Work on Preparatory studies for implementing measures of the Ecodesign Directive 2009/125/EC

ENER Lot 29– Pumps for Private and Public Swimming Pools, Ponds, Fountains, and Aquariums (and clean water pumps larger than those regulated under Lot 11) – Task 8: Scenario, policy, impact and sensitivity analysis

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Chapter 8: Scenario, policy, impact and sensitivity analysis

8.1 Introduction

This task summarises the outcomes of all previous tasks and tries to identify a suitable policy, which would allow achieving reduction of environmental impacts with consideration to Life Cycle Cost and the best available technologies in the market. Some scenarios analyses allow examining and quantifying the potential energy and economic savings for the period of 2013-2040.

Although Tasks 1-7 set the foundations for future work to be carried out by the European Commission, Task 8 presents an analysis of various policy options that the authors of the report believe to be of use in order to achieve the desired reduction of the environmental impacts of clean water pumps. A sensitivity analysis on some of the key parameters is carried out in order to examine the robustness of the results.

Note that the preliminary policy discussions are the opinions of the consultants and do not reflect the views of the European Commission.

8.2 Policy analysis

The purpose of Task 8 is to suggest the most beneficial policy on the products studied. In this section, policy options are identified considering the outcomes of all previous tasks. They are based on the definition of the product, according to Task 1 and modified/ confirmed by the other tasks. Specific recommendations to the pumps covered by the ENER Lot 29 study are detailed in the following sub-sections.

The pumps covered by Lot 29 use electric motors, which may be subject to specific ecodesign regulation (e.g. 640/2009). All motors over 120 W are studied within the preparatory study ENER Lot 30. Motors used in borehole pumps are also studied in Lot 30.

8.2.1 **Caveat**

Some of the options considered in this section require the conversion of electricity into primary energy. For that purpose, the conversion factor of 2.5 used is derived from Annex II of the Energy Service Directive (2006/32/EC), reflecting the estimated 40% average EU generation efficiency. This factor is also used in other Ecodesign preparatory studies including the ENER Lot 11 and ENER Lot 28 studies on motors and pumps.

Please note that all other primary energy consumption values presented in this study (Task 5, Task 7 and in the other sections of Task 8) were calculated using the EcoReport tool[1], as required by the European Commission to undertake the cost and environmental impact analysis in Ecodesign preparatory studies.

8.2.2 Swimming pools

Swimming pool pumps: devices sold for residential use as well as some commercial use. Domestic swimming pool pumps are typically made from plastic for reasons of efficiency, and of steel in commercial pool pumps for wear resistance and longevity. Domestic swimming pool pumps are typically rated from 40W to around 1kW, depending on the size and design of the pool. Commercial swimming pool pumps are usually above 2.2 kW. Swimming pool pumps come as packaged units that comprise an integrated motor, pump, strainer and controls, and sometimes integrated in a filtering unit. Domestic swimming pool pumps can also be used for jacuzzis.

The final user of swimming pool pumps is normally biased towards the performance and reliability of the pump, and commonly energy efficiency plays a secondary role in the product characteristics. Furthermore, the choice of pumps for swimming pools as per usual goes to the contractors involved with the construction of the swimming pool, rather than to the final user. This implies that the energy efficiency of swimming pool pumps, broadly speaking, may not be a major issue for customers, and therefore, for manufacturers.

The results of Tasks 6 and 7 of this preparatory study show that for swimming pool pumps there is some potential for improvement of the energy efficiency of the products. The payback periods of these improvements depend on the type of pump and its potential for improvement.

The possibilities for regulating swimming pool pumps are several:

A. Information requirements regarding energy efficiency of pumps
B. Energy labelling
C. Mandatory requirement of speed controls
D. Mandatory use of time controls
E. Minimum Energy Performance Standards
F. Voluntary use of correct sized pipes to reduce friction

The following sections present the benefits and drawbacks of each of these policy options.

8.2.2.1 *Information requirements for swimming pool pumps*

The generalisation of a standardised method of communicating the energy performance of swimming pool pumps would be useful to installers and customers to have the right information to make their choice when purchasing a pump.

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[1] Available at http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/methodology/index_en.htm

One of the key factors to ensure energy efficient pump systems is the correct dimensioning, design and installation of the specific pumping system needed for each function. It is therefore recommended to set requirements of minimum information that the manufacturers should provide to designers, installers and customers.

For swimming pool pumps, manufacturers should provide the following information:

- Information on how to install, use and maintain the water pump in order to minimise its impact on the environment. Information about the recommended use and load profiles for the pump shall be provided on the packaging and in the technical documentation of water pumps.
- Information concerning disassembly, recycling, or disposal at end-of-life of components and materials, shall be made available for treatment facilities.
- The energy efficiency index of pumps, calculated in accordance with section 8.2.2.4, shall be indicated on the name plate and packaging of the product and in the technical documentation. It could be given as follows: "MEI ≥ 0,[##]". If no MEI calculation method is developed for swimming pool pumps, the energy efficiency information can be given as efficiency (η) at Best Efficiency Point (BEP), at Part Load (PL), and at Over Load (OL)[2].
- The following information shall be provided: "The benchmark for most efficient swimming pool pumps is MEI ≥ 0,[##]". If no MEI is developed for swimming pool pumps, the benchmark can be given as efficiency (η) at Best Efficiency Point (BEP), at Part Load (PL), and at Over Load (OL)[3].

The information listed above shall be visibly displayed on freely accessible websites of the water pump manufacturers.

8.2.2.1 *Energy labelling*

An alternative to the information requirements explained in the previous section is an energy label that would inform consumers and installers of the relative efficiency of the whole pump in relation to the pumps in the EU market. This type of energy label is similar to the existing EU energy label mandatory for some product types, the US Energy Star scheme and a similar voluntary scheme is used in the Australian standard AS 5102.2.

Energy labelling can be an effective policy tool for the consumer market to help consumers make the right choice of best performing product. Therefore, it is proposed that an energy label that gives an indication of the energy consumption of that pump is used on packaging and other

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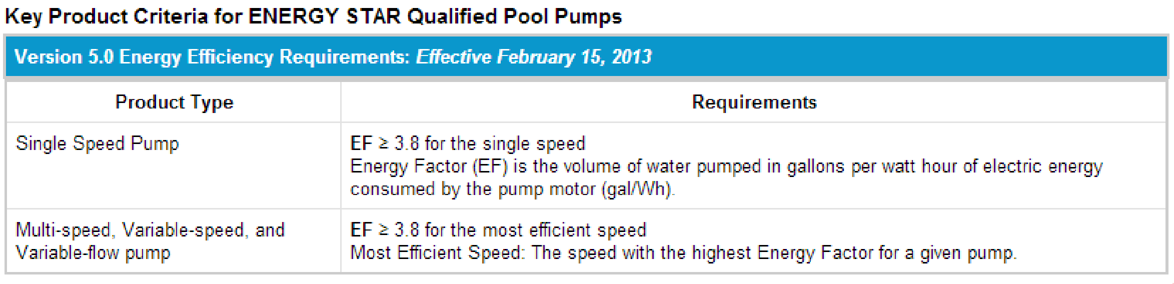
[2] See definition of MEI, ηBEP, ηPL and ηOL in section 8.2.2.4. Although the efficiency (η) and MEI are parameters already used in the EU for water pumps, the development of MEI would require a full market analysis of the swimming pool pumps in the EU. The efficiency (η) at BEP, PL and OL are already in use in the industry and should not pose major problems to implement the information requirements.

