AEA Energy & Environment
From the AEA group

Work on Preparatory Studies for Eco-Design Requirements of EuPs (II)

Lot 17 Vacuum Cleaners

TREN/D3/390-2006

Final Report

Report to European Commission

Restricted Commercial
ED 04902
Issue 1
February 2009

Intertek ETL SEMKO

ConsumerResearchAssociates LTD

Executive Summary

This is the final report for the preparatory study for vacuum cleaners (EuP (II) Lot 17). The work was carried out by AEA Energy & Environment, Intertek, and Consumer Research Associates between November 2007 and January 2009.The study has followed the European Commission's MEEuP methodology, and our findings (in Task order) have shown that:

Task 1

There is a wide range of devices available for the cleaning of surfaces. To facilitate a successful outcome to the work, we reached agreement with the Commission and stakeholders to focus on those products that collectively account for the vast majority of energy consumption due to vacuum cleaners – in broad terms uprights and canister types whether for domestic or commercial users. Centralised vacuum cleaners, industrial/commercial vacuum cleaners designed for specialist applications, and sweepers are not covered by the work reported here.

Test standards for vacuum cleaners exist, but have been shown to be lacking with respect to determining real life performance. EU Eco-labelling criteria for vacuum cleaners have lapsed having attracted no applicants. However, work is in progress, led by CENELEC, with respect to possible energy labelling of vacuum cleaners.

Task 2

It is estimated that over 45 million vacuum cleaners of the type covered within this study are sold on the EU market annually. The number of vacuum cleaners bought annuallyis increasing due to a combination of declining product lifetime and the increasing trend towards multiple ownership whereby households have two or more units. Another market trend since the 1960s has been towards increasing input power ratings. Vacuum cleaner input power ratings have increased markedly since the 1960s from a typical 500W to over 2500W today. However, the energy efficiency of vacuum cleaners has dropped over the years; in other words more power does not necessarily equate to better cleaning. The production of vacuum cleaners has tended to move from the EU to China and the Far East where production costs are cheaper.

Task 3

The typical time that a consumer spends vacuum cleaning is about one hour per week. Some people vacuum clean every day: others less often, depending on the routine that they have developed. The routine achieves a level of cleanliness they want, and takes the amount of time they are prepared to devote to it. If people who had a poor vacuum cleaner replaced it with a much more effective one we have found no evidence that they would alter their habits greatly in terms of frequency or time spent on the activity, Information that exists for consumers in terms of vacuum cleaner performance is at best confusing and sometimes misleading.

Task 4

Vacuum cleaners comprise of greater than 50% by weight of plastics (various types) and about 20-30% metals (motor assembly). Cardboard packaging accounts for about 10-20% of the weight as purchased. For the purposes of this study, compliance with the WEEE Directive has been assumed for the 'end-of-life' phase of vacuum cleaners.

Task 5

The base cases agreed with stakeholders for this study were canister vacuum cleaners (domestic and commercial), upright vacuum cleaners (domestic and commercial), and battery/cordless vacuum cleaners. It was later agreed that this latter base case be excluded from consideration of improvement options (Task 7) because the key improvement options for this type are already in the preparatory study on chargers. The Eco-report outputs on the base cases indicated that the 'use phase' accounted for more than 90% of the impacts of vacuum cleaners. Total annual consumer expenditure was significant at around 13.7 billion Euros – mainly on energy costs.

Task 6

Our analysis of best available technology (BAT) identified a range of techniques for improving the energy and cleaning efficiency of vacuum cleaners. We concluded that the use of optimally designed centrifugal fan systems driven by a universal motor with possible microprocessor control was probably the most effective way forward for improvement. Improvements can be enhanced by adopting other

measures such as good nozzle design, the use of agitators and controlling emissions to air with well-fitting HEPA filters.

Task 7

Our work indicated that maximising fan efficiency, improved air ways, use of better seals, minimising energy losses from filters and nozzle design improvements represent LLCC (least life cycle cost) securing environmental improvement at little cost to business and significant cost savings to consumers. The improvements can be accommodated within the design cycle typical for this product. These design solutions combined with materials lightweighting represent BAT (Best Available Technology). BNAT (Best Not Available Technology) options relate to changes in vacuum cleaner type and consumer behaviour (i.e. automation that releases the consumer to do other things). Thus, BNAT options include: improved battery life, robot vacuum cleaners, smart homes, and methods for emptying dust receptacles that ensure lower dust emissions. On the basis of these findings, in the next section, we have considered policy options for implementing improvements.

Task 8

The Energy Label scheme should be extended to include vacuum cleaners as a means of aiding consumer choice by differentiating products. The Energy Label also allows ready identification of the worst performing products and would facilitate the removal of these from the market as has been done successfully for domestic refrigerators. We recommend that any such removal of less efficient products be phased over time. Whilst we would support the CENELEC proposed method for energy label ratings, we strongly recommend that ratings for energy consumption and cleaning efficiency should appear separately on the energy label. However, an energy label on its own will not be enough to effect real energy savings. We are firmly of the belief that limiting input power ratings whilst maintaining good cleaning performance is achievable through the design improvement options described in Task 7. These improvements do not involve fundamental research and the rationale for implementing them is supported by the calculated pan-EU energy savings and life cycle costs. The following table presents our proposed caps on input power ratings.

Type\Year	2011	2014
Uprights without integral hose and cleaning tools	750 watts	500 watts
Canister cleaners and uprights with integral hose and tools	1100 watts	750 watts
Commercial Vacuum cleaners with single motor	1200 watts	1000 watts
Commercial Vacuum cleaners with dual motor	1500 watts	1250 watts

If these caps are adopted, we calculate the savings in energy and consumer expenditure over the period from 2005 to 2020 would be:

	Business as Usual (BAU)	Scenario 1 (Implementation of 1st Stage Cap Only)	Scenario 2 (Implementation of 1st and 2nd Stage Caps)
Potential Savings			
Total Energy (PJ)	-	1,230	2,032
of which Electricity (TWh)	-	342	565
Annual Consumer Expenditure M Euro	-	13,538	23,359

With regard to test standards for vacuum cleaners, the current IEC (EN) method for measuring cleaning efficiency on carpets has drawbacks (See Section 8.2.4.1). We recommend that a different method is devised for the Energy Label and EuP Implementing Measures that uses multiple carpet types (as in ASTM F608), as well as a hard floor test. The new method should not include averaging the results obtained for cleaning carpets and hard floors.

Table of contents

1 Task 1 Definition

1.1 Product Definitions

Product definition is an important issue because it helps set the scope of work for this preparatory study, which itself will inform the extent of EuP implementing measures that may be required.

Vacuum cleaners (VCs) are made in a variety of shapes and sizes for domestic and commercial use and for different applications. Generally, a vacuum cleaner can be defined as: “An electrically operated appliance that removes soiled material (dust, fibre, threads) from the surface to be cleaned by an airflow created by a vacuum developed within the unit by an electrically powered vacuum generator or fan. The material thus removed is separated and stored in the appliance and the cleaned suction air is returned to the ambient.” The project team understands that IEC are considering a definition along these lines for the next edition of standard IEC 60312.

1.1.1 Vacuum Cleaner Type Descriptions

The following list gives the most common types of vacuum cleaner put on the market.

(These first two definitions are purely technical)
Clean Air type (also known as indirect air)
A type of vacuum cleaner where the dirty air is pulled into a receptacle by the suction airflow ensuring that the airflow which subsequently passes through the vacuum generator (fan) is cleaned and filtered. This same airflow is used to keep the electric motor cooled.

Dirty Air type (also known as direct air)
A type of vacuum cleaner where the dirty air is pulled through the vacuum generator (fan) directly before being “blown” into the dirt storage facility. The electric motor has a separate cooling facility in this case. Historically this type of system has only been used for dry upright vacuum cleaners. They tend to require less energy for the cleaning process.

Upright Cleaner
A vacuum cleaner with the cleaning head forming an integral part of or permanently connected to the cleaner housing, the cleaning head normally being provided with an agitation device to assist dirt removal and the complete cleaner being moved over the surface to be cleaned by means of an integral handle. It is suited to cleaning carpet and floor areas.

Canister/ Cylinder/Suction Cleaner
A vacuum cleaner with the cleaning head separated from the vacuum generator (fan) and soil storage facility, usually by means of a flexible hose. The dirt is normally removed using suction power only. This type of cleaner is better suited to cleaning above floor level, e.g. upholstery, stairs etc., but is also used for cleaning carpets and floors however.

Stick Cleaner
A lighter weight vacuum cleaner with dirt storage facility and vacuum generator (fan) mounted centrally on a handle and integrated with a rigid connection to the cleaning head. The dirt is normally removed using suction power only.

Handheld
A lightweight vacuum cleaner with cleaning head, dirt storage and vacuum generator integrated in a compact housing allowing the cleaner to held and operated whilst being held in the hand. It may or may not have an agitation device incorporated.

Combination
A. With the addition of a powered nozzle (may be electric, air or mechanically driven agitation device incorporated into a separate cleaning head) a canister or stick cleaner can have an equivalent cleaning action to that of an upright.

B. An upright may be fitted with an integral housing allowing use of a separate cleaning head which may use suction power alone or a powered agitation device to remove dirt from surfaces in the same manner as a canister cleaner.

Extractor
An "Upright" vacuum cleaner with means of storing and dispensing water based cleaning solution on to the surface being cleaned and removing the dirty liquid into a second storage facility. Used to "wash" carpets and hard floors

3 in 1
A "canister" vacuum cleaner with means of storing and dispensing water based cleaning solution through a flexible hose to a separate cleaning head. With a second storage facility for storing the removed dirty liquid. Also used for "washing" carpets and hard floors.

Wet/Dry
A "canister" vacuum cleaner with a single tank for storing dirty water which has previously and separately been placed on the surface being cleaned or dried through a flexible hose and the separate cleaning head. Often used in garages and home workshops.

Other definitions relate to the function or applications of the vacuum cleaner:

Mains Powered
A vacuum cleaner connected to a mains voltage electrical supply during its operation.

Cordless
A vacuum cleaner with integrated electrical supply (usually low voltage DC) using rechargeable battery storage of electricity for operational use. It is only connected to the mains electrical supply for the purpose of recharging the batteries.

Robot
A cordless vacuum cleaner with "self drive", using sensory feedback control to clean surfaces automatically.

Bagless
A vacuum cleaner which employs a reusable container, usually rigid in form, and separate filters to remove and store the soil from the airflow. Dirt container is reusable thus saving the usage of bags.

Bagged
A type of vacuum cleaner which uses a disposable dirt storage container. Once filled it is (disposed of and a clean container is fitted in its place..

Household
A vacuum cleaner which is used primarily in household or domestic situations. (Normal maximum life expectancy – 500 hours actual use)

Commercial
A vacuum cleaner intended for professional housekeeping purposes and for use by laymen, cleaning staff or contracting cleaners, which is used primarily in office, shop, hospitals and hotel environments for longer periods of time than a household vacuum cleaner. (Normal maximum life expectancy – 1500 hours actual use)

1.1.2 Types of Filtration

Vacuum cleaners filter the dust and dirt from the airflow after picking up from the surface being cleaned. This prevents any dirt being blown back into the atmosphere after cleaning. There are various types of filtration used and these are defined here.

1.1.2.1 Barrier Filters.

Cloth.
The earliest vacuum cleaners used woven cloth bags to "capture" the dirt. They were usually quite large to increase the filter area and it was generally recommended to empty them weekly. Some vacuum cleaners still use reusable cloth filter bags.

Paper.

Paper bags started appearing in the 1930s and were designed to be used once only so the dirt was thrown away with the bag. Paper bags have been used as reusable with the danger of breakage being increased every time used! Some bags use multiple layers of paper to improve the ability to trap more dust without losing suction power.

Paper is also used as a medium for basic fixed filters (i.e. used in addition to a bag or receptacle), these would need to be replaced regularly as they filled with dirt. Heavier, impregnated papers, usually formed in a concertina fashion (to increase filter area) are designed to be cleaned and reused.

Artificial Fibres.

Materials such as polypropylene are used as fibres to form filters, they may be rigidised or left "soft". Man made fibres form the basis of a material commonly known as "fleece". This is generally heavier and provides bulk to hold large quantities of dust before "clogging". When used as a bag material this generally produces very low loss of suction as it fills.

Liquid.

Water is normally used as the filter medium, the air is forced through the water entrapping the dust as it passes through. The dirty water is then thrown away at the end of the cleaning process.

An alternative use of water is simply to inject a fine stream into the dirty airflow to entrap the dust and dirt which is then collected in a receptacle to be thrown away as before.

Solid.

Sintered plastic materials are sometimes used to form a moulded rigid dirt receptacle. The sintering process causes the walls of the receptacle to be porous so that they act as a filter.

1.1.2.2 Non Barrier Filters.

Cyclones.

A cyclonic filter is usually cone shaped and directs the air in a centrifugal manner with sufficient velocity to "throw" heavier than air particles out of the airflow to be trapped in a fixed receptacle. Single cyclones are good over a specific range of particle sizes and weight. Usually they are not sufficient to filter out the whole range of particle sizes encountered by a vacuum cleaner. The Dual Cyclone uses two different sized conical cyclones in series to increase the range of particle sizes filtered. Multi cyclones usually have a single first stage and multiple second stage cyclones in parallel. Cyclones are excellent for filtering dust type solids but can have some problems with fibrous materials due to a tendency to agglomerate as they enter the cyclone. This may be dealt with by use of a coarse filter or barrier prior to that occurring.

Electrostatic.

Not commonly found, but they use an electrostatic charge to attract dust from the airflow.

N.B. some barrier filters have an electrostatic charge applied.

1.1.2.3 Combination Filters.

These are usually cyclones (first) and barrier filters used subsequently in series. Single cyclones will need good barrier filtration to trap other particles not affected by the cyclone. Even second stage multi cyclones may require additional barrier filtration as they can allow certain amounts of dust to pass through.

1.1.3 Product Classifications

PRODCOM[1] classifies vacuum cleaners in the NACE[2] 29.71 (Manufacture of electric domestic appliances). PRODCOM 2006 lists:

29712113 (Domestic vacuum cleaners with self-contained electric motor for a voltage >= 110V), and
29712115 (Domestic vacuum cleaners with self-contained electric motor for a voltage < 110V)

[1] PRODCOM classification: List of PRODucts of the European COMmunity.
[2] NACE -- Classification of Economic Activities in the European Community

PRODCOM 2007 (introduced 11th December 2006) lists:

29712123 (Vacuum cleaners with a self-contained motor of a power <= 1500 watt and having a dust bag or receptacle <=20 litres)
29712125 (Other vacuum cleaners)
29713010 Parts for vacuum cleaners

1.2 Scope of the study

Key aspects in the considerations of the scope of this study are

- Functionality – the function of a vacuum cleaner is to "remove soiled material (dust, fibre, threads) from a surface to be cleaned by an airflow created by a vacuum developed within the unit by an electrically powered vacuum generator or fan".
- End use (domestic / commercial) – this study focuses on products designed for domestic/household use and similar usage by laymen in a commercial or institutional environment such as shops, hospitals, offices, and hotels, for removal of settled dust on carpets and dry hard floors. Because of their specialist application, it is not sensible to include industrial vacuum cleaners used, for example, on construction sites or in factories.
- Availability of test standards – For example, the definition according to Standard 60335 is: "This International Standard deals with the safety of electrical appliances for households and similar purposes, their rated voltage being not more than 250 V for single-phase appliances and 480 V for other appliances. Appliances not intended for normal household use but which nevertheless may be a source of danger to the public, such as appliances intended to be used by laymen in shops, in light industry and on farms, are within the scope of this standard. Note 1: Examples of such appliances are catering equipment, cleaning appliances for industrial and commercial use, and appliance for hairdressers. Note 3: This standard does not apply to: appliances intended exclusively for industrial purposes;…."
- Complementary to other EU initiatives (e.g. the EU Energy-Label covers cylinders and uprights but not central VCs and cordless/battery VCs as they consume small amounts of energy or are only found in a few locations).
- Energy required for the function. What is the optimum energy required for good cleaning?

1.2.1.1 Products excluded from scope

- Central vacuum cleaners as these are only found in limited applications in Europe.
- Industrial / commercial VCs designed for specialist applications as these are limited in use, possibly custom designed or used in hazardous or dangerous situations.
- Sweepers (e.g. appliances that do not use a vacuum for dust pick up but use an electric motor driven brush roller to sweep surface dust into a collection tray)[3].

1.2.1.2 Products to be considered in scope

Household and similar use vacuum cleaners of all types found in homes, offices, hospitals, hotels, and shops.

[3] However, these alternatives to vacuum cleaners appear of interest – and so manufacturers of these should be encouraged to participate in the process.

1.3 Test Standards and Product Testing Procedures

1.3.1 Europe

There are two major standards applicable to vacuum cleaners in Europe and these are EN 60335.2.2 and EN 60312. Both are harmonised with the equivalent IEC standards in accordance with the Dresden Agreement, although there are some small common European amendments for EN 60335.2.2. Each European country adopts them as their own National Standards (e.g. BS EN 60312).

EN 60 335 is relevant to safety and also gives the method by which input power is defined. Nominal input power is the arithmetic average of maximum input power (watts) and minimum input power (watts). Maximum input power is measured when the airflow is at the highest, sometimes called “open airflow”. Minimum Airflow is measured when airflow is zero, sometimes called sealed suction. The rating label of the vacuum cleaner will display the nominal input watts and allows for a tolerance of 10 percent. Some manufacturers use the tolerance and refer to this as “IEC” input watts and also add “maximum” input watts with a 10% tolerance. This device allows manufacturers to claim the “highest” input power figures and some do this to gain benefit in the market place where consumers generally associate high power with good cleaning efficiency (see below).

EN 60312 is relevant to performance and contains many test methods to measure performance relative to cleaning on different surfaces and with different types of soiling (see Box 1).

1.3.2 Box 1

Performance test measurements for vacuum cleaners included in the 60312 standards.

1. Dust removal from hard flat floors
2. Dust removal from hard floors with crevices
3. Dust removal from carpets (measured using a wool Wilton carpet)
4. Edge cleaning effectiveness
5. Fibre removal effectiveness from carpets and cushions
6. Thread removal from carpets effectiveness
7. Maximum volume of dirt receptacle
8. Airflow performance data
9. Performance with a loaded receptacle
10. Dust emission
11. Manipulative effort
12. Durability Tests
13. Life Test
14. Energy consumption

EN 60312 also contains test methods for indicating product life and also air flow characteristics. The major airflow characteristic is known as Suction Power or Airwatts and this occurs as a combination of both suction and airflow; it is evaluated by measuring the airflow in litres per second and multiplying that by the measured suction at that airflow and by a “constant” which gives the suction power. It usually peaks somewhere between sealed suction and open airflow. The maximum suction power divided by the input power at the same point determines the maximum airflow efficiency (energy conversion efficiency) of the vacuum cleaner. This value, which is not related to cleaning efficiency, is normally quite low, rarely above 50% and is often around 30%. So input power is, in many cases, converted mostly to heat and some 2000+ watt vacuum cleaners are more or less 1200 watt fan heaters! This is typical for all types of vacuum cleaners as it is a consequence of inefficiencies in the vacuum generating fan where high airflows are moved through tight turns and restrictions whilst passing through the fan chamber. The motor alone is much more efficient, usually above 90%, as it converts electrical power into rotational mechanical power.

This study should examine this in more detail as it has become common practice for vacuum cleaners to require very high inputs, up to 2700 watts to date, and yet they are alleged to not clean any better than vacuum cleaners with lower input power requirements. It is also important to highlight that neither input power nor airflow efficiency necessarily have any correlation with cleaning performance.(See Box 2)

1.3.3 Box 2

Cleaning Performance Parameters.

There are test methods to measure the cleaning performance of vacuum cleaners, however the following gives a guide to actual requirements to produce good cleaning performance.

1. Input Power.
It is the project team's experience that there is no correlation between input power and cleaning performance other than the fact that there is a lower limit below which no cleaning performance would occur at all and then a small band of rapid improvement followed by a wider band of small or negligible improvement and finally no discernable improvement can be seen. These values will differ between upright and cylinder cleaners, i.e. those cleaners which use agitation to remove dirt and those which use suction power alone.
To give a guide to the level of these values it should be noted that a typical Hoover Junior upright vacuum cleaner as sold in the 1960s, with 250 watts input would clean a carpet as effectively as many of vacuum cleaners on sale today, including those with 2700 watts input. A cylinder cleaner may typically require 1000 watts input to match an upright if suction power alone is to be used, however with a power brush this could be reduced significantly, even accounting for the additional power required by the brush. The team aims to prove this assertion by subjecting a cordless 250 watt vacuum cleaner to "on carpet" and hard floor with crevice testing.

2. Suction Power.
There is a little more correlation between suction power and cleaning performance, particularly when comparing cylinder cleaners only using suction power for cleaning. However the design of the actual nozzle is more important.

3. Airflow.
Airflow is a key element in carrying removed soil away from the cleaning head, into the dirt receptacle. Below a certain level the airflow will simply not be sufficient to transport the dirt, this value is normally around 8.5dm3 per sec (18 ft3 per minute).

4. Agitation (brushing).
Agitator or brush design has more effect on carpet cleaning performance than any other factor. Typically there is an optimum speed of rotation for an agitator (usually around 3000rpm). The bristle rigidity and length is also important. Modern upright vacuum cleaners tend to have more aggressive brushing than those sold 20 years ago and this may lead to some form of carpet wear in some cases. It should be noted that whilst an agitator is good at removing soil from surfaces, the vacuum cleaner must provide sufficient airflow in order to carry the removed soil to the receptacle.

5. Dirt Receptacle and Filtration.
Dirt receptacles may either be filters in their own right or may be rigid containers which require separate filtration. Some disposable dirt receptacles have a form of auto sealing when removed from the vacuum cleaner which may improve the situation regarding the hygienic disposal of dirt.

Filters vary enormously in efficiency and effectiveness and there are standard test methods to determine how effective a vacuum cleaner is at retaining its dirt and dust once picked up. Usually the more effective a filter is at stopping and trapping the dirt the more energy it absorbs from the airflow and this can affect the cleaning performance. Barrier filter efficiency can be measured in accordance with a European Standard (EN 1822) which is used to measure the efficiency of retaining the most penetrative particle size. The more effective filter media are defined as HEPA (High Efficiency Particulate Airflow), there are grades of HEPA, the highest being HEPA 13. Even more efficient filters are known as ULPA (Ultra Low Particulate Airflow). However even a high quality filter media loses its effectiveness if it is not fitted well into the vacuum cleaner. Generally, the thicker the filter barrier the more capacity it has to retain dirt before affecting airflow. However the distance the air has to pass through the barrier will, in itself, reduce airflow, So there is a balance to be sought when designing the most efficient filters. The most effective way to reduce airflow loss is simply to increase the overall area of the filter. The original cloth bags had such a large filter area that despite their relatively low filtering ability were still able to trap dust and dirt effectively because the velocity of airflow through

was also low hence the energy of particles was also low, making them easier to stop.
Cyclones also absorb energy, in order to create the centrifugal velocities and forces. Multiple Cyclones in series can absorb as much energy as a clean heavy duty barrier filter. The use of multiple second stage cyclones in parallel has led to a reduction in energy absorbed but may allow more dust to pass through thus requiring the subsequent use of barrier filters in addition to the cyclones.
Dust emissions from vacuum cleaners are measured in accordance with a method specified in EN 60312 4th Edition, Clause 2.10. In addition an ASTM test method, F1977 can be used to measure the overall fractional filtration efficiency of a vacuum cleaner and a new ASTM standard, F2308 can be used to measure the overall emissions of a vacuum cleaner while in use. These standards are methods of measurement and do not specify “pass” or “fail” criteria.

EN 60 312 also refers to IEC 60704 which measures noise level of vacuum cleaners.

When making performance claims in the UK the ASA code of practice determines that manufacturers use IEC 60312 for performance measurement methods, but this is not extended through the rest of Europe. However it is normal for 60312 to be used.

Noise levels for vacuum cleaners are measured using EN60704-1-2. Noise levels are measured as Sound Power (LwA) and presented in Decibels (dBA), the “A” represents a scale weighting which more closely represents the hearing of the human ear. Sound Power is an absolute measurement of noise level and is what is generated by the vacuum cleaner. It is independent of environment and gives a more accurate representation of the power of a vacuum cleaner to produce noise. Sound Pressure (LpA) is also measured in decibels on an “A” weighted scale. However this value will vary dependent on location. When measured in an anechoic chamber the value will be lower, as some sound is effectively absorbed by the soundproofing material in the chamber. If measured in a hard chamber the value will be higher due to reflected noise adding to the total being measured. Hence Sound Pressure is not a good method to use as it can vary depending upon the type of measurement chamber. Where Sound Pressure is measured in an anechoic chamber the value in dB will be lower than the Sound Power value. This has lead to some confusion in the past and comparisons should not be made on an ad hoc basis between Pressure and Power. As the decibel scale is logarithmic an increase of 3dB means that the sound power is doubled, however a difference of 3dB is the smallest difference that is normally audible to the human ear.

Sometimes the Consumers Organisations develop their own test methods but these are rarely proven by extensive ‘round robin’ tests and field correlation, as IEC tests are supposed to, and many manufacturers object to them! Some examples of such tests can be found in the UK Consumer’s Association developed test to measure the removal of pet hair from surfaces using actual pet hair, which is accepted by many as a useful test. Another is the use of actual household dirt in some cleaning tests by Stiftung Warentest.

1.3.4 International

There is one other major, international test organisation which has published extensive vacuum cleaner performance test methods and that is the US based ASTM International. These test methods and standards have been developed in the US but are increasingly being determined by European members of ASTM who are also on the IEC committees. The ASTM committee F11 which deals with these standards was originally established to provide test methods for labelling and found that some of the IEC test methods did not provide statistically acceptable results, hence they developed alternatives. In general these give similar results, in airflow measurements for example, but since they measure cleaning on four different carpets give differing results from the IEC single carpet test.

IEC 60312 has recently been republished as the 4th Edition and the EN document will be revised to reflect this. One major change is to include energy measurement, which links with the work being done by CENELEC TC59 WG6 who are developing a test methodology for a potential vacuum cleaner energy label (see Section 1.5 below). Another change has been to introduce a test method to measure performance when the dirt receptacle is filled. It should be noted that the actual word used in the standard is “loaded”, this does not represent any specific point during filling but simply gives a guide to performance during filling. There is no acceptable definition for “full”!

The 5th edition of IEC 60312 is currently being worked on and an initial Draft document has already been circulated. It is scheduled for publication in December 2009. Changes include new dust emission and filtration efficiency tests as well as improvements to air data measurement. It should be clear then that there are many changes being examined for new or modified performance test methodologies at this time and progress will be monitored.

In the United States customer pressure has driven ASTM and AHAM to start the development of energy measurement standards for implementation in 2009. There is a strong possibility that the energy measurement method will be that already included in IEC 60312 and EN60312 (Clause 4.14) 4th editions, possibly with different surfaces being used for the measurement. The method being developed by CENELEC WG6 for energy labelling purposes will also be examined, however it is possible that the “Energy Star” rating may be used as the method of indication to users that the product uses low energy.

1.3.5 Eco Approval Schemes

1.3.5.1 Allergies.

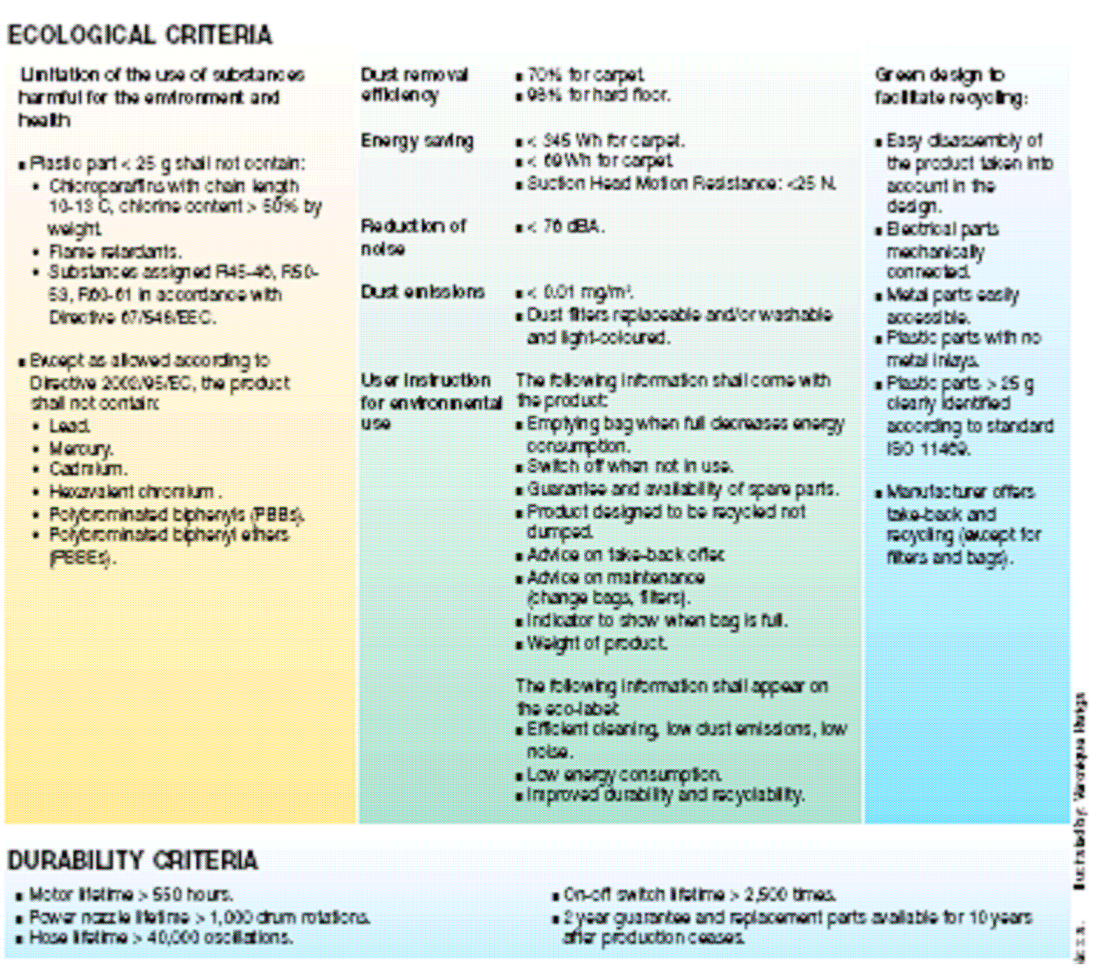
European Centre for Allergy Research Foundation (ECARF) Seal of Approval. This is a free issue seal of approval based on Manufacturers claims relating to filtration efficiency.

British Allergy Foundation Mark of Approval: this approval mark is awarded by the British Allergy Foundation (Allergy UK). It uses actual allergens in a controlled manner to test how many are actually removed during a cleaning test.

1.3.5.2 EU Eco-Labelling Scheme

The existing criteria[4] valid from 1 April 2003 until 31 March 2007 with an extension to 31 March 2008. However, as there were no applications made for an Ecolabel, these vacuum cleaner criteria have now expired, and we understand that the European Commission has no plans to extend them.

Figure 1 - Extract of EC Ecolabel Criteria for Vacuum Cleaners[5]



ECOLOGICAL CRITERIA

Limitation of the use of substances harmful for the environment and health

- Plastic part < 25 g shall not contain:
  - Chloroparaffins with chain length 10-13 C, chlorine content > 50% by weight.
  - Flame retardants.
  - Substances assigned R45-46, R50-53, R60-61 in accordance with Directive 67/548/EEC.
- Except as allowed according to Directive 2002/95/EC, the product shall not contain:
  - Lead.
  - Mercury.
  - Cadmium.
  - Hexavalent chromium .
  - Polybrominated biphenyls (PBBs).
  - Polybrominated biphenyl ethers (PBBEs).

Dust removal efficiency	■ 70% for carpet. ■ 98% for hard floor.
Energy saving	■ < 345 Wh for carpet. ■ < 60 Wh for carpet. ■ Suction Head Motion Resistance: <25 N.
Reduction of noise	■ < 76 dBA.
Dust emissions	■ < 0.01 mg/m³. ■ Dust filters replaceable and/or washable and light-coloured.
User instruction for environmental use	The following information shall come with the product: ■ Emptying bag when full decreases energy consumption. ■ Switch off when not in use. ■ Guarantee and availability of spare parts. ■ Product designed to be recycled not dumped. ■ Advice on take-back offer. ■ Advice on maintenance (change bags, filters). ■ Indicator to show when bag is full. ■ Weight of product. The following information shall appear on the eco-label: ■ Efficient cleaning, low dust emissions, low noise. ■ Low energy consumption. ■ Improved durability and recyclability.

Green design to facilitate recycling:

- Easy disassembly of the product taken into account in the design.
- Electrical parts mechanically connected.
- Metal parts easily accessible.
- Plastic parts with no metal inlays.
- Plastic parts > 25 g clearly identified according to standard ISO 11469.
- Manufacturer offers take-back and recycling (except for filters and bags).

DURABILITY CRITERIA

- Motor lifetime > 550 hours.
- Power nozzle lifetime > 1,000 drum rotations.
- Hose lifetime > 40,000 oscillations.
- On-off switch lifetime > 2,500 times.
- 2 year guarantee and replacement parts available for 10 years after production ceases.

1.3.6 Recent Developments

1.3.6.1 IEC 62430: Environmentally Conscious Design for Electrical and Electronic Products

This voluntary standard is about to be published and, at the moment (February 2009) the committee (TC111) responsible is seeking approval that this becomes a horizontal standard, i.e. it applies to all relevant product groups within IEC and each committee (including vacuum cleaners committee) can have input to future editions.

Every product has an effect on the environment, which may occur at any or all stages of its life cycle - raw-material acquisition, manufacture, distribution, use, maintenance, re-use and end of life. These effects may range from slight to significant; they may be short-term or long term; and they may occur at the local, national, regional or global level (or a combination thereof).

The widespread use of electrical and electronic products has drawn increased awareness to their environmental impacts. As a result, legislation, as well as market-driven requirements for environmentally conscious design, is emerging.

This International Standard is intended for use by all those involved in the design and development of electrical and electronic products. This includes all parties in the supply chain regardless of organization type, size, location and complexity. It is applicable for all types of products, new as well as modified. Sector-specific documents may be developed to address needs not covered in this document. The use of this document as a base reference is encouraged so as to ensure consistency throughout the electrotechnical sector.

1.4 Existing Policies and Measures (or Policy Instruments)

Legislation relevant to vacuum cleaners is summarised in Table 1 below.

Table 1- Existing Policies and Measures relevant to Vacuum Cleaners

No.	Description	Reference	Applicability	Link	Comment
1.3.1	**EU policies and measures**				
1.3.1.1	EU Energy label	In development?	All products		CENELEC TC 59 WG6 working on programme
1.3.1.2	EU eco-label	Voluntary (2003/121/EC)	Self contained vacs such as cylinders and uprights, does not cover cordless or battery operated products nor central vacuuming systems	http://ec.europa.eu/environment/ecolabel/product/pg_vacuumcleaners_en.htm	
1.3.1.3	RoHS	Mandatory (2002/95/EC)	All products		
1.3.1.4	WEEE	Mandatory (2002/96/EC, 2003/108/EC)	All products		
1.3.1.5	Noise	Mandatory (2000/14/EC - Noise Emissions for Outdoor Equiptment Directive)	Leaf suction machines used outdoors only		
1.3.1.6	Packaging	Mandatory (94/62/EC - Packaging Directive)	The packaging vacs are supplied in, if any		
1.3.1.7	Safety (electrical)	Mandatory (2006/95/EC -Low Voltage Directive)	All products		Harmonised standards cover emission of toxic material under fault (on fire) conditions. Directive otherwise deals just with safety
1.3.1.8	Safety (explosive atmospheres)	Mandatory (94/9/EC - ATEX Directive)	Only vacs formally certified by a notified body can be used in areas classified as potentially explosive		Equipment and protective systems intended for use in potentially explosive atmospheres.

