bio Intelligence Service

Preparatory Study for Eco-design Requirements of EuPs
[Contract N° S12.515749]

Lot 1

Refrigerating and freezing equipment:

Service cabinets, blast cabinets, walk-in cold rooms, industrial process chillers, water dispensers, ice-makers, dessert and beverage machines, minibars, wine storage appliances and packaged condensing units

Summary document

Final Report

May 2011

Bio Intelligence Service - Scaling sustainable development
Industrial Ecology - Nutritional Health

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1. Introduction to ENTR Lot 1

Refrigeration products covered in ENTR Lot 1 span a large range of applications and are used in diverse environments such as restaurants, hotels, pubs, cafés, supermarkets and industrial processes. These products consume significant amounts of electricity and cause other negative environmental impacts during their life-cycle due to their material content, such as refrigerants and insulating agents.

The Ecodesign Directive (2009/125/EC) is expected to improve the environmental performance the refrigerating and freezing equipments in the EU through ecodesign. These studies aim at proposing solutions to improve the energy performance of product categories and reduce their environmental impacts. They follow the European Commission's MEEuP methodology and consist of seven Tasks:

1. Definition
2. Economic and market analysis
3. User behaviour
4. Assessment of Base Case
5. Technical analysis BAT and BNAT
6. Improvement potential
7. Policy and impact analysis

The products that have been selected as Base Cases are described in detail in this summary:

- Service cabinets
- Blast cabinets
- Walk-in cold rooms
- Process chillers
- Remote condensing units

The timeline for ENTR Lot 1 is as follows:

December 2008	Project launch
End March 2009	Task 1 working document published
Mid April 2009	Task 2 working document published
End May 2009	Tasks 1-3 working documents published
July 2009	First stakeholder meeting held
May 2010	Tasks 4-5 working documents, and update Tasks

	1-3 working documents, published
June 2010	Second stakeholder meeting held
September 2010	Tasks 1-7 working documents published
25th October 2010	Final stakeholder meeting held
November 2010	Final report submitted

This summary covers the main findings for Task 1 to 7 and the refrigeration systems annex.

For further information on this preparatory study please consult the project website: www.ecofreezercom.org

1. Contact with stakeholders

1.1 WEBSITE

Over 770 registered stakeholders were granted with access to the documents publicly available on the project website (www.ecofreezercom.org). The following table shows some of the statistics related to this communicational tool over the two years.

Web statistics

Website:	www.ecofreezercom.org	
	Visitors	**Pages**
Total	9738	53942
Highest number	874	6816
Month/year highest indicator	October/2010	October/2010
Average per month	423	2345
Average pages/visitor		5.54
Average visit/visitor	1.82	

1.2 STAKEHOLDER MEETING

3 stakeholder meetings were held in Brussels, at the European Commission premises.

- Kick-off: December/2008
- 1st stakeholder meeting: July/2009
- 2nd stakeholder meeting: June/2010
- Final stakeholder meeting: October/2010

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2. Summary of data for service cabinets

Please find the following relevant sections throughout the working documents:

Service cabinets			
Key section	Title	Document	Page
§ 1.2.1	Product definition, first classification and description	Task 1	22
§ 1.3.1.	Existing standards for service cabinets	Task 1	60
§ 1.4. 1	Existing legislation and voluntary measures	Task 1	116
§ 2.4.1.1	Estimated sales	Task 2	14
§ 2.4.1.2	Estimated CAGR (annual growth of the market)	Task 2	16
§ 2.4.2	Estimated installed base	Task 2	17
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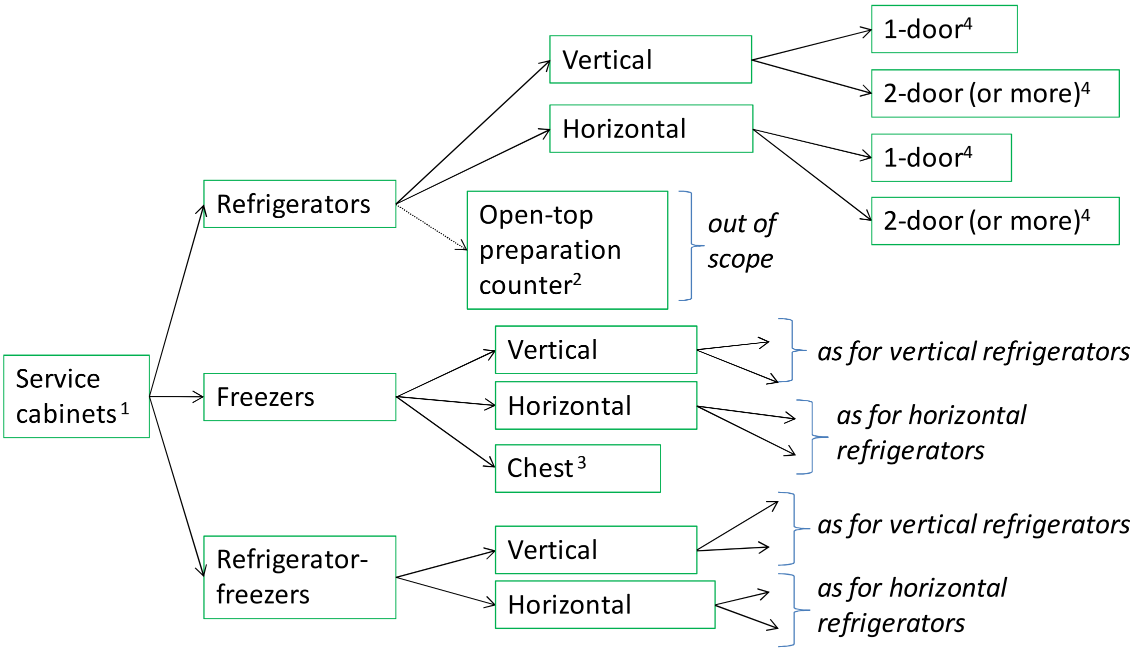
§ 3.5.1	Usage patterns	Task 3	9
§ 4.7.1	Technical description of the typical product	Task 4	59
§ 4.8.1	Technical specifications of the Weighted Base Case	Task 4	82
Table 4-69	Technical specifications of the Real Base Case	Task 4	142
§ 4.10.1	Impact analysis from Ecoreport for the Weighted Base Case (per litre chilled at 5°C)	Task 4	98
Annex 4-3	Full results of Ecoreport	Task 4	158
§ 5.3.1	Applicability of best available techniques to the real product	Task 5	82
§ 5.4.1	Specifications of the BAT model	Task 5	89
§ 5.5.5.1	Specifications of the BNAT model	Task 5	106
§ 5.6	Base Case model/BAT/BNAT comparison (summary)	Task 5	113
§ 6.2.1	Design options	Task 6	9
§ 6.3.1	BAT and LLCC analysis	Task 6	26
§ 7.2.3.2	Proposed MEPS	Task 7	26

2.1 DEFINITION

Commercial refrigerated cabinets are designed for the storage, but not the sale, of chilled and frozen foodstuff. A service cabinet is a refrigerated enclosure (with a gross internal volume of 100 to 2,000 litres) containing goods which are accessible via one or more doors and/or drawers. The sizes of the products are based around the Gastronorm standard and are used in a non-domestic environment.

2.2 CLASSIFICATION



1 – Professional products, either plug-in or remote
2 – Also known as 'saladettes', this product configuration is not included in the scope of ENTR Lot 1 due to different functionality
3 – Freezers and 1-door only
4 – Or with a combination of drawers

Exclusion from the scope: open-top preparation counters.

2.3 FUNCTION AND PERFORMANCE

Functional unit: litre of net volume maintained at 5°C.
Primary performance parameter: kWh/litres per year.

2.4 CURRENT TEST STANDARDS

Regarding testing methodologies, there are plenty of EU and international standards covering the performance of these appliances. EN 441 is also currently in use in certain MS, and is the basis of the UK ECA and DK ETL. Service cabinet performance data quoted in ENTR Lot 1 refer to this test standard.

EN ISO 23953:2005 is currently being analysed to be evaluated by CECED Italia to establish its adaptability to service cabinets, beyond display cabinets. This mainly requires adaptation of the door/lid openings pattern and M-package loading. EFCEM has taken responsibility for the development of a harmonised standard in the EU.

AHRI 1200 (in the US) is not commonly used in EU. Most of the identified third-country standards deal with household equipment. Broadly speaking, an analysis of applicability of household standards (such as EN 153:2006 or EN ISO 15502:2005) and display equipment standards (EN ISO 23953) to solid-door professional equipments is needed in consultation with industry, to identify the most suitable approach for ENTR Lot 1. This variety of options provides a good basis from which to develop a harmonised standard within the EU.

Although uncommon, remote service cabinets pose a greater challenge when measuring electricity consumption. Indeed, remote service cabinets need to receive a certain amount of refrigerating energy from a remote condensing unit in order to operate and are therefore not considered as standalone products. In the EN ISO 23953 standard on refrigerated display cabinets the energy consumption is given by the total energy consumption in kWh per 24h period (TEC). This approach is similar to what is proposed in the ANSI/AHRI 1200:2008 standard

2.5 CURRENT EU LEGISLATION AND INITIATIVES

Equipment	EU	US	Canada	Australia / New Zealand
Service Cabinets	VEPS: UK ECA[1]	MEPS: DOE, CEC[2]	MEPS[3]	(MEPS[4] for refrigerated display cabinets only)

In general, apart from the US CEC MEPS at low net volume, remote product standards are more stringent than those for plug-in products. In addition, it is interesting to note that different ranges of standards have been set for distinct ranges of product net volumes in the UK ECA, US Energy Star and CAN EER schemes. Finally, through examination of the standards, it appears that there is significant variation in the differentiation of similar products across operation temperatures by mandatory and voluntary schemes. Although the figures show that the US DOE MEPS are more stringent, this may be due to their scope (remote equipment) compared to the scopes of the other standards, most of which cover plug-in only.

2.6 MARKET DATA

Estimated sales of service cabinets and forecast until 2020 in EU (units)

Product type	1990	2006	2007	2008	2012	2020	2025
Service cabinets	313,237	390,578	393,985	397,444	412,096	440,230	461,396

Estimated stock of service cabinets and forecast until 2020 in EU (units)

Product type	1990	2006	2007	2008	2012	2020	2025
Service cabinets	2,404,852	3,196,511	3,228,919	3,260,163	3,380,904	3,621,615	3,824,409

[1] UK Enhanced Capital Allowance Scheme
[2] California Appliance Efficiency Regulation
[3] Canadian Energy Efficiency Regulation
[4] AU/NZ Minimum Energy Performance Standards

Estimated average service cabinet price ranges by capacity and operation temperature

Net storage volume, V (litres)	Description	Average selling price (€)
V <400	Refrigerator	850 – 1,300
	Freezer	1,000 – 1,400
400 < V <600	Refrigerator	1,000 – 2,000
	Freezer	1,400 – 2,500
V >600	Refrigerator	1,500 – 3,000
	Freezer	1,500 – 3,000

2.7 BASE CASE ENVIRONMENTAL AND ECONOMIC IMPACT ASSESSMENT

METHODOLOGY: the Base Case used for the environmental analysis is based on 3 Bills of Materials obtained for typical plug-in one-door service cabinets. Results have then been extrapolated through a weighting based on the market shares and estimated energy consumptions, material quantities and other factors for the different configurations of service cabinets, as described in Task 4. This leads to an abstract model, not comparable to any specific product in the market but which is meant to be representative of the market: it is used to provide inputs to the EcoReport analysis tool, whose outputs are useful as a statistical calculation of overall EU market impacts. The characteristics described below for these weighted Base Cases are those essential for the EcoReport assessment.

2.8 IMPACT ANALYSIS FROM ECOREPORT

Main impacts (per product)

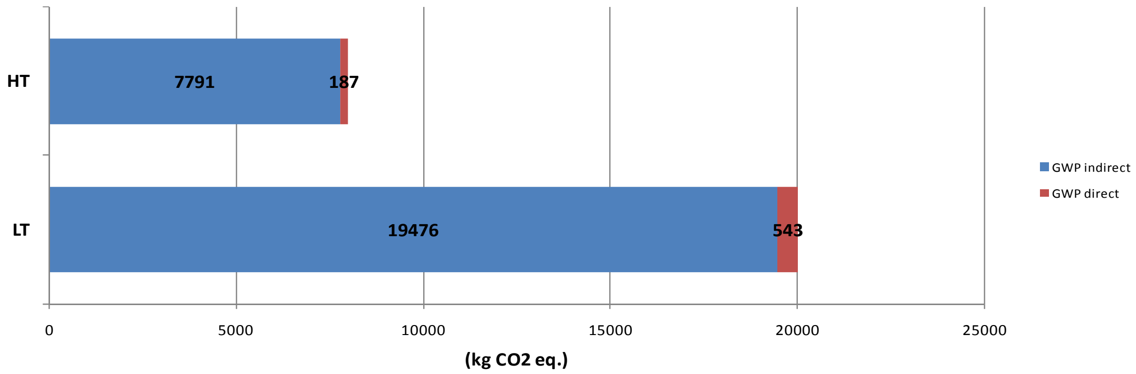
EcoReport LCA analysis results– lifecycle impacts per functional unit per year– Weighted Base Case

Impact indicator	Impact per litre of capacity at 5°C per year	Impact per litre of capacity at -18°C per year
Total Energy (GER) (MJ)	50.97	121.35
of which, electricity (in primary MJ)	47.60	117.69
Use-phase electricity consumption (kWh)	4.85	11.56
Water (process) (ltr)	4.75	9.58
Waste, non-haz./ landfill (g)	107.80	194.31
Waste, hazardous/ incinerated (g)	6.52	8.68
Greenhouse Gases in GWP100 (kg CO_2 eq.)	2.42	5.80
Acidification, emissions (g SO_2 eq.)	13.71	31.89
Volatile Organic Compounds (VOC) (g)	0.03	0.06
Persistent Organic Pollutants (POP) (ng i-Teq)	0.75	1.26
Heavy Metals (mg Ni eq.)	3.33	4.79
PAHs (mg Ni eq.)	0.36	0.53

Impact indicator	Impact per litre of capacity at 5°C per year	Impact per litre of capacity at -18°C per year
Particulate Matter (PM, dust) (g)	2.49	2.96
Heavy Metals (mg Hg/20)	1.92	2.54
Eutrophication (g PO4)	0.07	0.08

The environmental impacts of the blast cabinets at different life phases are represented below. Use phase and production material are the two phases with the biggest impact. Almost 100% of the electricity consumed during the life-time of this equipment is related to the use-phase, which in terms of Total Energy is around 92% for HT and 96% for LT.

EcoReport LCA analysis results for service cabinets - Life cycle Total Equivalent Warming Impact (TEWI)



EcoReport LCA analysis results for service cabinets - Life Cycle Cost breakdown per unit and total annual consumer expenditure

	HT - LCC new product (€)	LT - LCC new product (€)	Total annual consumer expenditure in EU25 (mln €)
Product price	1000	1100	409
Installation/ acquisition costs	0	0	0
Electricity	1701	4252	1327
Repair & maintenance costs	83	83	38
Total	2784	5436	1775

<u>**Main impacts (EU wide)**</u>

EcoReport LCA analysis results for service cabinets - environmental impacts of stock

		TOTAL
Other Resources & Waste		
Total Energy (GER)	**PJ**	122.87
Water (process)	**mln. m3**	11.20
Total use-phase electricity consumption	**TWh**	10.32

		TOTAL
Water (cooling)	**mln. m3**	313.41
Waste, non-haz./ landfill	**kt**	218.83
Waste, hazardous/ incinerated	**kt**	11.21
Emissions (Air)		
Greenhouse Gases in GWP100	**mt CO2 eq.**	5.80
Ozone Depletion, emissions	**t R-11 eq.**	0.00
Acidification, emissions	**kt SO2 eq.**	32.56
Volatile Organic Compounds (VOC)	**kt**	0.07
Persistent Organic Pollutants (POP)	**g i-Teq**	1.46
Heavy Metals	**ton Ni eq.**	5.96
PAHs	**ton Ni eq.**	0.65
Particulate Matter (PM, dust)	**kt**	4.07
Emissions (Water)		
Heavy Metals	**ton Hg/20**	3.29
Eutrophication	**kt PO4**	0.11
Persistent Organic Pollutants (POP)	**g i-Teq**	0.00

2.9 SUB-BASE CASES AND CURRENT BAT TECHNICAL SPECIFICATIONS

The weighted Base Cases have been developed from one or two sub-Base Cases, and these sub-Base Cases are comparable to the most common product configuration on the market. The sub-Base Cases are necessary in order to have real product characteristics from which to extrapolate the weighted models, and also to compare against BAT.

Technical characteristics of service cabinet sub-Base Cases and BAT

Product characteristic	Sub-Base Case HT	Sub-Base Case LT	BAT HT	BAT LT
Product type/model/design:	Vertical, 1-door	Vertical, 1-door	Vertical, 1-door	Vertical, 1-door
Location of condensing unit:	Integral (plug-in)	Integral (plug-in)	Integral (plug-in)	Integral (plug-in)
Climate class:	4	4	4	4
M-package temperature class:	M1	L1	M1	L1
Test standard:	EN 441	EN 441	EN 441	EN 441
Internal cold storage temperature [°C]:	+5°C	-18°C	+5°C	-18°C
Internal cold storage temperature range(s) (°C):	+2 to +12°C	-5 to -25°C	+2 to +12°C	-5 to -25°C
Air-on temperature (ambient temperature) [°C]:	+30°C	+30°C	+30°C	+30°C
Net internal volume [litres][5]:	450	450	441	441
Product use pattern [hours/year]:	8760	8760	8760	8760
Functional unit:	Litre of net volume at +5°C	Litre of net volume at -18°C	Litre of net volume at +5°C	Litre of net volume at -18°C
Power input [kW]:	0.315	N.A.	0.291	0.425
Cooling capacity [kW]:	0.35	N.A.	0.389 (to = -10 °C)	0.475 (to = -25 °C)
COP:	1.11	N.A.	1.87	1.38
AEC [kWh/year]:	2,000	5,000	508	2,220

[5] Calculated according to EN 441 method

Product characteristic	Sub-Base Case HT	Sub-Base Case LT	BAT HT	BAT LT
TEC [kWh/48hrs]:	10.96	27.40	2.79	12.16
EEI [kWh/48hrs / m3]:	24.35	60.88	6.32	27.58
Performance [kWh/litre net volume at storage temperature/year]:	4.44	11.11	1.15	5.03
Price (ex VAT) [€]:	1,000	1,100	2,300	2,550
Lifetime [years]:	8.5	8.5	10	10
Refrigerant:	R134a	R404A	R290	R290
Refrigerant charge [g]:	300	400	102	92
Refrigerant leakage [% per annum]:	1%	1%	1%	1%
Defrost type [natural/electric/hot gas/cool gas]:	Natural	Electric	Natural (Air)	Electric
Defrost control (if applicable) [timed/off-cycle/on-demand]:	Off-cycle	Off-cycle	Timed	Timed
Anti-condensation (if applicable):	None	None	None	None
Expansion valve type:	Capillary tube	Capillary tube	Capillary tube	Capillary tube
Other features not covered above:	-	-	-	-
Weight of product [kg]:	114	114	145	145
External height [m] :	2.06	2.06	2.01	2.01
External width [m] :	0.7	0.7	0.695	0.695
External depth [m] :	0.84	0.84	0.876	0.876
Gross total (shipping) volume [m3] :	1,211	1,211	1.52	1.52
Number of compressors:	1	1	1	1
Type of compressor:	Hermetic reciprocating	Hermetic reciprocating	Hermetic reciprocating	Hermetic reciprocating
Power of compressor [W]:	195	N.A.	208 (to = -10 °C)	344 (to = -25 °C)
Capacity of compressor [W]:	320	N.A.	389 (to = -10 °C)	475 (to = -25 °C)
Weight of compressor [kg]:	10	N.A.	7.5	13.1
Compressor motor control [none/two-speed/VSD]:	None	None	None	None
Evaporator heat exchanger type and material:	Fin and tube	Fin and tube	Fin evaporator with copper tubes and aluminium fins.	Fin evaporator with copper tubes and aluminium fins.
Evaporator face area [cm²]:	240	N.A.	24,069	24,069
Evaporator fan motor type:	Shaded pole axial	Shaded pole axial	Electric commutated with permanent magnets	Electric commutated with permanent magnets
Evaporator fan motor power [W]:	5	5	10 W	10 W
Evaporator fan motor control [none/two-speed/VSD]:	None	None	None	None
Weight of evaporator module [kg]:	1	1	2,87 (Evaporator, heatexchanger, suspension and shieldings)	3,15 (Evaporator, heatexchanger, defrosting heating element, suspension and shieldings)
Condenser cooling:	Air-cooled	Air-cooled	Air-cooled	Air-cooled
Condenser heat exchanger type	Fin and tube	Fin and tube	Fin condenser with	Fin condenser

Product characteristic	Sub-Base Case HT	Sub-Base Case LT	BAT HT	BAT LT
and material:			copper tubes and aluminium fins.	with copper tubes and aluminium fins.
Condenser face area [cm²]:	N.A.	N.A.	7,500	15,000
Condenser fan motor type:	Shaded pole axial	Shaded pole axial	Electric commutated with permanent magnets	Electric commutated with permanent magnets
Condenser fan motor power [W]:	10	N.A.	10 W	10 W
Condenser fan motor control [none/two-speed/VSD]:	None	None	None	None
Weight of condenser module [kg]:	1.5	N.A.	2,6 (Condenser, fan shroud and motor)	3,13 (Condenser, fan shroud and motor)
Number of doors:	1	1	1	1
Insulation type:	Polyurethane	Polyurethane	Polyurethane	Polyurethane
Insulation thickness [mm]:	60	60	60	60
Foaming agent:	Cyclo-Pentan / Isopentane	Cyclo-Pentan / Isopentane	Cyclopenthane	Cyclopenthane
Lighting type [incandescent/fluorescent/LED]:	Incendescent	Incendescent	Halogen	Halogen
Lighting power [W]:	20	20	2x10	2x10

2.10 IMPROVEMENT POTENTIAL

The table below presents the improvement options, estimates of their current market penetration, their energy saving potential and cost.

