AEA Energy & Environment
From the AEA group

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

Lot 17 Vacuum Cleaners

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Task 8 Report

Report to European Commission

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1 Task 8

1.1 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.

The findings of our study has shown that:

There is a wide range of devices available for the cleaning of surfaces. In order to keep the scope of this study manageable, centralised vacuum cleaners, 'wet and dry' vacuum cleaners, industrial/commercial vacuum cleaners designed for specialist applications, and sweepers have been excluded.

Test standards for vacuum cleaners exist, but have been shown to be inadequate with respect to ecodesign (see Section 1.2.4 below). Eco-labelling criteria for vacuum cleaners have lapsed. However, work is in progress, led by CECED, with respect to possible energy labelling of vacuum cleaners.

Over 45 million vacuum cleaners are sold on the EU market annually. Consumption is increasing due to a combination of declining product lifetime and increasing trend towards multiple ownership whereby households have two or more units. The market trend since the 1960s has been towards increasing input power ratings (See Task 2 section). 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 equate to better cleaning. The production of vacuum cleaners has tended to move to China and the Far East where labour costs are cheaper.

The typical time that a consumer spends on vacuum cleaning is about one hour per week. Some people vacuum every day: others less often, depending on the routine that they have developed. The routine gets a level of cleanliness they want, and takes the amount of time they want 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, Information that exists for consumers in terms of vacuum cleaner performance is at best confusing and sometimes misleading.

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.

The base cases agreed 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 because the improvement options for this type are already covered in other preparatory studies 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.

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. In combination with good nozzle design, the use of agitators and controlling emissions to air with well-fitting HEPA filters, improvements can be maximised.

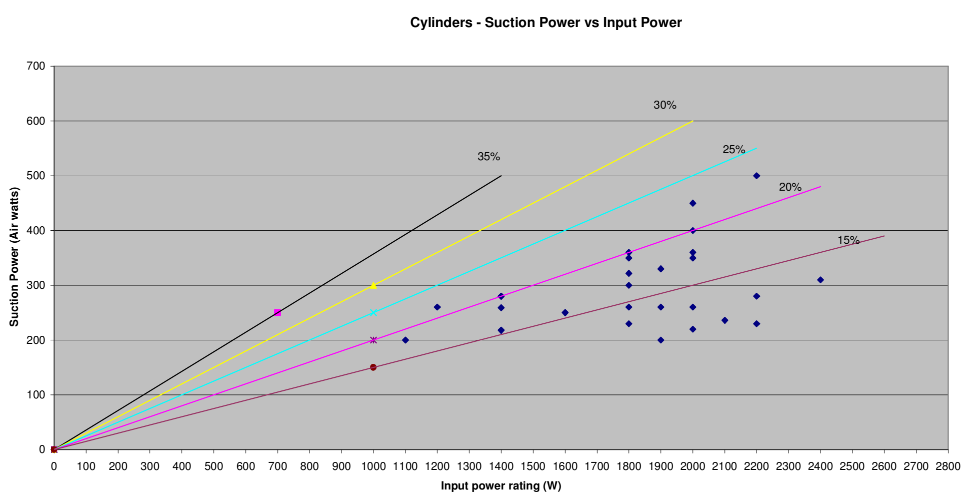
Our Task 7 work indicated that maximising fan efficiency, improved air ways, use of better seals, minimising energy losses from filters and nozzle design improvements represent LLCC (least life cycle cost) securing environmental improvement at little cost to business and significant cost savings to consumers. The improvements can be accommodated within the design cycle typical for this product. This combined with materials lightweighting would represent BAT. BNAT 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.

1.2 Policy and Scenario Analysis

1.2.1 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 1 below shows the results of an analysis of one retailer’s range of vacuum cleaners[1] currently on sale. Quoted suction power is plotted against quoted input power rating.

Figure 1 – 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 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.

1.2.2 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.

[1] www.dixons.co.uk

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 representative Trade Association, CECED (Conseil Européen de la Construction d'appareils Domestiques) 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.