[3] No information can be found at the time of writing on the benchmark of swimming pool pumps measured as efficiency at BEP, OL or PL. These parameters are not commonly published by manufacturers.

information. This would be based on the US Energy Star and Australian swimming pool pump labelling information schemes.



Key Product Criteria for ENERGY STAR Qualified Pool Pumps

Version 5.0 Energy Efficiency Requirements: ***Effective February 15, 2013***

Product Type	Requirements
Single Speed Pump	EF ≥ 3.8 for the single speed Energy Factor (EF) is the volume of water pumped in gallons per watt hour of electric energy consumed by the pump motor (gal/Wh).
Multi-speed, Variable-speed, and Variable-flow pump	EF ≥ 3.8 for the most efficient speed Most Efficient Speed: The speed with the highest Energy Factor for a given pump.

Figure 8-1: Energy Star requirements for pool pumps

The US Energy Star criteria for swimming pool pumps are set on Energy Factor (EF), which is the volume of water pumped in gallons per watt-hour of electrical energy consumed by the pump motor (gal/Wh).

The US Energy Star has been adopted by EU Regulation for of office equipment. The EU Energy Star programme was possible thanks to an agreement between the US and the EU to co-ordinate energy labelling of a number of products. The EU Energy Star is managed by the European Commission, with the support of the US EPA, which is the founder and responsible of the US Energy Star.

A similar approach could be taken in the case of swimming pool pumps, which would help homogenise the labelling of these products in the US and EU markets.

The US Energy Star certified pumps are thought to save over $300 per year per pump or $113 million per year[4], which would correspond to around 26 kWh per pump per year[5]. According to a manufacturer, the average swimming pool pumps in the US are slightly more efficient than the average swimming pool pumps in the EU. The entire stock of swimming pool pumps in the EU (i.e. 4,915,000 units, as stated in Task 2 of this preparatory study) is in the same order of magnitude as the US stock of in-ground pool pumps (i.e. 5,000,000 units[4]).

The advantage of the Energy Star is that it is an already existing scheme, which would ease its implementation. The drawbacks are that this scheme is of voluntary application by manufacturers, which does not ensure the penetration of efficient pumps in the market. Furthermore, it differs from already existing EU Regulation for water pumps, which could make it more complex for manufacturers.

Figure 8-2 shows the benchmark of swimming pool pumps as per the Energy Factor used in the US Energy Star scheme.

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[4] http://www.energystar.gov/certified-products/detail/pool_pumps?fuseaction=find_a_product.showProductGroup&pgw_code=PP (accessed in March 2014)

[5] Calculated at a retail price of electricity to ultimate customers of $11.65 per kWh. (Source: http://www.eia.gov/electricity/monthly/ accessed in March 2014)

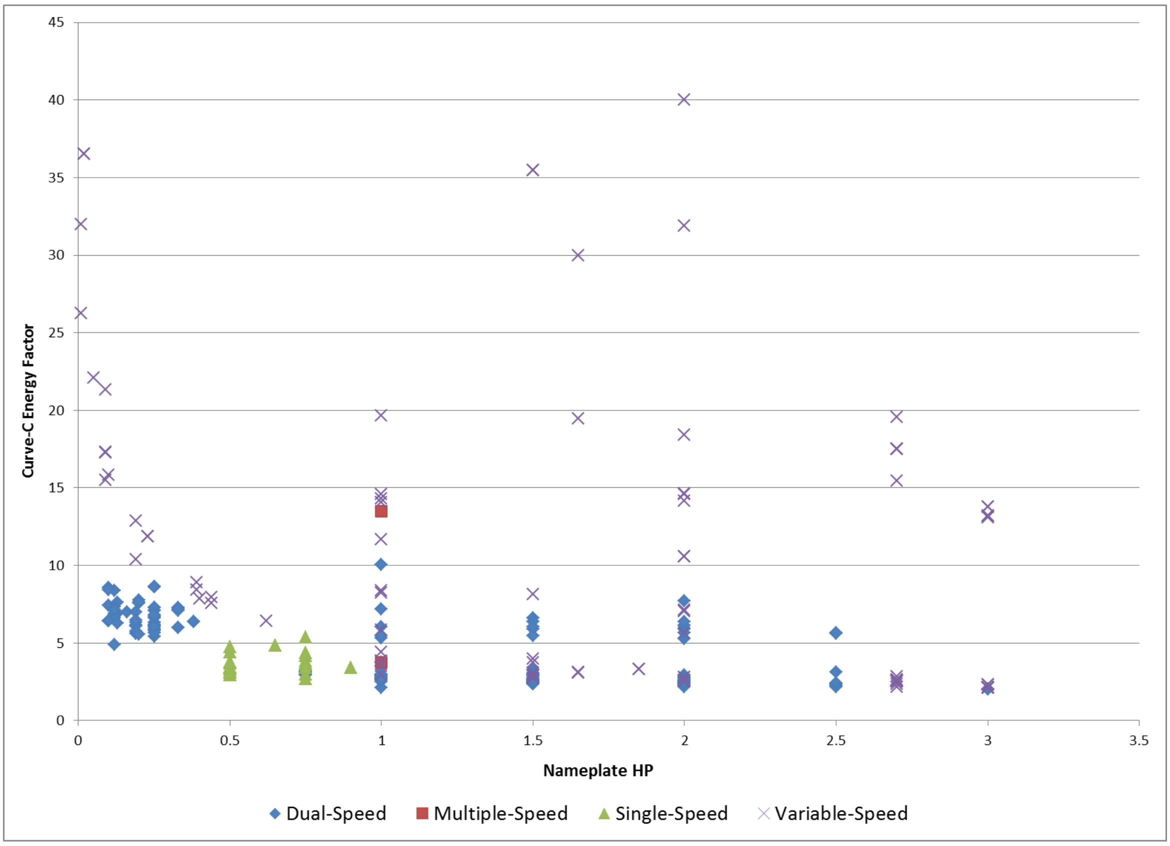

Figure 8-2: Energy Factor of Energy Star-certified swimming pool pumps[6]

8.2.2.2 *Mandatory requirement of speed controls for swimming pool pumps*

Literature sources, legislation and voluntary schemes already in place in the US consistently quote significant energy and economic savings due to the use of variable speed motors instead of single speed in swimming pool pumps. Swimming pool pumps running half-speed for twice the time can theoretically offer 1/8 of the power at 1/4 the energy consumed. The requirement of variable speed or two-speeds is already used in the ANSI/APSP/ICC-15-2011 American National Standard for Residential Swimming Pool and Spa Energy Efficiency. Other states such as California have financial incentives to install variable speed pumps in swimming pools.

The option of implementing two speed drives in swimming pool pumps would not be so precise at setting speeds as VSD, and has much worse energy consumption at low speed than a VSD. Two-speed may be a good regulatory baseline, but is far from the optimum energy saving potential. Two-speed pumps are typically low efficiency operating on low speed, while the motors on variable speed products tend to hold up efficiency at lower speeds. A two-speed pump

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[6] Source: http://www.appliances.energy.ca.gov/AdvancedSearch.aspx. Accessed on March 2014. The Energy Factor (Gallons/watt-hr) calculated as per Head Curve-C of a plumbing system, which represents typical pools using 2" pipe size. The plumbing curve crosses the pump's head curve at a single point, called the operating point of the pump/plumbing system. The Energy Factor is standardised in ANSI/APSP/ICC-15a 2013 American National Standard for Residential Swimming Pool and Spa.

operating at half speed can be expected to save up to 55%, while a good variable speed one could save theoretically up to 75%. The variable speed can be set to the lowest speed that works for the pool, while the two-speed offers only 2 choices. The scenario analysis in section 8.4.5 presents an estimation of the potential impacts of this policy option.

