailed picture of the materials used in remote multi decks, the material distribution of the three predominant modules is also given.

Housing

The housing module aggregates the insulated casing (e.g. external housing[4], foam insulation, shelves/grids...) and the lighting system (light bulbs, light box and lighting ballast). Furthermore, the screw and rivets used in the entire product are listed under this module.

Most of the materials in the housing are ferro metals (~87 % according to Table 4-8) used in the panels (~60 % of the cabinet mass according to Table 4-9) and the shelves (~30 % of the cabinet mass according to Table 4-9), followed by the plastic used for the insulation (between ~ 4 to ~ 6 %).

Table 4-8: Material proportion in Housing

Housing	RCV2_1	RCV2_2	RCV2_3	RCV2_4
Materials				
Bulk Plastic	1.16%	0.00%	5.61%	3.32%
Tec Plastics	5.11%	5.26%	0.00%	3.93%
Ferro	91.72%	88.78%	91.86%	76.84%
Non-ferro	0.00%	1.59%	0.00%	5.94%
Coating	1.62%	3.65%	2.11%	9.49%
Misc. (Blowing agent)	0.07%	0.27%	0.29%	0.09%
Misc. (Glass)	0.10%	0.09%	0.07%	0.13%
Misc. (Ballast)	0.23%	0.36%	0.06%	0.26%

[4] The external housing comprises all the components which are part of the cabinet structure such as side/back panels, the machine cover, the evaporator cover, glass panels (if any)…

Table 4-9: Material proportion per sub-module

Housing	RCV2_1	RCV2_2	RCV2_3	RCV2_4
Sub-Modules				
External housing	68.67%	57.62%	56.37%	69.15%
Foam insulation	4.77%	5.53%	5.90%	3.84%
Shelves	23.62%	34.65%	35.68%	23.30%
Lighting System	1.68%	2.04%	1.68%	2.12%
Components for assebling (screws, rivets, etc.)	1.25%	0.16%	0.37%	1.59%

Evaporation module

The evaporation module includes the evaporator (copper and aluminium) used to absorb the heat from the internal air of the cabinet and the fans (fan motor, frame, blades) allowing air circulation. Most of the material used in this module is copper (this explained the high proportion of non-ferro material observed in Table 4-10) for the suction line of the evaporator (the evaporator represents over 70 % of the module according to Table 4-11).

Table 4-10: Material proportion for Evaporation module

Evaporation Module	RCV2_1	RCV2_2	RCV2_3	RCV2_4
Materials				
Bulk plastics	0.00%	0.99%	0.80%	1.16%
Tec Plastics	4.28%	0.00%	0.00%	0.00%
Ferro	9.86%	25.63%	15.66%	22.59%
Non-ferro	85.87%	73.39%	83.53%	76.25%
Coating				0.00%

Table 4-11: Material proportion per sub-module

Evaporation Module	RCV2_1	RCV2_2	RCV2_3	RCV2_4
Sub-Modules				
Evaporator	83.40%	63.52%	77.91%	66.99%
Evaporator fan	5.87%	16.75%	6.02%	9.85%
Evaporator fans motors	10.72%	19.74%	16.06%	23.17%
Evaporator tray	0.00%	0.00%	0.00%	0.00%

Expansion valve module

This module comprises the expansion valve used in the cabinet. Typically it is a thermostatic expansion valve.

Electric assembly

This module comprises all material existing in the electric panels and the power cables.

Packaging

This section includes al the packaging material used to transport the multi deck. Table 4-12 shows that wood is the main material used in the packaging.

Table 4-12: Material proportion in Packaging

Packaging	RCV2_1	RCV2_2	RCV2_3	RCV2_4
Materials				
Bulk plastics	0.00%	0.00%	0.59%	0.24%
Tec Plastics	11.49%	0.00%	0.00%	0.00%
Ferro	22.97%	0.00%	0.00%	9.82%
Coating	0.84%	0.00%	0.00%	0.00%
Misc. (Cardboard)	0.00%	22.22%	2.69%	0.00%
Misc. (Paper)	0.00%	11.11%	2.69%	1.57%
Misc. (Wood)	64.70%	66.67%	94.04%	88.37%

Miscellaneous

All pipes and coils included in the cabinet are listed in this module. Furthermore, all materials/components not being part of the above mentioned six groups are sated under this module. The four normalised BOMs, completed by various assumptions were merged to form the Base Case in task 5. Task 5 provides the detailed BOM of the base case for RCV2.

- **Open Frozen Island**

The Bill of Materials of 3 standard open frozen islands (RHF4_1, RHF4_2, RHF4_3) have been gathered among 3 major European manufacturers. Those three RHF4 present the same characteristics as presented in Table 4-13, which allows making a comparison, and merging them in order to create the base case in task 5.

Table 4-13: Characteristics of a typical remote open frozen island

Temperature class	3L2
Length (m)	3.75
Height (m)	~ 0.9
Width (m)	~ 1.9
Lighting system	No light
Night curtains	No night curtain
Defrost and Anti-sweat heaters	Electrical defrost and anti-sweat heaters
Expansion device	Standard thermostatic expansion valve

These features were decided together with manufacturers, as they represent the current average European open frozen island.

Although the three product cases present the same characteristics, there are some slight design differences, such as the number and the output power of the evaporator fans (see Table 4-14).

Table 4-14: Configuration of the RHF4 product cases

	RHF4_1	RHF4_2	RHF4_3
Evaporator Fans	4 x 2 W	6 x 10 W	8 x 5 W

The three cabinets are running with R404a and have a Total Display Area (TDA) ranging from 6.4 m² to 7.27 m². The operating temperature range is L2 as defined in the ISO 23953: (-18 ℃) to (-12 ℃).

Where providing the BOMs, manufacturers were not always able to detail the material composition or the weight of all components included in their appliance. Thereby, assumptions were made together with the industry and with refrigeration components manufacturers.

- Material composition for the fans/fan motors

Depending on the output power, the total mass of the fan motor and the distribution of the materials vary. For RHF4_2 containing a 10 W output motor, this component has the same characteristics as for the open vertical chilled multi deck; the overall weight is 1710 g, with 1200 g for the motor Table 4-3**.**

For RHF4_3, using a fan of 5 W output power with a shaded pole motor the overall weight of the fan module (including the fan blade, the fan grid and the fan motor) is 1,280 g (900 g for the motor). Materials used are the same as for a 10 W fan, but the mass repartition is slightly different for the motor. Table 4-15 details the bill of materials of the evaporator fan module.

Table 4-15: Material composition of a typical fan and fan motor of 5W output

MATERIALS Extraction & Production **Description of component**	**Weight** **in g**	**Category** **Click &select**	**Material or Process** **select Category first !**	**Mass %**
Evaporator fans motors				
Aluminium	180	4-Non-ferro	**27-Al diecast**	20%
Iron	540	3-Ferro	**24-Ferrite**	60%
Copper	135	4-Non-ferro	**28-Cu winding wire**	15%
PVC	45	1-BlkPlastics	**8-PVC**	5%
Fan Blade				
Aluminium	90	4-Non-ferro	**26-Al sheet/extrusion**	100%
Fan grid				
Iron	290	3-Ferro	**25-Stainless 18/8 coil**	100%
TOTAL WEIGHT	1280			

Moreover, for the fan of 2 W output power used in RHF4_1, we assumed than the mass distribution of the fan of 5 W can be applied, but with a total weight of 675 g. The fan blade is made of aluminium and weights 67.5 g, and the fan grid is made of iron for a total weight of 217.5 g.

- Other

In collaboration with manufacturers, the weight and material composition of missing parts of the BOM were evaluated based on "expert guesses" (e.g. cables...). For some other data missing in one BOM we used the average of the other BOMs.

The BOMs were completed based on the assumptions presented above in order to obtain the best available estimations of the material inventory of each remote open frozen island. Thereby, Table 4-16 presents the specifications of the three appliances studies.

Table 4-16: RHF4 specifications for the 3 product cases

	RHF4_1	RHF4_2	RHF4_3
Gross weight (total mass - catalogue data)	820 kg	770 kg	775 kg
Weight from BOM data	804 kg	749 kg	774 kg
% data missing	1.89 %	2.78 %	0.09 %
TDA	6.4 m²	6.95 m²	7.27 m²

As for the remotes RCV2, to allow useful comparison the material data was normalised by adjusting up or down to a Total Display Area of 7 m². Thereby, all material data as normalised, except for some specific components that are assumed to remain the same, such as the temperature controller or the electric panel.

The TDA was chosen as normalisation factor, instead of the Total Display Volume or another parameter, for the same reasons as for the remote open chilled vertical multi deck.

The detailed BOMs of the three open frozen islands are not presented to preserve confidentiality. The mass proportion of the different material used is given instead for each product case in Table 4-17.

Table 4-17: Total mass proportion per category of material

Materials	**RHF4_1**	**RHF4_2**	**RHF4_3**
Bulk Plastics	6.15%	1.44%	3.95%
Tec Plastics	0.00%	4.44%	3.99%
Ferro	59.98%	63.02%	49.71%
Non-ferro	8.01%	6.98%	9.85%
Coating	1.22%	7.16%	0.00%
Electronics	0.35%	0.04%	0.08%
Misc. (cardboard)	0.05%	0.00%	0.06%
Misc. (glass)	17.63%	13.28%	7.01%
Misc. (office paper)	0.05%	0.24%	0.01%
Misc. (wood)	6.28%	3.34%	25.18%
Misc. (blowing agent)	0.28%	0.06%	0.00%
Misc. (putty/sealant)	0.00%	0.00%	0.15%

As shown in the table above, the most significant materials used in open frozen islands are:

- The ferro-metal used for the housing and the shelves (21-St sheet galv.)
- The glass used in the side panels
- The wood used for the packaging
- The non-ferro metal used in the evaporator
- The coating used by RHF4_2 for the housing

In order to proceed to a more detailed analysis, and to identify the component groups being the most environmentally impacting, the BOMs were split into eight modules as presented in Table 4-18.

Table 4-18: Total mass proportion per module

Modules	RHF4_1	RHF4_2	RHF4_3
Housing	81.67%	87.36%	62.22%
Evaporation module	9.60%	7.36%	9.82%
Expansion device module	0.04%	0.05%	0.04%
Anti-sweat heater	0.19%	0.18%	0.21%
Defrost	0.44%	0.20%	0.89%
Electric assembly	0.92%	0.87%	0.19%
Packaging	6.39%	3.73%	25.56%
Miscellaneous	0.75%	0.25%	1.06%

This table shows that the housing is the heaviest part of the cabinet of an open frozen island, followed by the evaporation module and the packaging.

The next paragraphs give a short description of the eight modules, in order to provide a more detailed picture of the materials used in a RHF4. Moreover, the material distribution of the three dominant modules is given.

Housing

The housing module comprises the external and internal structures, the foam insulation and components for assembling. Most of the materials are ferro-metals (~ 70 % according to Table 4-19) used in the chassis of the cabinet (~ 93 % of the module mass according to Table 4-20), followed by the glass (between 11 and 22 %).

Table 4-19: Material proportion in Housing

Housing	**RHF4_1**	**RHF4_2**	**RHF4_3**
Materials			
BlkPlastics	7.10%	1.12%	5.68%
TecPlastics	0.00%	5.06%	6.40%
Ferro	69.23%	68.43%	73.78%
Non-ferro	0.25%	1.92%	2.86%
Coating	1.49%	8.19%	0.00%
Misc. (glass)	21.58%	15.21%	11.27%
Misc. (blowing agent)	0.34%	0.07%	0.00%

Table 4-20: Material proportion per sub-module

Housing	**RHF4_1**	**RHF4_2**	**RHF4_3**
Sub-Modules			
External housing	92.58%	94.87%	92.84%
Foam insulation	7.13%	4.14%	6.81%
Components for assembling (screws, rivets…)	0.28%	0.99%	0.35%

Evaporation module

The evaporation module includes the evaporator, the fans and the tray. Most of materials used in this module are aluminium and copper (in the evaporator) which explains the high proportion of non-ferro metals (see Table 4-21).

Table 4-21: Material proportion for Evaporation module

Evaporation Module	**RHF4_1**	**RHF4_2**	**RHF4_3**
Materials			
Bulk Plastics	0.2%	1.3%	0.6%
Tec Plastics	0.0%	0.0%	0.1%
Ferro	32.2%	40.0%	28.8%
Non-ferro	67.7%	58.7%	70.4%

Table 4-22: Material proportion per sub-module

Evaporation Module	**RHF4_1**	**RHF4_2**	**RHF4_3**
Sub-Modules			
Evaporator	66.1%	54.1%	66.4%
Evaporator fans	1.5%	5.6%	4.0%
Evaporator fans motors	3.5%	13.1%	9.5%
Evaporator tray	28.9%	27.2%	20.1%

Expansion device module

This module comprises the thermostatic expansion valve, used in the three product cases.

Anti-sweat heater

The three manufacturers use electric anti-sweat heaters, made in copper with different powers.

Defrost

Defrost heaters are in same material composition as anti-sweat heaters. They have also various powers depending on the manufacturer.

Electric assembly

This module comprises all material existing in the electric panels and cables.

Packaging

This section includes all the packaging material used to transport the open frozen island. As presented in Table 4-23, the wood used for the pallet represents the heaviest material.

Table 4-23: Material proportion in Packaging

Packaging	RHF4_1	RHF4_2	RHF4_3
Materials			
Bulk Plastics	0.2%	0.0%	0.5%
Ferro	0.0%	4.0%	0.7%
Misc. (cardboard)	0.8%	0.0%	0.3%
Misc. (wood)	98.2%	89.6%	98.5%
Misc. (office paper)	0.8%	6.4%	0.1%

Miscellaneous

All pipes included inside the cabinet are listed in this module. Furthermore, the temperature controller is also part of the miscellaneous module, likewise all materials/components which can not be included in the other seven modules.

The three normalised BOMs, completed by various assumptions were merged to form the Base Case in task 5, where a detailed BOM is presented.

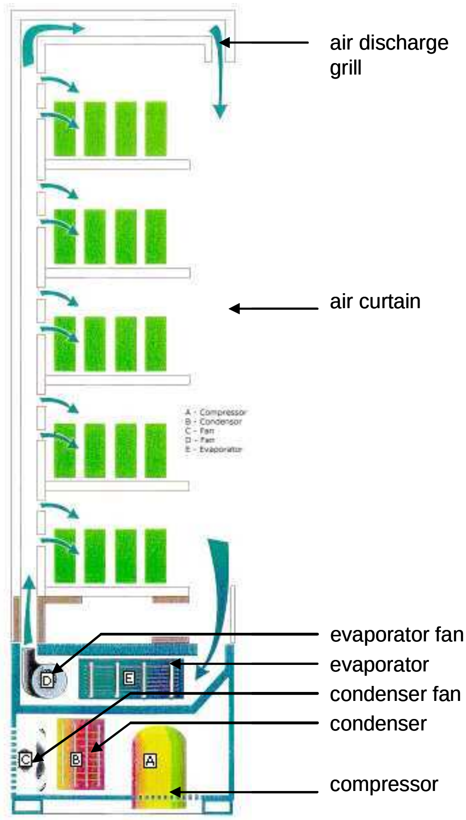
4.1.2 PLUG IN REFRIGERATED DISPLAY CABINETS

4.1.2.1 EQUIPMENT DESCRIPTION

Plug in refrigerated display cabinets have an envelope structure similar to remote cabinets. The difference is that the condensing unit is integrated in the case and the equipment is designed to plug into an available electricity supply. Refrigeration is supplied by a compressor usually located at the bottom of the unit (see Figure 4-5). The condenser is also located in the bottom space which is insulated from the storage space with polyurethane panels. The heat generated by the compressor and the condenser is released to the surroundings through a simple grill. Figure 4-4 presents typical plug in refrigerated cabinets.

Figure 4-4: Plug in refrigerated food display cabinets[5]

Figure 4-5: Typical multi deck refrigerated plug in cabinet[6]



Beverage coolers (Figure 4-6) are fronted glass cabinets for displaying and selling goods, primarily canned and bottled beverages but also ice creams. The case is typically insulated with a 40 mm thick panel of blown polyurethane foam.

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[5] Source: Carrier

[6] Source: EcoQuip (http://www.ecoquip.co.uk)

Open beverage merchandisers also exist. Units typically comprise of one hermetic compressor, two evaporator fans and one condenser fan. Heat is rejected to the surrounding environment and most units have an integral lighting for product display and logo display.

Other type of plug in refrigerated display cabinets is the ice cream freezer (Figure 4-7). It is usually with a transparent top lid which can be slid open for access. The large majority are supplied and owned by ice cream suppliers. Typically these units comprise an insulated box and a hermetic compressor, located at the bottom rear of the chest. Generally no lighting is provided and there is no evaporator associated to the fan (static evaporation).

Figure 4-6: Beverage coolers and ice cream merchandiser[7]

Figure 4-7: Ice cream freezer

[7] Source: Carrier

4.1.2.2 BILL OF MATERIALS

The overall weight of plug in cabinets is function of its display volume and of its design. Very slim cabinets need to be heavier to retain stability and use higher amounts of stainless steel[8].

With the help of major manufacturers of plug in refrigerated display cabinets, two major appliances have been identified as categories of real life products that are typically used in EU-25:

1- Beverage cooler, also know as bottle cooler of beverage merchandiser

2- Ice cream freezer for packaged ice cream (IHF6)

For each of these families of products, the BOM of existing products (further referred to as the product cases) have been collected among manufacturers.

- **Beverage coolers (BvC)**

The BOM of two standard beverage coolers have been collected (BvC1 and BvC2). Both of them are vertical cabinets with a one door. The door is a double glass door with air trapped between the two panes of glass for better insulation. BvC2 also uses low emissivity coating (also known as anti-fog glass) to prevent moisture condensation. The two cabinets run on R134a (HFC) and are insulated using 40 mm thick polyurethane panels. They have a net volume (internal capacity) of about 500 litres (0.5 m^3) and an average operating temperature range of: (-3 °C) ~ (+10 °C) for BvC1 a nd (-1 °C) ~ (+5 °C) for BvC2.

They are both fitted with the same range of components:

- Standard evaporator and condenser fans of 10 W output power with a shaded pole motor
- Hermetic piston compressor of cooling capacity ranging between 0.4 and 0.6 kWh at an evaporating temperature of -10 °C (me asured with EN 12900, condensing temperature of 55 °C). The weight of the compressor is between 10 and 14 kg)
- Lighting system using standard T8 fluorescent tubes of 36 W for the internal lighting system and 20 W for the external lighting (lighting for the logo in canopy). Both tubes are connected to magnetic ballasts.

When providing the BOMs, refrigerated cabinet manufacturers were not always able to specify the material composition or the weight of the components included in their product. Where manufacturer's data was not available:

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8 Reference: R. Watkins, S. A. Tassou, *Life Cycle Analysis Of The Environmental Impact Of Different Cabinet Designs*, School of Engineering & Design, Brunel University, Uxbridge, UB8 3PH, England.

http://iufost.edpsciences.org/index.php?option=com_base_ora&access=standard&Itemid=39&url=articles/iufost/pdf/2006/01/iufost06000701.pdf

assumptions were made together with industry and component manufacturers to fill the gaps and to identify the typical components of beverage coolers.

- Material composition of the fans/fan motors

For the evaporator, the condenser fan and fan motors, the identified components show the same characteristics as for the open vertical chilled multi deck: the overall weight of the fan module[9] is 1,710 g (1,200 g for the motor) (see Table 4-3). The input power of the motor is estimated to 36 W and the output power if of 10 W.

- Material composition of the compressor

Typical compressors in 0.5 m^3 beverage coolers are reciprocating hermetic compressors and present the following characteristics: a 0.4 – 0.7 kW cooling capacity (at an evaporating temperature of -10 ℃, measured with EN 12900, condensing temperature of 55 ℃) and a weigh t between 10-14 kg.

The approximated material composition of this type of compressors was estimated together with compressor manufacturers. The data collected was then averaged and showed the following distribution of materials (example for a 10 kg compressor) (Table 4-24):

Table 4-24: Material composition of a typical hermetic piston compressor

Pos nr	MATERIALS Extraction & Produc Description of component	Weight in g	Category	Material or Process	Mass %
1	cast iron of the compressor casing	2100	3-Ferro	**23-Cast iron**	21.0%
2	steel of the compressor	2850	3-Ferro	**21-St sheet galv.**	28.5%
3	steel for motor lamination	3850	3-Ferro	**24-Ferrite**	38.5%
4	aluminium	190	4-Non-ferro	**27-Al diecast**	1.9%
5	rubber	10	1-BlkPlastics	**4-PP**	0.1%
6	epoxy	10	2-TecPlastics	**14-Epoxy**	0.1%
7	ester oil	250	7-Misc.		2.5%
8	polypropylen	10	1-BlkPlastics	**4-PP**	0.1%
9	copper	700	4-Non-ferro	**28-Cu winding wire**	7.0%
10	PET	30	1-BlkPlastics	**2-HDPE**	0.3%
11	TOTAL WEIGHT	10000	1-BlkPlastics		100.0%

The weight of the compressor was provided by each of the manufacturers and the same distribution of the materials was applied to the compressors of the two beverage coolers (BvC1 and BvC2) in order to complete the BOMs.

- Lighting System

The lighting system in both cabinets is very similar. For the lamps, they both use standard T8 fluorescent light tubes of about 190 g (36 W tube in canopy) and 80 g (20 W inside cabinet) and it was assumed the lamps were made of glass only (over 90 % of a florescent tube is glass). The ballasts are typical magnetic ballasts. However the material composition of these components was not investigated as these products are already covered by a European directive (DIRECTIVE 2000/55/EC) and only their weight was taken into consideration.

[9] includes the fan blade, fan grid and fan motor

- Heat exchangers

Both manufacturers provided the total weight of the evaporator and of the condenser. However, where further data on material composition was not available the distribution of materials showed in Table 4-25 was applied. Where manufacturer's data was provided, these figures were not taken into account.

Table 4-25: Material composition of the heat exchangers

Pos nr	MATERIALS Extraction & Produc Description of component	Weight in %	Category Click &select	Material or Process select Category first !
1	**Evaporator**			
2	Suction line	1/3 mass	4-Non-ferro	**30-Cu tube/sheet**
3	Aluminium fins	2/3 mass	4-Non-ferro	**26-Al sheet/extrusion**
5	**Condenser**			
6	Suction line	1/2 mass	4-Non-ferro	**30-Cu tube/sheet**
7	Aluminium fins	1/4 mass	4-Non-ferro	**26-Al sheet/extrusion**
8	Steel	1/4 mass	3-Ferro	**22-St tube/profile**

- Other

In cooperation with the different manufacturers the weight and material composition of missing parts of the BOMs (e.g. electric cables, evaporation tray…) were evaluated based on "expert guesses" but will not be detailed to preserve confidentiality.

Based on the assumptions presented above, the BOMs were completed with the best estimations available in collaboration with the industry (either refrigerated cabinet manufacturers or component manufacturers). This resulted in a BOM with 93.5 % of the material data (including the packaging) for BvC1 and 96.4 % of the material data (including the packaging) for BvC2 (see Table 4-26).

Table 4-26: Beverage cooler product specifications for the two product cases

	BvC1	BvC2
Gross weight (kg)	92	152
Weight from the BOM (kg)	86	146.6
% of data missing	6.6 %	3.6 %
Net volume (m^3)	0.4	0.5295
Dimensions h, w, d (mm)	2062 x 600 x 710	2030 x 725 x 710

To allow useful comparison the material data was adjusted up or down by normalising according to the net volume. All material data was normalised to a 0.5 m^3 volume product, except for some components that are assumed to remain the same such as: the fans, the compressor, the lamps, the ballasts, the thermostat and the plug.

The net volume of the cabinet was chosen as the reference to normalise the data because in the case of cabinets fitted with doors it is the most relevant parameter to consider (in task 1 most of the existing standards for refrigerated cabinets with doors are adjusted using the net volume). Another option could have been to normalise according to the total display area, however, in case of closed appliances the refrigeration load is less affected by the display area as the infiltrations through the door are less important than for open appliances and the energy consumption is more affected by the net volume.

The normalised weights present a 45 kg difference (103.8 kg for BvC1 and 139.4 kg for BvC2) that is possibly related to a more incomplete BOM in the case of BvC1 and to different cabinet designs (the major differences in the weights are in the panels used for the cabinet structure and in the shelves).

The detailed BOMs for the beverage coolers are not presented to preserve confidentiality. The mass proportion of the different materials used is given instead.

As shown in Table 4-27 the most significant materials in a beverage coolers are:

- The ferro-metal mostly used for the panels of the housing (21-St sheet galv.)

- The glass used for the door (54-Glass for lamps)

- The non-ferro metal used for the heat exchangers and the pipes.

Table 4-27: Total mass proportion per category of material

Materials	BvC1	BvC2
Bulk Plastics	3.45%	3.62%
Tec Plastics	9.31%	5.30%
Ferro	44.22%	65.33%
Non-ferro	14.97%	7.31%
Coating	0.00%	0.65%
Electronics	1.31%	0.05%
Misc. (cardboard)	0.46%	0.34%
Misc. (glass)	20.08%	12.47%
Misc. (Cyclopentane)	0.76%	0.19%
Misc. (ballast)	1.16%	0.76%
Misc. (ester oil)	0.29%	0.23%
Misc. (Wood)	3.68%	3.38%
Misc. (paper)	0.03%	0.06%
Misc. (refrigerant liquid)	0.26%	0.26%
Misc. (ink)	0.00%	0.06%

The differences in the mass proportions predominantly come from the panels and shelves used in BvC2 compared to BvC1. In order to proceed to a more detailed analysis, the BOMs were split into eight modules (see description below). They are the same modules as for the remote cabinets with two additional modules for the compressor and the condenser and no mo anti-sweat heater module. The choice of this modular approach will be further developed in task 5.

Table 4-28: Total mass proportion per module

Modules	BvC1	BvC2
Housing	69.01%	78.52%
Evaporation Module	4.72%	2.25%
Compression Module	11.62%	9.21%
Condensation Module	5.53%	2.47%
Expansion Device module	0.09%	0.06%
Electric Assembly	2.24%	2.13%
Packaging	4.65%	3.78%
Miscellaneous	2.12%	1.59%

The mass proportion per module is given in Table 4-28. This table shows that the housing of the beverage cooler represents the biggest mass of materials of the beverage cooler (~75 %), followed by the compression module (~10 %), the condensation module (~6 %) and the packaging (~5 %).

The next paragraphs give a short description of the eight relevant modules for beverage coolers. In order to provide a better picture of the materials used in beverage coolers, the material distribution of the four predominant modules is given in the following paragraphs.

Housing

The housing module aggregates the insulated casing (e.g. external housing[10], foam insulation, shelves/grids...) cabinet door and the lighting system (light bulbs, light box and lighting ballast). Furthermore, the screw and rivets used in the entire product are listed under this module.

Table 4-30 confirms that the predominant parts of the cabinet in terms of mass proportion are the panels (i.e. external housing) which represent 35 – 55 % of the housing. Approximately 95 % of the external housing is made of materials from the ferro group (stainless steel sheets) thus explaining the high proportion of the ferro category in Table 4-29.

Between 15 and 30 % of the housing is made of the glass for the double panel door. The third major material is the plastic used in the foam insulation. In Table 4-30, the differences in the mass proportions can be explained by the difference in cabinet design (heavier shelves and cabinet structure in BvC2 compared to BvC1).

[10] The external housing comprises all the components which are part of the cabinet structure such as side/back panels, the machine cover, the evaporator cover, glass panels (if any)…

Table 4-29: Material proportion in Housing

Housing	BvC1	BvC2
Materials		
Bulk Plastics	2.65%	3.46%
Tec Plastics	13.25%	6.74%
Ferro	43.23%	69.25%
Non-ferro	7.45%	2.56%
Coating	0.00%	0.83%
Electronics	0.00%	0.00%
Misc. (cardboard)	0.41%	0.00%
Misc. (glass)	28.61%	15.88%
Misc. (Cyclopentane)	1.08%	0.24%
Misc. (ballast)	3.31%	0.97%
Misc. (ink)	0.00%	0.07%

Table 4-30: Material proportion per sub-module

Housing	BvC1	BvC2
Sub-Modules		
External housing	34.95%	55.02%
Foam insulation	14.57%	6.71%
Shelves	9.43%	15.91%
Door	36.38%	19.68%
Lighting system	2.98%	1.72%
Components for assembling (screws, rivets…)	1.68%	0.96%

Evaporation module

The evaporation module includes the evaporator used to absorb the heat from the internal air of the refrigerator or the freezer, the evaporator tray, and fans (fan motor, frame and blades) allowing the air circulation.

Compression module

The compression module is composed of the compressor and of the compressor motor. The material composition of the compressor for both cabinets is the same due to the use of the same assumptions for the bill of material of this component (see Table 4-31).

Table 4-31: Material proportion in Compression module

Compression Module	BvC1 & BvC2
Materials	
Bulk Plastic	0.50%
Tec Plastics	0.10%
Ferro	88.00%
Non-ferro	8.90%
Coating	0.00%
Electronics	0.00%
Misc. (ester oil)	2.50%

Table 4-31 shows that the ferro group of material is the most represented.

Condensation module

This module contains the condenser, the related fans and fan motor and the liquid receiver. Most of the material used in this module is of the non ferro group (58 – 66 % see Table 4-32) the majority of which is comprised in the condenser itself (see Table 4-33) and in the fan motor (copper winding wire).

Table 4-32: Material proportion in Condensation module

Condensation Module	BvC1	BvC2
Materials		
Bulk Plastic	1.26%	1.66%
Tec Plastics	0.00%	0.00%
Ferro	40.34%	32.34%
Non-ferro	58.40%	66.00%
Coating	0.00%	0.00%
Electronics	0.00%	0.00%
Misc. (cardboard)	0.00%	0.00%
Misc. (glass)	0.00%	0.00%
Misc. (Cyclopentane)	0.00%	0.00%
Misc. (ballast)	0.00%	0.00%

Table 4-33: Material proportion per sub-module

Condensation Module	BvC1	BvC2
Sub-Modules		
Condenser	63.03%	48.65%
Condenser fan	10.71%	14.10%
Condenser fan motor	25.21%	33.17%
Liquid receiver/Dryer	1.05%	4.09%

Expansion device module

This module comprises the expansion device used in the refrigeration system (i.e. a capillary tube).

Electric assembly

This module comprises all materials existing in the electric panel, the cables, including the power cables, which are not included in other modules.

Packaging

This section includes all packaging materials used to deliver the beverage cooler at the final point of sale. BvC1 uses more plastic and less cardboard than BvC2 for his packaging. In both product cases, the wood palette used to facilitate the transport of the cabinets represents the predominant material of the packaging (Table 4-34).

Table 4-34: Material proportion in Packaging

Packaging	BvC1	BvC2
Materials		
Bulk Plastic	13.89%	0.00%
Tec Plastics	0.00%	0.14%
Ferro	0.00%	0.00%
Non-ferro	0.00%	0.00%
Coating	0.00%	0.00%
Electronics	0.00%	0.00%
Misc. (cardboard)	3.21%	9.02%
Misc. (paper)	0.64%	1.52%
Misc. (Wood)	82.26%	89.32%

Miscellaneous

All pipes and coils included in the beverage cooler are listed in this module. Furthermore, all materials/components not being part of the above mentioned seven groups are stated under miscellaneous (e.g. temperature display systems…).

The normalised BOMs completed by the various assumptions on the material composition of missing components were merged to form the Base Case in task 5. Task 5 provides the detailed BOM of the Base Case for beverage coolers.

- **Ice cream Freezer**

The BOM of two standard ice cream freezers have been collected (ICF1 and ICF2). Both are meant to store packaged ice-cream at a temperature between (-18 °C) and (-23 °C) (L1 according to ISO 23953) and have a net volume of about 300 L. The cabinets are fitted with a sliding door made of low emissivity glass (two single panels) and comprise a hermetic piston compressor of cooling capacity ranging around 0.4 kW at an evaporating temperature of -35 °C (measured with EN 12900). The weight of the compressor is between 10 and 14 kg. The blowing agent used in both cases is Cyclopentane.

Both cabinets were analysed separately because of major differences in the design that would have made the comparison irrelevant, more specifically in terms of energy consumption (see 4.3.3.2). The next section provides the aggregated BOM of ICF1 and ICF2 and a description of the major features they comprise.

The ICF1 refers to a cabinet commonly called a “chest freezer” it has no lights, no evaporate or fan (static cooling) (see Figure 4-7) and runs with R 507. R 507 is a mix of R 125a (50 % mass) and R 143a (50 % mass). The walls of the cabinets are made of insulating material (70 mm thick plastic foam) and metal panels. The condenser is equipped with a fan attached to a 30 W motor. The BOM for the fan assembly was determined using the same material distribution as presented in Table 4-3 and the weight of the motor was assumed to be of 2,200 g. The compressor weights 10.91 kg and its material distribution was assumed to be as described in Table 4-24.

The total weight of the packaged ice cream freeze ICF1 is 75 kg for a net volume of 0.291 m^3 and a TDA of 0.52 m². The BOM was provided as accurately as possible and represents 99 % of the materials. The mass proportion of the different materials used in the freezer is given in Table 4-35.

The three main categories of materials included in the cabinet are:

- The coated materials, mostly due to the pre-painted panels of the external cabinet housing
- The ferro metal
- The Tec plastics (used for the plastic foam insulation).

Table 4-35: Total mass proportion per category of material

Materials	ICF1
Bulk Plastic	4.71%
Tec Plastics	10.83%
Ferro	26.10%
Non-ferro	8.82%
Coating	31.83%
Electronics	0.00%
Misc. (Cardboard)	0.77%
Misc. (Glass)	8.32%
Misc. (Blowing agent)	0.54%
Misc. (Ester oil)	0.37%
Misc. (Wood)	5.75%
Misc. (Paper)	0.27%
Misc. (Refrigerant liquid)	0.30%
Misc. (unknown)	1.40%

As it was done for other the other cabinets studied so far, the BOM was split into 8 different modules to allow a more detailed analysis (Table 4-36). The modules are the same as for beverage coolers.

Table 4-36: Total mass proportion per module

Modules	ICF1
Housing	65.07%
Evaporation Module	4.23%
Compression Module	14.65%
Condensation Module	5.80%
Expansion Valve	0.09%
Electric Assembly	0.53%
Packaging	7.97%
Miscellaneous	1.68%

Once again, the housing is the heaviest assembly of the cabinet (~ 65 %), followed by the compression module (~ 15 %) and the packaging (~ 8 %). The material proportion of the compression module is as defined in Table 4-24, the ones for the housing and the packaging are given in the paragraphs below.

Housing

As mentioned earlier, the predominant material is the "coating" (~50 %) due to the large quantity of pre-painted panels used for the cabinet structure (Table 4-37). Consequently the external housing is the predominant sub-assembly of the housing (Table 4-38). Compared to beverage coolers, the insulation (Tec Plastic) represents a greater proportion of the housing.

Table 4-37: Material proportion in housing

Housing	ICF1
Materials	
Bulk Plastic	4.85%
Tec Plastics	16.62%
Ferro	16.00%
Non-ferro	0.00%
Coating	48.92%
Electronics	0.00%
Misc. (Glass)	12.79%
Misc. (Blowing agent)	0.83%

Table 4-38: Material proportion per sub-module

Housing	ICF1
Sub-Modules	
External housing	67.63%
Foam insulation	17.39%
Shelves	1.59%
Door	12.79%
Lighting system	0.00%
Components for assembling (screws, rivets…)	0.60%

Packaging

The packaging is the third predominant module. Most of it is made of wood (~70 %) as for the other cabinets studied so far it is from the palette used to facilitate the transport. The other significant material used is plastic for the cabinet protection (~13 %).

Packaging	ICF1
Materials	
Bulk Plastic	13.45%
Tec Plastics	0.00%
Ferro	1.26%
Non-ferro	0.00%
Coating	0.00%
Electronics	0.00%
Misc. (cardboard)	9.71%
Misc. (paper)	3.37%
Misc. (Wood)	72.21%

The second ice cream freezer, ICF2, refers to a horizontal cabinet with sliding doors on the top and glass walls.

Table 4-39: Plug in freezer for packaged ice-creams

The cabinet is fitted with lights and with an evaporator fan attached to an 18 W motor. The lighting system comprises two 18 W fluorescent tubes and two 36 W fluorescent tubes. The walls of the cabinet are predominantly made of glass and it includes 2 anti-sweat heaters of 68 W each and a defrost system. The defrost is electric and hot gas. The same assumptions for the material compositions were used to determine the BOM of the main components (compressor, fan motors, lights) as the ones presented so far.

The cabinet runs with R 404 A and the thickness of the insulation foam is of about 45 mm. The total packaged mass is of 280 kg for a net volume of 0.3 m^3 and a TDA of 1.16 m^2.

Table 4-40 shows the material distribution in horizontal closed ice cream freezer. The BOM was provided however, full data was not available and 18.9 % of the materials are missing (50 kg).

The predominant materials are:

- The ferro metal category (~ 67 %), mostly due to the metal panels of the cabinet structure
- The bulk plastics (~14 %), mostly used for the packaging (protection)
- The non-ferro materials used in the heat exchangers.

Table 4-40: Total mass proportion per category of materials

Materials	ICF2
Bulk Plastic	14.16%
Tec Plastics	5.03%
Ferro	67.35%
Non-ferro	9.77%
Coating	0.00%
Electronics	0.05%
Misc. (Blowing agent)	0.07%
Misc. (Glass)	2.09%
Misc. (Ballast)	0.88%
Misc. (Ester oil)	0.15%
Misc. (Paper)	0.07%
Misc. (Refrigerant liquid)	0.38%

The BOM was also split into 10 different modules. As it is shown in Table 4-41, the main assembly of the cabinet, in terms of mass is the housing (~67 %), followed by the packaging (~13 %) and the evaporation module (~7 %). The difference compared to ICF1 is explained by the presence of an evaporator fan (which adds about 2.4 kg for the blade and motor).

Table 4-41: Total mass proportion per module

Modules	ICF2
Housing	67.10%
Evaporation Module	6.95%
Compression Module	6.03%
Condensation Module	2.91%
Expansion Valve	0.04%
Anti-sweat heater	0.13%
Defrost heater	0.53%
Electric Assembly	1.28%
Packaging	13.36%
Miscellaneous	1.68%

Housing

Table 4-42 and Table 4-43 confirm that the major part of the housing is the external housing (~ 82 %) made of ferro metal panels. Other major categories of materials used in the housing include the Tec Plastics used for the insulation and for the light box as well as the glass panels used for the cabinet walls and sliding doors.

Table 4-42: Material proportion in Housing

Housing	ICF2
Materials	
Bulk Plastic	0.00%
Tec Plastics	7.48%
Ferro	87.99%
Non-ferro	0.00%
Coating	0.00%
Electronics	0.00%
Misc. (blowing agent)	0.10%
Misc. (glass)	3.11%
Misc. (ballast)	1.31%

Table 4-43: Material proportion per sub-module

Housing	ICF2
Sub-Modules	
External housing	82.02%
Foam insulation	2.21%
Shelves	4.79%
Door	2.76%
Lighting system	7.05%
Components for assembling (screws, rivets…)	1.18%

Evaporation Module

The materials in the module evaporation are mostly non ferro metals (copper and aluminium) that are used in the evaporator, and the fan (aluminium fan blades). The main component of this assembly is the evaporator (~80 %) (see Table 4-44 and Table 4-45).

Table 4-44: Material proportion in the Evaporation Module

Evaporation module	ICF2
Materials	
Bulk Plastic	5.9%
Tec Plastics	0.0%
Ferro	10.1%
Non-ferro	84.0%
Coating	0.0%
Electronics	0.0%
Misc.	0.0%

Table 4-45: Material proportion per sub-module

Evaporation module	ICF2
Sub-Modules	
Evaporator	79.9%
Evaporator fan	4.5%
Evaporator fans motors	10.1%
Evaporation tray	5.4%

Packaging

The packaging for this cabinet does not include wood for transportation but only plastic protection and the manual.

Table 4-46: Material proportion in packaging

Packaging	ICF2
Materials	
Bulk Plastic	99.51%
Tec Plastics	0.00%
Ferro	0.00%
Non-ferro	0.00%
Coating	0.00%
Electronics	0.00%
Misc. (paper)	0.5%

4.1.3 COLD VENDING MACHINES

4.1.3.1 EQUIPMENT DESCRIPTION

Three types of cold vending machines, for indoor or outdoor use, are available on the market (Figure 4-8):

- Spiral machines (vending food and/or drinks): 55 - 60 % of market share
- Cans & bottles machines: 30 % of market share
- Drum machines (vending food and/or drinks): 10 - 15 % of market share

Figure 4-8: Drum, can and spiral vending machines

The case of a vending machine is constructed with a metallic structure made from various ferrous metals. It is insulated from the outside by using foam and a blowing agent. The thickness of the panels is approximately 40 mm. A front opening panel is also required allowing the purchased item to pass through into dispensing tray. On the front side of the appliance, a payment system is incorporated, with selection buttons, coin and bill validators, display screen and a processor and controller board. Of course, some manufacturers suggest other functionalities, like credit card payment, LCD screen, rain-proof protection covering for outdoor use…

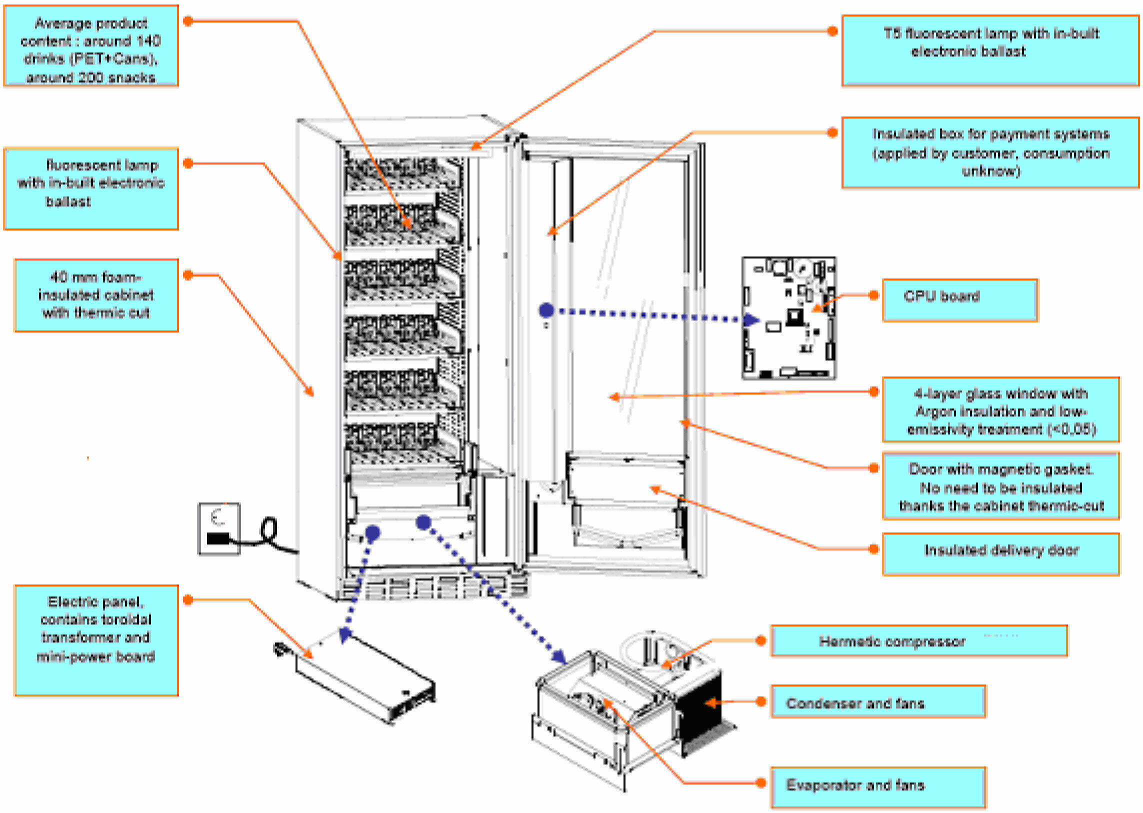
The refrigeration equipment is located on the base frame and its main components includes the evaporator (and evaporator fans), the condenser (and condenser fans), the expansion valve and the compressor. Typical compressors in such appliances are aluminium reciprocating hermitically sealed type and common refrigerants include R 134a. Refrigerant flow is governed by capillary flow restrictor and all fans are equipped with shaded pole motors.

The lighting represents a relevant part in a vending machine. In a marketing point of view, it aims at showing off the products to their maximum advantage. In an economic point of view, the energy consumption of illuminations represents between 30 % and 40 % of the whole energy consumption. Typically lighting consists of fluorescent lamps.

- **Spiral machine**

In a spiral vending machine, drinks (cans or bottles) and food are lined up on shelves, and segregated by one or two spirals depending on the size of the product. When a shopper selects a product, a motor causes the spiral to rotate, moving the full line of the chosen product forward one revolution so that the front item falls off into the delivery station. This kind of vending machine has a glass door to present products to the customer. Figure 4-9 presents an inner view of a spiral vending machine, with consumption values proper to a manufacturer, but it can reflect the current trend of the European spiral machine.

Figure 4-9: Typical spiral vending machine[11]



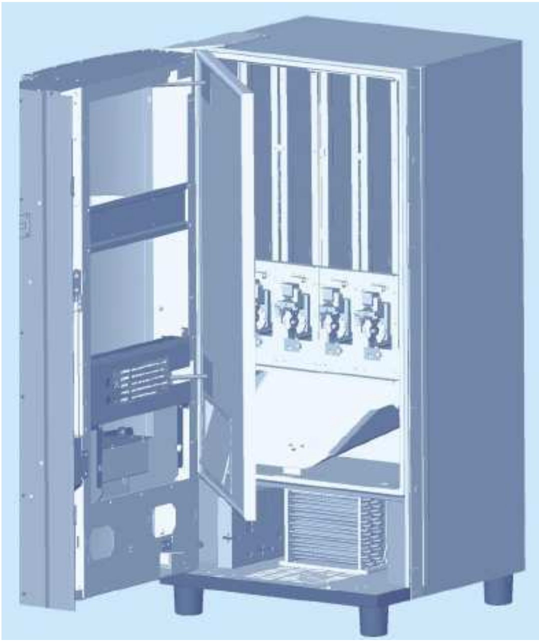
Cans & bottles machines

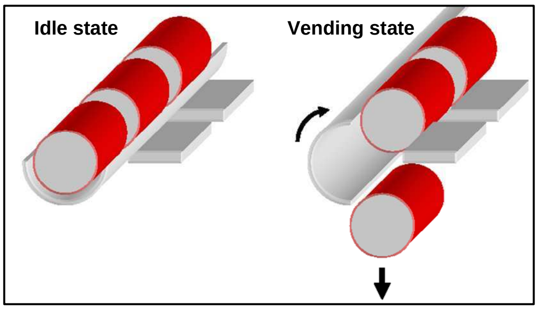
There are two full height hinged doors on the can vending machine. An inner door which is insulated, gives access to the refrigerated space where cans, snacks or bottles are stored. An outer door, generally in acrylic, houses the logo and its associated lighting equipment for display purposes. The latter, also contains the electronic controls that allow customers to purchase and receive goods. Cans and bottles machines typically show a smaller energy consumption than spiral machines due to a better insulation (acrylic door vs. glass door).

In the refrigerated compartment, cans and bottles are set in feeder stack columns. Lower products are sold first, using the system shown on Figure 4-10 (the motor is not drawn), where the can or the bottle falls to the access area with a dispensing slide.

[11] Source : FAS

Figure 4-10: Typical can vending machine[12] and dispensing operation





Drum machines

As for spiral machines, drum vending machines have a glass door to present products. Drums are stacked up on shelves and products are set in each compartment. The product is provided to the customer either by an access area in the lower place of the appliance, like for other vending machines, or by a lateral slot. In the latter case, the shopper rotates the drum to present the product in front of the slot.

Figure 4-11 presents an inner view of a drum vending machine.

[12] Source: Bianchi

Figure 4-11: Typical drum vending machine[12]

More modern controls can be sophisticated and include energy saving controls that enable the machine to conserve energy during periods of inactivity, this ability to power down is an Energy Star criteria.

The vending machine trend is an increase of the internal space available, in order to enhance the profitability of the appliance.

4.1.3.2 BILL OF MATERIALS

The Bills of Materials (BOM) of two standard cold vending machines have been collected (VM1 and VM2). To preserve confidentiality, the names of the companies are not disclosed.

Both of the vending machines are spiral vending machines, with one glass door. They are used for the sale of snack, sandwiches, cans and bottles (PET). Besides, they are designed for an indoor use. The two cabinets run on R 134a (HFC refrigerant) and are insulated using 40 mm thick polyurethane panels and R 134a as blowing agent.

These two spiral vending machines can contain 288 cans (8 cans by row, 6 rows by shelf and 6 shelves by cabinet), and the minimum operating temperature is +3 °C in the whole cell, for the pre servation of fresh foods (e.g. sandwiches).

When providing the Bill of Materials of spiral vending machines, manufacturers were not always able to specify the material composition or the weight of the components included in their product. In those cases, assumptions were made together with industry and component manufacturers to fill the gaps and to identify the typical components of spiral vending machines.

- Material composition of the fans/fan motors

Both of spiral vending machines have an evaporator fan of 5 W output power with a shaded pole motor. Even if the input power differs from VM1 (31 W input power) to VM2 (39 W input power), we assumed that the BOMs were the same. The overall weight of the fan module (including the fan blade, the fan grid and the fan motor) is 1,280 g (900 g for the motor). Materials used and mass repartition are the same as for a remote open frozen island as described in Table 4-15.

Besides, only one spiral vending machine contains a condenser fan (VM2). The output power is of 10 W and the input power is of 45 W. This component has the same characteristics as for the open vertical chilled multi deck; the overall weight is 1,710 g, with 1,200 g for the motor (see Table 4-3).

- Material description of the compressor

Typical compressors in this type of spiral vending machines are reciprocating hermetic compressors, with a 0.3 – 0.7 kW cooling capacity and a weight between 10 kg and 14 kg. The material composition is the same as for a beverage cooler (see Table 4-24). This distribution was applied to the weight of the compressor provided by each manufacturer.

- Lighting system

VM1 uses only one T8 fluorescent light tube of 98 g (36 W tube), and VM2 uses two T5 fluorescent light tubes of about 12 0g (21 W tube) and 90W (13 W tube). It was assumed that the lamps were made of glass only (over 90 % of a fluorescent tube is glass). Moreover, VM2 uses neon supports in steel (1,960 g).

The ballasts used by both of them are electronic ballast. However the material composition of these components was not investigated as these products are already covered by a European directive (Directive 2000/55/EC) and only their weight was taken into consideration in the BOM.

- Heat exchangers

Both manufacturers provide the total weight of the evaporator and of the condenser. However, where further data on material composition was not always available the distribution of materials shown in Table 4-25 was applied. Even if manufacturers' data was provided, these figures were nevertheless taken into account.

- Motors of the dispensing mechanism

It was assumed that the material composition of motors allowing rotating spirals and dispensing goods, was the same as the fan motor of a 5 W power input. The BOM is detailed in Table 4-15. Nevertheless, the total weight of motors for the dispensing mechanism was provided by manufacturers, and this material distribution was used.

- Other

Material compositions of missing parts of the BOMs (e.g. electric panel, cables…) were evaluated based on "expert guesses" but will not be detailed. For instance it was assumed that cables are composed by half of copper (29-Cu wire) and by half of plastic (8-PVC).

Based on the assumptions presented above, the BOMs were completed and refined with the best estimations available in collaboration with the industry. This resulted in a BOM with 100.8 % of the material data for VM1, and 99.1 % of the material data for VM2. Table 4-47 summarizes specifications of the two spiral vending machines.

Table 4-47: Spiral vending machine specifications for the two product cases

	VM1	VM2
Gross weight (W1) in kg	325	270
Weight from the BOM (W2) in kg	327,5	267,9
Difference between W2 and W1	+0.8%	-0.8%
# cans	288	288
Internal Volume Refrigerated in Litres	750	750
Dimensions H, W, D in mm	1830 x 910 x 925	1830 x 910 x 790

The detailed BOMs of the two spiral vending machines are not presented to preserve confidentiality. The mass proportion of the different materials used is given instead in Table 4-48.

Table 4-48: Total mass proportion per category of material

Materials	VM1	VM2
Bulk Plastics	6.973%	18.846%
Tec Plastics	0.193%	1.887%
Ferro	36.452%	66.889%
Non-ferro	2.456%	3.426%
Coating	43.682%	0.000%
Electronics	0.318%	0.347%
Misc. (cardboard)	0.476%	0.747%
Misc. (glass)	6.135%	6.666%
Misc. (ballast)	0.043%	0.053%
Misc. (ester oil)	0.105%	0.102%
Misc. (office paper)	0.008%	0.187%
Misc. (wood)	2.993%	0.560%
Misc. (screen)	0.032%	0.049%
Misc. (refrigerant)	0.134%	0.243%

This table shows that the most significant materials in a spiral vending machine are:

- The ferro-metal mostly used for the chassis and also for the panels (only for VM1) of the housing (21-St sheet galv.)

- The bulk plastics used for the shelves and also for the door (mainly for VM2) of the housing
- The coating used for the panels of the housing only for VM1 (38-Pre-coating coil)
- The glass used for the door (54-Glass for lamps)

The differences in the mass proportions mainly come from the panels and the door. Indeed, the manufacturer of VM1 chose to use pre-coating coil and steel sheet galvanised (only for the door), whereas the manufacturer of VM2 preferred using only steel sheet galvanised.

In order to proceed to a more detailed analysis, the BOMS were split into nine modules (see description below). The choice of his modular approach will be further developed in task 5. The mass proportion per module is given in Table 4-49.

Table 4-49: Total mass proportion per module

Modules	VM1	VM2
Housing	88.35%	86.65%
Evaporation module	1.06%	2.03%
Compression module	4.18%	4.07%
Condensation module	0.11%	1.20%
Expansion device module	0.02%	0.03%
Anti-sweat heater	0.01%	0.00%
Electric assembly	0.98%	2.02%
Packaging	3.48%	1.49%
Miscellaneous	1.80%	2.51%

This tables shows that the housing represents the biggest mass of materials of the spiral vending machine (~ 87 %), followed by the compression module (~ 4 %). The third heaviest module is the packaging for VM1 (~ 3.5 %), due to the weight of the wood palette, whereas it is the miscellaneous module for VM2 (~ 2.5 %). The miscellaneous module comprises among others, the motors of the dispensing mechanism and the selection and payment systems.

The next paragraphs give a short description of the nine modules for spiral vending machines. In order to provide a better picture of the materials used in spiral vending machines, the material distribution of the four predominant modules is given.

Housing

The housing module aggregates the insulated casing (external housing, foam insulation, shelves, grids and brackets), the cabinet door, the lighting system and the spirals. Furthermore, screws and rivets are listed under this module.

Table 4-50 and Table 4-51 confirm that the heaviest parts of the cabinet are the panels and the chassis (i.e. external housing) which represent 40 – 60 % of the housing. The chassis of both vending machines is made in ferro-metal, and the panels are made either in ferro-metal and bulk plastics for VM2, or in pre-coating coil for VM1.

About 7 % of the weight of the housing of the two VM is due to the glass of the door. Besides, bulk plastics represent a relevant part of the weight of the spiral vending machine, especially for VM2 which uses this material for the door and the panels, unlike VM1.

In Table 4-51, the differences in the mass proportions can be explained by the heavier shelves in VM2 compared to VM1.

Table 4-50: Material proportion in Housing

Housing	VM1	VM2
Materials		
Bulk Plastics	7.39%	20.97%
Tec Plastics	0.21%	2.15%
Ferro	35.67%	68.95%
Non-ferro	0.29%	0.00%
Coating	49.44%	0.00%
Electronics	0.00%	0.00%
Misc. (glass)	6.94%	7.69%
Misc. (ballast)	0.05%	0.06%
Misc. (blowing agent)	0.00%	0.17%

Table 4-51: Material proportion per sub-module of the housing

Housing	VM1	VM2
Sub-Modules		
External housing	59.36%	40.75%
Foam insulation	1.16%	2.33%
Shelves & Grids	6.30%	20.19%
Door	29.41%	31.22%
Lighting System	0.08%	1.00%
Spirals	3.08%	4.09%
Components for assembling	0.61%	0.43%

Evaporation module

The evaporation module includes the evaporator used to absorb the heat from the internal air of the vending machine, the evaporator tray and the fan (fan motor, frame and blades) allowing the air circulation.

Compression module

The compression module is composed of the compressor and of the compressor motor. The material composition of the compressor for both cabinets is the same due to the use of the same assumptions for the bill of material of this component (see Table 4-24). This compressor is the same as for the beverage cooler.

Table 4-52: Material proportion in Compression module

Compressor	VM1 & VM2
Materials	
Bulk Plastics	0.5%
Tec Plastics	0.1%
Ferro	88.0%
Non-ferro	8.9%
Coating	0.0%
Electronics	0.0%
Misc. (ester oil)	2.5%

Table 4-52 shows that the ferro-group of material is the most represented.

Condensation module

This module contains the condenser, the related fans and fan motor and the liquid receiver. Only VM2 uses a condenser fan.

Expansion device module

This module comprises the expansion device used in the refrigeration system (i.e. a capillary tube).

Anti-sweat heater

Only VM1 uses an electric anti sweat-heater. Indeed, the manufacturer of VM2 has developed a technology of the air distribution inside the cabinet allowing avoiding condensation and therefore the use of an anti-sweat heater.

Electric assembly

This module comprises all materials existing in the electric panel, the cables, including the power cables, which are not included in other modules.

Packaging

This section includes all packaging materials used to deliver the spiral vending machine at the final point of sale. VM1 uses more wood and less cardboard than VM2 for his packaging.

Table 4-53: Material proportion in Packaging

Packaging	VM1	VM2
Bulk Plastics	0.0%	0.0%
Tec Plastics	0.0%	0.0%
Ferro	0.0%	0.0%
Non-ferro	0.0%	0.0%
Coating	0.0%	0.0%
Electronics	0.0%	0.0%
Misc. (wood)	86.1%	37.5%
Misc. (cardboard)	13.7%	50.0%
Misc. (office paper)	0.2%	12.5%

Miscellaneous

Motors of the dispensing mechanism, as well as the selection and payment system are listed in this module. Furthermore, all materials/components not being part of the above mentioned seven groups are stated under miscellaneous (e.g. temperature display systems…).

The material distribution of the dispensing motors is assumed to be the same as for a fan motor of 5 W output. The material composition is detailed in Table 4-15.

Table 4-54: Material proportion in Miscellaneous

Miscellaneous	VM1	VM2
Bulk Plastics	4.54%	4.47%
Tec Plastics	0.00%	0.67%
Ferro	54.46%	51.30%
Non-ferro	31.77%	27.10%
Coating	0.00%	0.00%
Electronics	0.00%	10.87%
Misc. (refrigerant)	7.45%	3.65%
Misc. (screen)	1.78%	1.94%

The BOMs completed by the various assumptions on the material composition of missing components were merged to form the Base Case in task 5. Task 5 provides the detailed BOM of the Base Case for spiral vending machines.

4.2. Distribution phase

4.2.1 Remote refrigerated display cabinet

Remote display cabinets are typically packed in canopy wood protection to ensure maximum protection of all sensitive parts. They sit on a wood base to be used as a fork lift for easy loading and unloading.

Figure 4-12: Remote multi deck ready to be shipped[13]

Depending of the model of remote cabinet considered, the weight of the package product is between 200 and 900 kg. The volume range of the package product is between 3 and 10 m^3.

For open vertical chilled multi deck, the collected data, normalised to a 7 m² TDA cabinet present the following specifications:

Table 4-55: Distribution data for remote open chilled vertical multi deck

TDA	7 m²
Volume of the packaged RCV2	9.47 m^3
Weight of the packaged product (from BOMs)	614 kg
Weight of the packaged product (Catalogue)	710 kg

For open frozen island, the collected data, normalised to a 7 m² TDA cabinet present the following specifications:

Table 4-56: Distribution data for remote open frozen island

TDA	7 m²
Volume of the packaged RCV2	8.52 m^3
Weight of the packaged product (from BOMs)	794 kg
Weight of the packaged product (Catalogue)	806 kg

4.2.2 PLUG IN REFRIGERATED DISPLAY CABINET

The approximate weight of a plug in display cabinet is estimated to range between 60 and 500 kg (between 60 and 160 kg for a beverage cooler) with an

[13] Source: Carrier

average volume of 0.5 to 4 m^3 (0.5 to 2 m^3 for a beverage cooler) depending of the size and the model.

The collected data from BvC1 and BvC2 were normalised to a 0.5 m^3 beverage cooler and then averaged, leading to the following specifications (Table 4-57):

Table 4-57: Distribution data for a typical one door beverage cooler

Net volume	0.5 m^3
Volume of the packaged beverage cooler	1.14 m^3
Weight of the packaged product (from BOMs)	121.6 kg
Weight of the packaged product (Catalogue)	126.2 kg

For the ice cream freezer ICF1 and ICF2 the data was not averaged and is presented in Table 4-58.

Table 4-58: Distribution data for ice-cream freezer

	ICF1	ICF2
Net volume	0.291 m^3	0.3 m^3
TDA	0.52 m²	1.16 m²
Volume of the packaged ice cream freezer	0.797 m^3	2.36 m^3
Weight of the packaged product (from the BOMs)	74.5 kg	227.1 kg
Weight of the packaged product (Catalogue)	75 kg	280 kg

4.2.3 COLD VENDING MACHINE

The shipping weight of a typical vending machine is 300 kg.

An average estimation of the volume of a packaged vending machine, based on manufacturer's estimation is 1.62 m^3 [14].

The collected data from VM1 and VM2 were averaged, leading to the following specifications (Table 4-59):

Table 4-59: Distribution data for a typical spiral vending machine

Dimensions H, W, D (mm)	1830 x 905 x 855
# cans	288
Internal Volume Refrigerated (m^3)	0.75
Volume of the packaged Spiral Vending Machine (m^3)	1.4825
Weight of the packaged product (kg)	297

[14] Source: EVA

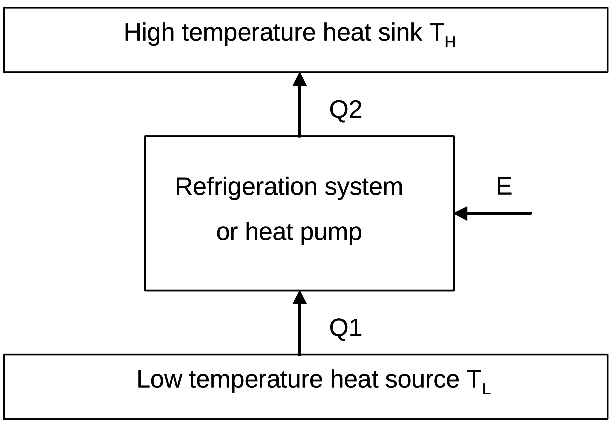
4.3. USE PHASE (PRODUCT)

In this section, the annual energy and resources consumption that can be measured at the product and the direct emissions during product life are discussed. For commercial refrigerators and freezers, the electrical energy consumption and the direct emissions related to refrigerant use are considered.

4.3.1 REFRIGERATION CYCLE

Commercial refrigerators and freezers technically work on the principle of heat pumps (Figure 4-13). The refrigeration unit removes heat (Q1) from a low temperature source and then transfers heat (Q2) to a high temperature source using a certain amount of electrical energy input (E) for the purpose of cooling the cold region. Heat pumps do the same thing with the intent of heating the hot region.

Figure 4-13: Principle of heat pumping system



The efficiency of the refrigeration system is expressed by the COP (coefficient of performance) which is the ratio of the refrigeration effect (heat extracted) and the energy input required: $COP = \frac{Q1}{E}$

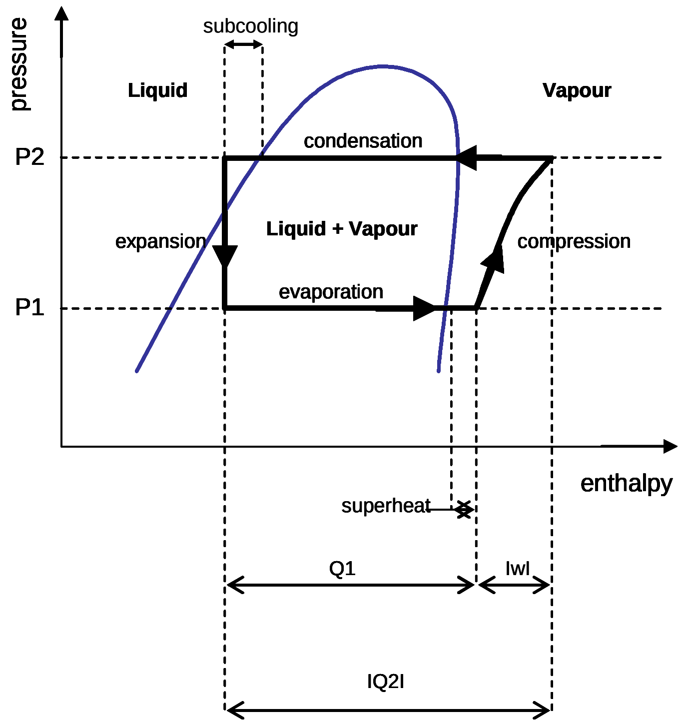
The purpose of the refrigeration unit is to keep the low temperature heat source at the desired temperature T_L. Heat leakage from the surroundings to the low temperature heat source (i.e. the space where foodstuff is stored) tends to increase this temperature. In order to keep the cold region at T_L a certain amount of heat Q1 has to be removed. This is done through the use of a heat exchanger: the evaporator. A refrigerant liquid at a saturated state flows in the heat exchanger and evaporates, absorbing heat from the cold region in its latent heat of evaporation.

These heat transfers are made possible through the vapour compression refrigeration cycle, which as the name suggests, employs a compression process to supply cool saturated liquid or a mixture or liquid and vapour refrigerant to the evaporator.

Almost all commercial refrigerators and freezers in operation are based on the vapour compression cycle which consists of evaporation, compression, condensation, and expansion. The main components in a vapour compression system are the compressor, the expansion valve and two heat exchangers referred to as evaporator and condenser. The components are connected to form a closed circuit, as shown in Figure 4-15**.** A volatile liquid, known as the working fluid or refrigerant, circulates through the four components.

The thermodynamic properties of the refrigerant can be plotted in a pressure-enthalpy chart (Figure 4-14). The blue curve represents the saturated liquid line (on the left) and the saturated vapour line (on the right) and limits the liquid domain, the vapour domain and the liquid-vapour domain of the refrigerant. The refrigeration cycle is represented in bold black.

Figure 4-14: Pressure-Enthalpy chart of the refrigeration cycle – Vapour compression system

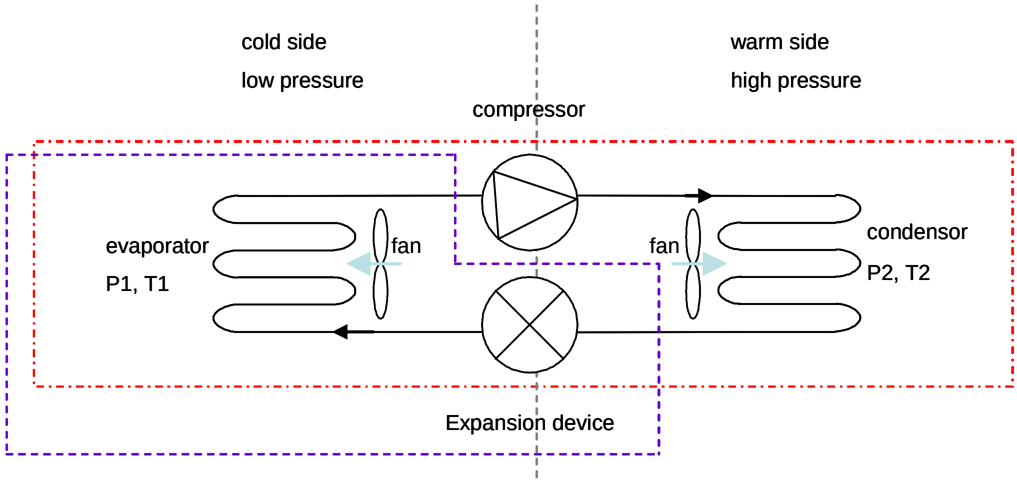


Q1: heat transferred at the evaporator (pressure P1) corresponding to the refrigeration effect

Q2: heat transferred at the condenser to the heat sink (pressure P2)

w: compression work

Figure 4-15: Schematic representation of the refrigeration cycle – Vapour compression system



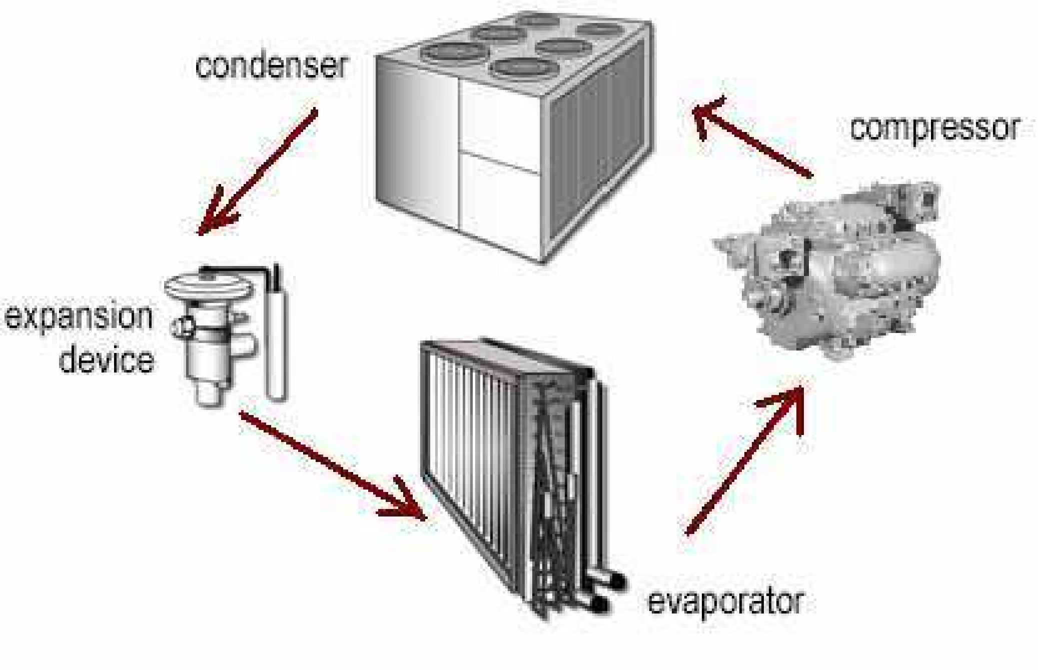
Cabinet case for plug in refrigerated cabinets and cold vending machine case
Cabinet case for remote refrigerated cabinets

In principle, the cycle starts with a low temperature (T1), low pressure-pressure (P1) mixture of liquid and vapour refrigerant entering the evaporator where it absorbs heat from the relatively warm air surrounding the evaporator. This heat transfer, corresponding to the refrigeration effect (Q1) boils the liquid refrigerant in the evaporator and this superheated vapour is drawn in the compressor. Evaporator fans are used in order to increase the heat transfers. The compressor sucks the superheated refrigerant and compresses it into a hot high pressure refrigerant vapour which is released in the condenser. The refrigerant is superheated (heat is added so that the temperature of the refrigerant vapour is increased above its saturation temperature) to prevent the presence of liquid droplets in the compressor, which would alter its operation. Within the condenser, the high pressure (P2) refrigerant is condensed at high temperature (T2) by heat transfer (Q2) to the relatively cool ambient surroundings. The condenser is often located in a cool area and condenser fans are used to increase the heat transfer. The condensation causes the vapour to cool down, condense into liquid and further sub-cool. A liquid receiver at the exit of the condenser serves to accumulate the reserve liquid refrigerant, acting as a stock for off-peak operation, and to permit pumping down of the system. The receiver also serves as a seal against the entrance of gaseous refrigerant into the liquid line. The refrigerant liquid then travels to the expansion device where it is reduced to a low pressure, and low temperature (T1). This pressure drop causes a small part of the refrigerant to boil off. The cooled liquid-vapour mixture then re-enters the evaporator to repeat the cycle.

4.3.2 COMPONENTS AND PARAMETERS INFLUENCING THE REFRIGERATION CYCLE

The performance of the refrigeration cycle and the energy consumption of the refrigeration equipment depend on the components it includes. This section describes the different components found in commercial refrigeration equipment and the way they can influence the energy performance of the product.

Figure 4-16: Major components in commercial refrigeration equipment



Various type of commercial refrigeration equipment utilising compression systems exist but the main components remain the same. For plug in refrigerated display cabinets and cold vending machines, all these components are integrated in the product. **For remote refrigerated display cabinets, the evaporator, the refrigerant and the expansion device are the only components included in the equipment and the considerations made on the compressor and the evaporator, which are located outside from the cabinet, do not apply to this category of product.**

4.3.2.1 Refrigerant

The right refrigerant selection is important for energy efficiency and can affect the energy consumption of the refrigeration equipment.

Before, the main refrigerant used in commercial refrigerated display cabinets was R 22, a hydro chlorofluorocarbon (HCFC) component. Now that it is banned in new equipments, following the Montreal protocol, more and more new refrigerants are developed and fit refrigeration systems. The typical ones are hydro fluorocarbons HFC: R 404A (low temperature remote and plug in display cabinets), R 134a (medium temperature remote and plug in display cabinets and vending machines), R 507 (low temperature) and R 410 (low temperature applications and less frequently used).

Others refrigerants, called halogen-free agents, as Ammonia, Isobutane, Propane and CO_2 show no ODP (Ozone Depletion Potential) and lower GWP (Global Warming Potential), compared to the other ones. Nevertheless, some of their characteristics have until now limited their widespread use. For instance, propane is highly flammable, and is therefore its use in indirect systems is limited for safety issues. The use of “natural refrigerants” is now proposed by some plug in cabinet manufacturers. Such products are covering a bigger share of the market in some countries (i.e. Denmark, Sweden); however, HFC applications remain dominant at the EU-25 wide level.

The choice of the appropriate refrigerant is a compromise between its environmental and thermodynamic properties. Environmental and safety data of several refrigerants used in commercial refrigerated systems are presented in Figure 4-17.

Figure 4-17: Environmental and safety data for commercial refrigerant [15]

Refrigerant		Boiling point (°C)	ODP	HGWP[1)]	GWP[2)]	Toxicity	Flammability	Remarks
CFCs	R 12	-30	1.0	3.0	7300	No	No	
	R 502 (R 22/R 115)	-46	0.33	3.75	4300	No	No	Azeotropic mixture
HCFCs	R 22	-41	0.05	0.34	1600	No	No	
	R 401A (R 22/R 152a/R 124)	-33	0.03	0.27	1000	No[3)]	No	Substitute for R 12
	R 402A (R 22/R 125/R 290)	-49	0.03	0.63	2000	No[3)]	No	Substitute for R 502
HFCs	R 134a	-26	0	0.28	1200	No	No	Not suited for low-temperature systems
	R 404A (R 143a/R 125/R 134a)	-47	0	0.94	3700	No[3)]	No	Zeotropic mixture
	R 507 (R 143a/R 125)	-47	0	0.98	3800	No[3)]	No	Azeotropic mixture
	R 407A (R 32/R 125/R 134a)	-46	0	0.49	1900	No[3)]	No	Zeotropic mixture
Ammonia	R 717	-33	0	0	0	Yes	Yes	For supermarkets only in combination with secondary refrigerant circuit
HCs[4)]	R 290 (propane)	-42	0	0	0	No	Yes	For supermarkets only in combination with secondary refrigerant circuit
	R 1270 (propene)	-48	0	0	0	No	Yes	For supermarkets only in combination with secondary refrigerant circuit

[1)] Referred to base of 1.0 for CFC 11
[2)] Referred to CO_2 over a time horizon of 100 years
[3)] No toxicity anticipated from available test results
[4)] Hydrocarbons

The following thermodynamic properties of the refrigerant have significant impact on the heat transfer and therefore on the performance of the refrigeration system.

- **Latent heat of vaporisation**

High latent heat of vaporisation is desirable because the refrigerant mass flow rate per unit of refrigeration effect is reduced. When a high latent heat of vaporisation is combined with a low specific volume in the vapour state, the compressor work needed is reduced allowing the use of smaller and more compact equipment. However, in small systems, if the latent heat of vaporisation is too high, the amount of refrigerant will be insufficient for accurate control of the liquid.

15 Source: Linde/Carrier

Compression ratio

The compression ratio is the ratio of the absolute discharge pressure (P2) to the absolute suction pressure (P1). In the case of system with reciprocating compressors, all factors being equal, the refrigerants with the lowest compression ratio are the most desirable. It results in low power consumption and high volumetric efficiency.

Specific heat of the refrigerant (both in liquid and vapour state)

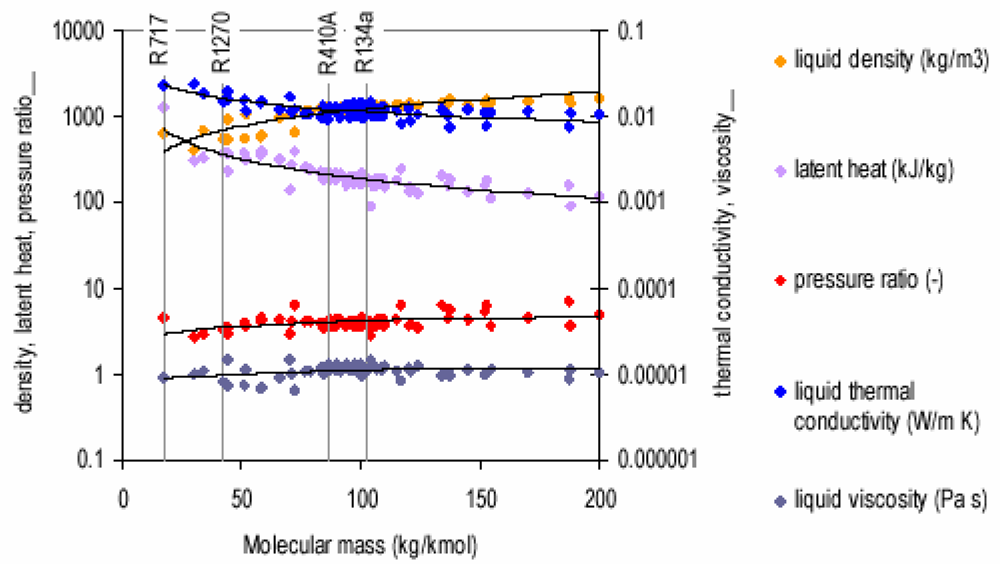
High specific heat translates into good heat transfer properties. Increasing these factors will allow the use of a smaller charge of refrigerant.

Regarding thermodynamic properties, the “best” refrigerant would have the following characteristics:

- Low liquid viscosity: improves heat transfer primarily in condenser
- Low vapour viscosity: reduces single-phase and two-phase pressure drops
- High liquid thermal conductivity: improves heat transfer in evaporator and condenser
- Low liquid density: improves heat transfer in evaporator
- High vapour density: improves heat transfer in condenser and reduces pressure drops
- **High latent heat of vaporisation**: reduces evaporator and condenser pressure drops
- **High liquid specific heat**: improves heat transfer in evaporator and condenser
- **Low saturated temperature-pressure gradient**: reduces compression ratio and therefore compressor power consumption

Figure 4-18 shows the variation of some of the selected properties listed above with molecular mass of the fluid (based on mass fraction in the case of mixtures) for a lot of refrigerants, where the properties were calculated for 0 °C using the Refprop database (Lemmon et al, 2002). A limited number of common refrigerants are indicated.

Figure 4-18: Variation of refrigerant thermodynamic properties[16]



Refrigerants with a lower molecular mass, as ammonia (R 717) and propylene (R 1270) seem to have the favourable thermodynamic properties, thus higher efficiency. However environmental and safety characteristics have to be taken into account to have a global point of view on benefits and weakness of the refrigerant.

4.3.2.2 EVAPORATOR

Air type evaporator and flooded evaporators are the most typically used in commercial refrigeration equipment. The difference is that the air evaporator wholly vaporizes the refrigerant before it reaches the suction line in the compressor. In the case of flooded evaporator, to avoid liquid refrigerant getting into compressor, and damaging it, a receiver is added at the outlet of the evaporator. Vapour and liquid phases are separated; the vapour circulates through the compressor, and the liquid is reinserted into the evaporator. Thus, flooded evaporators are also called recirculation-type evaporators. This one has a heat transfer coefficient higher than air evaporator, and then is more efficient. However, flooded evaporators are more expansive to operate, and it is relevant to make sure that oil return to the compressor for its good performance.

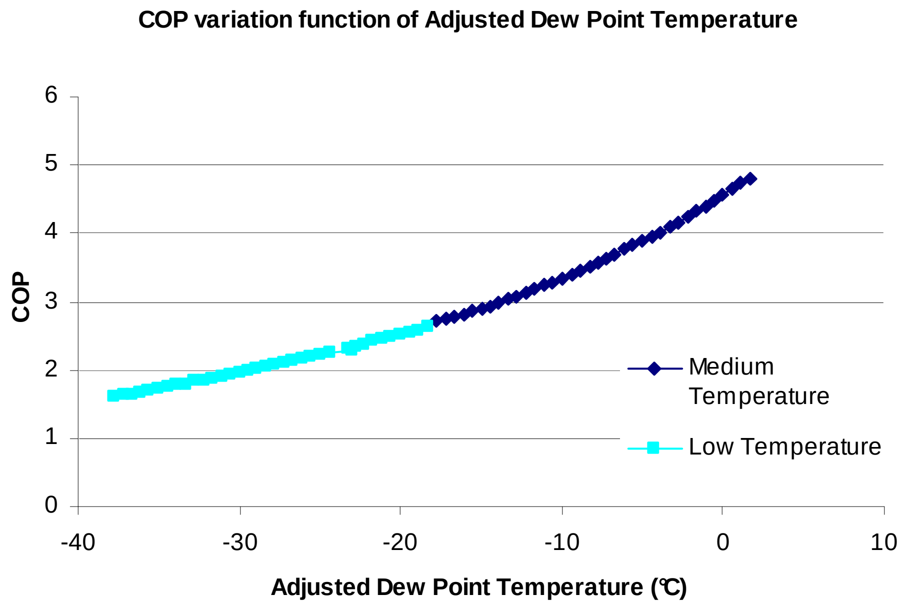
The evaporating temperature is one of the operation conditions of the refrigeration equipment which is determined according to the refrigerating effect needed. High evaporating temperature is desirable. The density of the refrigerant suction vapour entering the compressor is a function of the evaporating pressure P1. Higher the vaporising pressure, the greater is the density of the suction vapour. For a given volume of vapour handled by the compressor, a greater mass of refrigerant is drawn when the suction pressure is

[16] Reference : *BNCR37: Characteristics of refrigerants in relation to efficiency*, Market Transformation Programme

high (when the suction temperature is high). Q2 increases and the performance is improved.

ARI 1200 2006 standard provides COP values for a typical reciprocating compressor used for remote refrigerated display cabinets (merchandisers and storage cabinets). It is clearly visible (Figure 4-19) that the higher the Adjusted Dew Point, the higher the COP. The adjusted dew point temperature is defined in ARI 1200 2006 as being "lower than the actual Dew Point temperature (refrigerant vapour saturation temperature at a specified pressure) resulting from suction line pressure losses, equal to saturated suction temperature at the compressor".

Figure 4-19: Influence of the Adjusted Dew Point Temperature on the efficiency of the refrigeration cycle (source: ARI 1200 2006 standard)



Q2 is also a function of the heat transfer properties at the evaporator.

Evaporator fans are used in most of refrigerated display cabinets, to increase the heat transfer coefficient and a regular defrost allows the evaporator coils to be kept free from layers of insulating frost. Most of evaporator fans motors in refrigeration systems operate continually at constant speed. But more and more manufacturers suggest variable speed motors or two-speed fans, allowing the decrease of the speed and then of energy consumption, when less refrigeration load is required. Moreover, when supermarkets are closed, single-speed fans operate only 20 minutes per hour, which causes the stratification of the air. By using other fans, running constantly at lower speed, this phenomenon disappears.

The most common evaporator defrost methods (compressor shutdown, electric and hot gas) are described in the section 3.2.3.1 of the task 3 of the study.

4.3.2.3 CONDENSER

The condenser is where the refrigerant releases the heat picked up in the foodstuff storage space. Condensers are used with condenser fans, and large surface on the outside of condenser tubes to compensate the poor heat transfer characteristics of air.

Because of the lack of space, plug in refrigerated display cabinets and vending machines use an air cooled condenser. In the case of remote display cabinets they can also be linked to water cooled or evaporative condensers.

In an air cooled condenser, the refrigerant flows through tubes and air is drawn over the tubes by a fan to assure mechanical air circulation. A typical air cooled condenser uses propeller type fans to draw the surrounding air over a finned-tube heat transfer surface and increase the heat transfer coefficient. To make sure of the good operation of the condenser, it has to be cleaned to avoid debris blocking it and limiting the heat transfer.

The condensing temperature has an impact on the product efficiency. The condensing temperature should be kept as low as possible. When T2 increases, Q1 decreases. A 1 °C increase in condensing tempera ture can lead to a higher energy use by 2 - 4 % for the whole refrigeration system. All other factors being equal, increasing the condensing temperature increases the compression ratio and reduces the volumetric efficiency of the compressor. As a result, the volume of vapour displaced by the compressor per unit time decreases. Thus, some systems may have a control to regulate the condensing pressure, and then the condensing temperature, using mostly a pressure switch.

Good ventilation will help keep head pressure (compressor exit pressure) down, reduce power consumption, and contribute to a long service life for the compressor.

Further, a simple way to reduce the condensing temperature of the refrigeration system is to use an electronic expansion valve.

For proper operation of the expansion valve, the refrigerant on the high pressure side must be all in liquid phase. To ensure this, the refrigerant should, if possible, be subcooled a few degrees at the exit of the condenser. If the refrigerant is not subcooled, pressure drop in the tubes, and height differences between the condenser and the expansion valve, may cause formation of vapour bubbles. A liquid receiver is usually placed between the condenser and the expansion valve. During operation, the receiver is partially filled with refrigerant liquid and as the outlet is placed in the bottom, only liquid phase can leave the receiver. Some types of condensers also operate as receivers.

In condensers with condensation inside the tubes and no receiver, the amount of refrigerant can be controlled so that the last section of the heat exchanger acts as a subcooler. In air cooled condensers, the subcooling section is placed on the air inlet side. From Figure 4-14 we can see that the greater the subcooling, the larger the cooling capacity in the evaporator (Q1).

As for evaporator fans, condenser fans can be controlled to reduce their energy consumption. Thus, variable speed or two-speed motors are more and more proposed by manufacturers.

4.3.2.4 EXPANSION DEVICE

In case of plug in refrigerated display cabinets and vending machines, the expansion device used is a capillary tube. For remote refrigerated display cabinets, the expansion device used is an expansion valve.

The expansion valve is a precision device used to control the refrigerant flow rate to match the amount of refrigerant being boiled off in the evaporator. It provides the flow resistance necessary to maintain a pressure drop in the system, separating the high pressure side (P2) from the low pressure side (P1).

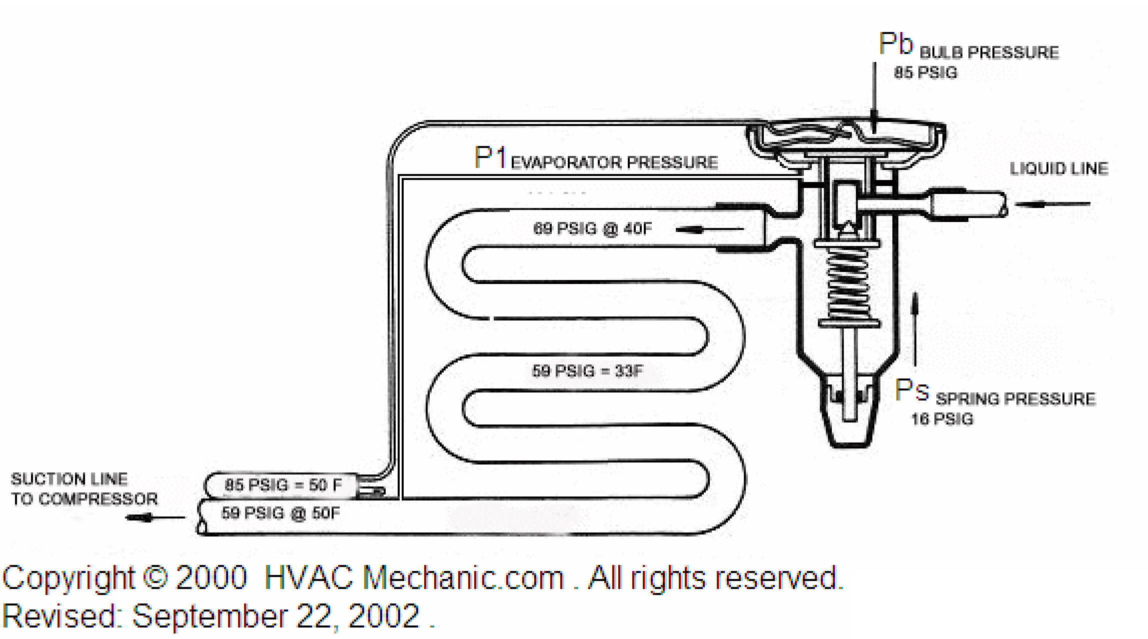
The expansion valve may be a thermostatic expansion valves controlled by the evaporator exit temperature, an electric expansion valve.

The most common type of expansion device is the thermostatic expansion valve (TXV). A typical TXV comprises a valve body, a stem connected to a spring and to a metal membrane, and a sensing system consisting of a bulb and a capillary tube which is partially filled with some refrigerant. The inside of the valve is in open contact with the evaporator but separated from the sensing system by the membrane. The bulb is placed in contact with the suction line. Above the membrane, the pressure corresponds to the evaporation temperature of the refrigerant in the bulb (bulb pressure) which itself corresponds to the temperature of the superheated refrigerant vapour.

A TXV is chosen according to the system's pressure drop and design evaporator cooling capacity adjusted with the subcooling to ensure the desired evaporating temperature and superheat is reached for a set condensing temperature. This type of valve is set to maintain approximately the same superheat in the suction line (inlet of the compressor) at all conditions. The mass flow of refrigerant through the evaporator will vary in response to changes in the heat load sensed by the bulb. If the compressor is stopped, no superheat is sensed and the valve is closed.

A basic thermostatic expansion valve operates depending on three forces: one closing force Pb: the bulb pressure and two opening forces: the spring pressure Ps and the evaporator pressure P1. When the evaporator pressure increases while Pb remains the same, the valve closes. If the bulb pressure increases to the larger amount, the valve opens (Pb > P1+Ps)

Figure 4-20: Thermostatic Expansion Valve (TXV)[17]



Although more expensive, electronic expansion valves (EXV) can also be used in commercial refrigeration equipments. EXV make it possible to avoid the minimum pressure drop required to allow proper operation of a standard thermostatic valve. Therefore it is possible to optimise the condensing pressure at the minimum level permitted by the ambient conditions. Using an electronic expansion valve, it is possible to regulate the superheating of the evaporator improving the cabinet's performances. Moreover, it allows a better control of the temperature, which insures a better preservation of products, whatever external conditions.

4.3.2.5 COMPRESSOR

The compressor sucks in the refrigerant coming from the evaporator, at low pressure and low temperature, and flows it back towards the condenser at high pressure and high temperature.

This section provides a general description of the different types of compressors and more specific data on compressors included in plug in refrigerated display cabinets and vending machines. For remote refrigerated display cabinets, the compressor is located externally and its detailed analysis falls out of the scope of this study.

In order to protect the compressor, a low-pressure controller and a high-pressure controller are located before and after it respectively. The motor of the compressor is stopped when the inlet pressure is lower than a minimum value, or when the outlet pressure is higher than a maximum value.

[17] Source: HVAC Mechanic.com

We can differentiate compressors in two categories with the compression type:

- Positive displacement compressors: they confine successive volumes of refrigerant within a closed space in which the pressure of the fluid is increased as the volume of the closed space is decreased. Reciprocating or piston, screw, scroll and rotary vane are common positive displacement compressors.
- Dynamic compressors: they use rotating vanes or impellers to impart velocity and pressure to the refrigerant. Centrifugal compressors are the most popular.

A complementary selection is also required to define the compressor, based on the motor configuration:

- Open compressor: motor and compressor are separated and access to components is available. However, leaks of refrigerant are frequent, because of the lack of tightness. This type of configuration is only used in remote refrigeration systems. When ammonia is used as refrigerant, open compressor is the only solution because of incompatibility of ammonia with cupper in motor.
- Hermetic compressors: motor and compressor are located in a closed space, which allows tightness. In this kind of compressor, the refrigerant is used to cool the motor. These compressors are most of all used for small and medium powers (less than 40 kW[18]).
- Semi hermetic compressor: motor and compressor assembled together, with possible access to key parts such as valves and connecting rods. In comparison with open compressors, tightness is improved but not absolute. As with hermetic compressors, the refrigerant is used to cool the motor.

The following table gives an overview of the use of different type of compressors.

Table 4-60: Range of refrigeration power according to the type of compressor[19]

Type of compressor	Scroll	Screw	Rotative vane	Reciprocating			Centrifugal
				Open	Hermetic	Semi Hermetic	
Rage of use	up to 40 kW*	20 kW up to 1200 kW	up to 10 kW	up to 1200 kW	up to 60 kW	up to 500 kW	1000 kW up to 4000 kW*

**: several compressors can be set in parallel.*

Most plug in refrigerated display cabinets and cold vending machines use hermetically sealed, electric motor driven compressors units with a reciprocating compressor. Figure 4-21 and Figure 4-22 show the inside and outside views of a typical hermetic reciprocating compressor.

[18] Reference: *Guide technique, systèmes de compression et de réfrigération*, Hydro Québec

[19] Reference: Direction générale des Technologies, de la Recherche et de l'Energie (DGTRE) du Ministère de la Région wallonne

Figure 4-21: Cutaway diagram of a hermetic reciprocating compressor

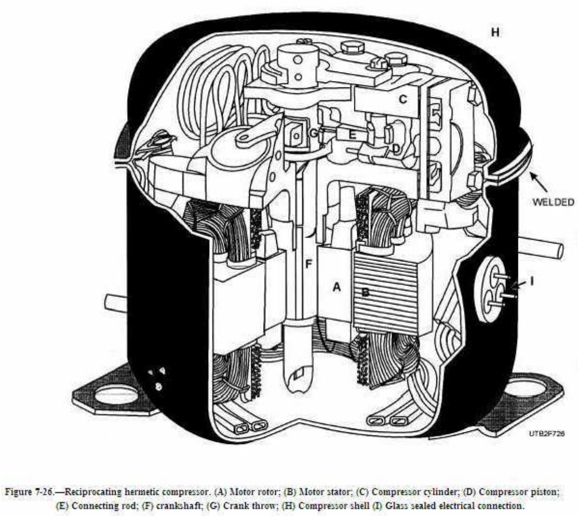


Figure 4-22: External view of a hermetic reciprocating compressor

Table 4-61 gives an overview of main characteristic values of compressors depending on the type of appliance (plug in, remote and vending machines). The standard followed is EN12900. The following data are assessed at the following rating points:

Low Temp.: Evaporating -35 °C / Condensing 40 °C / SGT 20 °C / Subcooling 0 K

Medium Temp: Evaporating -10 °C / Condensing 45 °C / SGT 20 °C / Subcooling 0 K

SGT: Suction Gas Temperature

Table 4-61: Overview of compressor characteristics

Type of Appliance	**Feature**	**Range**	
		LT (*1)	**MT** (*2)
Supermarket Self-Contained (R404A)	Cooling Capacity Range Nom. COP Range Average COP	0.5 ... 2.0 kW 0.9 ... 1.28 1.10	0.8 ... 4.0 kW 1.4 ... 2.0 1.7
Supermarket Remote Systems (R404A)	Cooling Capacity Range Nom. COP Range Average COP	≥ 3 kW 1.10 ... 1.48 1.25	≥ 8 kW 1.83 ... 2.37 2.10
Vending Machines (R404A)	Cooling Capacity Range Nom. COP Range Average COP	n/a	0.8 ... 1.2 kW 1.4 ... 2.0 1.7

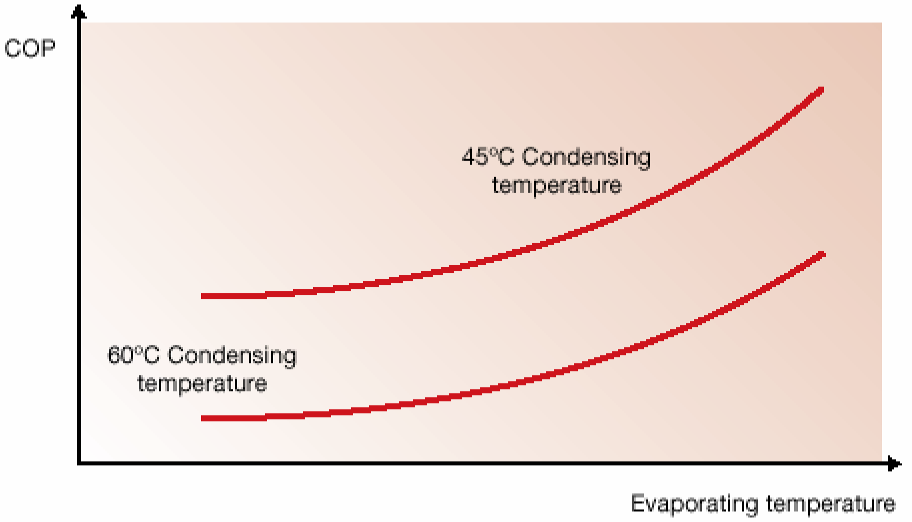
The compressor efficiency is affected by:

- The compressor displacement
- The temperature lift (difference between evaporating and condensing temperatures)
- The properties of the refrigerant

* The temperature of the superheated suction vapour (if it is too low, liquid refrigerant may return to the compressor and damage it)

Concerning the influence of the temperature lift on the compressor efficiency and furthermore, on Coefficient Of Performance (COP), the Figure 4-23 shows that for the same evaporating temperature, the lower the condensing temperature, the higher the COP. A decrease of 1℃ in temperature lift, will involve an increase on the COP by 2 – 4 %.

Figure 4-23: COP for a typical compressor according to the temperature lift[20]



In order to increase the energy efficiency of the complete refrigeration system, the compressor control has got a relevant part. The compressor is chosen to supply power at the limiting conditions of the refrigerated display cabinet (maximum temperature and moisture). Most of the time, it does not operate at 100 %. Thereby, the compressor with the best COP under nominal conditions is not necessarily the best under real operation conditions.

In medium temperature applications, the COP of a scroll compressor is assumed to be higher than for a reciprocating compressor at the actual operating conditions, assuming an annual average condensing temperature between 20℃ and 30℃ which is representative of to day's applications. For low temperature applications, standard scroll compressors show less favorable COPs.

The choice of the compressor depends mostly on average annual evaporator and condenser temperatures.

The compressor control enables adapting the cooling capacity to conditions. Several systems are available to regulate this capacity:

* Variable speed or two-speed control: the speed of the motor is adapted regarding to the cooling power required.

[20] UK Energy Efficiency Best Practice Program. *Energy efficient refrigeration technology – the fundamentals,* Good Practice Guide n°280. http://www.cibse.org/pdfs/GPG280.pdf

- Digital modulation control: a continuous capacity modulation technique specifically developed for scroll compressors.
- Cascade control: used when several compressors are set in parallel. The rule is that it is more energy efficient to use a small compressor at 50 % than a big one at 20 %.
- Cylinders control: the suction vapour is stopped from entering one or more cylinders, thus reducing the pumping rate of the compressor.

Without taking into account the price, the choice of the control depends on the type of compressor, and on real operation conditions.

Another control, the pumpdown control, allows avoiding liquid refrigerant entering into the compressor and damaging it. Thus, the compressor is switched off when the suction pressure reaches the cut-out setting on the low-pressure controller, and switched on when the suction pressure is above the limit.

4.3.2.6 LIQUID SUCTION HEAT EXCHANGER

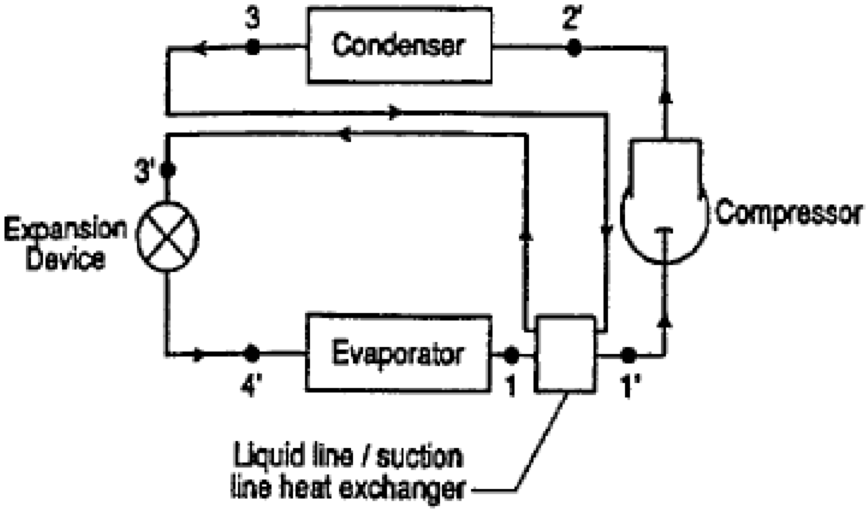
Liquid suction heat exchangers are commonly used in refrigeration systems to ensure the right operation of the system and increase its performance. ASHRAE[21] states that heat exchangers are effective in:

- Increasing the system performance
- Subcooling liquid refrigerant to prevent flash gas formation at inlets to expansion devices
- Fully evaporating any residual liquid that may remain in the liquid-suction prior to reaching the compressor

Figure 4-24 shows the refrigeration cycle including the liquid suction heat exchanger, which allows exchanging energy between the cool gaseous refrigerant leaving the evaporator and warm liquid refrigerant exiting the condenser.

Figure 4-24: Schematic representation of refrigeration cycle with a liquid suction heat exchanger

[21] ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers



The main benefit of the use of a liquid suction heat exchanger is to avoid vapour existing into the expansion device, and to reduce the possibility of liquid transfer between the evaporator and the compressor, which could harm the latter. However, liquid-suction heat exchangers could increase the temperature and reduce the pressure of the refrigerant entering the compressor causing a decrease in the refrigerant density and compressor volumetric efficiency.

The choice to install a liquid suction heat exchanger is a compromise, and depends on the temperature lift (difference between condensing and evaporating temperatures) of the system and on the kind of refrigerant. For example, it is detrimental to system performance in systems using R 22, R 32 or R 717 as refrigerant, for low temperature lifts.

4.3.3 ENERGY CONSUMPTION

The following table gives an overview of the typical annual energy consumptions of the different commercial refrigeration equipments.

Table 4-62: Typical energy consumption of commercial refrigeration equipment

Type of equipment	Annual electricity consumption in standard conditions(kWh/year)	Annual electricity consumption in off-standard conditions(kWh/year)
Remote refrigerated display cabinet (chilled)	28,265[22]	-
Remote refrigerated display cabinet (frozen)	29.689[23]	-

[22] This data is indicative, it corresponds to the energy consumption of a remote vertical open cabinet (RCV2) with a total display area of 7 m²

[23] This data is indicative, it corresponds to the energy consumption of a remote horizontal open frozen island (RHF4) with a total display area of 7 m²

Plug in cabinet	30,660[24]	15,000
Cold cans and bottles vending machine	2,800	2,600 – 5,400
Snack vending machine	2,900	-

The energy consumption of remote refrigerated display cabinets, refrigerated plug in cabinets and cold vending machines is given in both standard conditions and off-standard conditions. A test standard is necessary to create a frame enabling the comparison of different products. However real-life use differs from the standard specifications resulting in different the energy consumptions.

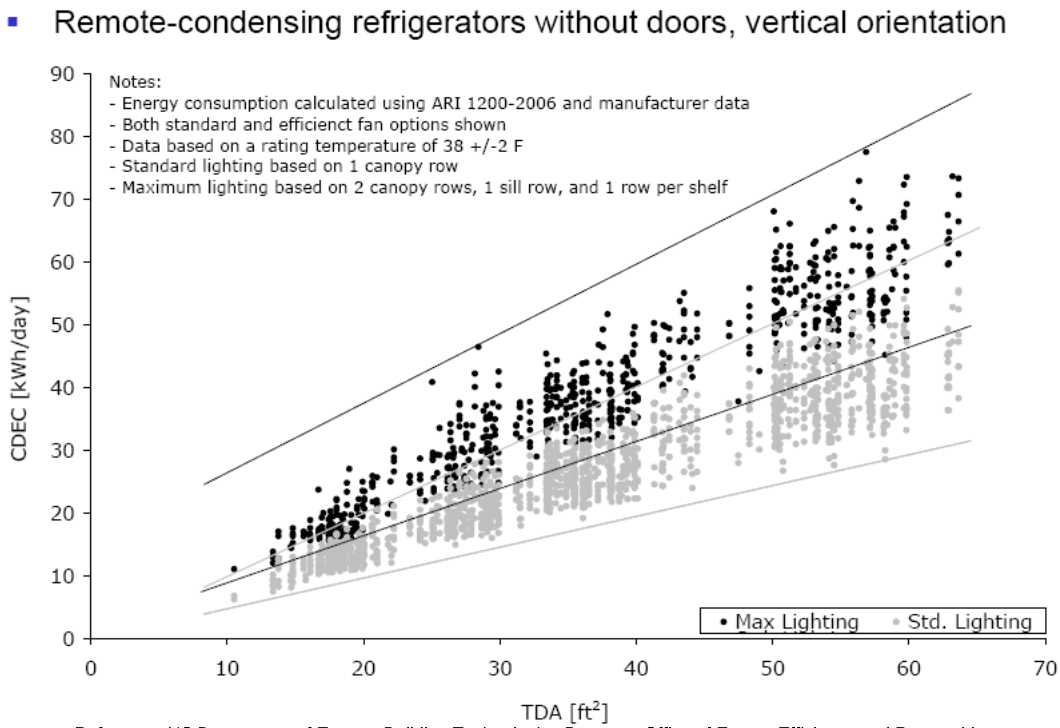
4.3.3.1 ENERGY CONSUMPTION OF REMOTE REFRIGERATED DISPLAY CABINETS

- **Standard condition: ARI 1200-2006 standard**

The Air-conditioning and Refrigeration Institute (ARI) in the US will launch a new certification program in April 2006. The ARI 1200 2006 certification program also measures the performance of display cabinets to allow comparison between competing products. Figure 4-25 illustrates the laboratory results related to the average electricity consumption of a remote vertical multi deck. It shows an average consumption ranging from 6.5 kWh/day/m² to 7.6 kWh/day/m².

[24] This data is indicative, it corresponds to the energy consumption of a plug-in vertical open cabinet (ICV2) with a total display area of 4 m²

Figure 4-25: Daily energy consumption of vertical open refrigerators according to the ARI 1200 2006 program (source: US Department of Energy)



Reference: US Department of Energy, Building Technologies Program, Office of Energy Efficiency and Renewable Energy (http///eere.energy.gov/buildings/appliance_standards)

Standard conditions: ISO 23953 standard

In the ISO 23953 standard on refrigerated display cabinets, the energy consumption is given by the total energy consumption in kilowatt hours per 24 h period (TEC). As mentioned in task 1, the TEC indicator for remote refrigerated display cabinet is the sum of the two following:

DEC: direct electrical energy consumption, in kilowatt hours per 24 h period

REC: refrigeration electrical energy consumption, in kilowatt hours per 24 h period, for remote cabinet

As described in task 1, the Eurovent Certification Program on refrigerated display cabinets tests the products' energy consumption according to the ISO 23953 standard.

Direct electrical Energy Consumption (DEC) calculation

$$DEC = [(P_V.t_V) + (P_H.t_H) + (P_D.t_D) + (P_L.t_L) + (P_A.t_A)]$$

Refrigeration electrical Energy Consumption (REC) calculation

$$\mathrm{REC} = \mathrm{t_R} \cdot \phi_0 , \frac{(\mathrm{T_c} \text{ -} \mathrm{T_0})}{(0.34 \cdot \mathrm{T_0})}$$

Total Energy Consumption (TEC) calculation

$\mathrm{TEC} = \mathrm{DEC} + \mathrm{REC}$ in kWh/24h

$P_{V,H,D,L,A}$ respectively fan, heaters, defrost heaters, lighting and accessories power (W)

$T_{V,H,D,L,A}$ respectively fan, heaters, defrost heaters, lighting and accessories running time within 24h

t_R 24h minus defrost period in h

T_C conventional condensing temperature

T_0 refrigerant evaporating temperature (based on test with 24h lighting)

Φ_0 heat extraction rate in kW (based on test with 24h lighting)

The heat extraction rate Φ_0 is defined by:

$$\phi_0 = \frac{Q_{tot}}{t_R}$$

Q_{tot} represents the total heat extraction in kWh

$$Q_{tot} = \sum_{n=1}^{n=N_{\max}} \phi_n \times \Delta t$$

ϕ_n represents the instant heat extraction rate in kW. It is defined as

$\phi_n = q_m \times (h_8 - h_4)$ (See Figure 4-26)

n indicates the measuring sample.

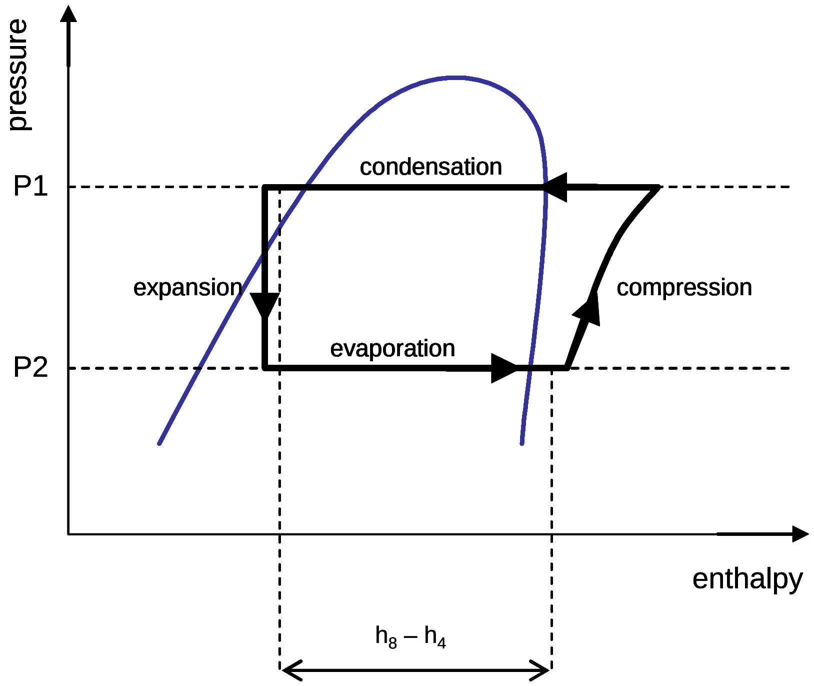
N_{max} is the number of measuring samples in 24 hours

Δt is the time between two measuring sample

q_m is the mass flow rate of refrigerant is kg/s

$h_{8,4}$ are the specific enthalpy in kJ/kg at point 8 corresponding to the refrigerant outlet and point 4 corresponding to the refrigerant inlet, of cabinet.

Figure 4-26: Pressure Enthalpy diagram showing measurement points



The TEC depends on the size, type and temperature range of the display cabinet. To allow a comparison of the different energy consumptions, the standard TEC is given in kWh per 24 hours per m² of total display area (TDA) for a given temperature class.

The table below (Table 4-63) gives the average European average figures of the ratio TEC/TDA for remote refrigerated display cabinets determined in 1997 (* = 2001) taking into account cabinets manufactured and sold in Finland, France, Germany, Italy, Sweden and the United Kingdom.

The cabinet temperature class is defined as follows:

Cabinet temperature class: classification in test room climate class 3 (ambient temperature of 25 °C): 3H2 (-1; +10), 3H1 (+1; +10) , 3M2, 3M1, 3L3 (-12; -15), 3L2, 3L1 according to EN ISO23953 (where H class is substitute by H2 and H1 as above defined and L3 defined in EUROVENT/Cecomaf recommendation).

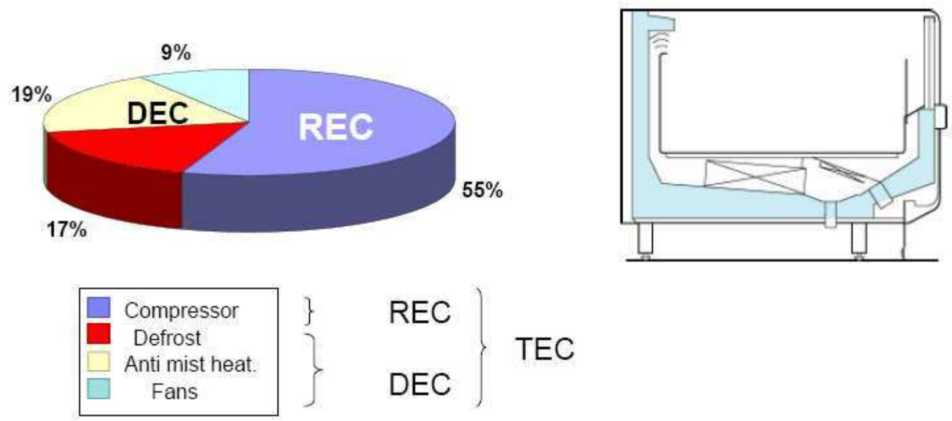
Table 4-63: Average figures for the European market[25].

Cabinet family	Cabinet temperature class	European average TEC/TDA (kWh/day.m²)	European annual average TEC/TDA (kWh/year.m²)
RHC1	3H	6.2	2,263
	3M2	6.7	2,445.5
RHC3, RHC4	3H	5.5	2,007.5
	3M2	5.8	2,117
RCV1, **RCV2**	3H	10.1	3,686.5
	3M2	**12.3**	**4,489.5**
	3M1*	13.4	4,891
RCV3	3H	13.8	5,037
RHF3, RHF4	3L3	13	4,745
RVF4	3L1	28.5	10,402.5
RVF1	3L3	29	10,585

The purpose of the standard is not to measure the real life energy consumption but to verify that the product is working in the worst conditions and to provide a tool to compare competing products.

The typical distribution of the TEC for different types of remote refrigerated display cabinets is shown in Figure 4-27 to Figure 4-29.

Figure 4-27: Electricity consumption distribution of a frozen open wall site remote display cabinet[26]

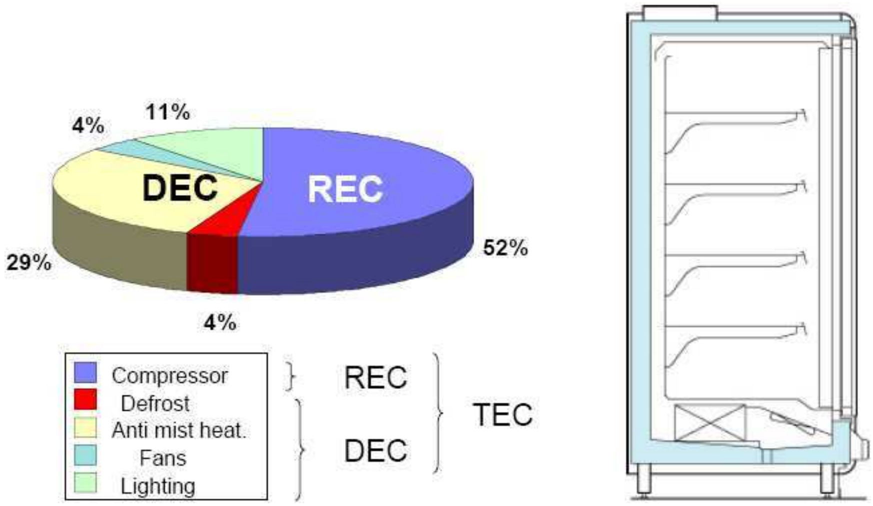


Reference: ARNEG – IZW IEA Hannover Symposium (1/11/2005)

[25] Reference: Data based on field experience and manufacturing numbers from Eurovent Refrigerated Display Cabinets Certification Program Available at <http://www.eurovent-certification.com/en/Programmes/Characteristics.php?rub=02&srub=01&ssrub=&&find=&lg=en&select_prog=RDC&rub=02&srub=01>

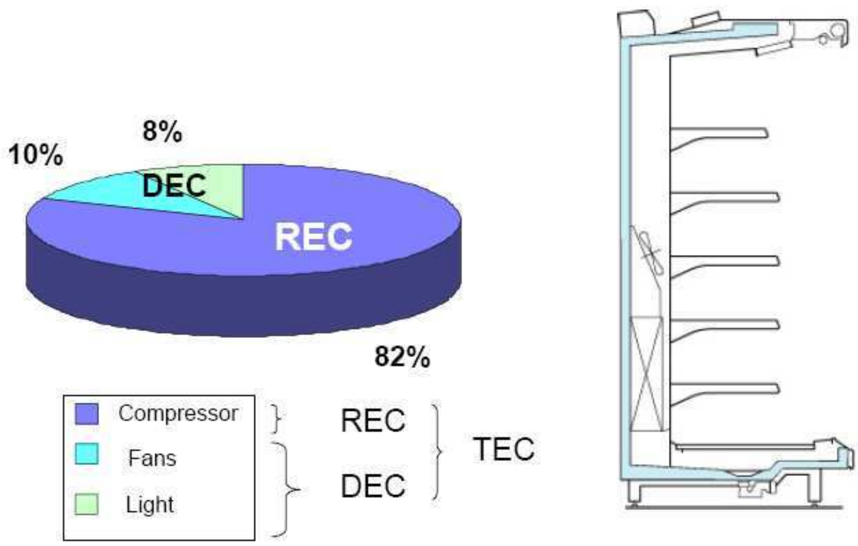
[26] Source: ARNEG

Figure 4-28: Electricity consumption distribution of a frozen glass doors remote cabinet[26]



Reference: ARNEG – IZW IEA Hannover Symposium (1/11/2005)

Figure 4-29: Electricity consumption distribution of a chilled vertical multi deck remote display cabinet[27]



Reference: ARNEG – IZW IEA Hannover Symposium (1/11/2005)

Remote open vertical chilled multi deck

The average energy consumption of a typical remote open vertical chilled multi deck as described in section 4.1.1.2 was calculated based on the energy

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[27] Source: ARNEG

consumption data from the four product cases and from an additional energy consumption data provided by a fifth manufacturer. All measurement were made according to the ISO 23953 standard at the climate class 3M2 (ambient condition: 25 ℃ – 60 % RH; operating temperature r ange: -1 ℃ ~ 7 ℃) and then normalised to a 7 m² TDA.

Based on the data collected, the typical total energy consumption of a RCV2 with a TDA of 7 m² can be estimated to 77.31 kWh/d[28] when measured with the ISO 23953 standard at climate class 3M2.

Table 4-64 provides details on the distribution of the electricity consumption for each of the five existing products. The REC represents approximately 91 % of the total energy consumption.

Table 4-64: REC and DEC in RCV2

(kWh/d)	RCV2_1	RCV2_2	RCV2_3	RCV2_4	RCV2_5
REC	89.02%	88.75%	92.77%	92.62%	89.80%
DEC	10.98%	11.25%	7.23%	7.38%	10.20%

Table 4-65: Distribution of the energy consumption in typical RCV2

	Energy consumption distribution	RCV2_1	RCV2_2	RCV2_3	RCV2_4	RCV2_5
DEC	Evaporator module (Fans)	7.40%	N/A	4.88%	5.08%	7.23%
	Housing (Lighting system)	2.19%	N/A	2.35%	2.30%	2.98%
	Anti-sweat heater	1.40%	0.00%	0.00%	0.00%	0.00%
	REC	89.02%	88.75%	92.77%	92.62%	89.80%

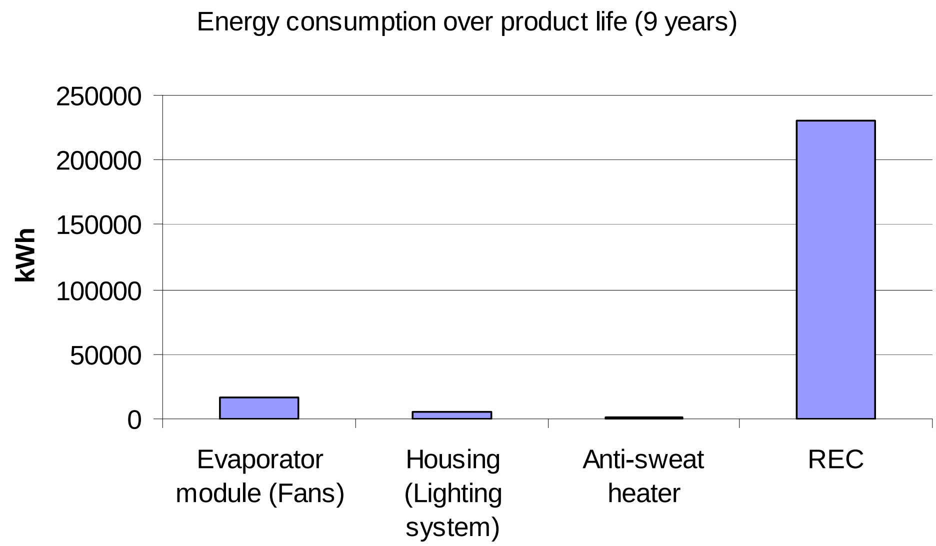
The analysis of the electricity consumption of the received data provides the following distribution for a 7 m² TDA remote open vertical chilled multi deck (Table 4-66):

[28] Equivalent to 11.04 kWh/d/m² TDA

Table 4-66: Average electricity consumption of a RCV2

	Aggregated values from 5 existing RCV2	Energy consumption (kWh/d)	Energy consumption (kWh/product life 9 years)	% over TEC	% over DEC
DEC	Evaporator module (Fans)	5.15	6.66%	16919.38	72.0%
	Housing (Lighting system)	1.79	2.32%	5884.78	25.0%
	Anti-sweat heater[29]	0.21	0.28%	701.06	3.0%
	DEC	7.15	9.25%	23505.22	100.00%
	REC	70.16	90.75%	230477.29	0.00%
	TEC (DEC+REC)	77.31	100.00%	253982.51	0.00%

Figure 4-30: Distribution of the total electricity consumption



These aggregated data on energy consumption will serve as inputs in task 5.

Remote open frozen Island

The average energy consumption of a typical remote open frozen island as described in section 4.1.1.2 was calculated on the basis of energy consumption data provided by three manufacturers. Measurements were made following ISO 23953 standard at the climate class 3L2 (ambient condition: 25 °C – 60 % RH;

[29] The anti sweat heater electricity consumption is the average of the 5 product cases. Only one cabinet featured a anti-sweat heater thus the electricity consumption here might appear low as is it equal to a fifth of the real electricity consumption of a anti-sweat heater.

operating temperature range: (-18 ℃ ~ -12 ℃), and then normalised to a 7 m² TDA.

Therefore, the total energy consumption of a typical open frozen island with a TDA of 7 m² can be estimated to 81.34 kWh/day, when measured with the ISO 23953 standard at climate class 3L2.

Table 4-67 details the repartition of electricity consumption for each of the three product cases. The REC represents about 77 % of the total energy consumption.

Table 4-67: REC and DEC in RHF4

	RHF4_1	RHF4_2	RHF4_3
REC	76.62%	78.38%	74.87%
DEC	23.38%	21.62%	25.13%

Table 4-68: Distribution of the energy consumption in typical RHF4

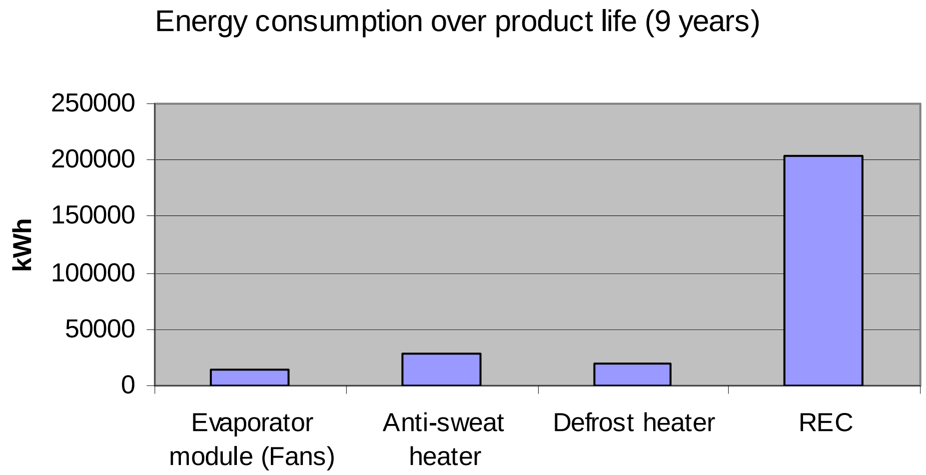
	Energy consumption distribution	RHF4_1	RHF4_2	RHF4_3
DEC	Evaporator module (Fans)	2.31%	7.20%	7.50%
DEC	Anti-sweat heater	12.59%	8.42%	11.07%
DEC	Defrost heater	8.48%	6.00%	6.56%
	REC	76.62%	78.38%	74.87%

The analysis of the electricity consumption of the received data provides the following distribution for a 7 m² TDA remote open frozen island (Table 4-69).

Table 4-69: Average electricity consumption of a typical RHF4

	Aggregated values from 3 existing RHF4	Energy consumption (kWh/d)	Energy consumption (kWh/product life 9 years)	% over TEC	% over DEC
DEC	Evaporator module (Fans)	4.45	14,609.84	5.47%	23.39%
DEC	Anti-sweat heater	8.79	28,878.25	10.81%	46.24%
DEC	Defrost heater	5.77	18,970.41	7.10%	30.37%
	DEC	19.01	62,458.50	23.37%	100.00%
	REC	62.33	204,745.40	76.63%	
	TEC (DEC+REC)	81.34	267,203.89	100.00%	

Figure 4-31: Distribution of the total electricity consumption over product life



These aggregated data on energy consumption will serve as inputs in task 5.

Real life situation

The real life conditions lead to different energy consumption. The DEC will remain the same as in standard conditions, however the REC will vary due to different ambient conditions (temperature and relative humidity) and conditions of use (use of night curtain, maintenance practices), leading to a different total energy consumption.

The EUROVENT certification program tool is not a tool to measure the efficiency of a cabinet in real life conditions but its purpose is to verify that the equipment is working, even in the worst conditions, according to what the manufacturer is claiming. The laboratory conditions are “the ideal worst conditions” and are far from simulating the real life conditions of use of refrigeration equipment and therefore standard measurements are an overestimation of the real electricity usage of these products. For remote multi decks, the standard refrigeration electrical consumption can be 60 – 80 % higher than in real life conditions[30]. For other types of cabinets, the difference is less important because the surroundings have a less strong impact (e.g. cabinets with doors, horizontal cabinets…). A comparison of the laboratory conditions and the real life conditions (in store) is provided in the Annex C of the ISO 23953. The interactions between the refrigerated remote display cabinet and the surroundings as well as the differences between laboratory and in-store conditions will be further discussed in section 4.4.

Also, the energy consumption of a remote refrigerated display cabinet is function of the energy usage of its components. A breakdown of the direct energy consumption of a remote cabinet will help target the components representing the most environmentally impacting subassemblies. The following paragraphs are based on existing studies.

[30] Reference: Study by ARNEG

The importance of the electricity usage of each component varies depending of the cabinet type and temperature range[31]. For instance, the lighting usage ranges from 0 percent of the case electric load for single-level open freezer cases to 59 percent for non-meat multi deck medium temperature cases. Defrost and anti-sweat heaters become less important for higher temperature cases. The non-meat medium-temperature cases do not require such heaters.

The remote refrigerated display cabinets can be broken up in 4 main components: the fans (evaporator fans), the anti-sweat heaters, the lights, and the defrost heaters. Table 4-70 and Table 4-71 give the electricity usage breakdown per component and the annual energy consumption per meter of equipment.

Table 4-70: Medium temperature remote refrigerated display cabinets[31].

Cabinet type	Component	Duty Cycle (%)	Energy consumption (%)	Annual energy consumption kWh/m
Multi deck Meat	Fans (evaporator fans)	100	48	766
	Anti-sweat heaters	50	18	287
	Electric defrost	5.6[32]	13	216
	Lights	100	21	336
	Total		**100**	**1,605**
Other Multi deck	Fans (evaporator fans)	100	41	365
	Anti-sweat heaters	0	0	0
	Electric defrost	0	0	0
	Lights	100	59	530
	Total		**100**	**895**

[31] Reference: Arthur D. Little, Inc., *Energy Savings Potential for Commercial Refrigeration Equipment Final Report*, Building Equipment Division Office of Building Technologies U.S. Department of Energy, June 1996.

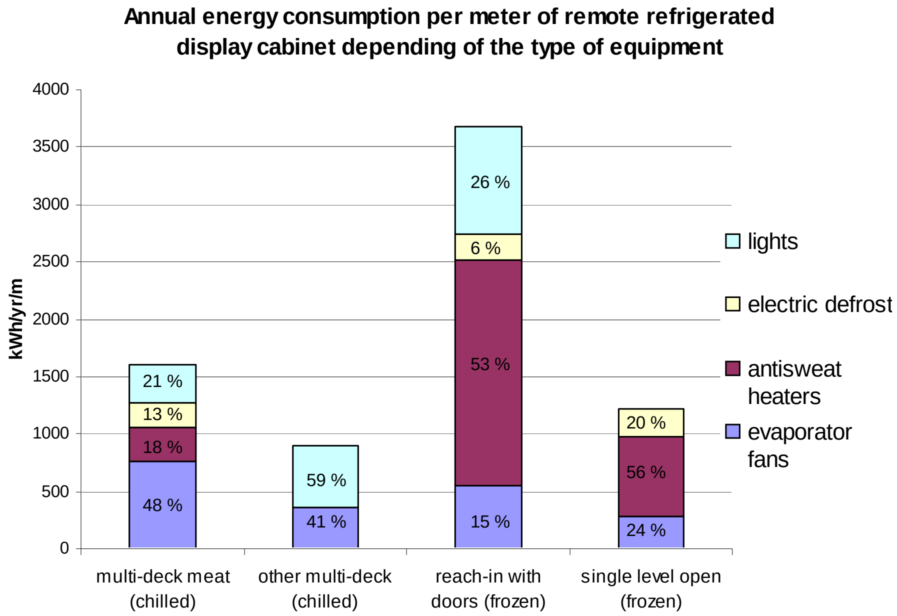
http://www.eere.energy.gov/buildings/info/documents/pdfs/comm_refridg_equip.pdf

[32] 20 min every 6 hours

Table 4-71: Low temperature remote refrigerated display cabinets[33]

Cabinet type	Component	Duty Cycle (%)	Energy consumption (%)	Annual energy consumption kWh/m
Reach-in	Fans (evaporator fans)	96[34]	15	552
	Anti-sweat heaters	96[35]	53	1,956
	Electric defrost	2[36]	6	229
	Lights	100	26	944
	Total		**100**	**3,681**
Single-level open	Fans (evaporator fans)	100	24	287
	Anti-sweat heaters	100	56	690
	Electric defrost	2	20	241
	Lights	0	0	0
	Total		**100**	**1,218**

Figure 4-32: Remote refrigerated display cabinet energy consumption



[33] Reference: Arthur D. Little, Inc., *Energy Savings Potential for Commercial Refrigeration Equipment Final Report*, Building Equipment Division Office of Building Technologies U.S. Department of Energy, June 1996.

http://www.eere.energy.gov/buildings/info/documents/pdfs/comm_refridg_equip.pdf

[34] 23 min per day

[35] 23 min per day

[36] 30 min per day

Remote open vertical chilled multi deck (RCV2)

Real life energy consumption data was not easily available from manufacturers and neither from the end-users. First reason is that the majority of the electricity consumption measurements are made in standard conditions. Second, the definition of "real life conditions" is not possible for the whole Europe. Real life conditions include the ambient condition (temperature and humidity); the user behaviour (use of night curtain, maintenance of the components…) and they cannot be averaged for all countries.

To serve as an example, data was gathered from one manufacturer. It represents the real life electricity consumption of a RCV2 remote cabinet installed in an Italian supermarket. The averaged ambient conditions for the whole year are 20 °C and 50 % RH. A night curtain is used 12 hours a day. The TEC remains the same as in standard conditions in climate class 3M2, however the REC is reduced of 40 %! Applied to Table 4-66, this reduction leads to the following electricity consumption (Table 4-72):

Table 4-72: Example of real life electricity consumption

Example of real life condition electricity consumption	Energy consumption (kWh/d)	Energy consumption (kWh/product life 9 years)	% over TEC
Evaporator module (Fans)	5.15	16,919.38	6.66%
Housing (Lighting system)	1.79	5,884.78	2.32%
Anti-sweat heater	0.21	701.06	0.28%
DEC	7.15	23,505.22	14.52%
REC (reduced of 40 %)	42.10	138,286.38	85.48%
TEC	49.25	161,791.59	100.00%

The TEC is then reduced of 36 % (standard conditions are 60 % higher than real life conditions). This result is only an example of how the electricity consumption of a RCV2 can be influenced by the real life conditions. However it cannot be assumed that every cabinet in Europe will be used in the same conditions leading to a 40 % reduction of the REC. For this reason, no real life condition electrical energy consumption was defined but further analysis in task 5 will help providing a better evaluation of the real life situation compared to the standard conditions.

4.3.3.2 Energy consumption of plug in refrigerated display cabinets

- **Standard conditions**

The ISO 23953 standard on refrigerated display cabinets specifies the method to use when measuring the energy consumption of plug in refrigerated cabinets. The following parameters are defined:

- Cycling of the door opening
- Loading of the cabinet
- Position of the cabinet in the testing room
- Ambient conditions (temperature, relative humidity (RH), air velocity and direction)

For plug in refrigerated display cabinets, the TEC equals the DEC as it includes the condensing unit energy consumption. Refrigeration electrical energy consumption (REC) is not defined for these cabinets.

The table below (Table 4-73) gives the average European figures of the ratio TEC/TDA for plug in refrigerated display cabinets determined according to the Eurovent certification program in 2001 taking into account manufactured and sold cabinets in Finland, France, Germany, Italy and Spain.

Table 4-73: Average figures for the European market of plug in cabinets[37].

Cabinet family	Cabinet temperature class	European average TEC/TDA (kWh/day.m²)	European annual average TEC/TDA (kWh/year.m²)
IHC1, IHC2, IHC3, IHC4	3H2	8.2	2993
	3H2	9.6	3504
IVC1, IVC2, (IVC3)	3H2	17.3	6,314.5
	3H2	21	7,665
IVC4	3M1	13.9	5,073.5
IHF1, IHF3, IHF4	3L3	21.5	7,847.5
	3L1	36	13,140
IHF5, IHF6	3L1	17.8	6,497
IVF4	3L1	30.5	11,132.5
IYF1, IYF2, IYF3, IYF4	3L3	32.3	11,789.5
IYM6	3H2/3L1	25.3	9,234.5

Beverage Coolers

The average energy consumption of a one door beverage cooler as described in section 4.1.2.2 was calculated based on the electricity consumption data from BvC1 and BvC2.

For BvC1 the measurement was made according to the ISO 23953 standard at the climate class 4 (30 ℃ – 55 % RH) and with an average operating temperature of 5 ℃.

[37] Reference: Eurovent Refrigerated Display Cabinets Certification Program

http://www.eurovent-certification.com/en/Programmes/Characteristics.php?rub=02&srub=01&ssrub=&&find=&lg=en&select_prog=RDC&rub=02&srub=01

For BvC2, the measurement was made using the Coca-Cola testing method with ambient conditions of 32 °C and 65 % RH and an operating temperature between 2.46 – 3.06 °C. However, together with the manufacturer it was assumed that the energy consumption under ISO 23953 climate class 4 could be considered to be the same as in the Coca-Cola conditions even if in reality it would be a little lower due to more favourable operating conditions under ISO 23953.

Considering this assumption, the average of the normalised data from the received product cases was possible. And according to the data collected, the typical energy consumption of a one door beverage cooler with a net volume of 0.5 m^3 can be estimated to 7.043 kWh /d when measured with the ISO 23953 standard at climate class 4M2.

The table below (Table 4-26) provides details on the distribution of the electricity consumption per module for each of the product cases. The overall distribution of the electricity consumption per module is rather similar from one product to another. However the duty cycle[38] differs leading to different power inputs per component (the power inputs are not presented here to preserve confidentiality).

Table 4-74: Distribution of the energy consumption per module

Module	Duty cycle (%)		Electricity Consumption %	
	BvC1	BvC2	BvC1	BvC2
Compression module (compressor)	66.7%	38.3%	49.8%	52.1%
Evaporation module (Evaporator Fan)	100.0%	100.0%	12.1%	12.4%
Condensation module (Condenser Fan)	66.7%	38.3%	8.1%	4.8%
Housing (Lights)	100.0%	100.0%	30.0%	30.7%

The analysis of the electricity consumption of the received product cases provides the following distribution for a 0.5 m^3 beverage cooler (Table 4-75):

[38] Duty cycle: percentage of time when the component is operating. E.g. a duty cycle of 50 % means that the component operated 12hours a day.

Table 4-75: Electricity consumption of a typical one door beverage cooler

Module	Electricity Consumption kWh/yr	Electricity Consumption kWh/product life 8 years	Electricity Consumption %
Compression module (compressor)	1,309.9	10,479.57	51%
Evaporation module (Evaporator Fan)	315.4	2,522.88	12%
Condensation module (Condenser Fan)	165.6	1,324.60	6%
Housing (Lights)	788.4	6,307.20	31%
Total	2,570.5	20,564.16	100%

Two modes of operation can be defined: the ON mode for which all components are operating (fans, compressor, and lights) and the OFF mode when only the evaporator fan and the lights are in operation.

The table below specifies the parameters of the ON mode and of the OFF mode for a typical one door beverage cooler

	kWh/h	Duty Cycle %
ON MODE (all components operating)	0.447	52.5%
OFF MODE (only lights and evaporator fans are operating)	0.126	47.5%

These aggregated data from the received product cases will serve as inputs in task 5.

Ice cream freezers

The energy consumption measurements for the two ice cream freezers studied (ICF1 and ICF2) were done under the ISO 23953 standard but without opening the doors and with the lights turned on 24h for ICF2.

For a typical ice cream freezer as currently found in corner stores and petrol stations (ICF1), the energy consumption is 4.5 kWh/d (13,140 kWh/ product life of 8 years) (Table 4-76).

Table 4-76: Energy consumption of a typical ice cream freezer (chest freezer)

ICF1	Power (W)	Duty cycle (%)	Electricity consumption kWh/ product life 8 years	Electricity consumption share %
Housing module (Lights)	0	0%	0	0%
Evaporation Module (Evaporator fan)	0	0%	0	0%
Condenser Module (Condenser fan)	30	62.5%	1,314	10%
Anti-sweat heater	0	0%	0	0%
Defrost	0	0%	0	0%
Compressor Module	270	62.5%	11,826	90%
Total			13,140	100%

ICF2 is less widespread than ICF1, it is mostly found in medium sized stores and supermarkets. The bigger display area (double TDA compared to ICF1) and the large amount of glass panels imply much higher energy consumption. The electricity consumption for a typical horizontal freezer for ice creams with sliding doors and glass panels is of 25.8 kWh/d (75,336 kWh over a product life of 8 years) (Table 4-17).

Table 4-77: Energy consumption of a horizontal freezer with doors and glass panels

ICF2	Power (W)	Duty cycle (%)	Electricity consumption kWh/ product life 8 years	Electricity consumption share %
Housing module (Lights)	108	100.00%	7,568.64	10%
Evaporation Module (Evaporator fan)	18	99.17%	1,250.93	2%
Condenser Module (Condenser fan)	40	100.00%	2,803.20	4%
Anti-sweat heater	136	100.00%	9,530.88	13%
Defrost	500	0.56%	194.67	0%
Compressor Module	915.29	84.17%	53,987.69	72%
Total			75,336	100.00%

- **Real life situation**

The use-phase is the most environmentally impacting phase of the life cycle of a plug in refrigerated display cabinet. 95 % of the environmental impact is associated with the energy used during the use-phase and only 5 % attributable to the materials used in the production-phase[39].

[39] Reference: Watkins, R. and al. *Life Cycle Analysis of a Commercial Refrigerated Display Cabinet*. Department of Mechanical Engineering, Brunel University, UK. (October 2004)

For reach-in refrigerators and freezers, about 80% of the electricity is consumed by the refrigeration system (compressor, evaporator fans, and condenser fan), while the other 20 % is used for by defrost system[40].

The energy consumption by component for plug in refrigerated display cabinets is given in Table 4-78.

Table 4-78: Energy consumption by component, plug in cabinets[41]

Component	Percentage
Compressor	53%
Lights	20%
Evaporator fans	16%
Condenser fans	7%
Anti-sweat heaters	3%
Electric defrost	1%

The energy consumption of a plug in refrigerated display cabinet varies depending on the type of cabinet considered. They can be either closed or open. Closed cabinets mostly comprise beverage coolers and ice cream merchandisers. For plug in cabinets without doors, the product group can be divided in two categories of products: those designed for the display and sale of bottled or canned beverages and those who are not.

For beverage coolers (Table 4-79), the share of electricity use of the lighting systems is more important as this equipment is designed to present product attractively.

Table 4-79: Distribution of energy consumption in beverage coolers[42]

Component	Percentage
Compressor	43%
Lights	27%
Evaporator fans	24%
Condenser fans	6%
Anti-sweat heaters	-
Electric defrost	-

The average annual consumption of a chilled glass door merchandiser is estimated to approximately 4,500 kWh[42]. Other estimations evaluate the

[40] Reference: Arthur D. Little, Inc. Application of Best Industry Practices to the Design of Commercial Refrigerators, Development of a High Efficiency Reach-in Refrigerator. Final report to the National Energy Technology Laboratory, US Department of Energy. June 2002. Available at <http://www.cee1.org/com/com-ref/doe-rep02.pdf >

[41] Reference: Mark Ellis & Associates, *National Appliance and Equipment Energy Efficiency Program, Analysis of Potential for Minimum Energy Performance Standards for Self-Contained Commercial Refrigeration, Final Draft Report March 8th, 2000.* Available at <http://www.energyrating.gov.au/library/pubs/tech-sccommrf2000.pdf>. (24/11/2006)

[42] Reference: data for a one door beverage cooler in Arthur D. Little Inc. Energy Saving Potential for Commercial Refrigeration Equipment. US Department of Energy report. (June 1996) http://www.eere.energy.gov/buildings/info/documents/pdfs/comm_refridg_equip.pdf

average annual energy use of beverage merchandisers with doors to 3900 kWh[42] and to 4,083 kWh[43].

Ice cream merchandisers typically present an annual electricity consumption of 13,149 kWh[43].

The average annual electricity consumption per is estimated to 15,000 kWh[43] for open refrigerators and freezers displaying other goods than canned and bottled beverages.

For the product cases BvC1 and BvC2 it was not possible to gather real life consumption figures for the whole EU 25. These consumption data are highly dependable of the ambient conditions and user behaviour and end-users are not aware of the energy consumption of there appliance.

4.3.3.3 ENERGY CONSUMPTION OF COLD VENDING MACHINES

- **Standard conditions**

For cold vending machines, the common European test standard is the European Vending Machine Energy measurement protocol (EVA-EMP) as defined in task 1

The average energy consumption calculated with this standard is 7.6 kWh/day for can and bottle machines and 7.9 kWh/day for refrigerated confectionary and snack machines[44]. Assuming that the vending machine runs 7 days a week and 24 hours a day, the total energy consumption is equal to 2,800 kWh/year for a can and bottle machine and equal to 2,900 kWh/year for a refrigerated confectionary and snack machine (see Table 4-80).

Table 4-80: Typical energy consumption of cold vending machines according to EVA-EMP standard

Machine type	Energy Consumption kWh/24hrs	Energy Consumption kWh/yr
Can and bottle machines	7.6	2,774
Refrigerated confectionary and snack machines	7.9	2,884
Refrigerated food machines	8	2,920
Ice-cream and frozen food machines	no data	No data

The average energy consumption of a spiral vending machine being able to sell refrigerated food, snack, cans and bottles (as described in section 4.1.3) was calculated based on the electricity consumption data from VM1 and VM2.

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[43] Reference: Holland J. and al. *Update of Appliance Efficiency Regulations*. California Energy Commission Staff Report. (November 2004). http://www.energy.ca.gov/reports/2004-11-30_400-04-007F.PDF

[44] UK Market Transformation Programme (MTP). http://www.mtprog.com/ApprovedBriefingNotes/PDF/MTP_BNCR33_2006September5.pdf.

For the two appliances, the measurement was made following the EVA-EMP protocol Idle mode (25 °C and 60 % RH), with an operation temperature of + 3 °C. According to the data collected, the typical energy consumption of a spiral vending machine which can contain 288 cans can be estimated to 7.465 kWh/day, with the conditions described above.

Table 4-81 provides details on the distribution of electricity consumption per module for each of the product cases. This distribution is rather similar from VM1 to VM2. Nevertheless, the duty cycle differs due to different power inputs per component (these power inputs are not presented here to preserve confidentiality).

Furthermore, it was assumed that the energy consumptions of the dispensing and payment mechanisms were negligible, as it was in the study carried out by the US Department of Energy (see Table 4-84). This assumption was also confirmed with the technical committee of EVA.

Table 4-81: Distribution of electricity consumption per module

Module	Duty Cycle, %		Electricity Consumption, %	
	VM1	VM2	VM1	VM2
Compression module (compressor)	40%	66.7%	62.9%	69.0%
Evaporation module (evaporator fan)	100%	75.0%	10.3%	9.1%
Condensation module (condenser fan)	–	66.7%	–	9.4%
Anti-sweat heater	100%	–	11.6%	–
Housing (lighting system)	100%	100.0%	15.2%	12.5%

The analysis of the electricity consumption of the two spiral vending machines provides the following distribution. It was assumed that a typical spiral vending machine uses an anti-sweat heater (same characteristics as for VM1) and contains a condenser fan (same characteristics as for VM2). This assumption will be further detail in task 5 for the definition of the base case.

Table 4-82: Electricity consumption of a typical spiral vending machine in EU

Module	Electricity Consumption per year, kWh/y	Electricity Consumption over product life (8.5 years), kWh/product life	Electricity consumption, %
Compression module (compressor)	1,544.85	13,131.26	56.70%
Evaporation module (evaporator fan)	306.60	2,606.10	11.25%
Condensation module (condenser fan)	172.47	1,466.01	6.33%
Anti-sweat heater	306.60	2,606.10	11.25%
Housing (lighting system)	394.20	3,350.70	14.47%
TOTAL	2,724.73	23,160.16	100.00%

Furthermore, as for the beverage coolers, two modes of operation can be defined: the ON mode for which all components are operating (fans, compressor and lights) and the OFF mode for which only the evaporator fan, the anti-sweat heater and the lights are in operation. Thereby, Table 4-83 details the characteristics of these two modes.

Table 4-83: Electricity distribution regarding to the operation mode

	Electricity consumption, kWh/h	Duty Cycle, %
ON MODE (all components operating)	0.246	43.8%
OFF MODE (only lights, anti-sweat heater and evaporator fan operating)	0.065	56.2%

Real life situation

Beverage machines represent 60-70 % of the total refrigerated vending machines installed. The next paragraph focuses on beverage machines. The figures for the annual electricity consumption in real life conditions reported are very disparate as they depend on the ambient conditions (see section 4.4 for further discussion on the influence of ambient conditions) and on the operating conditions.

The annual electricity consumption of refrigerated beverage vending machines is estimated to range between 2,800 and 3,200 kWh depending of the lighting system chosen at an ambient temperature of 21 °C [45]. The distribution of total consumption per components is given in Table 4-84 .

In other studies, the daily energy consumption is estimated to 12 kWh per refrigerated beverage machine (with 100 sales per week – sales typically vary from 50 to 500 cans/bottles a week) [46]. This estimation represents an annual consumption of 4,380 kWh. Other estimates[47] the energy consumption of refrigerated canned and bottled beverage vending machines to 3,077 kWh.