Improvement options

	Applicability (years)	Market penetration (%)	Savings for HT (% TEC)	Savings for LT (% TEC)	Increase in price of HT product (€)	Increase in price of product LT (€)	Priority HT	Priority LT
High efficiency compressor*	Now	40	7	10	20	40	5	4
ECM evaporator fan	Now	20	12	7	18	18	2	3
ECM condenser fan	Now	20	8	3	20	20	4	5
High efficiency fan blades	Now	20	3	3	5	5	3	2
Sealing door face frame	Now	N.A.	19	26	0	0	1	1
Insulation thickness	Now	35	4	5	100	110	7	8
R290	Now	10 to 20	5**	5**	40	40	6	6
Zeolite filter cassettes	Now	N.A.	0.5	2	90	90	9	10
Bubble expansion valve	Now	NA	10 to 20	10 to 20	N.A.	N.A.	9	11
Defrost control	Now	30	-	3	-	50	-	7
Anti-condensation control	Now	N.A.	2 to 20	-	N.A.	-	10	-
Insulation material	Now	N.A.	2	2	330	1115	8	9

BNAT

	Applicability (years)	Market penetration (%)	Savings for HT (% TEC)	Savings for LT (% TEC)	Increase in price of HT product (€)	Increase in price of product LT (€)	Priority HT	Priority LT
VSD compressor	2 to 3	N.A.	10	10	80	168	2	4
Hot gas anti-condensation	2 to 3	N.A.	18	9	94	94	1	2
ECM compressor	2 to 3	N.A.	12	12	108	122	3	1
Hot gas defrost	2 to 3	N.A.	N.A.	8	N.A.	129	4	3
R744	2 to 3	N.A.	N.A.**	N.A.**	N.A.	N.A.	5	5

**Selected from technologies related to the component*
***The benefit of this improvement is also the lower GWP of the refrigerant and reduced refrigerant charge – although it could provide high energy savings at no extra cost, it has not been selected as top priority due to its flammability.*
N.A.: Data not available
Note: Savings are not additive.

This table includes improvement options for which relevant information was found.

It is assumed that the best available service cabinet, BNAT, within next 5 years might achieve energy savings of 76% based on the following:

Product characteristic	BNAT HT model	BNAT LT model
Product type/model/design:	Vertical, 1-door	Vertical, 1-door
Location of condensing unit:	Integral (plug-in)	Integral (plug-in)
Climate class:	4	4
M-package temperature class:	M1	L1
Internal cold storage temperature [°C]:	5°C	5°C
Net internal volume [litres][6]:	450	450
Product use pattern [hours/year]:	8760	8760
Functional unit:	Litre of net volume at 5°C	Litre of net volume at 5°C
AEC [kWh/year]:	480	1,350
TEC [kW/48hrs]:	2.63	7.4
EEI [kWh/48hrs/ m3]:	5.84	16.44

[6] Calculated according to EN 441 method

Product characteristic	BNAT HT model	BNAT LT model
Performance [kWh/litre net volume at 5°C/year]:	1.07	3
Lifetime [years]:	10	10
Refrigerant:	Low GWP*	Low GWP*
Compressor:	VSD ECM	VSD ECM
Expansion device:	Bubble expansion valve	Bubble expansion valve
Evaporator:	ECM with efficient fan blades and improved heat exchanger	ECM with efficient fan blades and improved heat exchanger
Condenser:	ECM with efficient fan blades and improved heat exchanger	ECM with efficient fan blades and improved heat exchanger
Defrost :	Hot gas, controlled	Hot gas, controlled
Anti-condensation heaters :	Hot gas, controlled	Hot gas, controlled
Lighting:	LED	LED
Insulation:	80mm PUR	80mm PUR
Other:	Liquid suction heat exchanger	Liquid suction heat exchanger

** For example: R290, R600a, R744, or an un-saturated HFC – for the purposes of modelling R717 has been used*

The following approximate energy savings potentials have been gathered:

2.11 BASE CASE/BAT/BNAT COMPARISON

Electricity consumption, performance and refrigerants for service cabinet BOM, BAT and BNAT

		Base Case model	Weighted Base Case	Current available BAT model	Weighted current available BAT	Theoretical BNAT product model (available in approximately 5 years)	Weighted theoretical BNAT (available in approximately 5 years)
Service cabinet HT	AEC [kWh/year]:	2,000	2,000	500	500	480	480
	EEI [kWh/48hrs / m3]:	10.96	10.96	2.74	2.74	2.63	2.63
	Performance [kWh/litre net volume at 5°C/year]:	4.44	4.44	1.05	1.05	1.07	1.07
	Improvement over Base Case (%):	-	-	75	75	76	76
Service cabinet LT	AEC [kWh/year]:	5,000	5,000	2,200	2,200	1,350	1,350
	EEI [kWh/48hrs / m3]:	27.40	27.40	12.16	12.16	16.44	16.44
	Performance [kWh/litre net volume at -18°C/year]:	11.11	11.11	4.67	4.67	3	3
	Improvement over Base Case (%):	-	-	56	56	73	73

2.12 DESIGN OPTIONS

Identified energy saving potentials for the HT service cabinet Base Case

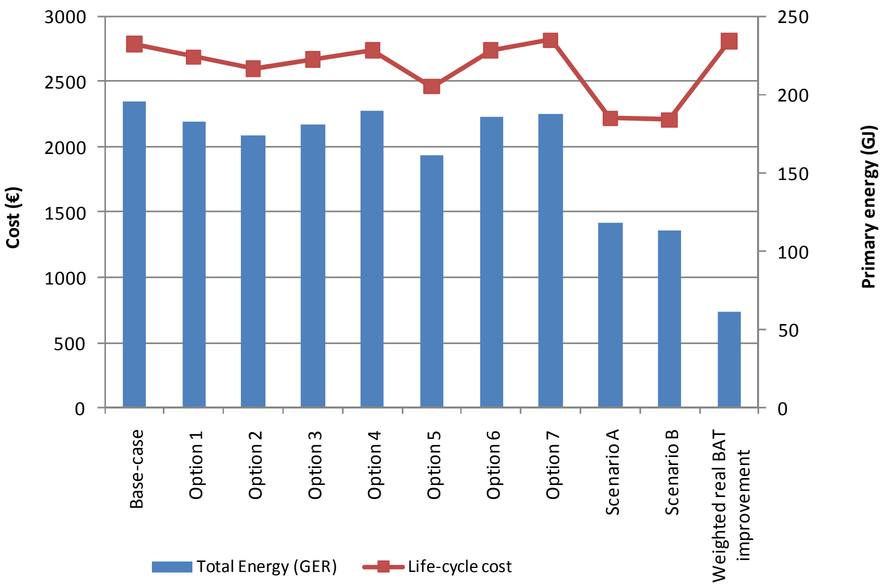
	Improvement option	TEC savings compared to Base Case (%)	Increase of product price compared to Base Case (€)	Payback time (years)
Option 1	High efficiency compressor	7%	20	1.19
Option 2	ECM evaporator fan motor	12%	18	0.63
Option 3	ECM condenser fan motor	8%	20	1.04
Option 4	High efficiency fan blades	3%	5	0.69
Option 5	Sealing door frame	19%	0	0.00
Option 6	R290	5%	40	3.33
Option 7	Thicker insulation	4%	100	10.42
Scenario A	Incorporates options 1+2+3+4+5+7	43%	163	1.58
Scenario B	Incorporates options 1+2+3+4+5+6+7	46%	203	1.84
Weighted real BAT improvement	As described in Task 5, this product includes R290	75%	1300	7.22

Identified energy saving potentials for the LT service cabinet Base Case

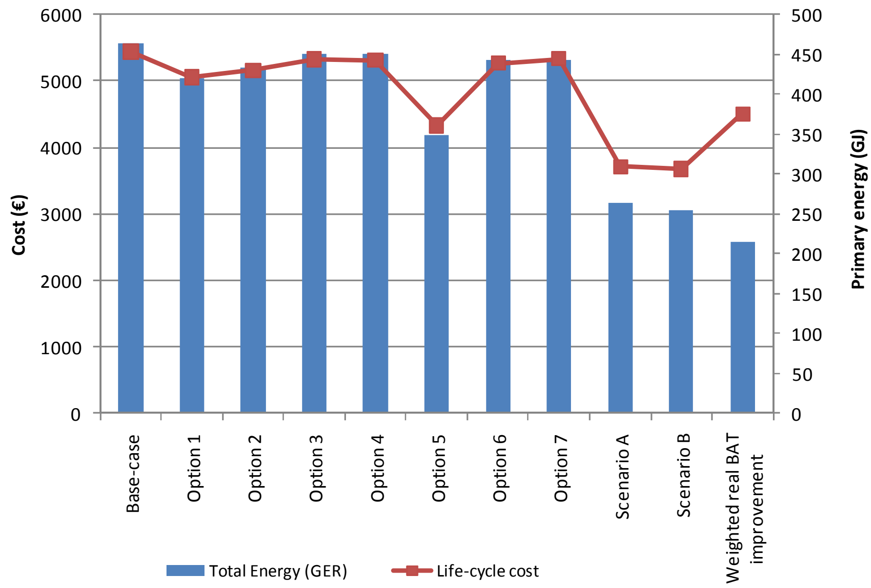
	Improvement option	TEC savings compared to Base Case (%)	Increase of product price compared to Base Case (€)	Payback time (years)
Option 1	High efficiency compressor	10%	40	0.67
Option 2	ECM evap	7%	18	0.43
Option 3	ECM cond	3%	20	1.11
Option 4	High Efficiency Fan Blades	3%	5	0.28
Option 5	Sealing door frame	26%	0	0.00
Option 6	R290	5%	40	1.33
Option 7	Thicker insulation	5%	110	3.67
Scenario A	Incorporates options 1+2+3+4+5	45%	193	0.71
Scenario B	Incorporates options 1+2+3+4+5+6+7	47%	233	0.83
Weighted real BAT improvement	As described in Task 5, this product includes R290	56%	1450	4.32

2.13 BAT AND LLCC

HT service cabinet Base Case – TEC and LCC



LT service cabinet Base Case – TEC and LCC



2.14 PROPOSED MEPS

Possible MEPS for service cabinets, defined using an energy efficiency index (EEI[7]) performance threshold, could be established following the Least Life Cycle Cost and BNAT options, and are described below.

Possible MEPS for service cabinets: EEI performance threshold

Configuration	Operation temperature	Net internal volume, V (litres)	Short-term MEPS based on LLCC (max. EEI)	Long-term MEPS based on BNAT (max. EEI)
Vertical	**Refrigerator**	0 < V < 600	13.88	5.84
		> 600	11.11	4.68
	Freezer	0 < V < 600	33.49	16.44
		> 600	31.81	15.62
Under-counter	**Refrigerator**	*Any size*	18.74	7.89
	Freezer	*Any size*	35.16	17.26
Chest	**Freezer**	*Any size*	26.79	13.15

Both plug-in and remote types would be covered under these MEPS levels.

The MEPS would be measured under the following:

- Total Electrical Energy Consumption as defined in EN 441:1995 (until revision of EN 23953:2005 is completed);
- Net internal calculation according to EN 441 (until revision of EN 23953 is completed). Hence the equipment shall have all movable parts installed. The load limits shall be identified, considering areas where the air channels that should not be blocked at any moment. Volume inferior to

[7] Calculated from the TEC over 48 hours, divided by the net internal volume of the product in m^3

100x100x100mm (cubic testing package) should not be included for the calculation. The measurement should fit primitive geometrical shapes. The volume of the bottom shelf shall not be included in the total volume.

- Adjustment factor for refrigerator-freezers: to calculate the adjusted volume of these models, add the volume of the refrigeration compartment in litres to the product of 1.63 and the volume of freezing compartment in litres [AV = volume of refrigeration compartment in litres + (1.63 x volume of freezing compartment in litres)]. If it is assumed that the energy consumption of freezing per unit volume is 2.5 times that of refrigeration, this adjustment allows for just over 65% of the product's internal volume to be freezing storage.

It is proposed that there be mandatory declaration of energy consumption at standard conditions, be enforced to provide consumers with a basis for product comparison.

3. Summary of data for blast cabinets

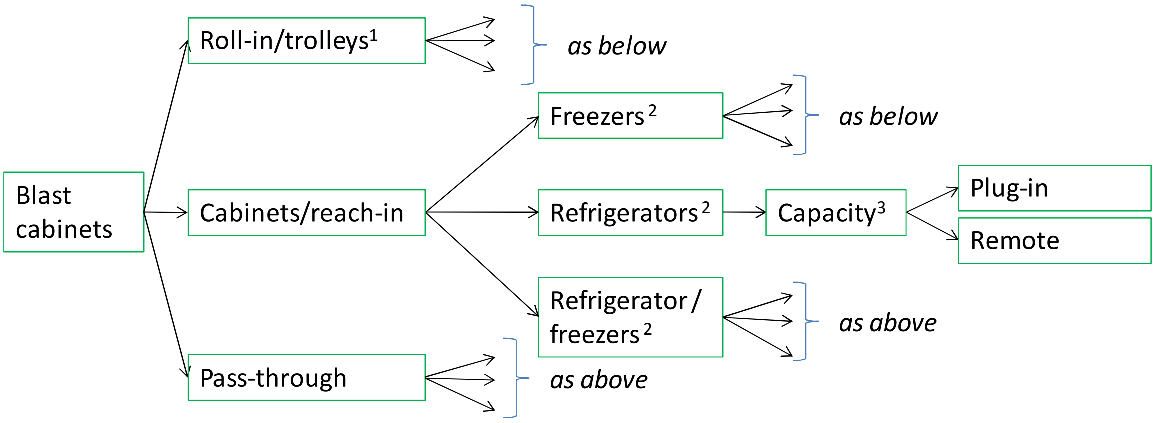
Please find the following relevant sections throughout the working documents:

Blast cabinets			
Key section	Title	Document	Page
§ 1.2.2.1	Product definition, first classification and description	Task 1	28
§ 1.3.2	Existing standards for blast cabinets	Task 1	75
§ 1.4.2	Existing legislation and voluntary measures	Task 1	123
§ 2.4.1.1	Estimated sales	Task 2	14
§ 2.4.1.2	Estimated CAGR (annual growth of the market)	Task 2	16
§ 2.4.2	Estimated installed base	Task 2	17
§ 2.6.1.2	Average consumer prices	Task 2	38
§ 3.5.1	Usage patterns	Task 3	8
§ 4.7.2	Technical description of the typical product	Task 4	60
§ 4.8.2	Technical specifications of the Weighted Base Case	Task 4	78
Table 4-68	Technical specifications of the Real Base Case	Task 5	137
§ 4.10.2	Impact analysis from Ecoreport for the Weighted Base Case (per functional unit)	Task 4	99
Annex 4.4	Full results of Ecoreport	Task 4	163
§ 5.3.2	Applicability of best available techniques to the real product	Task 5	78
§ 5.4.2	Specifications of the BAT model	Task 5	87
§ 5.5.1.2	Specifications of the BNAT model	Task 5	103
§ 5.5.2	Base Case model/BAT/BNAT comparison (summary)	Task 5	108
§ 6.2.2	Design options	Task 6	11
§ 6.3.2	BAT and LLCC analysis	Task 6	31
§ 7.2.3.3	Proposed MEPS	Task 7	32

3.1 DEFINITION

Blast cabinets use a blast of cold air to bring down the temperature of hot food rapidly so it can be stored safely avoiding bacteria growth, either chilled or frozen.

3.2 CLASSIFICATION



1 – Small Roll-in equipment is can be found in Plug-in configuration (normally up to 60kg or 90kg), bigger units in remote configuration
2 – For large equipments (from around 60kg or 90kg) remote configuration represents 90% of sales
3 – Lower capacities correspond to reach-in equipment, being from 3kg to 100kg. Pass-though and roll-in equipment capacity varies from around 30kg to 240kg

3.3 FUNCTION AND PERFORMANCE

Functional unit: one kg of food (testing material specified in NF AC D 40-003) cooled in a specific cycle (kg/cycle) occupying a specific volume; the cycle defining the temperature change and duration of cooling.

Performance: Electricity consumption per unit of foodstuff (referred to the testing material as per NF AC D 40-003) refrigerated/frozen weight in kWh/kg within the fixed cooling or freezing cycle.

3.4 CURRENT TEST STANDARDS

For blast cabinets there are no specific standards regarding energy efficiency or performance in EU (nor in third countries). This may be due to the current focus on cooling performance (to meet food hygiene requirements) rather than energy efficiency.

3.5 CURRENT EU LEGISLATION AND INITIATIVES

For blast cabinets there is no specific legislation related to energy efficiency or performance in EU (nor in third countries). This may be due to the current focus on cooling performance (to meet food hygiene requirements) rather than energy efficiency.

3.6 MARKET DATA

Estimated sales of blast cabinets and forecast until 2020 in EU (units):

Product type	1990	2006	2007	2008	2012	2020	2025
Blast cabinets	95,110	165,600	170,000	173,655	189,078	224,155	249,310

Estimated stock of blast cabinets and forecast until 2020 in EU (units):

Product type	1990	2006	2007	2008	2012	2020	2025
Blast cabinets	516,141	1,035,798	1,292,529	1,331,197	1,478,884	1,761,092	1,958,727

The estimated average price for blast cabinets is related to mass capacity of foodstuff to refrigerate, according to stakeholders:

Number of trays (GN 1/1)	Approximate capacity of the equipment (kg)	Description	Average selling price (€)
1 – 3	3 – 9	Refrigerator and/or Freezer	2,000 – 5,000
4 – 7	12 – 21	Refrigerator and/or Freezer	5,000 – 15,000
8 – 70 (trolleys)	24 – 240	Refrigerator and/or Freezer	10,000 – 30,000

3.7 WEIGHTED BASE CASE ENVIRONMENTAL AND ECONOMIC IMPACT ASSESSMENT

METHODOLOGY: For each product group, the Base Case used for the environmental analysis is represented by weighted Base Cases, calculated using the market shares of the different configurations and various assumptions on relative energy consumption, material quantities and other factors, as described in Task 4. This leads to an abstract model, not comparable to any specific product in the market, but used to provide inputs to the EcoReport analysis tool, whose outputs are useful as a statistical calculation of overall EU market impacts. The characteristics described below for these weighted Base Cases are those essential for the EcoReport assessment.

3.8 IMPACT ANALYSIS FROM ECOREPORT

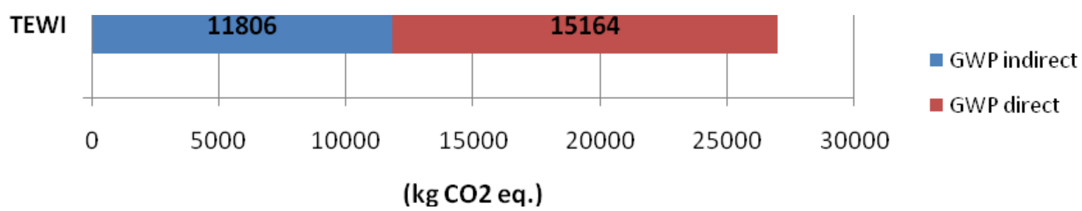
Main impacts (per product)

EcoReport LCA analysis results for blast cabinets – lifecycle impacts per functional unit per year - Weighted Base Case

Impact indicator	Impact per kg of foodstuff (as referred in NF AC D 04-003) over 220 per year
Total Energy (GER) (MJ)	2.06
of which, electricity (in primary MJ)	1.98
electricity (kWh)	0.19
Water (process) (Ltr)	0.17
Waste, non-haz./ landfill (g)	3.67
Waste, hazardous/ incinerated (g)	0.13
Greenhouse Gases in GWP100 (kg CO2 eq.)	0.20
Acidification, emissions (g SO2 eq.)	0.55
Volatile Organic Compounds (VOC) (g)	0.00
Persistent Organic Pollutants (POP) (ng i-Teq)	0.02
Heavy Metals (mg Ni eq.)	0.09
PAHs (mg Ni eq.)	0.01
Particulate Matter (PM, dust) (g)	0.04
Heavy Metals (mg Hg/20)	0.05
Eutrophication (g PO4)	0.00

Almost 100% of the electricity consumed during the life-time of this equipment is related to the use-phase, which in terms of Total Energy becomes around 95%.