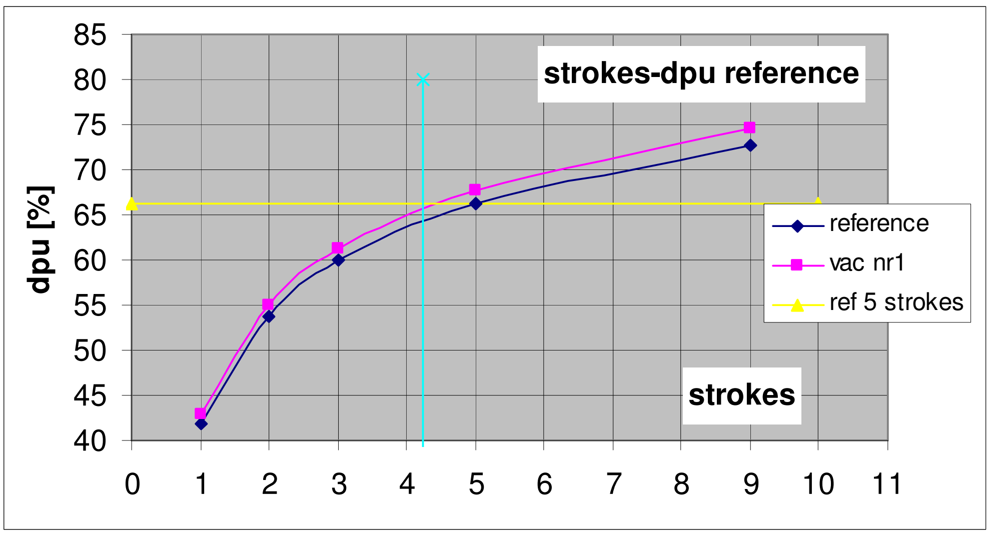


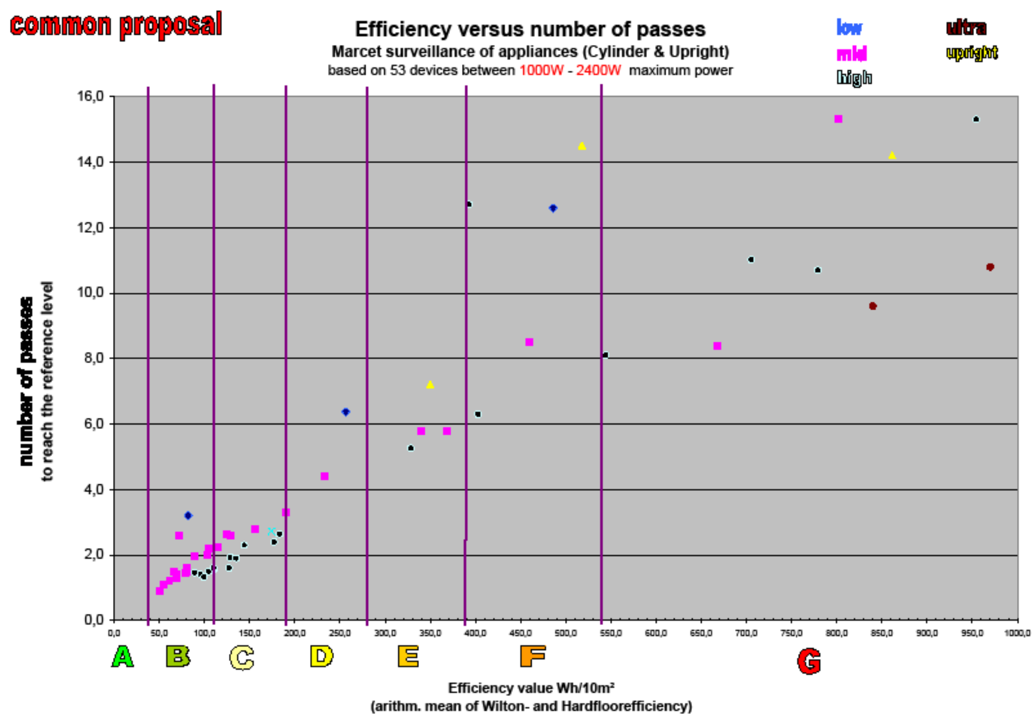
Figure 2 - Curve Fitting Comparison (Example)

5. In Figure 2 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 3 below).

Figure 3 - 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%).

1.2.3 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 3 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.