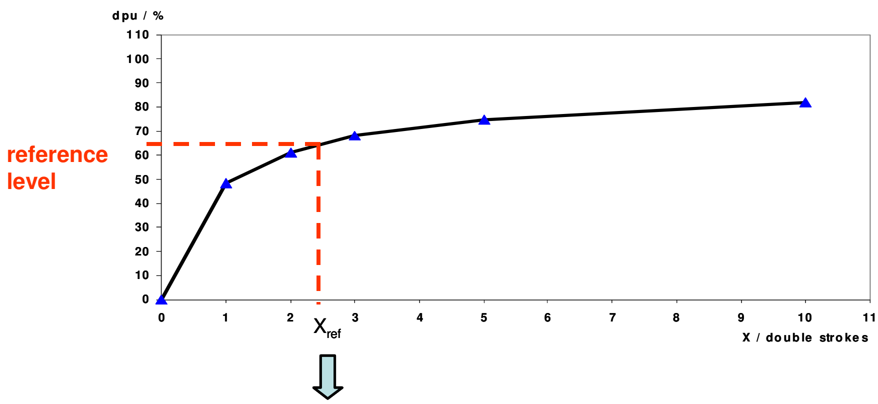
No.	Description	Reference	Applicability	Link	Comment
1.3.1.9	Built environment	Complicated but potentially mandatory (89/106/EC - Construction Products Directive)	(potentially) all products fitted into buildings e.g. centrally sited vacuum cleaning systems	-	
1.3.1.10	Electromagnetic Compatibility (EMC)	Mandatory (2004/108/EC - EMC Directive)	All products	-	
1.3.1.11	Chemicals	Mandatory (2006/121/EC - REACH)	Vacs supplied complete with chemical treatments	-	
1.3.1.12	Batteries	Mandatory (2006/66/EC - Batteries Directive)	Vacs supplied with battery powered heads	-	
1.3.1.13	Existing eco-design standards	None		-	
1.3.1.14	Minimum efficiency directives	None		-	
1.3.1.15	Product liability	None		-	
1.3.1.16	Industry voluntary commitments	None			
1.3.2	**Policies and measures in EU member states**				
1.3.2.1	National eco-label schemes	France			
1.3.2.2	National energy saving recommended schemes	None			
1.3.2.3	Swedish EPD scheme	Voluntary	Scheme is applicable to cylinders, may be open to other types too	http://www.environdec.com/reg/epde26e.pdf	
1.3.2.4	Economic incentives for efficient appliances	None			
1.3.2.5	Economic incentives for low allergen vacs	None			
1.3.2.6	National building regulations	Could be applicable in a number of EU countries	(potentially) all products fitted into buildings		
1.3.2.7	Additional local legislation	None			

No.	Description	Reference	Applicability	Link	Comment
1.3.2.8	Voluntary labelling schemes for low allergen or HEPA vacs	None			May be included on energy label
1.3.3	**Environmental policies and measures in non-EU countries**				
1.3.3.1	Australia and New Zealand	None			
1.3.3.2	USA and Canada	None			
1.3.3.3	China	None			
1.3.3.4	Japan	None			
1.3.3.5	Brazil	None			
1.3.3.6	Other countries	None			

1.5 Progress of CENELEC CLC TX 59X WG 6

1.5.1 Mandate M 353: Energy Labelling for Vacuum Cleaners

An amendment will be made to EN60312 following work on energy consumption and cleaning performance of vacuum cleaners. "Energy-efficiency" will be defined as energy consumption necessary to reach a reference level of dust pick up (on carpet and hard floor). The diagram below illustrates this.



$$W_{(Xref)} = W_{(10m2)} / 5 * x_{ref}$$

[Diagram source: H. Schellenberger, BSH]

Filtration performance will be defined as "fractional filtration efficiency", taking into account the dust entering and emitted by the vacuum cleaner. The result will be shown as percentage of retained dust. The medium used will allow consideration of particle sizes upto 4 microns.

The criteria for: useable size of dust receptacle, radius of operation, and supplementary information will be kept unchanged.

Currently, Ringtests are in planning. The procedure on how to do the measurements and the tests are described in detail, Wilton test carpets are available from a new supplier, costs are estimated and call for funding has been sent to the EU by CENELEC (currently awaiting response). The planned timescale for the amendments are for Ringtests to start in February 2008 with a view to final completion by November 2008.

1.6 Conclusions

All household and similar use vacuum cleaners will be considered for their usage of energy, effect on the environment, use of materials and disposability with consideration to cleaning performance and general use. Only specialist vacuum cleaners such as central vacuum cleaners and those designed for highly specialised tasks are excluded as they are small in number and do not easily correspond with general test procedures.

2 Task 2 Economic and Market Analysis

Economic and Market data on vacuum cleaners are important to understand because we need to identify the extent to which the market place is homogenous across the EU. This is key to ensure that any implementing measures do not disadvantage a particular MS or business sector.

2.1 Generic Economic Data

Eurostat provides the following data on production of domestic vacuum cleaners in the EU.

Table 2 – Domestic Vacuum Cleaners Production (000 units) ex PRODCOM

Nr.	Country	Year:	2000	2001	2002	2003	2004	2005	2006
1	France		-	-	-	-	-	-	-
3	Netherlands		-	-	-	-	-	-	-
4	Germany		6087	6536	4895	4361	4371	4812	5315
5	Italy		2609	2507	2616	2551	2963	2744	2498
6	United Kingdom		2491	2638	2454	2679	3682	1458	1831
8	Denmark		141	101	89	36	-	-	-
9	Greece		-	-	-	-	-	-	-
10	Portugal		-	-	-	-	-	-	-
11	Spain		-	-	-	-	-	-	-
17	Belgium		-	-	-	-	-	-	-
18	Luxemburg		-	-	-	-	-	-	-
24	Iceland		-	-	-	-	-	-	-
28	Norway		-	-	-	-	-	-	-
30	Sweden		1108	944	885	-	-	-	-
32	Finland		-	-	-	-	-	-	-
38	Austria		-	-	-	-	-	-	-
46	Malta		-	-	-	-	-	-	-
53	Estonia		-	-	-	-	-	-	-
54	Latvia		-	-	-	-	-	-	-
55	Lithuania		0	-	-	-	-	-	-
60	Poland		-	-	-	-	-	-	-
61	Czech Republic		-	-	-	-	-	-	-
63	Slovakia		-	-	-	-	-	-	-
66	Romania		-	-	114	-	-	-	-
68	Bulgaria		-	-	-	-	-	-	-
91	Slovenia		-	-	-	-	-	630	-
92	Croatia		-	-	-	-	-	-	-
600	Cyprus		-	-	-	-	-	-	-
1110	EU15TOTALS		16135	15346	13843	12129	12759	9383	-
1111	EU25TOTALS		-	-	-	15647	15713	13328	195
1112	EU27TOTALS		-	-	-	522	-	251	14046

Note: Table 2 has been created directly from the ProdCom data query system. It should be noted with care that the EU Totals figures exhibit some discontinuities, particularly for years 2003 to2006 data for EU-15, EU-25 and EU-27. The reasons for these are not apparent. However, the totals figures indicate a general decline in the numbers of vacuum cleaners produced in the European Union. The above data covers PRODCOM code numbers 29712113 and 29712115 (Domestic vacuum cleaners with self-contained electric motor for a voltage >= 110V and < 110V respectively).

Note: PRODCOM 2007 code numbers for vacuum cleaners are:

29712123 (Vacuum cleaners with a self-contained electric motor of a power <= 1500 W and having a dust bag or other receptacle capacity <= 20 l)

29712125 (Other vacuum cleaners) were identified, and

29713010 (Parts for vacuum cleaners)

Thus, it can be expected that production data for 2007 will differ from previous years due to these changes.

PRODCOM also provides information on the total value of production across the EU27 and the average unit values for these 2 product groups.

Table 3 - PRODCOM: Total Value of Production (million Euros) and Average EU27 unit values (Euros) – Domestic Vacuum Cleaners

	Product Groups (M Euros)			Unit Values (Euros)	
Year	29712113 value	29712115 value	Total Production Value	29712113 item	29712115 item
2006	1253	16	1268	101.98	79.94
2005	1222	16	1238	92.22	72.74

2.2 Market and Stock Data

2.2.1 Domestic Vacuum Cleaners

Data are also provided by PRODCOM on imports and exports of domestic vacuum cleaners.

Table 4 - Imports of Domestic Vacuum Cleaners (000 units) ex PRODCOM

Nr.	Country	Year:	2000	2001	2002	2003	2004	2005
1	France		4294	4549	4342	4897	6266	6188
3	Netherlands		2837	3420	4913	5863	5625	5165
4	Germany		5829	6200	7301	8393	10627	11718
5	Italy		2340	2451	2969	3517	5014	5024
6	United Kingdom		3807	4976	6621	8365	9956	8977
7	Ireland		269	293	358	398	410	462
8	Denmark		509	596	582	948	938	943
9	Greece		565	660	600	838	973	1103
10	Portugal		503	420	453	506	602	659
11	Spain		1860	1626	1746	2360	2901	2949
17	Belgium		2522	2886	3384	3763	3953	3763
18	Luxemburg		44	48	68	55	69	72
30	Sweden		853	835	888	1093	1202	1682
32	Finland		408	420	449	499	707	742
38	Austria		793	776	784	895	1164	1252
46	Malta		-	-	-	21	15	18

Nr.	Country	Year:	2000	2001	2002	2003	2004	2005
53	Estonia		45	53	55	63	64	82
54	Latvia		-	72	70	97	104	115
55	Lithuania		53	61	84	94	145	165
60	Poland		-	-	754	880	941	1045
61	Czech Republic		-	331	426	567	724	752
63	Slovakia		256	158	186	214	222	269
64	Hungary		-	439	538	597	676	725
66	Romania		-	-	191	27	56	68
68	Bulgaria		-	125	165	245	288	302
91	Slovenia		-	94	79	111	171	189
600	Cyprus		-	-	-	38	40	48
1110	EU15TOTALS		27435	30158	35460	42390	50405	50700
1111	EU25TOTALS		27789	31366	37652	45070	53508	54108
1112	EU27TOTALS		27789	31491	38008	45342	53852	54477

Table 5 - Exports of Domestic Vacuum Cleaners (000 units) ex PRODCOM

Nr.	Country	Year:	2000	2001	2002	2003	2004	2005
1	France		1455	1364	774	731	894	880
3	Netherlands		2056	1667	1973	1787	3431	2686
4	Germany		4690	4865	5048	5108	6117	6721
5	Italy		1897	1646	1631	1910	1807	1719
6	United Kingdom		3432	5122	787	755	707	651
7	Ireland		698	619	422	359	254	215
8	Denmark		332	355	281	322	319	226
9	Greece		28	16	17	83	119	87
10	Portugal		183	171	284	170	18	10
11	Spain		680	816	775	800	715	434
17	Belgium		2184	2176	2402	2650	2824	3104
18	Luxemburg		5	7	13	7	7	17
30	Sweden		1200	1070	1282	1290	950	527
32	Finland		85	129	154	209	281	314
38	Austria		308	277	233	215	333	447
46	Malta		-	-	-	0	0	0
53	Estonia		1	4	2	2	3	13
54	Latvia		-	7	12	19	16	12
55	Lithuania		1	2	7	3	8	10
60	Poland		-	-	938	874	1130	1050
61	Czech Republic		-	526	438	367	239	280
63	Slovakia		154	8	9	9	24	18
64	Hungary		-	1053	1659	1818	2119	2321
66	Romania		-	-	59	6	1	3
68	Bulgaria		-	3	2	1	3	1
91	Slovenia		-	735	897	904	843	703
600	Cyprus		-	-	-	0	0	0
1110	EU15TOTALS		19234	20300	16077	16395	18776	18038

Nr.	Country	Year:	2000	2001	2002	2003	2004	2005
1111	EU25TOTALS		19391	22635	20039	20393	23158	22445
1112	EU27TOTALS		19391	22638	20101	20399	23162	22449

Thus, at the overall European level, the apparent consumption of domestic vacuum cleaners (i.e. production + imports – exports) shows the following trends.

Table 6 - Apparent Consumption of Domestic Vacuum Cleaners (000 units) ex PRODCOM

Nr.	Country	Year:	2000	2001	2002	2003	2004	2005
1110	EU15TOTALS		24335	25203	33226	38124	44388	42045
1111	EU25TOTALS					40323	46063	44992
1112	EU27TOTALS		No data	No data	No data	No data	No data	No data

Table 6 shows there has been a major increase in the consumption of vacuum cleaners. Imports for most Member States have doubled in the period; exports about the same.

Consumption increases are most likely due to a combination of:

- Declining product lifetime
- Increase in multiple ownership

Falling lifetimes can be for many reasons including premature replacement of vacuum cleaners by owners who perceive their vacuum cleaner technology to be ‘out of date’.

2.2.2 Commercial Vacuum Cleaners

Information on sales of non-domestic vacuum cleaners has been obtained from the first project questionnaire survey. Data is very limited.

Table 7 - Sales of Non-Domestic Vacuum Cleaners (2006)

	Total	Upright with bag	Upright bagless	Cylinder with bag	Cylinder - bagless	Wet/dry	Centralised	Tub[6]
France	115,000 (a) 70,000 (b)							
Germany	230,000 (a) 90,000 (b)							
Italy	20,000 (a) 10,000 (b)							
Spain	10,000 (a) 10,000 (b)							
Poland	30,000 (a) 10,000 (b)							
Scandinavia	40,000 (a) 30,000 (b)							
UK[7]	1,000,000	50,000				40,000	1000	750,000
EU25	**700,000 (a)** **300,000 (b)**							
Total EU27	**1,300,000**							

(a) = vacuum cleaners, (b) = wet/dry vacuum cleaners

[6] Includes both bagged and bag-less systems.
[7] Source: ICMMA

2.3 Market Trends - Background

2.3.1 Early vacuum cleaners

Self contained vacuum cleaners are a little over 100 years old, the first suction-only machines being invented and introduced by Hubert Booth into Europe in the early 1900s. His company eventually became known as Goblin. The next stage was the development of upright vacuum cleaners with a revolving brush to loosen debris. This was invented by James Murray Spangler and introduced by Hoover into the US a few years later.

In Europe, Electrolux (1908[8]), Vorwerk (1929[9]) and Miele (1931[10]) were all early entrants into the vacuum cleaner market.

2.3.2 Early development trends

The development of vacuum cleaners tended to be slow for the first 60 years, with vacuum cleaners in 1960 being clearly recognisable to the originals from the turn of the century. Performance was improved by further development of revolving brushes (agitators) and hygiene was improved by the introduction of the disposable paper bag soon after World War 2.

2.3.3 Wet and dry vacuum cleaners

In the 1960s Martin Miller, in the US, introduced the wet and dry pick up vacuum cleaner under the Shop Vac and Aqua Vac brands allowing liquids to be picked up for the first time. Around the same time professional cleaning of carpets was being introduced where liquids were dispensed onto surfaces and subsequently picked up by the same machine. This carpet washing was refined and introduced domestically by Alan Brazier in the 1980s under the Vax brand. In Europe this was the biggest revolution in vacuum cleaning since its introduction at the beginning of the 20th century, with Vax taking over half the UK market value with a single orange and black suction vacuum cleaner by the end of the 1980s.

Upright carpet washers or extractors were introduced into the US and Europe in the first years of the 21st century by Bissell and Hoover.

2.3.4 Cyclonic filtration bagless cleaners

James Dyson introduced the cyclonic filtration bagless vacuum cleaner, first to Japan, winning a prize in 1991[11], and then into the UK and Continental Europe under the Dyson brand in the 1990s. Following Dyson's successes, many other vacuum cleaner manufacturers introduced bagless vacuum cleaners, some with elements of cyclonic filtration and some with suitably positioned filters.

Bagless vacuum cleaners tend to predominate in the UK but bagged machines still command a large part of the market in other EU countries, such as Germany, for example. It should be noted that although Dyson machines are bagless, it is the cyclonic filtration system that sets them apart.

[8] http://www.electrolux.co.uk/node36.aspx?categoryId=5106 accessed 16 January 2008
[9] http://www.vkdirect.co.uk/AboutUs-VorwerkCompanyHistory.asp accessed 16 January 2008
[10] http://www.miele.de/de/haushalt/unternehmen/2335_4856.htm#p4848 accessed 16 January 2008
[11] http://www.dyson.co.uk/about/story/2kvacuum.asp

2.3.5 Other types of vacuum cleaner

Black and Decker introduced cordless hand held vacuum cleaners into the European market in the early 1980s.

2.3.6 Development of bags

Miele were among the first to introduce high efficiency filter media disposable bags, allowing bagged machines to maintain performance during filling.

2.3.7 Regional differences

In Europe, the UK generally preferred upright vacuum cleaners until the early 2000s, but by 2003 suction cleaners had overtaken upright cleaners in volume sales[12]. Continental Europe historically prefers suction cleaners. Lightweight suction cleaners mounted on a handle with integrated cleaning head (stick cleaners) also tended to be found more in Continental Europe than the UK.

2.3.8 Increase in power consumption

With plastics taking over from metal during the 1970s and electric motor developments allowing large input wattage claims, manufacturers have developed products with higher and higher input wattage. These have been marketed to consumers on the basis that the higher the wattage the better the product cleans to the point that consumers now associate power rating with cleaning efficiency. Input wattage values up to 2700 watts have been found in the European vacuum cleaner market.

Analysis of Which? Magazines (publications of the UK Consumer Testing organisation) that contained vacuum cleaner tests reveal how input power ratings of vacuum cleaners have increased over the last 40 years or so. The 1960 report showed that tested products had an average wattage of 400 W, with a range of 150 to 950W. By 1978, typical wattages of each type of vacuum cleaner were:

- hand held up to 300W
- cylinder around 650W
- canister 500 to 1100W
- upright 300W
- stick 450W

Information obtained from retail catalogues[13] confirm the trend:

Type	Input Power Range 2003	Input Power Range 2008
Bagged upright cleaners	1300 to 1800 Watts	1150* to 2000 Watts
Bagless upright cleaners	1450 to 1700 Watts	1000** to 2000 Watts
Bagged cylinders	1100 to 1800 Watts	1200 to 2500 Watts
Bagless cylinders	1400 to 2000 Watts	1400 to 2700 Watts

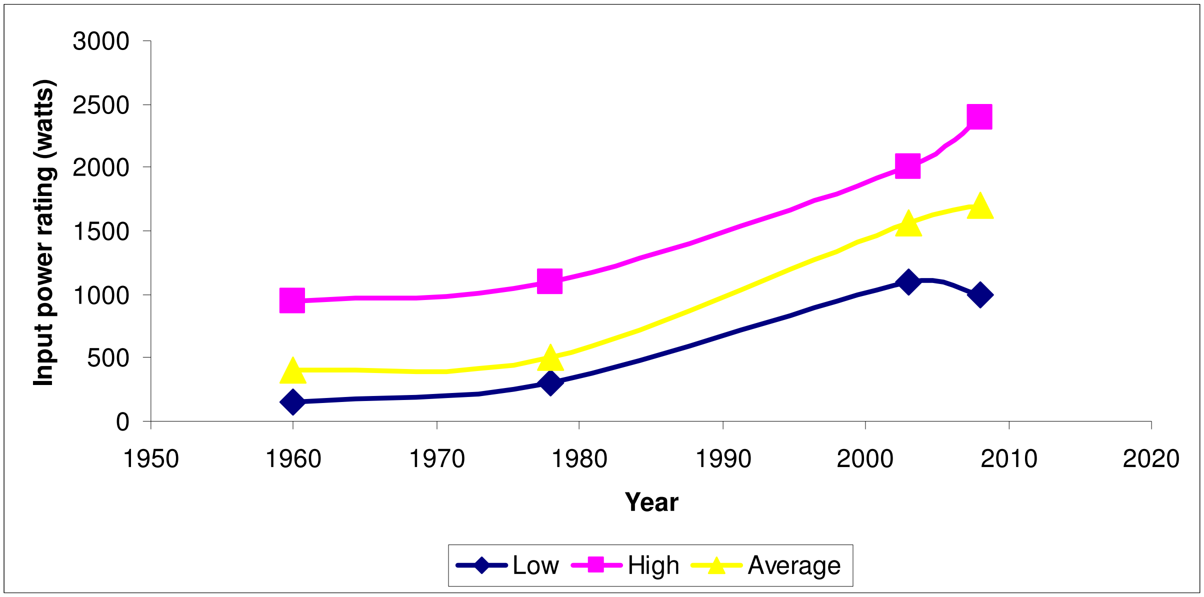
* - Sebo model only. The rest surveyed were in the range 1700 to 2000 watts.

** - Morphy Richards low energy Storm model only. The rest were in the range 1400 to 2000 watts.

The above data can be illustrated graphically as below.

[12] Mintel August 2006 Vacuum Cleaners Market Intelligence.
[13] Argos catalogues Spring/Summer 2003 and 2008.

Figure 2 - Increase in Input Power Rating over Time



This trend towards increasing input power rating in recent years is confirmed by Dutch Trade Association[14] annual overview reports, which show increasing proportions of vacuum cleaner sales for cleaners over 1800 watts (see table below)

Table 8 - Percentage of Vacuum Cleaner Sales rated over 1800 Watts

Year	2003	2004	2005	2006	2007
>1800 W	8%	14%	18%	28%	39%

(Extracted from Vlehan Overview Reports)

2.3.9 Cleaning performance

Historically upright cleaners performed better than suction cleaners, but some, more expensive suction cleaners have motorised cleaning heads with agitators, which can improve their performance compared to upright cleaners. Stick cleaners with motorised cleaning heads, also found in Continental Europe, narrow that difference even further in the sense that they are almost true uprights.

2.3.10 Motors

Electric motors used in vacuum cleaners are beginning to change as we move into the 21st century, having remained the same for almost 100 years. Electronics have been used to control motor speeds and power for around 35 years and some have even used feedback from the suction head to modify suction power dependent upon dirt entering the machine or the "clogging" of bags or filters. Hence if sensors detect dirt being picked up then motor power is increased until no more dirt is detected. Equally if bags or filters become clogged the power can be increased to compensate.

The motors themselves have remained the same however, and rely on carbon brushes to supply electrical power to the rotating armature. These carbon brushes tend to wear down and this wearing down means there is a finite life to the motor, usually more than 500 hours which is equivalent to around 10 years use in a typical home. Some commercial cleaners will run for up to 1500 hours before the brushes wear out. Typically a domestic vacuum cleaner motor cannot be serviced and at the end

[14] www.vlehan.nl

of the brush life the motor has to be thrown away. With commercial vacuum cleaners many can be serviced and new brushes fitted, thus extending the life of the motor and of the vacuum cleaner.

More recently a new generation of electric motors has begun to appear; these do not have carbon brushes and use pure electronic control to provide the electrical field which will drive a permanent magnet rotor without physical contact. These motors will have extended lives and ultimately this life will depend on the reliability of the rotor bearings rather than the wearing down of carbon brushes. These motors can be smaller and can run at extremely high speeds (up to 100,000 rpm compared with approximately 30,000 rpm for carbon brush motors).

Until recently, vacuum cleaner manufacturers typically made their own motors, but today it is increasingly common for specialist companies to manufacture them.

2.4 Market Trends – Current Status

2.4.1 Market saturation

By most definitions the EU vacuum cleaner market is saturated and many homes in Europe will have more than one vacuum cleaner.

2.4.2 Main market players

Dyson, Vax, Electrolux, Hoover, Miele, Siemens, Rowenta and Philips are probably the main market players. (Vax are part of TTI, the world's largest vacuum cleaner manufacturer). Additionally, brands from the Far East have produced products for the EU market, including LG, Panasonic and Samsung. Own brand products sold by retailers also have a part in the EU market.

2.4.3 Production structure

The majority of vacuum cleaners are now manufactured in China, the larger players using their own Chinese-based manufacturing facilities, but many simply purchase from OEM companies. There is relatively little manufacture in Western Europe, however Numatic currently makes around 10,000 vacuum cleaners per week in the UK. Miele still manufactures a large number of cleaners in Germany, although automated manufacture features highly in this. Chinese or Hong Kong based companies have also moved outward and currently TTI (Hong Kong) owns the Royal, Hoover (US), Dirt Devil and Vax brands making them the largest manufacturer of vacuum cleaners in the world.

- Dyson manufactures in Malaysia.
- Electrolux manufactures in China, Mexico, US and Europe
- Miele manufactures in Germany
- Vax manufactures in China, Mexico and the US
- Hoover (Europe) manufactures in China

2.4.4 Consumer tests

IEC-based CENELEC performance standards are accepted in Europe, with the Advertising Standards Authority in the UK stating that IEC standards should be used when advertising performance claims in the UK. Consumer organisations largely use IEC-based standards and use laboratories such as SLG in Germany to undertake Europe-wide testing for them. Some consumer organisations use test methods developed by themselves, for example Consumers Association in the UK uses a test measuring pet hair pick up using real pet hair and Stiftung Warentest in Germany has used real household dirt in some testing.

There has been some friction over the years between manufacturers and consumer organisations when test methods have been developed unilaterally by consumer organisations. However, these test methods were usually developed because there was not an appropriate IEC or CENELEC test method and this has tended to drive the subsequent inclusion of the test in an official international test method.

Currently there is an increasing liaison between IEC and ASTM (US vacuum cleaner performance tests are produced by ASTM and they do not use IEC methods generally). Some emissions tests are now being jointly developed by IEC and ASTM

2.4.5 Product trends

There is a trend towards the development of bagless vacuum cleaners with high input power and low selling prices to consumers. The input power is often used in marketing claims to indicate how 'powerful' the cleaner is and thus persuade consumers that it will perform better than one with a lower input wattage.

Bagless vacuum cleaners are sometimes seen as unhygienic. New tests are driving products to have lower dust emissions, including during emptying. Self-sealing disposable containers may increase in popularity.

Cordless vacuum cleaners that offer performance equivalent to mains powered models may soon be available. These will use less energy than mains models, without any loss of cleaning performance.

More users tend to have multiple vacuum cleaners, using each one for special areas or tasks within the household. So, for example, there could be an upright for downstairs, a smaller suction vacuum for upstairs, a cleaner for use in the garage and a hand-held for quick cleaning indoors.

As sales of vacuum cleaners have increased it is possible that the working life of the products has declined from over 8 years to around 4 years. However, in the multiple ownership scenario it is not clear how the lifespan is affected by households having multiple units.

New product development has been slow in recent years. However, carpet washing extractors have been marketed in the UK.

Some emphasis is noticeable on products designed to be easier to use, either in terms of ergonomics or additional features and tools.

Lower noise emission has been a focus for some manufacturers.

2.4.6 Consumer Expenditure Base Data

A Discount rate of 5% will be assumed and an electricity price of 0.15 Euro/kWh will be taken[15]. The product life for vacuum cleaners has been estimated at 8 years[16].

2.4.6.1 Average product price – low, mean, high.

Average product prices for 2006 in ProdCom were ~102 Euro (29712113) and ~80 Euro (29712115). These were considered to be inaccurate, the upper figure being too low: the lower figure being too high[17]. It is proposed that the following data is used from the MEEUP product study[18] for vacuum cleaners:

Average product price – EU product price average 125 Euro, low 98 Euro from Germany 2005, medium 123 Euro from the Netherlands 2003 and high 200 Euro from Germany 2005 figures.

2.4.6.2 Consumption of bags, filters and other accessories per year and cost.

Consumption of bags, filters and other accessories per year and cost – five bags and one filter, cost 12 Euro.

[15] Based on uswitch.com best deal for average household consumption of 3000 kWh per month.
[16] For UK vacuum cleaners, the average lifespan (after rationalising ownership and volume of sales data) was estimated by the Market Transformation Programme to be 7.8 years.
[17] General consensus at the First Stakeholder Workshop, 1st February 2008.
[18] MEEuP Product Cases Report, Final, 28/11/2005, VHK for the European Commission.

2.4.6.3 Estimate of repairs per year and average repair cost.

A survey of members of the UK consumer organisation Which? about product reliability showed that at least 1 in 5 upright vacuum cleaners in the survey required repair during the first 6 years, compared with around 1 in 10 for suction models[19]. The top three reasons for the repair of upright cleaners were - split/broken hose - 21% of breakdowns, suction - 19% of breakdowns, motor - 16% of breakdowns. For suction cleaners the most frequent reasons were - split/broken hose - 25% of breakdowns, suction – 15% of breakdowns, broken casing – 11% of breakdowns, power cable – 11% of breakdowns

The MEEUP study for vacuum cleaners assumed that 50% of vacuum cleaners were taken for repair during their product life, which was estimated as eight years. The Which? survey suggests that only 10 to 20% of vacuum cleaners are repaired in the first six years of their lifespan. Responses to our first questionnaire tended to agree with this estimate. It is therefore suggested that for this project the figure of 20% is used for the number of cleaners ever taken for repair in their lifespan.

The cost of repair is estimated at 50 Euro per repair, or 10 Euro per product. (averaged over all products).

[19] https://www.which.co.uk/reports_and_campaigns/house_and_home/Reports/cleaning/Cleaning%20appliances/Vacuum%20cleaners/Vacuum_cleaners_essential_guide_574_70328_5.jsp The total sample size for uprights was 3854 and the average score was 79%. The majority of respondents owned Dyson cleaners. For suction the sample size was 3062 and the average score was 93%.

3 Task 3 Consumer Behaviour and Local Infrastructure

3.1 Real life usage

3.1.1 Ownership

Ownership of vacuum cleaners may vary across the EU. There are no published data that compare all 27 countries.

The following table is drawn from searches of different country household budget surveys and official statistical sites[20]. The most recently available year is given.

Country	% ownership	Year
Belgium	C 95%	2004[21]
France	c. 90%	2006[22]
Ireland	95.5%	2004-2005[23]
Netherlands	99.6%	2000[24]
Poland	94.2%	2006[25]
Portugal	67.4%	2003[26]

In some countries, the ownership is in excess of one vacuum per household that has a vacuum cleaner. For example, in the UK ownership is likely to be in the region of 1.5 per household as consumers have bought separate cleaners for different floors in their home or for different functions such as use in a garage or wet and dry cleaning. Many homes also have a hand held battery cleaner. The overall time spent cleaning the home is unlikely to vary from the total suggested below. However the multiple number of cleaners should be considered in the sensitivity of the manufacturing and waste projections.

3.1.2 Time spent cleaning

An average of 70 minutes per week or 60 hours per year was given in the MEEUP study on vacuum cleaners for the Netherlands[27].

UK sources suggest that this figure of about one hour is also reasonable for the UK for household cleaning[28].

Miele suggest that their carbon filters are changed after one year or fifty hours cleaning[29]. This suggests an hour per week is a reasonable average.

As discussed in the MEEuP study on vacuum cleaners, the amount of time spent cleaning may depend on the size of the dwelling, the amount and type of dirt, the surfaces being cleaned, the effectiveness of the cleaner and the hygienic standards of the user. In practice, however, the time available for cleaning is at least as important.

The Swiss TopTen website for vacuum cleaners calculates annual running costs on the basis of cleaning 150 m^2 twice per week[30]. They do not indicate how long this might take.

[20] Countries checked but data not found: Denmark, Finland, Germany, Greece, Italy, Norway, Sweden, Spain, United Kingdom, Latvia, Estonia, Lithuania, Slovenia, Austria, Romania, Bulgaria, Bosnia, Czech, Ukraine, Belarus, Serbia.
[21] Belgium 2004 Dossier seniors Profil des seniors: qui sont-ils ? Comment vivent-ils? http://statbel.fgov.be/press/pr109_fullreport_fr.pdf
[22] France: Enquête Budget de famille 2006 http://www.insee.fr/fr/ppp/ir/BDF06/dd/excel/BDF06_D4.xls
[23] Ireland: Central Statistics Office 2007 *Household Budget Survey 2004-2005* http://www.cso.ie/releasespublications/documents/housing/hbsfinal/text.pdf
[24] VHK 2005 MEEuP Product Cases Report Vacuum Cleaners page 7.12
[25] Poland: Household Budget Surveys in 2006 http://www.stat.gov.pl/cps/rde/xbcr/gus/PUBL_household_budget_surveys_in_2006.pdf
[26] Statistical Year Book of Portugal 2004 http://www.ine.pt/ngt_server/attachfileu.jsp?look_parentBoui=13847047&att_display=n&att_download=y
[27] VHK 2005 MEEuP Product Cases Report Vacuum Cleaners page 7.12
[28] MTP BNXS30 Vacuum cleaners http://www.mtprog.com/ApprovedBriefingNotes/pdf.aspx?intBriefingNoteID=344
[29] Miele UK website accessed 1 May 2008 https://www.miele.co.uk/accessories/Details.aspx?rdid=5&aid=424

IEC 60312 and EN60312 have tests to measure motor life based on field data from the 1970s and not currently refuted, which suggests that a ten year life is equivalent to 500 hours running, equating to an hour per week use.

It is suggested at this stage that an average of one hour per week is used for cleaning time, with a 'light' pattern of 15 minutes per week, and a 'heavy' pattern of four hours per week.

3.1.3 Power measurement

Many cleaners have controls for consumers to adjust power consumption. Instruction books may recommend that the power consumption is adjusted if the cleaner is to be used for a long period of time to prevent the motor overheating or if the user is cleaning more delicate fabrics, such as curtains, that might be sucked into the nozzle. There are no data available on whether consumers take notice of these recommendations. In any case, the majority of regular cleaning is likely to take place at full power.

Other cleaners may automatically adjust the power consumption depending on the floor surface being cleaned. Consumers may or may not choose to use this function on their cleaners.

In recent tests Which? found that the average energy consumption was around 260Wh to vacuum a $10m^2$ area of carpet at full suction In the April Which? 2008 test consumption ranged from 176 to 342Wh[31].

The average power consumption of 1500W from Task 2 will be used as a typical input power for a domestic vacuum cleaner (slightly less for a commercial cleaner – 1100W).

3.1.4 Auxiliary inputs – bags, filters and belts

Bagged vacuum cleaners require the bag to be changed to prevent a reduction in cleaning performance. The frequency of changing will vary depending on the type and amount of dirt collected by each bag and the perception of the user of the need for changing. For example, if high amounts of very fine particles such as plaster dust are collected it is usually recommended that the bag is changed sooner than if an equivalent quantity of normal household dust is collected, because the fine particles block the air flow through the bag. Many models indicate when the bag should be changed, but consumers may choose to change the bag more or less frequently than the machine indicates.

Where manufacturers offer free bags with products or schemes to supply them with extended warranties they usually offer 10 per product per year[32]. It is therefore proposed that 10 bags per year are used by each bagged cleaner.

Filters are required to prevent dirt reaching the motor and to prevent small particles returning to the room in the exhaust air. For bagged cleaners, there is often a set of filters supplied with a set of bags and it is recommended that the filters are changed when the first bag is used. If filters are not supplied with bags, manufacturers typically recommend that the filters are changed, although this can very from annually (Vax) to every two months (Oreck).

It is proposed that one set of filters is used by each cleaner per year.

Consumers may also choose to use filters with a higher extraction level than those originally supplied with their machines. The frequency of changing these may vary from the recommended time because users extend the time needed because of the cost of these items or change more frequently because they are concerned about health issues such as allergies and asthma.

It is proposed that one filter per year is used for a small proportion of the market, perhaps 10%.

Carbon filters are sometimes chosen for their ability to remove odours. These are usually recommended to be changed every six months (Bosch[33]) or annually or after 50 hours (Miele[34]).

[30] Swiss TopTen criteria for vacuum cleaners http://www.topten.ch/index.php?page=auswahlkriterien_staubsauger&fromid=
[31] Which? website accessed 2 May 2008 http://www.which.co.uk/reports_and_campaigns/house_and_home/Reports/cleaning/Cleaning%20appliances/Vacuum%20cleaners/Vacuum_cleaners_essential_guide_574_70328_7.jsp
[32] Electrolux website accessed 1 May 2008 http://www.electrolux.co.uk/Files/United_Kingdom_English/Files/Electrolux07_SpecBrochure_8pp.pdf
Miele UK website accessed 1 May 2008 http://www.miele.co.uk/Resources/CustomerSupport/GuaranteesWarranties/Vacuum_Guarantee.pdf

It is proposed that one filter per year is used for a small proportion of the market, perhaps 10%.

Manufacturers also supply washable pre-motor and exhaust filters or filters that are described as 'self-cleaning', where the user can use the vacuum cleaner to clean the filter, or 'lifetime' where they do not require cleaning. These are unlikely to be replaced unless they are damaged.

Upright cleaners may require the drive belt to be changed if it becomes slack or breaks. Anecdotal evidence suggests this is unlikely to occur during the lifespan of the appliance (if it is as short as 4 to 5 years), and in the case of cheaper appliances may be the cause of the unit's disposal at this point. The belt is sometimes covered under the product guarantee, as in the case of Sebo, who offer a 5 year parts and labour guarantee on all domestic machines in the UK which includes the drive belts on upright machines[35].

For the more expensive appliances, the belt may be replaced but it is suspected that even a proportion of them will be replaced if the belt breaks. Belts are available from various spares outlets but are seldom stocked by High Street retailers, the delay in delivery may be sufficient to encourage replacement of the cleaner by the user.

3.2 End-of-Life behaviour

Consideration of end-of-life behaviour involves the identification of actual consumer behaviour (average EU) regarding end-of-life aspects. Some of the items discussed below will have already been introduced from a cost angle in the consumer expenditure section of the Task 2 report.

3.2.1 Product Lifetime

It is important to be very clear on the definitions of lifetimes, i.e.

- Economical lifetime / Planned Lifetime (Manufacturer, in product design specification)
- Service lifetime (i.e. when the product is actively used), and
- Lifetime to disposal (the product may spend some time in storage not being used prior to disposal)

Most useful for this preparatory study is the service lifetime (as this reflects the duration in which the product is mostly using energy). The typical service life of vacuum cleaners has been quoted as high as around 10 years and as low as 6.3 years. A figure of 8 years is suggested to accommodate these longest and shortest lifespans[36].