EcoReport LCA analysis results for blast cabinets - Life cycle Total Equivalent Warming Impact (TEWI)



EcoReport LCA analysis results for blast cabinets - Life Cycle Cost breakdown per unit and total annual consumer expenditure

Blast Cabinet *Item*	LCC new product		total annual consumer expenditure in EU25	
Product price	6,400	€	1,111	mln.€
Installation/ acquisition costs (if any)	0 0	0	0	€
Fuel (gas, oil, wood)	0	€	0	mln.€
Electricity	2,578	€	494	mln.€
Water	0	€	0	mln.€
Aux. 1: None	0	€	0	mln.€
Aux. 2 :None	0	€	0	mln.€
Aux. 3: None	0	€	0	mln.€
Repair & maintenance costs	534	€	100	mln.€
Total	**9,512**	€	**1,705**	mln.€

Main impacts (EU wide)

EcoReport LCA analysis results for blast cabinets - environmental impacts of stock

Life Cycle phases --> **Resources Use and Emissions**		**TOTAL**
Other Resources & Waste		
Total Energy (GER)	PJ	46
of which, electricity (in primary PJ)	PJ	44
Water (process)	mln. m3	4
Water (cooling)	mln. m3	116
Waste, non-haz./ landfill	kt	83
Waste, hazardous/ incinerated	kt	3
Emissions (Air)		
Greenhouse Gases in GWP100	mt CO2 eq.	5
Ozone Depletion, emissions	t R-11 eq.	negligible
Acidification, emissions	kt SO2 eq.	12
Volatile Organic Compounds (VOC)	kt	0
Persistent Organic Pollutants (POP)	g i-Teq	1
Heavy Metals	ton Ni eq.	2
PAHs	ton Ni eq.	0
Particulate Matter (PM, dust)	kt	1
Emissions (Water)		
Heavy Metals	ton Hg/20	1
Eutrophication	kt PO4	0
Persistent Organic Pollutants (POP)	g i-Teq	negligible

3.9 SUB-BASE CASES AND CURRENT BAT TECHNICAL SPECIFICATIONS

The weighted Base Cases have been developed from one or two sub-Base Cases, and these sub-Base Cases are comparable to the most common product configuration on the market. The sub-Base Cases are necessary in order to have real product characteristics from which to extrapolate the weighted models, and also to compare against BAT.

Technical characteristics of the blast cabinet sub-Base Case and BAT

Product characteristic	Sub-Base Case	BAT	BAT
Product type/model/design:	Vertical	Vertical	Vertical
Location of condensing unit:	Integrated	Integrated	Integrated
Capacity [kg]:	20	21	21
Maximum number of trays (GN 1/1):	5	6	6
Cooling cycle*:	chilling from +70°C to +3°C in 90 minutes	chilling from +70°C to +3°C in 90 minutes	freezing from +70°C to -18°C in 240 minutes
Electricity consumption [kWh/cycle]:	2.0	1.3	3.7
Product use pattern [cycles/year]:	2 cycles per day, 220 days per year	2 cycles per day, 220 days per year	1 cycles per day, 220 days per year
Condensing unit function [hours/day]:	3	3	4
Product use pattern [hours/year]:	660	660	880
Functional unit*:	1 kg of foodstuff (referred to material proposed by NF AC D 40-003) chilling from +70°C to +3°C in 90 minutes	1 kg of foodstuff (referred to material proposed by NF AC D 40-003) chilling from +70°C to +3°C in 90 minutes	1 kg of foodstuff (referred to material proposed by NF AC D 40-003) freezing from +70°C to -18°C in 240 minutes
Power input [kW]:	1.2	2.3	-
Cooling capacity [kW]:	0.83	0.83	1.012
AEC [kWh/year]:	880	572	814
Performance [kWh/kg of foodstuff (referred to material proposed by NF AC D 40-003) chilling from +70°C to +3°C in 90 minutes/year]:	44.00	27.23	-
Performance [kWh/kg of foodstuff (referred to material proposed by NF AC D 40-003) freezing from +70°C to +3°C in 90 minutes/cycle]:	0.100	0.0619	-
Performance [kWh/kg of foodstuff (referred to material proposed by NF AC D 40-003) freezing from +70°C to -18°C in 240 minutes/year]:	-	-	38.76
Performance [kWh/kg of foodstuff (referred to material proposed by NF AC D 40-003) freezing from +70°C to -18°C in 2490 minutes/cycle]:	-	-	0,176
Price (ex VAT) [€]:	3,400	3,800	*N.A.*
Lifetime [years]:	8.5	8.5	8.5
Refrigerant:	R404A	R404A	R404A
Refrigerant charge [kg]:	0.8	1.5	1.5
Refrigerant leakage [% per annum]:	5	5	5
Defrost type [natural/electric/hot gas/cool gas]:	not included	not included	Automatic
Defrost control (if applicable) [timed/off-cycle/on-demand]:	not included	not included	Timed
Door frame heater wire:	not included	2,200mm	2,200mm
Defrost load [amps]:	-	-	1.0
Anti-condensation (if applicable):	not included	not included	-
Expansion valve type:	Thermostatic	Electronic expansion	Electronic expansion

Product characteristic	Sub-Base Case	BAT	BAT
	expansion valve	valve	valve
Weight of product [kg]:	120	130	130
External height [cm]:	850	1291	1291
External width [cm]:	800	700	700
External depth [cm]:	700	800	800
Net volume [m³]:	52	69	69
Gross total (shipping) volume [m3] :	0.81	1.23	1.23
Shipping weight [kg]:	150	*N.A.*	*N.A.*
Number of compressors:	1	1	1
Type of compressor:	Hermetic reciprocating	Hermetic reciprocating	Hermetic reciprocating
Power of compressor [W]:	969	*1089*	*1248*
Capacity of compressor [W]:	1120	*N.A.*	*N.A.*
Weight of compressor [kg]:	12.5	23	23.7
Compressor motor control [none/two-speed/VSD]:	*N.A.*	*N.A.*	*N.A.*
Evaporator heat exchanger type and material:	*Fined tube / aluminum copper*	*Fined tube / aluminum copper*	*Fined tube / aluminum copper*
Evaporator face area [cm²]:	*N.A.*	*N.A.*	*N.A.*
Evaporator fan motor type:	Axial	Axial	Axial
Evaporator fan motor power [W]:	160	*N.A.*	*N.A.*
Evaporator fan motor control [none/two-speed/VSD]:	*N.A.*	*N.A.*	*N.A.*
Weight of evaporator module [kg]:	*N.A.*	*N.A.*	*N.A.*
Condenser cooling:	Air-cooled	Air-cooled	Air-cooled
Condenser heat exchanger type and material:	*Fined tube / aluminum copper*	*Fined tube / aluminum copper*	*Fined tube / aluminum copper*
Condenser face area [cm²]:	*N.A.*	*N.A.*	*N.A.*
Condenser fan motor type:	Axial	Axial	Axial
Condenser fan motor power [W]:	60	*N.A.*	*N.A.*
Condenser fan motor control [none/two-speed/VSD]:	*N.A.*	*N.A.*	*N.A.*
Weight of condenser module [kg]:	2.5	*N.A.*	*N.A.*
Number of doors:	1	1	1
Door material :	Stainless steel	Stainless steel	Stainless steel
Insulation type:	Polyurethane	Polyurethane	Polyurethane
Insulation thickness [mm]:	55	55	55
Foaming agent:	Water	Cyclo-Pentan/Isopentane (CFC free)	Cyclo-Pentan/Isopentane (CFC free)
Other features:	Self closing door, evaporation temperature control with thermostat valve, inner door stop, temp. detector probe	Self closing door, temperature detector probe	Self closing door, temperature detector probe

**As referred commonly in brochures. Only for comparison purposes*

3.10 IMPROVEMENT POTENTIAL

The table below presents the improvement options, estimates of their current market penetration, their energy saving potential and cost.

Improvement options

	Applicability (years)	Market penetration (%)	Savings (% TEC)	Increase in price of product (€)	Priority
High Efficiency Fan Blades	Now	0%	9%	10	1
Electronic expansion valve	Now	5%	15%	100	2
Variable speed drive (VSD) compressor	Now	2%	10%	400	3
Insulation thickness	Now	5%	4%	100	4
ECM Fan for evaporator	Now	<5%	7%	40	5
Defrost Control	Now	5%	3%	10	6
Electronic Expansion Valve (EEV) when integrated with floating head pressure	Now	2%	20%	100	7
Remote condensing	Now	<1%	15%	1200	8
Full baffling	Now	99%	6%	Negligible	9
R290	N.A.	N.A.	5%	200	10
CO2	Now*	N.A.	N.A.	N.A.	11
BNAT					
ECM compressor	2 to 3 years	0%	10%	100	1
Improved heat exchanger**	Now***	5%	5%	60	2
Unsaturated HFC blends	3 to 4 years	0%	0****	300	3

**Selected from technologies related to the component*
***Tested in prototypes but no evidence found of application in the market*
****The benefit of this improvement is the lower GWP of the refrigerant*
N.A.: Data not available
Note: Savings are not additive.

This table includes improvement options for which relevant information was found.

It is assumed that the best available blast cabinet within next 5 years will achieve energy savings of 55% using the following.

Product characteristic	**BNAT**
Product type/model/design:	Vertical
Location of condensing unit:	Integrated
Functional unit:	1 kg of foodstuff (referred to material proposed by NF AC D 40-003) chilling cycle
Cooling cycle:	chilling cycle from +70°C to +3°C in 90min
Capacity [kg]:	20
Maximum number of trays (GN 1/1):	5
Net volume [m³]:	52
Electricity consumption [kWh/cycle]:	1.00
Product use pattern [cycles/year]:	2 cycles per day, 220 days per year

Product characteristic	BNAT
AEC (base model) [kWh/year]:	440
Performance [kWh/kg of foodstuff (referred to material proposed by NF AC D 40-003) freezing from +70°C to +3°C in 90 minutes/cycle]:	0.050
Performance [kWh/kg of foodstuff (referred to material proposed by NF AC D 40-003) freezing from +70°C to +3°C in 90 minutes/year]:	22
Power input [kW]:	1.2
Cooling capacity [kW]:	0.83
Refrigerant:	Low GWP*
Compressor:	VSD ECM
Condenser:	ECM fan with high efficiency blades and improved heat exchanger
Expansion valve type:	Electronic expansion valve
Full baffling:	Included

**For example: R717, or an un-saturated HFC – for the purposes of modelling R717 has been used*

The following approximate energy savings potentials have been gathered:

3.11 BASE CASE/BAT/BNAT COMPARISON

Energy consumption, performance and refrigerants for blast cabinet BOM, BAT and BNAT

	Base Case model	Weighted Base Case	Current available BAT model	Weighted current available BAT	Theoretical BNAT product model (available in approximately 5 years)	Weighted theoretical BNAT (available in approximately 5 years)
AEC [kWh/year]:	880	3,031	572	1,970	440	1,516
Performance [kWh/ kg of foodstuff (referred to material proposed by NF AC D 40-003) chilling from +70°C to +3°C in 90 minutes (with the assumption of 1100 chilling cycles per year)]:	0.100	0.187	0.061	0.121	0.050	0.094
Improvement over Base Case (%):	-	-	35	35	50	50

3.12 DESIGN OPTIONS

Identified energy saving potentials for the Base Case Blast Cabinets

	Improvement option	TEC savings compared to base-case (%)	Increase of product price compared to base-case (€)	Payback time (years)
Option 1	High Efficiency Fan Blades	9%	10	0.3
Option 2	Electronic expansion valve	12%	100	1.8
Option 3	Variable speed drive (VSD) compressor	10%	200	5.5
Option 4	Insulation thickness	4%	100	6.9
Option 5	ECM Fan for evaporator	7%	64	1.6
Option 6	R290	5%	200	11.0
Scenario A	1+2+3+4	31%	410	5.1
Scenario B	1+2+3+4+5	36%	450	4.7
Scenario C	1+2+3+4+5+6	39%	650	5.7
Weighted real BAT improvement	As described in Task 5	35%	753	5.9

3.13 BAT AND LLCC

Blast cabinet Base Case – TEC and LCC

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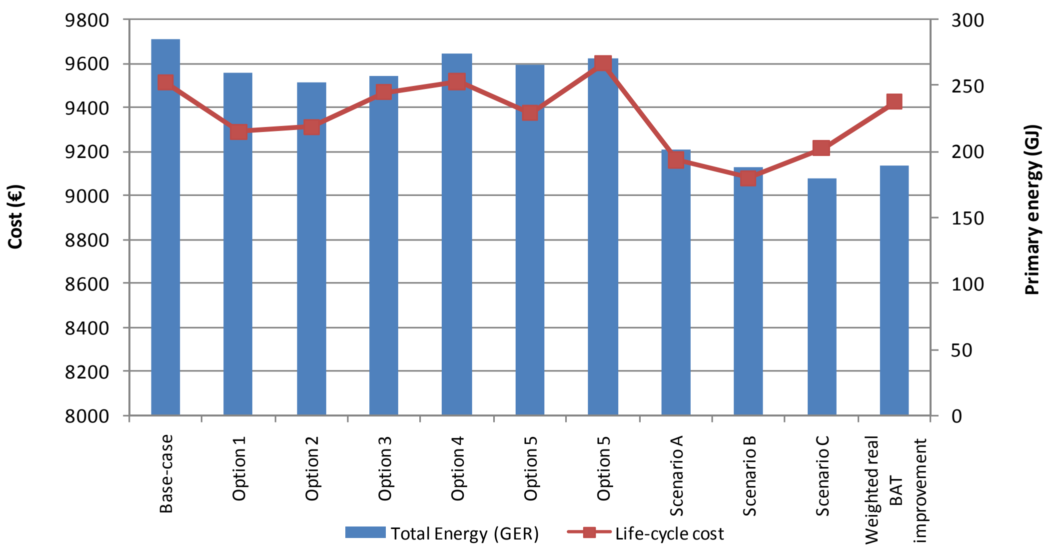

3.14 PROPOSED MEPS

No MEPS for blast cabinets have been identified. One of the issues that must be overcome to properly formulate MEPS is the lack of standards for energy consumption testing as it was specified in Task 1. These standards can take as guidelines the French norm for food safety.

Based on the information from Task 2 and Task 4, it is possible to determine the energy consumption of each category in the market by using conversion factors. Besides, the relation between the average model and BAT model is also shown in Task 4 and Task 5.

Possible MEPS levels could be established following the Least Life Cycle Cost and BNAT options as presented in Task 5 and Task 6. Thus, the proposed MEPS can be lead only to three different levels of energy consumption as described below:

- Short-term: LLCC scenario, leading to a reduction of 37% of the energy consumption, which is assumed to be applicable and achievable in the same measure for all products. This is represented by the combination of different improvement options.
- Long-term: BNAT scenario, leading to a reduction of 50% of energy consumption, which is assumed to be applicable and achievable in the measure for all products. This option integrates additional characteristics to those presented in the LLCC scenario.

Possible MEPS for blast cabinets

Configuration	Operation temperature	Size	Average consumption per year (kWh/year)	Average consumption LLCC per year (kWh/year)	Average consumption BAT per year (kWh/year)	Average consumption BNAT per year (kWh/year)	Total kg processed in a year	Average performance (kWh/kg of foodstuff)	Average performance LLCC (kWh/kg of foodstuff)	Average performance BAT (kWh/kg of foodstuff)	Average performance BNAT (kWh/kg of foodstuff)	MEPS short term (kWh/kg of foodstuff)	MEPS long term (kWh/kg of foodstuff)
Reach-in	Chilling	Small R	528	348	343	264	4,400	0.120	0.079	0.078	0.060	0.066	0.053
		Medium R	880	581	572	440	8,800	0.100	0.066	0.065	0.050		
		Large R	2,112	1,394	1,373	1,056	22,000	0.096	0.063	0.062	0.048		
		Extra-large R	3,344	2,207	2,174	1,672	31,680	0.106	0.070	0.069	0.053		
	Freezing	Small	660	436	429	330	2,200	0.300	0.198	0.195	0.150	0.166	0.132
		Medium	1,100	726	715	550	4,400	0.250	0.165	0.163	0.125		
		Large	2,640	1,742	1,716	1,320	11,000	0.240	0.158	0.156	0.120		
		Extra-large	4,180	2,759	2,717	2,090	15,840	0.264	0.174	0.172	0.132		
	Chilling / Freezing*	Small	924	610	601	462	4,400	0.210	0.139	0.137	0.105	0.116	0.092
		Medium	1,540	1,016	1,001	770	8,800	0.175	0.116	0.114	0.088		
		Large	3,696	2,439	2,402	1,848	22,000	0.168	0.111	0.109	0.084		
		Extra-large	5,852	3,862	3,804	2,926	31,680	0.185	0.122	0.120	0.092		
Roll-in (trolley)	Chilling	Small	4,148	2,738	2,696	2,074	35,200	0.118	0.078	0.077	0.059	0.074	0.059
		Medium	6,219	4,105	4,042	3,110	52,800	0.118	0.078	0.077	0.059		
		Large	10,102	6,668	6,567	5,051	85,800	0.118	0.078	0.077	0.059		
	Freezing	Small	5,185	3,422	3,370	2,593	17,600	0.295	0.194	0.191	0.147	0.186	0.147
		Medium	7,774	5,131	5,053	3,887	26,400	0.294	0.194	0.191	0.147		
		Large	12,628	8,334	8,208	6,314	42,900	0.294	0.194	0.191	0.147		
	Chilling/ Freezing*	Small	7,259	4,791	4,718	3,630	35,200	0.206	0.136	0.134	0.103	0.130	0.103
		Medium	10,883	7,183	7,074	5,442	52,800	0.206	0.136	0.134	0.103		
		Large	17,679	11,668	11,491	8,840	85,800	0.206	0.136	0.134	0.103		
Pass-through	Chilling	Small	4,148	2,738	2,696	2,074	35,200	0.118	0.078	0.077	0.059	0.074	0.059
		Medium	6,219	4,105	4,042	3,110	52,800	0.118	0.078	0.077	0.059		
		Large	10,102	6,668	6,567	5,051	85,800	0.118	0.078	0.077	0.059		
	Freezing	Small	5,185	3,422	3,370	2,593	17,600	0.295	0.194	0.191	0.147	0.186	0.147
		Medium	7,774	5,131	5,053	3,887	26,400	0.294	0.194	0.191	0.147		
		Large	12,628	8,334	8,208	6,314	42,900	0.294	0.194	0.191	0.147		
	Chilling/ Freezing*	Small	7,259	4,791	4,718	3,630	35,200	0.206	0.136	0.134	0.103	0.130	0.103
		Medium	10,883	7,183	7,074	5,442	52,800	0.206	0.136	0.134	0.103		
		Large	17,679	11,668	11,491	8,840	85,800	0.206	0.136	0.134	0.103		

It is proposed that there be mandatory declaration of energy consumption at standard conditions, be enforced to provide consumers with a basis for product comparison.