However, European swimming pool pump manufacturers represented in Europump association do not fully acknowledge these claims for savings. The key arguments against is that the diversity of swimming pool pumps and their uses in the EU would make it difficult to state that VSD would be a beneficial solution for all swimming pool applications. Not all swimming pool pumps would need a pump at variable speed, some could meet the water pumping needs with two-speed pumps or with fixed-speed pumps controlled by contactors. This would depend much on the load profile and the use pattern of the swimming pool and the pump, and so the implementation of VSD in all pumps in the EU might be counter-productive. However, it is unclear why this situation might be significantly different to that found in the USA.

Facing the lack of agreement on the potential benefits of this policy option, no mandatory requirements of speed controls can be proposed for swimming pool pumps.

8.2.2.3 *Mandatory use of time controls for swimming pool pumps*

In the absence of speed controls, time-switches or other controller with time control function could be added to swimming pool pumps. An appropriate time switch sold together with the pump could limit the operation time of the pumps. This would reduce the energy consumption of the pump in hours where the turnover is not necessary. This requirement is already applied in some states of the US such as Florida[7].

For domestic swimming pools, the turnover time could be estimated as 8 hours in Europe, meaning that the pump should turn over the pool water at least once in this period. This could vary for the time in which any additional equipment such as water heater or water treatment dosing equipment need to work to maintain the water temperature or quality.

The main barrier for this policy option is that the turnover rate for swimming pool pumps is not homogenised across Europe, and usually depend on national health and safety requirements. In any case, the installer or the user, depending on the legal requirements applicable in their country, could adjust the time switch.

It is therefore recommended that mandatory use of time controls is put forward into regulation for swimming pool pumps. The potential energy savings would therefore vary depending on the specific regulation in each Member State. To give an example, if 25% of all the pumps used in the EU are operating for 30% longer than required, then a 7.5% reduction in energy consumption could be expected at EU level.

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[7] http://www.floridapoolpro.com/industry/govtrelations/Energy%20Law%20Code%20QA.pdf (accessed on March 2014)

8.2.2.4 *Minimum Energy Performance Standards for swimming pool pumps*

Ecodesign Implementing Measures regarding energy efficiency of products (i.e. Minimum Energy Performance Standards) are already in place for some water pumps and circulators, in the form of Minimum hydraulic Efficiency Index (MEI) and/or Energy Efficiency Index (EEI). [8], [9]

A Regulation on energy efficiency of swimming pool pumps in the form of MEI or EEI, based on parameters and approaches comparable to other pump regulations mentioned before, would help homogenise the regulation affecting water pumps in the EU. It could consist on an extension of the existing MEI and EEI methodologies for pumps and circulators to define the most beneficial energy performance index scheme for swimming pool pumps.

This section presents the possible benefits and downsides of a regulation for swimming pool pumps based on Minimum Energy Performance Standards.

Tasks 6 and 7 of this preparatory study show the potential energy savings and the associated cost increase for swimming pool pumps. Hydraulic improvements and motor improvements for these pumps would allow reductions of around 0.5% to 1.5% of annual energy consumption per pump. The use of speed controls could realise conservative energy savings of 10% to 40% per year, although there is not yet stakeholder consensus on this claim. In this report, an average energy saving of 10% for domestic swimming pool pumps below 2.2 kW and 40% for swimming pool pumps above 2.2 kW are assumed in all calculations. Assuming these potential savings, the payback times of these improvement options for domestic swimming pool pumps below 2.2 kW are between 3 and 45 years. In the case of domestic and commercial swimming pool pumps over 2.2 kW, the payback times would be between 1 and 2.5 years.

Regarding the potential benefits of speed control, some literature sources quote from 50% to 80% energy savings in swimming pools after the substitution of a single speed pump by a variable speed pump[10]. The US Energy Star scheme estimates that multiple speeds in swimming pool pumps could potentially save over $100 million per year in electricity across the US[11]. European swimming pool pump manufacturers represented in Europump association do not fully acknowledge these potential savings. The potential energy savings of speed control for swimming pool pumps in Europump's opinion would be between 10% to 12.5%.

Furthermore, according to Europump, swimming pool pumps are designed to meet 24 hours water circulation, and therefore there would be little or no scope to vary the speeds. Often these pumps have inverters that allow the exact flow to be achieved, which optimises the energy

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[8] Commission Regulation (EC) No 641/2009 of 22 July 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products.

[9] Commission Regulation (EU) No 547/2012 of 25 June 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for water pumps.

[10] Hunt and Easley (2012) Measure guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings.

[11] http://www.energystar.gov/certified-products/detail/pool_pumps

consumed by the pump. Other stakeholder suggested that for domestic swimming pools, the turnover time could be estimated as 8 hours in Europe.

Ideally, any regulation on energy efficiency of pumps should be based on the Extended Product Approach presented in Task 1 of this preparatory study. This would help homogenise the regulation affecting water pumps in the EU. The Extended Product Approach takes into account the load profile of pumps for specific applications, in a way that a single energy efficiency parameter (i.e. EEI, Energy Efficiency Index) would reflect the efficiency of the pump for a specific application and load profile. This would solve the question whether the speed controls are beneficial for all swimming pool pumps or not.

EEI is an efficiency index, where a lower value is equivalent to higher efficiency. It takes into consideration efficiency related factors from load profiles and control methods. The EEI is based on the market distribution of pumps in the EU and their efficiencies, and on the load profiles of the pumps equipped with fixed speed, variable speed or two speeds.

This EEI index is part of an on-going project on the Extended Product Approach being carried out by Europump and the University of Darmstadt, and expected to continue over 2015. Until that work is finished, the present preparatory study cannot develop policy recommendations based on EEI. The formulation of EEI values corresponding to each pump type and load profiles will have to be calculated during the above mentioned project, and standardised for the specific swimming pool pumps to be regulated. More information about the EEI is presented in Annex I

Another efficiency parameter, the Minimum hydraulic Efficiency Index (MEI), is defined in the Commission Regulation 547/2012 on ecodesign regulation for water pumps. MEI is a dimensionless figure that is derived from a complex calculation based on a pump’s efficiencies at the best efficiency point (BEP), 75% BEP and 110% BEP and the specific speed. MEI is based on the efficiency of swimming pool pumps at product level. MEI is a value between 0 and 1. This index value, multiplied by 100, corresponds to the percentage of pumps currently in the market that do not meet the required level of efficiency.

MEI is based on the market distribution of pumps in the EU and their efficiencies, but unlike EEI, the MEI does not take into account the load profiles of different pump applications.

For the aim of this preparatory study, different policy options or scenarios based on MEI are modelled in a scenario analysis in section 8.4. That analysis of different scenarios will help estimate and compare the potential benefits at EU level of regulation on swimming pool pumps with different levels of ambition. Section 8.6 will analyse other possible impacts of those policy options.

The MEI values are estimated based on the energy savings and market data for swimming pool pumps presented previously in Task 7 report of this study.