3.2.2 Repair and Maintenance Practice

A Which? Survey in 2008 showed that cylinder vacuum cleaners were more reliable than uprights[37]. At least one in five uprights up to six years old required repairs. Top reasons for breakdowns were as follows:

Reason for Breakdown	Upright - types	Cylinder - types
Split/broken hose	21%	25%

[33] Bosch UK website accessed 1 May 2008 http://www.bosch-eshop.com/eshop/bosch/gb/article426967.htm
[34] Miele UK website accessed 1 May 2008 https://www.miele.co.uk/accessories/Details.aspx?rdid=5&aid=424
[35] Sebo UK website accessed 1 May 2008 http://www.sebo.co.uk/Pages/aftercare.html
[36] See Task 2 Report and http://www.mtprog.com/ApprovedBriefingNotes/PDF/MTP_BNXS30_2008February11.pdf.
[37] Which? January 2008.

Suction	19%	15%
Motor	16%	-
Broken casing	-	11%
Power cable	-	11%

Note that this survey only covered branded products, it did not cover the own brand products from supermarkets, catalogues and catalogue stores etc., which due to their budget, low-price nature may be more likely to fail. (In 2006 GfK hitlists recorded 40% of UK sales as Tradebrand which are either branded models that are exclusive to a particular retailer or retailer own brand models, the next most important brands were Dyson 14%, Vax 10% and Electrolux 6%).

Most manufacturers provide spare filters with their new products. Presumably, the reason for this is to provide extra stimulus for regular filter change. Although we have found no evidence[38], it is possible that failure to replace filters could reduce product life. Reduced air flow past the motor could lead to overheating of the motor. However, in the event of the filters simply becoming blocked gradually, then the load on the motor will also reduce as the airflow is reduced, this may compensate for the reduction in cooling effect.

3.2.3 Reuse, Recycling and Disposal

Reuse

Overall 40,000 people work in Social Organisations throughout the EU. 17,000 people collect, repair and recycle 300,000 tonnes of WEEE through 1,200 centres[39]. This represents about 4% of the estimated WEEE arisings in the EU27. Given that the main focus of reuse activity in this area is predominantly towards repair of washing machines and fridges, it can be assumed that opportunities for reuse of vacuum cleaners are limited to second life reuse (e.g. vacuum cleaner is used by the owner for another purpose such as car valetting/cleaning).

Consumer Behaviour for EOL Equipment

Take-back schemes for WEEE items are being established in both the EU Member States and other European countries. These are usually based on the provision of collection points by municipal authorities (sometimes, retailers can take items that they collect to these collection points), and the take-back schemes arrange for the collected materials to be recycled (according to the requirements of the WEEE Directive). Many of the European collection schemes are focusing primarily on achieving the 4 kg/inhabitant/year target, but appear to be comfortably exceeding this. For example, collection schemes in Norway, Sweden and Switzerland are currently collecting over 10 kg/person per year of WEEE items. European householders tend to recycle as the norm – the recycling of small WEEE is seen as a normal part of this behaviour. Education/promotional campaigns are important for raising awareness, but where they are required they are usually targeted at WEEE in general, rather than at small WEEE. The use of incentives to encourage householders to submit their small WEEE for collection appears to be unnecessary. Householders' normal behaviour is to recycle wherever it is possible to do so[40].

In terms of disposal behaviour, vacuum cleaners are generally too large to be disposed of with the normal household waste. Consumers will tend to take EOL vacuum cleaners to a household waste collection centre, which may or may not provide facilities for the separate collection of WEEE (waste electrical and electronic equipment). An analysis of the results from a number of pilot collection trials at household waste centres in the UK[41] showed that Category 2 (small household appliances) equipment collected was dominated by vacuum cleaners.

Table 9 - Weight Proportions of Collected Category 2 Equipment

[38] Many machines are only used for between 3 and 5 years could be the reason not to have much data on failures.
[39] Craig Anderson, Re-use and Recycling: European Social Enterprises, FRN – UK, October 2006.
[40] Environment Agency, "Consumer Behaviour in Relation to Small Household WEEE", R2239, AEA Technology, July 2006.
[41] Environment Agency, "Information from Local Authority WEEE Collection Trials", AEA Technology, May 2004

Item	Average Weight %
Vacuum cleaners	**48.8%**
Irons	**5.2%**
Toasters	**4.3%**
Fryers	**4.3%**
Kettles	**5.2%**
Coffee machines	**1.7%**
Electric knives	**0.4%**
Hair dryers	**5.2%**
Clocks	**0.9%**
Electric scales	**1.3%**

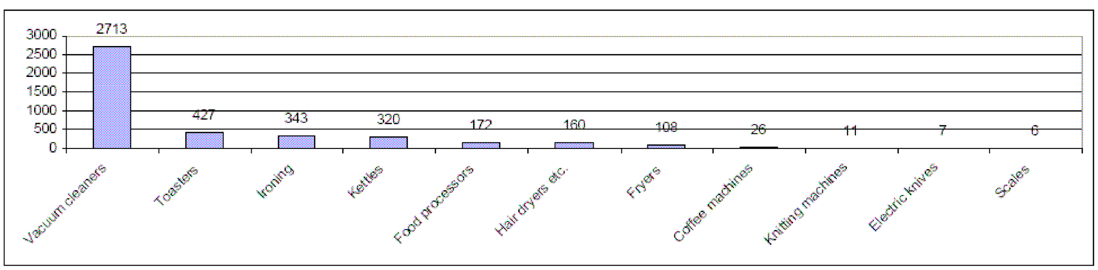
More recently, a set of trials were conducted to establish protocols for WEEE collections[42]. This study involved the hand sorting of 125 tonnes, made up from 16,401 individual items, of small mixed WEEE (SMW). The items were segregated into 10 categories, provided in the WEEE Regulations, and counted and weighed. Each segregated SMW category was homogenised by processing through a WEEE plant or a shredder/fragmentiser. Samples of the mixed output streams from these processes were handsorted to characterise and determine their compositions.

The Category Protocol values of SMW were established as:

- 10.3% - Category 1
- 19.9% - Category 2
- 22.7% - Category 3
- 22.2% - Category 4
- 2.0% - Category 5 – This household source is to be included as Non -WEEE
- 10% - Category 6
- 0.3% - Category 7
- 0.7% - Category 9
- 12% - Non-WEEE and unallocated

The analysis of the Category 2 element of small mixed WEEE confirmed that vacuum cleaners dominated this waste stream.

Figure 3 - Category 2 Analysis - Small Household Appliances



The average separate collection rate for Category 2 equipment has been estimated at 0.42 kg/inhabitant/year[43]. Based on a 2006 population estimate for the EU27 of about 492 million, this equates to about 205,000 tonnes collected. Thus on the basis of Table 9 above, the amounts of EOL vacuum cleaners collected is about 100,000 tonnes per year. The average weight of EOL domestic

[42] CIWM(EB)/DEFRA, "Trial to establish WEEE protocols", Mayer Environmental, January 2007.
[43] European Commission, "2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE)", UN University, August 2007.

vacuum cleaners was determined as 7.2kg[44], therefore indicating that around 14 million EOL domestic vacuum cleaners are collected annually in the EU27 (this would represent about 30% of the number of vacuum cleaners sold in Europe annually – ref. Task 2 report).

3.2.4 Second Product Life

This is very difficult to quantify because the item is not considered either EOL or a waste but has been transferred to a second use application by the owner. Probably, the difference between service life and manufacturers design lifetime could be used as an indicator of the extent to this practice.

3.2.5 Best Practice for End-of-Life

Best practice for end-of-life has to take into account best practice in sustainable product use. Given that average input power ratings for vacuum cleaners have increased steadily over the last few decades, there is currently no justification for early product replacement for reasons of improved energy efficiency. Thus a long product life would not be detrimental for the environment[45].

Once EOL is reached, then the broad aim of the WEEE Directive is to address the environmental impacts of electrical and electronic equipment when it reaches the end of its life and to encourage its separate collection, subsequent treatment, re-use, recovery, recycling and environmentally sound disposal. It seeks to improve the environmental performance of all operators involved in the lifecycle of EEE. This directive sets targets for the separate collection of WEEE (currently 4 kg/inhabitant/year) and targets for the recovery (currently minimum of 70% by an average weight per appliance for category 2 equipment) and the reuse and recycling (currently a minimum of 50% by an average weight per appliance for category 2 equipment) of this collected WEEE. The European Commission is currently (Spring 2008) consulting widely on possible changes to targets as part of their review of the WEEE Directive. The suggested changes, which are ‘out for consultation’ are:

- Increase the current targets, for all or some categories;
- Introduce a target for category 8 equipment (medical devices);
- Material based targets for all WEEE or per product category;
- Stimulation of outlet market for recycled and recovered products, in particular for encouraging high level of material re-application.

The consultation closes in June 2008. It remains to be seen which improvement option(s) are most favoured.

3.3 Local infrastructure

3.3.1 Energy supply

Given that vacuum cleaning can be undertaken at any time of the day, short term interruption of the power supply is unlikely to affect overall consumer behaviour. Local tariffs aimed at shifting consumer use to off peak demand times are unlikely neither to affect the amount of domestic vacuum cleaning undertaken nor to influence the time of day that it is done. Vacuum cleaners are often considered to be noisy appliances, so it is unlikely that much cleaning is done when the rest of the household is asleep. Non-domestic cleaning such as offices and schools is likely to take place when the day-time workers are not present.

[44] Defra, “WEEE and Hazardous Waste: Part II”, AEA Technology, R2233, June 2006.
[45] European Commission, MEEuP Product Cases Report, VHK, November 2005.

3.3.2 Physical environment

As mentioned above, there is some evidence that in some countries households own more than one vacuum cleaner. This may not influence the total amount of cleaning, but each type of cleaner may be used for specific tasks, i.e. cleaning carpet or hard floors; or for a specific area of the house i.e. one cleaner used for upstairs and another one for downstairs.

It is unlikely that many households habitually share vacuum cleaners for regular cleaning. They are typically a relatively cheap appliance that can be bought very easily for relatively small amounts of money. However, some of the more expensive appliances, for example wet/dry types suitable for carpet cleaning which are used on an infrequent basis may be shared between households, such as parents and children.

Spare parts are typically available through local retailers or via on-line suppliers. As noted above and in Task 2, however, it is believed that the level of vacuum cleaner repair is currently around 20% of all cleaners being repaired in their lifetime. The cost of spare parts is usually quite low, but unless there is a tradition of vacuum cleaner repair by owners in a particular country, the likelihood of it occurring is low.

Repair services are provided by some manufacturers in some countries, either directly or via third party companies. Examples from the UK demonstrate why many owners may opt to replace a product if it breaks down outside the guarantee, rather than pay for regular servicing or repairs. In the UK, Dyson offer guarantees, up to 5 years on new products in the UK for "The repair or replacement of your machine if your machine is found to be defective due to faulty materials, workmanship or function within 5 years of purchase"[46]. Dyson also offers a service package for products outside of the guarantee period and charges £65 (~90 euros) including VAT for labour and parts[47]. It does not give the price of spare parts for repair. Hoover charges £68.50 (~92.50 euros) for labour to repair an out of guarantee product and parts will be charged separately if used[48]. Consumers are therefore faced with the option of a repair to a relatively old machine that might cost more than the price of a new vacuum cleaner or buying a new cleaner. They may consider that they have had the vacuum cleaner for a reasonable amount of time and opt for buying a new cleaner.

Local independent businesses may specialise in the repair of domestic appliances. The range of repairs that they can complete will depend on the range of parts that is supplied by the different manufacturers. The cost of the repairs must also be low enough to encourage owners to seek a repair rather than replacing the product. These businesses may also offer servicing and their prices are likely to be lower than those charged by manufacturers[49].

The cost of vacuum service and repair could also be considered in the context of repairs and services for other domestic appliances and cars. For example, average repair costs for a washing machine in the UK were £77 (~105 euros) in 2005[50] and an interim car service by a multinational company in the UK would cost around £80[51]. (~110 euros)

Vacuum cleaners were identified as one of the domestic appliances that UK consumers would like to see having a longer lifespan[52], but their unwillingness to seek a repair, or inability (for whatever reason) to repair products themselves is acting against this desire.

[46] Dyson UK website accessed 1 May 2008 http://www.dyson.co.uk/support/help.asp?article=1098&product=DC19
[47] Dyson UK website accessed 1 May 2008 http://www.dyson.co.uk/support/help.asp?article=65&product=DC19
[48] Hoover UK website accessed 1 May 2008 http://service.hoover.co.uk/repair/OutOfGuarantee.aspx
[49] http://www.thameselectronics.co.uk/services/ quoted £35 for a service on 2 May 2008
D&D Electrical, Solihull quoted £18 plus parts and VAT for a service on 2 May 2008
Watts Electrical, Derby quoted £38 for a service on 2 May 2008.
[50] Which? June 2006 survey of Which? members in 2005
[51] Kwikfit website 2 May 2008 Ford Focus interim service £79 http://www.kwik-fit.com/mot-and-service-pricing.asp
[52] Cooper T and Mayer K 2000 *Prospects for Household Appliances* http://research.shu.ac.uk/csc/docs/Commsumm.pdf

4 Technical Analysis of Existing Products

This chapter contains all the technical inputs for the MEEUP model for each of the vacuum cleaner types in this study. This comprises the production phase (materials), distribution, In use phase (energy and maintenance costs) and end of life phase.

4.1 Production Phase

The material composition of vacuum cleaners is presented in the following Bills of Materials (BoMs) provided either by manufacturers and or by disassembly of certain products. Anonymous and averaged BoM data is presented in order to protect the confidentiality of those manufacturers who provided data.

The data will be used in the definition of the Base Case models and the evaluation of best available technologies (BAT).

The detailed Bill of Material (BOM) data lists all materials, by weight, for each base case vacuum cleaner. The base case is seen as being representative of current “best sellers”. The method of derivation varies for each type, but is generally based on an average of real models, with some parameters adjusted to be more widely representative of all models. An example of an upright vacuum cleaner is presented in Table 10.

Table 10 - BoM Example of an Upright Vacuum Cleaner

Nr	Component	Weight in g	Material category
1	Handle	600	1-BlkPlastics
2	Main upright housing	800	1-BlkPlastics
3	Cord hook swivel	10	1-BlkPlastics
4	Lower cover	250	1-BlkPlastics
5	Dirt receptacle cover	500	1-BlkPlastics
6	Bag retainer	30	1-BlkPlastics
7	Duct cover	30	1-BlkPlastics
8	Bag collar	7	7-Misc.
9	Bag	20	7-Misc.
10	Filter media	15	2-TecPlastics
11	Filter cover	30	1-BlkPlastics
12	Mains lead	650	1-BlkPlastics
13	Plug top	36	2-TecPlastics
14	Motor	637	3-Ferro
15	Motor part 2	213	4-Non-ferro
16	Fan	27	4-Non-ferro
17	Fan housing	66	3-Ferro
18	Fan washer	5	4-Non-ferro
19	Fan fixing nut	2	3-Ferro
20	Motor mounting	40	2-TecPlastics
21	Internal wiring	35	4-Non-ferro
22	Connectors	4	4-Non-ferro
23	on/off switch	12	4-Non-ferro
24	exhaust filter	15	7-Misc.
25	screws	30	3-Ferro
26	Base chassis	450	1-BlkPlastics
27	Rear wheels	80	1-BlkPlastics
28	Rear wheel axles	40	3-Ferro
29	Front wheels	13	1-BlkPlastics
30	Front wheels axles	35	3-Ferro
31	Internal duct	60	1-BlkPlastics
32	Agitator cylinder	50	1-BlkPlastics
33	Agitator bristle	30	2-TecPlastics
34	Agitator bearing	20	4-Non-ferro

Nr	Component	Weight in g	Material category
35	Agitator drive belt	7	2-TecPlastics
36	Base top cover	180	1-BlkPlastics
37	Nozzle plate	75	1-BlkPlastics
38	Agitator motor	250	3-Ferro
39	Packaging	600	7-Misc.
40	Internal packaging	250	1-BlkPlastics
41	Polybag	20	1-BlkPlastics
42	**Manuals and paper work**	50	**7-Misc.**

Table 11 - Averaged Materials Compositions of Various Vacuum Cleaner Types

		Domestic Canister	Commercial Canister	Domestic Upright	Commercial Upright	Battery / Cordless
Materials	**unit**					
Bulk Plastics	g	4188	5880	3927	4995	3035
TecPlastics	g	695	0	894	1494	426
Ferro	g	1467	1450	1048	1308	1120
Non-ferro	g	478	2250	440	711	1428
Coating	g	8	0	0	0	0
Electronics	g	29	0	0	20	0
Misc.	g	1612	1585	1626	2065	824
Total weight	g	8475	11165	7934	10593	6832

Note1: Batteries and chargers have been included in the battery/cordless vacuum cleaner compositions.

Note2: The average total weight for Battery/Cordless types may have been skewed by one device that was over 11 kg in weight. Typical battery cleaners tend to be 1 to 2 kg.

Material	Domestic Canister	Commercial Canister	Domestic Upright	Commercial Upright	Battery / Cordless
Plastics	56.82%	52.66%	55.61%	59.89%	50.70%
Ferrous metal	16.53%	17.02%	11.67%	15.43%	19.71%
Non-Ferrous metal	6.36%	16.12%	8.14%	3.81%	18.47%
Cardboard/Paper	18.69%	14.20%	22.66%	19.49%	9.95%
Glass	0.25%	0%	0.74%	0%	0.32%
Other	1.35%	0%	1.18%	1.37%	0.84%
TOTAL	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Cardboard/Paper content refers to the packaging materials used and instruction manuals respectively.

4.2 Distribution Phase

Examination of the Bills of Materials (BoMs) indicates that the packaging for vacuum cleaner products is predominantly cardboard material along with smaller amounts of plastics (e.g. LDPE bags).

The average volume of the packaged products for each vacuum cleaner type is considered in the analysis of the Base Case models and BAT.

4.3 Use Phase (product)

The purpose of this section is to identify the resource consumption associated with a vacuum cleaner's use throughout its lifetime.

For vacuum cleaners, the main resource consumed during life is electricity. In addition, filters have to be replaced at regular intervals, (where applicable) dust bags require replacement when filled and, occasionally items such as replacement drive belts are required when products need repairing. The typical replacement frequency of filters, dust bags and replacement drive belts have been estimated in Task 3. These were: a) one set of filters per cleaner per year, b) 10 bags per year for each bagged domestic cleaner, and c) one replacement belt per upright in its lifetime.

4.4 Use Phase (system)

In principle, most of the system parameters relating to vacuum cleaners in use are those mentioned in Section 3.1 on real-life usage. In addition, a vacuum cleaner will interface with the surfaces and materials it comes into working contact with. Alternative routes to fulfil the same or a similar function exist in some cases. For example, it is possible to manually sweep a hard floor surface, but this may introduce other unwanted side effects such as increasing airborne dust.

The vacuum cleaner also interfaces in unwelcome ways with consumers and others in close proximity – it emits noise and particulate matter, both of which could be deleterious to health. The eco-label criteria for vacuum cleaners (now expired) included criteria for noise and dust emissions - <76 dBA and <0.01 mg/m^2 respectively. Vacuum cleaners exhibiting this performance can be considered as best performing is these respects.

At a high level, a vacuum cleaner interacts with its surroundings through the filtered movement of air with functions overlapping with brushing, beating and grooming.

4.5 End-of-life Phase

The Waste Electrical and Electronic Equipment (WEEE) Directive governs the end-of-life (EoL) disposal of vacuum cleaners (VCs). VCs fall under Category 2 (small household appliances) in Annexes IA and IB of this Directive.

Separately collected Category 2 WEEE must have a rate of recovery of at least 70% by an average weight per appliance, and component, material and substance reuse and recycling must achieve at least a 50% rate by an average weight per appliance.

To date, studies on the composition of Category 2 WEEE collections[53] have shown that VCs account for a major proportion (typically around 50% of the total collected). Other appliances (e.g. irons, toasters and kettles) feature at much lower weight % levels (around 5% each). Because EoL VCs are big items, they tend to be taken to central waste collection points rather than disposed with the general household waste. A very small percentage of EoL VCs is reused perhaps involving refurbishment by organisations such as community and charity groups or simply given by their first owners to someone else for example, in their family. In terms of typical materials and component composition, EoL VCs contain significant proportions of plastics. Metal casings and parts have tended to give way to the use of plastics, largely because of cost and flexibility in design.

Our assumptions for EoL phase for vacuum cleaners are as follows:

- All EoL vacuum cleaners are separately collected in accordance with the WEEE Directive
- 70% of separately collected EoL vacuum cleaners are recovered, complying with the WEEE Directive.
- 50% of separately collected EoL vacuum cleaners undergo reuse and recycling, also complying with the WEEE Directive.
- Metals – 95% recycling is assumed (fixed in Eco-Report)
- Plastics – 1% reuse, closed loop recycling assumed. The percentage of material recycling is calculated so that an overall 50% reuse and recycling rate for vacuum cleaners is achieved. The percentage of thermal recycling is such as to achieve an overall recovery rate for vacuum cleaners of 70%.

[53] Study undertaken by AEA in confidence for a client and CIWM/Defra Study on “Trials to Establish WEEE Protocols”, Mayer Environmental Ltd., January 2007.

- Landfill – 30% of products are not recovered.

These assumptions represent the minimum level for compliance with the WEEE Directive currently in force.

5 Definition of Base Case

Task 5 involves the development of descriptions of average EU products that can be assumed as "base cases". The life-cycle characteristics of these base cases are built from the results of Tasks 1 to 4. These base cases will act as the foundation for Task 6 (technical analysis of BAT), Task 7 (improvement potential) and Task 8 (impact analysis).

The base cases have been chosen to be sufficiently broad to cover environmental impacts across the range of vacuum cleaners. Through close collaboration with industry, particularly during the second workshop, we have considered a wide range of actual product cases which has lead to aggregation of product cases into a select few base cases. The five base cases agreed are:

Canister vacuum cleaners – (domestic and commercial types, includes Wet and Dry)

Upright vacuum cleaners – (domestic and commercial types)

Battery operated / cordless vacuum cleaners.

This section will describe the modelling of base case models that provide the reference for the environmental and technical/economical improvements to be established further on.

5.1 Product specific inputs

5.1.1 Bill of Materials

The averaged Bill of Materials for each of the 5 base cases are presented in Section 4.1.

The MEEuP EcoReport assumes 1% of the total weight as spare parts. This is considered to be reasonable by the study team.

5.1.2 Primary scrap production during sheet metal manufacturing

The EcoReport default value of 25% has been used.

5.1.3 Volume of packaged product

The average volumes of the packaged products for Domestics Uprights and Canisters have been derived from information provided by stakeholders. Assumptions made for the other base cases are shown in the table below:

Table 12 - Average Volume of Packaged Product

Base Case	Average volume (m^3)	Assumed dimensions of packaged product
Domestic Canister	0.08	-
Commercial Canister	0.1	0.6m x 0.6m x 0.3m
Domestic Upright	0.09	-
Commercial Upright	0.1	0.6m x 0.6m x 0.3m
Battery/cordless	0.05	0.6 m x 0.3m x 0.3m

5.1.4 Use Phase

The inputs for the use phase are:

Table 13 - Use Phase Inputs by Base Case

	Domestic Canister	Commercial Canister	Domestic Upright	Commercial Upright	Battery / Cordless
Lifetime (years)	8	8	8	8	5
Electricity consumption per hour (kWh)	1.5	1.1	1.5	1.1	0.024
No. of hours per year in use	62.5	187.5	62.5	187.5	832
Standby electricity consumption per hour (kWh)	0	0	0	0	0.00082
No. of hours per year at standby	0	0	0	0	7891

Note 1 – The total hours in use for canisters and uprights equate to 500 hours (domestic) and 1500 hours (commercial) over the product lifetime.

Note 2 – The electricity consumption for battery/cordless base case has been taken as the overall electricity consumed by the charger. This was considered to be the true electricity consumption for battery/cordless devices because it takes account of total electricity consumed. This total has been calculated from typical charger cycles plus the time spent in standby 'trickle charging' state. Thus, the time that the charger spends in charging mode is taken to represent the annual hours in use. However, whilst the battery/cordless vacuum cleaner is being used, the charger is assumed to be switched off. The detailed calculations used are as follows:

Typical charger is rated as follows:

	Charger Input requirement	Charger Output
Volts	240 v	12 v
Amperes	0.1 A	0.5 A
Power (Watts)	24 W	6 W

Typical charger usage:

a) 15 minutes/week using the battery cordless vacuum cleaner. During this time, the charger is assumed to be switched off)

b) 16 hours/week at full charging rate. (C/10.56[54] – where C is the capacity of the battery),

c) The remaining hours/week, the charger is at trickle-charge rate(C/300):

Table 14 - Annual Power Consumption for a Typical Battery/Cordless Vacuum Cleaner

	Hours per week	Hours per year	Power drawn from mains supply (W)	Annual energy Consumption (kWh)
Hours VC in use per week:	0.25	13	0	0
Hours VC full charging rate per week:	16	832	24	20
Hours VC in trickle-charging rate per week:	151.75	7891	0.8	6.5
TOTAL				**26.5**

5.1.5 Annual Sales 2005 and Stock Model

The following assumptions in Table 15 were used for the 2005 sales and stock (numbers of units) for input in the EcoReport for the Base Case models. A simple Stock Model was created for the calculation of total stock and sales. Stock estimates were derived from population data based on

[54] Assumes the charging efficiency of 66% (this is the best achievable for NiMH batteries)

assumptions made about ownership levels and numbers of households. Sales data gathered in Task 2 were used to derive future sales estimates based on an assumption of an average 3% per year sales growth. Good correlation for estimates of end-of-life arisings was achieved where a lifetime of 8 years was applied to the model.

A ratio of 25:75 was assumed for upright:canister vacuum cleaners.

Table 15 - 2005 Stock and Sales Estimates from Stock Modelling

	% share Canister:Upright	Stock (units)	Annual Sales (units)
Canister domestic	85%	273,595,932	36,543,200
Canister commercial	85%	8,840,000	1,105,000
Upright domestic	15%	48,281,635	6,448,800
Upright commercial	15%	1,560,000	195,000
Battery/cordless	n/a	10,000,000	2,000,000
TOTALS		**342,277,567**	**46,292,000**

5.2 Base Case Environmental Impact Assessment

The summary environmental impacts for the EU stock 2005 is presented in the table below.

Table 16 - Summary Environmental Impacts EU-Stock 2005

Main life cycle indicators	unit	Canister Domestic	Canister Commercial	Upright Domestic	Upright Commercial	Battery Cordless	TOTAL
Total Energy (GER)	PJ	315.92	21.28	55.30	3.73	7.52	**403.74**
of which, electricity	TWh	26.32	1.85	4.64	0.33	0.56	**33.69**
Water (process)*	mln.m3	28.88	2.03	5.08	0.36	0.76	**37.11**
Waste, non-haz./ landfill*	kton	803.35	64.69	118.94	6.30	23.06	**1016.33**
Waste, hazardous/ incinerated*	kton	71.80	2.96	11.91	0.51	2.92	**90.10**
Emissions (Air)							
Greenhouse Gases in GWP100	mt CO2eq.	14.28	0.95	2.50	0.17	0.35	**18.25**
Acidifying agents (AP)	kt SO2eq.	82.39	5.75	14.19	0.95	1.85	**105.13**
Volatile Org. Compounds (VOC)	kt	0.23	0.01	0.04	0.00	0.01	**0.30**
Persistent Org. Pollutants (POP)	g i-Teq.	3.39	0.22	0.62	0.04	0.27	**4.54**
Heavy Metals (HM)	ton Ni eq.	11.07	0.59	1.91	0.09	0.39	**14.06**
PAHs	ton Ni eq.	2.34	0.12	0.37	0.02	0.07	**2.92**
Particulate Matter (PM, dust)	kt	30.18	1.21	5.39	0.21	1.23	**38.22**
Emissions (Water)							
Heavy Metals (HM)	ton Hg/20	4.96	0.33	0.82	0.04	0.16	**6.31**
Eutrophication (EP)	kt PO4	0.35	0.02	0.06	0.00	0.01	**0.44**

*=caution: low accuracy for production phase

The tables presented below show the environmental impact per product for each of the Base Case models developed from use of the MEEuP Methodology.

Table 17 - Lifecycle impact (per product) of Canister (Domestic) Vacuum Cleaner

Nr	Life cycle Impact per product:	Date	Author
0	Canister (domestic) Vacuum Cleaners	0	AEA

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**4334**			1461	2873	**4334**	**0**
2	TecPlastics	g			**695**			234	461	**695**	**0**
3	Ferro	g			**1467**			440	1027	**1467**	**0**
4	Non-ferro	g			**478**			143	334	**478**	**0**
5	Coating	g			**8**			2	5	**8**	**0**
6	Electronics	g			**29**			14	14	**29**	**0**
7	Misc.	g			**1612**			483	1128	**1612**	**0**
	Total weight	g			**8621**			2779	5843	**8621**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	592	219	**811**	**125**	**7965**	297	133	**164**	**9065**
9	of which, electricity (in primary MJ)	MJ	59	129	**188**	**0**	**7881**	0	5	**-5**	**8065**
10	Water (process)	ltr	101	2	**103**	**0**	**631**	0	4	**-4**	**730**
11	Water (cooling)	ltr	573	62	**635**	**0**	**21006**	0	18	**-18**	**21623**
12	Waste, non-haz./ landfill	g	9141	696	**9837**	**87**	**9356**	3174	17	**3156**	**22436**
13	Waste, hazardous/ incinerated	g	86	0	**86**	**2**	**182**	1709	4	**1706**	**1976**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	23	12	**36**	**9**	**349**	22	8	**15**	**408**
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	213	53	**266**	**25**	**2043**	45	12	**33**	**2368**
17	Volatile Organic Compounds (VOC)	g	0	0	**0**	**1**	**3**	1	0	**1**	**6**
18	Persistent Organic Pollutants (POP)	ng i-Teq	20	1	**22**	**0**	**52**	22	0	**22**	**96**
19	Heavy Metals	mg Ni eq.	79	3	**82**	**4**	**141**	84	0	**84**	**311**
	PAHs	mg Ni eq.	38	0	**38**	**5**	**21**	0	0	**0**	**64**
20	Particulate Matter (PM, dust)	g	20	8	**28**	**185**	**132**	401	1	**400**	**745**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	64	0	**64**	**0**	**51**	24	1	**23**	**139**
22	Eutrophication	g PO4	4	0	**5**	**0**	**3**	1	0	**1**	**9**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Table 18 - Lifecycle impact (per product) of Canister (Commercial) Vacuum Cleaner

Nr	Life cycle Impact per product:	Date	Author
0	Canister (commercial) Vacuum Cleaners	0	AEA

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**5880**			2233	3648	**5880**	**0**
2	TecPlastics	g			**0**			0	0	**0**	**0**
3	Ferro	g			**1450**			435	1015	**1450**	**0**
4	Non-ferro	g			**2250**			675	1575	**2250**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**1585**			476	1110	**1585**	**0**
	Total weight	g			**11165**			3818	7347	**11165**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	865	275	**1140**	**198**	**17868**	383	149	**233**	**19439**
9	of which, electricity (in primary MJ)	MJ	51	164	**215**	**0**	**17359**	0	2	**-2**	**17572**
10	Water (process)	ltr	95	2	**97**	**0**	**2067**	0	1	**-1**	**2163**
11	Water (cooling)	ltr	645	76	**722**	**0**	**46207**	0	12	**-12**	**46917**
12	Waste, non-haz./ landfill	g	32216	927	**33142**	**122**	**21595**	4108	8	**4100**	**58959**
13	Waste, hazardous/ incinerated	g	45	0	**45**	**2**	**400**	2233	1	**2231**	**2679**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	35	15	**50**	**13**	**788**	29	10	**19**	**870**
15	Ozone Depletion, emissions	mg R-11 ec					negligible				
16	Acidification, emissions	g SO2 eq.	516	66	**582**	**39**	**4573**	57	13	**44**	**5238**
17	Volatile Organic Compounds (VOC)	g	0	0	**0**	**2**	**7**	1	0	**1**	**11**
18	Persistent Organic Pollutants (POP)	ng i-Teq	55	5	**60**	**1**	**114**	28	0	**28**	**204**
19	Heavy Metals	mg Ni eq.	104	12	**116**	**6**	**304**	108	0	**108**	**534**
	PAHs	mg Ni eq.	64	0	**64**	**7**	**40**	0	0	**0**	**111**
20	Particulate Matter (PM, dust)	g	29	10	**39**	**370**	**184**	504	0	**504**	**1097**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	155	0	**155**	**0**	**113**	32	0	**32**	**301**
22	Eutrophication	g PO4	6	0	**6**	**0**	**12**	2	0	**2**	**19**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Table 19 - Lifecycle impact (per product) of Upright (Domestic) Vacuum Cleaner

Nr	Life cycle Impact per product:	Date	Author
0	Upright (domestic) Vacuum Cleaners	0	AEA

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**3806**			1323	2484	**3806**	**0**
2	TecPlastics	g			**760**			264	496	**760**	**0**
3	Ferro	g			**1109**			333	776	**1109**	**0**
4	Non-ferro	g			**433**			130	303	**433**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**25**			13	13	**25**	**0**
7	Misc.	g			**1776**			533	1243	**1776**	**0**
	Total weight	g			**7910**			2595	5315	**7910**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	545	206	**750**	**125**	**7963**	276	133	**143**	**8981**
9	of which, electricity (in primary MJ)	MJ	59	122	**181**	**0**	**7881**	0	5	**-5**	**8057**
10	Water (process)	ltr	101	2	**103**	**0**	**628**	0	4	**-4**	**727**
11	Water (cooling)	ltr	569	58	**626**	**0**	**21006**	0	21	**-21**	**21612**
12	Waste, non-haz./ landfill	g	5918	668	**6586**	**87**	**9321**	2912	19	**2894**	**18887**
13	Waste, hazardous/ incinerated	g	78	0	**78**	**2**	**182**	1600	4	**1596**	**1858**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	22	11	**33**	**9**	**349**	21	7	**13**	**404**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	163	50	**213**	**25**	**2043**	42	12	**30**	**2311**
17	Volatile Organic Compounds (VOC)	g	0	0	**1**	**1**	**3**	1	0	**1**	**6**
18	Persistent Organic Pollutants (POP)	ng i-Teq	24	2	**26**	**0**	**52**	20	0	**20**	**99**
19	Heavy Metals	mg Ni eq.	76	5	**81**	**4**	**141**	78	0	**78**	**304**
	PAHs	mg Ni eq.	32	0	**32**	**5**	**21**	0	0	**0**	**57**
20	Particulate Matter (PM, dust)	g	19	8	**27**	**185**	**132**	377	1	**377**	**721**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	57	0	**57**	**0**	**51**	23	1	**22**	**130**
22	Eutrophication	g PO4	5	0	**5**	**0**	**2**	1	0	**1**	**8**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Table 20 - Lifecycle impact (per product) of Upright (Commercial) Vacuum Cleaner

Nr	Life cycle Impact per product:	Date	Author
0	Upright (commercial) Vacuum Cleaners	0	AEA

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**4995**			1631	3364	**4995**	**0**
2	TecPlastics	g			**1494**			488	1006	**1494**	**0**
3	Ferro	g			**1308**			392	916	**1308**	**0**
4	Non-ferro	g			**711**			213	498	**711**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**20**			10	10	**20**	**0**
7	Misc.	g			**2065**			620	1446	**2065**	**0**
	Total weight	g			**10593**			3354	7239	**10593**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	733	297	**1029**	**198**	**17867**	370	172	**197**	**19292**
9	of which, electricity (in primary MJ)	MJ	92	176	**268**	**0**	**17359**	0	6	**-6**	**17621**
10	Water (process)	ltr	110	3	**113**	**0**	**2068**	0	5	**-5**	**2176**
11	Water (cooling)	ltr	731	83	**814**	**0**	**46208**	0	29	**-29**	**46993**
12	Waste, non-haz./ landfill	g	6398	978	**7376**	**122**	**21337**	3901	24	**3877**	**32712**
13	Waste, hazardous/ incinerated	g	79	0	**79**	**2**	**401**	2129	5	**2125**	**2607**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	32	17	**49**	**13**	**788**	28	9	**19**	**868**
15	Ozone Depletion, emissions	mg R-11 ec				negligible					
16	Acidification, emissions	g SO2 eq.	185	72	**257**	**39**	**4570**	56	14	**42**	**4907**
17	Volatile Organic Compounds (VOC)	g	0	0	**1**	**2**	**7**	1	0	**1**	**11**
18	Persistent Organic Pollutants (POP)	ng i-Teq	46	4	**50**	**1**	**114**	27	0	**27**	**192**
19	Heavy Metals	mg Ni eq.	37	10	**46**	**6**	**303**	104	0	**104**	**460**
	PAHs	mg Ni eq.	48	0	**48**	**7**	**40**	0	0	**0**	**95**
20	Particulate Matter (PM, dust)	g	26	11	**37**	**370**	**184**	506	1	**505**	**1097**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	88	0	**88**	**0**	**113**	30	1	**29**	**230**
22	Eutrophication	g PO4	6	0	**6**	**0**	**12**	2	0	**2**	**19**
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Table 21 - Lifecycle impact (per product) of Battery/Cordless Vacuum Cleaner

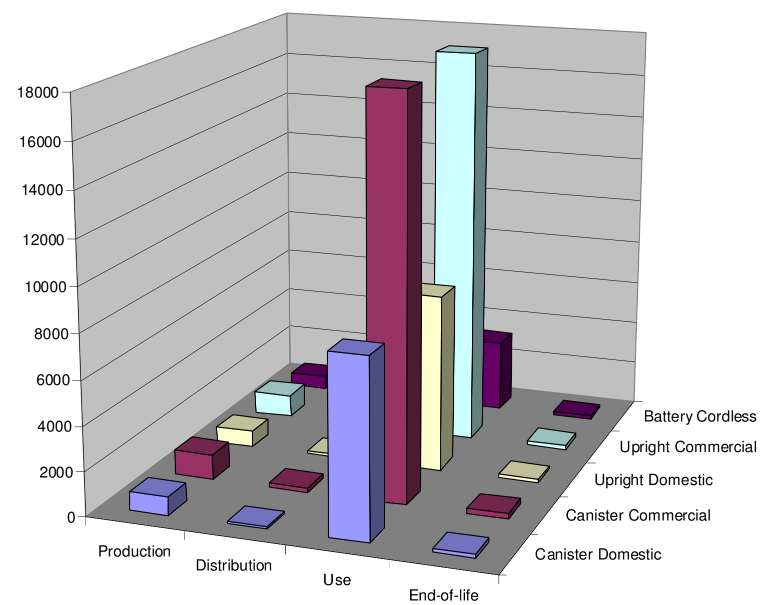
Nr	Life cycle Impact per product:	Date	Author
0	Battery/Cordless Vacuum Cleaners	0	AEA

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**3035**			1198	1837	**3035**	**0**
2	TecPlastics	g			**426**			168	258	**426**	**0**
3	Ferro	g			**1120**			336	784	**1120**	**0**
4	Non-ferro	g			**1428**			428	999	**1428**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**824**			247	577	**824**	**0**
	Total weight	g			**6832**			2377	4455	**6832**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	423	165	**588**	**125**	**3256**	233	80	**154**	**4122**
9	of which, electricity (in primary MJ)	MJ	33	99	**132**	**0**	**3174**	0	1	**-1**	**3306**
10	Water (process)	ltr	59	1	**60**	**0**	**317**	0	1	**-1**	**376**
11	Water (cooling)	ltr	446	46	**492**	**0**	**8454**	0	5	**-5**	**8942**
12	Waste, non-haz./ landfill	g	4919	556	**5475**	**87**	**3856**	2514	3	**2510**	**11927**
13	Waste, hazardous/ incinerated	g	30	0	**30**	**2**	**73**	1366	1	**1366**	**1470**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	18	9	**27**	**9**	**143**	17	5	**12**	**191**
15	Ozone Depletion, emissions	mg R-11 ec	negligible								
16	Acidification, emissions	g SO2 eq.	96	40	**136**	**25**	**830**	35	7	**28**	**1019**
17	Volatile Organic Compounds (VOC)	g	0	0	**0**	**1**	**2**	1	0	**1**	**4**
18	Persistent Organic Pollutants (POP)	ng i-Teq	96	3	**99**	**0**	**22**	17	0	**17**	**138**
19	Heavy Metals	mg Ni eq.	66	7	**73**	**4**	**60**	66	0	**66**	**203**
	PAHs	mg Ni eq.	20	0	**20**	**5**	**12**	0	0	**0**	**37**
20	Particulate Matter (PM, dust)	g	15	6	**21**	**185**	**106**	305	0	**304**	**617**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	40	0	**40**	**0**	**21**	19	0	**19**	**81**
22	Eutrophication	g PO4	3	0	**3**	**0**	**3**	1	0	**1**	**6**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

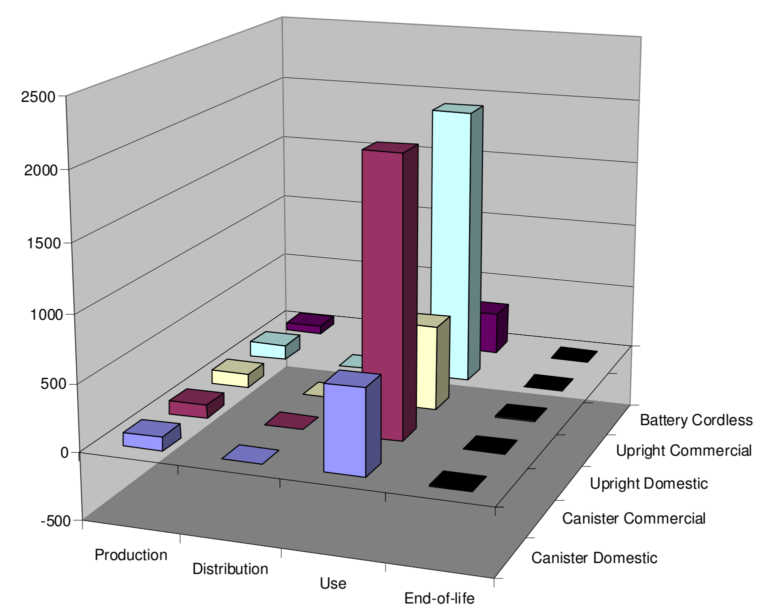
Note: batteries and chargers have been included in the assessment.