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4. Summary of data for walk-in cold rooms

Please find the following relevant sections throughout the tasks:

Walk-in cold rooms			
Key section	Title	Document	Page
§ 1.2.3.1	Product definition, first classification and description	Task 1	33
§ 1.3.3	Existing standards for walk-in cold rooms	Task 1	75
§ 1.4.3	Existing legislation and voluntary measures	Task 1	123
§ 2.4.1.1	Estimated sales	Task 2	14
§ 2.4.1.2	Estimated CAGR (annual growth of the market)	Task 2	16
§ 2.4.2	Estimated installed base	Task 2	17
§ 2.6.1.3	Average consumer prices	Task 2	38
§ 3.5.1	Usage patterns	Task 3	9
§ 4.7.3	Technical description of the typical product	Task 4	68
§ 4.8.3	Technical specifications of the Weighted Base Case	Task 4	87
Table 4-71	Technical specifications of the Real Base Case	Task 5	146
§ 4.10.3	Impact analysis from Ecoreport for the Weighted Base Case (per functional unit)	Task 4	112
Annex 4-5	Full results of Ecoreport	Task 4	174
§ 5.3.3	Applicability of best available techniques to the real product	Task 5	84
§ 5.4.3	Specifications of the BAT model	Task 5	96
§ 5.5.1.3	Specifications of the BNAT model	Task 5	109
§ 5.6	Base Case model/BAT/BNAT comparison (summary)	Task 5	113
§ 6.2.3	Design options	Task 6	15
§ 6.3.3	BAT and LLCC analysis	Task 6	37
§ 7.2.3.4	Proposed minimum standards	Task 7	39 and 40

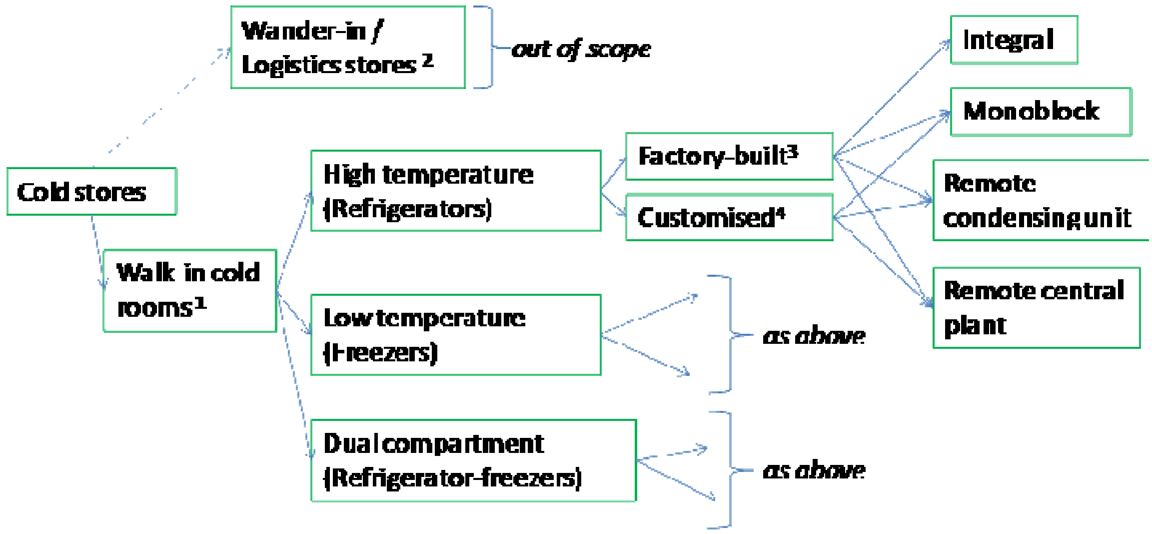
1.3 DEFINITION

According to the definition provided in the International Dictionary of Refrigeration, a cold room is a room or cabinet maintained by a refrigerating system at a temperature lower than ambient temperature. Walk-in cold rooms are insulated rooms that provide refrigerated storage for a variety of items (mainly foodstuff, but also flowers, etc.). They may exist solely as refrigerators or freezers, or a refrigerator-freezer combination

1.4 CLASSIFICATION

Larger walk-in cold rooms are typically bespoke projects constructed in-situ with component parts from various sources to match the specifications of the end-user (henceforth termed "customised"), while smaller rooms are typically constructed from pre-fabricated insulated enclosures (henceforth termed "factory-built").

The following classification, adapted from those above and informed by stakeholder feedback, is proposed for walk-in cold rooms.



1 – Products up to 400m³ designed for indoor applications
2 – Cold stores above 400m³ in size, or those forming part of a building, or those as a stand-alone external building, or those incorporating loading bays are not covered in ENTR Lot 1
3 – Products that are pre-designed and supplied in modular series
4 – Designed and constructed by specialist installers

Walk-in cold rooms size categorization

Equipment type	Size (m^3)
Small	< 20
Medium	20 < 100
Large	100 < 400

There are three main options for the refrigeration system configuration: packaged, remote condensing unit and remote central plant.

There are certain products that are excluded from the scope, including products designed and marketed exclusively for medical, scientific, or research purposes; due to tighter temperature control requirement they have a different functionality, which will have an impact on testing and energy consumption. The scope covers only "walk-in" products and not cold stores (which are more complex constructions). Large systems over 400m² are therefore excluded; there would be smaller cold air spill from the product when its door is opened and there are likely to be other heat loads such as vehicle loading bays. Those products incorporated into a building are excluded (apart from cold storage building kits) as they are already covered by existing regulations and are a not similar type of product.

1.5 FUNCTION AND PERFORMANCE

Function unit: m^3 of net volume maintained at storage temperature. .
Primary performance parameter: kWh/m^3 net volume at storage temperature/year. .

1.6 CURRENT TEST STANDARDS

AHRI 1251 (SI) can be used currently to evaluate the performance of walk-in cold rooms, and a development of a more comprehensive test standard, in parallel to the US DOE proposal, should be considered. Computerised modelling may be an alternate route to assessing performance, but this approach has been dropped by the DOE.

In terms of individual components, ETAG 021 specifies standards to be taken into account when designing the insulating enclosure of walk-in cold rooms, including thermal performance, thermal resistance, air permeability, water vapour permeability and thermal inertia. For the insulating panels, EN 14509:2006 (itself referencing EN 13165) is the reference standard for calculating the aged thermal performance of insulation material. For the evaluation refrigeration systems (to be connected to insulated enclosures), standards described within other product sections are also relevant. These include EN 327 for packaged systems, and EN 13771 and EN 13215 for remote condensing systems. Another example of refrigeration system testing (for cellar coolers) is provided by PAS 57. The ATP agreement provides an example of methods to test an insulated enclosure and refrigeration system as a whole product, and also testing and matching of these two elements of a refrigerated cold storage space as separate components.

1.7 CURRENT EU LEGISLATION AND INITIATIVES

Equipment	EU	US	Canada	Australia / New Zealand
Walk-in cold rooms	-	MEPS: US CEC minimum component requirements	N/A	N/A

A test standard is under development by the US DOE, and MEPS are due to be defined in around 2013 (3 years after final rule on testing standards is made).

1.8 MARKET DATA

Estimated sales of walk-in cold rooms and forecast until 2020 in EU (units):

Product type	1990	2006	2007	2008	2012	2020	2025
Walk-in cold rooms	73,481	87,926	88,052	88,289	91,059	99,230	103,522

Estimated stock of walk-in cold rooms and forecast until 2020 in EU (units):

Product type	1990	2006	2007	2008	2012	2020	2025
Walk-in cold rooms	1,122,444	1,491,948	1,507,074	1,521,659	1,578,022	1,690,370	1,785,024

Price ranges of walk-in cold rooms according to the storage volume

Size	Storage volume (m^3)	Approximate price ranges (€) ex VAT
Small	Up to 20	2,000 – 7,000
Medium	20 to 100	7,000 – N/A
Large	100 to 400	N/A
Average[8]	*27*	*8,800*

N/A: data not found

1.9 WEIGHTED BASE CASE ENVIRONMENTAL AND ECONOMIC IMPACT ASSESSMENT

METHODOLOGY: the Base Case used for the environmental analysis is based on a partial Bills of Material obtained for a $25m^3$ walk-in cold room enclosure, in addition to an extrapolated Bill of Materials for a monoblock (packaged) refrigeration unit of correct specifications to supply the $25m^3$ cold room. Results have then been extrapolated through a weighting based on the market shares and estimated energy consumptions and other factors for the different configurations of walk-in cold rooms, as described in Task 4. This leads to an abstract model, not comparable to any specific product in the market but which is meant to be representative of the market: it is used to provide inputs to the EcoReport analysis tool, whose outputs are useful as a statistical calculation of overall EU market impacts. The characteristics described below for these weighted Base Cases are those essential for the EcoReport assessment.

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1.10 IMPACT ANALYSIS FROM ECOREPORT

<u>Main impacts (per product)</u>

EcoReport LCA analysis results for walk-in cold rooms – lifecycle impacts per functional unit per year – Weighted Base Case

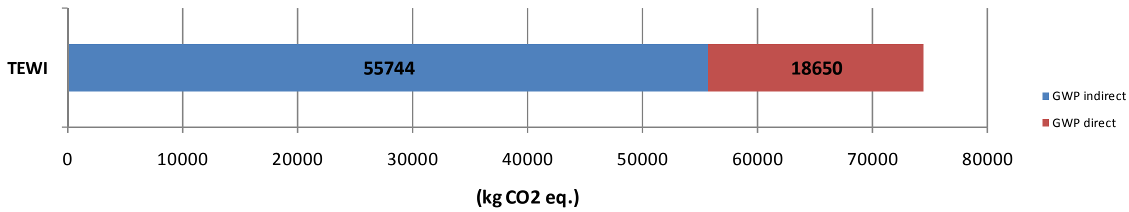
Impact indicator	Impact per m3 of capacity at 2°C per year
Total Energy (GER) (MJ)	5901.34
of which, electricity (in primary MJ)	5546.00
Use-phase electricity consumption (kWh)	562.03
Water (process) (ltr)	594.43
Waste, non-haz./ landfill (g)	14053.99
Waste, hazardous/ incinerated (g)	481.40

[8] Defra MTP, based on an evaluation of the UK market

Impact indicator	Impact per m3 of capacity at 2°C per year
Greenhouse Gases in GWP100 (kg CO2 eq.)	346.23
4Acidification, emissions (g SO2 eq.)	1771.66
Volatile Organic Compounds (VOC) (g)	4.18
Persistent Organic Pollutants (POP) (ng i-Teq)	129.18
Heavy Metals (mg Ni eq.)	3280.65
PAHs (mg Ni eq.)	32.06
Particulate Matter (PM, dust) (g)	318.50
Heavy Metals (mg Hg/20)	317.35
Eutrophication (g PO4)	21.02

The environmental impacts of the blast cabinets at different life phases are represented below. Use phase and production material are the two phases with the biggest impact. Almost 100% of the electricity consumed during the life-time of this equipment is related to the use-phase, which in terms of Total Energy becomes around 95%.

EcoReport LCA analysis results for walk-in cold rooms - Life cycle Total Equivalent Warming Impact (TEWI)



EcoReport LCA analysis results for walk-in cold rooms - Life Cycle Cost breakdown per unit and total annual consumer expenditure

Walk-in cold room	LCC new product		total annual consumer expenditure in EU25	
Item				
Product price	8800	€	777	mln.€
Installation/ acquisition costs (if any)	880 1760		€ 155	
Fuel (gas, oil, wood)	0	€	0	mln.€
Electricity	11830	€	2286	mln.€
Water	0	€	0	mln.€
Aux. 1: None	0	€	0	mln.€
Aux. 2 :None	0	€	0	mln.€
Aux. 3: None	0	€	0	mln.€
Repair & maintenance costs	714	€	134	mln.€
Total	**23104**	€	**3352**	mln.€

Main impacts (EU wide)

EcoReport LCA analysis results for walk-in cold rooms - environmental impacts of stock

		TOTAL
Other Resources & Waste		
Total Energy (GER)	PJ	217.72
Total use-phase electricity consumption	TWh	19.98
Water (process)	mln. m3	18.99
Water (cooling)	mln. m3	541.71
Waste, non-haz./ landfill	kt	412.81
Waste, hazardous/ incinerated	kt	12.64
Emissions (Air)		
Greenhouse Gases in GWP100	mt CO2 eq.	11.46
Ozone Depletion, emissions	t R-11 eq.	0.00
Acidification, emissions	kt SO2 eq.	61.67
Volatile Organic Compounds (VOC)	kt	0.13
Persistent Organic Pollutants (POP)	g i-Teq	3.44
Heavy Metals	ton Ni eq.	74.45
PAHs	ton Ni eq.	0.88
Particulate Matter (PM, dust)	kt	7.52
Emissions (Water)		0.00
Heavy Metals	ton Hg/20	7.62
Eutrophication	kt PO4	0.47
Persistent Organic Pollutants (POP)	g i-Teq	0.00

1.11 SUB-BASE CASE AND BAT TECHNICAL SPECIFICATIONS

The weighted Base Cases have been developed from one or two sub-Base Cases, and these sub-Base Cases are comparable to the most common product configuration on the market. The sub-Base Cases are necessary in order to have real product characteristics from which to extrapolate the weighted models, and also to compare against BAT.

Technical characteristics of the walk-in cold rooms sub-Base Case.

Product characteristics	Estimated Base Case	Estimated BAT
Product type/model/design:	Factory-built	Packaged refrigeration unit
Location of condensing unit:	Packaged	Packaged
Test standard:	-	-
Internal cold storage temperature [°C]:	+2°C	+2°C
Internal cold storage temperature range(s) (°C):	+1°C to +4°C	+1°C to +4°C
Air-on temperature (ambient temperature) [°C]:	+32°C	+32°C
Net internal volume [m³]:	25	25
Condensing unit function [hours/day]:	16hrs to 18hrs condensing unit (on/off)	16hrs to 18hrs condensing unit (on/off)
Product use pattern [hours/year]:	8,760	8,760
Functional unit:	m³ of net internal volume at	m³ of net internal volume at

Product characteristics	Estimated Base Case	Estimated BAT
	+2°C	+2°C
Power input [kW]:	2	0.95
Cooling capacity [kW]:	2.1	2.1
COP:	1.5	2
AEC [kWh/year]:	10,570	6,870
TEC [kW/48hrs]:	58	38
Performance [kWh/m³ at 2°C/year]:	423	275
Price (ex VAT) [€]:	8,800	10,560
Lifetime [years]:	10	12
Refrigerant:	R404A	R134a for HT/R410A for LT
Refrigerant charge [g]:	2,400	2,040
Refrigerant leakage [% per annum]:	5	5
Defrost type [natural/electric/hot gas/cool gas]:	*N.A.*	*N.A.*
Defrost control (if applicable) [timed/off-cycle/on-demand]:	*N.A.*	*N.A.*
Anti-condensation (if applicable):	*N.A.*	*N.A.*
Expansion valve type:	*N.A.*	*N.A.*
Other features not covered above:	-	-
Weight of product [kg]:	1,000	*N.A.*
External height [cm] :	232	*N.A.*
External width [cm] :	362	*N.A.*
External depth [cm] :	342	*N.A.*
Gross total (shipping) volume [m3] :	29	*N.A.*
Number of compressors:	1	1
Type of compressor:	Hermetic reciprocating	Hermetic reciprocating
Power of compressor [W]:	*N.A.*	*N.A.*
Capacity of compressor [W]:	*N.A.*	*N.A.*
Weight of compressor [kg]:	*N.A.*	*N.A.*
Compressor motor control [none/two-speed/VSD]:	Not applicable	*N.A.*
Evaporator heat exchanger type and material:	Fin and tube	Fin and tube
Evaporator face area [cm²]:	*N.A.*	*N.A.*
Evaporator fan motor type:	Shaded pole axial	ECM
Evaporator fan motor power [W]:	*N.A.*	*N.A.*
Evaporator fan motor control [none/two-speed/VSD]:	None	None
Weight of evaporator module [kg]:	*N.A.*	*N.A.*
Condenser cooling:	Air-cooled	Air-cooled
Condenser heat exchanger type and material:	Fin and tube	Fin and tube
Condenser face area [cm²]:	*N.A.*	*N.A.*
Condenser fan motor type:	Shaded pole axial	ECM
Condenser fan motor power [W]:	*N.A.*	*N.A.*
Condenser fan motor control	None	None

Product characteristics	Estimated Base Case	Estimated BAT
[none/two-speed/VSD]:		
Weight of condenser module [kg]:	*N.A.*	*N.A.*
Number of doors:	1	1
Type of door	Hinged; 800x1900mm	Sliding; 800x1900mm
Strip door curtains	None	Yes
Insulation type:	Polyurethane	Polyurethane
Insulation thickness [mm]:	80	180
Foaming agent:	Cyclo-Pentan/Isopentane	Cyclo-Pentan/Isopentane
Lighting type [incandescent/fluorescent/LED]:	Incendescent	LED
Lighting power [W]:	80	*N.A.*

**Due to no current measurement standard for walk-in cold rooms and no information provided on annual electricity consumption, TEC is based on expert assumption*

1.12 IMPROVEMENT POTENTIAL

The table below presents the improvement options, estimates of their current market penetration, their energy saving potential and cost.

Improvement options

	Applicability (years)	Market penetration (%)	Savings (% TEC)	Increase in price of product (€)	Priority
Strip door curtains	Now	60	13	70	1
Auto door closer	Now	N.A.	12	111	2
PSC evaporator fan	Now	N.A.	10	100	3
ECM evaporator fan	Now	N.A.	13	150	4
High efficiency fan blades	Now	N.A.	3	50	5=
Insulation thickness	Now	N.A.	15	250	5=
ECM condenser fan	Now	N.A.	3	60	8
High efficiency LED light bulbs	Now	N.A.	4	200	12
R134a to replace R404A at HT, and R410A to replace R404A at LT	Now	N.A.	0**	0	9
Floating head pressure (plus electronic expansion valve) HighCap	Now	1	8	150	7
Ambient subcooling	Now	N.A.	4	170	11
High efficiency compressor* HighCap	Now	N.A.	5	200	10
Anti-condensation control	Now	N.A.	3	370	13
Defrost control	Now	0	3***	108	14
VSD compressor HighCap	Now	N.A.	15	N.A.	15
ECM compressor HighCap	Now	N.A.	4	N.A.	16
Zeolite filter cassettes	Now	N.A.	25	650	17
R290	Now	N.A.	N.A.**	N.A.	18
BNAT					
Hot gas defrost	2 to 3	N.A.	4***	81	1
Hot gas anti-condensation	2 to 3	N.A.	13***	323	2
Fan motor control	2 to 3	0	3	N.A.	3
R744	Now	N.A.	N.A.**	N.A.	6

**Selected from technologies related to the component*
***The benefit of this improvement is also the lower GWP of the refrigerant*
****Applicable to low temperature only*
N.A.: Data not available
Note: Savings are not additive.

This table includes improvement options for which relevant information was found.

It is assumed that the best available walk-in cold room within next 5 years will achieve energy savings of 69% using the following:

Product characteristics	BNAT model

Product characteristics	BNAT model
Product type/model/design:	Factory-built
Location of condensing unit:	Packaged
Test standard:	-
Internal cold storage temperature [°C]:	+2°C
Net internal volume [m³]:	25
Product use pattern [hours/year]:	8,760
Functional unit:	m³ of net internal volume at +2°C
AEC [kWh/year]:	3,277
Performance [kWh/m³ at 2°C/year]:	131
Lifetime [years]:	18
Refrigerant:	Low GWP*
Compressor:	VSD ECM
Expansion device:	EEV
Evaporator:	ECM with efficient fan blades and improved heat exchanger
Condenser:	ECM with efficient fan blades and improved heat exchanger
Defrost :	Hot gas, controlled
Anti-condensation heaters :	Hot gas, controlled
Lighting:	LED
Insulation:	+25% thickness PUR
Other:	Strip door curtain and auto door closer; floating head pressure and ambient subcooling

*For example: R717, or an un-saturated HFC – for the purposes of modelling R717 has been used

The following approximate energy savings potentials have been gathered:

1.13 BASE CASE/BAT/BNAT COMPARISON

Energy consumption, performance and refrigerants for walk-in cold rooms BOM, BAT and BNAT

		Base Case model	Weighted Base Case	Current available BAT model	Weighted current available BAT	Theoretical BNAT product model (available in approximately 5 years)	Weighted theoretical BNAT (available in approximately 5 years)
Walk-in cold room	AEC [kWh/year]:	10,570	12,155	6,870	7,901	3,277	3,768
	Performance [kWh/m³ net internal volume at storage temperature/year]:	423**	486	275	316	131	151
	Improvement over Base Case (%):	-	-	35	35	69	69

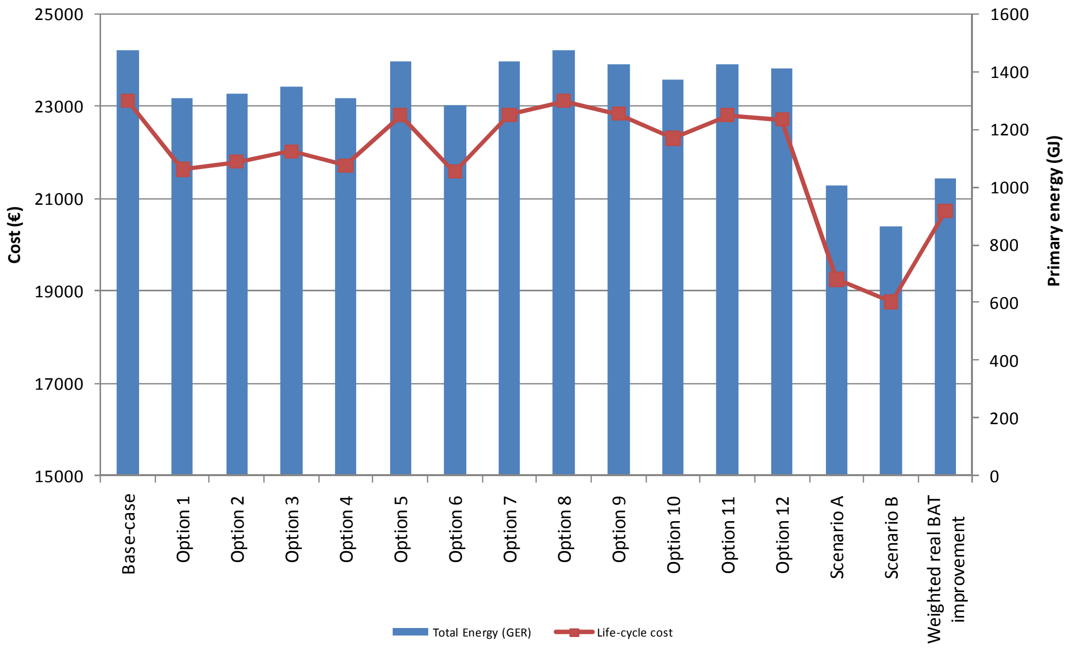
1.14 DESIGN OPTIONS

Identified energy saving potentials for the walk-in cold room Base Case.