It would be reasonable to assume an MEI value of 0.5 for the average product placed on the market (sales). However, due to the long lifetime of these pumps, the energy (hydraulic) efficiency of the pump in the average installed stock would be a bit lower than the average pump sold today. This can be explained based on degradation in original hydraulic efficiency due numerous years of use for the installed stock and considering the natural evolution of the energy efficiency of the pumps over these years. In order to take into account this discrepancy, a penalty of 0.1 MEI is applied to the MEI value of average product sold (MEI = 0.5) in order to reflect the average energy consumption of the installed stock. Therefore, an MEI value corresponding to 0.4 is assigned to the Base-Cases analysed in this study.

To calculate the cumulative energy savings and consumer expenditure (changes in product purchase price and maintenance and repair costs)[12] from setting the different MEI requirements, the distribution of swimming pool pumps is split into 10 discrete bands from 0% (reference, denoted by WP: Worst pump) to 100% cut off, as presented in Table 8-18-1. The maximum energy savings presented in this table refer to the potential energy savings related to the hydraulic efficiency and motor improvements, since as discussed in Task 7 and previously in this section, the application of Variable Speed Drives might not be beneficial for all swimming pool pumps in the EU market.

An additional scenario is presented in section 8.4 using the maximum energy savings due to VSD as the BAT level, in order to estimate what would be the maximum potential energy savings of speed controls at EU level.

It is important to note that this method is an approximation made by the study authors and would need an exhaustive data collection on pumps in the EU market in order to calculate the appropriate MEI values.

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[12] Installation cost is not considered as a parameter here as there are no changes in installation cost concerning the hydraulic efficiency improvements for the various design options considered for these Base-Cases, as described earlier in Task 7.

Table 8-1: Estimation of swimming pool pumps market distribution

	Cut-off value									
Reference product	BAT						BC			WP
Base-case 1: SPPS (Domestic swimming pool pumps up to 2.2 kW)										
Cut-off	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%
MEI	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Annual energy consumption per product (kWh)	1,411	1,416	1,421	1,426	1,430	1,435	1,440	1,445	1,450	1,454
Difference in annual energy consumption to Base-Case (%)	-2.0%	-1.7%	-1.3%	-1.0%	-0.7%	-0.3%	0.0%	0.3%	0.7%	1.0%
Difference in purchase cost to Base-Case (%)	4.0%	3.2%	2.4%	1.6%	0.8%	0.0%	0.0%	0.0%	-0.8%	-1.6%
Difference in life cycle cost to Base-Case (%)	-1.6%	-1.4%	-1.1%	-0.8%	-0.6%	-0.3%	0.0%	0.3%	0.6%	0.8%
Base-case 2: SPPL(Domestic and commercial swimming pool pumps above 2.2 kW)										
Cut-off	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%
MEI	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Annual energy consumption per product (kWh)	19,845	19,913	19,980	20,048	20,115	20,183	20,250	20,318	20,385	20,453
Difference in annual energy consumption to Base-Case (%)	-2.0%	-1.7%	-1.3%	-1.0%	-0.7%	-0.3%	0.0%	0.3%	0.7%	1.0%
Difference in purchase cost to Base-Case (%)	4.0%	3.2%	2.4%	1.6%	0.8%	0.0%	0.0%	0.0%	-0.8%	-1.6%
Difference in life cycle cost to Base-Case (%)	-1.9%	-1.6%	-1.3%	-1.0%	-0.6%	-0.3%	0.0%	0.3%	0.6%	1.0%

BAT: best energy efficient pump in the market
BC: Base-case
WP: worst energy efficient pump in the market

Based on the selected cut-off MEI values, the Implementing Measure could be developed with requirements of minimum efficiency (η) at Best Efficiency Point (BEP), at Part Load (PL), and at Over Load (OL) and phrased as follows:

Swimming pumps shall have a minimum efficiency:

— at the best efficiency point (BEP) of at least (η BEP)

— a minimum efficiency at part load (PL) of at least (η PL)

— a minimum efficiency at over load (OL) of at least (η OL):

$$(\eta\ BEP) = F_1 x + F_2 y - F_3 x^2 - F_5 y^2 - F_6 x y - C$$

$$(\eta\ PL) = F_7 \cdot (\eta\ BEP)$$

$$(\eta\ OL) = F_8 \cdot (\eta\ BEP)$$

Where:

$x = \ln (n\ s)$;

$y = \ln (Q)$;

ln = natural logarithm;

Q = flow in [m^3 /h];

n s = specific speed in [min –1]; and

C = specific values calculated for each pump type and MEI.

F_1 to F_8 = specific factors of the formulae calculated for each pump type.

Based on a market data collection, the C-values and function factors will need to be adjusted in the possible regulation so that MEI of 0.1 corresponds to banning 10% of the worst performing pumps of each type. An initial estimation by the study authors of the C-values is presented in Annex II. However, an exhaustive data collection on pumps in the EU market should be carried out in order to calculate the appropriate C-values.

The choice of the optimal cut-off values regarding energy savings and consumer expenditure is described in the scenario analysis, section 8.4. In that section, various possibilities of cut-off values are assessed in order to propose the best options and evaluate the potential energy savings at EU level.

8.2.2.5 *Voluntary use of correct sized pipes for swimming pools*

The size of the water pipes and the design of elbows and turns in them influence highly the friction of the fluid passing through them and therefore the energy consumption of the pump in the system. The SPATA Standards Volume Two (1999) give a Suction Velocity maximum 1.2 m/s and Return Velocity maximum 2.0 m/s. The Pool Water Treatment Advisory Group “Swimming Pool Water – Treatment and Water Quality Standards for Pools and Spas – Second Edition 2009” recommend 1.5 m/s suction and 2-2.5 m/s discharge. In principle, there would be no need for higher flow velocities, and therefore the pipe size could be designed accordingly.

The requirements on pipe design and time controls go beyond the ecodesign of swimming pool pumps, and are mostly responsibility of the designer or installer of the swimming pool system. Even though improvements on the pipe design could lead to optimisation of the energy consumed by swimming pool pumps, the manufacturers of swimming pool pumps do not have influence on the elements of the swimming pool system other than pumps.

It could be possible, however, that pump manufacturers include guidelines on the correct design and installation of elements of the pumping system with influence on the energy efficiency of the pump, such as pipe diameter and pipe elbows, in order to optimise the energy performance of the pump. A clear best practice could be given in printed materials and on the pump box to state the cost to the user of not sizing correctly the pipes.

In this context, installer education is needed. A voluntary agreement with installers for the use of properly sized connecting pipework could also be used to put forward this requirement. Installers would sign up to installer association voluntary agreements.

The following figure shows the difference in head loss between two different pipe sizes for a range of flow rates. For a pump rated at 150 l/m the difference in head loss due to pipe size is approximately 3 m. This is approximately equal to 110W of additional power, or 0.9kWh per day based on an 8-hour day.