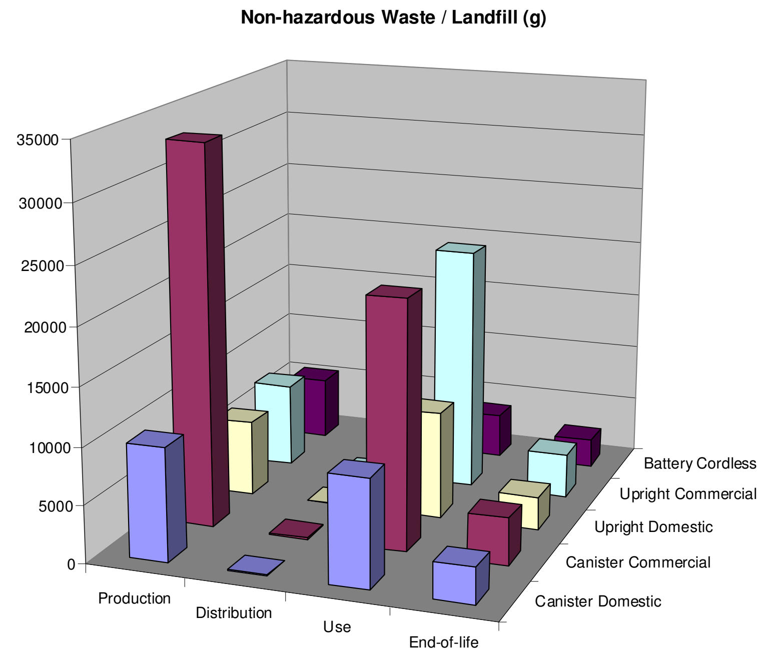
The impacts per product given in the above tables are illustrated graphically below and plotted by Base Case type and life-cycle phase where the impacts occur for each impact category.

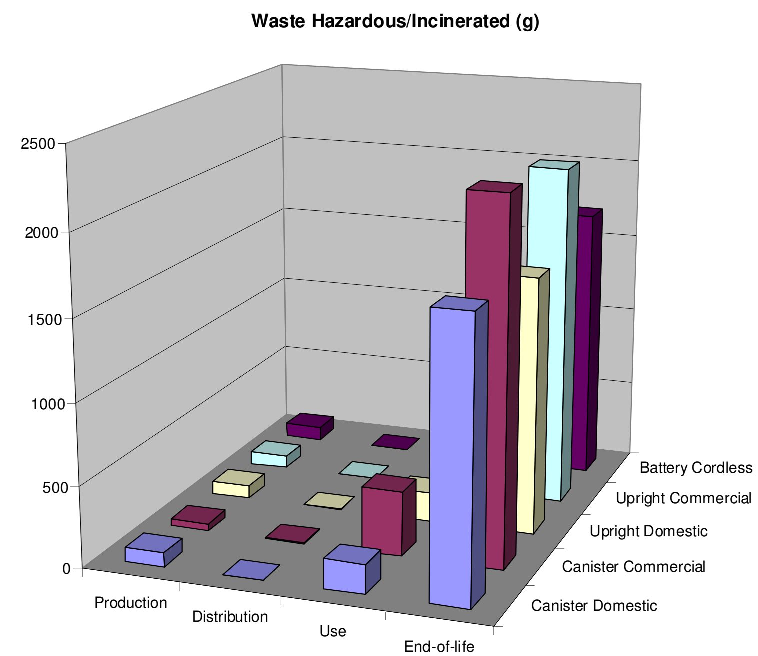
Resources Usage - Total Energy (MJ)

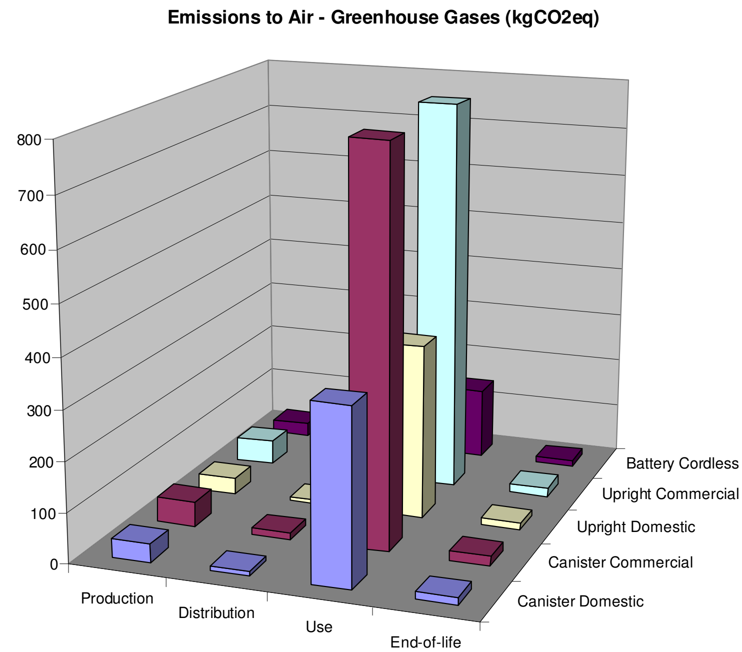


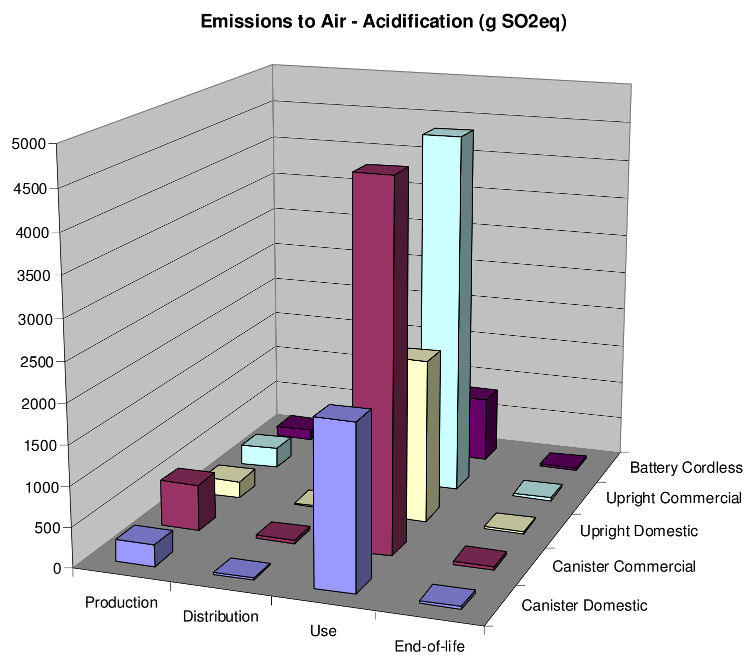
Resources Usage - Process Water (l)



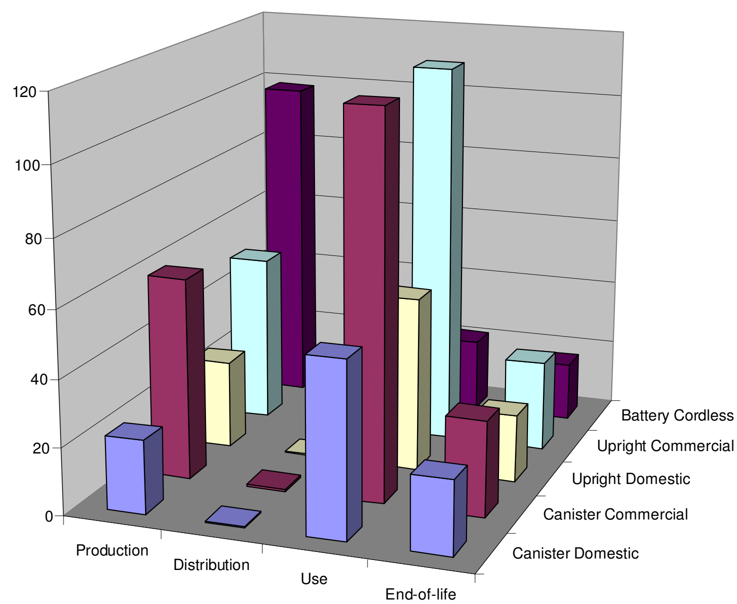

Non-hazardous Waste / Landfill (g)
35000
30000
25000
20000
15000
10000
5000
0
Production
Distribution
Use
End-of-life
Battery Cordless
Upright Commercial
Upright Domestic
Canister Commercial
Canister Domestic


Waste Hazardous/Incinerated (g)
2500
2000
1500
1000
500
0
Production
Distribution
Use
End-of-life
Battery Cordless
Upright Commercial
Upright Domestic
Canister Commercial
Canister Domestic

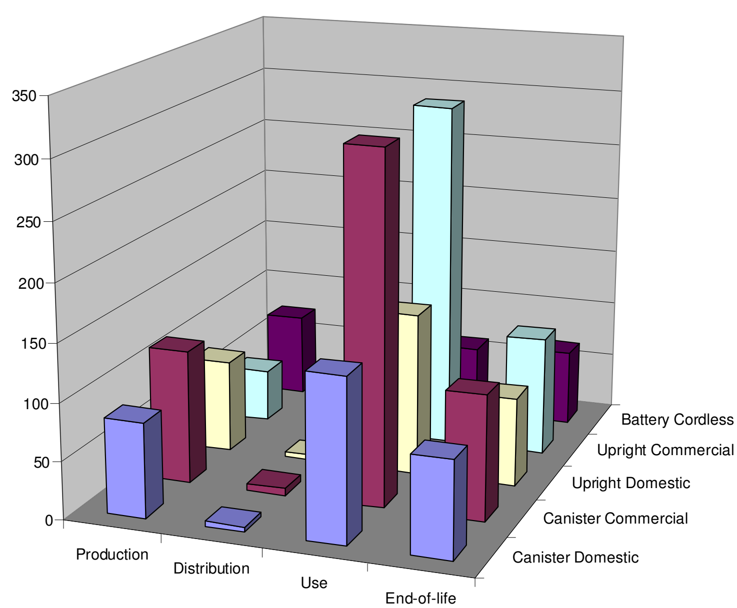

Emissions to Air - Greenhouse Gases (kgCO2eq)
800
700
600
500
400
300
200
100
0
Production
Distribution
Use
End-of-life
Battery Cordless
Upright Commercial
Upright Domestic
Canister Commercial
Canister Domestic


Emissions to Air - Acidification (g SO2eq)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Production
Distribution
Use
End-of-life
Battery Cordless
Upright Commercial
Upright Domestic
Canister Commercial
Canister Domestic

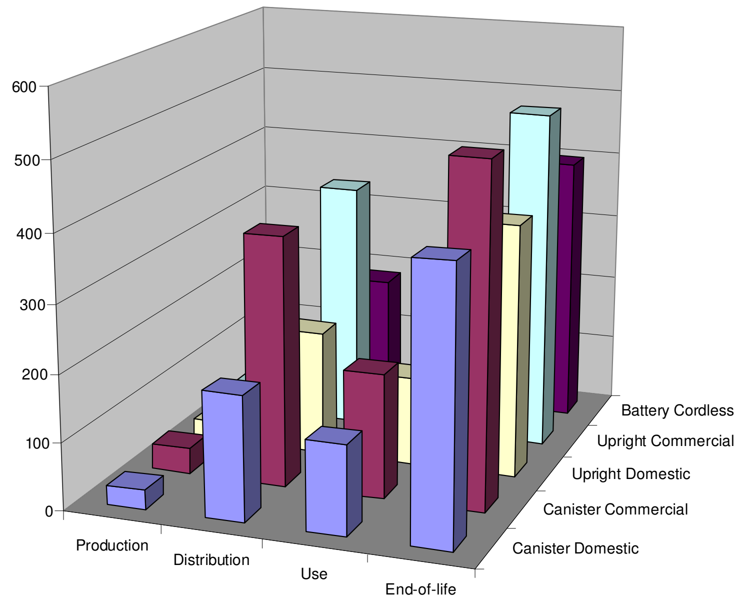
Emissions to Air - Persistent Organic Pollutants (POP) (ng i-Teq)



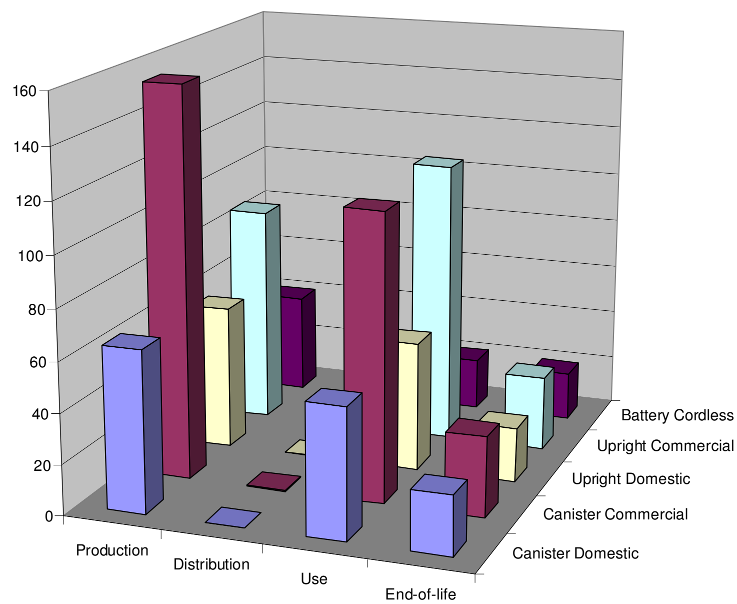
Emissions to Air - Heavy Metals (mg Ni eq)

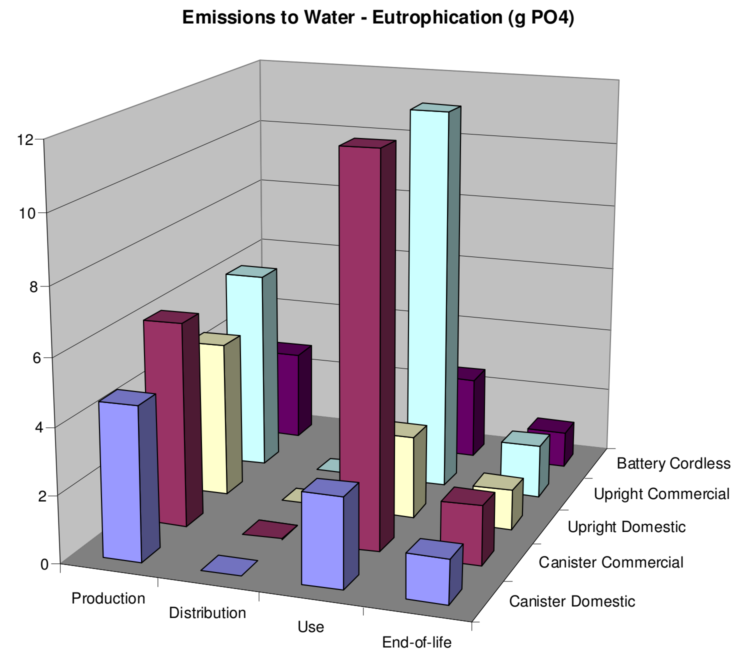


Emissions to Air - Particulate Matter (g)



Emissions to Water - Heavy Metals (mg Hg/20)





It should be noted that, in many of the impact categories, the use-phase clearly has the most impact, dominating the life-cycle impact of the product. This is particularly the case for Total energy and process water resources consumed, greenhouse gas and acidification emissions to air.

Table 22 - Percentage of Use Phase Impact of Base Cases

	Canister Domestic	Canister Commercial	Upright Domestic	Upright Commercial	Battery / cordless
Other Resources & Waste					
Total Energy (GER)	87.9%	91.9%	88.7%	92.6%	79.0%
of which, electricity (in primary MJ)	97.7%	98.8%	97.8%	98.5%	96.0%
Water (process)	86.4%	95.6%	86.3%	95.0%	84.2%
Water (cooling)	97.1%	98.5%	97.2%	98.3%	94.5%
Waste, non-haz./ landfill	41.7%	36.6%	49.4%	65.2%	32.3%
Waste, hazardous/ incinerated	9.2%	14.9%	9.8%	15.4%	5.0%
Emissions (Air)					
Greenhouse Gases in GWP100	85.5%	90.5%	86.2%	90.7%	75.1%
Ozone Depletion, emissions	n/a	n/a	n/a	n/a	n/a
Acidification, emissions	86.3%	87.3%	88.4%	93.1%	81.5%
Volatile Organic Compounds (VOC)	56.7%	63.9%	56.8%	63.3%	43.6%
Persistent Organic Pollutants (POP)	54.0%	56.2%	52.5%	59.4%	15.8%
Heavy Metals	45.4%	56.9%	46.4%	66.0%	29.7%
PAHs	32.9%	36.0%	36.7%	41.9%	31.7%
Particulate Matter (PM, dust)	17.7%	16.8%	18.3%	16.8%	17.2%
Emissions (Water)					
Heavy Metals	37.0%	37.8%	39.4%	49.0%	25.9%
Eutrophication	31.3%	59.5%	29.6%	60.2%	39.6%
Persistent Organic Pollutants (POP)	n/a	n/a	n/a	n/a	n/a

5.3 Base Case Life Cycle Costs

The lifecycle costs of the Base Case models are presented in the table below. A typical lifespan of 8 years has been used in the calculations. In all the presented LCC analysis, the total consumed energy, electricity rate of 0.15 euro/kWh, vacuum cleaner bags and filter costs both costed at 10 euro/kg and a discount rate (interest minus inflation) of 5% have been used. Note also: the analysis has assumed all vacuum cleaners are of the disposable bag type. Bagless vacuum cleaners avoid the life cycle costs for bags consumed during the life cycle of the product.

Table 23 - Base Case Life Cycle Costs per Product

	Canister / Upright Domestic	Canister / Upright Commercial	Battery / cordless
Product price	110 €	250 €	110 €
Electricity	91 €	200 €	17 €
Aux. 1: Vacuum cl. bags	52 €	155 €	35 €
Aux. 2 :Office paper (~filters, instruction manuals etc.)	2 €	2 €	2 €
Repair & maintenance costs	8 €	40 €	8 €
Total	**263 €**	**647 €**	**172 €**

Electricity costs are calculated from input power rating, lifetime (years), hours per year usage and the price per kWh for electricity (assumed 0.15 euro/kWh). Costs of vacuum cleaner bags have been calculated from and assumed cost of 10 euros/kg and an assumed bag weight of 100g and 10 bags per year consumption by domestic vacuum cleaners and 30 bags per year for commercial vacuum cleaners.

Note: Although the life cycle cost for the battery/cordless product appears to be cheaper than the mains electricity base cases, this does not suggest that battery/cordless types are better because the hours per week in use differ significantly (i.e. 6 mins/week for battery/cordless cf. 1-3 hours/week for mains vacuum cleaners)

Note: the input value for Overall Improvement Ratio (stock versus New, use phase) has been set at 1.00 in the EcoReport. If anything, the energy consumption of new products is probably higher than the average installed stock. Thus the ratio may be greater than 1.00.

The calculated total annual consumer expenditure (2005) is shown in the table below.

Table 24 - Total Annual Consumer Expenditure 2005 (Million Euros)

Item	Canister Domestic	Canister Commercial	Upright Domestic	Upright Commercial	Battery Cordless	TOTAL
Product price	4020	276	709	49	220	**5274**
Electricity	3847	273	679	48	40	**4888**
Aux. 1: Vacuum cl. bags	2189	212	386	37	80	**2905**
Aux. 2 :Office paper	96	3	14	0	4	**117**
Repair & maintenance costs	342	55	60	10	20	**487**
Total	**10494**	**820**	**1849**	**145**	**363**	**13671**

5.4 EU Totals

The tables presented in Appendix 1 illustrate the outputs from the EcoReport for the impact of base case models sold in 2005 over their lifetime.

5.5 EU Total System Impact

The tables presented in Appendix 2 illustrate the output from the EcoReport for the EU impact of base case models (produced, in use and discarded).

6 Technical Analysis BAT

This section looks beyond products that are currently on the market to consider what products might be available in the future. While the detail of how both the energy and cleaning efficiency of vacuum cleaners can be improved is the responsibility of the manufacturer, there are some general techniques that can be applied for improving the efficiency of the different types of vacuum cleaner. Although they are all theoretically possible, some will be unrealistically expensive to implement. Costing of modifications is not attempted, since the expense will vary with vacuum cleaner type, size, materials and existing individual design details. The examples in this section should not be generalised.

6.1 State-of-the-Art in Applied Research for the Product

6.1.1 History

The electric vacuum cleaner is a relatively mature product that has been under development for a little over 100 years. The suction only vacuum cleaner, with passive nozzle, first appearing in Europe by 1900 and the vacuum cleaner with rotating brush roll, or agitator, also known as "Upright", first appearing in the USA in 1908. However the designs of the early 21st century would still be familiar to the original inventors with motor technology being largely unchanged and the use of centrifugal fans as vacuum generators still the only technique being used.

The use of cloth bags for collecting and filtering dirt has been augmented by disposable containers, rigid reusable dirt collection receptacles, separate barrier filters as well as non barrier filters such as cyclones.

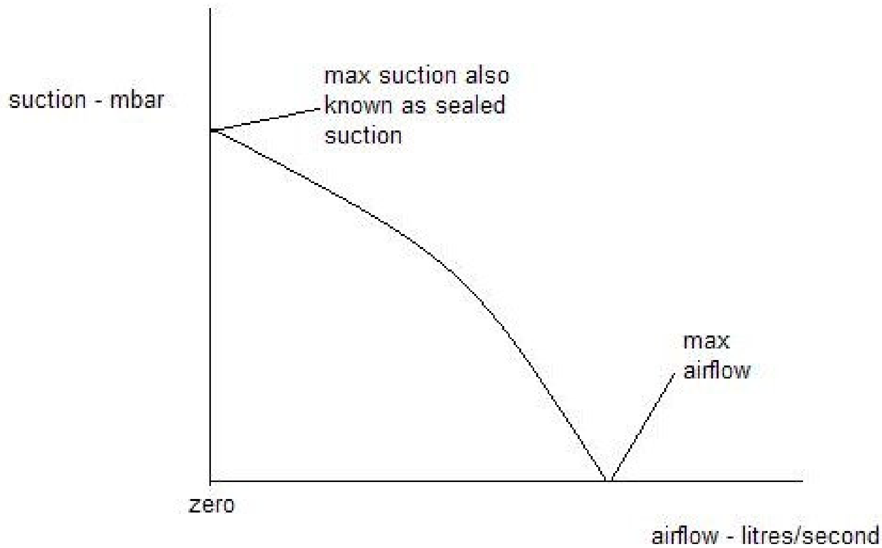
Motor input power was limited to less than 1000 watts until the late 1970s but has since increased significantly to well over 2000 watts, Tesco stores has recently been selling a 2700 watt vacuum cleaner in the UK.

The design of passive suction nozzles is still similar to what it was 100 years ago.

The basic design of agitators, to remove surface and embedded dirt is also similar now as to when it was first introduced. The main changes being the introduction of plastics for the rotating cylinder and man made fibres replacing horsehair for the bristles. Whereas both brushes and beater bars used to figure on an agitator, nowadays only brushes tend to be used. In some cases a separate motor is used to drive the agitator so it can easily be switched off for cleaning certain surfaces.

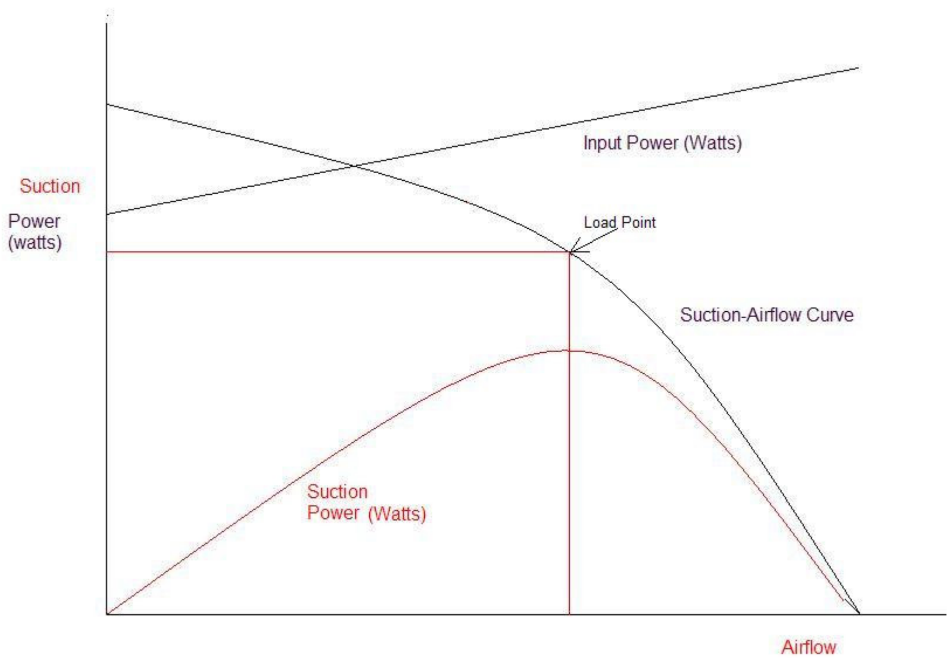
6.1.2 Suction power

Suction power is required to remove dirt from surfaces and transport the dirt to a receptacle, where it can be stored until emptied. Suction power is a combination of airflow and suction and is measured in watts. The following curve shows the relationship between suction and airflow on a typical vacuum cleaner.



Typical suction/airflow curve for vacuum cleaner

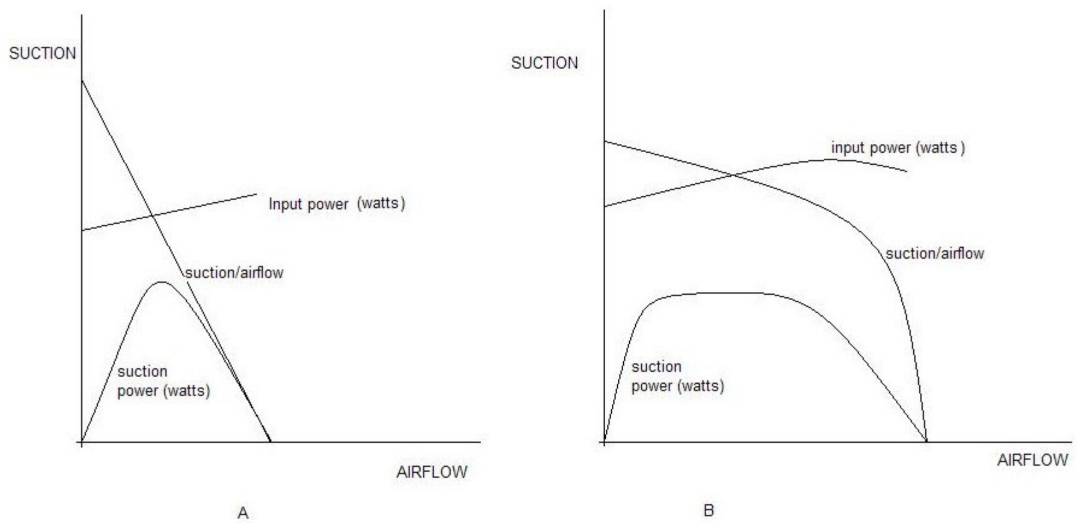
The following curves show the effects of input power and suction power, which is a combination of suction and airflow.



SUCTION-AIRFLOW CURVES

The efficiency of conversion from electrical power into suction power can be extracted from these curves and is the ratio of suction to the input power (both in watts) multiplied by 100. It can be seen that both suction power and therefore efficiency will vary between zero and a maximum at peak suction power. Normally when suction power is quoted for a vacuum cleaner it is the highest or peak suction power and the energy conversion efficiency is usually quoted at the same point. This point is also known as the "load point" and when extrapolated to the key suction airflow curve, as shown, both the suction and airflow at this point can be read off. These are the parameters the vacuum cleaner designer seeks to achieve when the cleaning nozzle is on the surface to be cleaned. This is all particularly true for suction only canister cleaners with passive nozzles. For a vacuum cleaner, which uses an agitator to remove soil from the surface, it is less critical but nevertheless should also factor into the agitator nozzle design

The electrical and torque characteristics of the motor can be tuned to help produce a suction airflow curve that is more bowed outwards and also tends to move the peak suction power closer to maximum airflow. The fan design also contributes to this feature. It is quite possible to achieve a high suction power value, especially when high input powers are available, however it is more difficult to achieve a sufficient level of suction power spread over a longer range. The following curves show, firstly, a vacuum cleaner with high maximum suction but with a relatively low maximum airflow. In this case the motor has higher torque at the highest speeds but as the airflow increases the torque falls away. The second set of curves show what happens when motor characteristics are more closely matched to the additional torque required at higher airflows. In this case the maximum suction power is below that of the first example, however good suction power levels exist over a much greater range of airflow and this can help significantly in producing good cleaning performance over a wide range of surfaces and receptacle/filter dirt levels.



Vacuum Cleaner "A" has higher suction and higher maximum suction power than cleaner "B". However the characterisitics of the motor and the fan system of "B" will allow the performance load point to be extended over a greater range and thus lead to portentially better overall cleaning performance.

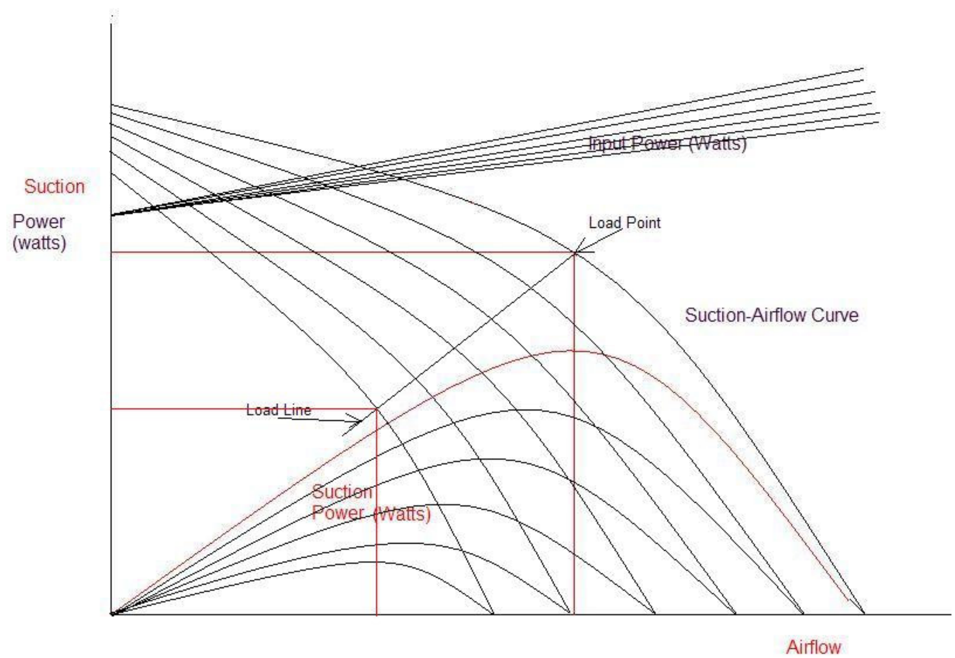
6.1.3 Energy efficiency

Historically, centrifugal fans have been used to create suction power and, in the configuration used, tend to be relatively inefficient at energy conversion. The maximum efficiency can be as low as 15% and has seldom been greater than 50%. When the leaks and inefficiencies of the vacuum cleaner and its connecting tubes and filters are taken in to account the overall energy conversion capability of a vacuum cleaner can be anything between 10% and 33%. It should be emphasised that this energy conversion efficiency has no relationship with cleaning efficiency or ability to pick up dirt where absolute levels of suction, airflow and suction power are more critical.