	Improvement option	TEC savings compared to Base Case (%)	Increase of product price compared to Base Case (€)	Payback time (years)
Option 1	Strip door curtains	13%	70	0.37
Option 2	Auto door closer	12%	111	0.63
Option 3	PSC evaporator fan	10%	100	0.69
Option 4	ECM evaporator fan	13%	150	0.79
Option 5	High efficiency fan blades	3%	50	1.14
Option 6	Insulation thickness	15%	250	1.14
Option 7	ECM condenser fan	3%	60	1.37
Option 8	R134a to replace R404a at HT, and R410a to replace R404a at LT	0%	0	0.00
Option 9	High efficiency LED light bulbs	4%	200	3.43
Option 10	Floating head pressure (plus electronic expansion valve)	8%	150	1.29
Option 11	Ambient subcooling	4%	170	2.91
Option 12	High efficiency compressor	5%	200	2.74
Scenario A	Incorporates options 1+3+5+6+7	37%	530	0.98
Scenario B	Incorporates all options 2+4+5 to 12	48%	1,341	1.92
Weighted real BAT improvement	As described in Task 5, this product includes R134a/R410a	35%	1,760	3.45

1.15 BAT AND LLCC

Walk-in cold room Base Case – TEC and



LCC

1.16 PROPOSED POLICY APPROACHES

Options for regulation

When considering approaches for regulation to take into account of the issues discussed above, it is valuable to consider the range of regulatory options available to support the approach.

These options are:

- Requirements for harmonised standards to be developed;
- product measurement requirements, including test standards and methods;
- minimum requirements;
- labelling/ benchmark categories;
- self-regulation;
- requirements on installation of the product; and/or
- requirements for the provision of information to the customer/user.

Recommendations:

Harmonised standards

The first recommendation would be the harmonisation of standards to test the performance of the walk-in cold room components, and subsequently for evaluation of their energy performance, as described in Task 7.

Certification

The certification framework for this component approach would have combined component and installer responsibility is set out in the US DOE final rule. In summary, the responsibility for compliance extends to both component manufacturer and assembler. Component manufacturers are responsible for certifying compliance of the components to be used for walk-in cold rooms, while assemblers of the complete walk-in cold room are required to use only certified components (the component manufacturer is not responsible for the end-users implementation of the component – only of the components compliance as designed). Characteristics and performance measured would need to be documented, along with description of test conditions and/or calculations. Ensuring that the final product is CE marked would be the responsibility of the actor placing the product on the market (whether sold directly to end-user or through a third party such as a wholesaler), although the testing of the component(s) or the refrigeration system could be carried out by a separate manufacturer in the supply chain.

Provision of standard documentation to consumers by manufacture (or designer) placing the product on the market should be enforced, covering component types and performance levels in respect to the minimum requirements set out.

In addition, it is proposed that a basic model at the component is permitted, as is the case for both ETAG 021 and US DOE. In essence this allows products to be grouped, under the understanding that the documented performance is that of the "worst" possible performance (or most onerous component tested) and hence that any product under the basic model should meet the certified performance when tested. Hence changes to parameters such as the thickness of the insulating material would need to be taken into account.

Short-term requirements

The short-term performance standards set out for RCUs would apply to those used for walk-in cold rooms.

In addition, minimum requirements for components, providing a basic level of performance that covers all products sold on the market, should be enforced; the following requirements are proposed:

- strip-door curtains (or other device or structure designed to reduce ingress of ambient air into the refrigerated space);
- wall, ceiling, and door insulation of a maximum U value (U ≤ 0.25 W/m^2.K for storage spaces above 0°C and U ≤ 0.2 W/m^2.K for products with storage at or below 0°C);
- floor insulation of a maximum U value for freezers (U ≤ 0.2 W/m^2.K);

- solid doors of maximum U value (U ≤ 1.0 W/m^2.K);
- fully transparent doors and display panels of maximum U value (U ≤ 1.4 W/m^2.K); and
- banning of shaded pole motors, hence use of PSC or ECM motors only, for fans in condensing and evaporating units (or, when a harmonised test procedure be developed, motors with an equivalent efficiency).

It is estimated that application of these will enable a reduction in consumption of an average of approximately 24% using the improvement option saving levels, as the minimum requirements set out above being equivalent to options 1, 3 and 7 analysed in Task 6, hence this figure and the equivalent costs for these options are used for evaluation of this policy recommendation.

Long-term requirements

The long-term performance standards set out for would apply to those used for walk-in cold rooms.

In addition, the following are suggested minimum requirements to be considered for enforcement in the long-term. It is recommended that these be reassessed at the time of implementation of the short-term targets, in order that they take into account the performance data that will have been gathered, as well as the technological state of the art.

The following requirements are tentatively proposed:

- slam-type doors to reduce ingress of ambient air into the refrigerated space;
- automatic door closers to fully close doors left ajar;
- wall, ceiling, and door insulation of a maximum U value (U ≤ 0.2 W/m^2.K for storage spaces above 0°C and U ≤ 0.15 W/m^2.K for products with storage at or below 0°C);
- floor insulation of a maximum U value for freezers (U ≤ 0.15 W/m^2.K);
- floor insulation of a maximum U value for refrigerators (U ≤ 0.2 W/m^2.K);
- solid doors of maximum U value (U ≤ 0.75 W/m^2.K); and
- fully transparent doors and display panels of maximum U value (U ≤ 1.1 W/m^2.K).

It is estimated that these and minimum requirements will enable a reduction in consumption of an average of approximately 50%, the equivalent to the sum of all improvement options analysed in Task 6 (apart from Option 3 due to overlap with ECM evaporator motor), hence this figure is used for evaluation of this policy recommendation.

Setting minimum COP levels for the refrigeration systems at respective operation conditions will also be important, once harmonised test procedures provide comparable performance data. MEPS may also be set in future, calculated via the estimation of component energy consumptions.

Design standards

The use of hot box testing of the panels and doors will account for thermal performance of the components. In addition, there are aspects of design that could be considered best practice.

In terms of matching refrigeration cooling capacity to walk-in cold room loads, the AHRI 1251 box load calculation provides an indication of best practice. For example, the high loading point is a function of the cooling capacity of the refrigeration system at specific temperatures, being 0.7 times the cooling capacity for a cooler at +32°C ambient, and 0.8 cooling capacity for a freezer at +32°C ambient. Hence, the U-factors for panels, doors and electronic components at the respective temperatures can be summed for the relevant size of the walk-in cold room, and the relevant refrigeration capacity calculated. Therefore required cooling capacity for a refrigerator is the heat load from the box, multiplied by the inverse of 0.7, and for a freezer the heat load of its box multiplied by the inverse of 0.8.

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5. Summary of data for chillers

Please find the following relevant sections throughout the tasks:

Process chillers			
Key section	Title	Document	Page
§ 1.2.4.1	Product definition, first classification and description	Task 1	40
§ 1.34	Existing standards for chillers	Task 1	94
§ 1.4.4	Existing legislation and voluntary measures	Task 1	131
§ 2.4.1.1	Estimated sales	Task 2	14
§ 2.4.1.2	Estimated CAGR (annual growth of the market)	Task 2	16
§ 2.4.2	Estimated installed base	Task 2	17
§ 2.6.1.4	Average consumer prices	Task 2	38
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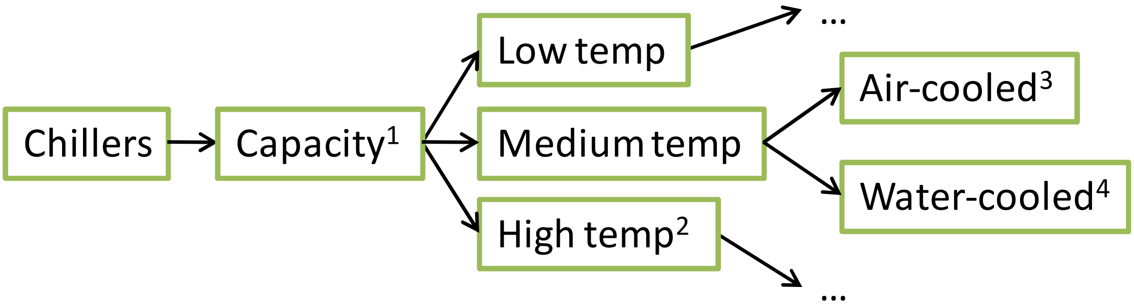
§ 4.7.4	Technical description of the typical product	Task 4	75
§ 4.8.4	Technical specifications of the Weighted Base Case	Task 4	88
Table 4.-72	Technical specifications of the Real Base Case	Task 5	148
§ 4.10.4	Impact analysis from Ecoreport for weighted Base Case per functional unit	Task 4	120
Annex 4-6	Full results of Ecoreport	Task 4	180
§ 5.3.4	Applicability of best available techniques to the real product	Task 5	85
§ 5.4.4	Specifications of the BAT model	Task 5	99
§ 5.5.1.4	Specifications of the BNAT model	Task 5	110
§ 5.6	Base Case model/BAT/BNAT comparison (summary)	Task 5	110
§ 6.2.4	Design options	Task 6	18
§ 6.3.4	BAT and LLCC analysis	Task 6	42
§ 7.2.3.5	Proposed MEPS	Task 7	44 and 45

5.1 DEFINITION

According to the International Dictionary of Refrigeration[9], a chiller is a piece of equipment designed to cool water for air-conditioning plants or units in commercial and industrial processes.

In general, a chiller is a refrigerating machine that removes heat from a liquid through vapour compression or absorption cycle. Chillers can be used in wide of applications[10].

5.2 CLASSIFICATION



[1] Capacities considered to be from 15kW to 1000kW. The compressor type will be related to the capacity required
[2] Low temperature: -25°C / -8°C, Medium temperature: -12°C / 3°C, High temperature: 2°C / 15°C
Not considered under the scope of Lot 1, therefore absorption chillers are not considered in the preparatory study. Equipments to be considered by Lot 6
[3] Relevant especially for small capacity equipments
[4] Only relevant for big capacity equipments

5.3 FUNCTION AND PERFORMANCE

Functional unit: cooling capacity, in kW
Performance parameter: Coefficient of Performance (ratio between the cooling capacity and the power input)

5.4 CURRENT TEST STANDARDS

Existing test standards apply only to packaged chiller energy performances when it comes to measuring their efficiency (e.g. EN 14511 part 1 to 4 and CEN TS 14825, AHRI 550/590:2003, CAN/CSA-C743-02).

The existing EU standards for testing of chillers seem to cover the same information as their US equivalents; there is currently no identified need to modify the existing EU

[9] International Institute of Refrigeration. *International Dictionary of Refrigeration*. 2007
[10] Source: http://www.1stchoicechillers.com/products.htm

standards (EN 14511:2007) in light of US standards. However, feedback from stakeholders is anticipated in response to this.

5.5 CURRENT EU LEGISLATION AND INITIATIVES

Equipment	EU	US	Canada	Australia / New Zealand
Process chillers	VEPS: UK ECA[1] EU EUROVENT (A/C only)	N/A	MEPS[3]	MEPS[11]

N/A: No standards found

MEPS have been set in UK, USA, Canada, and Australia. Canada and USA share the same standard of exigency for chillers. These standards are related only to packaged units. All of the values are reported respect COP. The least demanding scheme is the UK ECA, which requires half of the efficiency for equipment then its American equivalent.

The UK ECA scheme and standard AS/NZS 4776:2008 could be used as a model to develop energy performance requirements for Packaged Chillers in EU. Nevertheless, their ranges of classification are different and any approach developed would need to be homogenised. As for all other products within the scope, it is very important to take into account the type of refrigerant for environmental reasons. However, the energetic performance of the equipment is more related to the configuration than the employed refrigerant[12].

5.6 MARKET DATA

Estimated sales of chillers and forecast until 2020 in EU (units)

Product type	1990	2006	2007	2008	2012	2020	2025
Industrial process chillers*	3,491	5,644	6,364	6,441	6,918	8,105	8,949

* *Packaged chillers*

Estimated stock of chillers and forecast until 2020 in EU (units)

Product type	1990	2006	2007	2008	2012	2020	2025
Industrial process chillers*	8,455	76,417	78,707	80,929	89,471	106,442	117,282

* *Packaged chillers*

From stakeholders' comments, the price for end-user is between 200 to 250 Euros per kW of cooling capacity. This price includes manufacturing, installation, and training (if

[11] AU/NZ Minimum Energy Performance Standards

[12] Mark Ellis consultation 2010.

required). According to stakeholders, the estimated price for an average (270kW cooling capacity) chiller is € 60 000, where 15% VAT is not included.

5.7 BASE CASE ENVIRONMENTAL AND ECONOMIC IMPACT ASSESSMENT

METHODOLOGY For each product group, the Base Case used for the environmental analysis is represented by weighted Base Cases, calculated using the market shares of the different configurations and various assumptions on relative energy consumption, material quantities and other factors, as described in Task 4. This leads to an abstract model, not comparable to any specific product in the market, but used to provide inputs to the EcoReport analysis tool, whose outputs are useful as a statistical calculation of overall EU market impacts. The characteristics described below for these weighted Base Cases are those essential for the EcoReport assessment.

5.8 IMPACT ANALYSIS FROM ECOREPORT

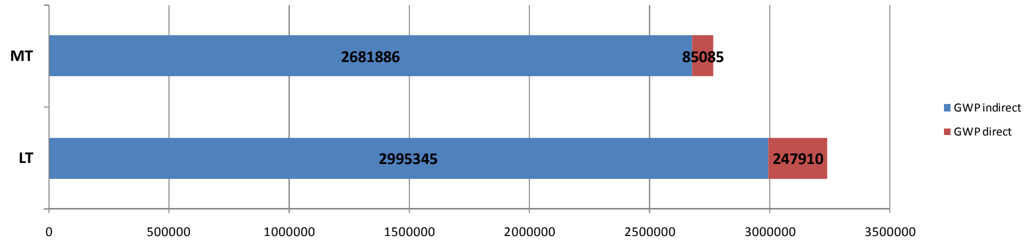
Main impacts (per product)

EcoReport LCA analysis results for chillers – lifecycle impacts per functional unit per year - Weighted Base Case

Impact indicator	Impact per kW of capacity at -8°C per year	Impact per kW of capacity at -18°C per year
Total Energy (GER) (MJ)	14,775.6	20,676.0
of which, electricity (in primary MJ)	14,741.1	20,636.4
electricity (kWh)	1,403.9	1,965.4
Water (process) (ltr)	990.8	1,384.5
Waste, non-haz./ landfill (g)	17,985.4	24,950.1
Waste, hazardous/ incinerated (g)	341.9	478.1
Greenhouse Gases in GWP100 (kg CO2 eq.)	664.5	958.4
Acidification, emissions (g SO2 eq.)	3,811.2	5,331.5
Volatile Organic Compounds (VOC) (g)	5.7	8.0
Persistent Organic Pollutants (POP) (ng i-Teq)	105.3	144.8
Heavy Metals (mg Ni eq.)	280.8	385.1
PAHs (mg Ni eq.)	29.7	41.4
Particulate Matter (PM, dust) (g)	97.6	133.0
Heavy Metals (mg Hg/20)	104.9	144.4
Eutrophication (g PO4)	1.3	1.6

The direct and indirect greenhouse gasses emissions comparison is shown below. The higher GWP for LT products is due to the use of R404a in place of R134a.

EcoReport LCA analysis results for process chillers - Life cycle Total Equivalent Warming Impact (TEWI)



EcoReport LCA analysis results for chillers - Life Cycle Cost breakdown per unit and total annual consumer expenditure

	MT – LCC new product (€)	LT – LCC new product (€)	Total annual consumer expenditure in EU25 (mln €)
Product price	55,000	70,000	361
Installation/acquisition costs	5,500	7,000	36
Electricity	561,628	784,058	5,136
Repair and maintenance costs	4,077	5,189	33
Total	**626,205**	**866,246**	**5,566**

Main impacts (EU wide)

EcoReport LCA analysis results for process chillers - environmental impacts of stock

		Total
Other Resources & Waste		
Total Energy (GER)	PJ	451
of which, electricity (in primary TWh)	TWh	43
Water (process)	mln. m3	30
Water (cooling)	mln. m3	1199
Waste, non-haz./ landfill	kt	546
Waste, hazardous/ incinerated	kt	10
Emissions (Air)		
Greenhouse Gases in GWP100	mt CO2 eq.	21
Ozone Depletion, emissions	t R-11 eq.	0
Acidification, emissions	kt SO2 eq.	116
Volatile Organic Compounds (VOC)	kt	0
Persistent Organic Pollutants (POP)	g i-Teq	3
Heavy Metals	ton Ni eq.	8
PAHs	ton Ni eq.	1
Particulate Matter (PM, dust)	kt	3
Emissions (Water)		
Heavy Metals	ton Hg/20	3
Eutrophication	kt PO4	0
Persistent Organic Pollutants (POP)	g i-Teq	0

5.9 SUB-BASE CASE AND BAT TECHNICAL SPECIFICATIONS

The weighted Base Cases have been developed from one or two sub-Base Cases, and these sub-Base Cases are comparable to the most common product configuration on the market. The sub-Base Cases are necessary in order to have real product characteristics from which to extrapolate the weighted models, and also to compare against BAT.

Technical characteristics of the process chiller sub-Base Cases and BAT

Product characteristics	Sub-Base Case MT	BAT MT	Sub-Base Case LT	BAT LT
Product type/model/design:	Packaged	Packaged	Packaged	Packaged
Location of condensing unit:	Integral (packaged)	Integral (packaged)	Integral (packaged)	Integral (packaged)
Evaporator output temperature [°C]:	-8	-11	-18	-25
Water on [°C]:	+25	+25	+25	+25
Air-on temperature (ambient temperature) [°C]:	30	30	30	30
Water solution [%]:	Ethylene glycol 40%	Ethylene glycol 40%	Ethylene glycol 40%	Ethylene glycol 40%
Condensing unit function [hours/day]:	12	12	12	12
Product use pattern [hours/year]:	4,380	4,380	4,380	4,380
Functional unit:	1 kW cooling capacity to reach -10°C at 30°C ambient temperature	1 kW cooling capacity to reach -10°C at 30°C ambient temperature	1 kW cooling capacity to reach -25°C at 30°C ambient temperature	1 kW cooling capacity to reach -25°C at 30°C ambient temperature
Power input [kW]:	98.8	90	128	94
Cooling capacity [kW]:	276	279	251.95	260.2
Performance [COP]*:	2.80	2.89	1.96	2.1
AEC [kWh/year]:	346,206	315,360	450,068	409,968
Price (ex VAT) [€]:	55,000	82,500	70,000	105,000
Lifetime [years]:	15	15	15	15
Refrigerant:	R134a	R717	R404A	R717
Refrigerant charge [g]:	100	26	250	32
Refrigerant leakage [% per annum]:	1	1	1	1
Expansion valve type:	Thermostatic	Electronic	Thermostatic	Electronic
Weight of product [kg]:	2,757	4,940	3,171	5,681
External height [cm]:	188	260	188	260
External width [cm]:	86	240	86	240
External depth [cm]:	430.5	285	430.5	285
Gross total (shipping) volume [m3]:	11.6	29.6	13.34	29.6
Number of compressors:	2	*2*	2	*N.A.*

Product characteristics	Sub-Base Case MT	BAT MT	Sub-Base Case LT	BAT LT
Type of compressor:	Semi-hermetic screw	Rotary screw	Semi-hermetic screw	*N.A.*
Power of compressor [W]:	*N.A.*	*N.A.*	*N.A.*	*N.A.*
Capacity of compressor [W]:	*N.A.*	*N.A.*	*N.A.*	*N.A.*
Weight of compressor [kg]:	*N.A.*	*N.A.*	*N.A.*	*N.A.*
Compressor motor control [none/two-speed/VSD]:	Included	Included	Included	Included
VSD compressor motor control (if applicable):	Not included	Capacity controller	Not included	*N.A.*
Evaporator heat exchanger type and material:	Stainless steel	Stainless steel	Stainless steel	Stainless steel
Evaporator face area [cm²]:	*N.A.*	*N.A.*	*N.A.*	*N.A.*
Evaporator fan motor type:	*N.A.*	*N.A.*	*N.A.*	*N.A.*
Evaporator fan motor power [W]:	*N.A.*	*N.A.*	*N.A.*	*N.A.*
Evaporator fan motor control [none/two-speed/VSD]:	*N.A.*	*N.A.*	*N.A.*	*N.A.*
Weight of evaporator module [kg]:	*N.A.*	*N.A.*	*N.A.*	*N.A.*
Condenser cooling:	Water-cooled	Water-cooled	Water-cooled	Water-cooled
Condenser heat exchanger type and material:	Shell-tube / stainless steel	Semi-welded	Shell-tube / stainless steel	Shell-tube
Condenser face area [cm²]:	*N.A.*	*N.A.*	*N.A.*	*N.A.*
Condenser fan motor type:	*N.A.*	*N.A.*	*N.A.*	*N.A.*
Condenser fan motor power [W]:	*N.A.*	*N.A.*	*N.A.*	*N.A.*
Condenser fan motor control [none/two-speed/VSD]:	*N.A.*	*N.A.*	*N.A.*	*N.A.*
Weight of condenser module [kg]:	*N.A.*	*N.A.*	*N.A.*	*N.A.*

*COP: Ratio between cooling capacity and power input. Measured at 30°C inlet temperature at the condenser.