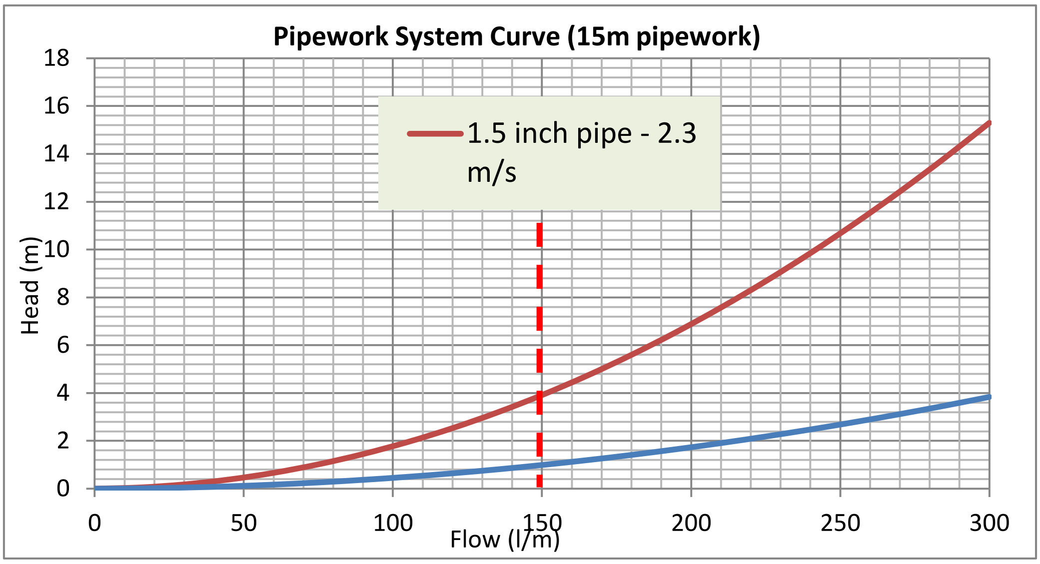

Figure 8-3: Difference in head loss between 2 inch and 1.5 inch pipe for a range of flow rates

Pumps would have to have inlet and outlet fittings sized for the correct sized pipes. A voluntary scheme for installers, through national installer associations, could be used to drive through this requirement, such as a label or certification to installations that respect the recommended pipe size. The real impact that such recommendations would have on pumps energy consumption can be estimated at around 10% savings, although more ambitious claims up to 40% can be found in the literature[13, 14].

8.2.3 Fountain, aquarium, pond, spa and counter current pumps

Fountain and pond pumps: pond pumps and fountain pumps are basically built in the same way and differ only for the point of work on the flow/head characteristic curve. Pond pumps drive water through a filter whereas fountain pumps are designed for higher heads for decorative features such as fountains or waterfalls. In pond pumps dirty water will be sourced from a ground filtration unit and often also from a protein skimmer that removes residue from the surface

Spa pumps: the same technology as swimming pool pumps but lower capacity. These pumps work in the same way as swimming pool pumps.

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[13] Residential Swimming Pool Efficiency, 2006. Prepared by Building a Safer Florida and the University of Florida's Program for Resource Efficient Communities

[14] 2008 California Building Energy Efficiency Standards. Residential Swimming Pools. Measure Information Template. Pacific Gas & Electric Company, 2006.

Counter-current pumps: the same technology as swimming pool pumps but bigger capacity. These pumps work in the same way as swimming pool pumps but at a higher fixed speed.

Aquarium pumps: circulation pumps connected to a device that works as a filter. Inside the filter, water is forced to flow through different types of filtering materials, in such a way that water is cleared from dirt and detoxified from fish waste. Most Aquarium pumps use the technology of integrated motor with wet rotor and nowadays aquarium pumps exclusively employ high efficiency permanent magnet motors.

The assessment of environmental impacts of fountain pumps, aquarium pumps, pond pumps, spa pumps and counter-current pumps made in Task 5 of this preparatory study showed that this group of pumps have little impact over the different impact categories, compared to the rest of pumps studied in ENER Lot 29. In Tasks 6 and 7, the technical improvements at a product and component level were studied to evaluate the improvement potential of these options. The result showed that the potential improvements offer very little energy savings per pump (between 0.25% and 1%), which at the end results in very high payback times. This is due to very specific use patterns (for spa, counter-current, fountain and pond pumps) and high efficiency of existing products in the EU market (for aquarium pumps).

Hence, Implementing Measures regarding mandatory requirements on energy efficiency for these pumps would not achieve great energy savings and would connote higher costs to consumers. However, requirements regarding the information that manufacturers offer to customers on energy efficiency can be recommended.

8.2.3.1 Information requirements for fountain, aquarium, pond, spa and counter current pumps

One of the key factors to ensure energy efficient pump systems is the correct dimensioning and use of the specific pumping system needed for each function. It is therefore recommended to set requirements of minimum information that the manufacturers should provide to users.

For fountain pumps, pond pumps, aquarium pumps, spa pumps and counter-current pumps, manufacturers should provide the following information:

- Information on how to install, use and maintain the water pump in order to minimise its impact on the environment.
- Information about the recommended use and load profiles for the pump shall be provided on the packaging and in the technical documentation of water pumps.
- Information concerning disassembly, recycling, or disposal at end-of-life of components and materials, shall be made available for treatment facilities;
- The energy efficiency of pumps (η) at Best Efficiency Point (BEP), at Part Load (PL), and at Over Load (OL) shall be indicated on the name plate and technical documentation of the product.

- The following information shall be provided: "The benchmark for most efficient pump is η BEP=##; η PL=##; and η OL= ##".[15]

The information listed above shall be visibly displayed on freely accessible websites of the water pump manufacturers.

8.2.4 End suction, submersible bore-hole and vertical multi-stage pumps

End suction water pumps: glanded single stage end suction rotodynamic water pumps. These pumps could either have own bearings and the suction side in axial and the water pressure outlet in radial direction in the case; the motor shaft is extended to become also the pump shaft with the suction side in axial and the water pressure outlet in radial direction or the suction side of the pump is in one line with the water pressure outlet of the pump. Such pumps have many uses, such as water supply or industrial cooling systems.

Submersible bore-hole water pumps: multi stage (i > 1)[16] rotodynamic water pumps designed to be operated in a borehole.

Vertical multistage water pumps: pumps with a glanded multi stage (i > 1) rotodynamic water pump in which the impellers are assembled on a vertically rotating shaft

The results of Task 7 of this preparatory study show that the potential energy savings of this kind of pumps is around 15% to 25% per year. This is mainly due to variable speed drives in the motors, but these technologies are already implemented in some existing pumps in the market. This means that many of the installed pumps in the EU are high efficient (i.e. 50% of end suction pumps and vertical multi-stage pumps; 15% of submersible bore-hole pumps[17]) and so the possibilities of improvement by application of Extended Product Approach at EU level would be lower for end suction and vertical multi-stage pumps than for submersible bore-hole pumps. However, the uptake of speed controls in these types of pumps would depend highly on the needs of the pump application for which they are designed. The hydraulic efficiency of end suction pumps, submersible bore-hole pumps and vertical multi stage pumps sold in the EU is thought to be high, as this is usually a requirement of the client.

The end suction, submersible bore-hole and vertical multi-stage pumps analysed in this preparatory study are commonly tailor-made and build especially to fit the customer's needs. These pumps have very specific functions and requirements, and as a rule, these pumps are not produced in mass. Some of these pumps are also large machines that consume big quantities of energy, so energy efficiency of the pump frequently plays an important role in the purchase decision. For these reasons, Ecodesign Implementing Measures regarding energy performance

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[15] No information can be found at the time of writing on the benchmark of fountain, aquarium, pond, spa and counter current pumps measured as efficiency at BEP, OL or PL. These parameters are not commonly published by manufacturers.

[16] Multi stage pumps are designed with multiple impellers in the same shaft.

[17] See Task 1 of the present study.

requirements would not accomplish a big shift in the EU market for end suction pumps, submersible bore-hole pumps and vertical multi-stage pumps.

The mandatory inclusion of Variable Speed Drives and controls or the recommendation of the minimum pipe size would not apply to these engineered pumps, since the load profile is much related to the specific need of the pump application, and the pump is usually designed accordingly.