[45] Reference: Arthur D. Little, Inc., *Energy Savings Potential for Commercial Refrigeration Equipment Final Report*, Building Equipment Division Office of Building Technologies U.S. Department of Energy, June 1996. Available at :
< http://www.eere.energy.gov/buildings/info/documents/pdfs/comm_refridg_equip.pdf>

[46] Reference: American Council for an Energy-Efficient Economy. *Commercial Packaged Refrigeration: An Untapped Lode for Energy Efficiency*. (May 2002)

[47] Reference: Holland J. and al. *Update of Appliance Efficiency Regulations*. California Energy Commission Staff Report. (November 2004). http://www.energy.ca.gov/reports/2004-11-30_400-04-007F.PDF

Table 4-84: Typical 400 cans refrigerated vending machine - Energy consumption breakdown (source: US Department of Energy)

Component	Power consumption, (W)	Duty Cycle, (%)	**Energy consumption, (kWh/yr)**	Energy consumption[48], (%)
Compressor	425[49]	35[50]	**1,303**	47
Evaporator Fan	37	100	**324**	12
Condenser Fan	37	35[51]	**113**	4
Lighting	117–163[52]	100	**1,022–1,424**	37
Dispensing Mechanism	120	~0[53]	**1**	–
Total	–	–	**2,763–3,165**	100

Considering these data, the annual energy consumption of cold vending machines typically ranges between 2,800 – 4,400 kWh and can be assumed to 3,500 kWh.

For VM1 and VM2, it was not possible to gather data of electricity consumption in real life conditions.

4.3.4 DIRECT EMISSIONS RELATED TO THE USE OF REFRIGERANTS

Both plug in refrigerated display cabinets and cold vending machines have a self-contained refrigeration system. It includes the refrigerant loop and the refrigerant charge itself. In remote refrigerated display cabinets, the refrigerant flows in and out of the cabinet.

Two major environmental issues are associated with the use of refrigerants:

- **Ozone depletion when using hydro chlorofluorocarbon (HCFCs)**

The chlorine found in R 22 refrigerants can be harmful to the ozone layer. HCFCs are currently being phased out (Montreal protocol) and replaced by other refrigerants such as HFCs or halogen-free refrigerants.

[48] Assuming standard lighting wattages

[49] Nominal power draw

[50] Manufacturer estimated of duty cycle based on a 70 °F (21.11 °C) ambient temperature plus 10 % for pulldown.

[51] Condenser fan cycles with the compressor.

[52] Range based on machines with standard T12 lighting at 2.8 kWh/day and machines with high output lighting at 3.9 kWh/day.

[53] The dispending mechanism operates about 2 seconds/vend. At an average of 190 vends/week, this translates to only 5.5 hours of total annual run time.

Global warming when using either HCFCs or hydro fluorocarbons (HFCs)

HFCs and HCFCs are both green house gases. The global warming potential of refrigerants is characterised by the GWP indicator (global warming potential). Other alternatives exist to avoid the use of HFCs, such as the use of hydrocarbon or carbon dioxide.

Experience has shown[54] that, in certain ambient conditions, refrigeration systems running with HC and carbon dioxide can achieve the same levels of efficiency as HFC based systems. For example, the coefficient of performance of compressors running with hydrocarbons is generally slightly better than compared to HFC systems due to better thermodynamic properties (particularly R290 and R1270). When comparing the GWP of systems running with different types of refrigerant, the global warming potential is often characterised by the TEWI, total equivalent warming potential which also takes into account the emissions of greenhouse gases due to the electricity consumption of the system.

These two environmental impacts are only an issue if the refrigerant leaks. Key requirement to reduce environmental impact is containment during use.

The F-Gas Regulation EC 842/2006 requires recovery of HFC refrigerants during service, and at end-of-life. It establishes standard inspection requirements and indirect and direct leakage measurements for refrigeration systems (among others).

During the use phase of plug in cabinets and vending machines, and according to literature the annual leakage rates are low (≤ 1 % of the refrigerant charge), so are the refrigerant charges and the environmental impacts negligible (≤ 0.002 – 0.001 kg[55]) compared to the ones generated by the electricity consumption (Figure 4-33). However the impacts of the refrigerant are to be considered in the end-of-life phase. End-of-life recovery data are mostly not included, and therefore the annual average leakage rates may be 5 − 10 % higher depending of the product life.

Leakage rates for remote refrigerated display cabinets are typically not documented. Instead leakage rates for overall refrigeration systems are given. This will be further discussed in section 4.4. .

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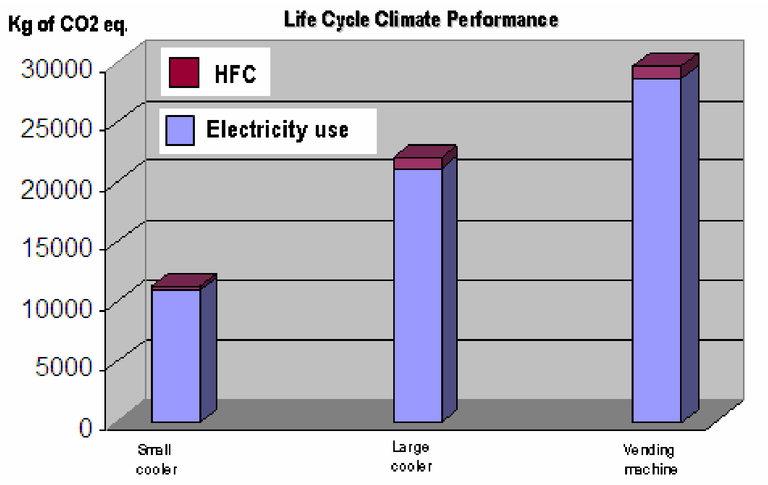
[54] Feedback from the Refrigerants, Naturally! initiative

[55] These data were calculated based on refrigerant charge data found in the *IPCC/TEAP Special report, Safeguarding the Ozone Layer and the Global Climate System, chapter 4.*

Figure 4-33: CO2 equivalent emissions related to refrigerant use and electricity use[56]



- Beverage coolers

According to data collected among beverage cooler manufacturers, the annual leakage rate of refrigerant for a typical 0.5 m^3 net volume beverage cooler can be estimated to 2 %. This value takes into account the end-of-life recovery on a global basis in EU 25.

- Spiral Vending Machine

As for beverage coolers, the annual leakage rate of refrigerant for a typical spiral vending machine of 0.75 m^3 (about 288 cans) can be estimated to 2 %, on the basis of data given by manufacturers. This value takes into account the end-of-life recovery on a global basis in EU 25.

4.4. Use Phase (system)

Commercial refrigerators and freezers are used in supermarkets, small retail stores and other facilities where they interact with their surroundings. This section gives an overview of the energy use and environmental impacts that can be attributed to or influenced by the product during its use.

The first objective of this section is to identify and describe the functional system to which the products identified in task 1 belong. The second one is to assess how the design of commercial refrigerators and freezers can improve the system's overall environmental performance.

4.4.1 Remote refrigerated display cabinet

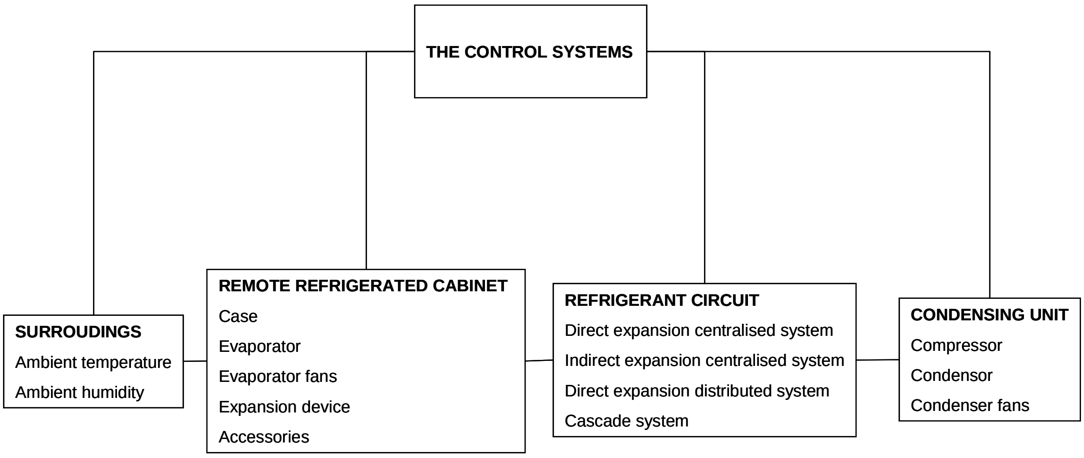
Remote refrigerated display cabinets are not used as stand-alone products. They need to receive refrigeration energy from a remote condensing unit

[56] Source: Coca-Cola

through a refrigerant circuit. The display cabinets also interact with its surroundings and with the building's air conditioning and heating system.

4.4.1.1 DESCRIPTION OF THE FUNCTIONAL SYSTEM

Figure 4-34: Functional system of remote refrigerated display cabinets



The functional system of remote refrigerated display cabinet includes:

- The product itself (cabinet case including accessories e.g. anti-sweat heaters, defrost heaters, lightings…)
- The surroundings of the product (ventilation system influencing the room temperature, humidity…)
- The different regulation systems that can be linked to a commercial refrigerator or freezer (timer …)
- Other cabinets linked to the same refrigeration system (case of a large supermarket)
- The refrigeration system (condensing unit)
- The refrigeration system installation (centralised, direct…)

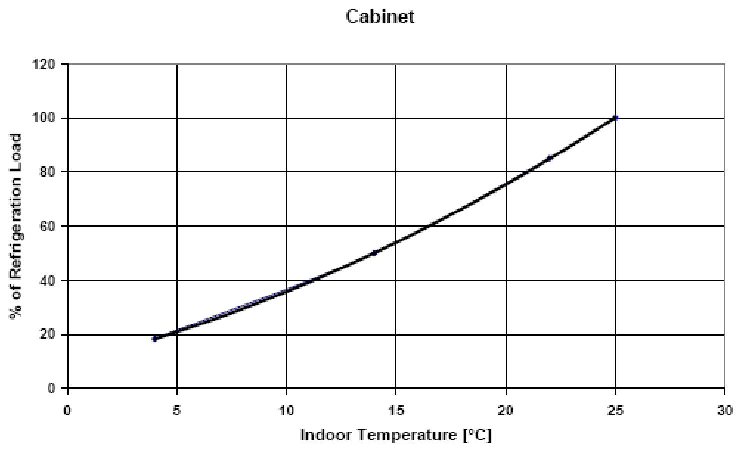
Interactions with the surroundings of the product

Most of the remote refrigerated display cabinets are open vertical display cabinets with a large open front area. The refrigeration load in display cabinet is dependent of the surrounding environment. A higher ambient temperature and relative humidity increases the cooling demand and energy consumption of the overall system

The heat and moisture exchanged between the products and the cabinet and the surroundings affect the refrigeration load as shown in Figure 4-35[57]:

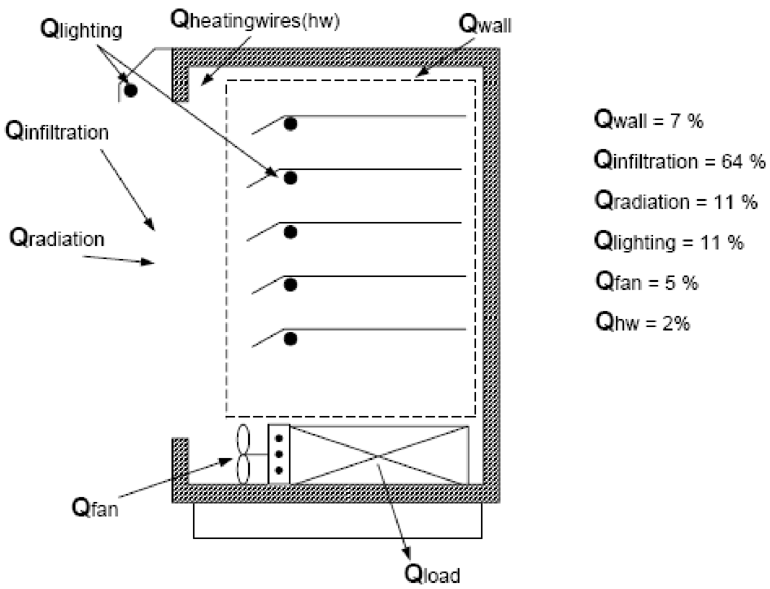
[57] Reference: Arias J., *Energy Usage in Supermarkets- Modelling and Field Measurements*, Division of Applied Thermodynamics and Refrigeration, Department of Energy Technology,

Figure 4-35: Indoor temperature vs. refrigeration load in vertical open display cases (Source: Swedish Department of Energy Technology)



Infiltration represents about 60 - 70 % of the refrigeration load for a typical vertical remote refrigerated display cabinet and about 30 % for a horizontal freezer. The refrigeration load is the sum of the refrigerating effect Q_{load}, with all the heat losses from infiltration, radiation (external lighting and sunlight), conduction lighting, fans, heating wires and defrost. Figure 4-36 gives the typical distribution of the refrigeration load. The higher the surrounding temperature, the higher the heat load will be.

Figure 4-36: Distribution of the refrigeration load (Source: Swedish Department of Energy Technology)



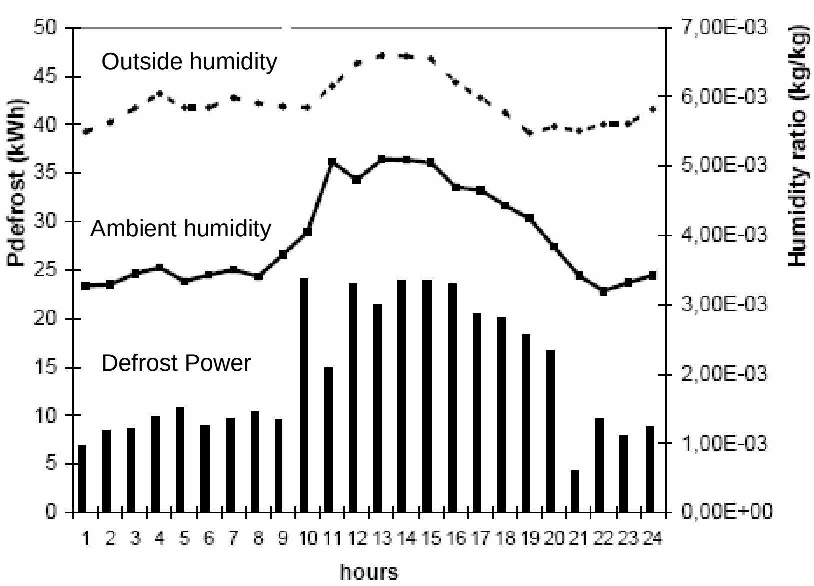
Royal Institute of Technology (Sweden). (2005). Available at <http://www.diva-portal.org/diva/getDocument?urn_nbn_se_kth_diva-217-1__fulltext.pdf>

Laboratory tests evaluated that putting a glass door on an open five shelves display cabinet could reduce the total refrigeration load by 68 %. However, to avoid placing an obstacle between the customer and the products display the open cabinets are the more popular. Night covers can be used during off hour periods, they can save up to 25 % of the REC for a period of 12 hours a day. In open cabinets, fan forced air curtains are used to minimise the heat gains from the surroundings.

Display cabinets are designed to operate in air conditioned areas. High relative humidity favours the formation of layers of frost in the cabinet and on the evaporator which reduces the heat transfer. Frequent defrost cycles are necessary to remove this frost, increasing energy use. As shown on Figure 4-37, the high moisture loads during opening hours coming from air infiltration and customer traffic increase the defrosting energy consumption.

For closed cabinets, high relative humidity also increases the condensation which increases the energy consumption when anti-sweat heaters are used.

Figure 4-37: Daily humidity ratios evolution and corresponding defrosting values (reference: Orphelin and Al.)



Humidity impacts the refrigeration system energy use by 10 - 20 kWh/day per % RH[58] in an average store mainly influencing the anti-sweat heaters and the electric defrost, and having a less significant impact on hot gas defrost systems.

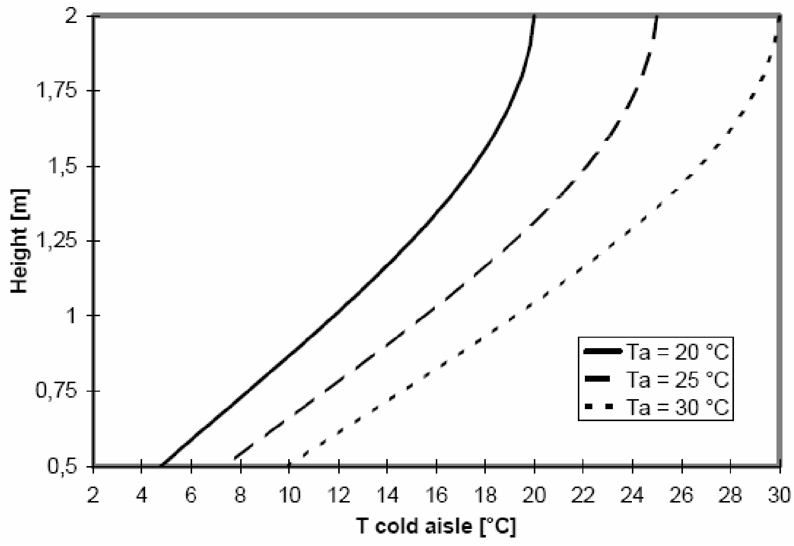
Display cabinets, more specifically frozen ones, also have an impact on the thermal behaviour of supermarkets. The aisles where the commercial refrigeration equipment is located are characterised by cool loads created by the cabinets which are also moisture traps. Thermal assessments of a 5,000 m² supermarket show that in winter the commercial refrigeration equipment (mostly

[58] ASHRAE Winter meeting presentation, January 24th 1999.

remote products) condense about 50 g of water per hour and 120 g per hour in summer. The removal of 1 kg of water from the ambient air costs 2,700 Wh to a frozen vertical display cabinet and 1,000 Wh to a vertical chilled cabinet vs. 250 Wh for a classic air conditioning system[59].

The interactions between open display freezers and air conditioning systems in large supermarkets have been analysed[60]. This type of display cases are normally tested under specific laboratory conditions (25 °C, 60% relative humidity) experiencing a constant ambient temperature. These conditions are very different from the real life situation: in a typical supermarket, display cases are concentrated in approximately 20 % of the total sales area. The vertical frozen cabinets, typically 2 m high, are generally facing each other creating aisles where the temperature is below the rest of the sales area's temperature (Ta), with very often ground temperature near 10 °C. In this cold area a vertical stratification is experienced which influences the heat infiltration (Figure 4-38). A mean temperature in the cold aisle can be calculated (Tca). In the summer (Ta= 30 °C, RH= 55 %) the difference between Ta and Tca exceeds 10 °C, in winter it is near 3 °C (Ta= 12 °C, RH= 35 %).

Figure 4-38: Vertical stratification in cold aisle, temperature profile (reference: Orphelin and Al.)

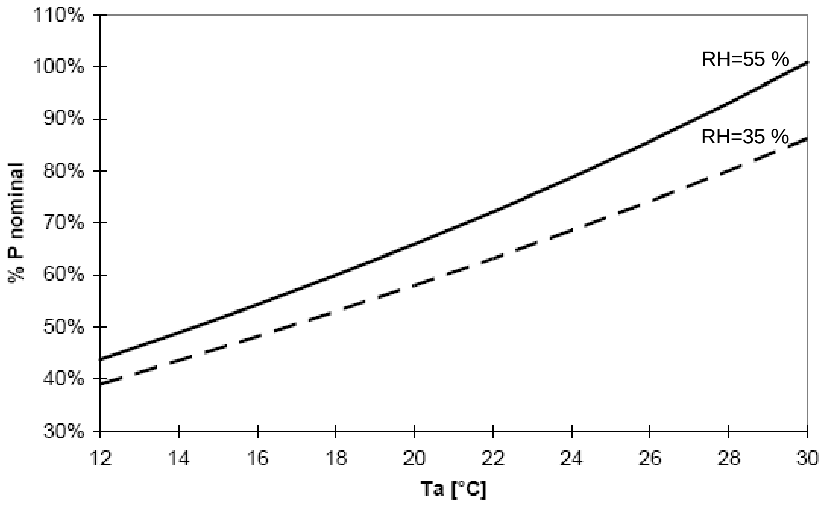


The influence of the relative humidity (RH) and of the temperature is illustrated in Figure 4-39.

[59] Reference : Générale Frigorifique France (http://www.ecr-ref.com)

[60] Reference : Orphelin and Al. *Significant Parameters for Energy Consumption in Frozen Food Area of Large Supermarkets*. Ecole des Mines de Paris, Centre Energétique (2000).

Figure 4-39: Real load of frozen remote refrigerated display cabinets in the cold aisle (100 % corresponding to 25 °C and RH =60 %)



One big energy efficiency issue is the determination of the optimum set points for Ta and RH (optimal ambient conditions) taking into account considerations for the comfort of the shoppers. Simulation programs are currently under development.

Role of the control systems

The control systems in commercial refrigerators and freezers are mainly used to protect the appliance, and to improve its performance. Several types of controls were listed in the section 4.3.2 according to the component of the system. Table 4-85 summarizes them:

Table 4-85: Control systems in commercial refrigerators and freezers

Component	Safety controller	Performance controllers
System	Thermostat: to start and stop the refrigeration cycle	Thermostat: to start and stop the refrigeration cycle
Evaporator & Condenser fans		Variable speed or two-speed motor
Compressor	✓ Low-pressure and high-pressure controllers ✓ Pumpdown control	✓ Variable speed or two-speed motor ✓ Cascade control ✓ Cylinders control
Expansion device		Electronic expansion valve
Condenser		Condensing pressure controller

Of course, this list is not exhaustive, and some manufacturers suggest other control systems, always in the purpose of improving their appliance.

- **Interaction with the refrigeration system (compressor + condenser + condenser fans)**

In remote refrigerated display cabinets, the major proportion of the Total Energy Consumption as defined in the ISO 23593 comes from the Refrigeration Electrical energy Consumption (REC) (see Figure 4-29).

The choice of the compressor, and the condenser as well as their location can strongly impact the energy consumption of the whole system. Regulations of the condensing temperature can lower the electricity bill as much as 25 % and choosing an evaporative condenser instead of an air cooled condenser can lead to 8.2 % reduction in electricity consumption[61].

Locating the condenser and the compressor in cool and well ventilated areas outside the building will remove their heating effect and improve efficiency. In addition, the remaining refrigeration equipment will provide a cooling effect which will reduce air conditioning requirements further. Furthermore, the heat generated by the condensing unit can be recovered to heat the building and can cover 50 – 80 % of the needs in medium and large supermarkets[62].

Even if high refrigeration demand increases the compressor work, implying that low efficiency display cabinets increase the energy consumption of the condensing unit; the main parameter to focus on, for increasing the energy efficiency, is the refrigeration system and its installation.

As presented in task 3, maintenance is a key parameter to preserve optimum efficiency for the refrigeration appliances. For remote refrigerated display cabinets, the REC can be greatly affected by the type of maintenance of the refrigeration system. Regular maintenance inspection carried out correctly will not only prevent breakdowns but also ensure that the refrigerating system is running at its maximum performance. The system condenser and the pipe work are the main components to be annually checked.

Refrigeration systems often use air-cooled condensers located on a roof or in a machinery room. Restriction of the airflow by blocking the air path to or from the condenser, or by accumulation of dirt will cause the condensing temperature to increase. A 1 °C increase in condensing temperature will lead to higher running costs through higher electricity use by between 2 % and 4 %[63]. Keeping the condenser, the condenser coils and the condenser fans' blades clean helps to maintain design energy consumption. A 10 °C uplift due to dirt is not unusual, resulting in a 20 % to 40 % electricity consumption increase. In case of water

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[61] Walker D.H., Van D.B. *Analysis of Advanced, Low-Charge Refrigeration Systems for Supermarkets.* Oak Ridge National Laboratory.

[62] Reference: ADEME. *Fiche OX "Optimisation des installations de froid alimentaire commerciale"* (14/04/2003)

[63] Mitchell N., Annual System Inspections Reduce Electric Energy Consumption. ASERCOM Symposium 2000. http://www.afce.asso.fr/stock_images/mcpid/puces/puce06.gif

cooled condensers, a regular maintenance prevents fouling, corrosion or scale accumulation which could hinder the heat transfer properties of the condenser.

Moreover, the pipe work linking the refrigeration components together can have a significant impact on the REC. It represents a potential source of refrigerant leakage from the system. Loss of refrigerant liquid causes a decrease in refrigeration capacity which results in higher electricity consumption. The leakage rates depend on many parameters including the type of installation (see next paragraph).

In conclusion, it has been estimated that 20 % plus saving in energy consumption can be achieved by good maintenance[64].

Interaction with the refrigeration circuit installation

Four main configurations exist for the refrigeration system. It can either be connected to the remote display cabinets through a direct expansion system, a secondary loop, a distributed system or a cascade system.

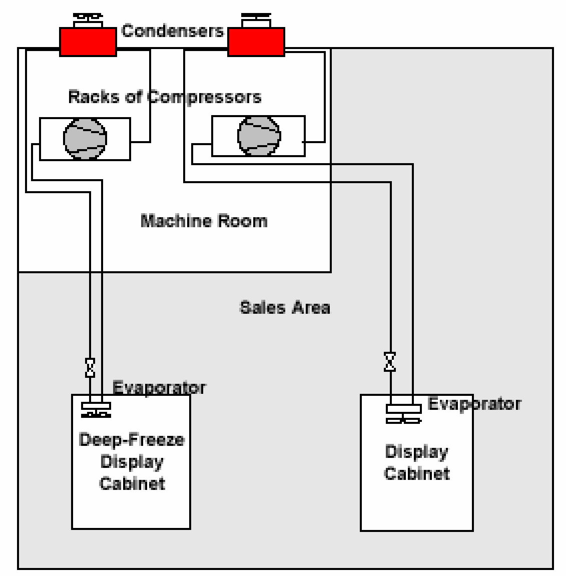
- Direct expansion system

  This design is the typical design for supermarket refrigeration systems. The high pressure refrigerant is circulated across the store directly to the display cases where it is expanded and evaporated. Thousands of meters of piping can be required to connect the display cases to the remote condensing unit which results in large refrigerant charges and increases the number of potential leakage sources.

  Figure 4-40: Typical direct expansion system in supermarket[65]

[64] Reference: ADEME. *Fiche OX Optimisation des installations de froid alimentaire commerciale.* (14/04/2003)

[65] Reference: Arias J., *Energy Usage in Supermarkets- Modelling and Field Measurements*, Division of Applied Thermodynamics and Refrigeration, Department of Energy Technology, Royal Institute of Technology (Sweden). (2005). Available at <http://www.diva-portal.org/diva/getDocument?urn_nbn_se_kth_diva-217-1__fulltext.pdf>



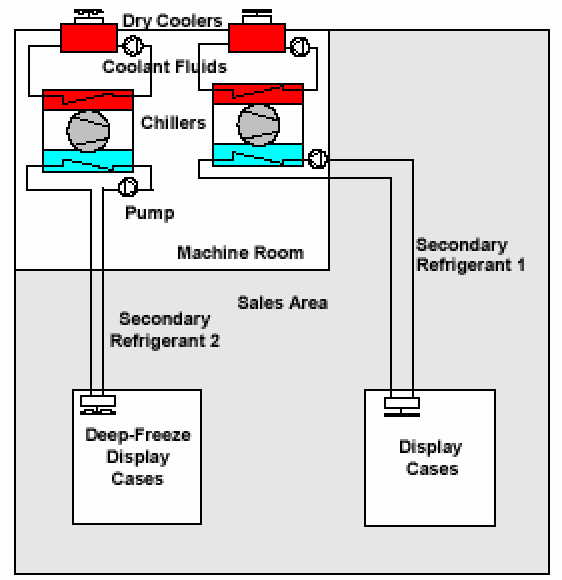
This above figure (Figure 4-40) contains one rack of compressors; it is a multiplex direct refrigeration system, the most common direct system in supermarkets. For small sets of display cases, a single-compressor condensing unit is used.

- Indirect expansion system or secondary refrigerant loop

The refrigerant charge can be reduced using a secondary refrigerant loop (Figure 4-41). They are composed of a primary heat exchanger where a heat transfer fluid (i.e. the secondary refrigerant or brine) is cooled down by the refrigerating system and then pumped towards the display cases where it absorbs heat and then comes back in the primary heat exchanger. This system can allow the refrigerant charge to be reduced to 10 % of the quantity required for direct expansion systems. It also decreases the risk of leakage because there is less piping containing refrigerant. However, the secondary loop system requires additional power consumption to operate the pump to circulate the brine.

Figure 4-41: Typical indirect expansion system in supermarket[66]

[66] Reference: Arias J., *Energy Usage in Supermarkets- Modelling and Field Measurements*, Division of Applied Thermodynamics and Refrigeration, Department of Energy Technology, Royal Institute of Technology (Sweden). (2005). Available at <http://www.diva-portal.org/diva/getDocument?urn_nbn_se_kth_diva-217-1__fulltext.pdf>



Other secondary loops, containing coolant fluid, are used in the system to transport heat rejected from condensers, to dry coolers often located on the roof of the supermarket. This allows not to warm over the machine room, and therefore to less use air conditioning.

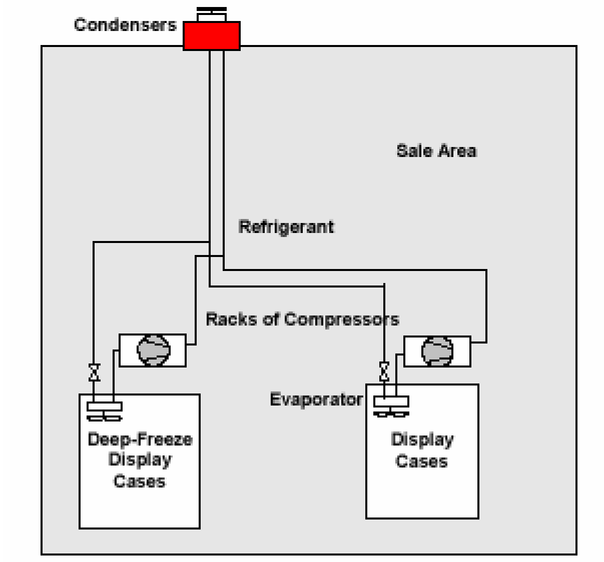
Partially indirect systems also exist. They consist of a mix between direct and indirect refrigeration systems: the low temperature system has a direct system between the compressors and the deep-freeze display cases, whereas the medium temperature system has an indirect system the display cases and the chillers.

- Distributed system

This system has been developed for large and medium sized supermarkets to limit the refrigerant charge by shortening the distance between the display cases and the refrigerating system. In these installations one or more compressors on a small rack are distributed throughout the supermarket near the display cases they are serving. A single water-cooled condenser is used (see Figure 4-42).

Figure 4-42: Typical distributed system in supermarket[67]

[67] Reference: Arias J., *Energy Usage in Supermarkets- Modelling and Field Measurements*, Division of Applied Thermodynamics and Refrigeration, Department of Energy Technology, Royal Institute of Technology (Sweden). (2005). Available at <http://www.diva-portal.org/diva/getDocument?urn_nbn_se_kth_diva-217-1__fulltext.pdf>



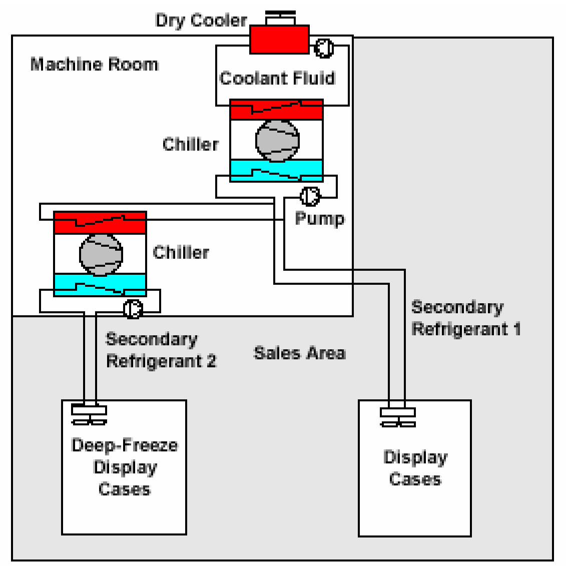
Distributed systems can also have an indirect configuration. These systems have a secondary loop for heat rejection between condensers and dry coolers on the roof of the supermarket.

- Cascade system

This system has been developed to avoid the large pressure ratio in the low temperature system. The rule is that the condenser heat from the low temperature system is rejected to the secondary refrigerant of the medium temperature system. Thus, the condensing temperature for the low temperature system is decreased, which increases the coefficient of performance of the refrigeration cycle.

As for indirect systems, the heat from medium temperature condensers is rejected to the outside by using a dry cooler.

Figure 4-43: Typical cascade system in a supermarket[68]



We can summarize benefits and drawbacks of these different refrigeration systems in the table below (Table 4-86):

Table 4-86: Comparison of different refrigeration systems designs

	Strengths	Weakness
Direct system	✓ Good efficiency ✓ Less components than indirect system ✓ Lower investment cost than indirect system	✓ Large refrigerant charges ✓ Leakages of refrigerant ✓ No possibility to use ammonia or HC refrigerants
Indirect system	✓ Lower refrigerant charges ✓ Simple and cheaper service ✓ Use of natural refrigerants possible	✓ Risk for low energy efficiency ✓ Pump work ✓ Risk for corrosion ✓ Pipes need to be insulated
Distributed system	✓ Good efficiency ✓ Reduction of refrigerant circuit length => lower refrigerant charges ✓ Less leakages	✓ No possibility to use ammonia or HC refrigerants ✓ Noise
Cascade system	✓ Lower refrigerant charges, less leakages ✓ Simple and cheaper service ✓ Natural refrigerants possible	✓ Both medium and low temperature interact ✓ Pump work ✓ Risk of corrosion ✓ Pipes need to be insulated

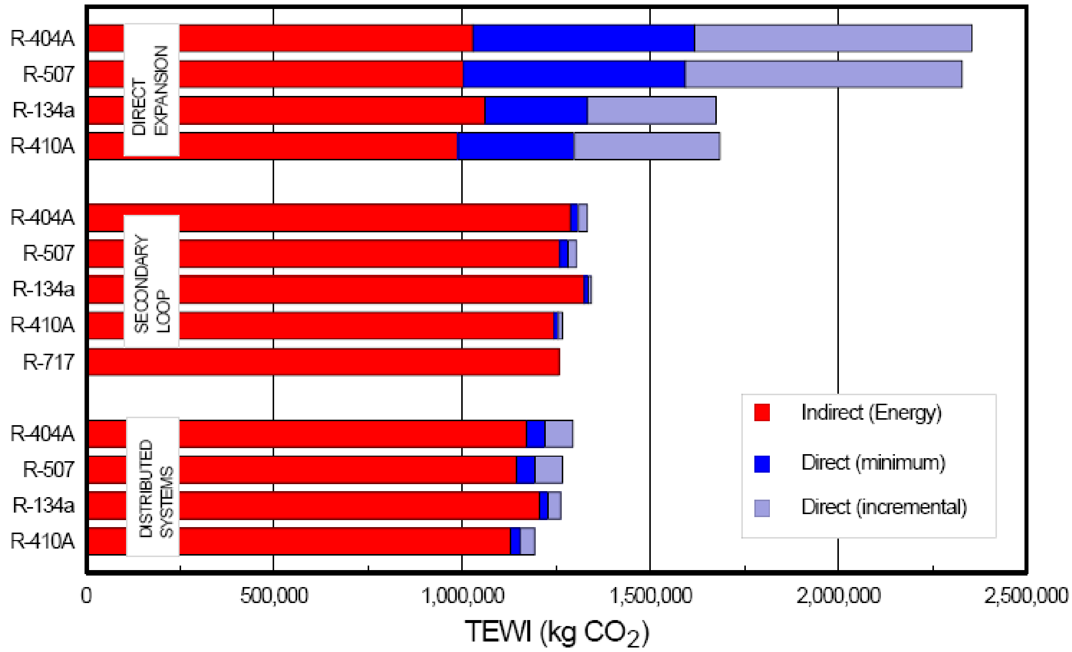
68 Reference: Arias J., *Energy Usage in Supermarkets- Modelling and Field Measurements*, Division of Applied Thermodynamics and Refrigeration, Department of Energy Technology, Royal Institute of Technology (Sweden). (2005). Available at <http://www.diva-portal.org/diva/getDocument?urn_nbn_se_kth_diva-217-1__fulltext.pdf>

Nowadays, direct refrigeration systems are the most common in supermarkets. Regarding indirect and cascade systems, the interest is growing up to increase energy efficiency.

The configuration of the refrigeration system can highly increase the environmental impacts and energy consumption of the overall system. These impacts can be measured using the TEWI indicator (Total Equivalent Warming Impact). The TEWI is the sum of the total emissions associated with both the refrigerant and energy used to run the equipment. Figure 4-44 shows that although direct expansion systems have the lowest electricity consumptions (implying higher COP) the distributed systems have a lower TEWI.

Distributed systems have a COP 4 - 6 % lower than direct expansion systems[69].

Figure 4-44: Medium temperature refrigeration in Europe[69]



However, refrigeration experts agree that it is very difficult to compare the quality in terms of environmental impacts and energy efficiency of different refrigeration systems because no objective tool of comparison exists. In Sweden indirect systems have been used for along time and experiences show that it can be the opposite – an indirect system can actually be more energy efficient than a DX system.

The quality of a system is the result of a balance between its energy efficiency and the choice of the refrigerant (e.g. in regards with the global warming potential) but the weight of each parameter is hard to assess. As shown on

[69] Oak Ridge, Laboratory *Energy and Global Warming Impacts of HFC and Emerging Technologies*. (1997)

Figure 4-45, some systems provide good energy efficiency however at the cost of higher direct emissions. TEWI is one attempt to serve as a basis for comparison. It only considers the use phase. Another attempt is to use the Life Cycle Climate Performance indicator (LLCP) expressed in CO_2 eq which takes production, emissions and energy usage into account and not only the operating stage.

LCCP values have been estimated for various types of supermarket systems and are presented in Table 4-87 and illustrated Figure 4-46.

Figure 4-45: Various full supermarket system comparisons[70]

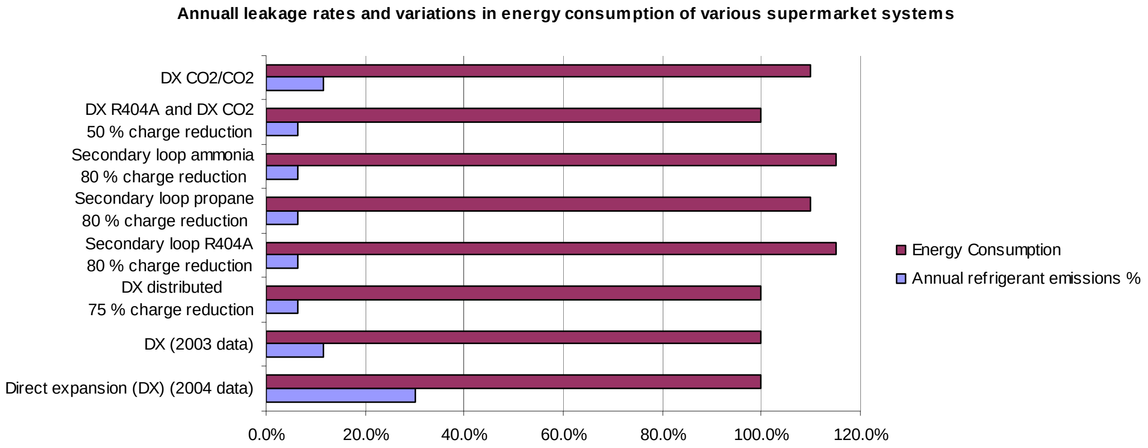
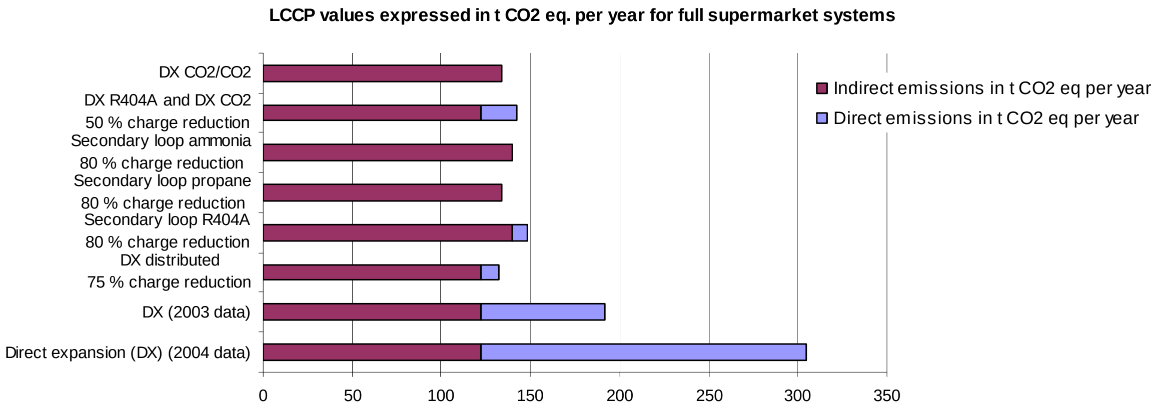


Figure 4-46: LCCP values for full supermarket systems



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70 *IPCC/TEAP Special report, Safeguarding the Ozone Layer and the Global Climate System, chapter* (2005)

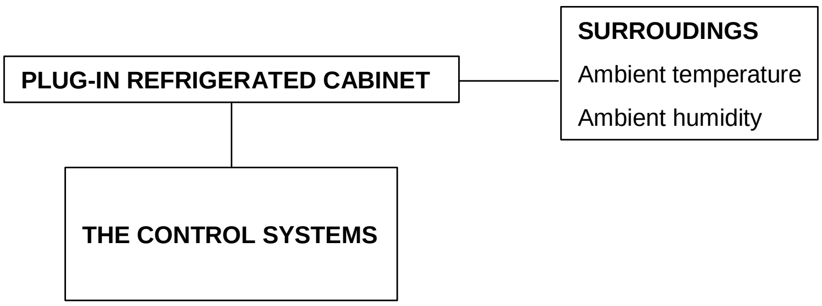
Table 4-87: LCCP values for full supermarket systems[71]

Configuration	Annual refrigerant emissions %	Energy Consumption	LCCP in tCO_2 eq per year		
			Indirect	Direct	Total
Direct expansion (DX) (2004 data)	30%	baseline	122	183	305
DX (2003 data)	11.50%	baseline	122	70	192
DX distributed 75 % charge reduction	6.50%	baseline	122	10	132
Secondary loop R404A 80 % charge reduction	6.50%	baseline + 15 %	140	8	148
Secondary loop propane 80 % charge reduction	6.50%	baseline + 10 %	134	0	134
Secondary loop ammonia 80 % charge reduction	6.50%	baseline + 15 %	140	0	140
DX R404A and DX CO_2 50 % charge reduction	6.50%	baseline	122	20	142
DX CO_2/CO_2	11.50%	baseline + 10 %	134	0	134

4.4.2 PLUG IN REFRIGERATED DISPLAY CABINET

The functional system for plug in refrigerated display cabinets has been identified.

Figure 4-47: Functional system for plug in refrigerated display cabinets



The functional system for plug in refrigerated display cabinets consists of:

- Product itself
- Surroundings
- Control systems

[71] *IPCC/TEAP Special report, Safeguarding the Ozone Layer and the Global Climate System, chapter* (2005)

Interaction with the surroundings

Plug in refrigeration equipment and indoor vending machines add heat to the building. In most cases, this heat must be removed by the air-conditioning system. This increases cooling costs and may also necessitate a larger capacity cooling system.

The interaction of a plug in display cabinet with the surroundings is the same as for the remote cabinet.

Role of the control systems

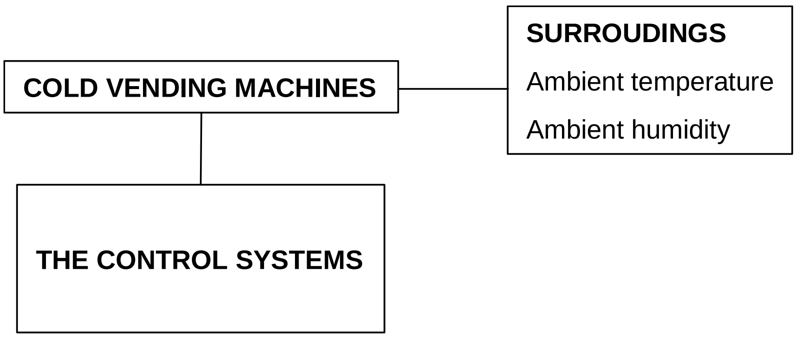
In order to enhance the operation and the performance of the appliance, the control systems in a plug in or in a remote refrigerated display cabinet are equal (see Table 4-85).

4.4.3 COLD VENDING MACHINE

The functional system for cold vending machines comprises:

- Product itself
- Surroundings
- Control systems

Figure 4-48: Functional system for cold vending machines



Interaction with the surroundings

As for refrigerated display cabinets, the energy consumption of the cold vending machine will increase with high temperature and relative humidity. The Southern California Edison's Refrigeration and Thermal Test Centre (RTTC) estimates that a refrigerated beverage vending machine consumes anywhere between 7 to 16 kWh per day depending on the ambient conditions. For example the energy consumption will increase of 120 % when ambient temperature increases from 25 °C to 45 °C.

Cold vending machines can be located outside. Then, manufacturers propose several options to protect the appliance against rain and vandalism. Rain-proof coin introduction plate and protection, and reinforced panels are often incorporated. Moreover, the most common cold vending machine intended for outdoor use is the solid-front machine.

- **Role of the control systems**

In order to enhance the operation and the performance of the appliance, the control systems in a cold vending machine or in a remote refrigerated display cabinet are equal (see Table 4-85). In addition, a vending machine uses payment and dispensing mechanisms, which also have to be controlled. Nevertheless, the description of these control systems does not fall into the scope of our study and will not be detailed here as they do not affect the energy consumption/ environmental impacts of the machine.

4.5. END OF LIFE PHASE

4.5.1 REMOTE AND PLUG IN REFRIGERATED DISPLAY CABINETS

Very little commercial refrigeration equipment is found in refrigerator recycling plants in Europe (less than 1 %). Most common way is to dismantle the cabinet, and recycle the raw material through specific recycling companies. Besides, according to manufacturers, "second life" has been getting smaller, and nowadays it represents less than 1 % of appliances.

As the end-users are in charge of the cabinets' end-of-life, manufacturers are not always involved. Actually, it depends a lot on the country, and the disposal cost is assumed to represent around 1 % of the total cost purchase.

Plug in refrigerators and freezers can be handled like household equipment. The RAL association, specialised in demanufacturing of refrigeration equipment containing CFCs, has been working on a certification for recycling plants which includes the following steps:

- Step 1: extraction of refrigerant
- Step 2: extraction of the insulating foam and other components containing harmful substances
- Step 3: breaking up, sorting out and classification of the material obtained in step 1 and 2 and preparative steps needed to the re-use, and/or disposal of these materials.

After the treatment of harmful substances, the compressor, in the case of a plug in, is withdrawn and handled separately. Then, the rest of the appliance is ground in order to segregate ferrous and non-ferrous metals, along with plastics. The metallic part is removed thanks to a magnet, and will be re-used in new refrigerated display cabinets. About 85 % of materials (metals and plastics) included in a refrigerated display cabinet is recycled. Moreover, about 10 % of materials (only plastics) is burned in order to recover the heat created, and only

5 % of plug in and remote refrigerated display cabinets is thrown away in landfills.[72]

4.5.2 COLD VENDING MACHINES

According to the industry, both refurbishing and cannibalisation (component re-use) of components is a common practice. It is considered that in average, 50 %[72] of the machines are re-used (in total or single parts) at the end of their lives. The treatment of the old appliances is the same as for remote or plug in refrigerated display cabinets.

Typical compressors in such appliances are aluminium reciprocating hermitically sealed type and are generally redundant at end-of-life.

4.5.3 REFRIGERANT END-OF-LIFE PHASE

Data on refrigerant has been collected from different studies and from the EFCTC (European Fluorocarbon Technical Committee).

The F-Gas Regulation EC 842/2006 requires recovery of HFC refrigerants during service, and at end-of-life. In addition, the WEEE directive requires end-of-life recovery and treatment of HFCs. EFCTC member companies directly or via their distributors offer recycling and destruction (typically incineration) schemes for HFC refrigerants. The HFC refrigerant currently returned to suppliers is relatively small and the percentage of recycled refrigerant returned to supply chain by HFC producers is small. Refrigerant recycling can extend its lifespan to 15 years.

Typically, the second hand refrigerant would be reclaimed and supplied to the same specifications as a virgin refrigerant. Recovery/recycle machines allow engineers to reuse HFC without returning them to suppliers. Because refrigerants are simple to be treated locally, more than 90 % of all recovered refrigerant is treated that way. EFCTC comments that it is expected that the WEEE directive will impact on the quantity of refrigerant recovered at end-of-life.

In plug in refrigerated display cabinets, the refrigerant charges are small (0.2 – 1 kg) but end-of-life recovery is almost inexistent[73]. This results in an average annual leakage of 7 – 12 % of the refrigerant charge.

For remote display cabinets, the refrigerant is pumped out of the refrigeration system on site. In case of cold vending machines, the refrigerant is generally recovered at specialist fridge recycling plants as it is contained within a domestic style sealed system.

[72] Estimations from manufacturers

[73] IPCC *Special Report on Safeguarding the Ozone Layer and the Global Climate System. Chapter 4 Refrigeration*. (2005)

4.6. CONCLUSIONS

The real life products identified for the purpose of task 4 will be used to define our base cases in task 5. This task presented the diversity of existing products that can fall into lot 12 and also setup the input database for the environmental analysis to be conducted during the task 5. It also analysed the products in a system context and illustrated how the external factors can affect their environmental and energy efficiency.

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5. DEFINITION OF BASE CASE

This document is the final document for task 5 of the lot 12 EuP preparatory study on commercial refrigerators and freezers. Task 5 comprises of an assessment of average EU products, the so called “base cases”.

A base case is “a conscious abstraction of reality”. The description of the base cases is the synthesis of the results of tasks 1 to 4. Most of the environmental and life cycle cost analysis are built on these base cases throughout the rest of the study and it serves as the point-of-reference for task 6 (technical analysis of BAT), task 7 (improvement potential), and task 8 (impact analysis).

The Bills of Material (BOMs) of the base cases are derived from the product-cases presented in task 4. When providing the inputs for the BOMs of the product cases, a modular approach was adopted and the material inputs were made per assembly of components. When establishing the BOMs of the base cases, this modular approach is preserved to better identify the most significant components in terms of environmental impacts and to help identify module (assembly) specific improvement options further in task 7.

The evaluation of the environmental impacts is done with the EuP EcoReport tool as specified in the MEEuP methodology. This allowed identifying the significance of the different phases of the life cycle. However, EcoReport is a simplified life cycle analysis (LCA) tool and meant for a relative analysis of two products rather than an absolute life cycle analysis. To understand the contribution of different modules of a base case to environmental impact indicators, another LCA tool (Simapro) was used. However, MEEuP database module supplied with Simapro was used for this analysis. Data comparison across modules provides a better understanding of the significance of each module during different life cycle phases and thus provides better and logical means to identify improvement options.

According to the MEEuP, the scope should be covered by one or two base cases in task 5. However, in the case of products being analysed in the lot 12, different configurations exist (open, closed, chilled, frozen, etc.), therefore, it was decided to study a larger number of base cases to portray the market segment in a comprehensive manner. Detailed analyses of a larger number of base cases also allowed us a more realistic assessment of improvement potentials in the subsequent tasks.

As explained in task 1, the lot 12 study focuses on three categories of commercial refrigeration appliances:

- remote refrigerated display cabinets,
- plug in refrigerated display cabinets,
- cold vending machines,

More specifically, it focuses on 5 appliances which have been identified as being the most representative of these three families of products as presented in task 4. For each of these 5 types of commercial refrigeration equipment, BOM and energy consumption data have been collected as presented in task 4 and aggregated in task 5 to form the following base cases:

- remote open vertical chilled multi deck (base case RCV2)
- remote open horizontal frozen island (base case RHF4)
- plug in one door beverage cooler (beverage cooler base case)
- plug in horizontal ice-cream freezer (ice-cream freezer base case)
- spiral cold vending machine (spiral vending machine base case)

The MEEuP methodology specifies that the environmental assessment has to consider both standard conditions and real life conditions. However, in the case of products studied in Lot 12, it was not possible to make real life use measurements to average for the whole Europe and hence only standard conditions were analysed. The sensitivity analysis in task 8 will evaluate the differences between real life and standard conditions.

The following boxes give the summary of the main characteristics and EcoReport results of each base case which are further detailed in sections 5.2 to 5.5.

Base case RCV2 – summary of main characteristics

General description

Type of appliance: Open Vertical chilled (-1 °C – 7 °C) multi deck (RCV2)

TDA[1] : 7 m²

Refrigerant: R 404 A

Total weight: 614 kg

Total packaged volume: 9.47 m^3

Product life: 9 years

Total Electrical Consumption (TEC): 77.31 kWh/day (ambient 25 °C – 60 % RH)

Materials	Base case RCV2
Bulk Plastic	2.27%
Tec Plastics	4.43%
Ferro	75.93%
Non-ferro	8.00%
Coating	3.58%
Electronics	0.02%
Misc. (Blowing agent)	0.15%
Misc. (Glass)	0.08%
Misc. (Ballast)	0.19%
Misc. (Cardboard)	0.22%
Misc. (Paper)	0.17%
Misc. (Wood)	4.94%
Misc. (Other)	0.00%

Main results per product

Impacts

The use phase is the most significant stage of the lifetime in terms of environmental impacts, predominantly due to the production of the refrigeration energy. It represents over 97 % of the total energy consumption (GER) and global warming potential (GWP). During the production phase the housing of the cabinet and the evaporator are the assemblies responsible of most of the emissions and energy and resource consumption.

Life cycle cost: € 28,300

Main results (EU wide)

Impacts

The EU wide impact of such products in 2006 is estimated to a total energy consumption of 436 PJ[2] and to a GWP of 19 mt CO_2 eq.

Total annual consumer expenditure: € 4,100 million

[1] TDA: Total Display Area (m²)

[2] PJ = Penta joule = 1015 joules

Base case RHF4 – summary of main characteristics

General description

Type of appliance: Open Horizontal Frozen (-18 ℃; -12 ℃) Island (RHF4)

TDA : 7 m²

Refrigerant: R 404 A

Total weight: 794 kg

Total packaged volume: 8.52 m^3

Product life: 9 years

Total Electrical Consumption (TEC): 81.34 kWh/day (ambient 25 ℃ – 60 % RH)

Materials	Base Case RHF4
Bulk Plastics	3.97%
Tec Plastics	2.66%
Ferro	57.76%
Non-ferro	8.26%
Coating	2.72%
Electronics	0.16%
Misc. (cardboard)	0.04%
Misc. (glass)	12.91%
Misc. (office paper)	0.10%
Misc. (wood)	11.26%
Misc. (blowing agent)	0.12%
Misc. (putty/sealant)	0.05%

Main results per product

Impacts

The use phase is the most significant stage of the lifetime in terms of environmental impacts, predominantly due to the production of the refrigeration energy. It represents over 97 % of the total energy consumption (GER) and global warming potential (GWP). During the production phase the housing of the cabinet and the evaporator are the assemblies responsible of most of the emissions and energy and resource consumption.

Life cycle cost: € 30,187

Main results (EU wide)

Impacts

The EU wide impact of such products in 2006 is estimated to a total energy consumption of 60 PJ and to a GWP of 3 mt CO_2 eq.

Total annual consumer expenditure: € 673 million

Base case beverage cooler – summary of main characteristics

General description

Type of appliance: One door beverage cooler (average operating temperature 5 °C)

Net volume : 500 litres

Refrigerant: R 134 a

Total weight: 123 kg

Total packaged volume: 1.14 m^3

Product life: 8 years

Total Electrical Consumption (TEC): 7.04 kWh/day (ambient 30 °C – 55 % RH)

Materials	Base Case Beverage cooler
Bulk Plastics	4.46%
TecPlastics	7.11%
Ferro	55.97%
Non-ferro	10.40%
Coating	0.73%
Electronics	0.05%
Misc.(Ink)	0.06%
Misc.(Blowing agent)	0.44%
Misc.(glass)	15.75%
Misc.(Ballast)	0.81%
Misc.(ester oil)	0.24%
Misc.(Cardboard)	0.15%
Misc. (Paper)	0.05%
Misc. (Wood)	3.51%
Misc. (Refrigerant)	0.26%

Main results per product

Impacts

The use phase is the most significant stage of the lifetime in terms of environmental impacts, predominantly due to compressor operation and to the lighting system. It represents over 95 % of the total energy consumption (GER) and global warming potential (GWP).

During the production phase the housing of the cabinet, the heat exchangers and the compressor are the assemblies responsible of most of the emissions and energy and resource consumption.

Life cycle cost: € 3,058

Main results (EU wide)

Impacts

The EU wide impact of such products in 2006 is estimated to a total energy consumption of 195 PJ and to a GWP of 9 mt CO_2 eq.

Total annual consumer expenditure: € 2,710 million

Base case ice cream freezer – summary of main characteristics

General description

Type of appliance: Packaged horizontal ice cream freezer with lids (-23 °C – -18 °C)

Net volume : 291 litres

Refrigerant: R 507

Total weight: 74.5 kg

Total packaged volume: 0.797 m^3

Product life: 8 years

Total Electrical Consumption (TEC): 4.5 kWh/day (ambient 30 °C – 55 % RH)

Materials	Base case ice cream freezer
Bulk Plastic	4.71%
Tec Plastics	10.83%
Ferro	26.10%
Non-ferro	8.82%
Coating	31.83%
Electronics	0.00%
Misc. (Cardboard)	0.77%
Misc. (Glass)	8.32%
Misc. (Blowing agent)	0.54%
Misc. (Ester oil)	0.37%
Misc. (Wood)	5.75%
Misc. (Paper)	0.27%
Misc. (Refrigerant liquid)	0.30%
Misc. (unknown)	1.40%

Main results per product

Impacts

The use phase is the most significant stage of the lifetime in terms of environmental impacts, due to compressor and condenser fan operation. It represents over 92 % of the total energy consumption (GER) and global warming potential (GWP).
During the production phase the housing of the cabinet and the compressor are the assemblies responsible of most of the emissions and energy and resource consumption.

Life cycle cost: € 2,226

Main results (EU wide)

Impacts

The EU wide impact of such products in 2006 is estimated to a total energy consumption of 55 PJ and to a GWP of 3 mt CO_2 eq.

Total annual consumer expenditure: € 840 million

Base case Spiral Vending Machine – summary of main characteristics

General description

Type of appliance: Spiral Vending Machine (+3℃)

Net Volume: 0.75 m^3

Refrigerant: R 134a

Total weight: 297 kg

Total packaged volume: 1.4825 m^3

Product life: 8.5 years

Total Electrical Consumption: 7.465 kWh/day (ambient 25 ℃ – 60 % RH, following the EVA – EMP Idle State Protocol)

Materials	Base Case Spiral VM
Bulk Plastics	11.74%
Tec Plastics	1.51%
Ferro	48.58%
Non-ferro	2.82%
Coating	25.68%
Electronics	0.35%
Misc. (cardboard)	0.60%
Misc. (glass)	6.39%
Misc. (ballast)	0.05%
Misc. (ester oil)	0.10%
Misc. (office paper)	0.09%
Misc. (wood)	1.90%
Misc. (refrigerant)	0.18%

Main results per product

Impacts

The use phase is the most significant stage of the lifetime in terms of environmental impacts, predominantly due to the compressor and the lights. It represents over 85 % of the total energy consumption (GER) and over 78 % of the global warming potential (GWP).
During the production phase the housing of the appliance and the electric assembly are the assemblies responsible of most of the emissions and energy and resource consumption.

Life cycle cost: € 6,104

Main results (EU wide)

Impacts

The EU wide impact of such products in 2006 is estimated to a total energy consumption of 53 PJ and to a GWP of 2 mt CO2 eq.

Total annual consumer expenditure: € 979 million

5.1. PRODUCT-SPECIFIC INPUTS

5.1.1 ASSUMPTIONS

To establish each of the 5 base cases, the approach is to average the data from the product-cases (arithmetic average). This is done for all components that are made using the same type of material in all cabinets. For example for the base case RCV2, the foam insulation is made of 15-Rigid PUR in all four product cases, thus the material used in the base case is 15-Rigid PUR and the weight is the average of the four product cases.

When different materials (between the four product cases) are used for the same part of the cabinet, it is assumed the component is made with the most environmentally impacting material in terms of GER (total energy consumption) and GWP (Global Warming Potential). The average weight was taken into account and parts of the cabinets which data are listed for “n” cabinets are averaged and weighted by “n/p” where “p” is the number of product cases. For example, only one out of the four product cases RCV2 has an anti-sweat heater, thus the base case will have 1/4 of the materials included in the anti-sweat heater.

The material database of the EcoReport does not contain materials of some components (e.g. the blowing agent used in the foam insulation, the wood of the packaging). In such a case, only their weight was specified and the consequences on the calculation of the environmental impacts will be discussed later in section 5.2 when assessing the impacts related to the end-of-life.

End-of-life scenario is assumed to be same for all three product categories, i.e. remote and plug ins and cold vending machines. As described in task 4, about 85 % of materials (metals and plastics) included in a refrigerated display cabinet are recycled. Moreover, about 10 % of materials (only plastics) are burned in order to recover the heat created, and only 5 % of plug in and remote refrigerated display cabinets are disposed in landfills.[3]

5.1.2 REMOTE REFRIGERATED DISPLAY CABINET

5.1.2.1 BASE CASE VERTICAL OPEN CHILLED MULTI DECK (RCV2)

- **Bill of Material**

The BOM for this base case is derived from the four product-cases presented in task 4 (section 4.1.1).

In task 4 (section 4.1.1), the product cases not being exactly of same size, hence the BOM data of each product-case is normalised to 7 m² TDA (Total Display Area). This adjustment was applied to all material data except for the

[3] Estimations from manufacturers

electronic temperature control system which is assumed to remain the same for all cabinets.

The resulting BOM using the approach describe in section 5.1.1 for the RCV2 is shown in the following table (Table 5-1):

Table 5-1: EcoReport material input table for Base Case RCV2

ECO-DESIGN OF ENERGY-USING PRODUCTS		EuP EcoReport: INPUTS Assessment of Environmental Impact	
Product name		Date	Author
BASE CASE REMOTE OPEN VERTICAL CHILLED MULTI DECK			**BIO**
MATERIALS Extraction & Production **Description of component**	**Weight** **in g**	**Category**	**Material or Process**
Housing			
External housing			
Panels and cabinet structure (external panels, internal parts, air discharge grill)	189,712.4	3-Ferro	**21-St sheet galv.**
Panels pre coating	5,435.2	5-Coating	**38-pre-coating coil**
Chassis	58,595.2	3-Ferro	**21-St sheet galv.**
Chassis pre-coating	1,678.7	5-Coating	**38-pre-coating coil**
Mounting internal components	41,883.4	3-Ferro	**21-St sheet galv.**
Mounting internal components pre coating	1200.0	5-Coating	**38-pre-coating coil**
Epoxy coating	7,931.8	5-Coating	**39-powder coating**
PVC parts	1,568.6	1-BlkPlastics	**8-PVC**
PC parts	465.3	2-TecPlastics	**12-PC**
ABS parts	358.8	1-BlkPlastics	**10-ABS**
PS parts	2,948.1	1-BlkPlastics	**5-PS**
HDPE parts	23.8	1-BlkPlastics	**2-HDPE**
PMMA parts	14.2	2-TecPlastics	**13-PMMA**
Al die cast parts	6,241.1	4-Non-ferro	**27-Al diecast**
Al sheet	3,204.5	4-Non-ferro	**26-Al sheet/extrusion**
Foam Insulation			
Foam insulation	25,133.3	2-TecPlastics	**15-Rigid PUR**
Blowing agent (1/4 Cyclopentane)	338.7	7-Misc.	
Blowing agent (3/4 R134a)	583.9	7-Misc.	
Shelves			
Shelves	133,665.3	3-Ferro	**21-St sheet galv.**
Brackets	20,508.1	3-Ferro	**21-St sheet galv.**
Epoxy coating	3,676.1	5-Coating	**39-powder coating**
PC parts	156.6	2-TecPlastics	**12-PC**
ABS parts	44.2	1-BlkPlastics	**10-ABS**
PVC parts	830.0	1-BlkPlastics	**8-PVC**
Lighting System			
Fluorescent tubes	493.1	7-Misc.	**54-Glass for lamps**
Ballasts	1,182.2	7-Misc.	

Light box metal sheets	5,672.1	3-Ferro	**21-St sheet galv.**
Light box epoxy painting	172.3	5-Coating	**39-powder coating**
Light box plastic parts	134.2	2-TecPlastics	**12-PC**
Light box metal sheets Al	345.2	4-Non-ferro	**26-Al sheet/extrusion**
Light box coated metal sheets	1,784.3	5-Coating	**38-pre-coating coil**
Components for assembling (screws, rivets, etc.)			
Screws and rivets	4,360.3	3-Ferro	**23-Cast iron**
Evaporation module			
Evaporator			
Copper suction line	16,218.2	4-Non-ferro	**30-Cu tube/sheet**
Aluminium fins	10,920.5	4-Non-ferro	**26-Al sheet/extrusion**
Evaporator fans			
Fan Blades	686.8	4-Non-ferro	**26-Al sheet/extrusion**
Fan grid	2,720.8	3-Ferro	**25-Stainless 18/8 coil**
Evaporator fan motor			
PVC parts	233.8	1-BlkPlastics	**8-PVC**
Iron	3,631.5	3-Ferro	**24-Ferrite**
Aluminium	467.5	4-Non-ferro	**27-Al diecast**
Copper	1,115.0	4-Non-ferro	**28-Cu winding wire**
PC parts	519.6	2-TecPlastics	**12-PC**
Other copper	10.9	4-Non-ferro	**31-CuZn38 cast**
Expansion valve module			
Thermostatic expansion valve	407.4	4-Non-ferro	**31-CuZn38 cast**
Anti-sweat heater			
Resistance wire	100.0	4-Non-ferro	**29-Cu wire**
Electric assembly			
Electric panel			
Electric panel metal sheet	991.8	3-Ferro	**21-St sheet galv.**
Electric panel coated metal sheet	60.3	5-Coating	**38-pre-coating coil**
Cables			
Cables plastic parts	3,889.5	1-BlkPlastics	**8-PVC**
Cables metal parts	2,510.9	4-Non-ferro	**29-Cu wire**
Packaging			
Manual	1,030.6	7-Misc.	**57-Office paper**
Wood palette	29,053.7	7-Misc.	
Cardboard	1,362.8	7-Misc.	**56-Cardboard**
Plastic sheet/bag	54.0	1-BlkPlastics	**1-LDPE**
Nylon	775.5	2-TecPlastics	**11-PA 6**
Frame	1,551.0	3-Ferro	**22-St tube/profile**
PVC parts	34.0	1-BlkPlastics	**8-PVC**
Metal parts	1,415.9	3-Ferro	**23-Cast iron**
Powder coating	56.9	5-Coating	**39-powder coating**
Miscellaneous			
Electronic temperature control			
LED screen	100.0	6-Electronics	**48-SMD/ LED's avg.**
Housing	400.0	1-BlkPlastics	**10-ABS**
Sensor	50.0	3-Ferro	**22-St tube/profile**

Integrated circuit	50.0	6-Electronics	**47-IC's avg., 1% Si**
Pipes in the refrigeration system			
Pipes in the refrigeration system	6,906.4	4-Non-ferro	**30-Cu tube/sheet**
Drain pipes	558.7	1-BlkPlastics	**2-HDPE**
Plastic pipes	4.2	2-TecPlastics	**16-Flex PUR**
Others			
Bumpers	2,994.4	1-BlkPlastics	**8-PVC**
Blending	1,497.2	3-Ferro	**21-St sheet galv.**
Wood	1,303	7-Misc.	
TOTAL	**614,023**		

Table 5-2 presents the aggregated BOM as provided by MEEuP EcoReport. It can be observed that the distribution of the materials is similar to the four product cases presented in task 4 (section 4.1.1.2) with ferro metal being the most represented category of materials (Table 5-3).

Table 5-2: Overview of the Bill of Material for RCV2 Base Case

Table. Life Cycle Impact (per unit) of BASE CASE REMOTE OPEN VERTICAL CHILLED MULTI DECK											
Nr	**Life cycle Impact per product:**						Date	Author			
0	BASE CASE REMOTE OPEN VERTICAL CHILLED MULTI DECK							BIO			
	Life Cycle phases -->		**PRODUCTION**			**DISTRI-**	**USE**	**END-OF-LIFE***			**TOTAL**
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**13938**			1394	12544	**13938**	**0**
2	TecPlastics	g			**27203**			2720	24483	**27203**	**0**
3	Ferro	g			**466255**			23313	442942	**466255**	**0**
4	Non-ferro	g			**49134**			2457	46678	**49134**	**0**
5	Coating	g			**21996**			1100	20896	**21996**	**0**
6	Electronics	g			**150**			100	50	**150**	**0**
7	Misc.	g			**35348**			1767	33580	**35348**	**0**
	Total weight	g			**614023**			32851	581173	**614023**	**0**

Table 5-3: Material distribution for base case RCV2

Materials	Base case RCV2
Bulk Plastic	2.27%
Tec Plastics	4.43%
Ferro	75.93%
Non-ferro	8.00%
Coating	3.58%
Electronics	0.02%
Misc. (Blowing agent)	0.15%
Misc. (Glass)	0.08%
Misc. (Ballast)	0.19%
Misc. (Cardboard)	0.22%
Misc. (Paper)	0.17%
Misc. (Wood)	4.94%
Misc. (Other)	0.00%

Primary scrap production during sheet metal manufacturing

Collected data indicates an estimate of 5 % scrap production during sheet metal manufacturing.

Volume and Weight of the Packaged Product

The weight of the base case RCV2 is of 614.023 kg and it has a packaged volume of 9.47 m^3 (Total Display Area of 7 m^2).

Table 5-4: Inputs for the calculation of the distribution impacts using EcoReport

Packaged Weight (kg)	614.023
Packaged Volume (m^3)	9.47

Annual resources consumption

The total electricity consumption of the base case RCV2 in ISO 23953 standard conditions 3M2 (25 °C – 60 % RH for dairy application) is of 77.31 kWh/d (28219.97 kWh/yr). Table 5-5 shows the electricity consumption breakdown into REC (Refrigeration Energy Consumption) and DEC (Direct electrical Energy Consumption). Table 5-6 gives the DEC breakdown for each module.

Table 5-5: Annual electrical energy consumption (standard conditions)

Base case RCV2	Energy consumption (kWh/yr)	Electricity Consumption %
REC	25608.59	90.75
DEC	2611.38	9.25
TEC	28219.97	100

Table 5-6: DEC breakdown for each module

Modules	Energy consumption (kWh/yr)	Share (%)
Evaporator module (Fans)	1879.93	72
Housing (Lighting system)	653.86	25
Anti-sweat heater	77.90	3
DEC	2611.69	100

5.1.2.2 BASE CASE HORIZONTAL OPEN FROZEN ISLAND (RHF4)

Bill of Material

As for the base case RCV2, the product cases not presenting exactly the same TDA were normalised to a common value of 7 m². This adjustment was applied to all material data except for the electric assembly and the temperature controller which were assumed to remain the same.

The resulting BOM for the base case RHF4 using the approach described above, is shown in the following table.

Table 5-7: EcoReport material input table for Base Case RHF4

ECO-DESIGN OF ENERGY-USING PRODUCTS		EuP EcoReport: INPUTS Assessment of Environmental Impact	
Product name		Date	Author
Product Base Case remote open frozen island (RHF4)			**BIO**
MATERIALS Extraction & Production	**Weight**	**Category**	**Material or Process**
Description of component	**in g**	**Click &select**	**select Category first !**
Housing			
External housing			
Chassis and panels (internal structure, bottom part, air grill…)	412176.0	3-Ferro	**21-St sheet galv.**
	9247.9	4-Non-ferro	**26-Al sheet/extrusion**
	5398.9	3-Ferro	**22-St tube/profile**
	8903.6	3-Ferro	**25-Stainless 18/8 coil**
	205.0	3-Ferro	**23-Cast iron**
Chassis and panels pre coating	16801.7	5-Coating	**38-pre-coating coil**
Epoxy coating	4755.1	5-Coating	**39-powder coating**
Plastics profiles	8723.7	1-BlkPlastics	**8-PVC**
Plastics tube	980.5	1-BlkPlastics	**4-PP**
ABS parts	756.5	1-BlkPlastics	**10-ABS**
PS parts	175.9	1-BlkPlastics	**5-PS**
HDPE parts	20.1	1-BlkPlastics	**2-HDPE**
Glass	102484.0	7-Misc.	**54-Glass for lamps**
Glass joint	676.8	1-BlkPlastics	**10-ABS**
Glass support	2182.3	2-TecPlastics	**12-PC**
Foam Insulation			
Polyurethane	18831.9	2-TecPlastics	**15-Rigid PUR**
Expandable Polystyrene	16886.2	1-BlkPlastics	**6-EPS**
Blowing agent (1/3 Cyclopentane)	813.0	7-Misc.	
Blowing agent (1/3 R134a)	151.8	7-Misc.	
Components for assembling (screws, rivets, etc.)			
Screws and rivets	3405.9	3-Ferro	**23-Cast iron**
Evaporation module			

Evaporator			
Copper suction line	19552.6	4-Non-ferro	**30-Cu tube/sheet**
Aluminium fins	24949.8	4-Non-ferro	**26-Al sheet/extrusion**
Insulation pipes	25.7	2-TecPlastics	**15-Rigid PUR**
Valves	272.8	4-Non-ferro	**28-Cu winding wire**
Plastics parts	38.5	1-BlkPlastics	
Evaporator fans			
Fan Blades	571.1	4-Non-ferro	**26-Al sheet/extrusion**
Fan grid	1847.6	3-Ferro	**25-Stainless 18/8 coil**
Evaporator fan motor			
PVC parts	406.7	1-BlkPlastics	**8-PVC**
Iron	3548.6	3-Ferro	**24-Ferrite**
Aluminium	1142.8	4-Non-ferro	**27-Al diecast**
Copper	615.2	4-Non-ferro	**28-Cu winding wire**
Evaporator tray			
Evaporator tray	18084.0	3-Ferro	**21-St sheet galv.**
Expansion valve module			
Thermostatic expansion valve	336.8	4-Non-ferro	**31-CuZn38 cast**
Anti-sweat heater			
Resistance wire	1511.4	4-Non-ferro	**29-Cu wire**
Defrost			
Resistance wire	3063.4	4-Non-ferro	**29-Cu wire**
Fasteners	32.1	3-Ferro	**21-St sheet galv.**
	898.7	3-Ferro	**22-St tube/profile**
Electric assembly			
Electric panel			
Controller board	850.0	6-Electronics	**98-controller board**
Connectors	200.0	6-Electronics	**45-slots / ext. ports**
	80.0	1-BlkPlastics	**8-PVC**
	100.0	1-BlkPlastics	**10-ABS**
	165.0	4-Non-ferro	**29-Cu wire**
Contactors	185.0	6-Electronics	**47-IC's avg., 1% Si**
	50.0	2-TecPlastics	**11-PA 6**
Cables			
Cables plastic parts	1763.5	1-BlkPlastics	**8-PVC**
Cables metal parts	1763.5	4-Non-ferro	**29-Cu wire**
Packaging			
Manual	766.7	7-Misc.	**57-Office paper**
Wood palette	89390.6	7-Misc.	
Cardboard	306.5	7-Misc.	**56-Cardboard**
Plastic sheet/bag	325.2	1-BlkPlastics	**1-LDPE**
Tape	25.7	1-BlkPlastics	**4-PP**
Metal parts	829.7	3-Ferro	**22-St tube/profile**
Miscellaneous			
Electronic temperature control			

LED screen	31.3	6-Electronics	**48-SMD/ LED's avg.**
Housing	110.0	1-BlkPlastics	**10-ABS**
Probes	300.0	1-BlkPlastics	**8-PVC**
	300.0	4-Non-ferro	**29-Cu wire**
Integrated circuit	16.0	6-Electronics	**47-IC's avg., 1% Si**
Control box, metal parts	2500.0	3-Ferro	**21-St sheet galv.**
	600.0	3-Ferro	**22-St tube/profile**
Control box, plastics parts	100.0	1-BlkPlastics	**4-PP**
Pipes in the refrigeration system			
Pipes in the refrigeration system	2038.9	4-Non-ferro	**30-Cu tube/sheet**
Others			
Putty/Sealant	385.3	7-Misc.	
TOTAL	**793658**		

Table 5-8 presents the aggregated BOM as provided by the EcoReport. As for the three product cases presented in task 4, the material distribution shows that ferro metals and miscellaneous (including glass and wood) are the most represented categories of materials (Table 5-9).

Table 5-8: Overview of the Bill of Material for RHF4 Base Case

Table. Life Cycle Impact (per unit) of Base Case remote open frozen island (RHF4)											
Nr	**Life cycle Impact per product:**					Date	Author				
0	Base Case remote open frozen island (RHF4)						BIO				
	Life Cycle phases -->		**PRODUCTION**			**DISTRI-**	**USE**	**END-OF-LIFE***			**TOTAL**
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**31469**			3147	28322	**31469**	**0**
2	TecPlastics	g			**21090**			2109	18981	**21090**	**0**
3	Ferro	g			**458430**			22922	435509	**458430**	**0**
4	Non-ferro	g			**65531**			3277	62255	**65531**	**0**
5	Coating	g			**21557**			1078	20479	**21557**	**0**
6	Electronics	g			**1282**			1167	116	**1282**	**0**
7	Misc.	g			**194298**			9715	184583	**194298**	**0**
	Total weight	g			**793658**			43413	750244	**793658**	**0**

Table 5-9: Material distribution for base case RHF4

Materials	Base Case RHF4
Bulk Plastics	3.97%
Tec Plastics	2.66%
Ferro	57.76%
Non-ferro	8.26%
Coating	2.72%
Electronics	0.16%
Misc. (cardboard)	0.04%
Misc. (glass)	12.91%
Misc. (office paper)	0.10%
Misc. (wood)	11.26%
Misc. (blowing agent)	0.12%
Misc. (putty/sealant)	0.05%

- **Primary scrap production during sheet metal manufacturing**

As for RCV2, 5 % scrap production during sheet metal manufacturing is estimated for open frozen islands.

- **Volume and Weight of the Packaged Product**

The weight of the base case RHF4 is of 793.658 kg, for a packaged volume of 8.52 m^3, the TDA being equal to 7 m².

Table 5-10: Inputs for the calculation of the distribution impacts with EcoReport

Packaged Weight (kg)	793.658
Packaged Volume (m^3)	8.52

- **Annual resources consumption**

The total electricity consumption of the base case RHF4 in ISO 23953 standard conditions 3L2 (25 ℃ – 60 % RH, with an operating temperature between -18 ℃ and -12 ℃) is of 81.34 kWh/d (i.e. 29689.3 kWh/ yr). Table 5-11 presents the electricity consumption breakdown into REC and DEC. Table 5-12 gives the DEC breakdown for each module.

Table 5-11: Annual electricity consumption (standard conditions)

Base case RHF4	Energy consumption (kWh/yr)	Electricity Consumption %
REC	22749.49	76.63
DEC	6939.83	23.37
TEC	29689.32	100

Table 5-12: DEC breakdown for each module

Modules	Energy consumption (kWh/yr)	Share (%)
Evaporation module (Fans)	1623.32	23.39
Anti-sweat heater	3208.69	46.24
Defrost heater	2107.82	30.37
DEC	6939.83	100

5.1.3 PLUG IN REFRIGERATED DISPLAY CABINETS

5.1.3.1 BASE CASE BEVERAGE COOLER

- **Base Case Bill of Material**

The Bill of Material for Beverage cooler base case is presented in Table 5-14.

In task 4 (section 4.1.2.2), the product cases not being exactly of the same sizes, the BOM data of each product case was normalised to a 0.5 m^3 net volume. This adjustment was applied to all material data excluding some components such as compressor, lamps, ballasts, fans, thermostat (see task 4) that were assumed to remain the same for beverage coolers in the range of 0.4 – 0.6 m^3 net volume.

Table 5-13 presents different assumptions made related to the material composition of the beverage cooler. The consequence of these assumptions on the evaluation of the environmental impacts will be assessed further in task 8.

Table 5-13: Material composition assumptions for Base Case Beverage Cooler

Module	Component	BvC1	BvC2	BvC Base Case
Housing	Evaporator fan housing	5-PS	7-HI-PS	7-HI-PS
	Shelves brackets	21-St sheet galv.	11-PA 6	11-PA 6
	Door handle	5-PS	10-ABS	10-ABS
	Canopy	10-ABS 5-PS	10-ABS	10-ABS
Packaging	Packaging	Total plastic ~830 g 3-LLDPE 6-EPS 56-Cardboard	Total plastic ~8g 11-PA 6 56-Cardboard	3-LLDPE 6-EPS 56-Cardboard

For some components, such as the ink used on the external panels, the blowing agent used in the foam insulation, packaging wood, etc. the list of available materials in EcoReport do not allow their classification in a particular material category. Only their weight was specified and the consequences on the calculation of the environmental impacts of these components are discussed in section 5.2.2.

However, concerning the ink, its impact was considered negligible and not taken into account. The blowing agent has also been ignored in the determination of the environmental impacts (only its weight is taken into account) as in EU 25 this is more likely to be Cyclopentane which has a very low Global Warming Potential (GWP). Another impact related to Cyclopentane is the emission of volatile organic compounds (VOC). Previous LCA[4] on refrigerated display cabinets show that the mass of the blowing agent can be considered insignificant compared to other sources of VOC and can be ignored.

Using this approach, following BOM for the base case beverage cooler was obtained:

Table 5-14: EcoReport Material Input Table for base case beverage cooler

ECO-DESIGN OF ENERGY-USING PRODUCTS			EuP EcoReport: INPUTS Assessment of Environmental Impact
Product name **BASE CASE BEVERAGE COOLER**		Date	Author **BIO**
MATERIALS Extraction & Production **Description of component**	**Weight** **in g**	**Category**	**Material or Process**
Housing			
External housing			
Plastic ring for cable	1.5	1-BlkPlastics	**1-LDPE**
Cooler feet	80.0	1-BlkPlastics	**4-PP**
Fan housing	1,166.1	1-BlkPlastics	**7-HI-PS**
Plastic grids and panel cover	210.0	1-BlkPlastics	**10-ABS**
Powder polyester (coating)	900.0	5-Coating	**39-powder coating**
Panels and cabinet structure	40,058.3	3-Ferro	**21-St sheet galv.**
Back grid (condenser)	1,350.0	3-Ferro	**22-St tube/profile**
Inks	80.0	7-Misc.	
Foam Insulation			
Polyurethane	8,514.2	2-TecPlastics	**15-Rigid PUR**
Cyclopentane	537.5	7-Misc.	
Shelves			
Shelves	11,453.6	3-Ferro	**22-St tube/profile**

[4] R. Wattkins, S.A. Tassou, D. Datta. *Life Cycle Analysis of a Commercial Refrigerated display cabinet*. Department of Mechanical Engineering, Brunel University, UK. HPC 2004 – 3rd International Conference on Heat Powered Cycles, Cyprus October 2004 and R. Watkins, S.A. Tassou. *Life Cycle Analysis of the Environmental Impact of Different Cabinet Designs*. Brunel University, UK. 2006.

Brackets	230.0	2-TecPlastics	**11-PA 6**
Door			
Gasket	690.0	1-BlkPlastics	**8-PVC**
Handle and plastic cover	720.0	1-BlkPlastics	**10-ABS**
Hinges	100.0	3-Ferro	**21-St sheet galv.**
Spring	100.0	3-Ferro	**25-Stainless 18/8 coil**
Aluminium	4,201.1	4-Non-ferro	**26-Al sheet/extrusion**
Glass	19,123.6	7-Misc.	**54-Glass for lamps**
Lighting System			
Light bulbs			
Internal fluorescent tube	190.0	7-Misc.	**54-Glass for lamps**
External fluorescent tube	80.0	7-Misc.	**54-Glass for lamps**
Lighting ballast			
ballast	1,000.0	7-Misc.	
Light box			
canopy	589.6	1-BlkPlastics	**10-ABS**
Components for assembling (screws, rivets, etc.)			
screws, rivets, etc.	1,145.6	3-Ferro	**23-Cast iron**
Evaporation Module			
Evaporator			
Al-lamel	1,701.4	4-Non-ferro	**26-Al sheet/extrusion**
suction line	350.7	4-Non-ferro	**30-Cu tube/sheet**
Evaporator fan			
Fan Grid	390.0	3-Ferro	**25-Stainless 18/8 coil**
Blades	120.0	4-Non-ferro	**26-Al sheet/extrusion**
Evaporator fan motor			
PVC	60.0	1-BlkPlastics	**8-PVC**
Iron	780.0	3-Ferro	**24-Ferrite**
Aluminium	120.0	4-Non-ferro	**27-Al diecast**
Copper	240.0	4-Non-ferro	**28-Cu winding wire**
Evaporation tray			
Drip tray	167.4	1-BlkPlastics	**4-PP**
Compression Module			
cast iron of the compressor casing	2,467.5	3-Ferro	**23-Cast iron**
steel of the compressor	3,348.8	3-Ferro	**21-St sheet galv.**
steel for motor lamination	4,523.8	3-Ferro	**24-Ferrite**
aluminium	223.3	4-Non-ferro	**26-Al sheet/extrusion**
rubber	11.8	1-BlkPlastics	**4-PP**
epoxy	11.8	2-TecPlastics	**14-Epoxy**
ester oil	293.8	7-Misc.	
polypropylene	11.8	1-BlkPlastics	**4-PP**
copper	822.5	4-Non-ferro	**28-Cu winding wire**
PET	35.3	1-BlkPlastics	**2-HDPE**
Condenser Module			

Condenser			
Copper pipe	1,377.5	4-Non-ferro	**30-Cu tube/sheet**
Aluminium	688.8	4-Non-ferro	**26-Al sheet/extrusion**
Steel	688.8	3-Ferro	**22-St tube/profile**
Condenser fan			
Fan Grid	390.0	3-Ferro	**25-Stainless 18/8 coil**
Blades	120.0	4-Non-ferro	**26-Al sheet/extrusion**
Condenser fan motor			
PVC	60.0	1-BlkPlastics	**8-PVC**
Iron	780.0	3-Ferro	**24-Ferrite**
Aluminium	120.0	4-Non-ferro	**27-Al diecast**
Copper	240.0	4-Non-ferro	**28-Cu winding wire**
Liquid receiver			
Drier/Accumulator	140.0	4-Non-ferro	**30-Cu tube/sheet**
Expansion device module			
Capillary tube	88.7	4-Non-ferro	**30-Cu tube/sheet**
Electric Assembly			
Electric panel			
Electrical box	418.0	1-BlkPlastics	**10-ABS**
Electrical plate	1,288.8	3-Ferro	**21-St sheet galv.**
Electrical parts	34.8	6-Electronics	**49-PWB 1/2 lay 3.75kg/m2**
Cables			
Cables	454.0	1-BlkPlastics	**8-PVC**
Cables	454.0	4-Non-ferro	**29-Cu wire**
Terminal (plug)	29.1	6-Electronics	**45-slots / ext. ports**
Packaging			
Plastic cover	190.0	1-BlkPlastics	**3-LLDPE**
Plastic corners	630.0	1-BlkPlastics	**6-EPS**
partial carton box	190.0	7-Misc.	**56-Cardboard**
Manuals	58.4	7-Misc.	**57-Office paper**
palette wood (classification not possible)	4,318.4	7-Misc.	
Miscellaneous			
Temperature control and display system			
Set thermostat	50	3-Ferro	**25-Stainless 18/8 coil**
Set thermostat	50	4-Non-ferro	**30-Cu tube/sheet**
Pipes in the refrigeration system			
Copper tubes	1,746.3	4-Non-ferro	**30-Cu tube/sheet**
Others			
Refrigerant liquid R134A	317.7	7-Misc.	
TOTAL	123,124		

Table 5-15 provides an overview of the BOM detailed above. The distribution of the material is similar to the one of the product cases in task 4 (section 4.1.2.2), with ferro metal being the predominant category of materials (> 50 %).

Table 5-15: Overview of the Bill of Material for Base Case Beverage Cooler

Nr	Table. Life Cycle Impact (per unit) of BASE CASE BEVERAGE COOLER										
0	**Life cycle Impact per product:** BASE CASE BEVERAGE COOLER							Date	Author BIO		
	Life Cycle phases --> **Resources Use and Emissions**		**PRODUCTION** Material	Manuf.	**Total**	**DISTRI- BUTION**	**USE**	**END-OF-LIFE*** Disposal	Recycl.	**Total**	**TOTAL**
	Materials	**unit**									
1	Bulk Plastics	g			**5495**			550	4946	**5495**	**0**
2	Tec Plastics	g			**8756**			876	7880	**8756**	**0**
3	Ferro	g			**68915**			3446	65469	**68915**	**0**
4	Non-ferro	g			**12804**			640	12164	**12804**	**0**
5	Coating	g			**900**			45	855	**900**	**0**
6	Electronics	g			**64**			32	32	**64**	**0**
7	Misc.	g			**26189**			1309	24880	**26189**	**0**
	Total weight	g			**123124**			6898	116226	**123124**	**0**

Table 5-16: Material distribution in Base Case Beverage Cooler

Materials	Base Case Beverage cooler
Bulk Plastics	4.46%
Tec Plastics	7.11%
Ferro	55.97%
Non-ferro	10.40%
Coating	0.73%
Electronics	0.05%
Misc.(Ink)	0.06%
Misc.(Blowing agent)	0.44%
Misc.(glass)	15.75%
Misc.(Ballast)	0.81%
Misc.(ester oil)	0.24%
Misc.(Cardboard)	0.15%
Misc. (Paper)	0.05%
Misc. (Wood)	3.51%
Misc. (Refrigerant)	0.26%

Primary scrap production during sheet metal manufacturing

Collected data among plug in cabinet manufacturers indicates an estimate of 9 % scrap production during sheet metal manufacturing.

Volume and Weight of the Packaged Product

The weight of the base case Beverage Cooler is of 123.124 kg and it has a packaged volume of 1.14 m^3 (net volume 500 litres).

Annual resources consumption

Based on the results from task 4, the electrical energy consumption of the base case is of 7.04 kWh/d and of 2,570.5 kWh/yr. Table 5-17 shows the breakdown of the electricity consumption for each module.

Table 5-17: Annual energy consumption for each module

Module	Power consumption (W)	Duty cycle (%)	Electricity Consumption kWh/yr	Electricity Consumption %
Compression module (Compressor)	285	52.5%	1309.9	51%
Evaporation module (Evaporator Fan)	36	100.0%	315.4	12%
Condensation module (Condenser Fan)	36	52.5%	165.6	6%
Housing (Lights)	90	100.0%	788.4	31%
Total			2570.5	100%

5.1.3.2 Base case Ice cream freezer

Two bills of materials were collected in task 4 (section 4.1.2.2), however, the differences in the design could not allow aggregating them to form the base case. It was chosen to further analyse the ICF1 product only, which was identified to be the most representative of ice cream freezers.

ICF1 is a typical ice cream freezer of 0.291 m^3 net volume and is considered representative of an average European product. It has a rather small internal volume and no fan is needed at the evaporator (static evaporator).

Table 5-18: EcoReport Material Input Table for Base Case Ice Cream Freezer

ECO-DESIGN OF ENERGY-USING PRODUCTS			EuP EcoReport: INPUTS Assessment of Environmental Impact
Product name BASE CASE ICE CREAM FREEZER		Date	Author BIO
MATERIALS Extraction & Production Description of component	Weight in g	Category	Material or Process
Housing			
External housing			
Bulk Plastics	2,350	1-BlkPlastics	
Tec Plastics	26	2-TecPlastics	
Ferro	7,464	3-Ferro	
Coating	22,940	5-Coating	

Foam Insulation			
Tec Plastics	8,030	2-TecPlastics	
Misc. (Blowing agent)	400	7-Misc.	
Shelves			
Coating	769	5-Coating	
Door			
Misc. (Glass)	6,200	7-Misc.	
Components for assembling (screws, rivets, etc.)			
Ferro	290.0	3-Ferro	
Evaporation Module			
Evaporator			
Non-ferro	3,152	4-Non-ferro	
Compression Module			
cast iron of the compressor casing	2,291.1	3-Ferro	**23-Cast iron**
steel of the compressor	3,109.4	3-Ferro	**21-St sheet galv.**
steel for motor lamination	4,200.4	3-Ferro	**24-Ferrite**
aluminium	207.3	4-Non-ferro	**26-Al sheet/extrusion**
rubber	10.9	1-BlkPlastics	**4-PP**
epoxy	10.9	2-TecPlastics	**14-Epoxy**
ester oil	272.8	7-Misc.	
polypropylene	10.9	1-BlkPlastics	**4-PP**
copper	763.7	4-Non-ferro	**28-Cu winding wire**
PET	33	1-BlkPlastics	**2-HDPE**
Condenser Module			
Condenser			
Ferro	551.0	3-Ferro	
Non-ferro	547.0	4-Non-ferro	
Condenser fan			
Non-ferro	57	4-Non-ferro	
Misc. (unknown)	964.0	7-Misc.	
Condenser fan motor			
PVC	110.0	1-BlkPlastics	**8-PVC**
Iron	1,430.0	3-Ferro	**24-Ferrite**
Aluminium	220.0	4-Non-ferro	**27-Al diecast**
Copper	440.0	4-Non-ferro	**28-Cu winding wire**
Expansion device module			
Copper	67.0	4-Non-ferro	
Electric Assembly			
Electric panel			
No data			
Cables			
Cables plastic parts	196	1-BlkPlastics	**8-PVC**
Cables metal parts	196	4-Non-ferro	**29-Cu wire**
Packaging			
Bulk Plastics	798.0	1-BlkPlastics	
Ferro	75.0	3-Ferro	

Misc. (Cardboard)	576.0	7-Misc.	
Misc. (Paper)	200	7-Misc.	
Misc. (Wood)	4,285.0	7-Misc.	
Miscellaneous			
Temperature control and display system			
Ferro	30.5	3-Ferro	
Non-ferro	30.5	4-Non-ferro	
Misc. (unknown)	82	7-Misc.	
Pipes in the refrigeration system			
Non-ferro	887.0	4-Non-ferro	
Other			
Misc. (R507)	220	7-Misc.	
Total	74,493		

Table 5-19 and Table 5-20 provide an overview of the BOM detailed above.

Table 5-19: Overview of the Bill of Material for Base Case Ice cream Freezer

Table. Life Cycle Impact (per unit) of BASE CASE ICE CREAM FREEZER

Nr	Life cycle Impact per product:							Date	Author		
0	BASE CASE ICE CREAM FREEZER								BIO		
	Life Cycle phases --> **Resources Use and Emissions**		**PRODUCTION** Material	Manuf.	**Total**	**DISTRI-BUTION**	**USE**	**END-OF-LIFE*** Disposal	Recycl.	**Total**	**TOTAL**
	Materials	**unit**									
1	Bulk Plastics	g			**3509**			351	3158	**3509**	**0**
2	Tec Plastics	g			**8067**			807	7260	**8067**	**0**
3	Ferro	g			**19441**			972	18469	**19441**	**0**
4	Non-ferro	g			**6568**			328	6239	**6568**	**0**
5	Coating	g			**23709**			1185	22524	**23709**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**13200**			660	12540	**13200**	**0**
	Total weight	g			**74493**			4303	70190	**74493**	**0**

Table 5-20: Total mass proportion for each category of material

Materials	Base case Ice cream freezer
Bulk Plastic	4.71%
Tec Plastics	10.83%
Ferro	26.10%
Non-ferro	8.82%
Coating	31.83%
Electronics	0.00%
Misc. (Cardboard)	0.77%
Misc. (Glass)	8.32%
Misc. (Blowing agent)	0.54%
Misc. (Ester oil)	0.37%
Misc. (Wood)	5.75%
Misc. (Paper)	0.27%
Misc. (Refrigerant liquid)	0.30%
Misc. (unknown)	1.40%

- **Primary scrap production during sheet metal manufacturing**

The scrap production was assumed to 9 % as for the beverage coolers.

- **Volume and weight of the packaged product**

The total weight of the ice cream freezer is 74.493 kg and it has a packaged volume of 0.797 m^3.

- **Annual resources consumption**

The electrical energy consumption of the base case is of 4.5 kWh/d and 1,642.5 kWh/yr. The break-down of the electricity consumption for each module is given in Table 5-21.

Table 5-21: Annual electricity consumption for each module

Module	Power consumption (W)	Duty cycle (%)	Electricity consumption kWh/ yr
Housing module (Lights)	0	0	0.00
Evaporation Module (Evaporator fan)	0	0	0.00
Condenser Module (Condenser fan)	30	100	164.25
Anti-sweat heater	0	0	0.00
Defrost	0	0	0.00
Compressor Module	270	100	1,478.25
Total			1,642.50

5.1.4 COLD VENDING MACHINES

5.1.4.1 BASE CASE SPIRAL VENDING MACHINE (SPIRAL VM)

- **Base Case Bill of Material**

One of the product cases for vending machines does not use a condenser fan and contains an anti-sweat heater. Indeed, the second product case uses a special technology of the air distribution inside the cabinet allowing avoiding condensation on the glass, and thereby avoiding the need of an anti-sweat heater .It was decided together with manufacturers that the base case contained a condenser fan and an anti-sweat heater.

Table 5-22 presents the different assumptions made related to the material composition of the spiral vending machine. The consequence of these assumptions on the assessment of the environmental impacts will be studied in task 8.

Table 5-22: Material composition assumptions for the Base Case Spiral VM

Module	Component	Product case 1 (Spiral VM)	Product case 2 (Spiral VM)	Base Case Spiral VM
Housing	Foam Insulation	5-PS	15-Rigid PUR	15-Rigid PUR
	Shelves brackets	4-PP	9-SAN	10-ABS
		5-PS		
		10-ABS	10-ABS	
	Screws & Rivets	25-Stainless coil	24-Ferrite	25-Stainless coil
		27-Al diecast		27-Al diecast
	Spirals	25-Stainless coil	38-Pre-coating coil	38- Pre-coating coil
Condensation Module	Condenser Fan	NO	YES	YES (same as VM2)
Anti-Sweat Heater		YES	NO	YES (same as VM1)

For some components, such as the ester oil in the compressor, the ballast or packaging wood, the list of the available materials in the EcoReport does not allow their classification in a particular material category. Thereby, only their weight was specified and the consequences on the calculation of the environmental impacts will be discussed later in section 5.2 when assessing the impacts related to the end-of-life.

Using this approach, following BOM for the base case Spiral VM was obtained:

Table 5-23: EcoReport BOM for base case Spiral VM

ECO-DESIGN OF ENERGY-USING PRODUCTS		EuP EcoReport: INPUTS Assessment of Environmental Impact	
Product name		Date	Author
Base case Spiral Vending Machine			**BIO**
MATERIALS Extraction & Production	**Weight**	**Category**	**Material or Process**
Description of component	**in g**	**Click &select**	**select Category first !**
Housing			
External housing			
Chassis	56118.5	3-Ferro	**21-St sheet galv.**
	1029	3-Ferro	**22-St tube/profile**
	952	3-Ferro	**25-Stainless 18/8 coil**
Panels	819	1-BlkPlastics	**6-EPS**
	845	1-BlkPlastics	**5-PS**
	25637	3-Ferro	**21-St sheet galv.**
	47770	5-Coating	**38-pre-coating coil**
Foam insulation			
Polyurethane	4175	2-TecPlastics	**15-Rigid PUR**
Blowing agent R134A	202.4	7-Misc.	
Shelves & Grids & Brackets			
	6630	3-Ferro	**21-St sheet galv.**
	309	2-TecPlastics	**11-PA 6**

	25608	1-BlkPlastics	**10-ABS**
Doors			
Gasket	1853	1-BlkPlastics	**8-PVC**
Handle and plastic cover	4237	1-BlkPlastics	**10-ABS**
	33811	3-Ferro	**21-St sheet galv.**
	760	3-Ferro	**25-Stainless 18/8 coil**
	19299	5-Coating	**38-pre-coating coil**
Glass	18820	7-Misc.	**54-Glass for lamps**
Lighting system			
Light bulbs			
Light bulb Output Power=35W	159	7-Misc.	**54-Glass for lamps**
Lighting ballast			
Ballast	141	7-Misc.	
Light box			
Canopy	980	3-Ferro	**21-St sheet galv.**
Spirals			
	9201	5-Coating	**38-pre-coating coil**
Components for assembling (screws, rivets…)			
Screws	740	3-Ferro	**25-Stainless 18/8 coil**
Rivets	650	4-Non-ferro	**27-Al diecast**
Evaporation module			
Evaporator			
Al-lamel	1225.0	4-Non-ferro	**26-Al sheet/extrusion**
Suction line	615.0	4-Non-ferro	**30-Cu tube/sheet**
Evaporator fan			
Fan Grid	290.0	3-Ferro	**25-Stainless 18/8 coil**
Fan Blades	90.0	4-Non-ferro	**26-Al sheet/extrusion**
Evaporator fan motor			
Aluminium	180.0	4-Non-ferro	**27-Al diecast**
Iron	540.0	3-Ferro	**24-Ferrite**
Copper	135.0	4-Non-ferro	**28-Cu winding wire**
PVC	45.0	1-BlkPlastics	**8-PVC**
Compression module			
Cast iron of the compressor casing	2583.0	3-Ferro	**23-Cast iron**
Steel of the compressor	3505.5	3-Ferro	**21-St sheet galv.**
Steel for motor lamination	4735.5	3-Ferro	**24-Ferrite**
Aluminium	233.7	4-Non-ferro	**27-Al diecast**
Rubber	12.3	1-BlkPlastics	**4-PP**
Epoxy	12.3	2-TecPlastics	**14-Epoxy**
Ester oil	307.5	7-Misc.	
Polypropylen	12.3	1-BlkPlastics	**4-PP**
Copper	861.0	4-Non-ferro	**28-Cu winding wire**
PET	36.9	1-BlkPlastics	**2-HDPE**
Condensation module			
Condenser			
Aluminium	426.0	4-Non-ferro	**26-Al sheet/extrusion**
Steel	213.0	3-Ferro	**22-St tube/profile**
Copper	213.0	4-Non-ferro	**30-Cu tube/sheet**
Condenser fan			
Fan Grid	390.0	3-Ferro	**25-Stainless 18/8 coil**
Fan Blades	120.0	4-Non-ferro	**26-Al sheet/extrusion**
Condenser fan motor			

Aluminium	120.0	4-Non-ferro	**27-Al diecast**
Iron	780.0	3-Ferro	**24-Ferrite**
Copper	240.0	4-Non-ferro	**28-Cu winding wire**
PVC	60.0	1-BlkPlastics	**8-PVC**
Liquid receiver	72.0	1-BlkPlastics	**4-PP**
Expansion valve module			
Capillary tube	80.0	4-Non-ferro	**30-Cu tube/sheet**
Anti-sweat heater			
Electric anti-sweat	33.0	4-Non-ferro	**28-Cu winding wire**
Electric assembly (not included in other modules)			
Electric panel			
Box	1425	3-Ferro	**21-St sheet galv.**
Transformer	350	4-Non-ferro	**28-Cu winding wire**
Electronic Cards	60	6-Electronics	**49-PWB 1/2 lay 3.75kg/m2**
	200	6-Electronics	**47-IC's avg., 1% Si**
	300	6-Electronics	**46-IC's avg., 5% Si, Au**
	60	6-Electronics	**44-big caps & coils**
Cables			
	958	4-Non-ferro	**29-Cu wire**
	958	1-BlkPlastics	**8-PVC**
Packaging			
Manuals			
Manuals	262.5	7-Misc.	**57-Office paper**
Protection			
Pallet	5650	7-Misc.	
Protections	1780	7-Misc.	**56-Cardboard**
Miscellaneous			
Screen			
LCD Screen	117.5	6-Electronics	**42-LCD per m2 scrn**
Selection & Payment systems			
Electronic cards brackets	40.0	1-BlkPlastics	**10-ABS**
Electronic cards	30.0	6-Electronics	**49-PWB 1/2 lay 3.75kg/m2**
	100.0	6-Electronics	**47-IC's avg., 1% Si**
	150.0	6-Electronics	**46-IC's avg., 5% Si, Au**
	30.0	6-Electronics	**44-big caps & coils**
Motors of the dispensing mechanism			
Aluminium	1046.0	4-Non-ferro	**27-Al diecast**
Iron	3138.0	3-Ferro	**24-Ferrite**
Copper	784.5	4-Non-ferro	**28-Cu winding wire**
PVC	261.5	1-BlkPlastics	**8-PVC**
Others			
Refrigerant liquid R134A	342.5	7-Misc.	
TOTAL	**296956**		

Table 5-24 and Table 5-25 provide an overview of the BOM detailed above. As the base case is an average of the two product cases, ferro-metals, coating and bulk plastics are the predominant categories of materials.

Table 5-24: Overview of the BOM for the Spiral VM

Table. Life Cycle Impact (per unit) of Base Case Spiral Vending Machine										
Nr	**Life cycle Impact per product:**					Date		Author		
0	Base case Spiral Vending Machine					0		BIO		
	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*		
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**
	Materials	**unit**								
1	Bulk Plastics	g			**34860**			3486	31374	**34860**
2	Tec Plastics	g			**4496**			450	4047	**4496**
3	Ferro	g			**144258**			7213	137045	**144258**
4	Non-ferro	g			**8360**			418	7942	**8360**
5	Coating	g			**76270**			3814	72457	**76270**
6	Electronics	g			**1048**			616	315	**931**
7	Misc.	g			**27665**			1383	26282	**27665**
	Total weight	g			**296956**			17380	279461	**296840**

Table 5-25: Material distribution in the Base Case Spiral VM

Materials	Base Case Spiral VM
Bulk Plastics	11.74%
Tec Plastics	1.51%
Ferro	48.58%
Non-ferro	2.82%
Coating	25.68%
Electronics	0.35%
Misc. (cardboard)	0.60%
Misc. (glass)	6.39%
Misc. (ballast)	0.05%
Misc. (ester oil)	0.10%
Misc. (office paper)	0.09%
Misc. (wood)	1.90%
Misc. (refrigerant)	0.18%

- **Primary scrap production during sheet metal manufacturing**

Data collected among manufacturers resulted in a 9 % scrap production during sheet metal manufacturing.

- **Volume and Weight of the packaged product**

The weight of the Base Case Spiral Vending Machine is of 296.956 kg, and it has a packaged volume of 1.4825 m^3. It represents a capacity of 288 cans.

Annual resources consumption

The electrical energy consumption of the base case is of 7.465 kWh/day, which represents 2,724.73 kWh/year. Table 5-26 shows the repartition of the electricity consumption for each module.

Table 5-26: Annual energy consumption for each module

Module	Power consumption (W)	Duty cycle (%)	Electricity Consumption kWh/yr	Electricity Consumption %
Compression Module (Compressor)	403	43.8%	1,544.85	56.7%
Evaporation Module (Evaporator Fan)	35	100.0%	306.60	11.3%
Condensation Module (Condenser Fan)	45	43.8%	172.47	6.3%
Anti-sweat Heater	35	100%	306.60	11.3%
Housing (Lights)	45	100%	394.20	14.5%
Total			2,724.73	100%

5.1.5 CONCLUSIONS

The ferro metal category is the category of materials which is in highest proportion in refrigerated cabinets and vending machines due to the large amount of metal panels used for the housing of these appliances (30 - 75 % of the total mass). The second material used in large quantities is the wood for the pallets facilitating the transport of the refrigeration equipment (up to 5 % of the total mass). When fitted with doors, the second highest quantity of material used is glass (6 - 15 % of the total mass).

Annual resource consumptions per product are very different from one appliance to another depending of the operating temperature range (chilled, frozen) and of the design (open, closed) leading to environmental impacts of different significance.

5.2. BASE CASE ENVIRONMENTAL IMPACT ASSESSMENT

5.2.1 REMOTE REFRIGERATED DISPLAY CABINET

5.2.1.1 BASE CASE OPEN VERTICAL CHILLED MULTI DECK (RCV2)

Overview of the impact assessment results

Table 5-27 shows the results of the environmental impact assessment of base case RCV2 (Remote open vertical chilled multi deck). The use phase impacts are calculated with an average product lifetime of 9 years.

The functional unit is defined here as:

An open vertical remote display cabinet with unlit shelves for use in retail stores, operating 24 hours a day for 9 years providing a chilled display area of 7 m² and maintaining product temperatures between -1 °C and +7 °C (M2) under ambient conditions of 25 °C and 60 % RH. The light in the canopy is turned on 12 hours a day.

If we take the total energy consumption (also known as Gross Energy Requirement, GER[5]) as a reference for the environmental impact, the results indicate that the use phase contributes most significantly to the overall environmental impact (2,667,207 MJ representing almost 98 % of the total over the entire life cycle) followed by the production phase (41,971 MJ) and that the distribution and end-of-life phases represent a minor impact (Figure 5-1 and Figure 5-2). This trend is also true for the electricity consumption as presented in Figure 5-3 and Figure 5-4.

The following paragraphs further analyse the contribution of each module to the total environmental impacts during the whole life cycle, with a focus on the production phase and the use phase.

[5] Which is the primary energy set apart in the various stages of the product life

Table 5-27: Environmental assessment results from EcoReport (RCV2)

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below))

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: RESULTS
Assessment of Environmental Impact

Table . Life Cycle Impact (per unit) of Product Base Case remote open vertical chilled multi deck (RCV2)

Nr	Life cycle Impact per product:	Date	Author
0	Product Base Case remote open vertical chilled multi deck (RCV2)	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**13938**			1394	12544	**13938**	**0**
2	TecPlastics	g			**27203**			2720	24483	**27203**	**0**
3	Ferro	g			**466255**			23313	442942	**466255**	**0**
4	Non-ferro	g			**49134**			2457	46678	**49134**	**0**
5	Coating	g			**21996**			1100	20896	**21996**	**0**
6	Electronics	g			**150**			100	50	**150**	**0**
7	Misc.	g			**35348**			1767	33580	**35348**	**0**
	Total weight	g			**614023**			32851	581173	**614023**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	32401	9570	**41971**	**12904**	**2667207**	2605	2002	**603**	**2722685**
9	of which, electricity (in primary MJ)	MJ	3587	5697	**9284**	**27**	**2666880**	0	133	**-132**	**2676058**
10	Water (process)	ltr	2658	85	**2743**	**0**	**177813**	0	89	**-89**	**180467**
11	Water (cooling)	ltr	17645	2633	**20278**	**0**	**7111636**	0	700	**-700**	**7131213**
12	Waste, non-haz./ landfill	g	1142243	33504	**1175747**	**6248**	**3103746**	37751	509	**37242**	**4322983**
13	Waste, hazardous/ incinerated	g	1067	2	**1069**	**124**	**61461**	4166	84	**4082**	**66737**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	2131	535	**2665**	**762**	**116404**	193	54	**139**	**119970**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	9895	2309	**12205**	**2351**	**686820**	419	126	**293**	**701668**
17	Volatile Organic Compounds (VOC)	g	75	3	**78**	**197**	**1005**	14	1	**13**	**1293**
18	Persistent Organic Pollutants (POP)	ng i-Teq	12557	268	**12825**	**35**	**17608**	260	0	**260**	**30728**
19	Heavy Metals	mg Ni eq.	3287	627	**3914**	**317**	**45791**	740	1	**739**	**50761**
	PAHs	mg Ni eq.	2632	1	**2633**	**423**	**5280**	0	7	**-7**	**8328**
20	Particulate Matter (PM, dust)	g	2251	356	**2607**	**32382**	**14693**	4144	14	**4130**	**53813**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	4724	0	**4724**	**10**	**17242**	198	3	**195**	**22171**
22	Eutrophication	g PO4	343	4	**347**	**0**	**85**	11	3	**8**	**441**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Figure 5-1: Total energy consumption during all life cycle phases

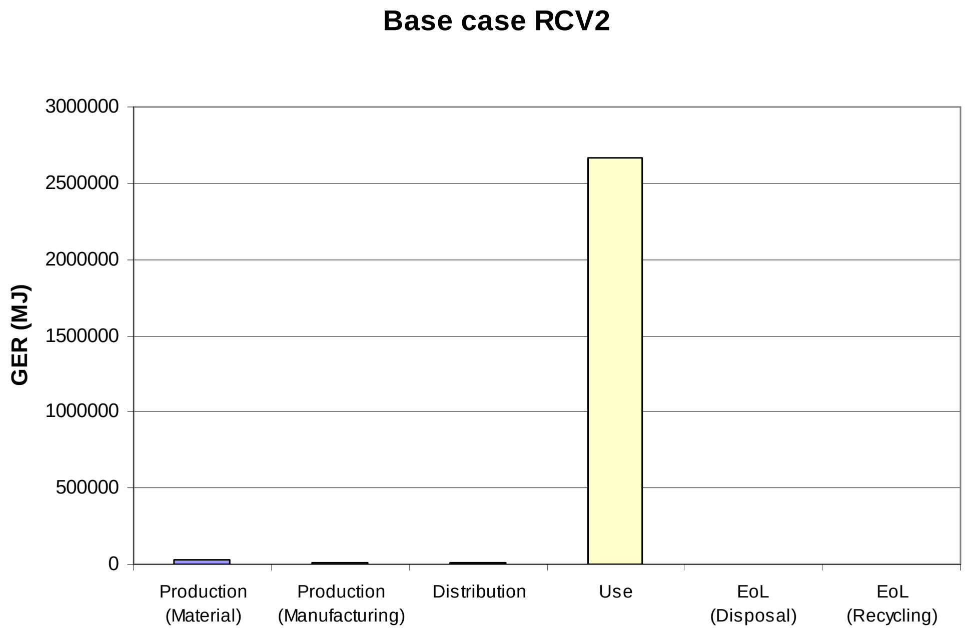


Figure 5-2: Total energy consumption during different life cycle phases (excluding the use phase)

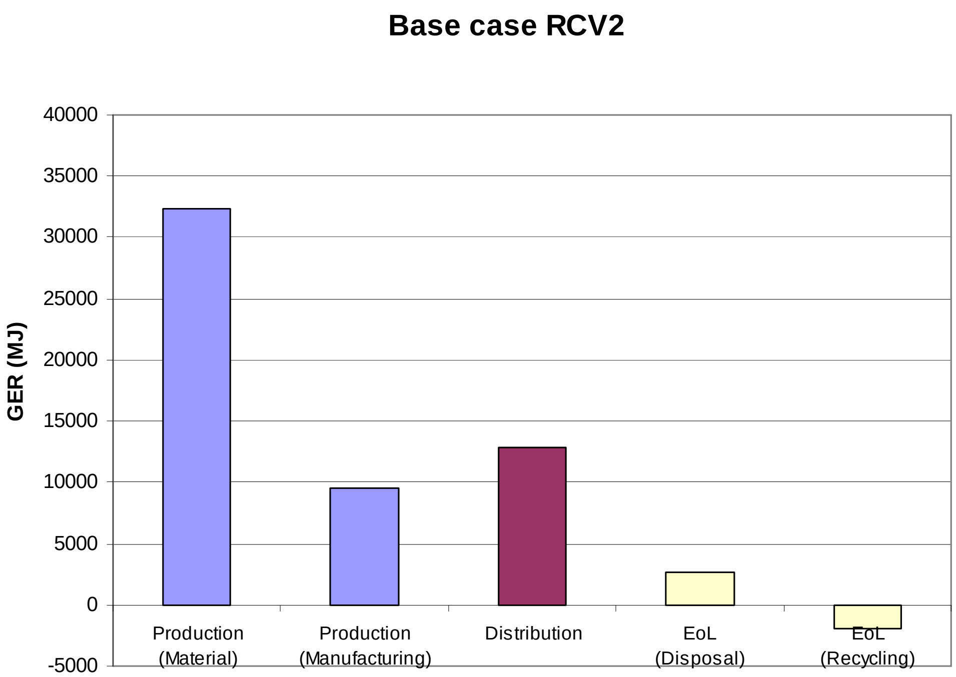


Figure 5-3: Total electricity consumption during all life cycle phases

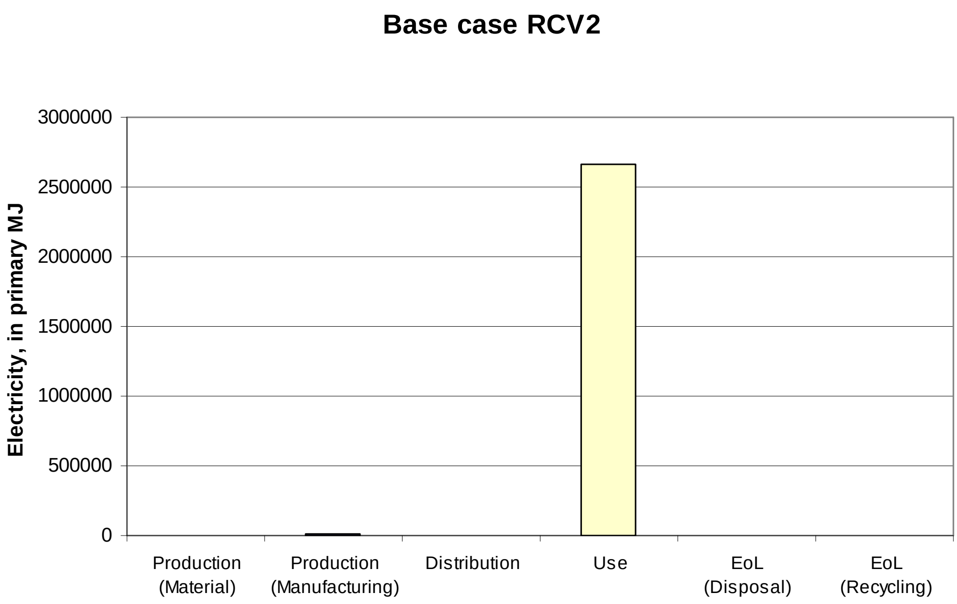
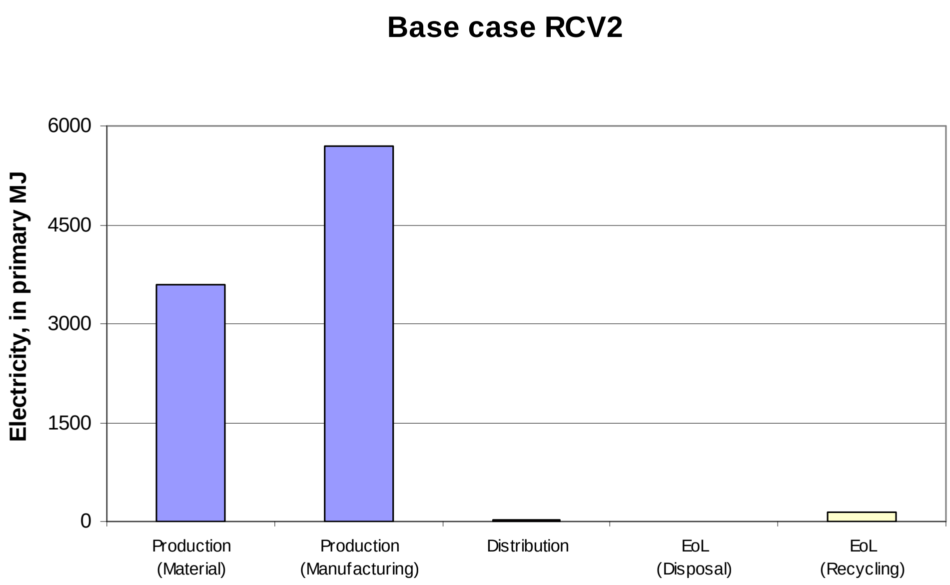


Figure 5-4: Total electricity consumption during different life cycle phases (excluding the use phase)



- **Raw material use (Production phase)**

In order to better identify the significance of each component and material of the cabinet in terms of environmental impacts, the data input of the EcoReport was made following a modular approach. The details of the environmental impacts of the production phase are presented in Annexe 5- 1.

Figure 5-5 and Figure 5-6 show the contribution to the total energy consumption (GER) of different modules during the production phase of the base case RCV2.

Figure 5-5: Total energy consumption (GER) related to the production phase

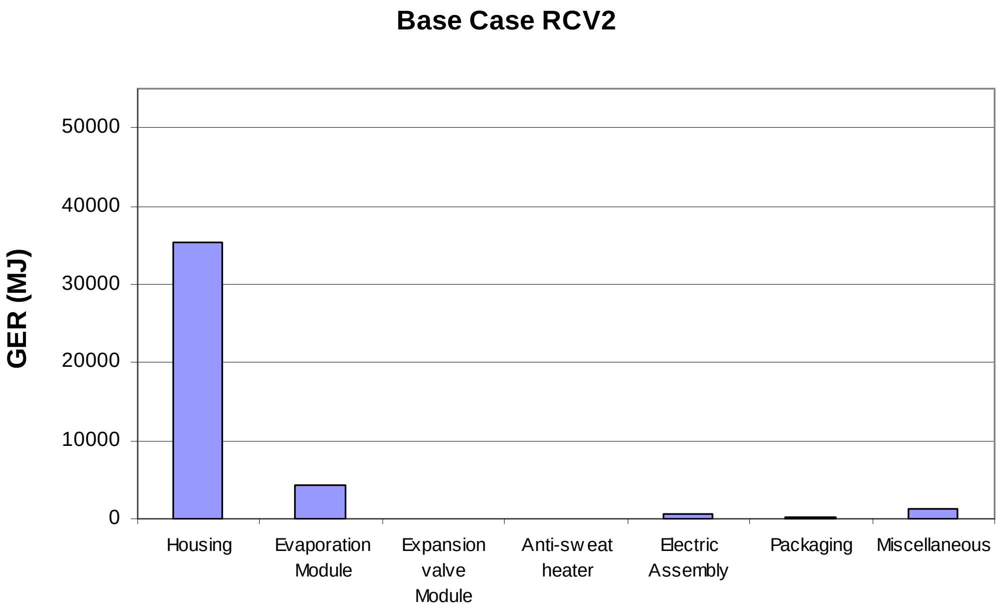
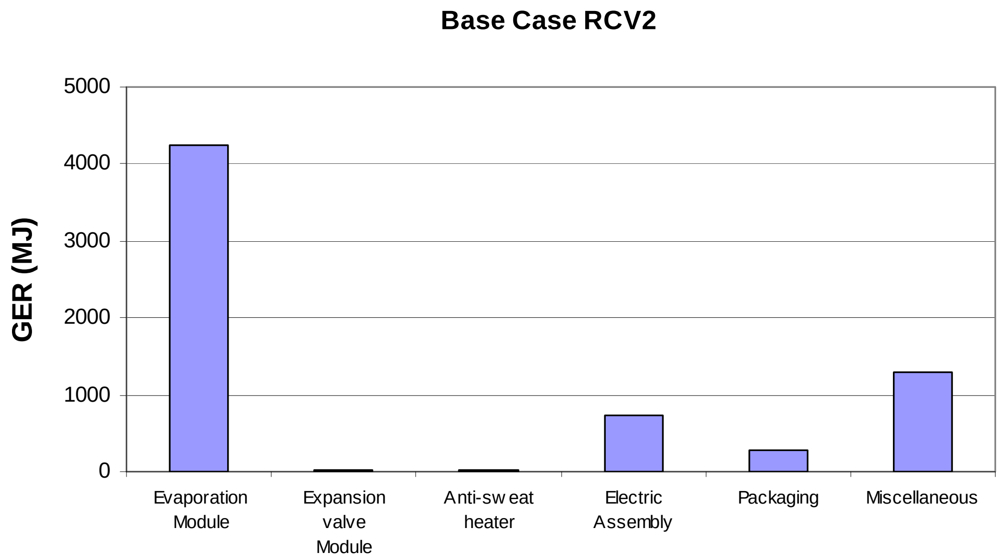


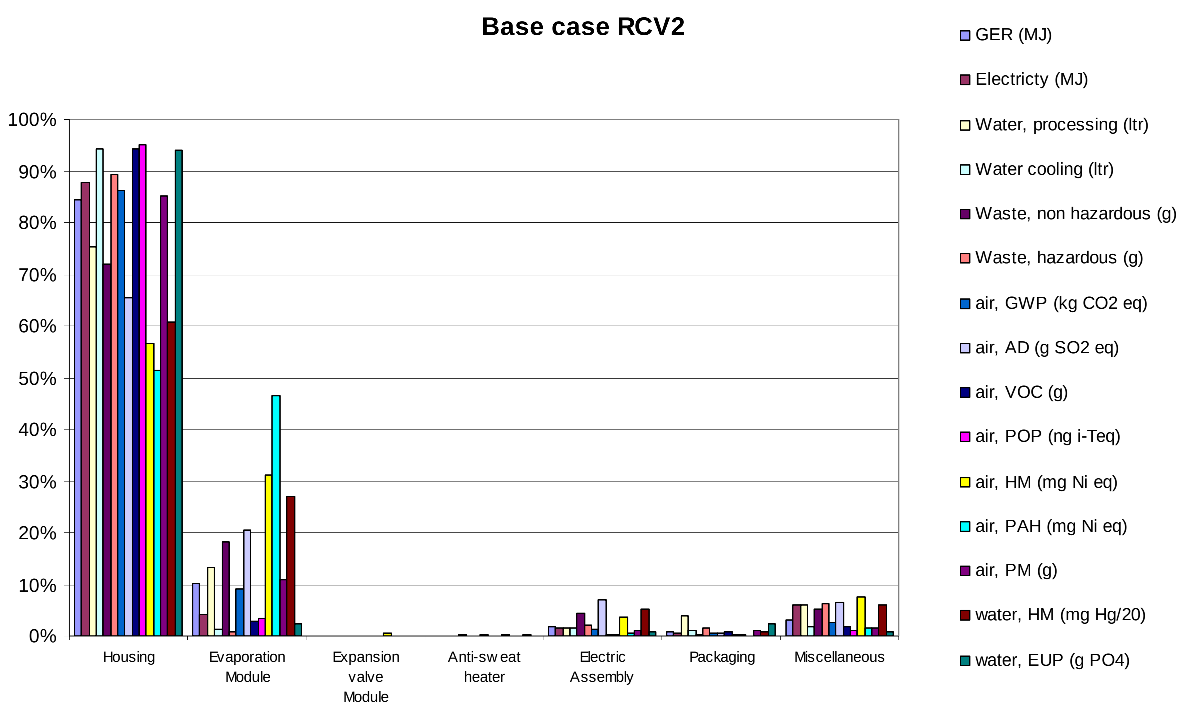
Figure 5-6: GER related to the production phase (excluding the housing)



It is clearly visible that the housing contributes the bulk (> 80 %) of the total energy consumption during production phase, followed by the evaporation module. This can be explained by the high mass proportion of these two modules (housing and evaporation modules represent 85 % and 5.95 % mass of the base case RCV2 respectively).

While looking at other environmental impacts, the results indicate that housing and the evaporation modules remain the most significant contributors (Figure 5-7).

Figure 5-7: Impacts related to production phase for each module



- Housing

Most of the environmental impacts from the housing derive from the 190 kg of stainless sheet metal (21-St Sheet galv.) used for the cabinet panels and structure (external panels, air discharge grill, and internal parts).

Taking into account the housing module only, the panels and cabinet structure represent the biggest proportion of the following environmental indicators: GER, Non-hazardous waste, Global warming potential (GWP), Acidification emission to air (AD), volatile organic compounds (VOC), persistent organic pollutant (POP), Heavy metal to air (HM), and particulate matter emission to air (PM).

Second major contribution to the impacts related to the housing originates from the plastic foam insulation made of about 25 kg of 15-Rigid PUR (polyurethane). The insulation represents the main source of impacts of the housing concerning the following EcoReport indicators: water (process), water (cool), hazardous waste, polycyclic aromatic hydrocarbon (PAH), heavy metal to water (HM) and eutrophication (EUP).

The epoxy coating on the surface of the panels also represents a non negligible impact as well as the 133 kg of 21-St Sheet galv. used for the shelves.

Considering these results, the potential reduction of the total mass of stainless sheet metals could be discussed as an area of improvement. When discussing the possibility of reducing the amount of plastic foam, it should be taken into account that reducing the foam insulation reduces the performance of the cabinet by increasing the risks of heat gains through conduction.

- Evaporation Module

In the evaporation module, the 16 kg of copper (30-Cu tube/sheet) used for the suction line of the evaporator are the main responsible of the environmental impacts and more specifically considering the following environmental indicators: AD, POP, HM to air and water.

The aluminium fins (26-Al sheet/extrusion, about 10 kg) used in the evaporator are the second big contributor to the impacts related to the production phase of the evaporation module and they represent the biggest part of the GER, GWP, PAH, and PM.

However, reducing these two materials would reduce the performance of the evaporator by decreasing the heat exchange surface, leading to a lower efficiency of the cabinet.

For each environmental indicator, the three major contributors are summarised in Table 5-28.

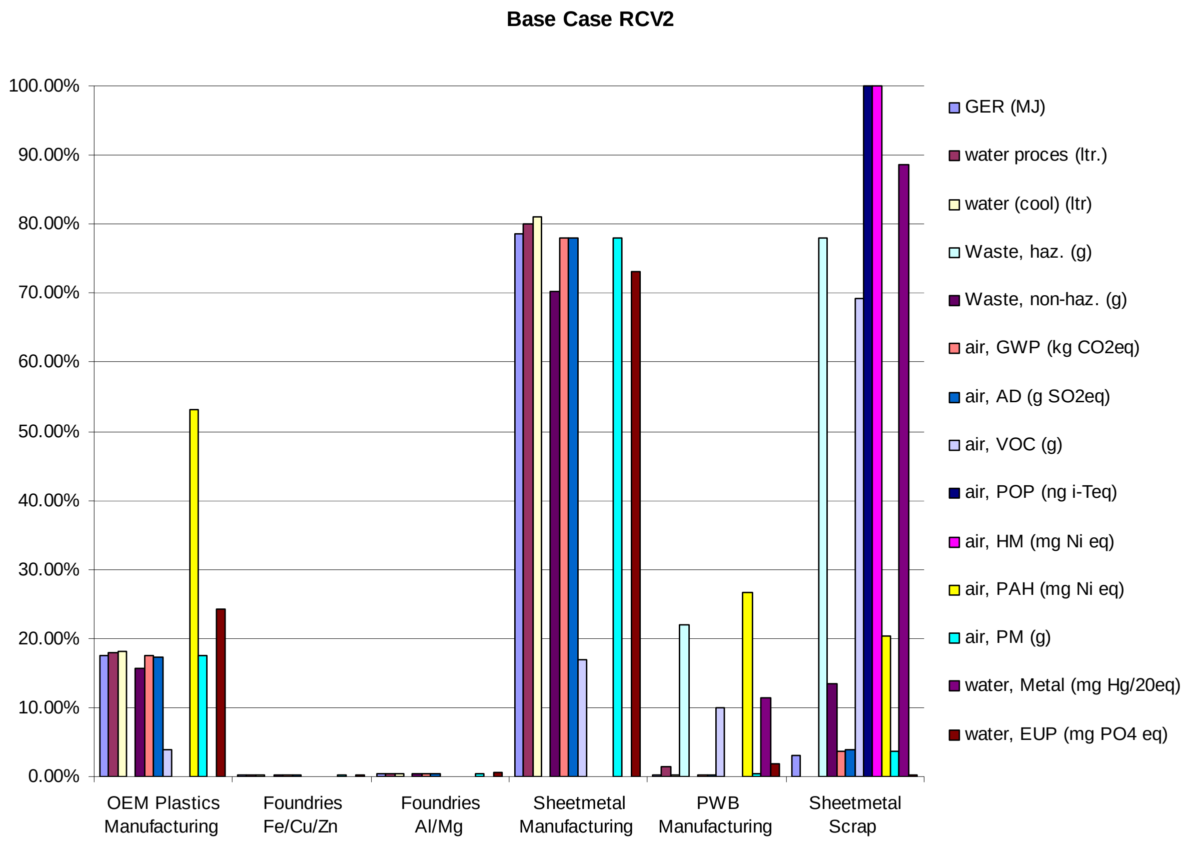
Table 5-28: Three highest contributors in terms of environmental impacts

Impact category		Highest contributor		Second highest contributor		Third highest contributor	
		component	percentage	component	percentage	component	percentage
Energy	GER	Panels and cabinet structure	20%	Shelves	14%	Epoxy coating (External housing)	9%
Water	water (proces)	Foam insulation	57%	Fan grid	8%	Epoxy coating (External housing)	6%
	water (cool)	Foam insulation	43%	Epoxy coating (External housing)	17%	Panels pre coating (External housing)	12%
Waste	haz. Waste	Foam insulation	46%	Epoxy coating (External housing)	15%	Panels pre coating (External housing)	10%
	non-haz. Waste	Panels and cabinet structure	29%	Shelves	20%	Copper suction line (Evaporator)	11%
Emissions to Air	GWP	Panels and cabinet structure	25%	Shelves	18%	Chassis (External housing)	8%
	AD	Panels and cabinet structure	14%	Copper suction line (Evaporator)	10%	Shelves	10%
	VOC	Panels and cabinet structure	35%	Shelves	24%	Chassis (External housing)	11%
	POP	Panels and cabinet structure	39%	Shelves	28%	Chassis (External housing)	12%
	HM	Panels and cabinet structure	20%	Copper suction line (Evaporator)	16%	Shelves	14%
	PAH	Aluminium fins (Evaporator)	40%	Foam insulation	19%	PS parts (External housing)	14%
	PM	Panels and cabinet structure	23%	Shelves	16%	Foam insulation	8%
Emissions to Water	Metal	Foam insulation	23%	Panels and cabinet structure	14%	Copper suction line (Evaporator)	13%
	EUP	Foam insulation	23%	Epoxy coating (External housing)	22%	Panels pre coating (External housing)	15%

- **Manufacturing phase (production phase)**

As shown in Figure 5-2, the manufacturing phase is of minor relevance compared to the “material extraction and production” phase. If we consider the manufacturing phase only, most of the environmental impacts are due to the sheet metal manufacturing (almost 500 kg) and to the sheet metal scrap (almost 25 kg) as shown in Figure 5-8.

Figure 5-8: Impacts related to the manufacturing phase



In the production phase (production and manufacturing) for the base case RCV2, major impacts are due to the material and manufacture of the housing and of the evaporator. However, modification of the design of these components would imply reduction of the performance of the appliance during the use phase and therefore cannot really be considered as an area of improvement. Focus should be made on the use phase which represents the most impacting phase (over 95 % of the total life cycle GER).

Distribution, Use and End-of-Life phase

When comparing the environmental impacts of the distribution phase with the other life cycle stages, the contribution of the distribution phase is negligible as illustrated in Figure 5-9 and Figure 5-10.

Due to electricity consumption, the use phase represents most of the total GER, waste production, and emissions to air and water. The GER consumed during the use phase is over 60 times higher than for the production phase. This indicates that the most significant environmental improvement should be reduction of the electricity consumption. As described in task 4 (section 4.3.3.1), the REC is the predominant proportion of the total electrical energy consumption and DEC represents only 9.25 % of the TEC. For this reason, the task 7 will investigate technologies that help to reduce the power consumption (e.g.

improved air curtain) and improve the energy efficiency (e.g. high efficiency fan motors).

Figure 5-9: Environmental impacts during all life cycle phases

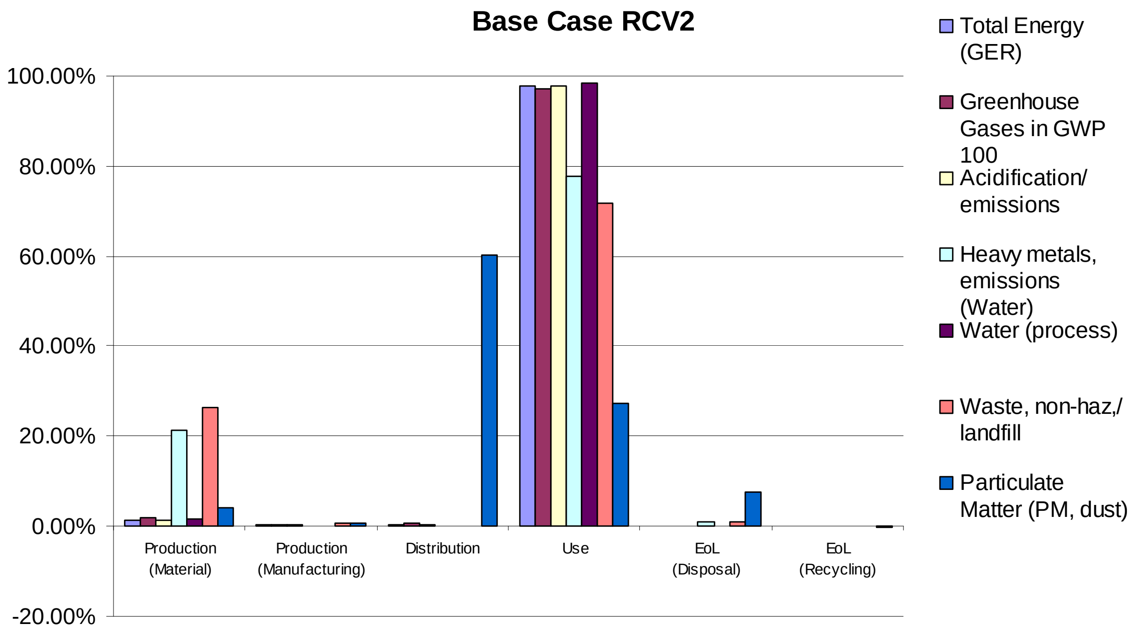
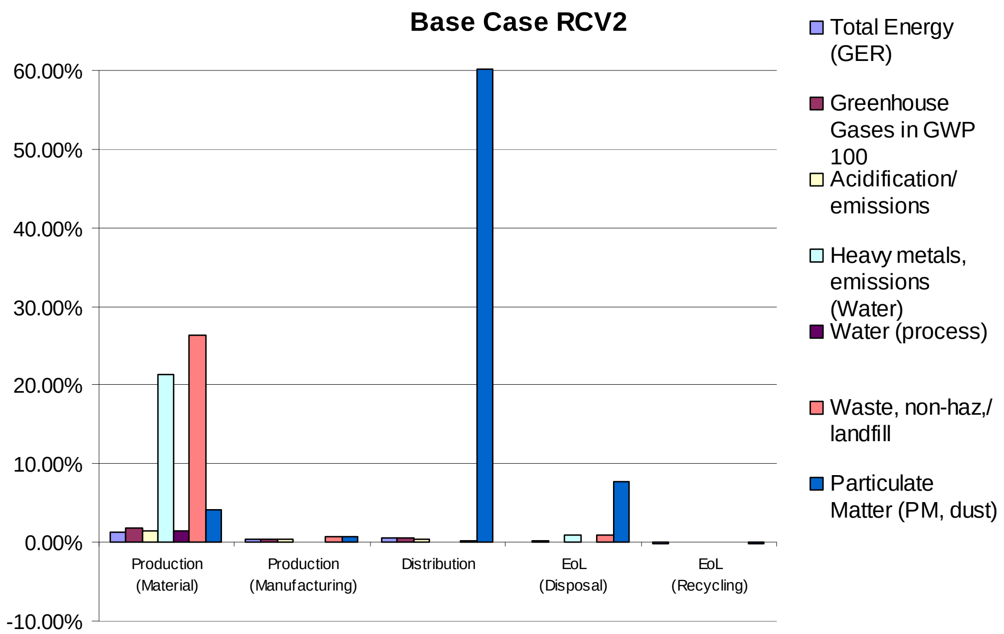


Figure 5-10: Environmental impacts during different life cycle phases (excluding the use phase)



Environmental impact of the blowing agent

The base case RCV2 contains 338.7 g of Cyclopentane and 583.9 g of R 134a used in the plastic foam insulation. The EcoReport tool does not consider the impacts of the production phase of the refrigerants (such as R 134a) as they represent minor emissions with respect to the direct impact. The impacts during use phase are non-existent as the blowing agent is contained in the insulation material. During end-of-life, when considering the worst scenario: the blowing agent is not recovered, the contribution to the GWP of the R 134a is of about 764 kg CO_2 eq. which is negligible compared to the 116,377 kg eq. CO_2 due to the electricity consumption.

Cyclopentane has no GWP but can be responsible of VOC emissions. However, these were ignored as they represent a minor impact compared to the other sources of VOC during the whole life cycle.

5.2.1.2 Base case Horizontal open frozen island (RHF4)

Overview of the impact assessment results

Table 5-29 shows the results of the environmental impact assessment of the base case RHF4 (remote open frozen island). The use phase impacts are calculated with an average product lifetime of 9 years.

The functional unit is defined here as:

An open horizontal display cabinet for use in retail stores, operating 24 hours a day for 9 years, providing a frozen display area of 7 m² and maintaining product temperatures between -18℃ and -12℃ (L2) under amb ient conditions of 25℃ and 60 % RH.

If we take the total energy consumption (GER) as reference for the environmental impact, the results indicate that the use phase is the most important contributor to the overall environmental impact (2,806,108 MJ representing almost 98 % of the total over the whole life cycle), followed by the production phase (48,835 MJ). The distribution and end-of-life phases represent a low impact (see Figure 5-11 and Figure 5-12). This trend is also verified for the electricity consumption, as shown in Figure 5-13 and Figure 5-14.

Table 5-29: Environmental assessment results from EcoReport (RHF4)

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below))

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: RESULTS
Assessment of Environmental Impact

Table . Life Cycle Impact (per unit) of Base Case remote open frozen island (RHF4)

Nr	Life cycle Impact per product:	Date	Author
0	Base Case remote open frozen island (RHF4)	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**31469**			3147	28322	**31469**	**0**
2	TecPlastics	g			**21090**			2109	18981	**21090**	**0**
3	Ferro	g			**458430**			22922	435509	**458430**	**0**
4	Non-ferro	g			**65531**			3277	62255	**65531**	**0**
5	Coating	g			**21557**			1078	20479	**21557**	**0**
6	Electronics	g			**1282**			1167	116	**1282**	**0**
7	Misc.	g			**194298**			9715	184583	**194298**	**0**
	Total weight	g			**793658**			43413	750244	**793658**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	38723	10111	**48835**	**11993**	**2806108**	3363	2551	**812**	**2867748**
9	of which, electricity (in primary MJ)	MJ	5460	6012	**11472**	**25**	**2805735**	1	176	**-175**	**2817057**
10	Water (process)	ltr	4319	91	**4410**	**0**	**187085**	0	119	**-119**	**191376**
11	Water (cooling)	ltr	18512	2786	**21298**	**0**	**7481866**	0	896	**-896**	**7502268**
12	Waste, non-haz./ landfill	g	1260053	35205	**1295258**	**5809**	**3265910**	48794	667	**48126**	**4615103**
13	Waste, hazardous/ incinerated	g	1627	2	**1629**	**115**	**64666**	5374	114	**5260**	**71671**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	2457	565	**3022**	**709**	**122466**	249	68	**181**	**126377**
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	13277	2441	**15718**	**2186**	**722604**	540	164	**376**	**740884**
17	Volatile Organic Compounds (VOC)	g	85	4	**89**	**183**	**1058**	18	1	**17**	**1346**
18	Persistent Organic Pollutants (POP)	ng i-Teq	12085	271	**12356**	**33**	**18513**	336	0	**336**	**31237**
19	Heavy Metals	mg Ni eq.	4731	635	**5366**	**295**	**48188**	955	2	**953**	**54802**
	PAHs	mg Ni eq.	5057	1	**5059**	**393**	**5578**	0	10	**-10**	**11019**
20	Particulate Matter (PM, dust)	g	2566	377	**2943**	**30088**	**15460**	5340	18	**5322**	**53813**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	6334	0	**6334**	**9**	**18153**	256	8	**248**	**24745**
22	Eutrophication	g PO4	343	4	**348**	**0**	**90**	15	4	**11**	**448**
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Figure 5-11: Total energy consumption during all life cycle phases

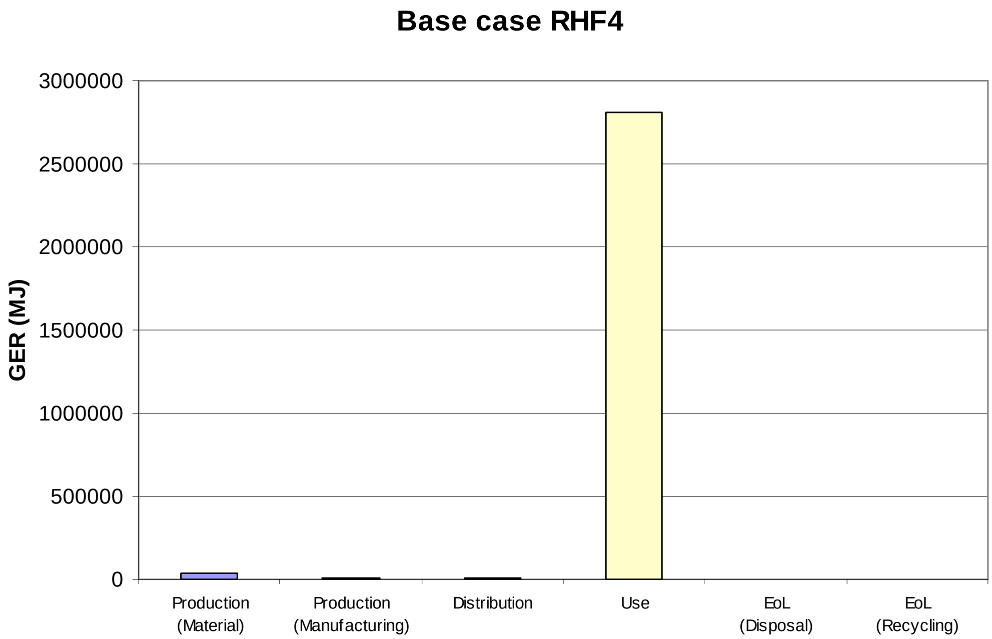


Figure 5-12: Total energy consumption during different life cycle phases (excluding the use phase)

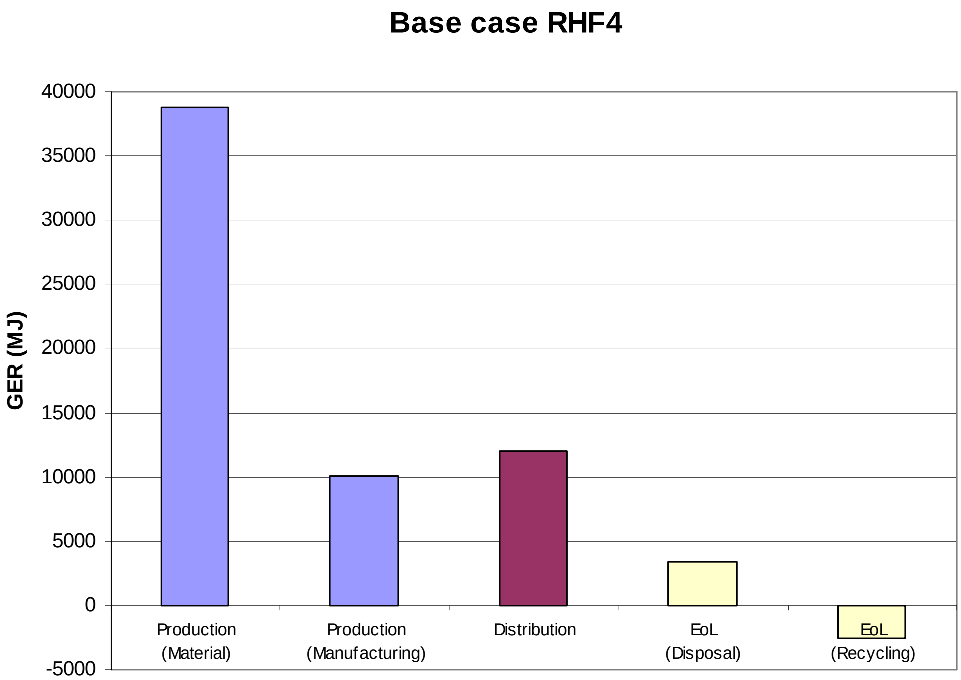


Figure 5-13: Total electricity consumption during all life cycle phases

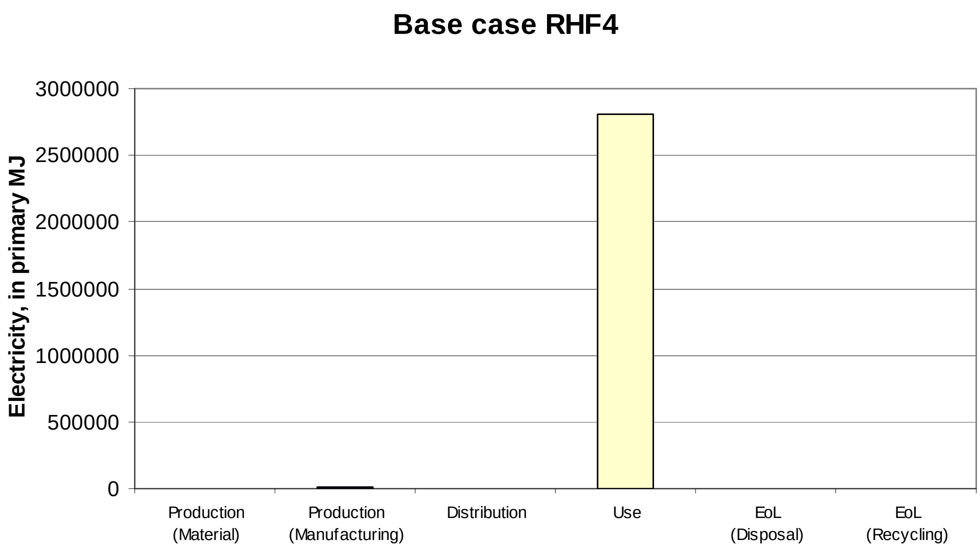
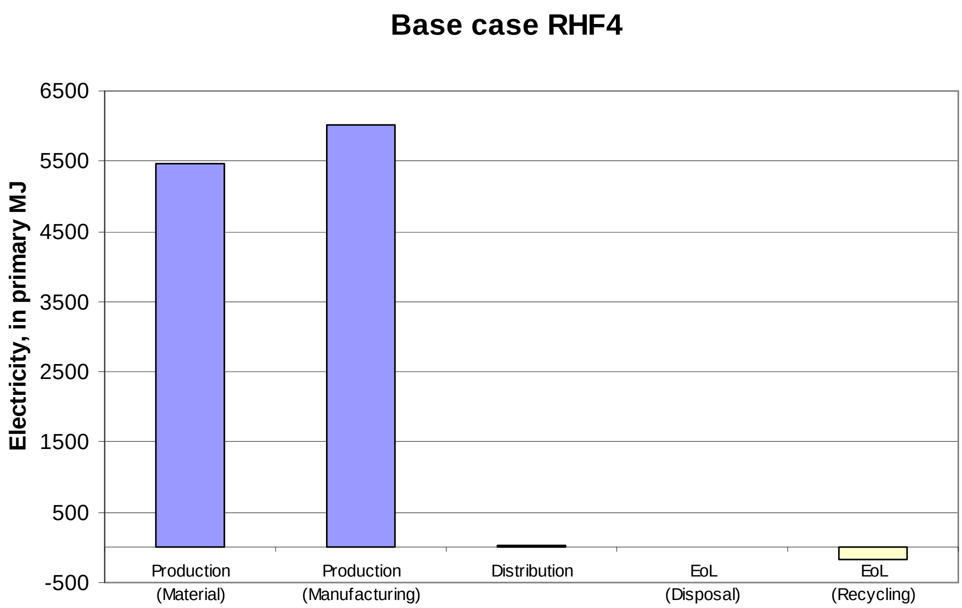


Figure 5-14: Total electricity consumption during different life cycle phases (excluding the use phase)



- **Raw material use and manufacturing (Production phase)**

The details of the environmental impacts of the production phase are presented in Annexe 5- 2.