5.10 IMPROVEMENT POTENTIAL

The table below presents the improvement options, estimates of their current market penetration, their energy saving potential and cost.

Improvement options

	Applicability	Market penetration (%)	Savings MT (% TEC)	Savings LT (% TEC)	Increase in price of MT product (€)	Increase in price of LT product (€)	Priority
Electronic expansion valve	Now	N.A.	5%	5%	1,000	1,000	1
High efficiency compressor*	Now	N.A.	5%	5%	6,000	7,000	6
Improved heat exchangers*	Now	N.A.	15%	15%	11,000	14,000	4
ECM fan condenser**	Now	N.A.	2%	2%	2,200	2,800	5
R290	Now	less than 1	5%	5%	2,750	3,500	3
Ambient subcooling	Now	less than 5	5%	5%	3,000	3,000	2
Economiser	Now	less than 2	10%	15%	N.A.	N.A.	7
R744/R717***	Now	N.A.	30%	30%	N.A.	N.A.	8
BNAT							
HFC 1234yf	2 to 4 years	0	3%	5%	11,000	14,000	1
Energy integration	Now	less than 5	5%	10%	6,000	6,000	2
Vacuum-process technology	Now	less than 1	20%	0%	60,000	-	3

** Including several features within the options for increasing the component efficiency*
*** Only applicable to air-cooled chillers*
**** Changes in the system are required. Integrated with a secondary fluid*
N.A.: Data not available
Note: Savings are not additive.

This table includes improvement options for which relevant information was found.

It is assumed that the best available process chiller within next 5 years will achieve energy savings of 20 to 50% using the following:

Product characteristics	CH BNAT MT	CH BNAT LT
Product type/design:	Packaged	Packaged
Functional unit:	1 kW cooling capacity to reach -10°C at 30°C water temperature	1 kW cooling capacity to reach -15°C at 30°C water temperature
Cooling capacity [kW]:	265.98	265.20
Power input [kW]:	68	116

Product characteristics	CH BNAT MT	CH BNAT LT
Performance [COP]*:	3.88	2.29
Annual electricity consumption [kWh/year]:	214,682	346,719
Use pattern [hours/year]:	4,380	4,380
Evaporator output temperature [°C]:	-8	-8
Water solution [%]:	Ethylene glycol 40%	Ethylene glycol 40%
Input condenser temperature [°C]:	30	30
Refrigerant:	Low GWP**	Low GWP**
Number of compressors:	2	2
Compressor:	VSD	VSD
Condenser:	ECM fan with more efficient blades and improved heat exchanger	ECM fan with more efficient blades and improved heat exchanger
Evaporator:	Flooded (pool boiling)	Flooded (pool boiling)
Vacuum-process technology:	Included	Included
Other:	Energy integration	Energy integration

**COP: Coefficient of Performance calculated as cooling capacity divided by power input*

***For example: R717, or an un-saturated HFC – for the purposes of modelling R717 has been used*

5.11 BASE CASE/BAT/BNAT COMPARISON

Energy consumption, performance and refrigerants for chiller BOM, BAT and BNAT

		Base Case model	Weighted Base Case	Current available BAT model	Weighted current available BAT	Theoretical BNAT product model (available in approximately 5 years)	Weighted theoretical BNAT (available in approximately 5 years)
Process chiller MT	AEC [kWh/year]:	338,767	336,192	315,360	305,935	167,141	144,563
	Performance [COP] at -10°C water outlet temperature and 30°C ambient temperature:	2.80	2.71	2.89	2.98	5,28	5,11
	Improvement over Base Case (%):	-	-	10*	10*	60	60
Process chiller LT	AEC [kWh/year]:	467,498	435,789	435,197	396,568	269,822	257,116
	Performance [COP] at -25°C water outlet temperature and 30°C ambient temperature:	1.96	1.93	2.10	2.12	3.16	3,11
	Improvement over Base Case (%):	-	-	10*	10*	35	35

* The low improvement is due to the lack of information available on BAT in the market.

5.12 DESIGN OPTIONS

Identified energy saving potentials for the MT chillers Base Case

	Improvement option	TEC savings compared to base-case (%)	Increase of product price compared to base-case (€)	Payback time (years)
Option 1	Electronic expansion valve*	5%	1,000	0.40
Option 2	High efficiency compressor**	5%	6,000	2.38
Option 3	Improved heat exchange**	15%	11,000	1.45
Option 4	ECM fan condenser***	2%	2,200	2.18
Option 5	R290	5%	2,750	1.09
Scenario A	Option 1+2+3	23%	18,000	1.53
Scenario B	Option 1+2+3+5	27%	20,750	1.51
Weighted real BAT improvement	As described in Task 5	9%	27,500	6.05

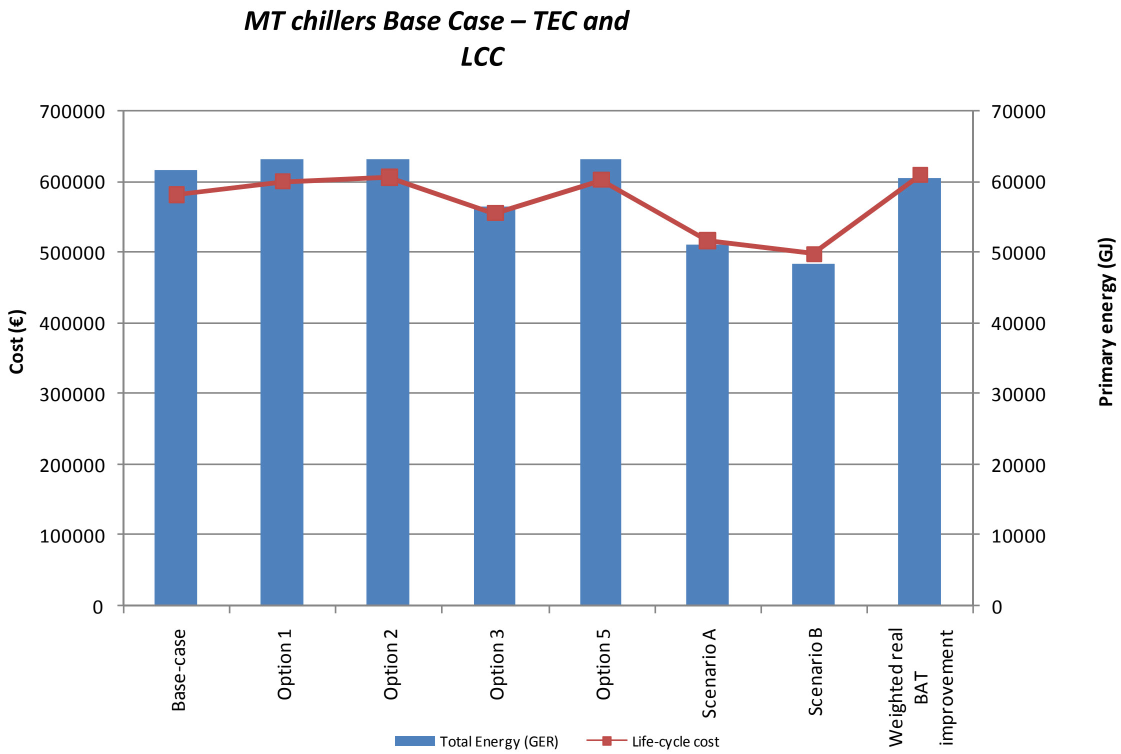
**Savings only applicable to part-load. Energy savings possible, but this options does not change the COP value*
***Including several features within the options for increasing the component efficiency*
****Only applicable to air-cooled chillers. To be considered for the MEPS (see Task 7)*

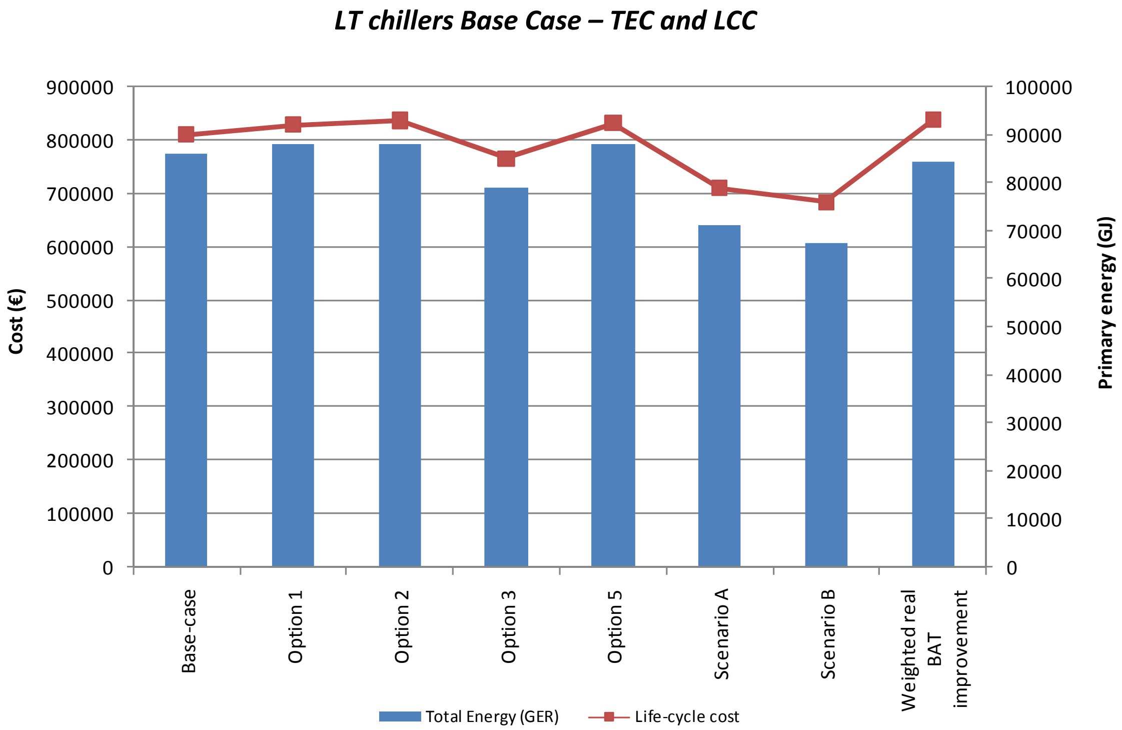
Identified energy saving potentials for the LT chillers Base Case

	Improvement option	TEC savings compared to base-case (%)	Increase of product price compared to base-case (€)	Payback time (years)
Option 1	Electronic expansion valve*	5%	1,000	0.28
Option 2	High efficiency compressor**	5%	7,000	1.99
Option 3	Improved heat exchange**	15%	14,000	1.32
Option 4	ECM fan condenser***	2%	2,800	1.99
Option 5	R290	5%	3,500	0.99
Scenario A	Option 1+2+3+4	23%	22,000	1.34
Scenario B	Option 1+2+3+4+6	27%	25,500	1.33
Weighted real BAT improvement	As described in Task 5	9%	35,000	5.51

**Savings only applicable to part-load. Energy savings possible, but this options does not change the COP value*
***Including several features within the options for increasing the component efficiency*
****Only applicable to air-cooled chillers. To be considered for the MEPS (see Task 7)*

5.13 BAT AND LLCC





5.14 PROPOSED MEPS

The evaluation of the equipment must be done with a single standard, e.g. prEN14825, and taking into account the operation conditions. As the most common equipment for low and medium temperature chillers is water cooled, the reference condenser inlet temperature is fixed at 30°C.

The analysis made in Task 5 and Task 6 regarding the possible improvement options and the potential of improvement for chillers showed that the theoretical BAT correspond to the LLCC escenario for both temperature ranges. Therefore, for process chillers only two energy levels for MEPS will be proposed:

- LLCC/BAT scenario: this short-term energy performance requirement is determined by the LLCC, which provides energy savings equal to 27% for MT and LT process chillers. Nevertheless, the option 1 included in this scenario does not influence the COP value. The expected increase of the COP is 23%.
- BNAT scenario: this would apply in the long term. The possible saving through this scenario are 49% for MT process chillers and 41% for LT process chillers. Nonetheless, similar to LLCC/BAT, the option 1 found in this scenario does not have an impact on the COP value. Hence, the expected COP increase is 43% for MT and 31% for low temperature.

Proposed MEPS for water-cooled low and medium temperature chillers

Applicability	COP*	
	Medium Temperature	Low Temperature
Short-term	2.88	2.05
Long-term	3.88	2.29

*Net cooling capacity (kW)/efective power input (kW), condenser inlet temperature +30°C. Evaportator leaving brine temperature -8°C/-25°C

The impact of the improvement options in air-cooled chillers is assessed taking into account the technologies only applicable for air-cooled on the basis of the MEPS for water-cooled. The water to air energy consumption factors as seen in Task 5 (1.15), and the possibility of using option 4 as seen in Task 5 and Task 6 are the key elements that determine the MEPS. This will lead to an additional increase of 2% COP, but a decrease due to the extra energy required (1:1.15). The values of COP are shown below:

Proposed for air-cooled low and medium temperature chillers

Applicability	COP*	
	Medium Temperature	Low Temperature
Short-term	2.57	1.83
Long-term	3.50	2.05

*Net cooling capacity (kW)/efective power input (kW), condenser inlet temperature +35°C. Evaportator leaving brine temperature -8°C/-25°C

6. Summary of data for remote condensing units

Please find the following relevant sections throughout the working documents:

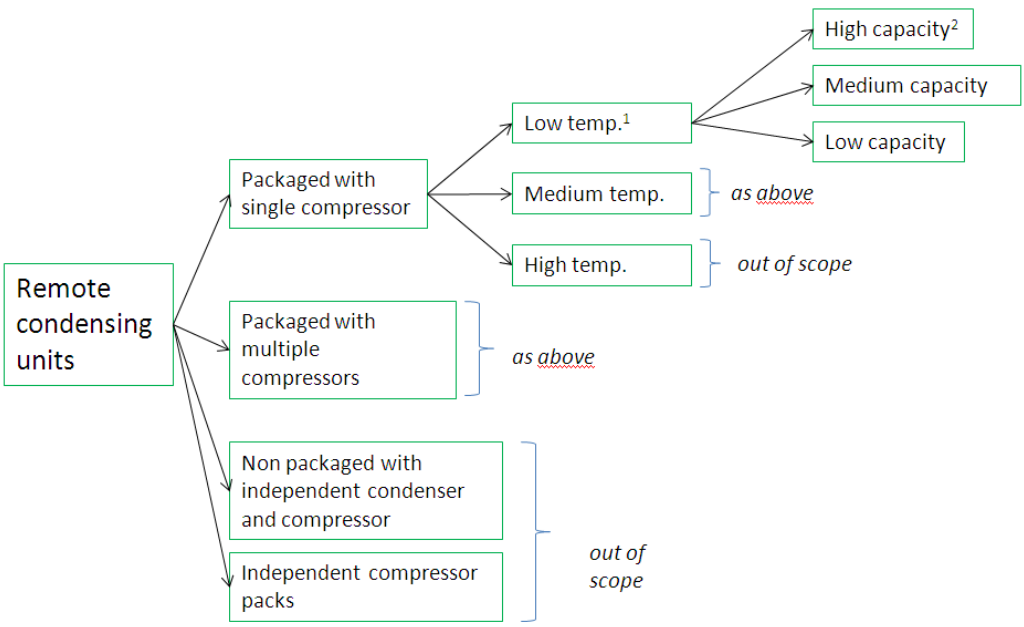
Remote condensing units			
Key section	Title	Document	Page
§ 1.2.5.1	Product definition, first classification and description	Task 1	52
§ 1.3.5	Existing standards for remote condensing units	Task 1	103
§ 1.4.5	Existing legislation and voluntary measures	Task 1	138
§ 2.4.1.1	Estimated sales	Task 2	14
§ 2.4.1.2	Estimated CAGR (annual growth of the market)	Task 2	16
§ 2.4.2	Estimated installed base	Task 2	17
§ 2.6.1.5	Average consumer prices	Task 2	38
§ 3.5.1	Usage patterns	Task 3	9
§ 4.7.5	Technical description of the typical product	Task 4	79
§ 4.8.5	Technical specifications of the Weighted Base Case	Task 4	91
Table 4-73	Technical specifications of the Real Base Case	Task 5	150
§ 4.10.5	Impact analysis from Ecoreport for the Weighted Base Case (per functional unit)	Task 4	128
Annex 4-6	Full results of Ecoreport	Task 4	180
§ 5.3.5	Applicability of best available techniques to the real product	Task 5	86
§ 5.4.5	Specifications of the BAT model	Task 5	102
§ 5.5.1.5	Specifications of the BNAT model	Task 5	111
§ 5.6	Base Case model/BAT/BNAT comparison (summary)	Task 5	113
§ 6.2.5	Design options	Task 6	21
§ 6.3.5	BAT and LLCC analysis	Task 6	48
§ 7.2.3.6	Proposed MEPS	Task 7	52

6.1 DEFINITION

According to the International Dictionary of Refrigeration[13], a condensing unit is an assembly including a compressor with motor, a condenser, and a liquid receiver when required.

Remote condensing units are a classification of products which only comprise of part of the refrigeration cycle, normally the compressor and condensing unit. The evaporator and expansion valve are components which are supplied integrated on the cold storage devices (cabinets, cold rooms, etc.) and are required to complete the system.

6.2 CLASSIFICATION



1 – High temperature: +5°C; Medium temperature: -10°C; Low temperature: -35°C
2 – High capacity: > 50kW; Medium capacity: 20kW-50kW; Low capacity: 0.2kW-20kW

6.3 FUNCTION AND PERFORMANCE

Functional unit: kW of cooling capacity at specified evaporating and ambient temperature.
Performance parameter: coefficient of performance (COP).

[13] International Institute of Refrigeration. *International Dictionary of Refrigeration*. 2007

6.4 CURRENT TEST STANDARDS

The use of EN 13771-2:2007 in the EU for testing remote condensing units has been identified. For condensing units in general the DK EN 13215 has been identified to provide rating conditions that can be used for comparison of different appliances.

6.5 CURRENT EU LEGISLATION AND INITIATIVES

Equipment	EU	US	Canada	Australia / New Zealand
Remote condensing units	VEPS: UK ECA (air cooled only)	N/A	N/A	N/A

N/A: No standards found

Only the UK ECA scheme establishes voluntary minimum standards, for air-cooled remote condensing units.

6.6 MARKET DATA

Estimated sales of remote condensing units and forecast until 2020 in EU (units)

Product type	1990	2006	2007	2008	2012	2020	2025
Remote condensing units	766,702	632,100	617,516	599,759	573,023	502,614	458,608

Estimated stock of remote condensing units and forecast until 2020 in EU (units)

Product type	1990	2006	2007	2008	2012	2020	2025
Remote condensing units	3,688,270	5,048,537	5,147,339	5,243,301	5,618,759	6,301,534	6,682,502

An estimate of the price of remote condensing units based on responses to the 1st questionnaire[14] shows that the selling price of such products is very large, between € 1,000 and € 20,000. The distribution channels also have influence in the price, being usual price discounts up to 50%-60% for big retailers or installers. The installation costs depend on the product, the installer and the country, and can be up to 20% of the total cost of the product.

The public price of the product varies depending on the cooling capacity of the condensing unit, the number and size of the compressors, the technology used in the compressor, the housing, insulations, etc.

A typical remote condensing unit it thought to be between 5-7KW of cooling capacity for medium temperature (evaporation temperature -10°C), with a single hermetic

[14] BIO Intelligence Service. *First ENTR Lot 1 online questionnaire to stakeholders*. Different versions of the questionnaire are available depending on the product category and can be downloaded from www.ecofreezercom.org/documents_1.php

reciprocating compressor, and uses R404a as refrigerant. The average price of a product with these characteristics is around € 5000.

6.7 BASE CASE ENVIRONMENTAL AND ECONOMIC IMPACT ASSESSMENT

For each product group, the Base Case used for the environmental analysis is represented by weighted Base Cases, calculated using the market shares of the different configurations and various assumptions on relative energy consumption, material quantities and other factors, as described in Task 4. This leads to an abstract model, not comparable to any specific product in the market, but used to provide inputs to the EcoReport analysis tool, whose outputs are useful as a statistical calculation of overall EU market impacts. The characteristics described below for these weighted Base Cases are those essential for the EcoReport assessment.