Other options for EU product policy are energy labelling or specific design requirements, as in swimming pool pumps. No energy labelling requirements are proposed for end suction, submersible bore-hole and vertical multi-stage pumps, since the EU market of these pumps is mostly within business-to-business. Energy labelling is an effective policy tool for the consumer market to help consumers make the right choice of best performing product. However, energy labelling would not be effective as professional pump engineers and designers are capable of correctly dimensioning and designing pumping systems if they are provided with the relevant information from manufacturers. Furthermore, after observation of the maximum efficiency improvement potential of existing pumps, it can be said that there is not a large range between least and best performing products in the EU for creating different efficiency bands within the energy label. Still, information requirements could be recommended for these pump types, and thus this option will be discussed in the following section.

8.2.4.1 *Information requirements for end suction, submersible bore-hole and vertical multi-stage pumps*

One of the key factors to ensure energy efficient pump systems is the correct dimensioning, design and installation of the specific pumping system needed for each function. It is therefore recommended to set requirements of minimum information that the manufacturers should provide to designers, installers and users.

For end suction, submersible bore-hole and vertical multi-stage pumps, manufacturers should provide the following information:

- Information on how to install, use and maintain the water pump in order to minimise its impact on the environment.
- Information about the recommended use and load profiles for the pump shall be provided in the technical documentation of water pumps.
- Information concerning disassembly, recycling, or disposal at end-of-life of components and materials, shall be made available for treatment facilities.
- The energy efficiency of pumps (η) at Best Efficiency Point (BEP), at Part Load (PL), and at Over Load (OL) shall be indicated on the name plate and technical documentation of the product.

- The following information shall be provided: "The benchmark for most efficient pump is η BEP=##; η PL=##; and η OL= ##".[18]

8.3 Recommendations on standardisation mandates

As stated in the previous section, the method for calculation of the MEI and corresponding C-values and function factors for the swimming pool pumps covered in this study should be standardised. This can be done by means of a CEN standard or in the regulation issued in the framework of the Ecodesign Directive.

At the time of writing, the University of Darmstadt and Europump are carrying out research work in this context that would contribute to the development of a CEN standard for EEI calculation. This work is expected to continue over 2015. Standardisation of EEI calculation methods and generalisation in the EU market of EEI values could facilitate the correct selection of sizing of water pumps depending on the load profile of the application and therefore provide energy savings for pump applications with variable load.

It would also be necessary to standardise across EU Member States the minimum water quality requirements for swimming pools and therefore a minimum turnover rate for domestic and commercial swimming pool pumps. This influences the load profile of the pumps and thus their energy consumption. A working group at CEN (CEN/TC 164) is working on how to standardise drinking water across the EU, including swimming pool water within their work since it can enter the mouth when bathing. On the other hand, some Member States have less exigent requirements for swimming pool water. A common quality standard and minimum turnover rate across the EU would ease the calculation of the energy consumption of pumps and the definition of the optimum load profiles.

8.4 Scenario analysis

8.4.1 Timeline of specific ecodesign measures

The Ecodesign requirements discussed hereafter are proposed in a provisional timetable consisting in one or several progressive steps. Either option has benefits and drawbacks: a single tier would cut off the worst products in the market in one step, thus achieving energy savings in a relatively short time frame. It would also be a simple regulation that would ease its implementation and comprehension by manufacturers and consumers. This option could be possible for the pumps in ENER Lot 29 proposed for regulation since the available improvement

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[18] No information can be found at the time of writing on the benchmark of end suction, submersible bore-hole and vertical multi-stage pumps measured as efficiency at BEP, OL or PL. These parameters are not commonly published by manufacturers.

options are already implemented in some pumps in the market and the redesign cycle of these pumps is relatively short.

Additional tiers would allow setting several progressive levels of ambition and introducing new standards developed (i.e. EEI calculation method). These steps allow implementing ambitious requirements in a long term, so that the benefits obtained are optimised with respect to the redesign efforts to be done by manufacturers.

The implementation of Ecodesign requirements in the form of tiers takes into account the redesign cycles of around 2 to 4 years[19], as stated in the report of Task 2 of this preparatory study, and the availability of new technologies. It also enables to keep the most ambitious targets as a final goal and gives a clear signal to industry regarding the direction in which the market should be heading. As seen in Task 7, the most efficient technologies are already available in the market and there is no BNAT expected to be developed in the near future. For this reason, it can be thought that a tiered approach in 2-year steps could be beneficial in terms of energy and economic savings. A maximum of three tiers is considered sufficient to introduce ambitious requirements and provide a long-term roadmap to the manufacturers. In order to simplify the assessment, the scenario analysis has been carried out by using tiers at 2-year steps, but the timeline for the entry into force of the first tier would depend on the level of ambition of the policy. It would be possible to make a first tier mandatory after one year of the entry into force of the regulation, if this first tier does not require high investment and redesign efforts from the manufacturers. Following tiers could introduce more ambitious requirements 3 and 5 years after the regulation.

The potential benefits in terms of energy savings and the related consumer expenditure estimated for each of the approaches proposed of one, two and three tiers will be analysed in detail in the Scenario Analysis.

The specific ecodesign requirements discussed hereafter are therefore based on the following tiers of their combinations:

- **First tier**: 2016 or two years after the approval of the proposed Implementing Measures;
- **Second tier**: 2018 or four years after the approval of the proposed Implementing Measures; and
- **Third tier**: 2020 or six years after the approval of the proposed Implementing Measures.

8.4.2 **Type of scenarios considered**

Based on the policy options proposed in the previous section, different scenarios were drawn up to illustrate quantitatively the improvements that each possible MEPS could achieve.

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[19] One manufacturer stated that the redesign cycles of end suction pumps, submersible bore-hole pumps and vertical multi-stage pumps is of around 10 years.

The implementation of different sets of improvements options at EU level by 2040 was compared to a reference scenario of no additional policy. In this scenario, the current situation and trends are extended to the future and policy does not influence their evolution. This scenario is also called the "Business-as-usual" (BaU) scenario. This situation may be recommended in cases where intervention from policy is not expected to provide significant gains, or when these gains would entail too high costs for customers, too much burden to manufacturers, or thwart innovation. This scenario reflects the natural evolution of the market assuming no further changes in energy performance of the new pumps manufactured if no new policy is adopted. In other words, the BaU can therefore also be represented by MEI cut-off value as zero (0).

An Excel tool was created to allow the impacts of the different scenarios to be modelled from 2013 to 2040. The time duration (28 years) of the scenario analysis is more than the longest lifetime of the Base-Cases considered (i.e. 20 years). Ecodesign Implementing Measures only apply to the new sales. The choice of long duration of scenario analysis in this section allows replenishment of the overall EU stock of pumps by the more efficient pumps (due to their sales resulting from Ecodesign Implementing Measures), thus reflecting on the overall energy savings potential and impact on consumer expenditure. The four policy options scenarios (see Table 8-28-2) are compared against the BaU scenario in order to estimate the overall potential of energy savings and consumer expenditure impact of potential Implementing Measures.

The scenario analysis is performed for only those pumps for which specific ecodesign requirements are recommended earlier, which include:

- Base-Case 1: Domestic swimming pool pumps up to 2.2 kW; and
- Base-Case 2: Domestic/commercial swimming pool pumps over 2.2 kW.