6.1.4 Filters

In order to prevent dust and dirt from re-entering the atmosphere vacuum cleaners require filtration. Filters are positioned either in the surface of the receptacle containing the dirt, if it is a disposable type, or immediately after the receptacle if the filters are reusable. As an alternative, or in addition, cyclones can be used as a non-barrier form of filtration and these may even form part of the dirt receptacle itself. Barrier filters, hold dust and dirt on their surfaces and within their media. Poorly designed filters tend to clog and cause a reduction in airflow and also suction power throughout the vacuum cleaner and at the cleaning nozzle. Even well designed filters with high dust loading materials being used, and even cyclones in some cases, may also tend to reduce airflow when dust becomes lodged within and on them. A well-designed vacuum cleaner overcomes this hurdle, to a degree, by designing the motor fan characteristics and the cleaning nozzle configuration to always ensure that cleaning takes place at the point of peak suction. This can be seen in the following set of curves.

As the airflow is reduced by filter “clogging”, the suction airflow curve shrinks back towards the zero point and a new suction power curve can be plotted; also the input power tends to reduce. The main design idea is to ensure that the cleaning nozzle is always at the optimum suction power level for each reduction in overall suction and airflow. This is known as the load line. The suction and airflow can reduce to a point where cleaning is significantly affected and the designer should ensure that this point is always well below the normal full receptacle condition of the vacuum cleaner



SUCTION-AIRFLOW CURVES

6.1.5 Rotational speed

To complete the technical understanding and improvement potential it is necessary to understand one more factor and that is the effect of motor and fan speed. Perversely, as the airflow increases the motor fan speed reduces, this is a resultant of the increased load on the motor due to more air flowing through. The electrical characteristics of a universal motor are not able to match the increased load, depending on the actual torque characteristics of the motor. This causes the motor to slow down despite an increase in input power. Conversely, as airflow reduces, the motor speed increases until no airflow is passing through and maximum rotational speed is reached. This point is known as “sealed suction" and is when the maximum suction is reached. For a clean or indirect air vacuum cleaner this represents a potential danger for the motor. Despite the input power being at its lowest it is still significant and there is no airflow to cool the motor. Safety requirements determine that if the motor temperature gets too high either a cut out will operate or a bleed valve will open. At the higher airflows and therefore higher input there is more air passing through to keep the motor cool. A dirty or direct air vacuum cleaner motor needs a separate cooling fan and, ironically, it is at the higher inputs that this fan is running slowest and therefore it must be designed to provide sufficient cooling air at lower speeds which has the further implication of passing more air than is necessary at lower airflows and higher suction levels (higher motor speed) which will therefore use more input power than necessary for the level of suction power. The percentage reduction in energy conversion efficiency due to this is small however, less than 1%.

6.1.6 Agitators

An agitator also rotates and is normally driven by the same motor driving the fan. Agitator speeds are important as they produce a vibration as well as a brushing action. Typically speeds of around 3000rpm produce the best cleaning effect through vibration and brushing. Gearing between motor and agitator is important and since a belt drive is normally utilised shaft diameters are critical when speed differences are of the order of 10:1. Increasingly a separate motor is being used to drive the agitator.

6.1.7 Motors

6.1.7.1 Universal Motors (Wire wound on laminated steel armature and field former, with carbon brushes and commutator).

This type of motor has been used in virtually every vacuum cleaner ever made. It is reliable, versatile, durable, cost effective, easy to manufacture and can be simply tailored by varying wire diameters, coil sizes and coil numbers to produce the torque characteristics necessary to drive a vacuum generator for optimum effectiveness. It can be made in sizes and weights suitable for use in the whole range of vacuum cleaners from battery operated to mains canister and upright types. It is also suitable to drive agitators independently of the main motor.

These motors generally have a high efficiency in converting electrical energy to mechanical (rotation) energy**,** 95% being typical. Improvements in bearings, windings and commutation have resulted in higher motor speed being achieved over the past 20 years. Typically up until the 1970s maximum motor speeds were limited to 30,000rpm, the latest universal motors are capable of speeds up to 40,000. The speeds at maximum suction power have increased from 25,000 rpm to around 32,000rpm. Losses are slightly higher at such speeds due to air friction and bearing losses but this reduction is measured as less than 2%. One benefit of higher speeds is the ability to reduce the number of fan stages (see 6.1.2) and another is to make small weight savings.

Inherently this type of motor produces a certain amount of noise caused by the carbon brushes maintaining contact with the rotating commutator. However it is not excessive and can be controlled to a degree by accurate manufacture and the use of surrounding noise absorbent materials if required. As the carbon brushes wear down over the life of the motor, usually in excess of 500 hours use, the carbon dust produced can enter the environment unless restrained by specific motor filtration.

Normally, in the domestic market these motors are not considered serviceable and thus, once the carbon brushes have worn out the motor is "dead". Commercial vacuum cleaner motors are usually designed to allow for carbon brush replacement and thus motor life can be extended by at least 3 times. Armature bearings would normally be expected to last for at least the life of the brushes and usually would continue to be serviceable long after that. Self-aligning sleeve bearings are used in suction only motors but ball bearings may well be used if the motor is also used to drive the agitator, particularly at the drive end.

6.1.7.2 A.C. frequency controlled brushless Motors (Wire wound field assembly, magnetised steel armature)

Normally this type of motor has been used in washing machines, it tends to be heavier than a universal motor and its speed is controlled by the number of poles it is given. A two-pole motor will rotate at 3000 rpm in a 50 Hz environment and 4-pole at 6000 rpm, for example. Whilst some consideration has been given over the years for the use of this type of motor it is generally considered to be too heavy and too large to fit into a vacuum cleaner. It is also considered to be less versatile in matching fan characteristics in producing airflow. It may well be quieter than a universal motor but it is more expensive, at least 50% more so as well as being heavier and is unlikely to have a role in domestic vacuum cleaner usage.

6.1.7.3 Electronically controlled brushless Motors (Switched Reluctance)

This type of electric motor has been developed during the past 15 years and has already found uses in vacuum cleaners. It is potentially quieter than a universal motor as it does not utilise carbon brushes in contact with a commutator, although electronic "noise" can be quite high. It works by switching the current flow electronically rather than "mechanically", via a commutator and uses permanent magnet materials for its armature. Electronic switching is inherently faster that the "mechanical" switching between armature coils via a commutator on a universal motor and this results in speed up to 100,000 rpm being achievable. Higher speeds also lead to smaller motors and fans being required as well as better torque characteristics being possible.

The negative aspect for this type of motor is that costs are significantly higher than for the universal motor, although they are likely to reduce if production volumes increase substantially. From an environmental aspect, materials used in the electronic circuitry and also for the permanent magnets need to conform to present and future materials directives. There is no evidence that, at present, there is any problem with those materials

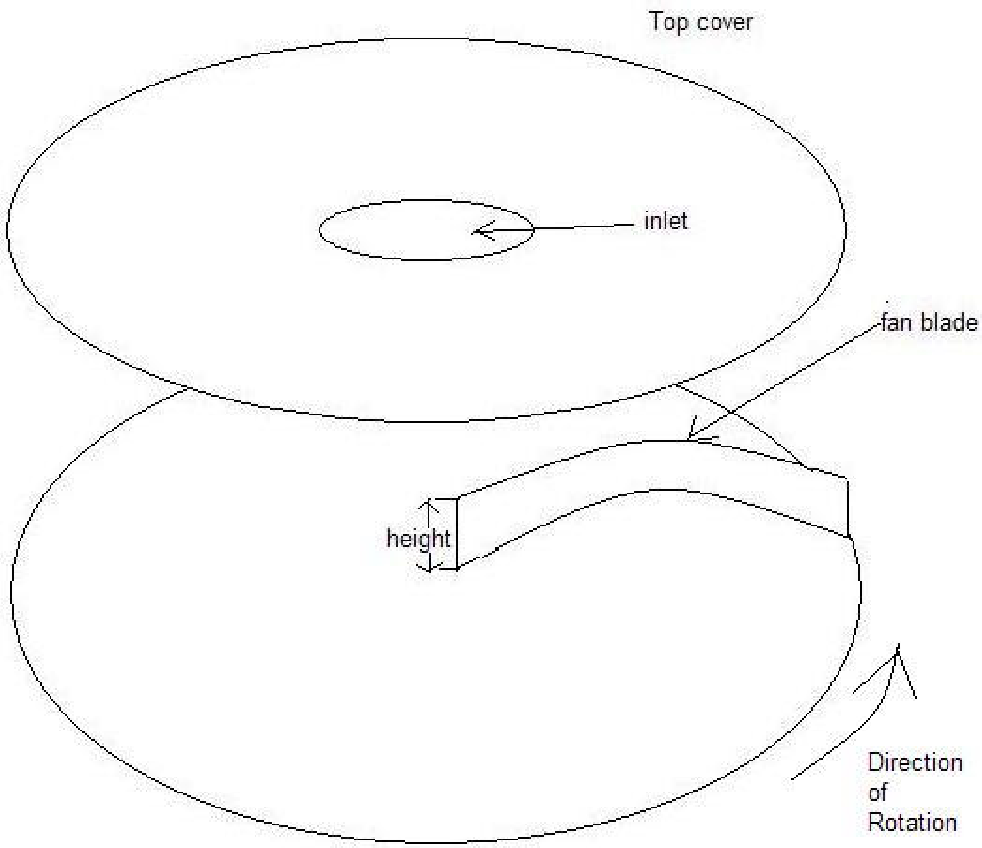
6.1.8 Suction and Airflow Generation

6.1.8.1 Centrifugal Fan Systems

6.1.8.1.1 Single stage

Centrifugal fans produce airflow by rotation of an impeller with curved vanes or blades which guide and drive the airflow to the periphery of the impeller or fan, as it rotates, in such a manner that, when it emerges it has velocity and direction which is close to tangential to the impeller. As the air passes across the fan it creates a lower pressure at the inlet that "sucks" in more air to continue the flow.

In simple terms the height of the fan blades is proportional to the amount of airflow and the diameter proportional to the amount of suction, see sketch below.



schematic exploded view of centrifugal fan assembly. There will be multple fan blades at equal spacing.

Rotational speed is proportional to both suction and airflow. As the fan rotates, airflow can “spill” over the top of the blades causing turbulence and losses. In a dirty air situation where dust and dirt are also passing through the fan it is normal to leave the blades “open”. However in a clean air situation it is normal to add a cover to the fan, which prevents such losses. This cover or shroud is open at the inlet to the blades. Conventionally clean air fans are made from sheet aluminium. The back and shroud are pressed out in circular form from the sheet. Blades are also pressed out and subsequently shaped into curves which when fixed to the fan allow the air to be given energy as it is forced to pass over their surfaces during rotation. The curves are backward in relation to the direction of rotation. The curve is a complex shape to ensure energy is given to the airflow consistently as it passes outwards over the blades to the periphery. The closer the shape is to its mathematical derivative, the more efficiently energy is transferred. However in many cases blades are simple circular arcs to allow easy manufacture.

As the air passes from the inlet to the periphery its velocity is increasing; to match this, the blade height should be reducing towards the periphery to ensure smooth flow and the shroud should be formed to match this. For simplicity this often results in a conical form but as with the blade curve it is theoretically more complex than that for highest efficiency. In many cases this shaping is ignored and the fan is flat in form, leading to inefficiencies of flow.

In a dirty air system the fan is often a die-casting or a plastic moulding. This makes it ideal for giving all the shaping necessary to both blade curving and height variation. To a degree this will help offset the losses occurring at the top of the blades as previously mentioned.

When the airflow leaves the periphery of the fan it has a high rotational velocity and ideally should be contained within a volute, which increases in cross sectional area until it reaches an outlet point that is tangential to the radius. This is the most efficient way of guiding the airflow into the air ducts of the vacuum cleaner. The cross sectional areas of the volute and the outlet should match the airflow to ensure laminar flow with minimal losses. Broadly this form of fan cover is possible in a dirty air system and is normally employed.

In a clean air system it has been normal to utilise circular fan covers and to exhaust the airflow over the motor continually around the periphery or in some cases, static reverse form blades are utilised which “catch the air” to guide it towards the centre where it may then be exhausted over the motor. In effect the airflow is being “turned” ninety degrees to its original direction in a relatively short distance. This introduces significant losses and is one reason why such fan systems are so inefficient, as low as 20% at maximum suction power for the simplest fan designs. However by employing maximum shaping and ensuring high quality finished surfaces within the fan system it is possible to increase efficiency to more like 55%.

There is one type of clean air system that does not use the main airflow to cool the motor; this is known as a bypass system. In this case the airflow is exhausted from the fan cover around its periphery though shaped ducts, which tend to result in fewer losses. However these gains are partly offset by the need to have a supplementary fan to provide cooling for the motor. Such systems are normally used in vacuum cleaners that are associated with water pick up or filtration.

Finally it must be said that centrifugal fan systems work at peak efficiency only at a specific rotational speed as blade shapes and angles are designed to match that speed. The designer should be sure that this point coincides with maximum suction power.

6.1.8.1.2 Multi stage

Here two or more centrifugal fans are used in series, with two stages being most common. The same principles apply as to the previous section however since both fans are mounted on a single shaft, in line, the problems associated with airflow direction is now compounded as it has to be taken from the periphery of the first fan stage, via a system of static blades to the inlet of the second fan in the centre. In order to save space the distance between the two fans is usually little greater than the depth of the fans themselves. This effectively means that the airflow has to pass though two 180-degree turns in a very short space indeed. It is not surprising that the overall energy conversion efficiency of multi stage fan systems can be much lower than single stage systems. As with the single stage system losses can be reduced by ensuring the best shapes for blades, and fans. Surface finishes should be of the highest order. To offset these increased losses somewhat, a multistage system can operate at lower speeds which will reduce the losses caused by the friction of air passing over internal surfaces and can ensure that suction power is maintained over a more significant range. So whilst the fan system efficiency might be in the order of 35 - 40%, the vacuum cleaner will be able to cope with a wider variation of cleaning situations, as the airflow is maintained more consistently over a wider speed range at maximum suction power.

6.1.8.2 Axial Flow fan systems

Historically, axial flow systems have not been used in vacuum cleaners although experiments have been undertaken from time to time. The axial flow system has the advantage of potentially increased energy conversion efficiency due to the fact that the air is flowing through the fans without any change of direction. It would be possible to mount an axial flow fan system to a Universal motor – in line - and still allow the cooling airflow to flow over the motor; however the overall length of the motor fan system would increase when using an axial flow impeller or fan for maximum efficiency. It may be easier to mount to a more compact switched reluctance motor with the motor actually being in the centre of the impeller in order to save space. An impeller or fan of this type may also make it easier to be a moulding, which could ensure the optimum fan blade shapes being used

6.1.8.3 Positive displacement systems

Although there are many practical reasons why positive displacement systems are inappropriate for use in vacuum cleaners, including cost and noise levels, they do offer higher efficiencies. They are therefore included here solely as a reference point for what is technically potentially achievable.

Most positive displacement systems tend to have low internal losses. As long ago as the end of the 19^{th} century, there were large reciprocating pumps with efficiencies of 90%.

Today, there are two basic types of relevant positive displacement pumps: rotary and reciprocating. The reciprocating system is best suited to relatively high heads and small flows. It tends to cause troublesome pressure fluctuations. The rotary system suits lower heads and small flows, and can maintain a practically continuous flow with low pressure fluctuations against a wide range of heads. Typically positive displacement systems are used in compressors and they tend to relatively bulky

6.1.8.4 Rotary Type

6.1.8.4.1 a) Progressing Cavity

These pumps normally comprise of a rotating eccentric steel 'screw' running in a stator housing.

6.1.8.4.2 b) Sliding vane

These comprise a rotor running eccentrically in a circular casing. Vanes slide in and out of the rotor (or casing) maintaining contact with the casing (or rotor).

6.1.8.4.3 c) Peristaltic

These pump by squeezing air through a hose it is low cost but produces only low airflows.

6.1.8.4.4 d) Screw

These consist of axial helical screws meshing together. High suction and airflow is possible. However, the screws must be very accurately located without touching by timing gears. This makes the pump expensive.

6.1.8.4.5 e) Lobe

These could be viewed as gear pumps, usually with only two or three teeth meshing constantly together. However, unlike gear pumps, they are designed (using timing gears) to avoid the 'teeth' actually coming into contact. They run at low speed and are therefore relatively large for their duties.

6.1.8.5 Reciprocating type

6.1.8.5.1 a) Diaphragm

These consist of reciprocating flexible diaphragms with the flow controlled by inlet and outlet valves. They can be driven by a crank or by compressed air. Because of the diaphragms, suction is restricted and cost is high.

6.1.8.5.2 b) Plunger

These generate suction by a reciprocating plunger of constant diameter passing through a seal. They are designed for very high suction levels but with low airflow.

6.1.8.5.3 c) Piston

These generate suction by a reciprocating piston, the principle could be considered to be the reverse of a car engine. However, mean piston speeds are very much lower, probably less than 1 m/s. Thus the system is relatively large. High suction levels are possible but pulsations can be high. Airflow range is almost unlimited.

6.1.8.6 Motor/Fan Systems with intelligent controls

We have established that motor fan system work at peak efficiency at a specific speed. It is also a fact that microprocessor controls have been used for the past 25 years in order to modify the performance of the vacuum cleaner under certain conditions, clogging filters for example could lead to increased power to overcome the resistance of the clogging.

However by use of a microprocessor programmed to measure and react to suction power, it may well be possible to extend the peak suction power to a range rather than a single point and thus extend the most efficient range of operation for the vacuum cleaner. This may best be suited to electronically controlled brushless motors and may lead to reduced energy consumption. In many cases this will allow for a physically smaller motor/fan system, which will use less material and so will also have a lower eco-impact during the production phase.

6.1.9 Agitator (Brush Roll)

The first agitator consisted of a wooden cylinder with horsehair bristles inserted at regular intervals to form a brush roll. It was driven by a rubber belt from an extension to the main motor spindle. Originally brushing was the main function but it became apparent that vibration from the brushes acting on the carpet was also very beneficial. Eventually the cylinder became primarily made of steel and beater bars were added to augment the vibration. Modern agitators tend to be made primarily from plastics, such as polypropylene, and many use large contents of recycled materials. The bristles tend to be made from polyamide. Modern agitators tend to have significantly higher numbers of bristles and are usually arranged spirally so some bristles are always in contact with the surface during rotation. This has tended to reduce the vibration effect and more vigorous brushing has been substituted. This had, in turn, led to an increased potential for carpet wear.

Most effective agitation however, with least carpet wear, is still likely to be speed sensitive brushing and “beating” but with the negative that noise levels would be slightly higher.

The use of an agitator is the most cost effective way to remove soil from carpets and can lead to significantly lower suction power needs and hence lower input power also. Agitators are not only good at removing dust but they remove fibres, hairs and threads well also. Brushes need replacing regularly (every two years or so) for optimum cleaning performance.

6.1.10 Filtration

6.1.10.1 Barrier or Mechanical

6.1.10.1.1 Cloth

Cloth filters, usually cotton, have been used traditionally as filter media. For more than 50 years this was the main form of filtration, either large as cloth bags on uprights or smaller cloth bags inside canister cleaners. These bags were reusable but were quite messy to empty. The large cloth bags used on uprights were not designed for large dust carrying capacity but more to provide a large filter area with low air velocity to ensure no significant clogging or, since they were “outside”, the passing through or emitting of dust. They were designed to be emptied every week. Cloth bags were featured on uprights right up until the 1980s when they were largely superseded by hard containment mouldings with internal filter bags. Reusable cloth filter bags are still available for use with canister cleaners. They are relatively low cost in relation to their reusability and ability to be washed clean regularly to remove residual dust. They tend to be fairly leaky of dust especially with modern high suction power vacuum cleaners.

Felt filters were used for a long period, usually as secondary filters within a canister cleaner. They have not been used, as such, for the past 30 years and offer no advantages over alternative materials now available

6.1.10.1.2 Paper

The use of paper for a filter medium first appeared in the 1930s, however in the late 1940s became popular made into disposable paper bags fitted inside the cloth bags already in use. This overcame the messy emptying problem, although, due to costs, some users still wanted to empty and reuse the paper bags, even if occasionally they would burst due to excess wear!

Paper bags are still in regular use today, some have more than one layer of paper in order to absorb more dust and still reduce clogging. More and more have some form of self-closing device to further enhance the hygienic properties. They are relatively low cost to manufacture although are a lifetime on cost for the user who has to continue to buy replacements.

Paper is also used in a corrugated form in a cartridge as a media for secondary filtration. When used in this manner it is relatively low cost but is relatively fragile, hence is not easy to clean or durable and needs regular replacement.

All paper bags/filters are easy to recycle.

Paper filter technology is certainly able to allow the production of HEPA levels of filtration but filters must also fit properly into the vacuum cleaner to ensure no airflow bypasses them, as this would negate the effectiveness of the filter itself!

6.1.10.1.3 Treated Paper

Treating paper to give more strength is quite common. The treatment does not significantly affect the filtration properties. Filter cartridges made from treated paper are more durable, easier to clean and even wash carefully. It may, however lead to some problems concerning recyclability.

6.1.10.1.4 Manmade fibre (“fleece”)

Manmade fibres such as polypropylene are increasingly being used to make up filters and filter bags. They are made with such density as to aid high dust loading, which means little or no emissions and little clogging or reduction in airflow. They are relatively expensive are not generally reusable, however due to their filtration ability are made to ensure that bags can hold maximum quantities of dirt with some larger ones used in uprights tending to need replacing only twice per year. Potentially they can be recycled.

6.1.10.1.5 Moulded (sintered plastic)

The use of sintered plastics (polyethylene for example) has allowed porous mouldings to be made. The porosity can be controlled and using such materials hard, durable reusable dirt containers can be manufactured which also act as filters. They can be recycled however their filtering ability may not be as effective as other materials.

6.1.10.1.6 Water

If dirt-carrying airflow is passed through a water bath then the dirt can be “washed” out of the airflow thus using the water as a filter. Water is a cheap filter medium and it is completely recyclable. However, due to cavitation effects as the airflow passes through the water, some quantities of dust are held inside air bubbles so produced and can pass right through the filter process. It can also be messy, as the water has to be emptied after each use.

6.1.10.2 Non Barrier filtration

6.1.10.2.1 Cyclone systems

Cyclonic systems have been used for more than 75 years to separate particles from airflow. In 1948 a single cyclone system was even designed to remove different sizes of particles from the airflow via specific tapping off points within the cyclone. However truly effective cyclonic filtration was not seen on vacuum cleaners until 1981 when the first dual cyclone system was shown on UK television, subsequently to be sold in Japan. It was not for another 10 years that mass marketed cyclonic filtration vacuum cleaners appeared in Europe, initially in the UK.

The benefit of using a cyclone filter is to overcome the propensity for a barrier filter to become loaded with dust that may reduce the airflow and potentially reduce the cleaning performance. However the amount of suction power and airflow needed to create the cyclone' filtration operation is quite significant and can be equated to the amount of energy lost in a loaded filter. The initial systems were indeed energy hungry however their benefits were quickly picked up by users. Subsequent cyclone systems have tended to require less energy but need significant secondary filtration (barrier type), to complete the overall filtering operation. It is also not unknown for some cyclone systems to become blocked with certain types of dust or soil. However the net benefit is a completely reusable filter with little or no effect on cleaning performance as the receptacle fills with dirt. The benefit is reduced where more secondary filtration is required however.

A cyclonic filtration system is normally used in a "bagless" container, which has to be emptied regularly. During emptying dust can be released in to the atmosphere and some question the potential hygiene issues. However it should be pointed out that many more bagless systems due not use cyclonic filtration to any degree, if at all, and these types may be considered even more unhygienic as the filters have the be cleaned every time of emptying also.

6.1.10.2.2 Electrostatic filtration

Charged plates mounted alongside the airflow path can be used to remove dust from that airflow. This type of system is used in some room air cleaners and has been proved to be reasonably effective. Historically there has been little interest shown in their use in vacuum cleaners.

6.1.10.2.3 UV

The use of UV within a vacuum cleaner to sterilise bacteria has been used intermittently.

6.1.11 Noise Control

Noise is an environmental pollutant and so the control of noise levels of vacuum cleaners should not be ignored. The most cost effective way to reduce noise levels is to use sound muffling and sound absorbing materials. This can add weight and some cost but can achieve reductions of more than 3 dBA when applied correctly. An alternative approach is to use the principle of noise cancelling. That is undertaken by generating a noise signal with exactly opposite frequency characteristics to those being produced normally by the vacuum cleaner. This is undertaking by sampling the noise frequency and applying the opposite signal from a frequency generator via a loudspeaker mounted on the vacuum cleaner. (Same principle as that used by noise cancelling headphones now popularly used on airplanes). This technology is expensive to apply however and adds to the complexity in a way that does not augment the cleaning performance.

6.1.12 Pneumatic principles

The design of nozzles and airways must comply with pneumatic principles for optimum benefits of suction power and airflow in particular to undertake work necessary in the task of removing soil from surfaces effectively and transporting that soil to a receptacle for storage. Airflow passes though and across a nozzle when it is in contact with the surface being cleaned. Whether or not an agitator is being used, it is vital that all shapes and cross sections comply with those principles. Similarly as the airflow passes through the connecting tubes, hoses and internal airways on the vacuum cleaner it should be laminar with no turbulence. All changes of direction should be accordingly designed.

6.1.13 Use of Materials

Vacuum cleaners have to look good as well as satisfying construction requirements. Whilst it is satisfactory to use low cost materials, such as polypropylene or polystyrene, the effects on appearance and longevity should not be ignored. The use of ABS, a good general purpose material can allow good looks and structural strength. The use of engineering plastics, such as polyamide or acetal may be kept to a minimum but must be used where appropriate. E.g. dirty air fan. Wheel bearings should be made with dissimilar materials. The use of modern moulding techniques, such as foaming and gas injection may be used to reduce material quantity without sacrificing strength. (weight saving also)

6.2 State of the art at component level (prototype, test and field trial level)

The study group is not aware of any developments in this category of products.

6.3 State of the art of best existing product technology outside the EU)

The study group is not aware of any developments in this category of products outside of the EU.

6.4 Summary

This section has discussed the many ways in which energy conversion efficiency of vacuum cleaners can be increased. Each of the design options has an economic cost, and in some cases may impact adversely on lifetime. The detailed decisions on what options are most appropriate for a particular vacuum cleaner will vary from design to design, and so in the LCC analysis in chapter 7 a generic relationship between efficiency and production cost is derived.

Beyond improvements to the actual design of the vacuum cleaner itself, the use of optimally designed centrifugal fan systems driven by a universal motor with possible microprocessor control is probably the most cost effective way to move forward at present. In combination with the use of an agitator fitted in a suitably designed nozzle producing appropriate vibration in addition to the brushing action the optimum cleaning performance on carpets may be achieved at the lowest suitable input power. Hard floors are generally easier to clean and agitation may be superfluous but good nozzle design is still important.

Emissions may best be controlled by use of well fitting High Efficiency Particulate Air (HEPA) filter media, either in conjunction with primary cyclonic filtration or with “fleece” material bags for more hygienic disposal. The use of suitable UV sterilising techniques may reduce significantly the emission of bacteria.

7 Task 7 Improvement Potential

This section reviews the design options that there are for improving the current designs of vacuum cleaners up to and beyond the base case reference designs. By considering the total economic lifecycle cost to the user, and comparing this with the environmental impact of each option, the attractiveness of the different options can be compared on an equal basis.

Because the initial MEEUP analysis showed that the environmental impact is dominated by the “In use” phase energy cost, other environmental impacts are not the central focus in this section. This means that the different options can be considered purely in terms of cost to the consumer and energy savings.

All analysis is undertaken relative to the base case reference models used earlier.

Article 12 of the Energy Using Product Directive states that “implementing measures shall not have a negative impact on …(c) the affordability and lifecycle cost to the user”. This analysis will show the lifecycle costs to the user for all products and will also consider the impact of its interaction with the wider system.

7.1 Background

7.1.1 Cleaning Effectiveness and Suction Power.

In 1980, the average input power ratings of vacuum cleaners were around 350 watts for uprights and between 600 and 1000 watts for suction (cylinder/canister) vacuum cleaners. By 2008, this had increased to between 1000 and 2000 watts for uprights and 1200-2700 watts for canister cleaners. However the best cleaning performance as measured by the EN60312 cleaning tests had not significantly improved. In 1980, the range of results for carpet cleaning performance efficiency ranged from 25% to 85%. In 2004, the results for a similar test ranged from 17% to 85%.

It has been recognised for more than 50 years that vacuum cleaners with some form of additionally powered agitators or rotating brushes could remove dirt from carpets more effectively than a passive suction only nozzle. Some rotating brushes used “spare” suction power airflow to drive the brush roll. However, since this type of active nozzle used airflow it would, by design, reduce the air flow that would carry dirt to the receptacle.

In 1979, the very first 1000 watt input power vacuum cleaner was introduced. This was driven purely by marketing desires to have the “highest” input power on the market. At that time, the motor was unusual because, in order to absorb 1000 watts input, the motor was placed before the fan (vacuum generator) so that the airflow was cold enough to cool the motor sufficiently (Note that the fan adds a great deal of heat to the airflow due to inefficiencies).

By 1980, the highest input power reached 1100 watts for suction cleaners. This product actually had a “suction power” of 340 watts. The nozzle was designed to outperform any on the market. However it was discovered that whilst the theoretical cleaning performance was good, it was actually very difficult to push the nozzle over the carpet. It appeared that a natural maximum “suction power” had been reached. From that point on, all nozzles had an element of more and more “leakage” built in. This is not necessarily a bad thing, as the “leakage” added to the airflow that could carry the dirt away to the receptacle. However, unlike a nozzle with an agitator, there is nothing in a passive nozzle that can remove dirt other than suction power and the natural “agitation” of moving the nozzle backwards and forwards, assuming that it wasn’t “stuck” to the carpet by that very same “suction power”!

The history of vacuum cleaner development shows us that a cleaner with 200 - 250 watts suction power generates sufficient air power to clean surfaces effectively given optimum airways and nozzle design. A motor/fan unit with 750 watts rated input power can generate a maximum of 375 watts of Suction Power at 50% efficiency. When placed into a vacuum cleaner further loss will occur. Good filtration can absorb as much as 50 watts but if the filter area is increased by 50% this could be reduced to a 35 watts loss. Additional filter area requires more filter media, which means an additional cost (approx €1) and may also require some volume increase to the size of the vacuum cleaner which would also generate additional cost (materials possibly €1). General leakage through joints and seals may lose around 15 watts and so attention must be given to ensure the best sealing arrangement throughout the vacuum cleaner. Losses occur in the hose due to the corrugated construction. A smooth wall hose would reduce losses but may be less flexible and would probably double the cost in order to maintain strength. The longer the hose the more the losses so a stretch hose may well increase losses when operated at full stretch but when cleaning up stairs or even high drapes and curtains this loss may not affect cleaning performance significantly. The loss in the hose could be as much as 40 watts. Once again, losses through seals between cleaner, hose, connecting tubes and nozzle must be kept to a minimum and can be kept to around 15 watts. Given this attention to design and construction detail then around 270 watts of suction power should be available at the nozzle. Finally the shape of the airways in the nozzle and at the surface interface must be optimised for the airflow.

However for best cleaning performance on carpets it is acknowledged that a nozzle with a powered agitator would be better. The additional cost over a standard passive nozzle is likely to be around €10.This powered nozzle would absorb as much as 75 watts input power, thus reducing the available input power to the main motor to 675 watts and maximum suction power at motor/fan unit to 337 watts leaving 232 watts at the nozzle. Given that an agitator is now present in the nozzle then this is more than adequate for best cleaning performance on carpet. Passive nozzles could be used on all other surfaces.

It is acknowledged that all cleaning performance tests are undertaken with clean bag and filters and that performance may reduce as dust starts to fill the pores of the filters and bag. To minimise this reduction, high dust loading materials should be used throughout, incurring additional costs of around €1. However disposable bags would carry an on cost of €0.50 for each bag, with *quid pro quo* that there would be an increase in capacity due to the enlargement of the cleaner already reported due to the larger filter area and this would reduce the number of bags used by 10%.

Since an upright vacuum cleaner normally has the agitator built in to the integrated nozzle or cleaning head and is primarily used for cleaning floor surfaces, much lower input powers are required for that function.An independent test already carried out in this study showed that 80% cleaning efficiency on carpets as well as 101% cleaning efficiency on hard floors with crevices can be realised with as little as 250 watts input power.

So far, our examination has focussed on the main cleaning function of the cleaning of floors. Normally, a canister type vacuum cleaner is also used to clean above the floor surfaces. However, such surfaces generally do not have the dirt embedded into them by walking or any other means. This means that the dirt, usually dust and light fluff, is easier to remove from its surface - meaning that less airpower is required. (An exception may be upholstery and cushions where people sit on them). However, the quantity of dirt is unlikely to be as great as on the floor, and is mostly limited to fibres and skin dust. Nozzles with “oriented” fibre strips either side of the nozzle opening can help to remove fibres from such surfaces. (Oriented fibre strips consist of short pile bent in one direction so that when moving one way over the surface the oriented fibre catches the fluff etc and when it moves in the reverse direction releases it to be sucked into the nozzle opening.)

Given the overall need to keep a house clean it would appear that the lowest energy use is achieved by an upright vacuum cleaner to clean all the flooring,(our research shows that input power as low as 250 watts is required) and a canister cleaner for all above floor cleaning (could be as low as 400 watts input power is required since carpets are being cleaned using the upright). The alternative would be either an integrated upright complete with hose and cleaning tools or a canister cleaner with powered nozzle. Such products would, in our view, require no more than 750 watts input power.

Finally it is recognised that cyclonic filters absorb more power than barrier filters but that they do not clog and require (in theory) less additional filtration. The lowest input power mainstream cyclonic vacuum cleaner currently is 650 watts. However this product has a significant additional barrier filter after the cyclonic filters which may indicate that higher input power is necessary for pure cyclonic filtration with no additional barrier filter requirement,

7.2 Options

The following design options have been considered in this technical analysis of improvement potential. The options represent what is possible in terms of improvements to move from the current situation (i.e. base case average status) to application of BAT to that particular design aspect. As such, all improvements would be capable of being introduced within the design life cycle of the product (typically 3 years).

7.2.1 Option 1 – Maximising Fan Efficiency

Improvement in the efficiency of the motor/fan (i.e. the vacuum generator) is the option with the largest potential for energy savings. Typically, for current vacuum cleaners on the market, energy losses are at best around 60% and at worst can be as high as 75%. These energy losses manifest themselves as heat via the exhaust air.

With application of best available technology, a target energy loss of 45% is achievable. This could be achieved through improvements in design to the fan case and fan blades. The estimated additional cost is around 10 euro cents (fan and blade shapes are more costly to manufacture plus additional stator blades and slightly deeper fan case is required).

7.2.2 Option 2 – Improved Efficiency Airways

Improvements can also be made to the design of the vacuum cleaner airways. Currently, the energy losses due to the airways are at best 5% and at worst 10%. The application of design for BAT suggests that a target energy loss of around 5% is the best achievable. Note: the estimated on cost is considered to be zero, because this target could be achieved within the design cycle lifetime with essentially no additional tooling cost.

7.2.3 Option 3 – Reduced Filtration Energy Losses

For current filters (HEPA 12), the energy losses due to the filtration process are at best 15% and at worst around 20%. The BAT position with regard to filtration would suggest an achievable target energy loss of 10%. This would require larger area filters thereby requiring increased amounts of filtration materials, thus leading to an estimated addition cost of 20 euro cents per filter set (increased material for larger area).

7.2.4 Option 4 – Reduced Energy Losses through Better Seals

Leakage between vacuum generator and the nozzle can lead to energy losses. Current energy losses are at best around 10% and at worst around 20%. Losses due to leakage could be reduced to a target energy loss of about 5%. The on cost for this improvement is estimated to be about 10 euro cents (as a consequence of more inspection, use of better seals).

7.2.5 Option 5 – Nozzle Improvements

Nozzle design is a critical area for ensuring most efficient cleaning effectiveness. Suction power requirements (as measured at the nozzle) can be as low as 50 watts where an agitator is present. There is, however, a requirement for airflow to be at least (when receptacle is full) 8.5 litres/sec.

Current energy losses exhibited are at best around 15% and at worst around 25%. With efficient nozzle design, a target energy loss of 10% is achievable. The estimated on cost would be about 5 euro cents (due to material increases that may be necessary)

7.2.6 Option 6 – Combination of Options 1 to 5

Clearly, by combining all the above options together, there is a potential to effect significant efficiency improvements. However, the effect of combination is not a simple addition of the individual improvements. Designers have to match or balance the whole system by optimising the efficiency of the individual aspects so that the overall potential for energy saving of the vacuum cleaner is maximised. Currently, total overall energy losses are at best 75% and at worst as high as 89%.

Through careful attention to overall design, an overall target energy loss of 60% (i.e. efficiency 40%) could be achieved.

7.2.7 Option 7 – Reduced Materials/Lightweighting

The life cycle impact of a vacuum cleaner can be reduced to some extent by reducing the amount of materials used in its construction. BAT in the aspect has been demonstrated in recent design (such as the Rowenta "Shock absorber" – which incorporates the use of foamed plastics in its construction thereby allowing lighter weight for the product), where the weight of materials usage can be reduced to 50% compared with a typical equivalent appliance. This option has taken into consideration the effect of a 50% cut in materials weight (with the exclusion of the packaging materials).