Figure 5-15 and Figure 5-16 show the contribution of each module to the GER for the production phase of the base case RHF4.

Figure 5-15: Total energy consumption (GER) related to the production phase

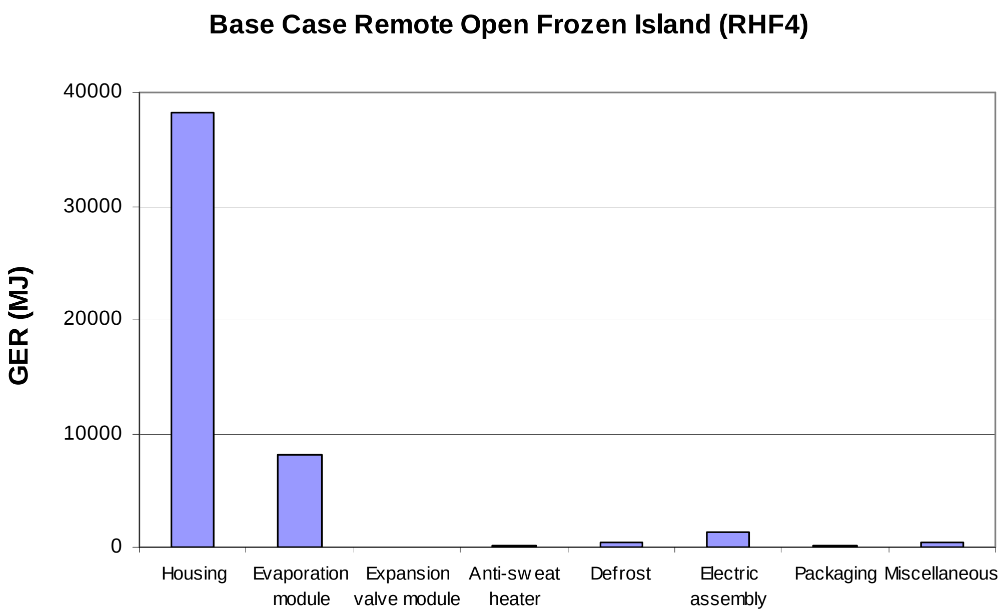


Figure 5-16: GER related to the production phase (excluding the housing)

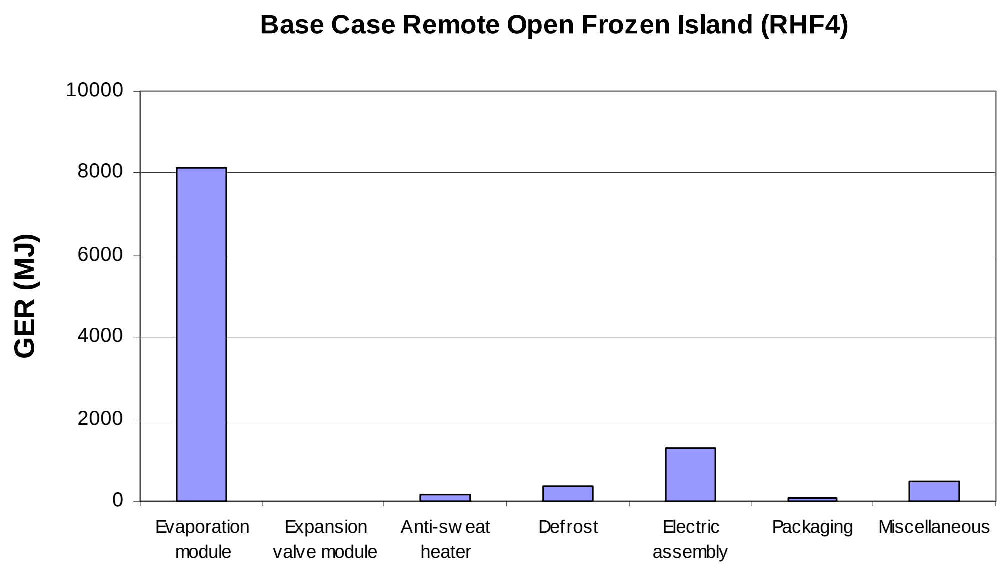
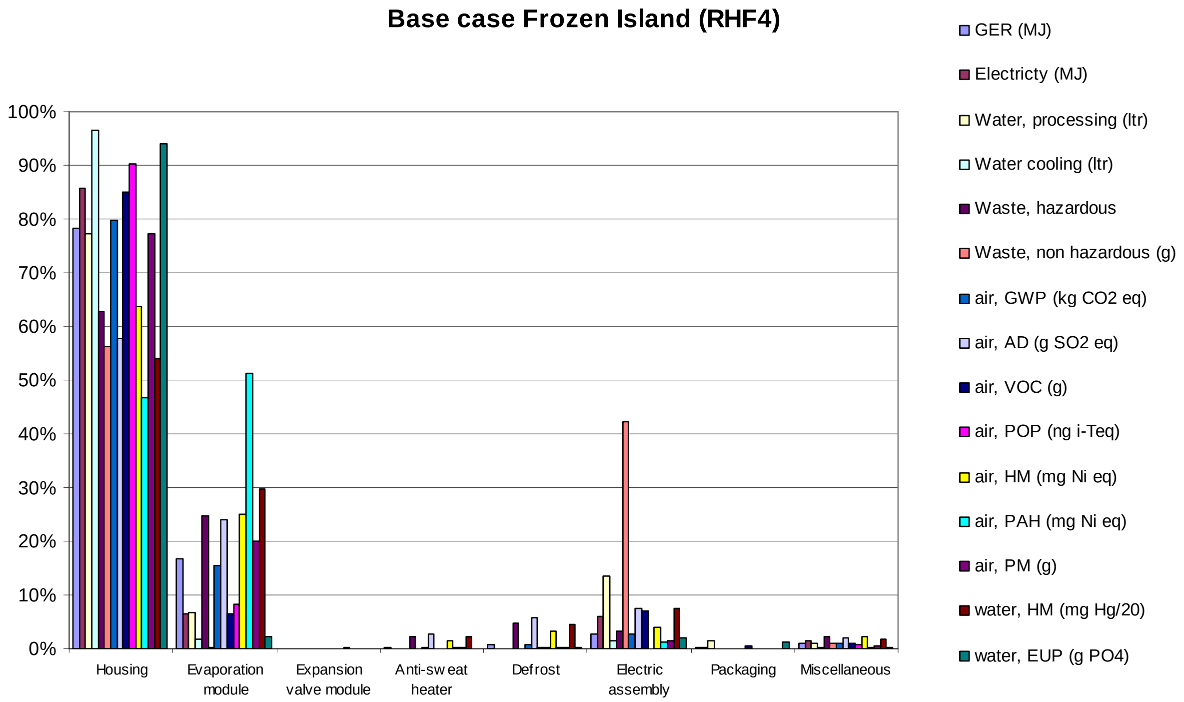


Figure 5-15 clearly shows that the housing contributes the greater part (~ 78 %) of the total energy consumption during production phase, followed by the evaporation module (~ 17 %). The high mass proportion of these two modules (~ 77 % for the housing and ~ 9 % for the evaporation module) can explain this trend.

While looking at other environmental impacts, the results indicate (Figure 5-17) that the housing and the evaporation module remain the most significant contributors. It is also noticeable that the electric assembly module has a high impact regarding non hazardous waste.

Figure 5-17: Impacts related to the production phase for each module



- Housing

Most of the environmental impacts from the housing derive from the 412 kg of stainless sheet metal (21-St sheet galv.) used for the cabinet chassis and panels. Thereby, these components represent the biggest proportion of the following environmental indicators: GER, non hazardous waste, GWP, AD, VOC, POP, HM, PM and emissions of metals to water.

Besides, the part of the chassis and the panels pre-coating (38-pre coating coil), weighting about 17 kg, has an important part of the environmental impacts related to the electricity and water used.

Then, the plastics used for the foam insulation, 19 kg of polyurethane (15-Rigid PUR) and 17 kg of expandable polystyrene (6-EPS), are the main responsible of PAH and EUP. One way of limiting these impacts could be the reduction of these materials. Nevertheless, reducing the foam insulation would increase the heat convection and thus the electricity consumption of the remote open frozen island.

- Evaporation Module

In the evaporation module, the 25 kg of aluminium (26-Al sheet/extrusion) used for the fins of the evaporator are the main responsible of the environmental impacts, especially for the following indicators: GER, GWP, AD, PAH, PM and emissions of metal to water.

The 20 kg of copper (30-Cu tube/sheet) used in the suction lines of the evaporator are the second big contributor to the environmental impacts related to the production phase of the evaporation module and they represent the biggest part of the non hazardous waste, HM and eutrophication.

As for the base case RCV2, reducing the amount of those two materials in the evaporator would affect the performance of the RHF4 and increase the electricity consumption.

For each environmental indicator, the three major contributors are summarised in Table 5-30.

Table 5-30: Three highest contributors in terms of environmental impacts

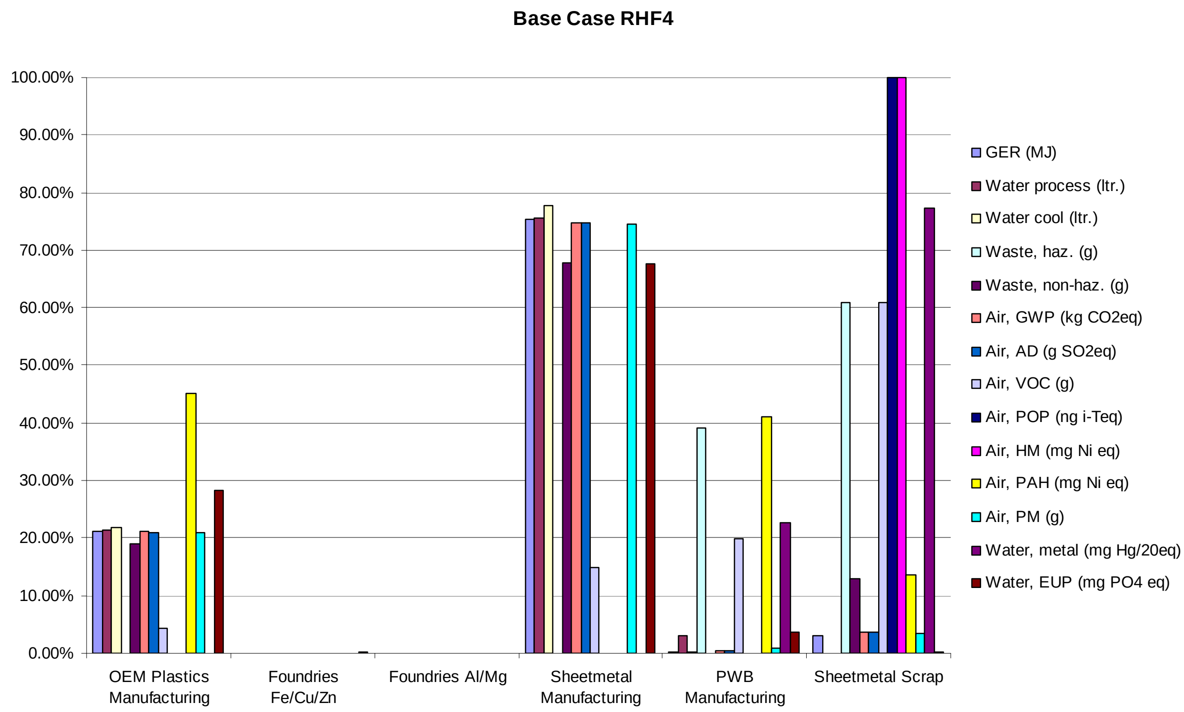
Impact category		Highest contributor		Second highest contributor		Third highest contributor	
		component	percentage	component	percentage	component	percentage
Energy	GER	Chassis and panels (external housing)	36%	Chassis and panels pre coating (external housing)	14%	Aluminium fins (evaporator)	12%
Water	water (proces)	Polyurethane (foam insulation)	26%	Glass (external housing)	20%	Chassis and panels (external housing)	16%
	water (cool)	Chassis and panels pre coating (external housing)	35%	Polyurethane (foam insulation)	31%	Expandable Polystyrene (foam insulation)	16%
Waste	haz. Waste	Controller board (electric panel)	34%	Polyurethane (foam insulation)	23%	Chassis and panels pre coating (external housing)	20%
	non-haz. Waste	Chassis and panels (external housing)	56%	Copper suction line (evaporator)	12%	Aluminium fins (evaporator)	8%
Emissions to Air	GWP	Chassis and panels (external housing)	47%	Chassis and panels pre coating (external housing)	11%	Aluminium fins (evaporator)	11%
	AD	Chassis and panels (external housing)	23%	Aluminium fins (evaporator)	13%	Copper suction line (evaporator)	9%
	VOC	Chassis and panels (external housing)	66%	Chassis and panels pre coating (external housing)	16%	Controller board (electric panel)	6%
	POP	Chassis and panels (external housing)	89%	Evaporator tray (evaporator)	4%	Copper suction line (evaporator)	2%
	HM	Chassis and panels (external housing)	31%	Chassis and panels (external housing)	28%	Copper suction line (evaporator)	14%
	PAH	Aluminium fins (evaporator)	48%	Expandable Polystyrene (foam insulation)	20%	Chassis and panels (external housing)	18%
	PM	Chassis and panels (external housing)	43%	Aluminium fins (evaporator)	16%	Chassis and panels pre coating (external housing)	10%
Emissions to Water	Metal	Chassis and panels (external housing)	23%	Aluminium fins (evaporator)	14%	Polyurethane (foam insulation)	13%
	EUP	Chassis and panels pre coating (external housing)	47%	Polyurethane (foam insulation)	17%	Epoxy coating (externam housing)	13%

- **Manufacturing phase (production phase)**

If we consider only the manufacturing in the whole production phase, most of the environmental impacts are due to the sheet metal manufacturing (about

500 kg) and to the sheet metal scrap (about 25 kg) as presented in Figure 5-18**.**

Figure 5-18: Impacts related to the manufacturing phase



The production phase, including the production and manufacturing stages, for the base case RHF4, has a very low environmental impact compared to the use phase, if we consider the GER as reference (1.70 % vs. 97.85 %). The housing and the evaporation module are responsible of most of the impacts in this production phase. Nevertheless, as for the base case RCV2, material improvements of these components could have a negative effect on the performance of the open frozen island. The reduction of the electricity consumption (i.e. the use phase) of this type of appliance seems to be the main stake.

- **Distribution, Use and End-of-Life phase**

Compared to the other life cycles phases, the distribution has a minor environmental impact as presented in Figure 5-19 and Figure 5-20, except for emissions of particulate matter to air.

Due to the electricity consumption, the use phase, defined by a product lifetime of nine years, contributes mostly to the GER, to the waste production, and to the emissions to air and water. This shows that the most important aspect related to the environmental improvement is the electricity consumption. As described in task 4 (section 4.3.3.1), the REC represents 76.63 % of the TEC.

Figure 5-19: Environmental impacts during all life cycle phases

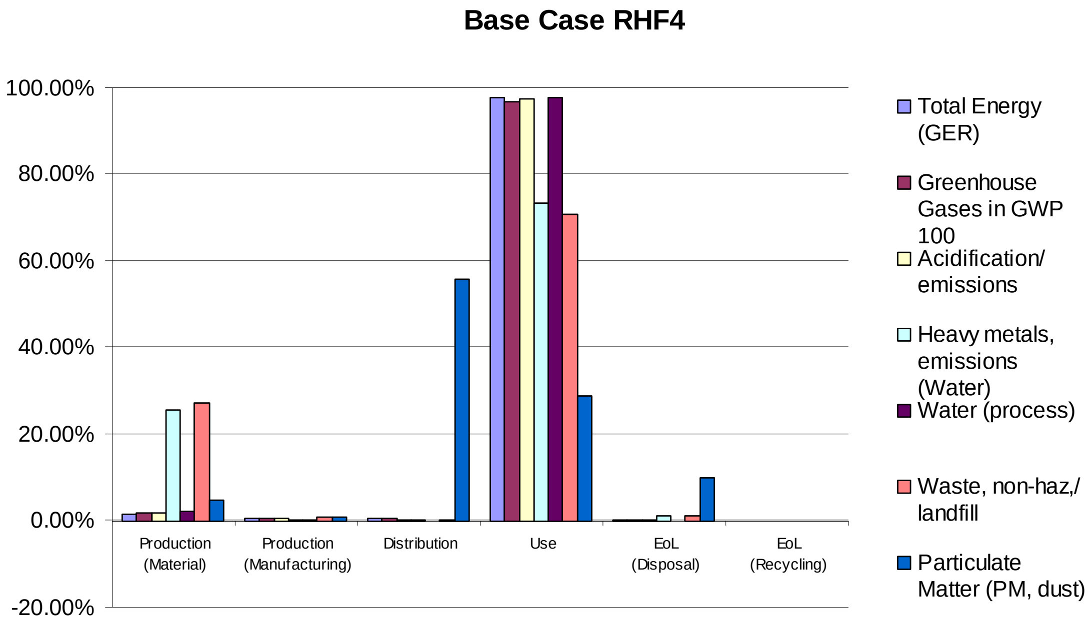
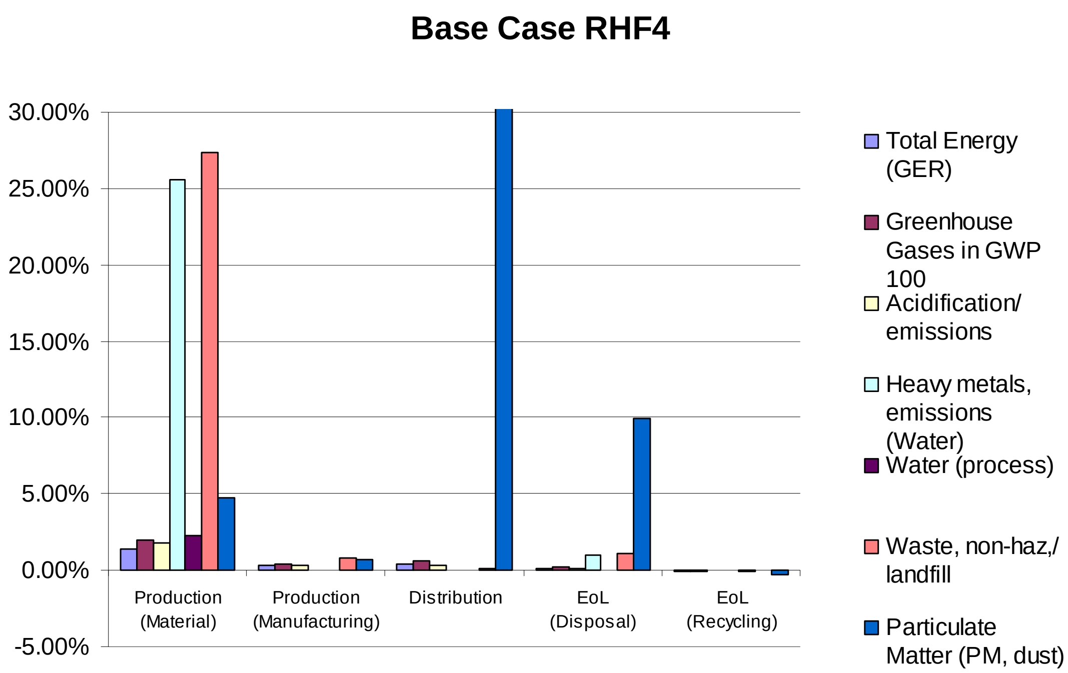


Figure 5-20: Environmental impacts during different life cycle phases (excluding the use phase)



- **Environmental impact of the blowing agent**

As for the base case RCV2, the blowing agents containing in the cabinet (Cyclopentane and R 134a) are not assessed in term of environmental impacts. Nevertheless, their contribution to the GWP and VOC are negligible compared to the entire life cycle.

5.2.2 PLUG IN REFRIGERATED DISPLAY CABINETS

5.2.2.1 BASE CASE BEVERAGE COOLER

- **Overview of the impact assessment results**

The results of the EcoReport impact assessment are given in Table 5-31. The impacts of the use phase are calculated on the basis of an 8 years life time.

The functional unit is defined here as:

A plug in vertical display cabinet fitted with doors with shelves, operating 24 hours a day for 8 years providing a chilled display volume of 500 litres and maintaining product temperatures around 5°C under ambient conditions of 30 °C and 55 % RH (climate class 4). The lights are turned on 12 hours a day. The doors are opened following the ISO 23953 standard parameters.

Concerning the refrigerant, the annual leakage rate, taking into account the fact that refrigerant recovery for these appliances is relatively non-existent is assumed to be 9.5 %. The overall percentage of fugitive and dumped refrigerant during the entire lifetime of 8 years is estimated to 76 %.

When taking the GER as reference for the environmental impacts, the results show that the use phase is once again the phase which is the most important. It is responsible of 96 % of the GER required during the whole product life (Figure 5-21). The production phase is the second most significant stage representing 3.4 % of the GER over product lifetime. The distribution and end-of-life phase are negligible (Figure 5-22). This trend is confirmed when taking the electricity consumption as reference, as presented in Figure 5-23 and Figure 5-24.

Table 5-31: Environmental assessment results from EcoReport

Table . Life Cycle Impact (per unit) of BASE CASE BEVERAGE COOLER

Nr	Life cycle Impact per product:	Date	Author
0	BASE CASE BEVERAGE COOLER	0	BIO IS

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**5495**			550	4946	**5495**	**0**
2	TecPlastics	g			**8756**			876	7880	**8756**	**0**
3	Ferro	g			**68915**			3446	65469	**68915**	**0**
4	Non-ferro	g			**12804**			640	12164	**12804**	**0**
5	Coating	g			**900**			45	855	**900**	**0**
6	Electronics	g			**64**			32	32	**64**	**0**
7	Misc.	g			**26189**			1309	24880	**26189**	**0**
	Total weight	g			**123124**			6898	116226	**123124**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	5984	1615	**7599**	**1598**	**216000**	597	671	**-73**	**225124**
9	of which, electricity (in primary MJ)	MJ	699	954	**1654**	**3**	**215940**	0	48	**-48**	**217550**
10	Water (process)	ltr	1069	15	**1084**	**0**	**14406**	0	32	**-32**	**15457**
11	Water (cooling)	ltr	3754	439	**4194**	**0**	**575838**	0	243	**-243**	**579789**
12	Waste, non-haz./ landfill	g	203636	5845	**209480**	**797**	**252446**	7586	181	**7405**	**470129**
13	Waste, hazardous/ incinerated	g	286	1	**287**	**16**	**4978**	1458	31	**1427**	**6708**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	363	90	**453**	**96**	**9427**	52	17	**36**	**10012**
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	2248	392	**2640**	**294**	**55627**	100	43	**58**	**58618**
17	Volatile Organic Compounds (VOC)	g	10	1	**11**	**24**	**81**	4	0	**3**	**120**
18	Persistent Organic Pollutants (POP)	ng i-Teq	1684	61	**1744**	**5**	**1433**	52	0	**52**	**3234**
19	Heavy Metals	mg Ni eq.	813	142	**955**	**40**	**3714**	167	0	**166**	**4876**
	PAHs	mg Ni eq.	1004	0	**1004**	**53**	**435**	0	3	**-3**	**1490**
20	Particulate Matter (PM, dust)	g	441	61	**502**	**3898**	**1193**	1038	5	**1034**	**6626**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	1108	0	**1108**	**1**	**1403**	43	2	**41**	**2554**
22	Eutrophication	g PO4	46	1	**46**	**0**	**7**	2	1	**1**	**55**
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Figure 5-21: Total energy consumption during all life cycle phases

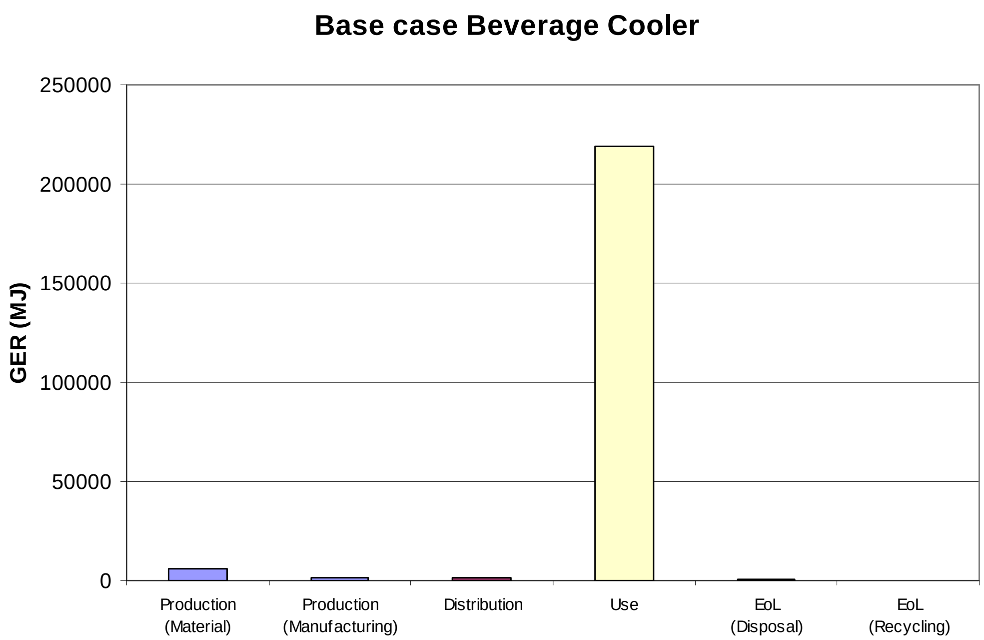


Figure 5-22: Total energy consumption during different life cycle phases (excluding the use phase)

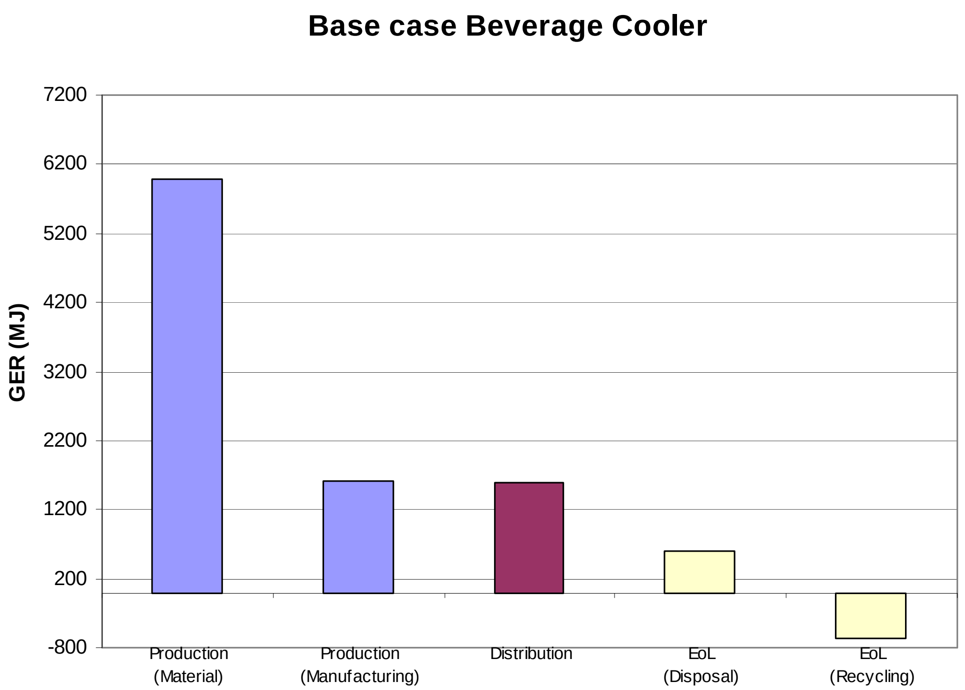


Figure 5-23: Total electricity consumption for all life cycle phases

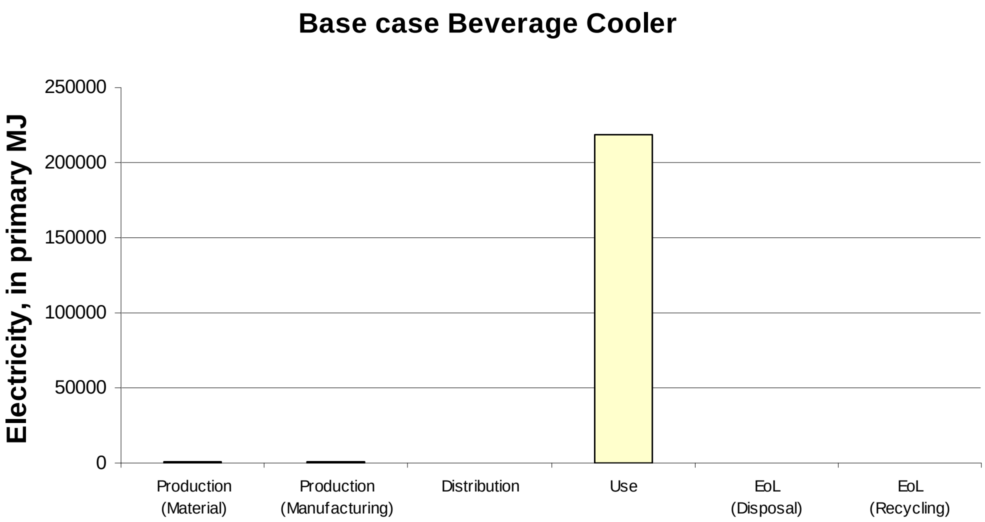
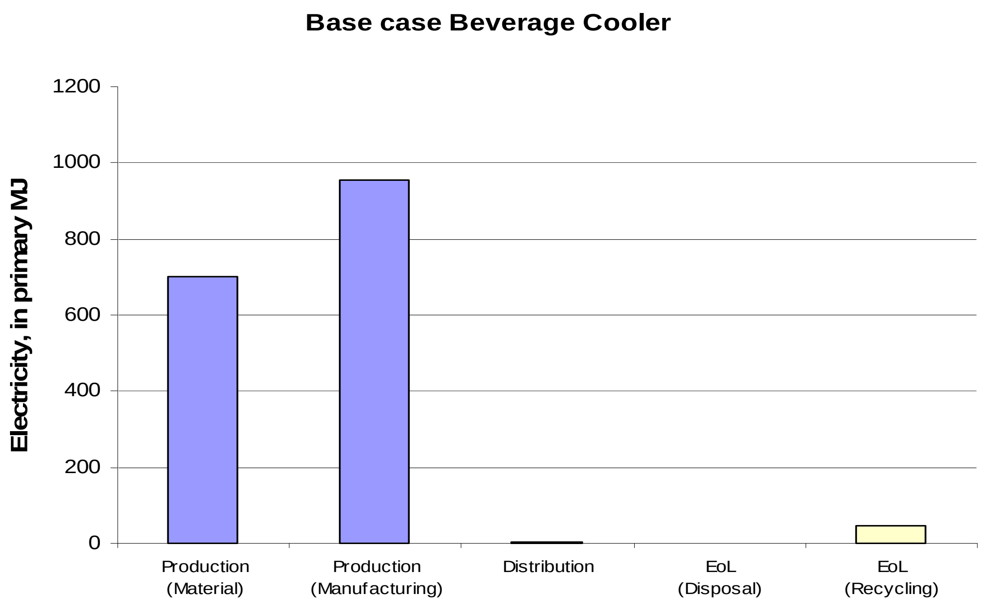


Figure 5-24: Total electricity consumption during different life cycle phases (excluding the use phase)



- **Raw material use (Production phase)**

The significance of each group of components (module) of the beverage cooler was determined individually. The details of the environmental impacts of the production phase are presented in Annexe 5- 3.

Figure 5-25 and Figure 5-26 show the distribution of the GER of different modules during the production phase as described in task 4.

Figure 5-25: GER related to the production phase for each module

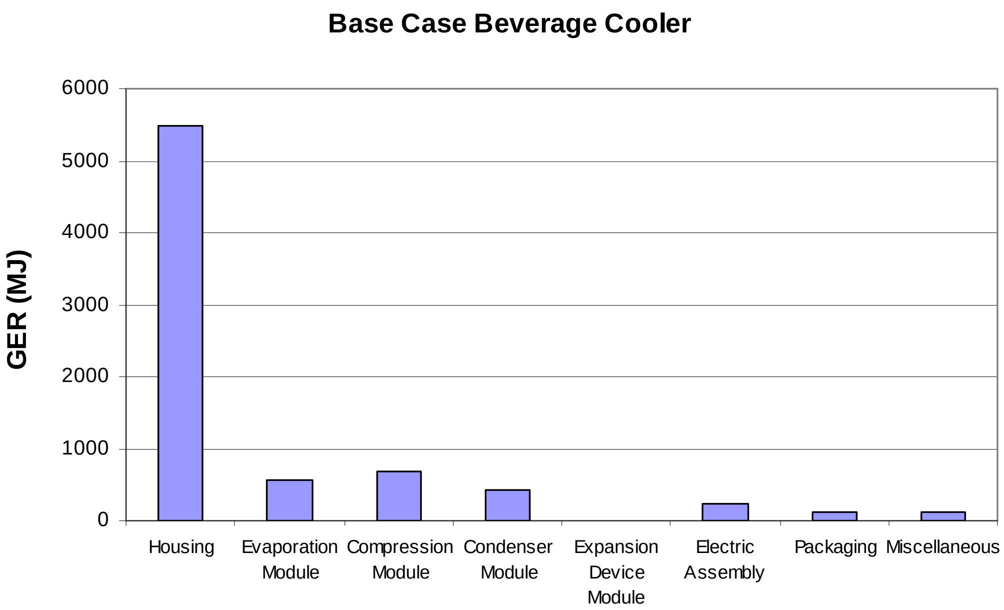
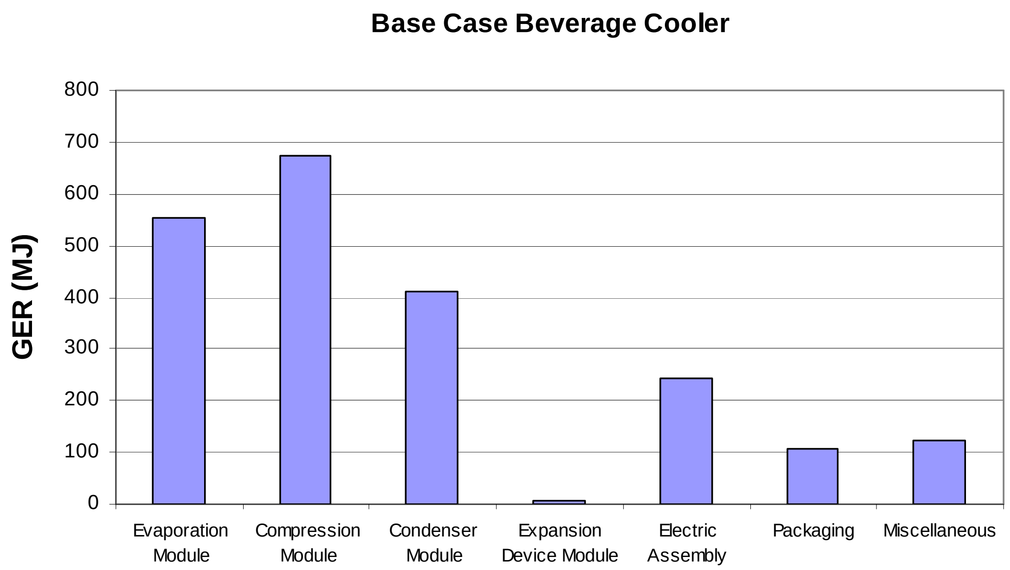


Figure 5-26: GER related to the production phase for each module (excluding the housing)



The GER during production phase is of 7,599 MJ. The housing makes up for more than 70 % of the total GER during production phase, followed the compression module, evaporation and condenser modules (9 %, 7 % and 5 % of the GER related to the production phase).

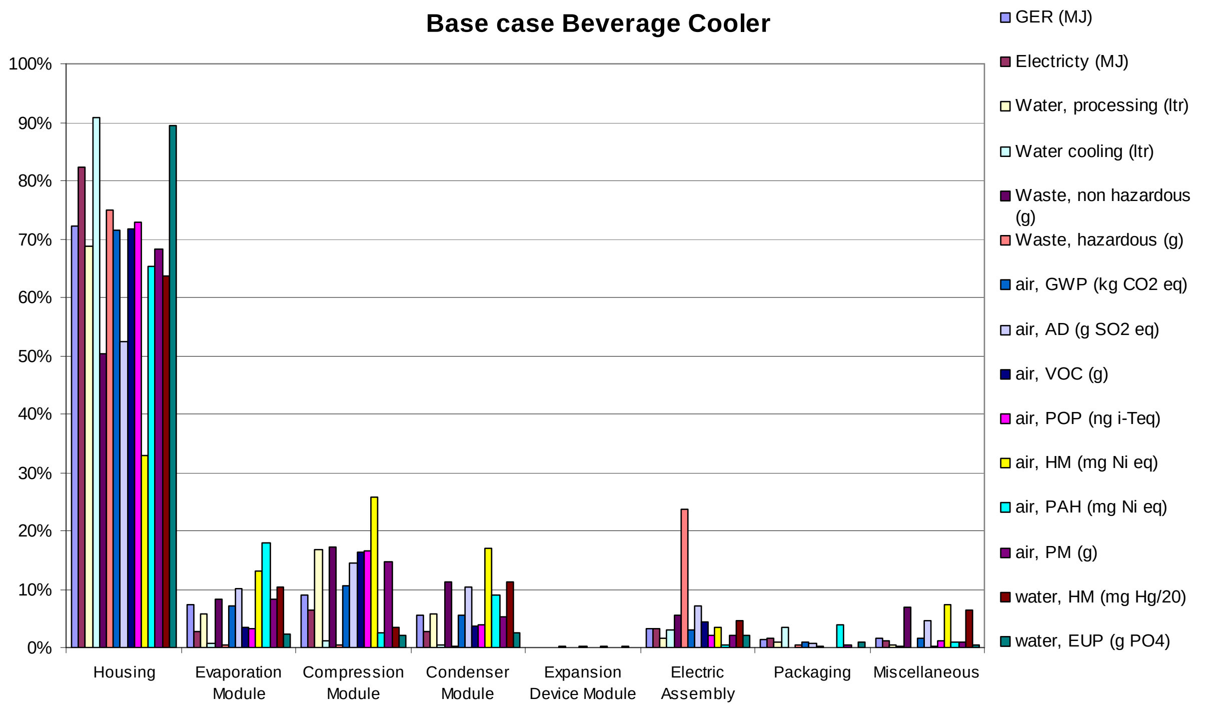
This can be explained by the high mass proportion represented by the housing (> 75 %) (Table 5-32). The most contributing modules are further analysed in the following paragraphs.

Table 5-32: Mass proportion for each module in Base case BvC

Modules	Base Case BvC
Housing	75.14%
Evaporation Module	3.19%
Compression Module	9.54%
Condensation Module	3.74%
Expansion Valve	0.07%
Electric Assembly	2.18%
Packaging	4.38%
Miscellaneous	1.76%

Other impacts can be taken as reference to compare the contribution of each module (Figure 5-27). The results show that the housing remains the major source of emissions. The evaporation module, the compression module and the condenser module come either in second, third or fourth position depending of the environmental indicator taken as reference.

Figure 5-27: Impacts related to production phase for each module



- Housing

In the module housing, the main components responsible of the environmental impacts are the 40 kg of steel panels used for the structure of the beverage cooler (21- St sheet galv.). This subassembly is responsible of most of the GER, non hazardous waste, GWP, AD, VOC, POP, HM to air, and PM emission during production phase of the housing.

The plastic foam insulation (8.5 kg) also represents a major proportion of the environmental impacts, and more specifically concerning the following indicators: use of water (process and cooling), hazardous waste, HM to water and EUP.

The third most impacting sub-assembly in the housing is the aluminium used for the door frame. It is the source of most of the PAH emissions and represents a rather important share of the GWP and AD related to the housing.

- Evaporation module

The evaporation module comprises the evaporator, the evaporator's fans and the fans' motors. The most important components regarding the environmental impacts are the aluminium sheets used to enhance the evaporator's heat exchange surface. They cause most of the GER, non hazardous waste, GWP, AD, PAH, PM, and HM to water.

- Compression Module

In the compression module, the 45 kg of iron (24-Ferrite) for the compressor motor represents most of the GER, GWP, VOC, POP, PM, and EUP. The second component with high impacts is the 800 g of copper wire found in the motor (28-Cu winding wire) which are responsible of most of the waste production and AD.

- Condensation module

The heat exchanger's aluminium (about 690 g of 26-Al sheet/extrusion) and copper (about 1380 g of 30-Cu tube/sheet) represent the most important source of the environmental impacts.

For each environmental indicator, the three major contributors are summarised in Table 5-33.

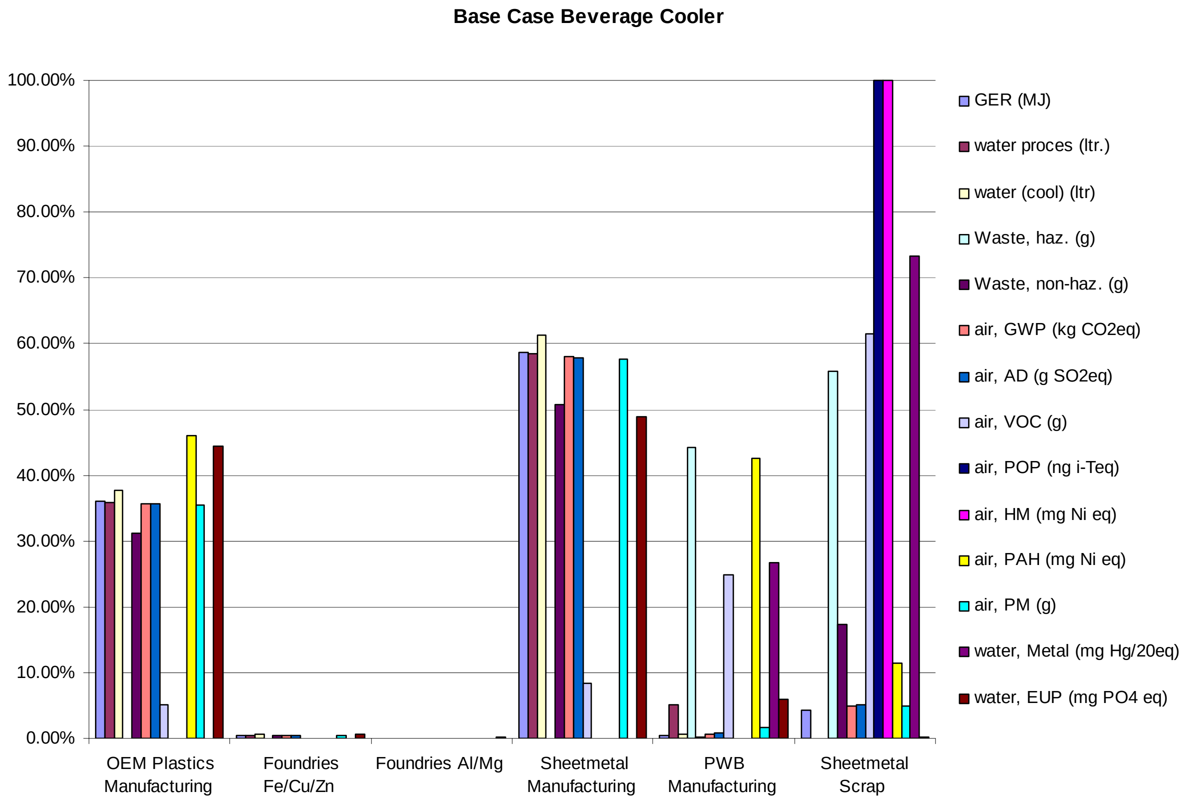
Table 5-33: Three highest contributors in terms of environmental impacts

Impact category		Highest contributor		Second highest contributor		Third highest contributor	
		component	percentage	component	percentage	component	percentage
Energy	GER	Panels and cabinet structure	23%	Polyurethane (Foam insulation)	15%	Aluminium (Door)	14%
Water	water (proces)	Polyurethane (Foam insulation)	48%	steel for motor lamination	17%	Glass(Door)	15%
	water (cool)	Polyurethane (Foam insulation)	68%	Powder polyester (coating)	9%	Fan housing	6%
Waste	haz. Waste	Polyurethane (Foam insulation)	58%	Electrical parts	21%	Powder polyester (coating)	7%
	non-haz. Waste	Panels and cabinet structure	34%	copper (compressor)	8%	Aluminium (Door)	8%
Emissions to Air	GWP	Panels and cabinet structure	31%	Aluminium (Door)	12%	Polyurethane (Foam insulation)	10%
	AD	Panels and cabinet structure	13%	Aluminium (Door)	13%	Polyurethane (Foam insulation)	12%
	VOC	Panels and cabinet structure	53%	Shelves	13%	steel for motor lamination	9%
	POP	Panels and cabinet structure	62%	steel for motor lamination	10%	Shelves	8%
	HM	steel for motor lamination	20%	Panels and cabinet structure	17%	Fan Grid	7%
	PAH	Aluminium (Door)	40%	Polyurethane (Foam insulation)	17%	Al-lamel(Evaporator)	16%
	PM	Panels and cabinet structure	25%	Aluminium (Door)	16%	Polyurethane (Foam insulation)	14%
Emissions to Water	Metal	Polyurethane (Foam insulation)	33%	Aluminium (Door)	13%	Panels and cabinet structure	13%
	EUP	Polyurethane (Foam insulation)	60%	Powder polyester (coating)	19%	Panels and cabinet structure	6%

- **Manufacturing phase (production phase)**

The impacts of the manufacturing phase are negligible over the whole life cycle. The predominant impacts originate from the sheet metal scrap and sheet metal manufacturing (Figure 5-28).

Figure 5-28: Impacts related to the manufacturing phase



The analysis of the production phase shows that the most impacting components are the stainless steel panels used for the cabinet structure, the foam insulation and the materials used for the heat exchangers. However, as for the base case RCV2 it is critical to consider the reduction of plastic foam or non ferro metal for the heat exchangers as the reduction of the use of these materials has a direct impact of the performance of the cabinet.

Distribution, Use and End-of-Life phase

Some of the results from the EcoReport environmental analysis are illustrated on Figure 5-9 and Figure 5-30. As for the previous base cases, the use phase (8 year product life) is the predominant phase in terms of environmental impacts. The distribution phase and end-of-life phase are negligible.

The use phase represents 96 % of the total GER over the whole life cycle. It is about 30 times higher than for the production phase (218,808 MJ compared to 7,599 MJ) and this is manly due to the electricity consumption (7.043 kWh/d as defined in task 4 in standard conditions).

Other impacts also clearly show that the use phase has to be considered in more details for the identification of improvement options of the base case.

Indeed, this stage of the life cycle represents:

- Between 93 and 96 % of the following impacts: GER, water (cooling and process), GWP, AD.

- Between 70 – 75 % of the production of hazardous waste and emissions of VOC and HM to air

- Between 45 – 55 % of the production of non-hazardous waste and emissions of POP to air and HM to water

- Between 20 – 30 % of PAH and PM (major contribution to PM is the transport/ distribution phase)

- About 13 % of the EUP (major contributor to EUP is the production phase).

Some of these figures are illustrated below (Figure 5-29).

Figure 5-29: Environmental impacts during all life cycle phases

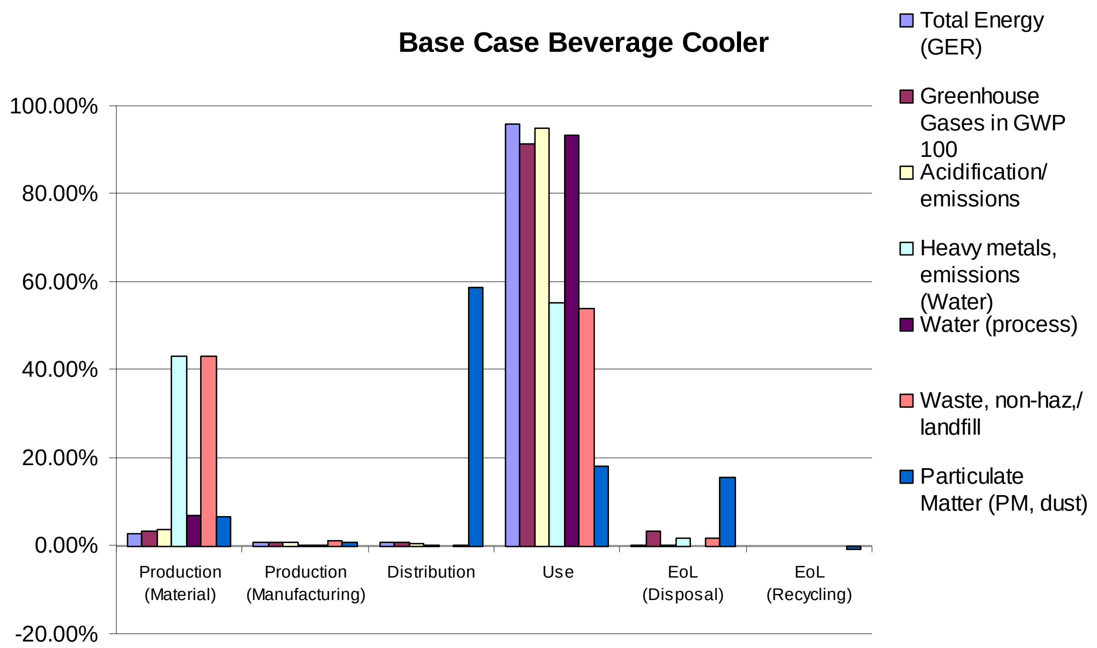
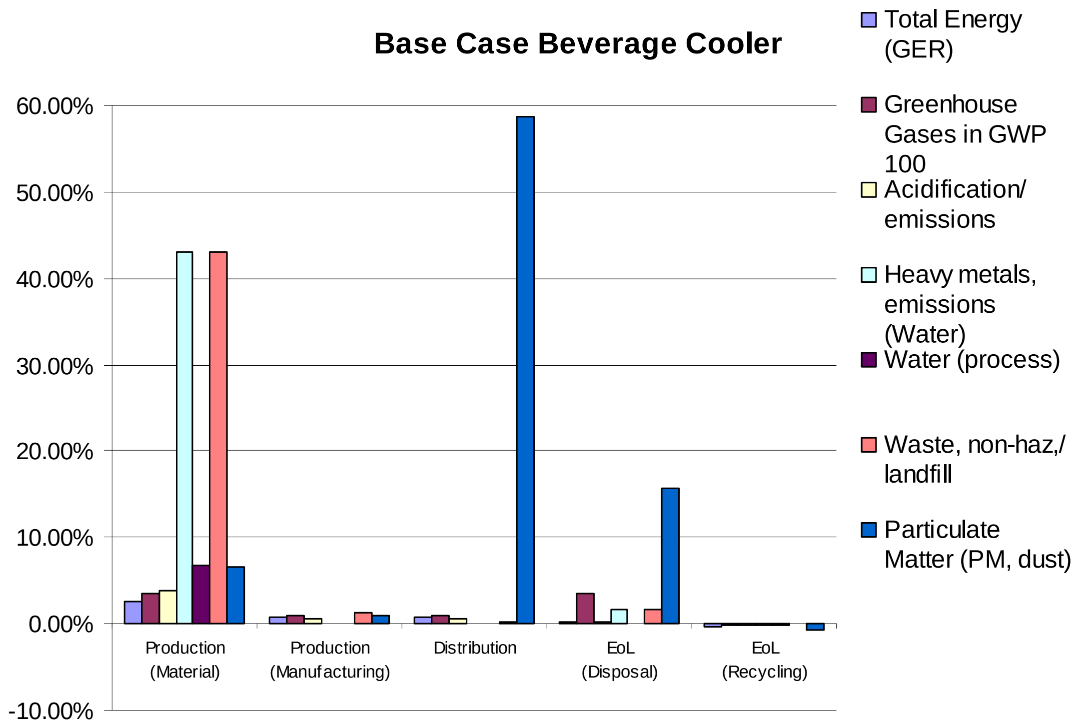


Figure 5-30: Environmental impacts during different life cycle phases (excluding the use phase)



5.2.2.2 BASE CASE ICE CREAM FREEZER

Overview of the impact assessment results

Table 5-34 provides the results of the EcoReport impact assessment. The impacts of the life phase are calculated on the basis of an 8 year life time.

The functional unit is defined here as:

A plug in horizontal display cabinet fitted with sliding glass doors (single panel), without lights for static cooling (no evaporator fan), operating 24 hours a day during 8 years providing a display volume of 291 litres and maintaining product temperatures between -23 °C and -18 °C under ambien t conditions of 30 °C and 55 % RH (climate class 4). The doors are assumed to be closed all time.

Concerning the refrigerant, the annual leakage rate, taking into account the fact that refrigerant recovery for these appliances is relatively non-existent is assumed to be 9.5 %. The overall percentage of fugitive and dumped refrigerant during the entire lifetime of 8 years is estimated to 76 %.

If the GER is taken as a reference for the environmental impacts, the results show that the use phase is the phase which is the most important. It is responsible of over 92 % of the GER required during the whole life time (Figure 5-31). The production phase is the second most significant stage and represents 7 % of the total GER. The distribution and end-of-life phases are negligible (Figure 5-32). This trend is confirmed by Figure 5-33 and Figure 5-34, which presented the repartition if electricity consumption is taken as reference.

Table 5-34: Environmental assessment results from EcoReport

Table . Life Cycle Impact (per unit) of Products Ice cream feezer

Nr	Life cycle Impact per product:	Date	Author
0	Products Ice cream feezer	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**3509**			351	3158	**3509**	**0**
2	TecPlastics	g			**8067**			807	7260	**8067**	**0**
3	Ferro	g			**19441**			972	18469	**19441**	**0**
4	Non-ferro	g			**6568**			328	6239	**6568**	**0**
5	Coating	g			**23709**			1185	22524	**23709**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**13200**			660	12540	**13200**	**0**
	Total weight	g			**74493**			4303	70190	**74493**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	9877	832	**10710**	**1133**	**138077**	396	636	**-239**	**149680**
9	of which, electricity (in primary MJ)	MJ	2261	497	**2758**	**2**	**137998**	0	36	**-36**	**140722**
10	Water (process)	ltr	1262	7	**1270**	**0**	**9211**	0	24	**-24**	**10457**
11	Water (cooling)	ltr	11824	230	**12054**	**0**	**368041**	0	197	**-197**	**379898**
12	Waste, non-haz./ landfill	g	114304	2887	**117191**	**573**	**161140**	4598	138	**4460**	**283363**
13	Waste, hazardous/ incinerated	g	627	0	**627**	**11**	**3186**	1158	22	**1136**	**4960**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	504	46	**550**	**68**	**6026**	678	21	**658**	**7303**
15	Ozone Depletion, emissions	mg R-11 eq.				negligible					
16	Acidification, emissions	g SO2 eq.	2619	201	**2819**	**209**	**35555**	69	41	**27**	**38611**
17	Volatile Organic Compounds (VOC)	g	22	0	**22**	**17**	**52**	3	0	**2**	**93**
18	Persistent Organic Pollutants (POP)	ng i-Teq	596	21	**618**	**3**	**911**	32	0	**32**	**1563**
19	Heavy Metals	mg Ni eq.	508	49	**557**	**29**	**2373**	110	0	**110**	**3069**
	PAHs	mg Ni eq.	321	0	**321**	**38**	**275**	0	2	**-2**	**632**
20	Particulate Matter (PM, dust)	g	540	31	**571**	**2725**	**765**	728	4	**724**	**4785**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	635	0	**635**	**1**	**896**	28	0	**28**	**1560**
22	Eutrophication	g PO4	258	0	**259**	**0**	**7**	2	1	**1**	**266**
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Figure 5-31: Total energy consumption during all life cycle phases

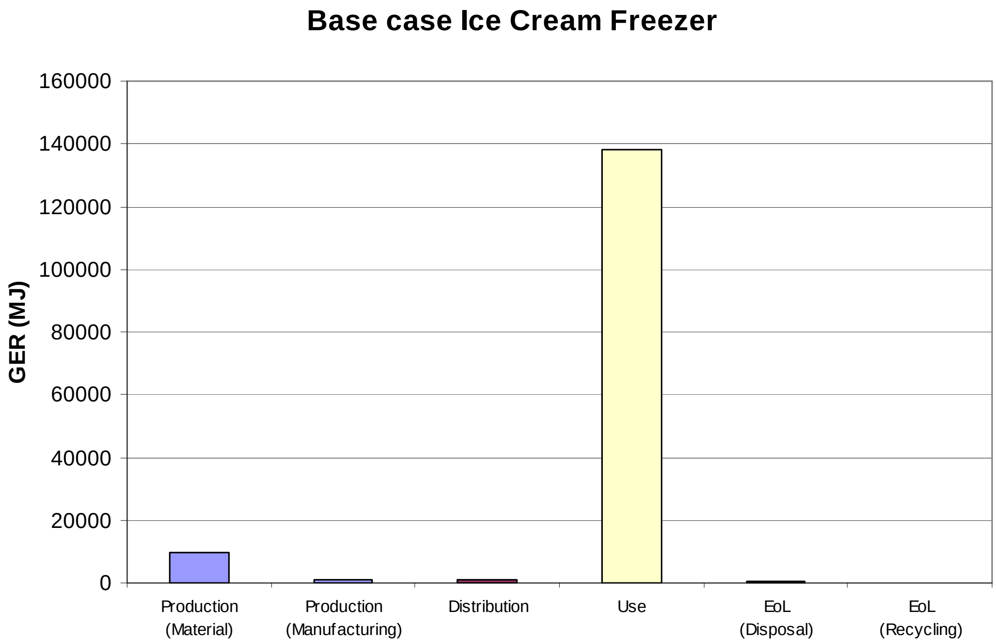


Figure 5-32: Total energy consumption during different life cycle phases (excluding the use phase)

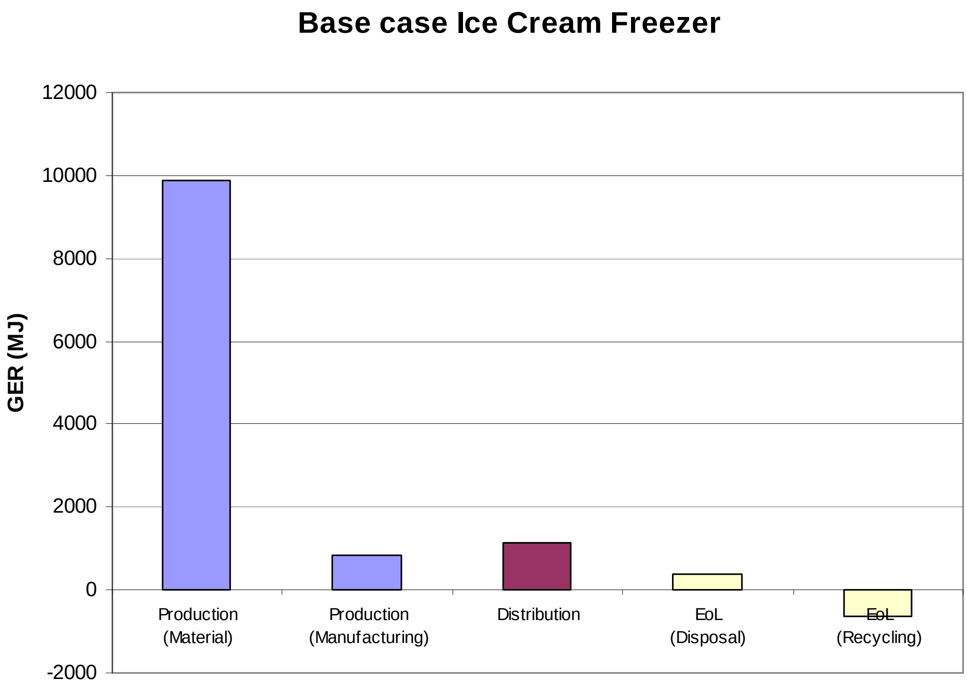


Figure 5-33: Total electricity consumption during all life cycle phases

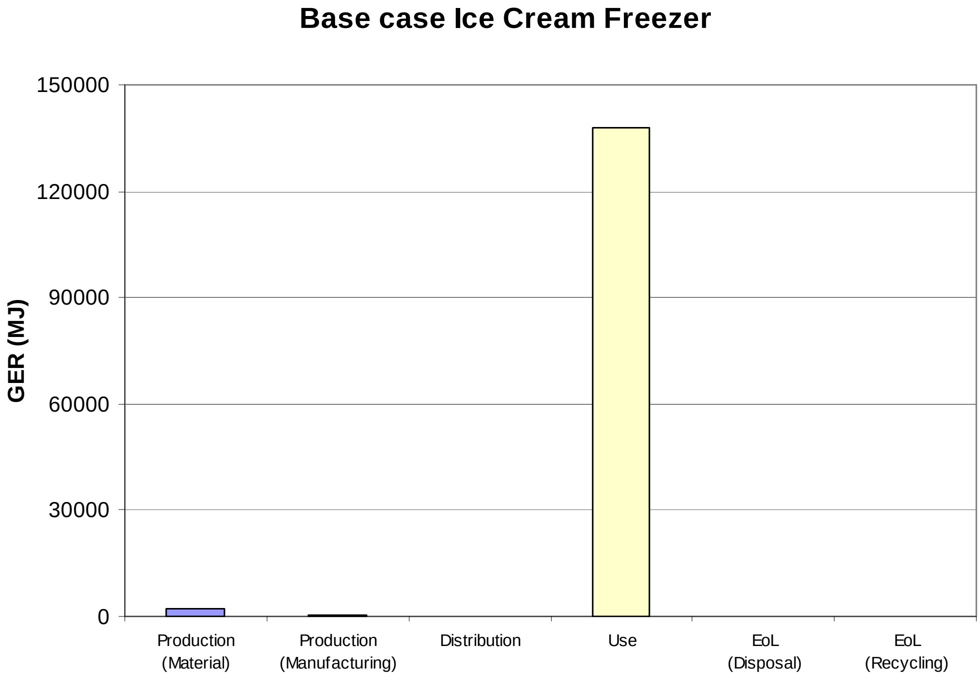
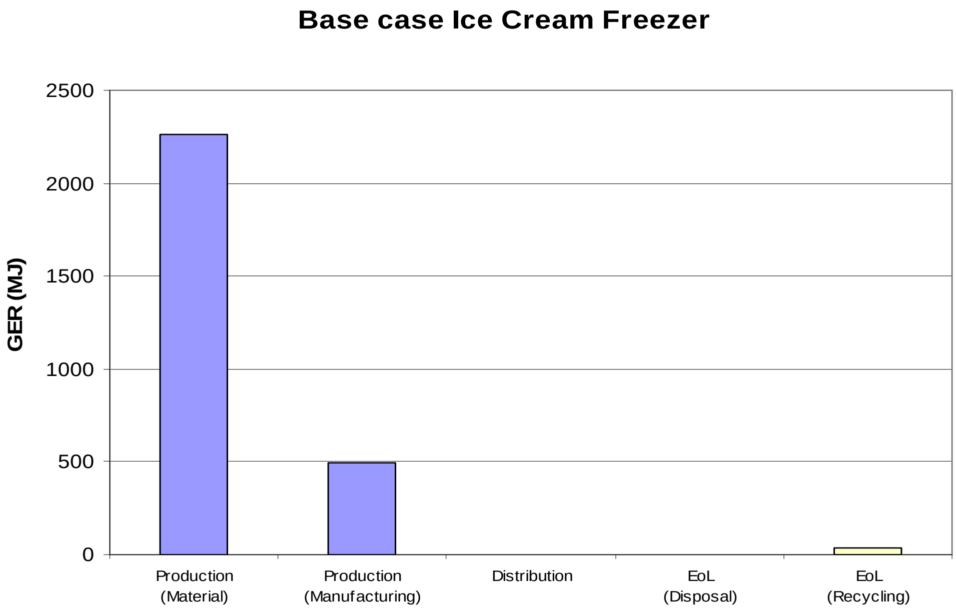


Figure 5-34: Total electricity consumption during different life cycle phases (excluding the use phase)



- **Raw material and manufacturing (Production phase)**

The significance of each assembly of ice-cream freezer was determined during the production phase**.** Figure 5-35 and Figure 5-36 show the contribution of each module to the GER related to the production phase. The details of the environmental impacts of the production phase are presented in Annexe 5- 4.

Figure 5-35: GER related to the production phase for each module

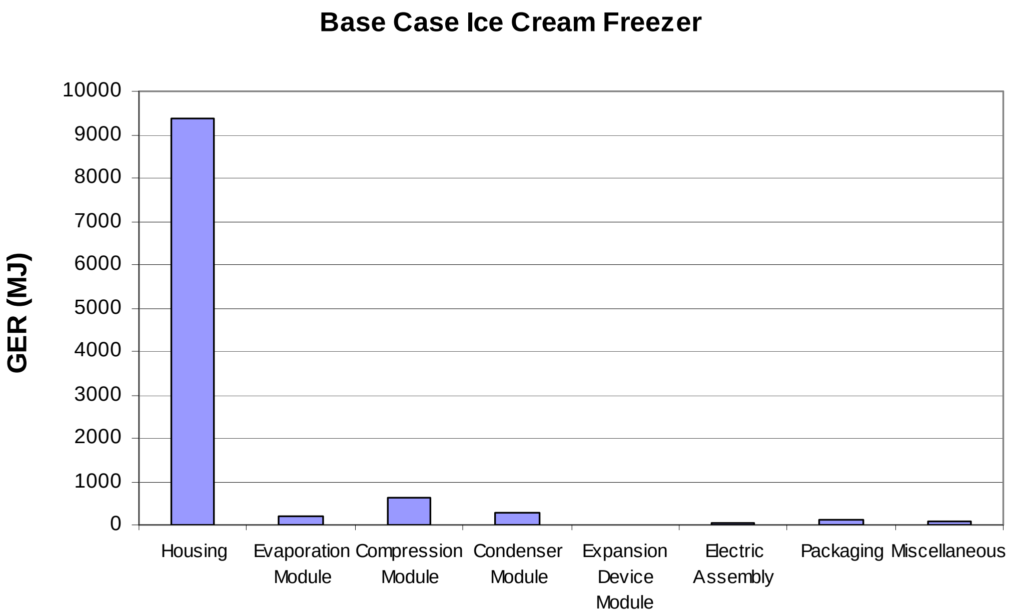
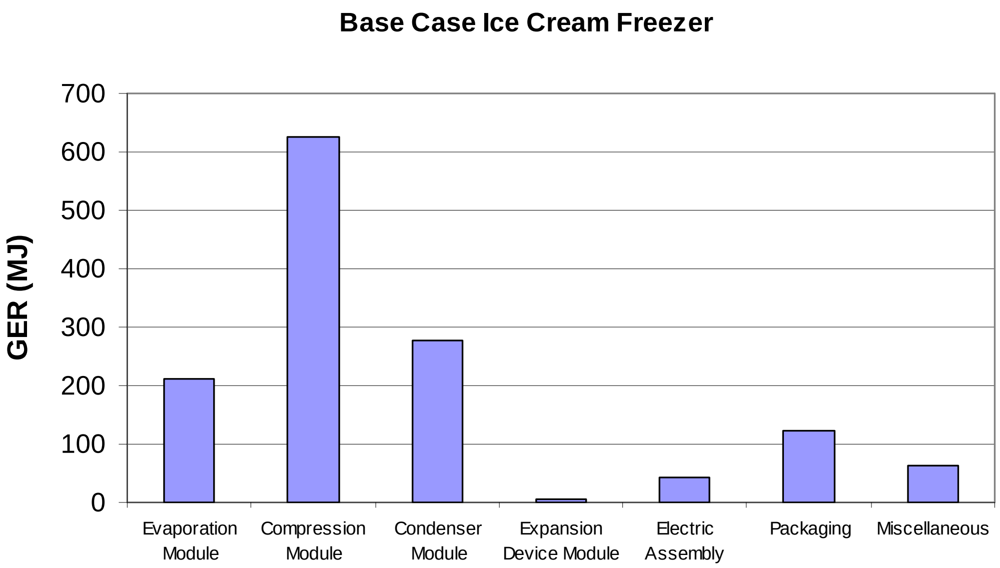


Figure 5-36: GER related to the production phase for each module (excluding the housing)



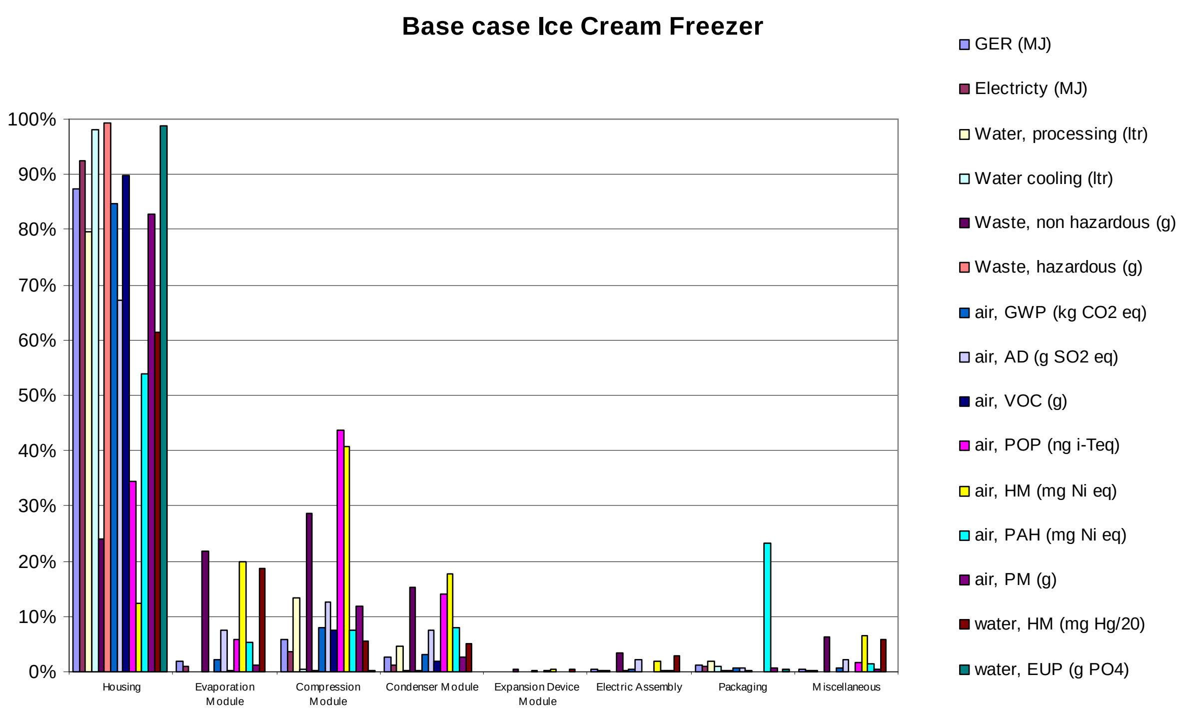
The GER during production phase is of 10,710 MJ. The housing represents over 87 % of this figure, followed by the compression module (~ 6 %), the condenser module (2.6 %) and the evaporation module (~ 2 %). As for the other cabinets studied so far, this can be explained by the high mass proportion represented by the housing (65 %) and the compressor (~15 %) (Figure 5-37).

Figure 5-37: Mass proportion for each module in base case ice cream freezer

Modules	Base Case Ice Cream Freezer
Housing	65.07%
Evaporation Module	4.23%
Compression Module	14.65%
Condensation Module	5.80%
Expansion Valve	0.09%
Electric Assembly	0.53%
Packaging	7.97%
Miscellaneous	1.68%

The EcoReport allows taking other impacts as reference to compare the contribution of each module (Figure 5-38). The results show that the housing is still the most significant in terms of resource consumption and emissions to air and water. The most contributing modules are further analysed in the following paragraphs.

Figure 5-38: Impacts related to production phase for each module



- Housing

In the housing the 23 kg of pre-painted metal panels used for the external housing (38-pre-coating coil) represents most of the GER, water (cool) consumption, waste production (hazardous), GWP, AD, VOC, PM and EUP. The second component with high impacts is the metal sheet used for the cabinet structure (21-St sheet galv.) which is responsible of most of the non hazardous waste production, POP and HM to air. The foam plastic used for the insulation material is also one of the most contributing sub-assembly of the housing being the highest contributor to water consumption (process), PAH and HM to water.

- Evaporation module

  The evaporation module only comprises copper (over 3 kg) which is a significant source of HM to air.

- Compression Module

  In the compression module, the main material responsible of the environmental impacts are the 42 kg of iron (24-Ferrite) used in the motor. It represents most of the GER, GWP, VOC, POP, PM and EUP. The 760 g of copper wire found in the motor are also a significant sub-assembly and are responsible of most of the waste production and AD.

- Condensation Module

  The motor of the condenser fan is the most significant component in terms of environmental impact related to the condensation module. More specifically, the iron part of the motor for the fan of the condenser is the main material responsible of the environmental impacts. It is the main source of GER, water (process), GWP, VOC, POP, HM to air, PM and EUP.

The three major contributors for each environmental indicator are summarised in Table 5-35.

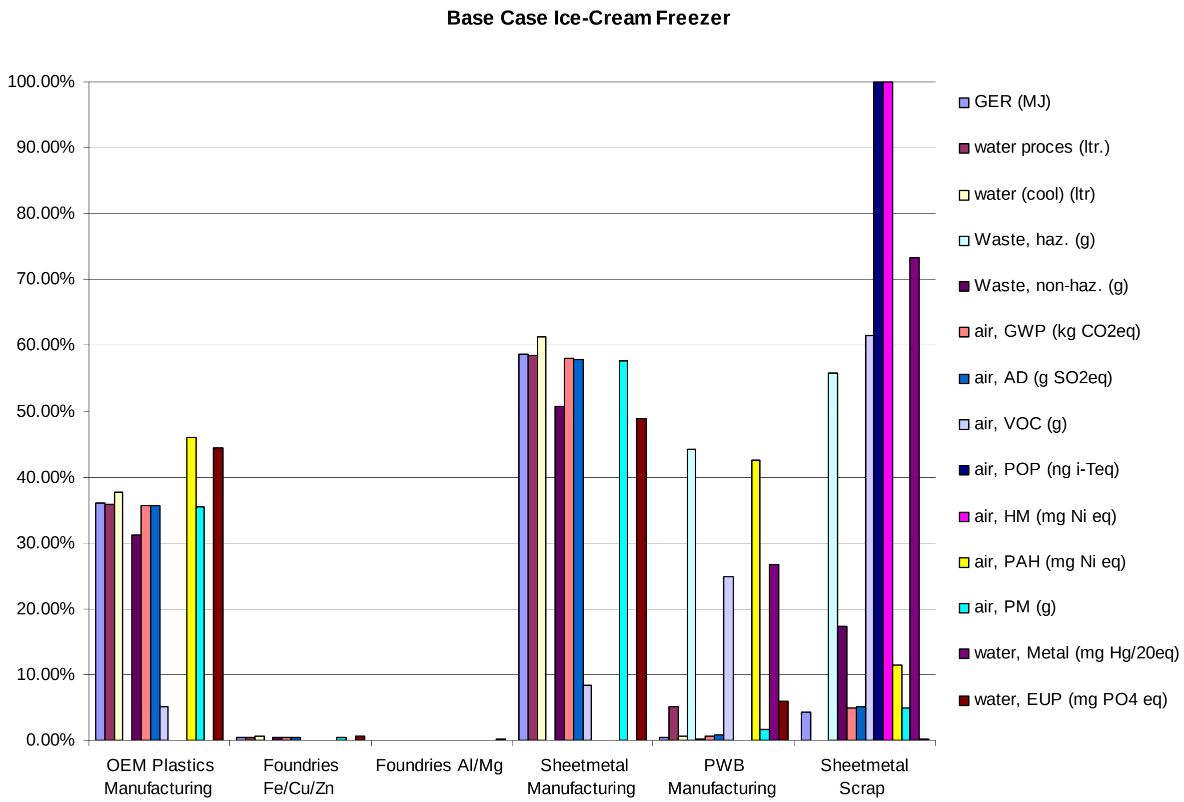
Table 5-35: Three highest contributors in terms of environmental impacts

Impact category		Highest contributor component	Highest contributor percentage	Second highest contributor component	Second highest contributor percentage	Third highest contributor component	Third highest contributor percentage
Energy	GER	white prepainted metal sheet (external housing)	73%	Plastic foam	8%	Plasticised grid (shelves)	3%
Water	water (proces)	white prepainted metal sheet (external housing)	72%	Plastic foam	20%	Misc. (Glass)(Door)	3%
	water (cool)	white prepainted metal sheet (external housing)	56%	Plastic foam	35%	PVC (external housing)	2%
Waste	haz. Waste	Plastic foam	47%	white prepainted metal sheet (external housing)	30%	Steel of the motor lamination	11%
	non-haz. Waste	white prepainted metal sheet (external housing)	81%	Plastic foam	14%	Plasticised grid (shelves)	3%
Emissions to Air	GWP	Plastic foam	54%	white prepainted metal sheet (external housing)	43%	Plasticised grid (shelves)	2%
	AD	evaporator wrapped on tank	21%	Copper (compressor)	14%	galvanized metal sheet (external housing)	11%
	VOC	Plastic foam	52%	white prepainted metal sheet (external housing)	37%	galvanized metal sheet (external housing)	2%
	POP	white prepainted metal sheet (external housing)	46%	Plastic foam	20%	Copper (compressor)	8%
	HM	Plastic foam	96%	white prepainted metal sheet (external housing)	4%	galvanized metal sheet (external housing)	0%
	PAH	Plastic foam	45%	galvanized metal sheet (external housing)	17%	Steel of the motor lamination	15%
	PM	Plastic foam	52%	white prepainted metal sheet (external housing)	35%	Cast iron of the compressor casing	3%
Emissions to Water	Metal	Plastic foam	69%	evaporator wrapped on tank	12%	Pipes in the refrigeration system	4%
	EUP	white prepainted metal sheet (external housing)	91%	Plastic foam	5%	Plasticised grid (shelves)	3%

- **Manufacturing (production phase)**

As it was the case for the beverage coolers, the impacts of the manufacturing phase are negligible over the whole life cycle. The predominant impacts come from the sheet metal scrap and the sheet metal manufacturing (Figure 5-39).

Figure 5-39: Impacts related to the manufacturing phase



Distribution, Use and End-of-Life phase

Some of the environmental indicators calculated by the EcoReport are presented Figure 5-40 and Figure 5-41. As for the other types of commercial refrigeration appliances that were studied so far, the use phase is the most significant stage of the lifetime. The distribution phase and the end-of-life phase are negligible, except in terms of PM emissions due to the transport.

The use phase represents over 92 % of the total GER over the whole life cycle. It is about 13 times higher than for the production phase (138,077 MJ compared to 10,710 MJ). The GER of the production phase for the base case ice-cream freezer is higher than for the one of the beverage cooler because of the larger amount of coating materials.

The high contribution of the use phase is due to the electricity consumption (4.5 kWh/d as defined in task 4 in standard conditions). Other environmental indicators also show that the use phase has to be the one on which to focus for the identification of improvement options of the base case. It represents:

- Between 82 and 92 % of the following impacts: GER, Water (process, cooling), GWP and AD
- Between 56 – 77 % of the waste production (hazardous and non-hazardous), VOC, POP, HM to air, HM to water.

- 43 % of the PAH (the rest is mostly due to the production phase, more specifically to the production of plastics used for the insulation foam and for the packaging)

- 16 % PM (major part comes from the distribution phase)

- 3 % of EUP (most of it comes originates from the production of the pre-painted panels).

Some of these figures are illustrated in Figure 5-40.

Figure 5-40: Environmental impact during all life cycle phases

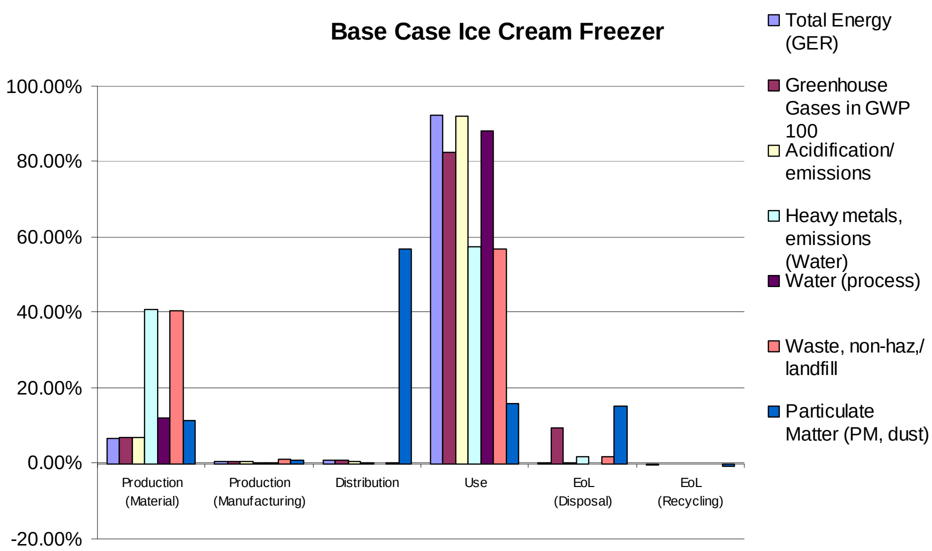
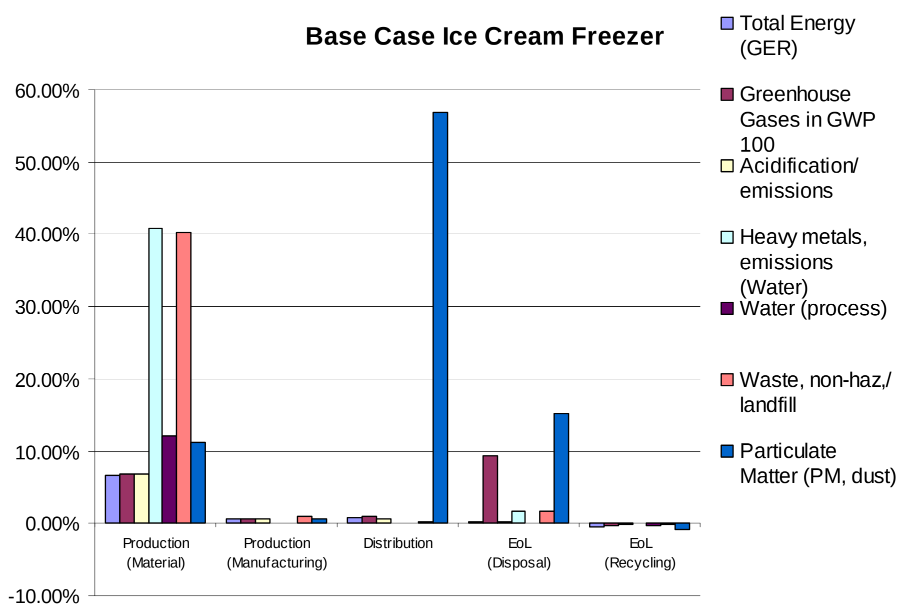


Figure 5-41: Environmental impact during different life cycle phases (excluding the use phase)



5.2.3 COLD VENDING MACHINES

5.2.3.1 BASE CASE SPIRAL VENDING MACHINE

- **Overview of the impact assessment results**

The results of the EcoReport impact assessment are given in Table 5-36. The impacts of the use phase are calculated on the basis of an 8.5 years life time.

The functional unit is defined here as:

A spiral vending machine with a glass door, operating 24 hours a day for 8.5 years enabling to contain 288 cans and maintaining product temperatures around 3 °C. The lights are turned on 24 hours a da y.

When taking into account the GER (Gross Energy Requirement) as reference for the environmental impacts, the results show that the use phase is the most important. It is responsible of 85 % of the GER required during the whole life cycle (Figure 5-42). The production phase is the second most significant stage, representing 14.3 % of the GER over product lifetime. The distribution and end-of-life phase are negligible (Figure 5-43). Besides, it is important to note that the end-of-life phase provides GER with the thermal recycling of some parts of the spiral vending machine. This trend is also true for the electricity consumption as presented in Figure 5-44 and Figure 5-45.

Table 5-36: Environmental assessment results from EcoReport

Table . Life Cycle Impact (per unit) of Base-Case Spiral Vending Machine

Nr	Life cycle Impact per product:	Date	Author
0	Base-Case Spiral Vending Machine	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**34860**			3486	31374	**34860**	**0**
2	TecPlastics	g			**4496**			450	4047	**4496**	**0**
3	Ferro	g			**144258**			7213	137045	**144258**	**0**
4	Non-ferro	g			**8360**			418	7942	**8360**	**0**
5	Coating	g			**76270**			3814	72457	**76270**	**0**
6	Electronics	g			**931**			616	315	**931**	**0**
7	Misc.	g			**27665**			1383	26282	**27665**	**0**
	Total weight	g			**296840**			17380	279461	**296840**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	36806	4030	**40835**	**2063**	**243557**	1518	2218	**-700**	**285756**
9	of which, electricity (in primary MJ)	MJ	9926	2350	**12275**	**4**	**243272**	0	158	**-157**	**255394**
10	Water (process)	ltr	5283	42	**5325**	**0**	**16263**	0	113	**-113**	**21475**
11	Water (cooling)	ltr	36123	1100	**37223**	**0**	**648770**	0	676	**-676**	**685317**
12	Waste, non-haz./ landfill	g	372181	14279	**386460**	**1021**	**285782**	18311	576	**17734**	**690998**
13	Waste, hazardous/ incinerated	g	2326	3	**2329**	**20**	**5626**	4253	115	**4138**	**12113**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	2025	226	**2251**	**123**	**10633**	688	74	**614**	**13622**
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	9328	985	**10313**	**378**	**62714**	258	168	**90**	**73494**
17	Volatile Organic Compounds (VOC)	g	112	3	**116**	**31**	**93**	9	1	**8**	**247**
18	Persistent Organic Pollutants (POP)	ng i-Teq	3907	139	**4045**	**6**	**1634**	126	0	**126**	**5811**
19	Heavy Metals	mg Ni eq.	1825	326	**2151**	**52**	**4193**	422	5	**417**	**6813**
	PAHs	mg Ni eq.	586	2	**588**	**68**	**485**	0	10	**-10**	**1131**
20	Particulate Matter (PM, dust)	g	1844	156	**2000**	**5069**	**1357**	2695	15	**2681**	**11107**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	2960	0	**2960**	**2**	**1597**	109	21	**88**	**4647**
22	Eutrophication	g PO4	800	2	**802**	**0**	**15**	6	3	**3**	**821**
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Figure 5-42: Total energy consumption during all life cycle phases

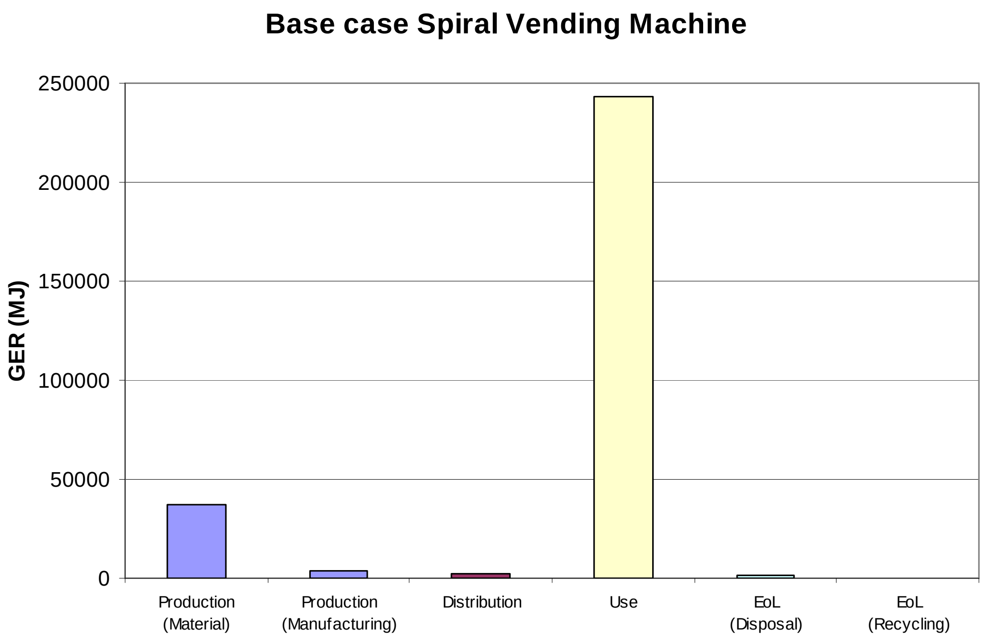


Figure 5-43: Total energy consumption during different life cycle phases (excluding the use phase)

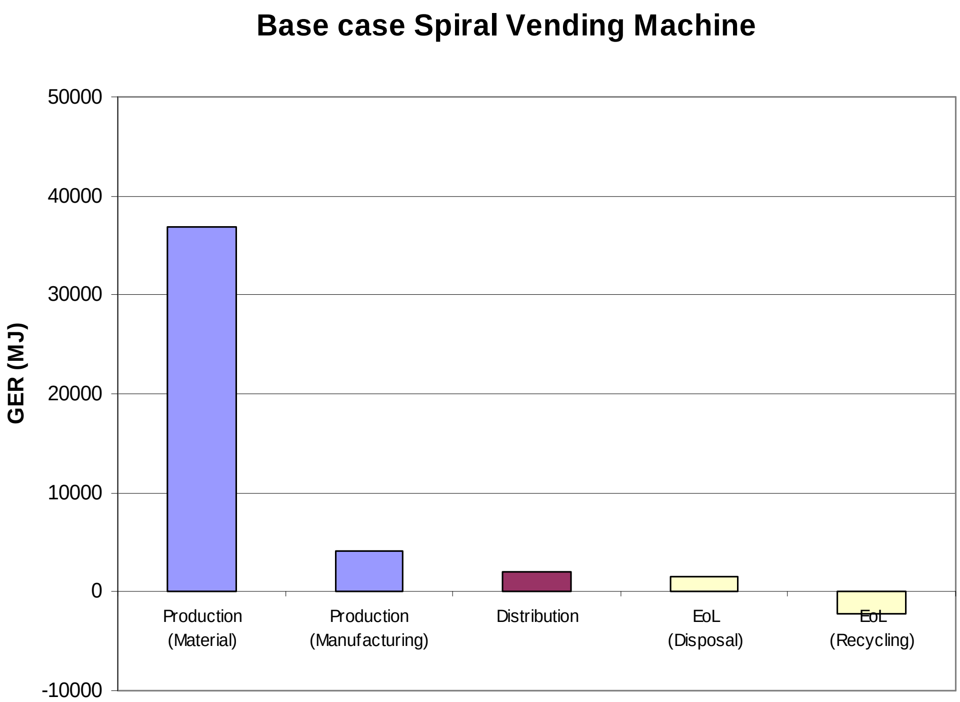


Figure 5-44: Total electricity consumption during all life cycle phases

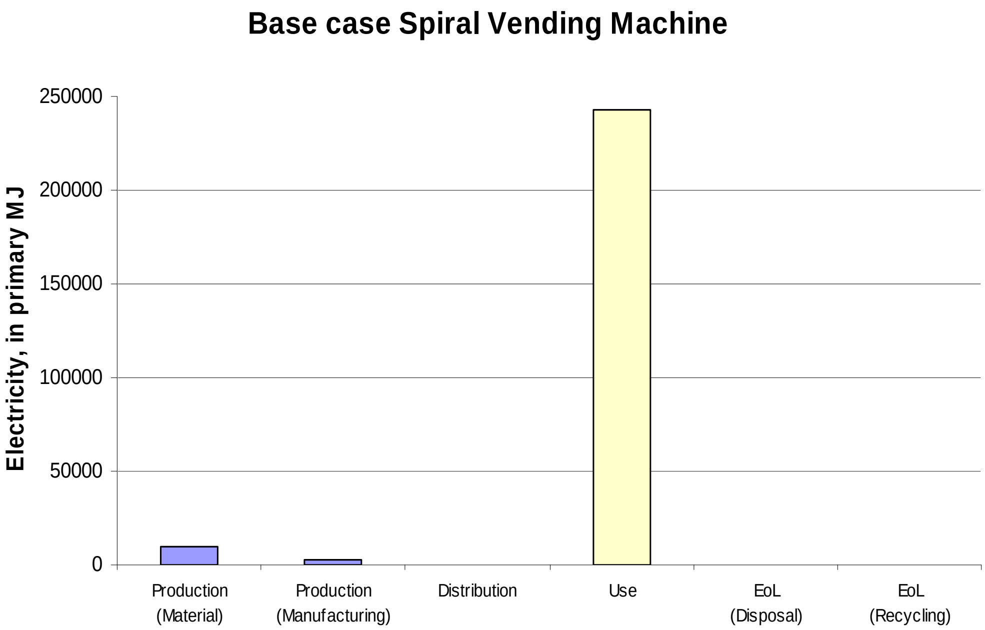
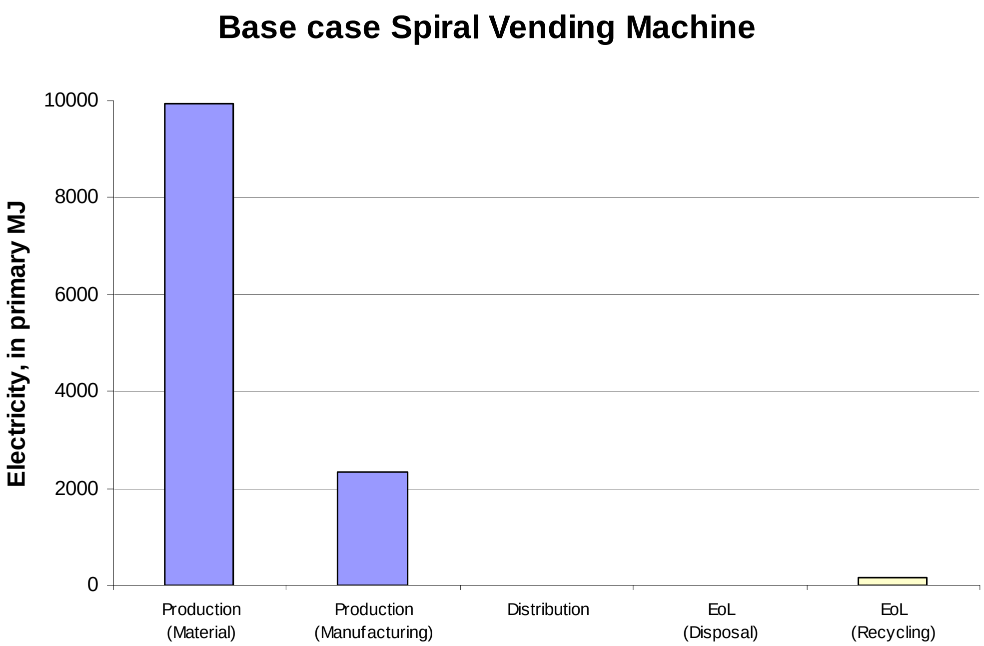


Figure 5-45: Total electricity consumption during different life cycle phases (excluding the use phase)



- **Raw Materials Use and Manufacturing (Production phase)**

The significance of each group of components (module) of the spiral vending machine was determined individually. Figure 5-46 and Figure 5-47 show the distribution of the GER related to the production phase for each module. The details of the environmental impacts of the production phase are presented in Annexe 5- 5.

Figure 5-46: GER related to the production phase for aech module

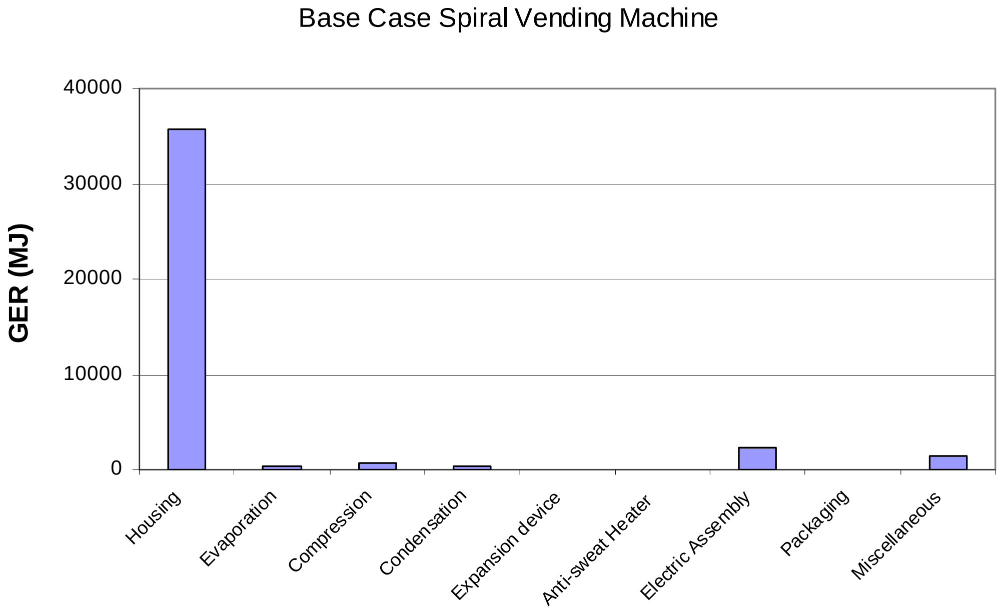
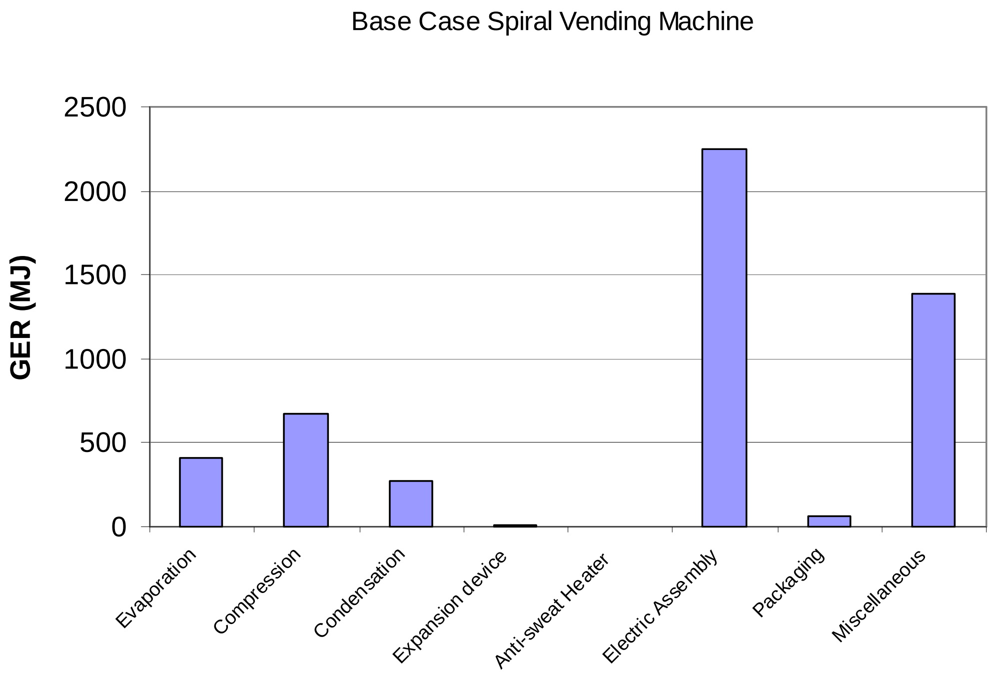


Figure 5-47: GER related to the production phase for each module (excluding the housing)



The GER during the production phase is of 40,831 MJ (36,801 MJ for the raw materials use and 4,030 MJ for the manufacturing). The housing makes up for more than 87 %, followed by the electric assembly module (5.5 %) and the miscellaneous module (3.4 %), for the whole production phase. This can be explained by the high proportion represented by the housing (about 87 %).

The most contributing modules are further analysed in the following paragraphs.

Furthermore, other environmental impacts can be taken as reference to compare the contribution of each module (Figure 5-48 and Figure 5-49). The results show that the housing remains the major source of emissions, except for the emissions of heavy metals in water where the electric assembly module is the most impacting. The latter and the miscellaneous module also contribute significantly to the environmental impacts, taking as reference other indicator.

Figure 5-48: Impacts related to the production phase for each module

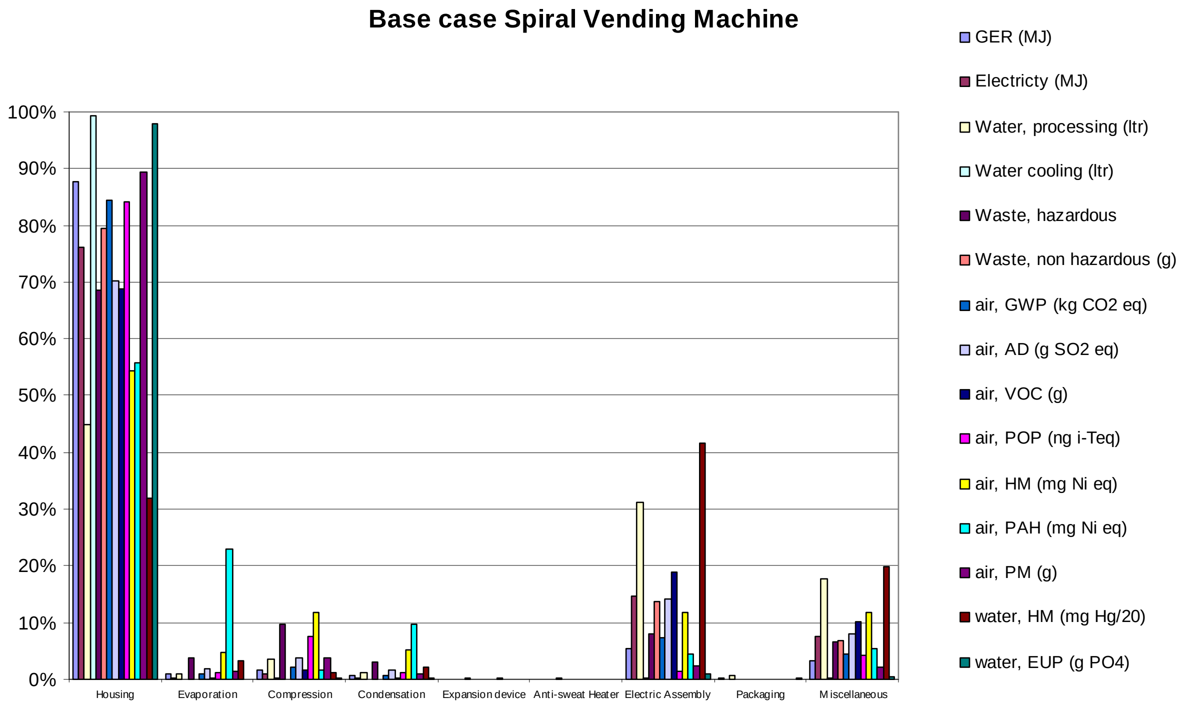
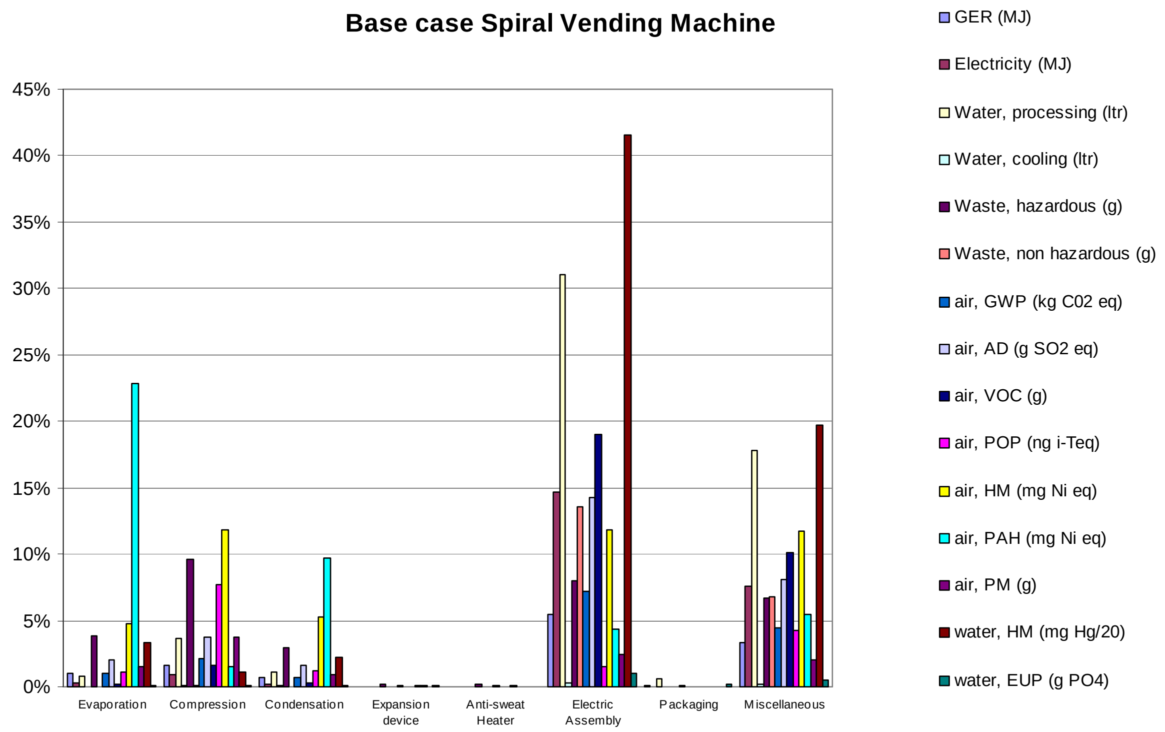


Figure 5-49: Impacts related to the production phase for each module (excluding the housing)



The raw materials use contributes to 90 % of the GER of the production phase. The most contributing modules are developed below.

- Housing

In the module housing, the main components responsible of the environmental impacts are the 48 kg of pre-coating coil using for the panels of the spiral vending machine, followed by the pre-coating coil material used for the door (19 kg) and the spirals (9 kg). These three components are responsible of most of the use of water (processing and cooling), the amount of hazardous waste, GWP, AD, VOC and PM emission to air.

The 56 kg of the chassis and the 26 kg of the panels made in steels (21-St sheet galv.) are also responsible of some of the environmental impacts, such as the non-hazardous waste, POP and HM to air.

- Electric Assembly

The electric assembly module comprises the electric panels, the electronic cards and the cables contained in the spiral vending machine. The most important components regarding the environmental impacts are the integrated circuits of the cards (46-IC's avg., 5 % Si, Au) and the copper used in the cables (29-Cu wire).

- Miscellaneous

The electronic cards (46-IC's avg., 5 % Si, Au) of the selection and payment system, as well as the ferrous metals (24-Ferrite) and non-ferrous metals (28-Cu winding wires) used in the motors of the dispensing mechanism , are the most contributing components of this module of the environmental impact.

The three major contributors for each environmental indicator are summarised in Table 5-37.

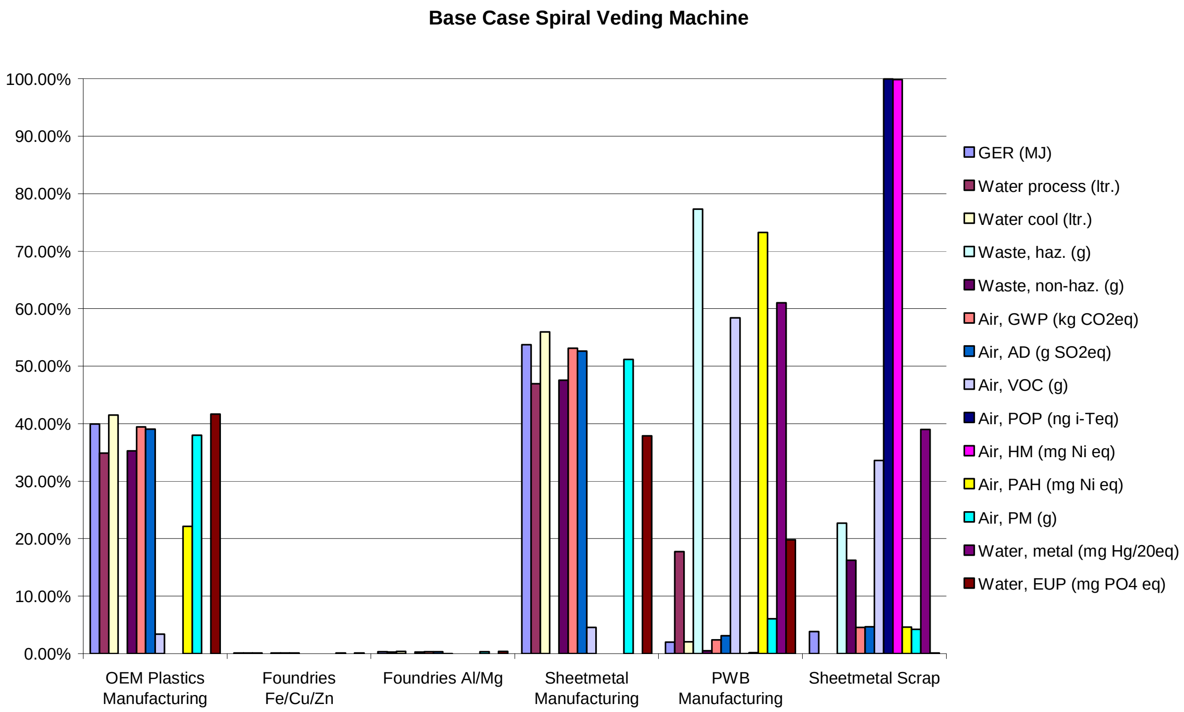
Table 5-37: Three highest contributors in terms of environmental impacts

Impact category		Highest contributor		Second highest contributor		Third highest contributor	
		component	percentage	component	percentage	component	percentage
Energy	GER	Panels	41%	Handle and plastic cover	16%	Spirals	8%
Water	water (proces)	Electronic cards	28%	Panels	17%	Electronic cards	14%
	water (cool)	Panels	51%	Handle and plastic cover	21%	Shelves & Grids & Brackets	12%
Waste	haz. Waste	Panels	39%	Handle and plastic cover	16%	Shelves & Grids & Brackets	11%
	non-haz. Waste	Chassis	26%	Handle and plastic cover	16%	Panels	12%
Emissions to Air	GWP	Panels	37%	Handle and plastic cover	15%	Chassis	8%
	AD	Panels	30%	Handle and plastic cover	12%	Electronic cards	9%
	VOC	Panels	34%	Electronic cards	18%	Handle and plastic cover	14%
	POP	Chassis	37%	Handle and plastic cover	23%	Panels	17%
	HM	Chassis	11%	steel for motor lamination	9%	Chassis	8%
	PAH	Al-lamel (Evaporator)	20%	Panels	17%	Polyurethane (Foam insulation)	14%
	PM	Panels	40%	Handle and plastic cover	16%	Chassis	8%
Emissions to Water	Metal	Electronic cards	38%	Electronic cards	19%	Chassis	7%
	EUP	Panels	58%	Handle and plastic cover	23%	Spirals	11%

- **Manufacturing (production phase)**

The impacts of the manufacturing phase are negligible over the whole life cycle. The predominant impacts originate from the sheet metal scrap and the sheet metal and PWB manufacturing (Figure 5-50).

Figure 5-50: Impacts related to the manufacturing phase



Distribution, Use and End-of-Life phases

Some of the results from the EcoReport environmental analysis are illustrated on Figure 5-52 and Figure 5-52.

The use phase represents 85 % of the total GER over the whole life cycle. It is about 6 times higher than for the production phase (243,590 MJ compared to 40,831 MJ) and this id mainly due to the electricity consumption (7.465 kWh/day, following the EVA-EMP Idle state protocol).

The distribution phase and the end-of-life phase are negligible, except for the particulate matter.

Other impacts also clearly show that the use phase has to be considered in more details for the identification of improvement options of the base case spiral vending machine. Indeed, it represents:

- Between 75 % and 86 % of the following impacts: GER, Water (process, cooling), GWP and Acidification/emissions.
- 42 % of the non-hazardous waste production (major part comes from the production phase).
- 34 % of the heavy metals emissions to water (the rest is mostly due to the production phase, more specifically to the production for the electronic cards)
- 12 % PM (major part comes from the distribution phase)

Figure 5-51: Environmental impacts during all life cycle phases

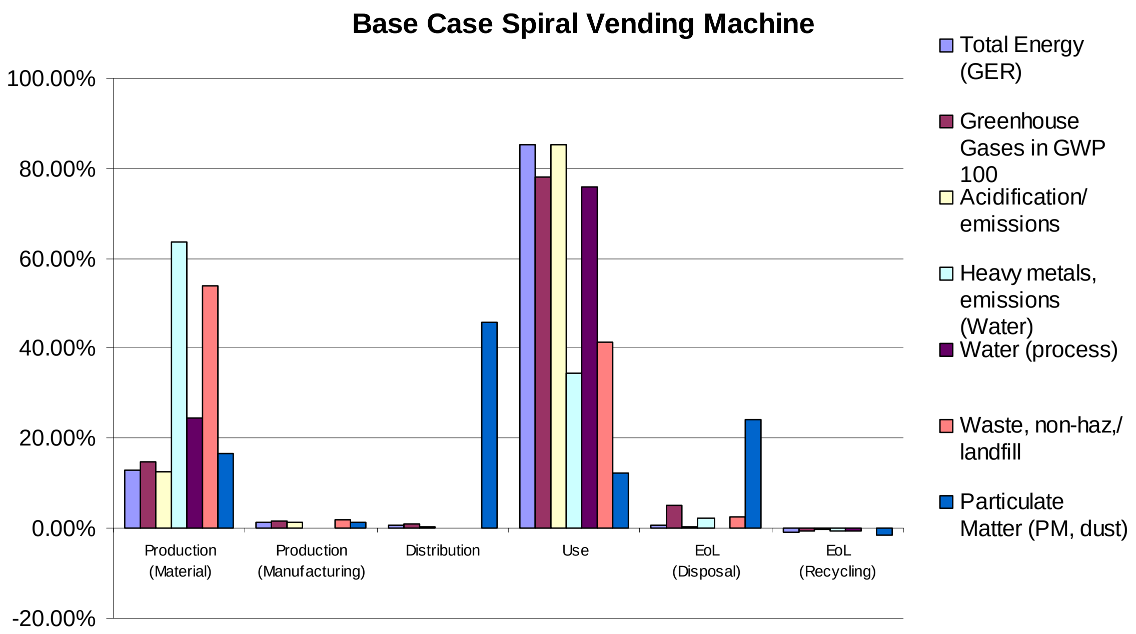
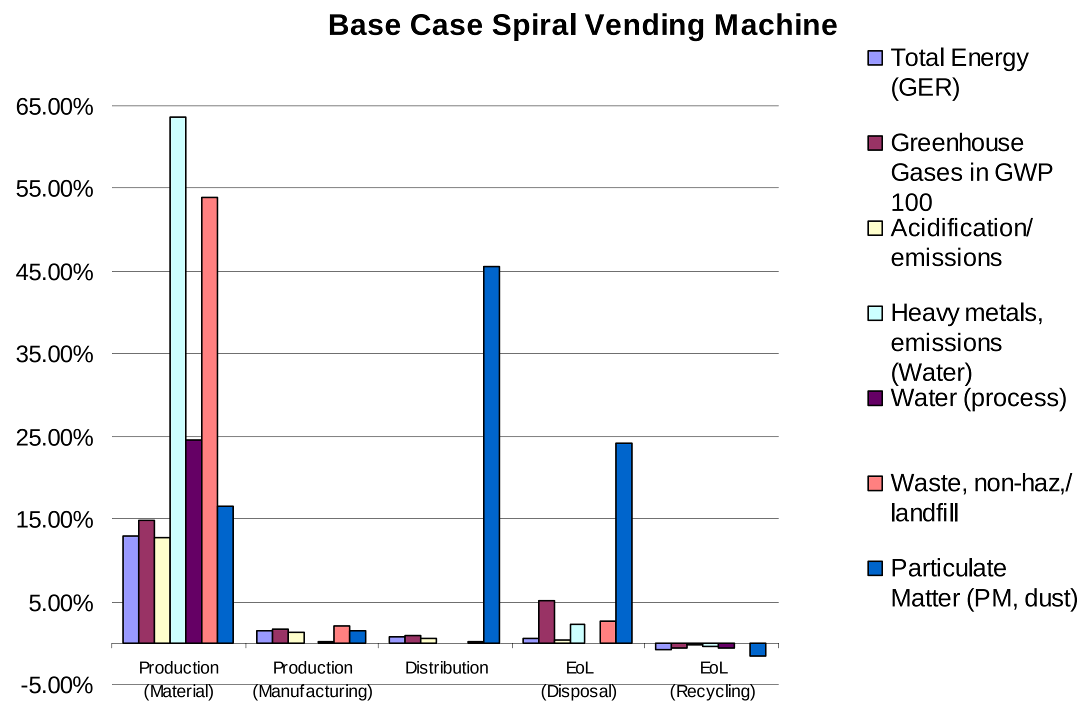


Figure 5-52: Environmental impacts during different life cycle phases (excluding the use phase)



5.2.4 CONCLUSIONS

The environmental impact assessment of each base case using EcoReport shows that the housing of the refrigeration equipment, predominantly made of stainless steel panels is the assembly responsible of most of the environmental impacts of the production phase for all base cases. Other significant modules in terms of environmental impacts are the evaporators for the remote appliances, the compressors for the plug in appliances and the electric assembly in case of cold vending machines.

For all the base cases studied, the use phase is the most significant stage of the life cycle in terms of energy and resource consumptions as well of emissions. Therefore, the analysis of the improvement potential in task 7 will primarily focus on technologies that reduce the power consumption and improve energy efficiency.

5.3. BASE CASE LIFE CYCLE COSTS

5.3.1 REMOTE REFRIGERATED DISPLAY CABINET

5.3.1.1 BASE CASE VERTICAL OPEN CHILLED MULTI DECK (RCV2)

Using the data from task 2 and task 4, the following inputs of the EcoReport were entered for the base case RCV2[6] (Table 5-38):

Table 5-38: Inputs for the calculation of the LCC (lines A to L)

Table . Inputs for EU-Totals & LCC

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	9	years
B	Annual sales	0.1464	mln. Units/year
C	EU Stock	1.31272	mln. Units
D	Product price	3440	Euro/unit
E	Installation/acquisition costs (if any)	344	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.097	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	2139	Euro/ unit
M	Discount rate (interest minus inflation)	1.8%	%
N	Present Worth Factor (PWF) (calculated automatically)	8.24	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	0.90	

[6] Repair and maintenance costs 7 % LCC this means that 93 % LCC = 3440 (product price) +344 (installation costs) +0.097*365*9*77.31 (electricity price during product life of 9 years) and that 7%= 2139 euros

The next table (Table 5-39) shows the results of the EcoReport for the life cycle cost (LCC):

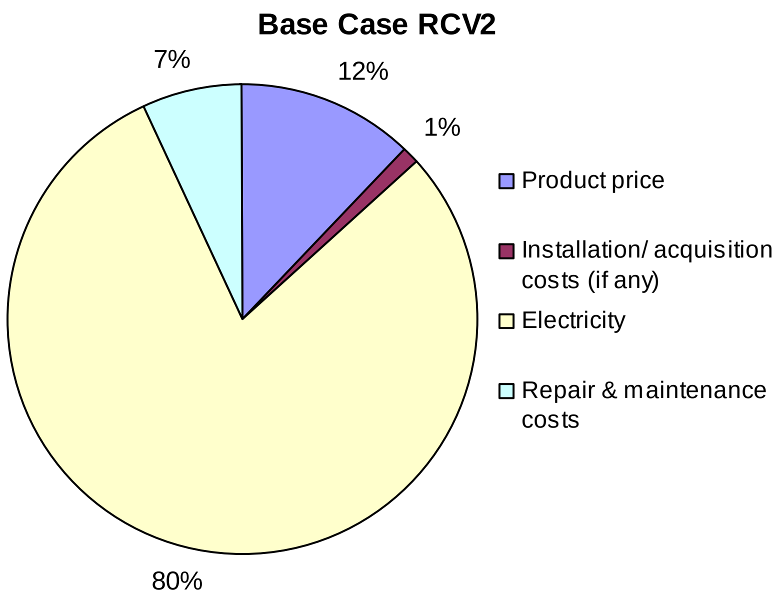
Table 5-39: EcoReport results LCC for the base case RCV2

Table . Life Cycle Costs per product and Total annual expenditure (2005) in the EU-25

	Product Base Case remote open vertical chilled multi deck (RCV2) *Item*	LCC new product		total annual consumer expenditure in EU25	
D	Product price	3440	€	504	mln.€
E	Installation/ acquisition costs (if any)	344	€	50	mln.€
F	Fuel (gas, oil, wood)	0	€	0	mln.€
F	Electricity	22558	€	3234	mln.€
G	Water	0	€	0	mln.€
H	Aux. 1: None	0	€	0	mln.€
I	Aux. 2 :None	0	€	0	mln.€
J	Aux. 3: None	0	€	0	mln.€
K	Repair & maintenance costs	1959	€	312	mln.€
	Total	**28300**	€	**4100**	mln.€

The electricity costs represent a major share of the LCC (80 %) followed by the product purchase cost (12 %) as shown in Figure 5-53.

Figure 5-53: LCC distribution for the base case RCV2



5.3.1.2 BASE CASE HORIZONTAL OPEN FROZEN ISLAND (RHF4)

As for the base case RCV2, using data from task 2 and task 4, the following inputs of the EcoReport were defined for the base case RHF4 (Table 5-40).

Table 5-40: Inputs for the calculation of the Life Cycle Cost (lines A to L)

Table . Inputs for EU-Totals & LCC

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	**9**	years
B	Annual sales	**0.0192**	mln. Units/year
C	EU Stock	**0.17216**	mln. Units
D	Product price	**3970**	Euro/unit
E	Installation/acquisition costs (if any)	**397**	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	**0.097**	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	**2280**	Euro/ unit
M	Discount rate (interest minus inflation)	**1.8%**	%
N	Present Worth Factor (PWF) (calculated automatically)	**8.24**	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	**1.10**	

Thanks to those inputs, Table 5-41 shows the results of the EcoReport for the LCC:

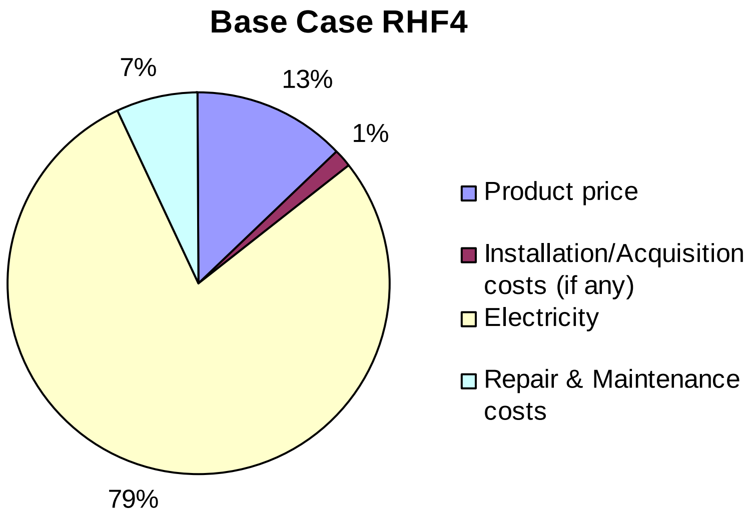
Table 5-41: EcoReport results LCC for the base case RHF4

Table . Life Cycle Costs per product and Total annual expenditure (2005) in the EU-25

	Base Case remote openfrozen island (RHF4) *Item*	LCC new product	total annual consumer expenditure in EU25
D	Product price	3970 €	76 mln.€
E	Installation/ acquisition costs (if any)	397 €	8 mln.€
F	Fuel (gas, oil, wood)	0 €	0 mln.€
F	Electricity	23732 €	545 mln.€
G	Water	0 €	0 mln.€
H	Aux. 1: None	0 €	0 mln.€
I	Aux. 2 :None	0 €	0 mln.€
J	Aux. 3: None	0 €	0 mln.€
K	Repair & maintenance costs	2088 €	44 mln.€
	Total	**30187** €	**673** mln.€

The electricity costs represent a major share of the LCC (79 %), followed by the product purchase cost (13 %) as shown in Figure 5-54.

Figure 5-54: LCC distribution for the base case RHF4



5.3.2 PLUG IN REFRIGERATED DISPLAY CABINETS

5.3.2.1 BASE CASE BEVERAGE COOLER

The inputs for the calculation of the LCC were defined according to the results of tasks 2, 3, and 4 as presented in Table 5-42[7].

[7] Repair and maintenance cost were calculated as being 7 % of the LCC. This means that 93 % LCC = 830 (purchase cost) + 365*8*7.043*0.105 (electricity cost) which leads to 7 % = 225 euros

Table 5-42: Inputs for the calculation of the LCC (lines A to L)

Table . Inputs for EU-Totals & LCC

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	8	years
B	Annual sales	0.79	mln. Units/year
C	EU Stock	6.32	mln. Units
D	Product price	830	Euro/unit
E	Installation/acquisition costs (if any)		Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.105	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	225	Euro/ unit
M	Discount rate (interest minus inflation)	1.8%	%
N	Present Worth Factor (PWF) (calculated automatically)	7.39	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.10	

The results of the LCC are given in the following table (Table 5-43):

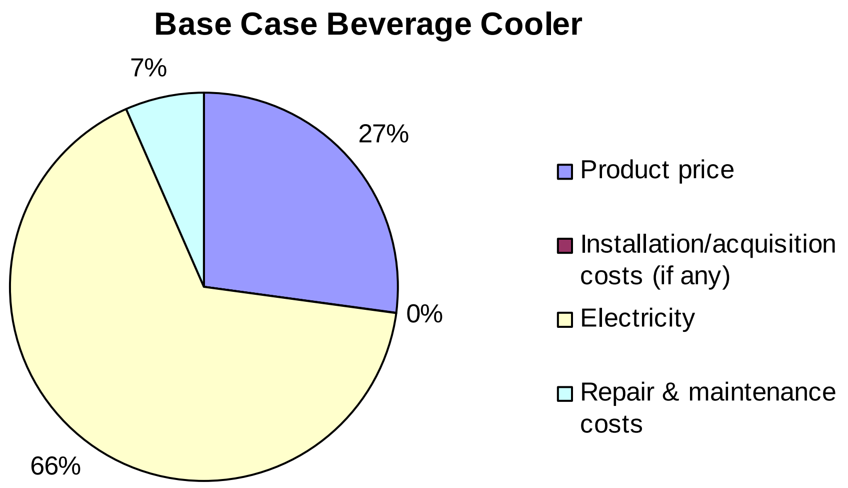
Table 5-43: EcoReport results LCC for the base case beverage cooler

Table . Life Cycle Costs per product and Total annual expenditure (2005) in the EU-25

	BASE CASE BEVERAGE COOLER *Item*	LCC new product	total annual consumer expenditure in EU25
D	Product price	830 €	656 mln.€
E	Installation/ acquisition costs (if any)	0 €	0 mln.€
F	Fuel (gas, oil, wood)	0 €	0 mln.€
F	Electricity	1994 €	1876 mln.€
G	Water	0 €	0 mln.€
H	Aux. 1: None	0 €	0 mln.€
I	Aux. 2 :None	0 €	0 mln.€
J	Aux. 3: None	0 €	0 mln.€
K	Repair & maintenance costs	208 €	178 mln.€
	Total	**3032** €	**2710** mln.€

About 66 % of the LCC is represented by the electricity consumption. The rest is due to the product price (27 %) and repair/ maintenance costs (7 %).

Figure 5-55: LCC distribution for the base case beverage cooler



5.3.2.2 BASE CASE ICE CREAM FREEZER

Data from tasks 2 and 4 was used to input the table of the EcoReport for the calculation of the LCC (Table 5-44).

Table 5-44: Inputs for the calculation of the LCC (lines A to L)

Table . Inputs for EU-Totals & LCC

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	8	years
B	Annual sales	0.338571	mln. Units/year
C	EU Stock	2.708568	mln. Units
D	Product price	800	Euro/unit
E	Installation/acquisition costs (if any)	0	Euro/ unit
F	Fuel rate (gas, oil, wood)	0	Euro/GJ
G	Electricity rate	0.105	Euro/kWh
H	Water rate	0	Euro/m3
I	Aux. 1: None	0	Euro/kg
J	Aux. 2 :None	0	Euro/kg
K	Aux. 3: None	0	Euro/kg
L	Repair & maintenance costs	164	Euro/ unit
M	Discount rate (interest minus inflation)	1.8%	%
N	Present Worth Factor (PWF) (calculated automatically)	7.39	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.10	

The EcoReport provides the following results for the LCC (Table 5-45):

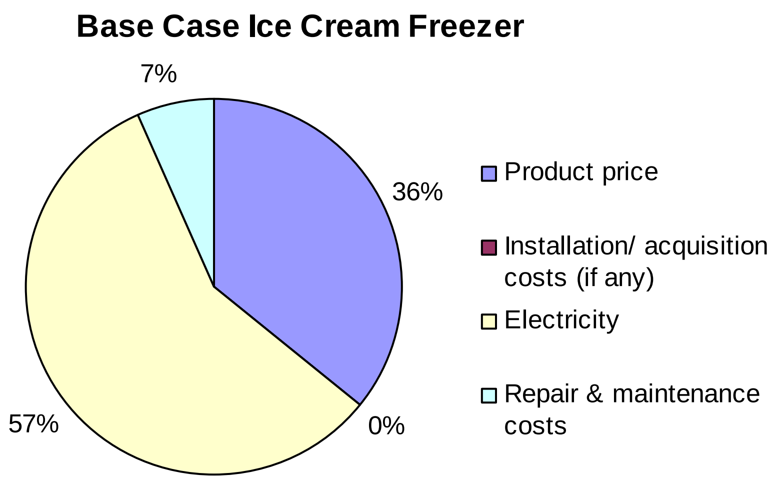
Table 5-45: EcoReport results LCC for the base case ice cream freezer

Table . Life Cycle Costs per product and Total annual expenditure (2005) in the EU-25

	Products Ice cream feezer *Item*	LCC new product		total annual consumer expenditure in EU25	
D	Product price	800	€	271	mln.€
E	Installation/ acquisition costs (if any)	0	€	0	mln.€
F	Fuel (gas, oil, wood)	0	€	0	mln.€
F	Electricity	1274	€	514	mln.€
G	Water	0	€	0	mln.€
H	Aux. 1: None	0	€	0	mln.€
I	Aux. 2 :None	0	€	0	mln.€
J	Aux. 3: None	0	€	0	mln.€
K	Repair & maintenance costs	151	€	56	mln.€
	Total	**2226**	€	**840**	mln.€

The electricity cost represents more than half of the LCC (57 %) and is followed by the product purchase cost (36 %) as shown in Figure 5-56.

Figure 5-56: LCC distribution for the base case ice cream freezer



5.3.3 COLD VENDING MACHINES

5.3.3.1 BASE CASE SPIRAL VENDING MACHINE

Data from tasks 2 and 4 was used to input the table of the EcoReport for the calculation of the LCC (Table 5-46).

Table 5-46: Inputs for the calculation of the LCC (lines A to L) (Year 2006)

Table . Inputs for EU-Totals & LCC

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	**8.5**	years
B	Annual sales	**0.126**	mln. Units/year
C	EU Stock	**1.378964327**	mln. Units
D	Product price	**3500**	Euro/unit
E	Installation/acquisition costs (if any)	**0**	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	**0.105**	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	**400**	Euro/ unit
M	Discount rate (interest minus inflation)	**1.8%**	%
N	Present Worth Factor (PWF) (calculated automatically)	**7.82**	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	**1.20**	

The EcoReport provides the following results for the LCC (Table 5-47):

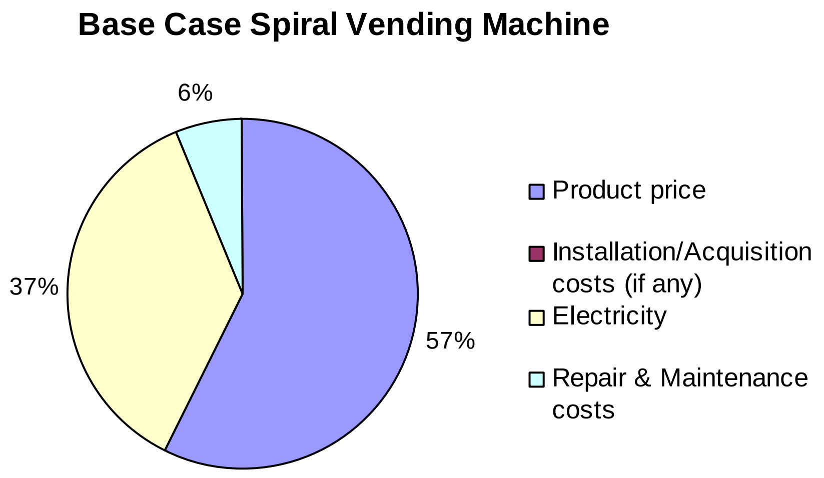
Table 5-47: EcoReport results LCC for the base case spiral vending machine

Table . Life Cycle Costs per product and Total annual expenditure (2005) in the EU-25

	Base-Case Spiral Vending Machine *Item*	LCC new product	total annual consumer expenditure in EU25
D	Product price	3500 €	441 mln.€
E	Installation/ acquisition costs (if any)	0 €	0 mln.€
F	Fuel (gas, oil, wood)	0 €	0 mln.€
F	Electricity	2236 €	473 mln.€
G	Water	0 €	0 mln.€
H	Aux. 1: None	0 €	0 mln.€
I	Aux. 2 :None	0 €	0 mln.€
J	Aux. 3: None	0 €	0 mln.€
K	Repair & maintenance costs	368 €	65 mln.€
	Total	**6104** €	**979** mln.€

The electricity cost represents more than half of the LCC (57 %) and is followed by the product purchase cost (37 %) as shown in Figure 5-57.

Figure 5-57: LCC repartition for the base case spiral vending machine



5.3.4 CONCLUSIONS

The results of the LCC calculations over the total product life (purchase, running costs, etc.) indicate that for both remote and plug in refrigerated display cabinets, the cost of the electricity is the highest investment. The purchase price of the products represents around 12 % of the LCC (electricity costs represent 80%) for a remote open cabinet and 30 % for a plug in appliance fitted with doors (electricity costs represents 60 %). Cold vending machines show a different distribution of the LCC with the product price being the most significant share of the LCC (over 50 %) followed by the cost of the electricity which represents almost 40 % of the LCC.

5.4. EU TOTALS

This section provides the environmental assessment of the base cases at the EU 25 level using stock and market data from the Market Analysis (task 2). The reference year for the EU totals is 2006 as for environmental impacts. ‘EU’ is synonymous to ‘EU-25’. It covers:

- The life cycle environmental impact of the new products designed in 2006 (this related to a period of 2006 up to 2006 + product life) (i.e. impacts of the sales)
- The annual (2006) impact of production, use and (estimated) disposal of the product group, assuming post-ROHS and post-WEEE conditions and the total LCC (i.e. impact and LCC of the stock).

5.4.1 REMOTE REFRIGERATED DISPLAY CABINET

5.4.1.1 BASE CASE VERTICAL OPEN CHILLED MULTI DECK (RCV2)

Environmental impacts of the sales (2006)

Table 5-48 shows the total environmental impact of all products sold in most recent year (2006).

Table 5-48: Output EuP EcoReport for new models sold in 2006 (EcoReport tool specifies 2005 as a default reference year)

Nr	EU Impact of New Models sold 2005 over their lifetime:		Date	Author
0	Product Base Case remote open vertical chilled multi deck (RCV2)		0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**2**			0	2	**2**	**0**
2	TecPlastics	kt			**4**			0	4	**4**	**0**
3	Ferro	kt			**68**			3	65	**68**	**0**
4	Non-ferro	kt			**7**			0	7	**7**	**0**
5	Coating	kt			**3**			0	3	**3**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**5**			0	5	**5**	**0**
	Total weight	kt			**90**			5	85	**90**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	5	1	**6**	**2**	**390**	0	0	**0**	**399**
9	of which, electricity (in primary PJ)	PJ	1	1	**1**	**0**	**390**	0	0	**0**	**392**
10	Water (process)	mln. m3	0	0	**0**	**0**	**26**	0	0	**0**	**26**
11	Water (cooling)	mln. m3	3	0	3	0	**1041**	0	0	0	1044
12	Waste, non-haz./ landfill	kt	167	5	**172**	**1**	**454**	6	0	**5**	**633**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**9**	1	0	**1**	**10**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**17**	0	0	**0**	**18**
15	Ozone Depletion, emissions	t R-11 eq.	negligible								
16	Acidification, emissions	kt SO2 eq.	1	0	**2**	**0**	**101**	0	0	**0**	**103**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	2	0	**2**	**0**	**3**	0	0	**0**	**4**
19	Heavy Metals	ton Ni eq.	0	0	**1**	**0**	**7**	0	0	**0**	**7**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**5**	**2**	1	0	**1**	**8**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	1	0	**1**	**0**	**3**	0	0	**0**	**3**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Environmental impact of the stock

The "overall improvement ratio stock vs. new, use phase" is estimated with 10 % (equals a ratio of 1.1), in accordance with major refrigerated display cabinet manufacturers.

Table 5-49 and Table 5-50 present the EU 25 environmental impacts in the current year (2006).

Table 5-49: Output EuP EcoReport for EU Stock (2006)

Nr	EU Impact of Products in 2005 (produced, in use, discarded)***	Date	Author
	Product Base Case remote open vertical chilled multi deck (RCV2)	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**2**			0	2	**2**	**0**
2	TecPlastics	kt			**4**			0	4	**4**	**0**
3	Ferro	kt			**68**			3	65	**68**	**0**
4	Non-ferro	kt			**7**			0	7	**7**	**0**
5	Coating	kt			**3**			0	3	**3**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**5**			0	5	**5**	**0**
	Total weight	kt			**90**			5	85	**90**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	5	1	**6**	**2**	**428**	0	0	**0**	**436**
9	of which, electricity (in primary PJ)	PJ	1	1	**1**	**0**	**428**	0	0	**0**	**429**
10	Water (process)	mln. m3	0	0	**0**	**0**	**29**	0	0	**0**	**29**
11	Water (cooling)	mln. m3	3	0	**3**	**0**	**1141**	0	0	0	**1144**
12	Waste, non-haz./ landfill	kt	167	5	**172**	**1**	**498**	6	0	**5**	**676**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**10**	1	0	**1**	**11**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**19**	0	0	**0**	**19**
15	Ozone Depletion, emissions	t R-11 eq.				negligible					
16	Acidification, emissions	kt SO2 eq.	1	0	**2**	**0**	**110**	0	0	**0**	**112**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	2	0	**2**	**0**	**3**	0	0	**0**	**5**
19	Heavy Metals	ton Ni eq.	0	0	**1**	**0**	**7**	0	0	**0**	**8**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**5**	**2**	1	0	**1**	**8**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	1	0	**1**	**0**	**3**	0	0	**0**	**3**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq				negligible					

Table 5-50: Summary of the environmental impacts of the EU 2006 stock (EcoReport specifies 2005 as the default reference value)

Table . Summary Environmental Impacts EU-Stock 2005, Product Base Case remote open vertical chilled multi deck (RCV2)

main life cycle indicators	value	unit
Total Energy (GER)	**436**	PJ
of which, electricity	40.9	TWh
Water (process)*	29	mln.m3
Waste, non-haz./ landfill*	676	kton
Waste, hazardous/ incinerated*	11	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**19**	mt CO2eq.
Acidifying agents (AP)	**112**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**5**	g i-Teq.
Heavy Metals (HM)	**8**	ton Ni eq.
PAHs	**1**	ton Ni eq.
Particulate Matter (PM, dust)	**8**	kt
Emissions (Water)		
Heavy Metals (HM)	3	ton Hg/20
Eutrophication (EP)	0	kt PO4

*=caution: low accuracy for production phase

5.4.1.2 BASE CASE HORIZONTAL OPEN FROZEN ISLAND (RHF4)

Environmental impacts of the sales (2006)

Table 5-51 shows the total environmental impact of all products sold in most recent year (2006).

Table 5-51: Output EuP EcoReport for new models sold in 2006 (EcoReport tool specifies 2005 as a default reference year)

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	Base Case remote open frozen island (RHF4)	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**1**			0	1	**1**	**0**
2	TecPlastics	kt			**0**			0	0	**0**	**0**
3	Ferro	kt			**9**			0	8	**9**	**0**
4	Non-ferro	kt			**1**			0	1	**1**	**0**
5	Coating	kt			**0**			0	0	**0**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**4**			0	4	**4**	**0**
	Total weight	kt			**15**			1	14	**15**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	1	0	**1**	**0**	**54**	0	0	**0**	**55**
9	of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**54**	0	0	**0**	**54**
10	Water (process)	mln. m3	0	0	**0**	**0**	**4**	0	0	**0**	**4**
11	Water (cooling)	mln. m3	0	0	**0**	**0**	**144**	0	0	**0**	**144**
12	Waste, non-haz./ landfill	kt	24	1	**25**	**0**	**63**	1	0	**1**	**89**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**2**	0	0	**0**	**2**
15	Ozone Depletion, emissions	t R-11 eq.	negligible								
16	Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**14**	0	0	**0**	**14**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**0**	0	0	**0**	**1**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**1**	**0**	0	0	**0**	**1**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**0**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Environmental impacts of the stock

The “overall improvement ratio stock vs. new, use phase” is estimated with 10 % (equals a ratio of 1.1) as for remotes RCV2.

Table 5-52 and Table 5-53 present the environmental impacts in the current year.

Table 5-52: Output EuP EcoReport for EU stock (2006)

Nr	EU Impact of Products in 2005 (produced, in use, discarded)***	Date	Author
	Base Case remote open frozen island (RHF4)	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	kt			**1**			0	1	**1**	**0**
2	TecPlastics	kt			**0**			0	0	**0**	**0**
3	Ferro	kt			**9**			0	8	**9**	**0**
4	Non-ferro	kt			**1**			0	1	**1**	**0**
5	Coating	kt			**0**			0	0	**0**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**4**			0	4	**4**	**0**
	Total weight	kt			**15**			1	14	**15**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	1	0	**1**	**0**	**59**	0	0	**0**	**60**
9	of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**59**	0	0	**0**	**59**
10	Water (process)	mln. m3	0	0	**0**	**0**	**4**	0	0	**0**	**4**
11	Water (cooling)	mln. m3	0	0	**0**	**0**	**157**	0	0	**0**	**158**
12	Waste, non-haz./ landfill	kt	24	1	**25**	**0**	**69**	1	0	**1**	**95**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**3**	0	0	**0**	**3**
15	Ozone Depletion, emissions	t R-11 eq.	negligible								
16	Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**15**	0	0	**0**	**16**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**0**	0	0	**0**	**1**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**1**	**0**	0	0	**0**	**1**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**1**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Table 5-53: Summary of the environmental impacts of the EU 2006 stock (EcoReport specifies 2005 as the default reference year)

Table . Summary Environmental Impacts EU-Stock 2005, Base Case remote open frozen island (RHF4)

main life cycle indicators	value	unit
Total Energy (GER)	**60**	PJ
of which, electricity	5.6	TWh
Water (process)*	**4**	mln.m3
Waste, non-haz./ landfill*	**95**	kton
Waste, hazardous/ incinerated*	**1**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**3**	mt CO2eq.
Acidifying agents (AP)	**16**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**1**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**1**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

***=caution: low accuracy for production phase**

5.4.2 PLUG IN REFRIGERATED DISPLAY CABINETS

5.4.2.1 BASE CASE BEVERAGE COOLER

- **Environmental impacts of the sales (2006)**

Table 5-54 shows the total environmental impact of all products sold in most recent yeas (2006).