Four policy scenarios are analysed, in order to compare the potential benefits and economic impacts on consumers of policies with different levels of ambition. The Scenario 1 corresponds to the approach taken in the regulation on water pumps issued from the preparatory study ENER Lot 11 (Commission Regulation (EU) No 547/2012). The Scenario 2 achieves the same level of ambition than Scenario 1 in a shorter time frame. The Scenario 3 follows the two tiers of Scenario 1 and adds more ambitious requirements in a third tier at long term, but without achieving the level of BAT. The Scenario 4 represents a very ambitious (and unsuitable) scenario in which any product worse than the EU average would be banned for sale at short term, and the BAT would become mandatory at EU level at medium term. This scenario is only intended to show which is the maximum potential savings of MEPS for swimming pool pumps at EU level.

Table 8-2: Proposed cut-off scenarios

	MEI*		
	Tier 1: 2016	Tier 2: 2018	Tier 3: 2020
Scenario 0 (BaU)	0	0	0
Scenario 1	0.1	0.4	-
Scenario 2	0.4	-	-
Scenario 3	0.1	0.4	0.7
Scenario 4	0.4	1	-

*MEI = 0.1 corresponds to the worst performing product in the market.
MEI = 0.4 corresponds to the Base-Case.
MEI = 1 corresponds to the BAT.

For each of these four-policy option scenarios (BaU excluded), following three different possibilities are further analysed as sub-scenarios to take into account the consumer market response to the potential Implementing Measures (entry into force of the MEI cut-off requirements):

- Pessimistic sub-scenario: the ban of pumps below a certain MEI will lead to increased sales of the least efficiency permitted. For example, an MEI requirement of 0.1 would mean that the worst 10% of pumps are improved to the 20% cut off line. The MEI requirement of 0.2 is calculated by assuming that the worst 20% pumps improve to the 30% cut off. This is repeated to the MEI requirement of 1.0.
- Pragmatic sub-scenario: the ban of pumps below certain MEI will lead to increased sales of mid-range efficiency pumps. For example, an MEI requirement of 0.1 would mean that the worst 10% of pumps are improved to the 40% cut off line (an MEI jump of 0.3 points). The MEI requirement of 0.2 is calculated by assuming that the worst 20% band of pumps improve to the 50% cut off. This is repeated to the MEI requirement of 1.0.
- Optimistic sub-scenario: the ban of pumps below certain MEI will lead to increased sales of high efficiency pumps (i.e. the efficiency of the BAT)[20].

Therefore, in total twelve scenarios are compared with the BaU scenario in order to estimate the overall potential of the four options of MEPS.

The assumptions about consumer response to the MEI requirements, banning the share of swimming pool and submersible bore-hole pumps below the MEI cut-off value for the four policy option scenarios across the three different possibilities (sub-scenarios) are presented in Table 8-3. The efficiency numbers in this table represent the value to which the worst performing pumps are improved to, under each of the sub-scenarios of concerning the tiers proposed for the

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[20] This sub-scenario is unlikely but allow estimating the maximum energy savings.

four policy options. This allows to in turn calculate the energy and economic inputs for the policy option scenarios.

Table 8-3: Improvement of worst performing pumps due to MEI requirements, for different levels of market response

Scenario	Sub-scenario	Expected efficiency of the worst performing pumps after a cut-off regulation entries into force		
		Tier 1	Tier 2	Tier 3
Scenario 1	Pessimistic 1	0.2	0.5	-
	Pragmatic 1	0.4	0.7	-
	Optimistic 1	1	1	-
Scenario 2	Pessimistic 2	0.5	-	-
	Pragmatic 2	0.7	-	-
	Optimistic 2	1	-	-
Scenario 3	Pessimistic 3	0.2	0.5	0.8
	Pragmatic 3	0.4	0.7	1
	Optimistic 3	1	1	1
Scenario 4	Pessimistic 4	0.5	1	-
	Pragmatic 4	0.7	1	-
	Optimistic 4	1	1	-

8.4.3 Inputs to scenario analysis tool

An Excel tool was created to allow the impacts of the different scenarios to be modelled (2013-2040). The tool was designed in a simple manner and relies on the following assumptions:

- The model builds upon a discrete annual basis to match the available data.
- Sales and stock forecast detailed in Task 2 report were used as input. The annual growth rate has been estimated as 3% from 2011 until 2040.
- 70% of the annual sales are replacement sales (for replacement of the existing installed stock, meaning that 30% of the annual sales are for new installations). The pumps that arrive to their end of lifetime are subtracted from the stock.
- Electricity consumption and consumer expenditure were judged to be the most relevant and representative indicators to be modelled using the tool and to allow the environmental cost – benefits to be compared with other Ecodesign Lots.
- Due to the growth of the market explained above, by 2040 the total electricity consumption in the use phase by swimming pool pumps at EU level is estimated as 16.4 TWh for swimming pool pumps below 2.2 kW, and 5.5 TWh for swimming pool pumps above 2.2 kW (i.e. 2.4 times higher than in 2011)

- The tool calculates the cost in Euros and electricity in GWh related to water pumps, for the different MEPS scenarios.
- The electricity results are not limited to the use phase but that into account the energy required over the whole lifetime (including the manufacturing distribution and end-of-life phases).
- Energy consumption is allocated uniformly over the lifetime of the product although in theory this is only true for the use phase. Given the relatively small shares of other life cycle phases in energy consumption (see Task 5), this assumption is considered reasonable in order to carry out the analysis; a more "realistic" modelling would not make a significant difference to the overall results.
- Expenditure measures the yearly value of the entire market. It consists of the money spent to buy the product (purchase and installation price, if any), taken into account at the time of purchase, and the operating costs (energy, maintenance and repair costs, if any), which are spread over the lifetime of the machine.

The electricity consumption and economic inputs used for the four policy option scenarios are presented in Table 8-4.

Table 8-4: Electricity consumption in the use phase and economic inputs for the policy option scenarios

	MEI 0.1			MEI 0.4			MEI 0.7			MEI 1.0
	Pessimistic	Pragmatic	Optimistic	Pessimistic	Pragmatic	Optimistic	Pessimistic	Pragmatic	Optimistic	Pessimistic Pragmatic Optimistic
Base-case 1: SPPS										
Annual electricity consumption (kWh)	1,432	1,431	1,429	1,428	1,424	1,418	1,420	1,413	1,413	1,411
Purchase cost (€)	333	334	335	334	336	339	339	342	342	343
Maintenance cost (€/year)	0	0	0	0	0	0	0	0	0	0
Base-case 2: SPPL										
Annual electricity consumption (kWh)	20,142	20,129	20,088	20,082	20,028	19,946	19,960	19,865	19,865	19,845
Purchase cost (€)	1,516	1,517	1,523	1,518	1,528	1,542	1,540	1,556	1,556	1,560
Maintenance cost (€/year)	49	49	49	49	49	49	49	48	48	48

8.4.4 Comparison of scenarios

This section provides a comparison of the results of the twelve policy option (sub-)scenarios against the BaU scenario over the period 2013-2040 for the following two indicators:

- Total electricity consumption at EU level: this includes the electricity consumed over the life cycle of the product, divided per year of lifetime; and
- Total consumer expenditure at EU level: this includes the life cycle cost of products divided per year of lifetime.

This comparative analysis is carried out for each of the two Base-Cases recommended for specific ecodesign requirements. The comparative analysis for these two indicators is presented for specific years in the period of analysis: 2018, 2020, 2030 and 2040.