7.2.8 Option 8 – Increased Product Lifetime

This option considers the effect of a 50% increase in the product lifetime (Increase from currently estimated 8 years to target of 12 years). The consequences of such an increase are likely to impinge on the need to improve the durability of the vacuum cleaner itself (i.e. increased weights of materials to strengthen items) and the increased likelihood of repairs necessary during the lifetime of the product. In addition, considerations have to be made regarding the total number of unit sales necessary to support a 12-year lifetime instead of an 8-year lifetime. By use of a simple stock model, it has been possible to make predictions about the likely level that annual unit sales would fall to due to the longer time interval between product replacements. Note: for the purposes of this technical analysis of improvement options, we have not considered here the complex question of whether or not it is better to replace more quickly an inefficient vacuum cleaner with an efficient vacuum cleaner. This will be discussed within Task 8.

7.3 Impacts

The MEEuP eco-report was used for the quantitative assessment of the environmental improvement for each of the above options. The outputs from the eco-report for each option are presented in the tables below against the respective base cases for Canister vacuum cleaners (Domestic and Commercial) and Upright vacuum cleaners (Domestic and Commercial). The cases for Battery/Cordless category of vacuum cleaners was not considered because the discussions at the 3rd Stakeholder Workshop reached agreement that the potential improvements for these types of vacuum cleaners were governed largely by improvements in battery chargers, which were already covered in a separate Preparatory Study.

Table 25 - Summary Environmental Impacts EU Stock 2005 - Domestic Canisters

Canister Domestic		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base Case
main life cycle indicators	**units**	**value**	**value**	**value**	**value**	**value**	**value**	**value**	**value**	**value**
Total Energy (GER)	**PJ**	**303**	**299**	**226**	**271**	**286**	**286**	**302**	**242**	**316**
of which, electricity	*TWh*	26.1	26.0	17.8	22.0	23.5	23.5	25.0	19.3	26.3
Water (process)*	mln m3	28	27	23	26	27	27	28	24	29
Waste, non-haz./ landfill*	kton	663	577	699	751	769	769	787	718	803
Waste, hazardous/ incinerated*	kton	53	39	70	71	71	71	71	70	72
Emissions (Air)										
Greenhouse Gases in GWP100	**mt CO2eq**	**14**	**13**	**10**	**12**	**13**	**13**	**14**	**11**	**14**
Acidifying agents (AP)	**kt SO2eq**	**79**	**77**	**59**	**71**	**75**	**75**	**79**	**63**	**82**
Volatile Org. Compounds (VOC)	**kt**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

(VOC)										
Persistent Org. Pollutants (POP)	**g i-Tec**	3	3	3	3	3	3	3	3	3
Heavy Metals (HM)	**ton Ni eq**	9	8	10	10	11	11	11	10	11
PAHs	**ton Ni eq**	2	2	2	2	2	2	2	2	2
Particulate Matter (PM, dust)	**kt**	21	23	30	30	30	30	30	30	30
Emissions (Water)										
Heavy Metals (HM)	**ton Hg/20**	4	3	4	5	5	5	5	4	5
Eutrophication (EP)	**kt PO4**	0	0	0	0	0	0	0	0	0

Table 26 - Summary Environmental Impacts EU Stock 2005 - Commercial Canisters

Canister Commercial		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base Case
main life cycle indicators	**units**	value	value	value	value	value	value	value	value	value
Total Energy (GER)	**PJ**	21	21	20	20	20	20	20	20	21
of which, electricity	*TWh*	1.8	1.8	1.7	1.7	1.8	1.7	1.7	1.7	1.8
Water (process)*	mln m3	2	2	2	2	2	2	2	2	2
Waste, non-haz./ landfill*	kton	52	44	63	63	64	63	63	63	65
Waste, hazardous/ incinerated*	kton	2	2	3	3	3	3	3	3	3
Emissions (Air)										
Greenhouse Gases in GWP100	**mt CO2eq**	1	1	1	1	1	1	1	1	1
Acidifying agents (AP)	**kt SO2eq**	6	5	5	5	6	5	5	5	6
Volatile Org. Compounds (VOC)	**kt**	0	0	0	0	0	0	0	0	0
Persistent Org. Pollutants (POP)	**g i-Tec**	0	0	0	0	0	0	0	0	0
Heavy Metals (HM)	**ton Ni eq**	1	0	1	1	1	1	1	1	1
PAHs	**ton Ni eq**	0	0	0	0	0	0	0	0	0
Particulate Matter (PM, dust)	**kt**	1	1	1	1	1	1	1	1	1
Emissions (Water)										
Heavy Metals (HM)	**ton Hg/20**	0	0	0	0	0	0	0	0	0
Eutrophication (EP)	**kt PO4**	0	0	0	0	0	0	0	0	0

Table 27 - Summary Environmental Impacts EU Stock 2005 - Domestic Uprights

Upright Domestic		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base Case
main life cycle indicators	**units**	value	value	value	value	value	value	value	value	value
Total Energy (GER)	**PJ**	53	53	39	47	50	50	53	42	55
of which, electricity	*TWh*	4.6	4.6	3.1	3.9	4.1	4.1	4.4	3.4	4.6
Water (process)*	mln m3	5	5	4	5	5	5	5	4	5
Waste, non-haz./ landfill*	kton	101	91	101	110	113	113	116	104	119
Waste, hazardous/ incinerated*	kton	9	7	12	12	12	12	12	12	12
Emissions (Air)										
Greenhouse Gases in GWP100	**mt CO2eq**	2	2	2	2	2	2	2	2	3
Acidifying agents (AP)	**kt SO2eq**	14	13	10	12	13	13	14	11	14
Volatile Org. Compounds (VOC)	**kt**	0	0	0	0	0	0	0	0	0

(VOC)										
Persistent Org. Pollutants (POP)	**g i-Tec**	1	0	1	1	1	1	1	1	1
Heavy Metals (HM)	**ton Ni eq**	2	1	2	2	2	2	2	2	2
PAHs	**ton Ni eq**	0	0	0	0	0	0	0	0	0
Particulate Matter (PM, dust)	**kt**	4	4	5	5	5	5	5	5	5
Emissions (Water)										
Heavy Metals (HM)	**ton Hg/20**	1	1	1	1	1	1	1	1	1
Eutrophication (EP)	**kt PO4**	0	0	0	0	0	0	0	0	0

Table 28 - Summary Environmental Impacts EU Stock 2005 - Commercial Uprights

Upright Commercial		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base case
main life cycle indicators	**units**	**value**	**value**	**value**	**value**	**value**	**value**	**value**	**value**	**value**
Total Energy (GER)	**PJ**	4	4	3	4	4	3	3	3	4
of which, electricity	*TWh*	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Water (process)*	mln m3	0	0	0	0	0	0	0	0	0
Waste, non-haz./ landfill*	kton	6	5	6	6	6	6	6	6	6
Waste, hazardous/ incinerated*	kton	1	0	1	1	1	1	1	1	1
Emissions (Air)										
Greenhouse Gases in GWP100	**mt CO2eq**	0	0	0	0	0	0	0	0	0
Acidifying agents (AP)	**kt SO2eq**	1	1	1	1	1	1	1	1	1
Volatile Org. Compounds (VOC)	**kt**	0	0	0	0	0	0	0	0	0
Persistent Org. Pollutants (POP)	**g i-Tec**	0	0	0	0	0	0	0	0	0
Heavy Metals (HM)	**ton Ni eq**	0	0	0	0	0	0	0	0	0
PAHs	**ton Ni eq**	0	0	0	0	0	0	0	0	0
Particulate Matter (PM, dust)	**kt**	0	0	0	0	0	0	0	0	0
Emissions (Water)										
Heavy Metals (HM)	**ton Hg/20**	0	0	0	0	0	0	0	0	0
Eutrophication (EP)	**kt PO4**	0	0	0	0	0	0	0	0	0

Table 29 - Summary Environmental Impacts EU Stock 2005 - Total VCs

Total VCs		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base Case
main life cycle indicators	**units**	**value**	**value**	**value**	**value**	**value**	**value**	**value**	**value**	**value**
Total Energy (GER)	**PJ**	381	376	289	342	360	359	377	308	396
of which, electricity	*TWh*	33	33	23	28	30	30	31	25	33
Water (process)*	mln m3	35	35	29	33	34	34	35	30	36
Waste, non-haz./ landfill*	kton	823	717	868	931	951	950	972	891	993
Waste, hazardous/ incinerated*	kton	65	48	85	86	86	86	87	85	87
Emissions (Air)										
Greenhouse Gases in GWP100	**mt CO2eq**	17	17	13	16	16	16	17	14	18
Acidifying agents (AP)	**kt SO2eq**	99	97	76	89	94	94	98	81	103

Volatile Org. Compounds (VOC)	**kt**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Persistent Org. Pollutants (POP)	**g i-Tec**	**4**	**3**	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Heavy Metals (HM)	**ton Ni eq**	**11**	**10**	**12**	**13**	**13**	**13**	**13**	**12**	**14**
PAHs	**ton Ni eq**	**2**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Particulate Matter (PM, dust)	**kt**	**26**	**28**	**36**	**37**	**37**	**37**	**37**	**37**	**37**
Emissions (Water)										
Heavy Metals (HM)	**ton Hg/20**	**5**	**4**	**5**	**6**	**6**	**6**	**6**	**6**	**6**
Eutrophication (EP)	**kt PO4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

7.4 Costs

An estimate of price increases due to implementation of the various design options was made by consideration of production costs and applying with appropriate margins typically expected. The life cycle costs for each vacuum cleaner type was then evaluated using the eco-report model. The results are presented in the following tables.

Table 30 - Life Cycle Costs (Euro) per Product - Domestic Canisters

		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base Case
Product price		121	110	111	110	110	110	110	110	110
Installation/ acquisition costs (if any)		0	0	0	0	0	0	0	0	0
Fuel (gas, oil, wood)		0	0	0	0	0	0	0	0	0
Electricity		125	91	61	76	81	81	86	66	91
Bags		71	52	52	52	52	52	52	52	52
Filters		3	2	4	2	2	4	2	2	2
Repair & maintenance costs		37	8	8	8	8	8	8	8	8
Total:		**357**	**263**	**235**	**248**	**253**	**254**	**258**	**238**	**263**

Table 31 - Life Cyle Costs (Euro) per Product - Commercial Canisters

		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base Case
Product price		275	250	251	250	250	250	250	250	250
Installation/ acquisition costs (if any)		0	0	0	0	0	0	0	0	0
Fuel (gas, oil, wood)		0	0	0	0	0	0	0	0	0
Electricity		274	200	182	189	191	182	182	182	200
Bags		213	155	155	155	155	155	155	155	155
Filters		3	2	3	2	2	3	2	2	2
Repair & maintenance costs		74	40	40	40	40	40	40	40	40
Total:		**838**	**647**	**631**	**637**	**639**	**630**	**629**	**630**	**647**

Table 32 - Life Cycle Costs (Euro) per Product - Domestic Uprights

		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base Case
Product price		121	110	111	110	110	110	110	110	110
Installation/ acquisition costs (if any)		0	0	0	0	0	0	0	0	0
Fuel (gas, oil, wood)		0	0	0	0	0	0	0	0	0

Electricity		125	91	61	76	81	81	86	66	91
Bags		71	52	52	52	52	52	52	52	52
Filters		3	2	3	2	2	3	2	2	2
Repair & maintenance costs		7	8	8	8	8	8	8	8	8
Total:		**327**	**263**	**234**	**248**	**253**	**254**	**258**	**238**	**263**

Table 33 - Life Cycle Costs (Euro) per Product - Commercial Uprights

		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base case
Product price		275	250	251	250	250	250	250	250	250
Installation/ acquisition costs (if any)		0	0	0	0	0	0	0	0	0
Fuel (gas, oil, wood)		0	0	0	0	0	0	0	0	0
Electricity		274	200	182	189	191	182	182	182	200
Bags		213	155	155	155	155	155	155	155	155
Filters		3	3	3	2	2	3	2	2	2
Repair & maintenance costs		74	40	40	40	40	40	40	40	40
		838	**649**	**631**	**637**	**639**	**630**	**629**	**630**	**647**

7.4.1 Costs to Manufacturers

It should be noted that, with the exception of Option 8 (extending product lifetimes), most of the additional costs of implementation were very small in comparison to the overall product price per unit, resulting in minimal effect on the product price per unit.

7.4.2 Costs to Users

The costs to users are reflected in the consumption of electricity, vacuum cleaner bags and replacement filters and the amount of repair and maintenance required during the lifetime of the product. The total annual consumer expenditure in the EU calculated by the eco-report shows that the purchase price of the product is only a fraction of the total annual consumer spend. The tables below present to results for these.

Table 34 - Total Annual Consumer Expenditure (MEuro) - Domestic Canisters

		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base Case
Product price		2874	4020	4047	4025	4031	4020	4020	4031	4020
Installation/ acquisition costs (if any)		0	0	0	0	0	0	0	0	0
Fuel (gas, oil, wood)		0	0	0	0	0	0	0	0	0
Electricity		3847	3847	2565	3206	3419	3419	3645	2798	3847
Bags		2189	2189	2189	2189	2189	2189	2189	2189	2189
Filters		96	96	150	96	96	150	96	96	96
Repair & maintenance costs		1140	342	342	342	342	342	342	342	342
Total:		**10146**	**10494**	**9293**	**9858**	**10076**	**10120**	**10291**	**9456**	**10494**

Table 35 - Total Annual Consumer Expenditure (MEuro) - Commercial Canisters

		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base Case
Product price		195	276	277	276	277	276	276	277	276

Installation/ acquisition costs (if any)		0	0	0	0	0	0	0	0	0
Fuel (gas, oil, wood)		0	0	0	0	0	0	0	0	0
Electricity		273	273	249	259	261	249	249	249	273
Bags		212	212	212	212	212	212	212	212	212
Filters		3	3	4	3	3	4	3	3	3
Repair & maintenance costs		74	55	55	55	55	55	55	55	55
Total:		**757**	**820**	**797**	**805**	**808**	**796**	**795**	**795**	**820**

Table 36 - Total Annual Consumer Expenditure (MEuro) - Domestic Uprights

		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base Case
Product price		528	709	714	710	711	709	709	711	709
Installation/ acquisition costs (if any)		0	0	0	0	0	0	0	0	0
Fuel (gas, oil, wood)		0	0	0	0	0	0	0	0	0
Electricity		679	679	453	566	603	603	643	494	679
Bags		386	386	386	386	386	386	386	386	386
Filters		14	14	23	14	14	23	14	14	14
Repair & maintenance costs		40	60	60	60	60	60	60	60	60
Total:		**1647**	**1849**	**1636**	**1737**	**1776**	**1782**	**1814**	**1666**	**1849**

Table 37 - Total Annual Consumer Expenditure (MEuro) - Commercial Uprights

		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base case
Product price		54	49	49	49	49	49	49	49	49
Installation/ acquisition costs (if any)		0	0	0	0	0	0	0	0	0
Fuel (gas, oil, wood)		0	0	0	0	0	0	0	0	0
Electricity		48	48	44	46	46	44	44	44	48
Bags		37	37	37	37	37	37	37	37	37
Filters		0	1	1	0	0	1	0	0	0
Repair & maintenance costs		13	10	10	10	10	10	10	10	10
		153	**145**	**141**	**142**	**143**	**141**	**140**	**140**	**145**

Table 38 - Total Annual Consumer Expenditure (MEuro) - Total VCs

		Option 8	Option 7	Option 6	Option 5	Option 4	Option 3	Option 2	Option 1	Base Case
Product price		**3650**	**5054**	**5087**	**5061**	**5067**	**5054**	**5054**	**5067**	**5054**
Installation/ acquisition costs (if any)		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fuel (gas, oil, wood)		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Electricity		**4848**	**4848**	**3310**	**4076**	**4330**	**4315**	**4581**	**3585**	**4848**
Bags		**2825**	**2825**	**2825**	**2825**	**2825**	**2825**	**2825**	**2825**	**2825**
Filters		**113**	**114**	**178**	**113**	**113**	**178**	**113**	**113**	**113**
Repair & maintenance costs		**1267**	**467**	**467**	**467**	**467**	**467**	**467**	**467**	**467**
		0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total:		**12703**	**13308**	**11867**	**12542**	**12802**	**12839**	**13040**	**12057**	**13308**

7.5 Analysis LLCC and BAT

7.5.1 Methodology

Our analysis of options has been informed by the feedback obtained from our 3rd questionnaire on improvement potential. The responses to our questionnaire have been summarised in Table 39. These responses indicate the consensus viewpoint of manufacturers on the possible positive or negative effects of individual design options.

Note: the options listed in Table 39 under 'reduction of input power' would be achievable through implementation of options 1, 2, 3, 4, or 5.

The outputs from the eco-report for LLC and total energy for commercial and domestic canisters and uprights are presented in the tables and figures following Table 39. Option 6 indicates the accumulative effect of implementing options 1 to 5. Note: option 6 would be the favoured option because vacuum cleaner engineers would seek to optimise motor/fan efficiency, airways, filtration, seals and nozzles for best overall improvement as a matter of course.

Note also: the energy savings are calculated with respect to a base case average input power rating. The fact that many modern vacuum cleaners on the market are well above this average means that the potential energy savings would be larger than these calculations in reality.

Option 7 (lightweighting) and option 8 (extended lifetime) are mutually opposing in respect to materials usage. Implementation of these two options in combination would be difficult to achieve because the effect of materials reduction (lightweighting) would be counteracted by the need for more materials for strengthening the vacuum cleaner for extended lifetime.

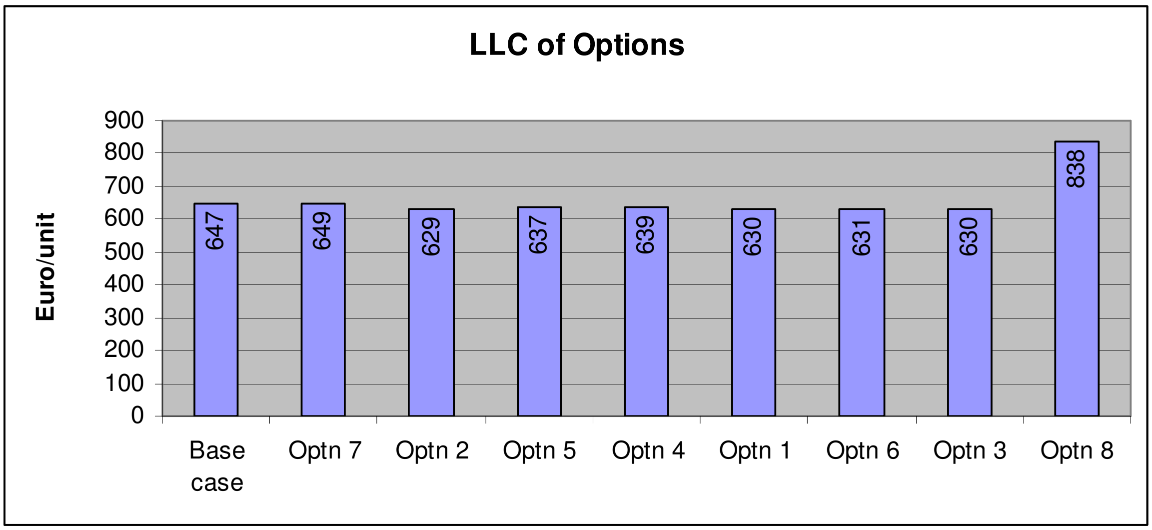
Thus the LLCC point would be reached at option 6 and BAT would be represented by a combination of option 6 and option 7.

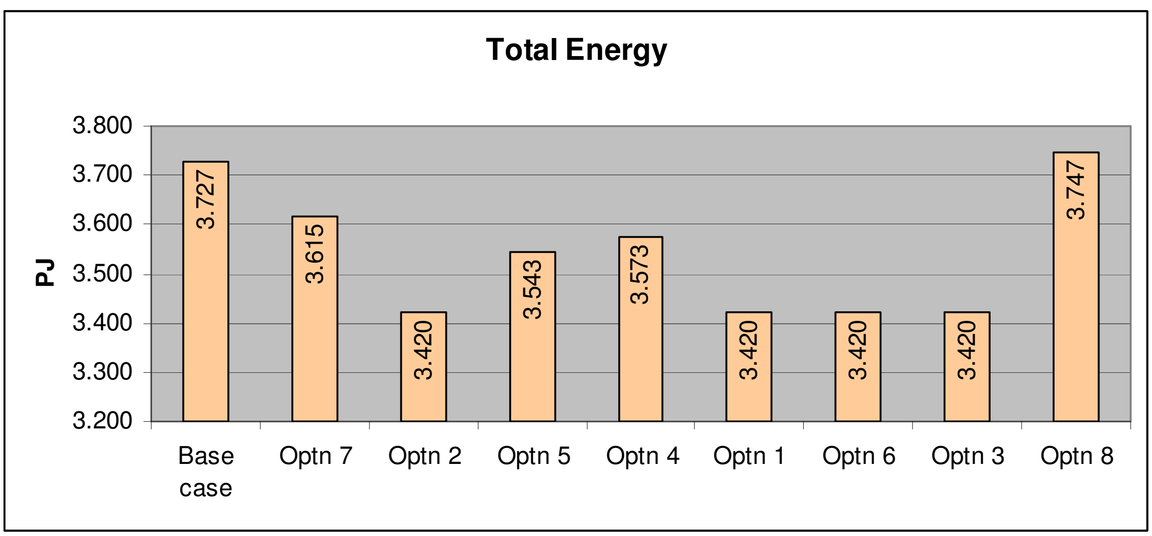
Table 39 - Potential Vacuum Cleaner Improvements - Compiled from Questionnaire

Potential Vacuum Cleaner Improvements.	Application to the Market (%)	BAT	Env impact	Cost to Manufacturers	Cost to Consumers	BNAT	Env impact	Cost to Manufacturers	Cost to Consumers	Base Case
Reduction in input **power uprights (500W)**	20%	✓	Energy saving in use	Saving						1500W
Reduction in input power cylinders with **power nozzles (650W)**	?		Energy saving in use	Saving						?
Reduction in input power **suction only (750W)**	70%		Energy saving in use	Saving						1500W
Reduction in input power **commercial (1000W)**	5%		Energy saving in use	Saving						1100W, Uprights & Canisters
Improve filtration to give zero emissions at, say, 0.3 micron particle size	100%	✓	Reduced dust circulation, Product life reduced (5%)	Plus €4						None
zero transfer of contained dirt to environment	?					Systems currently under development	Materials +10%			None
Self emptying systems	?					Emptying/dust handling not developed	Materials +20%	Plus >25%		None
Improve attention to dealing with allergens	?					Systems incorporating UV, silver iodide?	Complicated	Plus >25%		None
Specialist attachments using power outlet	?	✓	Plus 15% materials	Plus >€10		Depends on application	No details to assess			None
Full performance cordless vacuum cleaners	5%					Better power packs	Negative	Plus >25%		6-15 minutes use time per charge
Sweeping only function for light surface cleaning	30%	✓	Neutral	Neutral						None
Integrated systems with sweeping and vacuum cleaning alternated	?	✓	Neutral	Neutral						None
Self emptying robot vacuum cleaners	5%					Emptying/dust handling not developed	Materials +20%	Plus >25%		None
Reduce Noise levels.	100%	✓	Neutral	Neutral						?
Reduce overall weight	100%	✓	Less materials (5%)	Saving						10-11kg Commercial VCs, 7.5-8.5kg Domestic VCs
Increase useful life of vacuum cleaner by at least 50%.	100%	✓	Less materials (25%)	Plus >25%						8 years (500 hours domestic, 1500 hours commercial)
Apply eco-design design principles to facilitate dismantling	100%	✓	Neutral	Neutral						None
Minimise the number of dissimilar plastics used	100%	✓	Benefits in waste stream	Neutral						5 to 12 different polymer types used

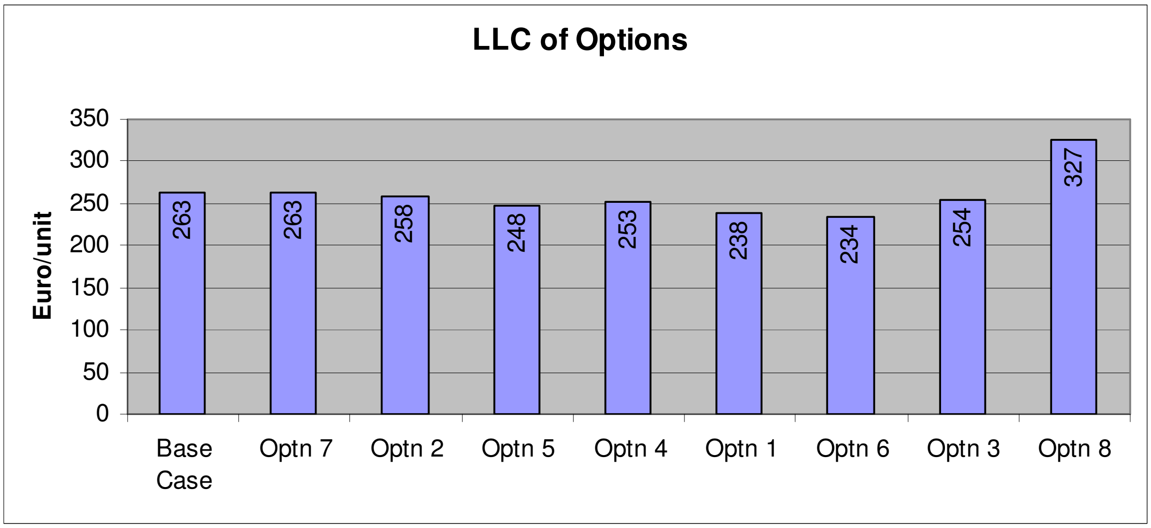
(note: Neutral cost assumes changes are incorporated in the normal design cycle)

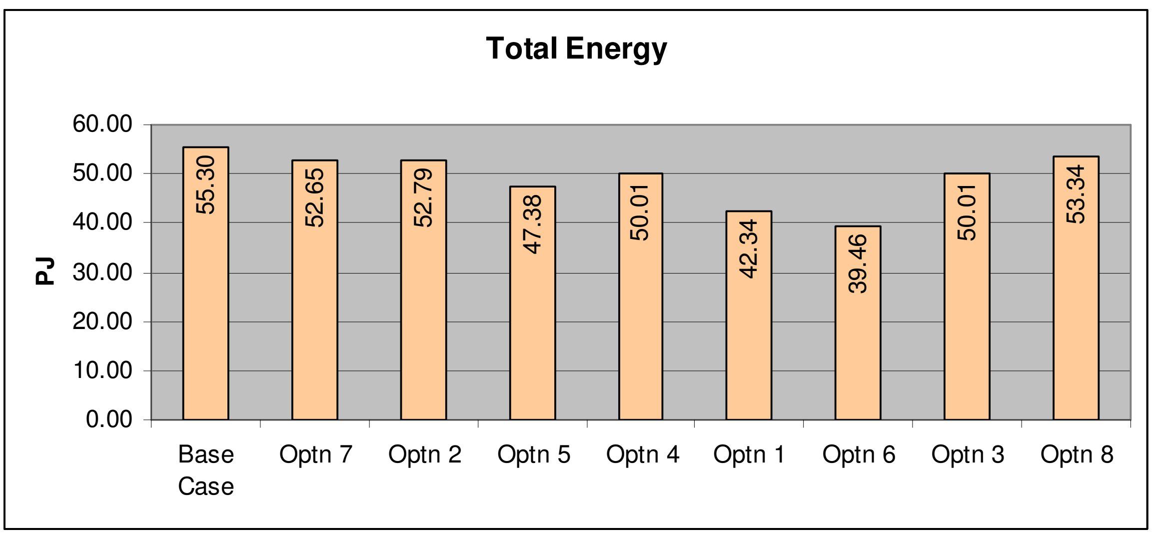
Upright Commercial		Base case	Optn 7	Optn 2	Optn 5	Optn 4	Optn 1	Optn 6	Optn 3	Optn 8
main life cycle indicators	units	value	value	value	value	value	value	value	value	value
Total Energy (GER)	PJ	3.727	3.615	3.420	3.543	3.573	3.420	3.420	3.420	3.747
Total:	LLC/unit (Eur)	647	649	629	637	639	630	631	630	838
Total:	Tot Consumer (Meuro	145	145	140	142	143	140	141	141	153



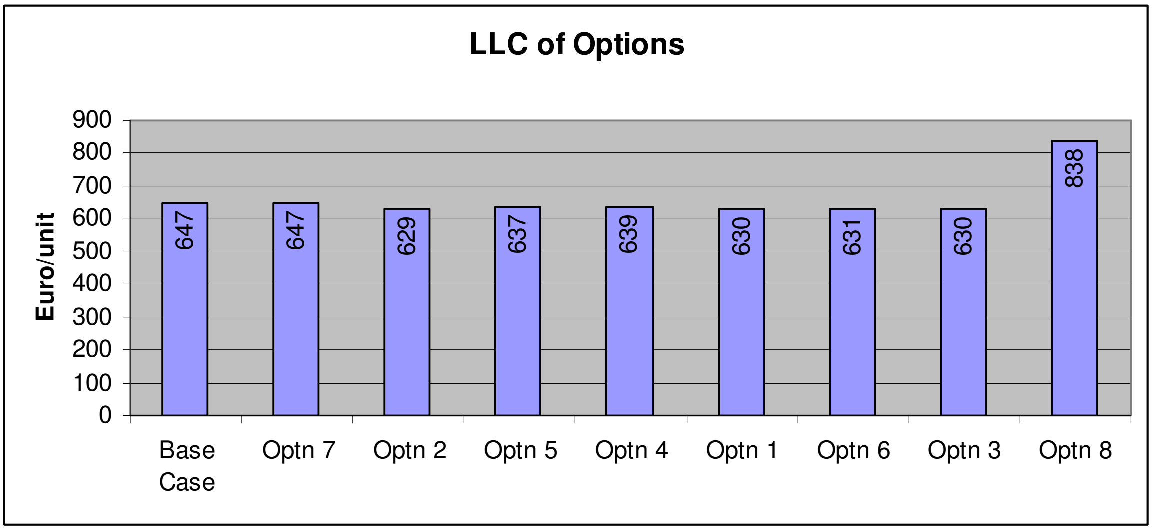


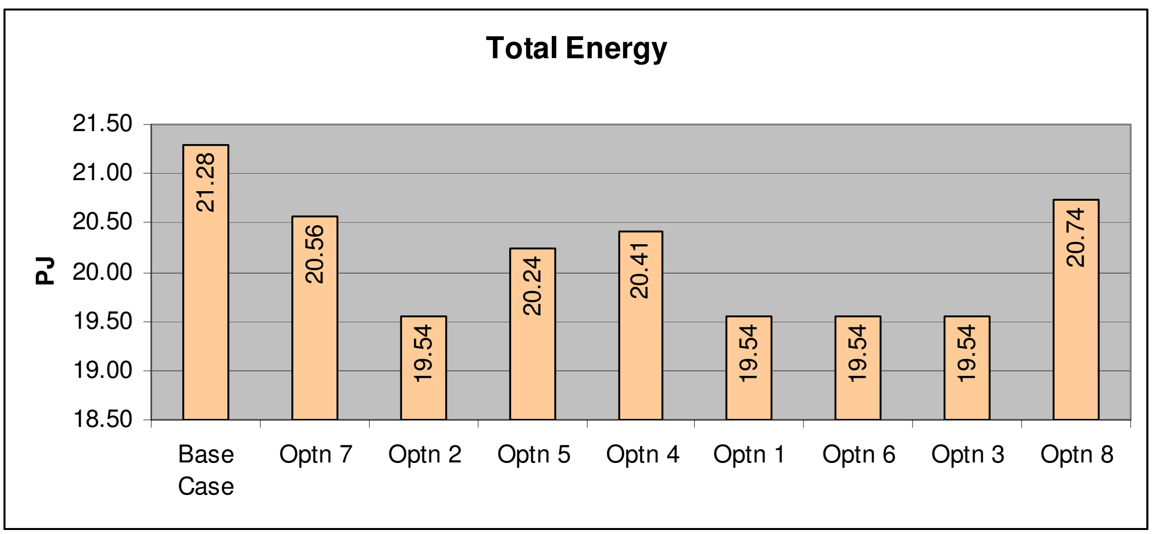
Upright Domestic		Base Case	Optn 7	Optn 2	Optn 5	Optn 4	Optn 1	Optn 6	Optn 3	Optn 8
main life cycle indicators	units	value	value	value	value	value	value	value	value	value
Total Energy (GER)	PJ	55.30	52.65	52.79	47.38	50.01	42.34	39.46	50.01	53.34
Total:	LLC/unit (Eur)	263	263	258	248	253	238	234	254	327
Total:	Tot Consumer (Meuro	1849	1849	1814	1737	1776	1666	1636	1782	1647



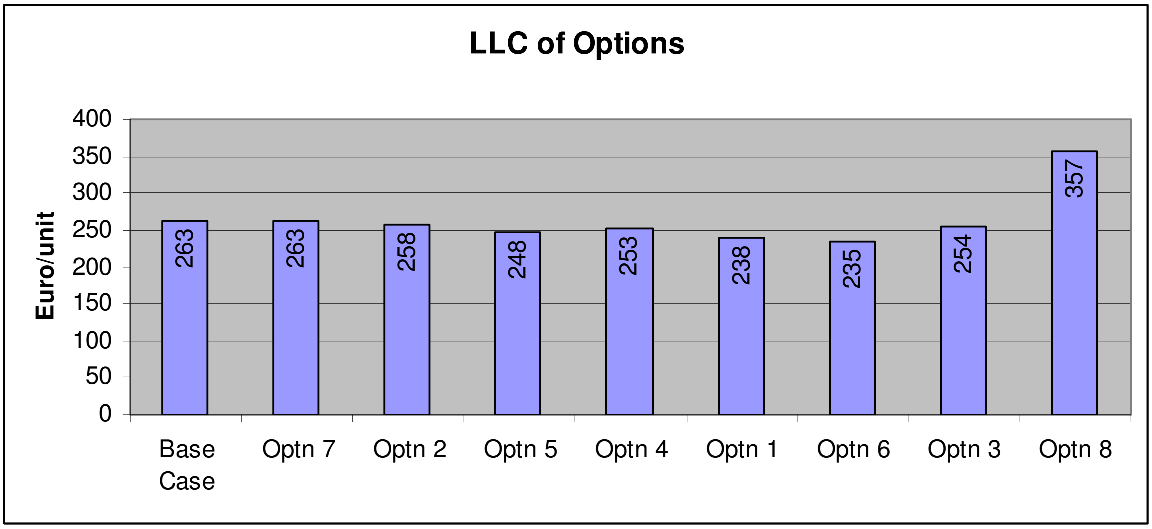


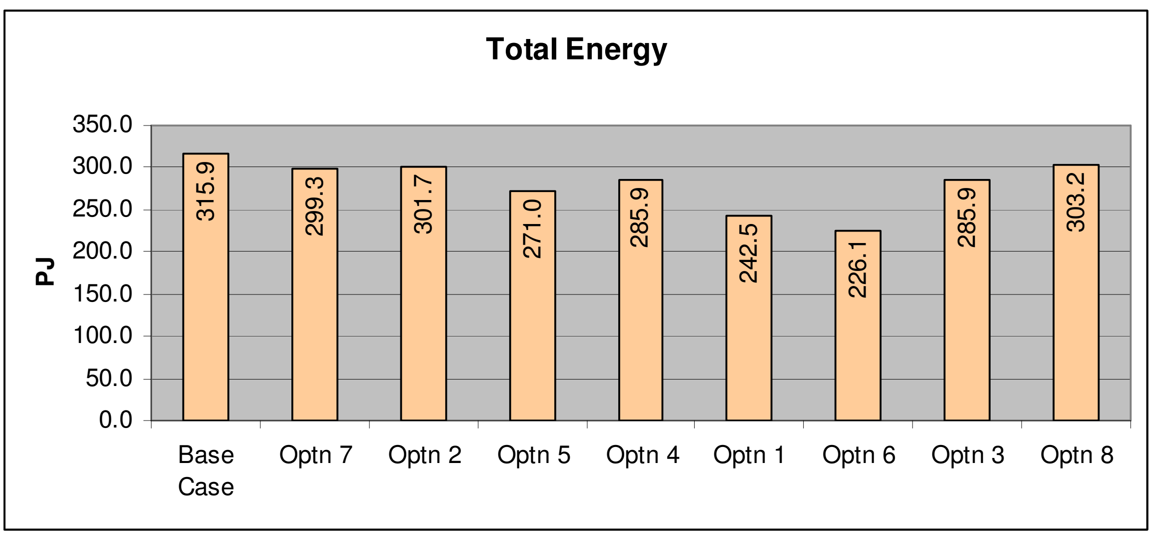
Canister Commercial		Base Case	Optn 7	Optn 2	Optn 5	Optn 4	Optn 1	Optn 6	Optn 3	Optn 8
main life cycle indicators	units	value	value	value	value	value	value	value	value	value
Total Energy (GER)	PJ	21.28	20.56	19.54	20.24	20.41	19.54	19.54	19.54	20.74
Total:	LLC/unit (Eur)	647	647	629	637	639	630	631	630	838
Total:	Tot Consumer (Meuro	820	820	795	805	808	795	797	796	757