Table 5-54: Output EuP EcoReport for new models sold in 2006 (EcoReport tool specifies 2005 as the default reference year)

Table . EU Total Impact of NEW BASE CASE BEVERAGE COOLER produced in 2005 (over their lifetime)

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	BASE CASE BEVERAGE COOLER	0	BIO IS

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**4**			0	4	**4**	**0**
2	TecPlastics	kt			**7**			1	6	**7**	**0**
3	Ferro	kt			**54**			3	52	**54**	**0**
4	Non-ferro	kt			**10**			1	10	**10**	**0**
5	Coating	kt			**1**			0	1	**1**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**21**			1	20	**21**	**0**
	Total weight	kt			**97**			5	92	**97**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	5	1	**6**	**1**	**173**	0	1	**0**	**180**
9	of which, electricity (in primary PJ)	PJ	1	1	**1**	**0**	**173**	0	0	**0**	**174**
10	Water (process)	mln. m3	1	0	**1**	**0**	**12**	0	0	**0**	**12**
11	Water (cooling)	mln. m3	3	0	3	0	**461**	0	0	0	**464**
12	Waste, non-haz./ landfill	kt	161	5	**165**	**1**	**202**	6	0	**6**	**374**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**4**	1	0	**1**	**5**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**8**	0	0	**0**	**8**
15	Ozone Depletion, emissions	t R-11 eq.	negligible								
16	Acidification, emissions	kt SO2 eq.	2	0	**2**	**0**	**45**	0	0	**0**	**47**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	1	0	**1**	**0**	**1**	0	0	**0**	**3**
19	Heavy Metals	ton Ni eq.	1	0	**1**	**0**	**3**	0	0	**0**	**4**
	PAHs	ton Ni eq.	1	0	**1**	**0**	**0**	0	0	**0**	**1**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**3**	**1**	1	0	**1**	**5**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	1	0	**1**	**0**	**1**	0	0	**0**	**2**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Environmental impacts of the stock (2006)

The “overall improvement ratio stock vs. new use phase” is estimated with 10 % (equals to a ratio of 1.1) as it was done for the remote category of refrigerated display cabinets.

Table 5-55 and Table 5-56 show the results of the environmental impacts of the EU stock for year 2006.

Table 5-55: Output EuP EcoReport for EU stock (2006)

Table . EU Total Impact of STOCK of BASE CASE BEVERAGE COOLER in 2005 (produced, in use, discarded)

Nr	EU Impact of Products in 2005 (produced, in use, discarded)***	Date	Author
	BASE CASE BEVERAGE COOLER	0	BIO IS

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**4**			0	4	**4**	**0**
2	TecPlastics	kt			**7**			1	6	**7**	**0**
3	Ferro	kt			**54**			3	52	**54**	**0**
4	Non-ferro	kt			**10**			1	10	**10**	**0**
5	Coating	kt			**1**			0	1	**1**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**21**			1	20	**21**	**0**
	Total weight	kt			**97**			5	92	**97**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	5	1	**6**	**1**	**188**	0	1	**0**	**195**
9	of which, electricity (in primary PJ)	PJ	1	1	**1**	**0**	**188**	0	0	**0**	**189**
10	Water (process)	mln. m3	1	0	**1**	**0**	**13**	0	0	**0**	**13**
11	Water (cooling)	mln. m3	3	0	**3**	**0**	**500**	0	0	**0**	**504**
12	Waste, non-haz./ landfill	kt	161	5	**165**	**1**	**219**	6	0	**6**	**391**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**4**	1	0	**1**	**6**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**8**	0	0	**0**	**9**
15	Ozone Depletion, emissions	t R-11 eq.				negligible					
16	Acidification, emissions	kt SO2 eq.	2	0	**2**	**0**	**48**	0	0	**0**	**51**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	1	0	**1**	**0**	**1**	0	0	**0**	**3**
19	Heavy Metals	ton Ni eq.	1	0	**1**	**0**	**3**	0	0	**0**	**4**
	PAHs	ton Ni eq.	1	0	**1**	**0**	**0**	0	0	**0**	**1**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**3**	**1**	1	0	**1**	**5**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	1	0	**1**	**0**	**1**	0	0	**0**	**2**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq				negligible					

Table 5-56: Summary of the environmental impacts of the EU stock 2006 (EcoReport specifies 2005 as the default reference year)

Table . Summary Environmental Impacts EU-Stock 2005, BASE CASE BEVERAGE COOLER

main life cycle indicators	value	unit
Total Energy (GER)	**195**	PJ
of which, electricity	18.0	TWh
Water (process)*	**13**	mln.m3
Waste, non-haz./ landfill*	**391**	kton
Waste, hazardous/ incinerated*	**6**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**9**	mt CO2eq.
Acidifying agents (AP)	**51**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**3**	g i-Teq.
Heavy Metals (HM)	**4**	ton Ni eq.
PAHs	**1**	ton Ni eq.
Particulate Matter (PM, dust)	**5**	kt
Emissions (Water)		
Heavy Metals (HM)	2	ton Hg/20
Eutrophication (EP)	0	kt PO4

***=caution: low accuracy for production phase**

5.4.2.2 BASE CASE ICE CREAM FREEZER

- **Environmental impacts of the sales (2006)**

As for beverage coolers, the reference year for the EU totals is 2006. The sales and stock data were estimated in task 2.

Table 5-57 shows the EU environmental impact assessment for all products sold in most recent year 2006.

Table 5-57: Output EuP EcoReport for new models sold in 2006 (EcoReport specifies 2005 as the default reference year)

Table . EU Total Impact of NEW Products Ice cream feezer produced in 2005 (over their lifetime)

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	Products Ice cream feezer	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**1**			0	1	**1**	**0**
2	TecPlastics	kt			**3**			0	2	**3**	**0**
3	Ferro	kt			**7**			0	6	**7**	**0**
4	Non-ferro	kt			**2**			0	2	**2**	**0**
5	Coating	kt			**8**			0	8	**8**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**4**			0	4	**4**	**0**
	Total weight	kt			**25**			1	24	**25**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	3	0	**4**	**0**	**47**	0	0	**0**	**51**
9	of which, electricity (in primary PJ)	PJ	1	0	**1**	**0**	**47**	0	0	**0**	**48**
10	Water (process)	mln. m3	0	0	**0**	**0**	**3**	0	0	**0**	**4**
11	Water (cooling)	mln. m3	4	0	4	0	**125**	0	0	0	129
12	Waste, non-haz./ landfill	kt	39	1	**40**	**0**	**55**	2	0	**2**	**96**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**1**	0	0	**0**	**2**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**2**	0	0	**0**	**2**
15	Ozone Depletion, emissions	t R-11 eq.				negligible					
16	Acidification, emissions	kt SO2 eq.	1	0	**1**	**0**	**12**	0	0	**0**	**13**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**0**	0	0	**0**	**1**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**1**	**0**	0	0	**0**	**2**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**1**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq				negligible					

Environmental impacts of the stock (2006)

The "overall improvement ratio stock vs. new use phase" is estimated with 10 % (equals to a ratio of 1.1) as it was done for the remote category of refrigerated display cabinets.

Table 5-58 and Table 5-59 show the results of the environmental impacts of the EU stock for year 2006.

Table 5-58: Output EcoReport for EU stock 2006 (EcoReport specifies 2005 as the default reference year)

Table . EU Total Impact of STOCK of Products Ice cream feezer in 2005 (produced, in use, discarded)

Nr	EU Impact of Products in 2005 (produced, in use, discarded)***	Date	Author
	Products Ice cream feezer	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**1**			0	1	**1**	**0**
2	TecPlastics	kt			**3**			0	2	**3**	**0**
3	Ferro	kt			**7**			0	6	**7**	**0**
4	Non-ferro	kt			**2**			0	2	**2**	**0**
5	Coating	kt			**8**			0	8	**8**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**4**			0	4	**4**	**0**
	Total weight	kt			**25**			1	24	**25**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	3	0	**4**	**0**	**51**	0	0	**0**	**55**
9	of which, electricity (in primary PJ)	PJ	1	0	**1**	**0**	**51**	0	0	**0**	**52**
10	Water (process)	mln. m3	0	0	**0**	**0**	**3**	0	0	**0**	**4**
11	Water (cooling)	mln. m3	4	0	**4**	**0**	**137**	0	0	**0**	**141**
12	Waste, non-haz./ landfill	kt	39	1	**40**	**0**	**60**	2	0	**2**	**101**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**1**	0	0	**0**	**2**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**2**	0	0	**0**	**3**
15	Ozone Depletion, emissions	t R-11 eq.					negligible				
16	Acidification, emissions	kt SO2 eq.	1	0	**1**	**0**	**13**	0	0	**0**	**14**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**0**	0	0	**0**	**1**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**1**	**0**	0	0	**0**	**2**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**1**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq					negligible				

Table 5-59: Summary of the environmental impacts of the EU 2006 stock (EcoReport specifies 2005 as the default reference year)

Table . Summary Environmental Impacts EU-Stock 2005, Products Ice cream feezer

main life cycle indicators	value	unit
Total Energy (GER)	**55**	PJ
of which, electricity	5.0	TWh
Water (process)*	**4**	mln.m3
Waste, non-haz./ landfill*	**101**	kton
Waste, hazardous/ incinerated*	**2**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**3**	mt CO2eq.
Acidifying agents (AP)	**14**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**1**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**2**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

***=caution: low accuracy for production phase**

5.4.3 COLD VENDING MACHINES

5.4.3.1 BASE CASE SPIRAL VENDING MACHINE

- **Environmental impacts of the sale (2006)**

Table 5-60 shows the environmental impacts of all products sold in most recent year (2006).

Table 5-60: Output EuP EcoReport for new models sold in 2006

Table . EU Total Impact of NEW Base-Case Spiral Vending Machine produced in 2005 (over their lifetime)

Nr	**EU Impact of New Models sold 2005 over their lifetime:**	Date	Author
0	Base-Case Spiral Vending Machine	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	kt			**4**			0	4	**4**	**0**
2	TecPlastics	kt			**1**			0	1	**1**	**0**
3	Ferro	kt			**18**			1	17	**18**	**0**
4	Non-ferro	kt			**1**			0	1	**1**	**0**
5	Coating	kt			**10**			0	9	**10**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**3**			0	3	**3**	**0**
	Total weight	kt			**37**			2	35	**37**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	5	1	**5**	**0**	**31**	0	0	**0**	**36**
9	of which, electricity (in primary PJ)	PJ	1	0	**2**	**0**	**31**	0	0	**0**	**32**
10	Water (process)	mln. m3	1	0	**1**	**0**	**2**	0	0	**0**	**3**
11	Water (cooling)	mln. m3	5	0	5	0	**82**	0	0	0	86
12	Waste, non-haz./ landfill	kt	47	2	**49**	**0**	**36**	2	0	**2**	**87**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**1**	1	0	**1**	**2**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**1**	0	0	**0**	**2**
15	Ozone Depletion, emissions	t R-11 eq.					negligible				
16	Acidification, emissions	kt SO2 eq.	1	0	**1**	**0**	**8**	0	0	**0**	**9**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**1**	**0**	**0**	0	0	**0**	**1**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**1**	**0**	0	0	**0**	**1**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**1**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq					negligible				

Environmental impacts of the stock (2006)

The “overall improvement ratio stock vs. new use phase” is estimated with 20 % (equals to a ratio of 1.2). Table 5-61 and Table 5-62 show the results of the environmental impacts of the EU stock for the year 2006.

Table 5-61: Output EuP EcoReport for EU stock (2006)

Table . EU Total Impact of STOCK of Base-Case Spiral Vending Machine in 2005 (produced, in use, discarded)

Nr	EU Impact of Products in 2005 (produced, in use, discarded)***	Date	Author
	Base-Case Spiral Vending Machine	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**4**			0	4	**4**	**0**
2	TecPlastics	kt			**1**			0	1	**1**	**0**
3	Ferro	kt			**18**			1	17	**18**	**0**
4	Non-ferro	kt			**1**			0	1	**1**	**0**
5	Coating	kt			**10**			0	9	**10**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**3**			0	3	**3**	**0**
	Total weight	kt			**37**			2	35	**37**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	5	1	**5**	**0**	**47**	0	0	**0**	**53**
9	of which, electricity (in primary PJ)	PJ	1	0	**2**	**0**	**47**	0	0	**0**	**49**
10	Water (process)	mln. m3	1	0	**1**	**0**	**3**	0	0	**0**	**4**
11	Water (cooling)	mln. m3	5	0	**5**	**0**	**126**	0	0	**0**	**131**
12	Waste, non-haz./ landfill	kt	47	2	**49**	**0**	**56**	2	0	**2**	**107**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**1**	1	0	**1**	**2**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**2**	0	0	**0**	**2**
15	Ozone Depletion, emissions	t R-11 eq.	negligible								
16	Acidification, emissions	kt SO2 eq.	1	0	**1**	**0**	**12**	0	0	**0**	**14**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**1**	**0**	**0**	0	0	**0**	**1**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**1**	**0**	0	0	**0**	**1**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**1**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Table 5-62: Summary of the environmental impacts of the EU stock (2006)

Table . Summary Environmental Impacts EU-Stock 2005, Base-Case Spiral Vending Machine

main life cycle indicators	value	unit
Total Energy (GER)	**53**	PJ
of which, electricity	4.7	TWh
Water (process)*	**4**	mln.m3
Waste, non-haz./ landfill*	**107**	kton
Waste, hazardous/ incinerated*	**2**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**2**	mt CO2eq.
Acidifying agents (AP)	**14**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**1**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**1**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

***=caution: low accuracy for production phase**

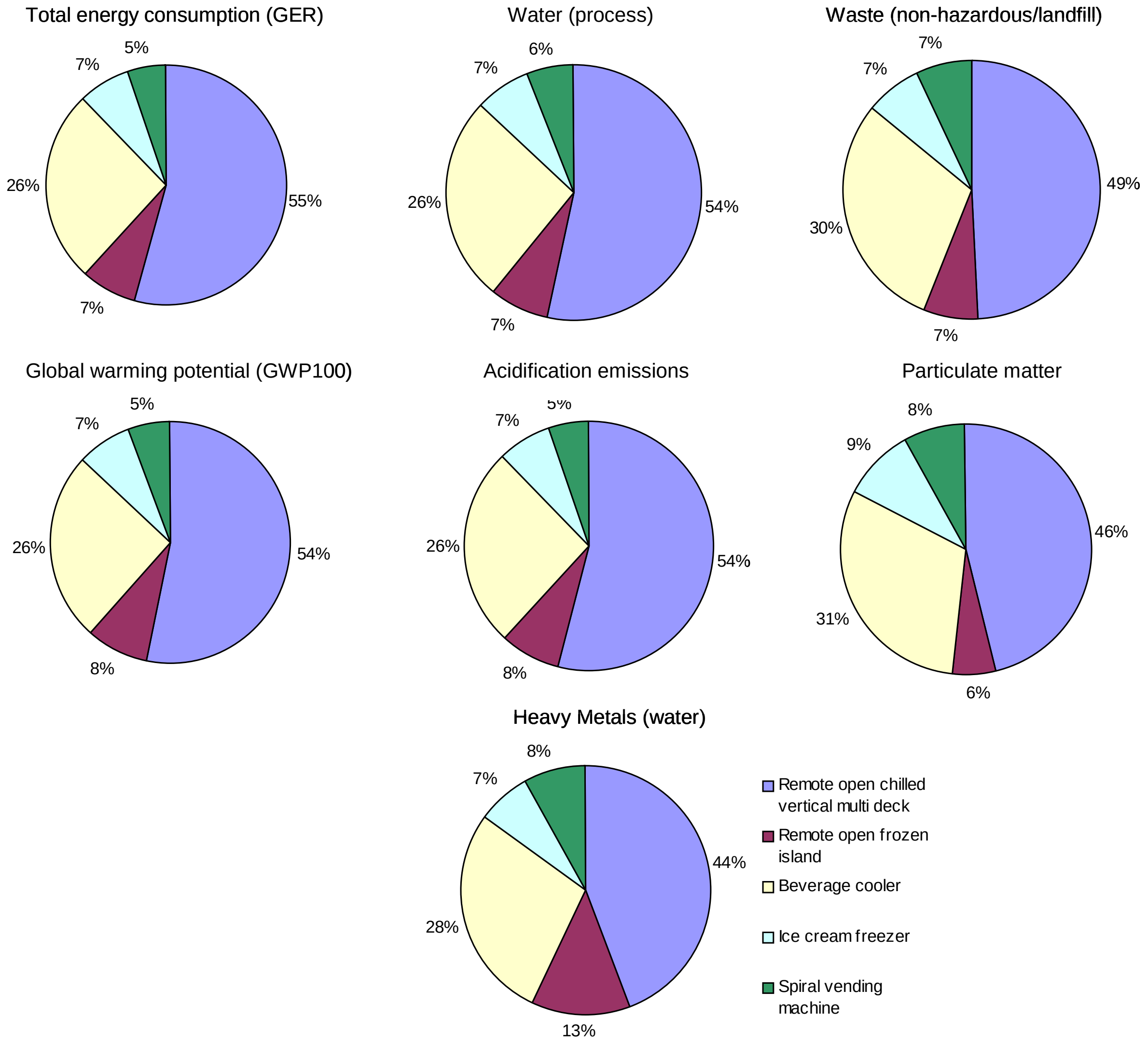
5.4.4 CONCLUSIONS

Summary of environmental impacts and life cycle costs of base cases, as well as the lot 12 totals are presented in Figure 5-58 and Figure 5-59.

Regarding the environmental impacts of the 2006 stock, the category of remote refrigerated display cabinets are the largest contributors to the total energy consumption (GER) (Figure 5-58). Regarding sub-product groups, the open vertical chilled multi decks (RCV2) make up for over half of the total. In general, spiral refrigerated vending machines contribute only few percent.

Impacts in all categories are mainly linked to energy consumption in the use phase. Consequently, regarding the relative importance of the base cases, the total energy consumption correlates closely with other impacts.

Figure 5-58: Base cases' share of the environmental impacts of the 2006 stock



Preliminary results, excluding open frozen islands, show that the annual consumer expenditure is 8670 million euros, over 70 % of which is due to electricity consumption.

Table 5-63: Comparison of total consumer expenditure (EU 25) in 2006

EU totals (million euros) in 2005	Remote open chilled multi deck	Open frozen island	Beverage cooler	Ice cream freezer	Spiral vending machine
Product price	504	76	656	271	441
Installation/acquisition costs (if any)	50	8	0	0	0
Electricity	3234	545	1876	514	473
Repair and maintenance costs	312	44	178	56	65
Total	4100	673	2710	840	979

Figure 5-59: Comparison of total annual expenditure for each base case

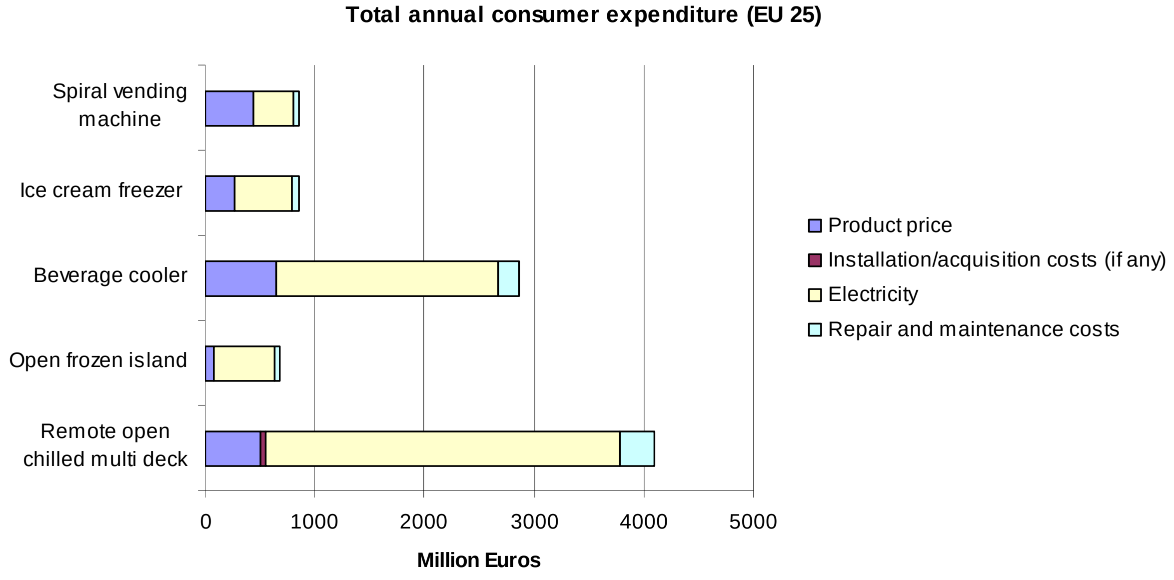


Table 5-64 summarises the total electricity consumption (during the use phase) based on the annual TEC and on the stock in 2006 of each base case, assuming that the stock is only composed of base cases. Therefore, the total electricity consumption in 2006 of commercial refrigerators and freezers which are in the scope of this study is 65.83 TWh (1 TWh = 1 million MWh). This represents about 0.35 % of the EU-25 total energy consumption[8].

Table 5-64: Total electricity consumption for the year 2006

Base case	EU-25 stock electricity consumption in 2006 (TWh)
Base case RCV2	37.04
Base case RHF4	5.11
Base case beverage cooler	16.25
Base case ice cream freezer	4.45
Base case spiral vending machine	2.98
TOTAL	65.83

5.5. EU-25 Total System Impact

5.5.1 Remote refrigerated display cabinet

When analysing the base cases of the remote refrigerated display cabinets, the focus was set on the products themselves, i.e. the cabinets and not on the

[8]Source Eurostat: EU-25 energy consumption in 2005 = 1,637 million toe

http://epp.eurostat.ec.europa.eu/pls/portal/docs/PAGE/PGP_PRD_CAT_PREREL/PGE_CAT_PREREL_YEAR_2006/PGE_CAT_PREREL_YEAR_2006_MONTH_09/8-21092006-EN-AP1.PDF system they belong to. However, all remote appliances operate in a store (e.g. supermarket, hypermarket…) and are linked to a refrigeration system which operation adds a consequent environmental impact. The refrigeration system of a supermarket mainly consists of the compressor module, the condensation module and of the refrigerant pipes distributing the refrigerant liquid to the display cases throughout the store. The resources used are the electricity for the operation of the compressor motors and fans at the condenser, and the refrigerant liquid.

The standard measurement of the energy consumption of the remote equipment includes the REC which is the electrical energy used by the refrigeration system to produce the refrigeration load needed by the cabinets. However, the impact analysis of the remote appliances does not include the direct emissions of refrigerant due to refrigerant leakage along the pipes. These emissions are far from being negligible: worldwide, commercial refrigeration is the refrigeration sub-sector with the largest refrigerant emissions (in CO_2 equivalent) representing 40 % of the world total CO_2 emissions[9] (Figure 5-60). Major leak sources are the condenser valves and connections, the hot gas defrost valves and the piping connections.

According to the IPCC/TEAP report[9] the global annual refrigerant emission rate from the commercial refrigeration sector worldwide is of 30 % and direct emission through refrigerant leakage represent 60 % of the total greenhouse gases emissions resulting from the whole system operation, the rest being indirect emissions from power production. The annual average leakage rates in different EU countries are given in Table 5-65. These leakage rates are in the process of being reduced, primary due to the implementation of the F-Gas regulation[10]. Depending of the cooling capacity, the total refrigerant charge varies between 100 and 2000 kg in a full supermarket system for a direct centralised installation and between 20 and 500 kg for an indirect centralised installation. On average it is estimated that 4.5 kg of refrigerant is used to produce 1 kW of refrigeration capacity. However, this value is purely indicative and can vary depending of the refrigeration system installation.

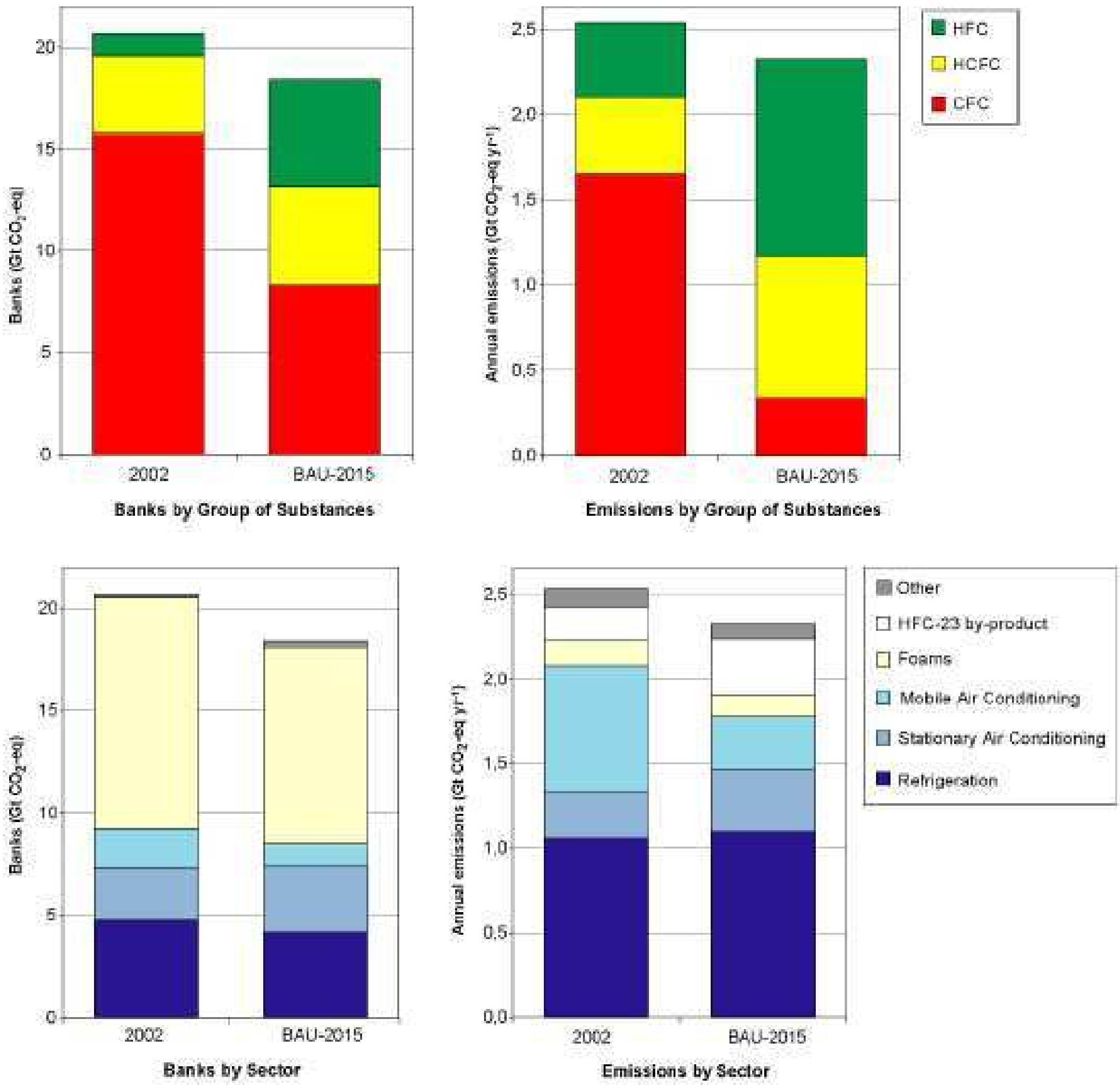
As described in task 4, the predominant refrigerants in use in Europe are HFC R-404 A and HFC R-507 A for supermarkets and hypermarkets refrigeration systems. With the Montreal Protocol and the ban of ODS (Ozone Depleting Substances) and HCFCs, the share of HFCs is predicted to increase. This trend implies that despite lower leakage rates, HFC leakages from refrigeration are set to increase considerably. In Europe, a 50 % cut in leakage rates due to industry efforts and regulations with respect to refrigerant containment, recovery, usage record keeping, increased personnel training and certification, and improved service procedures in every member state would result in emissions rising from 2.5 – 4.3 million tonnes CO_2 eq. in 1995 to around 30 million tonnes CO_2 eq. in 2010 instead of 45 tonnes CO_2 eq. under a business

[9] IPCC *Special Report on Safeguarding the Ozone Layer and the Global Climate System. Chapter 4 Refrigeration*. (2005)

[10] REGULATION (EC) No 842/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2006 on certain fluorinated greenhouse gases

as usual scenario[11]. The IPCC/ TEAP report states that there is a direct emission reduction potential of 34 % until 2015.

Figure 5-60: Greenhouse gas CO_2-equivalent banks and emissions related to the use of CFCs, HCFCs, and HFCs[12]



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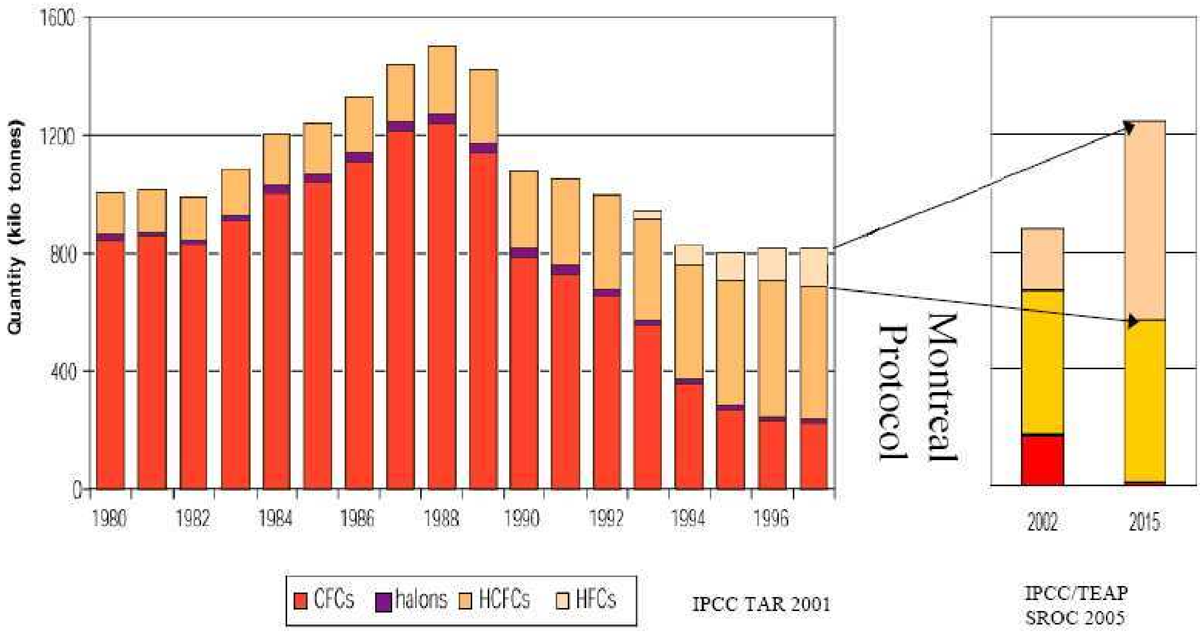
[11] IPCC *Special Report on Safeguarding the Ozone Layer and the Global Climate System. Chapter 4 Refrigeration*. (2005)

[12] Historic data for 2002 and Business-As-Usual (BAU) projections for 2015 of greenhouse gas CO2-equivalent banks (left) and direct annual emissions (right), related to the use of CFCs, HCFCs and HFCs. Breakdown per group of greenhouse gases (top) and per emission sector (bottom). 'Other' includes Medical Aerosols, Fire Protection, Non-Medical Aerosols and Solvents. "Refrigeration" sector comprises domestic, commercial, industrial (including food processing and cold storage) and transportation refrigeration. Source: http://www.ipcc.ch/press/SPM.pdf

Table 5-65: Leakage rates of supermarket refrigeration systems

Country	Year(s)	Annual refrigerant loss (%)
The Netherlands	1999	3.2
Germany	2000-2002	05-oct
Denmark	2003	10
Norway	2002-2003	14
Sweden	1993 1998 2001	14 12.5 10.4
United-Kingdom	1998	14.4

Figure 5-61: Effect of the Montreal Protocol on world refrigerant consumption[13]



13 http://www.mnp.nl/ipcc/docs/SROCF/SBSTA22/IPCC_TEAP_SROC.pdf

5.6. CONCLUSIONS

There is a great diversity in the type of existing appliances in the commercial refrigeration sector in terms of application (chilled/frozen), location of the condensing unit (remote/plug in) and design (open/closed cabinet), leading to different BOMs and energy consumption values depending of the equipment considered. The EcoReport analysis shows that for all base cases, the use phase is, not surprisingly, the highest contributor to the total environmental impacts over the whole lifetime of the products. The production phase is the second highest contributor with metal sheet panels being the most significant assemblies in term of resource consumption and emissions, followed by the heat exchangers modules and the compressor in case of plug in appliances.

The results for the total EU wide impacts represent about 75 % of the remote refrigerated display cabinet segment[14], 88 % of the plug in market and 100 % of the cold vending machine market, assuming all vending machines operate like spiral vending machines.

The base cases will serve as point of reference when evaluating the improvement potential (task 7) of various design options explored in task 6. And because most of the environmental impacts are due to the use phase, the analysis of the improvement potential in task 7 will primarily focus on technologies that reduce the power consumption and improve energy efficiency.

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[14] According to task 2, 61 % of the remote refrigerated display cabinets are very similar to open vertical multi decks (RCV2) and 13 % are open frozen islands.

ANNEXES

Annexe 5- 1: Detailed results of the Eco-report for Base Case RCV2

MATERIALS EXTRACTION & PRODUCTION

	Product	Energy			Water		Waste		Emissions to Air							to Water	
nr	component	GER	electr	feedst	water (proces)	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	Housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	External housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Panels and cabinet structure (external pa	6450.22	432.26	14.08	0.00	0.00	0.00	326593.68	536.37	1416.23	25.87	4932.52	672.46	13.14	513.62	673.51	12363.47
4	Panels pre coating	1706.17	453.08	231.76	103.27	2087.13	103.27	2209.72	84.60	321.49	4.35	2.09	5.48	1.26	83.29	2.26	52458.69
5	Chassis	1992.24	133.51	4.35	0.00	0.00	0.00	100872.85	165.66	437.42	7.99	1523.48	207.70	4.06	158.64	208.02	3818.62
6	Chassis pre-coating	526.97	139.94	71.58	31.90	644.64	31.90	682.50	26.13	99.30	1.34	0.65	1.69	0.39	25.72	0.70	16202.57
7	Mounting internal components	1424.04	95.43	3.11	0.00	0.00	0.00	72103.15	118.42	312.66	5.71	1088.97	148.46	2.90	113.39	148.69	2729.52
8	Mounting internal components pre coati	376.68	100.03	51.17	22.80	460.78	22.80	487.85	18.68	70.98	0.96	0.46	1.21	0.28	18.39	0.50	11581.48
9	Epoxy coating	2833.32	486.30	338.21	150.70	3045.82	164.14	3900.66	141.25	499.32	0.22	3.82	10.00	2.07	122.18	4.04	76558.43
10	PVC parts	88.80	17.43	35.97	17.25	97.25	7.84	105.24	3.39	23.52	0.00	0.00	0.00	0.04	4.55	4.41	492.53
11	PC parts	54.35	6.91	17.68	6.51	53.04	4.65	82.15	2.51	11.83	0.00	0.00	0.00	0.17	3.12	0.08	234.51
12	ABS parts	34.09	2.49	16.42	3.34	59.20	3.59	32.98	1.19	6.38	0.00	0.00	0.00	0.65	1.04	0.70	225.97
13	PS parts	255.69	10.67	140.12	14.45	521.81	2.02	64.37	8.23	50.78	0.00	0.00	0.00	356.26	4.42	0.00	163.60
14	HDPE parts	1.82	0.23	1.29	0.08	0.74	0.13	0.91	0.04	0.14	0.00	0.00	0.00	0.01	0.02	0.00	0.71
15	PMMA parts	1.56	0.19	0.59	0.14	0.37	0.02	1.48	0.08	0.62	0.00	0.00	0.00	0.00	0.07	0.04	29.28
16	Al die cast parts	344.10	0.00	0.00	0.00	0.00	0.00	4680.83	22.14	97.52	0.46	209.01	5.22	110.29	25.27	40.37	7.57
17	Al sheet	617.26	0.00	0.00	0.00	0.00	0.00	12561.64	33.16	215.67	0.21	16.00	11.65	309.35	54.21	112.22	15.86
18	Foam Insulation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	Foam insulation	2620.33	438.91	972.01	1508.00	7565.12	492.41	10736.11	104.88	778.77	0.00	0.00	0.00	507.64	185.01	1085.71	80069.65
20	Blowing agent (1/4 cyclopentane)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	Blowing agent (3/4 R134a)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	Shelves	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	Shelves	4544.62	304.56	9.92	0.00	0.00	0.00	230107.45	377.91	997.83	18.22	3475.30	473.80	9.25	361.88	474.53	8710.91
24	Brackets	697.28	46.73	1.52	0.00	0.00	0.00	35305.17	57.98	153.10	2.80	533.21	72.69	1.42	55.52	72.81	1336.51
25	Expoxy coating	1313.15	225.38	156.75	69.85	1411.63	76.07	1807.83	65.46	231.42	0.10	1.77	4.64	0.96	56.63	1.87	35482.26
26	PC parts	18.29	2.33	5.95	2.19	17.85	1.57	27.65	0.84	3.98	0.00	0.00	0.00	0.06	1.05	0.03	78.93
27	ABS parts	4.20	0.31	2.02	0.41	7.29	0.44	4.06	0.15	0.78	0.00	0.00	0.00	0.08	0.13	0.09	27.82
28	PVC parts	46.98	9.22	19.03	9.13	51.46	4.15	55.68	1.80	12.44	0.00	0.00	0.00	0.02	2.41	2.34	260.60
29	Lighting System	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	Fluorescent tubes	8.00	6.38	0.00	4.20	0.00	0.13	6.67	0.41	1.48	0.00	0.04	0.09	0.00	0.03	0.02	0.18
31	Ballasts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	Light box metal sheets	192.85	12.92	0.42	0.00	0.00	0.00	9764.61	16.04	42.34	0.77	147.47	20.11	0.39	15.36	20.14	369.65
33	Light box epoxy painting	61.55	10.56	7.35	3.27	66.17	3.57	84.74	3.07	10.85	0.00	0.08	0.22	0.05	2.65	0.09	1663.24
34	Light box plastic parts	15.67	1.99	5.10	1.88	15.30	1.34	23.69	0.72	3.41	0.00	0.00	0.00	0.05	0.90	0.02	67.63
35	Light box metal sheets Al	66.49	0.00	0.00	0.00	0.00	0.00	1353.13	3.57	23.23	0.02	1.72	1.25	33.32	5.84	12.09	1.71
36	Light box coated metal sheets	560.10	148.74	76.08	33.90	685.16	33.90	725.40	27.77	105.54	1.43	0.69	1.80	0.41	27.34	0.74	17221.03
37	Components for assembling (screws, ri	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	Screws and rivets	43.60	0.59	-0.26	5.67	15.96	0.00	1375.05	4.61	14.09	0.51	26.16	8.65	0.06	61.04	3.96	114.39
42	Evaporation module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	Evaporator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	Copper suction line	825.88	0.00	0.00	0.00	0.00	0.00	129972.66	44.24	1015.25	0.08	166.89	536.61	86.89	23.67	610.67	1003.62
45	Aluminium fins	2103.53	0.00	0.00	0.00	0.00	0.00	42808.27	113.01	734.96	0.72	54.52	39.69	1054.22	184.73	382.44	54.03
46	Evaporator fans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	Fan Blades	132.30	0.00	0.00	0.00	0.00	0.00	2692.40	7.11	46.22	0.05	3.43	2.50	66.30	11.62	24.05	3.40
48	Fan grid	168.80	26.37	11.01	206.06	22.95	0.00	2720.76	16.88	152.42	0.37	20.95	403.50	0.08	21.53	234.99	6333.75
49	Evaporator fan motor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	PVC parts	13.23	2.60	5.36	2.57	14.49	1.17	15.68	0.51	3.50	0.00	0.00	0.00	0.01	0.68	0.66	73.40
51	Iron	183.75	12.41	0.40	142.84	0.00	0.00	9377.57	15.40	40.49	0.74	141.63	130.47	0.00	14.75	8.58	285.54
52	Aluminium	25.78	0.00	0.00	0.00	0.00	0.00	350.66	1.66	7.31	0.03	15.66	0.39	8.26	1.89	3.02	0.57
53	Copper	159.13	0.00	0.00	0.00	0.00	0.89	22344.63	8.21	338.78	0.03	4.43	63.02	6.17	3.37	7.21	176.39
54	PC parts	60.69	7.72	19.74	7.27	59.23	5.20	91.73	2.80	13.21	0.00	0.00	0.00	0.19	3.48	0.09	261.87
55	Other copper	0.42	0.00	0.00	0.00	0.00	0.00	33.04	0.02	0.38	0.00	0.28	0.62	0.04	0.01	0.10	0.16
56	Expansion valve module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	Thermostatic expansion valve	15.67	0.00	0.00	0.00	0.00	0.19	1239.86	0.74	14.27	0.00	10.39	23.27	1.40	0.50	3.62	6.16
58	Anti-sweat heater	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59	Resistance wire	11.66	0.00	0.00	0.00	0.00	0.02	2001.20	0.62	29.21	0.00	0.37	5.51	0.54	0.28	9.41	15.45
60	Electric assembly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	Electric panel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	Electric panel metal sheet	33.72	2.26	0.07	0.00	0.00	0.00	1707.48	2.80	7.40	0.14	25.79	3.52	0.07	2.69	3.52	64.64
63	Electric panel coated metal sheet	18.93	5.03	2.57	1.15	23.16	1.15	24.52	0.94	3.57	0.05	0.02	0.06	0.01	0.92	0.03	582.14
70	Cables	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	Cables plastic parts	220.19	43.21	89.19	42.78	241.15	19.45	260.94	8.42	58.31	0.00	0.00	0.00	0.11	11.28	10.95	1221.27
72	Cables metal parts	292.65	0.00	0.00	0.00	0.00	0.61	50248.16	15.58	733.44	0.02	9.40	138.25	13.51	7.13	236.26	387.98
73	Packaging	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	Manual	41.23	6.18	27.83	78.48	0.00	0.35	69.62	0.58	5.18	0.21	0.04	0.11	0.01	1.71	0.04	5450.41
75	Wood palette	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	Cardboard	38.16	2.72	21.80	9.60	0.00	0.06	71.29	0.96	1.42	0.00	0.02	0.05	0.01	0.01	0.02	117.28
77	Plastic sheet/bag	4.20	0.72	2.78	0.16	2.43	0.24	2.39	0.10	0.40	0.03	0.00	0.00	0.01	0.05	0.00	1.44
78	Nylon	92.68	11.73	30.17	12.41	169.83	14.73	136.69	6.64	30.28	0.01	0.00	0.00	0.31	4.19	38.01	1451.92
79	Frame	26.37	7.09	-0.24	0.00	0.00	0.00	1241.83	2.13	5.57	0.18	18.61	4.01	0.05	1.56	2.43	59.45
80	PVC parts	1.92	0.38	0.78	0.37	2.11	0.17	2.28	0.07	0.51	0.00	0.00	0.00	0.00	0.10	0.10	10.67
81	Metal parts	14.16	0.19	-0.08	1.84	5.18	0.00	446.50	1.50	4.58	0.17	8.50	2.81	0.02	19.82	1.29	37.14
82	Powder coating	20.31	3.49	2.42	1.08	21.84	1.18	27.97	1.01	3.58	0.00	0.03	0.07	0.01	0.88	0.03	548.90
83	Miscellaneous	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	Electronic temperature control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	LED screen	296.89	288.56	0.00	92.54	0.00	13.07	283.09	16.70	162.05	0.75	1.50	42.17	0.45	5.08	1.47	219.55
86	Housing	38.01	2.78	18.31	3.72	66.00	4.00	36.77	1.33	7.11	0.00	0.00	0.00	0.72	1.16	0.78	251.94
87	Sensor	0.85	0.23	-0.01	0.00	0.00	0.00	40.03	0.07	0.18	0.01	0.60	0.13	0.00	0.05	0.08	1.92
88	Integrated circuit	43.71	33.66	0.15	30.57	5.18	32.23	87.42	2.94	40.81	0.00	0.49	9.25	0.15	1.21	0.48	214.82
89	Pipes in the refrigeration system	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	Pipes in the refrigeration system	351.70	0.00	0.00	0.00	0.00	0.00	55348.21	18.84	432.34	0.03	71.07	228.51	37.00	10.08	260.05	427.39
91	Drain pipes	42.77	5.49	30.22	1.90	17.32	3.04	21.42	1.01	3.40	0.09	0.00	0.00	0.19	0.48	0.00	16.66
92	Plastic pipes	0.44	0.08	0.17	0.30	1.27	0.14	2.33	0.02	0.14	0.00	0.00	0.00	0.09	0.03	0.01	24.15
93	Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
94	Bumpers	169.51	33.27	68.66	32.94	185.65	14.97	200.89	6.48	44.89	0.00	0.00	0.00	0.09	8.68	8.43	940.21
95	Blending	50.90	3.41	0.11	0.00	0.00	0.00	2577.45	4.23	11.18	0.20	38.93	5.31	0.10	4.05	5.32	97.57
96	Wood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	32,400.57	3586.66	2513.62	2657.53	17644.50	1066.79	1142243.01	2130.61	9895.45	74.89	12556.98	3286.93	2631.58	2251.41	4724.07	342629.13

Annexe 5- 2: Detailed results of the Eco-report for Base Case RHF4

Product	Energy			Water		Waste		Emissions to Air							to Water	
component	GER	electr	feedst	water (proces)	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
	MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
Housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
External housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chassis and panels (internal structure, bottom part, air grill…)	14013.98	939.15	30.58	0.00	0.00	0.00	709569.23	1165.33	3076.94	56.20	10716.58	1461.02	28.54	1115.91	1463.28	26861.33
	1781.36	0.00	0.00	0.00	0.00	0.00	36251.77	95.70	622.39	0.61	46.17	33.61	892.75	156.44	323.86	45.76
	91.78	24.69	-0.85	0.00	0.00	0.00	4322.82	7.43	19.40	0.63	64.79	13.96	0.18	5.42	8.47	206.94
	552.40	86.28	36.02	674.31	75.10	0.00	8903.60	55.25	498.79	1.21	68.56	1320.45	0.25	70.46	768.98	20726.96
	2.05	0.03	-0.01	0.27	0.75	0.00	64.65	0.22	0.66	0.02	1.23	0.41	0.00	2.87	0.19	5.38
Chassis and panels pre coating	5274.22	1400.59	716.42	319.23	6451.85	319.23	6830.82	261.51	993.80	13.44	6.48	16.95	3.91	257.46	6.97	162163.59
Epoxy coating	1698.57	291.54	202.76	90.35	1825.96	98.40	2338.43	84.68	299.34	0.13	2.29	6.00	1.24	73.25	2.42	45896.56
Plastics profiles	493.85	96.92	200.03	95.96	540.87	43.62	585.26	18.87	130.79	0.00	0.00	0.00	0.25	25.30	24.55	2739.15
Plastics tube	71.27	7.12	51.69	4.71	39.22	4.34	27.59	1.94	5.50	0.02	0.00	0.00	0.38	0.74	0.00	161.35
ABS parts	71.88	5.26	34.63	7.04	124.82	7.57	69.54	2.51	13.44	0.00	0.00	0.00	1.37	2.19	1.47	476.48
PS parts	15.26	0.64	8.36	0.86	31.13	0.12	3.84	0.49	3.03	0.00	0.00	0.00	21.26	0.26	0.00	9.76
HDPE parts	1.54	0.20	1.09	0.07	0.62	0.11	0.77	0.04	0.12	0.00	0.00	0.00	0.01	0.02	0.00	0.60
Glass	1662.80	1324.94	0.00	873.12	0.00	27.55	1386.28	85.40	307.88	0.31	7.84	18.12	0.03	6.58	4.05	36.76
Glass joint	64.31	4.70	30.98	6.29	111.67	6.77	62.22	2.25	12.03	0.00	0.00	0.00	1.22	1.96	1.31	426.28
Glass support	254.91	32.43	82.91	30.55	248.78	21.82	385.29	11.77	55.49	0.00	0.00	0.00	0.79	14.62	0.36	1099.92
Foam Insulation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polyurethane	1963.36	328.87	728.31	1129.91	5668.40	368.95	8044.37	78.58	583.52	0.00	0.00	0.00	380.37	138.62	813.50	59994.67
Expandable Polystyrene	1412.70	57.08	807.33	96.25	2971.97	15.70	639.18	45.63	306.21	0.00	0.00	0.00	1027.41	30.40	0.00	2104.46
Blowing agent (1/3 cyclopentane)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blowing agent (1/3 R134a)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Components for assembling (screws, rivets, etc.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Screws and rivets	34.06	0.46	-0.20	4.43	12.47	0.00	1074.07	3.60	11.01	0.40	20.44	6.75	0.04	47.68	3.09	89.35
Evaporation module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evaporator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Copper suction line	995.68	0.00	0.00	0.00	0.00	0.00	156694.54	53.34	1223.99	0.09	201.20	646.93	104.75	28.54	736.22	1209.96
Aluminium fins	4805.90	0.00	0.00	0.00	0.00	0.00	97803.22	258.19	1679.14	1.65	124.56	90.68	2408.55	422.05	873.75	123.45
Insulation pipes	2.68	0.45	0.99	1.54	7.74	0.50	10.98	0.11	0.80	0.00	0.00	0.00	0.52	0.19	1.11	81.88
Valves	38.93	0.00	0.00	0.00	0.00	0.22	5466.91	2.01	82.89	0.01	1.08	15.42	1.51	0.83	1.76	43.16
Plastics parts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evaporator fans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fan Blades	110.01	0.00	0.00	0.00	0.00	0.00	2238.71	5.91	38.44	0.04	2.85	2.08	55.13	9.66	20.00	2.83
Fan grid	114.63	17.91	7.47	139.93	15.58	0.00	1847.60	11.46	103.50	0.25	14.23	274.01	0.05	14.62	159.57	4301.08
Evaporator fan motor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PVC parts	23.02	4.52	9.33	4.47	25.22	2.03	27.28	0.88	6.10	0.00	0.00	0.00	0.01	1.18	1.14	127.70
Iron	179.56	12.13	0.39	139.58	0.00	0.00	9163.48	15.05	39.56	0.73	138.40	127.49	0.00	14.41	8.38	279.02
Aluminium	63.01	0.00	0.00	0.00	0.00	0.00	857.10	4.05	17.86	0.08	38.27	0.96	20.19	4.63	7.39	1.39
Copper	87.80	0.00	0.00	0.00	0.00	0.49	12328.61	4.53	186.92	0.02	2.44	34.77	3.40	1.86	3.98	97.32
Evaporator tray	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evaporator tray	614.86	41.20	1.34	0.00	0.00	0.00	31131.97	51.13	135.00	2.47	470.18	64.10	1.25	48.96	64.20	1178.53
Expansion valve module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thermostatic expansion valve	12.95	0.00	0.00	0.00	0.00	0.15	1024.88	0.61	11.80	0.00	8.59	19.23	1.16	0.41	3.00	5.09
Anti-sweat heater	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Resistance wire	176.15	0.00	0.00	0.00	0.00	0.37	30246.14	9.38	441.49	0.01	5.66	83.22	8.13	4.29	142.21	233.54
Defrost	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Resistance wire	357.04	0.00	0.00	0.00	0.00	0.74	61304.76	19.00	894.83	0.03	11.47	168.67	16.48	8.70	288.25	473.36
Fasteners	1.09	0.07	0.00	0.00	0.00	0.00	55.26	0.09	0.24	0.00	0.83	0.11	0.00	0.09	0.11	2.09
	15.28	4.11	-0.14	0.00	0.00	0.00	719.58	1.24	3.23	0.11	10.78	2.32	0.03	0.90	1.41	34.45
Electric assembly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electric panel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Controller board	664.25	492.55	2.59	444.85	89.79	554.57	1427.71	43.80	371.76	5.49	5.41	62.46	51.31	19.04	283.32	3996.81
Connectors	37.41	11.86	0.00	14.93	51.07	3.42	61.53	2.01	36.87	0.00	0.28	7.60	0.39	2.59	6.36	1293.95
	4.53	0.89	1.83	0.88	4.96	0.40	5.37	0.17	1.20	0.00	0.00	0.00	0.00	0.23	0.23	25.12
	9.50	0.70	4.58	0.93	16.50	1.00	9.19	0.33	1.78	0.00	0.00	0.00	0.18	0.29	0.19	62.98
	19.23	0.00	0.00	0.00	0.00	0.04	3301.98	1.02	48.20	0.00	0.62	9.08	0.89	0.47	15.53	25.50
Contactors	161.72	124.54	0.55	113.12	19.16	119.25	323.44	10.88	150.99	0.00	1.81	34.23	0.55	4.47	1.78	794.82
	5.98	0.76	1.95	0.80	10.95	0.95	8.81	0.43	1.95	0.00	0.00	0.00	0.02	0.27	2.45	93.61
Cables	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cables plastic parts	99.83	19.59	40.44	19.40	109.34	8.82	118.31	3.82	26.44	0.00	0.00	0.00	0.05	5.11	4.96	553.72
Cables metal parts	205.54	0.00	0.00	0.00	0.00	0.43	35291.16	10.94	515.12	0.02	6.60	97.10	9.49	5.01	165.94	272.50
Packaging	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manual	30.67	4.59	20.70	58.38	0.00	0.26	51.79	0.43	3.85	0.16	0.03	0.08	0.01	1.27	0.03	4054.61
Wood palette	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cardboard	8.58	0.61	4.90	2.16	0.00	0.01	16.04	0.22	0.32	0.00	0.00	0.01	0.00	0.00	0.00	26.38
Plastic sheet/bag	25.30	4.33	16.76	0.98	14.63	1.45	14.37	0.62	2.42	0.16	0.00	0.00	0.04	0.30	0.00	8.66
Tape	1.87	0.19	1.35	0.12	1.03	0.11	0.72	0.05	0.14	0.00	0.00	0.00	0.01	0.02	0.00	4.23
Metal parts	14.10	3.79	-0.13	0.00	0.00	0.00	664.33	1.14	2.98	0.10	9.96	2.15	0.03	0.83	1.30	31.80
Miscellaneous	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electronic temperature control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LED screen	93.01	90.40	0.00	28.99	0.00	4.09	88.69	5.23	50.77	0.23	0.47	13.21	0.14	1.59	0.46	68.78
Housing	10.45	0.76	5.03	1.02	18.15	1.10	10.11	0.37	1.95	0.00	0.00	0.00	0.20	0.32	0.21	69.28
Probes	16.98	3.33	6.88	3.30	18.60	1.50	20.13	0.65	4.50	0.00	0.00	0.00	0.01	0.87	0.84	94.20
	34.97	0.00	0.00	0.00	0.00	0.07	6003.60	1.86	87.63	0.00	1.12	16.52	1.61	0.85	28.23	46.36
Integrated circuit	13.99	10.77	0.05	9.78	1.66	10.31	27.97	0.94	13.06	0.00	0.16	2.96	0.05	0.39	0.15	68.74
Control box, metal parts	85.00	5.70	0.19	0.00	0.00	0.00	4303.80	7.07	18.66	0.34	65.00	8.86	0.17	6.77	8.88	162.92
	10.20	2.74	-0.09	0.00	0.00	0.00	480.41	0.83	2.16	0.07	7.20	1.55	0.02	0.60	0.94	23.00
Control box, plastics parts	7.27	0.73	5.27	0.48	4.00	0.44	2.81	0.20	0.56	0.00	0.00	0.00	0.04	0.08	0.00	16.46
Pipes in the refrigeration system	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pipes in the refrigeration system	103.83	0.00	0.00	0.00	0.00	0.00	16339.74	5.56	127.63	0.01	20.98	67.46	10.92	2.98	76.77	126.17
Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Putty/Sealant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	38,723.09	5,460.10	3,062.27	4,319.01	18,512.00	1,626.92	1,260,052.75	2,456.73	13,277.08	85.05	12,084.55	4,730.53	5,057.29	2,565.84	6,333.59	343,160.72

Annexe 5- 3: Detailed results of the Eco-report for Base Case BvC

nr	Product / component	Energy: GER	Energy: electr	Energy: feedst	Water: water (proces)	Water: water (cool)	Waste: haz. Waste	Waste: non-haz. Waste	Emissions to Air: GWP	Emissions to Air: AD	Emissions to Air: VOC	Emissions to Air: POP	Emissions to Air: HM	Emissions to Air: PAH	Emissions to Air: PM	to Water: Metal	to Water: EUP
		MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	Housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	External housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Plastic ring for cable	0.12	0.02	0.08	0.00	0.07	0.01	0.07	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04
4	Cooler feet	5.82	0.58	4.22	0.38	3.20	0.35	2.25	0.16	0.45	0.00	0.00	0.00	0.03	0.06	0.00	13.16
5	Fan housing	107.55	5.45	57.29	6.41	216.89	0.75	35.04	3.38	22.66	0.00	0.00	0.00	70.90	2.10	0.00	69.43
6	Plastic grids and panel cover	19.95	1.46	9.61	1.95	34.65	2.10	19.30	0.70	3.73	0.00	0.00	0.00	0.38	0.61	0.41	132.27
7	Powder polyester (coating)	321.49	55.18	38.38	17.10	345.60	18.62	442.60	16.03	56.66	0.02	0.43	1.13	0.24	13.86	0.46	8686.86
8	Panels and cabinet structure	1361.98	91.27	2.97	0.00	0.00	0.00	68961.08	113.26	299.04	5.46	1041.51	141.99	2.77	108.45	142.21	2610.58
9	Back grid (condenser)	22.95	6.17	-0.21	0.00	0.00	0.00	1080.92	1.86	4.85	0.16	16.20	3.49	0.04	1.35	2.12	51.75
10	Inks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	Foam Insulation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Polyurethane	887.66	148.69	329.28	510.85	2562.76	166.81	3636.97	35.53	263.82	0.00	0.00	0.00	171.97	62.67	367.79	27124.42
13	Cyclopentane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	Shelves	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	Shelves	194.71	52.37	-1.80	0.00	0.00	0.00	9170.74	15.75	41.16	1.34	137.44	29.62	0.37	11.49	17.96	439.03
16	Brackets	27.49	3.48	8.95	3.68	50.37	4.37	40.54	1.97	8.98	0.00	0.00	0.00	0.09	1.24	11.27	430.62
17	Door	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	Gasket	39.06	7.67	15.82	7.59	42.78	3.45	46.29	1.49	10.34	0.00	0.00	0.00	0.02	2.00	1.94	216.65
19	Handle and plastic cover	68.41	5.00	32.95	6.70	118.80	7.20	66.19	2.39	12.79	0.00	0.00	0.00	1.30	2.09	1.40	453.49
20	Hinges	3.40	0.23	0.01	0.00	0.00	0.00	172.15	0.28	0.75	0.01	2.60	0.35	0.01	0.27	0.36	6.52
21	Spring	6.20	0.97	0.40	7.57	0.84	0.00	100.00	0.62	5.60	0.01	0.77	14.83	0.00	0.79	8.64	232.79
22	Aluminium	809.22	0.00	0.00	0.00	0.00	0.00	16468.21	43.47	282.74	0.28	20.97	15.27	405.55	71.07	147.12	20.79
23	Glass	310.28	247.23	0.00	162.92	0.00	5.14	258.68	15.94	57.45	0.06	1.46	3.38	0.01	1.23	0.76	6.86
24	Lighting System	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	Light bulbs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	Internal fluorescent tube	3.08	2.46	0.00	1.62	0.00	0.05	2.57	0.16	0.57	0.00	0.01	0.03	0.00	0.01	0.01	0.07
27	External fluorescent tube	1.30	1.03	0.00	0.68	0.00	0.02	1.08	0.07	0.24	0.00	0.01	0.01	0.00	0.01	0.00	0.03
28	Lighting ballast	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	ballast	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	Light box	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	canopy	56.02	4.10	26.98	5.48	97.28	5.90	54.20	1.96	10.48	0.00	0.00	0.00	1.07	1.71	1.14	371.33
32	Components for assebling (screws, rivets, etc.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	screws, rivets, etc.	11.46	0.15	-0.07	1.49	4.19	0.00	361.28	1.21	3.70	0.14	6.87	2.27	0.02	16.04	1.04	30.05
34	Evaporation Module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	Evaporator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	Al-lamel	327.72	0.00	0.00	0.00	0.00	0.00	6669.37	17.61	114.50	0.11	8.49	6.18	164.24	28.78	59.58	8.42
37	suction line	17.86	0.00	0.00	0.00	0.00	0.00	2810.39	0.96	21.95	0.00	3.61	11.60	1.88	0.51	13.20	21.70
38	Evaporator fan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	Fan Grid	24.20	3.78	1.58	29.54	3.29	0.00	390.00	2.42	21.85	0.05	3.00	57.84	0.01	3.09	33.68	907.89
40	Blades	23.11	0.00	0.00	0.00	0.00	0.00	470.40	1.24	8.08	0.01	0.60	0.44	11.58	2.03	4.20	0.59
41	Evaporator fan motor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	PVC	3.40	0.67	1.38	0.66	3.72	0.30	4.03	0.13	0.90	0.00	0.00	0.00	0.00	0.17	0.17	18.84
43	Iron	39.47	2.67	0.09	30.68	0.00	0.00	2014.18	3.31	8.70	0.16	30.42	28.02	0.00	3.17	1.84	61.33
44	Aluminium	6.62	0.00	0.00	0.00	0.00	0.00	90.00	0.43	1.87	0.01	4.02	0.10	2.12	0.49	0.78	0.15
45	Copper	34.25	0.00	0.00	0.00	0.00	0.19	4809.60	1.77	72.92	0.01	0.95	13.56	1.33	0.73	1.55	37.97
46	Evaporation tray	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	Drip tray	12.17	1.22	8.83	0.80	6.70	0.74	4.71	0.33	0.94	0.00	0.00	0.00	0.06	0.13	0.00	27.55
48	Compression Module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	cast iron of the compressor casing	24.68	0.33	-0.15	3.21	9.03	0.00	778.14	2.61	7.98	0.29	14.81	4.89	0.03	34.55	2.24	64.73
50	steel of the compressor	113.86	7.63	0.25	0.00	0.00	0.00	5764.94	9.47	25.00	0.46	87.07	11.87	0.23	9.07	11.89	218.24
51	steel for motor lamination	228.90	15.46	0.50	177.94	0.00	0.00	11681.59	19.18	50.44	0.93	176.43	162.52	0.00	18.37	10.68	355.69
52	aluminium	43.00	0.00	0.00	0.00	0.00	0.00	875.14	2.31	15.02	0.01	1.11	0.81	21.55	3.78	7.82	1.10
53	rubber	0.85	0.09	0.62	0.06	0.47	0.05	0.33	0.02	0.07	0.00	0.00	0.00	0.00	0.01	0.00	1.93
54	epoxy	1.65	0.29	0.50	0.22	4.51	0.22	4.78	0.08	0.52	0.00	0.00	0.00	0.00	0.18	0.00	113.39
55	ester oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	polypropylen	0.85	0.09	0.62	0.06	0.47	0.05	0.33	0.02	0.07	0.00	0.00	0.00	0.00	0.01	0.00	1.93
57	copper	117.39	0.00	0.00	0.00	0.00	0.66	16482.90	6.06	249.90	0.02	3.27	46.49	4.55	2.49	5.32	130.12
58	PET	2.70	0.35	1.91	0.12	1.09	0.19	1.35	0.06	0.21	0.01	0.00	0.00	0.01	0.03	0.00	1.05
59	Condenser Module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	Condenser	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	Copper pipe	70.15	0.00	0.00	0.00	0.00	0.00	11039.29	3.76	86.23	0.01	14.17	45.58	7.38	2.01	51.87	85.24
62	Aluminium	132.67	0.00	0.00	0.00	0.00	0.00	2699.90	7.13	46.35	0.05	3.44	2.50	66.49	11.65	24.12	3.41
63	Steel	11.71	3.15	-0.11	0.00	0.00	0.00	551.47	0.95	2.47	0.08	8.27	1.78	0.02	0.69	1.08	26.40
64	Condenser fan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	Fan Grid	24.20	3.78	1.58	29.54	3.29	0.00	390.00	2.42	21.85	0.05	3.00	57.84	0.01	3.09	33.68	907.89
66	Blades	23.11	0.00	0.00	0.00	0.00	0.00	470.40	1.24	8.08	0.01	0.60	0.44	11.58	2.03	4.20	0.59
67	Condenser fan motor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	PVC	3.40	0.67	1.38	0.66	3.72	0.30	4.03	0.13	0.90	0.00	0.00	0.00	0.00	0.17	0.17	18.84
69	Iron	39.47	2.67	0.09	30.68	0.00	0.00	2014.18	3.31	8.70	0.16	30.42	28.02	0.00	3.17	1.84	61.33
70	Aluminium	6.62	0.00	0.00	0.00	0.00	0.00	90.00	0.43	1.87	0.01	4.02	0.10	2.12	0.49	0.78	0.15
71	Copper	34.25	0.00	0.00	0.00	0.00	0.19	4809.60	1.77	72.92	0.01	0.95	13.56	1.33	0.73	1.55	37.97
72	Liquid receiver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	Drier/Accumulator	7.13	0.00	0.00	0.00	0.00	0.00	1121.96	0.38	8.76	0.00	1.44	4.63	0.75	0.20	5.27	8.66
74	Expansion valve module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	Capillary tube	4.52	0.00	0.00	0.00	0.00	0.00	710.97	0.24	5.55	0.00	0.91	2.94	0.48	0.13	3.34	5.49
76	Electric Assembly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	Electric panel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	Electrical box	39.72	2.91	19.13	3.89	68.97	4.18	38.42	1.39	7.43	0.00	0.00	0.00	0.76	1.21	0.81	263.27
79	Electrical plate	43.82	2.94	0.10	0.00	0.00	0.00	2218.68	3.64	9.62	0.18	33.51	4.57	0.09	3.49	4.58	83.99
80	Electrical parts	9.79	5.24	0.30	5.92	2.68	60.37	91.45	0.39	7.45	0.08	0.09	1.26	0.12	0.18	0.51	128.41
81	Cables	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	Cables	25.70	5.04	10.41	4.99	28.15	2.27	30.46	0.98	6.81	0.00	0.00	0.00	0.01	1.32	1.28	142.54
83	Cables	52.91	0.00	0.00	0.00	0.00	0.11	9084.77	2.82	132.61	0.00	1.70	25.00	2.44	1.29	42.72	70.15
84	Terminal (plug)	5.44	1.73	0.00	2.17	7.43	0.50	8.95	0.29	5.36	0.00	0.04	1.11	0.06	0.38	0.93	188.27
85	Packaging	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	Plastic cover	14.06	1.93	9.02	0.46	22.04	0.64	5.84	0.35	1.12	0.01	0.00	0.00	0.02	0.27	0.00	7.44
87	Plastic corners	52.71	2.13	30.12	3.59	110.88	0.59	23.85	1.70	11.42	0.00	0.00	0.00	38.33	1.13	0.00	78.51
88	partial carton box	5.32	0.38	3.04	1.34	0.00	0.01	9.94	0.13	0.20	0.00	0.00	0.01	0.00	0.00	0.00	16.35
89	Manuals	2.34	0.35	1.58	4.45	0.00	0.02	3.95	0.03	0.29	0.01	0.00	0.01	0.00	0.10	0.00	308.90
90	palette wood (classification not possible)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91	Miscellaneous	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92	Temperature control and display system	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	Set thermostat	3.10	0.48	0.20	3.79	0.42	0.00	50.00	0.31	2.80	0.01	0.39	7.42	0.00	0.40	4.32	116.40
94	Set thermostat	2.55	0.00	0.00	0.00	0.00	0.00	400.70	0.14	3.13	0.00	0.51	1.65	0.27	0.07	1.88	3.09
95	Pipes in the refrigeration system	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
96	Copper tubes	88.93	0.00	0.00	0.00	0.00	0.00	13994.70	4.76	109.32	0.01	17.97	57.78	9.36	2.55	65.75	108.06
97	Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	Refrigerant liquid R134A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	5,984.42	699.46	617.80	1069.20	3754.29	286.35	203635.82	362.92	2248.18	10.24	1683.51	812.91	1004.01	441.35	1108.28	45540.72

Annexe 5- 4: Detailed results of the Eco-report for Base Case ice-cream freezer

Version 5 VHK for European Commission 28 Nov. 2005 | Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS | EuP EcoReport: RAW OUTPUTS Environmental Impact | Assessment of

Nr: 0 | **Date: 00/01/00** | **Author: BIO**

MATERIALS EXTRACTION & PRODUCTION

	Product	Energy			Water		Waste		Emissions to Air							to Water	
nr	component	GER	electr	feedst	water (proces)	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	Housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	External housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	white prepainted metal sheet	7201.10	1912.28	978.16	435.86	8808.96	435.86	9326.37	357.05	1356.88	18.35	8.84	23.14	5.33	351.52	9.52	221408.11
4	galvanized metal sheet	243.44	16.31	0.53	0.00	0.00	0.00	12326.08	20.24	53.45	0.98	186.16	25.38	0.50	19.38	25.42	466.61
5	PVC	97.14	19.06	39.35	18.88	106.39	8.58	115.12	3.71	25.73	0.00	0.00	0.00	0.05	4.98	4.83	538.81
6	ABS	3.23	0.24	1.56	0.32	5.61	0.34	3.13	0.11	0.60	0.00	0.00	0.00	0.06	0.10	0.07	21.41
7	PP	23.84	2.38	17.29	1.57	13.12	1.45	9.23	0.65	1.84	0.01	0.00	0.00	0.13	0.25	0.00	53.98
8	PA	3.11	0.39	1.01	0.42	5.69	0.49	4.58	0.22	1.02	0.00	0.00	0.00	0.01	0.14	1.27	48.68
9	PS	3.12	0.13	1.71	0.18	6.37	0.02	0.79	0.10	0.62	0.00	0.00	0.00	4.35	0.05	0.00	2.00
10	adhesive rubber	15.56	2.66	10.31	0.60	9.00	0.89	8.84	0.38	1.49	0.10	0.00	0.00	0.03	0.18	0.00	5.32
11	wheels	10.34	0.69	0.02	0.00	0.00	0.00	523.34	0.86	2.27	0.04	7.90	1.08	0.02	0.82	1.08	19.81
12	insulating material for pipes	2.02	0.35	1.34	0.08	1.17	0.12	1.15	0.05	0.19	0.01	0.00	0.00	0.00	0.02	0.00	0.69
13	silicon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	Foam insulation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	Plastic foam	350.30	58.68	129.95	201.60	1011.36	65.83	1435.28	14.02	104.11	0.00	0.00	0.00	67.87	24.73	145.15	10704.29
16	Plastic foam	486.88	81.55	180.61	280.20	1405.67	91.49	1994.87	19.49	144.70	0.00	0.00	0.00	94.32	34.38	201.73	14877.69
17	Misc. (Cyclopentane)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	Shelves	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	Plasticised grid	274.69	47.15	32.79	14.61	295.30	15.91	378.17	13.69	48.41	0.02	0.37	0.97	0.20	11.85	0.39	7422.44
20	Door	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	Misc. (Glass)	100.59	80.16	0.00	52.82	0.00	1.67	83.87	5.17	18.63	0.02	0.47	1.10	0.00	0.40	0.25	2.22
22	Components for assembling (screw rivets	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	screw rivets, etc.	2.90	0.04	-0.02	0.38	1.06	0.00	91.45	0.31	0.94	0.03	1.74	0.58	0.00	4.06	0.26	7.61
24	Evapoartion Module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	Evaporator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	evaporator wrapped on tank	152.77	0.00	0.00	0.00	0.00	0.00	24042.00	8.18	187.80	0.01	30.87	99.26	16.07	4.38	112.96	185.65
27	connection with boiler	7.74	0.00	0.00	0.00	0.00	0.00	1218.13	0.41	9.52	0.00	1.56	5.03	0.81	0.22	5.72	9.41
28	Compression Module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	Cast iron of the compressor casing	22.91	0.31	-0.14	2.98	8.39	0.00	722.51	2.42	7.41	0.27	13.75	4.54	0.03	32.08	2.08	60.10
30	Steel of the compressor	105.72	7.08	0.23	0.00	0.00	0.00	5352.89	8.79	23.21	0.42	80.84	11.02	0.22	8.42	11.04	202.64
31	Steel of the motor lamination	212.54	14.36	0.47	165.22	0.00	0.00	10846.61	17.81	46.83	0.86	163.82	150.90	0.00	17.06	9.92	330.27
32	Aluminium	39.93	0.00	0.00	0.00	0.00	0.00	812.62	2.15	13.95	0.01	1.03	0.75	20.01	3.51	7.26	1.03
33	Rubber	0.79	0.08	0.57	0.05	0.44	0.05	0.31	0.02	0.06	0.00	0.00	0.00	0.00	0.01	0.00	1.79
34	Epoxy	1.53	0.27	0.46	0.21	4.19	0.21	4.43	0.07	0.48	0.00	0.00	0.00	0.00	0.16	0.00	105.18
35	Misc. (Ester oil)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	Polypropylene	0.79	0.08	0.57	0.05	0.44	0.05	0.31	0.02	0.06	0.00	0.00	0.00	0.00	0.01	0.00	1.79
37	Copper	109.00	0.00	0.00	0.00	0.00	0.61	15304.55	5.63	232.04	0.02	3.03	43.16	4.22	2.31	4.94	120.82
38	PET	2.50	0.32	1.77	0.11	1.01	0.18	1.25	0.06	0.20	0.01	0.00	0.00	0.01	0.03	0.00	0.97
39	Condenser Module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	Condenser	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	copper tubes	21.74	0.00	0.00	0.00	0.00	0.00	3421.98	1.16	26.73	0.00	4.39	14.13	2.29	0.62	16.08	26.42
42	galvanized metal sheet	18.73	1.26	0.04	0.00	0.00	0.00	948.56	1.56	4.11	0.08	14.33	1.95	0.04	1.49	1.96	35.91
43	alluminium fins	23.11	0.00	0.00	0.00	0.00	0.00	470.40	1.24	8.08	0.01	0.60	0.44	11.58	2.03	4.20	0.59
44	Condenser fan (1 x 40W)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	Frame	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	Blades	10.98	0.00	0.00	0.00	0.00	0.00	223.44	0.59	3.84	0.00	0.28	0.21	5.50	0.96	2.00	0.28
47	Condenser fan motor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	PVC	6.23	1.22	2.52	1.21	6.82	0.55	7.38	0.24	1.65	0.00	0.00	0.00	0.00	0.32	0.31	34.54
49	Iron	72.36	4.89	0.16	56.25	0.00	0.00	3692.66	6.06	15.94	0.29	55.77	51.37	0.00	5.81	3.38	112.44
50	Aluminium	12.13	0.00	0.00	0.00	0.00	0.00	165.00	0.78	3.44	0.02	7.37	0.18	3.89	0.89	1.42	0.27
51	Copper	62.80	0.00	0.00	0.00	0.00	0.35	8817.60	3.24	133.69	0.01	1.75	24.87	2.43	1.33	2.85	69.61
52	Expansion valve module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53	Capillary tube	3.41	0.00	0.00	0.00	0.00	0.00	536.94	0.18	4.19	0.00	0.69	2.22	0.36	0.10	2.52	4.15
54	Electric assembly (not included in other m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	Electric panel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	Cables	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	Cables plastic parts	11.10	2.18	4.49	2.16	12.15	0.98	13.15	0.42	2.94	0.00	0.00	0.00	0.01	0.57	0.55	61.54
58	Cables metal parts	22.84	0.00	0.00	0.00	0.00	0.05	3922.35	1.22	57.25	0.00	0.73	10.79	1.05	0.56	18.44	30.29
59	Packaging	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	Manuals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	Misc. (Paper)	8.00	1.20	5.40	15.23	0.00	0.07	13.51	0.11	1.00	0.04	0.01	0.02	0.00	0.33	0.01	1057.68
62	Protection	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	Misc. (Wood)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
64	polystirol	53.60	2.24	29.37	3.03	109.39	0.42	13.49	1.73	10.64	0.00	0.00	0.00	74.68	0.93	0.00	34.30
65	cardboard paper	16.13	1.15	9.22	4.06	0.00	0.03	30.13	0.40	0.60	0.00	0.01	0.02	0.00	0.01	0.01	49.57
66	film	10.19	2.00	4.13	1.98	11.16	0.90	12.08	0.39	2.70	0.00	0.00	0.00	0.01	0.52	0.51	56.52
67	metal connections	0.75	0.01	0.00	0.10	0.27	0.00	23.65	0.08	0.24	0.01	0.45	0.15	0.00	1.05	0.07	1.97
68	Miscellaneous	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	Temperature control and display system	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	Mechanical thermometer	1.89	0.30	0.12	2.31	0.26	0.00	30.50	0.19	1.71	0.00	0.23	4.52	0.00	0.24	2.63	71.00
71	Mechanical thermometer	1.55	0.00	0.00	0.00	0.00	0.00	244.43	0.08	1.91	0.00	0.31	1.01	0.16	0.04	1.15	1.89
72	Mechanical thermostat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	Pipes in the refrigeration system	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	Pipes in the refrigeration system	45.17	0.00	0.00	0.00	0.00	0.00	7108.42	2.42	55.53	0.00	9.13	29.35	4.75	1.29	33.40	54.89
75	Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	Misc. (R507)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	9,877.22	2261.00	1454.01	1262.45	11824.21	627.10	114303.55	503.73	2618.62	21.64	596.45	508.15	321.03	540.14	635.37	258303.17

Annexe 5- 5: Detailed results of the Eco-report for Base Case vending machine

Version 5 VHK for European Commission 28 Nov. 2005

Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: RAW OUTPUTS Environmental Impact

Assessment of

Nr: 0 Date: 00/01/00 Author: BIO

MATERIALS EXTRACTION & PRODUCTION

	Product	Energy			Water		Waste		Emissions to Air							to Water	
nr	component	GER	electr	feedst	water (proces)	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	Housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	External housing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	CHASSIS	1908.03	127.87	4.16	0.00	0.00	0.00	96609.12	158.66	418.93	7.65	1459.08	198.92	3.89	151.93	199.23	3657.22
5	22-St tube/profile	17.49	4.71	-0.16	0.00	0.00	0.00	823.90	1.42	3.70	0.12	12.35	2.66	0.03	1.03	1.61	39.44
6	25-Stainless 18/8 coil	59.06	9.23	3.85	72.10	8.03	0.00	952.00	5.91	53.33	0.13	7.33	141.19	0.03	7.53	82.22	2216.19
7	PANELS	68.52	2.77	39.16	4.67	144.14	0.76	31.00	2.21	14.85	0.00	0.00	0.00	49.83	1.47	0.00	102.07
8	5-PS	73.29	3.06	40.16	4.14	149.57	0.58	18.45	2.36	14.55	0.00	0.00	0.00	102.11	1.27	0.00	46.89
9	21-St sheet galv.	871.66	58.41	1.90	0.00	0.00	0.00	44134.61	72.48	191.38	3.50	666.56	90.87	1.78	69.41	91.02	1670.75
10	38-pre-coating coil	14995.48	3982.11	2036.91	907.63	18343.68	907.63	19421.13	743.52	2825.55	38.22	18.41	48.19	11.11	732.00	19.83	461057.79
11	Foam insulation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Polyuréthane	435.27	72.91	161.46	250.50	1256.68	81.80	1783.42	17.42	129.37	0.00	0.00	0.00	84.33	30.73	180.35	13300.72
13	Blowing agent R134A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	Shelves & Grids & Brackets	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	21-St sheet galv.	225.42	15.11	0.49	0.00	0.00	0.00	11413.68	18.74	49.49	0.90	172.38	23.50	0.46	17.95	23.54	432.07
16	11-PA 6	36.93	4.68	12.02	4.94	67.67	5.87	54.47	2.65	12.06	0.00	0.00	0.00	0.12	1.67	15.15	578.53
17	10-ABS	2433.27	177.98	1172.08	238.15	4225.32	256.08	2354.07	85.03	455.06	0.00	0.00	0.00	46.29	74.26	49.68	16128.99
18	Doors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	Gasket	104.90	20.59	42.49	20.38	114.89	9.27	124.31	4.01	27.78	0.00	0.00	0.00	0.05	5.37	5.21	581.82
20	Handle and plastic cover	402.60	29.45	193.93	39.40	699.11	42.37	389.49	14.07	75.29	0.00	0.00	0.00	7.66	12.29	8.22	2668.64
21	21-St sheet galv.	1149.57	77.04	2.51	0.00	0.00	0.00	58206.31	95.59	252.40	4.61	879.09	119.85	2.34	91.54	120.03	2203.45
22	25-Stainless 18/8 coil	47.15	7.37	3.07	57.56	6.41	0.00	760.00	4.72	42.58	0.10	5.85	112.71	0.02	6.01	65.64	1769.23
23	38-pre-coating coil	6058.15	1608.76	822.91	366.68	7410.82	366.68	7846.10	300.38	1141.52	15.44	7.44	19.47	4.49	295.73	8.01	186266.57
24	Glass	305.35	243.31	0.00	160.34	0.00	5.06	254.58	15.68	56.54	0.06	1.44	3.33	0.01	1.21	0.74	6.75
25	Lighting system	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	Light bulbs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	Light bulb Output Power=35W	2.58	2.06	0.00	1.35	0.00	0.04	2.15	0.13	0.48	0.00	0.01	0.03	0.00	0.01	0.01	0.06
28	Lighting ballast	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	Ballast	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	Lightbox	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	Canopy	33.32	2.23	0.07	0.00	0.00	0.00	1687.09	2.77	7.32	0.13	25.48	3.47	0.07	2.65	3.48	63.87
32	Spirals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	38-pre-coating coil	2888.29	767.00	392.33	174.82	3533.18	174.82	3740.71	143.21	544.23	7.36	3.55	9.28	2.14	140.99	3.82	88804.54
34	Components for assembling (screws, rive	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	SCREWS	45.91	7.17	2.99	56.04	6.24	0.00	740.00	4.59	41.46	0.10	5.70	109.75	0.02	5.86	63.91	1722.67
36	RIVETS	35.84	0.00	0.00	0.00	0.00	0.00	487.50	2.31	10.16	0.05	21.77	0.54	11.49	2.63	4.20	0.79
37	Evaporation module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	Evaporator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	Al-lamel	235.96	0.00	0.00	0.00	0.00	0.00	4802.00	12.68	82.44	0.08	6.12	4.45	118.26	20.72	42.90	6.06
40	Suction line	31.32	0.00	0.00	0.00	0.00	0.00	4928.61	1.68	38.50	0.00	6.33	20.35	3.29	0.90	23.16	38.06
41	Evaporator fans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	Frame	17.99	2.81	1.17	21.96	2.45	0.00	290.00	1.80	16.25	0.04	2.23	43.01	0.01	2.30	25.05	675.10
43	Blades	17.34	0.00	0.00	0.00	0.00	0.00	352.80	0.93	6.06	0.01	0.45	0.33	8.69	1.52	3.15	0.45
44	Evaporator fans motors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	Aluminium	9.92	0.00	0.00	0.00	0.00	0.00	135.00	0.64	2.81	0.01	6.03	0.15	3.18	0.73	1.16	0.22
46	Iron	27.32	1.85	0.06	21.24	0.00	0.00	1394.43	2.29	6.02	0.11	21.06	19.40	0.00	2.19	1.28	42.46
47	Copper	19.27	0.00	0.00	0.00	0.00	0.11	2705.40	0.99	41.02	0.00	0.54	7.63	0.75	0.41	0.87	21.36
48	PVC	2.55	0.50	1.03	0.50	2.79	0.23	3.02	0.10	0.67	0.00	0.00	0.00	0.00	0.13	0.13	14.13
49	Compression module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	Compressor + Compressor motor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	cast iron of the compressor casing	25.83	0.35	-0.15	3.36	9.45	0.00	814.56	2.73	8.35	0.30	15.50	5.12	0.03	36.16	2.35	67.76
52	steel of the compressor	119.19	7.99	0.26	0.00	0.00	0.00	6034.79	9.91	26.17	0.48	91.14	12.43	0.24	9.49	12.45	228.45
53	steel for motor lamination	239.61	16.18	0.53	186.27	0.00	0.00	12228.39	20.08	52.80	0.97	184.68	170.13	0.00	19.23	11.18	372.34
54	aluminium	12.89	0.00	0.00	0.00	0.00	0.00	175.28	0.83	3.65	0.02	7.83	0.20	4.13	0.95	1.51	0.28
55	rubber	0.89	0.09	0.65	0.06	0.49	0.05	0.35	0.02	0.07	0.00	0.00	0.00	0.00	0.01	0.00	2.02
56	epoxy	1.73	0.30	0.52	0.23	4.72	0.23	5.00	0.08	0.54	0.00	0.00	0.00	0.00	0.18	0.00	118.69
57	ester oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58	polypropylen	0.89	0.09	0.65	0.06	0.49	0.05	0.35	0.02	0.07	0.00	0.00	0.00	0.00	0.01	0.00	2.02
59	copper	122.88	0.00	0.00	0.00	0.00	0.69	17254.44	6.34	261.60	0.03	3.42	48.66	4.76	2.61	5.57	136.21
60	PET	2.83	0.36	2.00	0.13	1.14	0.20	1.41	0.07	0.22	0.01	0.00	0.00	0.01	0.03	0.00	1.10
61	Condensation module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	Condenser	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	Aluminium	82.06	0.00	0.00	0.00	0.00	0.00	1669.92	4.41	28.67	0.03	2.13	1.55	41.12	7.21	14.92	2.11
64	Steel	3.62	0.97	-0.03	0.00	0.00	0.00	170.55	0.29	0.77	0.02	2.56	0.55	0.01	0.21	0.33	8.16
65	Copper pipe	10.85	0.00	0.00	0.00	0.00	0.00	1706.98	0.58	13.33	0.00	2.19	7.05	1.14	0.31	8.02	13.18
66	Condenser fans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	Frame	24.20	3.78	1.58	29.54	3.29	0.00	390.00	2.42	21.85	0.05	3.00	57.84	0.01	3.09	33.68	907.89
68	Blades	23.11	0.00	0.00	0.00	0.00	0.00	470.40	1.24	8.08	0.01	0.60	0.44	11.58	2.03	4.20	0.59
69	Condenser fans motors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	Aluminium	6.62	0.00	0.00	0.00	0.00	0.00	90.00	0.43	1.87	0.01	4.02	0.10	2.12	0.49	0.78	0.15
71	Iron	39.47	2.67	0.09	30.68	0.00	0.00	2014.18	3.31	8.70	0.16	30.42	28.02	0.00	3.17	1.84	61.33
72	Copper	34.25	0.00	0.00	0.00	0.00	0.19	4809.60	1.77	72.92	0.01	0.95	13.56	1.33	0.73	1.55	37.97
73	PVC	3.40	0.67	1.38	0.66	3.72	0.30	4.03	0.13	0.90	0.00	0.00	0.00	0.00	0.17	0.17	18.84
74	Liquid receiver	5.23	0.52	3.80	0.35	2.88	0.32	2.03	0.14	0.40	0.00	0.00	0.00	0.03	0.05	0.00	11.85
75	Expansion valve module	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	CAPILLARY TUBE	4.07	0.00	0.00	0.00	0.00	0.00	641.12	0.22	5.01	0.00	0.82	2.65	0.43	0.12	3.01	4.95
77	Anti-sweat heater	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	28-Cu winding wire	4.71	0.00	0.00	0.00	0.00	0.03	661.32	0.24	10.03	0.00	0.13	1.87	0.18	0.10	0.21	5.22
79	Electric assembly (not included in other m	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	Electric panel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	BOX	48.45	3.25	0.11	0.00	0.00	0.00	2453.17	4.03	10.64	0.19	37.05	5.05	0.10	3.86	5.06	92.87
82	TRANFORMATOR	49.95	0.00	0.00	0.00	0.00	0.28	7014.00	2.58	106.34	0.01	1.39	19.78	1.94	1.06	2.26	55.37
83	ELECTRONIC CARDS	16.86	9.03	0.51	10.20	4.61	104.00	157.52	0.67	12.83	0.14	0.16	2.17	0.21	0.30	0.88	221.19
84	47-IC's avg., 1% Si	174.83	134.64	0.60	122.29	20.71	128.92	349.66	11.76	163.24	0.00	1.96	37.00	0.59	4.83	1.93	859.27
85	46-IC's avg., 5% Si, Au	1652.79	1607.53	0.00	1505.10	0.00	75.55	1554.44	127.04	836.20	20.33	14.65	133.97	4.41	21.86	1122.00	6444.32
86	44-big caps & coils	23.00	0.00	0.00	2.08	3.30	1.18	36.03	1.30	8.51	0.01	0.13	0.46	12.28	2.14	4.45	0.43
87	Cables	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	Cables (metal parts)	111.65	0.00	0.00	0.00	0.00	0.23	19171.50	5.94	279.84	0.01	3.59	52.75	5.15	2.72	90.14	148.03
89	Cables (plastic parts)	54.23	10.64	21.97	10.54	59.40	4.79	64.27	2.07	14.36	0.00	0.00	0.00	0.03	2.78	2.70	300.80
90	Packaging	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91	Manuals	10.50	1.57	7.09	19.99	0.00	0.09	17.73	0.15	1.32	0.05	0.01	0.03	0.00	0.44	0.01	1388.20
92	Protection	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	PALLET	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
94	PROTECTIONS	49.84	3.56	28.48	12.54	0.00	0.08	93.12	1.25	1.85	0.00	0.02	0.06	0.01	0.02	0.02	153.19

95	Miscellaneous	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
96	Temperature control and display system	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
97	LCD 18x2 / 1.318 10-2 m² / 117.5g	4.70	2.99	0.00	0.06	0.88	0.00	0.07	0.24	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	WEIGHT DISPLAY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
99	Selection & Payment systems	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	ELECTRONIC CARDS BRACKETS	3.80	0.28	1.83	0.37	6.60	0.40	3.68	0.13	0.71	0.00	0.00	0.00	0.07	0.12	0.08	25.19
101	ELECTRONIC CARDS	8.43	4.52	0.26	5.10	2.30	52.00	78.76	0.34	6.41	0.07	0.08	1.08	0.11	0.15	0.44	110.59
102	47-IC's avg., 1% Si	87.42	67.32	0.30	61.15	10.36	64.46	174.83	5.88	81.62	0.00	0.98	18.50	0.30	2.42	0.96	429.63
103	46-IC's avg., 5% Si, Au	826.40	803.76	0.00	752.55	0.00	37.77	777.22	63.52	418.10	10.16	7.33	66.99	2.20	10.93	561.00	3222.16
104	44-big caps & coils	11.50	0.00	0.00	1.04	1.65	0.59	18.02	0.65	4.25	0.00	0.06	0.23	6.14	1.07	2.23	0.21
105	Motors of the dispensing mechanism	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
106	Aluminium	57.67	0.00	0.00	0.00	0.00	0.00	784.50	3.71	16.34	0.08	35.03	0.88	18.48	4.24	6.77	1.27
107	Iron	158.78	10.72	0.35	123.43	0.00	0.00	8103.19	13.31	34.99	0.64	122.38	112.74	0.00	12.74	7.41	246.74
108	Copper	111.96	0.00	0.00	0.00	0.00	0.63	15721.38	5.78	238.36	0.02	3.12	44.34	4.34	2.37	5.07	124.11
109	PVC	14.80	2.91	6.00	2.88	16.21	1.31	17.54	0.57	3.92	0.00	0.00	0.00	0.01	0.76	0.74	82.11
110	Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
111	Refrigerant liquid R134A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	**36,805.66**	**9925.62**	5013.35	**5283.07**	36123.18	**2325.61**	372180.68	**2025.17**	9327.69	**112.45**	**3906.52**	**1825.26**	**585.94**	**585.94**	**1843.59**	**2959.54**

6. TECHNICAL ANALYSIS BAT

This section presents the task 6 of the Lot 12 EuP preparatory study on Commercial Refrigerators and Freezers. Task 6 entails a description and technical analysis of Best Available Technologies (BAT) either at product or component[1] level.

BAT is a technology, leading to minimised environmental impacts, which is already available on the market (existing products inside and outside the EU market will be reviewed) or at least its technical feasibility has already been demonstrated (expected to be introduced at product level within 2-3 years).

The assessment of the BAT provides input for the identification of the improvement potential in task 7. Intellectual property, technical feasibility, and availability on market in a strict sense are not judged here as the objective is to illustrate various technically available (or potentially available) options. However, the task 7 will take these issues into account when suggesting possible improvement options applicable to the lot 7 products.

The description of technologies presented here is based on ongoing research. New cutting edge technologies are highly guarded secrets and detailed public information is limited. Thus, the information presented here should be seen as a general overview of technologies and potential improvement options rather than a thorough technical analysis.

For the plug in appliances and wherever possible, comparisons were made with similar domestic appliances concerning the improvement potential and energy consumptions.

Note:

As a commercial refrigerator or freezer is an assembly of many components aiming at creating the refrigeration load required, there is a wide range of best available technologies at the component level. The current document details and assesses the most relevant ones according to manufacturers and to other available studies[2].

[1] In this section « component » refers to the refrigeration components (i.e. compressor, evaporator (and evaporator fan), condenser (and condenser fan), expansion valve, refrigerant) **and** to the other components of the product (e.g. lighting system, air discharge grill etc.).

[2] M. Ellis & Associates, *Analysis Potential for MEPS for Remote Commercial Refrigeration* and *Analysis Potential for MEPS for Self-Contained Commercial Refrigeration*. (March 2000)
Arthur D. Little, *Energy Savings Potential for Commercial Refrigeration Equipment.* (June 1996)
T. Kubo and S. Nadel, *Commercial Packaged Refrigeration: An Untapped Lode for Energy Efficiency.* (May 2002)
Davis Energy Group – Energy Solutions, *Analysis of Standards Options for Refrigerated Beverage Vending Machine.* (May 2004)

All the registered Lot 12 stakeholders were invited to provide input to this task, and others were also welcome to contribute. Most of the technical data for this task has been provided directly by the manufacturers/designers or come from other published information. However, the efficiency or other performance levels claimed by them have not been verified independently.

6.1. STATE-OF-THE-ART ALREADY ON THE MARKET (PRODUCT LEVEL)

All products presented in this section are for illustration purposes only. They provide examples of what is technically feasible but should not be looked at as "role models". Also, it should be kept in mind that some barriers to the production of such efficient products exists such as the limitation in the amount of hydrocarbon authorised in plug in appliances and other end-user related barriers such as the importance of the purchase cost as seen in task 3 (section 3.4).

6.1.1 REMOTE REFRIGERATED DISPLAY CABINET

6.1.1.1 OPEN CHILLED VERTICAL MULTI-DECK (RCV2)

Some manufacturers have launched RCV2 (3M2 climate class and TDA = 7m²) using high efficiency components and allowing reducing Total Energy Consumption (TEC) between 25 and 30 % compared to the base case defined in task 5, such as Norpe, Ingersoll, and Carrier.

6.1.1.2 OPEN FROZEN ISLAND (RHF4)

Few outstanding products in terms of energy consumption exist for this category of appliances as customer's focus is more on the improvement of the product temperatures than on energy consumption and more on the product price than on its efficiency. However, some companies propose low energy consumption cabinets such as the Norpe, Arneg, and EPTA which can provide up to 40 % reduction in TEC.

6.1.2 PLUG IN REFRIGERATED DISPLAY CABINET

The Procool competition[3] (2006) winners provide a good insight of the Best Available Technology at the product level for the plug in refrigerated display cabinet family. Five innovative appliances produced by European manufacturers.

Comparison with the domestic refrigeration sector shows that there is a big gap in energy consumption which is partly due to the use of a solid door in household appliances but also to the use of different technologies at

[3] See task 1 for further details on the Procool competition

component level. Even if these appliances seem very similar (functionality, overall design) their electricity consumption varies widely.

6.1.2.1 BEVERAGE COOLER

- **Procool winner for beverage cooler category**

Table 6-1: Procool Winner beverage cooler

Specifications for Procool winner Vertical cooling shelf with glass door (Beverage cooler)	
Net volume	329 L
Refrigerant	R600a (Isobutane)
Quantity of Refrigerant	50 g
Energy consumption for cooling	0.251 kWh/100L, 24h
Climate class	4
Temperature class	H1 (1 - 10℃)
Acoustic pressure	21.7 dB(A)
Dimensions	600x600x1650 mm

Figure 6-1: Procool winner beverage cooler

Although the temperature class of this beverage cooler differs from the one of the base case described in task 5 (M2), if the value of the energy consumption for cooling (0.251 kWh/100L.day), which means without lighting, is applied to the base case (500 L), the daily energy consumption could be about 1.26 kWh/day, which represents a reduction of 74 % in TEC. Indeed, daily energy consumption of the beverage cooler base case without lighting is about 4.88 kWh/day.

However, these numbers are for illustration only, as the operating temperature of the base case is lower than Procool winner beverage cooler, no direct comparison can be made.

- **Comparison with similar domestic appliances**

This energy consumption of 1.26 kWh/day for a net volume of 500 litres can be compared to the electricity consumption of a domestic refrigerator of category 1 (without low temperature compartment).

If we use the baseline reference model of the EU energy labelling scheme, the baseline total energy consumption for a 500 litres domestic refrigerator is about 1 kWh/day.

However, this energy consumption has to be adjusted for a fair comparison. Indeed domestic fridges are fitted with solid doors which are typically more efficient than glass doors providing on average electricity savings of 30 %.

Table 6-3 summarises the electricity consumptions of domestic refrigerators of different classes normalised to 500 litres volume. The electricity consumption is adjusted with an increase of 43 %[4] to simulate the switch from a solid door to a glass door. These adjustments were applied to allow a fair comparison with the base case beverage cooler and with the data from the Procool winner beverage cooler.

Table 6-2: Electricity consumption of commercial beverage coolers

Type of beverage cooler (500 litres net volume)	Daily energy consumption (kWh/day)
Base case beverage cooler without lights - operating temperature around 5℃	4.88
Procool winner beverage cooler without lights - operating temperature around 5℃	1.26

Table 6-3: Electricity consumption of domestic refrigerators

Energy efficiency grades used in EU energy label	EU Energy Label	EEI* used for comparison with beverage cooler	Daily electricity consumption for V=500 litres (kWh/day) for a category 1 domestic refrigerator (except last line)	Daily electricity consumption for V=500 litres + 43 % allowance for glass door (kWh/day)
I<30 % of base line	A++	29	0.33	0.48
30<I<42	A+	30	0.34	0.58
42<I<55	A	42	0.42	0.77
55<I<75	B	55	0.54	1.05
75<I<90	C	75	0.74	1.32
90<I<100	D	90	0.89	1.53
100<I<110	E	100	0.99	1.69
110<I<125	F	110	1.09	1.89
125<I	G	125	1.24	2.10

Base line (2003/66/EC) annual electricity consumption is (0.233*Veq+245)+50 kWh/yr for category 1 domestic refrigerators where Veq=V for classes A+ and A++

Base line (94/2/EC) annual electricity consumption is 0.233*Veq+245 kWh/yr for category 1 domestic refrigerators where Veq=V

*EEI=30 means that the appliances has a electricity consumption equal to 30 % of the base line

[4] This 30 % increase in the electricity consumption was assumed based on the differences in the electricity consumption standards between solid door and glass door appliances in California.

http://www.energy.ca.gov/2006publications/CEC-400-2006-002/CEC-400-2006-002-REV2.PDF

When comparing the two tables above (Table 6-2 and Table 6-3), a gap can be noticed between the total electricity consumptions (TEC) of domestic and commercial appliances. The Procool winner beverage cooler is equivalent to a category 1 domestic refrigerator of class G and B if we consider the 43 compensation for the solid door. The base case beverage cooler uses almost four times more electricity as a domestic refrigerator of class G and category 1 (4.88 kWh/day compared to 1.24 kWh/day for 500 litre refrigerated volume).

Another adjustment of the domestic electricity consumption data should be made related to the differences in operating temperature (inside cabinet temperature). However, the typical temperatures of domestic appliance are around 3 - 4℃ which is lower than 5℃ observed in beverage coolers and therefore the adjustment was not made. This adjustment to a 5℃ operating would only lower the electricity consumption and therefore not affect the conclusions.

6.1.2.2 ICE CREAM FREEZER

- **Procool winner ice cream freezer category**

The winner of the Procool competition (Figure 6-2), has following specifications (Table 6-4):

Table 6-4: Procool Winner ice cream freezer

Specifications for Procool winner Deep freezer with glass lid	
Net volume	189 L
Refrigerant	R600a (Isobutane)
Quantity of Refrigerant	63 g
Energy consumption for cooling	0.545 kWh/100L, 24h
Climate class	4
Temperature class	L1
Acoustic pressure	31.5 dB(A)
Dimensions	830x660x900 mm

Figure 6-2: Procool winner deep freezer

The measurement conditions for freezers in the Procool competition follow the standard ISO 23953 climate class 4, and temperature class (L1) is also the same as for the base case ice cream freezer described in task 5 (section 5.1.3.2), a useful comparison could be made.

Thereby, if the value of energy consumption for cooling (0.545 kWh/100L.day) is applied to a cabinet with a size comparable to the base case (292 L), the daily energy consumption would be of about 1.6 kWh/day, which means an overall reduction of 64 % compared to the base case (4.5 kWh/day).

- **Comparison with similar domestic appliances**

This energy consumption (Table 6-5) can be compared to that of domestic chest freezers (Table 6-6). Total electricity consumption (TEC) data from domestic chest freezers with solid doors from different class can be normalised to a net volume of 292 litres to provide comparison with the similar commercial appliance. An adjustment of 93 % increase in the energy consumption was applied to the electricity consumption to simulate a more fair comparison when comparing the domestic appliance with the solid door and the commercial ice cream freezer with a glass door. The estimation of the increase is based on the difference between the Californian standards for ice cream freezers with solid doors and transparent doors (with a volume of 292 litres).

Table 6-5: Electricity consumption of commercial ice cream freezers

Type of ice cream freezer	Daily energy consumption (kWh/day)
Base case ice cream freezer	4.5
Procool winner deep freezer	1.6

Table 6-6: Electricity consumption of domestic chest freezers

Energy efficiency grades used in EU energy label	EU Energy Label	EEI* used for comparison with ice cream freezer	Daily electricity consumption for V=292 litres (kWh/day)	Daily electricity consumption for V=292 litres + 93 % allowance for glass door (kWh/day)
I<30 % of base line	A++	29	0.53	0.81
30≤I<42	A+	30	0.54	0.97
42≤I<55	A	42	0.56	1.30
55≤I<75	B	55	0.74	1.76
75≤I<90	C	75	1.00	2.22
90≤I<100	D	90	1.21	2.57
100≤I<110	E	100	1.34	2.84
110≤I<125	F	110	1.47	3.16
125≤I	G	125	1.67	3.52
Average domestic chest freezer (category 9)[5]	B	64.4	0.95	1.83

Base line (2003/66/EC) annual electricity consumption is 0.472*Veq+286+50 kWh/yr where Veq=2.15*V*1.05 for A+ and A++ classes
Base line (94/2/EC) annual electricity consumption is 0.446*Veq+181 kWh/yr where Veq=2.15*V*1.1
*EEI=30 means that the appliances has a electricity consumption equal to 30 % of the base line

[5] Electricity consumption data from the EuP preparatory Study on Lot 13 "Domestic refrigerators and freezers" Task 5 final draft report – data related to base case freezer of category 9
http://www.ecocold-domestic.org/index.php?option=com_docman&task=doc_download&gid=66&Itemid=40

The Procool winner ice cream freezer can be compared to a domestic chest freezer with solid door of class F and of class A if considering the 93 % increase in energy use to compensate for the solid door. The base case ice cream freezer uses over twice as much electricity as a domestic freezer category 9 of class G.

Other products in this category of Procool awards were appliances running with Isobutane with CO_2 and Propane, but their characteristics differ from the bases cases defined in this study.

6.1.3 COLD VENDING MACHINE

Many manufacturers are aware of the environmental challenge facing their industry and have developed activities working towards a better efficiency of their cold vending machines. For example, FAS has developed a refrigeration system using a side to side airflow combined with the use of triple glazed glass door to provide better distribution of the cold air and eliminate condensation thus limiting the use of anti sweat heaters. Selecta is working to incorporate energy-saving LED light technology into their vending machines for improved energy efficiency by providing 60 % energy savings in the lighting and 20 % savings for the cooling of the vending machine.

6.2. STATE-OF-THE-ART ALREADY ON THE MARKET (COMPONENT LEVEL)

Note: It is quite difficult to estimate the energy savings by the use of a specific component as it depends on the type of refrigerated equipment in which they are used and many other factors influencing the overall performance. The data presented below are taken from literature and/or from manufacturers' specifications. However, energy savings and additional costs for the components identified as design improvement options for the base cases will be discussed in section 6.3.

For some improvement options, energy savings can be measured in real life conditions but hardly in standard conditions. Therefore, in the following paragraphs all figures of TEC savings are given under standard conditions see Table 6-7) unless otherwise specified. Moreover, for real life conditions, values (i.e. average values for one year) are estimated considering average European seasonal variations and an average annual outside temperature of 12℃.

Table 6-7: Measurement standard conditions for the five base cases

	Base case RCV2	Base case RHF4	Base case beverage cooler	Base case ice cream freezer	Base case spiral vending machine
Standard conditions	ISO 23953 - Climate class 3 (25℃ – 60 % RH)		ISO 23953 - 30℃ / 55% RH		EVA EMP Protocol (Idle Mode) 25℃ / 60% RH

6.2.1 Compressor

The compressor is the major electricity consuming component for cold vending machines and plug in refrigerated display cabinets.

6.2.1.1 High Efficiency Compressor

Most plug in refrigerated display cabinets and cold vending machines use hermetically sealed and electric motor driven compressors units with a reciprocating compressor.

The aim of a high efficient compressor is to increase its COP (Coefficient of Performance), which for instance is between 1.7 and 2.2 for the compressors used in the spiral vending machines (see section 4.1.3).

This objective can be achieved by reducing suction and discharge gas pressure losses, mechanical losses (frictions), and electrical losses (motor). Most of components used in commercial refrigerators and freezers, and especially the compressor, are over-sized, to ensure a good operation of the refrigeration system even in the worst conditions (e.g. very hot summer). Therefore, a better adaptation of the size of the compressor to the required cooling capacity allows a displacement reduction of the cylinders, and thus a reduction of the electricity consumption of the refrigeration equipment.

The energy savings depend on the type of compressor used in the commercial refrigerator. For a typical beverage cooler, the energy savings already achieved by using a high efficient compressor is about 5 % of the total electricity consumption. For a typical spiral vending machine, the reduction of about 27 % of the volume of the compressor allowed a reduction of 10 % of the electricity consumption.

6.2.1.2 Compressor Modulation

During past several years, the variable-speed-drive (VSD) compressor has become a more and more interesting choice for manufacturers of refrigeration equipments. The VSD compressor's popularity is partly due to rising energy prices and its efficiency as a lag compressor.

Because a direct proportionality ratio exists between rotation speed and mass flow rate, variable speed is the power control system that seems most adequate.

Energy savings associated with variable speed are linked to the reduction of the mass flow rate, because lower internal mass flow rate permits smaller temperature differences at the heat exchangers. When the refrigerant flow is reduced at the condenser, the condensing pressure decreases and energy consumption of the compressor is lower. The control of internal and external flows at the evaporator is more complex and lower refrigerant flow does not generate automatic energy savings.

In product catalogues, VSD compressors use the percent power versus percent capacity graph to show how much efficient the VSD compressor is compared to a constant-speed compressor operating in either modulation or load/unload mode.

The modulation of the compressor can be achieved mainly in two ways:

- by using an Electronically Commutated Motor (ECM) instead of a classic direct current motor, or
- by adding a clipper allowing to modulate the frequency of the motor, which is unchanged.

For example, at full load, a VSD compressor using a clipper is not as efficient as the comparable load/unload compressor from the same manufacturer because the variable-frequency drive increases power draw by 2 % to 4 %. As we approach 100 % power, the constant-speed compressor is more efficient than the VSD compressor. VSD compressors allowed energy savings when working under part load conditions. This is because they will speed up and slow down to maintain minimum pressure changes in the compressed air system thereby reducing the KWh.

Generally, if it is expected that a constant-speed trim compressor will operate above 80 % of its capacity, it is the more efficient choice. On the other hand, if the constant-speed trim compressor operates below 80 % of its capacity, then replacing it with a VSD compressor will provide additional savings.

The addition of a clipper also allows using the modulation for fan motors, or other motors included in the cabinet.

6.2.1.3 Compressor Choice

ASERCOM has a performance certification program which has been established to assist manufacturers of commercial refrigeration and air conditioning systems. Reliable performance data are presented in a comparable manner to optimise product selection, based on the European Standard EN12900, EN13771, and a common refrigerant data base.

6.2.2 Electronic Expansion Valve

Electronic expansion valves (EEV) can be used in commercial refrigeration equipments instead of capillary tubes or thermostatic expansion valves. EEV makes it possible to avoid the minimum pressure drop required to allow proper operation of a standard thermostatic valve. Therefore, it is possible to optimise the condensing pressure at a minimum level permitted by the ambient conditions. Using an electronic expansion valve, it is possible to regulate the superheating of the evaporator and thus improving display cabinet's performance. Moreover, it allows a better control of the temperature, which ensures a better preservation of products, whatever are the external conditions, and an increase of the compressor lifespan, through the reduction of the duty cycle and inside pressure.

The reduction of the electricity consumption with the use of an electronic expansion valve mainly depends on seasonal variations, and thus it is difficult to measure in standard conditions. Indeed, for a typical remote RCV2, an EEV does not provide any significant TEC saving in standard conditions (ISO 23953 – Climate Class 3) and between 6 % and 16 % in real life conditions.

For a typical RHF4, the reduction is between 5 % and 8.5 % in real life conditions.

6.2.3 Fans

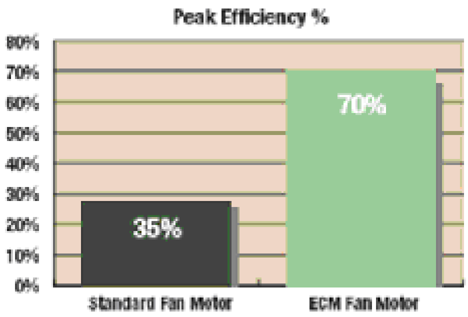
6.2.3.1 ECM Fan Motor

Most fans motors used in conventional remote and plug in refrigerated display cabinets and cold vending machines are shaded pole motors.

The ECM (Electronically Commutated Motor) is an ultra high efficiency programmable brushless DC (Direct Current) motor using a permanent magnet motor and a built-in inverter. DC motors are significantly more energy efficient than single phase shaded pole AC (Alternative Current) motors and are much easier to control. The major weakness of commercial fan coil units is their low fan motor efficiency.

The main benefit of an ECM is to maintain a high efficiency of 70 % at all speeds.

Figure 6-3: Comparison of the efficiency of two types of fan motors[6]



Besides, ECM fan technology provides 90,000 hours of operation on average, which is twice of that a standard fan motor.

6.2.3.2 High Efficiency Fan Blades

The fans typically used in commercial refrigeration have sheet metal blades, with an energy efficiency of around 40 %[7]. This could be improved by a better design.

For instance, Delphi Corporation has launched a new generation of metal axial fans designed for the residential and light commercial Heating, Ventilation, and Air Conditioning (HVAC) market. This new product portfolio uses leading-edge air management technology to help HVAC manufacturers design higher efficiency products and ultimately take cost out of their system. Using Delphi's patented fan technology, HVAC manufacturers may

[6] Source: Puget Sound Energy

[7] Source: Mark Ellis & Associates, *Analysis of Potential for MEPS for Remote commercial Refrigeration*. (March 2000)

significantly reduce the amount of power required to run their condenser fans. Studies performed both by Delphi and major HVAC Original Equipment Manufacturers (OEMs) have proven that this blade technology can increase efficiency by 30 to 35 % as compared to other premier fans in the marketplace, which generally focus on noise reduction alone. HVAC OEMs may also be able to use Delphi's metal axial fans to increase airflow volume by 12 to 15 % without having to increase power to the fan motor.

Furthermore, some manufacturers replace metal blades by plastic ones for a more efficient design. Usually, ECM fans include high efficient fan blades.

6.2.4 LIGHTING

Lighting is an important energy “eater” in commercial refrigeration equipments. As presented in task 5, lighting represents about 25 % of the DEC (Direct Energy Consumption) for a typical open chilled vertical multi-deck i.e. about 31 % of the TEC (total electricity consumption) for a beverage cooler and 14.5 % for a spiral vending machine. Besides, the heat emitted by bulbs increases the REC (Refrigeration Energy Consumption) of commercial refrigeration products.

6.2.4.1 HIGH EFFICIENCY FLUORESCENT BULBS

Most of the beverage coolers, cold vending machines, and open chilled vertical multi-deck use T8 or T12 fluorescent lamps. Energy savings could be achieved by using T8 instead of T12, or T5 instead of T8. Table 6-8 compares the luminous efficiency of these three types of bulbs.

Table 6-8: Characteristics of common fluorescent lamps (at 20°C) [8]

Type of neon	Diameter (mm)	Luminous efficiency (lumen/Watt)
T12	38	40 - 65
T8	26	80 - 95
T5	16	95 - 105

The experience of a manufacturer of spiral vending machine who replaced T8 by T5 shows that the energy savings of the lighting system is about 40 %, which means about 6 % of the TEC[9]. However, it is important to note that the use of a T5 requires more efficient electronic ballast than the commonly used magnetic ballast (used in T8), which adds to the advantages of using T5 bulbs.

[8] Source : Direction générale des Technologies, de la Recherche et de l'Energie (DGTRE) du Ministère de la Région wallonne

[9] Assuming that the lighting represents about 15 % of the TEC (see task 5 section 5.1.4.1) .

6.2.4.2 ELECTRONIC BALLAST

Lighting ballast is a device to control the starting and current flow of electrical discharge gas lights. The group “starter – magnetic ballast – power factor capacitor” can be substituted by electronic ballast. Its benefits compared to conventional magnetic ballast are:

- lower electricity consumption
- better luminous efficiency
- extended lifespan
- less noise
- less flickering

Therefore, a T8 fluorescent lamp of 36 W with conventional magnetic ballast consumes 46 W, but when equipped with electronic ballast, the consumption goes down to 35 W[10].

6.2.5 AIR DISTRIBUTION

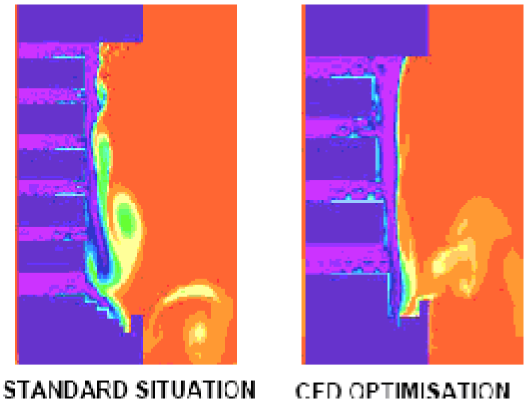
As discussed in task 4 (section 4.4.1.1), about 64 % of the refrigeration load in an open vertical display cabinet is a result of the warm air entrainment across the air curtain.

- **Optimisation of air curtain**

Improvements of the air distribution inside the cabinet are analysed using design and analysis tools such as Computational Fluid Dynamics (CFD). CFD is one of the branches of fluid mechanics that uses numerical methods and algorithms to solve and analyse problems that involve fluid flows. Figure 6-4 shows the air distribution inside and outside of an open vertical multi-deck. The use of CFD allows testing different configurations hypothetically in order to find optimum velocity and angle of the air discharge system, aiming at limiting infiltrations of ambient air from surroundings.

[10] Source : Institut Bruxellois pour la Gestion de l’Environnement (IBGE)

Figure 6-4: Air Curtain improvement using CFD



Such an optimisation allows designing for fewer infiltrations and thereby energy savings in REC. Moreover, it decreases temperature variation of products across the lowest and highest shelves.

- **Secondary air curtain**

To reduce infiltrations and energy consumption of an open display cabinet, another solution is to add a secondary air curtain. Some manufacturers of display cases have two adjacent, parallel, but independently generated air curtains. Typically, the first one is installed in order to minimise the introduction of warmer ambient air and the second air curtain (the one used in the case of single air curtain) is cooled down at the temperature required to preserve fresh food. The outer air curtain has a slightly higher temperature than the inner one.

6.2.6 HEAT EXCHANGERS' SURFACE AREA

As explained in task 4 (section 4.3.2.5), the lower the difference between evaporating and condensing temperatures, the higher is the COP and thus lower energy consumption. One way to achieve this objective is to increase heat exchangers' surface area at the evaporator and at the condenser. It can be done:

- either through the increase of core dimensions; the increase in the fin density, however this option can lead to higher risks of fouling for the condenser and potential for frost at the evaporator;
- or through the use of rifled tubing rather than smooth tubing.

However, increasing evaporator and/or condenser surface requires increasing the fan power by the same ratio. Hence, an optimal surface area has to be defined in order to maximise energy savings. According to cold vending machines manufacturers, this design option is not applicable because of the lack of space in these kinds of appliances.

6.2.7 INSULATION

Insulation improvement can be achieved either by using new technologies (see 6.2.7.1) or by choosing design options (see 6.2.7.2, 6.2.7.3 and 6.2.7.4) for the cabinet.

6.2.7.1 INSULATION MATERIAL

One way to improve the insulation of the cabinet is to replace the common polyurethane and the blowing agent (R134a, cyclopentane, etc.) with a better insulation material, such as silica powder or vacuum.

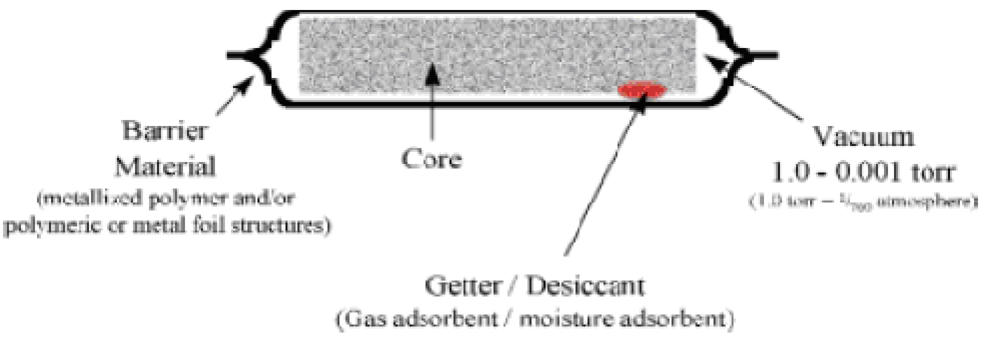
- **Insulation Improvement**

Insulation improvement can be achieved by decreasing foam's thermal resistance. This reduction is mainly due to the formation of smaller cells within the foam insulation structure and better cell-size consistency.[15] Nevertheless, implementation of the improved foaming technology requires the purchase of new foaming equipment, which can significantly increase the cost of the insulation.

- **Vacuum Insulated Panels**

Vacuum insulation panels are highly efficient insulating materials made by placing micro-porous filler inside a high barrier containment system and evacuating the air from inside of the panel (see Figure 6-5).

Figure 6-5: Vacuum Panel Construction[11]

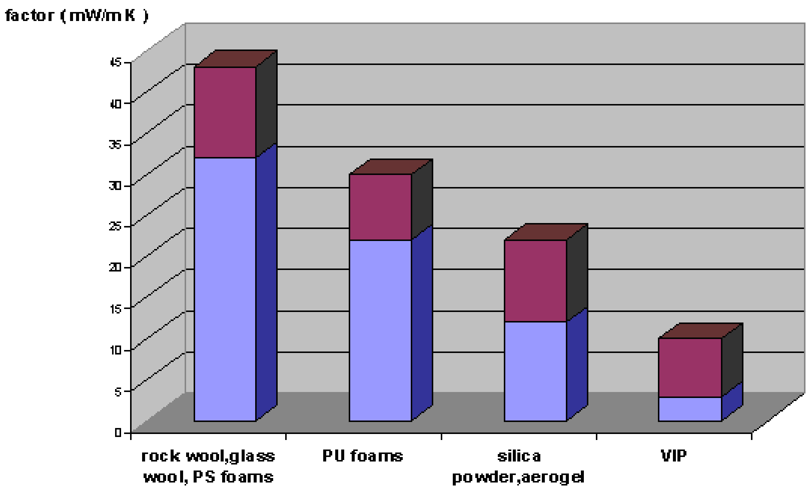


The benefit of using vacuum insulated panels is that they have thermal conductivity lower than conventional insulators such as polyurethane and polystyrene foams, thus allows achieving superior insulation performances. This implies energy savings without increasing insulation thickness.

[11] Source: B. Malone and K. Weir, *State of the Art for Vacuum Insulated Panel Usage in Refrigeration Applications* (2001)

Figure 6-6 presents thermal conductivity (expressed in mW/m.K) of various insulating materials with minimum (in blue) and maximum (in purple) values. The range of values depends on the internal pressure of the panel.

Figure 6-6: Thermal conductivity of various insulating materials[12]



Several core materials can be used in vacuum insulated panels: open-cell polyurethane[13], open-cell polystyrene, precipitated (also called fumed) silica powder, nanogel, glass fibre, etc.

To fully exploit their insulation performances, panels must be evacuated and kept at a suitable vacuum level during operation. Table 6-9 presents characteristics of various core materials.

Table 6-9: Comparison of various vacuum insulated panels core materials[14]

	Polystyrene	Open-cell PU	Silica powder	Glass fibre
Conductivity at 10 Pa abs. (mW/m.K)	4,8–5,8	9,7	5,8	2,4
Manufacturing time	Fast	Medium	Medium	Long
Density (kg/m^3)	80–144	64	192	128
Drying need	No	Yes	Yes	No
Thermal stability	Low	Medium	Good	Very good
Recyclability	Yes	Difficult	Yes	n.a.
Cost	Low	Medium	High	Very high

Abbreviation: NA = not applicable.

Use of a getter, as presented in Figure 6-5, allows keeping internal pressure as low as possible to limit the thermal conductivity of vacuum insulated panels.

[12] Source: M. Paolo, G. Pastore and P. Di Gregorio, *Vacuum Insulated Panels Technology: A Viable Route to Reduce Energy Consumption in Domestic, Industrial and Civil Applications*

[13] The conventional polyurethane (or polystyrene) foam is also called closed-cell polyurethane (or polystyrene).

[14] Source: Preparatory Study for Eco-design Requirements of EuP, Lot 13, ISIS

This technology is not used in average products currently being analysed in this study, but research is still going on and some cold vending machine manufacturers estimate that the potential energy savings could be between 5 % and 10 % of the total electricity consumption with polyurethane as core material. However, their reliability in the long term has also to be proved.

- **F-free Blowing Agent**

The environmental impacts of HFCs are encouraging commercial refrigeration equipments manufacturers to identify other blowing agents more “eco-friendly”.

Some manufacturers already use cyclopentane instead of HFC such as R134a, for a variety of appliances (RCV2, RHF4, beverage cooler, cold vending machine, etc.). Besides, few also use isopentane, CO_2, and water. However, the thermal conductivity of such blowing agents is higher than the one made with HFCs. Therefore, this doesn’t lead to a reduction of the energy consumption but will help in reducing environmental impacts such as Global Warming Potential (GWP).

6.2.7.2 THICKER INSULATION

Increasing the insulation thickness reduces the heat load inside the cabinet. Nevertheless, the manufacturer has to make a choice between decreasing the storage volume and increasing the external dimensions of the cabinet. This solution is not considered as a BAT, but as a design option.

One manufacturer of cold vending machines has already increased the insulation thickness of his spiral models from 30 mm to 40 mm. Moreover, according to a publication of the American Department of Energy[15], an insulation thickness of 63.5 mm (2.5 inches) instead of 38.1 mm (1.5 inches) reduces the electricity consumption of a beverage cooler by 6 %. Finally, for remote display cabinets RCV2 or RHF4, these cabinets being open, insulation thickness has a negligible impact on the energy consumption.

6.2.7.3 ADDITIONAL GLASS DOOR OR GLASS LID

An easy way to reduce infiltrations and electricity consumption of open commercial refrigeration equipments is to close them with doors for open vertical cases or glass lids for open horizontal display cases. Nevertheless, this energy efficient solution has a major merchandising drawback. Indeed, consumers will have to open doors or lids to access to products and most purchasers of these display cabinets (e.g. supermarkets) go against this design option as this is perceived as a sales barrier. Moreover, another issue is that after opening door (or lid) for few seconds when you close it, because of sweat formation the products inside are not visible for some time unless the heaters remove the sweat, which itself may take some time and consume

[15] Source: Arthur D. Little, *Energy Savings Potential for Commercial Refrigeration Equipment*. (June 1996)

additional electricity. Nevertheless, to avoid the use of anti-sweat heaters, most manufacturers of closed cabinets (typically glass door beverage cooler) have developed highly insulated glass doors with low emissivity coating (see task 4 section 4.1.2.2).

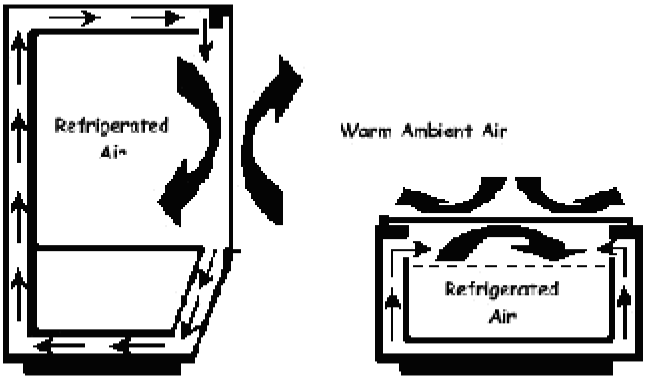
According to manufacturers, the reduction of energy by adding glass door (or lid) to a typical open chilled vertical multi-deck (RCV2) is between 50 % and 59 % of the TEC, and between 30 % and 43 % of the TEC for open frozen island (RHF4) in standard conditions with the following assumptions:

- with closed door (or lid),
- without addition of an anti-sweat heater, and
- still with a single air curtain.

6.2.7.4 NIGHT CURTAIN

An alternative of the closed door/lid design option is to use night curtain during store's closing hours (commonly 12 hours a day for supermarkets), although more and more supermarkets are now 24h open.

Figure 6-7: Air flow diagram for display cabinets with night cover on[16]



In the case of vertical open cabinets, it ideally consists of a woven aluminium fabric which is pulled down in front of the opening either manually or automatically. The woven pattern of night curtains disperses radiated heat in many directions which is more effective than thermal blinds with smooth surfaces, which only reflect the heat in the perpendicular direction. Refrigeration covers are not visible during business hours. The night curtain fabric normally rolls up and is stored in the top casing of upright refrigeration display cases, out of sight. The material used for such cover should be of high quality to ensure no condensation which could alter the quality of the stored foodstuff. The curtain is made of a food safe and perforated material which allows condensation to evaporate and prevent mildew from forming.

On average, according to refrigerated display cabinet manufacturers, by using night curtains during 12 hours, the electricity consumption can be reduced of

[16] Source : http://www.econofrost.com/products_covers.html

25 % of the TEC for a typical RCV2. For a typical RHF4 the decrease is between 12 % and 21 %.

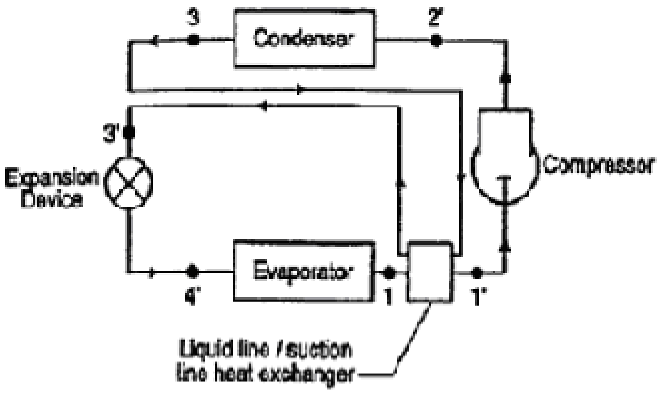
6.2.8 LIQUID SUCTION HEAT EXCHANGER

Liquid suction heat exchangers (LSHX) could be used in refrigeration systems to ensure the right operation of the system and increase its performance. However, this component can only be used in remote refrigerated display cabinets. ASHRAE[17] states that heat exchangers are effective in:

- Increasing the system performance
- Subcooling liquid refrigerant to prevent flash gas formation at inlets to expansion devices
- Fully evaporating any residual liquid that may remain in the liquid-suction prior to reaching the compressor

Figure 6-8 shows the refrigeration cycle including the liquid suction heat exchanger, which allows exchanging energy between the cool gaseous refrigerant leaving the evaporator and the warm liquid refrigerant exiting the condenser.

Figure 6-8: Schematic representation of refrigeration cycle with a LSHX



The main benefit of the use of a liquid suction heat exchanger is to avoid vapour existing into the expansion device and to reduce the possibility of liquid transfer between the evaporator and the compressor, which could harm the latter. However, liquid-suction heat exchangers could increase the temperature of the refrigerant and reduce the pressure of the refrigerant entering the compressor causing a decrease in the refrigerant density and compressor volumetric efficiency.

The choice to install a liquid suction heat exchanger is a compromise, and depends on the temperature lift (difference between condensing and evaporating temperatures) of the system and on the kind of refrigerant. For example, it is detrimental to system performance in systems using R22, R32 or R717 as refrigerant, for low temperature lifts.

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[17] American Society of Heating, Refrigerating and Air-Conditioning Engineers

This option is not available for plug in refrigerated display cabinets and cold vending machines.

6.2.9 DEFROST CONTROL

Defrosting involves the introduction of heat inside the display cabinet and this penalises the refrigeration system performance due to the fact that process energy is used while producing no useful cooling. Furthermore, during defrosting, the temperature inside the cabinet rises above the set limit for normal operation. Energy efficiency and better temperature control can be helped by initiating defrost operations only when it is required (and not through a timer), through control systems detecting lack of performance and by stopping the defrost cycle as soon as the evaporator is clear of ice.

A number of defrost control strategies have been applied over the years such as: measuring the air pressure drop across the evaporator, sensing the temperature difference between the air and the evaporator surface, fan power sensing, variable time defrost based on relative humidity, and air differential across the coil. Most recent methods include measuring the ice thickness through monitoring the resonant frequency of an acoustic oscillator installed on the evaporator, measuring the thermal conductivity of the ice, using photo optical systems and fibre optic sensors to measure the presence of frost.

The energy savings by using "on demand" defrost control rather than timed defrost is quite difficult to estimate, as it depends on the type of appliance and the defrost time.

6.2.10 ANTI-SWEAT

6.2.10.1 ANTI-SWEAT HEATER CONTROL

Anti-sweat heaters are used to reduce condensation. Anti-sweat heater controls ensure that the heater is used only when needed. It requires measurement of the local dewpoint or humidity level. The heaters can be turned on when a given dewpoint temperature is exceeded, or the heaters can be cycled, with on-time increasing with dewpoint. Dewpoint sensors can be factory-installed in individual cases.

Anti-sweat heater controls save money in two ways. First, they reduce the amount of time the anti-sweat heater needs to run. Second, because the anti-sweat heater runs less often, the refrigeration system does not have to compensate for that extra heat generated. Thus there are two areas of energy savings: in the anti-sweat heater and in the operation of the refrigeration system.

Energy savings through anti-sweat heater control for low temperature supermarket display cabinets can be in the range of 6 % of the TEC in real life conditions, according to remote cabinet manufacturers.

6.2.10.2 LOCATION OF THE ANTI-SWEAT HEATERS

For cold vending machines with transparent door (as the base case), normally anti-sweat heaters are located all around the glass in the door frame. By installing these heaters in the glass, it allows choosing anti sweat heaters of lower power. For instance, a 35 W anti-sweat heater (in the base case spiral vending machine) can be replaced by a 18 W anti-sweat heater when located in the glass.

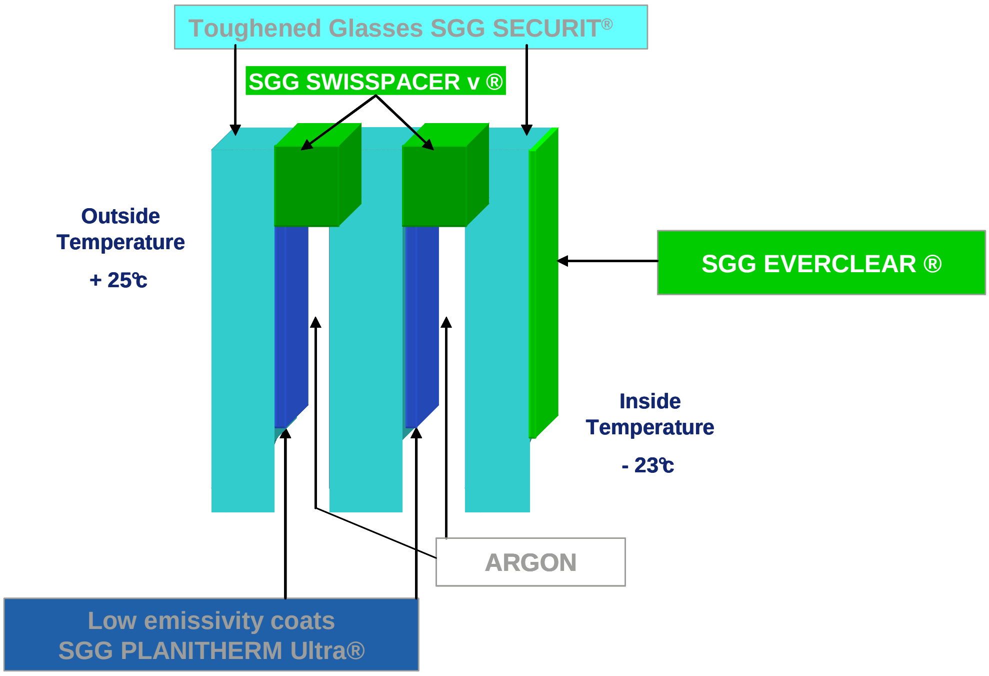
6.2.10.3 ANTI-SWEAT AND ANTI-FROST COATING

The main drawback of anti-sweat heaters (and of defrost heaters) is that they require electricity to operate. Moreover, the heat generated by heaters implies an increase of the cold demand.

In order to avoid the use of such heaters, Solvis Saint-Gobain (SGG) developed a coating, the SGG Everclear®, for glass front frozen cabinets either plug in or remote and either vertical or combined. This technology is a combination of:

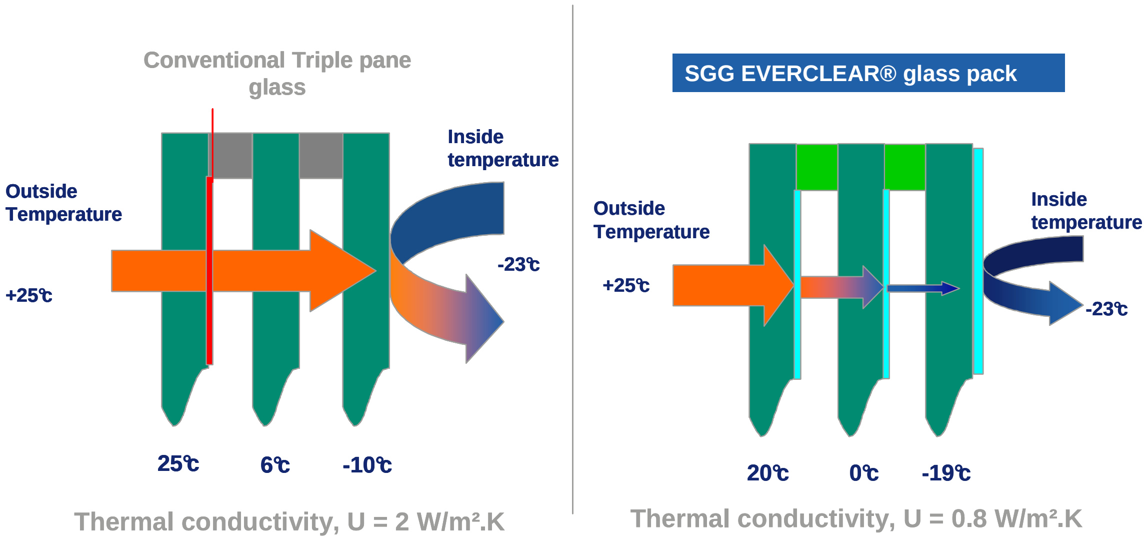
- A high performance triple pane glass composed by low emissivity coats (SGG Planitherm®) allowing reflecting infrared rays.
- Toughened pane glasses (SGG Securit®) increasing the strength.
- Spacers in glass fibres and composite (SGG Swisspacer®) reducing the electricity and thermal conductivity (instead of the conventional aluminium) and absorbing humidity.
- An anti-frost coating inside the frozen cabinet with a thickness of about 20 µm thickness made from solvent (SGG EVerclear®).

Figure 6-9: Cutaway of the SGG Everclear® glass pack



As shown in Figure 6-10, the lower thermal conductivity with the SGG Everclear® implies a lower temperature for products inside the cabinet and a better homogeneity.

Figure 6-10: Comparison of a conventional and the SGG Everclear triple pane glass



Besides of the electricity savings, the high light transmission of the SGG Everclear® glass pack allows a better visibility of products, and does not require any maintenance.

6.3. POTENTIAL APPLICATION TO THE 5 BASE CASES

The following table lists the best available technologies for components detailed in section 6.2. and their potential applications to the 5 base cases:

- Beverage Cooler
- Ice Cream Freezer (IHF6)
- Open Chilled Vertical Multi-deck (RCV2)
- Open Frozen Island (RHF4)
- Spiral Vending Machine

For each technology and for each base case, energy savings (tested or forecasted) and the increase of the product cost for the end-user are estimated. Energy savings are given in standard conditions unless otherwise specified.

Table 6-10: Effects of various BAT on the five Base cases

Best Available Technology	Beverage Cooler		Ice Cream Freezer (IHF6)		Open Chilled Vertical Multi-deck (RCV2)		Open Frozen Island (RHF4)		Spiral Vending Machine	
	Energy Savings, % of TEC	Additional Cost (€)	Energy Savings % of TEC	Additional Cost (€)	Energy Savings, % of TEC	Additional Cost (€)	Energy Savings, % of TEC	Additional Cost (€)	Energy Savings % of TEC	Additional Cost (€)
High Efficiency Compressor	4 %	8 €	4.8 %	8 €	*N/A*		*N/A*		-	-
Compressor Modulation	9 - 15 %	50 €	7 - 15 %	75 €	*N/A*		*N/A*		22 %	80-300 €
Electronic Expansion Valve (in real life conditions)	*N/A*		*N/A*		6 – 16 %	120-600 €	5 – 8.5 %	250-560 €	1.5 %	15 €
ECM Fan Motor (for evaporator)	7 %	25 €	*N/A*		5-11.4 %	90-170 €	1 – 5.9 %	135-220 €	-	-
High Efficiency Fan Blades (for evaporator)	*Included in ECM fan*		*Included in ECM fan*		*Included in ECM fan*		*Included in ECM fan*		*Included in ECM fan*	
ECM Fan Motor (for condenser)	6.5 %	25 €	5 %	25 €	*N/A*		*N/A*		-	-
High Efficiency Fan Blades (for condenser)	*Included in ECM fan*		*N/A*		*N/A*		*N/A*		*Included in ECM fan*	
High Efficiency Fluorescent Bulb	3.5 %	15 €	*N/A*		1.5 %	-	*N/A*		-	-
Secondary Air Curtain	*N/A*		*N/A*		8 - 11%	60-300 €	*N/A*		*N/A*	*N/A*
Increase of Heat Exchangers' Surface	15 %	10 €	4 %	12.5 €	-	-	-	-	*N/A*	
Thicker Insulation	6 %	50 €	-	-	*No Benefit*		*No Benefit*		-	-
Insulation Improvement	**-**		-	-	*No Benefit*		*No Benefit*		-	-
Vacuum Insulated Panels	-		-	-	-	-	-	-	5 - 9 %	20 - 30 €

Best Available Technology	Beverage Cooler		Ice Cream Freezer (IHF6)		Open Chilled Vertical Multi-deck (RCV2)		Open Frozen Island (RHF4)		Spiral Vending Machine	
	Energy Savings, % of TEC	Additional Cost (€)	Energy Savings % of TEC	Additional Cost (€)	Energy Savings, % of TEC	Additional Cost (€)	Energy Savings, % of TEC	Additional Cost (€)	Energy Savings % of TEC	Additional Cost (€)
Additional Glass Door or Glass Lid	*N/A*		*N/A*		50 - 59 %	1,500-2,000 €	30 - 43 %	1,500-3,000 €	*N/A*	
Night Curtain (12 hours/day)	*N/A*		*N/A*		24 - 29 %	105-250 €	12 - 24 %	350-450 €	*N/A*	
Liquid Suction Heat Exchanger	*N/A*		*N/A*		1 - 4.5 %	30 - 80 €	1 - 3 %	30 - 70 €	*N/A*	
Defrost Control	*N/A*		*N/A*		*N/A*		*Depends on ambient conditions*	-	*N/A*	
Anti-Sweat Heater Control	*N/A*		*N/A*		*N/A*		6 %	110-220 €	-	-
Anti-sweat heaters inside the glass	-	-	*N/A*		*N/A*		*N/A*		18 %	30 €

N/A: Not Applicable
'-' : qualitative data only

Results from Table 6-10 can be compared to what could be achieved in the domestic refrigeration sector.

Recent American data from 2005[18] shows that 15 % electricity savings can be obtained in domestic refrigerators/freezers (compared to the 2001 US standard) using a combination of options: high efficiency compressor, high efficiency fan motors, and defrost control. 25 % electricity saving could be achieved when adding a fourth option: the increase of the insulating panels.

An analysis of improvement options for domestic appliances enabling a better comparison of the improvement potentials between the commercial and the domestic sector products is provided in Table 6-11. A domestic refrigerator of category 1 could be compared to a beverage cooler (see section 6.1.2.1) and a chest freezer (category 9) to an ice cream freezer (see section 6.1.2.2).

Table 6-11: Effects of various BAT on two domestic base cases[19]

	Category 1		Category 9	
Best Available Technology	**Energy Savings, % of TEC**	**Additional cost for the consumer**	**Energy Savings, % of TEC**	**Additional cost for the consumer**
Vacuum Insulated Panels (for the door)	4 %	50 €	6 %	70 €
Vacuum Insulated Panels (for cabinet walls)	10 %	100 €	12 %	125 €
Thicker Insulation (+ 10 - 15 mm)	12 %	25 €	10 %	30 €
Increase of the Evaporator Surface (+ 10 - 20 %)	3 %	7.50 €	3 %	7.5 €
Increase of the Condenser Surface (+ 10 - 20 %)	1 %	5 €	1 %	5 €
High Efficiency Compressor	13 %	17.5 €	13 %	37.5 €
Compressor Modulation (VSD)	20 %	45 €	20 %	75 €
Use of phase-change materials integrated into the heat exchangers + Compressor on/off cycling optimisation	3 %	25 €	3 %	25 €

Most of BATs that could be implemented in domestic refrigerators or chest freezers were also identified for commercial refrigeration equipments. Nevertheless, manufacturers of domestic refrigerators and freezers already propose vacuum insulated panels (VIP) as an improvement option allowing a significant reduction of the electricity consumption. As the commercial

[18] *Analysis of Amended Energy Conservation Standards for Residential Refrigerators-Freezers*, US Department of Energy, October 2005.
http://www.eere.energy.gov/buildings/appliance_standards/pdfs/refrigerator_report_1.pdf

[19] Source: EuP preparatory study on Lot 13 “Domestic refrigerators and freezers”.

refrigeration sector is a "follower" rather than a "leader" in technological innovations, it is possible that VIP will be investigated as an option for beverage coolers or ice cream freezers in the future when its benefit and reliability will be proved in the domestic sector.

IMPROVEMENT OF THE SYSTEM FOR REMOTES CABINETS

The lot 12 study uses a product based approach suggested by the EuP Directive and does not perform an LCA of the complete system of refrigerated remote display cabinets. However, a cabinet cannot operate without the refrigeration system and needs the compressor and the condenser; hence some improvements to the whole system can also be brought by improving individual components. Thereby, for the compressor, new technologies such as high efficiency compressor (see 6.2.1.1) or compressor modulation (see 6.2.1.2) could be applied to the remote refrigeration system. Likewise, for the condenser fan, ECM fan as described in section 6.2.3.1, and high efficiency fan blades as detailed in section 6.2.3.2 are also relevant for the remote refrigeration system.

The assessment of the potential reduction of the Refrigeration Electricity Consumption (REC) will be further discussed during the task 7 in the system analysis (section 7.4).

6.4. STATE-OF-THE-ART IN APPLIED RESEARCH FOR COMPONENTS

6.4.1 IMPROVEMENT OF HEAT EXCHANGERS

- **Non-circular and Flattened Heat Exchangers**

Several projects have addressed the potential enhancement in the performance of heat exchangers through the use of small tube, oval, and flattened-tube designs. In addition to taking advantage of reduced air-side pressure losses over the coil and its associated reduction in fan power consumption, these tube designs have the potential of providing the same cooling capacity with a much smaller refrigerant charge. Manufacturing cost, tube integrity, and durability play a key role in enhanced coil tube design and marketability.

Figure 6-11: Flattened-tube heat exchangers[20]

[20] Source: ARTI (Air-Conditioning & Refrigeration Technology Institute), *Basic Research Driving the Future of America's Heating, Ventilation, Air Conditioning and Refrigeration Technologies.* (2004)

Heat Transfer Semi-Welded plates

API Heat Transfer, an American company specialised in heat exchangers, features plates that are welded using advanced laser welding techniques. The resulting plate pack has every other plate fully serviceable, while maintaining integrity of the welded plate pair. This is especially suitable for critical fluids and gases, such as Ammonia or caustic process chemicals where fluid loss is not acceptable. In the case of Ammonia refrigeration, the reduced volume results in significant savings. This type of heat exchangers is thus well appropriate for plug in or remote refrigerated display cabinets using Ammonia.

Figure 6-12: Cut away of semi-welded plates for heat exchangers

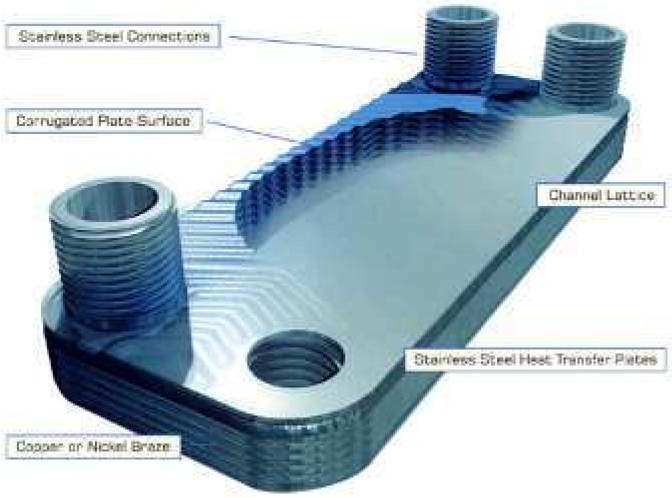
Brazed Plate Heat Exchangers

Brazed plate heat exchangers are carving a big chunk out of the heat transfer industry with their compact size and high efficiency design. Brazed plate units are up to six times smaller than alternative methods of heat exchange with the same capacity. Up to 150 corrugated stainless steel plates are brazed together with every second plate turned 180 degrees. This design creates two highly turbulent fluid channels that flow in opposite directions over a massive surface area. This results a significantly higher heat transfer coefficient with less required surface area and outstanding performance characteristics.

Figure 6-13: Flow channel diagram in a Brazed Plate Heat Exchanger[21]

[21] Source: Diversified Heat Transfer Inc.

Figure 6-14: Cutaway of a Brazed Plate Heat Exchanger[21]



Brazed plate heat exchangers are used in various applications of the commercial refrigeration sector, such as in liquid coolers, in supermarket systems, in ice making machines or in water chillers.

- **Aluminium Micro-Channels Heat Exchangers**

The micro-channel heat exchangers are being developed for advanced cooling and climate control applications. Bulk and surface micromachining techniques are used to fabricate the test devices. Each heat exchanger section consists of over 150 micro-channels etched in silicon substrates by either chemical etching or ion milling processes. The channels are 100 micrometers deep, 100 micrometers wide, and spaced 50 to 100 micrometers apart and connected with headers. Other heat exchangers have also been fabricated in copper and aluminium using machining and ion milling processes. Process steps involved are photolithographic patterning, deposition of etch masks, ion or chemical etching, electrostatic bonding of the silicon to glass, insulator deposition, lamination of silicon to metals, application of thin heater coatings with busbars, and installation of the inlet/outlet hardware and valves. Recent heat exchangers have the silicon laminated to copper substrates.