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 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 1 - Proposed Caps for Input Power Ratings of Vacuum Cleaners

	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

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 CECED), 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.

1.2.4 Test standards

1.2.4.1 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.

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. 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 CECED 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 multiple carpet types, as in ASTM F608, as well as a hard floor test but without averaging the results between carpets and hard floors.

1.2.5 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 (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

1.2.5.1 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.

1.2.6 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.

1.3 Impact Analysis Industry and Consumers

The results from our modelling of scenarios are presented below. Figure 4 shows the forecast annual total energy consumption in the EU-27 from 2005 to 2020 for the three scenarios.

Figure 4 - Modelling Forecast of Annual Total Energy Consumption 2005-2020

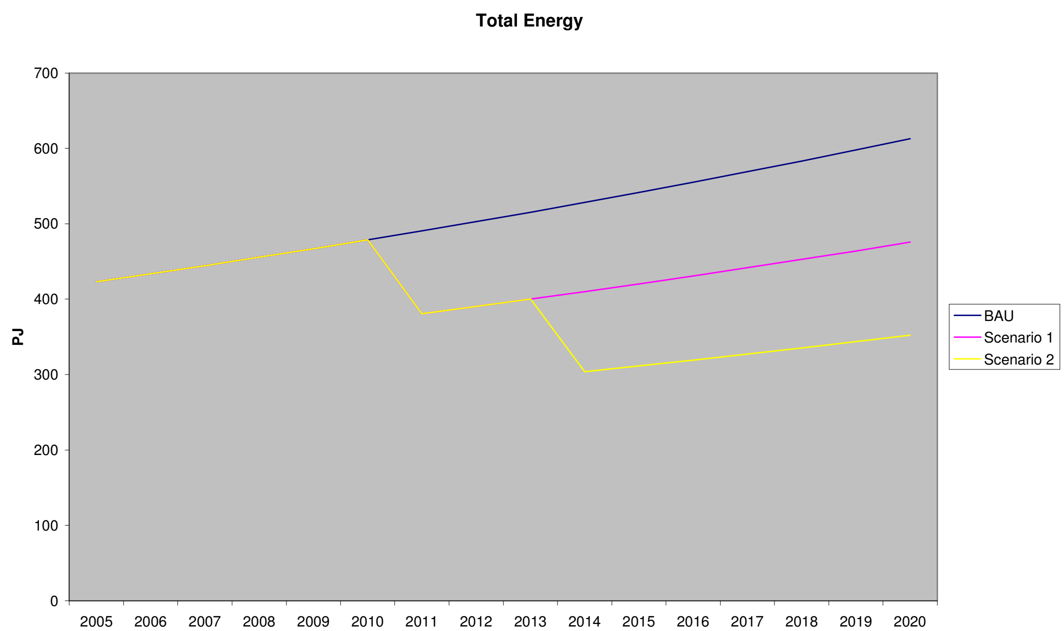
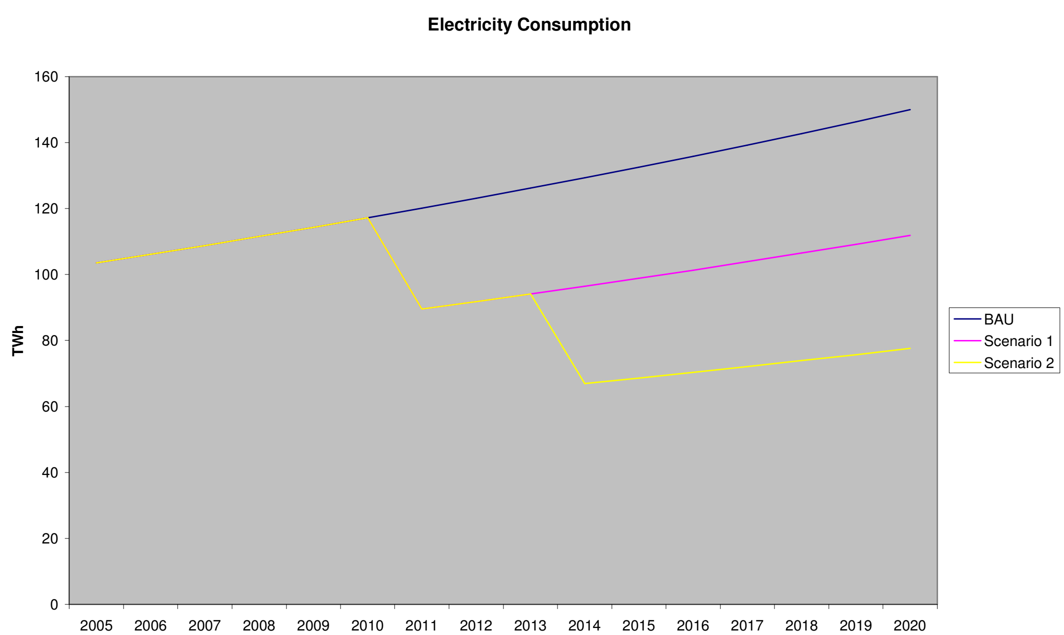