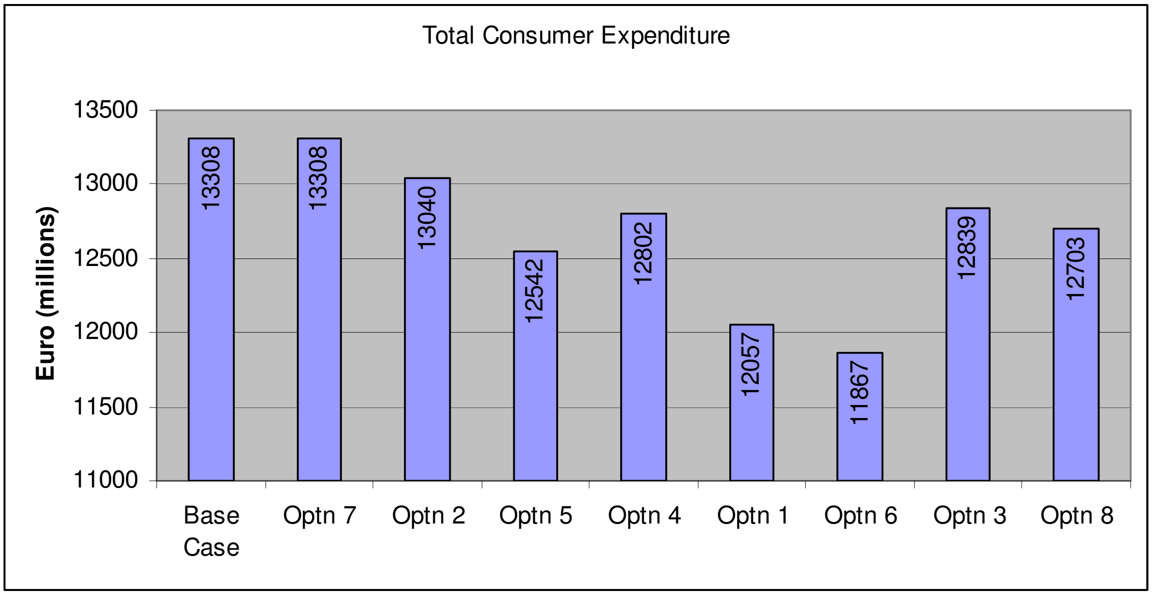


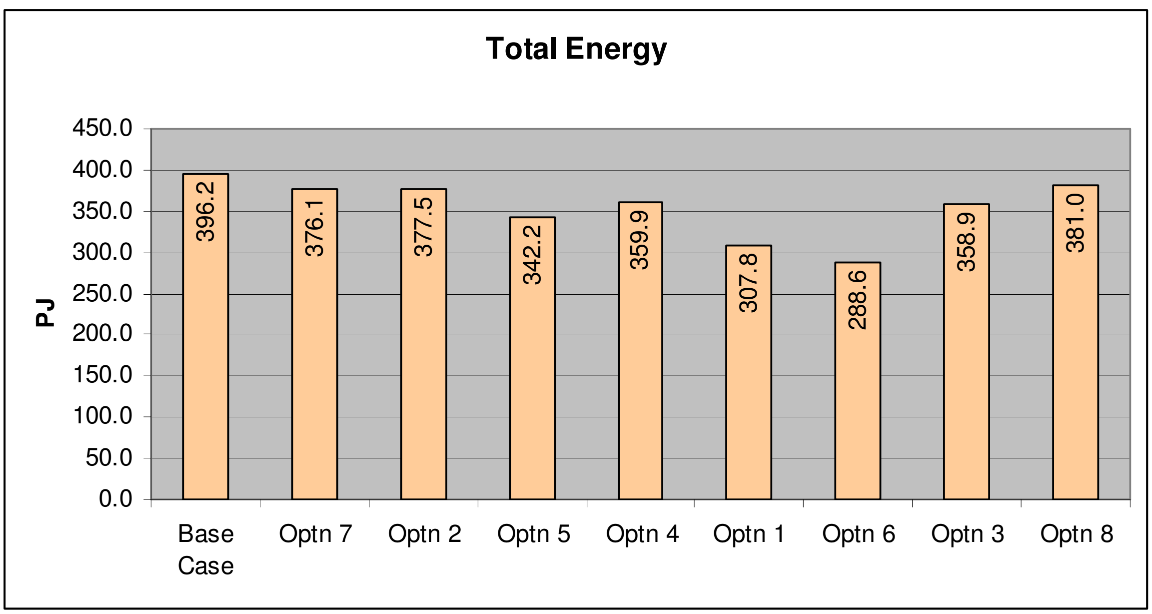
Canister Domestic		Base Case	Optn 7	Optn 2	Optn 5	Optn 4	Optn 1	Optn 6	Optn 3	Optn 8
main life cycle indicators	units	value	value	value	value	value	value	value	value	value
Total Energy (GER)	PJ	315.9	299.3	301.7	271.0	285.9	242.5	226.1	285.9	303.2
Total:	LLC/unit (Eur)	263	263	258	248	253	238	235	254	357
Total:	Tot Consumer (Meuro	10494	10494	10291	9858	10076	9456	9293	10120	10146





Total VCs		Base Case	Optn 7	Optn 2	Optn 5	Optn 4	Optn 1	Optn 6	Optn 3	Optn 8
main life cycle indicators	units	value	value	value	value	value	value	value	value	value
Total Energy (GER)	PJ	396.2	376.1	377.5	342.2	359.9	307.8	288.6	358.9	381.0
Total:	LLC/unit (Eur)	1820	1821	1774	1769	1783	1736	1731	1768	2360
Total:	Tot Consumer (Meuro	13308	13308	13040	12542	12802	12057	11867	12839	12703





7.6 Long Term Targets (BNAT) and Systems Analysis

7.6.1 Forthcoming product Developments

Due to the commercially sensitive nature of research and development, it is difficult to persuade manufacturers to disclose those developments that they have in the pipeline for introduction in the coming two or three years. The following is an educated assessment of likely new product developments.

1. Cordless vacuum cleaners, which clean floors as well as current mains operated products and which have sufficient battery life to clean an average home on a single charge are under development. Initially, a cordless upright vacuum cleaner has already reached the prototype stage. Such products will consume lower energy than currently marketed vacuum cleaners, typically 250 watts at 24 volts. Vacuum cleaners that rely on suction only (i.e. those with passive nozzles) require more energy to produce sufficient cleaning performance, typically requiring between 500 watts and 650 watts. These vacuum cleaners will require further development in battery technology before becoming readily available as full performance cordless vacuum cleaners. This category of product is already in the prototype stage and it is likely that such a product will become available within 3 years.

2. Improved performance robotic vacuum cleaners. It is highly likely that such products are already in the prototype developments stage and will be available to market within 3 years. These new products will clean better than those already on the market and will provide more even coverage over a given area – they will be better at taking obstacles in to account. However, they will not be capable of self cleaning stairs. Further development will allow such performance but not for around 5 years at least. The products will all be self charging, i.e. they will find their own way back to a base charger when their charge runs low. They will have longer run times between recharge cycles. They will remember room layouts. They will also become self emptying, thus reducing harmful dust and allergen emissions. Generally the robot vacuum cleaner will use less energy to clean a given area but may not clean as well as current fixed wire mains vacuum cleaners. However energy savings and time savings are possible by using the robot to perform surface cleaning to such an extent that deeper cleaning may only be required half as often or even less. With the development of “smart homes”, it will be possible to program a complete cleaning pattern over a longer period and there need be no human intervention, other than to ensure that doors are open. The following generation of robot vacuum cleaners will have improved cleaning performance but will still use less energy to perform their task.

3. Lighter weight vacuum cleaners are under development. One manufacturer has already demonstrated this with their “ShockAbsorber” model. Another manufacturer has confirmed that they are working on foamed plastic mouldings (Note: this may now be considered to be BAT, rather than BNAT). However, other manufacturers have concerns that lighter weight may not be deliverable at the same time as increased durability.

4. Vacuum cleaners with lower input power are under current development. This development will begin the process of putting pressure on manufacturers to “go green” and this would be accentuated by the introduction of energy labelling. It is likely that many models of vacuum cleaners from leading European manufacturers, with maximum input power of around 1500 watts, will be available to market over the coming 18 months to two years. Anticipated forthcoming mandatory energy labelling of vacuum cleaners is already driving this downward trend. Further input power reductions will require a change of marketing strategy by manufacturers.

5. Improved filtration techniques are under development using the higher grades of HEPA filter media (up to HEPA13). Better sealing of filters into the vacuum cleaner system are being prototyped. Initially, the move to such high levels of filtration has required higher input power but developments which effectively increase the area of filtration would reduce this requirement. New test methods are being developed which could measure particle sizes down to 0.1 micron which may well increase the pressure to use only the highest grade filter media. However, it is questionable whether this further level of improvement is worthwhile given that, in the ordinary room context, dust which is disturbed into the atmosphere during the cleaning process may well negate the benefits.

6. Dust receptacles with lower emissions when emptying are being tested. New test methods (IEC and ASTM) to measure emissions whilst emptying will be one of the drivers towards this trend. The environmental issue here is that currently the manual dust transfer can result in a significant amount of dust being lost back into the atmosphere.

7.6.2 Consumer behaviour

It is not certain that the use of robots will lead to lower energy consumption overall. However, one manufacturer has indicated that the use of cordless stick cleaners does encourage this since they are used for spot cleaning, thereby potentially resulting in less full cleaning being undertaken with the corded main cleaner and thus an overall reduction in energy consumed.

8 Task 8 - Scenario, Policy, Impact and Sensitivity Analysis

8.1 Introduction

This task looks at suitable policy means to achieve the potential improvements e.g. implementing LLCC as a minimum and BAT as a promotional target, using legislative or voluntary agreements, labelling and promotion. It draws up scenarios current to 2020 quantifying the improvements that can be achieved vs. a Business-as-Usual (BAU) scenario and compares the outcomes with EU environmental targets.

It makes an estimate of the impact on consumers (purchasing power, societal costs) and industry (employment, profitability, competitiveness, investment level etc.) as described in Annex II of the Directive, explicitly describing and taking into account the typical design cycle (platform change) in this product sector. Finally, in a sensitivity analysis of the main parameters, it examines the robustness of the outcome.

8.2 Policy and Scenario Analysis

8.2.1 Efficiency of Vacuum Cleaners

The efficiency with which current vacuum cleaners convert electricity into suction power has not improved since the 1970s. If anything, efficiency levels are worse. The reasons for this mainly revolve around the use of input power rating as a marketing tool which has led to the myth that “the higher the input power: the better the cleaning performance” in the minds of the consumer. Figure 4 below shows the results of an analysis of one retailer’s range of vacuum cleaners[55] currently on sale. Quoted suction power is plotted against quoted input power rating.

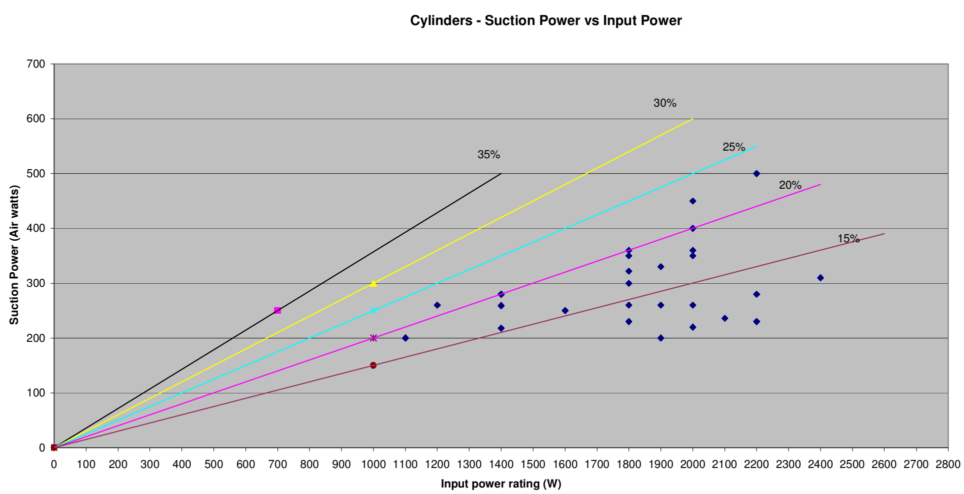


Figure 4 – Variation in Efficiency of Current Vacuum Cleaners

The figure above shows the example for cylinder vacuum cleaners (a similar graph is also obtained for upright vacuum cleaners). The coloured lines represent the percentage energy efficiency thresholds

[55] www.dixons.co.uk

for a given input power rating. Clearly, all of the appliances exhibit energy efficiencies less than 25%. Indeed, a large proportion of models exhibit energy efficiencies of less than 15%. Given, that vacuum cleaners with energy efficiencies of 30-35% were marketed in the 1970s, then the move towards higher and higher input power ratings appears to have had a detrimental effect on energy efficiency.

8.2.2 Energy Labelling

There is a case for an energy label as a mechanism for aiding consumer choice by differentiating products and also for identifying and thus facilitating the removal of the worst performing products e.g. as has successfully been done for domestic refrigerators. We would suggest that any removal of the less efficient products is phased over time. There are a number of options for the basis upon which an energy label could be founded with pros and cons for each.

The vacuum cleaner manufacturers, through their Working Group 6 of CENELEC TC 59X have proposed the following option. This uses a methodology for defining energy efficiency in combination with cleaning performance:

1. Establish the curve [Number of strokes against dust pick up (dpu)] from a reference cleaner.
2. Establish the dpu at 5 strokes (x% dpu)
3. If a "test" cleaner reaches y%% dpu at 5 strokes, use the ratio test vac./ref vac. for calculating the dpu at 1,2,3,5 and 9 strokes etc.
4. With the curves derived from the reference cleaner, the amount of strokes needed to reach the ref. level can be defined and with that, the energy needed to do those strokes is easily calculated. A curve fitting program. using an exponential function, follows a Weibull function.

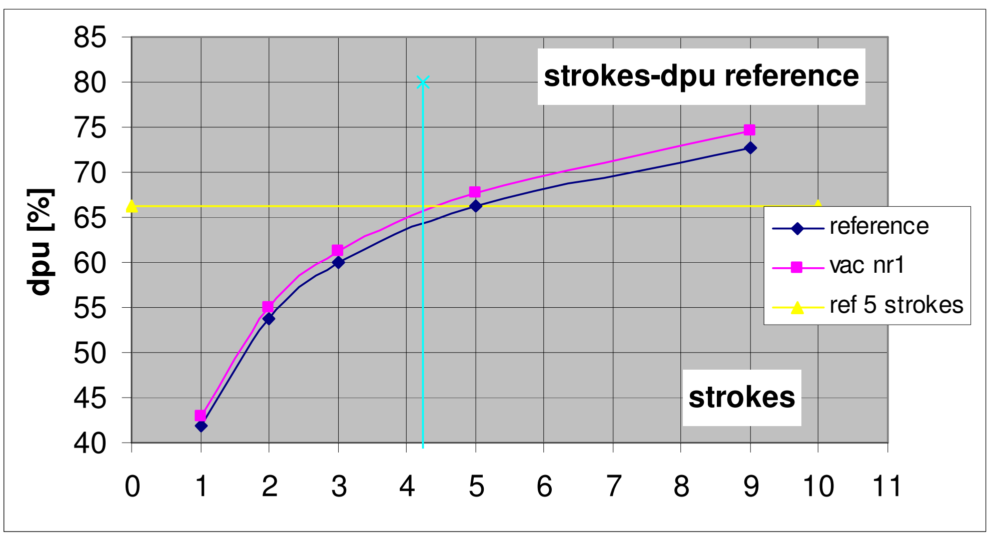


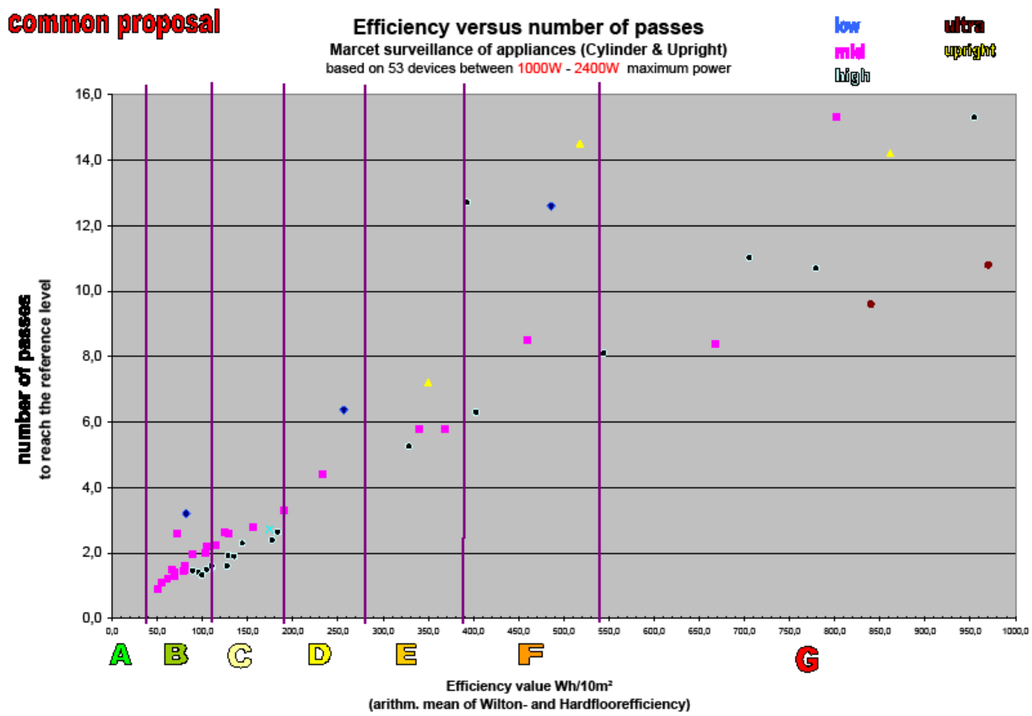
Figure 5 - Curve Fitting Comparison (Example)

5. In Figure 5 the results of this "translation" can be seen.

Note: Some values could not be calculated because the curve fitting program yielded infinite stroke numbers. For this case, estimation is used. In addition, the new data are the result of an estimation/assumption and should be interpreted with care.

Thus, the number of stokes required to reach a reference level of dust pick up can be calculated and compared against Wh/10m^2 (the energy consumed to clean a fixed area to reference level of dust pick up. The CECED group have proposed a possible energy label grading on the basis of this comparison (see Figure 6 below).

Figure 6 - CECED Energy Label - Draft Proposals



Over the course of time, as lower rated vacuum cleaners are removed from the market, vacuum cleaners will tend towards B and C-ratings. Further room for improvement could be promoted by revisions to the label with regard to the percentage dust pick up reference level (say increasing from 65% to 80%).

8.2.3 Input Power Capping

The key criticism of an energy label based on the CECED proposals is that it does not take into account consumer behaviour. The notion that a consumer will employ fewer strokes with an efficient vacuum cleaner will be difficult to realise without the need for a very lengthy consumer awareness campaign. In reality, a consumer is more likely to devote a certain amount of time every week to do the vacuuming. Typically, this is around about one hour per week, and the consumer is unlikely to break from this routine. Thus, the amount of electricity consumed is still dependent on the time spent vacuuming. In Figure 6 above, there are 'B' rated vacuum cleaners which have high input power ratings to achieve reference level dust pick up in 1 or 2 strokes. If the consumer continues to use these at one hour per week, then the energy consumed remains high, and more importantly, energy savings cannot be achieved. In addition to this scenario it is not certain that consumers would only purchase vacuum cleaners with high ratings if products with lower ratings and higher energy usage are available at significantly lower purchase prices.

In order to avoid this situation, a cap on input power is needed. Such a cap could be used in combination with the Energy Label proposed by CECED. The case for limiting input power whilst maintaining cleaning performance is achievable through the design improvement options described in Task 7. These options do not involve fundamental research. The rationale for implementing them is supported by calculated EU25 energy savings and life cycle costs (see Task 7).

Uprights used exclusively for cleaning flooring surfaces need a lower cap than straight suction cleaners because they need less energy to do their job. Whilst suction only cleaners are good at other things, which may well require more energy.

Care is needed regarding commercial VCs: with regard to:

a) The need to avoid leaving a loop hole that can be exploited by domestic VCs, and

b) The need to treat these separately from domestic VCs.

8.2.3.1 Clarification of Definition of Commercial Vacuum Cleaners

Comments received from commercial vacuum cleaner representatives (EUnited Cleaning) following the last stakeholder meeting on 19th of January are as follows:

- The distinction for commercial vacuum cleaners between one and two motors makes sense but it has to be clarified that only suction motors are meant (i.e. a vac with one suction motor and one additional motor for an active brush is not considered as an appliance with two motors).
- A clarification is needed that commercial upright vacuum cleaners are covered by the item "commercial VCs" instead of "upright VCs (household)"; they should be considered as a normal business-to-business (B2B) VC even with regard to the number of suction motors (see above).
- For the distinction of B2B and business-to-consumer (B2C) appliances, the declaration of conformity may be sufficient: B2C products are covered by the Low Voltage Directive (LVD), while commercial VCs are falling under the new Machinery Directive (MD); since safety requirements are more restrictive under the new MD, this distinction will avoid a legal loophole for manufacturers of B2C products due to higher production costs. A new safety standard for commercial VCs taking into account the new MD requirements was published in December 2008 and will come into effect in December 2009.

We do have to make clear that our intention for multi-motor commercial VCs is referring to the motor fan unit and NOT an active brush motor as this is the actual intent. Otherwise, we would have many domestic cleaners with twin motors as they often use a separate motor to drive the agitator. Thus we agree with the above

8.2.3.2 Capping Proposals

CECED/manufacturers have indicated a preference for a 2-stage rather than 3-stage capping, because this would allow 3 years between targets, which is more in line with the design cycle period.

We are convinced that capping of input power[56] levels is the right thing to do. The levels should be truly adequate for ensuring good cleaning performance and could be achieved through changes to motor/fan efficiencies as well as improvements to airways and nozzle designs. From discussion with several vacuum cleaner engineers, it is clear that the level of overall energy conversion efficiencies experienced today is low - 25% is typical. (For example, a 2000 watt vacuum cleaner is equivalent to a 1500 watt fan heater in waste heat produced). There is great potential to eliminate this waste of energy. High input wattages create no incentive to reduce power, as it is so easy to generate sufficient suction power without worrying about efficiency. It is worth pointing out that there are a great number of low-cost imported vacuum cleaners that can easily generate the necessary power to provide adequate cleaning performance. These figure highly in sales volumes and have in themselves been drivers of increased sales volumes of vacuum cleaners over the past 20 years. In the 1970s, vacuum cleaners with overall efficiency levels of 30 - 40% and lower input wattages were available. Thus, even with 30 year old technology, a 700 watt vacuum cleaner would produce around 250 watts of suction power, which is perfectly adequate when used in conjunction with efficient airways and good nozzle design to produce good cleaning performance. (In contrast, a 2000 watt input modern vacuum cleaner at 25% efficiency will produce 500 watts of suction power and the nozzle must be modified to "leak" airflow in order for it not to "stick" to the surface and become difficult to push).

Table 40 - Proposed Caps for Input Power Ratings of Vacuum Cleaners

	2011	2014
Uprights without integral hose and cleaning tools	750 watts	500 watts

[56] Use of the term 'input power' refers to 'nominal input power' as defined in EN60335

	2011	2014
Canister cleaners and uprights with integral hose and tools	1100 watts	750 watts
Commercial Vacuum cleaners with single motor	1200 watts	1000 watts
Commercial Vacuum cleaners with dual motor	1500 watts	1250 watts

Ideally, it is necessary to end up with a situation that will save energy but **not** at the expense of reducing current levels of cleaning performance. We would have, therefore, an integrated energy and performance label situation that will give the purchasers a single indication of better or worse cleaning and energy efficiency, clearly an "A" rating would clean as well or better than a "D" rating - or would it? The "D" rating could well have a cleaning performance of 90% but an input power of 2500 watts, whereas the "A" could have cleaning performance of 65% but input power of 500 watts. Alternatively, it might be possible to have two "B" rated vacuum cleaners - one with input power of 2000 watts and reaches 65% in 2 strokes and the other of 500 watts but takes 8 strokes to reach 65%. If input power is capped at suitable levels, it takes away the ability to exploit energy input and the ratings would not allow excessive energy usage anyway. However the cleaning performance would be exposed for all to see.

For an energy label, both energy consumption and cleaning efficiency need to be considered. These could be combined (as proposed by CLC TC59X WG 6), but the better thing may be to keep them apart because of the reasons given in the previous paragraph. The label would also carry other information such as noise and dust emissions.

8.2.4 Test standards

8.2.4.1 Cleaning Performance

The IEC (EN) method for measuring cleaning efficiency on carpets has two serious flaws. The first is that it uses only a single carpet type (Wilton) and it is relatively easy to design the nozzle to produce good pick up levels on a single carpet type. In the past, although it was usual company policy to produce vacuum cleaners that cleaned well on all surfaces, there was always a specification that ensured that the vacuum cleaner could perform well on the Wilton carpet. This could be achieved, for example, by having one of the set nozzle height positions tuned to the Wilton carpet. The instruction manual would be written in such a way as to ensure that testers always selected this height setting when conducting an IEC (EN) test. We believe that this sort of tuning has been used by many manufacturers.

The second flaw has only come to light recently. This derives from the use of separate carpets for passive and active (with an agitator) nozzles. Each carpet is conditioned and maintained by the use of the appropriate type of nozzle. Hence a suction cleaner with passive nozzle is tested on a different carpet from that of an upright or a suction cleaner with an active nozzle. What has been discovered is that the "passive" carpet maintains a tighter pile through its life of testing whilst the "active" carpet develops a more open pile. During the embedding of the test dust, the dust is more deeply embedded on an "active" carpet due to the more "open" pile and hence is more difficult to remove than dust embedded on the "passive" carpet. This means that it is not possible to compare the results between active and passive nozzles as passive nozzle results tend to be "flattered" by the easier to remove embedded dust. This can be as much as 10 percentage points in extreme cases.

Note: in the next edition of the IEC 60312 standard, it is proposed that there will be a note to that effect - i.e. it is not possible to compare results between active and passive nozzles.

One solution to this flaw would be to use the same carpet for both but currently there is not sufficient consensus between European manufacturers to accept this. Another possibility would be to condition and maintain the carpets with an active nozzle on both types but again this has not been widely accepted. This highlights the need for updating test methods and is currently being evaluated by the IEC Working Group responsible.

Elsewhere, the ASTM International equivalent test method to measure cleaning efficiencies on carpet is ASTM F608. In this test method, 4 different types of carpet are used and each is tested. The geometric mean of all 4 results is then used as the value of cleaning effectiveness or efficiency. In order to get the best results the vacuum cleaner must be designed to clean well on all four types of carpet and in such a circumstance a good result on this test is almost certain to guarantee a good result in the home, whatever carpet type is used[57]. Both active and passive nozzles are tested on the same carpets so a true comparison can be made. On a note of interest, US vacuum cleaners are limited to 1400 watts input power by the current and voltage ratings of the US domestic electricity supply, and yet they achieve cleaning performances as good as or better than many European vacuum cleaners (even when tested at appropriate voltage (i.e. 230 volts for European cleaners and wattages in excess of 1400). Unfortunately, the results we have access to are private and confidential, which prevents publication in this report.

The Problem with Averages

The cleaning performance figures determined for the proposed energy label are an arithmetic average of measurements for carpet and hard floor with crevices, using EN 60312 tests. This may artificially boost the published value of performance levels in some cases. Since it is possible to achieve more than 100% with the crevices test an average of 80% is quite possible from separate performance levels of only 55% on carpets and boosted by say 105% on hard floor with crevice for example.

Note: our independent testing of a prototype 250 watt upright would attain 90.5% using this average score.

We believe that this poses a problem for a possible energy label where an average figure for cleaning performance on carpets and on hard floors with crevices is used.

In conclusion, there are various test methods adopting different approaches, the pros and cons of which have been described above. We conclude that the existing IEC/EN method for carpet cleaning performance measurement has serious drawbacks and we recommend that a different method is devised for the energy label and EuP that uses results based on multiple carpet types, as in ASTM F608[58], as well as a hard floor test but without averaging the results between carpets and hard floors.

8.2.5 Proposed or adopted EuP policy (“implementing”) measures

The following table presents our suggestions for EuP policy measures in comparison with those proposed as a result of other studies completed for other energy using products.

Policy measure	Standby	Battery chargers and external power supplies	Simple STBs	Street and office lighting*	TVs	Vacuum cleaners
Capped maximum power consumption	✓		✓		✓	✓
Time based further reductions in maximum power consumption	✓				✓	✓
Standby maximum power consumption	✓	✓	✓		✓	✓

[57] It is worth noting that because some carpet types are easier to clean than others, then it could be said that the carpet is part of the ‘system’. Therefore, there may be a case that carpets should be labelled.
[58] NOTE It is worth noting that IEC are proposing four carpet types for testing, independently however, in the next edition of IEC 60312 due in 2009/10

Policy measure	Standby	Battery chargers and external power supplies	Simple STBs	Street and office lighting*	TVs	Vacuum cleaners
(and/or off-mode)						
Average active efficiency		✓				
Time based further increases in average active efficiency		✓				
Minimum Lamp Efficacy				✓		
Maximum noise level						?
Energy labelling scheme					✓	✓
Additional label info: Cleaning performance - carpet						✓
Additional label info: Cleaning performance – hard floors						✓

* there are a number of other requirements not listed here

8.2.5.1 Noise

From an eco design point of view, reduced noise levels are beneficial and should be included on the energy label as additional information along with filtration and emissions. Given that energy savings are unlikely with reduced noise levels and significant on costs or additional weights (sound proofing materials) may be involved, we believe that no further elaboration is needed.

8.2.6 Scenarios

8.2.6.1 Effect of the Proposed Energy Label in the Scenarios

At the final stakeholder workshop, the question was asked: What effect would there be for a scenario of having an energy label ONLY?

An energy label serves as a guide to the consumer, allowing him/her to take the energy efficiency of the product into their purchasing considerations. Whichever product model the consumer decides to purchase, his/her decision will be based on a wide range of criteria. He/she is not compelled to buy the best rated product on the energy label ratings. However, competitive pressures will encourage manufacturers to produce better rated products and to withdraw poorer rated products. Thus, over time, the average energy efficiency of the product category will improve.

The current Industry proposal for an energy label shows that well-designed and good cleaning performance vacuum cleaners can reach class 7 (=A). However, some of these also have quite high input power ratings. Thus, for example, a consumer could be purchasing a vacuum cleaner with an ‘A’ rating but with an input power rating of 2700 watts, or one at 750 watts. Similarly, for ‘G’ rated vacuum cleaners. Therefore, if the energy label encourages (say) removal of ‘G’ rated appliances by manufacturers, overall cleaning performance may be improved but the overall average input power rating of vacuum cleaners is likely to be unaffected.

Our findings in Task 3 (Consumer Behaviour and Local Infrastructure) indicate that the average time that the consumer spends vacuum cleaning is around 50-60 hours per year. There is no evidence to suggest that consumers will change their vacuum cleaning routines unless there is a long protracted awareness raising campaign. Consequently, we conclude that although the effect of the energy label, as proposed by Industry, will lead to overall improvements in cleaning performance, it will have little or no effect on overall consumers’ consumption of electricity.

8.2.6.2 Choice of Scenarios

The scenarios, which have been modelled, are designed to simulate the effects of having a combination of an energy Label (along the lines proposed by CECED) and the imposition of mandatory capping of input power ratings for mains powered vacuum cleaners.

Thus the situation in Europe would move in two stages towards end targets (to accommodate 3-year design cycle of manufacturers). The scenarios modelled are:

1. Business-as-Usual (BAU)
2. Stage 1 (Energy Label plus 1st stage cap)
3. Stage 2 (Energy label plus 2nd stage cap)

In order to model these scenarios, we have base our modelling on our simple stock model of future projections of vacuum cleaner sales, changes in stock levels, and units reaching end-of-life. We have extended this model to incorporate the outputs from the eco-report workbooks used to simulate the effects of imposing input power caps for the various base cases.

BAU represents the forecast situation where no changes are made – no legislative or policy pressure to make changes to improvement energy or resource efficiency.

Scenario 1 represents the situation where energy labelling is introduced and the first stage proposed capping targets are imposed from 2011 without going on to impose the second stage target. This situation could occur, for example, if unforeseen changes in policy (for whatever reason) render further progress unnecessary.

Scenario 2 represents the forecast situation under full implementation of our proposed input power capping targets promoted also by use of an energy label.

8.3 Impact Analysis Industry and Consumers

The results from our modelling of scenarios are presented below. Figure 7 shows the forecast annual total energy consumption in the EU-27 from 2005 to 2020 for the three scenarios.

Figure 7 - Modelling Forecast of Annual Total Energy Consumption 2005-2020

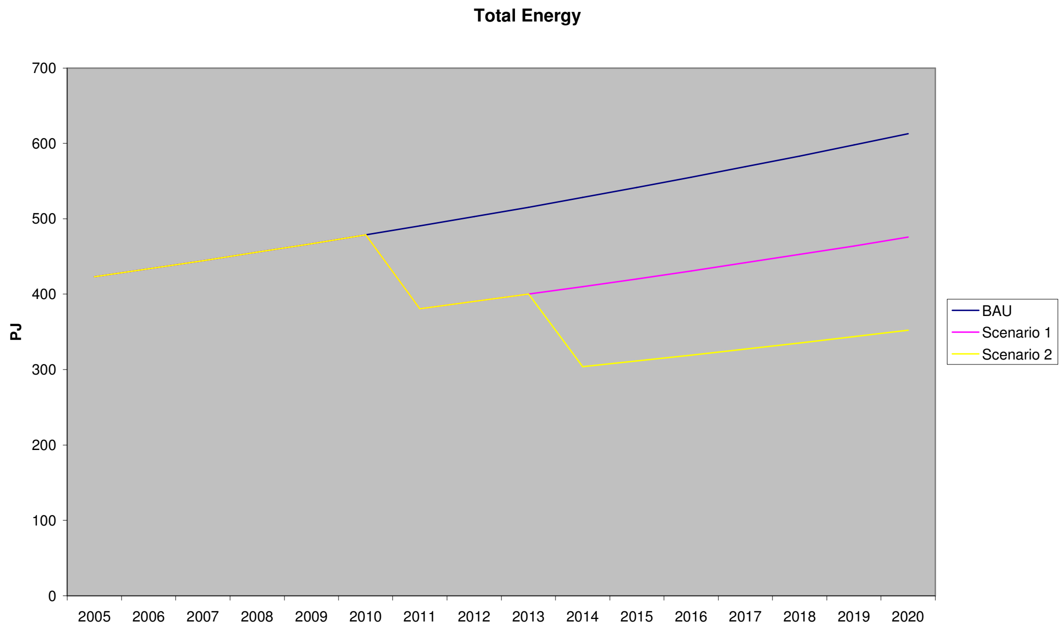
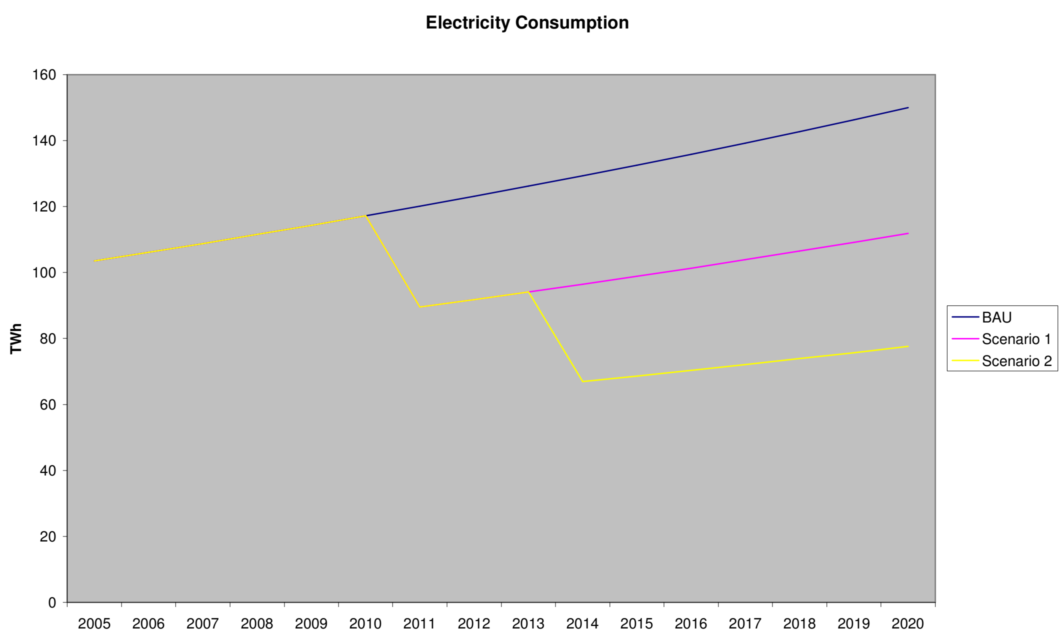


Figure 8 shows the total annual energy consumption proportion that is consumption of electricity for the three scenarios.