Table 6-12: Performance comparison of various heat exchangers[22]

Parameter	Shell and Tube Heat Exchanger	Compact Heat Exchanger	Micro-channel Heat Exchanger
Surface Area Per Unit Volume (m^2/m^3)	50 – 100	850 – 1500	> 1500
Heat Transfer coefficient ($W/m^2/K$) (liquid)	~ 5000 (tube side)	3000 – 7000	> 7000
Heat Transfer coefficient ($W/m^2/K$) (Gas)	20 – 100	50 – 300	400 – 2000
Approach Temperature (°C)	~ 20°C	~ 10°C	< 10°C
Flow Regime	Turbulent $\frac{\Delta P}{L} \propto V^{1.75}$	Turbulent $\frac{\Delta P}{L} \propto V^{1.75}$	Laminar $\frac{\Delta P}{L} \propto V$

This technology is already utilised in the automobile and aeronautics industries for many years. One manufacturer of remote refrigerated display cabinets has tested micro-channels evaporators for multi-deck, but it seems that this technology cannot be applied due to the impossibility to operate below for evaporating temperatures under 0°C.

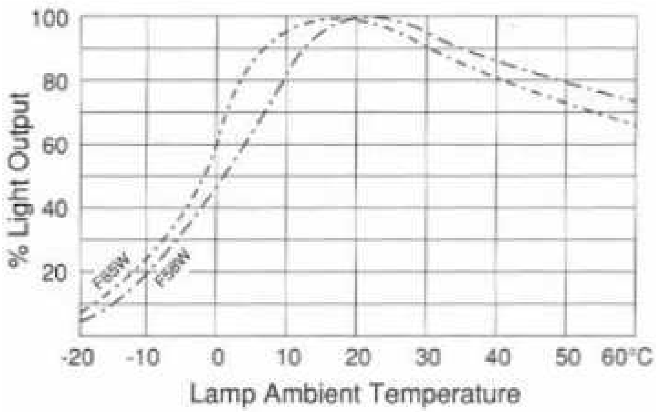
6.4.2 LED LIGHTING

Although fluorescent lamps provide superior energy efficiency in many lighting applications, their use in commercial refrigeration is not ideal. Indeed, for this application, they have several drawbacks:

- poor performance (with conventional ballast), due to heat losses (Joule effect)
- wasted light
- non uniform lighting
- sensitive to temperature (see Figure 6-15), due to the decrease in mercury vapour pressure

[22] Source: A. Lee Tonkovich, Velocys Inc., *Micro-channel Heat Exchanger: Applications and Limitations*.

Figure 6-15: Percentage of light output versus temperature for two typical T8[23]



Alternative lighting technologies may provide better solutions to settle those matters. One such technology is the Light-Emitting Diode (LED), which has been around since the 1960s, but they are just now reaching the levels of luminous output and power that open the door to more applications, such as commercial refrigeration.

The main benefits of LED are:

- LED light output and efficacy are not affected by cold temperature
- White LEDs provide luminous efficiency near levels produced fluorescent lamps under cold temperatures.

Even if typical available LEDs have luminous efficiency of 40 – 45 lumen/Watt, laboratory prototypes of white LEDs have demonstrated luminous efficiency of 65 – 100 lumens/Watt[24], up to twice the efficiency of T8 in cold appliances. The US Department of Energy's long-term research and development goal calls for white-light LEDs producing 160 lumens/Watt in cost-effective, market-ready systems by 2025[25].

- LEDs produce little radiant heat[26]
- LEDs have a long rated Life, up to 50,000 hours[27] compared to 35,000 hours for typical fluorescent lamps.
- LEDs offer multiple luminance distributions to provide more efficient lighting, directly onto products (see Figure 6-16).

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[23] Source: Sylvania Fluorescent Lamps Technical Manual

[24] Sources: LEDs Magazine 2006 – Narendran and al., 2005 – US Department of Energy, 2006

[25] Source: Navigant Consulting Inc, *Solid-State Lighting Research and Development Portfolio.* (March 2006)

[26] Source: Rensselaer Polytechnic Institute – Lighting Research Centre, *Energy-Efficient Lighting Alternative for Commercial Refrigeration*. (November 2006)

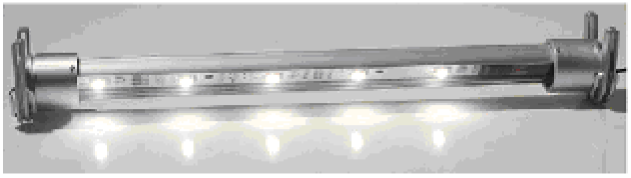
[27] Source: General Electric

Figure 6-16: Refrigerated display cases with fluorescent lighting vs. LEDs[28]

Nevertheless, LEDs are currently expensive but the prices continue to drop significantly, from approximately $250/kilo-lumen in 2004 to around $50/kilo-lumen in 2006. For comparison, fluorescent light source costs around $1/kilo-lumen[29].

Research studies are still ongoing for commercial refrigeration application, but a few companies[30] have recently (2005) commercialised LED lighting solutions for refrigerated display cabinets (Figure 6-17) and vending machines.

Figure 6-17: Nualight CryoLED™ designed for freezers



6.4.3 BUBBLE EXPANSION VALVE

In 2006, ASERCOM (Association of European Refrigeration Compressor and Controls Manufacturers) awarded an innovative expansion device[31], providing a

[28] Source: R. Raghavan and N. Narendran, *Refrigerated display case lighting with LEDs*. (2002)

[29] Source: US Department of Energy

[30] Among them figure the Irish manufacturer Nualight (http://www.nualight.com), Labcraft (http://www.labcraft.co.uk) in UK.

[31] Swedish Bubble Expansion Valve BXV(R)AB (http://www.bxv.se/)

better overall refrigerant heat transfer in the evaporator, and thus better system efficiency.

In small and medium sized refrigeration units, a dry expansion system controlled by a thermostatic valve is a common practice. This system requires that the vapour leaves the evaporator in a superheated state. Thus, part of the evaporator is used to attain a dry and superheated condition, and this deteriorates the overall heat transfer of the heat exchanger. This drawback is not found with flooded evaporators used in large industrial applications. In these types of systems, more liquid refrigerant is supplied to the evaporator than is evaporated in one pass. The surplus of liquid not evaporated at the outlet is re-circulated. These so called liquid overfeed of flooded systems show excellent refrigerant side behaviour of the evaporator because the entire surface is for boiling heat transfer.

This invention aims to extend the liquid overfeed system to small equipment as well. The expansion (throttling) is controlled by a valve, whose position is derived from the condition of no liquid level in the condenser, similar to the float valve system described above. The new device allows that liquid together with a small amount of gas leaves the condenser. This non condensed gas 'slip stream', which of course must be low, is measured and this acts as a signal for the expansion valve. The new device incorporates an ejector to get a good fluid recirculation in the evaporator loop, a tiny drum to separate flash gas and a unit to return oil to the compressor, heated by sub cooling of the liquid from the condenser. All these functions are integrated into a compact unit. In the control no electronics are found. Beside the advantage for the evaporation the new device allows for a good performance of the condenser (no liquid build up), which pressure can go along with the seasonal and daily air temperature (floating pressure).

The energy savings depend on the type of equipment, leading to a reduction of total electricity consumption between 10 % and 20 %. It is expected that the equipment using this bubble expansion valve can, in several applications, compete successfully with the traditional dry expansion equipment with superheating controls, in terms of electricity consumption. Nevertheless, further verifications are required to prove its reliability and its technical performances.

6.5. Alternative Refrigerants

The ban of HFC refrigerants in the automotive sector in 2010 conduced manufacturers of commercial refrigeration equipments to anticipate its potential extension to this sector. Therefore, other refrigerants with less environmental impacts are currently being experimented.

6.5.1 Carbon dioxide (R-744) CO_2

- **Properties**

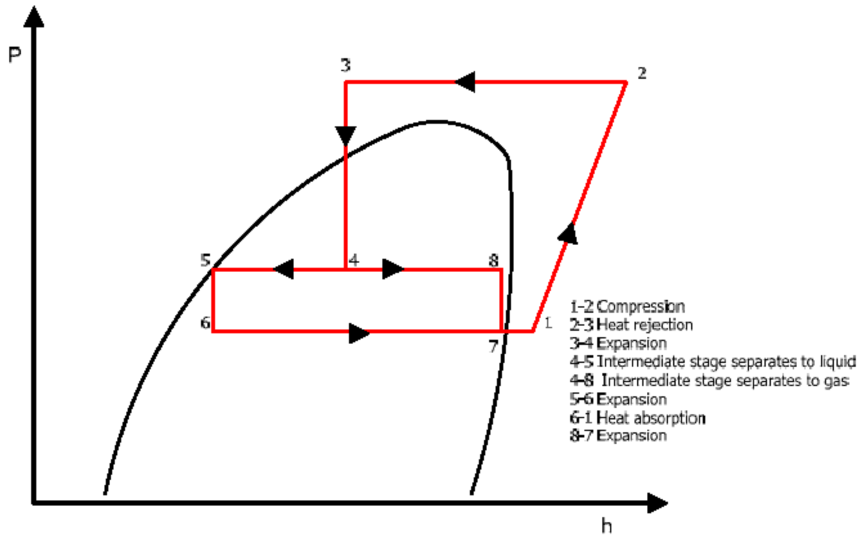
Although the use of carbon dioxide (CO_2) as a refrigerant declined drastically in the 1930s due to the appearance of CFCs and HCFCs, recently CO_2 as a natural and environmentally favourable refrigerant has gained more attention.

One of the solutions to mitigate ozone depletion and global warming is the use of natural refrigerants.

Compared to conventional refrigerants, the most remarkable property of CO_2 is the low critical temperature of 31.1ºC. Vapour compression systems with CO_2 operating at normal ambient temperatures work close to and even above the critical pressure of 73.8 bars. This leads to three distinct features of CO_2 systems:

- Heat is rejected at supercritical pressure in many situations. The system then uses a transcritical cycle that operates partly below and partly above the critical pressure (see Figure 6-18). High-side pressure in a transcritical system is determined by refrigerant charge and not by saturation pressure. The system design thus has to consider the need for controlling high-side pressure to ensure sufficient COP and capacity.

Figure 6-18: Pressure-Enthalpy chart of a transcritical CO_2 refrigeration system



- The pressure level in the system are quite high (around 30-100 bar). Components therefore have to be redesigned to fit the properties of CO_2. Due to smaller volumes of piping and components, the stored explosion energy in a CO_2 system is not much different from a conventional system. Moreover, the high pressure in the system requires a smaller displacement of the piston for a given capacity (i.e. compression ratio) which implies that CO_2 compressors have a higher volumetric cooling capacity than the ones running with HFC. It is estimated that an 80 - 90 %[32] smaller compressor displacement is needed when using carbon dioxide. Nevertheless, reducing the compressor size does not necessarily imply to a decrease of the electricity consumption.

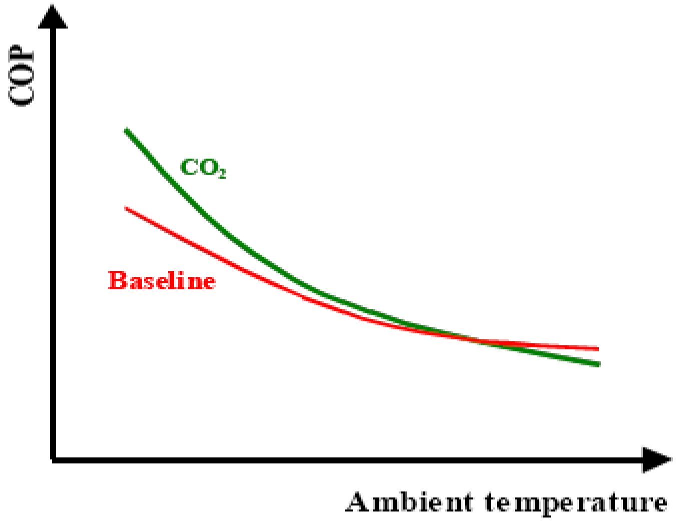
[32] Source: P. Neksa, J. Pettersen and G. Skaugen, *CO2 Refrigeration, Air Conditioning and Heat Pump Technology*. (August 2005)

- Large refrigerant temperatures glide during heat rejection. At supercritical or near-critical pressure, all or most of the heat transfer from the refrigerant takes place by cooling the compressed gas. The heat rejecting heat exchanger is then called gas-cooler instead of condenser.

Benefits and Drawbacks

Experience from testing and modelling of CO_2 refrigeration shows that the COP is more sensitive to ambient temperature variation than with conventional refrigerants. This typically leads to the situation, where the CO_2 system is superior at moderate and low ambient temperature and slightly inferior at very high temperature (Figure 6-19).

Figure 6-19: Principal COP behaviour of CO_2 system and conventional (base line) system at varying ambient temperature



Another drawback ok CO_2 is high pressures required in the refrigeration system for a good operation, due to transcritical operation of the process. This has consequences on the use of raw materials (more material is used) and therefore on the final cost of the appliance.

Main advantages of the use of CO_2 as refrigerant in commercial refrigeration equipments are:

- Largely available in nature
- Greenhouse Warming Potential: R404A = 3700 / CO_2 =1
- Very low direct cost respect to traditional HFC refrigerants
- High refrigerating capacity – Good efficiency
- Non toxic / Non flammable
- Small displacement for the compressor
- Small pipe dimensions

Applications

Several manufacturers of commercial refrigeration equipments already propose appliances running with CO_2. For instance, in the context of the Procool competition, Frigoglass has developed an open beverage cooler (Figure 6-20 and Table 6-13) and a double door beverage cooler running with CO_2.

Figure 6-20: Frigoglass beverage cooler Easy Reach CO_2

Table 6-13: Frigoglass CO_2 beverage cooler specifications

specifications for Easy Reach CO_2 Open cooling shelf (Beverage cooler)	
Net volume	493 L
Refrigerant	R744 (CO_2)
Quantity of Refrigerant	2300 g
Energy consumption for cooling	7.5 kWh/m² TDA, 24h
Climate class	3
Temperature class	M2
Acoustic pressure	58 dB(A)
Dimensions	1330x950x2122 mm
Net weight	348 kg

Moreover, Coca-Cola has launched a programme in 2004 aiming at phasing out HFCs in its appliances (both cans vending machines and beverage coolers). Thereby, some comparisons have been made between equipments running with R134a or carbon dioxide which are presented in Figure 6-21 and Figure 6-22. Further information related to the application of CO_2 in beverage coolers is provided in task 7 (section 7.3.2).

Presently, the CO_2 based refrigeration appliances show a performance comparable to the one that can be obtained with classic HFCs. The latest models developed with CO_2 are often very efficient however this is mainly due to the use of high efficiency components (e.g. fan blades, fan motors, optimum sizing of the heat exchangers…) rather than to the intrinsic use of carbon dioxide and results have to be carefully looked at when comparing cabinets.

Figure 6-21: Comparison of a one door beverage cooler using R134a or CO_2[33]

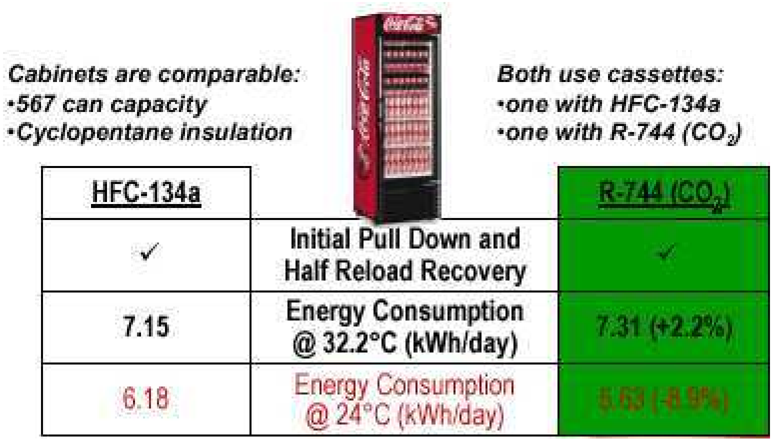
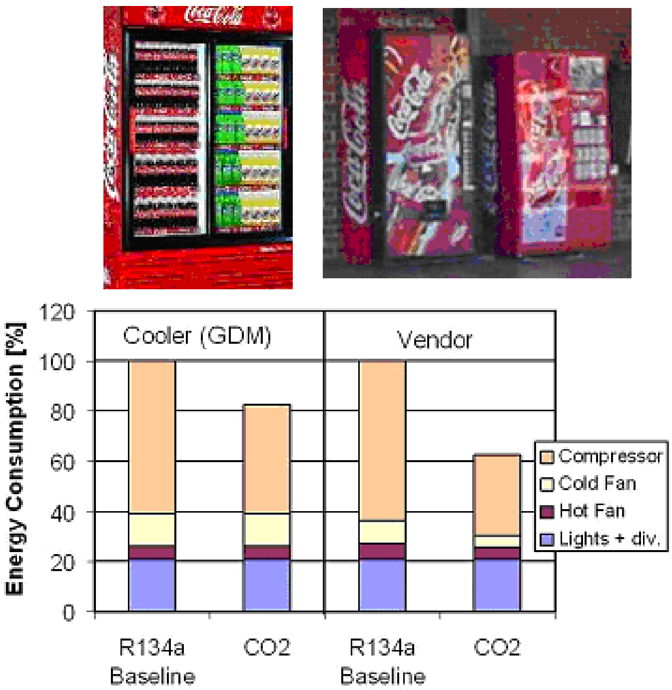


Figure 6-22: Comparison of two refrigeration equipments using R134a and CO_2[34]



Although energy reduction by using CO_2 instead of R134a in cold vending machines seems to be relevant for a certain range of temperatures, few are available on the EU-27 market. Likewise, for ice cream freezers only a small number of appliances using carbon dioxide as refrigerant are put on the market. More generally, CO_2 based refrigeration for ice cream freezer is still a technical challenge, specifically for single stage compressors.

[33] Source: Coca-Cola (March 2007)

[34] Source: Presentation of S. Gabola, Director European Public Affairs of Coca-Cola at the EurOps 2005 conference http://www.vending-europe.eu/documents/europs2005/Gabola.pdf

The industry is extensively working on the development of CO_2 components and solutions, however, larger systems are far more demanding than compact units (plug in). Regarding remote refrigerated display cabinets, several manufacturers already propose products running with CO_2. Moreover, some supermarkets, such as Tesco, announced their will to substitute their current refrigerants (HFCs) by carbon dioxide. CO_2 seems to be the suitable alternative refrigerant in case of the ban of HFCs for vertical multi-deck, open frozen islands, and other supermarkets display cabinets. The use of CO_2 in supermarkets will be further discussed in task 7 during the system analysis.

Components Modification

The switch to CO_2 based refrigeration is not straightforward and requires a complete change in the design of the system. Using CO_2 in commercial refrigeration equipments requires a modification of components, due to thermo-dynamic properties of this gas. The following paragraphs give an overview of those changes.

COMPRESSOR

Compression of CO_2 needs different characteristics compared to standard compressors. The design criteria at some points therefore differ much from the common compressors due to the different operating conditions compared to a compressor operating in a traditionally sub-critical process. Due to high pressures, the compressor needs a very solid construction (gasket, shaft, etc) using enhanced quality material.

All major compressor manufacturers have already developed CO_2 compressors; however, they are not yet available for mass production. A classic compressor typically costs around € 40~50 for a cabinet manufacturer compared to € 150 for a compressor running with CO_2.

HEAT EXCHANGERS

The good heat transfer characteristics of CO_2, even in the supercritical region, combined with the high volumetric capacity, can be utilised in developing compact and efficient heat exchangers.

Ordinary tube-in-fin designs can be made also for the high pressures required for CO_2. In general smaller tube diameters and longer circuits should be chosen for CO_2 due to the good heat transfer, the high volumetric capacity and the small temperature losses associated with a given pressure drop. If comparing an evaporator tube for CO_2 and one for R134a with equal capacity, length and temperature loss, both with a saturated outlet of 0℃, and assuming that the inner diameter of the R134a tube is 12 mm, it gives a corresponding diameter for the CO_2 tube of 5.7 mm[35]. With this reduction in tube diameter, comparable wall thickness with the one for R134a can be used, even though the pressure

[35] Source: M. Casini and M. Darin, *CO_2 Compressors and Equipment, Use and Availability*. (May 2003)

rating of the CO_2 tubes must be much higher. The weight of the CO_2 tube then becomes considerably lower than for the R134a tube.

VALVES

Several companies have developed valves for CO_2. Currently, three valves are concentrated on:

- Electronic modulating coil valve, electronically adjustable flow resistance, variable application. Depending on the system design, this valve may be used for any purpose, for example as a back-pressure valve in the system design most commonly adapted so far, using a low pressure receiver.
- Mechanical thermostatic valve, keeping the superheat at the outlet of the evaporator at a set value.
- Mechanical automatic valve, keeping the pressure at the valve outlet at a set value.

PIPING

Higher pressures in the refrigeration systems require the use of thicker copper pipes and thus the use of more raw materials. Typically, the copper pipes in a cabinet running with HFC are about 30 mm thick compared to 75 mm in CO_2 appliances.

Although enabling the use of low GWP refrigerant, CO_2 based refrigeration is still an expensive solution which provides comparable energy efficiencies depending of the ambient temperatures.

6.5.2 AMMONIA

Among "natural" refrigerants, Ammonia (R717) holds one of the first places as an alternative to R22 and R502. In 2004, production of Ammonia all over the world reaches 109 million tons [36], and only small portion of it (up to 5 %[37]) is used in the refrigeration equipment. Ammonia is an alternative refrigerant for new and existing refrigerating systems. Ammonia has a low boiling point (-33℃), an Ozone Depletion Potential (ODP) of zero when released to atmosphere, and a high latent heat of vaporisation (9 times greater than R-12). In addition, Ammonia in the atmosphere does not directly contribute to global warming.

However, it is highly toxic, and therefore cannot be used for refrigeration in direct applications. Its toxicity requires strict leakage avoidance measures and containment measures for maintenance and service companies. Safety is a critical issue when using Ammonia as a refrigerant. ASHRAE standard 32 gives

[36] Source: US Geological Survey, Mineral Commodity Summaries (January 2005)

[37] Source: http://www.allchemi.com/eng/refregerants/alternative.html

Ammonia a B2 safety rating which means it has lower flammability and higher toxicity while other halocarbon refrigerants such as R-22, R-407C, R-410A, and R-134a are not flammable and have lower toxicity.

Additional difficulties while refrigeration equipment production are caused by Ammonia high activity towards copper and copper alloys; that's why, pipelines, heat-exchangers and accessories are made of steel. Due to Ammonia's high toxicity and combustibility, welded connections are thoroughly controlled. Due to high conductivity of R717, creation of semi-hermetic and hermetic compressors is impeded.

Main advantages of using Ammonia are:

- Ammonia is environmentally compatible. It does not deplete the ozone layer and does not contribute to global warming.
- Ammonia has superior thermodynamic qualities, as result ammonia refrigeration systems use less electricity.
- Ammonia's recognisable smell is its greatest safety asset.
- Ammonia refrigeration systems cost 10 - 20 % less to install than systems using competitive industrial refrigerants[38].
- The cost of Ammonia itself is significantly less than competitive industrial refrigerants and generally lesser Ammonia is required to do the job compared to other industrial refrigerants.

Therefore, Ammonia can only be used as primary refrigerant in indirect refrigeration systems in supermarkets.

6.5.3 HYDRO-CARBON (HC)

6.5.3.1 PROPANE

- **Properties**

R290 is pure Propane, a hydrocarbon and efficient naturally occurring refrigerant with similar properties to R22. Presenting no ozone depletion potential and an extremely low global warming potential, Propane is a possible replacement for other refrigerants, which have high impact on environment, in small hermetic systems, like factory made commercial refrigerators and freezers. Furthermore it is a substance which is a part of petrol gases from natural sources. The refrigerant R290 has been in use in refrigeration plants in the past, and is still used in some industrial plants. Because of the availability of Propane all over the world, it has been discussed widely for CFC replacements. Propane R290 is a possible refrigerant for this application, with good energy efficiency, but special care has to be taken because of its flammability.

[38] Source: International Institute of Ammonia Refrigeration (IIAR)

In the domestic sector, HCs are taking a predominant share of the market and a successful switch from HCFC and HFC to HC has been observed. However, some limitations of the charge of hydrocarbons exist depending on the types of applications defined in the safety standard EN 378.

The refrigeration system efficiency will normally not imply a need for changing evaporator or condenser size, which means outer surface can be left the same as with R22 or R404A. Inside design of the evaporator possibly needs some modification, because the refrigerant volume flow is different, according to the compressor swept volume. To keep the refrigerant flow speed within the recommended range, it may be necessary to adopt the cross flow sections.

Special care has to be taken when designing the accumulator in the system. When using R22 or R134a the refrigerant is heavier than the oil used, while with R290 the refrigerant is less heavy. This could lead to oil accumulation if the accumulator is too large and has a flow path which does not guarantee emptying sufficiently during start-up phase of the system, and if the miscibility of Propane and oil is not full.

The main characteristics of Propane are:

- Boiling Point: -42℃
- Critical Temperature: 97℃
- Flammability Limits: 2.1 - 9.5 % in Air
- Compatibility: Non corrosive

Benefits and drawbacks

The following table (Table 6-14) summarises main advantages and disadvantages of Propane for its use in commercial refrigeration equipments.

Table 6-14: Benefits and drawbacks of Propane in commercial refrigeration

Advantages	Disadvantages
• Evaporators will have to be designed similar as for R22 or R404A • Good thermal properties ⇨ Good efficiency • No ODP – Low GWP • Low cost • Less noisy due to the reduction of pressure in the compressor	• Flammability (⇨ In supermarkets, only used in indirect systems) • Limited charge permitted • High installation cost in supermarkets due to safety fittings

Application

Several manufacturers of plug in refrigerated display cabinets and cold vending machines plan to develop appliances running with Propane. Some of them have already begun, e.g. AHT for a large deep freezer.

In 2000, for the Olympic Games held in Sidney, Unilever (in collaboration with Austria Haustechnik AG and the Danish Technological Institute) tested several ice cream freezers running either with R404A or with Propane[39]. Excluding the refrigerant, cabinets and their components were similar. Two measurement campaigns were carried out:

- A first campaign during the Olympic Games, inside the Olympic Park, during two months showed that appliances running with Propane consumed about 14 % less than the references R404A ice cream freezers (3 kWh/day compared to 3.5 kWh/day), with an inside temperature of -20℃ and an outside tempe rature of 25℃. However, the operating conditions were very d ifferent as usual (i.e. very high product throughput and high thermal loads).
- A second campaign, after the Olympic Games, in petrol stations, shops and supermarkets, presented the same trend with a reduction of electricity consumption of about 9 % (2.8 kWh/day compared to 3.1 kWh/day) with the same temperatures.

For remote refrigerated display cabinets, as explained previously, the use of Propane is only possible as a primary refrigerant in indirect systems.

6.5.3.2 ISOBUTANE

Isobutane (R600a) has a very small direct impact on the greenhouse effect compared with the HFC substances. The GWP value of these hydrocarbons is almost null, whereas HFC-134a accounts for a GWP value of 1300 (time frame = 100 years, as reference GWP for CO_2 = 1)[40].

Lubricant and other material compatibility issues are minimal, but flammable vapour safe charging and repair stations are needed and the refrigerator design must account for the flammable refrigerant. The main characteristics of Isobutane are:

- Boiling Point: -11.7℃
- Critical Temperature: 135℃
- Flammability Limits: 1.6 - 8.4 % in Air
- Compatibility: Non corrosive

Benefits and drawbacks of Isobutane in commercial refrigerators and freezers are the same as Propane. As presented in section 6.1.2 several plug in refrigerated display cabinets are currently running with Isobutane.

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[39] Source: F. Elefsen, J. Nyvad, A. Gerrard, R. Van Gerwen, *Field test of 75 R404A and R290 ice cream freezers in Australia.* (November 2003)
http://www.airah.org.au/downloads/2003-11-02.pdf

[40] Source: H. Pedersen, Danish Technological Energy Institute, *Substitutes for Potent Greenhouse Gases : 3 Application of HFC substances and possible alternatives. (*1999)

In Denmark, two development projects have been carried out which have been subsidised by the Danish Energy Agency. In these projects, a new compressor is used (developed by Danfoss Compressors), in which Isobutane is used as refrigerant and which can operate with variable speed. In one of the projects, the Coca-Cola Company, Vestfrost, and the Danish Technological Institute have developed a new type of bottle cooler, which through field test of 40 bottle coolers has shown an energy saving of approximately 40 % compared to conventional bottle coolers. The saving is mainly due to the possibility of adjusting the cooling performance to the cooling requirement and more efficient fans, etc. As Danfoss, most of manufacturers of compressors have already developed components running with Isobutane (and also with Propane). In the second project, test of 50 ice cream freezers with the same compressor showed a saving of approximately 50 %. This project was carried out in cooperation between Frisko Is (Unilever), Caravell A/S and the Danish Technological Institute. The saving is again due to adjustment of the cooling performance and cooling requirement as well as better glass lids. For the application of Isobutane in cold vending machines, some manufacturers estimate that it is less appropriate than Propane. Besides, for remote refrigerated display cabinets, as Isobutane has lower evaporation temperature and lower pressure ranges than Propane, the latter is more used in supermarkets, as primary refrigerant in indirect systems.

6.5.4 COMPARATIVE TABLE

The following table summarises main characteristics, benefits and drawbacks of the alternative refrigerants presented above. Moreover, their potential application to the three categories of commercial refrigeration equipments is discussed.

Table 6-15: Comparative table for different refrigerants

<table>
<tr><th>Refrigerant</th><th>Properties</th><th>Benefits</th><th>Drawbacks</th><th>Application</th></tr>
<tr><td>CO_2</td><td>• Boiling Point: -78℃
• Critical Temperature: 31℃
• Flammability Limits: non flammable
• Compatibility: risks of corrosion to ferrous steel with humidity</td><td>• Low ODP – Low GWP
• Very low direct cost respect to traditional refrigerants
• High efficiency
• Non toxic / Non flammable
• Small displacement for the compressor
• Small pipe dimensions</td><td>• Less efficient than HFCs at high ambient temperatures
• High pressures in the system
• High capital cost due to low mass production of CO_2 compressors</td><td>• For remotes, used in several supermarkets, and seems to be the better alternative to HFCs
• For plug ins, already used in small quantity
• For vending machines, already used in small quantity</td></tr>
<tr><td>Ammonia</td><td>• Boiling Point: -33℃
• Critical Temperature: 133℃
• Flammability Limits: 15 - 28 % in Air
• Compatibility: Corrosive to copper alloys</td><td>• Low ODP – Low GWP
• Good thermal properties ⇨ Good efficiency
• Ammonia's recognisable smell is its greatest safety asset.
• Low cost
• Refrigeration systems cost 10 - 20 % less.
• Low charge of refrigerant</td><td>• Toxicity ⇨ Leakages not permitted
• Flammability
• Limited charge permitted</td><td>• For remotes, only usable in indirect systems
• For plug ins, not suitable
• For vending machines, not suitable</td></tr>
<tr><td>Propane</td><td>• Boiling Point: -42℃
• Critical Temperature: 97℃
• Flammability Limits: 2.1 - 9.5 % in Air
• Compatibility: Non corrosive</td><td rowspan="2">• No ODP – Low GWP
• Evaporators will have to be designed similar as for R22 or R404A
• Good thermal properties ⇨ Good efficiency
• Low cost
• Less noisy due to the reduction of pressure in the compressor</td><td rowspan="2">• Flammability
• Limited charge permitted
• High installation cost in supermarkets due to safety fittings</td><td>• For remotes, only usable in indirect systems
• For plug ins, already used
• For vending machines, use planned</td></tr>
<tr><td>Isobutane</td><td>• Boiling Point: -12℃
• Critical Temperature: 135℃
• Flammability Limits: 1.6 - 8.4 % in Air
• Compatibility: Non corrosive</td><td>• For remotes, only usable in indirect systems
• For plug ins, already used
• For vending machines, use planned</td></tr>
</table>

6.6. ALTERNATIVE REFRIGERATION TECHNOLOGY

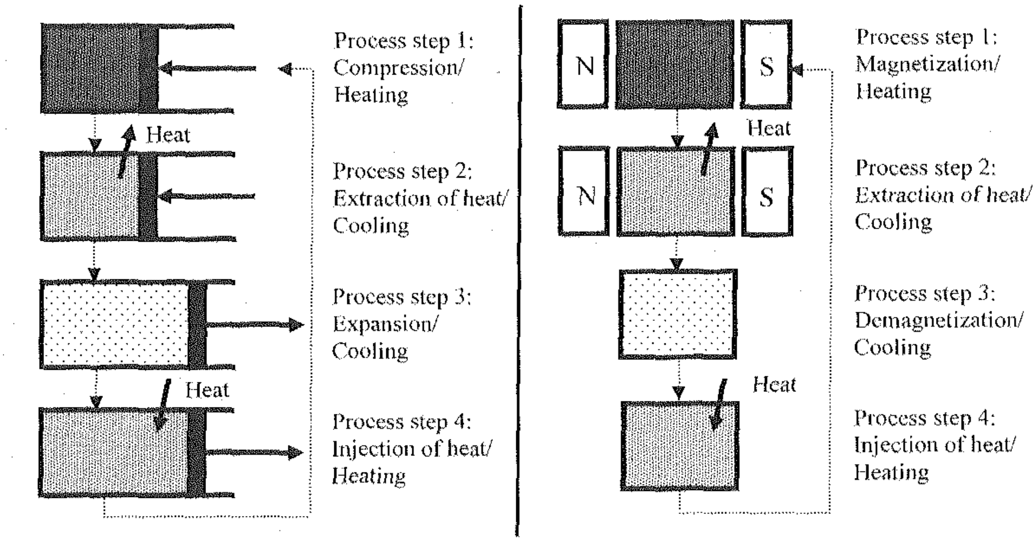
According to manufacturers of commercial refrigerators and freezers, the current vapour-compression technology is the most efficient one, and there is no relevant reason to change. However, other refrigeration technologies have been applied and tested to commercial refrigeration equipments. Some of them are described below.

6.6.1 MAGNETIC REFRIGERATION

Magnetic refrigeration is a cooling technology based on the magneto caloric effect. This technique can be used to attain extremely low temperatures (well below 1K), as well as the ranges used in common refrigerators, depending on the design of the system.

The magneto caloric effect is a magneto-thermodynamic phenomenon in which a reversible change in temperature of a suitable material is caused by exposing the material to a changing magnetic field. This is also known as adiabatic demagnetisation. Figure 6-23 compares the conventional refrigeration cycle with the magnetic cycle, by detailing the four processes.

Figure 6-23: Comparison of vapour-compression (on the left) and magnetic (on the right) refrigeration cycles[41]



The Camfridge programme from Cambridge University develops a revolutionary magnetic refrigeration technology. Magnetic refrigeration promises a number of benefits over the vapour compression technology, including a significant reduction in energy consumption, elimination of refrigerant leakage and ease of recycling.

[41] Source: P.W. Wolf, University of applied sciences of Western Switzerland, *An introduction to magnetic refrigeration*. (2007)

Very few laboratories are dedicated to research on magnetic refrigeration, but their number and the number of countries involved is slowly growing. The Danish Council for Strategic Research has recently donated 14 million DKK (~ 1.9 million Euros) to the Risø National Laboratory, at the Technical University of Denmark (DTU) – as well as Danfoss, Sintex and the DTU Department of Manufacturing Engineering and Management, for the development of a new prototype of magnetic refrigeration machine.

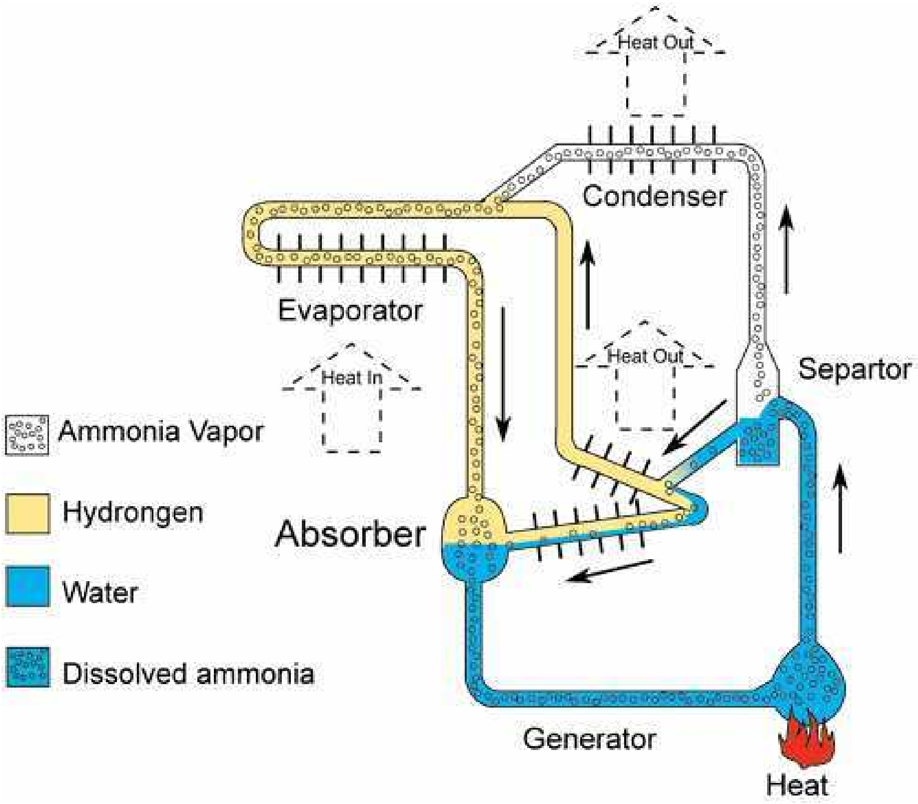
Magnetic refrigeration applications only exist as prototypes. Further research and development will aim at studying the possibility of a commercial application. Magnetic refrigeration is potentially very efficient, harmless to the environment and has low noise levels.

6.6.2 Absorption

Refrigeration plants using absorption principles have been around for many years with initial development taking place over 100 years ago. Although the majority of absorption cycles are based on water/lithium bromide cycle, any applications exist where Ammonia/water can be used, especially where lower temperatures are desirable.

With the application of heat at the generator, Ammonia vapour is driven from the solution. This hot vapour rises into the separator and a portion of the water condenses and flows by gravity into the absorber. The hot Ammonia vapour continues to rise into the condenser where it gives up its heat to the surrounding air and condenses into a liquid. The liquid Ammonia enters by gravity into the evaporator, where it is mixed with Hydrogen gas. Circulation of Hydrogen gas causes a reduction in pressure within the evaporator. The low pressure causes the Ammonia liquid to boil into a gas (evaporating) and absorbing heat in the process (refrigerating effect). The mixture of Hydrogen/Ammonia vapour that is carrying the absorbed heat is now drawn by gravity into-the absorber. Because the water from the separator has a greater affinity for Ammonia, it separates from the Hydrogen gas. The hydrogen gas being very light rises and returns to the generator to start the cycle again.

Figure 6-24: Operation of an absorption system for refrigeration



The following table (Table 6-16) summarises benefits and drawbacks of the absorption technology for refrigeration application.

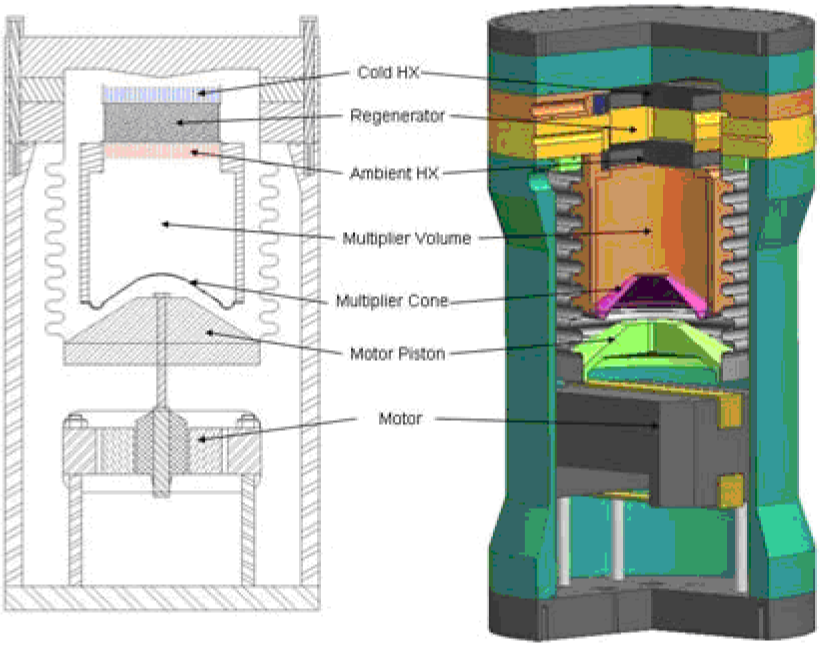
Table 6-16: Benefits and drawbacks of the absorption technology

Advantages	Disadvantages
• No moving parts • No vibration or noise on small systems • Small systems can operate without electricity using only heat • Can make use of waste heat	• Potential refrigerant leaks • Complicated and difficult to service and repair • Very bulky • High capital cost • More heat exchangers surfaces • Poor efficiency

6.6.3 THERMO-ACOUSTIC

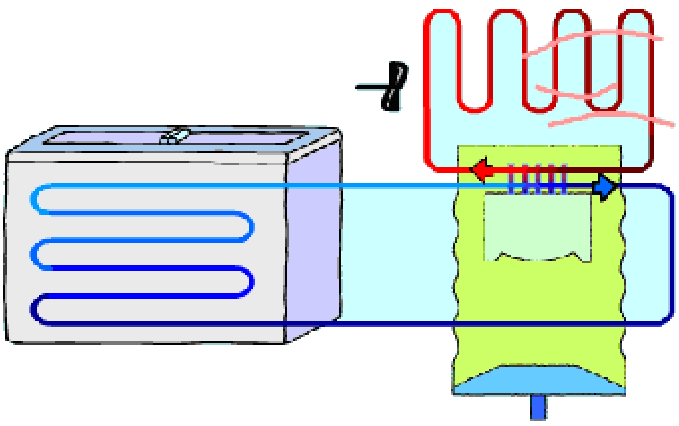
In 2002, Ben & Jerry's (ice-cream company) launched the development of a working thermo-acoustic refrigeration prototype, an environmentally friendly, alternative refrigeration technology that chills out to sound waves. The prototype (see Figure 6-25) developed by acousticians at The Pennsylvania State University, uses a 'Bellows Bounce' resonator.

Figure 6-25: Cut-away view of the thermo-acoustic chiller[42]



The freezer created uses a stack of small metal screens that can absorb and release more heat than air, and about 15 cents of helium. The sound waves compress and expand the gas while pushing it back and forth through the screens 100 times a second. Here, the freezer relies on another bit of physics that heat tends to move from a hot region to a cold one. As its pressure falls, the gas gets colder than the freezer, sucking warmth away from the ice cream. As the gas moves in the other direction, its pressure increases and it gets hotter than the air outside, so the heat becomes the freezer's exhaust and is blown outside.

Figure 6-26: Overview of an ice cream freezer using thermo-acoustic refrigeration



Main benefits of the thermo-acoustic refrigeration technology, compared to the conventional vapour-compression technology, are:

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[42] The abbreviation "HX" means "heat exchanger"

- Use of eco-friendly refrigerants, such as helium or argon
- Less components ⇨ less failures and maintenance
- No sliding seals, hence no lubrication
- Quiet operation
- Better control of the temperature

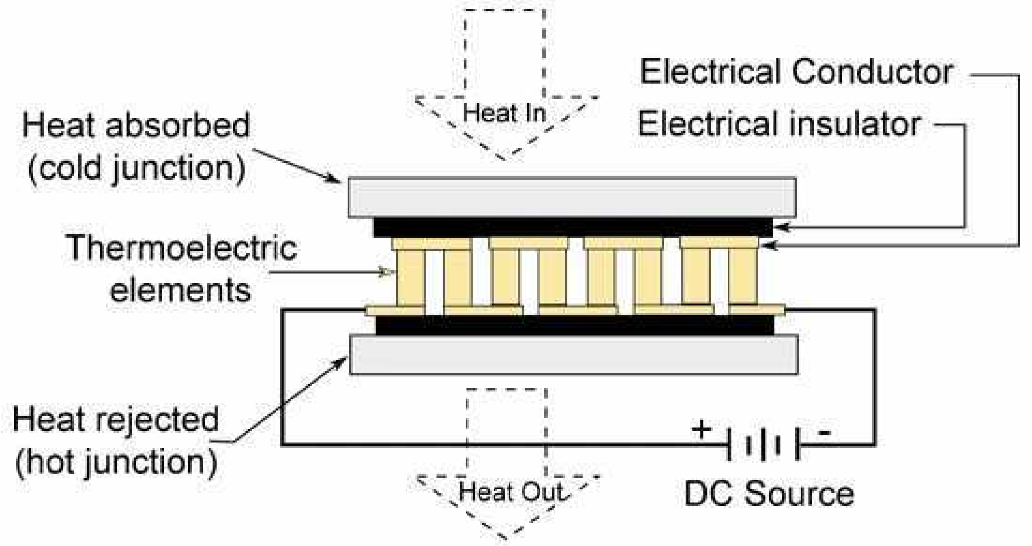
Nevertheless, the main drawback of this system is that, due to its size, the refrigeration unit is not integrated in the ice cream freezer. Moreover, the refrigeration unit is less efficient than in a vapour-compression system.

6.6.4 THERMO-ELECTRIC (PELTIER EFFECT)

Thermo-electric cooling, also called "the Peltier Effect," is a solid-state method of heat transfer through dissimilar semiconductor materials. Thermo-electric refrigeration replaces the three main working parts with:

- Cold junction
- Heat sink
- DC power source

Figure 6-27: Description of heat exchangers in thermo-electric refrigeration



The refrigerant in both liquid and vapour form is replaced by two dissimilar conductors. The cold junction (evaporator surface) becomes cold through absorption of energy by the electrons as they pass from one semiconductor to another, instead of energy absorption by the refrigerant as it changes from liquid to vapour. The compressor is replaced by a DC power source which pumps the electrons from one semiconductor to another. A heat sink replaces the conventional condenser fins, discharging the accumulated heat energy from the system. Thermo-electric modules are installed through mechanical clamping, epoxy bonding, and solder bonding. While the modules are strong in compression, they are weak in shear so excess loading should be avoided.

Advantages of thermo-electric refrigeration

- Compact size: Very little space is required by the cooling system. The thermoelectric module is the size of a matchbook.
- Lightweight
- Portable: Carries with one hand and is unaffected by motion or tilting.

Researchers are working on improving the efficiency of thermo-electric devices, reducing the cost of producing them and increasing their applications. Researchers are trying to maximise the electricity output for a given heat source by changing the materials used in construction. They are also studying materials so they can predict their reliability and long-term behaviour. Currently, this technology can only be used for very small refrigeration loads.

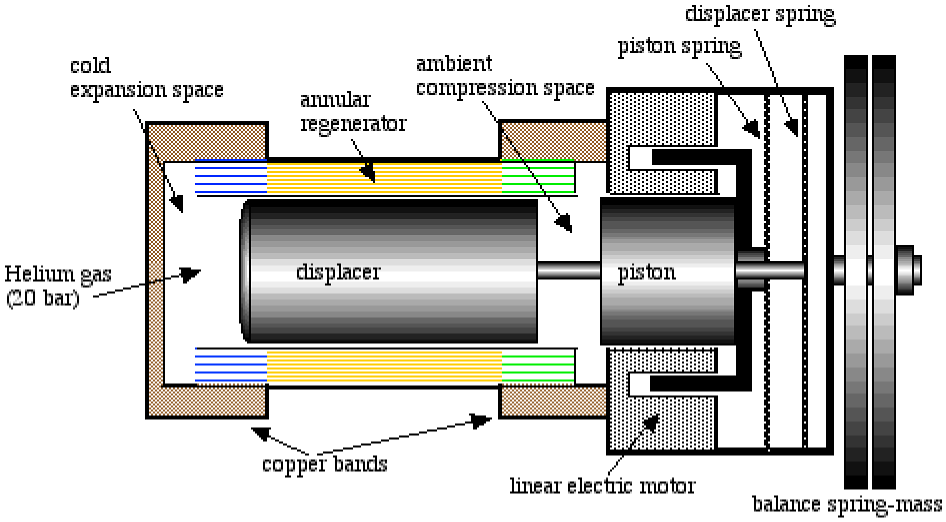
6.6.5 STIRLING CYCLE

The Stirling cycle cooler is a free piston, linear motor driven device. The internal running surfaces are supported by gas bearing, so no contact wear takes place. It is capable of continuous modulation and of maintaining high efficiencies down to very low lifts. This means that it adapts easily to cooling needs and keeps performing with high efficiency even at low demand. The Stirling cycle is fundamentally different to that used in conventional refrigerators (the Rankine cycle). Helium is employed as the working medium and no phase change occurs. The entire unit is hermetically sealed and dynamically balanced for low noise and vibration. Operational characteristics include the fact that the lift (capacity) is easily modulated since the piston amplitude is directly proportional to the drive voltage. Suffice it to say that in its ideal form, the Stirling cycle has the highest obtainable efficiency of any cooling device. Besides, the use of helium allows avoiding Ozone Depletion Potential (ODP) and Global Warming Potential (GWP).

The performance of the Stirling cycle cooling motor is on average about two to three times more efficient than the Rankine machine. According to Sunpower, the developers of Stirling cycle, the Stirling cycle compressor is a "drop-in" replacement for conventional compressors in domestic and commercial refrigerators, air conditioners and heat pumps.

Stirling has been used for particular niche applications (e.g. cryogenics) but recent developments, like the Free Piston Stirling Cooler has allowed testing as a viable alternative commercial refrigeration technology, especially for smaller sizes.

Figure 6-28: Diagram of the inside of a Free Piston Stirling Cooler[43]



6.6.6 COMPARATIVE TABLE

The following table (Table 6-17) summarises benefits and drawbacks of the alternative refrigeration technologies presented above. Moreover, their potential use in the three categories of commercial refrigeration equipments is assessed, based on manufacturers' predictions. However, time and investment due to research and development for these alternative refrigeration technologies are not taken into account.

[43] Source : Global Cooling

Table 6-17: Comparative table for alternative refrigeration technologies

Refrigeration Technology	Benefits	Drawbacks	Application in		
			Remote	Plug in	Vending Machine
Magnetic	• High efficiency • Ease of recycling • No refrigerant leakage • Low noise level	• Heavy coils and current to feed magnetic fields are required • Low degree of development • High capital cost	YES	?	YES
Absorption	• No moving parts • No vibration or noise on small systems • Small systems can operate without electricity using only heat • Can make use of waste heat	• Potential refrigerant leaks • Complicated and difficult to service and repair • Very bulky • High capital cost • More heat exchangers surfaces • Poor efficiency	YES	NO	NO
Thermo-acoustic	• Use of eco-friendly refrigerants, such as helium or argon • Less components ⇨ less failures and maintenance • No lubrication • Quiet operation • Better control of the temperature	• Poor efficiency • Bulky: remote refrigeration unit • High capital cost • Complex technology	NO	YES	YES
Thermo-electric	• Compact size • Lightweight • Portable	• Poor efficiency • High capital cost • Currently, only usable for small refrigeration load	NO	?	Only small
Stirling Cycle	• Safe • High efficiency • Use of eco-friendly refrigerants, such as helium or hydrogen	• Complex technology • High capital cost • Currently, only usable for small refrigeration load	Maybe in 10 years	YES	NO

6.7. State-of-the-art of Best Existing Product Technology Outside the EU

Some technologies applicable to various commercial refrigeration equipments are available outside the European Union, but currently not very much used in the EU.

6.7.1 MOTION SENSOR

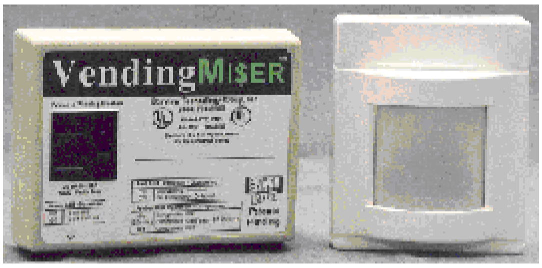
External motion detector devices, which switch off power to the vending machine when no movement is detected nearby, are also available and begin to be used mostly in the US. This device will also monitor room conditions and allow the machine to operate as required to keep the contents at a temperature not much different from that of regular operation.

In typical cold vending machine operations, power is cut off if the area has been vacant after 15 minutes and if the compressor is not running. When someone approaches the machine, the motion sensor senses the movement and power is resumed again. The internal thermostat of the cold vending machine will decide if the compressor needs to come on or not. The controller ensures that after the machine is re-powered, the compressor is allowed to run a complete cooling cycle before it is powered down again.

The motion sensor (and the associate controller) does not influence the internal thermostat or the compressor. Furthermore, this device also measures ambient room temperature. If the room is very warm, the motion sensor will more often send power to the machine than if the machine is in a cold room. The machine will switch on every 1-3 hours, even if nobody walks by the machine. Like this, the beverages stay cool, even if nobody walks by the vending machine for many hours.

Figure 6-29 presents the VendingMiser manufactured by the American company Bayview Technology.

Figure 6-29: VendingMiser containing a motion sensor and the miser itself



According to Bayview Technology, by the use of a motion sensor, up to 47 % reduction of the electricity consumption is possible. This figure was confirmed by a real test in the study *Vending Machine Engineering Evaluation and Test Report* carried out by "DPW Energy Management Office" in 2002.

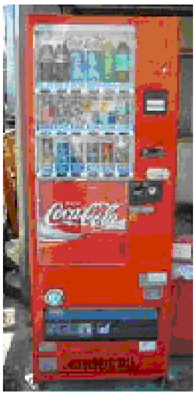
Nevertheless, this amount of reduction will probably not be achieved for a typical spiral vending machine as described in task 5 (section 5.1.4.1). Indeed, the test procedure is quite different following the EVA – EMP Idle state protocol, and the minimum internal temperature is + 3 °C for spirals vending machines detailed in the present study.

Thereby, tests conducted by some manufacturers of European cold vending machines show that frequent on/off (with motion sensor) are worse than continuous operating (without motion sensor), because of the high refrigeration load required when turning on the appliance to pull down the product temperature.

6.7.2 SPIRAL VENDING MACHINE WITH STIRLING REFRIGERATION

A Japanese manufacturer, Fuji, has developed a spiral vending machine for Coca-Cola, using the Stirling refrigeration presented in section 6.6.5.

Figure 6-30: Fuji spiral vending machine with Stirling refrigeration technology



6.8. CONCLUSIONS

As manufacturers of commercial refrigeration equipments are generally considered as “followers” than “leaders” in the use of new technologies, the trend is to use them when their feasibility and reliability have already been proved.

Most efforts are applied to high efficiency components, such as lights and compressors, and to a better control of the energy consumption, such as control for compressor and fan motors, and defrost control.

The summary Table 6-10 is based on the data collected among manufacturers and literature review of Best Available Technologies for commercial refrigeration equipments in the scope of the Lot 12 study. It gives for each BAT described in section 6.2. The potential energy savings and the additional cost for their possible application to the various base cases defined in task 5. These data will be part of the inputs required for the execution of task 7, for the identification and the impacts assessment of design options for each of the five base cases.

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7. IMPROVEMENT POTENTIAL

Task 7 consists of identifying the improvement options[1], quantifying the influence they have on environmental impacts, and monetising them in terms of Life Cycle Costs (LCC) for the consumer. Finally, one or more solutions of Best Available Technology (BAT) and with least life cycle cost (LLCC) are identified.

Key improvement options have been identified on the basis of current technology development and research as described in task 6. Such improvement options are further elaborated in the following sub-sections, listing their respective environmental improvement potential and associated costs when implemented in the base cases.

Task 5 showed that the indirect impacts due to the electricity consumption during use phase are the main environmental impacts. Therefore, suggested improvement options target the reduction of total electricity consumption (TEC). These options can be classified either as

- **Technical options** which aim at the reduction of the TEC through the use of high performance technology and increased efficiency of components (e.g. compressor and fan motor).

- **Design options** which aim at the reduction of the TEC through the reduction of cold spillage (e.g. use of night curtain, increased insulation thickness) and through the increase of heat transfers (e.g. increase of the size of the heat exchangers).

Direct impacts are also covered by task 7 by focusing on the reduction of the impacts due to the emissions of refrigerant liquid during use phase (leakages) and end-of-life, and on the use of alternative refrigerants with little or no climate impacts compared to the conventional ones.

The task 7 document is structured as follows:

- Section 7.1. presents the assessment of individual improvement options aiming at the reduction of indirect impacts by a product group for which an improvement option is applicable (base case). The impacts on the Bill of Materials (BOM), possible environmental improvements using a specific improvement option, LCC implications, and other possible constraints are presented.

- Section 7.2. analyses LLCC and BAT and the effects of the simultaneous implementation of several improvement options.

[1] **Please note that the terms "improvement option" and "option" are used interchangeably but they refer to the same thing i.e. a way to improve the energy/environment performance of a product under consideration**

- Section 7.3. presents some improvement options that lead to the reduction of the direct impacts.

- Section 7.4. discusses long-term targets (BNAT) and potential on the basis of changes of the total system.

7.1. IMPROVEMENT OPTIONS (INDIRECT IMPACTS REDUCTION)

This section presents the different improvement options applicable to each base case. Indeed, depending of the base case under consideration, some improvement options are more recommended than others (e.g. allow greater TEC reduction) or sometimes cannot even be implemented (see task 6, section 6.3). Table 7-1 lists the options for each base case and specifies if it is a technical option or a design option.

Table 7-1: List of the individual improvement options

IMPROVEMENT OPTIONS		Open Chilled Vertical Multi-deck (RCV2)	Open Frozen Island (RHF4)	Beverage Cooler	Ice Cream Freezer (IHF6)	Spiral Vending Machine
Technical Options	High Efficiency Compressor			X	X	
	Compressor Modulation (variable speed drive)			X	X	X
	ECM Fan Motor	X	X	X	X	
	High Efficiency Lights			X		
	Light Control			X		
	Liquid Suction Heat Exchanger	X	X			
	Anti-Sweat Heaters Control		X			X
Design Options	Optimisation of Air Curtain (double air curtain)	X				
	Increase of Heat Exchangers' Surface			X	X	
	Thicker Insulation			X		
	Vacuum Insulated Panels					X
	Addition of a Glass Door or Glass Lid	X	X			
	Night Curtain	X	X			
	Glass door insulated with argon instead of air			X		

For each of the improvement options, the modifications implied by their implementation in the base case are quantified by the change in bill of material (when available) and energy consumption. The improvement potential of a particular improvement option or a combination of improvement options is then evaluated using the EcoReport tool.

The cost effectiveness of an improvement option can be expressed in terms payback time in years, defined as a ratio between:

(Cost increase with reference to the base case) and (annual electricity consumption difference in kWh*electricity tariff)

The main assumptions used for the payback time calculations are summarised in Table 7-2.

Table 7-2: Assumptions used for the payback time calculation

	Base case RCV2	Base case RHF4	Base case beverage cooler	Base case ice-cream freezer	Base case spiral VM
Product lifetime (years)	9	9	8	8	8.5
Electricity consumption (KWh/day)	77.31	81.34	7.04	4.5	7.47
Electricity tariff (Euros/kWh)	0.097	0.097	0.105	0.105	0.105

7.1.1 IMPROVEMENT OPTIONS FOR BASE CASE RCV2

After a detailed analysis of available technologies in task 6, the improvement options selected to reduce the environmental impacts of a remote open vertical chilled multi deck aim at reducing the Total Electrical energy Consumption during use phase (TEC) of the cabinet, either through the use of more advanced components (e.g. ECM fans, electronic expansion valve), or through the reduction of the cooling capacity needed by reducing the heat losses (e.g. improved air curtain, glass door). Each of the improvement options applicable to the base case RCV2 are presented here with their relative impacts on the BOM and on the product cost compared to the base case.

Table 7-3 presents the summary of the selected improvement options of the base case RCV2 (remote open chilled vertical multi deck).

Table 7-3: Identified energy saving potentials for the base case RCV2

	Improvement option	TEC savings compared to base case RCV2	Increase of product cost compared to base case RCV2 (€)	Payback time (year)
Option 1	Night curtain	26.0 %	200	0.28
Option 2	Optimisation of the air curtain (double air curtain)	10.0 %	140	0.51
Option 3	ECM evaporator fans	8.2 %	135	0.60
Option 4	Liquid suction heat exchanger (LSHE)	2.5 %	60	0.88
Option 5	Addition of a glass door (alternative to night curtain)	52.0 %	1750	1.33

7.1.1.1 NIGHT CURTAIN (OPTION 1)

- Environmental impacts

The use of night curtain during stores' off hours (estimated to 12h a day) can reduce the TEC by 26 % on average.

It was assumed that an average night curtain is made of 6 kg of aluminium and the BOM of the base case was modified according to this assumption. The EcoReport results are presented in Annexe 7- 1 in terms of relative increase (positive percentages) and decrease of the impacts with reference to the base case RCV2 described in Task 5 (section 5.1.2.1). Despite higher impacts during the production phase, the overall lifetime impacts are reduced for all the environmental indicators. The emissions of polycyclic aromatic hydrocarbons (PAHs) to air present a smaller reduction compared to the modification of the other impacts due to the use of aluminium in the manufacturing of the night curtain which is an important source of PAHs in the production stage.

- Cost

The average costs associated to the installation and purchase of a night curtain is € 200 and the payback time is 0.28 year.

- Constraints

The application of night curtains is an option which is dependent of the end-user behaviour and of the store's environmental policy so even if the manufacturer provides this option its effectiveness and related energy saving are very much dependent on consumer behaviour.

7.1.1.2 OPTIMISATION OF THE AIR CURTAIN (OPTION 2)

As discussed in task 4 (Section 4.4), about 70 % of the refrigeration load in an open vertical display case is a result of the warm air entrainment across the air curtain.

- Environmental impacts

The use of a double air curtain in the base case RCV2 can reduce the total energy consumption of by 10 % on average. The increased BOM is due to the addition of fans. However, these changes in the production phase are negligible at the scale of the whole life cycle impacts and especially when compared to the impacts during the use phase (see task 5, section 5.2.1.1). For calculation of impacts, it was assumed that two additional standard fans were added to the base case for obtaining a double air curtain.

Annexe 7- 2 includes detailed EcoReport calculations for the relative increase (positive percentages) and decrease of the impacts for the base case RCV2 + option 1. It can be observed that despite higher impacts during the production phase, the impacts over whole lifetime are reduced for most of the environmental indicators.

- Cost

The implementation of an improved air curtain adds about € 140 to the baseline product cost of € 3440 with a payback time of 0.51 year.

- Constraints

As discussed in task 3 (section 3.4.1), consumer's focus on the product cost is the main barrier in implementing this option. Indeed, retailers' main criteria when purchasing refrigeration equipment is the product cost: they often choose the supplier proposing the lowest bid without considering long term saving potentials through reduced energy consumption.

7.1.1.3 ECM EVAPORATOR FANS (OPTION 3)

- Environmental impacts

On average, the use of ECM fans for the evaporator can reduce the TEC by 8.2 % (the savings are estimated to range between 8 and 8.5 % of the TEC). The BOM of an ECM motor is different from the one used in the base case. For a single 10 W output fan, the typical BOM for an ECM motor is as presented in Table 7-4.

In order to construct the BOM of the improved evaporation module for the base case RCV2, it was assumed that each of the four product cases presented in task 4 (section 4.1) was fitted with ECM fans. The associated modifications in the material composition were then calculated following the material distribution shown in Table 7-4 and assuming that the overall weight of a motor is proportionate to its power range. The modified product cases were then normalised to a 7 m² Total Display Area (as in task 5, section 5.1.2) and the material inventories of each product cases were aggregated to form the BOM of the base case as presented in Table 7-5.

Table 7-4: BOM of a typical 10 W ECM fan motor[2]

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Epoxy	188	2-TecPlastics	**14-Epoxy**
2	Iron	558	3-Ferro	**24-Ferrite**
3	LDPE	92	1-BlkPlastics	**1-LDPE**
4	PP	162	1-BlkPlastics	**4-PP**

[2] For a 24 W ECM motor it is assumed that the material distribution is the same than presented in Table7-4 however the overall weight is calculated to 1,536.6 g. This is assuming that a standard 24 W motor weights about 1,843.6 g and that the reduction in weight when comparing a 24 W standard motor to a 24 W ECM motor is the same than for 10 W motors (a standard 10 W motors weights 1,200 g and an ECM motor weights 1000 g)

Table 7-5: BOM of the improved evaporation module (with ECM fan) for the base case RCV2

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
42	**Evaporation module**			
43	Evaporator			
44	Copper suction line	16218.2	4-Non-ferro	**30-Cu tube/sheet**
45	Aluminium fins	10920.5	4-Non-ferro	**26-Al sheet/extrusion**
46	Evaporator fans			
47	Fan Blades	686.8	4-Non-ferro	**26-Al sheet/extrusion**
48	Fan grid	2720.8	3-Ferro	**25-Stainless 18/8 coil**
49	Evaporator fan motor			
50	epoxy	1058.0	2-TecPlastics	**14-Epoxy**
51	ferrite	3140.1	3-Ferro	**24-Ferrite**
52	LDPE	517.7	1-BlkPlastics	**1-LDPE**
53	PP	911.6	1-BlkPlastics	**4-PP**

Annexe 7- 3 gives the differences between the base case and the (base case + option 4) EcoReport results for each of the environmental indicators. EMC fans require the use of more materials and therefore the production phase has a higher contribution to the environmental impacts. However, on the whole lifecycle, most of the emissions and resource consumption are reduced.

- Cost

The switch from standard fans to ECM fans was estimated to about € 135 and the payback time is 0.60 year.

- Constraints

As it was already mentioned in task 3 (section 3.4.1), the focus on the product cost is the main barrier to the implementation of this option.

7.1.1.4 LIQUID SUCTION HEAT EXCHANGER (OPTION 4)

The use of a liquid suction heat exchanger to transfer energy between the cool gaseous refrigerant leaving the evaporator and the warm liquid refrigerant liquid leaving the condenser (remote component) can lead to improved performance in terms of energy efficiency.

- Environmental impacts

The implementation of a liquid suction heat exchanger in a remote open chilled vertical refrigerated display cabinet can reduce the TEC by 2.5 % on average.

It adds about 750 g of copper to the BOM (30-Cu Tube/sheet). However, this modification has a very low influence on the overall impact of the life cycle of the product as shown in Annexe 7- 4.

- Cost

The product cost increase associated to the liquid suction heat exchanger option applied to the base case RCV2 is estimated to € 60 and the payback time is 0.88 year.

- Constraints

The main barrier to the generalisation of this option in typical multi decks is the increase of the product cost.

7.1.1.5 ADDITION OF A GLASS DOOR (ALTERNATIVE TO NIGHT CURTAIN) (OPTION 5)

- Environmental impacts

Adding a glass door to the base case RCV2 limits the cold air spillage, allows a decrease of the temperature set point and reduces the TEC by 52 %.

It was estimated that the addition of a glass door on the multi deck implies the use of 150 kg of glass on average. However, the production phase impacts of glass being negligible, this estimate has not a strong impact on the overall lifetime environmental impacts as shown in Annexe 7- 5. The decrease in energy use reduces the environmental impacts by 10 to 50 % depending of the environmental indicator.

- Cost

The addition of a glass door adds about € 1750 to the baseline product cost and corresponds to a payback time of 1.33 year.

- Constraints

The major barrier to the implementation of this option is the importance of merchandising and the fact that retailers believe that the addition of a door, creates an obstacle between the shopper and the foodstuff and this will reduce his willingness to buy the displayed product. The increase in the product cost is also an obvious barrier.

7.1.1.6 COMPARISON OF THE IMPROVEMENT OPTIONS AND CONCLUSIONS

The different benefits and drawbacks for environmental impact of each individual option can be compared in terms of reduction with reference to the base case (100 %). Graphs in Figure 7-1 to Figure 7-3 show that the option leading to the highest reduction of all 17 environmental indicators is option 5, followed by option 1 and option 2 (with an exception for the emissions of PAHs , heavy metals and hazardous waste, where option 2 leads to higher emissions than option 3) (see Table 7-6). Not surprisingly, this ranking corresponds to the electricity saving potential of each option.

Figure 7-1: Comparison of the individual options[3] (resources and waste) for the base case RCV2

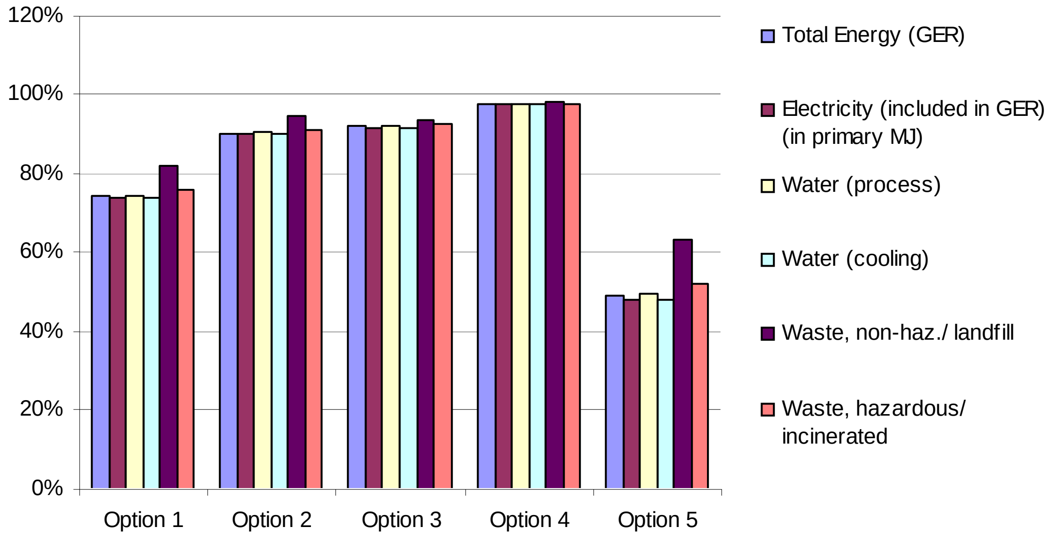
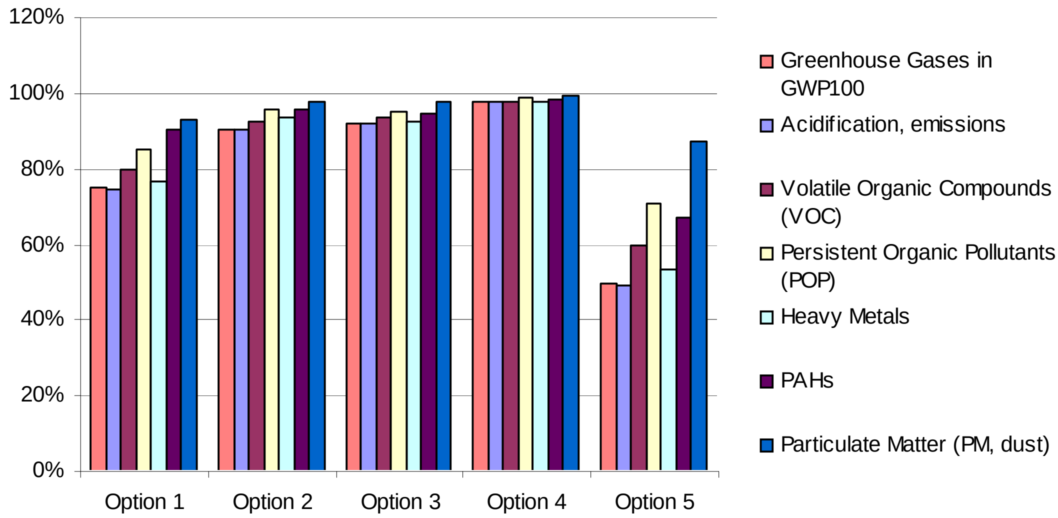


Figure 7-2: Comparison of the individual options (emissions to air) for the base case RCV2



[3] Option 1: night curtain; Option 2: optimisation of the air curtain; Option 3; ECM evaporator fans; Option 4: Liquid suction heat exchanger; Option 5: Addition of a glass door (alternative to night curtain)

Figure 7-3: Comparison of the individual options (emissions to water) for the base case RCV2

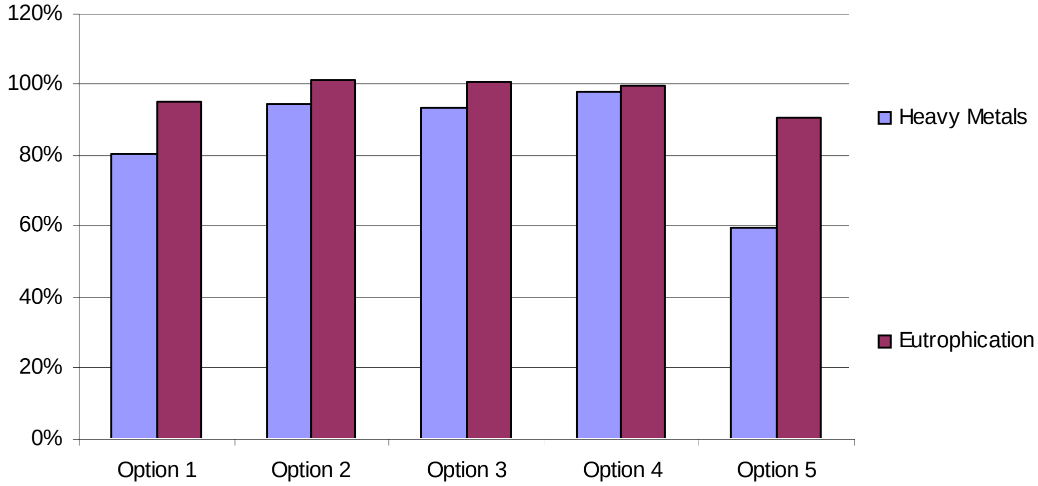


Table 7-6: Ranking of the 3 best performing improvement options of the base case RCV2 for each environmental impact indicator

Indicator	Best option for this indicator	Second best option for this indicator	Third best option for this indicator
Total Energy (GER)	Option 5	Option 1	Option 2
of which, electricity (in primary MJ)	Option 5	Option 1	Option 2
Water (process)	Option 5	Option 1	Option 2
Water (cooling)	Option 5	Option 1	Option 2
Waste, non-haz./ landfill	Option 5	Option 1	Option 3
Waste, hazardous/ incinerated	Option 5	Option 1	Option 2
Greenhouse Gases in GWP100	Option 5	Option 1	Option 2
Acidification, emissions	Option 5	Option 1	Option 2
Volatile Organic Compounds (VOC)	Option 5	Option 1	Option 2
Persistent Organic Pollutants (POP)	Option 5	Option 1	Option 2
Heavy Metals (air)	Option 5	Option 1	Option 3
PAHs	Option 5	Option 1	Option 3
Particulate Matter (PM, dust)	Option 5	Option 1	Option 2
Heavy Metals (water)	Option 5	Option 1	Option 2
Eutrophication	Option 5	Option 1	Option 2

7.1.2 IMPROVEMENT OPTIONS FOR BASE CASE RHF4

On the basis of the best available technologies listed in task 6, and data provided by the manufacturers of remote open frozen island (RHF4), Table 7-7 presents the selected improvement options of the base case RHF4. As for the RCV2, these options aim at reducing the TEC either by using more efficient components or by limiting the heat losses.

Table 7-7: Identified energy saving potential for the base case RHF4

	Improvement Option	TEC savings compared to base case RHF4	Increase of product cost compared to base case RHF4	Payback time (year)
Option 1	Night curtain	18.0 %	400	0.77
Option 2	Liquid Suction Heat Exchanger (LSHE)	2.0 %	50	0.87
Option 3	Anti-sweat heaters control	6.0 %	165	0.95
Option 4	ECM evaporator fans	3.5 %	225	2.23
Option 5	Addition of a glass lid (alternative to night curtain)	36.5 %	2250	2.40

7.1.2.1 NIGHT CURTAIN (OPTION 1)

- Environmental impacts

The use of a night curtain during stores' off hours (estimated to 12h a day) can lead to a reduction of the TEC by 18 % on average.

As for the night curtain in the case of base case RCV2, it was assumed to be made of 6 kg of aluminium. Based on this assumption, and on the modification of the energy consumption, the EcoReport results are presented in Annexe 7- 6 in terms of variations compared to the base case RHF4 described in task 5 (section 5.1.2.2). The overall lifetime impacts, expressed by the 17 environmental indicators, are reduced with the use of a night curtain. It is interesting to note that the decrease of the emissions of PAHs and particulate matter to air, as well as the eutrophication are smaller compared to the reductions of the other environmental impacts, due to the addition of aluminium.

- Cost

The average costs associated to the installation and purchase of a night curtain is € 400 and the payback time is 0.77 year.

- Constraints

The installation of a night curtain is already an option proposed by manufacturers. However, its use and related energy savings depend on the end-user behaviour.

7.1.2.2 LIQUID SUCTION HEAT EXCHANGER (OPTION 2)

The use of a liquid suction heat exchanger ensures that the refrigerant leaving the cabinet is sufficiently superheated and will not cause any damage. Indeed, if the refrigerant is still in a liquid phase when entering into the compressor, the latter could be harmed. Moreover, it also allows to improve the energy efficiency of the appliance.

- Environmental impacts

On average, the use of a liquid suction heat exchanger in the base case open frozen island can reduce the TEC by 2 %.

It adds 750 g of copper to the bill of materials (30-Cu Tube/sheet). As presented in Annexe 7- 7, all environmental impact indicators are lowered by using this option.

- Cost

The cost increase associated to the liquid suction heat exchanger option applied to the base case RHF4 is estimated to € 50 and the payback time is 0.87 year.

- Constraints

The main barrier for this improvement option is the increase of the product cost of the remote open frozen island.

7.1.2.3 ANTI-SWEAT HEATERS CONTROL (OPTION 3)

- Environmental impacts

On average, the use of an anti-sweat heaters control can reduce the TEC by 6 % with variations depending of ambient conditions in the supermarket.

It is assumed that this option modifies the BOM by adding 150 g of a controller board, which increases the total weight of the electronic parts of the RHF4 by 11.7 % as shown in Annexe 7- 8. The 17 environmental indicators of the entire life cycle are lower compared to the base case.

- Cost

The increase of the product cost by adding an anti-sweat heaters control is of € 165 and the payback time is 0.95 year.

- Constraints

The use of an anti-sweat heaters control is relevant if the ambient conditions of the supermarket change. Besides, as for the other options, the increase of the product cost could be a barrier.

7.1.2.4 ECM EVAPORATOR FANS (OPTION 4)

- Environmental impacts

On average, the use of ECM fans for the evaporator can reduce the TEC of the base case RHF4 by 3.5 % (the savings are estimated to range between 1 and 8 % of the TEC).

The BOM of a typical 10 W ECM fan motor is presented in Table 7-4. The application of this new BOM into the BOM of the new evaporation module is presented in Table 7-8.

Table 7-8: BOM of the improved evaporation module (with ECM fans) for the base case RHF4

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
25	**Evaporation module**			
26	Evaporator			
27	Copper suction line	19552.6	4-Non-ferro	**30-Cu tube/sheet**
28	Aluminium fins	24949.8	4-Non-ferro	**26-Al sheet/extrusion**
29	Insulation pipes	25.7	2-TecPlastics	**15-Rigid PUR**
30	Valves	272.8	4-Non-ferro	**28-Cu winding wire**
31	Plastics parts	38.5	1-BlkPlastics	
32	Evaporator fans			
33	Fan Blades	571.1	4-Non-ferro	**26-Al sheet/extrusion**
34	Fan grid	1847.6	3-Ferro	**25-Stainless 18/8 coil**
35	Evaporator fan motor			
36	PP	771.1	1-BlkPlastics	**4-PP**
37	LDPE	437.9	1-BlkPlastics	**1-LDPE**
38	Ferrite	2656.1	3-Ferro	**24-Ferrite**
39	Epoxy	894.9	2-TecPlastics	**14-Epoxy**
40	Evaporator tray			
41	Evaporator tray	18084.0	3-Ferro	**21-St sheet galv.**

The variations of the 17 environmental indicators are given in Annexe 7- 9. Only the eutrophication increase with the use of ECM fans compared to the base case, because of the use of more plastics.

- Cost

The increase of the product cost is estimated to be about € 225 and the payback time is 2.23 years.

- Constraints

The increase cost is the main barrier to the implementation of this improvement option.

7.1.2.5 ADDITION OF A GLASS LID (ALTERNATIVE TO NIGHT CURTAIN) (OPTION 5)

- Environmental impacts

With the addition of a glass lid to the base case RHF4, less warm air from the surroundings can enter into the cabinet. Therefore, the reduction of the TEC could be, about 36.50 % on average.

As the Total Display Area (TDA) of the base case RHF4 is the same as for the base RCV2 (7 m²) and it was assumed that the use of a glass modified the

BOM by additional 150 kg of glass. It implies an increase of the weight of the miscellaneous module of 77.2 % as presented in Annexe 7- 10. Most of the 17 environmental indicators present a reduction between 15 and 30 %.

- Cost

The addition of a glass lid leads to an increase of the product cost of € 2250 and the payback time is 2.4 years.

- Constraints

As for the addition of a glass door to a remote RCV2, the major barrier is the merchandising issue. This option could be seen as a physical obstacle between the shopper and the frozen goods. Moreover, the important increase of the product cost could also be a constraint.

7.1.2.6 COMPARISON OF THE IMPROVEMENT OPTIONS AND CONCLUSIONS

Similar to the base case RCV2, for each of the 15 environmental impact indicator (2 other environmental indicators are negligible for the five base cases and for all improvement options: ozone depletion and emissions to water of persistent organic pollutants), a comparison can be made between each individual option and the base case as reference (100 %). Graphs in Figure 7-4 to Figure 7-6 show that option 5 (addition of a glass lid) is the one allowing the highest reductions, following by option 1 (night curtain) and option 3 (anti-sweat heaters). This ranking (see Table 7-9) corresponds to the energy saving potential of each option.

Figure 7-4: Comparison of the individual options (resources and waste) for the base case RHF4

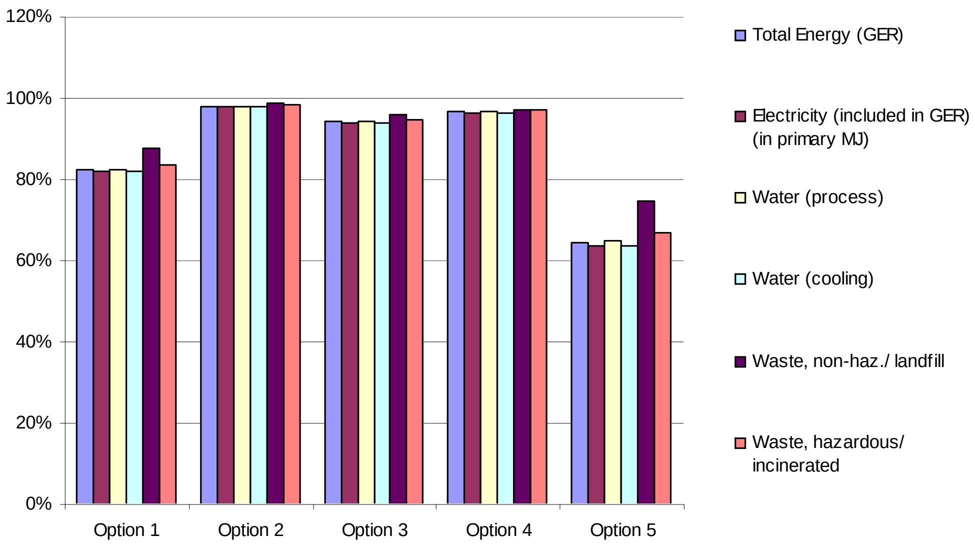


Figure 7-5: Comparison of the individual options (emissions to air) for the base case RHF4

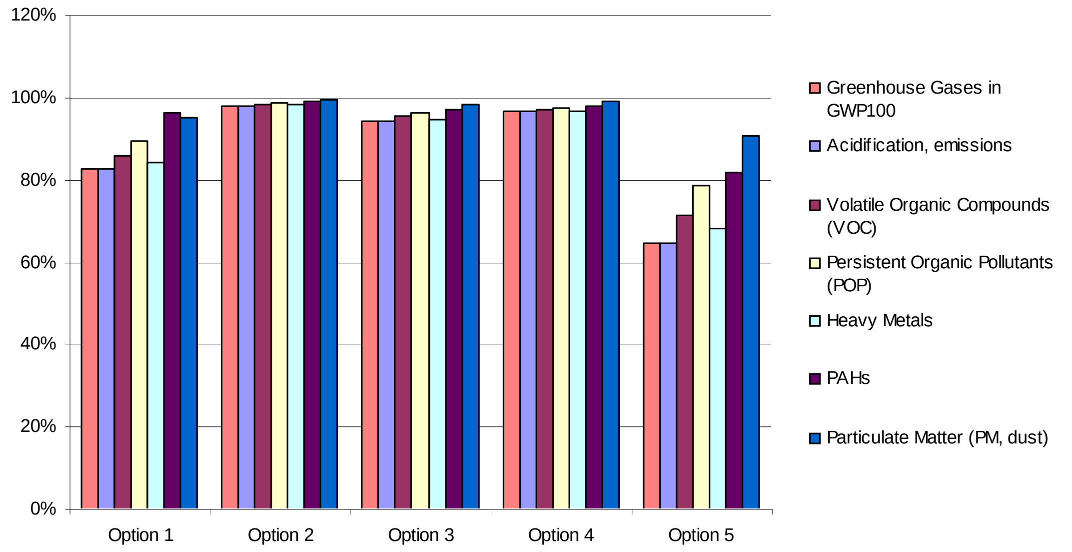


Figure 7-6: Comparison of the individual options (emissions to water) for the base case RHF4

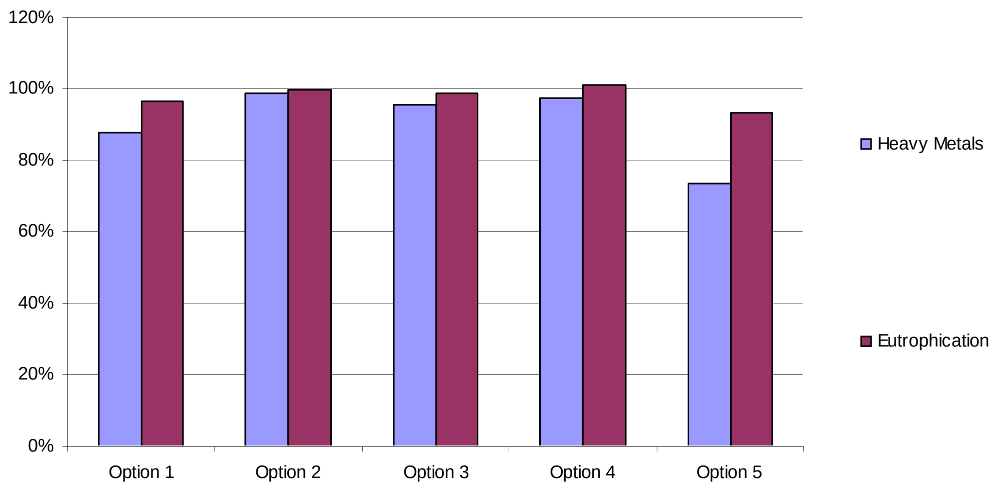


Table 7-9: Ranking of the 3 best performing improvement options of the base case RHF4 for each environmental impact indicator

Indicator	Best option for this indicator	Second best option for this indicator	Third best option for this indicator
Total Energy (GER)	Option 5	Option 1	Option 3
of which, electricity (in primary MJ)	Option 5	Option 1	Option 3
Water (process)	Option 5	Option 1	Option 3
Water (cooling)	Option 5	Option 1	Option 3
Waste, non-haz./ landfill	Option 5	Option 1	Option 3
Waste, hazardous/ incinerated	Option 5	Option 1	Option 3
Greenhouse Gases in GWP100	Option 5	Option 1	Option 3
Acidification, emissions	Option 5	Option 1	Option 3
Volatile Organic Compounds (VOC)	Option 5	Option 1	Option 3
Persistent Organic Pollutants (POP)	Option 5	Option 1	Option 3
Heavy Metals (air)	Option 5	Option 1	Option 3
PAHs	Option 5	Option 1	Option 3
Particulate Matter (PM, dust)	Option 5	Option 1	Option 3
Heavy Metals (water)	Option 5	Option 1	Option 3
Eutrophication	Option 5	Option 1	Option 3

7.1.3 IMPROVEMENT OPTIONS FOR BASE CASE BEVERAGE COOLER

There is a wide range of opportunities for improving energy efficiency of beverage coolers. However, as seen in task 3 (section 3.4), there exists also some barriers in their implementation. Following sub-sections present some options with energy saving potential for beverage coolers, their environmental/economical impacts over the product lifetime, and the limitations in their implementation.

Table 7-10 presents the summary of the main improvement options applicable to the base case beverage cooler ranked by increasing payback time.

Table 7-10: Identified energy savings potential for the base case beverage cooler

	Improvement option	TEC savings compared to base case Beverage cooler	Increase of product cost compared to base case Beverage cooler (€)	Payback time (year)
Option 1	Increasing heat exchangers' surface	15.0 %	10	0.25
Option 2	High efficiency compressor	4.0 %	8	0.74
Option 3	Glass door insulated with argon instead of air	10.0 %	20	0.74
Option 4	ECM fans at evaporator and condenser	13.5 %	50	1.37
Option 5	Light control (switched off 6 hours / day)	7.5 %	30	1.48
Option 6	Compressor modulation (variable speed drive)	12.0 %	50	1.54
Option 7	High efficiency lights[4]	3.5 %	15	1.59
Option 8	Increase of the insulation thickness (+ 25 mm)	6 %	50	3.09

7.1.3.1 Increasing heat exchangers' surface (option 1)

The increase of the evaporator and condenser's surface can potentially reduce the energy consumption of the beverage cooler by increasing the heat transfer rate. The evaporating temperature will increase and the condensing temperature will be reduced leading to a lower pressure ratio at the compressor and thus higher COP.

The increase of the heat exchanger's surface can be achieved either by increasing the core dimensions or through the increase in the fin density as explained in task 6 (section 6.2.6).

- Environmental impacts

On average, the increase of the heat exchangers' surface at the evaporator and at the condenser can reduce the TEC by 15 %. The environmental impacts on the BOM were assumed to be negligible.

If changes in the material composition are estimated to be negligible, and assuming a reduction of 15 % in the energy consumption during use phase, the changes between the base case and the base case + option 1 in the 17 environmental indicators expressed in percentage are as presented in Annexe 7- 11.

[4] Electronic ballasts and T8 fluorescent tubes

- Cost

The switch from a baseline evaporator and condenser to heat exchangers of increased surface adds about € 10 to the price of the appliance and the payback time is 0.25 year.

- Constraints

The first cost is not greatly affected by this improvement option; however, the restricted amount of space available in the cabinet case limits the increase in the size of the heat exchangers. Further, even if this option provides a considerable reduction of the energy, the energy costs associated with the use of a beverage cooler are small compared to the average sales revenues. The energy costs are about € 270 annually compared to beverage sales average revenue of € 6000 and this reduces the importance of energy efficiency as a major concern.

7.1.3.2 HIGH EFFICIENCY COMPRESSOR (OPTION 2)

- Environmental impacts

Typical beverage coolers are equipped with standard efficiency hermetic reciprocating compressors with a motor of 70 % efficiency. These typical compressors could be replaced by higher efficiency compressors. Higher efficiency compressors use higher-efficiency motor and display features such as lower suction gas pressure losses and lower mechanical losses.

The reduction of electricity consumption reached through the use of high efficiency compressors is estimated to range between 3 and 5 % of the TEC. An average value of 4 % is used for the determination of the improvement potential in terms of environmental impacts.

It is assumed that higher efficiency compressors do not differ greatly in terms of material composition compared to standard compressors and thus the impacts during production phase are not considered.

The EcoReport results of the implementation of this option are presented in Annexe 7- 12 which shows the relative increase (positive percentage) and decrease of the environmental impacts with reference to the base case analysed in task 5 (section 5.1.2.1).

- Cost

The cost associated to the retrofit of a standard compressor by a high efficiency compressor is estimated to € 8 and the payback time is 0.74 year.

- Constraints

Most beverage merchandisers are owned by food and beverages companies who do not pay the electricity bills associated with the operation of the bottle coolers. This implies that there is no incentive for the purchaser of the beverage cooler to pay even slightly higher price for more efficiency.

7.1.3.3 IMPROVEMENT OF THE DOOR INSULATION (OPTION 3)

A typical beverage cooler is fitted with a double panel glass door. The space between the panels is filled with air to provide insulation. The replacement of this air by an alternative gas could provide better insulation.

- Environmental impacts

The replacement of air with argon which has higher insulation properties can reduce the heat losses through convection and conduction at the door. The heat losses through the door represent 30 – 40 % of the total cold spillage and argon filled glass panels could reduce them of about 5 %. It was estimated that this reduction in the heat losses leads to a TEC reduction of an average of 10 %.

The environmental impacts measured through the use of the EcoReport tool are shown in Annexe 7- 13 which presents the results expressed in percentages with reference to the base case studied in task 5 (section 5.1.2.1).

- Cost

The replacement of air by Argon implies an increase of the product cost of € 20 and the payback time is 0.74 year.

- Constraints

As for option 2, the split incentive is a major barrier to the implementation of this option.

7.1.3.4 EVAPORATOR AND CONDENSER ECM FAN (OPTION 4)

Standard evaporator and condenser fan motors are inexpensive and not very efficient single-phase shaded pole motors. The efficiency of ECMs (Electronically Commutated Motors) is significantly higher.

ECMs are motors for which the speed can be programmed to offer best performance. Additionally, the fan speed can be switched between two speeds meaning it may operate at a lower speed during the night.

- Environmental impacts

Replacement of standard single-phase motors of the evaporator and condenser fan by ECM can potentially save between 13 to 14 % of the total electricity consumption per year. An average value of 13.5 % was chosen for calculation of the impacts.

If we consider the material composition of these two motors as presented in Table 7-4, the BOM of the product is modified, however, the impacts of the production phase being negligible these changes in the BOM do not greatly affect the environmental impacts over the whole lifetime of the beverage cooler. Changes in the material composition and modifications on the environmental impacts are summarised in Annexe 7- 4.

- Cost

The cost associated to the retrofit of standard fan motors at the evaporator and condenser by ECMs is estimated to € 50 and the payback time is 1.37 years.

- Constraints

As for option 2, the split incentive is the main barrier to the implementation of option 5.

7.1.3.5 LIGHT CONTROL (OPTION 5)

- Environmental impacts

The lights of a typical beverage cooler remain switched on 24 hours a day. The use of a timer allows the lighting system to switch off during closing hours (estimated to 6 hours per day). Moreover, reducing the energy consumption of the lighting in beverage coolers also reduces the compressor power by decreasing the internal heat load. On average, it is estimated that lighting management could reduce the total energy consumption by about 7.5 %.

The impacts on the BOM, and thus on the production phase are assumed to be negligible (Annexe 7- 15). Only the use phase is affected by this option.

- Cost

The cost associated to the implementation of a light management system is estimated to € 30 and the payback time is 1.48 years.

- Constraints

As for the previous options, the distinction between the equipment purchaser and the end-user implies that there is no incentive for the purchaser of the appliance to pay even slightly higher price for more efficient design.

7.1.3.6 COMPRESSOR MODULATION (VARIABLE SPEED DRIVE) (OPTION 6)

- Environmental impacts

The use of a variable speed drive compressor in a beverage cooler could reduce the TEC by 12 % on average. The impacts on the BOM are assumed to be negligible (Annexe 7- 16). The changes in the environmental impacts are only due to the reduction of the electricity consumption during use phase.

- Cost

The cost associated to the implementation of a compressor modulation system is estimated to € 50 and the payback time is 1.54 years.

- Constraints

As for option 2, the fact that the end-user is not the purchaser of the beverage cooler reduces the incentive for the beverage cooler owner to select an appliance with a higher first cost.

7.1.3.7 HIGH EFFICIENCY LIGHTS (OPTION 7)

The light output power is important for cabinets meant for merchandising and therefore the reductions in electricity usage can be achieved through the use of high-efficiency lamps and ballasts rather than by reducing the luminosity.

- Environmental impacts

The standard lighting system of a beverage cooler has T12 fluorescent tubes (one of 36 W for use in the external canopy and one of 20 W for the internal lighting) and standard magnetic ballasts.

The efficiency of this standard lighting system can be improved by using T8 fluorescent tubes and an electronic ballast. On average, this option could reduce the TEC of the beverage cooler by 3.5 %. This reduction in energy use leads to the reduction of most of the environmental impacts as presented in Annexe 7- 17.

As for the impacts related to the production phase, T8 and T12 lamps are assumed to use the same raw materials. The difference in the material composition of the ballasts is not taken into account in the scope of lot 12, as they are already cover by a European directive (see task 4 for details, section 4.1.2.2) and the material composition remains similar to the base case.

- Cost

The cost increase associated to the replacement of the standard lighting system by a T8 with electronic ballasts equipment if estimated to € 15 (on the basis of a product price of € 830 it corresponds to an increase of 1.8 %) and the payback time is 1.59 years.

- Constraints

The split incentive remains a major barrier also for the implementation of this option.

7.1.3.8 THICKER INSULATION (OPTION 8)

The insulation thickness in a beverage cooler is about 40 mm. Increasing the thickness of the insulation could reduce the heat leakages through conduction.

- Environmental impacts

On average, it is estimated that an increase of 25 mm of the insulation thickness can lead to a 6 % reduction in TEC. It could either affect the internal volume of the cabinet or increase the footprint. Less recent estimates from a previous study[5] estimate the TEC savings of about 3 % on average.

If we consider that the net volume remains the same, the footprint of the cabinet is increased leading to a higher packaged volume. However, as seen in task 5 (section 5.2.2.1) the impacts of the distribution phase being negligible, we consider that the packaged volume remains the same.

The quantity of plastic foam (polyurethane) increases by about 60 %. The BOM modifications and the effects on each environmental impact indicator expressed in percentage with reference to the base case are presented in Annexe 7- 18.

- Cost

The average cost associated to the increase of the insulation thickness is € 50 and the payback time is 3.09 years.

- Constraints

The lack of space and the need to preserve a high sales volume, limit the possible increase in insulation thickness. The insulation thickness increase is considered reasonable as long as the internal volume reduction is acceptable (in terms of equivalent sales revenues), or if the exterior dimensions can be increased.

7.1.3.9 COMPARISON OF THE IMPROVEMENT OPTIONS AND CONCLUSIONS

The changes in 15 environmental impact indicators due to the implementation of each individual option can be expressed in terms of percentage with reference to the base case (100 %). Figure 7-7 to Figure 7-9 allow the comparison of each option[6] and the identification of the most performing option for each environmental impact indicator (see also Table 7-11).

Once again, and not surprisingly considering the contribution of the use phase to the environmental impacts, the options are ranked according to their TEC savings potential (option 1 has 15 %, option 4 13.5 %, and option 6 has 12 % TEC saving potential).

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[5] Arthur D. Little. *Energy Saving Potential for Commercial Refrigeration Equipment*. US DOE 1996 http://www.eere.energy.gov/buildings/info/documents/pdfs/comm_refridg_equip.pdf

[6] Option 1: Increasing heat exchangers' surface; Option 2: High efficiency compressor; Option 3: Glass door insulated with argon instead of air; Option 4: Compressor modulation (variable speed drive); Option 5: ECM fans at the evaporator and condenser; Option 6: Light control (switched off 6 hours/day); Option 7: High efficiency lights; Option 8: Increase of the insulation thickness (+25 mm).

Figure 7-7: Comparison of the individual options (resources and waste) for the base case beverage cooler

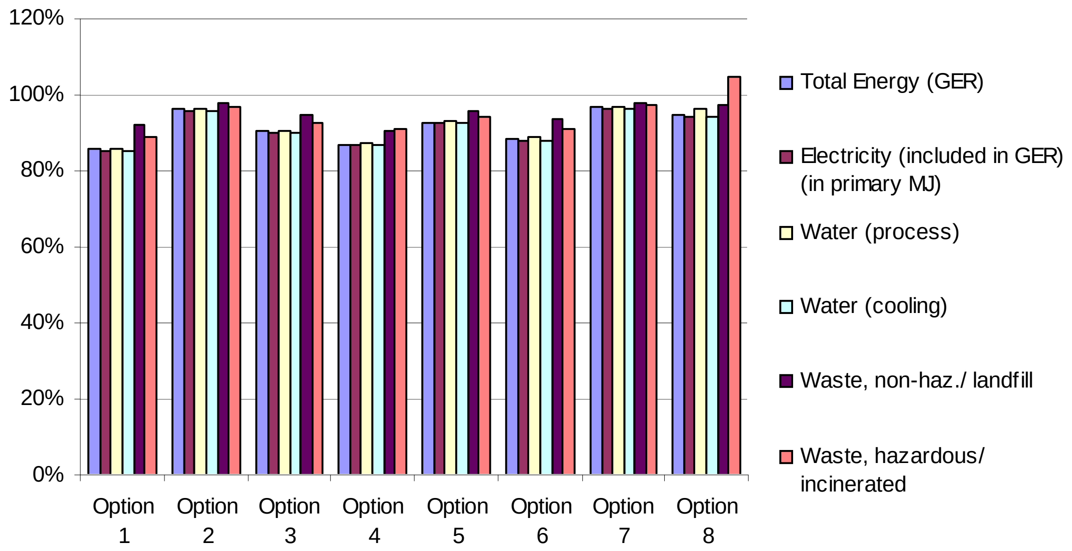


Figure 7-8: Comparison of the individual options (emissions to air) for the base case beverage cooler

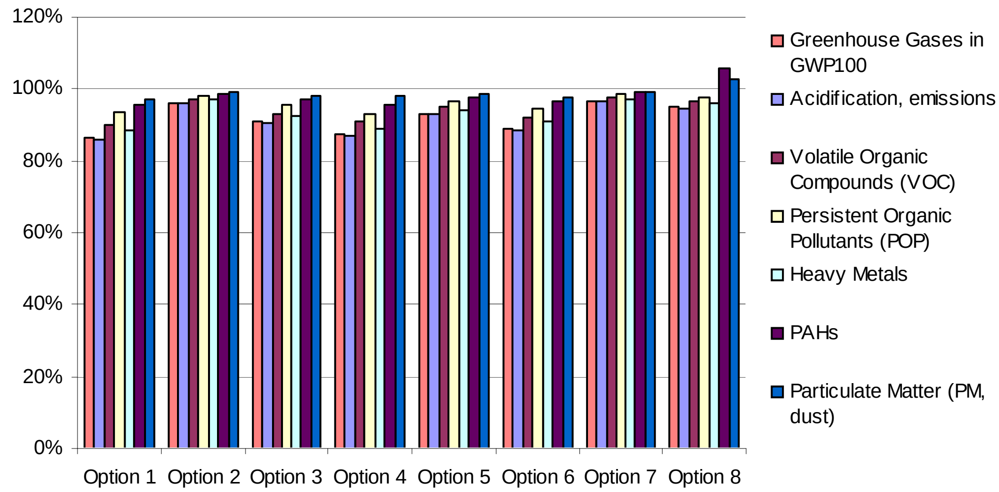


Figure 7-9: Comparison of the individual options (emissions to water) for the base case beverage cooler

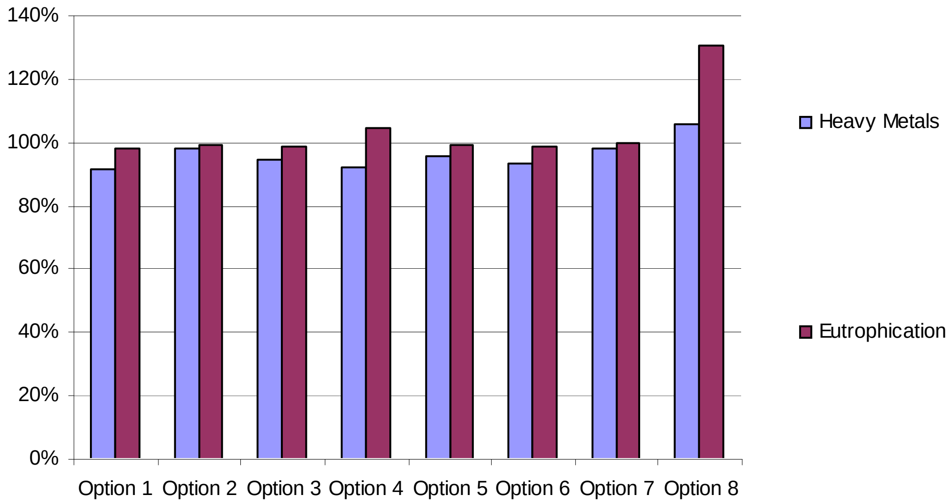


Table 7-11: Ranking of the 3 best performing improvement options of the base case beverage cooler for each environmental impact indicator

Indicator	Best option for this indicator	Second best option for this indicator	Third best option for this indicator
Total Energy (GER)	Option 1	Option 4	Option 6
of which, electricity (in primary MJ)	Option 1	Option 4	Option 6
Water (process)	Option 1	Option 4	Option 6
Water (cooling)	Option 1	Option 4	Option 6
Waste, non-haz./ landfill	Option 4	Option 1	Option 6
Waste, hazardous/ incinerated	Option 1	Option 6	Option 4
Greenhouse Gases in GWP100	Option 1	Option 4	Option 6
Acidification, emissions	Option 1	Option 4	Option 6
Volatile Organic Compounds (VOC)	Option 4	Option 4	Option 6
Persistent Organic Pollutants (POP)	Option 1	Option 1	Option 6
Heavy Metals (air)	Option 4	Option 4	Option 6
PAHs	Option 1	Option 1	Option 6
Particulate Matter (PM, dust)	Option 1	Option 6	Option 4
Heavy Metals (water)	Option 1	Option 4	Option 6
Eutrophication	Option 1	Option 6	Option 3

7.1.4 IMPROVEMENT OPTIONS FOR BASE CASE ICE CREAM FREEZER

Table 7-12 summarises the main improvement options applicable to the base case ice cream freezer ranked by increasing payback time.

Table 7-12: Identified energy saving potential for the base case ice cream freezer

	Improvement option	TEC savings compared to base case ice cream freezer	Increase of product cost compared to base case ice cream freezer (€)	Payback time (year)
Option 1	High efficiency compressor	4.8	8	0.97
Option 2	Increasing heat exchangers' surface	4	12.5	1.81
Option 3	ECM fans	5	25	2.90
Option 4	Compressor modulation (Variable speed drive)	11	75	3.95

No description of these individual options is provided as they are similar to when applied to beverage coolers in section 7.1.3. The impacts of each individual option with reference to the base case are given in Annexe 7- 19 to Annexe 7- 22. The increase in the insulation thickness is not proposed for the base case ice cream freezer as the panels are already 70 mm thick. Also most of the heat losses are through the lid and if efforts in reducing the infiltrations need to be done it would focus on the glass door rather than on insulated panels.

The implementation of each individual option leads to different EcoReport results. The comparison of each option in terms of environmental impacts (not only electricity savings during use-phase) is illustrated in Figure 7-10 to Figure 7-12 taking the base case ice cream freezer as reference (100 %).

Figure 7-10: Comparison of the individual options (resources and waste) for the base case ice cream freezer

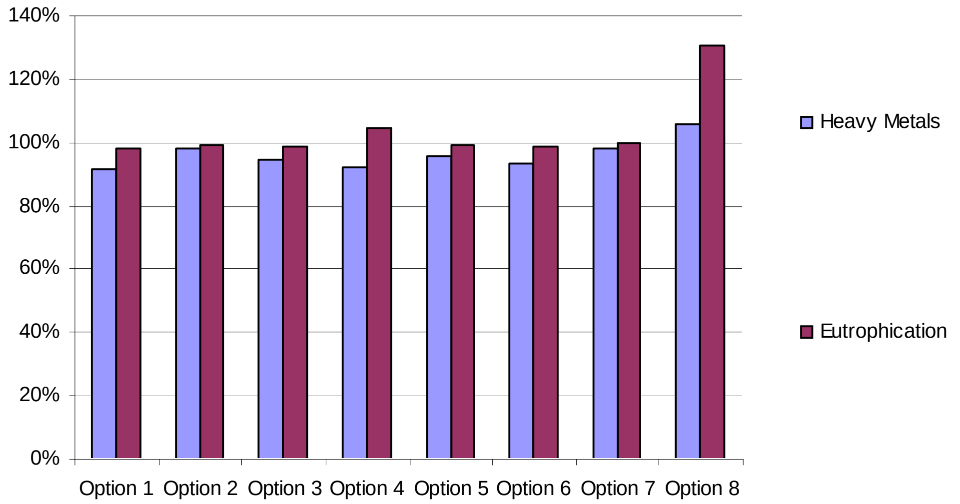


Figure 7-11: Comparison of the individual options (emissions to air) for the base case ice cream freezer

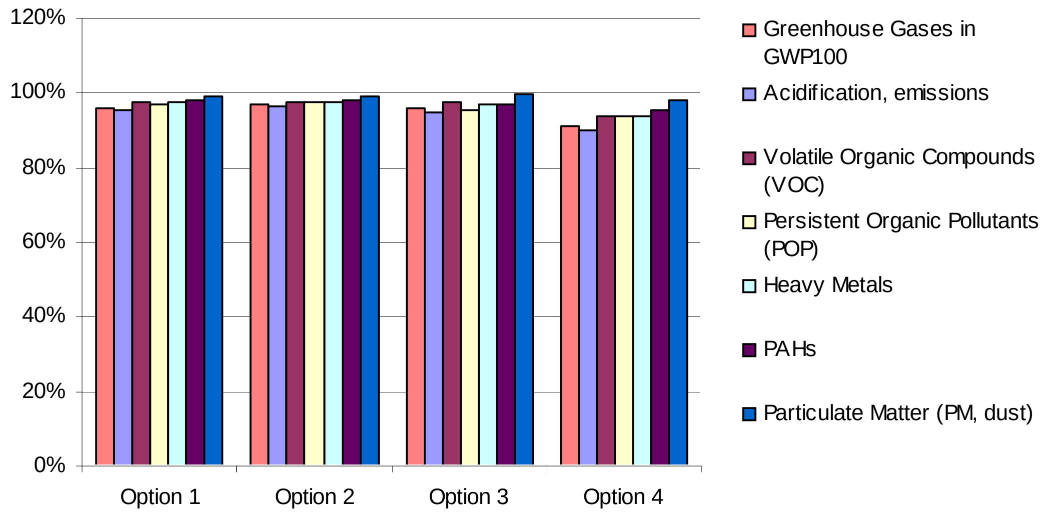
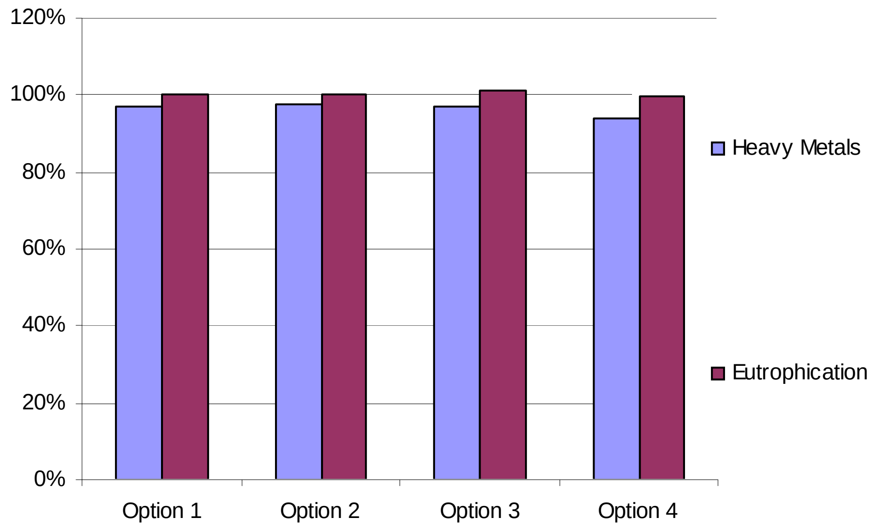


Figure 7-12: Comparison of the individual options (emissions to water) for the base case ice cream freezer



Option 4 is the option leading to the best environmental performance (highest reduction in the environmental indicators) for all 15 environmental indicators of the EcoReport (see Table 7-13). Option 3 is the second best performing option. This ranking corresponds to the energy saving potential during use phase.

Table 7-13: Ranking of the 3 best performing improvement options of the base case ice cream freezer for each environmental impact indicator

Indicator	Best option for this indicator	Second best option for this indicator	Third best option for this indicator
Total Energy (GER)	Option 4	Option 3	Option 1
of which, electricity (in primary MJ)	Option 4	Option 3	Option 1
Water (process)	Option 4	Option 3	Option 1
Water (cooling)	Option 4	Option 3	Option 1
Waste, non-haz./ landfill	Option 4	Option 3	Option 1
Waste, hazardous/ incinerated	Option 4	Option 3	Option 1
Greenhouse Gases in GWP100	Option 4	Option 3	Option 1
Acidification, emissions	Option 4	Option 3	Option 1
Volatile Organic Compounds (VOC)	Option 4	Option 3	Option 1
Persistent Organic Pollutants (POP)	Option 4	Option 3	Option 1
Heavy Metals (air)	Option 4	Option 3	Option 1
PAHs	Option 4	Option 3	Option 1
Particulate Matter (PM, dust)	Option 4	Option 3	Option 1
Heavy Metals (water)	Option 4	Option 3	Option 1
Eutrophication	Option 4	Option 3	Option 1

7.1.5 IMPROVEMENT OPTIONS FOR BASE CASE VENDING MACHINE

Vending machines manufacturers have already been taking into account environmental issues related to their appliances. Therefore, the base case spiral vending machine described in task 5 (section 5.1.4.1) uses some efficient lights and an efficient compressor. Nevertheless, some improvement potential still exists, and the following paragraphs present some options aiming at increasing the energy efficiency of the spiral vending machine.

Table 7-14 summarises the main improvement options applicable to the base case spiral vending machine ranked by increasing payback time.

Table 7-14: Identified energy savings potential for the base case spiral vending machine

	Improvement option	TEC savings compared to base case Spiral Vending Machine (%)	Increase of product cost compared to base case Spiral Vending Machine	Payback time (year)
Option 1	Anti-sweat heater location	18	30	0.58
Option 2	Vacuum Insulated Panels (VIPs)	6.5	25	1.34
Option 3	Compressor Modulation (Variable Speed drive)	22	200	3.18

Two options differ compared to the other base cases: the use of vacuum insulated panels and a better location of the anti-sweat heater, in order to prevent an increase in the temperature of the refrigerated volume in the vending machine.

7.1.5.1 LOCATION OF THE ANTI SWEAT HEATERS (OPTION 1)

- Environmental impacts

Changing the location of the anti sweat heaters allows to install anti sweat heaters of lower power for the same effect (evaporation of the condensation appearing in the glass door), leading to an reduction of the TEC of 18 %.

- Cost

The increase of the product cost due to the implementation of this option is of € 30 and the payback time is 0.58 year.

- Constraints

Main barrier for the implementation of this option is the increase in the product cost.

7.1.5.2 VACUUM INSULATED PANELS (OPTION 2)

- Environmental impacts

Vacuum insulated panels (VIPs) reduce both direct and indirect impacts. Indeed, the use of vacuum instead of R134a limits especially the Global Warming Potential. Besides, this better insulation decreases the infiltration in the vending machine, and thus its electricity consumption.

On average, the use of vacuum insulated panels instead can reduce the TEC by 6.5 %. The consequence of this modification is the disappearance of the R134a as blowing agent (202.4 g) in the BOM.

- Cost

The increase of the product cost due to the implementation of this option is of € 25 and the payback time is 1.34 year.

- Constraints

The main barrier in the use of VIPs is that this technology is quite recent, and the cost could also be a drawback as the buyer of a vending machine is not always the end-user.

Annexe 7- 23 to Annexe 7- 25 present the BOM modifications for each individual improvement option and the effects on each environmental impact indicator expressed in percentage with reference to the base case (100 %).

7.1.5.3 COMPARISON OF THE INDIVIDUAL OPTIONS AND CONCLUSIONS

The change in 15 environmental impact indicators due to the implementation of each individual option can be expressed in terms of percentage with reference to the base case (100 %). Figure 7-13 to Figure 7-15 allow the comparison of each option and the identification of the most performing option for each environmental impact indicator. Option 3 leads to the highest reduction of all environmental impacts, followed by option 1 (see Figure 7-15).

Figure 7-13: Comparison of the individual options (resources and waste) for the base case spiral vending machine

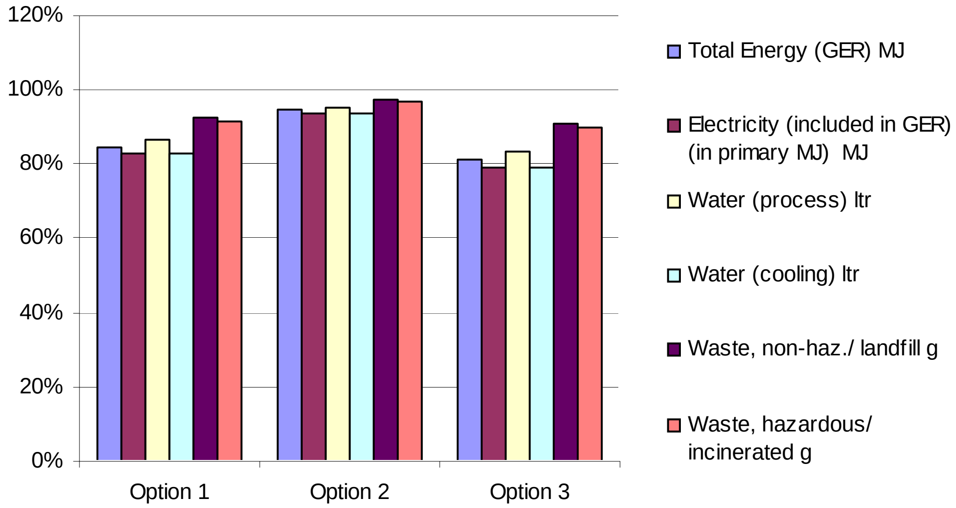


Figure 7-14: Comparison of the individual options (emissions to air) for the base case spiral vending machine

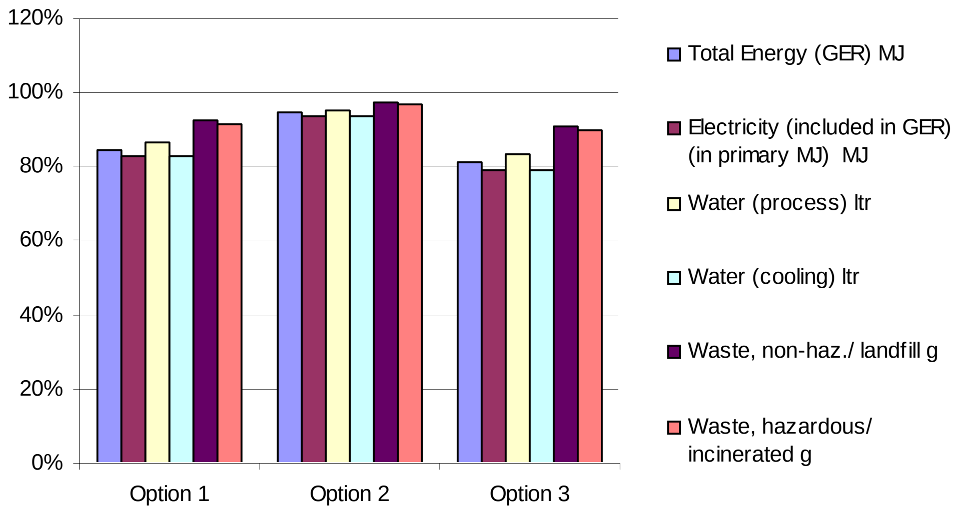


Figure 7-15: Comparison of the individual options (emissions to water) for the base case spiral vending machine

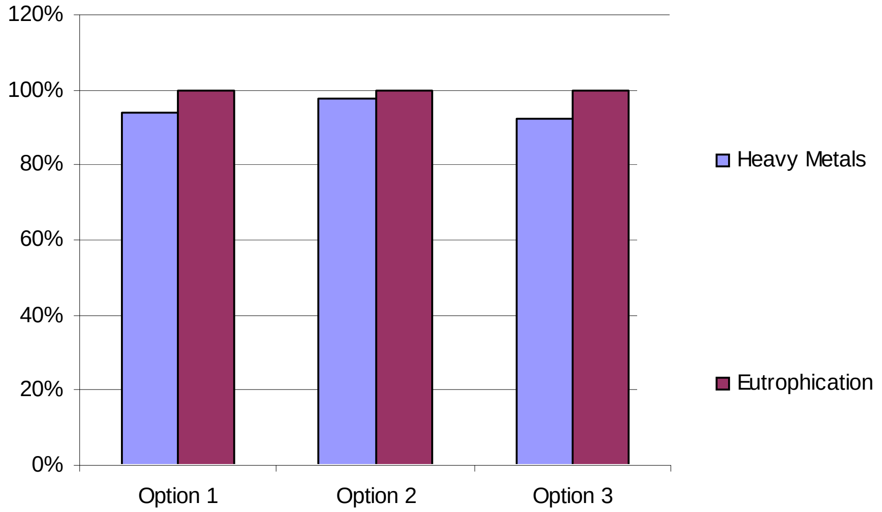


Table 7-15: Ranking of the 3 best performing improvement options of the base case spiral vending machine for each environmental impact indicator

Indicator	Best option for this indicator	Second best option for this indicator	Third best option for this indicator
Total Energy (GER)	Option 3	Option 1	Option 2
of which, electricity (in primary MJ)	Option 3	Option 1	Option 2
Water (process)	Option 3	Option 1	Option 2
Water (cooling)	Option 3	Option 1	Option 2
Waste, non-haz./ landfill	Option 3	Option 1	Option 2
Waste, hazardous/ incinerated	Option 3	Option 1	Option 2
Greenhouse Gases in GWP100	Option 3	Option 1	Option 2
Acidification, emissions	Option 3	Option 1	Option 2
Volatile Organic Compounds (VOC)	Option 3	Option 1	Option 2
Persistent Organic Pollutants (POP)	Option 3	Option 1	Option 2
Heavy Metals (air)	Option 3	Option 1	Option 2
PAHs	Option 3	Option 1	Option 2
Particulate Matter (PM, dust)	Option 3	Option 1	Option 2
Heavy Metals (water)	Option 3	Option 1	Option 2
Eutrophication	Option 3	Option 1	Option 2

7.2. ANALYSIS LLCC AND BAT

The LLCC and BAT analysis is an important step in the MEEuP where the suggested improvement options are evaluated for their environmental and economic implications extending over the complete life cycle of the product.

The objective of this sub-task is to analyse improvement options (which in turn are based on improvement potentials) using EcoReport and then prioritise them according to their life cycle costs (LCC) in order to identify the option using the BAT and with least life cycle cost (LLCC).

Different improvement options can be combined together if applicable to a specific base case or product range. Following subsections present such options (individual or combination of options) and their respective LCC.

Individual options have different effects: some generate considerable savings on running costs at hardly any extra production costs; some are more expensive and deliver smaller environmental improvement providing little reduction in running costs.

The resulting improvement potential (in terms of TEC savings) in the case of simultaneous implementation of multiple options was calculated by multiplying the remaining energy consumption after each option was implemented. The formula used to calculate the TEC saving potential of the implementation of n options is the following:

$$x(option\,1+2+\ldots+n)=1-\prod_{N=1}^{n}(1-x(N))$$

where is the potential TEC savings (%) of the option N and is the potential of TEC savings obtained through the implementation of n improvement options. However, when implementing several improvement options together, the interaction between the improvement options can lead to a reduced improvement compared to the one calculated with this formula.

On the basis of obtained results, following graphs show the environmental assessments for each base case with total electricity consumption during use phase expressed in electricity costs on the left Y-axis as key environmental parameter. It should be noted that the electricity cost scale has different starting unit for each graph to give a better overview of the differences among the options. Graphs with the GER (total energy consumption over lifetime including production phase) expressed in MJ/product, and GWP (Global Warming Potential in kg CO_2 eq.) as key environmental parameter are also presented.

The graphs provided in this section allow drawing conclusions only for each base case without taking into account the complete stock of products placed on the EU market e.g. some of them may have high improvement potential but with limited quantities placed on the market and hence limited potential energy gains. See task 5 (section 5.4) where a comparison of the stock for each base case is provided for relative importance of different base cases.

7.2.1 BASE CASE RCV2

7.2.1.1 INDIVIDUAL IMPROVEMENT OPTIONS

The EcoReport analysis of the various improvement options applicable to the base case RCV2 leads the results shown in Table 7-16. In this table, the options are ranked according to their payback time.

It can be observed that the payback times are not significantly high. However, when purchasing new equipment, most of the end-users (e.g. supermarkets) consider mainly product cost as the most important criterion and even a low payback time can be a barrier to the implementation of an improvement option.

Table 7-16: Summary of the cost and benefit effects of implementing individual improvement options for the base case RCV2

Option	Option description	Total Energy GER (MJ/product)	Electricity costs (Euros/lifetime)	LCC (Euros)	Payback time (year)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base Case RCV2	2,722,685	24,636	28,300	0.00	0	0	0
1	Night curtain (12 hours a day)	2,030,603	18,231	22,229	0.28	200	26	+ 6 kg Aluminium
2	Optimisation air curtain (double)	2,457,813	22,172	26,039	0.51	140	10	+ 2 fans standard
3	ECM fans	2,503,977	22,616	26,470	0.88	135	8.2	+modified fans
4	LSHE	2,656,068	24,020	27,764	0.88	60	2.5	+ 750 g copper
5	Addition of a glass door	1,338,926	11,825	18,672	1.33	1,750	52	+ 150 kg glass

The environmental performance can be plotted together with the LCC values. It can be either expressed in:

- Electricity costs (during use phase) over the product life (Euros/product), this reflects the electricity use,
- Total energy consumption during the whole lifetime of the beverage cooler (GER in MJ/product), or
- Global Warming Potential (GWP in kg CO2 eq./product)

If we plot the individual options (right Y-axis = LCC, left Y-axis= Environmental performance expressed in electricity costs, and X-axis = Options ranked by payback time), it is clearly visible that option 5 is both the BAT (i.e. leading to the best environmental performance) and the LLCC option (leading to the Least Life Cycle Cost). However, as mentioned in section 7.1.1.6, there is very low demand for closed cabinets in supermarkets. The next best option is option 1 which is the use of a night curtain. The improvement potential resulting from the use of a night blind depends on the number of hours during which it is applied. When evaluating the improvement potential of the night curtain, it was assumed that it was used 12 hours per day. However, the trend of supermarkets is to have longer opening hours, and this could reduce the period of time during which it is possible to use night blinds and may suggest the need to reconsider the option of a glass door (option 5).

Environmental impacts in all categories are mainly linked to energy consumption in the use phase (see task 5, section 5.2.1.1). Also, 80 % of the LCC is due to the electricity costs over the lifetime of a RCV2 (see task 5 section 5.3.1.1). Consequently, the electricity consumption during use phase (expressed in electricity costs) and the total energy consumption correlates closely with other impacts and with the LCC curve. If we express the environmental performance in terms of GWP (Global Warming Potential) the LCC curve is similar and leads to the same conclusions.

Figure 7-16: LCC curve - environmental performance expressed in total electricity costs for the base case RCV2

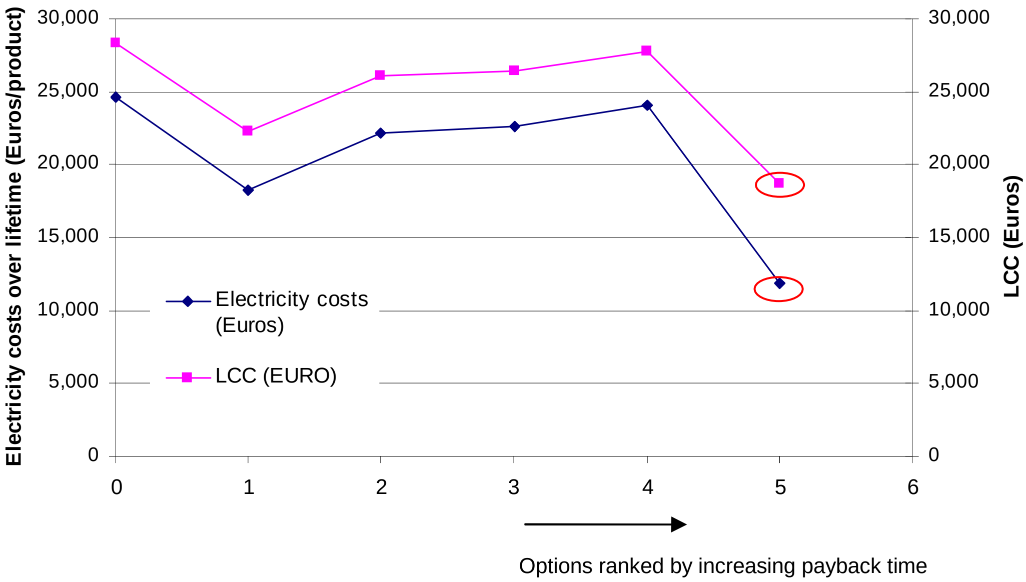


Figure 7-17: LCC curve - environmental performance expressed in total energy consumption (GER) for the base case RCV2

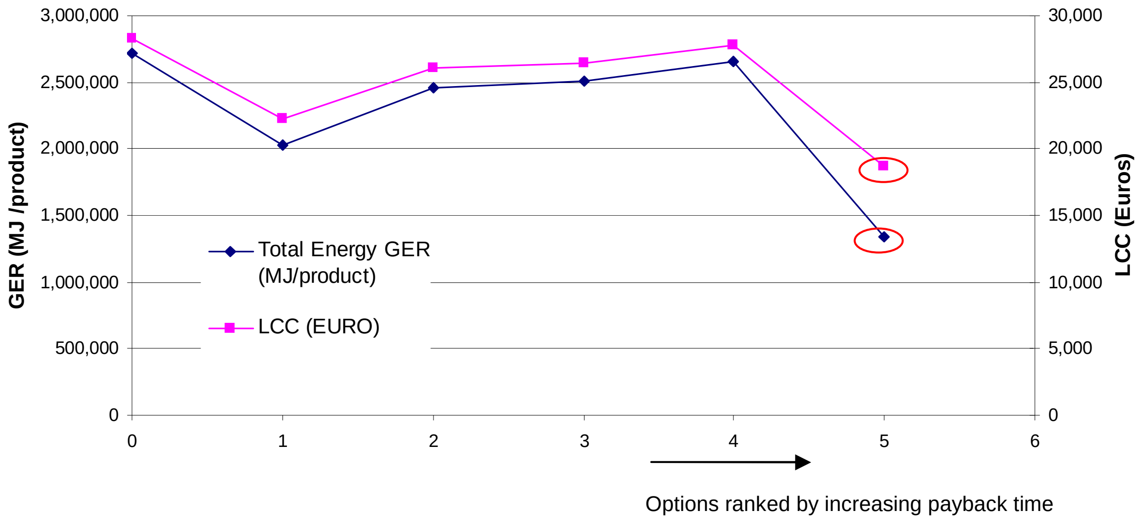
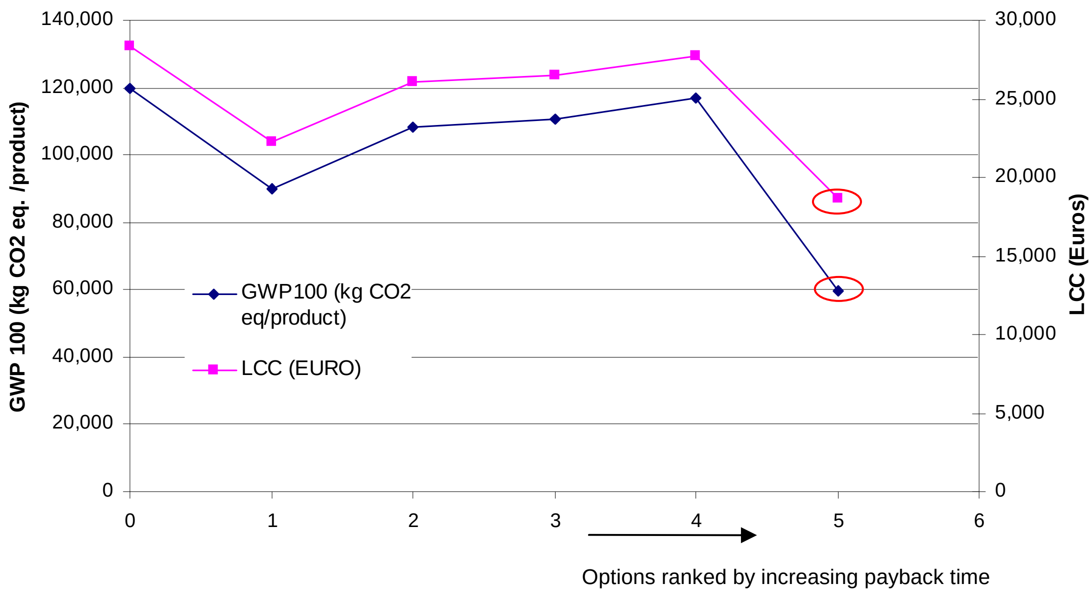


Figure 7-18: LCC curve – environmental performance expressed in GWP for the base case RCV2



7.2.1.2 EFFECT OF CUMULATING IMPROVEMENT OPTIONS

It is feasible to combine any of the 6 individual improvement options presented in section 7.2.1.1 with a few exceptions: the combination options 2+6 and 1+6 are not feasible. Indeed the use of a night curtain and the use of an improved air curtain may not lead to much additional benefit if a door is fitted on the cabinet.

According to manufacturers, not more than 2 or 3 options are commonly implemented in the same cabinet, because of restrictions due to the related increase in the cost. However, combinations of up to 5 options were investigated here.

The resulting improvement potential in the case of simultaneous implementation of multiple options is calculated as described in section 7.2.

- **Approach 1: cumulating options in the order of payback time**

The first step in identifying the combination of potions with the least life cycle cost (LLCC) is to combine the individual improvement options in the order of payback time. Second step is to plot key parameters such as the electricity costs and the LCC resulting from the implementation of each combination of options.

Three types of scenarios were analysed when combining individual options. The first one considers that option 6 (addition of a glass door) is used and thus excludes options 1 and 2 (optimisation of the air curtain and use of a night blind). The second considers that no glass door is used. The third scenario considers that neither option 1 nor option 2 is used. The third scenario will allow identifying the best combination of options which depends only on technical features and not the design related improvements.

- With glass door

The different combinations in the order of the payback time and excluding options 1 and 2 (not compatible with the use of a glass door) are summarised in Table 7-17.

Table 7-17: Combinations of individual improvement options in the order of payback time for the base case RCV2 (with glass door)

Combination	Options	Electricity costs (Euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base case RCV2	24,636	2,722,685	28,300	0	0	0	0
3	ECM fans	22,616	2,503,977	26,470	0.60	135	8.20	modified fan motors
3+4	ECM fans + LSHE	22,050	2,442,827	25,984	0.68	195	10.50	modified fan motors + 750 g copper
3+4+5	ECM fans + LSHE + addition of a glass door	10,584	1,204,606	17,680	1.34	1,945	57.04	modified fan motors + 750 g copper + 150 kg glass

Figure 7-19: LCC curve - environmental performance expressed in total electricity costs for the base case RCV2 (with glass door)

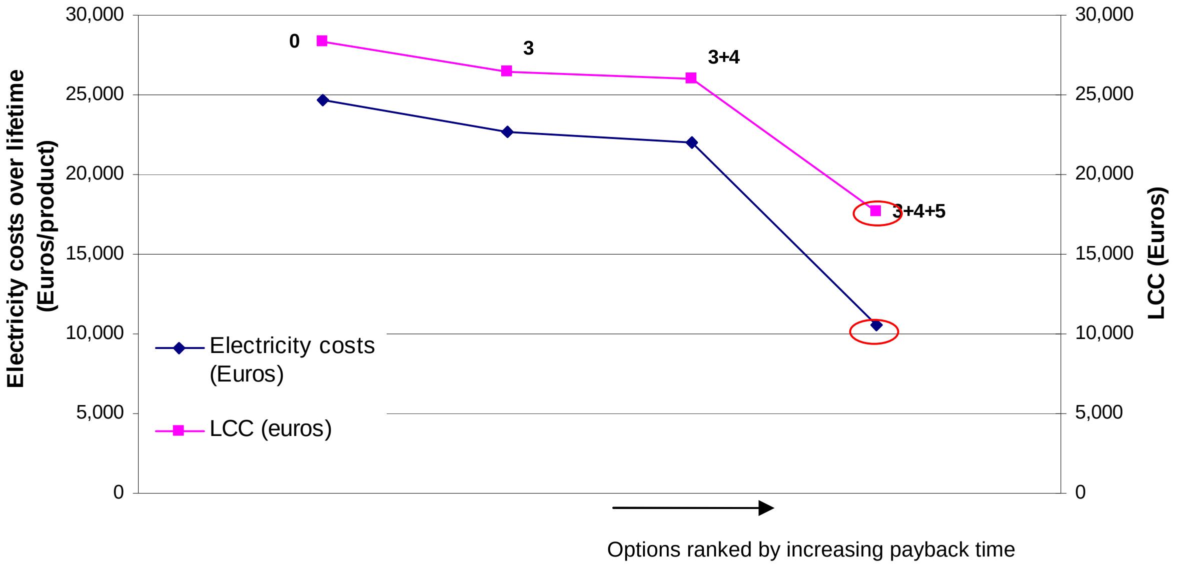
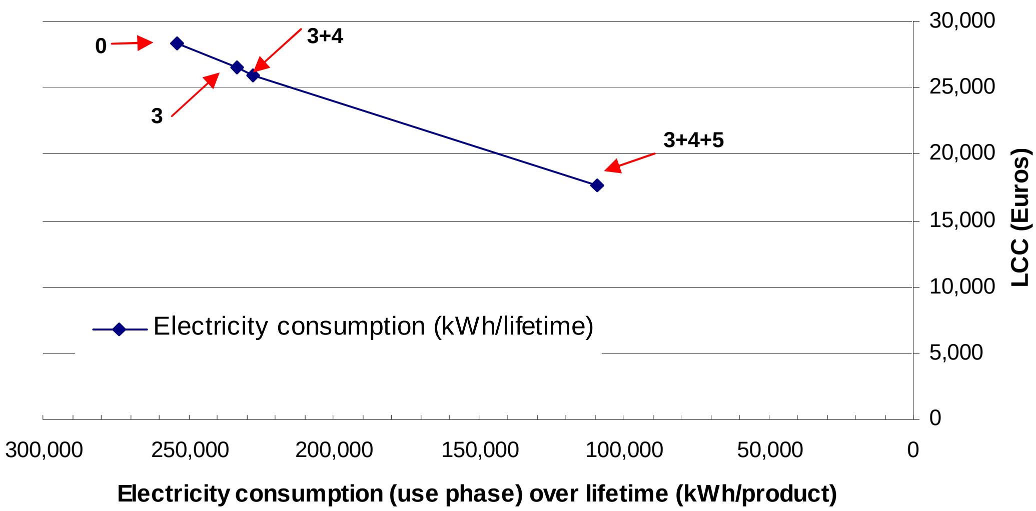


Figure 7-20: Energy consumption during use phase versus LCC for the base case RCV2 (with glass door)



When considering the addition of a glass door, the option 3+4+5 is the option with BAT and LLCC. It leads to over 57 % reduction in electricity consumption during use phase and a 37.5 % lower LCC (see Table 7-17).

Once again, the LCC curve closely matches the electricity costs (Figure 7-19) and the correlation between the LCC and the electricity consumption during use phase is further illustrated in Figure 7-20.

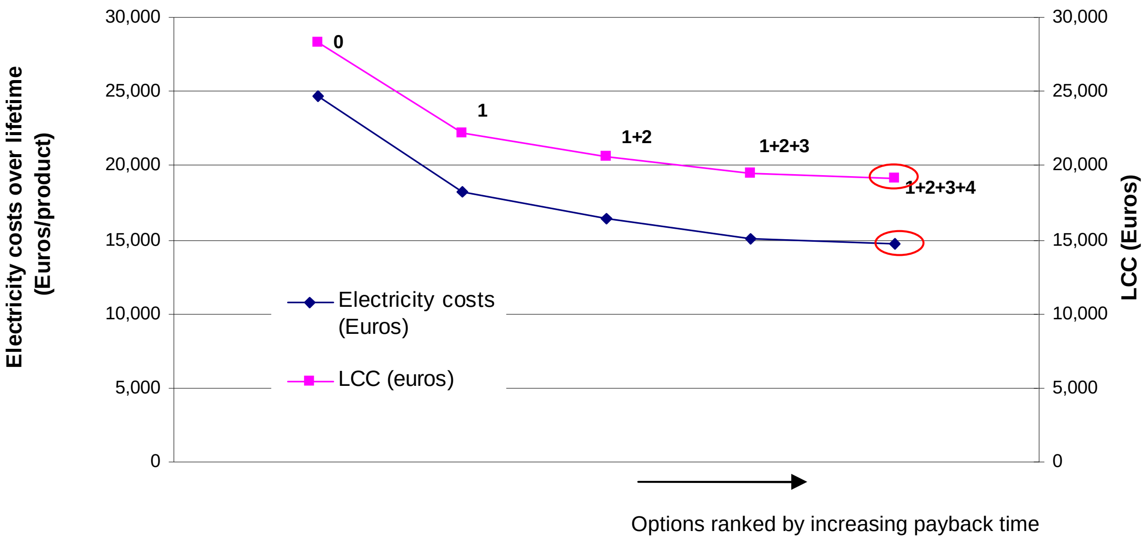
* Without glass door (and with night curtain)

Option 5 is an improvement option that should be considered separately. Indeed, the use of a glass door considerably reduces the cold spillage and the energy savings are not comparable with the other improvement options. Also adding a glass door implies an increase in the product cost of over 50 % which represents a high augmentation and combining multiple options would further increase the product cost. As mentioned in task 3 (section 3.4), most of the supermarkets focus on the initial cost (instead of LCC) of the equipment when acquiring new appliances and therefore it is interesting to evaluate the improvement potential attainable without the use of option 5.

Table 7-18: Combinations of individual improvement options in the order of payback time for the base case RCV2 (without glass door)

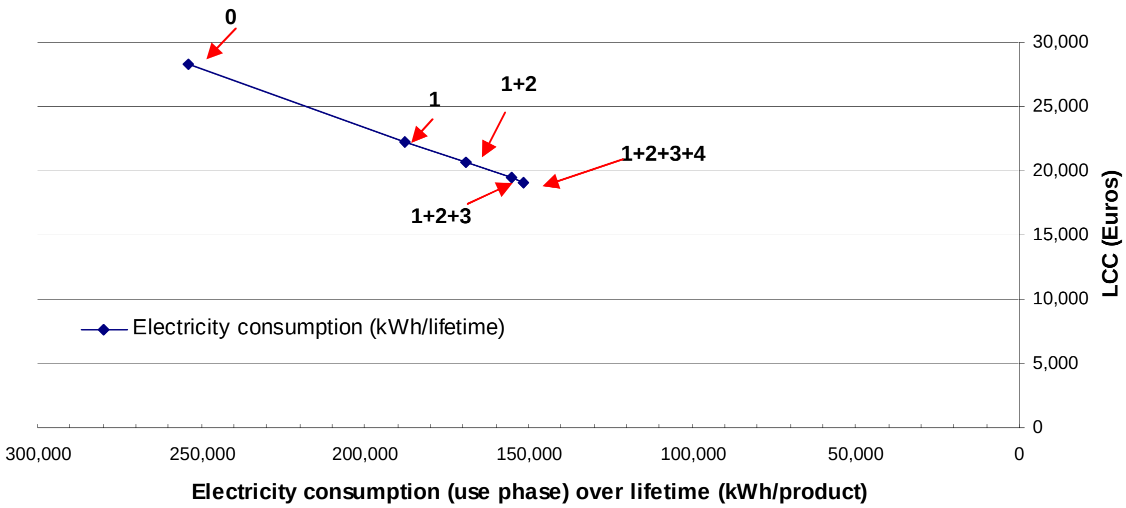
Combination	Options	Electricity costs (Euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base case RCV2	24,636	2,722,685	28,300	0	0	0	0
1	Night curtain (12 hours a day)	18,231	2,030,603	22,229	0.28	200	26.00	+ 2 standard fans
1+2	Night curtain (12 hours/day) + Optimisation air curtain	16,408	1,835,067	20,599	0.37	340	33.40	+ 2 standard fans + 6 kg aluminium
1+2+3	Night curtain (12 hours/day) + Optimisation air curtain + ECM fans	15,062	1,689,398	19,433	0.45	475	38.86	+ 2 standard fans + 6 kg aluminium + modified fan motors
1+2+3+4	Night curtain (12 hours/day) + Optimisation air curtain + ECM fans + LSHE	14,686	1,648,690	19,133	0.48	535	40.39	+ 2 standard fans + 6 kg aluminium + modified fan motors + 750 g copper

Figure 7-21: LCC curve - environmental performance expressed in total electricity costs for the base case RCV2 (without glass door)



The option with BAT and presenting the LLCC is the combination option 1+2+3+4 which leads to 40 % reduction in electricity consumption during use phase and a 32 % lower LCC (see Table 7-18). Figure 7-21 and Figure 7-22 illustrate once again how closely the LCC and the electricity consumption correlate and this explains why the BAT coincides with the LLCC since most of the environmental impacts are due to the use of electricity.

Figure 7-22: Energy consumption during use phase versus LCC for the base case RCV2 (without glass door)



- Without night curtain

When considering only the improvement options that are not influenced by the consumer behaviour (e.g. no night blinds) the option 2+3+4 leads to the LLCC and BAT point (Figure 7-23 and Figure 7-24).

This combination allows 19.4 % reduction in electricity consumption during use phase and 15 % saving in LCC (Table 7-19).