Figure 5 shows the total annual energy consumption proportion that is consumption of electricity for the three scenarios.

Figure 5 - Total Annual Electricity Consumption 2005-2020

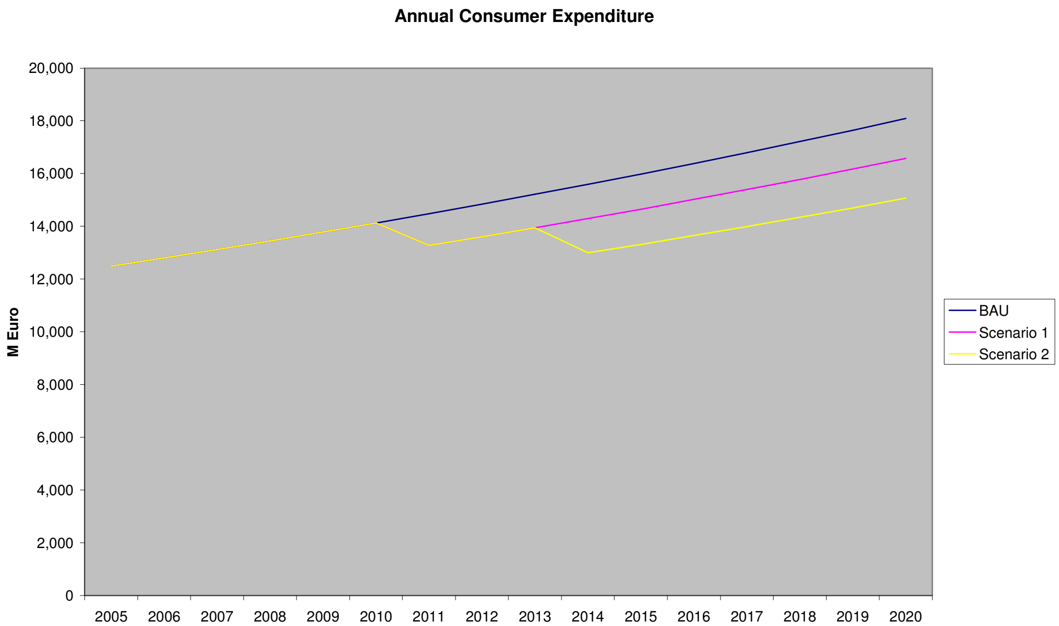


Clearly, from both graphs, there is the opportunity to effect significant reductions in energy consumption through implementation of the proposed targets.

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 6 shows the annual consumer expenditure forecasts for the three scenarios.

Figure 6 - Annual Consumer Expenditure 2005-2020



In summary, Table 2 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 2 - 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. **Possibilities for halting this rising trend will be discussed at the final stakeholder workshop.** This rising trend is also discussed further in the sensitivity analysis below.