Figure 8 - Total Annual Electricity Consumption 2005-2020

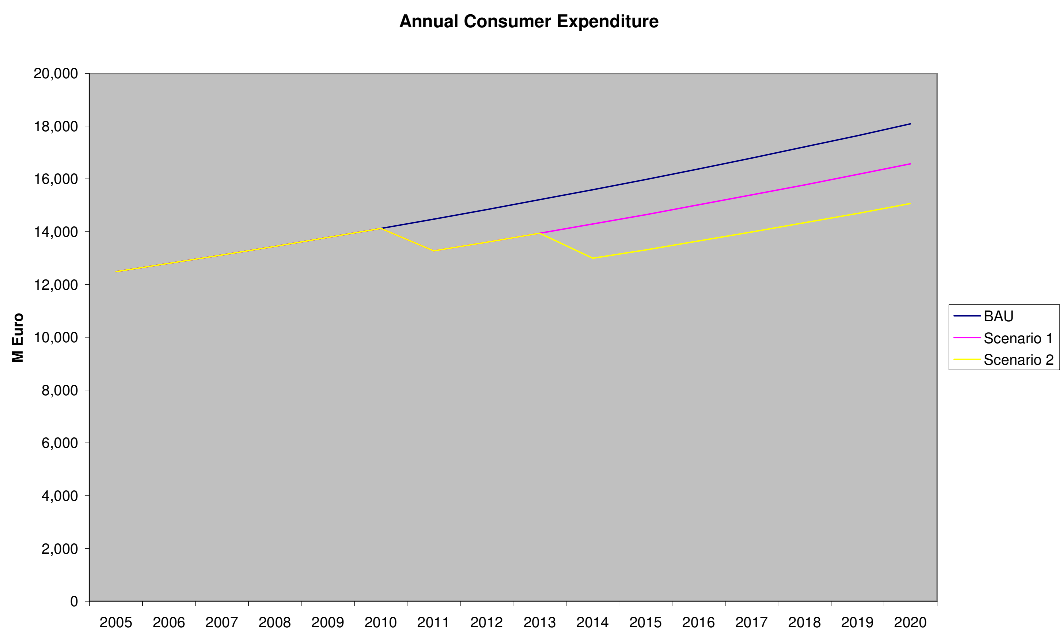


Clearly, from both graphs, there is the opportunity to effect significant reductions in energy consumption through implementation of the proposed targets.

We believe that the impacts on Industry are relatively small – mostly involve design work to produce vacuum cleaners to conform with energy label and input power capping targets. The actual impact on production costs is very small compared with the unit price commanded by vacuum cleaners.

Impacts on consumers are significant both in terms of energy consumed when using vacuum cleaners but also on the annual consumer expenditure. Figure 9 shows the annual consumer expenditure forecasts for the three scenarios.

Figure 9 - Annual Consumer Expenditure 2005-2020



In summary, Table 41 presents the totalled figures 2005-2020 for BAU, Scenario 1 and Scenario 2 for total annual energy consumed, of which electricity consumed and the annual consumer expenditure.

Table 41 - Summary Totals and Potential Savings

	BAU	Scenario 1	Scenario 2
Consumption			
Total Energy (PJ)	8,199	6,969	6,167
of which Electricity (TWh)	2,007	1,665	1,442
Annual Consumer Expenditure M Euro	242,014	228,476	218,655
Potential Savings			
Total Energy (PJ)	0	1,230	2,032
of which Electricity (TWh)	0	342	565
Annual Consumer Expenditure M Euro	0	13,538	23,359

Clearly, the annual savings achievable over BAU are significant, especially as these are realised only once the targets are implemented.

The continuously rising projections we show in the figures above are a result of the predicted population growth (Eurostat forecast) as applied in the stock modelling (i.e. more people = more households = more vacuum cleaners). Given the EU's carbon reduction targets, we would expect the Commission to wish to see an overall downward projection in total energy consumption. This rising trend is also discussed further in the sensitivity analysis below.

8.4 Sensitivity Analysis of the Main Parameters

8.4.1 Stock Replacement Rate

Figure 10 and Figure 11 show the forecast market shares of the vacuum cleaner stock, importantly showing how stock of old products (manufactured before targets were imposed) is replaced by new products (complying with the targets set). With typical lifetimes of vacuum cleaners estimated at around 8 years, then, theoretically, all old stock will be replaced by new after 8 years. In practice, individual vacuum cleaners reach end-of-life at any time dependent on a whole range of factors (such as how they are used, how they are treated, level of maintenance given etc.). Thus it is very likely that a small number of 'old stock' vacuum cleaners could remain in service well beyond the typical lifetime. As it is very difficult to predict the numbers of 'old stock' vacuum cleaners remaining in service after the typical lifetime, it is not possible to calculate what effect these might have on our calculated potential savings in given in Table 41 above. However, what we can say is that these calculated potential savings represent the maximum savings possible for a typical lifetime estimate of 8 years.

Figure 10 - Changeover from Old to New Stock (Scenario 1)

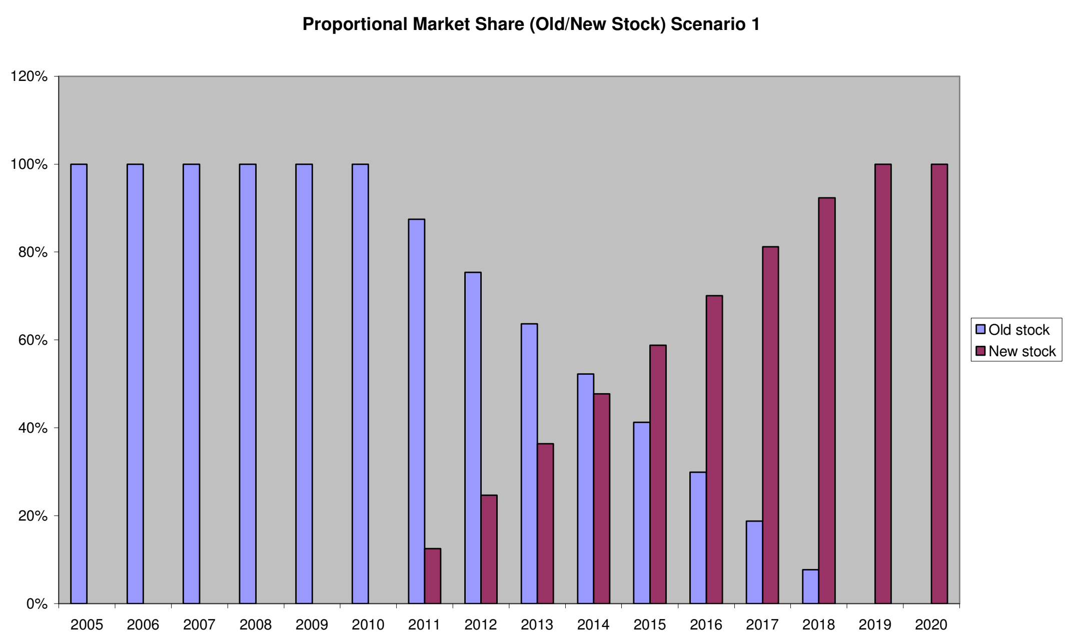
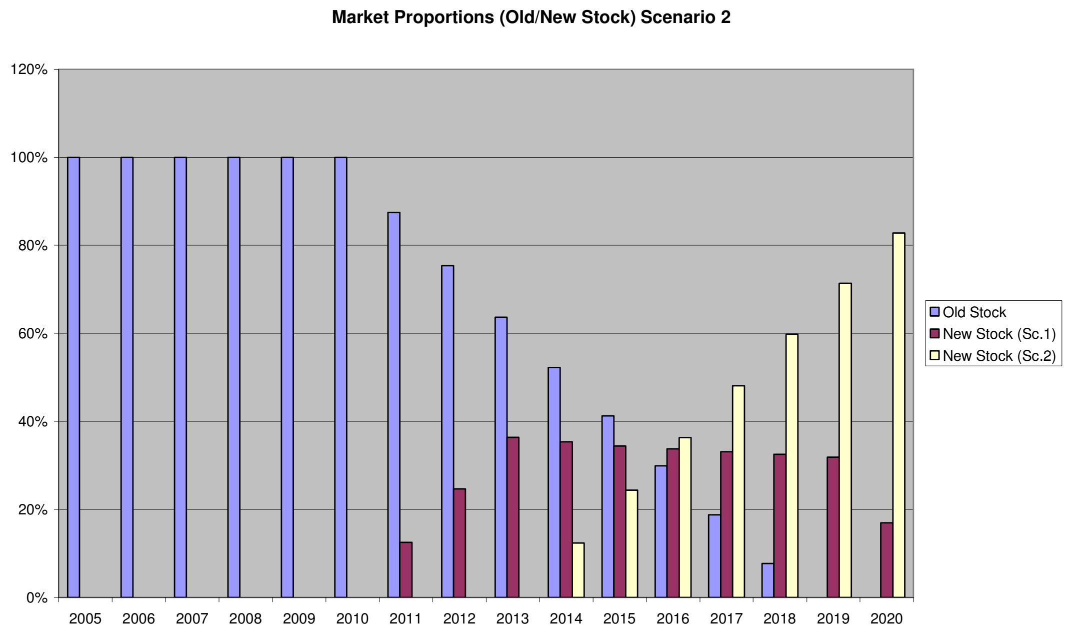


Figure 11 - Changeover from Old to New Stock (Scenario 2)



8.4.2 Active versus Passive Nozzles

At low powers an active nozzle is superior to a passive nozzle at cleaning carpets (this is why we have recommended that uprights without integrated tools are capped ultimately at 500 watts since their prime purpose is to clean floors only). Ironically, to clean above the floor (for example, furnishings and curtains) actually requires lower power levels also, because dirt tends not to be ground in to the material, as on carpets. However, since many people actually do clean carpets with passive nozzles (probably the vast majority throughout Europe) then this is where around 250 to 270 watts suction power is important. However, we do NOT recommend that ONLY active nozzles are to be used when cleaning carpets. The purpose of this analysis is to show how effective active nozzles are and the overall potential energy saving.

After allowing for energy losses due to motor/fan efficiencies, efficiencies of airways, filters and bags (if used), a 750 watt rated motor/fan unit could deliver around 270 watts of suction power at the nozzle. The additional cost of a powered agitator over a standard passive nozzle could add as much as 30 Euros to the product price. The agitator could absorb as much as 75 watts thus reducing the available input power for the motor/fan to 675 watt and ultimately deliver some 232 watts of suction power at the nozzle (more than adequate for best cleaning performance on carpet).

However, once an active cleaning head is used, the main requirement is for adequate airflow, hence the suction element of suction power is less critical. Thus, even with 232 watts at the head an active cleaning head would still be significantly better than the passive cleaning head. Our prototype vacuum cleaner had less than 100 watts of suction power at the head and still achieved 80% dust pick up from carpet. Thus, we conclude that in terms of equivalence of cleaning performance, we can compare 270 watts suction power through a passive nozzle with 100 watts suction power through an active nozzle.

Thus we have used the eco-report model to compare the impacts and life cycle costs of the following hypothetical vacuum cleaners:

1) Passive canister type

Input power: 750 watts

(delivering 270 air watts at the passive nozzle)

versus:

2) Canister with powered nozzle

Input power: 365 watts (calculated as follows: 75 watts for powered nozzle plus 675*100/232 for the motor = 75 + 290 = 365 watts)

(delivering 100 watts at the active nozzle)

Adding 30 euros to the product price.

The outputs obtained are interesting. The active head device would deliver:

~50% reduction in electricity consumption (rather obvious given the input wattages!)

~36% reduction in CO2 emissions

for:

~3% increase in product lifecycle cost, and

~1% increase in total annual consumer spend.

Using the active head, the Greenhouse Gas (GHG) emission saving per appliance is calculated at over 88 kg CO_2eq. An estimate of the value of CO_2eq savings was made using the shadow price of carbon (SPC)[59]. For a single appliance, the value of the saving is about 3.15 Euro at 2007 prices.

Thus, adding the cost of extra GHG emissions of the passive head type makes the life cycle cost per product:

LCC (passive) 217.5+3.15=**220.65** euro

For comparison, the active head lifecycle cost was calculated as:

LCC(active) of **224.2** euro

Thus at a 30 euros price premium for an active head model, the active head model is more expensive in LCC terms. However, if the price premium were only 25 euros, then the active head model is less expensive in LCC terms.

This supports our recommendation NOT to recommend that ONLY active nozzles should be used when cleaning carpets.

Overall, if all domestic canister sales from 2005 to 2020 were and continued to be active head models, then the net present value (in 2007 prices) of the cumulative potential CO2 savings would be about 1.8 Billion Euros. This is not a huge saving when compared with the cumulative annual consumer spend over the same period.

Thus, we conclude that this analysis does not support an “active heads ONLY” policy. However, it does point to a way, at a future time when further energy savings may be demanded, to once again have a close examination of the vacuum cleaner and surface cleaning arena. The proportion of carpeted floors to hard floors varies between different Member States, which very likely gives rise to differences in the way vacuum cleaners are used. If the balance of flooring types continues to shift towards hard floors then suction power requirements could be reduced further.

[59] http://www.defra.gov.uk/Environment/climatechange/research/carboncost/index.htm

8.4.3 Increasing Product Durability

As shown in Task 7 (Improvement Potential), the complex question of whether or not it is better to replace more quickly an inefficient vacuum cleaner with an efficient vacuum cleaner needs to be addressed alongside the supplementary question of whether or not it is better to delay product life extension until later targets are imposed. In the analysis of improvement options, we found that small benefits are derived over BAU for energy consumption and environmental impact. Although, consumers would be likely to pay more for a new longer life product, this only represents a fraction of the total EU consumer expenditure over the product lifetime. Thus, we conclude that the issue of product durability should be considered after the proposed measures have been put into place and older less efficient vacuum cleaners have disappeared from the working EU stock.

8.4.4 Behaviour Change

Further reductions in energy usage may be possible if consumers change their cleaning habits (or are educated so) by using more brushing (say with cordless brush machines at very low energy inputs) and therefore reduced use of the vacuum cleaner.

Appendices

Appendix 1 – EU Impact of Products sold 2005 over their lifetime

Appendix 2 – EU Impact of Products (Total System)

Appendix 3 – Summary Notes from Final Stakeholder Meeting

Appendix 1

Table 42 - EU Impact of Domestic Canister VCs sold 2005 over their lifetime

EU Impact of New Models sold 2005 over their lifetime:	Date	Author
Canister (domestic) Vacuum Cleaners	0	AEA

Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
Materials	**unit**									
Bulk Plastics	kt			**140**			47	93	**140**	**0**
TecPlastics	kt			**22**			8	15	**22**	**0**
Ferro	kt			**47**			14	33	**47**	**0**
Non-ferro	kt			**15**			5	11	**15**	**0**
Coating	kt			**0**			0	0	**0**	**0**
Electronics	kt			**1**			0	0	**1**	**0**
Misc.	kt			**52**			16	36	**52**	**0**
Total weight	kt			**278**			90	188	**278**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	PJ	19	7	**26**	**4**	**257**	10	4	**5**	**292**
of which, electricity (in primary PJ)	PJ	2	4	**6**	**0**	**254**	0	0	**0**	**260**
Water (process)	mln. m3	3	0	**3**	**0**	**20**	0	0	**0**	**24**
Water (cooling)	mln. m3	18	2	**20**	**0**	**677**	0	1	**-1**	**697**
Waste, non-haz./ landfill	kt	295	22	**317**	**3**	**302**	102	1	**102**	**723**
Waste, hazardous/ incinerated	kt	3	0	**3**	**0**	**6**	55	0	**55**	**64**
Emissions (Air)										
Greenhouse Gases in GWP100	mt CO2 eq.	1	0	**1**	**0**	**11**	1	0	**0**	**13**
Ozone Depletion, emissions	t R-11 eq.	negligible								
Acidification, emissions	kt SO2 eq.	7	2	**9**	**1**	**66**	1	0	**1**	**76**
Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	1	0	**1**	**0**	**2**	1	0	**1**	**3**
Heavy Metals	ton Ni eq.	3	0	**3**	**0**	**5**	3	0	**3**	**10**
PAHs	ton Ni eq.	1	0	**1**	**0**	**1**	0	0	**0**	**2**
Particulate Matter (PM, dust)	kt	1	0	**1**	**6**	**4**	13	0	**13**	**24**
Emissions (Water)										
Heavy Metals	ton Hg/20	2	0	**2**	**0**	**2**	1	0	**1**	**4**
Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Table 43 - EU Impact of Commercial Canister VCs sold 2005 over their lifetime

EU Impact of New Models sold 2005 over their lifetime:

Canister (commercial) Vacuum Cleaners

Date 0 | Author AEA

Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
Materials	**unit**									
Bulk Plastics	kt			**6**			2	4	**6**	**0**
TecPlastics	kt			**0**			0	0	**0**	**0**
Ferro	kt			**1**			0	1	**1**	**0**
Non-ferro	kt			**2**			1	2	**2**	**0**
Coating	kt			**0**			0	0	**0**	**0**
Electronics	kt			**0**			0	0	**0**	**0**
Misc.	kt			**2**			0	1	**2**	**0**
Total weight	kt			**11**			4	7	**11**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	PJ	1	0	**1**	**0**	**17**	0	0	**0**	**19**
of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**17**	0	0	**0**	**17**
Water (process)	mln. m3	0	0	**0**	**0**	**2**	0	0	**0**	**2**
Water (cooling)	mln. m3	1	0	**1**	**0**	**45**	0	0	**0**	**46**
Waste, non-haz./ landfill	kt	31	1	**32**	**0**	**21**	4	0	**4**	**57**
Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**0**	2	0	**2**	**3**
Emissions (Air)										
Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
Ozone Depletion, emissions	t R-11 eq.	negligible								
Acidification, emissions	kt SO2 eq.	1	0	**1**	**0**	**4**	0	0	**0**	**5**
Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**1**
PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**1**
Emissions (Water)										
Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Table 44 - EU Impact of Domestic Upright VCs sold 2005 over their lifetime

EU Impact of New Models sold 2005 over their lifetime:								Date	Author	
Upright (domestic) Vacuum Cleaners								0	AEA	

Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
Materials	**unit**									
Bulk Plastics	kt			**41**			14	27	**41**	**0**
TecPlastics	kt			**8**			3	5	**8**	**0**
Ferro	kt			**12**			4	8	**12**	**0**
Non-ferro	kt			**5**			1	3	**5**	**0**
Coating	kt			**0**			0	0	**0**	**0**
Electronics	kt			**0**			0	0	**0**	**0**
Misc.	kt			**19**			6	13	**19**	**0**
Total weight	kt			**85**			28	57	**85**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	PJ	6	2	**8**	**1**	**86**	3	1	**2**	**97**
of which, electricity (in primary PJ)	PJ	1	1	**2**	**0**	**85**	0	0	**0**	**87**
Water (process)	mln. m3	1	0	**1**	**0**	**7**	0	0	**0**	**8**
Water (cooling)	mln. m3	6	1	**7**	**0**	**226**	0	0	**0**	**232**
Waste, non-haz./ landfill	kt	64	7	**71**	**1**	**100**	31	0	**31**	**203**
Waste, hazardous/ incinerated	kt	1	0	**1**	**0**	**2**	17	0	**17**	**20**
Emissions (Air)										
Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**4**	0	0	**0**	**4**
Ozone Depletion, emissions	t R-11 eq.	negligible								
Acidification, emissions	kt SO2 eq.	2	1	**2**	**0**	**22**	0	0	**0**	**25**
Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**1**	0	0	**0**	**1**
Heavy Metals	ton Ni eq.	1	0	**1**	**0**	**2**	1	0	**1**	**3**
PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**1**
Particulate Matter (PM, dust)	kt	0	0	**0**	**2**	**1**	4	0	**4**	**8**
Emissions (Water)										
Heavy Metals	ton Hg/20	1	0	**1**	**0**	**1**	0	0	**0**	**1**
Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Table 45 - EU Impact of Commercial Upright VCs sold 2005 over their lifetime

EU Impact of New Models sold 2005 over their lifetime:	Date	Author
Upright (commercial) Vacuum Cleaners	0	AEA

Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
Materials	**unit**									
Bulk Plastics	kt			**2**			1	1	**2**	**0**
TecPlastics	kt			**0**			0	0	**0**	**0**
Ferro	kt			**0**			0	0	**0**	**0**
Non-ferro	kt			**0**			0	0	**0**	**0**
Coating	kt			**0**			0	0	**0**	**0**
Electronics	kt			**0**			0	0	**0**	**0**
Misc.	kt			**1**			0	0	**1**	**0**
Total weight	kt			**3**			1	2	**3**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	PJ	0	0	**0**	**0**	**6**	0	0	**0**	**6**
of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**6**	0	0	**0**	**6**
Water (process)	mln. m3	0	0	**0**	**0**	**1**	0	0	**0**	**1**
Water (cooling)	mln. m3	0	0	**0**	**0**	**15**	0	0	**0**	**15**
Waste, non-haz./ landfill	kt	2	0	**2**	**0**	**7**	1	0	**1**	**11**
Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**0**	1	0	**1**	**1**
Emissions (Air)										
Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Ozone Depletion, emissions	t R-11 eq.	negligible								
Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**1**	0	0	**0**	**2**
Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Emissions (Water)										
Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Table 46 - EU Impact of Battery/Cordless VCs sold 2005 over their lifetime

EU Impact of New Models sold 2005 over their lifetime:	Date	Author
Battery/Cordless Vacuum Cleaners	0	AEA

Life Cycle phases -->		**PRODUCTION**			**DISTRI-**	**USE**	**END-OF-LIFE***			**TOTAL**
Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
Materials	**unit**									
Bulk Plastics	kt			**6**			2	4	**6**	**0**
TecPlastics	kt			**1**			0	1	**1**	**0**
Ferro	kt			**2**			1	2	**2**	**0**
Non-ferro	kt			**3**			1	2	**3**	**0**
Coating	kt			**0**			0	0	**0**	**0**
Electronics	kt			**0**			0	0	**0**	**0**
Misc.	kt			**2**			0	1	**2**	**0**
Total weight	kt			**14**			5	9	**14**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	PJ	1	0	**1**	**0**	**7**	0	0	**0**	**8**
of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**6**	0	0	**0**	**7**
Water (process)	mln. m3	0	0	**0**	**0**	**1**	0	0	**0**	**1**
Water (cooling)	mln. m3	1	0	**1**	**0**	**17**	0	0	**0**	**18**
Waste, non-haz./ landfill	kt	10	1	**11**	**0**	**8**	5	0	**5**	**24**
Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**0**	3	0	**3**	**3**
Emissions (Air)										
Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Ozone Depletion, emissions	t R-11 eq.	negligible								
Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**2**	0	0	**0**	**2**
Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**0**	1	0	**1**	**1**
Emissions (Water)										
Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Appendix 2

Table 47 - EU Impact of Domestic Canister VCs (Total System)

EU Impact of Products in 2005 (produced, in use, discarded)***	Date	Author
Canister (domestic) Vacuum Cleaners	0	AEA

Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
Materials	**unit**									
Bulk Plastics	kt			**140**			47	93	**140**	**0**
TecPlastics	kt			**22**			8	15	**22**	**0**
Ferro	kt			**47**			14	33	**47**	**0**
Non-ferro	kt			**15**			5	11	**15**	**0**
Coating	kt			**0**			0	0	**0**	**0**
Electronics	kt			**1**			0	0	**1**	**0**
Misc.	kt			**52**			16	36	**52**	**0**
Total weight	kt			**278**			90	188	**278**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	PJ	19	7	**26**	**4**	**236**	10	4	**5**	**271**
of which, electricity (in primary PJ)	PJ	2	4	**6**	**0**	**233**	0	0	**0**	**239**
Water (process)	mln. m3	3	0	**3**	**0**	**19**	0	0	**0**	**22**
Water (cooling)	mln. m3	18	2	**20**	**0**	**622**	0	1	**-1**	**642**
Waste, non-haz./ landfill	kt	295	22	**317**	**3**	**277**	102	1	**102**	**699**
Waste, hazardous/ incinerated	kt	3	0	**3**	**0**	**5**	55	0	**55**	**63**
Emissions (Air)										
Greenhouse Gases in GWP100	mt CO2 eq.	1	0	**1**	**0**	**10**	1	0	**0**	**12**
Ozone Depletion, emissions	t R-11 eq.					negligible				
Acidification, emissions	kt SO2 eq.	7	2	**9**	**1**	**61**	1	0	**1**	**71**
Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	1	0	**1**	**0**	**2**	1	0	**1**	**3**
Heavy Metals	ton Ni eq.	3	0	**3**	**0**	**4**	3	0	**3**	**10**
PAHs	ton Ni eq.	1	0	**1**	**0**	**1**	0	0	**0**	**2**
Particulate Matter (PM, dust)	kt	1	0	**1**	**6**	**4**	13	0	**13**	**24**
Emissions (Water)										
Heavy Metals	ton Hg/20	2	0	**2**	**0**	**2**	1	0	**1**	**4**
Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq					negligible				

Table 48 - EU Impact of Commercial Canister VCs (Total System)

EU Impact of Products in 2005 (produced, in use, discarded)***	Date	Author
Canister (commercial) Vacuum Cleaners	0	AEA

Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
Materials	**unit**									
Bulk Plastics	kt			**6**			2	4	**6**	**0**
TecPlastics	kt			**0**			0	0	**0**	**0**
Ferro	kt			**1**			0	1	**1**	**0**
Non-ferro	kt			**2**			1	2	**2**	**0**
Coating	kt			**0**			0	0	**0**	**0**
Electronics	kt			**0**			0	0	**0**	**0**
Misc.	kt			**2**			0	1	**2**	**0**
Total weight	kt			**11**			4	7	**11**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	PJ	1	0	**1**	**0**	**17**	0	0	**0**	**19**
of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**17**	0	0	**0**	**17**
Water (process)	mln. m3	0	0	**0**	**0**	**2**	0	0	**0**	**2**
Water (cooling)	mln. m3	1	0	**1**	**0**	**45**	0	0	**0**	**46**
Waste, non-haz./ landfill	kt	31	1	**32**	**0**	**21**	4	0	**4**	**57**
Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**0**	2	0	**2**	**3**
Emissions (Air)										
Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
Ozone Depletion, emissions	t R-11 eq.	negligible								
Acidification, emissions	kt SO2 eq.	1	0	**1**	**0**	**4**	0	0	**0**	**5**
Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**1**
PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**1**
Emissions (Water)										
Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Table 49 - EU Impact of Domestic Upright VCs (Total System)

EU Impact of Products in 2005 (produced, in use, discarded)*	Date	Author
Upright (domestic) Vacuum Cleaners	0	AEA

Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
Materials	**unit**									
Bulk Plastics	kt			**41**			14	27	**41**	**0**
TecPlastics	kt			**8**			3	5	**8**	**0**
Ferro	kt			**12**			4	8	**12**	**0**
Non-ferro	kt			**5**			1	3	**5**	**0**
Coating	kt			**0**			0	0	**0**	**0**
Electronics	kt			**0**			0	0	**0**	**0**
Misc.	kt			**19**			6	13	**19**	**0**
Total weight	kt			**85**			28	57	**85**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	PJ	6	2	**8**	**1**	**79**	3	1	**2**	**90**
of which, electricity (in primary PJ)	PJ	1	1	**2**	**0**	**78**	0	0	**0**	**80**
Water (process)	mln. m3	1	0	**1**	**0**	**6**	0	0	**0**	**7**
Water (cooling)	mln. m3	6	1	**7**	**0**	**207**	0	0	**0**	**214**
Waste, non-haz./ landfill	kt	64	7	**71**	**1**	**92**	31	0	**31**	**195**
Waste, hazardous/ incinerated	kt	1	0	**1**	**0**	**2**	17	0	**17**	**20**
Emissions (Air)										
Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**3**	0	0	**0**	**4**
Ozone Depletion, emissions	t R-11 eq.	negligible								
Acidification, emissions	kt SO2 eq.	2	1	**2**	**0**	**20**	0	0	**0**	**23**
Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**1**	0	0	**0**	**1**
Heavy Metals	ton Ni eq.	1	0	**1**	**0**	**1**	1	0	**1**	**3**
PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**1**
Particulate Matter (PM, dust)	kt	0	0	**0**	**2**	**1**	4	0	**4**	**8**
Emissions (Water)										
Heavy Metals	ton Hg/20	1	0	**1**	**0**	**1**	0	0	**0**	**1**
Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Table 50 - EU Impact of Commercial Upright VCs (Total System)

EU Impact of Products in 2005 (produced, in use, discarded)***	Date	Author
Upright (commercial) Vacuum Cleaners	0	AEA

Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
Materials	**unit**									
Bulk Plastics	kt			**2**			1	1	**2**	**0**
TecPlastics	kt			**0**			0	0	**0**	**0**
Ferro	kt			**0**			0	0	**0**	**0**
Non-ferro	kt			**0**			0	0	**0**	**0**
Coating	kt			**0**			0	0	**0**	**0**
Electronics	kt			**0**			0	0	**0**	**0**
Misc.	kt			**1**			0	0	**1**	**0**
Total weight	kt			**3**			1	2	**3**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	PJ	0	0	**0**	**0**	**6**	0	0	**0**	**6**
of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**6**	0	0	**0**	**6**
Water (process)	mln. m3	0	0	**0**	**0**	**1**	0	0	**0**	**1**
Water (cooling)	mln. m3	0	0	**0**	**0**	**15**	0	0	**0**	**15**
Waste, non-haz./ landfill	kt	2	0	**2**	**0**	**7**	1	0	**1**	**11**
Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**0**	1	0	**1**	**1**
Emissions (Air)										
Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Ozone Depletion, emissions	t R-11 eq.	negligible								
Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**1**	0	0	**0**	**2**
Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Emissions (Water)										
Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Table 51 - EU Impact of Battery/Cordless VCs (total system)

EU Impact of Products in 2005 (produced, in use, discarded)*	Date	Author
Battery/Cordless Vacuum Cleaners	0	AEA

Life Cycle phases -->		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	**Total**			Disposal	Recycl.	**Total**	
Materials	**unit**									
Bulk Plastics	kt			**6**			2	4	**6**	**0**
TecPlastics	kt			**1**			0	1	**1**	**0**
Ferro	kt			**2**			1	2	**2**	**0**
Non-ferro	kt			**3**			1	2	**3**	**0**
Coating	kt			**0**			0	0	**0**	**0**
Electronics	kt			**0**			0	0	**0**	**0**
Misc.	kt			**2**			0	1	**2**	**0**
Total weight	kt			**14**			5	9	**14**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	PJ	1	0	**1**	**0**	**7**	0	0	**0**	**8**
of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**6**	0	0	**0**	**7**
Water (process)	mln. m3	0	0	**0**	**0**	**1**	0	0	**0**	**1**
Water (cooling)	mln. m3	1	0	**1**	**0**	**17**	0	0	**0**	**18**
Waste, non-haz./ landfill	kt	10	1	**11**	**0**	**8**	5	0	**5**	**24**
Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**0**	3	0	**3**	**3**
Emissions (Air)										
Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Ozone Depletion, emissions	t R-11 eq.	negligible								
Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**2**	0	0	**0**	**2**
Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**0**	1	0	**1**	**1**
Emissions (Water)										
Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Appendix 3

Summary of Final Stakeholder Meeting, EuP Vacuum Cleaners Brussels, 19 January 2009

Present:
Mathew Kestner, European Commission (Chair)
Martin Buchele, European Commission
Laurent Caro, Groupe SEB
Maya de Groot, Federale Overheidsdient Volksgezondheid
Harry Langdon, Numatic
Hakan Messler, Electrolux
Sandra Mueller, BSH
Peter Mueller-Baum, United Cleaning
Dietlinde Quack, Oeko Institute
Matteo Rambaldi, CECED
Morris Rollo, Hoover
Harald Schellenberg, BSH
Wolfgang Siefert, Miele
Paul van Wolfren, Philips
Steffen Reiser, Kaercher
Steve Ogilvie, AEA (Project manager)
Grahame Capron-Tee, Intertek
Chris Evans, Consumer Research Associates
Phil Dolley, AEA

Purpose of the Meeting:
To review the consultant's findings and the technical assessment contained in Task 7. If time allowed, Task 8 to be discussed.

Discussion
a) Tasks 1 to 6 – further comments were requested, none were raised. The presumption was that stakeholders are content with the findings of Tasks 1 to 6.

b) Task 7 – SO gave a brief presentation of the key findings and results. Several questions were raised:
Is it possible to go beyond 40% efficiency?
Key limitation is **fan design** and its influence on fan efficiency. If more attention was paid to developing more refined fan blades then efficiency gains could be realised. Stakeholders queried the assumed cost increment for such design saying there would be significant tooling costs and some material costs per fan.

Other **design types** are possible such as coaxial fans and displacement technology. Both would result in physically larger vacuum cleaners though. Neither is being considered for production.

Robot designs are expected to increase market share in coming years. They may evolve to be able to sense the amount of dirt present and alter their energy consumption accordingly.

There may be some efficiency to be gained in **motor design** (e.g. switched reluctance motors with electronic control) but the consultant's work has assumed that current technology remains dominant for some years to come, only such switched reluctance motor powered vacuum cleaner design exists for sale on the Japanese market but is very much a premium price product. For reasons of cost, stakeholders agreed. Lower speed, higher torque motors, whilst an option, would require up to an additional 40% by weight of materials and cost perhaps up to an extra five euros . .

How was BNAT chosen?

Difficult area to discuss as producers are unwilling, for obvious reasons, to discuss their R&D work. The identified BNAT solutions are those that the study team's experience of VC development has allowed them to identify.

How did the consultants identify consumer behaviour parameters (hours spent cleaning etc)?
From the limited information available and in discussion with stakeholders at earlier meetings. Experience from surveys in the USA also suggests that consumers typically spend around an hour a week cleaning. Whilst all parties accept the same for Europe the ideal would be for a European survey to be conducted. This would have additional benefits – for example, it would help correlate test method protocols with actual cleaning behaviour - a subject presently not well understood.

The above discussion was completed with plenty of time remaining. MK remarked that he was pleased with the Task 1 to 7 work and the input stakeholders have made facilitating such an efficient discussion today. MK progressed the meeting to discuss Task 8.

<u>c) Task 8</u> – SO gave a brief presentation of the key findings and results. There are a number of key issues for EuP implementing to take into consideration:

- that VC ownership is increasing,
- that input power ratings have increased markedly since the 1970s,
- energy efficiency has decreased over this period,
- CECED has developed proposals for an Energy Label,
- Current EN test standards are flawed,
- There is good technical potential for achieving energy savings,
- These savings can be won at little cost to producers and significant savings to consumers,
- Technology developments can be accommodated within existing design cycles.

Broadly the discussion centred on:

- Limiting rated input power (caps). Some stakeholders oppose caps arguing that high power allows consumers to clean to a certain level more quickly. Others are supportive if the time frame for implementation was adjusted to a later date. MK remarked that additional market data would be helpful to inform the Commission what the outcome of a cap might be.

- Active brush head. Canister VCs can achieve better cleaning performance with a motorised head. MK asked the consultants to include active brush heads in the scenario work – what are the benefits and costs?

- A proposal for an Energy Label. Both the consultants and CECED have identified that an Energy Label would drive product improvement. However, the two approaches differ in one key regard; that CECED's proposal combines energy consumption and cleaning performance into a single parameter. The consultants argue that the assumption that consumers will change their behaviour and use high powered VCs for less time is questionable. It is more likely that consumers will continue to use their VC for the same length of time. DQ advised that consumers would want energy and cleaning performance kept separate. CE remarked that there is a precedent for this in the Energy Label for washing machines where energy, cleaning and drying performance are all separate items leading to very good designs being 'triple A rated'. DQ added that consumers would also want additional information e.g. regarding noise and dust emissions included in the Energy Label.

- Test methods. The proposed CENELEC Working Group method produces an average result of the testing on a carpet and a hard floor. Results are skewed by the hard floor test where it is not uncommon for VCs to achieve 105% or higher. The issue is recognised and accepted by some stakeholders. It was noted that the ASTM method uses four different carpet types so producers cannot 'tune' their VC to a single type to achieve good performance. MK remarked the Commission will consider the case for a new test method. GCT added that the correlation between EN test methods and actual home cleaning is not known.

- Carpet cleaning. GCT noted that some carpets are easier to clean than others. MK remarked that this is part of the 'system' – perhaps carpets should be labelled. He asked the consultants to note the point in their report.

Actions

- Task 7 to include a scenario for active brush heads
- The effect of an Energy Label to be factored into the scenarios. What might it achieve if the worst performing products are phased out?
- Are there any differences in the way VCs are used in different member states that need to be considered? The consultants will comment in their report.
- The consultants will provide further commentary regarding the perceived need for updating test methods.
- Reported results to make clear whether data and figures refer to rated power or max input power.
- Need to review the proposed definition of commercial vacuum cleaners

MK requested the meeting not to provide feedback on the Task 8 discussion. He said that the development of policy options was the responsibility of the Commission.

AEA Energy & Environment
From the AEA group
Fermi Avenue
Harwell International Business Centre
Didcot
Oxfordshire
OX11 0QR

Tel: 0845 345 3302
Fax: 0870 190 6138

E-mail: info@aeat.co,uk

www.aea-energy-and-environment.co.uk