Table 7-19: Combinations of individual improvement options in the order of payback time for the base case RCV2 (without night curtain)

Combination	Options	Electricity costs (Euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base case RCV2	24,636	2,722,685	28,300	0	0	0	0
2	Optimisation air curtain	22,172	2,457,813	26,039	0.51	140	10.0	2
2+3	Optimisation air curtain + ECM fans	20,354	2,260,972	24,408	0.58	275	17.4	2+3
2+3+4	Optimisation air curtain + ECM fans + LSHE	19,845	2,205,943	23,978	0.63	335	19.4	2+3+4

Figure 7-23: LCC curve - environmental performance expressed in total electricity costs for the base case RCV2 (without night curtain)

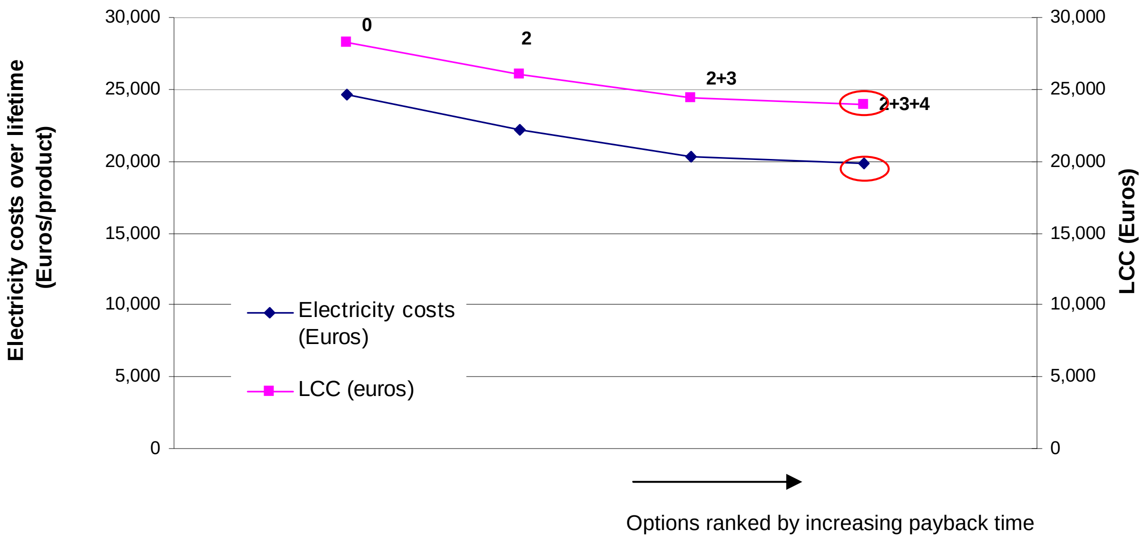
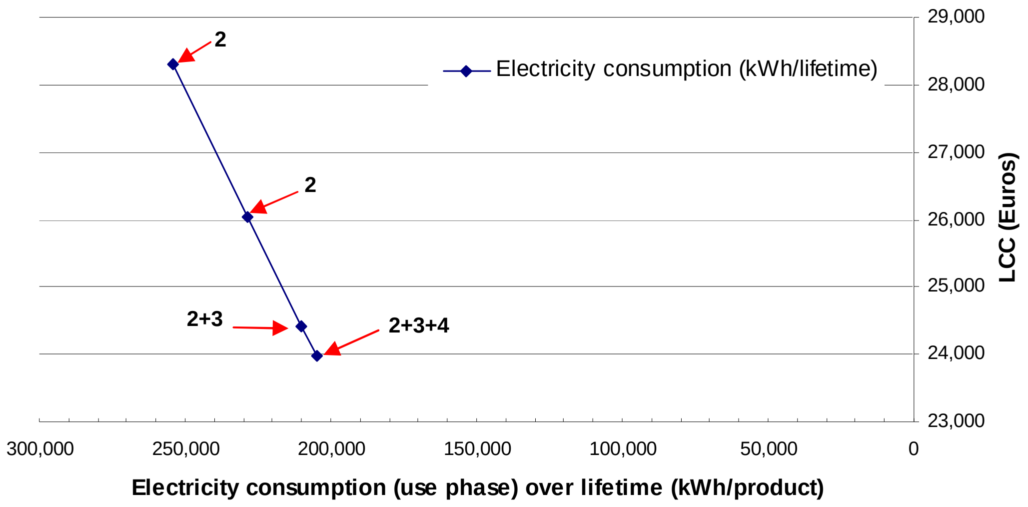


Figure 7-24: Energy consumption during use phase versus LCC for the base case RCV2 (without night curtain)



The results of the EcoReport for each combination of options from the three scenarios can be compared to provide description of the changes in other environmental aspects (not only in terms of electricity use). Figure 7-25 to Figure 7-27 show the relative modifications of 15 environmental impact indicators of the EcoReport and allow the identification of the most important option for each indicator (i.e. leading to the most important reduction of the related environmental impact indicator).

Figure 7-25: Comparison of the cumulative improvement options (resources and waste) for the base case RCV2

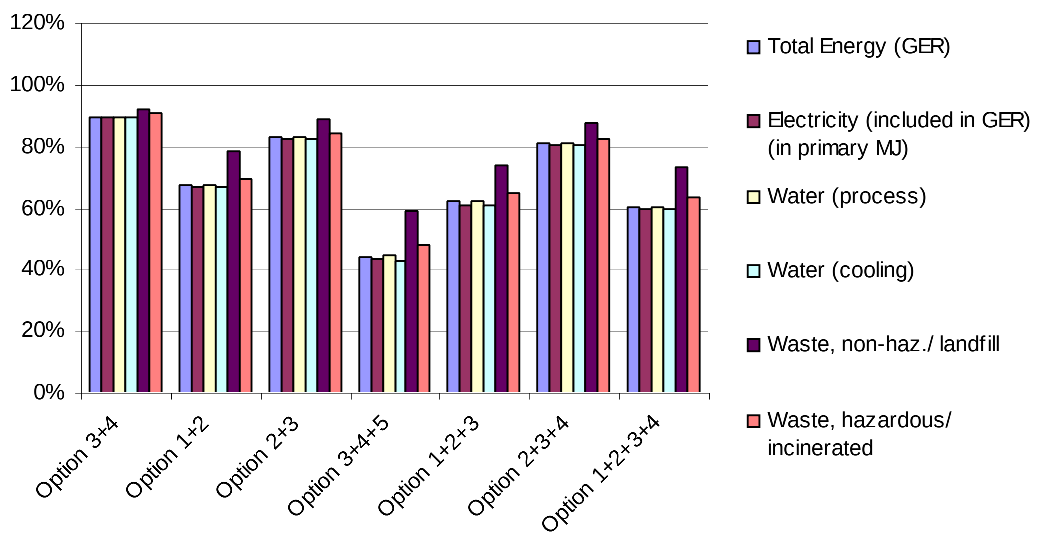


Figure 7-26: Comparison of the cumulative improvement options (emissions to air) for the base case RCV2

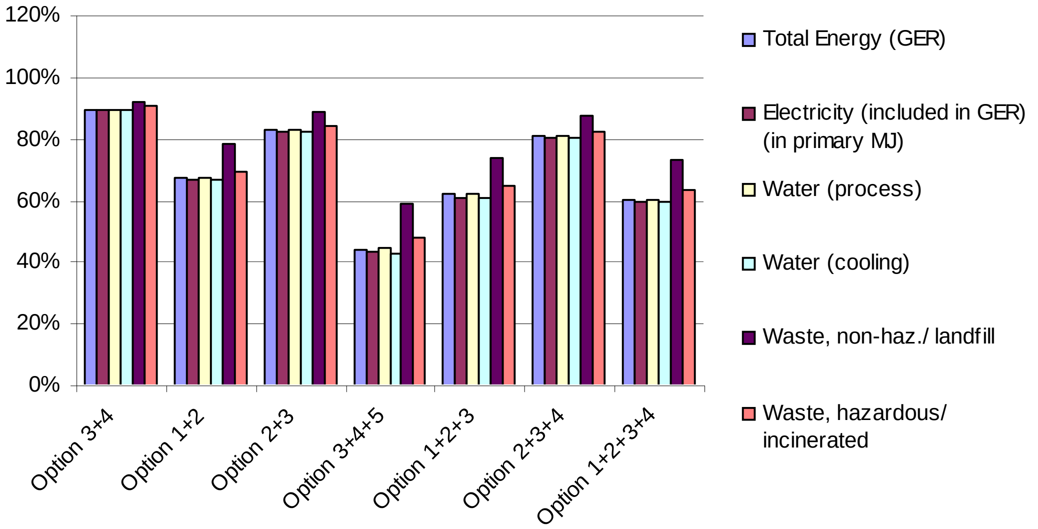
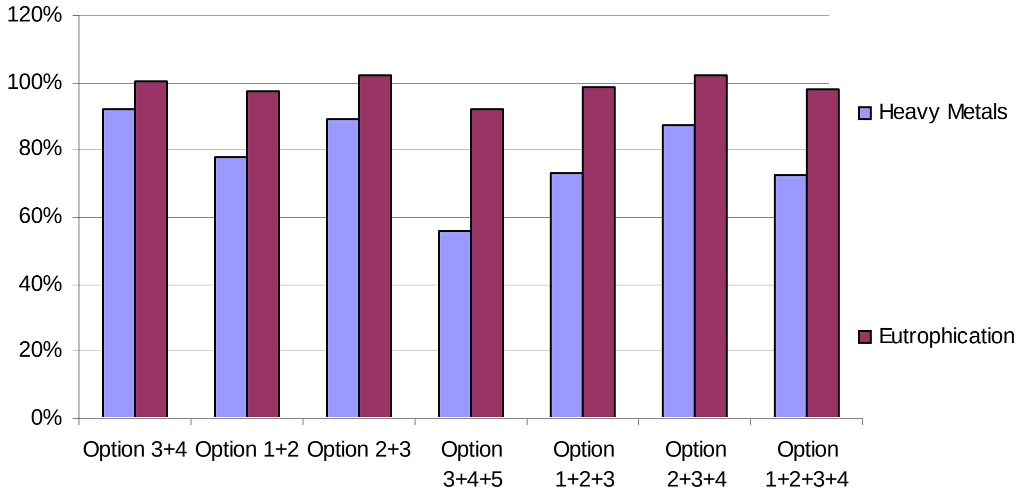


Figure 7-27: Comparison of the cumulative improvement options (emissions to water) for the base case RCV2



For all 15 environmental impact indicators (2 other are negligible for all base cases and for all combinations of improvement options), the best performing option (i.e. leading to the highest reductions with reference to the base case RCV2) is the option with glass door: option 3+4+5. The second best option is 1+2+3+4 (without glass door but with night curtain during 12 hours) and the third best performing option is option 1+2+3.

The highest relative reductions of impacts are observed among the following environmental impact indicators: water (cooling), total energy consumption over lifetime (GER), Acidification emissions, and GWP (Table 7-20).

Table 7-20: Improvement potential for each environmental impact indicator for the base case RCV2

Indicator	Unit	Impact variation with least performing option	Impact variation with best performing option
Total Energy (GER)	ltr	-2.45%	-55.76%
Total electricity (in primary MJ) (included in GER)	MJ	-2.49%	-56.76%
Water (process)	MJ	-2.46%	-55.48%
Water (cooling)	g SO2 eq.	-2.49%	-56.87%
Waste, non-haz./ landfill	kg CO2 eq.	-1.65%	-40.94%
Waste, hazardous/ incinerated	ltr	-2.30%	-52.17%
Greenhouse Gases in GWP100	g	-2.42%	-55.19%
Acidification, emissions	g	-2.44%	-55.78%
Volatile Organic Compounds (VOC)	mg Ni eq.	-1.94%	-44.07%
Persistent Organic Pollutants (POP)	g	-1.39%	-32.31%
Heavy Metals	mg Hg/20	-2.20%	-51.16%
PAHs	ng i-Teq	-1.53%	-36.11%
Particulate Matter (PM, dust)	mg Ni eq.	-0.67%	-14.16%
Heavy Metals	g	-1.81%	-43.94%
Eutrophication	g PO4	2.36%	-9.11%
Ozone Depletion, emissions	mg R-11 eq.	Negligible	negligible
Persistent Organic Pollutants (POP)	ng i-Teq	Negligible	negligible

- **Approach 2: cumulating options in the order of LCC**

A second approach was explored in order to identify the LLCC option. Instead of cumulating the options in the order of payback time, the LCC was chosen as key parameter. This approach leads to combinations allowing a lower LCC and a higher reduction in electricity consumption during use phase for the same number of options in one combination, e.g. option 3+4 (combination of 2 options in the order of payback time, with glass door see Table 7-17) compared to option 5+3 (combination of 2 options in the order of LCC, with glass door, see Table 7-21).

Cumulating the options in the order of LCC allows attaining lower LCC and electricity consumptions for a fixed number of individual options. However, the observed payback times are longer.

Following paragraphs provide complementary details on the combinations of options in the order of LCC for the scenario with glass door. For the two other scenarios the ranking in order of LCC is the same as the ranking in order of payback time.

The comparison of the effects of each combination of options for the 17 EcoReport environmental indicators is given in Annexe 7- 26 to Annexe 7-28.

- With glass door

The summary of the EcoReport results for all possible combinations of options including the glass door in the order of LCC is given Table 7-21.

LCCs are lower than when cumulating in the order of payback time. However, the payback times are longer, because the combinations of individual improvement options are different. The BAT and LLCC point is the same as in the first approach: option 3+4+5 leading to over 57 % of reduction in TEC (Figure 7-28 and Figure 7-29).

Table 7-21: Combination of individual options in the order of LCC for the base case RCV2 (with glass door)

Combination	Options	Electricity costs (Euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base case RCV2	24,636	2,722,685	28,300	0	0	0	0
5	Addition of a glass door	11,825	1,338,926	18,672	1.33	1,750	52.00	150 kg glass
5+3	Addition of a glass door +ECM fans	10,856	1,233,930	17,876	1.33	1,885	55.94	150 kg glass + modified fan motors
5+3+4	Addition of a glass door +ECM fans +LSHE	10,584	1,204,606	17,680	1.34	1,945	57.04	150 kg glass + modified fan motors + 750 g copper

Figure 7-28: LCC curve - environmental performance expressed in total electricity costs for the base case RCV2 (with glass door)

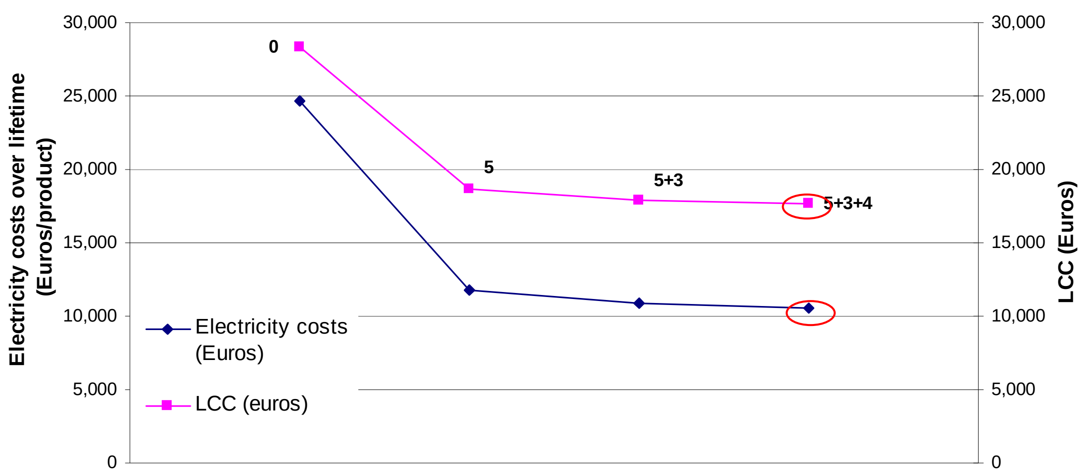
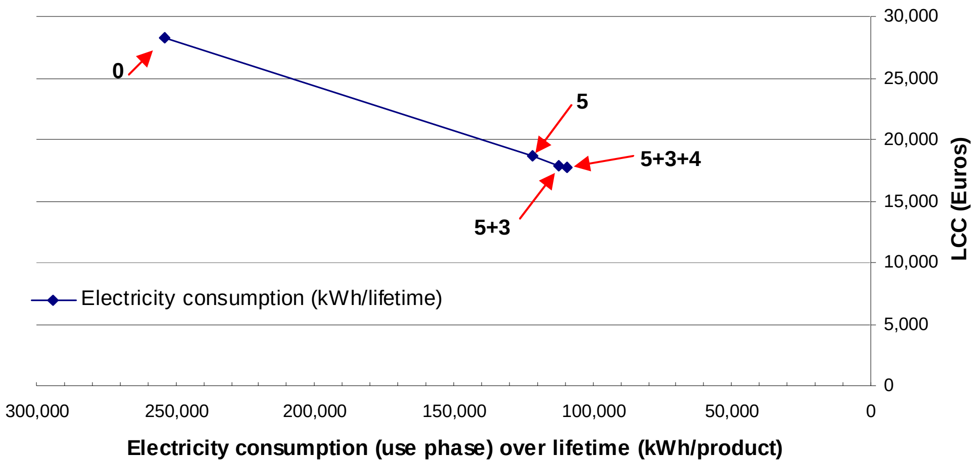


Figure 7-29: Energy consumption during use phase versus LCC for the base case RCV2 (with glass door)



7.2.2 BASE CASE RHF4

7.2.2.1 INDIVIDUAL IMPROVEMENT OPTIONS

The EcoReport analysis of the six improvement options applicable to the base case RHF4 leads the results shown in Table 7-22, by ranking the options in order of the increasing payback time.

Table 7-22: Summary of the cost and benefit effects of implementing individual improvement options for the base case RHF4

Option	Option description	Total Energy GER (MJ/product)	Electricity costs (Euros/lifetime)	LCC (Euros)	Payback time (years)	Cost increase (Euros)	TEC savings (%)	BOM modifications
0	Base Case RHF4	2,867,748	25,919	30,187	0.00	0	0	0
1	Night curtain (12 hours a day)	2,364,020	21,253	26,063	0.77	400	18	+ 6 kg Aluminium
2	LSHE	2,811,689	25,400	29,735	0.87	50	2	+ 750 g copper
3	Antisweat control	2,699,530	24,363	28,849	0.95	165	6	+ 150 g controller board
4	ECM fans	2,769,533	25,011	29,558	2.23	225	3.5	+ modified fans
5	Addition of a glass lid	1,846,668	16,458	24,445	2.40	2,250	36.5	+ 150 kg glass

Figure 7-30 to Figure 7-32 present the environmental performances of each individual improvement option by expressing either electricity costs, or the total energy consumption, or the GWP.

The three graphs present the same aspect, and lead to the conclusion that option 5 is both the BAT and the LLCC option, followed by option 1. However, as for the RCV2, there is very low demand for closed RHF4. Moreover, the use of a night curtain (option 1) is dependent of the end-user's behaviour, and of the closing hours of the store.

Figure 7-30: LCC curve – environmental performance expressed in total electricity costs for the base case RHF4

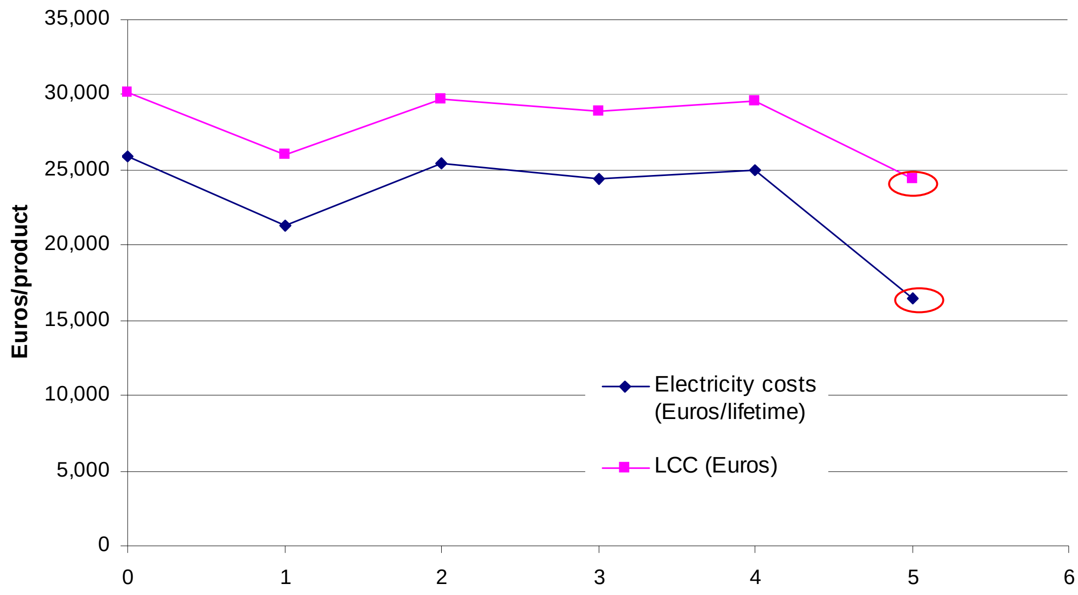


Figure 7-31: LCC curve – environmental performance expressed in total energy consumption (GER) for the base case RHF4

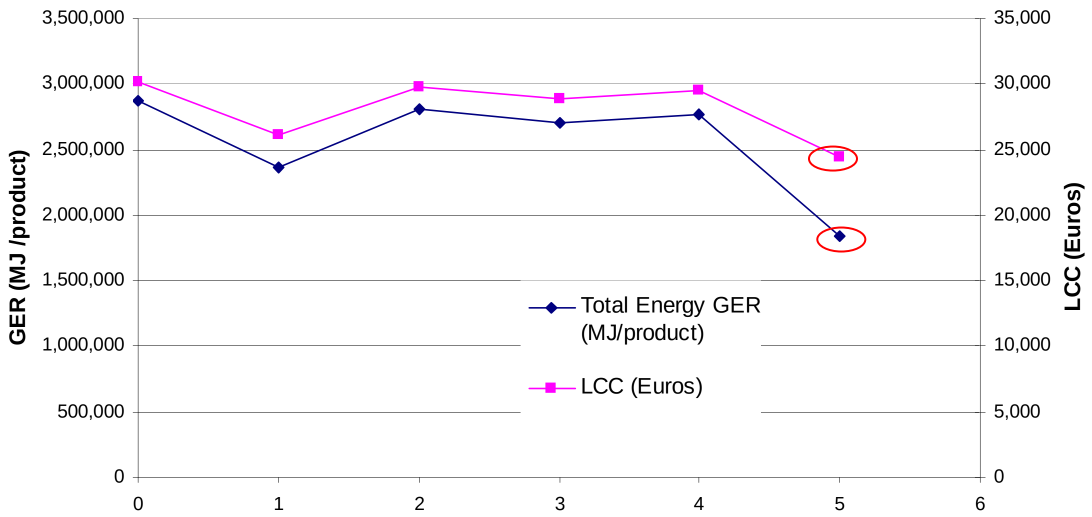
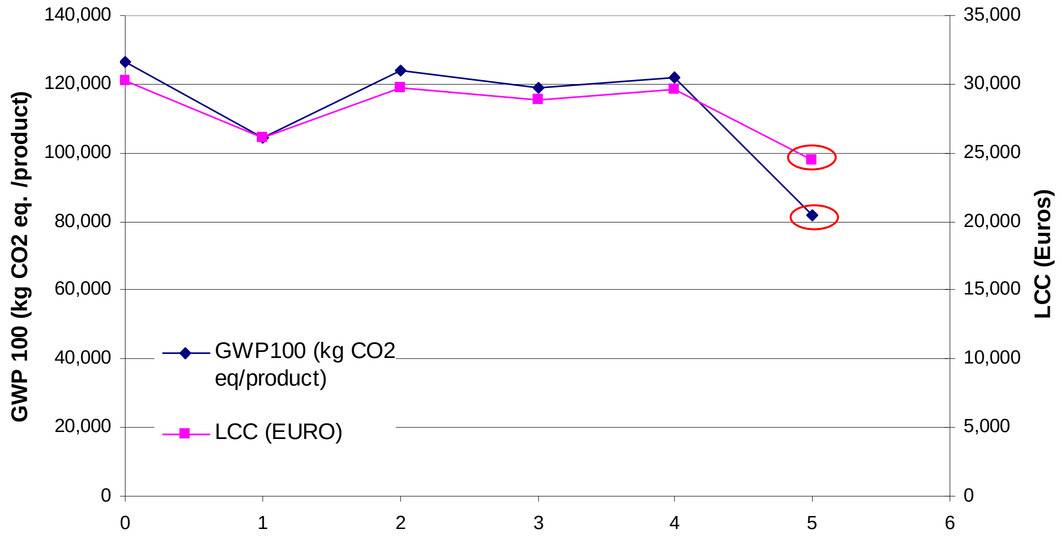


Figure 7-32: LCC curve – environmental performance expressed in GWP for the base case RHF4



7.2.2.2 EFFECT OF CUMULATING IMPROVEMENT OPTIONS

Any combination of the six individual improvement options is feasible except cumulating option 1 and option 5, as a glass lid is an alternative form of a night curtain. Therefore, combinations of up to 4 options were investigated.

- **Approach 1: cumulating options in the order of payback time**

The same approach as for the RCV2 is used here and three scenarios were considered: the first one with the use of a glass lid (and thus by excluding the night curtain), the second one with the use of a night curtain (and thus by excluding the glass lid, and the third one without a night curtain or a glass lid. The latter aims at identifying the best combination of individual improvement options which depends only on technical features.

- With glass lid

The different combinations ranking in the order of payback time and excluding option 1 (night curtain) are summarised in Table 7-23.

Moreover, the option with BAT and representing the LLCC is the combination option 2+3+4+5 which leads to 43.6 % reduction in electricity consumption during use phase and a 26 % lower LCC. Figure 7-33 presents the LCC and the electricity cost over the lifetime of the improved RHF4, which have the same aspect, and Figure 7-34 demonstrates the link between the electricity consumption and the LCC.

Table 7-23: Combinations of individual improvement options in the order of payback time for the base case RHF4 (with glass lid)

Combination	Options	Electricity costs (Euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base case RHF4	25,919	2,867,748	30,187	0	0	0	0
2	LSHE	25,400	2,811,689	29,735	0.87	50	2.0	+ 750 g copper
2+3	LSHE+Anti sweat control	23,876	2,646,837	28,428	0.95	215	7.88	+ 750 g copper + 150g controller board
2+3+4	LSHE+Anti sweat control+ECM fans	23,041	2,556,360	27,870	1.38	440	11.10	+ 750 g copper + 150g controller board + modified fans
2+3+4+5	LSHE+Anti sweat control+ECM fans+glass lid	14,631	1,648,992	22,339	2.36	2690	43.55	+ 750 g copper + 150g controller board + modified fans + 150 kg glass

Figure 7-33: LCC curve – environmental performance expressed in total electricity costs for the base case RHF4 (with glass lid)

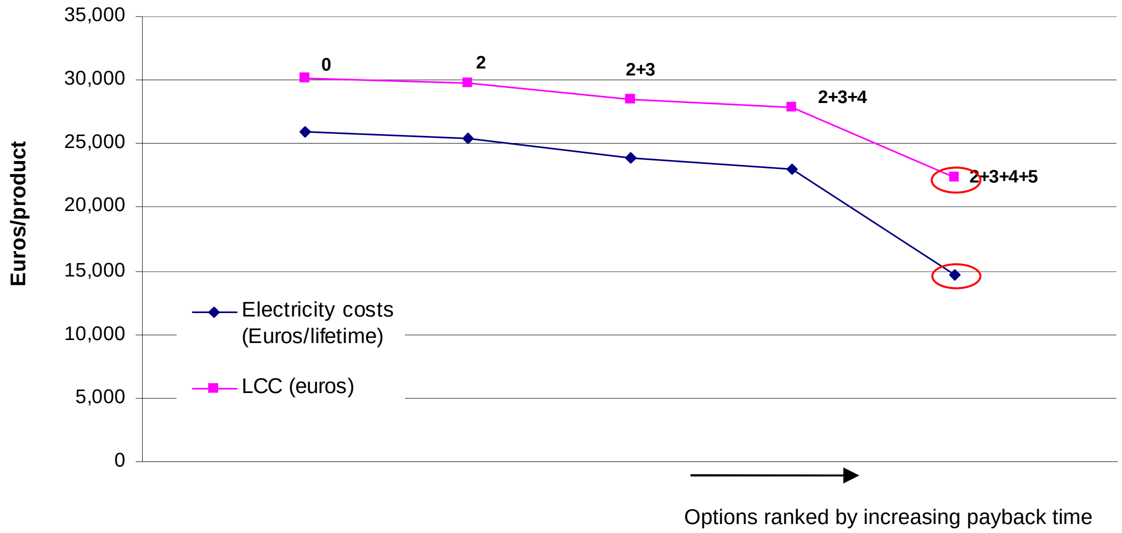
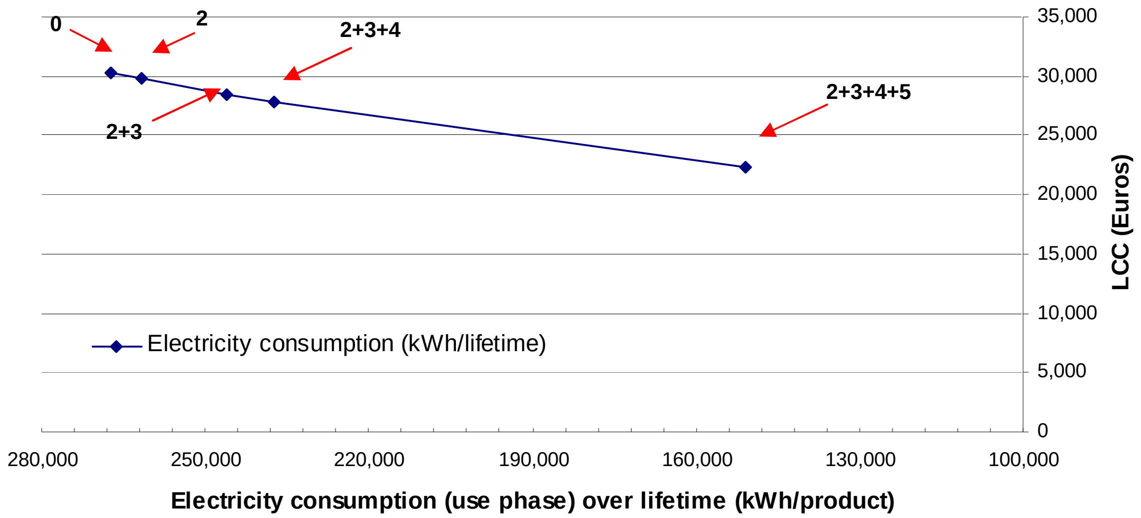


Figure 7-34: Energy consumption during use phase versus LCC for the base case RHF4 (with glass lid)



- Without glass lid (and with night curtain)

The different combinations ranking in the order of payback time and excluding option 5 (addition of a glass lid) are summarised in Table 7-24.

Figure 7-35 presents the LCC and the electricity cost over the lifetime of the improved RHF4, which have the same aspect, and Figure 7-36 demonstrates the link between the electricity consumption and the LCC.

Table 7-24: Combinations of individual improvement options in the order of payback time for the base case RHF4 (without glass lid)

Combination	Options	Electricity costs (Euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base case RHF4	25,919	2,867,748	30,187	0	0	0	0
1	Night curtain	21,253	2,364,020	26,063	0.77	400	18.0	+6kg Alu
1+2	Night curtain+LSHE	20,828	2,318,061	25,704	0.80	450	19.64	+6kg Alu + 750 g copper
1+2+3	Night curtain+LSHE+ Anti sweat control	19,578	2,182,904	24,667	0.87	615	24.46	+6kg Alu+ 750 g copper + 150g controller board
1+2+3+4	Night curtain+LSHE+ Anti sweat control+ ECM fans	18,893	2,108,709	24,257	1.08	840	27.11	+6kg Alu+ 750 g copper + 150g controller board +modified fans

The option with BAT and presenting the LLCC is the combination option 1+2+3+4 which leads to 27.1 % reduction in electricity consumption during the use phase, and a 19.6 % lower LCC.

Figure 7-35: LCC curve – environmental performance expressed in total electricity costs for the base case RHF4 (without glass lid)

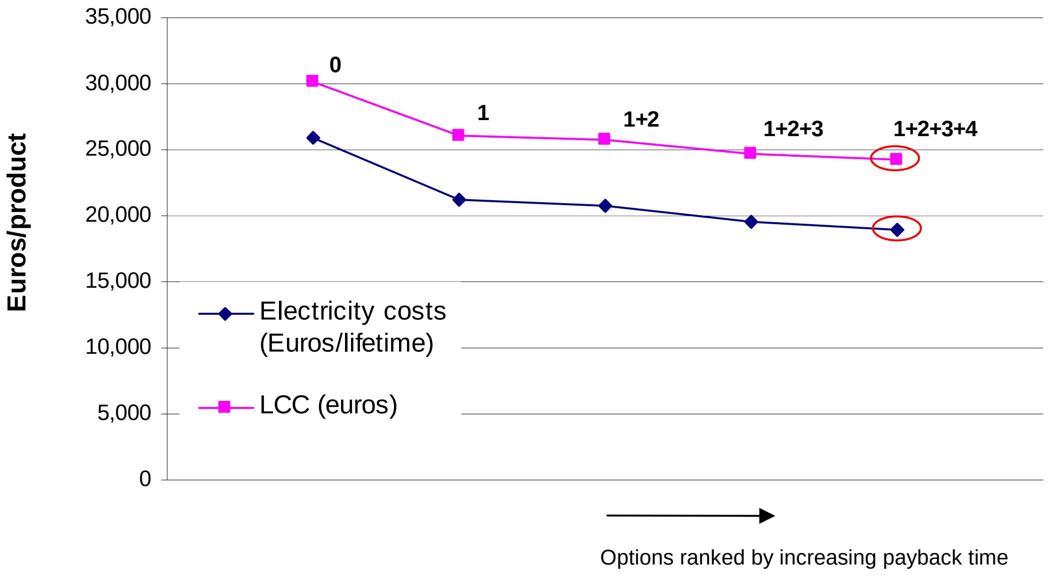
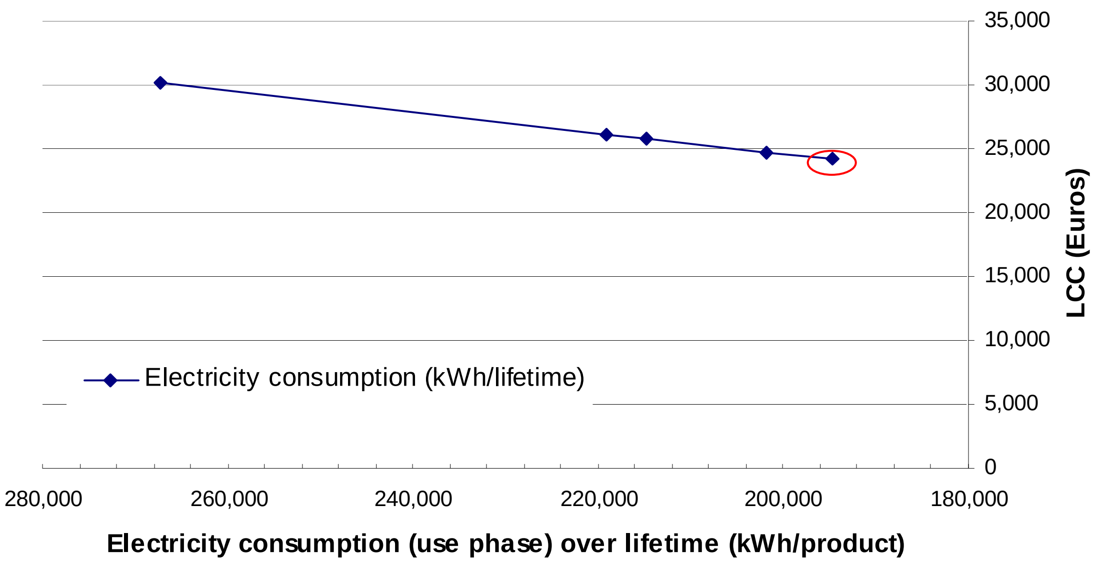


Figure 7-36: Energy consumption during the use phase versus LCC for the base case RHF4 (without glass lid)



- Without night curtain

When only considering improvement options that are not influenced by the end-user behaviour (i.e. without night curtain), the option 2+3+4 leads to the LLCC and BAT point (Figure 7-37 and Figure 7-38).

This combination allows 11.1 % reduction in electricity consumption during use phase and 7.7 % saving in LCC (Table 7-25).

Table 7-25: Combinations of individual improvement options in the order of payback time for the base case RHF4 (without night curtain)

Combination	Options	Electricity costs (euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base case RHF4	25,919	2,867,748	30,187	0	0	0	0
2	LSHE	25,400	2,811,689	29,735	0.87	50	2.0	+ 750 g copper
2+3	LSHE+Anti sweat control	23,876	2,646,837	28,428	0.95	215	7.88	+ 750 g copper + 150g controller board
2+3+4	LSHE+Anti sweat control+ECM fans	23,041	2,556,360	27,870	1.38	440	11.10	+ 750 g copper + 150g controller board + modified fans

Figure 7-37: LCC curve – environmental performance expressed in total electricity costs for the base case RHF4 (without night curtain)

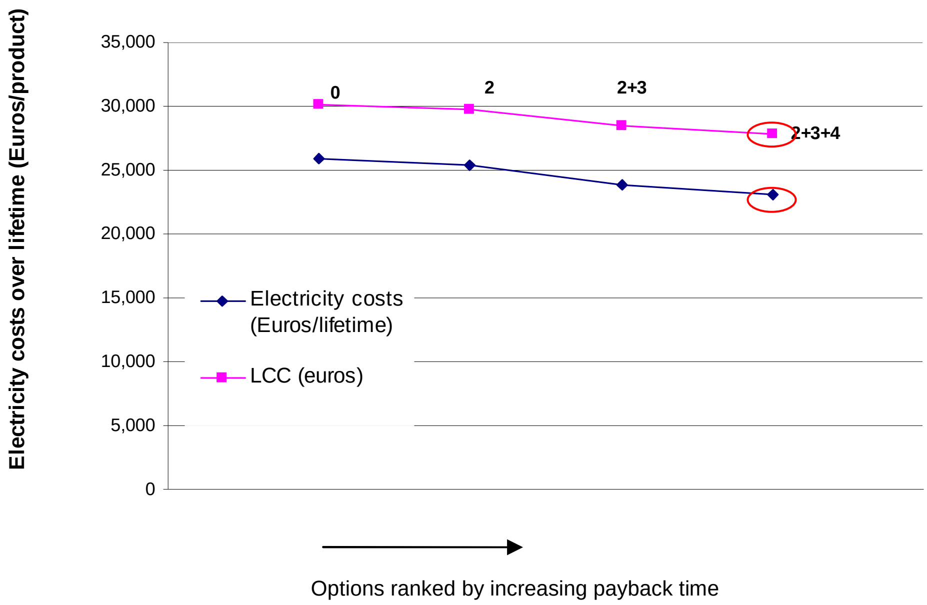
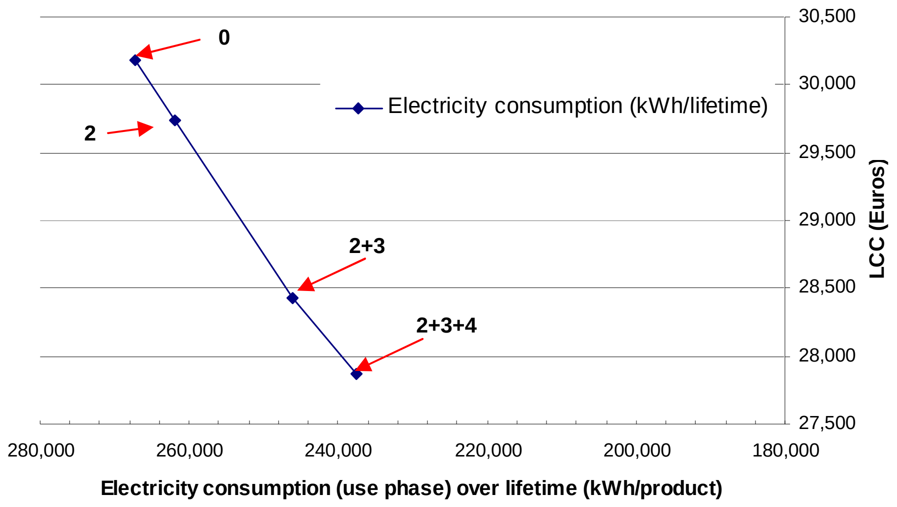


Figure 7-38: Energy consumption during use phase versus LCC for the base case RHF4 (without night curtain)



The results of the EcoReport for each combination of options from the three scenarios can be compared in terms of environmental impacts. Figure 7-39 to Figure 7-41 show the relative changes in the 15 indicators of the EcoReport and allow the identification of the most performing combination of improvement options for each environmental impact indicator.

Figure 7-39: Comparison of the cumulative options (resources and waste) for the base case RHF4

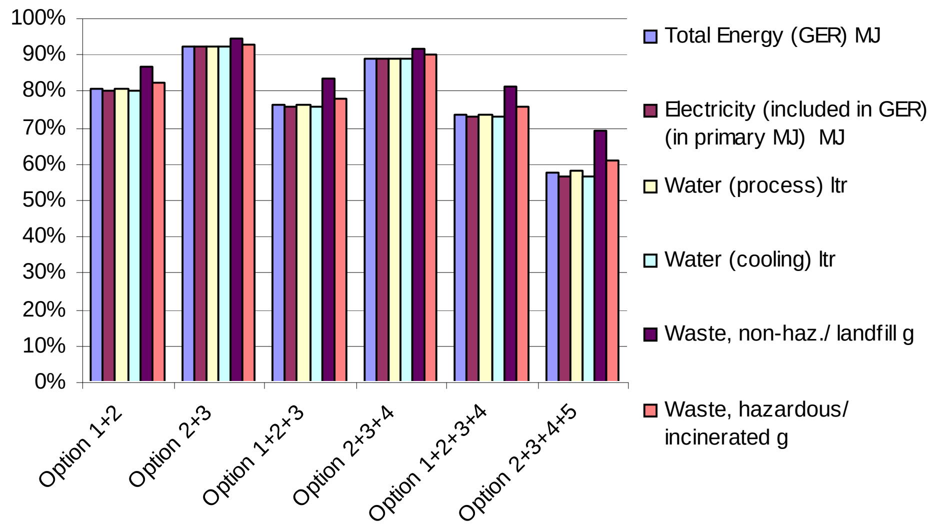


Figure 7-40: Comparison of the cumulative options (emissions to air) for the base case RHF4

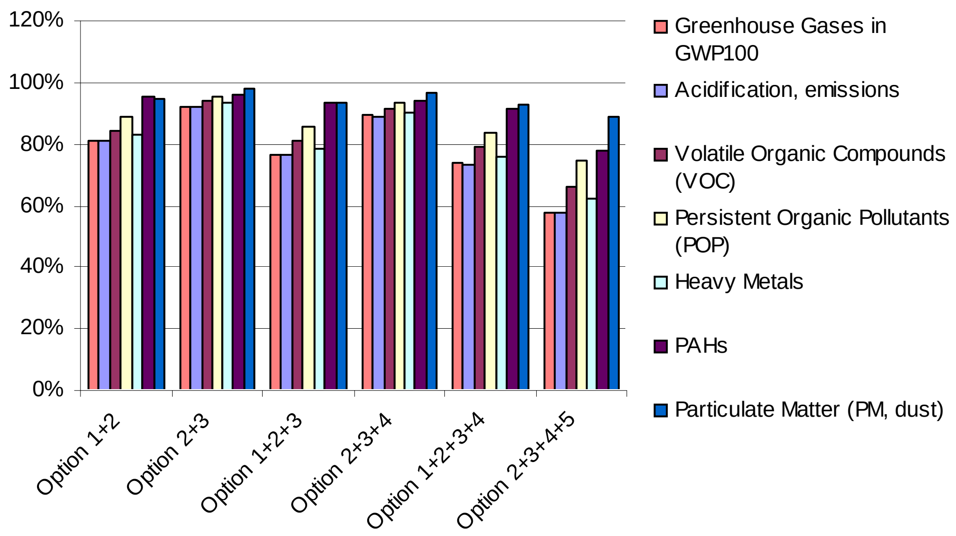
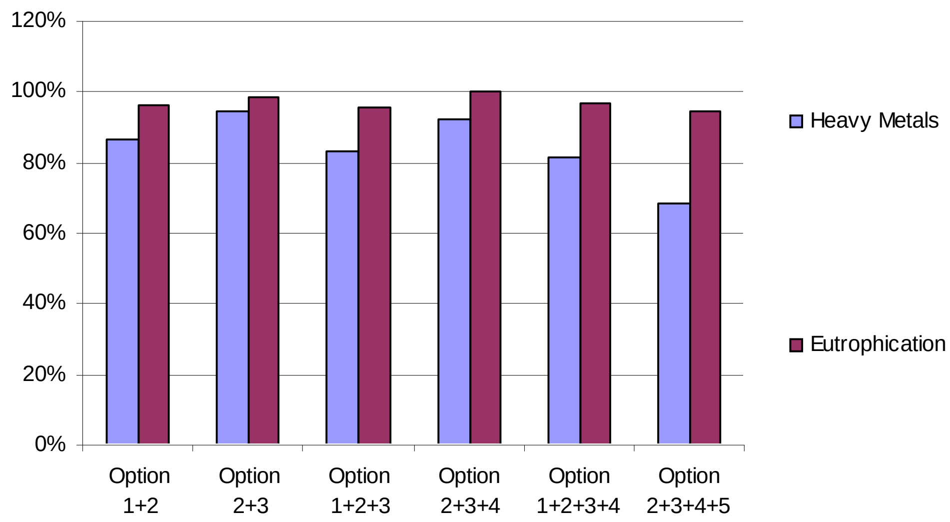


Figure 7-41: Comparison of the cumulative options (emissions to water) for the base case RHF4



For all 15 environmental indicators (2 other indicators are negligible for any option), the best performing option is the combination with the glass lid: 2+3+4+5, followed by the combination with the night curtain: 1+2+3+4. Finally, the third best performing combination is 1+2+3.

The highest relative reductions of impacts are observed amongst the following environmental impact indicators: water (cooling), total energy consumption over lifetime (GER), acidification emissions and GWP (Table 7-26). It is interesting to note that these indicators are the same as for the RCV2.

Table 7-26: Improvement potential for each environmental impact indicator for the base case RHF4

Indicator	Unit	Impact variation with least performing option	Impact variation with best performing option
Water (cooling)	g SO2 eq.	-1.99%	-43.43%
Total electricity (in primary MJ) (included in GER)	MJ	-1.99%	-43.30%
Total Energy (GER)	ltr	-1.95%	-42.50%
Acidification, emissions	mg Ni eq.	-1.94%	-42.40%
Greenhouse Gases in GWP100	g	-1.94%	-42.06%
Water (process)	MJ	-1.95%	-41.86%
Waste, hazardous/ incinerated	ltr	-1.80%	-38.83%
Heavy Metals	g	-1.74%	-37.98%
Volatile Organic Compounds (VOC)	g	-1.59%	-33.91%
Heavy Metals	g	-1.35%	-31.38%
Waste, non-haz./ landfill	kg CO2 eq.	-1.28%	-30.64%
Persistent Organic Pollutants (POP)	mg Hg/20	-1.16%	-25.62%
PAHs	ng i-Teq	-0.98%	-21.94%
Particulate Matter (PM, dust)	mg Ni eq.	-0.57%	-3.06%
Eutrophication	g PO4	1.23%	-0.06%
Ozone Depletion, emissions	mg R-11 eq.	negligible	negligible
Persistent Organic Pollutants (POP)	ng i-Teq	negligible	negligible

- **Approach 2: cumulating options in the order of LCC**

As for RCV2, this approach leads to combinations allowing a lower LCC and a higher reduction in electricity consumption during use phase for the same number of options in one combination, e.g. option 2+3 (LSHE+EEV as presented in Table 7-23) in the order of payback time, compared to option 5+3 (glass lid+anti sweat control as presented in Table 7-27) ranked by LCC.

Therefore, by using this approach, the combinations of options leading to the lower LCC and the higher electricity reduction were identified. However, the observed payback times are longer compared to combinations of individual options ranked in the order of the increasing payback time.

Following paragraphs provide complementary details on the combinations of options in the order of LCC for the three scenarios. The comparison of the effect of each combination of options on the 17 indicators is given in Annexe 7- 29 to Annexe 7-31.

- With glass lid

The summary of the EcoReport results for all possible combinations of options including the glass lid in the order of LCC is given in Table 7-27.

The BAT and LLCC point is the same as in the first approach: option 5+3+4+2 leading to 43.6 % of reduction in TEC, as presented in Figure 7-42 and Figure 7-43.

Table 7-27: Combination of individual options in the order of LCC for the base case RHF4 (with glass lid)

Combination	Options	Electricity costs (Euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base case RHF4	25,919	2,867,748	30,187	0	0	0	0
5	glass lid	16,458	1,846,668	24,445	2.40	2,250	36.5	+ 150 kg glass
5+3	glass lid+Antisweat control	15,471	1,739,892	23,666	2.30	2415	40.31	+ 150 kg glass + 150g controller board
5+3+4	glass lid+Antisweat control+ECM fans	14,929	1,681,261	23,398	2.16	2640	42.40	+ 150 kg glass + 150g controller board + modified fans
5+3+4+2	glass lid+Antisweat control+ECM fans+LSHE	14,631	1,648,992	23,163	2.36	2690	43.55	+ 150 kg glass + 150g controller board + modified fans + 750 g copper

Figure 7-42: LCC curve – environmental performance expressed in total electricity costs for the base case RHF4 (with glass lid)

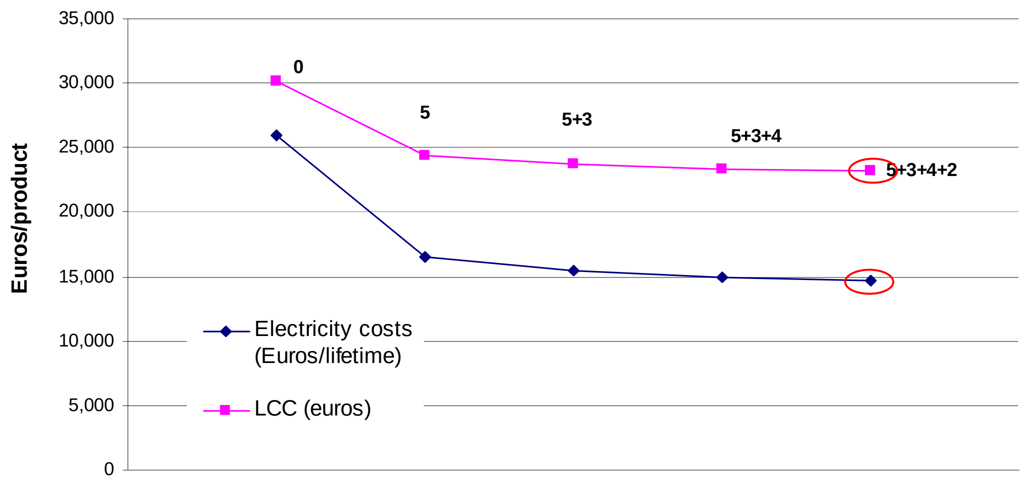
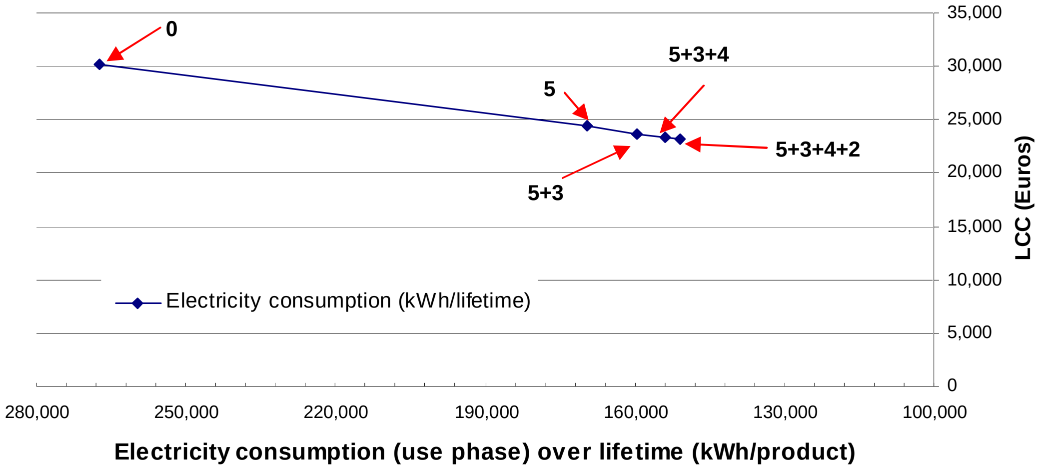


Figure 7-43: Energy consumption during use phase versus LCC for the base case RHF4 (with glass lid)



- Without glass lid (and with night curtain)

The summary of the EcoReport results for all possible combinations of options excluding the glass lid in the order of LCC is given in Table 7-28.

The BAT and LLCC point is the same as in the first approach: option 1+3+4+2 leading to 27.1 % of reduction in TEC, as presented in Figure 7-44 and Figure 7-45

Table 7-28: Combinations of individual improvement options in the order of LCC for the base case RHF4 (without glass lid)

Combination	Options	Electricity costs (Euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base case RHF4	25,919	2,867,748	30,187	0	0	0	0
1	Night curtain	21,253	2,364,020	26,063	0.77	400	18.0	+6kg Alu
1+3	Night curtain+Antisweat control	19,978	2,226,102	25,002	0.86	565	22.92	+6kg Alu + 150g controller board
1+3+4	Night curtain+Antisweat control+ ECM fans	19,279	2,150,394	24,578	1.07	790	25.62	+6kg Alu + 150g controller board + modified fans
1+3+4+2	Night curtain+Antisweat control+ ECM fans+LSHE	18,893	2,108,709	24,257	1.08	840	27.11	+6kg Alu + 150g controller board + modified fans + 750 g copper

Figure 7-44: LCC curve – environmental performance expressed in electricity costs for the base case RHF4 (without glass lid)

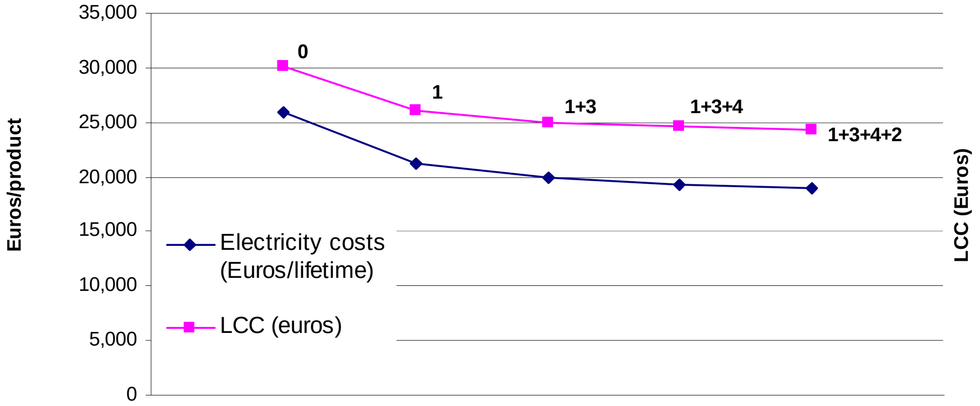
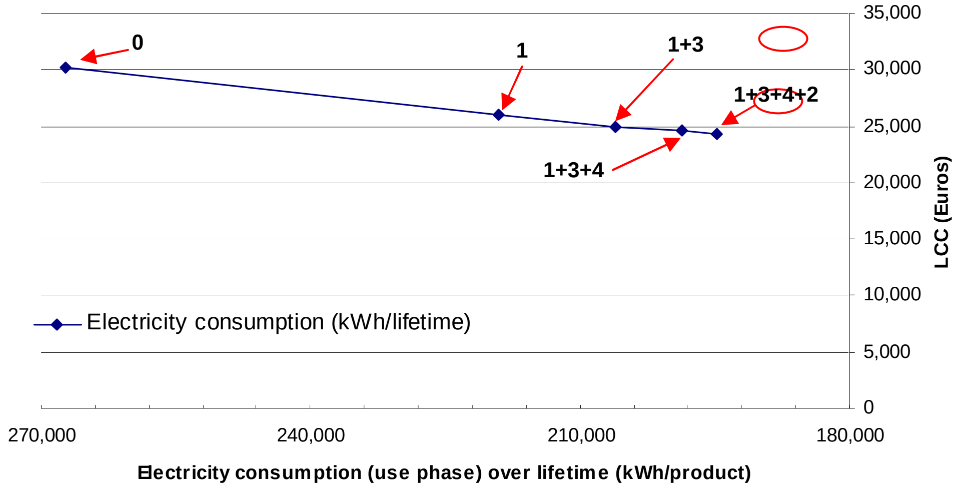


Figure 7-45: Energy consumption during use phase versus LCC for the base case RHF4 (without glass lid)



- Without night curtain

The summary of the EcoReport results for all possible combinations of options without using the night curtain in the order of LCC is given in Table 7-29.

The BAT and LLCC point is the same as in the first approach: option 3+4+2 leading to 11.1 % of reduction in TEC, as presented in Figure 7-46 and Figure 7-47.

Table 7-29: Combinations of individual improvement options in the order of LCC for the base case RHF4 (without night curtain)

Combination	Options	Electricity costs (Euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base case RHF4	25,919	2,867,748	30,187	0	0	0	0
3	Anti sweat control	24,363	2,699,530	28,849	0.95	165	6.0	+ 150g controller board
3+4	Anti sweat control+ECM fans	23,511	2,607,207	28,274	1.46	390	9.29	+ 150g controller board
3+4+2	Anti sweat control+ECM fans+LSHE	23,041	2,556,360	27,870	1.38	440	11.10	+ 150g controller board + modified fans + 750 g copper

Figure 7-46: LCC curve – environmental performance expressed in total electricity costs for the base case RHF4 (without night curtain)

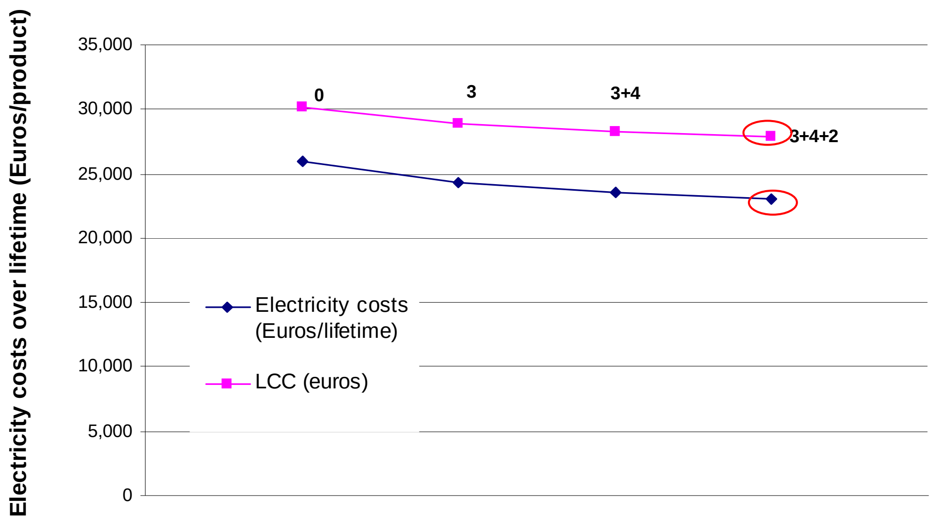
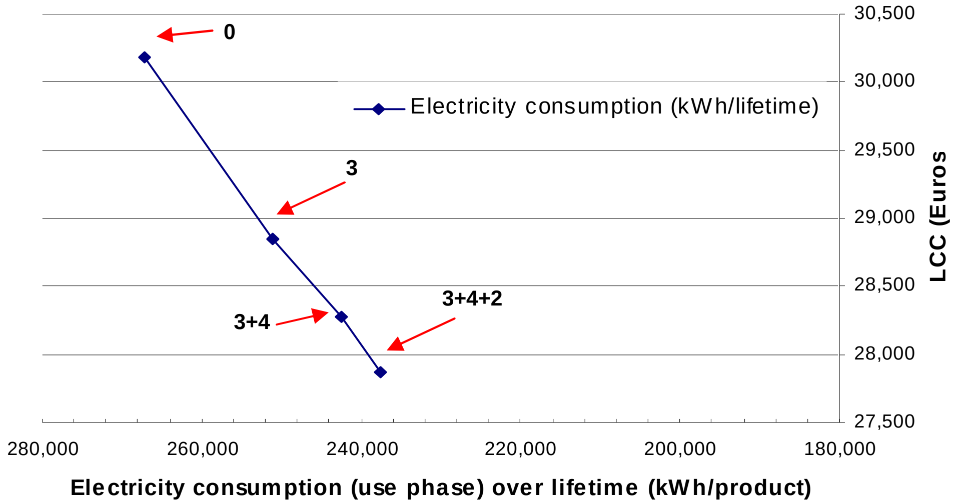


Figure 7-47: Energy consumption during use phase versus LCC for the base case RHF4 (without night curtain)



7.2.3 BASE CASE BEVERAGE COOLER

7.2.3.1 INDIVIDUAL IMPROVEMENT OPTIONS

The preliminary EcoReport analysis results of the various improvement options applicable to the base case beverage cooler are shown in Table 7-30. In this table, the options are ranked according to their payback time.

Table 7-30: Summary of the cost and benefit effects of implementing individual improvement options for the base case beverage cooler

Option	Option description	Total Energy GER (MJ/product)	Electricity costs (Euros/lifetime)	LCC (Euros)	Payback time (year)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base Case beverage cooler	225,124	2,159	3,032	0.00	0	0	0
1	Increase of the heat exchangers' surface area (condenser and evaporator)	192,736	1,835	2,721	0.25	10	15	in progress
2	High efficiency compressor	216,487	2,073	2,955	0.74	8	4	0
3	Glass door insulated with argon instead of air	203,532	1,943	2,839	0.74	20	10	0
4	ECM fans	195,948	1,868	2,796	1.37	50	13.5	modification of the fan motors
5	Light Control	208,930	1,997	2,903	1.48	30	7.5	0
6	Compressor modulation Variable speed compressor	199,213	1,900	2,828	1.54	50	12	0
7	Efficient Lights	217,567	2,084	2,973	1.59	15	3.5	0
8	Increase of the insulation thickness (25 mm)	212,787	2,030	2,957	3.09	50	6	increase in the mass of polyurethane and cyclopentane

The graph (Figure 7-48) allows the identification of the BAT and LLCC options. Figure 7-49 and Figure 7-50 allow the same conclusions using different environmental indicators as reference (GER and GWP).

Over 60 % of the LCC is due to the electricity cost. Moreover, the environmental impacts in all categories are mainly due to the electricity consumption during the use phase (see Task 5, section 5.2.2.1.). This explains why the electricity costs and LCC curve have the same aspect, why the BAT and LLCC option match and why the electricity costs and GER correlate closely with other impacts such as the GWP (Figure 7-50).

In the case of the base case beverage cooler, the BAT option with reference to electricity consumption during use phase (electricity costs) is the increase in the size of the heat exchangers' surface (option 1).

Figure 7-48: LCC curve - environmental performance expressed in total electricity costs for the base case beverage cooler

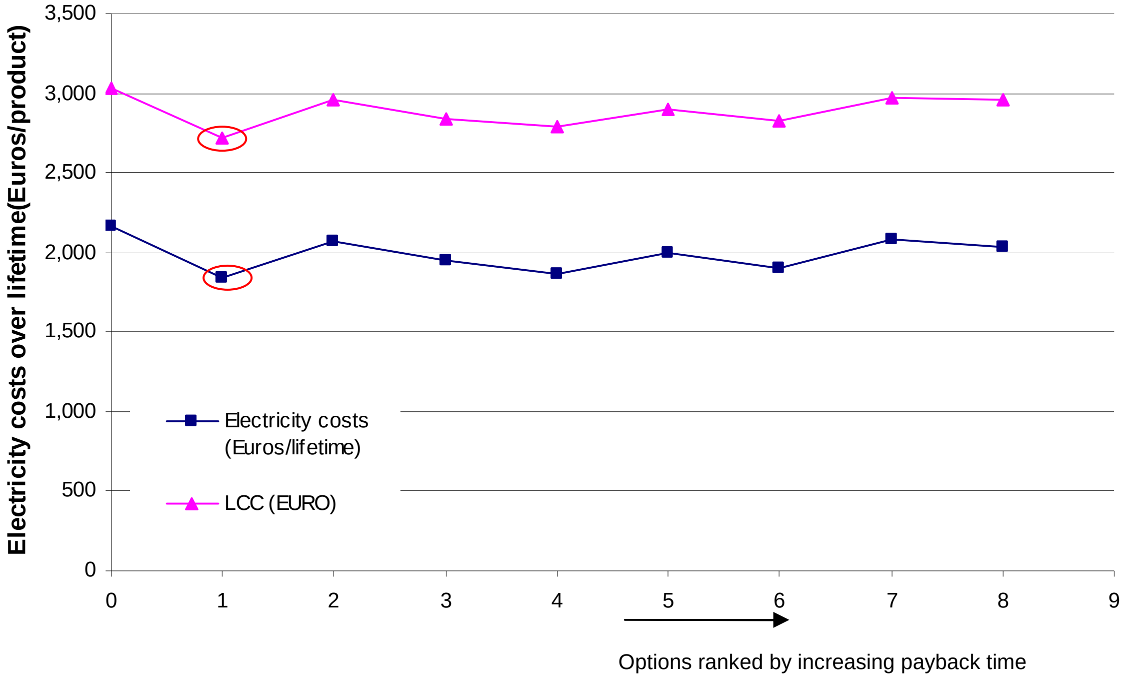


Figure 7-49: LCC curve - environmental performance expressed in total energy consumption (GER) for the base case beverage cooler

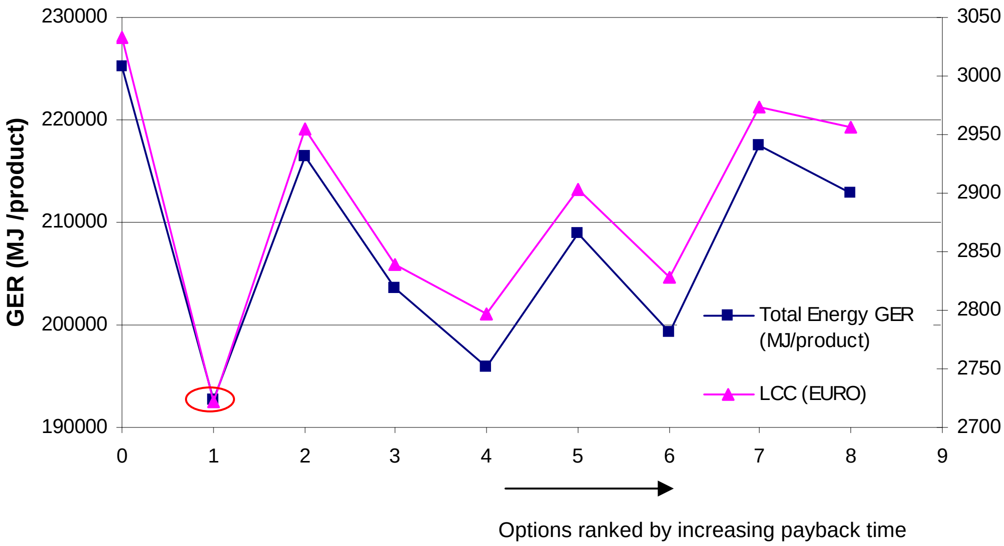
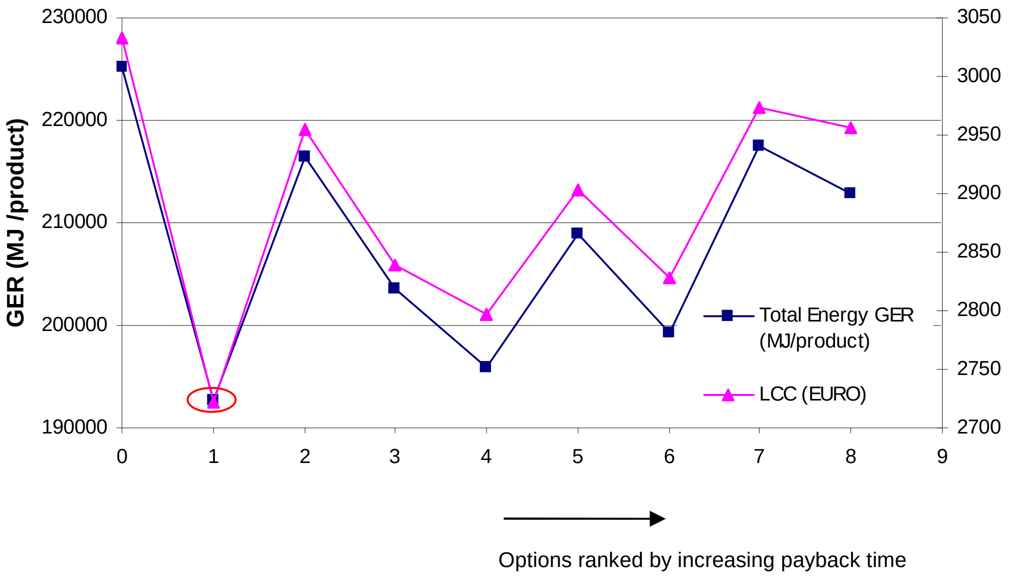


Figure 7-50: LCC curve - environmental performance expressed in GWP for the base case beverage cooler



7.2.3.2 EFFECT OF CUMULATING IMPROVEMENT OPTIONS

According to manufacturers, it is technically feasible to combine all 8 options in the same cooler. There is no technical restriction in combining them but the cost. Indeed, most of time the buyers of such equipment are not the end-users but a bottling company which provides the end-user (e.g. shop keeper) a beverage cooler free of charge for the display of its products, and therefore the owner of the equipment is not interested in investing in energy saving options as he is not the one paying the electricity bills. As a consequence, in real life situation there is no actual payback time for the equipment owner (e.g. bottling company) and the choice of the beverage cooler is mainly driven by the purchase price.

Also bottling companies usually buy equipment in big quantities (thousand of display cabinets a year) and therefore even an improvement option with a low cost increase in purchase price would imply great expenses for the company with no benefits in terms of payback time and energy savings as they are not the one operating the appliances.

- **Approach 1: cumulating options in the order of payback time**

Figure 7-51 plots the electricity costs and the LCC resulting from the implementation of each combination of improvement options.

Once again, the LCC curve closely matches the electricity costs curve. This can be explained by the fact that over 60 % of the LCC is due to the electricity cost. The correlation between LCC and electricity consumption during use phase is further illustrated in Figure 7-52.

The resulting improvement potential in the case of the simultaneous implementation of different options is calculated with the formula page 31.

When the cumulated individual improvement options affect the same component, it is assumed that the resulting improvement potential is lower. Therefore, when lighting management system is combined with the use of a more efficient lighting installation (options 6 and 7); the resulting improvement potential for the option 7 is 3.2 % reduction in TEC. Also, when combining a high efficiency compressor (4 % TEC savings) and a compressor modulation system (12 % TEC savings), it was assumed that the resulting TEC savings is of 10 % for option 6 (compressor modulation).

The payback times are not significantly high and do not reach longer than 1.66 years (see Table 7-31). Figure 7-48 shows that the combination of the 8 options is the improvement option leading to the LLCC which coincides with the BAT option as well. This option (1+2+3+4+5+6+7+8) could lead to a LCC reduction of 28.5 % and electricity consumption reduction of 51.9 % (Table 7-30).

Table 7-31: Combinations of individual improvement options in the order of payback time for the base case beverage cooler

Combination	Options	Electricity costs (Euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	cost increase (euros)	TEC savings (%)	BOM modification
0	Base Case BvC	2159	225124	3032	0.00	0	0	0
1	Increase of the heat exchangers' surface (condenser and evaporator)	1835	192736	2721	0.25	10	15	assumed negligible
1+2	Increase of the heat exchangers' surface (condenser and evaporator) + High efficiency compressor	1762	185394	2657	0.36	18	18.4	assumed negligible
1+2+3	Increase of the heat exchangers' surface (condenser and evaporator) + High efficiency compressor + Glass door insulated with argon instead of air	1586	167775	2503	0.53	38	26.56	assumed negligible
1+2+3+4	Increase of the heat exchangers' surface (condenser and evaporator) + High efficiency compressor + Glass door insulated with argon instead of air + ECM fans	1372	146341	2344	0.89	88	36.47	modified fans

1+2+3+4+5	Increase of the heat exchangers' surface (condenser and evaporator) + High efficiency compressor + Glass door insulated with argon instead of air + ECM fans + light control	1269	136054	2274	1.06	118	41.24	modified fans
1+2+3+4+5+ 6	Increase of the heat exchangers' surface (condenser and evaporator) + High efficiency compressor + Glass door insulated with argon instead of air + ECM fans + light control + Compressor modulation (Variable speed drive)	1142	123366	2201	1.32	168	47.11	modified fans
1+2+3+4+5+ 6+7	Increase of the heat exchangers' surface (condenser and evaporator) + High efficiency compressor + Glass door insulated with argon instead of air+Compressor modulation (Variable speed drive) + ECM fans + light control + light improvement	1105	119712	2181	1.39	183	48.81	modified fans
1+2+3+4+5+ 6+7+8	Increase of the heat exchangers' surface (condenser and evaporator) + High efficiency compressor + Glass door insulated with argon instead of air+Compressor modulation (Variable speed drive) + ECM fans + light control + light improvement + increase of the insulation thickness	1039	113079	2169	1.66	233	51.88	increase in the mass of polyurethane and cyclopentane and modification of the fan motor

Figure 7-51: LCC curve - environmental performance expressed in total electricity costs for the base case beverage cooler

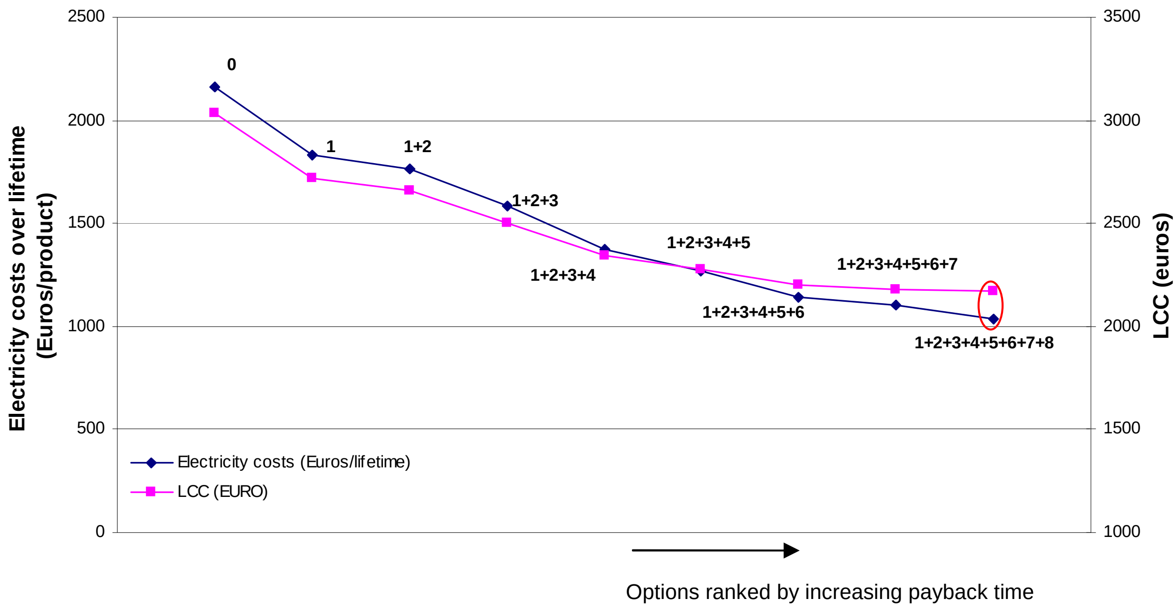


Figure 7-52: Energy consumption during use phase versus LCC for the base case beverage cooler

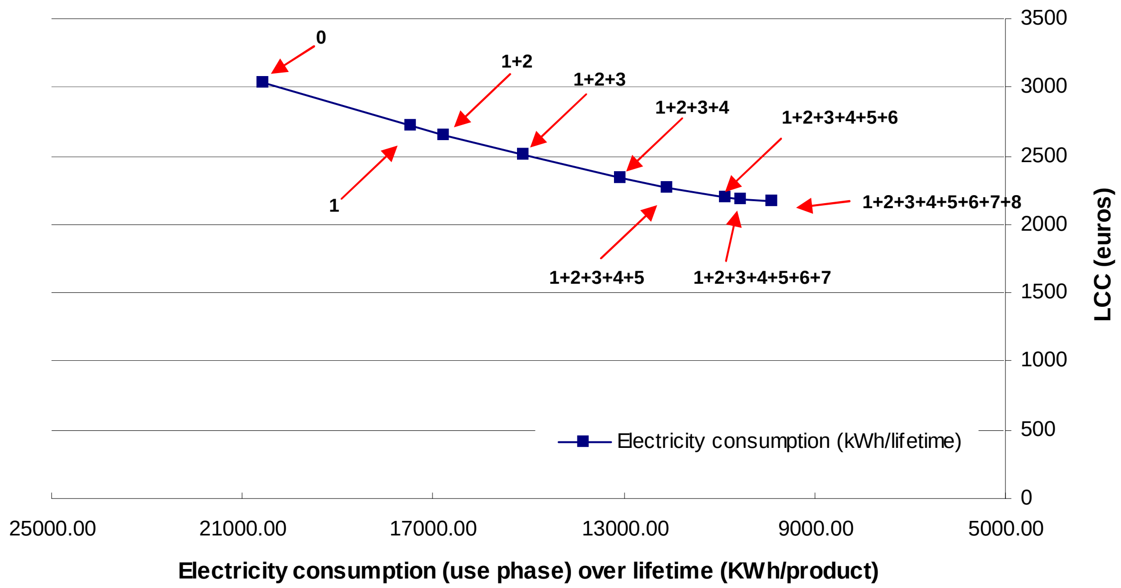


Figure 7-53 to Figure 7-55 show the relative changes in the 15 indicators of the EcoReport which are not negligible and allow the identification of the option which leads to the highest reduction for each environmental impact.

Figure 7-53: Comparison of the cumulative options (resources and waste) for the base case beverage cooler

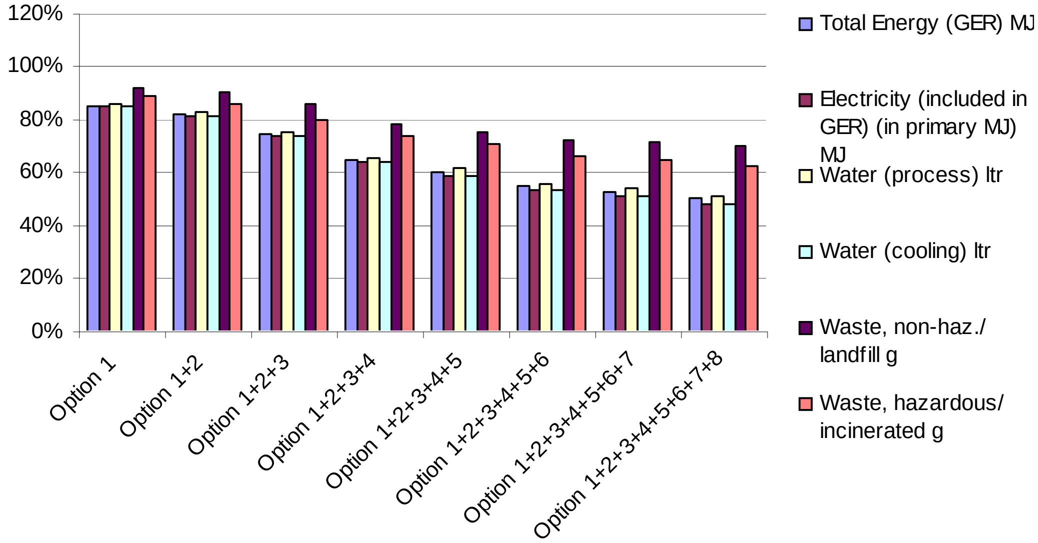


Figure 7-54: Comparison of the cumulative options (Emissions to air) for the base case beverage cooler

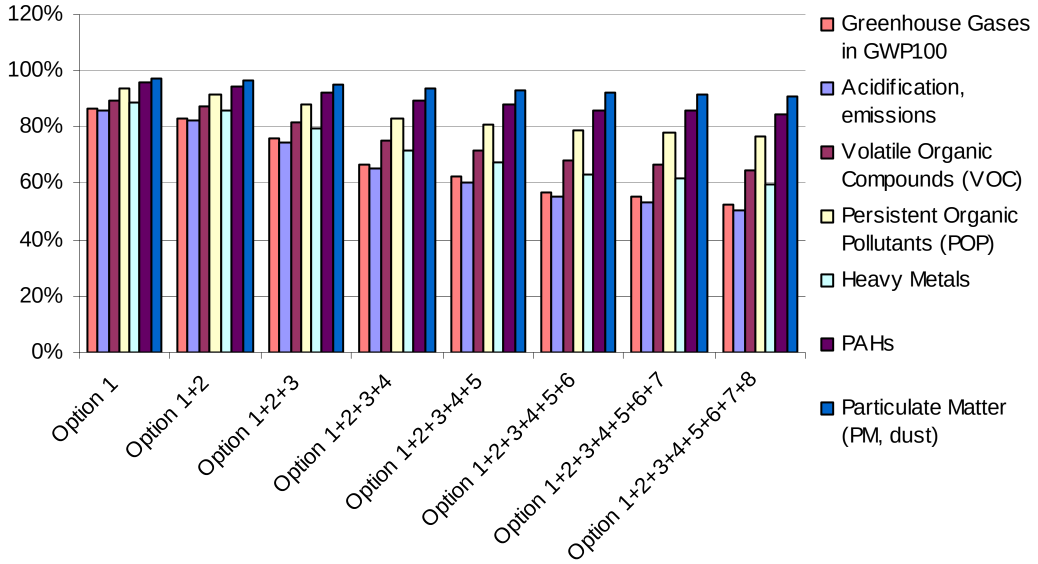
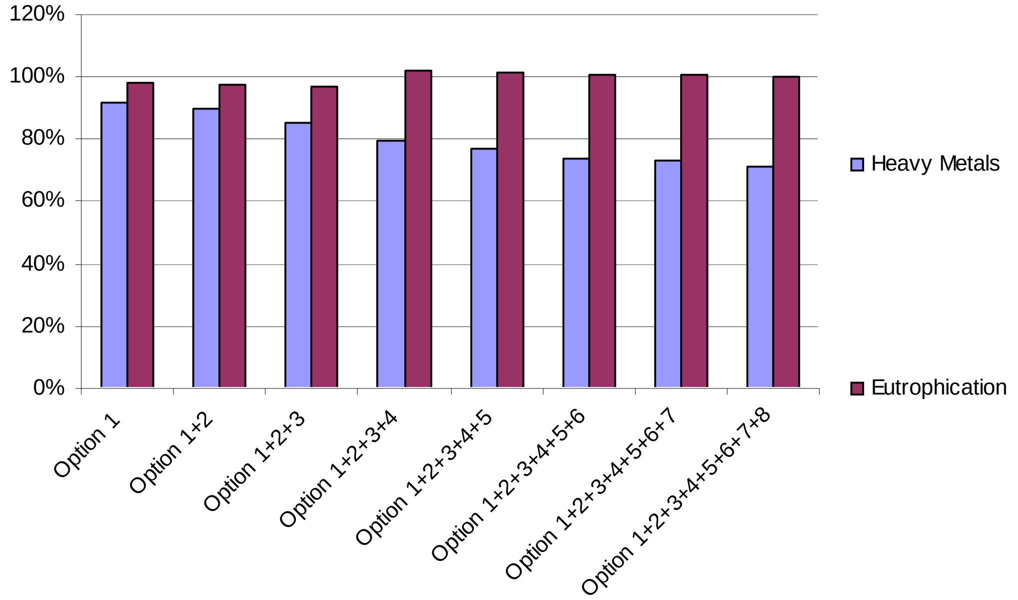


Figure 7-55: Comparison of the cumulative options (Emissions to water) for the base case beverage cooler



For all impacts except the eutrophication, the full combination of the 8 options leads to the highest reduction compared to the base case beverage cooler. It is followed by option 1+2+3+4+5+6+7 and option 1+2+3+4+5+6. This ranking corresponds to the LCC and total electricity consumption during lifetime. For the eutrophication, the most performing option is option 1+2+3, followed by option 1+2 and option 1 which are the three combinations not including the ECM fans. The epoxy in the motors of these fans is responsible of the higher eutrophication value (option 1+2+3+4 compared to option 1+2+3). When adding other improvement options to the base case (e.g. option 1+2+3+4+5) the eutrophication figure decreases again due to the positive effect of the energy savings.

The highest relative reductions of impacts are observed among the following environmental impact indicators: water (cooling), total electricity consumption over lifetime, Acidification emissions and GWP (see Table 7-32).

Table 7-32: Improvement potential for each environmental impact indicator for the base case beverage cooler

Indicator	Unit	Impact variation with least performing option	Impact variation with best performing option
Water (cooling)	g SO2 eq.	-3.48%	-51.50%
of which, electricity (in primary MJ)	MJ	-3.47%	-51.48%
Total Energy (GER)	ltr	-3.36%	-49.77%
Acidification, emissions	g	-3.32%	-49.44%
Water (process)	MJ	-3.26%	-48.38%
Greenhouse Gases in GWP100	mg Ni eq.	-3.20%	-47.39%
Heavy Metals	g	-2.66%	-40.29%
Waste, hazardous/ incinerated	kg CO2 eq.	4.91%	-37.23%
Volatile Organic Compounds (VOC)	g	-2.38%	-35.25%
Waste, non-haz./ landfill	ltr	-1.86%	-29.94%
Heavy Metals	g	6.00%	-28.50%
Persistent Organic Pollutants (POP)	mg Hg/20	-1.53%	-23.58%
PAHs	ng i-Teq	5.52%	-15.27%
Particulate Matter (PM, dust)	mg Ni eq.	2.75%	-8.90%
Eutrophication	g PO4	30.51%	-3.21%
Ozone Depletion, emissions	mg R-11 eq.	negligible	negligible
Persistent Organic Pollutants (POP)	ng i-Teq	negligible	negligible

- **Approach 2: cumulating options in the order of LCC**

The combinations obtained are different from when cumulating in the order of payback time when proceeding in the order of LCC. They lead to lower LCC and reduced environmental impacts for the same number of options in one combination (Table 7-32). For example, the combination 1+2 reduces the GER to about 18.4 % compared to 26.5 % with the combination 1+4 (in the order of LCC).

The comparison of the effects of each combination of options is given in Annexe 7-32 to Annexe 7- 35. However, the option with BAT and leading to the LLCC is once again the full combination of the eight options (Figure 7-56).

Table 7-33: Combinations of individual improvement options in the order of LCC for the base case beverage cooler

Combination	Options	Electricity costs (Euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	cost increase (euros)	TEC savings (%)	BOM modification
0	Base Case BvC	2,159	225,124	3,032	0.00	0	0	0
1	Increase of the heat exchangers'surface (condenser and evaporator)	1,835	192,736	2,721	0.25	10	15	Estimated negligible
1+4	Increase of the heat exchangers'surface (condenser and evaporator) + ECM fans	1,588	167,932	2,529	0.84	60	26.475	Estimated negligible
1+4+6	Increase of the heat exchangers'surface (condenser and evaporator) + Compressor modulation (Variable speed drive) + ECM fans	1,397	148,881	2,393	1.15	110	35.298	Estimated negligible
1+4+6+3	Increase of the heat exchangers'surface (condenser and evaporator) + Glass door insulated with argon instead of air+Compressor modulation (Variable speed drive) + ECM fans	1,257	134,911	2,275	1.15	130	41.77	modified fans
1+4+6+3+5	Increase of the heat exchangers'surface (condenser and evaporator) + Glass door insulated with argon instead of air+Compressor modulation (Variable speed drive) + ECM fans + light control	1,163	125,481	2,214	1.28	160	46.14	modified fans
1+4+6+3+5 +2	Increase of the heat exchangers'surface (condenser and evaporator) + High efficiency compressor + Glass door insulated with argon instead of air+Compressor modulation (Variable speed drive) + ECM fans + light control	1,142	123,366	2,201	1.32	168	47.11	modified fans

1+4+6+3+5 +2+8	Increase of the heat exchangers'surface (condenser and evaporator) + High efficiency compressor + Glass door insulated with argon instead of air+Compressor modulation (Variable speed drive) + ECM fans + light control + increase of the insulation thickness	1,073	116,514	2,187	1.61	218	50.29	modified fans
1+4+6+3+5 +2+8+7	Increase of the heat exchangers'surface (condenser and evaporator) + High efficiency compressor + Glass door insulated with argon instead of air+Compressor modulation (Variable speed drive) + ECM fans + light control + light improvement + increase of the insulation thickness	1,039	113,079	2,169	1.66	233	51.88	increase in the mass of polyurethane and cyclopentane and modification of the fan motor

Figure 7-56: LCC curve – environmental performance expressed in total electricity costs for the base case beverage cooler

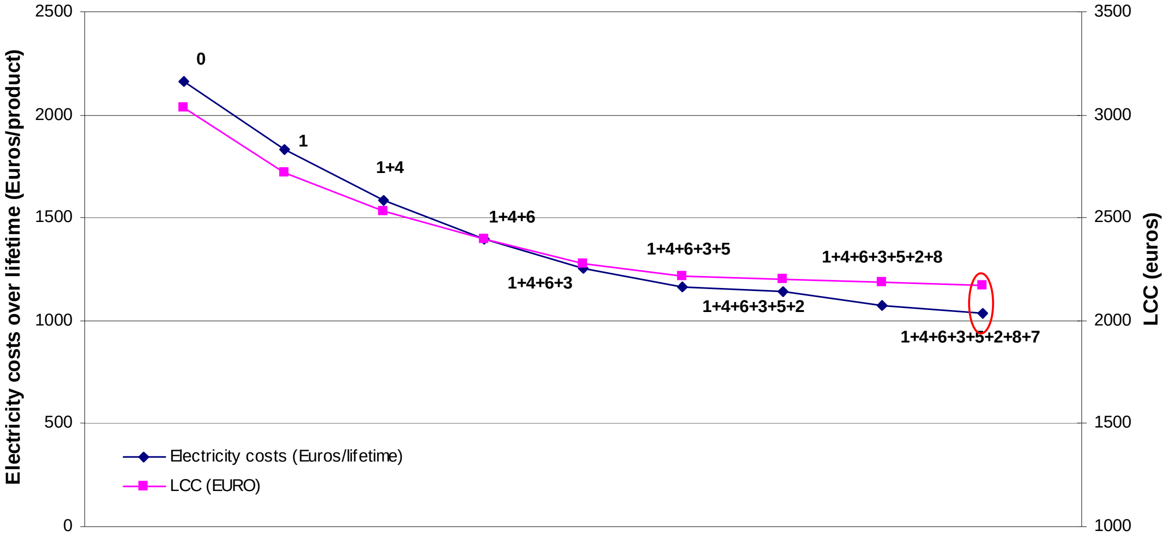
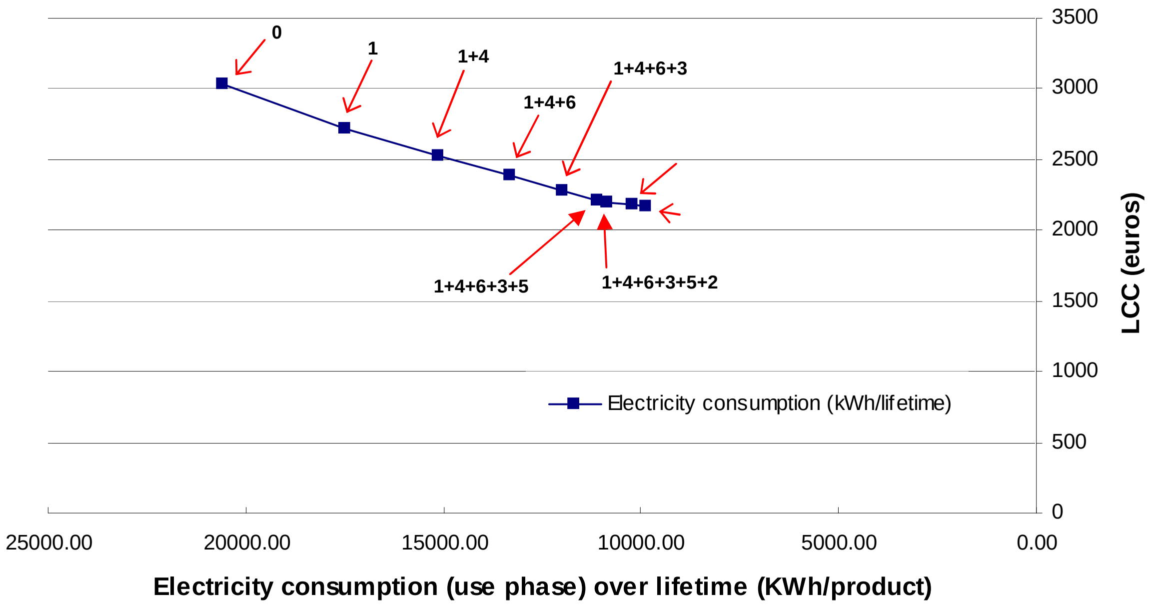


Figure 7-57: Electricity consumption during use phase versus LCC for the base case beverage cooler



7.2.4 BASE CASE ICE CREAM FREEZER

7.2.4.1 INDIVIDUAL IMPROVEMENT OPTIONS

The EcoReport analysis of the base case ice cream freezer to which each individual improvement option is applied according to the payback time is given in Table 7-34**.**

The options are similar to the ones applicable to the base case beverage cooler. However, in the case of ice cream freezer, the options related to the lighting systems and to the evaporator fan are not relevant (generally ice cream freezers do not have lights and static evaporation systems).

Table 7-34: Summary of the cost and benefit effects of implementing individual improvement options for the base case ice cream freezer

Option	Option description	Total Energy GER (MJ/product)	Electricity costs (Euros/lifetime)	LCC (Euros)	Payback time (year)	cost increase (euros)	TEC savings (%)	BOM modification
0	Base Case ice cream freezer	149680	1380	2226	0.00	0	0	0
1	High efficiency compressor	143058	1313	2169	0.97	8	4.8	Estimated negligible
2	Increase of the heat exchangers' surface	144161	1325	2184	1.81	12.5	4	Estimated negligible
3	ECM fans	142758	1311	2184	2.90	25	5	modification of the fan motor
4	Compressor modulation (Variable speed drive)	134504	1228	2155	3.95	75	11	Estimated negligible

The LCC curve (Figure 7-58) allows the identification of the BAT and LLCC option. As for the other base cases studied so far, these two points coincide and Figure 7-59 and Figure 7-60 show the same results.

Over 50 % of the LCC is due to the electricity costs (see task 5, section 5.3.2.2). Moreover, the environmental impacts in all categories of the EcoReport are mainly due to the electricity consumption during use phase (see task 5, section 5.2.2.2). Therefore the LCC and the total electricity costs curves have the same aspect and the BAT matched the LLCC point. Also this explains why the electricity costs correlate closely with the GER and GWP.

The option with BAT and LLCC is option 4: using a compressor modulation (variable speed drive). This option leads to a 11 % reduction in TEC and 3.1 % reduction in LCC.

Figure 7-58: LCC curve - environmental performance expressed in total electricity costs for the base case ice cream freezer

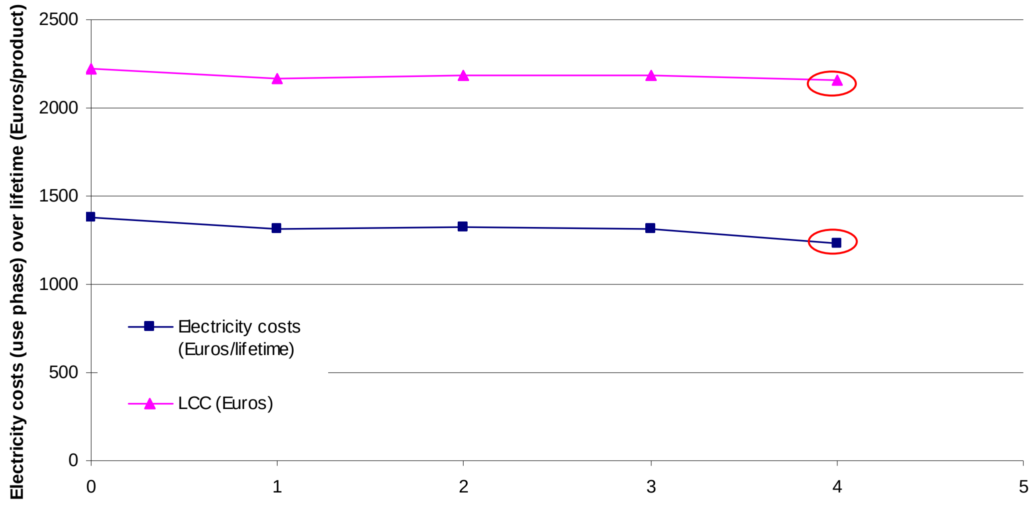


Figure 7-59: LCC curve - environmental performance expressed in total energy consumption (GER) for the base case ice cream freezer

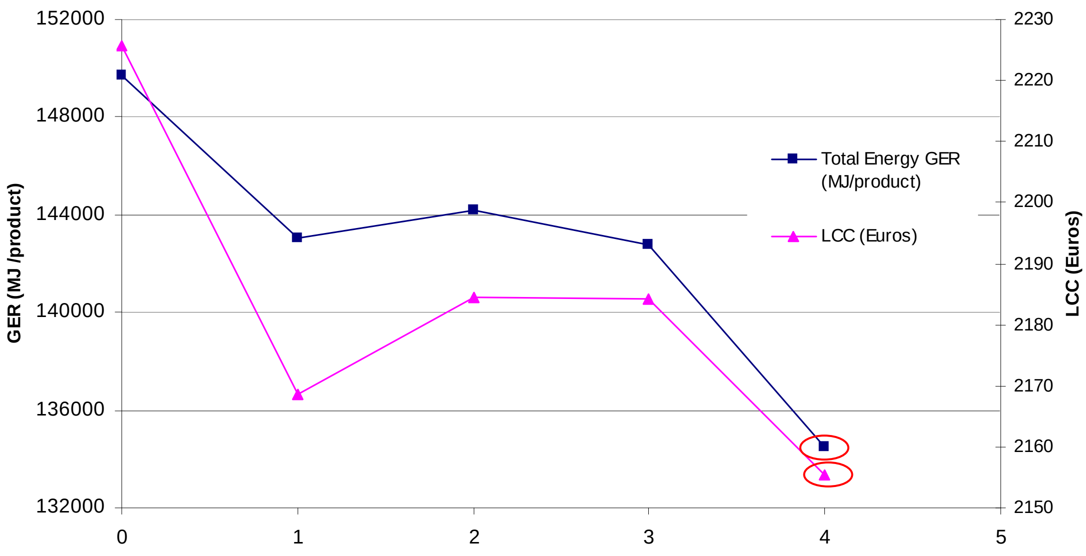
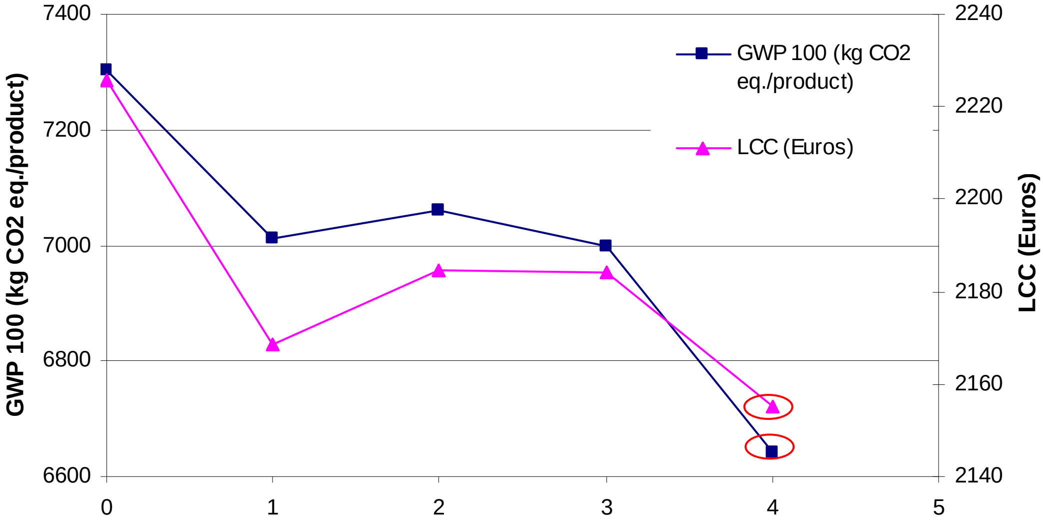


Figure 7-60: LCC curve - environmental performance expressed in GWP for the base case ice cream freezer



7.2.4.2 Effect of cumulating improvement options

It is technically possible to combine all improvement options; the only restriction is the cost. As for beverage cooler, most of the time the ice cream freezers are not owned by the equipment users. Therefore, buyers of such appliances have no interest in energy saving options even if they represent a low increase in product cost and a short payback time.

- **Approach 1: cumulating options in the order of payback time**

Figure 7-61 plots the electricity costs (use phase) and the LCC resulting from the implementation of the various combinations of options to the base case ice cream freezer. As for the base case beverage cooler, it is assumed that when the cumulated individual improvement options affect the same component, it is the resulting improvement potential is lower. Therefore, when combined with the option 1 (efficient compressor), the improvement potential of the option 4 (compressor modulation) is estimated to 9 % instead of 11 %.

Figure 7-61 shows that the option 1+2+3+4 is the one with BAT and leading to the LLCC. This improvement option could lead to a LCC reduction of 7.1 % and an electricity consumption reduction of 21 % during use phase (Table 7-35).

Table 7-35: Combination of individual improvement options in the order of payback time for the base case ice cream freezer

Combination	Option description	Total Energy GER (MJ/product)	Electricity costs (Euros/lifetime)	LCC (Euros)	Payback (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base Case ice cream freezer	149,680	1,380	2,226	0.00	0	0.00	0
1	High efficiency compressor	143,058	1,313	2,169	0.97	8.0	4.80	Estimated negligible
1+2	High efficiency compressor + Increase in the heat exchangers'surface	137,804	1,261	2,130	1.38	20.5	8.61	Estimated negligible
1+2+3	High efficiency compressor + Increase in the heat exchangers'surface + ECM fan	131,475	1,198	2,094	2.00	45.5	13.18	Estimated negligible
1+2+3+4	High efficiency compressor + Increase in the heat exchangers'surface + ECM fan + Compressor modulation (Variable speed drive)	120,694	1,090	2,067	3.33	120.5	20.99	modification of the fan motor

Figure 7-61: LCC curve - environmental performance expressed in total electricity costs for the base case ice cream freezer

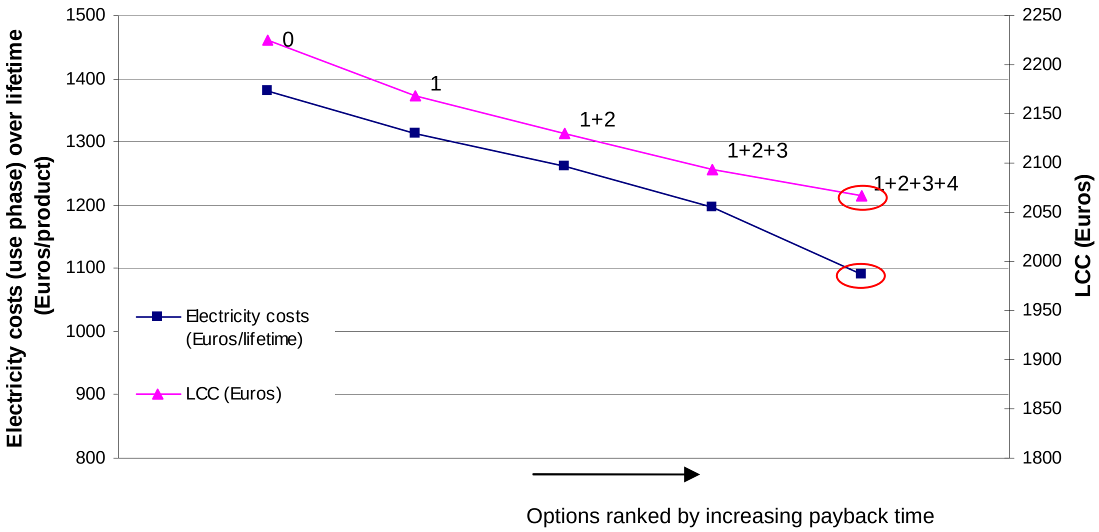


Figure 7-62: Energy consumption during use phase versus LCC for the base case ice cream freezer

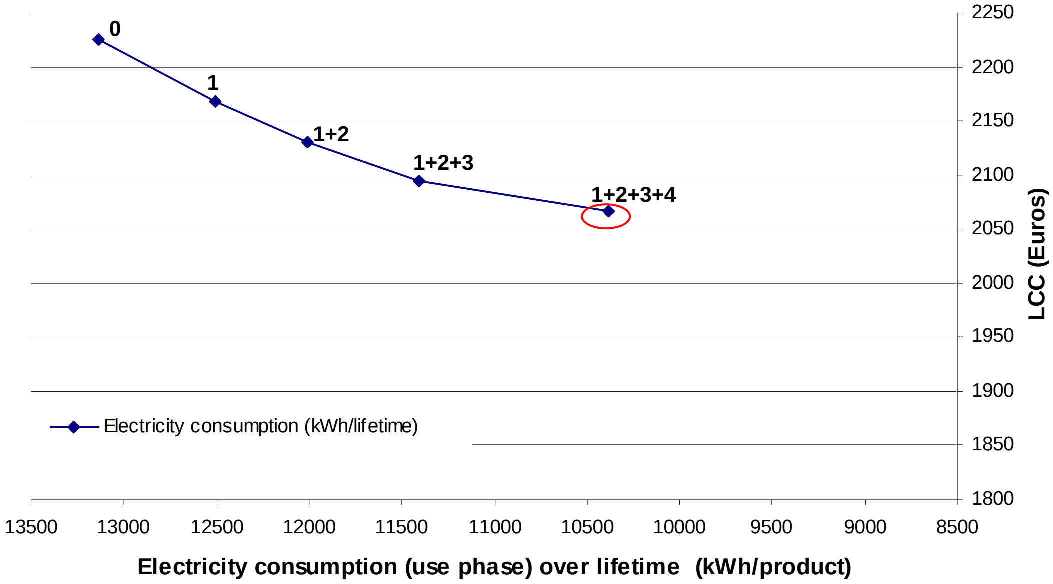


Figure 7-63 to Figure 7-65 illustrate the relative modifications of the 15 EcoReport environmental impact indicators and allow the identification of the most performing option for each of these indicators.

Figure 7-63: Comparison of the cumulative options (resources and waste) for the base case ice cream freezer

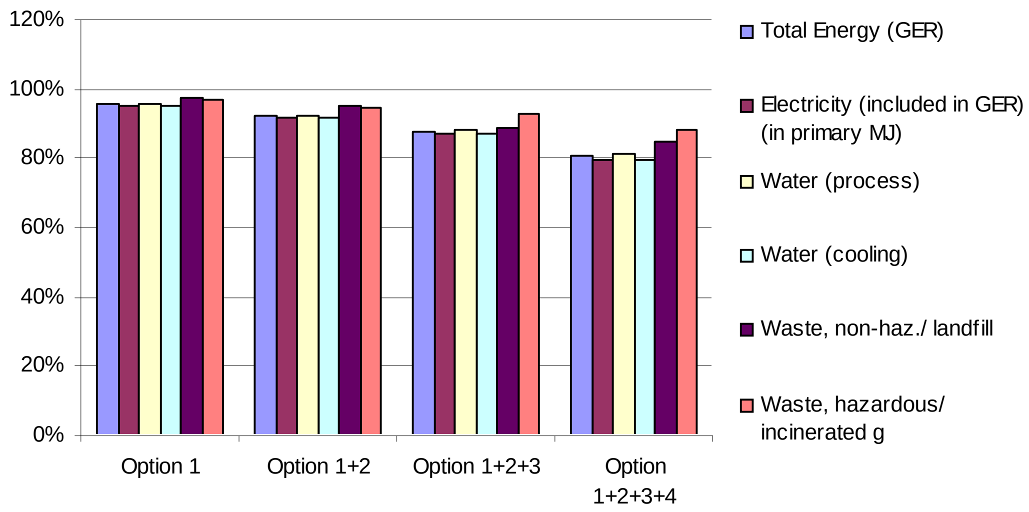


Figure 7-64: Comparison of the cumulative options (Emissions to air) for the base case ice cream freezer

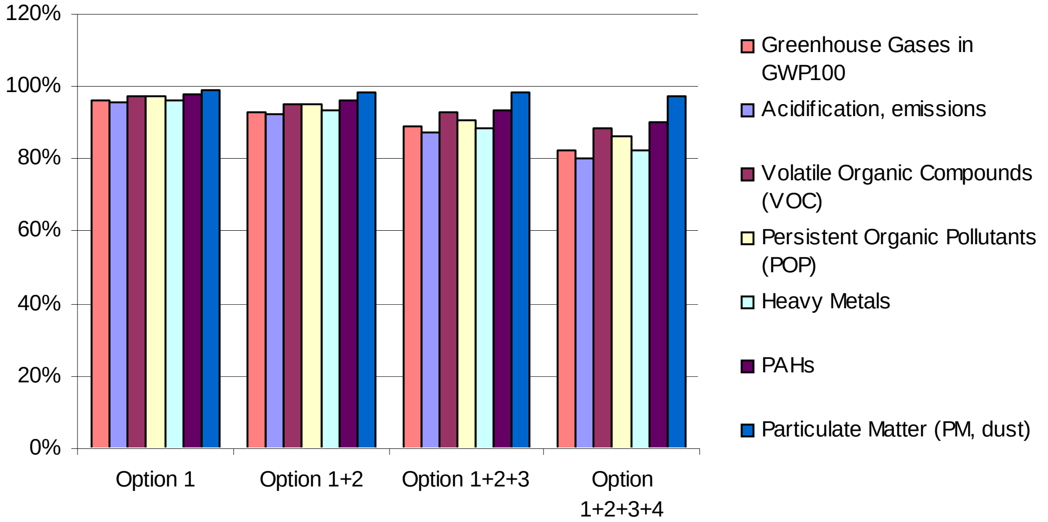
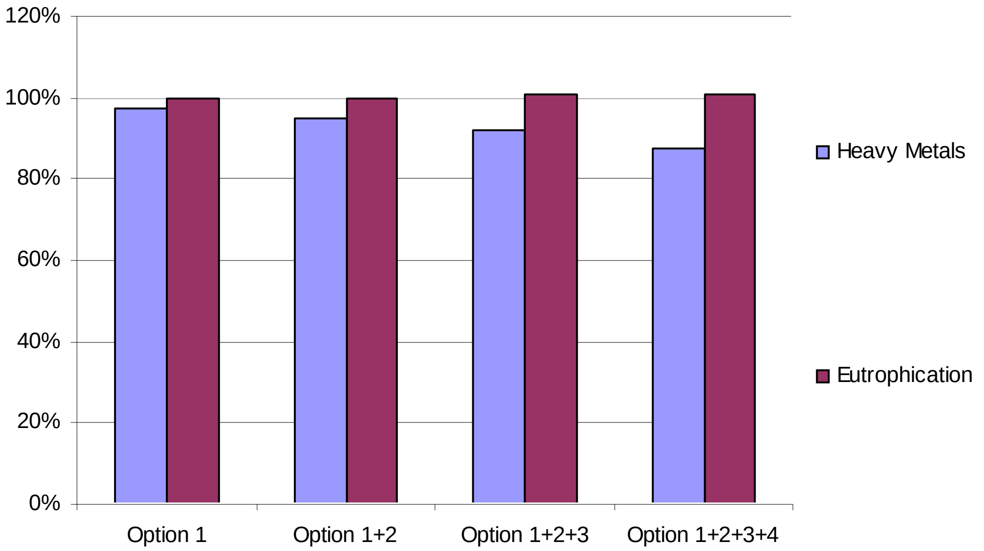


Figure 7-65: Comparison of the cumulative options (Emissions to water) for the base case ice cream freezer



For almost all environmental indicators (resource and waste, emission to air and water) except EUP, the option 1+2+3+4 leads to the highest impact reduction in comparison with the base case ice cream freezer. It is followed by option 1+2+3 and option 1+2.

The highest relative reductions of impacts are observed among the following environmental impact indicators: total electricity consumption (over whole life cycle), water consumption (cooling) and acidification (air) (Table 7-36).

Table 7-36: Improvement potential for each environmental impact indicator for the base case ice cream freezer

Indicator	Unit	Impact variation with least performing option	Impact variation with Best performing option
Total electricity (in primary MJ) (included in GER)	ltr	-3.92%	-20.57%
Water (cooling)	MJ	-3.87%	-20.29%
Acidification, emissions	g	-3.68%	-19.63%
Total Energy (GER)	MJ	-3.69%	-19.37%
Water (process)	g SO2 eq.	-3.52%	-18.56%
Heavy Metals	mg Hg/20	-3.09%	-17.47%
Greenhouse Gases in GWP100	mg Ni eq.	-3.30%	-17.34%
Waste, non-haz./ landfill	ltr	-2.26%	-15.36%
Persistent Organic Pollutants (POP)	g	-2.31%	-13.80%
Heavy Metals	g	-2.28%	-12.31%
Waste, hazardous/ incinerated	kg CO2 eq.	-1.66%	-11.91%
Volatile Organic Compounds (VOC)	ng i-Teq	-2.24%	-11.69%
PAHs	g	-1.72%	-10.02%
Particulate Matter (PM, dust)	mg Ni eq.	-0.29%	-2.82%
Eutrophication	g PO4	1.14%	-0.21%
Ozone Depletion, emissions	mg R-11 eq.	negligible	negligible
Persistent Organic Pollutants (POP) (water)	ng i-Teq	negligible	negligible

- **Approach 2: cumulating options in the order of LCC**

As it was already observed for the other base cases, cumulating the options in the order of LCC leads to different options with lower LCC, but with a higher payback time. However, Figure 7-66 shows that the BAT and LLCC point still refers to the same combination of options: 1+2+3+4.

The comparison of the effect of each combination of option is given in Annexe 7- 35 to Annexe 7- 36.

Table 7-37: Combination of individual improvement options in the order of LCC for the base case ice cream freezer

Combination	Option description	Total Energy GER (MJ/product)	Electricity costs (Euros/lifetime)	LCC (Euros)	Payback (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base Case BvC	149680	1380	2226	0.00	0	0	0
4	Compressor modulation (Variable speed drive)	134504	1228	2155	3.95	75	11	Estimated negligible
4+1	Compressor modulation (Variable speed drive) + High efficiency compressor	131236	1195	2131	3.60	83	13	Estimated negligible
4+1+3	Compressor modulation (Variable speed drive) + High efficiency compressor + ECM fan	125236	1135	2099	3.54	108	17.6996	Estimated negligible
4+1+3+2	Compressor modulation (Variable speed drive) + High efficiency compressor + ECM fan + increase in the heat exchangers'surface	120694	1090	2067	3.33	120.5	20.99	modification of the fan motor

Figure 7-66: LCC curve - environmental performance expressed in electricity costs for the base case ice cream freezer

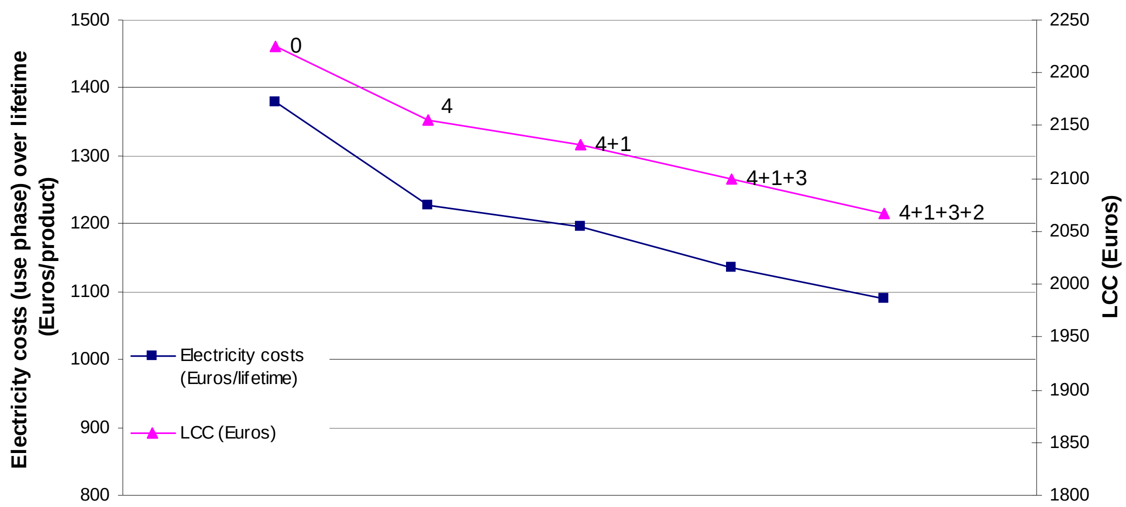
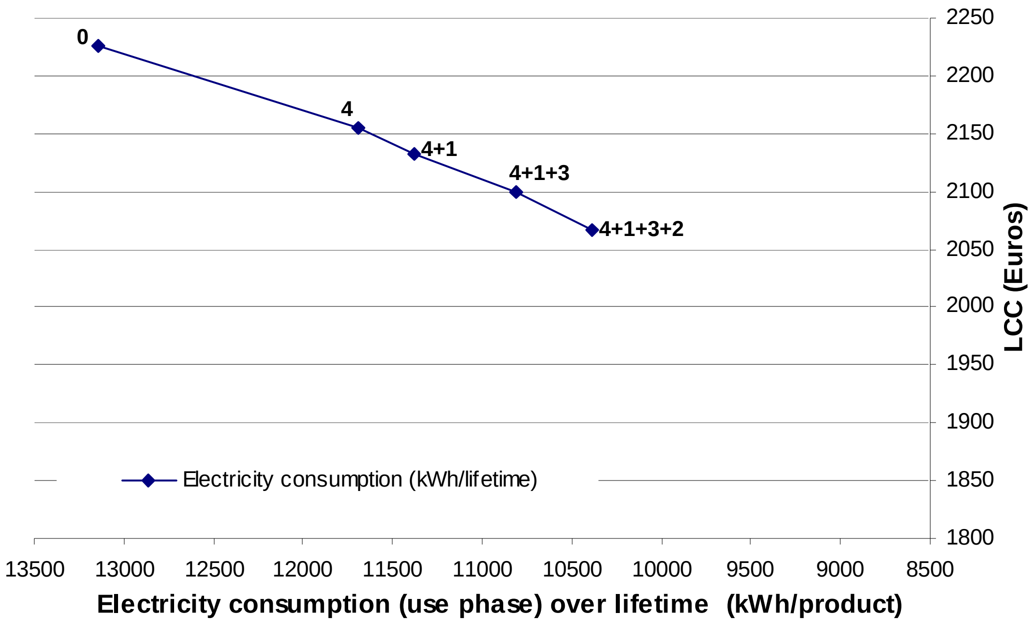


Figure 7-67: Electricity consumption during use phase versus LCC for the base case ice cream freezer



7.2.5 BASE CASE SPIRAL VENDING MACHINE

7.2.5.1 INDIVIDUAL IMPROVEMENT OPTIONS

The EcoReport results of the four individual improvement options applicable to the base case spiral vending machine (VM) are shown in Table 7-38. They are ranked according to their payback time.

Table 7-38: Summary of the cost and benefit effects of implementing individual improvement options for the base case spiral vending machine

Option	Option description	Total Energy GER (MJ/product)	Electricity costs (Euros)	LCC (Euros)	Payback time (year)	Cost increase (euros)	TEC savings (%)	BOM modifications
0	Base Case VM	285,789	2,432	6,104	0.00	0	0	0
1	Modification of the anti sweat heater location	242,016	1,994	5,692	0.58	30	18.00	Estimated negligible
2	Vacuum Insulated Panels (VIP)	269,981	2,274	5,960	1.34	25	6.50	Removal of the R134a (blowing agent)
3	Compressor modulation (variable speed drive)	232,289	1,897	5,776	3.18	200	22.00	Estimated negligible

Figure 7-68 to Figure 7-70 allow the identification of the BAT and LLCC options, which respectively correspond to option 3 and option 1. This is explained by the fact that these option lead to comparable improvement potential (22 % and 18 %); however, implementing option 3 increases the cost of € 200 whereas implanting option 1 only adds € 30.

Electricity costs represent between 32 % (option 3) and 38 % (option 2) of the life cycle cost.

As most of environmental impacts are due to the use phase, the curves taking the electricity cost, the GER and the GWP as parameters have the same aspect.

Figure 7-68: LCC curve – environmental performance expressed in total electricity costs for the base case spiral vending machine

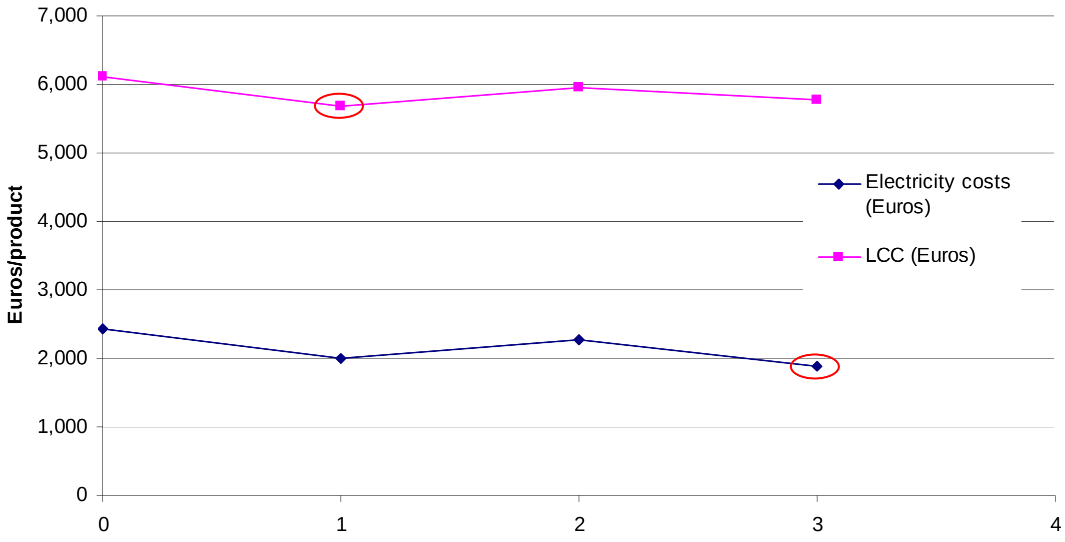


Figure 7-69: LCC curve – environmental performance expressed in total energy consumption (GER) for the base case spiral vending machine

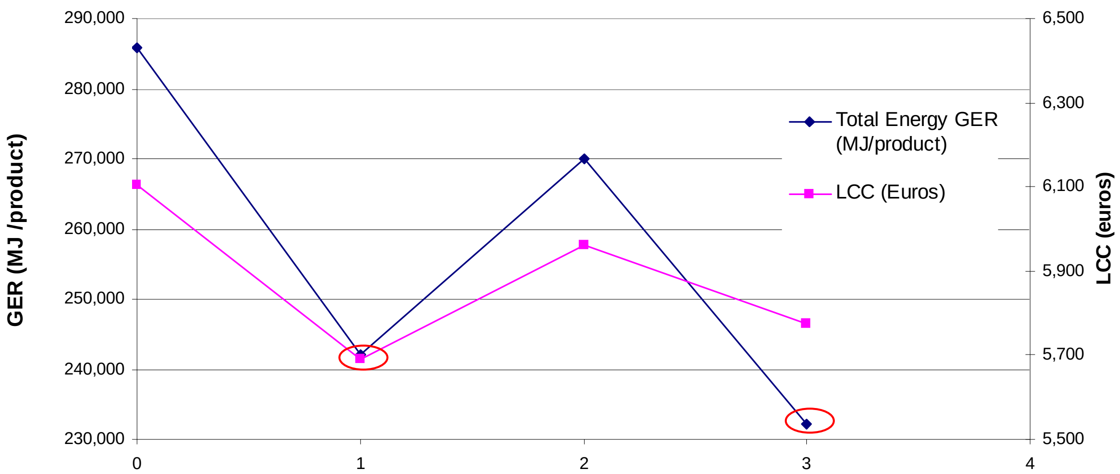
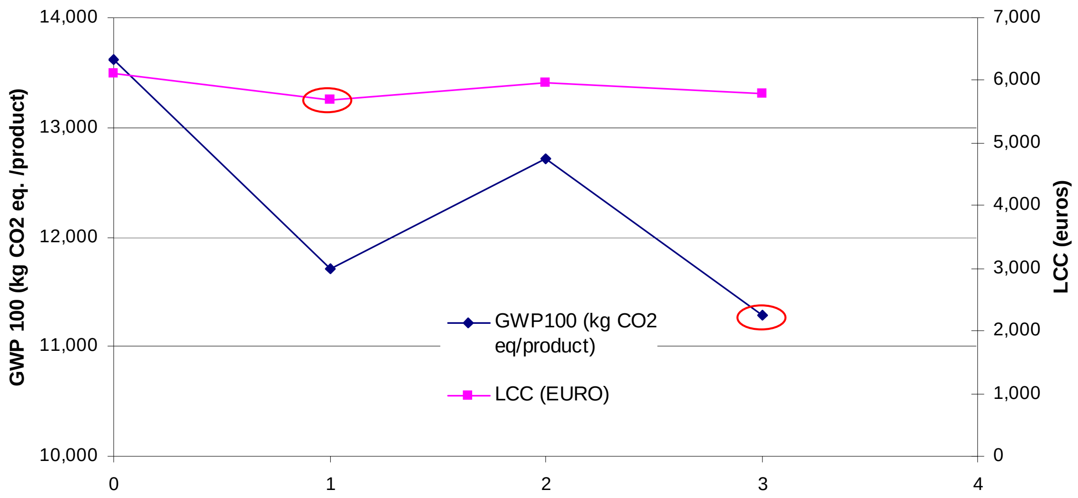


Figure 7-70: LCC curve – environmental performance expressed in GWP for the base case spiral vending machine



7.2.5.2 EFFECT OF CUMULATING IMPROVEMENT OPTIONS

It is technically possible to combine all improvement options; the only restriction is the cost. As for beverage coolers, most of buyers of cold vending machines are not the end-users. Thereby, manufacturers are not interested in including energy efficient options in their appliances because this significantly increases the cost. Besides, most of the time there is no actual payback time for the equipment owner, which is not the end-user.

- **Approach 1: cumulating options in the order of payback time**

Table 7-39 present the list of the best performing combinations of options with their main characteristics. The LLCC and BAT option for the base case spiral vending machine is the combination of the 4 options, which leads to a reduction of the TEC of 40.19 % and a reduction of 11.5 % of the LCC compared to the base case. The latter value is lower compared to other base case, as the electricity costs during the use phase represent “only” 37 % of the Life Cycle Cost.

Figure 7-71 and Figure 7-72 show the correlation between LCC and electricity costs and consumption during the use phase.

Table 7-39: Combinations of individual improvement options for the base case spiral vending machine in the order of payback

Combination	Options	Electricity costs (Euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base case RHF4	2,432	285,789	6,104	0	0	0	0
1	Modification of the anti sweat heater location	1,994	242,016	5,692	0.58	30	18	Estimated negligible
1+2	Modification of the anti sweat heater location + VIP	1,864	229,054	5,591	0.82	55	23.33	Removal of R134a (blowing agent)
1+2+3	Modification of the anti sweat heater location + VIP + Variable Speed Compressor	1,454	188,036	5,401	2.22	255	40.19	Removal of R134a (blowing agent)

Figure 7-71: LCC curve – environmental performance expressed in total electricity costs for the base case spiral vending machine

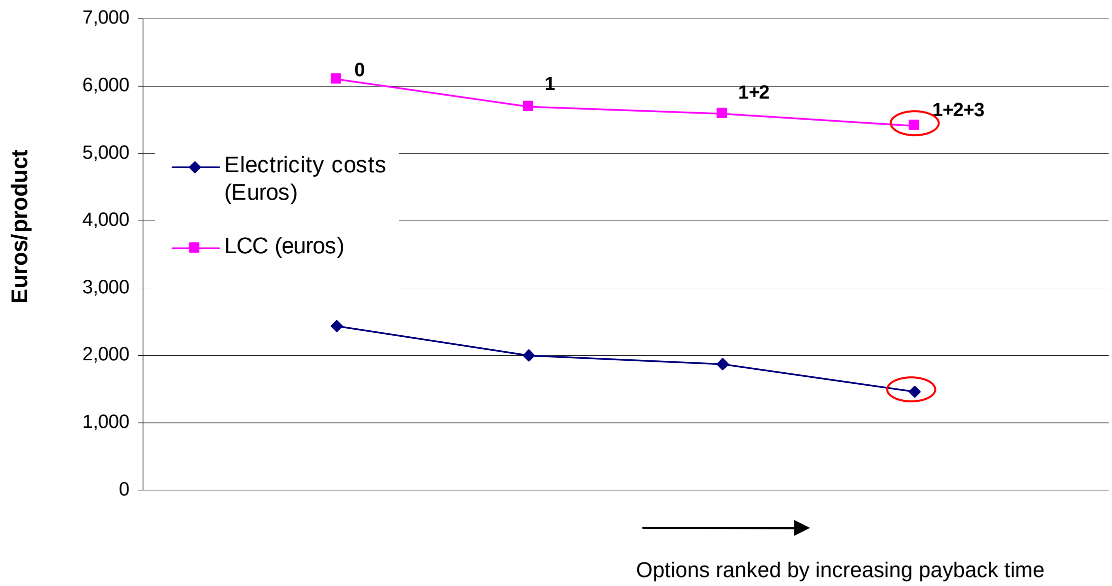


Figure 7-72: Energy consumption during use phase versus LCC for the base case spiral vending machine

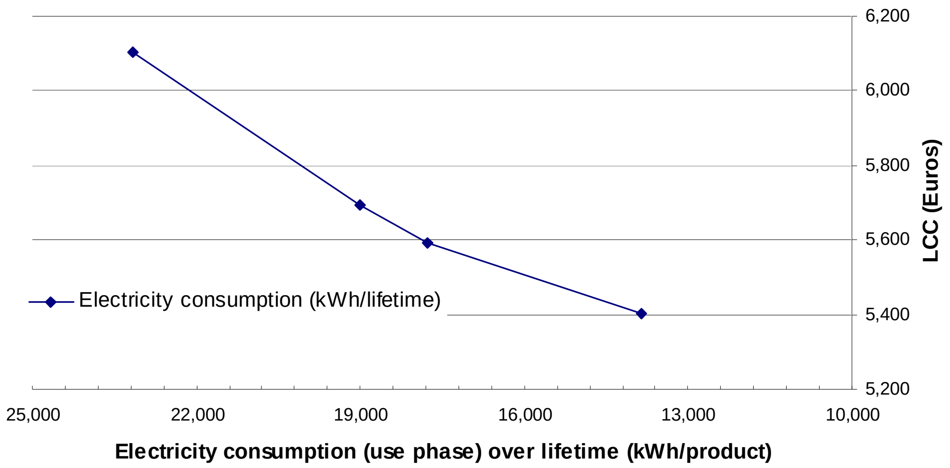


Figure 7-73 to Figure 7-75 show the relative modifications of the 15 indicators of the EcoReport and allow the identification of the option which leads to the highest reduction of the emissions/resources consumption/waste with reference to the base case (100 %) for each environmental impact indicator.

Figure 7-73: Comparison of the cumulative options (resources and waste) for the base case spiral vending machine

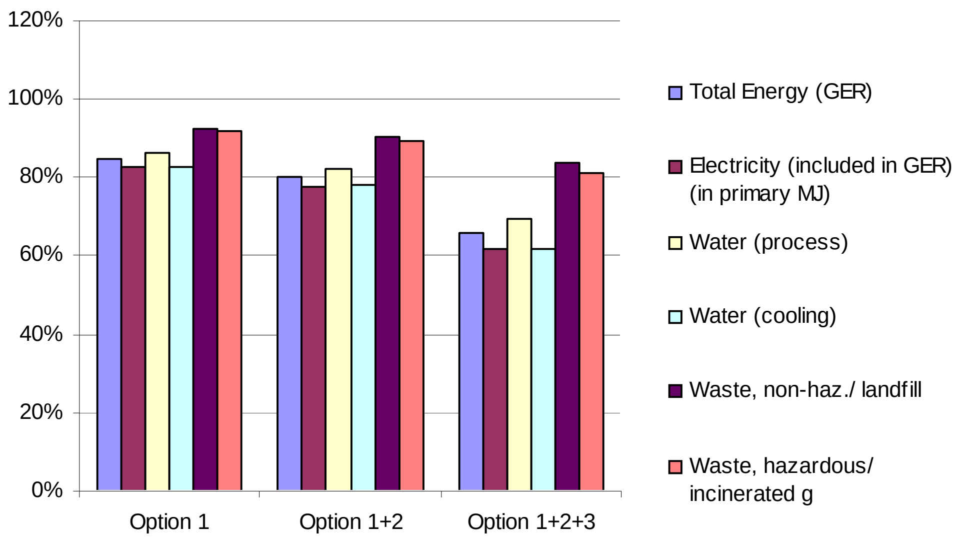


Figure 7-74: Comparison of the individual options (emissions to air) for the base case spiral vending machine

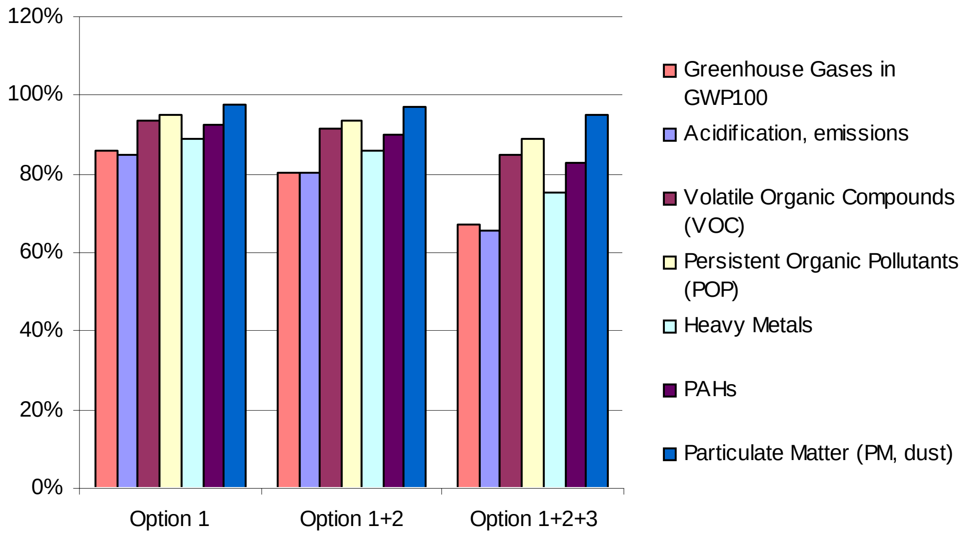
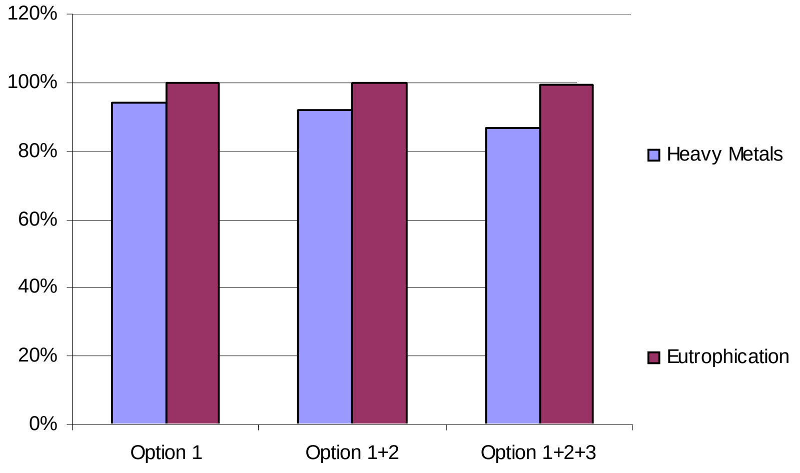


Figure 7-75: Comparison of the cumulative options (emissions to water) for the base case spiral vending machine



The full combination of the 3 options leads to the highest reduction for all environmental impacts. This ranking corresponds to the order of the LCC and to the order of total electricity consumption.

The highest relative reductions of environmental impacts, as presented in Table 7-40, are observed for the following indicators: total electricity consumption over lifetime, water (cooling), acidification emissions and total energy over lifetime.

Table 7-40: Improvement potential for each environmental impact indicator for the base case spiral vending machine

Indicator	Unit	Impact variation with least performing option	Impact variation with best performing option
Total electricity (in primary MJ), included in GER	ltr	-6.19%	-38.27%
Water (cooling)	MJ	-6.15%	-38.03%
Acidification, emissions	g	-5.54%	-34.25%
Total Energy (GER)	MJ	-5.53%	-34.20%
Greenhouse Gases in GWP100	mg Ni eq.	-6.63%	-32.88%
Water (process)	g SO2 eq.	-4.91%	-30.34%
Heavy Metals	g	-3.98%	-24.62%
Waste, hazardous/ incinerated	ltr	-3.01%	-18.59%
PAHs	mg Hg/20	-2.75%	-17.02%
Waste, non-haz./ landfill	kg CO2 eq.	-2.65%	-16.40%
Volatile Organic Compounds (VOC)	g	-2.41%	-14.89%
Heavy Metals	g	-2.19%	-13.57%
Persistent Organic Pollutants (POP)	mg Ni eq.	-1.78%	-11.03%
Particulate Matter (PM, dust)	ng i-Teq	-0.79%	-4.85%
Eutrophication	g PO4	-0.06%	-0.37%
Ozone Depletion, emissions	mg R-11 eq.	negligible	negligible
Persistent Organic Pollutants (POP)	ng i-Teq	negligible	negligible

- **Approach 2: cumulating options in the order of LCC**

As it was already observed for the other base cases, cumulating the options in the order of LCC leads to different options with lower LCC, but with a higher payback time (Table 7-41). However, shows that the BAT and LLCC point still refers to the same combination of options: 1+2+3 (Figure 7-76).

Table 7-41: Combinations of individual improvement options for the base case spiral vending machine in the order of LCC

Combination	Options	Electricity costs (Euros/lifetime)	Total Energy GER (MJ/product)	LCC (euros)	Payback time (years)	Cost increase (euros)	TEC savings (%)	BOM modification
0	Base case RHF4	2,432	285,789	6,104	0	0	0	0
1	Anti-sweat inside the glass	1,994	242,016	5,692	0.58	30	18	Estimated negligible
1+3	Anti-sweat inside the glass + Variable Speed Compressor	1,555	198,146	5,474	2.23	230	36.04	Estimated negligible
1+3+2	Anti-sweat inside the glass + Variable Speed Compressor + VIP	1,454	188,036	5,401	2.22	255	40.1974	Removal of R134a (blowing agent)

Figure 7-76: LCC curve – environmental performance expressed in total electricity costs for the base case spiral vending machine

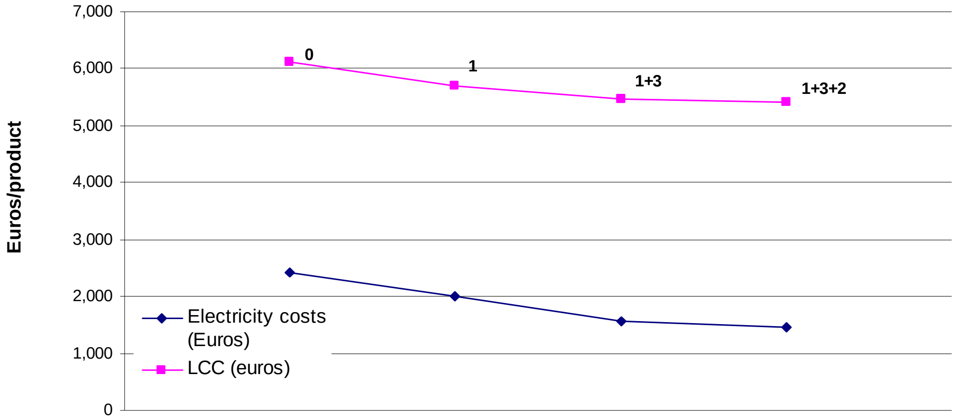
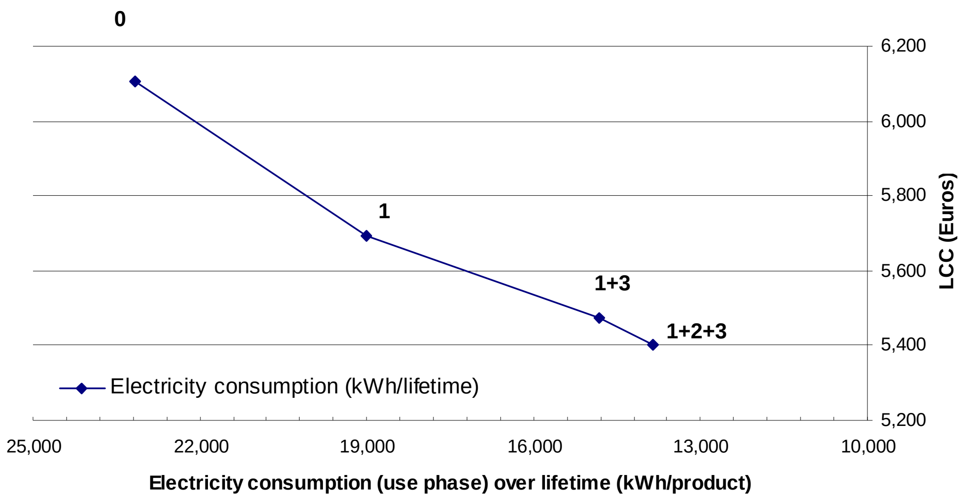


Figure 7-77: Energy consumption during use phase versus LCC for the base case spiral vending machine



7.2.6 CONCLUSIONS: SUMMARY OF THE OPTIONS (INDIVIDUAL AND COMBINED)

Table 7-42 summarises for each base case the individual option and the combinations of options leading to the BAT and LLCC point.

Depending on the base case the TEC savings are between 14 % (for the base case ice cream freezer) and 50 % (for the base case RCV2 with glass door) when only one improvement option is implemented. When cumulating several options, the TEC savings are between 26 % (for the base case RHF4 with night curtain) and 81.8 % (for the base case RCV2 with glass door).

Table 7-42: Summary of the LLCC and BAT for each base case

	Individual option (LLCC and BAT)		Combination (LLCC and BAT)	
Base case	Description	TEC savings	Description	TEC savings
RCV2 scenario with glass door	Glass door	52	ECM fans + LSHE + addition of a glass door	57.04
RCV2 scenario without glass door	Night curtain	26	Optimisation of air curtain + night curtain (12hours/day) + ECM fans + LSHE	40.39
RCV2 scenario without night curtain	Optimisation of air curtain	10	Optimisation of air curtain + ECM fans + LSHE	19.40
RHF4 scenario with glass lid	Glass lid	36.5	LSHE+Anti sweat control+ECM fans+glass lid	43.55
RHF4 scenario without glass lid	Night curtain	18	Night curtain + anti-sweat heater control + ECM fans + LSHE	27.11
RHF4 scenario without night curtain	Anti sweat heater control	6	anti-sweat heater control+ ECM fans + LSHE	11.10
Beverage cooler	Increase of the heat exchangers' surface	15	Increase of the heat exchangers' surface (condenser and evaporator) + High efficiency compressor + Glass door insulated with argon instead of air+ Compressor modulation (Variable speed drive) + ECM fans + light control + light improvement + increase of the insulation thickness	51.88
Ice cream freezer	Compressor modulation (variable speed drive)	11	Increase in the heat exchangers' surface + High efficiency compressor +Compressor modulation (Variable speed drive)+ECM fan	20.99
Spiral vending machine	Compressor modulation (variable speed drive)	22	Variable Speed Drive + Vacuum insulated panels + Modification in the location of the anti-sweat heater	40.19

7.3. IMPROVEMENT OPTIONS (DIRECT IMPACTS REDUCTION)

The reduction of the direct impacts can be achieved through improved refrigerant containment, refrigerant recovery and recycling, reclaiming and destruction; and through the use of refrigerants with lower overall impact on global warming and if ozone depletion.

This section will focus on the use of alternative refrigerants.

Switching from a typical refrigerant (mainly HFCs) to an alternative refrigerant such as ammonia, hydrocarbons and CO_2, implies some modifications in the design of the product at the component level (e.g. pipes, compressor) and at the system level (i.e. for remote cabinets).

Currently, carbon dioxide is the natural refrigerant with highest expectations. Unlike hydrocarbons and ammonia, it has very low safety risks, toxicity, and flammability.

7.3.1 REMOTE REFRIGERATED DISPLAY CABINETS

In the case of remote refrigerated display cabinets, leakages occur mostly in the refrigeration system itself, not in the cabinet.

The refrigerant liquid piping system and therefore the related leakages and refrigerant emissions are not part of the cabinet but more part of the overall supermarket refrigeration system. Section 7.4. provides an overview of the possible options to reduce the refrigeration system's refrigerant losses.

7.3.2 PLUG IN REFRIGERATED DISPLAY CABINETS

To serve as an example of what could be done in terms of direct impact reduction, and how this can affect the energy efficiency of an appliance, a case study of CO_2 beverage cooler is presented. Main drivers for the development of CO_2-based equipments are that carbon dioxide is the only natural fluid that can be used safely (non flammable, non toxic, unlike ammonia or hydrocarbon), it can be used in direct expansion systems, it's environmentally friendly and cheaper than other refrigerants.

This case study is the result of a project[7] which was presented at the 12th European Conference on the future of refrigeration technologies in Milan[8].

The project consisted in the design of a R744 bottle cooler starting from a traditional R-404A cabinet of 466 litres net volume. The aim was to demonstrate the feasibility of designing a CO_2 cabinet using components easily available on the market and reaching approximately the same level of energy performance than traditional ones.

The major changes in the material composition are listed below:

- The original finned coil condenser was replaced by a wire-on-tube heat exchanger acting as a gas cooler fitting in the same volume of space available in the cabinet. It consists of a steel tube arranged in one circuit, with steel fins. This material was chosen because of its high design pressure, which is suitable for CO_2 applications in transcritical cycle.

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[7] Reference: L. Cecchinato et al. *Design and Analysis of a Transcritical R744 Bottle Cooler.* University of Padova (Italy) (2007)

[8] http://www.centrogalileo.it/milano/CONGRESSODIMILANO2007english.html

- The evaporator (copper) was replaced by an evaporator with thicker tubes to comply with the PED directive (Pressure Equipment Directive (97/23/EC)) (from 1 mm to 1.3 mm) in copper as well.

- The length of the capillary tube was adapted to optimise the COP (experimental results).

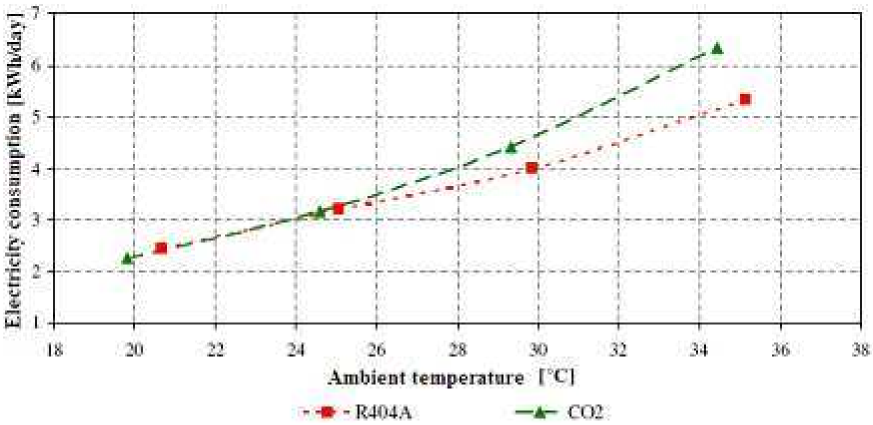
- The R-404A compressor was replaced by a CO_2 compressor. Currently, a compressor operating with CO_2 is estimated to be over € 100 more expensive than a classic HFC compressor.

Energy consumptions tests were carried out at 20 °C , 25, 30 and 35 °C ambient temperature with 60, 55 and 70 % relative humidity respectively. These results cannot be directly compared to the electricity consumption of the beverage cooler base case as the measurements were not established in the same conditions. However, these results provide a first estimate of what could be the potential of CO_2 based refrigeration in beverage cooler applications.

Compared to an HFC based refrigerant beverage cooler, the CO_2 one has lower electricity consumption at low ambient temperature (between 0.8 % and -7.4 % less at 20 and 25 °C) however beyond 25 °C the tren d is the opposite: the CO_2 system is less efficient leading to higher electricity consumptions (between 10.3 and 18.3 % more than the base line HFC beverage cooler). However, this might not be solely due to the use of carbon but also to the modifications in the heat exchanger No consideration is given to potential improvements for heat exchangers running with HFC and further verification should be made to assess the efficiency of refrigeration equipment running with carbon dioxide.

Still, the results at low ambient temperature are encouraging considering that the system could be further optimised through the improvement of the capillary tube dimensioning and of the gas cooler efficiency. This could lead to have better CO_2 performances up to 30 °C ambient temperatures. How ever, CO_2 operates at higher pressures and requires the use of more material such as copper and a complete redesign of the refrigeration system and still is a more expensive solution.

Figure 7-78: Energy consumption tests at different room temperature at 60, 55 and 70 % relative humidity[9]



Other plug in refrigerated display cabinets using hydrocarbons (HC) are under investigation. Some food and beverage companies have already put thousands of cabinets running with HC on the market[10] showing comparable efficiencies in comparison with cabinets running with HFC.