1.4 Sensitivity Analysis of the Main Parameters

1.4.1 Stock Replacement Rate

Figure 7 and Figure 8 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 2 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 7 - Changeover from Old to New Stock (Scenario 1)

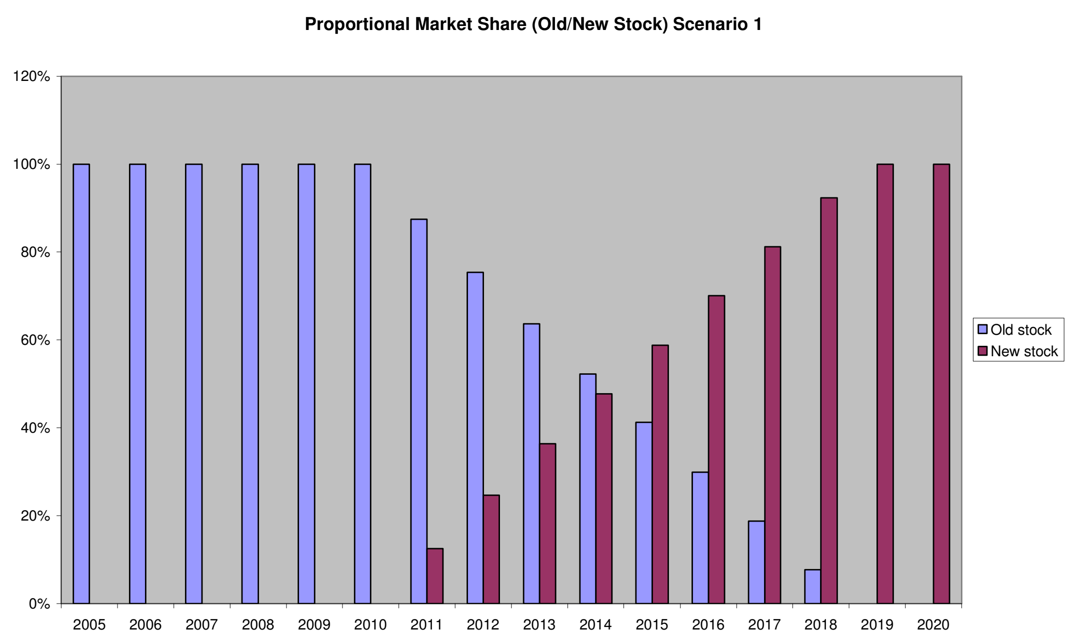
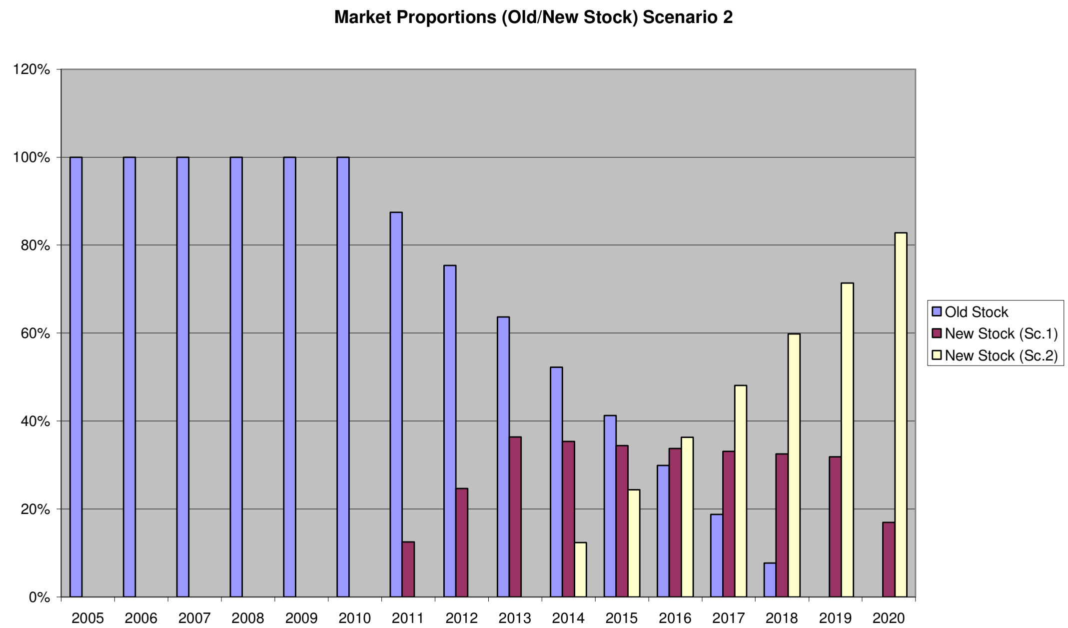


Figure 8 - Changeover from Old to New Stock (Scenario 2)



1.4.2 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.

1.4.3 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.

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