6.8 IMPACT ANALYSIS FROM ECOREPORT

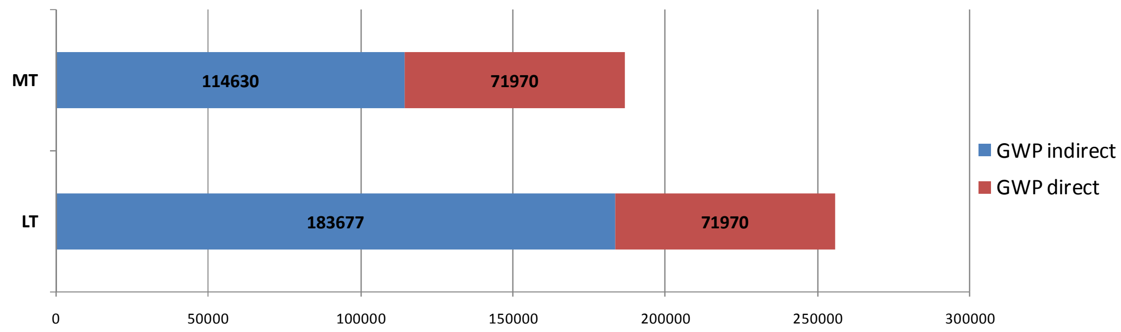
Main impacts (per product)

EcoReport LCA analysis results for remote condensing units – lifecycle impacts per functional unit per year - Weighted Base Case

Impact indicator	Impact per kW cooling capacity per year for MT	Impact per kW cooling capacity per year for LT
Total Energy (GER)	45,850	90,660
of which, electricity (in primary MJ)	45,729	90,481
electricity (in kWh)	4,355	8,617
Water (process)	3,066	6,057
Water (cooling)	121,899	241,216
Waste, non-haz./ landfill	58,083	112,410
Waste, hazardous/ incinerated	1,102	2,156
Greenhouse Gases in GWP100	3,257	5,509
Ozone Depletion, emissions	0	0
Acidification, emissions	11,816	23,360
Volatile Organic Compounds (VOC)	18	35
Persistent Organic Pollutants (POP)	358	679
Heavy Metals	815	1,597
PAHs	94	184
Particulate Matter (PM, dust)	318	596
Heavy Metals	303	595
Eutrophication	2	3
Persistent Organic Pollutants (POP)	0	0

The direct and indirect greenhouse gasses emissions comparison is shown below. The higher GWP for LT products is due to the use of R404a in place of R134a.

EcoReport LCA analysis results for remote condensing units - Life cycle Total Equivalent Warming Impact (TEWI)



EcoReport LCA analysis results for remote condensing units - Life Cycle Cost breakdown per unit and total annual consumer expenditure

	MT-LCC new product (€)	LT-LCC new product (€)	total annual consumer expenditure in EU25 (mln.€)
Product price	6,627	7,933	3,925
Installation/ acquisition costs (if any)	663	793	392
Electricity	25,264	40,482	21,303
Repair & maintenance costs	558	668	424
Total	33,111	49,875	26,044

Main impacts (EU wide)

EcoReport LCA analysis results for remote condensing units - environmental impacts of stock

		TOTAL
Other Resources & Waste		
Total Energy (GER)	**PJ**	1,868.99
Water (process)	**mln. m3**	124.91
Water (cooling)	**mln. m3**	4,971.47
Waste, non-haz./ landfill	**kt**	2,334.81
Waste, hazardous/ incinerated	**kt**	44.60
Emissions (Air)		
Greenhouse Gases in GWP100	**mt CO2 eq.**	122.70
Ozone Depletion, emissions	**t R-11 eq.**	0.00
Acidification, emissions	**kt SO2 eq.**	481.60
Volatile Organic Compounds (VOC)	**kt**	0.72

		TOTAL
Persistent Organic Pollutants (POP)	**g i-Teq**	14.20
Heavy Metals	**ton Ni eq.**	33.02
PAHs	**ton Ni eq.**	3.81
Particulate Matter (PM, dust)	**kt**	12.52
Emissions (Water)		
Heavy Metals	**ton Hg/20**	12.29
Eutrophication	**kt PO4**	0.07
Persistent Organic Pollutants (POP)	**g i-Teq**	0.00

6.9 SUB-BASE CASES AND BAT TECHNICAL SPECIFICATIONS

The weighted Base Cases have been developed from one or two sub-Base Cases, and these sub-Base Cases are comparable to the most common product configuration on the market. The sub-Base Cases are necessary in order to have real product characteristics from which to extrapolate the weighted models, and also to compare against BAT.

Technical characteristics of the remote condensing unit sub-Base Case

Product characteristics	Sub-Base Case MT	Sub-Base Case LT	BAT MT	BAT LT
Product type/design:	Packaged	Packaged	Packaged	Packaged
Evaporation temperature [°C]:	-10°C	-35°C	-10°C	-35°C
Operation temperature [°C]:	0°C	-25°C	0°C	-25°C
Ambient temperature [°C]:	+32°C	+32°C	+32°C	+32°C
Condensing unit function [hours/day]:	16	16	16	16
Functional unit:	1 kW of cooling capacity at evaporation temperature -10°C and ambient temperature +32°C	1 kW of cooling capacity at evaporation temperature -35°C and ambient temperature +32°C	1 kW cooling capacity at evaporation temperature -10°C and ambient temperature +32°C	1 kW cooling capacity at evaporation temperature -35°C and ambient temperature +32°C
Power input [kW]:	3.7	5.8	3.5	5.7
Cooling capacity [kW]:	7.1	5.8	7.6	6.3
Performance [COP]*:	1.9	1.0	2.1	1.1
Annual electricity consumption	19,068	30,418	14,526**	23,057**

Product characteristics	Sub-Base Case MT	Sub-Base Case LT	BAT MT	BAT LT
[kWh/year]:				
Price (ex. VAT) [€]:	3,095***	6,104***	3,430***	11,582***
Product lifetime [years]	8	8	8	8
Refrigerant:	R404A	R404A	R404A	R410A
Refrigerant charge [kg]:	7	6	N.A.	N.A.
Refrigerant leakage [% per annum]:	15%	15%	15%	15%
Height [cm]:	90.5	143.1	78.7	168
Width [cm]:	140	124.4	115	63.5
Depth [cm]:	55	51	43.5	76.5
Volume [m^3]:	0.7	0.8	0.4	0.8
Weight of product [kg]:	117	203	92	170
Number of compressors:	1	1	1	1
Type of compressor:	Reciprocating hermetic	Reciprocating hermetic	Scroll	Scroll
VSD compressor motor control (if applicable):	No	No	Yes	Yes
Condenser cooling:	Air cooled	Air-cooled	Air-cooled	Air-cooled
Condenser heat exchanger type and material:	Steel	Steel	Steel	Steel
Condenser fan motor type:	On/Off	On/Off	Variable speed	Variable speed
VSD condenser fan motor control (if applicable):	On/Off	On/Off	Yes	Yes
Condenser fan motor power [W]:	130	130	130	130
Other features not covered above:	-	-	-	-

* COP: cooling capacity (kW) divided by the energy power input (kW).
**AEC estimated based on information provided by stakeholders:
Base Case MT AEC= 19,068kWh;
Base Case LT AEC= 19,068kWh*(35°C+32°C/10°C+32°C);
BAT MT and LT supposed to achieve 20% energy savings over the Base Case
***Public prices

6.10 IMPROVEMENT POTENTIAL

The table below presents the improvement options, estimates of their current market penetration, their energy saving potential and cost.

Improvement options

	Applicability (Years)	Market penetration (%)	Energy savings MT (% of TEC)	Energy savings LT (% of TEC)	Increase in price of MT product (€)	Increase in price of LT product (€)	Priority
Increase heat exchanger surfaces	Now	5%	5%	5%	157	223	1
ECM compressor	Now	less than 10	9%	9%	525	742	2
Digital modulation control for compressor*	Now	less than 10	10%	10%	525	742	3
Scroll compressor	Now	5%	10%	10%	840	1,187	4
Variable speed drive*	Now	2%	10%	10%	1312	1,855	5
High efficiency fan blades	Now	20%	0.5%	0.5%	105	148	6
ECM for fans	Now	20%	0.5%	1%	262	371	7
R290**	Now	less than 10	5%	5%	262	371	8
BNAT							
Water cooling	Next five years	5%	5%	5%	663	793	1
Mini-channel heat exchangers	Next five years	0%	10%	10%	1,325	1,587	2
Unsaturated HFCs**	Next five years	0%	5%	5%	1,325	1,587	3
CO2**	Next five years	less than 10	0%	2%	3,313	3,966	4

**Improvement not reflected on COP tested in EN13215 standard conditions*
***The benefit of this improvement is also the lower GWP of the refrigerant*
N.A.: Data not available
Notes: Savings are not additive.

This table includes improvement options for which relevant information was found.

It is assumed that the best available remote condensing unit within next 5 years will achieve energy savings of 31% using the following:

Product characteristics	**Condensing unit MT BNAT**	**Condensing unit LT BNAT**
Product type/design:	Packaged	Packaged
Evaporation temperature [°C]:	-10	-35
Operation temperature [°C]:	0°C	-25°C
Ambient temperature [°C]:	+32°C	+32°C
Condensing unit function [hours/day]:	16	16
Product use pattern [hours/year]:	5,840	5,840

Product characteristics	Condensing unit MT BNAT	Condensing unit LT BNAT
Functional unit:	1 kW cooling capacity at -10°C evaporating temperature and +32°C ambient temperature	1 kW cooling capacity at -35°C evaporating temperature and +32°C ambient temperature
Cooling capacity [kW]:	7.2	5.8
Power input [kW]:	2.9	4.4
Annual electricity consumption [kWh/year]:**	13,157	20,988
Performance [COP]*:	2.49**	1.32**
Product lifetime [years]	8	8
Refrigerant:	Low GWP***	Low GWP***
Compressor:	Digital ECM VSD Scroll	Digital ECM VSD Scroll
Condenser:	ECM with efficient fan blades and mini-channel heat exchanger	ECM with efficient fan blades and mini-channel heat exchanger
Other features not covered above:	-	-

** COP: Coefficient of Performance defined as the cooling capacity divided by the power input*
*** calculated as the cooling capacity from the Base Case assumed to be the same and the power input decreased in 35%*
****For example: R290, R600a, R744, or an un-saturated HFC – for the purposes of modelling R717 has been used*

6.11 BASE CASE/BAT/BNAT COMPARISON

Energy consumption, performance and refrigerants for remote condensing unit BOM, BAT and BNAT

		Base Case model	Weighted Base Case	Current available BAT model	Weighted current available BAT	Theoretical BNAT product model (available in approximately 5 years)	Weighted theoretical BNAT (available in approximately 5 years)
Remote condensing unit MT	AEC [kWh/year]:	19,068	31,270	14,526	25,202	13,047	22,167
	Performance [COP] at -10°C evaporating temperature and 32°C ambient temperature:	1.9	1.9	2.12	2.1	2.5	2.5
	Improvement over Base Case (%):	-	-	20	20	31	31
Remote condensing unit LT	AEC [kWh/year]:	30,418	50,106	23,057	40,180	20,586	34,573
	Performance [COP] at -35°C evaporating temperature and 32°C ambient temperature:	1.0	1.0	1.11	1.1	1.3	1.3
	Improvement over Base Case (%):	-	-	20	20	31	31

6.12 DESIGN OPTIONS

Identified energy saving potentials for the MT remote condensing unit Base Case

	Improvement option	TEC savings compared to Base Case (%)	Power input reduction compared to Base Case (%)	Increase of product price compared to Base Case (€)	Payback time (years)
Option 1	**Increase heat exchanger surfaces**	5	5	199	1.1
Option 2	**ECM compressor**	9	9	663	2.0
Option 3	**Digital modulation control for compressor***	10	0	663	1.8
Option 4	**Scroll compressor**	10	10	1,060	2.8
Option 5	**Variable speed drive***	10	0	1,657	4.4
Option 6	**High efficiency fan blades**	0.5	0.5	133	7.1
Option 7	**ECM for fans**	0.5	0.5	331	17.7
Option 8	**R290****	5	5	30	0.2
Scenario A	**Options 1+4+5+6+7+8**	28	20	3,410	3.3
Scenario B	**Options 1+2+3+6+7**	23	14	1,988	2.3
Weighted real BAT improvement	**As described in Task 5**	19	10	335	0.5

*Improvement at part load not reflected in COP
**This improvement also has lower direct GWP emissions

Identified energy saving potentials for the LT remote condensing unit Base Case

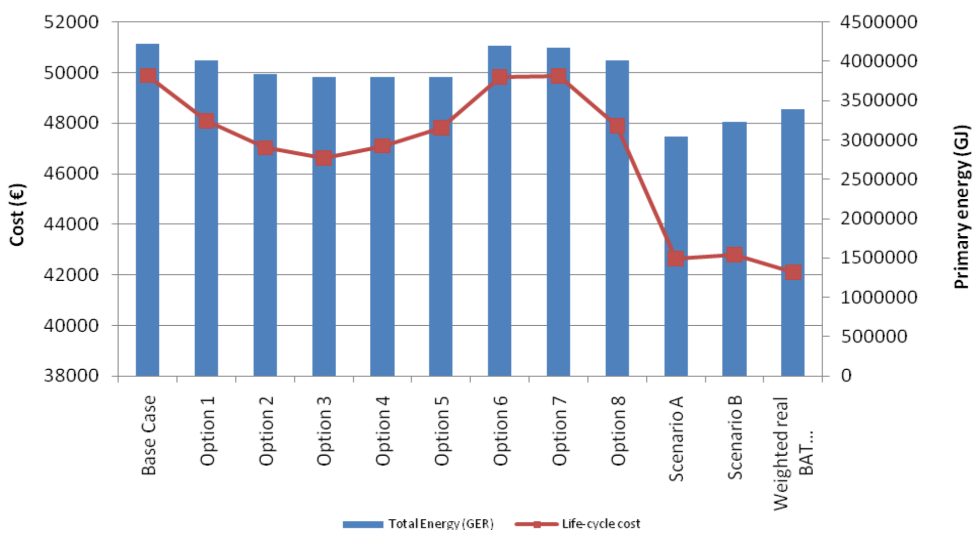
	Improvement option	TEC savings compared to Base Case (%)	Power input reduction compared to Base Case (%)	Increase of product price compared to Base Case (€)	Payback time (years)
Option 1	**Increase heat exchanger surfaces**	5	5	238	0.8
Option 2	**ECM compressor**	9	9	793	1.5
Option 3	**Digital modulation control for compressor***	10	0	793	1.3
Option 4	**Scroll compressor**	10	10	1,269	2.1
Option 5	**Variable speed drive***	10	0	1,983	3.3
Option 6	**High efficiency fan blades**	0.5	0.5	159	5.3
Option 7	**ECM for fans**	1	1	397	6.6
Option 8	**R290****	5	5	40	0.1
Scenario A	**Options 1+4+5+6+7+8**	28	20	4,086	2.4
Scenario B	**Options 1+2+3+6+7**	23	15	2,380	1.7
Weighted real BAT	**As described in Task 5**	20	11	5,478	4.6

	Improvement option	TEC savings compared to Base Case (%)	Power input reduction compared to Base Case (%)	Increase of product price compared to Base Case (€)	Payback time (years)
improvement					

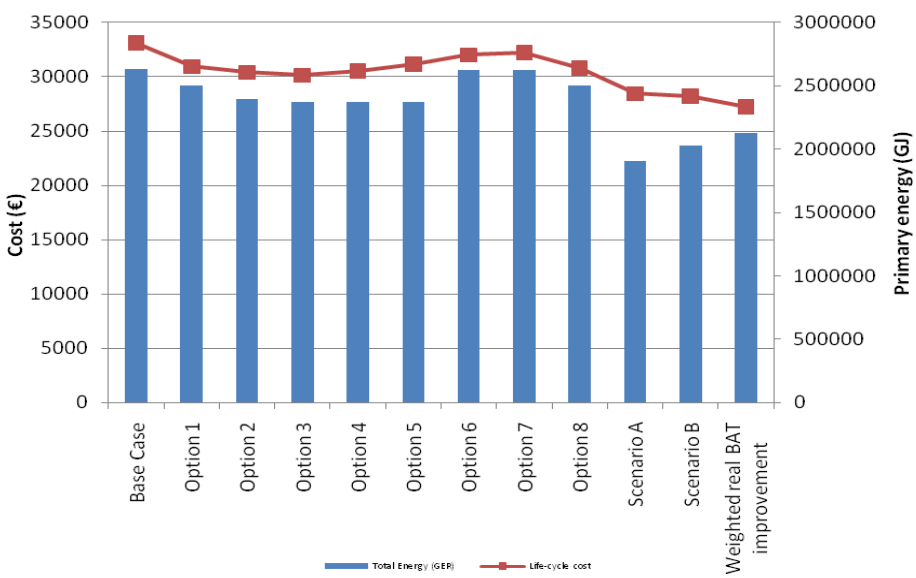
*Improvement at part load not reflected in COP
**This improvement also has lower direct GWP emissions

6.13 BAT AND LLCC

LT remote condensing unit Base Case – TEC and LCC



MT remote condensing unit Base Case – TEC and LCC



6.14 PROPOSED MEPS

In this study, MEPS requirements are proposed to be tested at EN 13215:2000 conditions, as these are the conditions most used for testing in the EU market.

The test conditions in EN 13215:2000 allow measuring the performance of remote condensing units by calculating the COP at one point. The proposed MEPS are calculated taking into account only improvement options that can achieve gains under these conditions. Therefore, all the improvements given by part load or seasonal performance controls were not included to calculate the MEPS levels. In order to do this distinction, different improvement potentials were used for Annual energy savings (including part load and seasonal performance) and COP increase (including only improvements at full load).

Nevertheless, there is a need to develop and harmonise standards for testing conditions for remote condensing units in variable conditions and part load, in order to adapt them to the real working conditions in the EU.

Following the approach using for all the products within the present study, the performance values of the LLCC options identified for LT and MT are proposed as short-term threshold for remote condensing units; and the performance values of BNAT for LT and MT are proposed as long-term thresold.

Proposed MEPS for low and medium temperature remote condensing units

Evaporating temperature	Short-term COP* threshold at +32°C ambient temperature	Long-term COP* threshold at +32°C ambient temperature
Medium temperature (-10°C)	2.2	2.5
Low temperature (-35°C)	1.2	1.3

*Net cooling capacity (kW)/efective power input (kW)
Short-term threshold: as per LLCC option
Long-term threshold: as per BNAT

7. Horizontal section on refrigeration systems

Definition

A refrigeration system generally refers to one or several remote refrigerating appliances connected together with one or several condensing units. A remote refrigerating appliance is a piece of refrigeration equipment (service cabinet, walk-in cold room, etc.) which does not include a compressor and a condenser, as opposed to a plug-in refrigerating appliance. The system is typically a collection of purchased components which are installed and tuned for operation together in-situ. There is great scope for considering the refrigeration system as a whole to be improved, rather than a collection of individual components each improved individually.

There are, to some extent, standard configurations of refrigeration systems. The commercial refrigeration systems using remote condensing units sector is divided in 4 categories. Benefits and drawbacks of these different refrigeration system categories are summarised in the table below:

Comparison of different refrigeration systems designs

Configuration	Strengths	Weaknesses
Direct system	✓ Good efficiency ✓ Less components than indirect system ✓ Lower investment cost than indirect system	✓ Large refrigerant charges ✓ Refrigerant leakages
Indirect system	✓ Lower refrigerant charges ✓ Simple and cheaper service ✓ Use of natural refrigerants possible	✓ Risk for low energy efficiency ✓ Pump work ✓ Risk of corrosion ✓ Pipes need to be insulated
Distributed system	✓ Good efficiency ✓ Reduction of refrigerant circuit length => lower refrigerant charges ✓ Less refrigerant leakages	✓ No possibility to use natural refrigerants such as ammonia or HC ✓ 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

These systems use both packaged and custom components, the proportion of these depending on the type of system under consideration.

Classification

The main parameters by priority to be considered for classification are:

1. System arrangement: packaged condensing units, independent compressor and condensing unit
2. Compressor: variable speed, parallel sequential, single compressor

The following parameters are not considered of high priority, but they can be used for classification as well. However, no data has been identified about their priority:

- Type of coolant, e.g. air (most common and relevant for this study according to stakeholders' feedback), water or evaporative
- Location: e.g. indoor or outdoor
- Temperature
- Cooling capacity

Current EU standards

Many standards for the design and construction of refrigeration systems is an answer to the European Directive on pressure equipment (97/23/EC) and to the European Directive on machinery 98/37/EC and 2006/42/EC.

Standards related to refrigeration systems are included in the Table below:

European standards on refrigerating systems

Reference	Title
EN 378	Refrigerating systems and heat pumps – safety and environmental requirements
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

Other system standards include:

- VDMA-Einheitsblatt
- EUROVENT certification programmes for refrigeration components

Current EU legislation and initiatives

Certain EU Directives are relevant, and need to be taken into consideration during the design of refrigeration systems. Currently, these focus mainly on health and safety issues, but environmental aspects are starting to be addressed.