7.4. SYSTEM ANALYSIS

The objective of this section is to provide an overview of the improvement potential in terms of energy savings and GWP reduction that can be reached through the optimisation of a whole supermarket refrigeration system. It presents several results from various sources.

Different parameters can influence the energy consumption of the whole refrigeration system and thus the value of REC:

- Refrigeration installation and choice of refrigerant: improvement through the choice of the refrigeration system configuration; improvement thought the reduction of direct emissions,
- Air conditioning and heating system.

The options presented here focus on the reduction of the refrigeration electrical energy consumption (REC) used by the refrigeration system to provide the cooling capacity required to each display case in the supermarket. The REC represents over 90 % of the total electricity consumption of the base case RCV2 and is a main parameter to investigate in order to reduce the environmental impacts of such products. Compressors and condensers account for 60-70 % of the REC. The rest is consumed by the display and storage cooler fans, display case lighting, evaporator defrosting, and anti-sweat heaters.

[9] Reference: L. Cecchinato et al. *Design and Analysis of a Transcritical R744 Bottle Cooler*. University of Padova (Italy) (2007)

[10] Unilever implemented almost 200.000 ice cream freezers with R290 in Europe.

Refrigeration system configuration and choice of the refrigerant

The International Energy Agency (IEA)[11] carried out a study to demonstrate and document the benefits of advanced supermarket refrigeration systems and HVAC[12] systems. This was motivated by the fact that supermarkets are within the most energy-intensive types of commercial buildings. The study comprises of 5 very detailed analysis from 5 different countries (UK, Canada, Denmark, Sweden, USA).

A brief overview of the main conclusions of this study, complemented by results from various sources provides a good relative indication of the energy savings and TEWI (Total Equivalent Warming Impact[13]) reduction potential that could be achieved at system level. However, these results are based on field measurements and assumptions and might not be applicable to all store sizes and locations.

Over 10 % in energy savings and up to 60 % in TEWI reduction are proven to be feasible with low charge refrigeration systems as compared to the predominant type of refrigeration system (baseline, see Figure 7-79) which is a multiplex DX system[14] with air cooled condensers. The advanced systems investigated included the use of distributed compressor systems, secondary loop systems, and low-charge multiplex systems, some of them being integrated with the store HVAC operation. All these systems were designed primarily to reduce the charge of refrigerant needed for operation and thereby the amount of annual refrigerant leakages.

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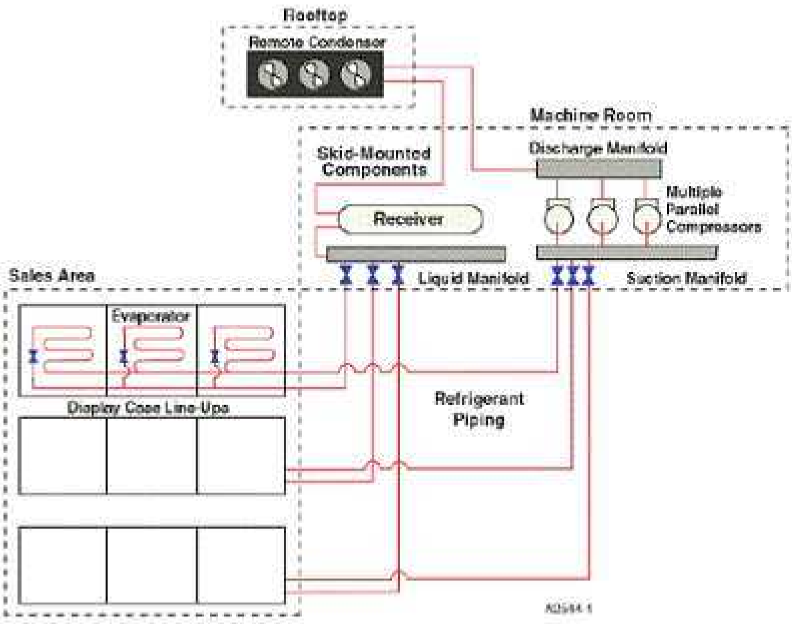
[11] International Energy Agency. *IEA Annex 26: Advanced Supermarket Refrigeration/Heat Recovery Systems, Final Report Volume 1 – Executive Summary* (April 2003). http://www.ornl.gov/~webworks/cppr/y2003/rpt/117000.pdf (IEA study)

[12] Heating, Ventilation and Air Conditioning systems

[13] TEWI computes the total impact of the refrigeration system on the environment over its lifetime. The calculation is based on the direct effects of the refrigerant release over the system's service life and the indirect effects of the energy consumed by the system.

[14] Typical direct expansion system where the display cabinets are linked to a central condensing unit with a multiple parallel compressor rack and air cooled condenser – see Task 4 for further details

Figure 7-79: Base-line refrigeration system



Other areas were investigated from the overall design of the energy supply, from CHP (Combined Heat and Power) to CCHP (Combined Cooling Heat and Power), and through the interaction of the store's environment and the cabinets.

Secondary loop system is the most investigated option in the IEA study and it estimated to lead to 30 % greater energy use to 10 % savings compared to the base-line, depending of the configuration, and allowed to reach a lower TEWI. These systems have features that tend to improve the efficiency compared to the base-line system: possible close coupling of the compressors to the intermediary heat exchangers (where heat between the primary (refrigerant) and secondary (brine) circuit is exchanged), ability to use the brine for the subcooling of the refrigerant and to use the warm brine for defrosting the display cases evaporators.

For all systems studied in the IEA report, the use of evaporative condensers (i.e. cooling towers) is the key option to obtain maximum energy savings through the reduction of the condensing temperature. However, cooling towers require greater maintenance and cost. In terms of costs (first cost), the secondary loop systems' cost premiums range from 0 % to 40 %, and distributed systems around 15 %. The low charge systems show no considerable increase in first cost[15].

Refrigeration leak reduction can also be an option to consider. However, the F-gas regulation (REGULATION (EC) No 842/2006) focuses on the emission reduction through better containment, emission monitoring and reporting and all ready covers this issue which is why it will not be further investigated here. This area is a main area of improvement; moreover, the success of the STECK

[15] IEA study

regulation in the Netherlands has shown that when addressing this issue (refrigerant emission reduction) a target of 2 - 5 % annual refrigerant leakage rate in supermarkets could be achievable and realistic.

Another area of focus on to reduce the direct impacts is to choose an alternative refrigerant with lower GWP such as CO_2. CO_2-based supermarkets systems have been expanding in Europe since beginning of 2000. They are now the state of the art in Denmark, Luxembourg and Sweden and generally show a energy consumption comparable to that of an HFC system.

Three refrigeration plants configuration are possible when considering the carbon dioxide option:

- the secondary fluid system: Medium Temperature (MT) and Low Temperature (LT) pack with R404A or NH3 and CO2 as a secondary refrigerant subject to phase change,

- the centralised CO_2 system with Direct expansion CO2 LT in cascade with R404A or NH3 MT,

- the centralised CO_2 system with Direct expansion CO2 LT and MT with heat realised directly into the atmosphere

As for an example, a case study in the Netherlands shows that a cascade NH_3/CO_2 supermarket refrigeration system can lead to 13 – 18 % annual energy savings compared to a typical R 404A system. The system has no significant direct emissions and the payback time is of 8 years (first investment being 28 % higher than the base-line).[16] However, CO_2 systems are known to be more efficient at low ambient temperature and the energy saving potential could significantly change from one location to another (e.g. The Netherlands compared to Greece) and from one period of the year to another as shown in Figure 7-80 and Figure 7-81[17].

These figures refer to a direct expansion system working only with CO_2 with a transcritical cycle. It is important to notice that the condensing temperatures differ in both systems (25℃ and 15 ℃). This gives an advantage to the CO_2 based system and the conclusions from these graphs are only valid for this specific supermarket and configuration.

[16]Gerrit Jan van Riessen. *NH3/CO2 Supermarket Refrigeration System with CO2 in the Cooling and Freezing Section* http://www.nightwind.eu/mediapool/48/485045/data/CO2_supermarket.pdf

[17] Source : EPTA Group June 2006

Figure 7-80: COP comparison of a traditional R 404A supermarket system and a CO_2 based system for medium temperature applications

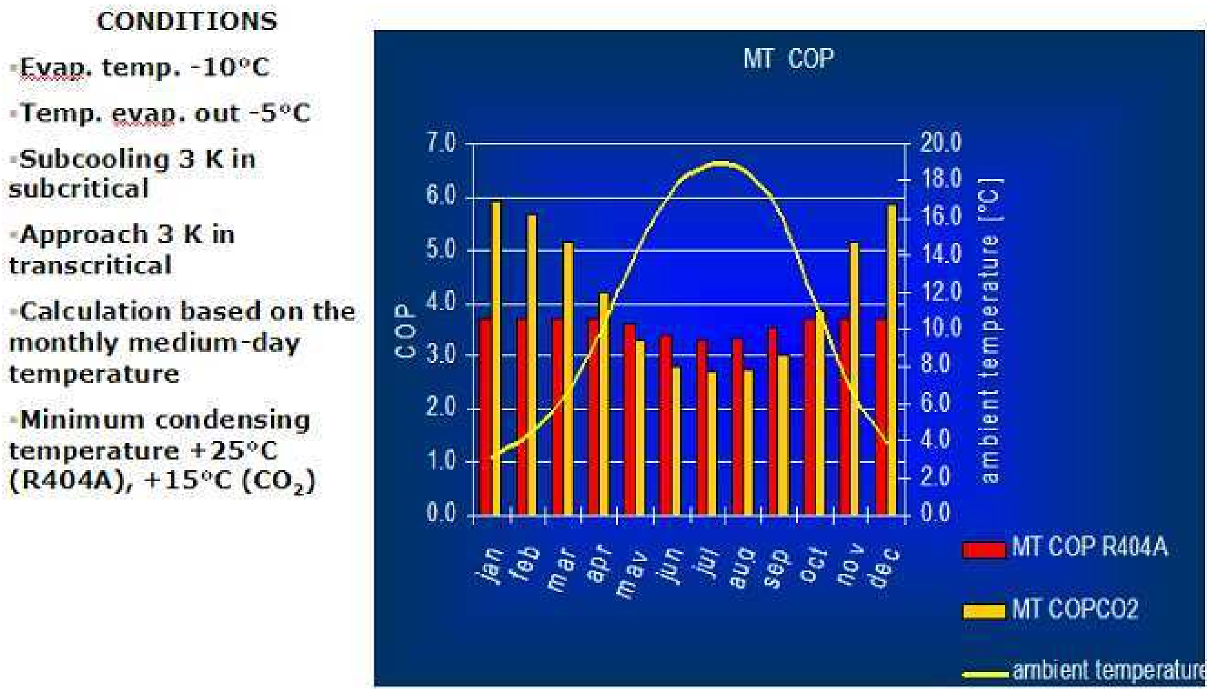
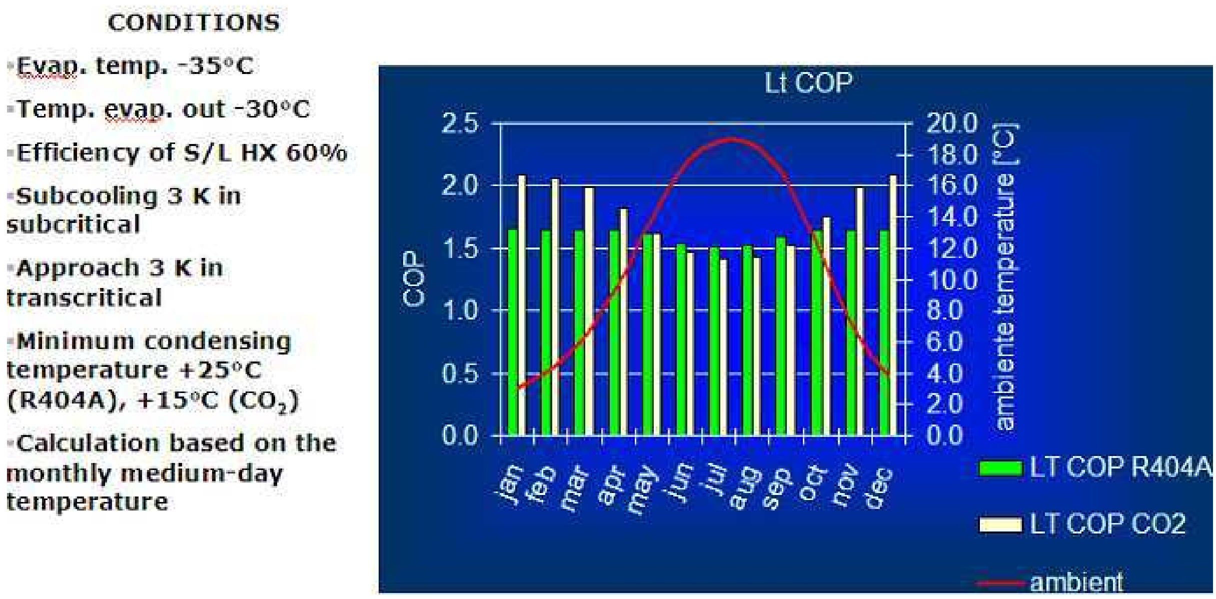
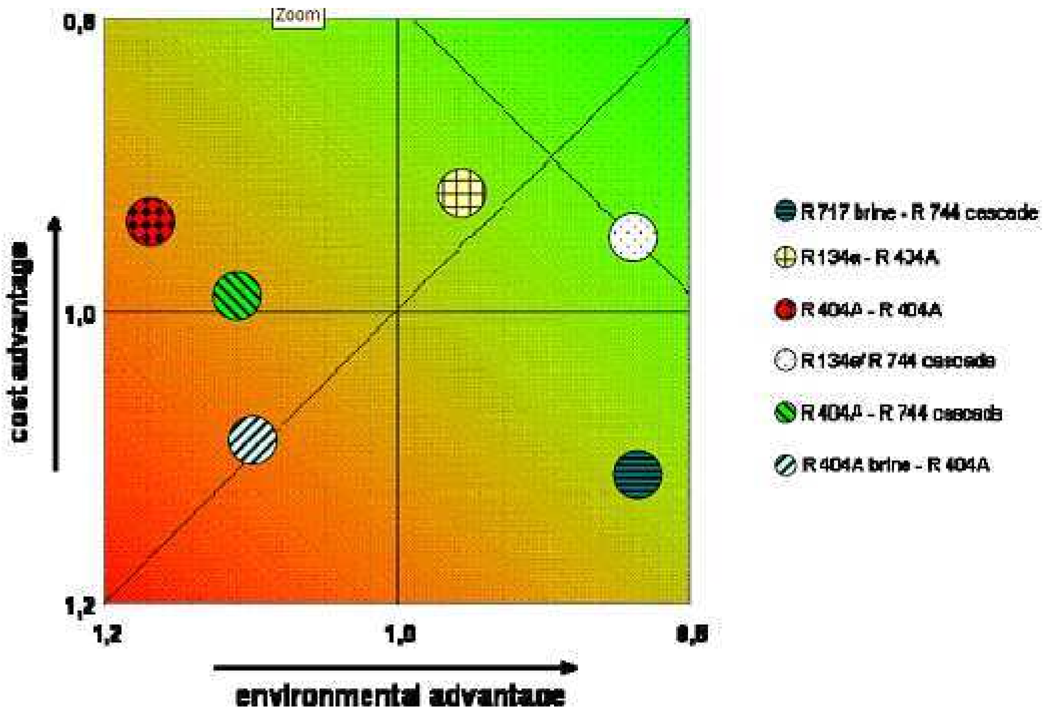


Figure 7-81: COP comparison of a traditional R 404A supermarket system and a CO_2 based system for low temperature applications



Other comparisons between 6 various types of refrigeration systems taking into account the whole life cycle of the supermarket refrigeration system[18] have been made[19]. The results are shown in Figure 7-82 and show that in this particular case, the most eco-efficient system is a combination of R-134a system with CO_2 in the medium temperature section and a CO_2 cascade system in the low temperature application. Furthermore, it can be seen that the standard option of refrigeration systems (R 404A/R404A) is moderately cost effective but has the highest GWP-impact. The investigated ammonia/carbon dioxide system could be shown to be the concept with the lowest environmental impacts. But the system has the poorest cost effectiveness. The obtained results clearly indicate that decisions based on a substance view can worsen the situation. An investment into the not in kind concept R 717 brine / R 744 cascade does not show much less environmental impact than the R 134a / R744 cascade concept. If the higher invest will be spent for e.g. thermal insulation of buildings, the CO_2 reduction would be much higher. The results also show that the cheapest investment is not always the best when considering the whole life cycle.

Figure 7-82: Comparison of the GWP of 6 refrigeration systems over their whole life cycle



[18] comprising the production of refrigerant, of the refrigeration unit, the operation of the supermarket including energy supply until the end of life and the disassembly of the unit

[19] Achim Diehlmann et al.. *Eco – Efficiency considerations for European Supermarket Refrigeration Systems*. IIR- International Conference on Commercial Refrigeration (2005) http://www.solvay-fluor.com/news/result/0,0,-_EN-1000390,00.html

Refrigeration and HVAC interactions

An additional area of focus to reduce the use of energy in supermarkets is to consider the large amount of heat rejected by the refrigeration system of a typical supermarket which can be used as a resource for space and water heating. Recovery of the heat is shown to be able to provide from about 40 % to all of heat needs (space and water) for the supermarkets[20]. This percentage depends upon the size of the refrigeration load, the refrigeration / HVAC control's system management and of the heating requirements at a given site. It was shown that the integration of HVAC is an excellent mean to reduce the store's overall energy use, and the one of the option recommended is the heat-pump-based heat recovery which does not require the condensing temperature to be maintained artificially high to facilitate heat recovery.

Ambient temperature and relative humidity can also strongly affect the performance of the cabinets (see Task 4). Therefore, an option to reduce the REC is to operate the refrigeration system at the optimal ambient conditions. It was shown[21] that for each supermarket, there exists an optimum ambient temperature set point and an optimum relative humidity set point from an energy point of view (Table 7-43 and Table 7-44).

Table 7-43: Influence of ambient temperature set point (Ta) on energy consumption[21]

Annual electric consumption (in MWh)						
Ta setpoint cooling	Heating	Cooling	Case +	Case -	Total	Total per m²
22 °C	647	624	1220	1436	3927	0.363
23 °C	647	561	1233	1451	3893	0.360
24 °C	647	485	1242	1462	3836	0.355

[20] IEA study

[21] Reference : Orphelin. *Significant Parameters for Energy Consumption in Frozen Food Area of Large Supermarkets.* Clima 2000 Brussels 1997 http://www.inive.org/members_area/medias/pdf/Inive%5Cclima2000%5C1997%5CP206.pdf

Table 7-44: Change in energy consumption due to humidity control (base case = 60 %)[21]

Energy consumption (in MWh per year)					
HR (%)	Conso MFV+	Conso MFV-	Conso clim	Conso Defr	Total
35	-92	-108	292	-52	40
40	-50	-58	132	-28	-4
45	-24	-28	36	-14	-29
55	-9	-10	10	-5	-14

There appears to be great scope for considering the whole refrigeration system, including the pipes, the refrigerant circuit, the remote condensing unit, etc. as a single system to be improved rather than a collection of individual components each operating individually. As it was the case for the display cabinets alone (product level), the efforts to reduce the TEWI of a whole refrigeration system would benefit more from a focus on the reduction in the energy usage (indirect impacts) than from further reduction of the direct impacts.

7.5. Conclusions

As presented in this task, the improvement potential of each of the 5 base cases is significant. The EcoReport analysis show that most of the 17 environmental indicators decrease thanks to the implementation of one or several improvement options, due to their electricity savings potential.

Moreover, for all base cases, the Least Life Cycle Cost option corresponds to the Best Available Technology option, as the use phase is both the highest contributor to the environmental impacts and the highest contributor to the LCC (except for the base case spiral vending machine).

Nevertheless, the implementation of one or several options could be limited by the related increase in the cost. Indeed, in several business areas (plug in refrigerated display cabinets and cold vending machines) the buyer of the appliance is seldom the end-user. As the buyer will not pay for the electricity bill of the product, its energy efficiency is not always an important criterion.

The assessment of the improvement potential of each base case will be further investigated in task 8 when defining several scenarios until the year 2020. These scenarios, based on relevant assumptions, will evaluate the energy savings potential for the whole EU market of commercial refrigerators and freezers, which are in the scope of this study.

Annexes

Annexe 7- 1: Option 1 relative improvement compared to the base case RCV2

Table . Life Cycle Impact (per unit) of Product Base Case remote open vertical chilled multi deck (RCV2)

Nr	Life cycle Impact per product: Product Base Case remote open vertical chilled multi deck (RCV2) with Option 1	Date	Author
0		0	BIO

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0
4	Non-ferro	g			12.21%			12.21%	12.21%	12.21%	0
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0
	Total weight	g			0.98%			0.91%	0.98%	0.98%	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	3.57%	0.99%	2.98%	0.00%	-26.00%	0.79%	0.00%	3.40%	-25.42%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.99%	0.60%	0.00%	-26.00%	0.00%	0.00%	0.00%	-25.91%
10	Water (process)	ltr	0.00%	0.97%	0.03%	0.00%	-26.00%	0.00%	0.00%	0.00%	-25.61%
11	Water (cooling)	ltr	0.00%	0.98%	0.13%	0.00%	-26.00%	0.00%	0.00%	0.00%	-25.93%
12	Waste, non-haz./ landfill	g	2.06%	1.01%	2.03%	0.00%	-25.89%	0.97%	0.00%	0.99%	-18.03%
13	Waste, hazardous/ incinerated	g	0.00%	0.94%	0.00%	0.00%	-26.00%	0.00%	0.00%	0.00%	-23.94%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	2.91%	0.99%	2.53%	0.00%	-25.99%	0.79%	0.00%	1.10%	-25.16%
15	Ozone Depletion, emissions	mg R-11 eq.				negligible					
16	Acidification, emissions	g SO2 eq.	4.08%	0.99%	3.50%	0.00%	-25.99%	0.72%	0.00%	1.03%	-25.38%
17	Volatile Organic Compounds (VOC)	g	0.53%	1.04%	0.55%	0.00%	-25.98%	0.61%	0.00%	0.64%	-20.15%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.24%	1.21%	0.26%	0.00%	-25.81%	0.97%	0.00%	0.97%	-14.67%
19	Heavy Metals	mg Ni eq.	0.66%	1.21%	0.75%	0.00%	-25.98%	0.81%	0.00%	0.81%	-23.36%
	PAHs	mg Ni eq.	22.01%	0.24%	22.00%	0.00%	-25.76%	0.00%	0.00%	0.00%	-9.38%
20	Particulate Matter (PM, dust)	g	4.51%	0.98%	4.03%	0.00%	-25.95%	0.64%	0.00%	0.65%	-6.84%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	4.45%	1.07%	4.45%	0.00%	-25.92%	0.86%	0.00%	0.87%	-19.20%
22	Eutrophication	g PO4	0.01%	0.88%	0.02%	0.00%	-24.94%	0.86%	0.00%	1.16%	-4.80%
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Annexe 7- 2: Option 2 relative improvement compared to the base case RCV2

Table . Life Cycle Impact (per unit) of Product Base Case remote open vertical chilled multi deck (RCV2) with Option 1

Nr	Life cycle Impact per product:	Date	Author
0	Product Base Case remote open vertical chilled multi deck (RCV2) with Option 2	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			3.35%			3.35%	3.35%	3.35%	0
2	TecPlastics	g			3.82%			3.82%	3.82%	3.82%	0
3	Ferro	g			2.72%			2.72%	2.72%	2.72%	0
4	Non-ferro	g			9.28%			9.28%	9.28%	9.28%	0
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0
	Total weight	g			3.06%			3.09%	3.06%	3.06%	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	4.59%	3.02%	4.23%	0.00%	-10.00%	3.17%	3.55%	1.90%	-9.73%
9	of which, electricity (in primary MJ)	MJ	2.74%	3.03%	2.92%	0.00%	-10.00%	3.66%	3.50%	3.50%	-9.96%
10	Water (process)	ltr	27.00%	2.99%	26.25%	0.00%	-9.99%	0.00%	3.45%	3.45%	-9.45%
11	Water (cooling)	ltr	1.10%	3.03%	1.35%	0.00%	-10.00%	0.00%	3.66%	3.66%	-9.97%
12	Waste, non-haz./ landfill	g	6.59%	3.00%	6.49%	0.00%	-9.94%	3.06%	3.54%	3.05%	-5.34%
13	Waste, hazardous/ incinerated	g	1.36%	2.21%	1.36%	0.00%	-10.00%	3.62%	3.38%	3.62%	-8.96%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	4.94%	3.02%	4.55%	0.00%	-10.00%	3.17%	3.36%	3.09%	-9.59%
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	12.17%	3.02%	10.44%	0.00%	-10.00%	3.21%	3.39%	3.14%	-9.60%
17	Volatile Organic Compounds (VOC)	g	3.27%	2.59%	3.25%	0.00%	-9.99%	3.28%	2.98%	3.30%	-7.53%
18	Persistent Organic Pollutants (POP)	ng i-Teq	2.97%	2.83%	2.97%	0.00%	-9.91%	3.06%	0.00%	3.06%	-4.41%
19	Heavy Metals	mg Ni eq.	36.54%	2.83%	31.14%	0.00%	-9.96%	3.16%	0.00%	3.16%	-6.54%
	PAHs	mg Ni eq.	6.16%	2.52%	6.16%	0.00%	-9.92%	0.00%	3.36%	3.36%	-4.35%
20	Particulate Matter (PM, dust)	g	5.09%	3.01%	4.81%	0.00%	-9.97%	3.26%	3.58%	3.26%	-2.24%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	11.80%	2.51%	11.80%	0.00%	-9.94%	3.12%	0.00%	3.18%	-5.19%
22	Eutrophication	g PO4	4.16%	3.05%	4.15%	0.00%	-9.43%	3.12%	3.60%	2.96%	1.49%
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Annexe 7- 3: Option 3 relative improvement compared to the base case RCV2

Table . Life Cycle Impact (per unit) of Product Base Case remote open vertical chilled multi deck (RCV2)

Nr	Life cycle Impact per product:	Date	Author
0	Product Base Case remote open vertical chilled multi deck (RCV2) with Option 3	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			8.58%			8.58%	8.58%	8.58%	0
2	TecPlastics	g			1.98%			1.98%	1.98%	1.98%	0
3	Ferro	g			-0.11%			-0.11%	-0.11%	-0.11%	0
4	Non-ferro	g			-3.24%			-3.24%	-3.24%	-3.24%	0
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0
	Total weight	g			-0.06%			0.21%	-0.07%	-0.06%	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	-0.09%	0.63%	0.07%	0.00%	-8.20%	0.77%	4.14%	-10.42%	-8.03%
9	of which, electricity (in primary MJ)	MJ	0.77%	0.64%	0.69%	0.00%	-8.20%	4.21%	4.03%	4.03%	-8.17%
10	Water (process)	ltr	-0.12%	0.64%	-0.09%	0.00%	-8.20%	0.00%	3.97%	3.97%	-8.08%
11	Water (cooling)	ltr	2.22%	0.65%	2.02%	0.00%	-8.20%	0.00%	4.21%	4.21%	-8.17%
12	Waste, non-haz./ landfill	g	-2.07%	0.55%	-1.99%	0.00%	-8.18%	-0.04%	4.08%	-0.10%	-6.41%
13	Waste, hazardous/ incinerated	g	1.80%	-0.08%	1.79%	0.00%	-8.20%	4.16%	3.89%	4.17%	-7.27%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	-0.26%	0.62%	-0.08%	0.00%	-8.20%	0.74%	4.02%	-0.52%	-7.96%
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	-3.17%	0.62%	-2.45%	0.00%	-8.20%	1.08%	3.98%	-0.18%	-8.07%
17	Volatile Organic Compounds (VOC)	g	0.14%	0.07%	0.13%	0.00%	-8.19%	1.55%	3.62%	1.44%	-6.34%
18	Persistent Organic Pollutants (POP)	ng i-Teq	-0.31%	-0.10%	-0.31%	0.00%	-8.14%	-0.04%	0.00%	-0.04%	-4.80%
19	Heavy Metals	mg Ni eq.	-2.49%	-0.10%	-2.10%	0.00%	-8.19%	0.66%	0.00%	0.66%	-7.54%
	PAHs	mg Ni eq.	-0.54%	2.22%	-0.54%	0.00%	-8.16%	0.00%	3.87%	3.87%	-5.35%
20	Particulate Matter (PM, dust)	g	0.25%	0.62%	0.30%	0.00%	-8.18%	1.40%	4.13%	1.39%	-2.11%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	-0.26%	-0.09%	-0.26%	0.00%	-8.18%	0.45%	0.00%	0.46%	-6.41%
22	Eutrophication	g PO4	2.87%	0.90%	2.84%	0.00%	-7.75%	0.45%	4.15%	-0.84%	0.72%
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Annexe 7- 4: Option 4 relative improvement compared to the base case RCV2

Table . Life Cycle Impact (per unit) of Product Base Case remote open vertical chilled multi deck (RCV2)

Nr	Life cycle Impact per product:	Date	Author
0	Product Base Case remote open vertical chilled multi deck (RCV2) with Option 4	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0
4	Non-ferro	g			1.53%			1.53%	1.53%	1.53%	0
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0
	Total weight	g			0.12%			0.11%	0.12%	0.12%	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.12%	0.12%	0.12%	0.00%	-2.50%	0.10%	0.00%	0.42%	-2.45%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.12%	0.08%	0.00%	-2.50%	0.00%	0.00%	0.00%	-2.49%
10	Water (process)	ltr	0.00%	0.12%	0.00%	0.00%	-2.50%	0.00%	0.00%	0.00%	-2.46%
11	Water (cooling)	ltr	0.00%	0.12%	0.02%	0.00%	-2.50%	0.00%	0.00%	0.00%	-2.49%
12	Waste, non-haz./ landfill	g	0.53%	0.13%	0.51%	0.00%	-2.49%	0.12%	0.00%	0.12%	-1.65%
13	Waste, hazardous/ incinerated	g	0.00%	0.12%	0.00%	0.00%	-2.50%	0.00%	0.00%	0.00%	-2.30%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.10%	0.12%	0.10%	0.00%	-2.50%	0.10%	0.00%	0.14%	-2.42%
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	0.47%	0.12%	0.41%	0.00%	-2.50%	0.09%	0.00%	0.13%	-2.44%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.13%	0.01%	0.00%	-2.50%	0.08%	0.00%	0.08%	-1.94%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.06%	0.15%	0.06%	0.00%	-2.48%	0.12%	0.00%	0.12%	-1.39%
19	Heavy Metals	mg Ni eq.	0.75%	0.15%	0.66%	0.00%	-2.50%	0.10%	0.00%	0.10%	-2.20%
	PAHs	mg Ni eq.	0.15%	0.03%	0.15%	0.00%	-2.49%	0.00%	0.00%	0.00%	-1.53%
20	Particulate Matter (PM, dust)	g	0.05%	0.12%	0.06%	0.00%	-2.50%	0.08%	0.00%	0.08%	-0.67%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.60%	0.13%	0.60%	0.00%	-2.49%	0.11%	0.00%	0.11%	-1.81%
22	Eutrophication	g PO4	0.01%	0.11%	0.01%	0.00%	-2.40%	0.11%	0.00%	0.14%	-0.45%
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Annexe 7- 5: Option 5 relative improvement compared to the base case RCV2

Table . Life Cycle Impact (per unit) of Product Base Case remote open vertical chilled multi deck (RCV2)

Nr	Life cycle Impact per product:	Date	Author
0	Product Base Case remote open vertical chilled multi deck (RCV2) + Option 5	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	0
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0
7	Misc.	g			424.36%			424.36%	424.36%	424.36%	0
	Total weight	g			24.43%			22.83%	24.52%	24.43%	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	7.51%	0.00%	5.80%	0.00%	-51.99%	19.67%	0.00%	84.96%	-50.82%
9	of which, electricity (in primary MJ)	MJ	54.07%	0.00%	20.89%	0.00%	-52.00%	0.00%	0.00%	0.00%	-51.75%
10	Water (process)	ltr	48.09%	0.00%	46.60%	0.00%	-51.98%	0.00%	0.00%	0.00%	-50.51%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-52.00%	0.00%	0.00%	0.00%	-51.86%
12	Waste, non-haz./ landfill	g	0.18%	0.00%	0.17%	0.00%	-51.80%	24.36%	0.00%	24.69%	-36.93%
13	Waste, hazardous/ incinerated	g	3.78%	0.00%	3.77%	0.00%	-51.99%	0.00%	0.00%	0.00%	-47.82%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	5.87%	0.00%	4.69%	0.00%	-51.99%	19.82%	0.00%	27.47%	-50.31%
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	4.55%	0.00%	3.69%	0.00%	-51.99%	17.92%	0.00%	25.63%	-50.81%
17	Volatile Organic Compounds (VOC)	g	0.60%	0.00%	0.58%	0.00%	-51.96%	15.24%	0.00%	16.05%	-40.18%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.09%	0.00%	0.09%	0.00%	-51.62%	24.36%	0.00%	24.36%	-29.34%
19	Heavy Metals	mg Ni eq.	0.81%	0.00%	0.68%	0.00%	-51.95%	20.28%	0.00%	20.30%	-46.52%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-51.74%	0.00%	0.00%	0.00%	-32.80%
20	Particulate Matter (PM, dust)	g	0.43%	0.00%	0.37%	0.00%	-51.91%	16.10%	0.00%	16.15%	-12.92%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.13%	0.00%	0.13%	0.00%	-51.86%	21.49%	0.00%	21.86%	-40.11%
22	Eutrophication	g PO4	0.02%	0.00%	0.02%	0.00%	-49.89%	21.51%	0.00%	29.00%	-9.11%
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Annexe 7- 6: Option 1 relative improvement compared to the base case RHF4

Table . Life Cycle Impact (per unit) of Base Case remote open frozen island (RHF4) - option1

Nr	Life cycle Impact per product:	Date	Author
0	Base Case remote open frozen island (RHF4) - option1	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0.00%
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0.00%
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0.00%
4	Non-ferro	g			9.16%			9.16%	9.16%	9.16%	0.00%
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0.00%
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0.00%
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0.00%
	Total weight	g			0.76%			0.69%	0.76%	0.76%	0.00%
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	2.98%	0.93%	2.56%	0.00%	-18.00%	0.61%	0.00%	2.52%	-17.57%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.93%	0.49%	0.00%	-18.00%	0.00%	0.00%	0.00%	-17.92%
10	Water (process)	ltr	0.00%	0.90%	0.02%	0.00%	-18.00%	0.00%	0.00%	0.00%	-17.59%
11	Water (cooling)	ltr	0.00%	0.93%	0.12%	0.00%	-18.00%	0.00%	0.00%	0.00%	-17.95%
12	Waste, non-haz./ landfill	g	1.87%	0.96%	1.84%	0.00%	-17.92%	0.75%	0.00%	0.76%	-12.16%
13	Waste, hazardous/ incinerated	g	0.00%	0.73%	0.00%	0.00%	-18.00%	0.00%	0.00%	0.00%	-16.24%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	2.53%	0.93%	2.23%	0.00%	-18.00%	0.61%	0.00%	0.85%	-17.38%
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	3.04%	0.93%	2.71%	0.00%	-18.00%	0.56%	0.00%	0.80%	-17.49%
17	Volatile Organic Compounds (VOC)	g	0.47%	0.90%	0.48%	0.00%	-17.98%	0.47%	0.00%	0.50%	-14.09%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.25%	1.19%	0.27%	0.00%	-17.88%	0.75%	0.00%	0.75%	-10.48%
19	Heavy Metals	mg Ni eq.	0.46%	1.19%	0.55%	0.00%	-17.98%	0.63%	0.00%	0.63%	-15.74%
	PAHs	mg Ni eq.	11.45%	0.16%	11.45%	0.00%	-17.73%	0.00%	0.00%	0.00%	-3.72%
20	Particulate Matter (PM, dust)	g	3.96%	0.93%	3.57%	0.00%	-17.96%	0.50%	0.00%	0.50%	-4.91%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	3.32%	0.92%	3.32%	0.00%	-17.93%	0.67%	0.00%	0.69%	-12.29%
22	Eutrophication	g PO4	0.01%	0.81%	0.02%	0.00%	-17.30%	0.67%	0.00%	0.90%	-3.43%
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Annexe 7- 7: Option 2 relative improvement compared to the base case RHF4

Table . Life Cycle Impact (per unit) of Base Case remote open frozen island (RHF4) - option2

Nr	Life cycle Impact per product:	Date	Author
0	Base Case remote open frozen island (RHF4) - option2	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0.00%
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0.00%
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0.00%
4	Non-ferro	g			1.14%			1.14%	1.14%	1.14%	0.00%
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0.00%
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0.00%
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0.00%
	Total weight	g			0.09%			0.09%	0.09%	0.09%	0.00%
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.10%	0.12%	0.10%	0.00%	-2.00%	0.08%	0.00%	0.32%	-1.95%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.12%	0.06%	0.00%	-2.00%	0.00%	0.00%	0.00%	-1.99%
10	Water (process)	ltr	0.00%	0.11%	0.00%	0.00%	-2.00%	0.00%	0.00%	0.00%	-1.95%
11	Water (cooling)	ltr	0.00%	0.12%	0.02%	0.00%	-2.00%	0.00%	0.00%	0.00%	-1.99%
12	Waste, non-haz./ landfill	g	0.48%	0.12%	0.47%	0.00%	-1.99%	0.09%	0.00%	0.10%	-1.28%
13	Waste, hazardous/ incinerated	g	0.00%	0.09%	0.00%	0.00%	-2.00%	0.00%	0.00%	0.00%	-1.80%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.08%	0.12%	0.09%	0.00%	-2.00%	0.08%	0.00%	0.11%	-1.94%
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	0.35%	0.12%	0.32%	0.00%	-2.00%	0.07%	0.00%	0.10%	-1.94%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.11%	0.01%	0.00%	-2.04%	0.06%	0.00%	0.06%	-1.59%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.06%	0.15%	0.07%	0.00%	-2.03%	0.09%	0.00%	0.09%	-1.16%
19	Heavy Metals	mg Ni eq.	0.52%	0.15%	0.48%	0.00%	-2.04%	0.08%	0.00%	0.08%	-1.74%
	PAHs	mg Ni eq.	0.08%	0.02%	0.08%	0.00%	-2.02%	0.00%	0.00%	0.00%	-0.98%
20	Particulate Matter (PM, dust)	g	0.04%	0.12%	0.05%	0.00%	-2.04%	0.06%	0.00%	0.06%	-0.57%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.45%	0.12%	0.45%	0.00%	-1.99%	0.08%	0.00%	0.09%	-1.35%
22	Eutrophication	g PO4	0.01%	0.10%	0.01%	0.00%	-1.92%	0.08%	0.00%	0.11%	-0.37%
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Annexe 7- 8: Option 3 relative improvement compared to the base case RHF4

Table . Life Cycle Impact (per unit) of Base Case remote open frozen island (RHF4) - option3

Nr	Life cycle Impact per product:	Date	Author
0	Base Case remote open frozen island (RHF4) - option3	0	BIO

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0.00%**
2	TecPlastics	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0.00%**
3	Ferro	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0.00%**
4	Non-ferro	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0.00%**
5	Coating	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0.00%**
6	Electronics	g			**11.70%**			**12.86%**	**0.00%**	**11.70%**	**0.00%**
7	Misc.	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0.00%**
	Total weight	g			**0.02%**			**0.35%**	**0.00%**	**0.02%**	**0.00%**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	**0.30%**	**0.00%**	**0.24%**	**0.00%**	**-6.00%**	**0.02%**	**0.00%**	**0.06%**	**-5.87%**
9	of which, electricity (in primary MJ)	MJ	**1.59%**	**0.00%**	**0.76%**	**0.00%**	**-6.00%**	**0.00%**	**0.00%**	**0.00%**	**-5.97%**
10	Water (process)	ltr	**1.82%**	**0.00%**	**1.78%**	**0.00%**	**-6.00%**	**0.00%**	**0.00%**	**0.00%**	**-5.82%**
11	Water (cooling)	ltr	**0.09%**	**0.00%**	**0.07%**	**0.00%**	**-6.00%**	**0.00%**	**0.00%**	**0.00%**	**-5.98%**
12	Waste, non-haz./ landfill	g	**0.02%**	**0.00%**	**0.02%**	**0.00%**	**-5.98%**	**0.02%**	**0.00%**	**0.02%**	**-4.22%**
13	Waste, hazardous/ incinerated	g	**6.02%**	**0.00%**	**6.01%**	**0.00%**	**-6.00%**	**0.00%**	**0.00%**	**0.00%**	**-5.27%**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	**0.31%**	**0.00%**	**0.26%**	**0.00%**	**-6.00%**	**0.02%**	**0.01%**	**0.02%**	**-5.81%**
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	**0.49%**	**0.00%**	**0.42%**	**0.00%**	**-6.00%**	**0.01%**	**0.00%**	**0.02%**	**-5.84%**
17	Volatile Organic Compounds (VOC)	g	**1.14%**	**0.00%**	**1.09%**	**0.00%**	**-5.99%**	**0.01%**	**0.01%**	**0.01%**	**-4.64%**
18	Persistent Organic Pollutants (POP)	ng i-Teq	**0.01%**	**0.00%**	**0.01%**	**0.00%**	**-5.96%**	**0.02%**	**0.00%**	**0.02%**	**-3.53%**
19	Heavy Metals	mg Ni eq.	**0.23%**	**0.00%**	**0.21%**	**0.00%**	**-5.99%**	**0.02%**	**0.00%**	**0.02%**	**-5.25%**
	PAHs	mg Ni eq.	**0.18%**	**0.00%**	**0.18%**	**0.00%**	**-5.94%**	**0.00%**	**0.00%**	**0.00%**	**-2.93%**
20	Particulate Matter (PM, dust)	g	**0.13%**	**0.00%**	**0.11%**	**0.00%**	**-5.99%**	**0.01%**	**0.00%**	**0.01%**	**-1.71%**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	**0.79%**	**0.00%**	**0.79%**	**0.00%**	**-5.98%**	**0.02%**	**0.00%**	**0.02%**	**-4.18%**
22	Eutrophication	g PO4	**0.21%**	**0.00%**	**0.20%**	**0.00%**	**-5.76%**	**0.02%**	**0.00%**	**0.02%**	**-0.99%**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Annexe 7- 9: Option 4 relative improvement compared to the base case RHF4

Table . Life Cycle Impact (per unit) of Base Case remote open frozen island (RHF4) - option5

Nr	Life cycle Impact per product:	Date	Author
0	**Base Case remote open frozen island (RHF4) - option5**	0	0

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			2.55%			2.55%	2.55%	2.55%	0
2	TecPlastics	g			4.24%			4.24%	4.24%	4.24%	0
3	Ferro	g			-0.19%			-0.19%	-0.19%	-0.19%	0
4	Non-ferro	g			-2.68%			-2.68%	-2.68%	-2.68%	0
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0
	Total weight	g			-0.12%			0.09%	-0.13%	-0.12%	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	-0.01%	0.47%	0.09%	0.00%	-3.50%	0.52%	3.18%	-7.82%	-3.42%
9	of which, electricity (in primary MJ)	MJ	0.47%	0.48%	0.48%	0.00%	-3.50%	3.23%	2.98%	2.98%	-3.48%
10	Water (process)	ltr	-0.41%	0.48%	-0.39%	0.00%	-3.50%	0.00%	2.90%	2.90%	-3.43%
11	Water (cooling)	ltr	1.99%	0.49%	1.80%	0.00%	-3.50%	0.00%	3.22%	3.22%	-3.49%
12	Waste, non-haz./ landfill	g	-1.20%	0.41%	-1.16%	0.00%	-3.49%	-0.11%	3.04%	-0.15%	-2.80%
13	Waste, hazardous/ incinerated	g	1.22%	-0.11%	1.22%	0.00%	-3.50%	3.16%	2.80%	3.17%	-2.90%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	-0.20%	0.47%	-0.08%	0.00%	-3.50%	0.50%	3.10%	-0.48%	-3.39%
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	-1.31%	0.47%	-1.03%	0.00%	-3.50%	0.76%	2.99%	-0.21%	-3.44%
17	Volatile Organic Compounds (VOC)	g	-0.07%	-0.01%	-0.06%	0.00%	-3.50%	1.13%	2.63%	1.04%	-2.74%
18	Persistent Organic Pollutants (POP)	ng i-Teq	-0.62%	-0.18%	-0.62%	0.00%	-3.48%	-0.11%	0.00%	-0.11%	-2.31%
19	Heavy Metals	mg Ni eq.	-1.43%	-0.18%	-1.28%	0.00%	-3.50%	0.44%	0.00%	0.44%	-3.19%
	PAHs	mg Ni eq.	-0.46%	1.44%	-0.46%	0.00%	-3.47%	0.00%	2.78%	2.78%	-1.97%
20	Particulate Matter (PM, dust)	g	0.12%	0.47%	0.17%	0.00%	-3.49%	1.01%	3.13%	1.00%	-0.90%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	-0.23%	-0.14%	-0.23%	0.00%	-3.49%	0.27%	0.00%	0.28%	-2.62%
22	Eutrophication	g PO4	2.47%	0.69%	2.45%	0.00%	-3.27%	0.27%	3.14%	-0.73%	1.23%
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Annexe 7- 10: Option 5 relative improvement compared to the base case RHF4

Table . Life Cycle Impact (per unit) of Base Case remote open frozen island (RHF4) - option5

Nr	Life cycle Impact per product:	Date	Author
0	Base Case remote open frozen island (RHF4) - option5	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	0
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0
7	Misc.	g			77.20%			77.20%	77.20%	77.20%	0
	Total weight	g			18.90%			17.28%	18.99%	18.90%	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	6.28%	0.00%	4.98%	0.00%	-36.49%	15.24%	0.00%	63.08%	-35.61%
9	of which, electricity (in primary MJ)	MJ	35.52%	0.00%	16.90%	0.00%	-36.50%	0.00%	0.00%	0.00%	-36.28%
10	Water (process)	ltr	29.59%	0.00%	28.98%	0.00%	-36.48%	0.00%	0.00%	0.00%	-35.00%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-36.50%	0.00%	0.00%	0.00%	-36.40%
12	Waste, non-haz./ landfill	g	0.16%	0.00%	0.16%	0.00%	-36.35%	18.84%	0.00%	19.11%	-25.48%
13	Waste, hazardous/ incinerated	g	2.48%	0.00%	2.47%	0.00%	-36.49%	0.00%	0.00%	0.00%	-32.87%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	5.09%	0.00%	4.14%	0.00%	-36.49%	15.35%	0.00%	21.13%	-35.23%
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	3.39%	0.00%	2.87%	0.00%	-36.49%	13.89%	0.00%	19.96%	-35.52%
17	Volatile Organic Compounds (VOC)	g	0.53%	0.00%	0.51%	0.00%	-36.47%	11.84%	0.00%	12.50%	-28.46%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.09%	0.00%	0.09%	0.00%	-36.26%	18.84%	0.00%	18.85%	-21.25%
19	Heavy Metals	mg Ni eq.	0.56%	0.00%	0.49%	0.00%	-36.46%	15.70%	0.00%	15.73%	-31.74%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-36.17%	0.00%	0.00%	0.00%	-18.31%
20	Particulate Matter (PM, dust)	g	0.38%	0.00%	0.33%	0.00%	-36.43%	12.49%	0.00%	12.54%	-9.21%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.09%	0.00%	0.09%	0.00%	-36.37%	16.63%	0.00%	17.15%	-26.49%
22	Eutrophication	g PO4	0.02%	0.00%	0.02%	0.00%	-35.09%	16.64%	0.00%	22.45%	-6.47%
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Annexe 7- 11: Option 1 relative improvement compared to the base case beverage cooler

Table . Life Cycle Impact (per unit) of BASE CASE BEVERAGE COOLER

Nr	Life cycle Impact per product:	Date	Author
0	BASE CASE BEVERAGE COOLER + Option 1	0	BIO IS

Nr	Life Cycle phases --> / Resources Use and Emissions	unit	PRODUCTION Material	PRODUCTION Manuf.	PRODUCTION Total	DISTRI-BUTION	USE	END-OF-LIFE* Disposal	END-OF-LIFE* Recycl.	END-OF-LIFE* Total	TOTAL
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	0
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0
	Total weight	g			0.00%			0.00%	0.00%	0.00%	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.00%	0.00%	0.00%	0.00%	-14.99%	0.00%	0.00%	0.00%	-14.39%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.00%	0.00%	0.00%	-15.00%	0.00%	0.00%	0.00%	-14.89%
10	Water (process)	ltr	0.00%	0.00%	0.00%	0.00%	-14.99%	0.00%	0.00%	0.00%	-13.97%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-15.00%	0.00%	0.00%	0.00%	-14.90%
12	Waste, non-haz./ landfill	g	0.00%	0.00%	0.00%	0.00%	-14.88%	0.00%	0.00%	0.00%	-7.99%
13	Waste, hazardous/ incinerated	g	0.00%	0.00%	0.00%	0.00%	-14.99%	0.00%	0.00%	0.00%	-11.13%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.00%	0.00%	0.00%	0.00%	-14.99%	0.00%	0.00%	0.00%	-13.70%
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	0.00%	0.00%	0.00%	0.00%	-14.99%	0.00%	0.00%	0.00%	-14.23%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.00%	0.00%	0.00%	-14.98%	0.00%	0.00%	0.00%	-10.20%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.00%	0.00%	0.00%	0.00%	-14.82%	0.00%	0.00%	0.00%	-6.57%
19	Heavy Metals	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-14.96%	0.00%	0.00%	0.00%	-11.40%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-14.65%	0.00%	0.00%	0.00%	-4.28%
20	Particulate Matter (PM, dust)	g	0.00%	0.00%	0.00%	0.00%	-14.94%	0.00%	0.00%	0.00%	-2.69%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.00%	0.00%	0.00%	0.00%	-14.88%	0.00%	0.00%	0.00%	-8.18%
22	Eutrophication	g PO4	0.00%	0.00%	0.00%	0.00%	-14.02%	0.00%	0.00%	0.00%	-1.81%
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Annexe 7- 12: Option 2 relative improvement compared to the base case beverage cooler

Table . Life Cycle Impact (per unit) of BASE CASE BEVERAGE COOLER

Nr	Life cycle Impact per product:	Date	Author
0	BASE CASE BEVERAGE COOLER + Option 2	0	BIO IS

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	0
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0
	Total weight	g			0.00%			0.00%	0.00%	0.00%	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.00%	0.00%	0.00%	0.00%	-4.00%	0.00%	0.00%	0.00%	-3.84%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.00%	0.00%	0.00%	-4.00%	0.00%	0.00%	0.00%	-3.97%
10	Water (process)	ltr	0.00%	0.00%	0.00%	0.00%	-4.00%	0.00%	0.00%	0.00%	-3.73%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-4.00%	0.00%	0.00%	0.00%	-3.97%
12	Waste, non-haz./ landfill	g	0.00%	0.00%	0.00%	0.00%	-3.97%	0.00%	0.00%	0.00%	-2.13%
13	Waste, hazardous/ incinerated	g	0.00%	0.00%	0.00%	0.00%	-4.00%	0.00%	0.00%	0.00%	-2.97%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.00%	0.00%	0.00%	0.00%	-4.00%	0.00%	0.00%	0.00%	-3.65%
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	0.00%	0.00%	0.00%	0.00%	-4.00%	0.00%	0.00%	0.00%	-3.79%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.00%	0.00%	0.00%	-3.99%	0.00%	0.00%	0.00%	-2.72%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.00%	0.00%	0.00%	0.00%	-3.95%	0.00%	0.00%	0.00%	-1.75%
19	Heavy Metals	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-3.99%	0.00%	0.00%	0.00%	-3.04%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-3.91%	0.00%	0.00%	0.00%	-1.14%
20	Particulate Matter (PM, dust)	g	0.00%	0.00%	0.00%	0.00%	-3.98%	0.00%	0.00%	0.00%	-0.72%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.00%	0.00%	0.00%	0.00%	-3.97%	0.00%	0.00%	0.00%	-2.18%
22	Eutrophication	g PO4	0.00%	0.00%	0.00%	0.00%	-3.74%	0.00%	0.00%	0.00%	-0.48%
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Annexe 7- 13: Option 3 relative improvement compared to the base case beverage cooler

Table . Life Cycle Impact (per unit) of BASE CASE BEVERAGE COOLER

Nr	Life cycle Impact per product:	Date	Author
0	BASE CASE BEVERAGE COOLER + Option 3	0	BIO IS

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	0
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0
	Total weight	g			0.00%			0.00%	0.00%	0.00%	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.00%	0.00%	0.00%	0.00%	-10.00%	0.00%	0.00%	0.00%	-9.59%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.00%	0.00%	0.00%	-10.00%	0.00%	0.00%	0.00%	-9.93%
10	Water (process)	ltr	0.00%	0.00%	0.00%	0.00%	-9.99%	0.00%	0.00%	0.00%	-9.31%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-10.00%	0.00%	0.00%	0.00%	-9.93%
12	Waste, non-haz./ landfill	g	0.00%	0.00%	0.00%	0.00%	-9.92%	0.00%	0.00%	0.00%	-5.33%
13	Waste, hazardous/ incinerated	g	0.00%	0.00%	0.00%	0.00%	-9.99%	0.00%	0.00%	0.00%	-7.42%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.00%	0.00%	0.00%	0.00%	-10.00%	0.00%	0.00%	0.00%	-9.13%
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	0.00%	0.00%	0.00%	0.00%	-10.00%	0.00%	0.00%	0.00%	-9.49%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.00%	0.00%	0.00%	-9.99%	0.00%	0.00%	0.00%	-6.80%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.00%	0.00%	0.00%	0.00%	-9.88%	0.00%	0.00%	0.00%	-4.38%
19	Heavy Metals	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-9.97%	0.00%	0.00%	0.00%	-7.60%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-9.77%	0.00%	0.00%	0.00%	-2.85%
20	Particulate Matter (PM, dust)	g	0.00%	0.00%	0.00%	0.00%	-9.96%	0.00%	0.00%	0.00%	-1.79%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.00%	0.00%	0.00%	0.00%	-9.92%	0.00%	0.00%	0.00%	-5.45%
22	Eutrophication	g PO4	0.00%	0.00%	0.00%	0.00%	-9.35%	0.00%	0.00%	0.00%	-1.21%
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Annexe 7- 14: Option 4 relative improvement compared to the base case beverage cooler

Table . Life Cycle Impact (per unit) of BASE CASE BEVERAGE COOLER

Nr	Life cycle Impact per product:	Date	Author
0	BASE CASE BEVERAGE COOLER + Option 5	0	BIO IS

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**7.06%**			**7.06%**	**7.06%**	**7.06%**	**0**
2	TecPlastics	g			**4.29%**			**4.29%**	**4.29%**	**4.29%**	**0**
3	Ferro	g			**-0.64%**			**-0.64%**	**-0.64%**	**-0.64%**	**0**
4	Non-ferro	g			**-5.62%**			**-5.62%**	**-5.62%**	**-5.62%**	**0**
5	Coating	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0**
6	Electronics	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0**
7	Misc.	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0**
	Total weight	g			**-0.32%**			**0.26%**	**-0.36%**	**-0.32%**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	**-0.34%**	**1.39%**	**0.03%**	**0.00%**	**-13.50%**	**1.34%**	**5.42%**	**38.79%**	**-12.96%**
9	of which, electricity (in primary MJ)	MJ	**1.60%**	**1.43%**	**1.50%**	**0.00%**	**-13.50%**	**5.36%**	**4.94%**	**4.94%**	**-13.39%**
10	Water (process)	ltr	**-0.89%**	**1.41%**	**-0.86%**	**0.00%**	**-13.49%**	**0.00%**	**4.81%**	**4.81%**	**-12.64%**
11	Water (cooling)	ltr	**4.21%**	**1.48%**	**3.93%**	**0.00%**	**-13.50%**	**0.00%**	**5.35%**	**5.35%**	**-13.38%**
12	Waste, non-haz./ landfill	g	**-5.30%**	**1.11%**	**-5.12%**	**0.00%**	**-13.43%**	**-0.30%**	**5.04%**	**-0.43%**	**-9.50%**
13	Waste, hazardous/ incinerated	g	**2.94%**	**0.00%**	**2.93%**	**0.00%**	**-13.49%**	**5.24%**	**4.64%**	**5.26%**	**-8.77%**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	**-0.84%**	**1.37%**	**-0.40%**	**0.00%**	**-13.49%**	**0.16%**	**5.55%**	**-0.11%**	**-12.35%**
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	**-6.08%**	**1.36%**	**-4.97%**	**0.00%**	**-13.50%**	**1.86%**	**5.16%**	**-0.57%**	**-13.03%**
17	Volatile Organic Compounds (VOC)	g	**-0.26%**	**0.00%**	**-0.26%**	**0.00%**	**-13.48%**	**2.57%**	**4.77%**	**2.42%**	**-9.14%**
18	Persistent Organic Pollutants (POP)	ng i-Teq	**-1.62%**	**-0.71%**	**-1.59%**	**0.00%**	**-13.35%**	**-0.30%**	**0.00%**	**-0.30%**	**-6.78%**
19	Heavy Metals	mg Ni eq.	**-5.32%**	**-0.71%**	**-4.64%**	**0.00%**	**-13.48%**	**1.15%**	**0.00%**	**1.15%**	**-11.13%**
	PAHs	mg Ni eq.	**-0.67%**	**2.38%**	**-0.67%**	**0.00%**	**-13.20%**	**0.00%**	**4.60%**	**4.60%**	**-4.32%**
20	Particulate Matter (PM, dust)	g	**0.33%**	**1.36%**	**0.46%**	**0.00%**	**-13.44%**	**2.35%**	**5.22%**	**2.34%**	**-2.02%**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	**-0.54%**	**-0.52%**	**-0.54%**	**0.00%**	**-13.40%**	**0.75%**	**0.00%**	**0.79%**	**-7.58%**
22	Eutrophication	g PO4	**7.77%**	**1.91%**	**7.67%**	**0.00%**	**-12.12%**	**0.74%**	**5.20%**	**-2.43%**	**4.84%**
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Annexe 7- 15: Option 5 relative improvement compared to the base case beverage cooler

Table . Life Cycle Impact (per unit) of BASE CASE BEVERAGE COOLER

Nr	Life cycle Impact per product:	Date	Author
0	BASE CASE BEVERAGE COOLER + Option 6	0	BIO IS

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	0
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0
	Total weight	g			0.00%			0.00%	0.00%	0.00%	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.00%	0.00%	0.00%	0.00%	-7.50%	0.00%	0.00%	0.00%	-7.19%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.00%	0.00%	0.00%	-7.50%	0.00%	0.00%	0.00%	-7.44%
10	Water (process)	ltr	0.00%	0.00%	0.00%	0.00%	-7.49%	0.00%	0.00%	0.00%	-6.98%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-7.50%	0.00%	0.00%	0.00%	-7.45%
12	Waste, non-haz./ landfill	g	0.00%	0.00%	0.00%	0.00%	-7.44%	0.00%	0.00%	0.00%	-3.99%
13	Waste, hazardous/ incinerated	g	0.00%	0.00%	0.00%	0.00%	-7.50%	0.00%	0.00%	0.00%	-5.56%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.00%	0.00%	0.00%	0.00%	-7.50%	0.00%	0.00%	0.00%	-6.85%
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	0.00%	0.00%	0.00%	0.00%	-7.50%	0.00%	0.00%	0.00%	-7.11%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.00%	0.00%	0.00%	-7.49%	0.00%	0.00%	0.00%	-5.10%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.00%	0.00%	0.00%	0.00%	-7.41%	0.00%	0.00%	0.00%	-3.28%
19	Heavy Metals	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-7.48%	0.00%	0.00%	0.00%	-5.70%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-7.33%	0.00%	0.00%	0.00%	-2.14%
20	Particulate Matter (PM, dust)	g	0.00%	0.00%	0.00%	0.00%	-7.47%	0.00%	0.00%	0.00%	-1.34%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.00%	0.00%	0.00%	0.00%	-7.44%	0.00%	0.00%	0.00%	-4.09%
22	Eutrophication	g PO4	0.00%	0.00%	0.00%	0.00%	-7.01%	0.00%	0.00%	0.00%	-0.91%
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Annexe 7- 16: Option 6 relative improvement compared to the base case beverage cooler

Table . Life Cycle Impact (per unit) of BASE CASE BEVERAGE COOLER

Nr	Life cycle Impact per product:	Date	Author
0	BASE CASE BEVERAGE COOLER + Option 4	0	BIO IS

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	0
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0
	Total weight	g			0.00%			0.00%	0.00%	0.00%	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.00%	0.00%	0.00%	0.00%	-12.00%	0.00%	0.00%	0.00%	-11.51%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.00%	0.00%	0.00%	-12.00%	0.00%	0.00%	0.00%	-11.91%
10	Water (process)	ltr	0.00%	0.00%	0.00%	0.00%	-11.99%	0.00%	0.00%	0.00%	-11.18%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-12.00%	0.00%	0.00%	0.00%	-11.92%
12	Waste, non-haz./ landfill	g	0.00%	0.00%	0.00%	0.00%	-11.90%	0.00%	0.00%	0.00%	-6.39%
13	Waste, hazardous/ incinerated	g	0.00%	0.00%	0.00%	0.00%	-11.99%	0.00%	0.00%	0.00%	-8.90%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.00%	0.00%	0.00%	0.00%	-11.99%	0.00%	0.00%	0.00%	-10.96%
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	0.00%	0.00%	0.00%	0.00%	-11.99%	0.00%	0.00%	0.00%	-11.38%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.00%	0.00%	0.00%	-11.98%	0.00%	0.00%	0.00%	-8.16%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.00%	0.00%	0.00%	0.00%	-11.85%	0.00%	0.00%	0.00%	-5.25%
19	Heavy Metals	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-11.97%	0.00%	0.00%	0.00%	-9.12%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-11.72%	0.00%	0.00%	0.00%	-3.43%
20	Particulate Matter (PM, dust)	g	0.00%	0.00%	0.00%	0.00%	-11.95%	0.00%	0.00%	0.00%	-2.15%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.00%	0.00%	0.00%	0.00%	-11.91%	0.00%	0.00%	0.00%	-6.54%
22	Eutrophication	g PO4	0.00%	0.00%	0.00%	0.00%	-11.22%	0.00%	0.00%	0.00%	-1.45%
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Annexe 7- 17: Option 7 relative improvement compared to the base case beverage cooler

Table . Life Cycle Impact (per unit) of BASE CASE BEVERAGE COOLER

Nr	Life cycle Impact per product:	Date	Author
0	BASE CASE BEVERAGE COOLER + Option 7	0	BIO IS

Nr	Life Cycle phases --> / Resources Use and Emissions	unit	PRODUCTION Material	PRODUCTION Manuf.	PRODUCTION Total	DISTRI-BUTION	USE	END-OF-LIFE* Disposal	END-OF-LIFE* Recycl.	END-OF-LIFE* Total	TOTAL
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	0
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0
	Total weight	g			0.00%			0.00%	0.00%	0.00%	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.00%	0.00%	0.00%	0.00%	-3.50%	0.00%	0.00%	0.00%	-3.36%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.00%	0.00%	0.00%	-3.50%	0.00%	0.00%	0.00%	-3.47%
10	Water (process)	ltr	0.00%	0.00%	0.00%	0.00%	-3.50%	0.00%	0.00%	0.00%	-3.26%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-3.50%	0.00%	0.00%	0.00%	-3.48%
12	Waste, non-haz./ landfill	g	0.00%	0.00%	0.00%	0.00%	-3.47%	0.00%	0.00%	0.00%	-1.86%
13	Waste, hazardous/ incinerated	g	0.00%	0.00%	0.00%	0.00%	-3.50%	0.00%	0.00%	0.00%	-2.60%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.00%	0.00%	0.00%	0.00%	-3.50%	0.00%	0.00%	0.00%	-3.20%
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	0.00%	0.00%	0.00%	0.00%	-3.50%	0.00%	0.00%	0.00%	-3.32%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.00%	0.00%	0.00%	-3.50%	0.00%	0.00%	0.00%	-2.38%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.00%	0.00%	0.00%	0.00%	-3.46%	0.00%	0.00%	0.00%	-1.53%
19	Heavy Metals	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-3.49%	0.00%	0.00%	0.00%	-2.66%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-3.42%	0.00%	0.00%	0.00%	-1.00%
20	Particulate Matter (PM, dust)	g	0.00%	0.00%	0.00%	0.00%	-3.49%	0.00%	0.00%	0.00%	-0.63%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.00%	0.00%	0.00%	0.00%	-3.47%	0.00%	0.00%	0.00%	-1.91%
22	Eutrophication	g PO4	0.00%	0.00%	0.00%	0.00%	-3.27%	0.00%	0.00%	0.00%	-0.42%
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Annexe 7- 18: Option 8 relative improvement compared to the base case beverage cooler

Table . Life Cycle Impact (per unit) of BASE CASE BEVERAGE COOLER

Nr	Life cycle Impact per product:	Date	Author
0	BASE CASE BEVERAGE COOLER + Option 8	0	BIO IS

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0**
2	TecPlastics	g			**60.77%**			**60.77%**	**60.77%**	**60.77%**	**0**
3	Ferro	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0**
4	Non-ferro	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0**
5	Coating	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0**
6	Electronics	g			**0.00%**			**0.00%**	**0.00%**	**0.00%**	**0**
7	Misc.	g			**1.28%**			**1.28%**	**1.28%**	**1.28%**	**0**
	Total weight	g			**4.59%**			**7.96%**	**4.39%**	**4.59%**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	**9.27%**	**13.46%**	**10.16%**	**0.00%**	**-5.99%**	**14.15%**	**36.69%**	**220.92%**	**-5.48%**
9	of which, electricity (in primary MJ)	MJ	**13.28%**	**13.71%**	**13.53%**	**0.00%**	**-6.00%**	**37.34%**	**34.43%**	**34.42%**	**-5.86%**
10	Water (process)	ltr	**29.86%**	**13.40%**	**29.64%**	**0.00%**	**-5.97%**	**0.00%**	**33.48%**	**33.48%**	**-3.56%**
11	Water (cooling)	ltr	**42.66%**	**14.05%**	**39.66%**	**0.00%**	**-6.00%**	**0.00%**	**37.23%**	**37.23%**	**-5.68%**
12	Waste, non-haz./ landfill	g	**1.12%**	**11.65%**	**1.41%**	**0.00%**	**-5.94%**	**4.76%**	**35.12%**	**4.02%**	**-2.50%**
13	Waste, hazardous/ incinerated	g	**36.40%**	**0.00%**	**36.33%**	**0.00%**	**-5.98%**	**36.52%**	**32.31%**	**36.61%**	**4.91%**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	**6.12%**	**13.33%**	**7.56%**	**0.00%**	**-5.99%**	**1.70%**	**35.51%**	**0.04%**	**-5.14%**
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	**7.33%**	**13.28%**	**8.22%**	**0.00%**	**-5.99%**	**17.13%**	**34.34%**	**4.47%**	**-5.31%**
17	Volatile Organic Compounds (VOC)	g	**0.00%**	**0.00%**	**0.14%**	**0.00%**	**-5.99%**	**21.26%**	**29.24%**	**20.71%**	**-3.49%**
18	Persistent Organic Pollutants (POP)	ng i-Teq	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**-5.93%**	**4.76%**	**0.00%**	**4.76%**	**-2.55%**
19	Heavy Metals	mg Ni eq.	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**-5.98%**	**13.06%**	**0.00%**	**13.09%**	**-4.11%**
	PAHs	mg Ni eq.	**10.70%**	**17.15%**	**10.71%**	**0.00%**	**-5.61%**	**0.00%**	**32.02%**	**32.02%**	**5.52%**
20	Particulate Matter (PM, dust)	g	**8.87%**	**13.22%**	**9.40%**	**0.00%**	**-5.94%**	**19.97%**	**36.14%**	**19.90%**	**2.75%**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	**20.74%**	**0.00%**	**20.74%**	**0.00%**	**-5.79%**	**10.74%**	**0.00%**	**11.30%**	**6.00%**
22	Eutrophication	g PO4	**37.22%**	**16.58%**	**36.88%**	**0.00%**	**-3.20%**	**10.71%**	**36.24%**	**-7.42%**	**30.51%**
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Annexe 7- 19: Option 1 relative improvement compared to the base case ice cream freezer

Table . Life Cycle Impact (per unit) of Products Ice cream feezer

Nr	Life cycle Impact per product:	Date	Author
0	Products Ice cream feezer	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	
5	Coating	g			0.00%			0.00%	0.00%	0.00%	
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	
	Total weight	g			0.00%			0.00%	0.00%	0.00%	
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.00%	0.00%	0.00%	0.00%	-4.80%	0.00%	0.00%	0.00%	-4.42%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.00%	0.00%	0.00%	-4.80%	0.00%	0.00%	0.00%	-4.71%
10	Water (process)	ltr	0.00%	0.00%	0.00%	0.00%	-4.79%	0.00%	0.00%	0.00%	-4.22%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-4.80%	0.00%	0.00%	0.00%	-4.65%
12	Waste, non-haz./ landfill	g	0.00%	0.00%	0.00%	0.00%	-4.77%	0.00%	0.00%	0.00%	-2.71%
13	Waste, hazardous/ incinerated	g	0.00%	0.00%	0.00%	0.00%	-4.79%	0.00%	0.00%	0.00%	-3.08%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.00%	0.00%	0.00%	0.00%	-4.80%	0.00%	0.00%	0.00%	-3.96%
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	0.00%	0.00%	0.00%	0.00%	-4.80%	0.00%	0.00%	0.00%	-4.42%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.00%	0.00%	0.00%	-4.78%	0.00%	0.00%	0.00%	-2.68%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.00%	0.00%	0.00%	0.00%	-4.77%	0.00%	0.00%	0.00%	-2.78%
19	Heavy Metals	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-4.79%	0.00%	0.00%	0.00%	-3.70%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-4.74%	0.00%	0.00%	0.00%	-2.06%
20	Particulate Matter (PM, dust)	g	0.00%	0.00%	0.00%	0.00%	-4.76%	0.00%	0.00%	0.00%	-0.76%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.00%	0.00%	0.00%	0.00%	-4.77%	0.00%	0.00%	0.00%	-2.74%
22	Eutrophication	g PO4	0.00%	0.00%	0.00%	0.00%	-2.98%	0.00%	0.00%	0.00%	-0.08%
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

Annexe 7- 20: Option 2 relative improvement compared to the base case ice cream freezer

Table . Life Cycle Impact (per unit) of Products Ice cream feezer

Nr	Life cycle Impact per product:	Date	Author
0	Products Ice cream feezer	0	BIO

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	
5	Coating	g			0.00%			0.00%	0.00%	0.00%	
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	
	Total weight	g			0.00%			0.00%	0.00%	0.00%	
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.00%	0.00%	0.00%	0.00%	-4.00%	0.00%	0.00%	0.00%	-3.69%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.00%	0.00%	0.00%	-4.00%	0.00%	0.00%	0.00%	-3.92%
10	Water (process)	ltr	0.00%	0.00%	0.00%	0.00%	-3.99%	0.00%	0.00%	0.00%	-3.52%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-4.00%	0.00%	0.00%	0.00%	-3.87%
12	Waste, non-haz./ landfill	g	0.00%	0.00%	0.00%	0.00%	-3.97%	0.00%	0.00%	0.00%	-2.26%
13	Waste, hazardous/ incinerated	g	0.00%	0.00%	0.00%	0.00%	-3.99%	0.00%	0.00%	0.00%	-2.56%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.00%	0.00%	0.00%	0.00%	-4.00%	0.00%	0.00%	0.00%	-3.30%
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	0.00%	0.00%	0.00%	0.00%	-4.00%	0.00%	0.00%	0.00%	-3.68%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.00%	0.00%	0.00%	-3.98%	0.00%	0.00%	0.00%	-2.24%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.00%	0.00%	0.00%	0.00%	-3.97%	0.00%	0.00%	0.00%	-2.31%
19	Heavy Metals	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-3.99%	0.00%	0.00%	0.00%	-3.09%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-3.95%	0.00%	0.00%	0.00%	-1.72%
20	Particulate Matter (PM, dust)	g	0.00%	0.00%	0.00%	0.00%	-3.97%	0.00%	0.00%	0.00%	-0.63%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.00%	0.00%	0.00%	0.00%	-3.97%	0.00%	0.00%	0.00%	-2.28%
22	Eutrophication	g PO4	0.00%	0.00%	0.00%	0.00%	-2.48%	0.00%	0.00%	0.00%	-0.06%
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Annexe 7- 21: Option 3 relative improvement compared to the base case ice cream freezer

Table . Life Cycle Impact (per unit) of Products Ice cream feezer

Nr	Life cycle Impact per product:	Date	Author
0	Products Ice cream feezer	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			10.14%			10.14%	10.14%	10.14%	
2	TecPlastics	g			4.27%			4.27%	4.27%	4.27%	
3	Ferro	g			-2.09%			-2.09%	-2.09%	-2.09%	
4	Non-ferro	g			-10.05%			-10.05%	-10.05%	-10.05%	
5	Coating	g			0.00%			0.00%	0.00%	0.00%	
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	
	Total weight	g			-0.49%			0.39%	-0.55%	-0.49%	
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	-0.19%	2.47%	0.02%	0.00%	-5.00%	1.85%	5.24%	10.85%	-4.62%
9	of which, electricity (in primary MJ)	MJ	0.45%	2.51%	0.82%	0.00%	-5.00%	6.05%	6.05%	6.05%	-4.89%
10	Water (process)	ltr	-0.69%	2.60%	-0.67%	0.00%	-4.99%	0.00%	6.05%	6.05%	-4.49%
11	Water (cooling)	ltr	1.23%	2.60%	1.25%	0.00%	-5.00%	0.00%	6.05%	6.05%	-4.81%
12	Waste, non-haz./ landfill	g	-8.65%	2.05%	-8.38%	0.00%	-5.02%	-0.45%	6.05%	-0.65%	-6.34%
13	Waste, hazardous/ incinerated	g	1.23%	-1.87%	1.23%	0.00%	-4.99%	6.05%	6.05%	6.05%	-1.66%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	-0.56%	2.45%	-0.30%	0.00%	-5.00%	0.08%	4.18%	-0.05%	-4.15%
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	-4.78%	2.44%	-4.27%	0.00%	-5.00%	2.49%	4.88%	-1.11%	-4.92%
17	Volatile Organic Compounds (VOC)	g	-0.11%	-0.75%	-0.12%	0.00%	-4.98%	3.32%	3.64%	3.28%	-2.75%
18	Persistent Organic Pollutants (POP)	ng i-Teq	-4.19%	-1.87%	-4.11%	0.00%	-4.99%	-0.45%	0.00%	-0.45%	-4.54%
19	Heavy Metals	mg Ni eq.	-7.81%	-1.87%	-7.28%	0.00%	-5.01%	1.60%	0.00%	1.60%	-5.14%
	PAHs	mg Ni eq.	-1.91%	5.29%	-1.91%	0.00%	-4.96%	0.00%	6.04%	6.04%	-3.15%
20	Particulate Matter (PM, dust)	g	0.25%	2.45%	0.37%	0.00%	-4.96%	3.07%	5.84%	3.06%	-0.29%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	-0.87%	-1.87%	-0.87%	0.00%	-4.97%	1.07%	0.00%	1.07%	-3.19%
22	Eutrophication	g PO4	1.26%	3.27%	1.26%	0.00%	-2.63%	1.06%	6.05%	-4.14%	1.14%
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Annexe 7- 22: Option 4 relative improvement compared to the base case ice cream freezer

Table . Life Cycle Impact (per unit) of Products Ice cream feezer

Nr	Life cycle Impact per product:	Date	Author
0	Products Ice cream feezer	0	BIO

Nr	Life Cycle phases --> / Resources Use and Emissions	unit	PRODUCTION Material	PRODUCTION Manuf.	PRODUCTION Total	DISTRI-BUTION	USE	END-OF-LIFE* Disposal	END-OF-LIFE* Recycl.	END-OF-LIFE* Total	TOTAL
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	
5	Coating	g			0.00%			0.00%	0.00%	0.00%	
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	
	Total weight	g			0.00%			0.00%	0.00%	0.00%	
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.00%	0.00%	0.00%	0.00%	-10.99%	0.00%	0.00%	0.00%	-10.14%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.00%	0.00%	0.00%	-11.00%	0.00%	0.00%	0.00%	-10.78%
10	Water (process)	ltr	0.00%	0.00%	0.00%	0.00%	-10.98%	0.00%	0.00%	0.00%	-9.68%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-11.00%	0.00%	0.00%	0.00%	-10.65%
12	Waste, non-haz./ landfill	g	0.00%	0.00%	0.00%	0.00%	-10.92%	0.00%	0.00%	0.00%	-6.21%
13	Waste, hazardous/ incinerated	g	0.00%	0.00%	0.00%	0.00%	-10.98%	0.00%	0.00%	0.00%	-7.05%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.00%	0.00%	0.00%	0.00%	-10.99%	0.00%	0.00%	0.00%	-9.07%
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	0.00%	0.00%	0.00%	0.00%	-10.99%	0.00%	0.00%	0.00%	-10.12%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.00%	0.00%	0.00%	-10.95%	0.00%	0.00%	0.00%	-6.15%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.00%	0.00%	0.00%	0.00%	-10.93%	0.00%	0.00%	0.00%	-6.36%
19	Heavy Metals	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-10.97%	0.00%	0.00%	0.00%	-8.48%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-10.87%	0.00%	0.00%	0.00%	-4.73%
20	Particulate Matter (PM, dust)	g	0.00%	0.00%	0.00%	0.00%	-10.92%	0.00%	0.00%	0.00%	-1.74%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.00%	0.00%	0.00%	0.00%	-10.92%	0.00%	0.00%	0.00%	-6.27%
22	Eutrophication	g PO4	0.00%	0.00%	0.00%	0.00%	-6.83%	0.00%	0.00%	0.00%	-0.18%
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Annexe 7- 23: Option 1 relative improvement compared to the base case spiral vending machine

Table . Life Cycle Impact (per unit) of Base Case Spiral Vending Machine - option1

Nr	Life cycle Impact per product:	Date	Author
0	Base Case Spiral Vending Machine - option1	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0.00%
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0.00%
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0.00%
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	0.00%
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0.00%
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0.00%
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0.00%
	Total weight	g			0.00%			0.00%	0.00%	0.00%	0.00%
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.00%	0.00%	0.00%	0.00%	-17.97%	0.00%	0.00%	0.00%	-15.32%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.00%	0.00%	0.00%	-17.99%	0.00%	0.00%	0.00%	-17.14%
10	Water (process)	ltr	0.00%	0.00%	0.00%	0.00%	-17.94%	0.00%	0.00%	0.00%	-13.59%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-17.99%	0.00%	0.00%	0.00%	-17.03%
12	Waste, non-haz./ landfill	g	0.00%	0.00%	0.00%	0.00%	-17.76%	0.00%	0.00%	0.00%	-7.34%
13	Waste, hazardous/ incinerated	g	0.00%	0.00%	0.00%	0.00%	-17.93%	0.00%	0.00%	0.00%	-8.33%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.00%	0.00%	0.00%	0.00%	-17.96%	0.00%	0.00%	0.00%	-14.02%
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	0.00%	0.00%	0.00%	0.00%	-17.97%	0.00%	0.00%	0.00%	-15.33%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.00%	0.00%	0.00%	-17.78%	0.00%	0.00%	0.00%	-6.67%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.00%	0.00%	0.00%	0.00%	-17.55%	0.00%	0.00%	0.00%	-4.94%
19	Heavy Metals	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-17.91%	0.00%	0.00%	0.00%	-11.02%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-17.78%	0.00%	0.00%	0.00%	-7.62%
20	Particulate Matter (PM, dust)	g	0.00%	0.00%	0.00%	0.00%	-17.73%	0.00%	0.00%	0.00%	-2.17%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.00%	0.00%	0.00%	0.00%	-17.67%	0.00%	0.00%	0.00%	-6.07%
22	Eutrophication	g PO4	0.00%	0.00%	0.00%	0.00%	-8.68%	0.00%	0.00%	0.00%	-0.16%
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Annexe 7- 24: Option 2 relative improvement compared to the base case spiral vending machine

Table . Life Cycle Impact (per unit) of Base Case Spiral Vending Machine - option2

Nr	Life cycle Impact per product:	Date	Author
0	Base Case Spiral Vending Machine - option2	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0.00%
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0.00%
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0.00%
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	0.00%
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0.00%
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0.00%
7	Misc.	g			-0.73%			-0.73%	-0.73%	-0.73%	0.00%
	Total weight	g			-0.07%			-0.06%	-0.07%	-0.07%	0.00%
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.00%	0.00%	0.00%	0.00%	-6.49%	-0.05%	0.00%	0.10%	-5.53%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.00%	0.00%	0.00%	-6.50%	0.00%	0.00%	0.00%	-6.19%
10	Water (process)	ltr	0.00%	0.00%	0.00%	0.00%	-6.48%	0.00%	0.00%	0.00%	-4.91%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-6.50%	0.00%	0.00%	0.00%	-6.15%
12	Waste, non-haz./ landfill	g	0.00%	0.00%	0.00%	0.00%	-6.41%	-0.07%	0.00%	-0.07%	-2.65%
13	Waste, hazardous/ incinerated	g	0.00%	0.00%	0.00%	0.00%	-6.47%	0.00%	0.00%	0.00%	-3.01%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.00%	0.00%	0.00%	0.00%	-6.49%	-31.11%	0.00%	-34.84%	-6.63%
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	0.00%	0.00%	0.00%	0.00%	-6.49%	-0.04%	0.00%	-0.11%	-5.54%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.00%	0.00%	0.00%	-6.42%	-0.03%	0.00%	-0.04%	-2.41%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.00%	0.00%	0.00%	0.00%	-6.34%	-0.07%	0.00%	-0.07%	-1.78%
19	Heavy Metals	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-6.47%	-0.05%	0.00%	-0.05%	-3.98%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-6.42%	0.00%	0.00%	0.00%	-2.75%
20	Particulate Matter (PM, dust)	g	0.00%	0.00%	0.00%	0.00%	-6.40%	-0.03%	0.00%	-0.03%	-0.79%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.00%	0.00%	0.00%	0.00%	-6.38%	-0.05%	0.00%	-0.07%	-2.19%
22	Eutrophication	g PO4	0.00%	0.00%	0.00%	0.00%	-3.14%	-0.05%	0.00%	-0.10%	-0.06%
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

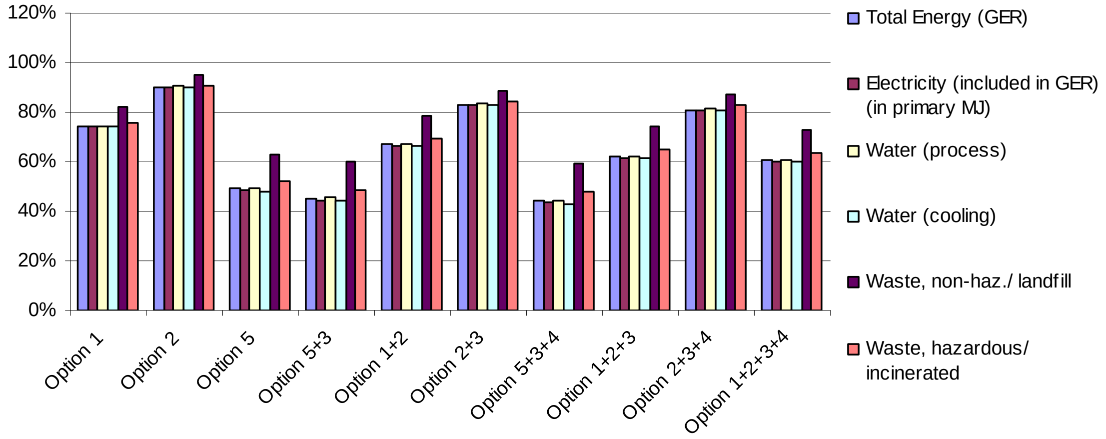
Annexe 7- 25: Option 3 relative improvement compared to the base case spiral vending machine

Table . Life Cycle Impact (per unit) of Base Case Spiral Vending Machine - option3

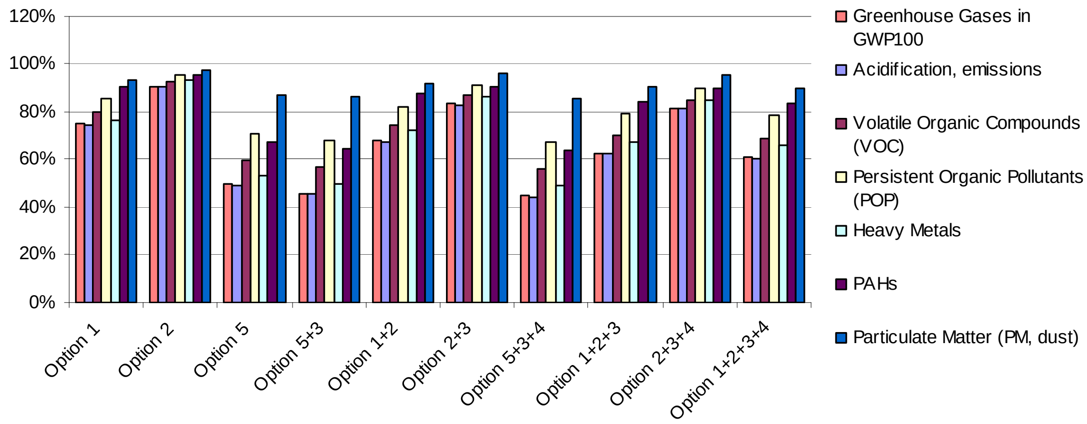
Nr	Life cycle Impact per product:	Date	Author
0	Base Case Spiral Vending Machine - option3	0	BIO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			0.00%			0.00%	0.00%	0.00%	0.00%
2	TecPlastics	g			0.00%			0.00%	0.00%	0.00%	0.00%
3	Ferro	g			0.00%			0.00%	0.00%	0.00%	0.00%
4	Non-ferro	g			0.00%			0.00%	0.00%	0.00%	0.00%
5	Coating	g			0.00%			0.00%	0.00%	0.00%	0.00%
6	Electronics	g			0.00%			0.00%	0.00%	0.00%	0.00%
7	Misc.	g			0.00%			0.00%	0.00%	0.00%	0.00%
	Total weight	g			0.00%			0.00%	0.00%	0.00%	0.00%
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0.00%	0.00%	0.00%	0.00%	-21.96%	0.00%	0.00%	0.00%	-18.72%
9	of which, electricity (in primary MJ)	MJ	0.00%	0.00%	0.00%	0.00%	-21.99%	0.00%	0.00%	0.00%	-20.95%
10	Water (process)	ltr	0.00%	0.00%	0.00%	0.00%	-21.93%	0.00%	0.00%	0.00%	-16.61%
11	Water (cooling)	ltr	0.00%	0.00%	0.00%	0.00%	-21.99%	0.00%	0.00%	0.00%	-20.81%
12	Waste, non-haz./ landfill	g	0.00%	0.00%	0.00%	0.00%	-21.70%	0.00%	0.00%	0.00%	-8.98%
13	Waste, hazardous/ incinerated	g	0.00%	0.00%	0.00%	0.00%	-21.91%	0.00%	0.00%	0.00%	-10.18%
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0.00%	0.00%	0.00%	0.00%	-21.95%	0.00%	0.00%	0.00%	-17.14%
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	0.00%	0.00%	0.00%	0.00%	-21.96%	0.00%	0.00%	0.00%	-18.74%
17	Volatile Organic Compounds (VOC)	g	0.00%	0.00%	0.00%	0.00%	-21.73%	0.00%	0.00%	0.00%	-8.15%
18	Persistent Organic Pollutants (POP)	ng i-Teq	0.00%	0.00%	0.00%	0.00%	-21.46%	0.00%	0.00%	0.00%	-6.03%
19	Heavy Metals	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-21.89%	0.00%	0.00%	0.00%	-13.47%
	PAHs	mg Ni eq.	0.00%	0.00%	0.00%	0.00%	-21.73%	0.00%	0.00%	0.00%	-9.32%
20	Particulate Matter (PM, dust)	g	0.00%	0.00%	0.00%	0.00%	-21.68%	0.00%	0.00%	0.00%	-2.65%
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0.00%	0.00%	0.00%	0.00%	-21.59%	0.00%	0.00%	0.00%	-7.42%
22	Eutrophication	g PO4	0.00%	0.00%	0.00%	0.00%	-10.61%	0.00%	0.00%	0.00%	-0.20%
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

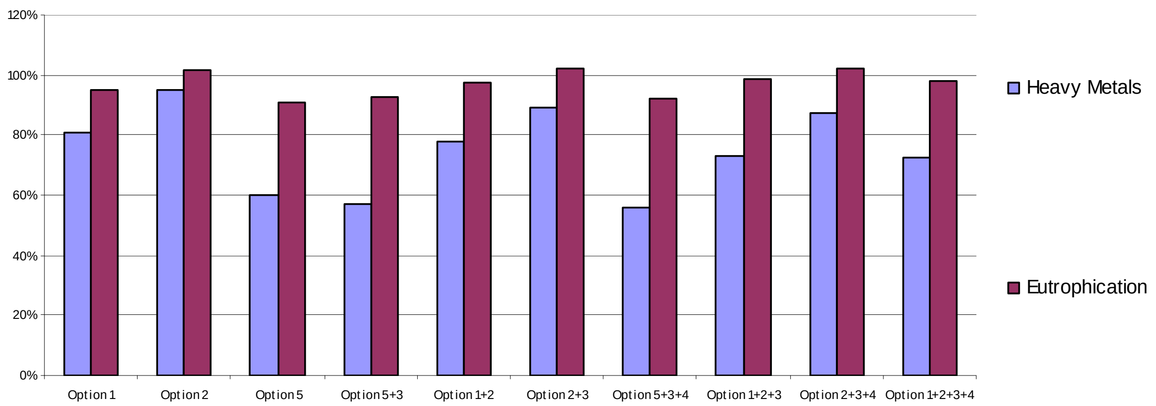
Annexe 7- 26: Comparison of the cumulative improvement options (resources and waste) base case RCV2 in the order of LCC



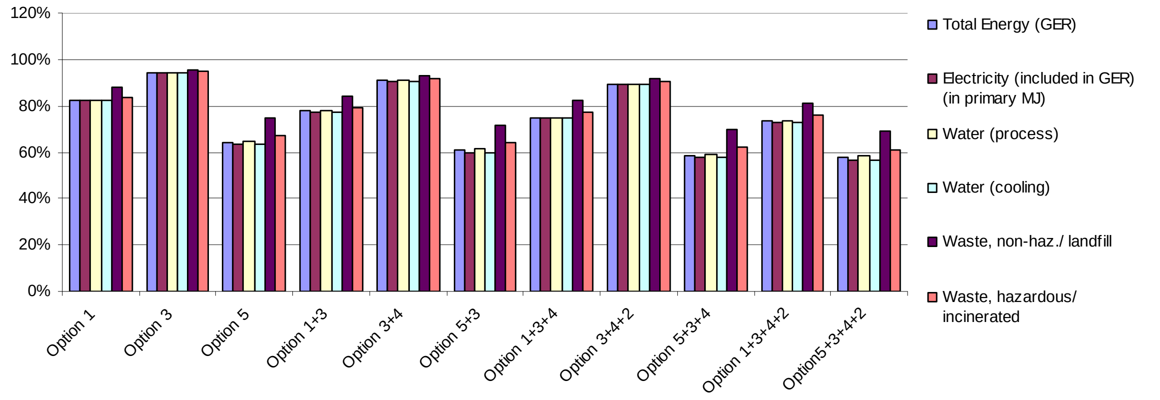
Annexe 7-27: Comparison of the cumulative improvement options (emissions to air) base case RCV2 in the order of LCC



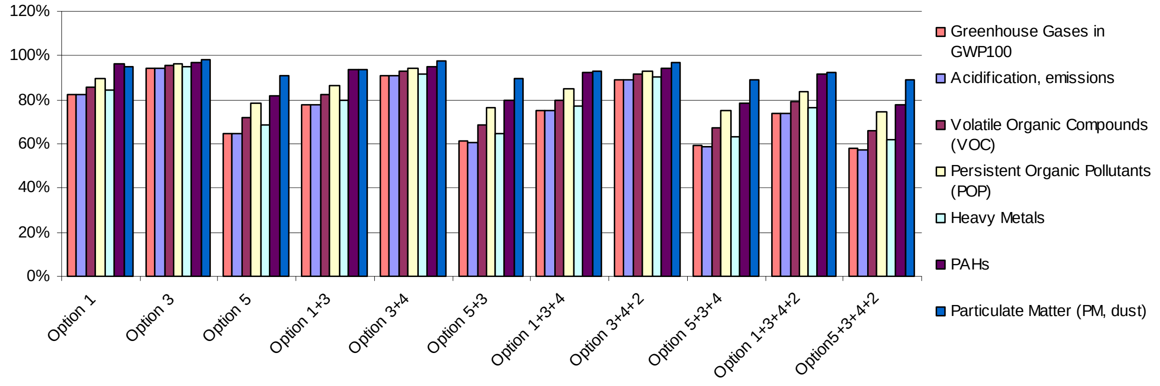
Annexe 7-28: Comparison of the cumulative improvement options (emissions to water) base case RCV2 in the order of LCC



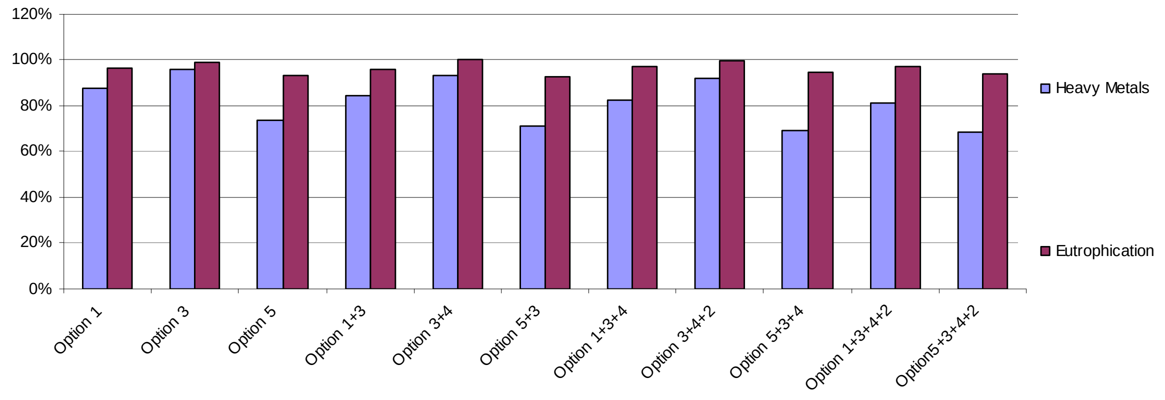
Annexe 7- 29: Comparison of the cumulative improvement options (resources and waste) base case RHF4 in the order of LCC



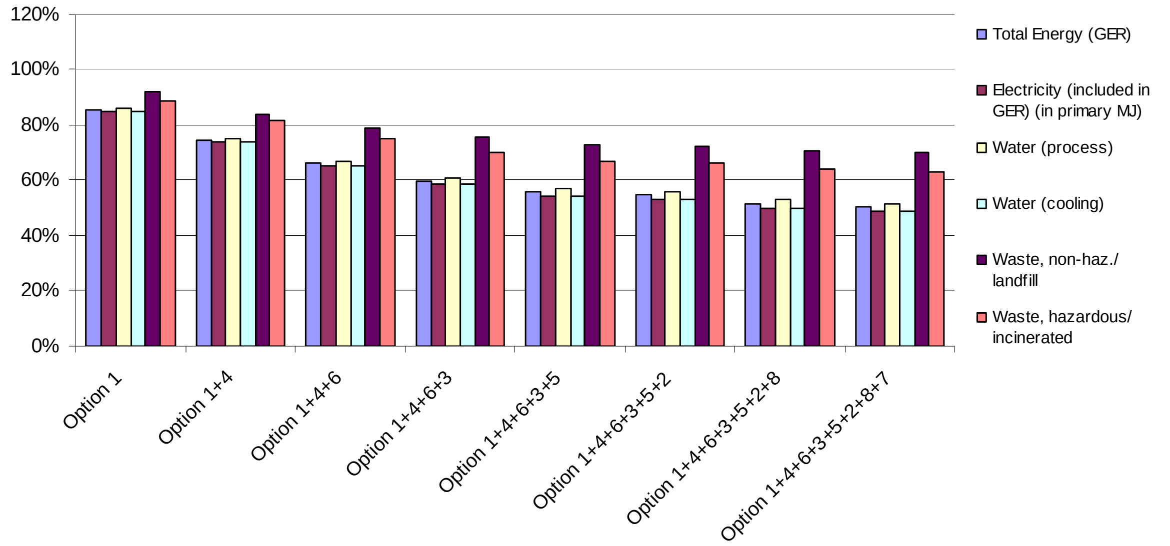
Annexe 7-30: Comparison of the cumulative improvement options (emissions to air) base case RHF4 in the order of LCC



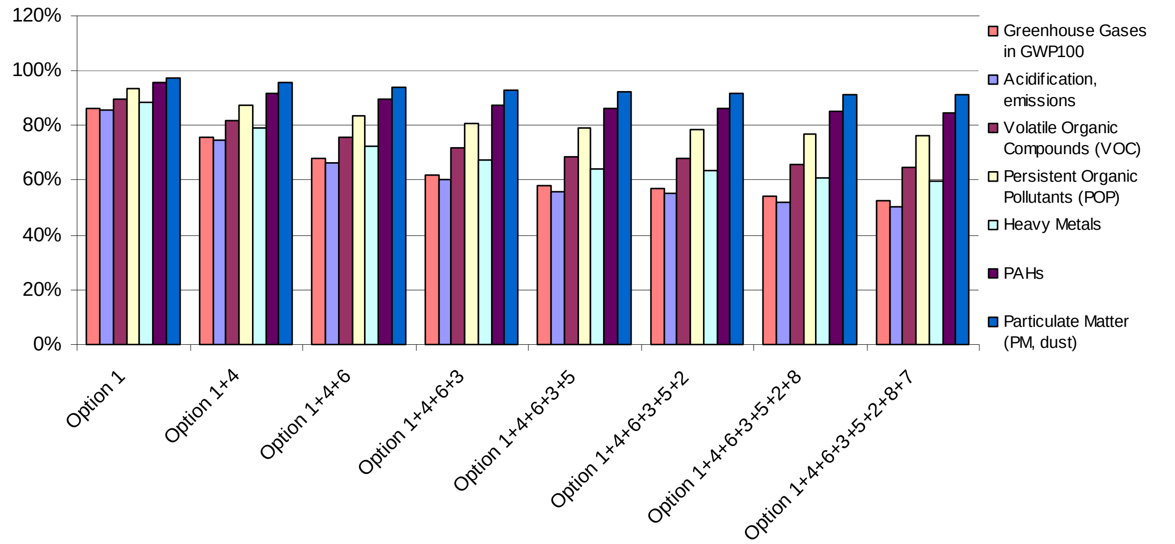
Annexe 7-31: Comparison of the cumulative improvement options (emissions to water) base case RHF4 in the order of LCC



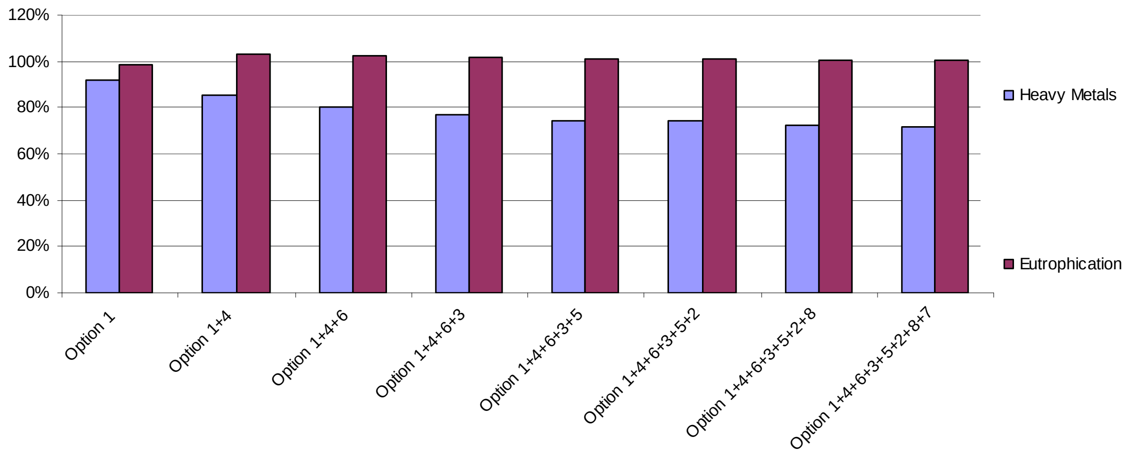
Annexe 7-32: Comparison of the cumulative improvement options (resources and waste) base case beverage cooler in the order of LCC



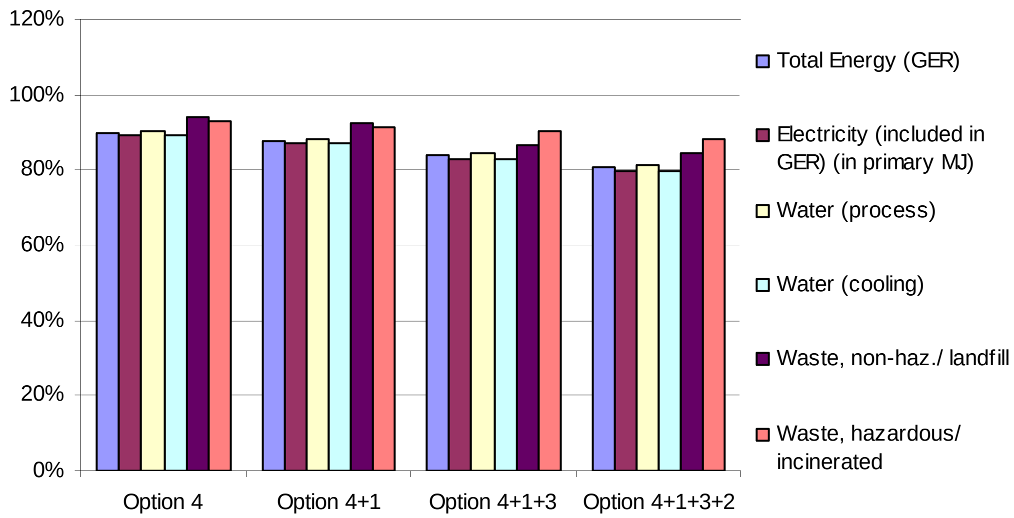
Annexe 7-33: Comparison of the cumulative improvement options (emissions to air) base case beverage cooler in the order of LCC



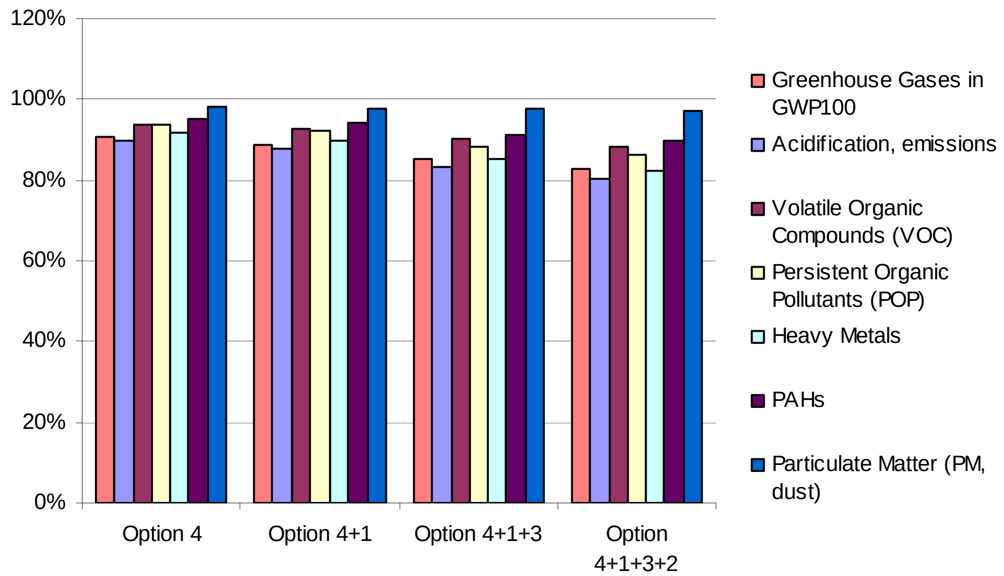
Annexe 7-34: Comparison of the cumulative improvement options (emissions to water) base case beverage cooler in the order of LCC



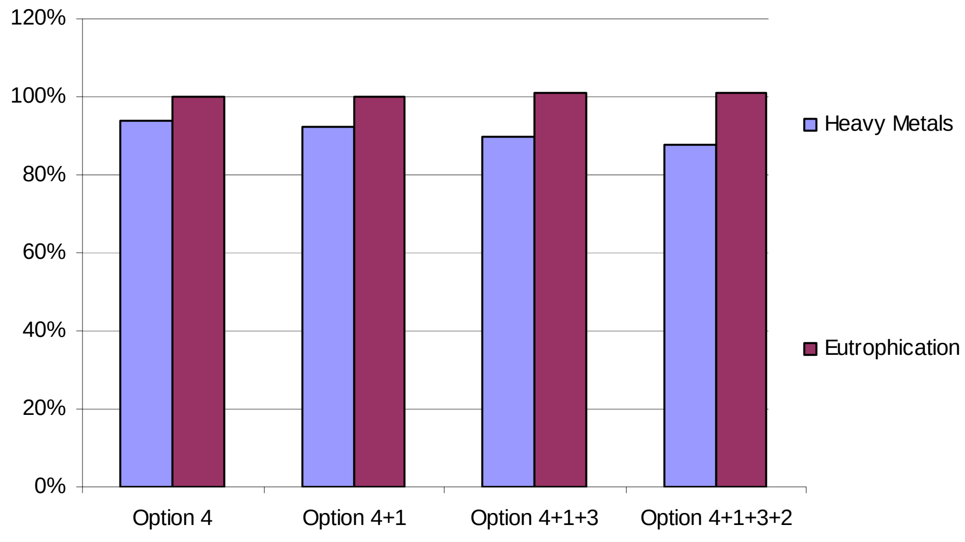
Annexe 7- 35: Comparison of the cumulative improvement options (resources and waste) base case ice cream freezer in the order of LCC



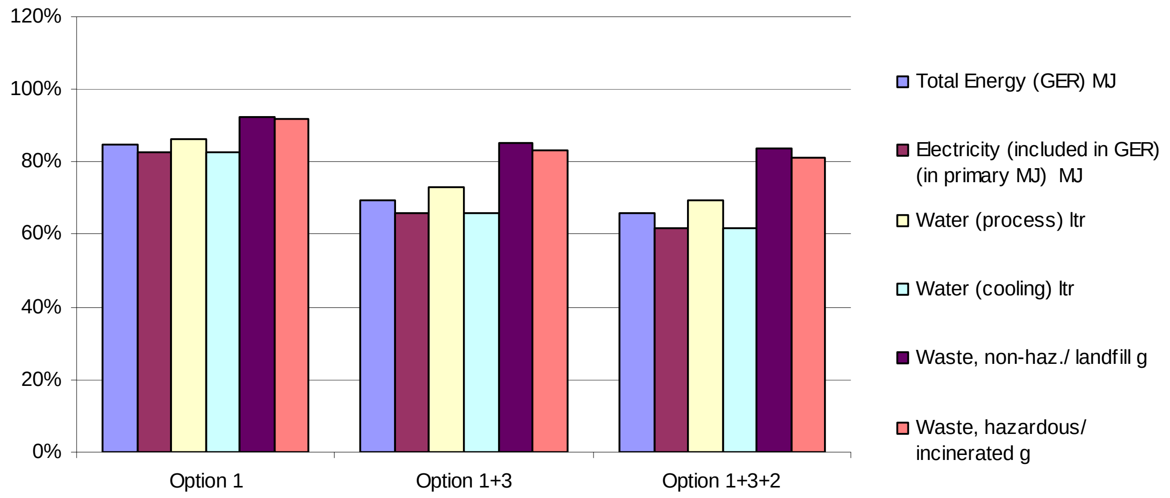
Annexe 7- 36: Comparison of the cumulative improvement options (emissions to air) base case ice cream freezer in the order of LCC



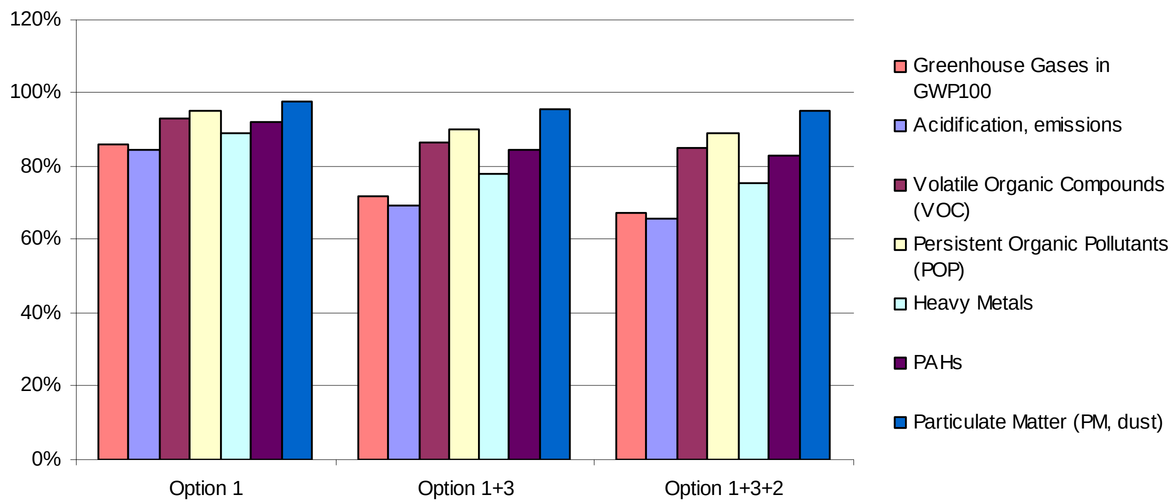
Annexe 7- 37: Comparison of the cumulative improvement options (emissions to water) base case ice cream freezer in the order of LCC



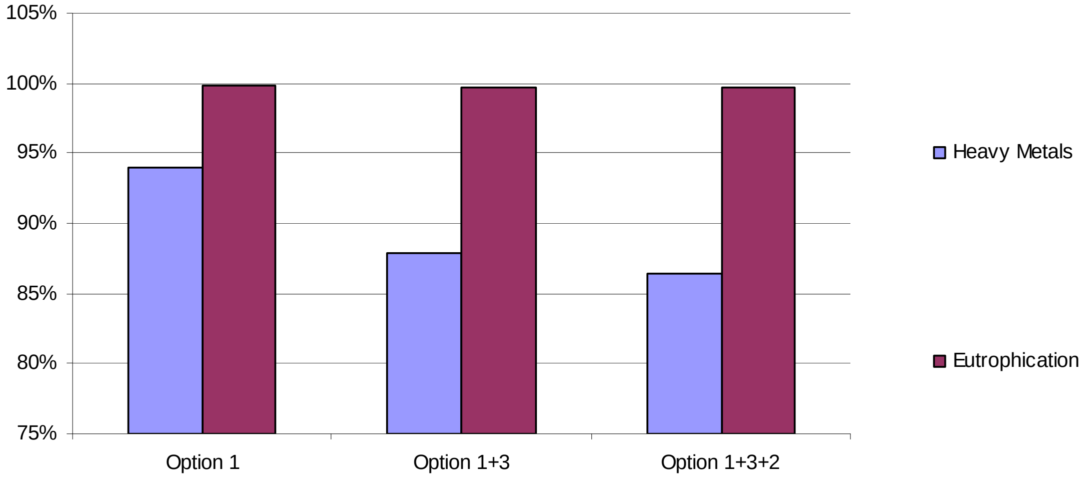
Annexe 7- 38: Comparison of the cumulative improvement options (resources and waste) base case spiral vending machine in the order of LCC



Annexe 7- 39: Comparison of the cumulative improvement options (emissions to air) base case spiral vending machine in the order of LCC



Annexe 7- 40: Comparison of the cumulative improvement options (emissions to water) base case spiral vending machine in the order of LCC



8. SCENARIO-, POLICY-, IMPACT- AND SENSITIVITY ANALYSIS

The objective of the task 8 is to put the results of this preparatory study in the overall policy context of the EuP Directive.

Impact scenarios for years 2010, 2015 and 2020 are provided to quantify the improvement that can be achieved through the implementation of different improvement options versus a business-as-usual scenario.

A policy analysis provides an overview of the existing voluntary and mandatory programs existing in Europe and overseas that have been developed to promote the energy efficiency of commercial refrigeration equipment.

The main results of this study are submitted to a sensitivity analysis to provide a critical review of the findings and test the robustness of the outcomes.

It has to be kept in mind that the conclusions drawn here are preliminary and represent solely a point of view of the consortium and they do not reflect the opinion of the European Commission in any way. Unlike task 1-7 reports, which will serve as the baseline data for the future work (impact assessment, further discussions in the consultation forum, and development of implementing measures, if any) conducted by the European Commission, the task 8 simply serves as a summary of policy implications as seen by the consortium. Further, some elements of this task may be analysed again in a greater depth during the impact assessment.

8.1. SCENARIO ANALYSES

Different scenarios 2006-2020 are drawn up to illustrate quantitatively the improvements that can be achieved through the implementation of different design options at EU level by 2020 versus a business-as-usual scenario (reference scenario).

For each base case, three scenarios are analysed:

- Reference scenario (Freeze),
- Business-as-Usual (BAU),
- Best Available Technology and Least Life Cycle Cost (BAT/LLCC[1]) ,

The first scenario assumes that no improvement will be made in the current average existing products (worst case scenario).

[1] In task 7, it was shown that for all 5 base cases, the combination of design options leading to the LLCC coincides with the BAT. Therefore the BAT and the LLCC scenario are the same.

The second scenario is a projection according to the short term trends related to the design of identified products. This scenario is a BAU scenario taking into account the short term market trends in the absence of any new regulatory measure.

The BAT/LLCC scenario projects a situation where products are improved through the implementation of the combinations of design options leading to the BAT/LLCC points identified in task 7 (section 7.4).

Following common assumptions apply to all the scenarios:

- The sales and stock data are projected at the base case level, using linear extrapolations of the available market and stock data of the past years (1998-2010). In the case of vending machines, however, the annual growth rate calculated in task 2 (section, 2.2.2.2) was used instead. As adequate EU-25 market data for cold vending machines was not available, no linear extrapolation was possible.
- For consumer expenditure, the average European electricity tariff (0.097 €/KWh for remote cabinets and 0.105 €/KWh for plug-in appliances and vending machines, as calculated in task 2, section 2.4.2.1[2]) is assumed to constant in the future. This is unlikely to be true but as it depends on many external factors it is difficult to predict realistic values without a detailed energy forecasting modelling. The product prices are also assumed to remain constant.

In these scenario analyses, and for each of the 5 base cases, the expected trends 2006-2020 for the following 4 indicators are presented:

- Annual electricity consumption[3] of the installed base of commercial refrigeration equipment during the use phase (expressed in kWh/year)
- Greenhouse gases emissions of the installed base over product life (in GWP100 – Global Warming Potential expressed in million ton CO_2 equivalent)
- Life Cycle Cost (LCC, expressed in Euros)
- Sales volume per year (expressed in million units)

In the first step, the sales/stock data for the reference years (i.e. 2006 – 2010 – 2015 – 2020) was calculated.

The summary of the market data estimations is presented in Table 8-1 and depicted graphically in

[2] These average European electricity tariffs were calculated based on data from Eurostat. Depending of the annual energy consumption, different electricity rates apply: for remote appliances used in medium and large supermarkets for which the annual electricity consumption is high, the electricity rate is lower than for beverage coolers and vending machines which are used in all types of locations (offices, universities, public transportation stations, small corner stores, etc…).

[3] This value refers to the Total Electrical energy Consumption (TEC) of the appliance

Figure 8-1 and Figure 8-2. Market data estimates from task 2 (section 2.2) for the period 2005 – 2010 were used and a linear extrapolation or the use of the annual sales growth rate allowed to extrapolate the data until 2020. A linear extrapolation was used to estimate the market data for the remote and plug-in category of appliances. For the spiral vending machines, where adequate market data was not available, the annual sales growth rate was used for extrapolation.

In the second step, EcoReport was used to evaluate the related environmental impacts and the above mentioned 4 indicators.

Table 8-1: Summary of the market data estimates

Year	Sales/Stock (million units)	Base case RCV2	Base case RHF4	Base case Beverage cooler	Base case ice cream freezer	Base case spiral vending machine
2006	Sales	0.1464	0.0192	0.7900	0.3386	0.1259
	Stock	1.3127	0.1722	6.3200	2.7086	1.3944
2010	Sales	0.1617	0.0212	0.8400	0.3600	0.1467
	Stock	1.4549	0.1908	6.7200	2.8800	1.9282
2015	Sales	0.1817	0.0238	0.8900	0.3814	0.1776
	Stock	1.6355	0.2145	7.1200	3.0514	2.7212
2020	Sales	0.2018	0.0265	0.9400	0.4029	0.2151
	Stock	1.8160	0.2382	7.5200	3.2229	3.6814

Figure 8-1: EU 25 stock for the 5 base cases

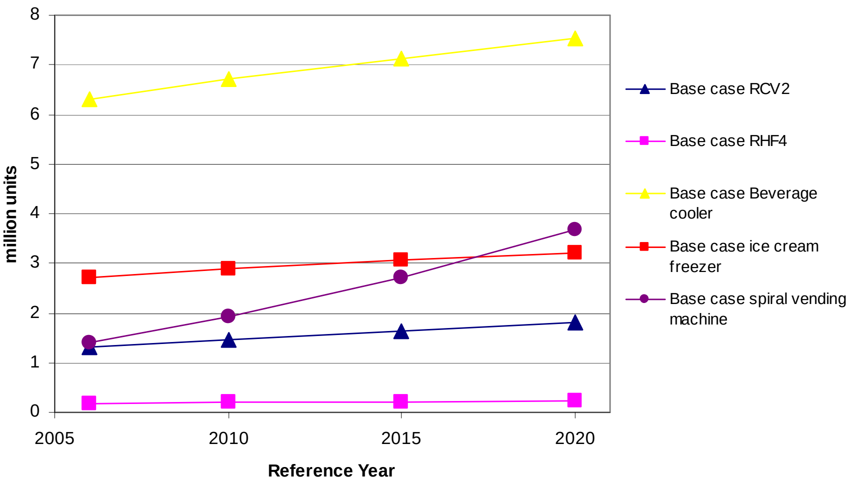
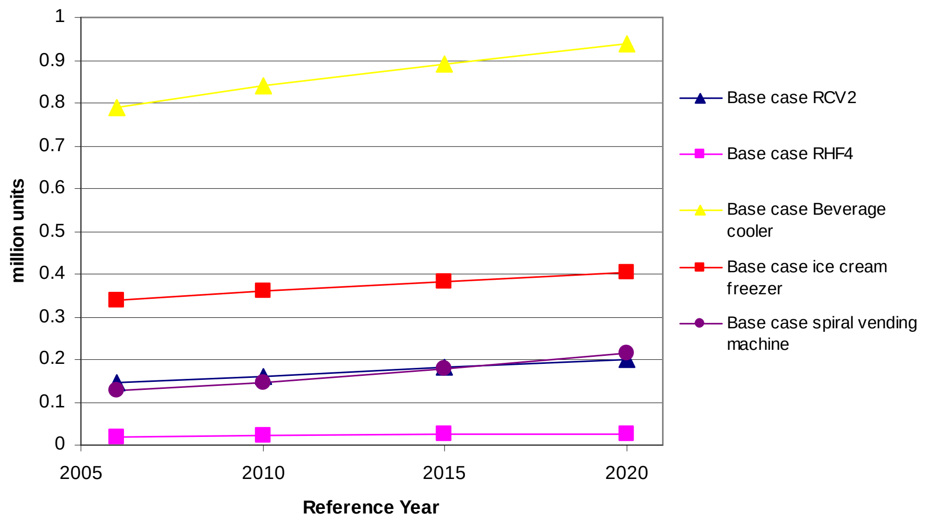


Figure 8-2: EU 25 Annual sales for the 5 bases cases



8.1.1 SCENARIO 1: "FREEZE"

This first scenario projects a scenario situation for which the current average products are not improved at all until 2020 (worst case scenario).

The results of the EcoReport analyses for each of the 5 base cases, using the market data from Table 8-1, are summarised in Annexe 8- 1. Table 8-2 provides an overview of the aggregated results.

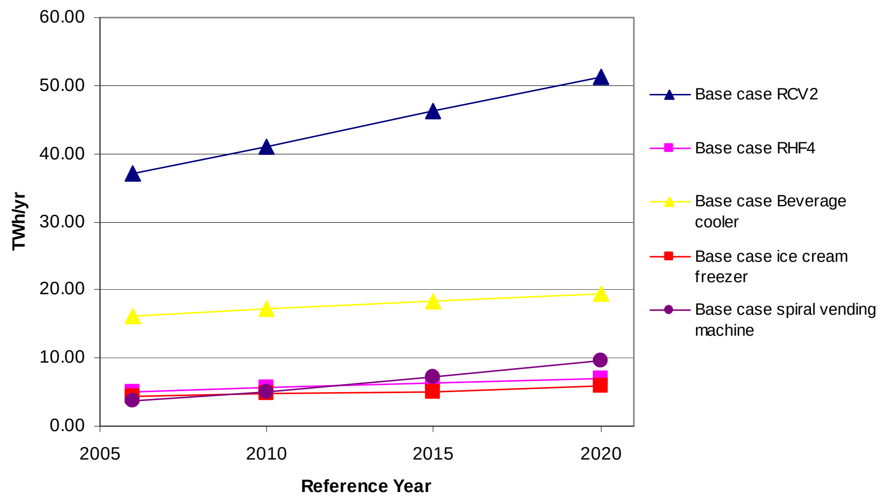
Table 8-2: Overview of the aggregated results (5 base cases) – (Freeze)

Parameter/Reference year	2006	2010	2015	2020
Sales (million units/yr)	1.4202	1.5296	1.6546	1.7862
Annual electricity consumption during use phase (TWh/yr)	67	74	83	93
GWP 100 (million ton CO_2 eq.) over lifetime	36	40	44	50
Total annual consumer expenditure over lifetime (million euros)	10,020.79	11,104.73	12,482.34	13,943.65

The figures indicate that the annual TEC of the installed base of products covered by the five base cases (i.e. stock), increases by over 39 % between 2006 and 2020. In the reference year 2006, the annual electricity consumption is 67 TWh/yr. It increases up to 74 TWh in 2010, 83 TWh in 2015 and 93 TWh in 2020.

The annual TEC of the installed base for each base case is illustrated in Figure 8-3. Between 2006 and 2020, it increases by 38 % for the remote family of appliances, and by about 19 % for the plug-in category of refrigerated cabinets. The most important increase in electricity consumption of the installed base is for the spiral refrigerated vending machines (155 %) due to the increase in stock. The GWP indicator shows approximately the same trends. In reality however, it should be assumed that some improvements will take place.

Figure 8-3: Annual electricity consumption by the installed base per base case



8.1.2 SCENARIO 2: "BUSINESS-AS-USUAL" (BAU)

The short term trends scenario is based on manufacturers' point of view of future trends and improvements for the five base cases, which could occur even in the absence of legislations.

For the remote refrigerated display cabinets (RCV2 and RHF4) some manufacturers estimate that the short term improvement would lead to average TEC savings of about 11 % when compared to the actual base case situation. Others foresee that appliances will run at lower operating temperature: for the base case RCV2 the temperature class of the base case could decrease from 3M2 (-1; +7 °C) to 3M1 (-1; +5°C), and from 3L2 (-1 8; -12 °C) to 3L1 (-18; -15 °C) for the base case RHF4. These modifications in the operating temperature range would imply an increase of the TEC (see Table 8-3) even when using more efficient components.

For the beverage cooler market, manufacturers were able to provide estimations of the short term improvement (> 5 years) as well as for the long term improvements (> 5 years). For the base case ice cream freezer, it was assumed for this scenario that there was no improvement for this category of products until 2020 (same assumption as for the "Freeze" scenario) as no specific trend was identified.

For the short term improvement, it was assumed that the improved products were introduced on the market in 2010 and in 2015 for the long term improvement of the base case beverage cooler. Table 8-3 summarises the TEC savings depending on the base case and on the temperature classes for the remote cabinets, as well as the increase of the product cost. All percentages refer to the 2006 base cases situations described in task 5.

Table 8-3: TEC savings for BAU scenario

		Short term improvement (< 5 years)		Long term improvement (> 5 years)	
Base case	Sub-scenarios	TEC savings	Increase of the product cost	TEC savings	Increase of the product cost
Base case RCV2	with same temperature class (3M2)	11.00 %	3 %	N/A	N/A
	with temperature class 3M1	-16.00 %	5 %	N/A	N/A
Base case RHF4	with same temperature class (3L2)	10.50 %	3 %	N/A	N/A
	with temperature class 3L1	-11.00 %	5 %	N/A	N/A
Base case beverage cooler	-	26.00 %	8 %	45.00 %	12 %
Base case ice cream freezer	-	0.00 %	0 %	N/A	N/A
Base case spiral vending machine	-	10.00 %	0 %	N/A	N/A

Depending on the base case, the time from getting the decision to change the design to the point when all old products are put out on the market and only redesigned products will be sold (i.e. the redesign cycle) by a manufacturer varies as shown in Table 8-4. The lower estimates (6 months for remote refrigerated display cabinets and 3 months for plug-in cabinets) of the redesign cycles related to small changes in the design related to improvement options which do not require strong modification in the production line or in the choice of the suppliers of components.

Table 8-4: Redesign cycle estimates

	Redesign approach	**Redesign cycle time**
Definition	Change of the product design, *based on available technologies* (available in-house or through solution providers), including redesign of the cabinet, and change of components (suppliers)	Time from getting the requirement / decision to change the design to the point, when all “old” products are put on the market and only redesigned products will be sold
Base case	Remote refrigerated display cabinets	6 – 120 months
	Plug-in refrigerated display cabinets	3 – 24 months
	Vending machines	36 months

Considering these differences in redesign cycles for each base case, the scenarios are based on different estimates concerning the share of the stock of “improved appliances” in EU 25 and first improved products are sold no sooner than 2010 assuming it will take at least 2 years for manufacturers to adapt their production lines.

The first step in order to estimate these stocks is to evaluate the share of improved appliances in the annual sales until 2020 for each base case (see Table 8-5 to Table 8-7). For ice cream freezers only the base case defined in task 5 will be sold until 2020 as no specific trend in energy efficiency was identified for this type of product.

Based on the assumptions presented in Table 8-3, the stock of beverage coolers is composed of three types of products from 2015: the base case, the "2010 improved base case", and the "2015 improved base case". Table 8-6 presents the share of each of these beverage coolers in the annual sales until 2020.

Table 8-5: Share of the "improved products" vs. "base case" in sales for remote refrigerated display cabinets

Share of the sales	Base case	Improved base case
2006	100 %	0 %
2007	100 %	0 %
2008	100 %	0 %
2009	100 %	0 %
2010	80 %	20 %
2011	74 %	26 %
2012	68 %	32 %
2013	62 %	38 %
2014	56 %	44 %
2015	50 %	50 %
2016	40 %	60 %
2017	30 %	70 %
2018	20 %	80 %
2019	10 %	90 %
2020	0 %	100 %

Table 8-6: Share of the "improved products (2010 and 2015)" vs. "base case" in sales for beverage coolers

Share of the sales	Base case	2010 improved base case	2015 improved base case
2006	100 %	0 %	0 %
2007	100 %	0 %	0 %
2008	100 %	0 %	0 %
2009	100 %	0 %	0 %
2010	80 %	20 %	0 %
2011	64 %	36 %	0 %
2012	48 %	52 %	0 %
2013	32 %	68 %	0 %
2014	16 %	84 %	0 %
2015	0 %	80 %	20 %
2016	0 %	64 %	36 %
2017	0 %	48 %	52 %
2018	0 %	32 %	68 %
2019	0 %	16 %	84 %
2020	0 %	0 %	100 %

Table 8-7: Share of the "improved products" vs. "base case" in sales for vending machines

Share of the sales	Base case	Improved base case
2006	100 %	0 %
2007	100 %	0 %
2008	100 %	0 %
2009	100 %	0 %
2010	80 %	20 %
2011	64 %	36 %
2012	48 %	52 %
2013	32 %	68 %
2014	16 %	84 %
2015	0 %	100 %
2016	0 %	100 %
2017	0 %	100 %
2018	0 %	100 %
2019	0 %	100 %
2020	0 %	100 %

Then, the second step was to apply the following formula to each base case to obtain the share of the improved products in stock which are presented in Table 8-8 to Table 8-10.

$$y_n = \frac{(y_{n-1} \times stock_{n-1}) + (x_n \times sales_n) - (x_{n-A} \times sales_{n-A})}{stock_n}$$, where:

y_n = share of the improved base case stock for year n,

x_n = share of the improved base case sales for year n,

A = product lifetime,

The sales and stocks are estimated in Table 8-1, and

$$y_{2010} = \frac{x_{2010}}{Lifetime}$$

Table 8-8: Share of the "improved products" vs. "base case" in stock (remote category)

Share of the stock REMOTES	Base case	Improved base case
2006	100 %	0 %
2010	98 %	2 %
2015	78 %	22 %
2020	37 %	63 %

Table 8-9: Share of the "improved products (short term/long term)" vs. "base case" in stock for beverage coolers

Share of the stock	Base case	Improved base case (short term)	Improved base case (long term)
2006	100 %	0 %	0 %
2010	98 %	2 %	0 %
2015	56 %	41 %	2 %
2020	10 %	46 %	44 %

Table 8-10: Share of the "improved products" vs. "base case" in stock (vending machines)

Share of the stock Vending machines	Base case	Improved base case
2006	100 %	0 %
2010	98 %	2 %
2015	77 %	23 %
2020	54 %	46 %

These estimates on the share of improved machines in stock were calculated according to the redesign cycles, the sales data and replacement rates presented in task 2 (section 2.2.2).

The resulting average total electricity consumption (TEC) was also calculated equal to the weighted average energy consumption of the products in stock:

$$resulting\ average\ TEC = (1 - y_n) \times TEC_{Basecase} + y_n \times TEC_{improved\ Basecase}$$

The difference between this "resulting average TEC" and the base case is also given in Table 8-11 for all base cases.

Table 8-11: Change in the average TEC of the products in stock compared to the base case

Base case	Sub-scenarios	Resulting average TEC savings of the products in stock compared to the base case			
		2006	2010	2015	2020
Base case RCV2	with same temperature class (3M2)	0 %	0.24 %	2.45 %	6.93 %
	with temperature class 3M1	0 %	- 0.36 %	- 3.57 %	- 10.08 %
Base case RHF4	with same temperature class (3L2)	0 %	0.23 %	2.34 %	6.61 %
	with temperature class 3L1	0 %	- 0.24 %	- 2.45 %	- 6.93 %
Base case beverage cooler	-	0 %	0.58 %	11.76 %	31.79 %
Base case ice cream freezer	-	0 %	0 %	0 %	0 %
Base case spiral vending machine	-	0 %	0.22 %	2.34 %	4.58 %

The data on the improvement potential and on the stock allows calculating new inputs for the EcoReport which are summarised in Annexe 8- 2.

Taking the 2006 situation as a reference, and with the same temperature classes for the base cases RCV2 (3M2) and RHF4 (3L2), the total annual TEC during use phase (resulting from the 5 base cases) increases by 23 % between 2006 and 2020 (Figure 8-4). It increases by 37.5 % between 2006 and 2020 if the remote refrigerated display cabinets operate at temperature classes 3M1 and 3L1 (Figure 8-5).

Figure 8-4: TEC (with same temperature classes: 3M2 and 3L2) with “BAU” scenario

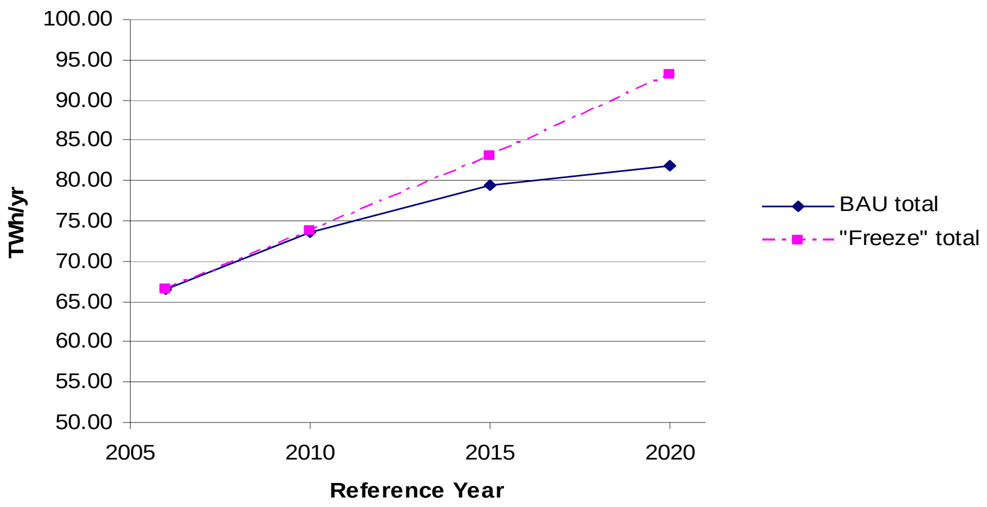
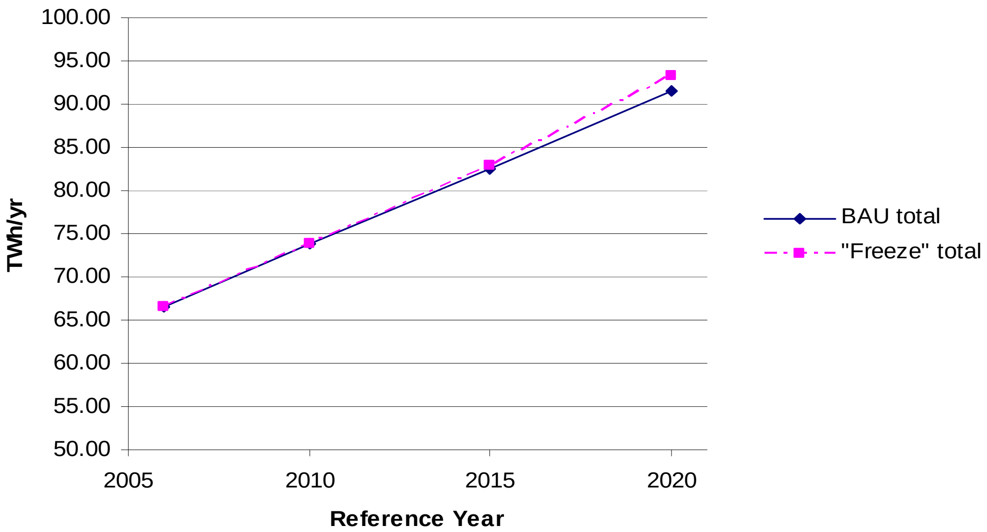


Figure 8-5: TEC (with temperature classes: 3M1 and 3L1) with "BAU" scenario



In 2020, when comparing BAU scenario to the "Freeze" scenario, the total annual TEC for the sub-scenario with the same temperature classes for remote cabinets is 14.3 % lower. The reduction is of 4.2 % when RCV2 and RHF4 operate with temperature classes 3M1 and 3L1.

The annual TEC of the installed base for each base case is presented in Annexe 8- 3 and illustrated in Annexe 8- 4 to Annexe 8- 7.

Compared to the "Freeze" situation in 2020, the annual TEC decreases by 6.9 % for the base case RCV2 with the same temperature class (3M2) and increases by 10.1 % with the temperature class 3M1. For the base case RHF4, the reduction is of about 6.6 % with the same temperature class (3L2) and the increase is of about 6.9 % with the temperature class 3L1.

The annual TEC of the stock decreases by about 31.8 % for the base case beverage cooler and by about 4.6 % for the base case spiral vending machine compared to the "Freeze" situation for the reference year 2020. Moreover, as mentioned before there is no variation of the TEC (and of the GWP) for the base case ice cream freezer compared to the "Freeze" scenario, as it is not improved.

The GWP emissions show approximately the same trends as described for the annual electricity consumption during use phase.

When the remote refrigerated cabinets operate with the same temperature classes (3M2 and 3L2), the total annual consumer expenditure over lifetime (resulting from the 5 base cases) increases by 27.4 % between 2006 and 2020 and is 8.5 % lower in 2020 compared to the same reference year with the "Freeze" scenario. With other temperature classes (3M1 and 3L1) for the bases cases RCV2 and RHF4, the total annual consumer expenditure over lifetime increases by 38.5 % but is still 0.5 % lower than compare to a "Freeze" scenario situation in 2020.

8.1.3 SCENARIO 3: BAT/LLCC

This scenario is based on the results from task 7 (section 7.4). It describes the BAT/LLCC situation, which means that the combination of improvement options leading to the BAT/LLCC point as identified in task 7 (section 7.4), is implemented progressively, achieving between 11 % and 57 % of total electricity savings during the use phase depending on the base case and on the use of a door. These BAT/LLCC scenarios correspond to the "best possible scenarios" in terms of energy savings and environmental impact reduction. Table 8-12 presents the main results in terms of improvement potential calculated in task 7.

Table 8-12: TEC reduction when implementing combinations of improvement options leading to the BAT/LLCC point

	TEC Savings reached with the combination leading to BAT/LLLCC point
Base case RCV2 - with glass door	57.04%
Base case RCV2 without glass door	40.39%
Base case RCV2 without night curtain	19.45%
Base case RHF4 with glass lid	43.55%
Base case RHF4 without glass lid	27.11%
Base case RHF4 without Night curtain	11.10%
Beverage cooler	51.88%
Ice cream freezer	20.99%
Spiral vending machine	40.20%

The BAT/LLCC scenarios are based on different estimates concerning the share of the stock of appliances to which the BAT/LLCC improvement option is implemented in Europe. In order to calculate these stocks, the data related to the share of sales of improved products is needed.

Depending on the assumptions on the sales of "improved" products (i.e. base case with combination of options leading to BAT/LLCC point) for each year, two scenarios are defined. One for which the introduction of improved remote refrigerated display cabinets occur at a "slow" rate, these products reaching 100 % of the sales in 2020 ("BAT "slow"/LLCC" scenario); and one sub-scenario where the sales of improved remote refrigerated display cabinets increase at a higher rate, reaching 100 % of the sales in 2015 instead ("BAT/LLCC" scenario). More details on each of these scenarios are given in section 8.1.3.1 and section 8.1.3.2.

8.1.3.1 BAT "SLOW"/LLCC SCENARIO

This section presents a BAT "slow"/LLCC situation where improved remote refrigerated display cabinets are first introduced on the market in 2010, and where they represent 100 % of the sales of such products in 2020 ("slow introduction") and where improved plug-in refrigerated display cabinets and vending machines are first introduced on the market in 2010 and where they represent 100 % of the sales of these types of products in 2015.

For remote refrigerated display cabinets, it is assumed that the redesign cycle is of 6-120 months and that 100 % of the products sold in 2020 are improved products (i.e. BAT), the first improved products being introduced in 2010. Market data related to the sales and stock of products calculated in section 8.1.2 is used.

For remote refrigerated display cabinets market data presented in Table 8-5 and Table 8-8 is used.

However, in this scenario, the targeted improvement potentials are not the same as in the BAU scenario and the resulting average TEC savings for the BAT "slow"/LLCC scenario are presented further down in Table 8-16.

For plug-in refrigerated display cabinets, different assumptions were made to calculate the share of improved product sales. In Table 8-4, the redesign cycles presented are related to a BAU situation where only slight improvements and changes in the design of the product are considered (usually through the implementation of 2 or three options). For the LLCC scenario, which implies more efforts in redesign (and therefore further modifications in the production line, ad suppliers) it was assumed that these redesign cycle extend to 2-5 years with the first products being introduced on the market in 2010. The sales data resulting from these assumptions are presented in Table 8-13.

Table 8-13: Share of the "improved products" vs. "base case" in sales for plug-in refrigerated display cabinets

Share of the sales	Base case	Improved base case
2006	100 %	0 %
2007	100 %	0 %
2008	100 %	0 %
2009	100 %	0 %
2010	80 %	20 %
2011	64 %	36 %
2012	48 %	52 %
2013	32 %	68 %
2014	16 %	84 %
2015	0 %	100 %
2016	0 %	100 %
2017	0 %	100 %
2018	0 %	100 %
2019	0 %	100 %
2020	0 %	100 %

Based on the same formula presented page 8, the following stock data were calculated (Table 8-14):

Table 8-14: Share of the "improved products" vs. "base case" in stock (plug-in category)

Share of the stock Plug in	Base case	Improved base case
2006	100 %	0 %
2010	98 %	2 %
2015	56 %	44 %
2020	10 %	90 %

The results in terms of impact on the average TEC of a beverage cooler in stock are presented in Table 8-16.

For spiral vending machine, the market data presented in Table 8-10 is used to calculate the stock data presented in Table 8-15. However, the targeted improvement potential in the LLCC scenario are not the same as in the BAU scenario and the resulting TEC saving was recalculated accordingly. Results are presented in Table 8-16.

Table 8-15: Share of the "improved products" vs. "base case" in stock (cold vending machines)

Share of the stock Vending machines	Base case	Improved base case
2006	100 %	0 %
2010	98 %	2 %
2015	77 %	23 %
2020	54 %	46 %

For the remote category of appliances and for each base case, 3 different combinations of options were analysed (see task 7, section 7.1.1 and 7.1.2): one including the optional glass door (or lid), one without the optional door (but using a night curtain) and one without the use of a night curtain. Therefore 3 sub-scenarios are presented in this section.

Table 8-16: Resulting average TEC savings of the products in stock compared to the base cases – BAT "slow"/LLCC scenario

	Resulting average TEC savings of the products in stock compared to the base case			
	2006	2010	2015	2020
Base case RCV2 - with glass door	0 %	1.27 %	12.72 %	35.92 %
Base case RCV2 without glass door	0 %	0.90 %	9.01 %	25.44 %
Base case RCV2 without night curtain	0 %	0.43 %	4.34 %	12.25 %
Base case RHF4 with glass lid	0 %	0.97 %	9.71 %	27.43 %
Base case RHF4 without glass lid	0 %	0.60 %	6.05 %	17.07 %
Base case RHF4 without Night curtain	0 %	0.25 %	2.48 %	6.99 %
Beverage cooler	0 %	1.15 %	22.83 %	46.69 %
Ice cream freezer	0 %	0.47 %	9.24 %	18.89 %
Spiral vending machine	0 %	0.89 %	9.39 %	18.40 %

Considering these values, new inputs for the EcoReport analysis were calculated in order to estimate the impacts until 2020 (see details presented in Annexe 8- 8)

Annexe 8- 9 gives the details of the outcomes of the EcoReport analysis for the reference years 2006, 2010, 2015 and 2020.

Considering the combinations of improvement options leading to the BAT "slow"/LLCC scenario for all base cases and including the glass door option for the remote refrigerated display cabinets, the TEC during use phase related to the commercial refrigeration equipment (resulting from the 5 base cases) decreases by over 9.31 % between 2006 and 2020 (Figure 8-6). It decreases by 0.16 % in the case of the sub-scenario without door (and with night curtain) (Figure 8-7) and increases by 11 % in the case of the sub-scenario without the use of a glass door (or lid) and neither the use of a night curtain (Figure 8-8).

Figure 8-6: Annual TEC of the installed base BAT "slow"/LLCC scenario with glass door/lid

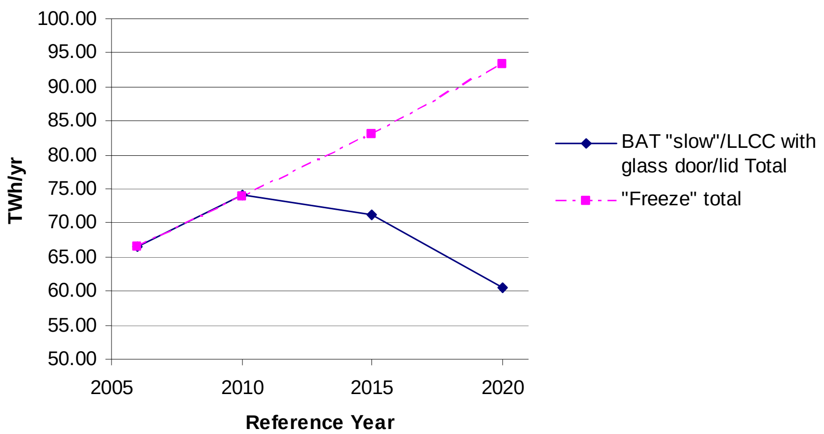


Figure 8-7: Annual TEC of the installed base BAT "slow"/LLCC scenario without door and with night curtain

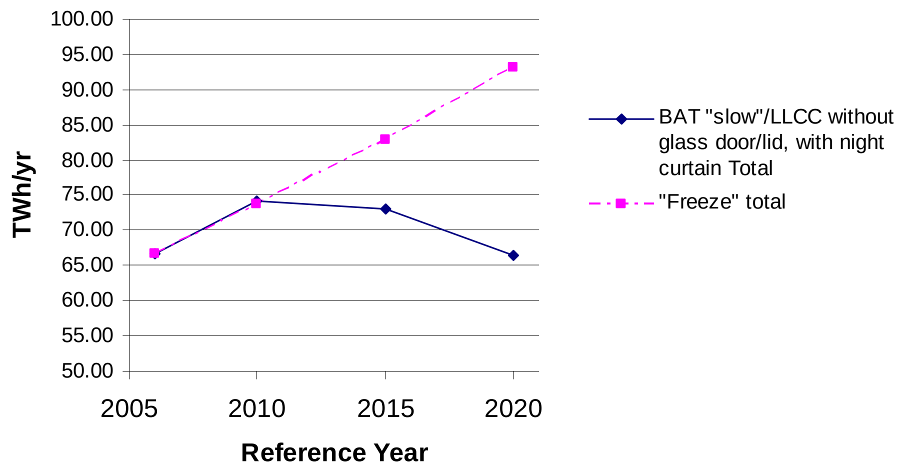
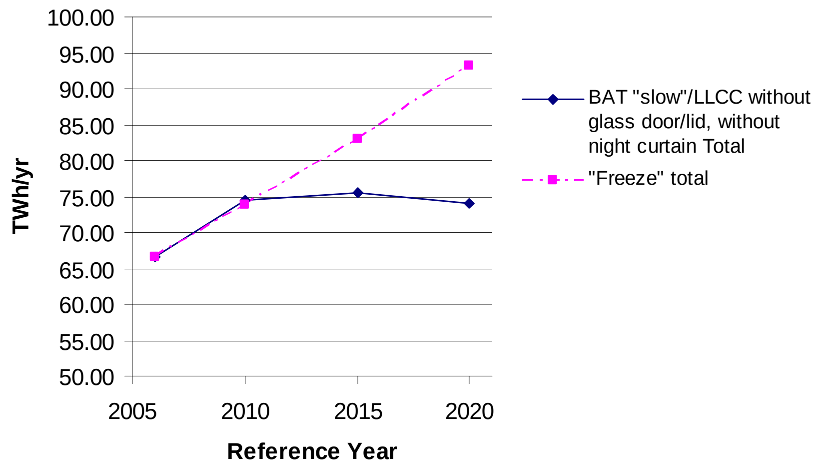


Figure 8-8: Annual TEC of the installed base LLCC scenario without door and without night curtain



In 2020, when compared to the "Freeze" scenario, the total annual TEC (aggregated results for the 5 base cases) with a BAT "slow"/LLCC sub-scenario with door is 35.22 % lower. This translates into savings of 32.8 TWH/yr and in a reduction of the green house gases emissions of 15.33 million ton eq. CO_2. The TEC of the stock aggregated for the five base cases is 28.67 % lower without the use of a glass door but using a night curtain (i.e. savings of 26.7 TWh/yr and 12.25 million ton eq. CO_2) and 20.65 % lower without the use of a night curtain on the remote family of appliances (i.e. savings of 19.25 TWh/yr and 8.49 million ton eq. CO_2).