- Pressure Equipment Directive 97/23/CE
- F-Gas legislation
- The Montreal protocol and Regulation EC No. 2037/2000 on substances that deplete the ozone layer

Market data

No estimations were found on the number of refrigeration systems installed in the EU27. However, VDMA estimated that approximately 120 million refrigerating systems are installed in Germany, with energy demand of 77,000 GWh/a, which represents about 14% of the total German energy demand[15]. Using a population basis to extrapolate these figures to the EU27 (accounting Germany for 16.3% of the total population of the EU27), the installed stock of refrigeration systems would be around 736 million and the energy consumed around 472 Twh per year. This would include plug-in, remote appliances and combined systems for air conditioning, heating and commercial refrigeration purposes. This would account for 188.8 Mt of CO2 equivalent per year.

Other source estimates the German food retail industry energy consumption in 24 billion kWh per year for refrigeration[16]. If this figure is extrapolated to the EU-27 in the same manner as above, the total energy consumption is around 147 TWh per year, which means 59 Mt of CO2 equivalent per year.

Stock of supermarket refrigeration systems

The stock of refrigeration systems in supermarkets in 1998 in the EU was 44,000 units[17]. In 2003, the numbers were 58,752 supermarkets, and 6,236 hypermarkets in the EU-25, and 10,503 supermarkets and 429 hypermarkets in the rest of Europe[18].

The estimated number of supermarkets in 2006 in the EU-27 is 73,724 small and 6,849 large hypermarkets[19].

A simplified diagram showing the different products which need to be connected on site of a refrigeration system are shown below.

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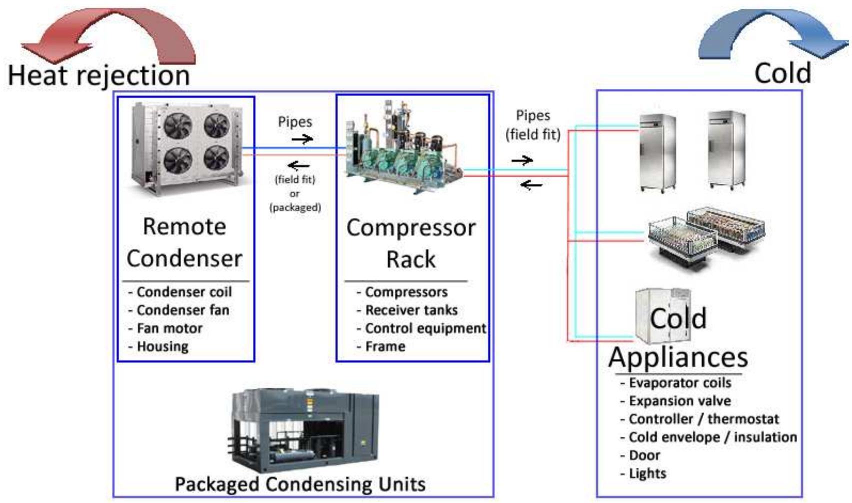
[15] VDMA.Energy-efficient refrigeration technology. 2010

[16] Umweltbundesamt. Comparative assessment of the climate relevance of supermarket refrigeration systems and equipment.

[17] UNEP 1998. *Report by the Refrigeration, Air Conditioning and Heat Pumps Option Committee.* 1998

[18] Clodic, D., Palandre, L., Barrault, S., and Zoughaib, A., 2006: Short report of Inventories of the worldwide fleets of refrigerating and air conditioning equipment in order to determine refrigerant emissions. The 1990 to 2003 updating. ADEME final report.

[19] Clodic et al.: Global inventories of the worldwide fleets of refrigerating and air-conditioning equipment in order to determinate refrigerant emissions. The 1990 to 2006 updating. April 2010



Environmental impacts of refrigeration systems

The energy consumption of refrigeration systems (electrical energy used to produce the refrigeration load, lighting, etc) has environmental impacts due to the generation of the electricity consumed. These impacts are referred to as “indirect”, as they occur elsewhere to the refrigeration system.

However, “direct” emissions of refrigerant from refrigeration systems (e.g. due to refrigerant leakage along the pipes) 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 emissions20

Major leak sources are the condenser valves and connections, the hot gas defrost valves and the piping connections. According to the IPCC/TEAP report[21] 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.

These leakage rates are in the process of being reduced, primarily due to the implementation of the F-Gas regulation[22]. Depending on 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.

[20] IPCC *Special Report on Safeguarding the Ozone Layer and the Global Climate System. Chapter 4 Refrigeration*. (2005)

[21] IPCC/TEAP Special report, Safeguarding the Ozone layer and the Global Climate System, chapter 4, 2005

[22] REGULATION (EC) No 842/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2006 on certain fluorinated greenhouse gases

Factors affecting energy consumption of refrigeration systems

The technical options that could improve system performance:

- The compressor
- Compressor vapour injection
- Location of the condenser
- Piping
- Defrost control and hot or cold defrosting
- Sources of pressure in a system
- Floating head pressure
- Raising liquid line pressure
- Suction pressure optimisation

The performance of a system is the result of the balance between its energy efficiency and the choice of the refrigerant (e.g. in regards with the global warming potential) but the relative weight of each factor is difficult to assess. 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 but it considers only the use phase. Another attempt is to use the Life Cycle Climate Performance indicator (LCCP) expressed in CO2 eq. which takes into account production, emissions, and energy use.
These values, however, can vary depending on the testing conditions: working temperature, configuration of the system, among other factors.

Other method to measure the energy efficiency of a refrigeration system is expressing it as the Coefficient of System Performance (COSP), which is the quantity of refrigeration produced divided by the total energy required by the system[23].

$$COSP = \text{capacity (kW)} / \text{power (kW)}$$

The power input is the sum of the compressors and all other motors and electrical appliances associated with the system. The COSP depends on the temperature lift of the system, the heat losses, the efficiency of the components, the quality of the installation, etc. The compressor usually accounts for between 80% and 100% of the system's total power input.

Improvement options

The FKT (Research Council for Refrigeration Technology) estimates potential energy savings up to 40% for the refrigeration and air conditioning technique by[24]:

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[23] Sustainable Energy Ireland. Reducing energy use in large-scale refrigeration and cooling systems

[24] Forschungsrat Kältetechnik: contribution to climate protection of cooling and air conditioning plants. Improvement of energy efficiency. Reduction of greenhouse-related emissions

Improvement	Energy savings
Efficient control, operation and design directives for refrigeration system	ca. 10%
Reduction of effective temperature differences on heat exchangers	ca. 12%
Use of highly efficient drives	ca. 3%
Saving in the refrigeration need	ca. 7%
System improvement, design in compliance with to the annual temperature profile, heat recovery and further improvements	ca. 8%

These energy savings could be achieved by means of applying some recommendations investigated by the FKT:

- Optimisation of system concepts, e.g. choice of refrigerant, choice of temperature level;
- Definition of the design directives (full load/partial load);
- Optimisation of operational concepts of already existing systems;
- Application of the refrigeration load;
- Energy recovering;
- Introduction of maintenance regulations in order to maintain the system efficiency;
- Introduction to energy efficiency criteria;
- Definition of minimum requirements for components;
- Certification programs for components (compressors, heat exchanger); and
- Optimisation of drives.

Non-quantified improvement options for refrigeration systems suggested by stakeholders include:

- Reducing pipe lengths to a minimum.
- Using electronic expansion valves.
- Using efficient compressors.
- Reducing joints and potential leak points.
- Monitoring refrigerant levels to ensure efficient operation.
- Monitoring performance of the entire system, especially energy consumption monitoring.
- Electronically commutated fans (additionally estimated to last 7 times longer than standard fans).

Defrost optimisation: freezing applications change to medium temperature to allow defrost without switching off.

- Frequent maintenance services
- 2-stage compression with intermediate de-superheating
- Multi-evaporator systems: freezers change for low temperature remote display cabinets
- Use of a chilled water circuit positioned within the display cases and coldrooms as low temperature condensing medium to water-cooled condensing units.

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8. Summary of data for refrigerants

Definition

All substances that exist in liquid and vapour states and absorb heat during evaporation can therefore be used as refrigerants. A refrigerant should evaporate at the required cooling temperature (i.e. at the temperature sought in the evaporator of the refrigerant equipment), at a reasonable pressure, and should be able to be condensed by an available cooling medium at a practical pressure. There is strong advocacy for the use of natural refrigerants, such as CO_2, due to their comparatively low environmental impact.

The variation of the Coefficient of Performance (COP) with the refrigerant can be considerable, depending on various parameters:

- the compressor displacement;
- the temperature lift (difference between evaporating and condensing temperatures);
- the properties of the refrigerant (e.g. centrifugal compressors are best suited for low evaporator pressures and refrigerants with large specific volumes at low pressure, on the other hand reciprocating compressors perform better over large pressure ranges and are better able to handle low specific volume refrigerants[25]); and
- the temperature of the superheated suction vapour (if it is too low, liquid refrigerant may return to the compressor and damage it).

General classification for refrigerants

- HCFCs: Hydrochlorofluorocarbons
- HFCs: Hydrofluorocarbons
- HCs: Hydrocarbons
- NH_3: Ammonia
- CO_2: Carbon dioxide

[25] http://www.scribd.com/doc/22244125/vapour-compression-refrigeration

Major environmental issues related to 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 phased out (Montreal protocol) and replaced by other refrigerants such as HFCs or halogen-free refrigerants.
- Global warming when using either HCFCs or hydro fluorocarbons (HFCs): HFCs and HCFCs are both greenhouse 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.

Safety Standards that can affect to refrigerant use:

- **EN IEC 60335: "Household and similar electrical appliances – Safety"** applies to service cabinets, blast cabinets, ice-makers, and beverage and dessert appliances. The relevant sections (different from part 1 – general requirements) are:
    - **EN IEC 60335-2-24:2006** "Household and similar electrical appliances – safety – part 2-24: particular requirements for refrigerating appliances, ice cream appliances and ice-makers"
    - **EN IEC 60335-2-34:2004 "Household and similar electrical appliances – safety – part 2-34: particular requirements for motor compressors"**
    - **EN IEC 60335-2-89:2005 "Household and similar electrical appliances – safety – part 2-89: particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor"**
- **EN 378:2009: "Refrigerating systems and heat pumps. Safety and environmental requirements. Design, construction, testing, marking and documentation"**
- **ASHRAE Standard 34-2008: "Designation and Safety Classification of Refrigerants".**

Current European legislation related to refrigerant fluids

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

The European Regulation N°2037/2000 covers production, importation, exportation, placing on the market, use, recovery, recycling and destruction of some substances.

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

The objective of this Regulation is to "contain, prevent and thereby reduce emissions of the fluorinated greenhouse gases covered by the Kyoto Protocol". It applies to the fluorinated greenhouse gases.

The F-Gas Regulation EC 842/2006 requires the 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 offer recycling and destruction (typically incineration) schemes directly or via their distributors 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 the product's lifespan to 15 years.
Typically, the second hand refrigerant would be reclaimed and supplied to the same specifications as a virgin refrigerant. Recovery/recycling machines allow engineers to reuse HFC without returning them to the suppliers. Because refrigerants are simple to be treated locally, more than 90 % of all recovered refrigerant is treated in this way. EFCTC comments that it is expected that the WEEE directive will impact on the quantity of refrigerant recovered at end-of-life.

Leakage rates

Annual refrigerant leakage rates						
		Service cabinets	Blast cabinets	Walk-in cold rooms	Industrial process chillers	Remote condensing units
Refrigeration roadmap study (UK)		<1% plug-in	<1% plug-in	<1% plug-in	<1% plug-in	10%-20%
BIO estimation before 2nd SHM		1%	1%	1%	1%	1%
SH comments in 2nd SHM		10%-12%	10%-12%	10%-12%	10%-12%	15%
BIO used in sub-Base Cases	Plug-in	1%	5%	5%	1%	-
	Remote	12%	12%	12%	1%	15%
BIO used in weighted Base Cases		6%	7%	9%	1%	15%

Best available technology (BAT) for refrigerants

Natural refrigerants are gases, which occur naturally in the environment and include ammonia, carbon dioxide, hydrocarbons, water and air. Environmentally superior due to their very low GWP values, can achieve similar or even higher efficiencies than traditional HFCs, but are not free of other concerns, such as corrosion, toxicity, high pressures, flammability, or in some cases lower operating efficiencies. These refrigerants are: Ammonia R-717, Carbon Dioxide R-744 and Hydrocarbons.
Also unsaturated HFCs are the new generation of the fluorocarbon refrigerant and are being tested for commercial refrigeration. The table below shows the main characteristics for all these refrigerants.

Characteristics of refrigerants

Refrigerant	Properties	Benefits	Drawbacks	Application
CO_2 R-744	• Boiling Point: -78°C • Critical Temperature: 31°C • Flammability Limits: non flammable • Compatibility: risks of corrosion to ferrous steel with humidity	• 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 • Safe in public premises • Higher COP at lower temperatures • Lower cost	• 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 • Lower COP at high temperatures • Very high operation pressure	• No – for service cabinets • Yes – for walk in cold rooms, however not appropriate for small cold rooms. May be used when cold room forms part of supermarket CO2 system
Ammonia R-717	• Boiling Point: -33°C • Critical Temperature: 133°C • Flammability Limits: 15 - 28 % in Air • Compatibility: Corrosive to copper alloys	• Low ODP – Low GWP • Good efficiency • Ammonia's recognisable smell is its greatest safety asset • Low cost • Refrigeration systems cost 10 - 20 % less. • Low charge of refrigerant • High heat transfer and good thermodynamic properties • Safe in public premises	• Toxicity ⇨ Leakages not permitted • Flammability • Limited charge permitted • Not compatible with copper/copper alloys • Provides extra-low temperature in cascade systems with Carbon Dioxide (CO_2)	• Not applicable for service cabinets, neither for walk in cold rooms
Propane R-290	• Boiling Point: -42°C • Critical Temperature: 97°C • Flammability Limits: 2.1 - 9.5 % in Air • Compatibility: Non corrosive	• No ODP – Very 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	• Flammability • Limited charge permitted • High installation cost in supermarkets due to safety fittings	• Yes for service cabinets • May be used in small cold rooms with small refrigerant charge
Isobutane R-600a	• Boiling Point: -12°C • Critical Temperature: 135°C • Flammability Limits: 1.6 - 8.4 % in Air • Compatibility: Non corrosive			• If hydrocarbons are to be used propane is more efficient option to choose
Unsaturated HFCs	• Boiling Point: -30°C • Critical Temperature: 94°C	• Low GWP • High energy efficiency • Used with min. modifications	• Flammability • Toxicity	• Still in the research area

Best Available Technology refrigerant per Base Case Refrigerants

R-134a and R-404a are two of the most commonly used and accepted refrigerants. These two substances were considered as the refrigerants for the 5 Base Cases.
Although they are a good initial alternative for CFC and other substances, R134a and R404a present some problems regarding their high GWP. For this reason, alternatives for them are being analyzed. Some of the more efficient refrigerants are hydrocarbons and ammonia, but their safety issues limit their charge and applicability. New technologies such as mini-channel heat exchangers can allow further development of machines running these refrigerants.

Physical properties and environmental impact of common refrigerants

Refrigerant	Boiling point (°C)	Critical point (°C)[26]	Ozone depletion potential (ODP)	GWP, 100y	Safety classification (ANSI/ASHRAE 34)
R134a (hydrofluorocarbon)	-26	101	0.0	1410	A1
R404A (hydrofluorocarbon)	-46	72	0.0	3300	A1
R410A (hydrofluorocarbon)	-49	73	0.0	1890	A1
R407A (hydrofluorocarbon)	-43	82	0.0	1900	A1
R290 (propane)	-42	97	0.0	3	A3
R600a (isobutane)	-12	135	0.0	3	A3
R1270 (propylene)	-48	92	0.0	3	A3
ECP717 (ethane + ammonia)	-55	41.9	0.0	2	A2
R717 (ammonia)	-33	132	0.0	0	B2
R718 (water)	100	373	0.0	0	A1
R744 (carbon dioxide)	-78	31	0.0	1.0	A1
R152a (difluoroethane)	-24	113	0.0	122	A2
HFC-1234yf (unsaturated HFC)	-30	94	0.0	4	A2
HFC-1234ze(E) (unsaturated HFC)	-19	110	0.0	6	A2

[26] The temperature and pressure at which the liquid and gaseous phases of a pure stable substance become identical. Also called critical state.

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9. Data matrix

The matrix below summarises the data used to prioritise the refrigeration products for further analysis in Task 4 of ENTR Lot 1.

These figures indicated that the products for further analysis as Base Cases, due to their significant energy saving potentials, should be:

- Service cabinets
- Blast cabinets
- Walk-in cold rooms
- Packaged condensing units
- Process chillers

Market and energy consumption figures for products in the scope of ENTR Lot 1

Product	Product type	EU-27 sales [units in 2008]	EU-27 stock [units in 2008]	EU-27 sales [units in 2020]	EU-27 stock [units in 2020]	Stock Increase Factor 2008-2020	Estimated average total energy consump. per product [kWh/year]	Total stock energy consump. TWh/year (2008)	Total stock energy consump. TWh/year (2020)	Estimated average energy saving potential per product [% in 2020]	Estimated EU-27 saving with annual BAU 1% annual improvment TWh/year (2020)	Total 2020 stock energy consumption with complete efficiency	Estimated EU-27 savings in TWh/year in 2020 with complete efficiency	Total 2020 stock energy consumption with gradual energy efficiency	Estimated saving with gradual energy efficiency
ENTR Lot 1											*Reference*				
Service Cabinets	*Remote*	39,744	326,016	44,023	362,162	1.111	2,198	0.72	0.80	40%	0.09	0.48	0.32	0.58	0.22
	Plug-in	357,700	2,934,147	396,207	3,259,454	1.111	2,198	6.45	7.16	40%	0.82	4.30	2.87	5.18	1.98
	Total	397,444	3,260,163	440,230	3,621,615	1.111	0	0.00	0.00	0%	0.00	0.00	0.00	0.00	0.00
Blast Cabinets	*Remote*	86,828	1,550,000	96,175	1,722,050	1.111	3,487	5.40	6.00	40%	0.69	3.60	2.40	4.57	1.43
	Plug-in	86,828	1,550,000	96,175	1,722,050	1.111	3,487	5.40	6.00	40%	0.69	3.60	2.40	4.57	1.43
	Total	173,655	1,331,197	224,155	1,761,092	1.323	0	0.00	0.00	0%	0.00	0.00	0.00	0.00	0.00
Walk-in cold rooms	*Remote*	22,072	380,415	24,808	422,593	1.111	12,155	4.62	5.14	40%	0.59	3.08	2.05	4.38	0.76
	*Remote + PCU**	22,072	380,415	24,808	422,593	1.111	12,155	4.62	5.14	40%	0.59	3.08	2.05	4.38	0.76
	Plug-in	44,145	760,830	49,615	845,185	1.111	12,155	9.25	10.27	40%	1.17	6.16	4.11	8.76	1.52
	Total	88,289	1,521,659	99,230	1,690,370	1.111	0	0.00	0.00	0%	0.00	0.00	0.00	0.00	0.00
Dessert and beverage machines	-	150,000	1,500,000	166,630	1,666,304	1.111	650	0.98	1.08	17%	0.12	0.90	0.18	0.97	0.11
Industrial process chillers	*Packaged*	28,986	364,179	36,473	478,987	1.315	364,513	132.75	174.60	40%	16.84	104.76	69.84	142.20	32.40
	Field erected	3,221	40,464	4,053	53,221	1.315	364,513	14.75	19.40	40%	1.87	11.64	7.76	15.80	3.60
	Total	32,207	404,643	40,525	532,208	1.315	0	0.00	0.00	0%	0.00	0.00	0.00	0.00	0.00
Water dispensers	*Bottled water*	222,222	2,000,000	250,000	2,222,200	1.111	950	1.90	2.11	23%	0.24	1.63	0.49	1.79	0.32
	Mains water	55,556	500,000	62,500	555,550	1.111	950	0.48	0.53	23%	0.06	0.41	0.12	0.45	0.08
	Total	277,778	2,500,000	312,500	2,777,750	1.111	0	0.00	0.00	0%	0.00	0.00	0.00	0.00	0.00
Ice-makers	-	120,148	985,756	133,081	1,095,052	1.111	5,000	4.93	5.48	10%	0.63	4.93	0.55	5.10	0.38
**Packaged condensing units (PCU)*	-	599,759	5,243,301	502,614	6,301,534	1.202	22,047	115.60	138.93	20%	14.66	111.14	27.79	123.65	15.28
Refrigeration compressors	*(not plug-in)*	253,000	1,771,000	253,076	1,771,533	1.000	22,920	40.59	40.60	5%	5.15	38.57	2.03	39.08	1.52
Refrigeration condensors	*(not plug-in)*	50,600	354,200	39,316	393,162	1.110	19,102	6.77	7.51	3%	0.86	7.28	0.23	7.36	0.15
TOTAL	**-**	**2,142,880**	**20,640,722**	**2,179,552**	**23,293,628**	**1**	**-**	**355**	**431**	**-**	**45**	**306**	**125**	**369**	**62**