The annual TEC of the installed base for each base case is presented in Annexe 8- 9 and illustrated in Annexe 8- 12 to Annexe 8- 18.

Compared to the “Freeze” situation in 2020, the annual TEC decreases by 35.92 % for the base case RCV2 when using a glass door (25.40 % when not using glass door and 12.25 % when not using a night curtain), by 27.43 % for the base case RHF4 when using a glass door (compared to 17.07 % without a glass door and 7 % without a night curtain).

The annual TEC of the stock decreases by about 46.7 % for the base case beverage cooler, by about 18.90 % for the base case ice cream freezers and by about 18.33 % for the base case spiral vending machine compared to the “Freeze” situation for the reference year 2020.

When considering the sub-scenario with the use of a door, the less important reduction in electricity consumption of the installed base is for the base cases spiral refrigerated vending machines and ice cream freezers due to the increase in stock and to the smaller potential in TEC savings allowed by the implementation of the BAT “slow”/LLCC combinations of improvement options.

The GWP emissions show approximately the same trends as the ones described above for the annual TEC of the stocks.

When the remote refrigerated cabinets are fitted with doors, the total annual consumer expenditure over lifetime increases of almost 10.35 % between 2006 and 2020 and is 19.83 % lower in 2020 compared to the same reference year with the “Freeze” scenario). Without doors, but with a night curtain, the total annual consumer expenditure over lifetime increases of 12.71 % and is 17.66 % lower than compare to a “Freeze” scenario situation in 2020.The total annual consumer expenditure over lifetime increases of 18.49 % when not using night curtains and is 11.82 % lower than in the “Freeze” scenario situation in 2020.

8.1.3.2 “BAT/LLCC” SCENARIO

This scenario presents a situation similar to the BAT “slow”/LLCC scenario for the plug-in category of refrigerated display cabinets and for vending machines, but where the sales of improved remote refrigerated display cabinets increase at a faster rate, starting in 2010 and reaching 100 % of the sales of remote display cabinets in 2015 (compared to 2020 in the BAT “slow” scenario”).

For the remote refrigerated display the following assumptions on the sales data were used (Table 8-17):

Table 8-17: Share of the "improved products" vs. "base case" in sales for remote refrigerated display cabinets

Share of the sales	Base case	Improved base case
2006	100%	0%
2007	100%	0%
2008	100%	0%
2009	100%	0%
2010	80%	20%
2011	64%	36%
2012	48%	52%
2013	32%	68%
2014	16%	84%
2015	0%	100%
2016	0%	100%
2017	0%	100%
2018	0%	100%
2019	0%	100%
2020	0%	100%

Based on the same formula presented page 8, the following stock data were calculated (Table 8-18):

Table 8-18: Share of the "improved products" vs. "base case" in stock (remote refrigerated display cabinets)

Share of the stock	Base case	Improved base case
2006	100%	0%
2010	98%	2%
2015	62%	38%
2020	12%	88%

The results in terms of impact on the average TEC of remote refrigerated display cabinet in stock (RCV2 type and RHF4 type) are presented in Table 8-19. Data for the plug-in category of cabinets and for cold vending machine is the same as in the BAT "slow"/LLCC scenario and is not repeated here (see Table 8-16).

Table 8-19: Resulting average TEC savings of the products in stock compared to the base cases – BAT/LLCC scenario

	Resulting average TEC savings of the products in stock compared to the base case			
	2006	2010	2015	2020
Base case RCV2 - with glass door	0 %	1.27 %	21.95 %	50.19 %
Base case RCV2 without glass door	0 %	0.90 %	15.54 %	35.54 %
Base case RCV2 without night curtain	0 %	0.43 %	7.48 %	17.11 %
Base case RHF4 with glass lid	0 %	0.97 %	16.76 %	38.32 %
Base case RHF4 without glass lid	0 %	0.60 %	10.43 %	23.85 %
Base case RHF4 without Night curtain	0 %	0.25 %	4.27 %	9.77 %

Considering these values, new inputs for the EcoReport analysis were calculated in order to estimate the impacts until 2020 (see details presented in Annexe 8- 10)

Annexe 8- 11 gives the details of the outcomes of the EcoReport analysis for the reference years 2006, 2010, 2015 and 2020.

Considering the combinations of improvement options leading to the BAT/LLCC scenario for all base cases and including the glass door option for the remote refrigerated display cabinets, the TEC during use phase related to the stock of commercial refrigeration equipment (5 base cases) decreases by over 21.5 % between 2006 and 2020 (Figure 8-9). It decreases by 8.7 % in the case of the sub-scenario without door (and with night curtain) (Figure 8-10) and increases by 7 % in the case of the sub-scenario without the use of a glass door (or lid) and neither the use of a night curtain (Figure 8-11).

Figure 8-9: Annual TEC of the installed base "BAT/LLCC" scenario with glass door/lid

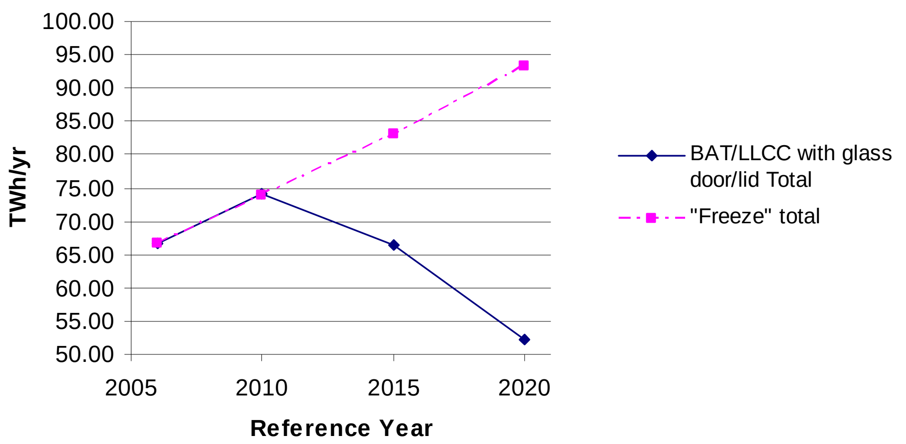


Figure 8-10: Annual TEC of the installed base “BAT/LLCC” scenario without door and with night curtain

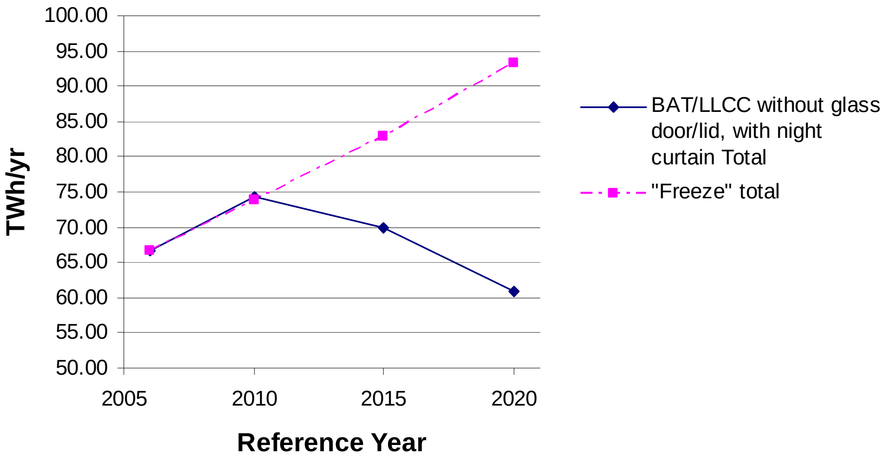
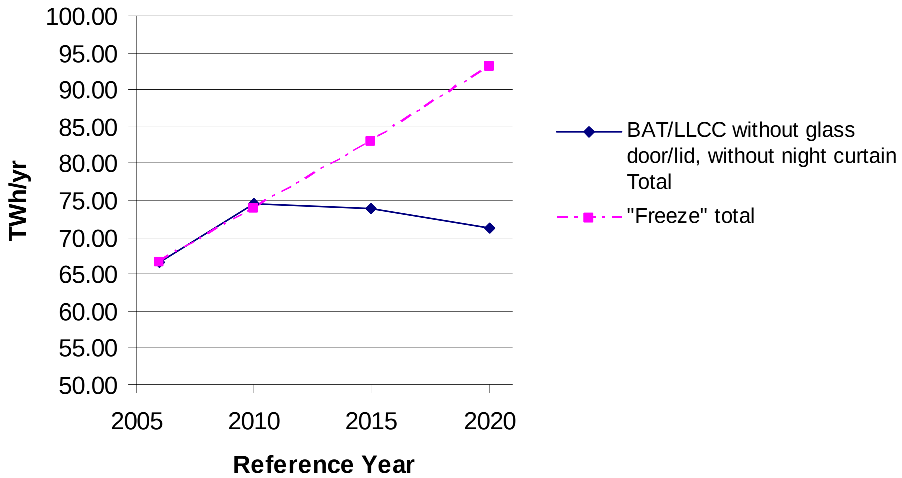


Figure 8-11: Annual TEC of the installed base LLCC scenario without door and without night curtain



In 2020, when compared to the “Freeze” scenario, the total annual TEC (aggregated results for the 5 base cases) with a BAT/LLCC sub-scenario with door is 43.9 % lower. This translates into savings of 40.9 TWH/yr and in a reduction of the green house gases emissions of 19.4 million ton eq. CO_2. The TEC of the stock aggregated for the five base cases is 34.7 % lower without the use of a glass door but using a night curtain (i.e. savings of 32.4 TWh/yr and 15.1 million ton eq. CO_2) and 23.5 % lower without the use of a night curtain on the remote family of appliances (i.e. savings of 21.9 TWh/yr and 9.84 million ton eq. CO_2).

The annual TEC of the installed base for each remote refrigerated display cabinet base case is presented in Annexe 8- 10 and illustrated in Annexe 8- 13 and in Annexe 8- 15. Data for plug-in base cases and for the cold vending machines is the same as in the BAT “slow”/LLCC scenario and is not repeated here.

Compared to the “Freeze” situation in 2020, the annual TEC decreases by 50.2% for the base case RCV2 when using a glass door (35.4 % when not using glass door and 17.11 % when not using a night curtain), by 38.32 % for the base case RHF4 when using a glass door (compared to 23.85 % without a glass door and 9.8 % without a night curtain).

The GWP emissions show approximately the same trends as the ones described above for the annual TEC of the stocks.

When the remote refrigerated cabinets are fitted with doors, the total annual consumer expenditure over lifetime decreases of almost 4.3 % between 2006 and 2020 and is 25 % lower in 2020 compared to the same reference year with the “Freeze” scenario). Without doors, but with a night curtain, the total annual consumer expenditure over lifetime decreases of 8.52 % and is 22 % lower than compare to a “Freeze” scenario situation in 2020.The total annual consumer expenditure over lifetime decreases of 19.9 % when not using night curtains and is 13.9 % lower than in the “Freeze” scenario situation in 2020.

8.1.4 CONCLUSIONS

Compared to a 2020 “Freeze” scenario situation, the 2020 BAU situation shows that in the absence of legislations, the annual electricity use of the installed base of product covered by the five base cases would decrease between 4.2 and 14.3 % depending on the potential modifications in the settings of the operating temperature of some remote appliances.

The improvement options identified in task 6 and 7 could lead to even more significant reductions in the total electricity use of the installed base of products covered by the five base cases: 23.5 % and up to 43.9 % when considering the addition of a glass door/lid on remote appliances.

Table 8-20 summarises the outcomes of the different scenarios.

Table 8-20: Summary of the outcomes of the different scenarios

Scenario - 2020 situation	sub-scenario	Evolution of the total TEC compared to Freeze 2006 situation	Evolution of the total TEC compared to Freeze 2020 situation
"Freeze"	N/A	+ 39 %	0 %
"BAU"	no change in temperature classes	+ 23 %	- 14.3 %
	change in temperature classes	+ 37.7 %	- 4.2 %
"BAT "slow"/LLCC "scenario	with door	- 9.32 %	- 35.22 %
	without door (with night curtain)	- 0.16 %	- 28.67 %
	without door and without night curtain	+ 11.06 %	- 20.65 %
"BAT/LLCC" scenario	with door	- 21.5 %	- 43.9 %
	without door (with night curtain)	- 8.7 %	- 34.7 %
	without door and without night curtain	+ 7 %	- 23.5 %

8.2. POLICY ANALYSIS

The calculations made in the task 7 (see section 7.2.6) show that the potential TEC savings range between 11 % (for the base case ice cream freezer) and 50 % (for the base case RCV2 with glass door) when only one improvement option is implemented. When cumulating several options, the TEC savings can go up to 57 % (for the base case RCV2 with glass door). Hence, by integrating some of these improvement potentials in the design, significant energy savings could be made by using more energy efficient refrigerated display cabinets.

This section presents both regulatory initiatives and non-regulatory actions such as voluntary labelling programs or financial incentives that have been put in place in countries outside Europe (Australia/New Zealand, Canada, etc.) to eliminate low efficiency appliances on the market or/and accelerate the number of high efficiency appliances.

8.2.1 MINIMUM ENERGY PERFORMANCE STANDARDS (MEPS)

A number of countries have already introduced mandatory legislation i.e. Minimum Energy Performance Standards (MEPS) for commercial refrigeration such as Australia/New Zealand and Canada and USA (California). Mandatory MEPS are designed to accelerate the elimination of less efficient appliances on the market rather than to promote the most efficient (as in the case of the Japanese Top Runner program).

To complement the review of these MEPS programs, market based initiatives such as the Energy Star in the USA, the ECA scheme in UK are also analysed in this section in order to provide insights on possible levels of performance applicable to commercial refrigeration equipment, and more specifically to the products covered by the lot 12.

This section provides an overview of the existing MEPS and levels of performance in and outside Europe[4]. Comparison of the levels of performance used in the various programs was only relevant when expressed in the same format (e.g. TEC/TDA, TEC as a linear function of the net volume). Performance levels for vending machines are discussed separately.

8.2.1.1 MEPS AND PERFROMANCE LEVELS EXPRESSED AS A FUNCTION OF THE TDA (TEC = α.TDA)

The MEPs in Australia/New Zealand (AS 1731 – see task 1, section 1.4.2.5) and the UK ECA scheme (see task 1, section 1.5.3.2) set levels of performance in terms of daily TEC/TDA (kWh/m²/day) for refrigerated display cabinets of both remote and plug-in types. These levels of performance are based on the same ISO 23953 standard; however, they have different ambition levels.

First reason is that the mandatory Australian/New Zealander MEPS are intended to remove the worst performing products from the market whereas the voluntary UK ECA scheme is designed to encourage the purchase of energy efficient appliances meeting the performance requirements set by the program.

Second reason is because the classification of the refrigeration equipment in both standards is different:

- In Australia/New Zealand, based on the analysis of a number of refrigerated display cabinets these levels have been set to typically 120 % of the average performance of each category of appliance they relate to (plug-in or remote), and for each sub category of appliance (according to e.g.: open/closed, vertical/horizontal, operating temperature, etc).
- The UK ECA scheme establishes performance threshold values for each category of refrigerated display cabinets (remote or plug-in) according to the operating temperature without taking into account other characteristics such as its orientation (vertical/horizontal), or its presence or absence of door which has a significant influence on the energy consumption of the appliance.

As a result, the UK ECA threshold levels are typically more stringent compared to the Australian/New Zealander ones. This is particularly true for open appliances as the UK levels are the same used to rate closed refrigerated display cabinets which are less energy demanding than open cabinets. However, for some closed cabinets the Australian/New Zealander MEPS are more strict as they only applies to cabinets with doors whereas the UK ECA one rates closed and open appliances with the same threshold. This is significantly

[4] Please refer to task 1 for their full description

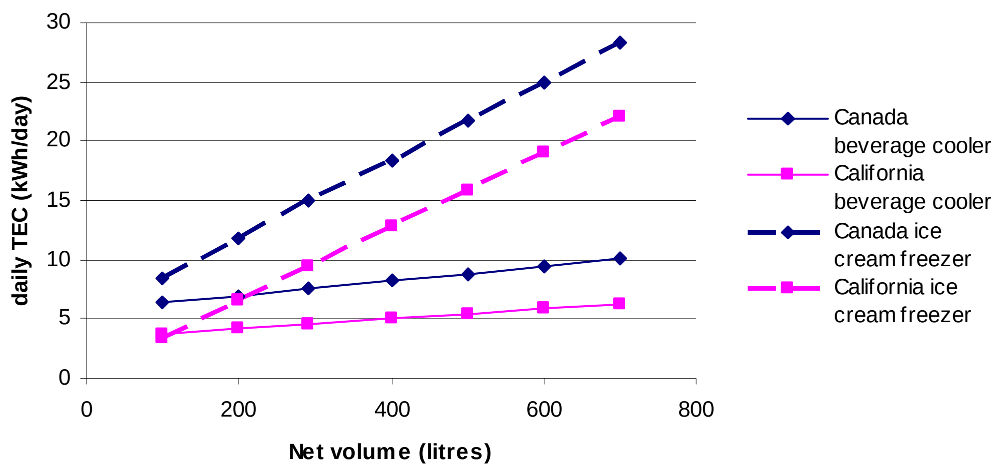
visible for ice cream cabinets and other appliances working at low temperature where the presence and absence of a door has a stronger influence on the energy consumption than in the case of cabinets working at medium temperature (chilled).

8.2.1.2 MEPS and performance levels expressed as a linear function of the volume (TEC = aV+b)

For plug-in refrigerated display cabinets fitted with doors, Canada and the state of California set mandatory MEPS as a function of the net volume of the cabinet ("aV+b" type of formula) and not as TEC/TDA. This can be explained by the fact that these standards are based on the standards for closed cabinets with solid doors for which the TDA cannot be defined as these products inherently do not have a display area. The USA Energy Star program for refrigerated display cabinets with solid door also uses an "aV+b" type of formula.

If we compare the MEPS for both beverage coolers and ice cream freezers, the Californian levels are more stringent than the Canadian requirements (approximated difference is 3.2 kWh/day for the beverage coolers and 5.6 kWh/day for the ice cream freezers). However, when the net volume is expressed in litres, the slopes ("a") are similar in both schemes with an average value of 0.005154 for beverage coolers and an average value of 0.03214 for ice cream freezers.

Figure 8-12: Californian and Canadian MEPS for plug-in cabinets with doors



8.2.1.3 MEPS expressed in TEC/length of cabinet

Canadian MEPS is expressed as a function of the length of the cabinet for remote refrigerated display cabinets. However, this rating system does not seem to be well accepted among manufacturers[5] as a relevant characterisation

[5] Feedback from stakeholders

of the energy use of remote refrigerated display cabinets. Taking the length of the cabinet as the normalising factor for the total electricity consumption would favour tall and deep cabinets over short and shallow ones. Also the length is not representative of the heat losses through the cabinet opening (such as the TDA) and neither of the refrigeration need (such as the refrigerated volume).

8.2.1.4 MEPS FOR VENDING MACHINES

Cold vending machines can be categorised in various types of vending machines: can machines (typically with solid door and only for selling beverages), drum machines, and spiral vending machines (typically glass door and displaying both snacks and beverages). Depending of the machine category, different types of MEPS already exist in Canada and USA. For beverage machines, the existing performance criterions are expressed as a function of the number of cans (capacity) and are based on the Energy Star requirement and on the ASHRAE 32.1-2004 standard.

For snack/food and beverage vending machines, the Canadian MEPS is based on the same standard (ASHRAE 32.1-2004), however, the MEPS is expressed as maximum daily electricity consumption per day for a class of vending machine (characterised by a product temperature range and a refrigerated volume capacity).

Table 8-21 presents a summary of the existing MEPS and performance threshold levels existing within and outside Europe related to the products covered by the lot 12 base cases.

Table 8-21: Summary of MEPS for commercial refrigeration and other non mandatory schemes

Base case	Reference	Corresponding type of product	MEPS	Ambient conditions	Operating conditions	Measurement based on
Remote open vertical chilled multi deck (RCV2)	Australia AS1731	RS2 - unlit shelves	12.73 Wh/m²/day (TEC/TDA/day)	25°C - 60 % RH	medium temperature (either M1 or M2)	ISO 23953
	Canada C657-03	Class 2	9.51 kWh/m/day (TEC/m/day)	~24°C - 54 % RH [6]	5°C	ASHRAE 72
	UK ECA scheme	Remote cabinet class M2	10.85 Wh/m²/day (TEC/TDA/day)	25°C - 60 % RH	M2 (-1°C ~7°C)	ISO 23953
Remote horizontal open frozen island (RHF4)	Australia AS1731	N/A	N/A	N/A	N/A	ISO 23953
	Canada C657-03	Class 5	15.10 kWh/m/day (TEC/m/day)	~24°C - 54 % RH	-17.7°C	ASHRAE 72
	UK ECA scheme	Remote cabinet between class L1 (-18°C~-15°C) class L3 (-15°C~-12°C)	Between 23.5 kWh/m²/day 21.0 kWh/m²/day (TEC/TDA/day)	25°C - 60 % RH	L1 L3	ISO 23953
Beverage cooler	Australia AS1731	VC4	17 kWh/m²/day (TEC/TDA/day)	25°C - 60 % RH	M2 (-1°C ~7°C)	ISO 23953
	Canada C827-98	Reach-in cabinets, pass-through cabinets and roll-in or roll-through cabinets that are refrigerators, and wine chillers that are not consumer products - transparent door	0.00607 V + 5.78 kWh/day (V: net volume in litres)	~24°C - 54 % RH	3.3°C ± 1.1°C	ASHRAE 117
	California Code of regulation	Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are refrigerators; and wine chillers that are not consumer products - transparent door	0.12V + 3.34 kWh/day (V: net volume in ft^3) 0.00424 V + 3.34 kWh/day (V in litres)	~24°C - 54 % RH	3.3°C ± 1.1°C [7]	ASHRAE 117
	UK ECA scheme	Integral cabinet class M2	12.7 kWh/m²/day (TEC/TDA/day)	25°C - 60 % RH	M2 (-1°C ~7°C)	ISO 23953

[6] Dry bulb temperature : 72.5 ± 1.8 °F - Wet bulb Tem perature: 64.4 ± 1.8 °F

[7] 38°F ± 2°F

Base case	Reference	Corresponding type of product	MEPS	Ambient conditions	Operating conditions	Measurement based on
Ice cream freezer	Australia AS1731	HF6	8 kWh/m²/day (TEC/TDA/day)	25℃ - 60 % RH	L1 (-18℃ ~ -15℃)	ISO 23953
	Canada C827-98	Reach-in cabinets, pass-through cabinets and roll-in or roll-through cabinets that are freezers - transparent door	0.0332 V + 5.10 kWh/day (V: net volume in litres)	24℃ - 54 % RH	-20.6℃ ± 1.1℃	ASHRAE 117
	USA California Code of regulation	Reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets that are freezers that are ice cream freezers - transparent door	0.88V + 0.33 kWh/day (V: net volume in ft^3) 0.0311 V + 0.33 kWh/day (V in litres)	~24℃ - 54 % RH	-20.6℃ ± 1.1℃ [8]	ASHRAE 117
	UK ECA scheme	Integral cabinet temperature class L1	19.10 kWh/m²/day (TEC/TDA/day)	25℃ - 60 % RH	L1 (-18℃ ~-15℃)	ISO 23953
Spiral vending machine (may contain items other than packaged beverages)	Canada C804-96	Category D “Cold Perishable Food” with gross volume > 300 L (indoor use)	14 kWh/day	~24℃ - 45 % RH	4℃ ± 1℃	ASHRAE Standard 32.1-2004
	USA California Code of regulation	Refrigerated multi package canned and bottled beverage vending machines when tested at 75°F ambient temperature	0.55 x (8.66 + 0.009 C) kWh/day (C: can number)	~24℃ - 45 % RH	2.2℃ ± 1℃	ASHRAE Standard 32.1-2004
	USA Energy star	Refrigerated beverage vending machine for indoor use	0.45 x (8.66 + 0.009 C) kWh/day (C: can number)	~24℃ - 45 % RH	2.2℃ ± 1℃	ASHRAE Standard 32.1-2004

[8] -5℉ ± 2℉

8.2.2 VOLUNTARY ENERGY LABELLING SCHEME

This section provides a review of the energy labelling schemes related to the commercial refrigeration sector. It covers two types of energy labels:

- Comparative (rating) labels which rank products
- Endorsement labels which identify only the products conforming to an efficiency level

8.2.2.1 COMPARATIVE ENERGY LABELLING

Comparative energy labelling promotes the introduction of energy efficient equipment on the market. Firstly, it helps buyers identify energy efficient cabinets without detailed technical knowledge. Secondly, it stimulates innovation and creates a challenge for manufacturers who seek to differentiate themselves from competitors on the basis of energy efficiency.

For the refrigerated display cabinets, the Dutch experience with the Stimeck scheme[9] (based on the Eurovent Certification program) provides an insight on the effectiveness of such labelling scheme. This voluntary European energy label for refrigerated display cabinets was a method for energy labelling, agreed between TNO[10] and EUROVENT and put in place in 1996. All data underlying the energy label was measured as per European Standard EN 441 (equivalent to ISO 23953) at climate class 3 (test room climate 25 ºC with 60 % relative humidity).

This labelling scheme used the efficiency classes was similar to domestic refrigerators and freezers (i.e. A, B, C, D, E, F, and G; with a decreasing order of efficiency). However, instead of using physical labels (adhesives attached to the products) a monthly list of refrigerated display cabinets (the "Stimeck list") was published according to data received from importers and manufacturers. The Stimeck program also included a verification scheme to ensure that the supplied data was correct.

The methodology used to place a cabinet into an energy efficiency class[11] defined the functionality of the appliance in TEC/TDA[12] (in kWh/m²/day) in relation to a certain temperature class as defined in the EN 441 (e.g. 3M2) and to the type of cabinet (e.g. frozen island, multi deck, etc.). This ratio was

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[9] S.M. Van der Sluis. *Experience with a Voluntary Energy Labelling Scheme for Refrigerated Display Cabinets*. TNO-MEP, Department of Refrigeration and Heat Pump Technology, Netherlands,(1999)
http://www.tno-refrigeration.com/mediapool/48/485045/data/Voluntary_Energy_Label_-_IIR.PDF

[10] http://www.tno-refrigeration.com/

[11] For a detailed guide, please visit
http://www.tno-refrigeration.com/mediapool/48/485045/data/RDC_energy_label_calculation_quick_guide.pdf

[12] Total Display Area (m²)

then compared to an average European value by the calculation of an Energy Efficiency Index (I) defined as:

$$Energy\ Efficiency\ Index = \frac{(TEC/TDA)\ tested\ cabinet}{(TEC/TDA)\ European\ average} \times 100$$

For example, a cabinet with an energy efficiency index of 55 has a TEC equal to 55 % of an average European cabinet (i.e. class B). The lower the index is, the higher the efficiency of the cabinet.

The average European values of (TEC/TDA) were based on the Eurovent measurements of average European figures[13] which were evaluated according to the Eurovent Recommendation 05 (see task 1, section 1.5.1). The Stimeck scheme thus followed the Eurovent classification of products and products categories. A lettering system translating the energy efficiency into the efficiency class was then established as in Table 8-22.

Table 8-22: Energy Efficiency classes for energy labelling (Stimeck scheme)

Energy Efficiency Index	Energy Efficiency Class
I < 55	A
55 ≤ I < 75	B
75 ≤ I < 90	C
90 ≤ I < 100	D
100 ≤ I < 110	E
110 ≤ I < 125	F
I ≥ 125	G

The Stimeck list does not exist anymore as it was abandoned, possibly because of the failure in the market surveillance. The overall experience had been supported by major European manufacturers of refrigerated display cabinets and by the government through financial incentives. A rebate paid for from the energy taxes in the Netherlands was given by the Dutch energy distribution companies for the purchase of an energy efficient cabinet[14]. The rating method could potentially serve as the basis to a European labelling scheme.

For the cold vending machines, the European Vending Association (EVA) plans to propose a labelling rating for cold vending machines, also based on the domestic classification.

Energy labels are effective instruments in consumer products (B2C) as buyers have a high level of recognition and understanding of the labels. However, the particularities of the commercial refrigeration sector, which is

[13] The average European TEC/TDA values according to Eurovent were measured in 1999 and 2001 and are available at :

http://www.eurovent-certification.com/en/Programmes/Programme_Descriptions.php?rub=02&srub=01&ssrub=&lg=en&select_prog=RDC

[14] 85 ECU for a class A cabinet

a “Business to Business” (B2B) sector, could lead to some difficulties for the implementation of an energy rating labelling scheme:

- For plug-in refrigerated display cabinets and cold vending machines, the purchaser of the product is not always the end-user. As mentioned in task 2 (section 2.3.1.1), more than 95 % of the beverage coolers are sold to the food and beverage industry and only 10 % of cold vending machines are sold directly to the end-users. Therefore, end-users, who pay the electricity bill, are unable to influence the choice of buyers who are more concerned by financial and aesthetic criteria.

- For remote refrigerated display cabinets, the distribution channel is different: most of the purchasers are also end-users (supermarket chains) and they are already informed of energy consumption of the appliances available on the market (most of them have a technical department) and a labelling scheme would not give any additional information. Moreover, the aesthetics and the size of the cabinet are important factors that could be favoured instead of energy efficiency.

- Testing products such as refrigerated display cabinets represents a significant cost for the manufacturer (about € 6,000 for a test under ISO 23953 when considering a remote refrigerated display cabinet) and such additional cost is a barrier, specifically for SMEs. This would result in the fact that only the most efficient models would be labelled making a comparison difficult and even a comparative label would be equivalent to an endorsement label.

Also, as in every comparative labelling program, setting limits makes the models to concentrate around the thresholds. As experienced with the Stimeck scheme, the limits were set to 55 % for category A, and 75 % for category B. As a result, most of the appliances targeted for 54.8 % and 74.8 %. Thus, at this stage a comprehensive assessment of the impacts and benefits related to the implementation of a labelling scheme for commercial refrigeration equipment cannot be made but the Dutch experience demonstrates that the success of such schemes could be further enhanced when coupled with financial incentives (see section 8.2.3).

8.2.2.2 Endorsement energy labels

- **USA Energy Star program for plug-in refrigerated display cabinets with solid doors**

Energy Star is a joint program of DoE (US Department of Energy) and the US Environmental Protection Agency (USEPA). It covers only the plug-in refrigerated display cabinets with solid doors (chilled and frozen). The American experience shows that the companies offering Energy Star refrigerated display cabinets represent over 90% of the market and about 1330 products qualify in this range of products.

DoE is also considering setting new minimum efficiency standards for commercial refrigeration equipment[15]. New standards will only be put in place if DoE determines that they would be technologically feasible and economically justified, and would result in significant energy savings. DoE is specifically considering new standards for commercial versions of ice-cream freezers; self-contained refrigerators, freezers, and refrigerator-freezers without doors; and remote refrigerators, freezers, and refrigerator-freezers.

Some barriers to the development of an endorsement label are:

- Setting the performance level for an endorsement label requires establishing a rigorous test performance procedure.
- Endorsement labels only apply to most efficient products which often tend to have higher initial cost and do not allow buyers to differentiate the energy efficiency of models in lower price ranges implying lesser energy gains as compared to comparative labelling programs.

8.2.3 CERTIFICATION PROGRAM

8.2.3.1 EUROVENT CERTIFICATION PROGRAM[16]

In Europe, the Eurovent certification program for refrigerated display cabinets more specifically covers remote display cabinets. It was put in place in 1999 for multi decks and semi-vertical (remote medium temperature) cabinets, and progressively expanded to counters and islands (remote medium temperature), glass door freezers, and plug-in medium temperature multi deck and semi-vertical cabinets in 2004. It is planned to cover all remote refrigerated display cabinet families by the end of 2009.

It is a program which is well perceived, with a recognised expertise among manufacturers. It does not set levels of performance but only provides information to the buyer and certifies the product's energy consumption measured in standard conditions.

However, the list of certified products gives technical information which is often difficult to understand by the purchasers. This certified product list is mostly used by manufacturers to compare his products with competitors' rather than by potential buyers to compare appliances.

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[15] The U.S. Department of Energy (DoE) is required by the Energy Policy and Conservation Act, to establish energy conservation standards for the following commercial refrigeration equipment manufactured on or after January 1, 2012: commercial ice-cream freezers; self-contained commercial refrigerators, commercial freezers, and commercial refrigerator-freezers without doors; and remote commercial refrigerators, commercial freezers, and commercial refrigerator-freezers. http://www.eere.energy.gov/buildings/appliance_standards/commercial/refrigeration_equipment.html

[16] See task 1 section 1.5.1.1 for full description

8.2.3.2 AIR-CONDITIONING AND REFRIGERATION INSTITUTE (ARI) CERTIFICATION PROGRAM

In USA, the recent ARI Certification Program for commercial refrigerated display merchandisers and storage cabinets (launched in April 2007 for plug-in cabinets and starting in January 2008 for remote cabinets) provides a common method for evaluating the performance of commercial refrigerators to give consumers confidence in the equipment they buy. Similar to the Eurovent program, the ARI certification does not set any levels of performance.

To perform the testing under the ANSI/ARI Standard 1200, ARI uses two independent laboratories: Intertek and Underwriter Laboratories. For remote refrigerated display cabinets, whether open or closed, the performance is expressed in TEC/TDA (in line with the European standards) and that is how the certified remote display cabinets are listed in the online certification directory[17]. For plug-in display cabinets, ARI evaluates the performance of the cabinet by calculating the daily energy consumption as a function of the refrigerated volume for products with doors and as a function of the TDA for open cabinets because these respective parameters (i.e. volume and TDA) appear to be the most representative of the energy consumption of these products.

8.2.4 FINANCIAL INCENTIVES

Labelling programs help customers to choose energy efficient appliances but they do not always encourage customers to invest into energy efficient equipment. Financial incentives are sometimes used for increasing the market penetration of energy-saving equipments. Through financial incentives, the buyers of efficient equipment are entitled to claim either a direct an allowance on products that are eligible on the basis of electricity consumption or an indirect rebate in the income tax.

8.2.4.1 UK ECA SCHEME

In the UK, the already existing Enhanced Capital Allowance program[18] (ECA scheme) provides a list of refrigerated display cabinets (both remote and plug-in) for which end-user can claim capital allowance.

The claims are set as presented in Table 8-23. The general rate of capital allowances is 25 % a year on a reducing balance basis. For example, if a business spent £4,000 on a new efficient appliance, it could claim capital allowances of £1,000 (25 % of £4,000) against the taxable profits of the period of investment.

[17] http://www.aridirectory.org/ari/crmd_results.php

[18] http://www.eca.gov.uk

Table 8-23: UK ECA scheme claim values

Cabinet type	Claim value	Per unit
Integral IVC1 chilled semi-vertical	£3,500	Per standard 2.44 metre length
Integral IVC2 chilled multi-deck	£3,500	Per standard 2.44 metre length
Integral IVC4 chilled vertical glass door	£1,000	Per standard door width
Remote RVC1 chilled semi-vertical	£4,000	Per standard 2.44 metre length
Remote RVC2 chilled multi-deck	£4,000	Per standard 2.44 metre length
Remote RVC4 chilled vertical glass door	£1,500	Per standard door width

The UK ECA scheme provides a list of eligible products on its website[19]. In order to be on this list, the refrigerated display cabinet has to fulfil criteria related to electricity consumption and TDA for a certain temperature class (threshold values). The performance is expressed in TEC/TDA and is measured using the Eurovent recommendation 05 (which is based on the ISO 23593 standard, see task 1 section 1.5.1). The criteria are defined for two categories of products: remote refrigerated display cabinets and plug-in refrigerated display cabinets and set performance threshold values for various temperature classes (operating temperature).

The same performance thresholds apply to cabinets both with and without door and do not depend on the design layout (vertical multi deck, horizontal cabinet, etc.) but only on the temperature class (chilled/frozen). This simplified categorisation of the products compared to the Eurovent classification can be seen as a barrier for setting a methodology of product eligibility adapted to the wide variety of commercial refrigeration equipments as the electricity consumption of a display cabinet greatly depends on the absence/presence of a door and on its design.

8.2.4.2 Dutch EIA program

The Dutch Stimeck scheme was supported by financial incentives which later became the Energy Investment Allowance (EIA) tax credit program (. This program now offers fiscal advantage to companies investing in energy saving technologies and products tested under EN 441 (equivalent to ISO 23593). 44 % of the annual investment costs of such equipment (purchase costs and production costs) are deductible from the fiscal profit over the calendar year in which the equipment was procured, subject to a maximum of € 110 million. Each year the Dutch Agency Senter Novem (Ministry of Economic Affairs) publishes a list of eligible products. Figure 8-13 presents the description of the qualifying commercial refrigeration equipment.

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[19] http://www.eca.gov.uk/etl/find/_P_Refrigeration/48.htm?Man=&DateFrom=01010001&DateTo=01010001

Figure 8-13: Extract of the Dutch Energy list[20]

220215 [W]

Energy-efficient professional refrigerator or freezer

a. *Meant for:* cooling products in the temperature category M1 (+5°C / -1°C), with an energy consumption of up to 15 kWh per m³ net contents in 48 hours, measured conform NEN-EN 441 in climate category D (30°C, 55% relative humidity), or

b. *Meant for:* freezing products in the temperature category L1 (-15°C / -18°C), with an energy consumption of up to 40 kWh per m³ net contents in 48 hours, measured conform NEN-EN 441 standard in climate category D (30°C, 55% relative humidity),

and consists of: refrigerators or freezers with a maximum net content of 1000 litre, running on a halogen-free coolant, fitted with forced ventilation in the cabinet and an individually mounted (not in the sides) built-in humidifier.

8.2.5 INFORMATION PROGRAMS

The study of consumer behaviour in task 3 showed the strong influence of the user's practices (in terms of product operation, repair and maintenance, and end-of-life) on the energy efficiency of commercial refrigeration equipment. "Good practice" guides for supermarkets, corner stores, and restaurants can be distributed to provide examples of savings on the running costs and diffuse information on how to optimise the operation of the refrigeration equipment. These guides can also provide information of existing MEPS if any and on how to purchase energy efficient equipment. In Australia, such leaflets already exist[21], promoting the smart use of refrigeration equipment and supporting the existing MEPS.

8.2.6 CATEGORISATION OF PRODUCTS AND NORMALISATION OF THE TOTAL ENERGY CONSUMPTION – GENERAL TRENDS

This section provides a general comparison of the various classifications of products used and normalisation factors (i.e. formula used to relate energy consumption to the size/capacity of the product) that are found in the MEPS and other programs described above.

8.2.6.1 CATEGORISATION OF PRODUCTS

The UK ECA scheme and the Dutch EIA tax credit program are the only programs not taking into consideration characteristics such as cabinet

[20] http://www.senternovem.nl/mmfiles/EIA%202007%20engels_tcm24-216436.pdf

[21] http://www1.sedo.energy.wa.gov.au/uploads/comm_refrig_28.pdf

orientation, presence of a door, and other parameters defining the type of cabinet when establishing energy consumption limits. The only criteria used are the type of cabinet (remote or plug-in) and the operating temperature range.

However, other programs as the Eurovent certification scheme, the Canadian MEPS, Australian MEPS, Californian code of Regulation and the USA Energy Star label set energy levels specific to a type of product. The categorisation of products as in ISO 23953 appears to be the reference in European initiatives. In the USA, the categorisations are similar giving the same level of specifications (distinction between remote and plug-in refrigerated display cabinet and further differentiation according to cabinet orientation i.e. horizontal/vertical/combination, operating temperature range i.e. chilled/frozen, presence of a door, etc.).

A detailed level of product categorisation, as used in the ISO 23953 and in the Eurovent scheme appears to be the common trend for the classification of refrigerated display cabinets in Europe, Australia, USA and Canada as the energy consumption of such products can only be compared within the same type of cabinets (i.e. TEC of a frozen island cannot be compared to the TEC of a beverage cooler).

For cold vending machines, it appears that the trend has been to use a categorisation of the machines according to the type of products stored (influencing the storage temperature) and to the internal refrigerated volume.

8.2.6.2 NORMALISATION OF THE TOTAL ENERGY CONSUMPTION

Within a product-type (e.g. remote open vertical chilled multi decks), the performance comparison of equipment of various size and capacity requires the energy consumption of one product to be normalised according to a parameter representative of the variations in energy use of this type of product (i.e. length, total display area, refrigerated volume).

The previous review of the different existing initiatives (e.g. MEPS, certification programs, financial incentives, and labelling programs, etc.) provides an insight on the choices of an appropriate metric system for each type of product. It can also be mentioned that the USA Department of Energy (DoE) has recently published a Technical Support Document for an Advance Notice of Proposed Rulemaking (ANOPR) for commercial refrigeration equipment[22]. In this context a Federal Register Notice[23] was published in which the DoE suggests that the future standards being developed should be normalised according to the TDA for remote

[22] http://www.eere.energy.gov/buildings/appliance_standards/commercial/comml_refrig_tsd.html

[23] From the Federal Register: July 26, 2007 (Volume 72, Number 143)] - This document gives official public notice of the public meeting and availability of the Framework Document, initiates information and data collection process, and encourages interested parties to submit comments http://www.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/comml_refrig_anopr_072607.pdf

appliances with transparent doors and no doors. Table 8-24 summarises the metric systems used (and possibly used in the future) by each program.

Table 8-24: Metric systems used for comparison of the daily TEC

	Remote refrigerated display cabinet			Plug-in cabinets			Cold vending machine
	Without door	Transparent door	Solid door	Without door	Transparent door	Solid door	
Australian/New Zealander MEPS	α TDA*	α TDA	not covered	α TDA	α TDA	not covered	not covered
Canadian MEPS	TEC/length	TEC/length	TEC/length	TEC/length	aV+b**	aV+b	fixed limit for a volume range
UK ECA scheme	α TDA	α TDA	not covered	α TDA*	α TDA	not covered	not covered
Eurovent Certification	α TDA	α TDA	not covered	α TDA	α TDA	not covered	not covered
Californian MEPS	not covered	not covered	not covered	not covered	aV+b	aV+b	xC+y*** C: can capacity
USA Energy star	not covered	not covered	not covered	not covered	not covered	aV+b	xC+y C: can capacity
Past Stimeck scheme	α TDA	α TDA	not covered	α TDA	α TDA	not covered	not covered
ARI certification 1200	α TDA	α TDA	not covered	α TDA	aV+b ?	not covered	not covered
USA EPACT 2005[24]	not covered	not covered	not covered	not covered	aV+b	aV+b	not covered
Future USA regulation (DoE)	α TDA?	α TDA?	aV+b?	α TDA?	α TDA?	aV+b?	not covered

* α : normalised energy consumption factor expressed in kWh/day/m² TDA
** a: expressed in kWh/day/m^3 Net volume – b: offset factor expressed in kWh/day
*** x: expressed in kWh/day/Can capacity – y: offset factor expressed in kWh/day

The analysis of the different normalisation metrics used internationally allows identifying the following trends:

- For open refrigerated display cabinets (remote and plug-in refrigerated display cabinets), there is a trend to express the TEC as a function of the TDA as it appears to be the most relevant indicator of the infiltrations load (infiltration of warm air from the surrounding inside the refrigerated volume) and thus of the energy use. However, it could be noticed that normalising the energy use by the TDA may favour “shallow” and “tall” equipment over “deeper” and “shorter” cabinets (i.e. considering two refrigerated display cabinets with the same TDA, the cabinet with the smallest refrigerated volume will be favoured).

24 See task 1 section 1.4.2.4

- Two trends were identified for the refrigerated display cabinets with transparent doors:
    - For remote refrigerated display cabinets: it appears that the TEC is normalised by the TDA in most cases.
    - For plug-in cabinets (open or with transparent doors): the TDA is also the normalisation metric which appears to be commonly used.

  In the Federal Register Notice[25] related to the rulemaking for commercial refrigerated display cabinets, the DoE justifies its intention to use the TDA for equipment with transparent doors by the fact that this type of door allows significant radiation loads to warm the refrigerated volume and that transparent doors have a poor insulation value compared to solid doors. Moreover, the TDA is also representative of the usefulness of the refrigerated display cabinet as it characterises its ability to display merchandise. Therefore the DoE directs its choice toward the use of the TDA as normalising factor.

- For refrigerated display cabinets with solid doors, the TDA is not defined (no visible merchandise) and the refrigerated volume appears to be the most appropriate parameter.
- For cold vending machines displaying perishable food or snacks and beverages, the trend is to consider the energy consumption for a specific refrigerated volume and the product temperature range. For beverage vending machines, the energy consumption is expressed as a function of the number of cans it can hold.

8.2.7 CONCLUSIONS

Possible measures to reduce the energy use of refrigerated display cabinets may include legislation, financial incentives, and guidelines for energy conservation. These measures can be combined to enhance their action. For example, financial incentives can be combined with an energy labelling scheme to encourage the take up of efficient products. Information programs could also complement regulatory measures.

Further, when implementing a rating system (either MEPS or labelling scheme), the various programs and the manufacturers insist on the importance of having an adequate surveillance system in place (e.g. third party verification). When a manufacturer provides data on energy consumption, it is very important to have a suitable control mechanism to ensure the information is correct as it represents a competitive data (unlike e.g. data related to safety).

Another important aspect to consider is the relevance of the standards used to evaluate the energy consumption of the products. Indeed, the performance of a refrigerated display cabinet and of a vending machine

25 http://www.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/comml_refrig_anopr_072607.pdf

depends very much on the climate conditions. Therefore, one product A could show the same level of performance than a product B in standard conditions but reach a higher level in real life conditions due to the use of control systems (adaptation to the variations of the ambient conditions leading to overall performance optimisation).

8.3. IMPACTS ON MANUFACTURERS

The goal of this section is to identify the potential impacts to setting eco-design requirements on manufacturers. Some identified impacts include:

- The capital investment needed by the manufacturer to upgrade or redesign his products and his production platforms, happening before the end-of-life of the production platform (typical life time is estimated to 15 to 20 years), can imply conversion costs that otherwise would not be required (earlier capital investments). However, redesign through component level modification does not always require upgrading the production platform.
- Higher efficiency products could result in higher product costs that may deter some customers from buying higher margin appliances.
- Redesign could affect the product quality and reliability for a short period of time. This could increase warranty costs to manufacturers.
- Major supermarkets drive innovation by demanding unique equipment to manufacturers and setting eco-design requirement could be a obstacle for manufacturers to meet the customers ‘requirements and enhance the utility of their products.

For the consumer – taking the LLCC as benchmark – any such requirements will lead to cost savings.

8.4. SENSITIVITY ANALYSIS OF THE MAIN PARAMETERS

The robustness of the outcomes of the study depends on the underlying assumptions. These assumptions are already mentioned at the single steps of the study. The most critical aspects and assumptions are tested under this section, related to:

- The economic data, such as the electricity tariff and the product cost which have an influence both on the LCC and on the payback time when implementing improvement options,
- The bill of material (BOM) data in relation with the assumptions made when constructing the base cases, and
- The energy consumption data.

Besides, the choice of the base cases as being representative of the market will be further discussed in section 0

8.4.1 Assumptions related to the electricity tariff

For the remote category of refrigerated display cabinets, an average EU 25 electricity tariff of 0.097 €/kW was based on the data from Eurostat (see task 2, section 2.4.2.1). However, if the lowest electricity tariff (i.e. 0.0476 €/kW in Latvia) and the highest electricity tariff (i.e. 0.1349 €/kW in Cyprus) are applied, this could lead to different LCC for the base cases (respectively the payback times are multiplied by about 2 and 0.7)

The same is true for the plug-in category of refrigerated display cabinets and for cold vending machines for which an average EU 25 electricity tariff of 0.105 €/kW was calculated in task 2 (section 2.4.2.1). The electricity price also has an impact on the payback time associated to any possible improvement option that could be implemented to the base case.

As it is shown in Table 8-25 and in Table 8-26 , the modifications in the electricity tariff have a strong impact on the LCC. Indeed the major part of the LCC is due to the electricity costs during the use phase of the commercial refrigeration equipments. However, in task 7 it is not so critical to have a strong uncertainty on this value as the relative improvement is the parameter which is analysed.

Table 8-25: Impacts of the electricity tariff on the LCC (remote cabinets)

Electricity tariff (€/kWh)	Base case RCV2 LCC (€)	Base case RHF4 LCC (€)
0.0476	16,812	18,100
0.0970	28,300	30,187
0.1349	37,114	39,459

Table 8-26: Impacts if the electricity tariff on the LCC (plug-ins and vending machines)

Electricity tariff (€/kWh)	Base case beverage cooler	Base case ice cream freezer	Base Case spiral vending machine
0.053	2,058	1,595	4,997
0.105	3,058	2,226	6,104
0.155	4,020	2,833	7,169

The influence of the electricity tariff on the payback time associated to the implementation of the combination of options with BAT identified in task 7 (section 7.2) is presented in Table 8-27 and Table 8-28 to illustrate the effect on the payback times (a lower tariff implies a longer payback time).

Table 8-27: Impact of the electricity tariff on the payback times (remote cabinets)

	Electricity tariff (€/kWh)	0.0476	0.097	0.1349
Payback times (years)	Base Case RCV2 BAT/LLCC option with door	1.25	0.61	0.44
	Base Case RCV2 BAT/LLCC option without door (with night curtain)	0.67	0.33	0.24
	Base Case RCV2 BAT/LLCC option without night curtain	0.75	0.37	0.26
	Base Case RHF4 BAT/LLCC option with door	2.58	1.26	0.91
	Base Case RHF4 BAT/LLCC option without door (with night curtain)	1.08	0.53	0.38
	Base Case RHF4 BAT/LLCC option without night curtain	1.47	0.72	0.52

Table 8-28: Impact of the electricity tariff on the payback times (plug-in appliances and cold vending machines)

	Electricity tariff (€/kWh)	0.0476	0.097	0.1349
Payback times (years)	Base Case beverage cooler BAT/LLCC option	1.25	0.61	0.44
	Base Case ice cream freezer BAT/LLCC option	0.67	0.33	0.24
	Base Case spiral vending machine BAT/LLCC option	0.75	0.37	0.26

8.4.2 ASSUMPTIONS RELATED TO THE PRODUCT COST

For the base case spiral vending machines, the product cost can vary depending on the quantity of products the customer purchases. The product cost considered in the study is of € 2,500 which is an estimate of the average cost of a spiral vending machine. However, when bought in large quantities the product cost can drop to € 2,000 due to discount offers and can reach up to € 3,500 when bought per unit. The impacts of the product cost of the base case spiral vending machine on the LCC at product level and at the EU 25 level are presented in Table 8-29.

Table 8-29: Impact of the variations in the product cost (Base case spiral vending machine)

Base case spiral vending machine product cost	LCC new product (€)	Total annual consumer expenditure in EU25 (M. €)
2,000 €	4,604	670
2,500 €	5,104	733
3,500 €	6,104	859

8.4.3 ASSUMPTIONS RELATED TO THE BILL OF MATERIAL (BOM)

The material data collection from different manufacturers of commercial refrigeration equipment in task 4 (section 4.1.) was not an easy process as manufacturers are not always aware of the exact material composition and weight of their product. Two major sources of error related to the BOM of the base cases are analysed in this section:

- Error coming from averaging the product cases for figures presenting large discrepancies when constructing the base case ("assumptions on the figures")

  The BOM of the collected product cases sometimes showed some large discrepancies when evaluating the weight of the same component (e.g. electric cables). The arithmetic average of the weight of the component was calculated and taken into account when constructing the base case, however, the reasonability of this assumption has to be tested considering the large deviations around the average value.

- Error coming from the construction of the base case when assumptions where made in terms of the choice of the materials in some parts of the product (e.g. some fans have aluminium blades, others plastic blades but it was assumed that the blades were made of aluminium because the production of this material is associated to bigger environmental impacts) ("assumptions on the type of material").

8.4.3.1 ASSUMPTIONS ON THE FIGURES

For the base case RCV2, five components show large discrepancies among the 4 products cases investigated (Table 8-30). However, the results of the EcoReport in terms of environmental impacts (here expressed in Gross Energy Requirement, GER) are not greatly modified by the variation of the weight of these components (less than 0.07% variation of the GER and other indicators are not strongly affected either).

Table 8-30: Uncertainties due to the assumptions on the figures in base case RCV2 BOM

Module	Component	Average Mass (kg) (base case figure)	Deviation (kg)	Deviation of the GER (%)
Housing	Mounting internal components	34.5	37	0.074%
Components for assembling	Screws and rivets	6.5	5.1	0.003%
Electric assembly	Cables PVC	3.9	2	0.005%
Electric assembly	Cables CU wire	2.5	0.7	0.003%
Misc.	Pipes for the refrigerant	6.7	2.8	0.008%

The same type of assumptions were tested for the other product cases (see Table 8-31 to Table 8-33) and also lead to the conclusion that the values and the uncertainty associated to these figures can be considered reasonable. This is due to the negligible importance of the environmental impacts of the production phase in comparison to the use phase as seen in task 5 (section 5.2.)

Table 8-31: Uncertainties due to the assumptions on the figures in base case RHF4 BOM

Module	Component	Average Mass (kg) (base case figure)	Deviation (kg)	Deviation GER (%)
Housing	Glass	102.5	24.7	0.00002%
Housing	Foam insulation	33.4	4.6	0.00071%
Packaging	Wood palette	89.4	49.25	0.00002%
Misc.	Pipes for the refrigerant	2.04	0.5	0.00006%

Table 8-32: Uncertainties due to the assumptions on the figures in base case beverage cooler BOM

Module	Component	Average Mass (kg) (base case figure)	Deviation (kg)	Deviation GER (%)
Housing	Shelves	11.5	3.46	0.000296%
Housing	Foam insulation	8.5	4,48	0.000296%
Housing (Door)	Aluminium	4.2	0.98	< 0.0000001%
Evaporation	Evaporator	2	0.48	< 0.0000001%

Table 8-33: Uncertainties due to the assumptions on the figures in base case spiral vending machine BOM

Module	Component	Average Mass (kg) (base case figure)	Deviation (kg)	Deviation GER (%)
External housing	Panels + chassis	133.5	25.7	0.00012%
Housing	Foam insulation	4.17	0.5	0.00467%
Housing	Shelves	32.5	9.6	0.01983%
Packaging	Wood palette	5.6	2.8	0.00012%

8.4.3.2 ASSUMPTIONS ON THE TYPE OF MATERIAL

The construction of the BOM of the base cases in task 5 (section 5.1) is based on the aggregation of the material inventory of several product cases.

However, some products of the same type of appliances (e.g. beverage cooler) showed differences in the type of material used for the same component (e.g. door handle). It was then assumed that the component was made using the material showing the highest environmental impacts in order to consider the “worst situation” when assessing the environmental impacts using the EcoReport. This section tests how the results of the EcoReport vary when assuming the components are made with an alternative material as found in some of the product cases.

The variations of the results of the EcoReport depending of the type of material used in some components are given in Table 8-34 for each of the base cases where such assumptions were necessary. On the basis of 5 environmental indicators related to resource consumption and to emissions to air and water, Table 8-34 shows that all the assumptions do not strongly impact the outcomes of the environmental assessment (the figures of the environmental indicators vary between less than 0.001 and less than 5 %) and that the assumptions made are acceptable.

For the base case RHF4 and the base case ice cream freezer such assumptions were not needed as the product cases showed a similar material composition.

Table 8-34: Impact of the material assumptions on the EcoReport results

Assumptions for construction of the base case	New assumptions for construction of the base case	Relative difference in the EcoReport environmental indicators when using the "new assumptions" compared to the original ones used in the base case				
		Total Energy (GER) (MJ)	Total electricity (MJ)	Greenhouse Gases in GWP100 (kg CO2 eq.)	Acidification, emissions (g SO2 eq.)	Heavy Metals, (water) (mg Hg/20)
BASE CASE RCV2						
Bumper : PVC	Bumper : cast iron	-0,0059%	-0,0035%	-0,0079%	-0,0091%	-0,0337%
Fan blade: Aluminium	Fan blade plastic	-0,0044%	0,0005%	-0,0054%	-0,0060%	-0,1071%
With electronic temperature control	Without electronic temperature control	-0,0146%	-0,0121%	-0,0190%	-0,0310%	-0,0010%
Foam insulation : 100% PUR	Foam insulation : 1/4 EPS and 3/4 PUR	-0,0050%	-0,0015%	-0,0081%	-0,0042%	-1,2365%
Foam insulation : 100% PUR to	Foam insulation : 100% EPS	-0,0200%	-0,0130%	-0,0325%	-0,0468%	-4,9459%
With anti-sweat heater	Without anti-sweat heater	-0,0004%	0,0003%	-0,0005%	-0,0042%	-0,0430%
BASE CASE BEVERAGE COOLER						
Condenser : 1/4 aluminium 1/4 steel 1/2 copper	Condenser : 2/3 aluminium 1/3 copper	0.087%	0.001%	0.108%	0.082%	0.854%
Condenser : 1/4 aluminium 1/4 steel 1/2 copper	Condenser : 1/5 aluminium 1/5 steel 3/5 copper	-0.005%	0.0004%	0.000%	0.013%	0.233%
Packaging : 190g LLDPE, 630g EPS, 190g cardboard	Packaging : 8g PA6, 470g cardboard	-0.028%	-0.009%	-0.029%	-0.034%	0.000%
Fan blades: Aluminium	Fan blades: plastic	0.003%	0.001%	0.009%	0.000%	-0.116%
Fan housing : HI-PS	Fan housing PS	-0.003%	0.000%	0.000%	-0.003%	0.000%
Liquid receiver : dryer only and accumulator	Liquid receiver : dryer only	-0.003%	0.000%	0.000%	-0.010%	-0.116%
Handle : ABS	Handle : PS	-0.002%	-0.001%	0.000%	0.000%	-0.039%
Shelf clips : 230g of PA6	Shelf clips : 630g of stainless steel sheets	0.002%	-0.0004%	0.000%	-0.007%	-0.349%
Canopy : ABS	Canopy : ABS and PS	-0.001%	-0.00045%	0.000%	0.000%	0.000%
BASE CASE SPIRAL VENDING MACHINE						
Foam insulation: PUR	Foam insulation: PS	-0.0269%	-0.0231%	-0.0440%	-0.0789%	-5.4444%
Shelves brackets: ABS	Shelves brackets: 65% ABS + 1% PP + 34 % PS	-0.0276%	-0.0114%	-0.0367%	1.3511%	-6.1975%
Screw rivets: Stainless + Al	Screw rivets: ferrite	-0.0017%	0.0004%	0.0000%	-0.0476%	-1.4203%
Spiral: Pre coating coil	Spiral: to stainless steel tube	-0.7538%	-0.2334%	-0.5579%	0.0150%	-17.1724%

8.4.4 ASSUMPTIONS RELATED TO THE ENERGY CONSUMPTION

When collecting product specific data from manufacturers of refrigerated display cabinets and cold vending machines it was also asked to provide data on the energy consumption of the appliance. As real life conditions of use were not possible to define at the EU 25 level, measurements of the TEC in standard conditions were collected to provide a common framework for comparison.

8.4.4.1 VARIATION DUE TO THE ESTIMATION OF THE AVERAGE TEC FOR EACH BASE CASE

For each of the base case, the TEC figure associated is the result of the average of the product cases individual TEC data normalised to the same total display area or net volume. However, for some of the base cases the mean value of the TEC presented a relatively large deviation and the purpose of this section is to quantify the impacts of this uncertainty on the outcomes of the EcoReport analysis and on the calculation of the payback times associated to the implementation of the combination of improvement options leading to the BAT/LLCC point.

The base cases without doors presented a large deviation for the TEC figure (i.e. base case RCV2 and base case RHF4). For example the TEC of the base case RCV2 was calculated to 77.31 kWh/d with a deviation of 7.41 kWh/day (9.6 %). This deviation (Table 8-35) implies an uncertainty on the outcomes of the EcoReport figures of environmental indicators as shown in Table 8-36.

The EcoReport results related to the base cases beverage cooler, ice cream freezer and cold vending machines present consistent TEC figures however, the uncertainty is a little less than 10 % for the results related to the remote base cases.

Table 8-35: Uncertainty on the TEC values of the base cases

	TEC deviation compared to base case (kWh/d)
Base case RCV2	± 9.6 %
Base case RHF4	± 7.9 %
Base case beverage cooler	± 0.012 %
Base case ice cream freezer	0
Base case cold vending machine	±0.03 %

Table 8-36: Uncertainty on the outcomes of the EcoReport

Base case	Deviation of some environmental indicators % due to deviation of the TEC figure			
	Total Energy (GER) (MJ)	Greenhouse Gases in GWP100 (kg CO2 eq.)	Acidification, emissions (g SO2 eq.)	Heavy Metals, (water) (mg Hg/20)
RCV2	± 9.4 %	± 9.3 %	± 9.4 %	± 7.3 %
RHF4	± 7.8 %	± 7.7 %	± 7.7 %	5.8 %
Beverage cooler	Negligible	Negligible	Negligible	Negligible
Ice cream freezer	No deviation	No deviation	No deviation	No deviation
Spiral vending machine	Negligible	Negligible	Negligible	Negligible

8.4.4.2 VARIATION DUE TO THE MEASUREMENTS IN STANDARD CONDITIONS

- **Standard conditions vs. real life conditions**

As seen in task 4 (section 4.3), the TEC in standard conditions differs greatly from the TEC in real life conditions specifically for the base case RCV2 where the ambient conditions have a strong influence on the electricity consumption of the appliance due to its relatively large open total display area. It was not possible to estimate an average "real life consumption" because of the too numerous parameters influencing the TEC (ambient temperature, humidity, and load, etc., see task 4 – section 4.3). However, a case study carried out by a manufacturer provides an insight of what could be a real life situation.

The conditions of measurement are following:

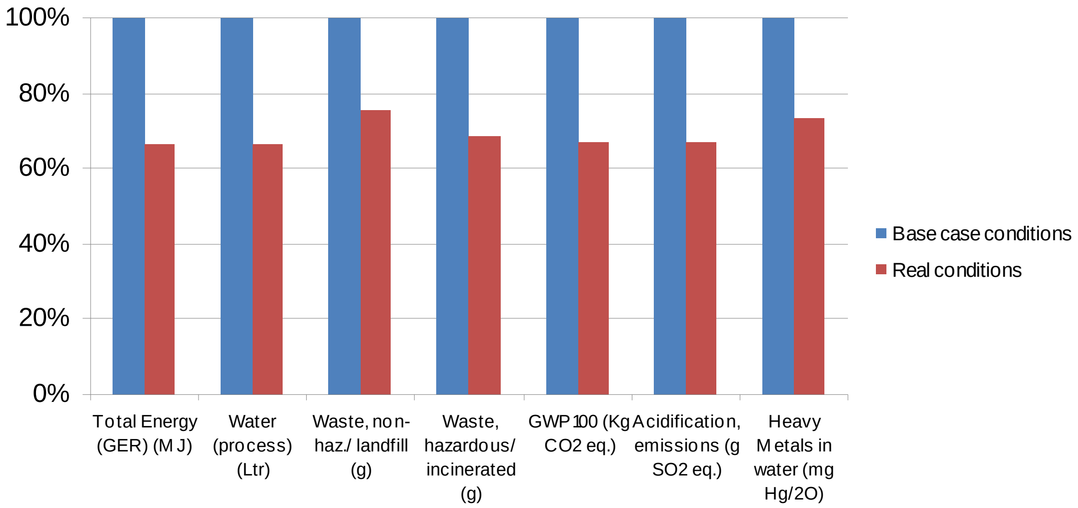
A single cabinet was equipped, connected to a parallel compressor refrigeration system installed in an Italian supermarket, with a flow meter sensor and temperature and pressure sensors fitted on inlet/outlet pipes. Thereby, it was possible to measure along one year period, the heat extraction rate of the cabinet and consequently the REC value was calculated as specified in ISO 23953 Standard.

The surrounding ambient conditions, averaged during the year, were 19 °C temperature and 50 % of rate humidity. The cabinet had also night curtains fitted on and used 12 hours/day (creating a further reduction on heat extraction rate). Finally, lights were switched on 12 hours/day.

The difference in real electricity consumption was measured to be around 34 % less than compared to the one in standard conditions.

To provide an illustration of what could be the differences between real life and standard conditions, an EcoReport analysis was performed considering a base case with a TEC reduced of 34 %. Figure 8-14 highlights that all environmental impact assessed would be lower in real life conditions, compared to standard conditions for this specific case.

Figure 8-14: Comparison between standard and real life conditions for significant impact indicators



No lighted shelves vs. lighted shelves

For the base case RCV2, different ways to light up the cabinet can be used. The first one is to enlighten outside of the cabinet and the second one is to enlighten the cabinet with lights on each shelf.

The base case RCV2 was assumed to have no lighted shelves due to the large variation in the type of lighting that can be used by retailers and by the impossibility of defining a "standard" installation.

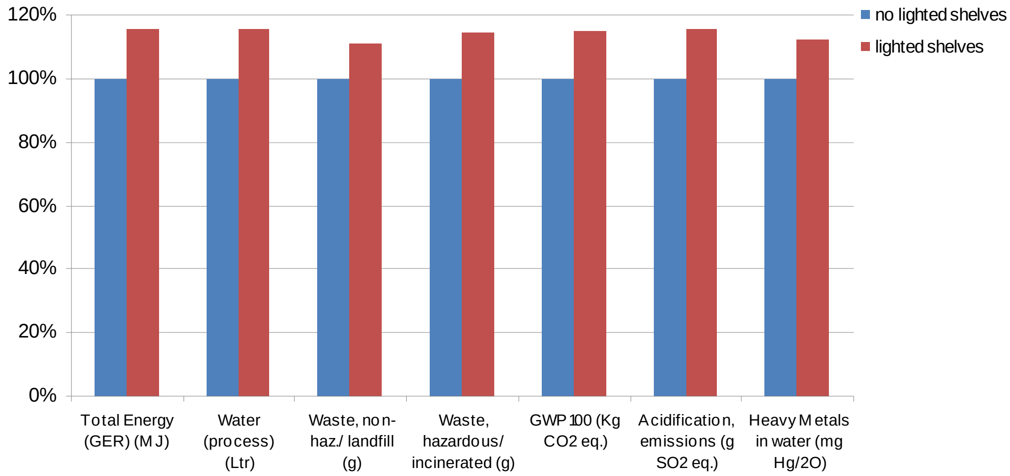
A case study was carried out by a manufacturer to test the influence of lighted shelves on the energy consumption of a remote refrigerated open multi deck. The test followed the ISO 23953 conditions and at 30 ℃, with 60 % of relative humidity.

For this test, lights were working 12 hours/day and the type of light used in each shelf was T5 neon of 28 W. In these conditions the TEC measured was approximately 16 % higher to when compared to the TEC of a cabinet with no lighted shelves.

The difference can be explained by the additional electricity consumption required for the lighting and also by the heat generated by the bulbs which implies the need of a greater refrigeration load (increase in the refrigeration energy consumption) to maintain the foodstuff at the right temperatures

In order to simulate the possible impact of having lighted shelves on the base case RCV2 an EcoReport analysis was carried out using an increased TEC of 16 % compared to the original TEC value. The outcomes for this specific case are presented in Figure 8-15 for some of the environmental indicators. Globally the values of the indicators are increased of 12 to 15.5 %.

Figure 8-15: EcoReport results assuming the base case has lighted shelves



8.4.5 CONCLUSIONS

The sensitivity analysis allows identifying the factors that could influence the various assumptions made on the improvement potential of the base cases. Some factors have a foreseeable effect such as the impact of the electricity tariff on the LCC and on the payback times. Other assumptions such as the ones related to the BOM do not strongly impact the outcomes of the EcoReport and therefore the various scenarios tested. However, the assumptions on the electricity consumption are more sensitive. This is due to the large diversity of the products on the market implying discrepancies in the TEC data collected and uncertainties on the results of the environmental indicators, even when placed in standard conditions. Also it should be kept in mind, more specifically for the base case RCV2 that the real life conditions can lead to very different assumptions on the TEC.

8.5. CHOICE OF THE BASE CASES – SCOPE OF LOT 12

Task 1, section 1.1 defined the scope of the lot 12 study as including three categories of appliances:

- Remote refrigerated display cabinets,
- Plug-in refrigerated display cabinets, and
- Cold vending machines.

The base cases are, as required by the EuP methodology, a "conscious abstraction of reality" but cannot claim to be in a scientific statistical sense representative. The base cases reflect a number of refrigerated display cabinets and cold vending machines and the market has been covered as largely as possible. The part of the remote market which is covered is around 68 %, around 60 % for the cold vending machines, and about 82 % for the for the plug-ins market (see task 2, section 2.2.1.1).

However, some other categories of appliances (e.g. service cabinets, chillers, ice makers, wine cellars, milk shake freezers, ice cream machines, serve-over counters, hotel minibars, etc.) are part of the commercial refrigeration equipment but could not be covered due to time constraints and to the need to focus on a smaller range of products in order to provide a thorough analysis for the selected products. Nevertheless, these products should not be put aside as they could present great improvement potential.

For example, a study[26] on the energy consumption of hotel minibars[27] in Denmark shows that the majority of the most widely used minibars are comparable to a domestic refrigerator of the energy labelling category G (consuming over 1.0 kWh/day[28] for a little over 30 litre net volume) but that improvements up to the category B, achieved by a reduction of the energy consumption to less than 0.5 kWh/day, is feasible with a payback time of 3 years. This makes an economic sense considering the product lifetime is 8 to 10 years.

Further, some other studies were carried out to assess improvement potentials of the following categories of refrigeration equipment which are outside the scope of the lot 12 study:

- Service cabinet[29]: 33 % of energy savings
- Ice makers[30]: 10 % of energy savings (with a payback under five years)
- Chillers[30]: 30 % of energy savings (with a payback under five years)

Finally, regarding the compressor-condenser unit of remote refrigerated cabinet, as well as the whole refrigeration system, energy savings are not negligible. Indeed, the Refrigeration Electricity Consumption of the base case RCV2 represents about 91 % of the TEC (task 5, section 5.1.2.1), and about 77 % of the TEC for the base case RHF4 (task 5, section 5.1.2.2).

Nevertheless, it is very difficult to assess the efficiency of a refrigeration system as no objective comparison tool exists in order to evaluate the

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[26] Stine Rasmussen, Per Henrik Pedersen. *Electricity consumption of minibars*. Danish Technological Institute. 2006

[27] Currently there is no compulsory labelling for minibars

[28] The electricity consumption measurements were performed according to the EN 153 test standard for domestic appliances at ambient temperature of 25 °C and 5 °C in the refrigerator as specified in the standard.

[29] TIAX LLC for the USA DoE, *Application of Best Industry Practices to the Design of Commercial Refrigerators*, June 2002

[30] Mark Ellis & Associates, *Analysis of Potential MEPS for Self-Contained Commercial Refrigeration*, March 2000

improvement potential and to compare the quality of different systems (taking into account parameters such as the choice of the refrigerant, the electricity consumption, etc.). The challenge is that refrigeration circuits in supermarkets are tailor-made, and therefore it is difficult to set a common framework and to establish a standard.

8.5.1 CONCLUSIONS

The various scenarios will allow quantifying the effects of an increase in the energy efficiency of the products covered by the base cases in Europe.

The policy analysis shows that many options exist, either regulatory or non-regulatory, and that these actions can be combined. For instance, mandatory requirements (MEPS) could be supported by information programs as it is the case in Australia, and complemented with an energy labelling system.

Also the lot 12 study provides an analysis of a portion of the commercial refrigeration sector. However other appliances such as hotel minibars, service cabinets and chillers should also be considered in future studies to provide a complete view of the sector.

ANNEXES

Annexe 8- 1: Summary of the reference scenario (Freeze)

Year	Parameter	Base case RCV2	Base case RHF4	Base case Beverage cooler	Base case ice cream freezer	Base case spiral vending machine
2006	Sales (million units/yr)	0.1464	0.0192	0.7900	0.3386	0.1260
	Annual electricity consumption during use phase (GWh/yr)	37,044.92	5,111.28	16,245.69	4,448.82	3,756.80
	GWP 100 (million ton CO_2 eq.) over lifetime	19.20	2.65	8.65	2.68	2.45
	Total annual consumer expenditure over lifetime (million euros)	4,818.66	672.83	2,709.83	840.22	979.25
2010	Sales (million units/yr)	0.1617	0.0212	0.8400	0.3600	0.1467
	Annual electricity consumption during use phase (GWh)	41,055.83	5,664.68	17,273.90	4,730.40	5,116.63
	GWP 100 (million ton CO_2 eq.) over lifetime	21.27	2.94	9.20	2.85	3.26
	Total annual consumer expenditure over lifetime (million euros)	5,338.11	745.34	2,881.33	893.40	1,246.54
2015	Sales (million units)	0.1817	0.0238	0.8900	0.3814	0.1776
	Annual electricity consumption during use phase (GWh)	46,152.71	6,367.92	18,302.10	5,011.97	7,136.87
	GWP 100 (million ton CO_2 eq.) over lifetime	23.92	3.30	9.75	3.02	4.46
	Total annual consumer expenditure over lifetime (million euros)	6,000.81	837.87	3,052.84	946.58	1,644.24
2020	Sales (million units/yr)	0.2018	0.0265	0.9400	0.4029	0.2151
	Annual electricity consumption during use phase (GWh)	51,248.64	7,071.03	19,330.31	5,293.54	9,583.01
	GWP 100 (million ton CO_2 eq.) over lifetime	26.56	3.67	10.30	3.18	5.92
	Total annual consumer expenditure over lifetime (million euros)	6,663.39	930.38	3,224.35	999.76	2,125.77

Annexe 8- 2: Inputs for the EcoReport – "BAU" scenario

Year	Parameter	Base case RCV2 with same temperature class (3M2)	Base case RCV2 with temperature class 3M1	Base case RHF4 with same temperature class (3L2)	Base case RHF4 with temperature class 3L1	Base case beverage cooler	Base case ice cream freezer	Base case vending machine
2006	Average daily TEC (kWh/d)	77.31	77.31	81.34	81.34	7.04	4.50	7.47
	Average product price (euros)	3,440.00	3,440.00	3,970.00	3,970.00	830.00	800.00	3,500.00
	Average installation costs	344.00	344.00	397.00	397.00	0.00	0.00	0.00
	Average repair and maintenance	2,139.00	2,139.00	2,279.56	2,279.56	225.00	164.00	400.00
2010	Average daily TEC (kWh/d)	77.13	77.59	81.15	81.54	7.00	4.50	7.45
	Average product price (euros)	3,442.29	3,443.82	3,972.64	3,974.42	831.47	800.00	3,500.00
	Average installation costs	344.23	344.38	397.26	397.44	0.00	0.00	0.00
	Average repair and maintenance	2,134.66	2,145.91	2,275.23	2,284.70	224.17	164.00	400.00
2015	Average daily TEC (kWh/d)	75.42	80.07	79.44	83.34	6.21	4.50	7.29
	Average product price (euros)	3,462.97	3,478.36	3,996.54	4,014.38	859.52	800.00	3,500.00
	Average installation costs	346.30	347.84	399.65	401.44	0.00	0.00	0.00
	Average repair and maintenance	2,095.44	2,208.38	2,236.07	2,331.10	208.12	164.00	400.00
2020	Average daily TEC (kWh/d)	71.96	85.11	75.96	86.98	4.80	4.50	7.12

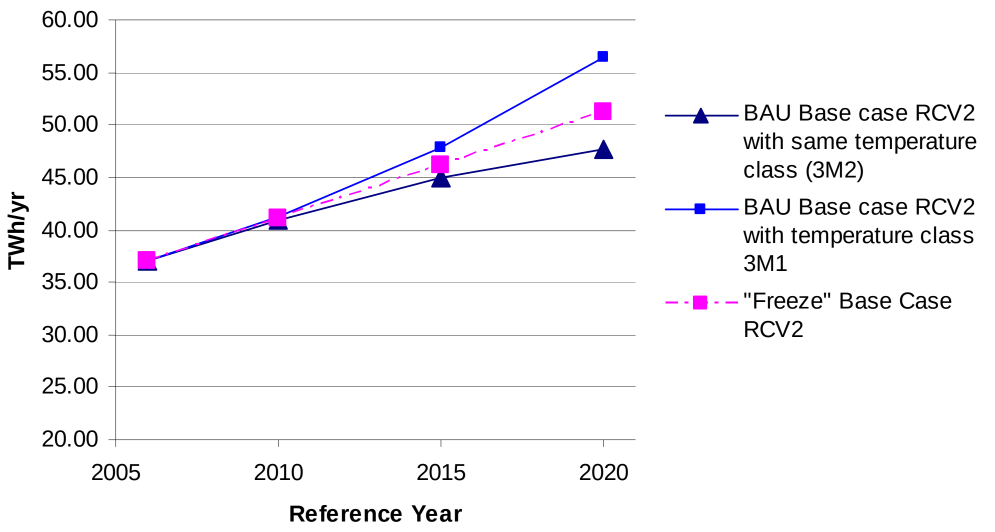
	Average product price (euros)	3,504.87	3,548.33	4,044.95	4,095.34	904.46	800.00	3,500.00
	Average installation costs	350.49	354.83	404.49	409.53	0.00	0.00	0.00
	Average repair and maintenance	2,015.99	2,334.92	2,156.75	2,425.10	178.93	164.00	400.00

Annexe 8- 3: Summary of the "BAU" scenario

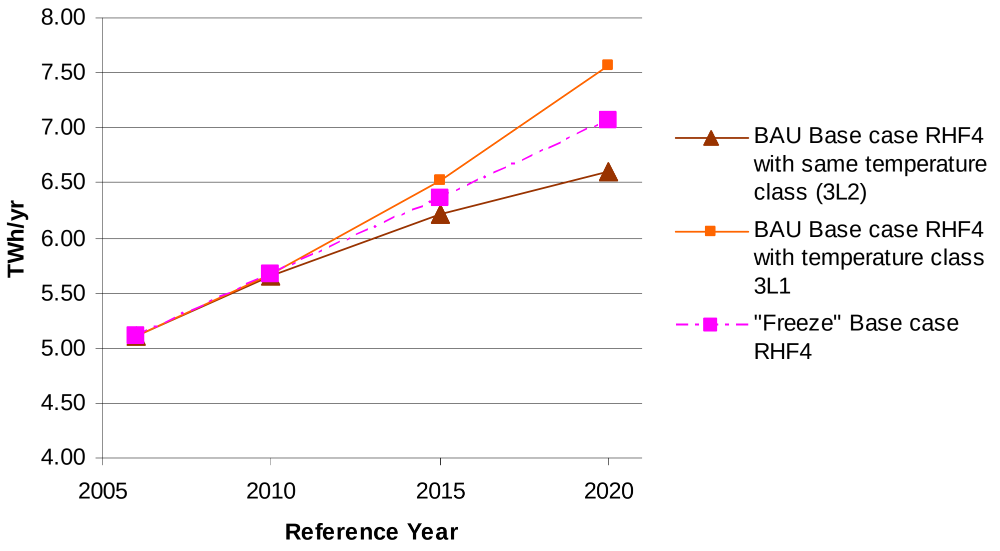
Year	Parameter	Base case RCV2 with same temperature class (3M2)	Base case RCV2 with temperature class 3M1	Base case RHF4 with same temperature class (3L2)	Base case RHF4 with temperature class 3L1	Base case beverage cooler	Base case ice cream freezer	Base case vending machine
2006	Sales (million units/yr)	0.1464	0.1464	0.0192	0.0192	0.7900	0.3386	0.1260
	Total average daily electricity consumption **per product** (kWh/d)	77.31	77.31	81.34	81.34	7.04	4.50	7.465
	Annual electricity consumption during use phase (GWh/yr)	37,044.92	37,044.92	5,111.28	5,111.28	16,245.69	4,448.82	3,756.80
	GWP 100 (million ton CO_2 eq.) over lifetime	19.20	19.20	2.65	2.65	8.65	2.68	2.45
	Total annual consumer expenditure over lifetime (million euros)	4,818.66	4,818.66	672.83	672.83	2,709.83	840.22	979.25
2010	Sales (million units/yr)	0.1617	0.1617	0.0212	0.0212	0.8400	0.3600	0.1467
	Total average daily electricity consumption **per product** (kWh/d)	77.13	77.59	81.15	81.54	7.00	4.50	7.45
	Annual electricity consumption during use phase (GWh)	40,955.47	41,201.80	5,651.46	5,678.53	17,174.09	4,730.40	5,105.94
	GWP 100 (million ton CO_2 eq.) over lifetime	21.22	21.35	2.93	2.95	9.15	2.85	3.25

	Total annual consumer expenditure over lifetime (million euros)	5,327.11	5,355.48	743.89	747.02	2,870.34	893.40	1,245.20
2015	Sales (million units)	0.1817	0.1817	0.0238	0.0238	0.8900	0.3814	0.1776
	Total average daily electricity consumption **per product** (kWh/d)	75.42	80.07	79.44	83.34	6.21	4.50	7.29
	Annual electricity consumption during use phase (GWh)	45,020.44	47,799.64	6,218.80	6,524.15	16,150.61	5,011.97	6,971.05
	GWP 100 (million ton CO_2 eq.) over lifetime	23.35	24.75	3.23	3.38	8.67	3.02	4.37
	Total annual consumer expenditure over lifetime (million euros)	5,876.67	6,196.81	821.61	856.92	2,815.60	946.58	1,623.34
2020	Sales (million units/yr)	0.2018	0.2018	0.0265	0.0265	0.9400	0.4029	0.2151
	Total average daily electricity consumption **per product** (kWh/d)	71.96	85.11	75.96	86.98	4.80	4.50	7.12
	Annual electricity consumption during use phase (GWh)	47,698.08	56,413.09	6,603.41	7,560.92	13,184.62	5,293.54	9,145.69
	GWP 100 (million ton CO_2 eq.) over lifetime	24.77	29.16	3.43	3.92	7.20	3.18	5.68
	Total annual consumer expenditure over lifetime (million euros)	6,274.12	7,278.01	879.41	990.14	2,541.21	999.76	2,070.67

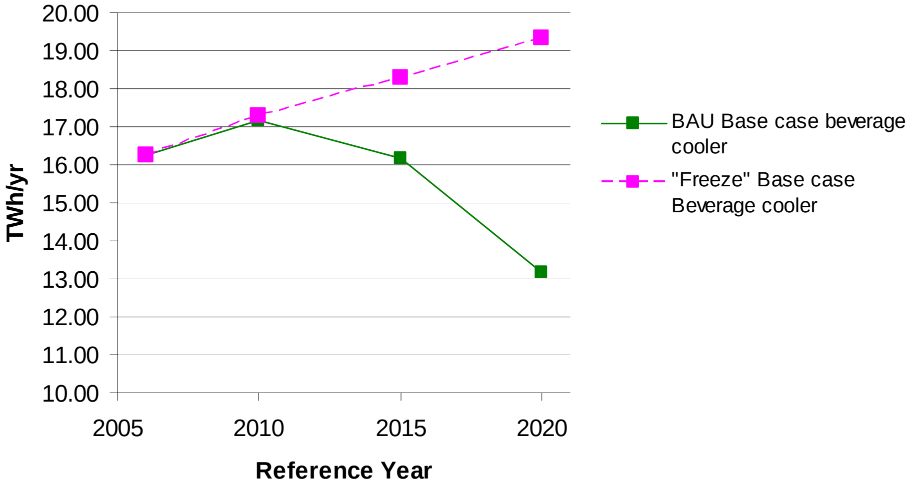
Annexe 8- 4: Base case RCV2 “BAU” scenario



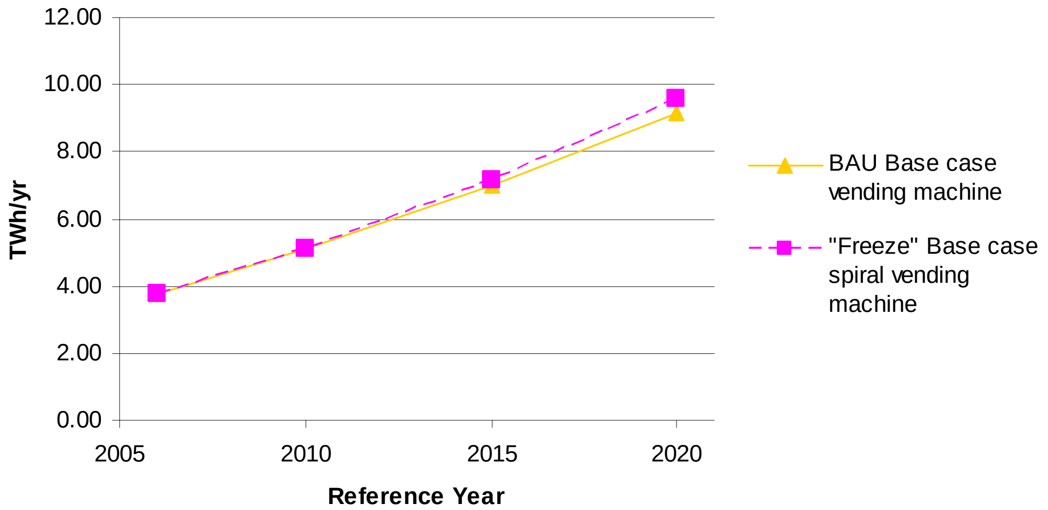
Annexe 8- 5: Base case RHF4 “BAU” scenario



Annexe 8- 6: Base case beverage cooler "BAU" scenario



Annexe 8- 7: Base case spiral vending machine "BAU" scenario



Annexe 8- 8: Inputs for the EcoReport – BAT "slow"/LLCC scenario

Year	Parameter	Base case RCV2 with door	Base case RCV2 without door (with night curtain)	Base case RCV2 without night curtain	Base case RHF4 with door	Base case RHF4 without door (with night curtain)	Base case RHF4 without night curtain	Base case beverage cooler	Base case ice cream freezer	Base case vending machine
2006	Average daily TEC (kWh/d)	77.31	77.31	77.31	81.34	81.34	81.34	7.04	4.50	7.47
	Average product price (Euros)	3,440.00	3,440.00	3,440.00	3,970.00	3,970.00	3,970.00	830.00	800.00	3,500.00
	Average installation cost (Euros)	344.00	344.00	344.00	397.00	397.00	397.00	0.00	0.00	0.00
	Average repair and maintenance cost (Euros)	2,139.00	2,139.00	2,139.00	2,279.56	2,279.56	2,279.56	225.00	164.00	400.00
2010	Average daily TEC (kWh/d)	76.34	76.62	76.98	80.55	80.85	81.14	6.96	4.48	7.40
	Average product price (Euros)	3,483.22	3,451.89	3,447.44	4,029.78	3,988.67	3,979.78	835.18	802.68	3,505.67
	Average installation cost (Euros)	348.32	345.19	344.74	402.98	398.87	397.98	0.00	0.00	0.00
	Average repair and maintenance cost (Euros)	2,141.58	2,123.34	2,131.61	2,288.13	2,269.35	2,275.56	223.52	163.72	398.58
2015	Average daily TEC (kWh/d)	67.48	70.35	73.96	73.44	76.42	79.33	5.43	4.08	6.76
	Average product price (Euros)	3,873.79	3,559.32	3,514.71	4,569.95	4,157.34	4,068.13	932.52	853.02	3,559.58

	Average installation cost (Euros)	387.38	355.93	351.47	456.99	415.73	406.81	0.00	0.00	0.00
	Average repair and maintenance cost (Euros)	2,164.88	1,981.87	2,064.80	2,365.56	2,177.14	2,239.37	195.62	158.43	385.07
2020	Average daily TEC (kWh/d)	49.54	57.65	67.85	59.03	67.45	75.65	3.75	3.65	6.09
	Average product price (Euros)	4,665.02	3,776.96	3,650.99	5,664.24	4,499.06	4,247.12	1,039.70	908.45	3,616.70
	Average installation cost (Euros)	466.50	377.70	365.10	566.42	449.91	424.71	0.00	0.00	0.00
	Average repair and maintenance (Euros)	2,212.07	1,695.28	1,929.45	2,522.42	1,990.32	2,166.07	164.90	152.60	370.75

Annexe 8- 9: Summary of the BAT "slow"/LLCC scenario

Year	Parameter	Base case RCV2 with glass door	Base case RCV2 without glass door	Base case RCV2 without night curtain	Base case RHF4 with glass door	Base case RHF4 without glass door	Base case RHF4 without night curtain	Base case Beverage cooler	Base case ice cream freezer	Base case spiral vending machine
2006	Sales (million units/yr)	0.1464	0.1464	0.1464	0.0192	0.0192	0.0192	0.7900	0.3386	0.1260
	Total average daily electricity consumption **per product** (kWh/d)	77.31	77.31	77.31	81.34	81.34	81.34	7.04	4.50	7.465
	Annual electricity consumption during use phase (GWh/yr)	37,044.92	37,044.92	37,044.92	5,111.28	5,111.28	5,111.28	16,245.69	4,448.82	3,756.80
	GWP 100 (million ton CO_2 eq.) over lifetime	19.20	19.20	19.20	2.65	2.65	2.65	8.65	2.68	2.45
	Total annual consumer expenditure over lifetime (million euros)	4,818.66	4,818.66	4,818.66	672.83	672.83	672.83	2,709.83	840.22	979.25
2010	Sales (million units/yr)	0.1617	0.1617	0.1617	0.0212	0.0212	0.0212	0.8400	0.3600	0.1467
	Total average daily electricity consumption **per product** (kWh/d)	76.34	76.62	76.98	80.55	80.85	81.14	6.96	4.48	7.40

	Annual electricity consumption during use phase (GWh)	40,535.44	40,687.33	40,878.42	5,609.86	5,630.56	5,650.70	17,074.75	4,708.33	6,135.51
	GWP 100 (million ton CO_2 eq.) over lifetime	21.01	21.09	21.19	2.91	2.92	2.93	9.10	2.70	3.82
	Total annual consumer expenditure over lifetime (million euros)	5,290.69	5,298.37	5,319.31	741.05	741.91	743.98	2,861.44	891.72	1,375.44
2015	Sales (million units)	0.1817	0.1817	0.1817	0.0238	0.0238	0.0238	0.8900	0.3814	0.1776
	Total average daily electricity consumption **per product** (kWh/d)	67.48	70.35	73.96	73.44	76.42	79.33	5.43	4.08	6.76
	Annual electricity consumption during use phase (GWh)	40,281.63	41,995.26	44,151.11	5,749.40	5,982.96	6,210.22	14,124.34	4,549.05	6,471.48
	GWP 100 (million ton CO_2 eq.) over lifetime	20.96	21.82	22.91	2.99	3.11	3.22	7.64	2.64	4.91
	Total annual consumer expenditure over lifetime (million euros)	5,465.78	5,552.51	5,788.69	789.64	799.25	822.65	2,635.40	911.21	1,752.85
2020	Sales (million units/yr)	0.2018	0.2018	0.2018	0.0265	0.0265	0.0265	0.9400	0.4029	0.2151

	Total average daily electricity consumption **per product** (kWh/d)	49.54	57.65	67.85	59.03	67.45	75.65	3.75	3.65	6.09
	Annual electricity consumption during use phase (GWh)	32,838.15	38,211.74	44,972.06	51,31.47	5,863.88	6,576.51	10,304.81	4,293.46	7,826.66
	GWP 100 (million ton CO_2 eq.) over lifetime	17.28	19.99	23.39	2.69	3.06	3.42	5.75	2.53	6.05
	Total annual consumer expenditure over lifetime (million euros)	4,985.64	5,257.60	5,998.22	779.16	809.31	882.67	2,322.53	923.35	2,167.85

Annexe 8- 10: Inputs for the EcoReport – BAT /LLCC scenario

Year	Parameter	Base case RCV2 with door	Base case RCV2 without door (with night curtain)	Base case RCV2 without night curtain	Base case RHF4 with door	Base case RHF4 without door (with night curtain)	Base case RHF4 without night curtain	Base case beverage cooler	Base case ice cream freezer	Base case vending machine
2006	Average daily TEC (kWh/d)	77.31	77.31	77.31	81.34	81.34	81.34	7.04	4.50	7.47
	Average product price (Euros)	3,440.00	3,440.00	3,440.00	3,970.00	3,970.00	3,970.00	830.00	800.00	3,500.00
	Average installation cost (Euros)	344.00	344.00	344.00	397.00	397.00	397.00	0.00	0.00	0.00
	Average repair and maintenance cost (Euros)	2,139.00	2,139.00	2,139.00	2,279.56	2,279.56	2,279.56	225.00	164.00	400.00
2010	Average daily TEC (kWh/d)	76.34	76.62	76.98	80.55	80.85	81.14	6.96	4.48	7.40
	Average product price (Euros)	3,483.22	3,451.89	3,447.44	4,029.78	3,988.67	3,979.78	835.18	802.68	3,505.67
	Average installation cost (Euros)	348.32	345.19	344.74	402.98	398.87	397.98	0.00	0.00	0.00
	Average repair and maintenance cost (Euros)	2,141.58	2,123.34	2,131.61	2,288.13	2,269.35	2,275.56	223.52	163.72	398.58
2015	Average daily TEC (kWh/d)	60.35	65.30	71.53	67.71	72.86	77.86	5.43	4.08	6.76
	Average product price (Euros)	4,188.41	3,645.86	3,568.90	5,005.08	4,293.22	4,139.31	932.52	853.02	3,559.58

	Average installation cost (Euros)	418.84	364.59	356.89	500.51	429.32	413.93	0.00	0.00	0.00
	Average repair and maintenance cost (Euros)	2,183.64	1,867.91	2,010.98	2,427.93	2,102.85	2,210.22	195.62	158.43	385.07
2020	Average daily TEC (kWh/d)	38.51	49.84	64.09	50.17	61.94	73.39	3.75	3.65	6.09
	Average product price (Euros)	5,151.57	3,910.79	3,734.79	6,337.16	4,709.19	4,357.19	1,039.70	908.45	3,616.70
	Average installation cost (Euros)	515.16	391.08	373.48	633.72	470.92	435.72	0.00	0.00	0.00
	Average repair and maintenance (Euros)	2,241.09	1,519.04	1,846.23	2,618.88	1,875.43	2,120.99	164.90	152.60	370.75

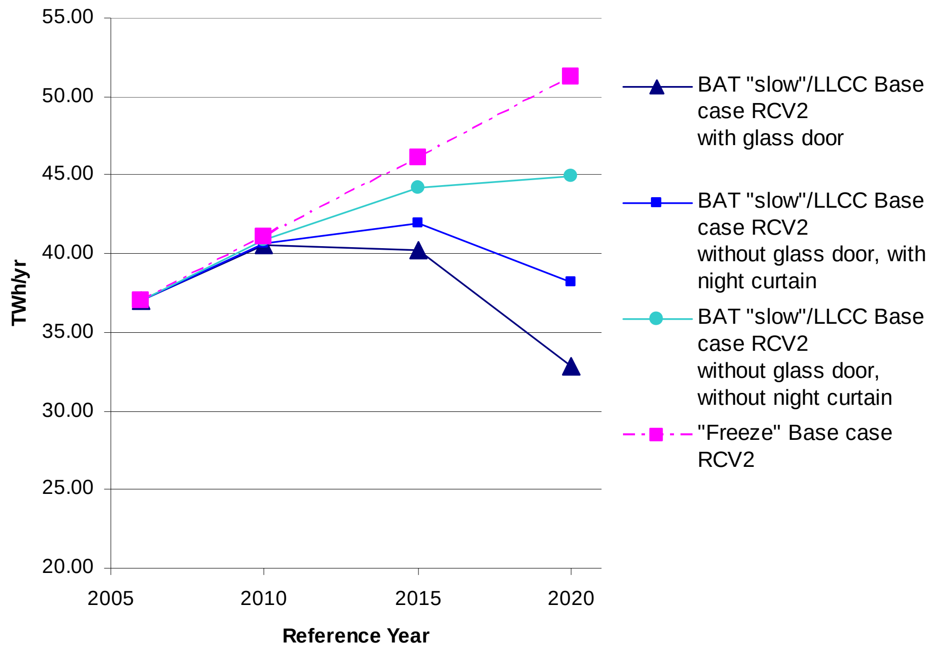
Annexe 8- 11: Summary of the BAT/LLCC scenario

Year	Parameter	Base case RCV2 with glass door	Base case RCV2 without glass door	Base case RCV2 without night curtain	Base case RHF4 with glass door	Base case RHF4 without glass door	Base case RHF4 without night curtain	Base case Beverage cooler	Base case ice cream freezer	Base case spiral vending machine
2006	Sales (million units/yr)	0.1464	0.1464	0.1464	0.0192	0.0192	0.0192	0.7900	0.3386	0.1260
	Total average daily electricity consumption **per product** (kWh/d)	77.31	77.31	77.31	81.34	81.34	81.34	7.04	4.50	7.465
	Annual electricity consumption during use phase (GWh/yr)	37,044.92	37,044.92	37,044.92	5,111.28	5,111.28	5,111.28	16,245.69	4,448.82	3,756.80
	GWP 100 (million ton CO_2 eq.) over lifetime	19.20	19.20	19.20	2.65	2.65	2.65	8.65	2.68	2.45
	Total annual consumer expenditure over lifetime (million euros)	4,818.66	4,818.66	4,818.66	672.83	672.83	672.83	2,709.83	840.22	979.25
2010	Sales (million units/yr)	0.1617	0.1617	0.1617	0.0212	0.0212	0.0212	0.8400	0.3600	0.1467
	Total average daily electricity consumption **per product** (kWh/d)	76.34	76.62	76.98	80.55	80.85	81.14	6.96	4.48	7.40

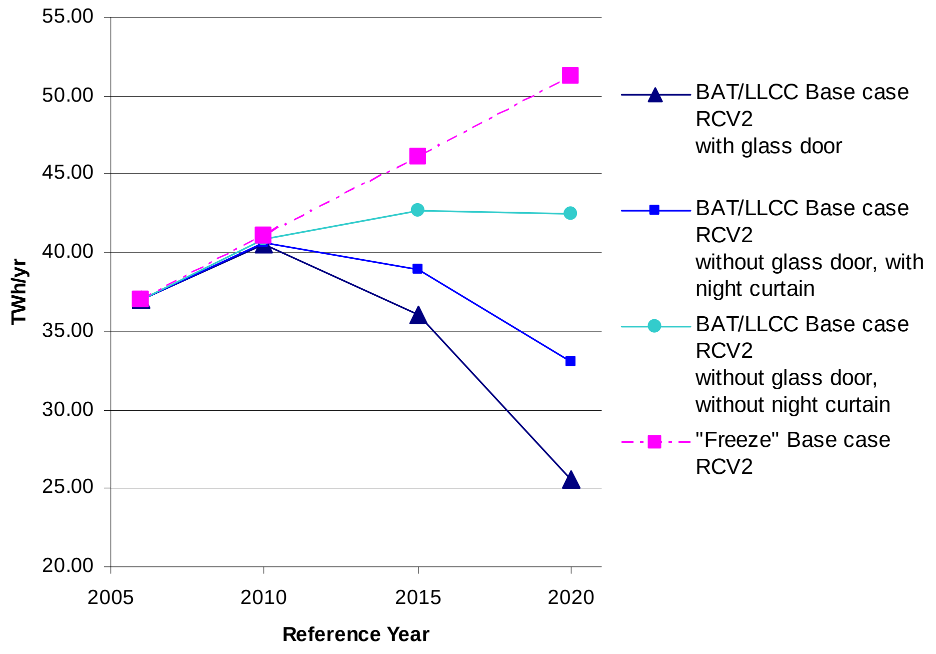
	Annual electricity consumption during use phase (GWh)	40,535.44	40,687.33	40,878.42	5,609.86	5,630.56	5,650.70	17,074.75	4,708.33	6,135.51
	GWP 100 (million ton CO_2 eq.) over lifetime	21.01	21.09	21.19	2.91	2.92	2.93	9.10	2.70	3.82
	Total annual consumer expenditure over lifetime (million euros)	5,290.69	5,298.37	5,319.31	741.05	741.91	743.98	2,861.44	891.72	1,375.44
2015	Sales (million units)	0.1817	0.1817	0.1817	0.0238	0.0238	0.0238	0.8900	0.3814	0.1776
	Total average daily electricity consumption **per product** (kWh/d)	60.35	65.30	71.53	67.71	72.86	77.86	5.43	4.08	6.76
	Annual electricity consumption during use phase (GWh)	36,023.41	38,979.91	42,699.38	5,300.79	5,703.76	6,095.84	14,124.34	4,549.05	6,471.48
	GWP 100 (million ton CO_2 eq.) over lifetime	18.81	20.30	22.18	2.77	2.97	3.17	7.64	2.64	4.91
	Total annual consumer expenditure over lifetime (million euros)	5,077.73	5,227.36	5,634.84	754.66	771.25	811.61	2,635.40	911.21	1,752.85
2020	Sales (million units/yr)	0.2018	0.2018	0.2018	0.0265	0.0265	0.0265	0.9400	0.4029	0.2151

	Total average daily electricity consumption **per product** (kWh/d)	38.51	49.84	64.09	50.17	61.94	73.39	3.75	3.65	6.09
	Annual electricity consumption during use phase (GWh)	25,525.82	33,033.70	42,479.11	4,361.11	5,384.42	6,380.09	10,304.81	4,293.46	7,826.66
	GWP 100 (million ton CO_2 eq.) over lifetime	13.59	17.38	22.14	2.30	2.82	3.32	5.75	2.53	6.05
	Total annual consumer expenditure over lifetime (million euros)	4,319.26	4,699.25	5,734.03	719.11	761.23	863.72	2,322.53	923.35	2,167.85

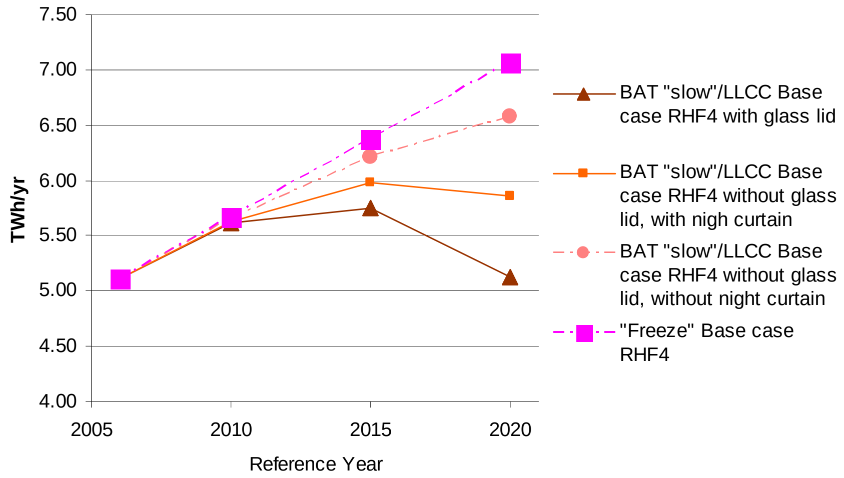
Annexe 8- 12: Base case RCV2 BAT "slow"/LLCC scenario



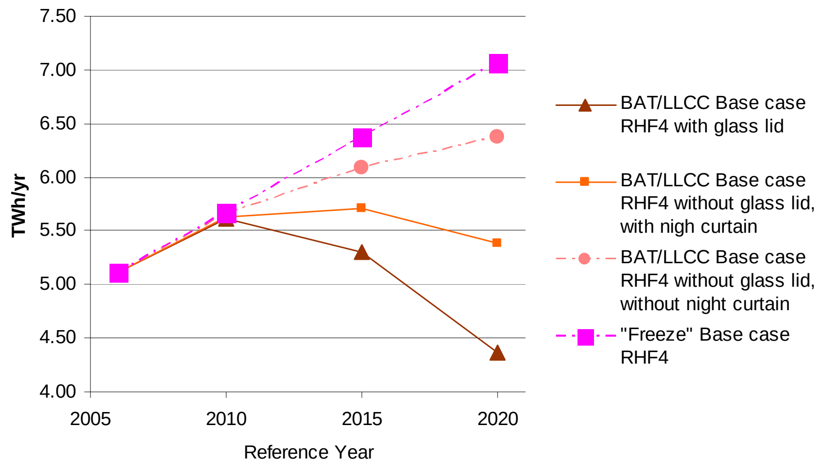
Annexe 8- 13: Base case RCV2 BAT /LLCC scenario



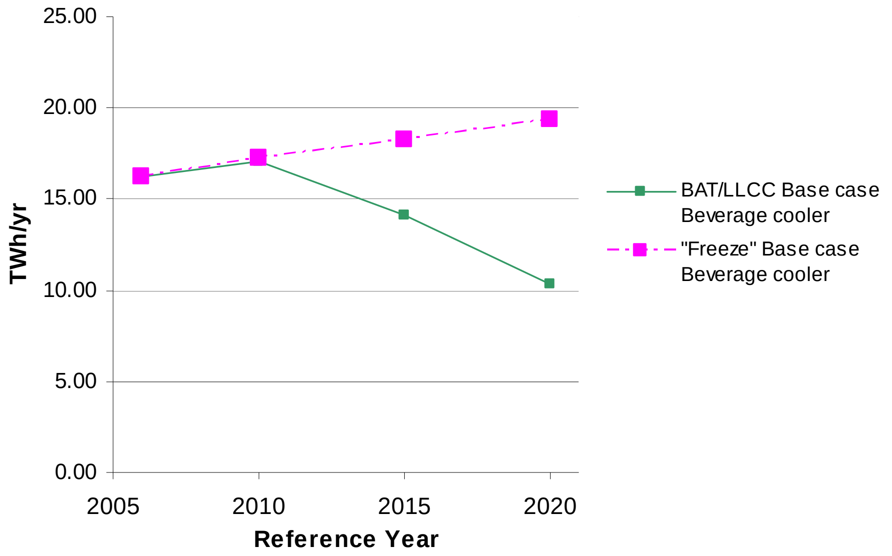
Annexe 8- 14: Base case RHF4 “BAT “slow”/LLCC” scenario



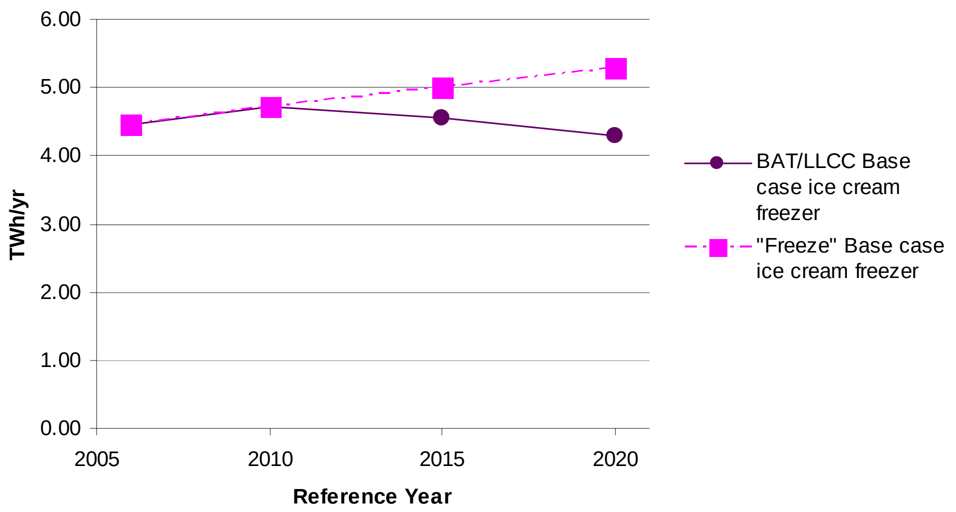
Annexe 8- 15: Base case RHF4 “BAT/LLCC” scenario



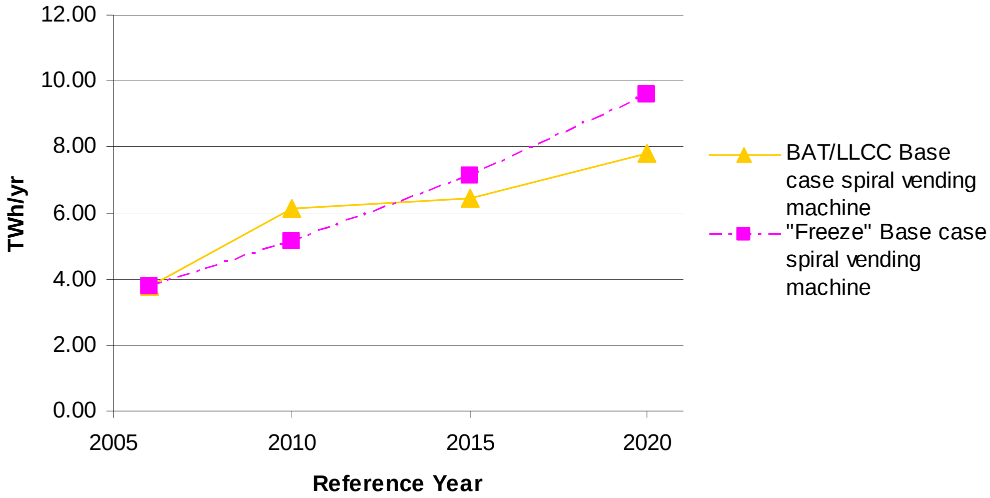
Annexe 8- 16: Base case beverage cooler "BAT "slow"/LLCC" and "BAT/LLCC "scenario



Annexe 8- 17: Base case ice cream freezer "BAT "slow"/LLCC" and "BAT/LLCC "scenario



Annexe 8- 18: Base case Spiral vending machine “BAT “slow”/LLCC” and “BAT/LLCC “scenario



REGISTERED STAKEHOLDERS

Below a list of lot 12 registered stakeholders (companies, associations, institutes, etc.) is provided. Please note that all of them did not participate actively in the study, but they were regularly informed about the study and encouraged to contribute, comment and provide feedback.

- **EuP INDUSTRY (COMPANIES)**

  ACC-Spain
  AHT Cooling Systems
  Arneg
  Bianchi Vending Group
  Caravell
  Carrier/Linde
  Copeland
  CSC Worldwide
  Daikin Europe
  Danfoss
  Dometic
  Dow Italia S.r.l.
  Ebm-papst GmbH & Co.KG
  Elastogran GmbH
  EPTA Group
  Fas International
  Frigoglass Group
  General Electric
  Helkama Forste Oy
  Honeywell
  Ingersoll Rand
  Johnson Controls Inc.
  Jordao Cooling Systems
  LGE
  Linde KT Italiana
  Mondial Elite
  Norpe
  Perchards
  Samsung Electronics
  Sanyo Fisher
  SPG
  Steptoe & Johnson LLP
  Taylor
  Tecumseh
  True Manufacturing
  United Technologies/Carrier
  Wellington Drive Technologies Ltd
  Williams Refrigeration
  Zanotti

- **EuP INDUSTRY (ASSOCIATIONS)**
  ARI (Air-conditioning and Refrigeration Institute, USA)
  ACRIB (Air-Conditioning and Refrigeration Industry Board, UK)
  AeA Europe
  AFCE (Alliance Froid Climatisation Environnement)
  AICVF (Association des Ingénieurs en Climatique, Ventilation et Froid, France)
  ASERCOM (Association of European Refrigeration Compressor and Controls Manufacturers)
  ASHRAE (American Society of Heating, Refrigerating and Air conditioning Engineers, USA)
  AssoFoodtech Anima
  CESA (Catering Equipment Suppliers Association)
  EPEE - Secretariat (European Partnership for Energy and Environment)
  EVA (European Vending Association)
  Eurovent - Cecomaf
  FETA (Federation of Environmental Trade Associations)
  HKI
  Industrieverband Haus-, Heiz- und Küchentechnik e.V.
  KEA
  Perifem
  PlasticsEurope
  REHVA (Federation of European Heating and Air Conditioning Associations)
  SKLL (Finnish Refrigeration Enterprises Association)
  SYNDIGEL
  Technology Industries of Finland
  Teknikföretagen (The Assocation of Swedish Engineering Industries)
  TNO Environment, Energy and Process Innovation
  UBF - ACA (l'Union Royale Belge du Froid et du Conditionnement de l'Air)
  UNICLIMA (French Association of Air-Handling, Air-Conditioning and Refrigeration Equipment)
  VDMA

- **MATERIAL PRODUCERS AND ASSOCIATIONS**
  Hydro
  Elastogran GmbH
  Eurofer
  Elastogran / BASF
  Bayer MaterialScience
  DuPont de Nemours Int'l. S.A.

- **DISTRIBUTION COMPANIES AND ASSOCIATIONS**
  Casino
  EHI Retail Institute
  FCD (Fédération des Entreprises du Commerce et de la Distribution, France)

- **ENVIRONMENTAL NGOs**
  Environment and Development Foundation

- **CONSUMER NGOs**
  ANEC

- **OTHER BUSINESS ASSOCIATIONS**
  FGK

- **INSTITUTES/CONSULTANTS**
  AEA
  AIRAH (Australian Institute of Refrigeration Air Conditioning and Heating)
  Ammonia Partnership AB
  Austrian Energy Agency
  Danish Technological Institute
  DIEM - Dept of Energy Technologies, University of Udine
  Envipro Ky
  EuP - Network Germany c/o Ökopol
  Foundation of Taiwan industry service
  Fraunhofer ISI
  Industrial Structure General Research Institute
  ISIS
  ISM Consulting
  Kreab
  Kryotec
  KTU Institute of environmental engineering
  Punchline Energy
  Re-phridge
  TWI
  Weber Shandwick Public Affairs

- **OTHER**
  Aht Cooling
  Eliwell
  Espec North America

- **MEMBER STATES REPRESENTATIVES**
  Danish Energy Authority
  German Federal Environment Agency
  Swedish Energy Agency

- **NATIONAL AND INTERNATIONAL AGENCIES**
  Dena - German Energy Agency
  Cyprus institute of energy
  IIR - IIF (International Institute of Refrigeration-Institut International du Froid)
  International Energy Agency
  KEMA
  US Department of Commerce, Office of the European Union

STAKEHOLDER COMMENTS TO TASK REPORTS

Task	Sub-section	Comment	Action
all	all	It is disappointing that the potential environmental advantages of natural refrigerants have not been documented within a report of this nature. For example, the emissions of greenhouse gases and other harmful substances during the production of HCs, CO2 and ammonia are far less than that those of HFCs. Also, these refrigerant have excellent heat and mass transfer properties, meaning that heat exchanger mass can be reduced (compared to common HFCs) for the same heat transfer capacity. Pressure drops are lower, so higher heat transfer coefficient can be achieved with no additional thermodynamic loss. Compressor efficiency is generally better thus improving overall cycle COP. Also the report should identify the political hindrances to the wider use of natural refrigerants such as those alluded to in the comments above.	No action - the report does not include the switch to natural refrigerants as an improvement option. However, some case studies are analysed in order to provide an insight on the potentialities of using such refrigerants.
all	all	For the remote refrigerated display cabinets only the equipment located in the cabinet (evaporator, refrigerant and expansion device) is included in the calculation. However, in order to compare different systems (direct, indirect, distributed, hybrid) in LCCP calculations it is essential to take the whole refrigeration system (including the piping system with the refrigerant) into account. If one looks only on the cabinet no general statements about the usability of certain refrigerants as done on page IV-47 could be given. Also the impact of the requirements of the Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases (recovery of HFC refrigerants during service and at end-of-life, standard inspections and leakage measurements for refrigeration systems) on the operating costs has not been taken into account due to the neglect of the system outside the cabinet. As a consequence, the cost analyses are wrong.	No action, as the remote unit (condenser + compressor) is not including in the scope of the study.
1	1.1	Table 1-2 Include R1270 – Propene (propylene)	Added

Task	Sub-section	Comment	Action
1		There are applicable German standards, 18872-1 “Equipment for commercial kitchens — Refrigeration technology equipment — Part 1: Refrigerators and refrigerated counters; Requirements and testing“, and 18872-3 “Equipment for commercial kitchens — Refrigeration technology equipment — Part 3: Refrigerated display cases for food distribution, Requirements and testing“, that deal with the energy consumption of commercial refrigerators in chapter 7. Please take these into consideration for further course of action.	Added to existing standards
1	1.2	The study concentrates on remote vertical cabinets (coolers), remote horizontal cabinets (freezers), plug-in bottle coolers, plug-in ice cream freezers and vending machines. We appreciate the good work done on these appliances. We think the study also should contain plug-in professional kitchen refrigerators (and freezers), since the number of these probably is bigger than e.g. vending machines.	No action - the scope of the study could not be changed at the final stage of the study
1	1.2	In Denmark there is a legislation banning the use of HFC in foam and in refrigeration system except with charges between 250 g – 10 kg: In the Danish Statutory Order no 552 on regulation of certain industrial greenhouse gases from 2002 there is a general ban on new products containing or using F-gases from 01.01.06. There are some exemptions from this general ban. For instance, the ban on HFCs will come into force for cooling equipment with HFC charges > 10 kg from 01.01.07 and the use of HFC for service purposes is exempted from the Order. Therefore alternative refrigerants are becoming standard for many uses. Bigger supermarkets are now built with CO2-refrigeration systems and also indirect systems are common.	added

Task	Sub-section	Comment	Action
1	1.5	1.5.2 The report says on page I-45 that the effect of an energy-label may be limited because aesthetic and size criteria dominate the purchasing patterns. But on page III-15 is remarked that end-users are often not aware of the difference of energy efficiency among competing products. And in Task 5 it is well shown that electricity consumption is the dominating cost except for vending machines. (...) an energy label would gain a great acceptance as it is the case in domestic refrigeration. Therefore we need standards for the measurement of energy efficiency covering the whole range of products as said in the conclusion of Task 1.	No action
2	2.2	Furthermore let me note that the yearly market input of Vending machine that could be included in the sub-categories of Lot 12, are less than 100.000 units. The half of the minimum quantity fixed at the beginning of the research.	Market data was re calculated based on assumptions from EVA.
2	2.2	The yearly market input of vending machines that could be included in the sub-categories of Lot12, are less than 100.000 units. The half of the minimum quantity fixed at the beginning of the research.	the "200,000 units" figure in the EuP Directive is indicative

Task	Sub-section	Comment	Action
3	3.4	3.4.3 “Technologies diverging from current practice take time to be introduced into a significant portion of the market. End-users are not ready to switch to natural refrigerants on remote equipment because only a few technicians know how to install and operate refrigeration systems with such “new” refrigerants.” ->This is not true anymore as shown by the RTOC Assessment Report 2006. The RTOC report generally states that for certain applications, CO2 equipment has been developed and extensively tested on the market, with an increasing number currently being installed. It takes into account the fast development and benefits of natural refrigerants. It also takes a more differentiated look on alternative refrigerants in existing systems as direct, indirect, distributed and hybrid systems. The former RTOC Assessment Report 2002 that is mentioned on page II-25 in the report point out that for certain applications CO2 equipment is under development and that the first demonstration components have reached the mar	The sentence was modified according to this comment.
4	4.4	Everything is correct, but I would have some specifications to add, in order to prove that the current average power consumption and eco-impact of Vending machines is lower (due to some new improvement made in the last period).	Comments of improvements already done in the vending machines market were taken into account.
4	4.3	Isobutane (R600a) is also in use in some appliances like bottle coolers.	No action - Task 4 only refers to the average European Product
4	4.3	Most plug-in cabinets use capillary tubes as expansion device.	Added "In case of plug in refrigerated display cabinets and vending machines, the expansion device used is a capillary tube. For remote refrigerated display cabinets, the expansion device used is an expansion valve."
4	4.3	(Nearly?) All compressors in plug-in cabinets are reciprocating compressors.	No action

Task	Sub-section	Comment	Action
4	4.3	The typical energy consumption of bottle coolers and ice cream freezers fits very well with our experiences	No action
4	4.3	The COP of hydrocarbon systems are general a little better compared to HFC-systems due to better thermodynamic process.	corrected in report
4	4.3	At low temperature reciprocating compressors are more efficient than scroll compressors, most of all for small refrigeration power, whereas at medium temperature scroll compressors are almost always more performing than reciprocating compressors.	This sentence was modified according to this comment.
4	4.3	4.3.2.5 Compressor (Page 201, chapter below Fig. 4-23) If the choice of a compressor depends on its performance, I suggest adding that it should be based on annual temperatures.	The sentence was modified according to this comment.
4	4.3	4.3.2.5 Compressor (Page 201, chapter below Fig. 4-23) Pumpdown control does not enable adapting the cooling capacity to conditions, but to aims at avoiding liquid refrigerant entering into the compressor; it is rather a safety control.	The sentence was modified according to this comment.
4	4.3	4.3.2.5 Compressor (Page 201, chapter below Fig. 4-23) Insert a section/bullet following this paragraph to describe another modulating technology called “Digital Modulation” specifically developed for scroll compressors.	A sentence was added presenting this compressor control.
4	4.3	IV-47, 4.3.2.1 “Others refrigerants, called halogen-free agents, as ammonia, propane and CO2 show lower ODP (Ozone Depletion Potential) and GWP (Global Warming Potential), compared to the other ones.” ->These refrigerants have zero ODP, not lower ODP.	The sentence was modified according to this comment.

Task	Sub-section	Comment	Action
4	4.3	IV-48, 4.3.2.1 "For instance, propane is highly flammable, and cannot be used in direct refrigeration system, and furthermore cannot circulate in a refrigerated display cabinet where products are sold to consumers. Even if these refrigerants are proposed by some manufacturers, they are still in study." ->This is not true anymore as shown by the RTOC Assessment Report 2006. The RTOC report generally states that for certain applications, CO2 equipment has been developed and extensively tested on the market, with an increasing number currently being installed. It takes into account the fast development and benefits of natural refrigerants. It also takes a more differentiated look on alternative refrigerants in existing systems as direct, indirect, distributed and hybrid systems. The former RTOC Assessment Report 2002 that is mentioned on page II-25 in the report point out that for certain applications CO2 equipment is under development and that the first demonstration components have reached the market.	The sentence was modified according to this comment.
4	4.3	4.3.4 The estimation of emission during use phase seems to be to low. The RTOC Assessment Report 2006 gives an average value of 18% just up to 30% depending of the refrigeration system. This fact has an impact on the choice of refrigerant.	No action, as the remote unit (condenser + compressor) is not including in the scope of the study.
4	4.3	IV-48, 4.3.2.1 "For instance, propane is highly flammable, and cannot be used in direct refrigeration system, and furthermore cannot circulate in a refrigerated display cabinet where products are sold to consumers. Even if these refrigerants are proposed by some manufacturers, they are still in study." ->There are many thousands of cabinets where propane is used in products that the public areas access to. Furthermore, there are no regulations, directive or even codes of practice that state this. We are not aware of where this statement comes from but it is misleading for those who may wish to include propane as a refrigerant option.	The sentence was modified according to this comment.

Task	Sub-section	Comment	Action
4	4.3	IV-81, 1st Para “Other alternatives exist to avoid the use of HFCs, such as the use of hydrocarbon or carbon dioxide. However the higher energy efficiency of HFCs can reduce the effect of the refrigeration system as a whole and offset a somewhat higher GWP” ->Both hydrocarbons and carbon dioxide refrigerants have outperformed HFCs. In the case of hydrocarbons, their properties (particularly R290 and R1270) are such that their potential efficiency will exceed all HFCs. Only HFC-152a and HFC-32 would come close to the theoretical and measured performance of R290 and R1270 due to their thermodynamic and transport properties.	Comment accepted - the end of the sentence was removed (this was kept:"Other alternatives exist to avoid the use of HFCs, such as the use of hydrocarbon or carbon dioxide. ")
4	4.4	Here the indirect refrigeration system is described and its strengths and weaknesses. Risk for low energy efficiency is listed as a weakness and in Table 4-87, p. IV-96, it is stated that they use 10-15% more energy than a baseline system. In Sweden indirect systems have been used for along time and experiences show that it can be the opposite – an indirect system can actually be more energy efficient than a DX system.	Comment accepted - "However, refrigeration experts agree that it is very difficult to compare the quality in terms of environmental impacts and energy efficiency of different refrigeration systems because no objective tool of comparison exists. In Sweden indirect systems have been used for along time and experiences show that it can be the opposite – an indirect system can actually be more energy efficient than a DX system."
4	4.4	Everything is correct, but I would have some specifications to add, in order to prove that the current average power consumption and eco-impact of Vending machines is lower (due to some new improvement made in the last period).	Telephonic conversation + past improvements done by the vending machines manufacturers were taken into account in Task 6 and Task 7
5	all	The conclusions in this chapter fit very well with earlier analyses done for a bottle cooler, an ice cream cabinet and for remote refrigeration system in a supermarket. So we do fully agree with the conclusions.	No action
5	5.1	Page V-8 No data about the loss of refrigerant at the end-of-life are presented. For such data the whole system must be assessed and not only the cabinets. This is also important for the comparison of refrigerants.	No action, as the remote unit (condenser + compressor) is not including in the scope of the study.
5	5.4	Page V-89 It is common practice, e.g. within the emission reporting scheme according to the Kyoto Protocol, to report emissions from production, use and disposal. In this task emissions of refrigerants from production (filling of the refrigeration system) and disposal are neglected.	No action, as the remote unit (condenser + compressor) is not including in the scope of the study.

Task	Sub-section	Comment	Action
6	6.1	VI-2, item 6.1. ->There is no restriction in plug-in appliances; there is only a restriction on the location of higher charge systems.	Corrected in the report
6	6.1	What is the definition of a high efficiency compressor in this context, what are the technically relevant features?	Addition of the following sentence: "For a typical spiral vending machine, the reduction of about 27 % of the volume of the compressor allowed a reduction of 10 % of the electricity consumption."
6	6.1	One of the reasons to relative high energy consumption for beverage coolers is the fact that the coolers are built to fulfil the requirements for pull-down test of a huge number of warm soft drink cans in a short time, due to specific company standards. This results in huge refrigeration systems with a big compressor and large fans. E.g. following the standard for one specific company, a typical one door cooler must have the capacity to cool more than 400 soft drink cans from 32 C to 3,3 C within less than 19 hours. If the major soft drink companies would reduce their company standards on this specific point, it would result in better and more efficient coolers that under normal conditions would have less energy consumption.	No action.
6	6.2	6.2.1.2 Compressor modulation (Page VI-8 last chapter) Comment on VSD compressor efficiency is valid for frequency inverter control with AC motors. If this is used as a reference, Figure 6-3 and Table 6-7 are not correct since both are showing identical power at 100 % load. With ECM technology this kind of comparison will look different since higher motor efficiencies can be reached.	Figure and Table deleted.
6	6.2	In fact, in the 6.2.1.1 paragraph (page 12), you speak about the COP compressor and I don't understand the following sentence: "This objective can be achieved by reducing ....of the reciprocating compressor". Could you please give me more details about that.	Addition of a sentence explaining that the displacement reduction aims at adapt the size of the compressor with the required cooling capacity.
6	6.2	6.2.1.1 High efficiency Compressor I suggest substituting the sentence "This objective…reciprocating compressor" by "This objective can be achieved by reducing suction and discharge pressure losses, mechanical losses (frictions), and electrical losses (motor".	The sentence was modified according to this comment.

Task	Sub-section	Comment	Action
6	6.2	6.2.1.2 Compressor Modulation I suggest substituting the term "trim" by "lag" (coming from lead lag running).	The sentence was modified according to this comment.
6	6.2	The main reason for VIP-panels not to be in use is the price and concerns of having reliability in the longer term.	Comment taken into account.
6	6.2	It is our experience that cyclopentane blown foam performs better than foam blown by HFC-134a.	No action.
6	6.2	Some more information about which assumptions that have been made when estimating the different saving potentials could be appropriate here. E.g. which condensing/evaporation/superheat temperatures have been assumed when estimating the saving potential for an electronic expansion valve to 19.1% etc?	A Questionnaire (Q4) was sent to stakeholders to verify all assumptions related to the improvement options and Task 6 and 7 were updated accordingly
6	6.2	The difference between the evaporation temperature and condensing temperature can be reduced not only by increasing the heat transfer area, but also by improving the heat transfer coefficients. The overall UA-value can be improved, not only the area.	Already mentioned in the report.
6	6.2	Some of the mentioned components are in a very early stage of development and their potential is unclear, e.g. BXV valve.	The BXV valve was moved in the BNAT section.
6	6.2	The energy saving potential of most of the presented components is based on their ability to adapt to the actual ambient condition following seasonal and daily variations. Nominal tests, following available standards, are performed at one fixed environment. In a standard test the performance values of the improved cabinet will therefore not show any savings.	Comment accepted - Task 6 was revised
6	6.2	Hot gas defrost: There is no standardized procedure defining how to determine the energy consumption of a cabinet with hot gas defrost. A standard test can just be conducted with electric defrost heaters. Therefore the improvement potential of hot gas defrost cannot be shown in a standard test.	Suppression of the section on hot gas defrost as it was not identified as an improvement option and as it was already discussed in Task 3.

Task	Sub-section	Comment	Action
6	6.2	The liquid suction heat exchanger is more a safety device than a means to save energy. The liquid suction heat exchanger is installed to ensure that the refrigerant leaving the cabinet is superheated sufficiently and will not cause any damage to the plant. This is already today a standard part of our frozen food cabinets and was therefore already included in our base case island. The energy saving is marginal.	The energy savings through the use of liquid suction heat exchangers was re-evaluated through a questionnaire (Q4) sent to all stakeholders
6	6.2	6.2.1.2, 2nd paragraph "… clearances are specific…": Clarify the meaning of this sentence.	This sentence was deleted.
6	6.2	6.2.1.2 2nd paragraph Variable speed compressors have an appropriate lubrication system.	This sentence was deleted.
6	6.2	6.2.1.2 "constant-speed compressors generally have a higher capacity". This is not true !	This sentence was deleted.
6	6.2	6.2.1.2 "VSD compressors are optimised when working under part load conditions." VSD compressors are not optimised at part load, but allow energy savings.	This sentence was modified according to this comment.
6	6.2	6.2.1.3 I propose the following paragraph which is more appropriate: "Asercom has a performance certification program which has been established to assist manufacturers of commercial refrigeration and air conditioning systems. Reliable performance data are presented in a comparable manner to optimise product selection, based on the European Standard EN12900, EN13771, and a common refrigerant data base."	The section was modified according to this comment.
6	6.2	Fig. 6-3 and Table 6-7 Figure is misleading as it does not account for the difference in full load between fixed and variable speed.	Figure deleted.

Task	Sub-section	Comment	Action
6	6.2	Bubble expansion valve is disputed in the controls industry and lacks experimental verification as far as known to us. Please provide the reference where this technology is described with sufficient technical verification.	The BXV valve was moved in the BNAT section and addition of the website of the project.
6	6.2.1.1	In fact, in the 6.2.1.1 paragraph (page 12), you speak about the COP compressor and I don't understand the following sentence: *"This objective can be achieved by reducing ....of the reciprocating compressor".* Could you please give me more details about that?	We add a sentence explaining that the displacement reduction aims at adapt the size of the compressor with the required cooling capacity.
6	6.2	As demonstrated in Task 6 and Task 7 we recommend the use of doors for open vertical cases or glass lids for open horizontal display cases as an easy and effective way to reduce electricity consumption. These measures have already been introduced in many supermarkets.	No action.
6	6.2	ECM Fan Motors: We disagree with the statement "DC motors are significantly more energy efficient than AC motors…", because it is not true in the general sense. It only applies to this specific comparison of a single phase shaded pole motor to DC motors. It must not be generalized to apply to the multitude of AC motor technologies on the market.	Modification of the sentence according to this comment.
6	6.5	When comparing the COP of different refrigerants in certain applications (see page VI-32, Figure 6-19) it is of fundamental importance to also explain the assumptions and conditions the calculations are based on. Otherwise the comparison is meaningless. As demonstrated in some studies CO2 and HC have a better COP than HFC-134a.	Comment accepted - assumptions were clarified where available
6	6.5	VI-37, Item 6.5.3.1 "In domestic heat pumps and air conditioners R290 has been used in Germany for some years, however, with different levels of success." -> It is our understanding that the consensus from heat pump manufacturers in Germany, Switzerland, Austria and Scandinavia is of a high level of success. The requirements of the Pressure Equipment Directive have apparently made it less competitive for the manufacturers of medium sized hermetic compressors available for use in this field. From a performance point of view there is no reason why R290 should not be used for heat pumps.	Suppression of the sentence.

Task	Sub-section	Comment	Action
6	6.5	VI-38, Item 6.5.3.1 “However, in the commercial sector, only small capacity plug in appliances would be able to use HCs because of the 150 g limitation in the quantity of hydrocarbon authorised for safety issues (ISO 5149:1993 (2004)).” -> The initial statement is not correct: ISO 5149: 1993 states that HCs should not be used under any circumstances, except for <1.5 kg in laboratories. The current EN 378: 2000 and revised EN 378: 2007 (due next month) permits up to 1.5 kg in public spaces and 2.5 kg in private spaces. The only limitation above 150 g is consideration of location or room size. “Indeed commercial applications typically have a more important volume requiring a higher cooling capacity and a refrigerant charge around 200~250 g. Presently, the use of HCs in commercial applications is very limited.” -> There are many tens of thousands of commercial refrigerant units containing HC refrigerants with charges ranging from less than 150 g to over 1 kg. Unilever’s ice cream business alone has 200,000 ice c	Use of propane in ice cream freezers is therefore developed with this case study in section 6.5.3.1
6	6.5	Table 6-13, -> These do not really represent the “main advantages and disadvantages of Propane for its use in commercial refrigeration equipments.” Also, the context for the table is unclear – environmental, mechanical, thermodynamic, safety, economic? Particularly, the comment on 150 g is incorrect, it is not only used in indirect systems in supermarkets as many use integral units, and the installation cost will generally be a little higher, but it largely depends upon the type and size of equipment, and the selection of components.	Modification of the Table according to this comment.
6	6.5	The choice of the refrigerant alone (like Propane) can improve the energy efficiency of selected target applications by 10-20% according to my knowledge. In general this is also confirmed in your document. The industry need to drive the extension of the 150gr restriction on Propane in order to use this opportunity. I do not feel that things are moving in this respect, but I am convinced that the final stakeholder meeting is a good forum to take this discussion again if not already done?!!	No action.

Task	Sub-section	Comment	Action
6	6.5	Heat exchanger with flat tubes could lead to improved heat transfer also in indirectly cooled display cabinets. In this section you could state more precisely in what applications the different heat exchanger types are used today and in which applications they could be used. E.g. brazed plate heat exchangers are used in liquid coolers in indirect cooling systems today. Could they be used in other applications?	Further applications are added in the report.
6	6.5	6.5.1 Carbon Dioxide (R744) CO2 (Page VI-31, last sentence) We disagree that CO2 compressors do have a higher volumetric efficiency than for example HFC compressors. Besides of pressure ratio which is lower with CO2 other properties are to be considered as well. Besides of this different compressor technologies have different characteristics with regard to pressure ratio. The same applies also to isentropic efficiencies where often the lower pressure ratio of CO2 is used as an argument for higher values which is not necessarily true.	Modification of the sentence.
6	6.5	Carbon Dioxide: In this paragraph you are mixing volumetric efficiency and volumetric cooling capacity. Volumetric efficiency is a feature of the compressor and relates the actual pumped volume to the theoretically displaced volume, mainly impacted by the pressure ratio at which the compressor operates. Volumetric cooling capacity is a feature of the refrigerant and relates cooling capacity to the pumped refrigerant volume. The volumetric efficiency of CO2 compressors is slightly higher than with HFC compressors due to the generally smaller pressure ratio. The volumetric cooling capacity is drastically different as it relates to the refrigerant properties and the figure of 80-90% in relation to R134a for required displacement is correct. This is by no means an indicator for energy consumption but only relates to the size of the pressure generating elements, however, not to the size of the motor. Reducing compressor size is in general terms detrimental to compressor energy consumption rather than beneficial.	Modification of the sentence.

Task	Sub-section	Comment	Action
6	6.5	6.5.1 (Page VI-36, "Piping") Second sentence in first chapter (Typically, the copper pipes ....) -- don't understand the 30 vs. 70 mm.	No action.
6	6.5	6.5.2 Ammonia (Page VI-37) Second chapter, last line: "half-hermetic" please change to "semi-hermetic". Last sentence of this paragraph -- this should read: Therefore, Ammonia can only be used with secondary refrigerant......	Modification of the sentence according to this comment.
6	6.5	6.5.2 Ammonia Ammonia cannot be used as refrigerant in air-conditionning systems due to its toxicity.	This sentence was modified according to this comment.
6	6.5	6.5.3.1 Propane "3-5 m/s": this is not a generally valid value. Lower density of HCs does normally not create a segregation problem with typical lubricants due to its full miscibility. This is different with NH3 since usual lubricants are not soluble/miscible.	Modification of the sentences according to this comment.
6	6.6	In Sweden there are already a number of supermarkets with direct expansion-CO2-systems in operation, working with a transcritical cycle during some periods of the year.	Already mentioned in the report.
6	6.6	The used cooling technology has a big influence on the applications energy efficiency. As you are stating thermoelectric and absorption technology are far behind the compressor technology. Why do we not establish regulations/labellings in those industries (hotels; camping; ...) where these technologies are dominating today, even though alternative technologies are already available with a much shorter pay back time than calculated in some of the focus applications in your study.	No action.
6	6.6	Your figure quoted from Coca Cola does not stand up to scientific verification. CO2 can only at best achieve the same efficiency as HFC systems in the cases considered. Please pay attention to separate the effects of refrigerant only and other system optimization applicable to both CO2 and incumbent refrigerants.	No action

Task	Sub-section	Comment	Action
6	6.6	Strictly speaking referred standard ISO 5149 for safety issues of refrigerants, and specially limiting charge to 150 g of flammable refrigerants is not correct. Standard ISO 5149 has no legal status in EU, hence it should not be referred here. Instead of it, standard EN378-1…-4:2000 should be referred as it forms "sound engineering practice" of refrigerating systems and part 2 is a "harmonised standard". There is a new set of EN 378 standards (prEN 378-1…-4:2003 or newer) under approval procedure in CEN. These standards will be so called "harmonised standards" after being published in "EU Official Journal", and because they will be given under "New approach" - directive 97/32/EC PED (Pressure Equipment directive). Now looking at normative tables of the said prEN-standards ammonia does not have any more restriction of max charge of 150 g (because it is in safety class B2), but propane and butane still do have it (safety class A3). Table 6-14 and respective texts should be corrected.	Comment accepted
6	6.5	This is not correct. Propane (R290) is widely used in many plug-in refrigerators and freezers in the EU. Most important is the Unilever implementation of R290 in ice cream freezers, where R290 is now standard in many countries. Nearly 200.000 ice cream freezers have now been installed by Unilever – mostly inside EU. The freezers are more energy efficient compared to similar freezers with HFC-refrigerants. In Scandinavia R290 is widely used in plug-in professional kitchen refrigerators and freezers. Gram Commercial has this as standard in Denmark, Sweden, Norway, Holland and Germany.	Use of propane in ice cream freezers is therefore developed with this case study in section 6.5.3.1
6	6.5	6.5.4 Comparative table For benefits of CO_2, I will change "Very low cost" by "Very low direct cost".	This sentence was modified according to this comment.
6	6.6	This table is misleading as it does not take into account the aspects of required development effort to bring a reliable product to the market and the associated investment required. I suggest adding an assessment for new technologies of time & investment until commercialization.	Addition of a sentence explaining that time and investment related to R&D were not assessed when comparing alternative refrigeration technologies.

Task	Sub-section	Comment	Action
6	6.6	Regarding the "Not in Kind" technologies, we generally go along with your assessment. There is divergence in the assessment of Magnetic Refrigeration where it states that this could lead to 50% reduction in energy consumption. This is strongly exaggerated since reducing the energy consumption of today's systems for the same output would make them more than 100% efficient. Moreover, all claims to the magnetic refrigeration efficiency have been derived from models and no public domain information points to practical results wherein the efficiency achieved was anywhere close to vapour compression level. We agree with the assessment on Absorption. It is capital intensive, bulky, low efficiency, has potential for leakage of unfriendly chemicals, but it can be acceptable where there is "free" low-grade energy waste available. We also agree with thermoacoustics. It attempts to remove some of the vapour compression loss, but replace them by other that have not proven to be less in magnitude. Some of those are in	Modification of the statement related to the magnetic refrigeration. The term "50% reduction" was substituted by "significant reduction".
6 and 7		I cannot follow the conclusion that the high efficient compressors and/or Variable capacity solutions are not applicable for Open Chilled Multi decks and especially not for Open Frozen Island Cabinets. I do not see a reasonable explanation for that??? Do I miss some information here???	No action: In case of remote refrigerated cabinets, the refrigeration system which includes the compressor is not included in the scope of the study (see tacks1) Therefore, options to improve the compressors of refrigeration systems for remote cabinets are not covered by the Lot 12 study
6 and 7		The calculated payback time is heavily influenced by the cost increase. As shown in the table VI-28 the additional costs are much higher than the cost increase on a component level. The price policy of the OEMs is determining the move towards energy efficient applications. Taking the US market as an example, we should think about incentive systems which compensate the added costs for the consumer??!!	No action

Task	Sub-section	Comment	Action
7	all	Conclusions and their tendencies seem to be right ones, so there should not be many changes. But all the TEC savings for combinations of individual improvement options seem to be wrong. TEC savings of combined options a mathematical operator “addition” seem to be used. However, for TEC savings of combined options mathematical operator “multiplication” should have been used. Basis of this is that with addition one could end over 100% TEC savings, which is physically impossible. Actually one should multiply ”TEC fraction left” for maximum saving potential.	Calculation method was revised
7	all	This contains interesting analysis for the combination of improvements.	No action
7	all	The declared improvement potential is very optimistic. • One reason is that performance data obtained in a standard test were compared to energy savings achieved in a supermarket subjected to seasonal and daily environmental variations (see also comments above). • Another reason is that savings with these seasonal and daily ambient variations are difficult to quantify (no test method; see comment above). Potentials given from suppliers can be true under one set of assumptions but not in general. • Further the reason is that the cumulation of different improvement options by simply summing up the declared individual energy savings leads to an overestimation of total savings.	Options for which the improvement potential cannot be measured under standard conditions were removed from the task 7. The calculation method for the combination of improvement options was revised
7	all	The calculation of payback times takes just the energy saving and the installed material into account, but there might be also higher costs because of increased service, cleaning etc. For example the payback time for glass doors for multidecks is given with 0.73 years. A study of TNO in the Netherland comes to the conclusion that the payback time is 5 years at least	Extra maintenance cost for the glass door/lid was included in the payback and LCC calculations

Task	Sub-section	Comment	Action
7	all	It seems like you have just summed the TEC savings for the different options. This must be wrong! If you consider it cumulating, it would be more correct to calculate the possible savings by multiplying the remaining energy use after each option.	Calculation method was revised
7	all	In Task 7 only technical options are mentioned. The use of alternative refrigerants as an appropriate measure has not been taken into account. Hence, an essential improvement option is missing here.	No action, as the use of "alternative" refrigerants is considered as a "substitution" option and not as an "improvement option".
7	7.1	When ranking the various improvement options all tables show that the ranking is (neglecting minor differences) identical for all chosen indicators. The conclusion is that the driving indicator is total energy (GER). Identifying the other 14 (!) indicators does not provide any additional guidance regarding a preferred option. We urgently request not to make the identification of these indicators a mandatory part of a product assessment nor of the development process and the product documentation.	No action
7	7.1	We disagree with the statement that variable speed compressors only have a negligible impact on BOM's because the material of the inverter has to be added.	No action
7	7.2	Could be appropriate to mention if the cost for glass doors is valid for new production or for after installation.	Valid for New production - EuP only related to the Eco-design of new products
7	7.2	In the draft final report you stated that "the use for an improved air curtain may not lead to much additional benefit if a door is fitted on the cabinet". On the other hand, if a door is fitted to the cabinet, a modified air curtain adapted to this application might be required.	No action

Task	Sub-section	Comment	Action
7	7.3	VII-92, item 7.3 "Switching from a typical refrigerant (mainly HFCs) to an alternative refrigerant such as ammonia, hydrocarbons and CO2, implies strong modifications in the design of the product at the component level (e.g. pipes, compressor) and at the system level (i.e. for remote cabinets)." ->This may be the case in some situations, but not in many others. Such a statement should be qualified. Many manufacturers have produced integral equipment using HCs with next to no additional costs or major modifications. Hydrocarbon systems running on small charges require little change from the HFC equivalent other than the adoption of sealed or protected electrical components and optimisation of the capillary tube.	"Switching from a typical refrigerant (mainly HFCs) to an alternative refrigerant such as ammonia, hydrocarbons and CO2, implies some modifications in the design of the product at the component level (e.g. pipes, compressor) and at the system level (i.e. for remote cabinets)."
7	7.3	I disagree with your conclusions which you quoting from your Ref. 7. Your Fig 7-80 (taken from Ref. 7) shows the R404A power consumption to be below the CO2 line, approaching the CO2 power consumption for low ambient temperatures. There is no energy savings effect resulting from the use of CO2 that can be concluded from that diagram. In Ref. 7 it is stated that CO2 systems have the potential to be more efficient that HFC systems, but this statement is based on assumed improvements for CO2 heat exchangers. No consideration is given to potential improvements for heat exchangers running with HFC's, but there also improvements must be assumed. We do not accept this document as a scientific verification for the statement that the use of CO2 has the potential to reduce energy consumption in the case of commercial refrigeration on a like-for-like basis.	Paragraph modified as follows "Compared to an HFC based refrigerant beverage cooler, the CO2 one has lower electricity consumption at low ambient temperature (between 0.8 % and -7.4 % less at 20 and 25 ℃) however beyo nd 25 ℃ the trend is the opposite: the CO2 system is les s efficient leading to higher electricity consumptions (between 10.3 and 18.3 % more than the base line HFC beverage cooler). However, this might not be solely due to the use of carbon but also to the modifications in the heat exchanger No consideration is given to potential improvements for heat exchangers running with HFC and further verification should be made to assess the efficiency of refrigeration equipment running with carbon dioxide. "
7	7.3	It would also be interesting to mention the environmental impact of the Unilever implementation of almost 200.000 ice cream freezers with R290 in Europe.	added
7	7.3	VII-94, 1st paragraph "Other plug in refrigerated display cabinets using hydrocarbons are under investigation. However, the limitation in terms of quantity of refrigerant (150g) due to safety reasons is one barrier to their development." ->This paragraph is incorrect, as indicated in previous comments.	Removed this sentence

Task	Sub-section	Comment	Action
7	7.4	We disagree with your assessment of a full CO_2 cycle being more efficient than an HFC cycle. Field experience states that on a yearly basis the CO_2 cycle did achieve energy consumption comparable to that of an HFC system.	in task 7 added: "Another area of focus on to reduce the direct impacts is to choose an alternative refrigerant with lower GWP such as CO_2. CO_2-based supermarkets systems have been expanding in Europe since beginning of 2000. They are now the state of the art in Denmark, Luxembourg and Sweden and generally show a energy consumption comparable to that of an HFC system."
7	7.3	Dans les deux graphes pourquoi la température de condensation est de +25℃ pour le R404A et de +15℃ pour le CO_2 cela am éliore les résultats du CO_2 artificiellement (Fig 7-82)	Added " It is important to notice that the condensing temperatures differ in both systems (25℃ and 15 ℃). This gives an advantage to the CO_2 based system and the conclusions from these graphs are only valid for this specific supermarket and configuration."
7	7.1.5	Although High Efficiency Compressor, High Efficiency Lights and Light Control have been in some cases used in the Vending industry, these are not a common practice. I wonder if you want to consider these Technical Options as BAT for Vending Machines. Same applies to Thicker Insulation and Glass Door insulated by Argon when we consider the Design Options.	No action - The improvement options to investigate were chosen according to the replies to a questionnaire on best available technologies and improvement options

Task	Sub-section	Comment	Action
7	all	Our impression from the minutes suggests that the authors belief that the issue of alternative refrigerant is not applicable to this work. • Point i) It is stated that the use of alternative refrigerants cannot be considered as best available technology and that they are not an improvement option but a substitution option, and that they cannot replace HFCs without complete change of system, which therefore their use implies a change of product. We have discussed these statements at a recent meeting and do not concur with that position. We summarise the basis for our objections, as follows: As we understand it, the preparatory studies under the EuP directive is meant to account for lifecycle of all components. The refrigerant is indeed one of the components of a refrigeration system and as such it should be taken into consideration. Certain refrigerants, and in particular, fluorinated fluids have a significant environmental impact associated with their production both in terms of greenhouse gas emissions	Point i) Task 7 does not consider alternative refrigerant as a improvement option but rather as a substitution option. However, section 7.3.2 mentions the potential of using refrigerated display cabinets using natural refrigerants. Also the impacts of the refrigerant are taken into account for plug-in refrigerated display cabinets and vending machines when assessing the environmental impacts in task 5. Point ii) comment accepted Point iii) comment accepted - "Some food and beverage companies have already put thousands of cabinets running with HC on the market showing comparable efficiencies in comparison with cabinets running with HFC."