The selection of these years allows for reflecting the savings across a wide timeline, reflecting the progressive penetration of more energy efficient pumps (as required by the different requirements on MEI and tiers for the twelve policy option scenarios) in the EU. The year 2018 corresponds to the time when the more energy efficient pumps just start to appear in the installed stock (2 years after the first tier of requirements). Year 2020 corresponds to the EU 2020 headline target set in the Europe 2020 strategy[21]. Year 2030 corresponds to almost half of the EU installed stock of ENER Lot 29 pumps represented by more energy efficient pumps. Lastly, year

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[21] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF

2040 corresponds to the time by when most of the EU installed stock of pumps is replenished by more energy efficient pumps (as required under the 12 policy option scenarios).

The comparison of scenarios is carried out regarding total energy consumption of the stock of pumps in the EU and the associated consumer expenditure per year.

- **Total electricity consumption at EU level**

The savings in annual electricity for each of the two Base-Cases for the twelve policy option scenarios are calculated by subtracting the overall annual electricity consumption in the policy option scenarios from those of BaU scenario.

Figure 8-4 to Figure 8-6 present the comparison of annual savings in electricity for each of the Base-Cases for the twelve different sub-scenarios[22].

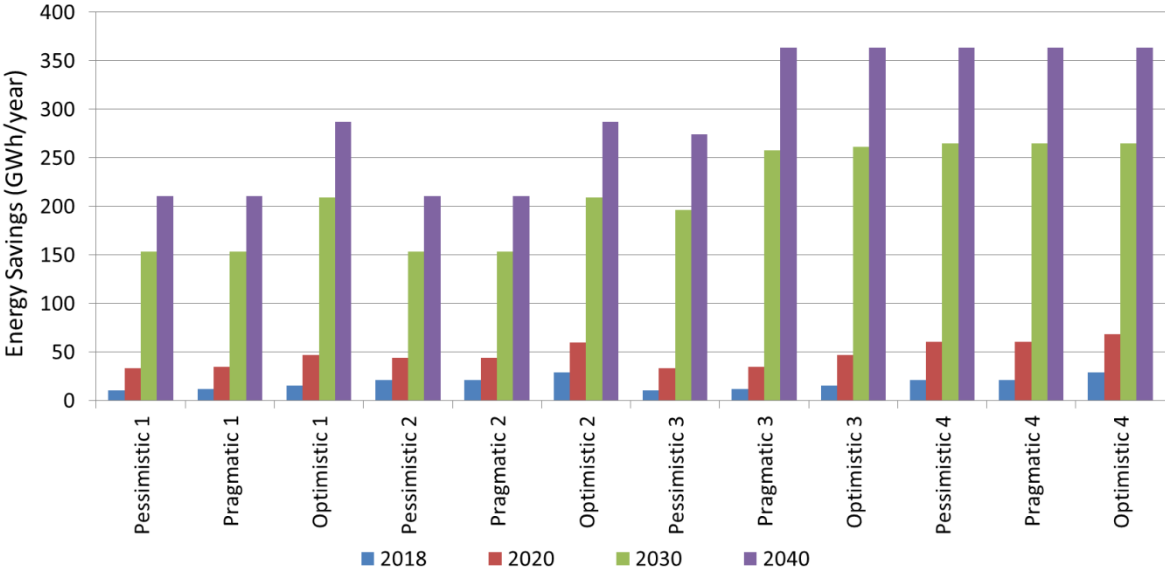

Figure 8-4: Annual electricity savings at EU level (in GWh) for BC 1 across four key years for the 12 policy option scenarios

For Base-Case 1, the most ambitious scenario corresponds to Scenario 4 (cut-offs of 0.4 and 1.0 in 2016 and 2018 respectively), which could save up to around 0.35 TWh per year in 2040 at EU level. If the most pessimistic scenario is considered (i.e. Scenario 1, cut-offs of 0.1 and 0.4 in 2016 and 2018 respectively); the maximum electricity savings at EU level in the same year would be around 0.2 TWh.

In this comparison of scenarios, it can be seen that the Scenario 2 (a single tier at 0.4) could bring savings faster than the Scenario 1 (two tiers at 0.1 and 0.4), but the difference in energy savings potential is negligible.

The difference between the maximum potential energy savings in pragmatic and optimistic scenarios of a cut-off of 0.7 (in Scenario 3) and 1.0 (Scenario 4) is also negligible; except in the

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[22] Note that the scale of the Y-axis is not always the same in all figures but was chosen each time to allow a comprehensive understanding of the figures.

case of the pessimistic sub-scenario. Scenario 4 would achieve slightly higher electricity savings faster than Scenario 3.

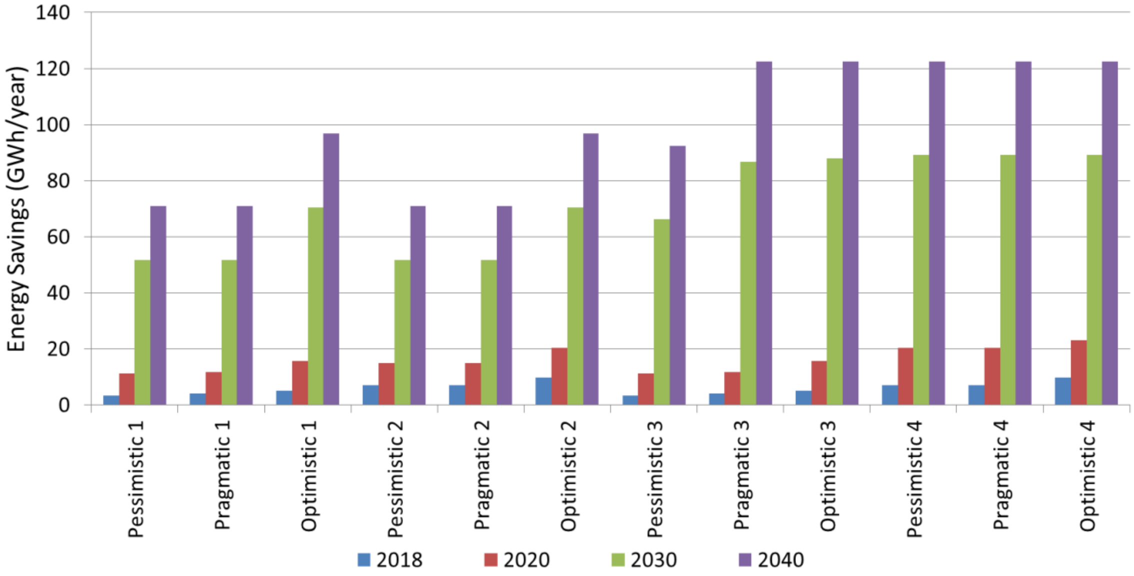

Figure 8-5: Annual electricity savings at EU level (in GWh) for BC 2 across four key years for the 12 policy option scenarios

For Base-Case 2, the most ambitious scenario corresponds to Scenario 4, which could save up to around 0.12 TWh per year in 2040 at EU level. The most pessimistic scenarios are Scenario 1 and 2, which would achieve less than 0.1 TWh per year in 2040.

As in the previous Base-Case, the difference in electricity savings potential between Scenario 1 and Scenario 2 is negligible, as well as the difference between Scenario 3 and Scenario 4, except in the case of the pessimistic sub-scenario. Scenario 4 would achieve slightly higher savings faster than Scenario 3 (the energy savings for pessimistic sub-scenario 3 are estimated to be 0.09 TWh as compared to 0.12 TWh for pessimistic sub-scenario 4).

In both cases, Scenario 2 and Scenario 4 could bring electricity savings faster at EU level than Scenario 1 and Scenario 3, respectively.

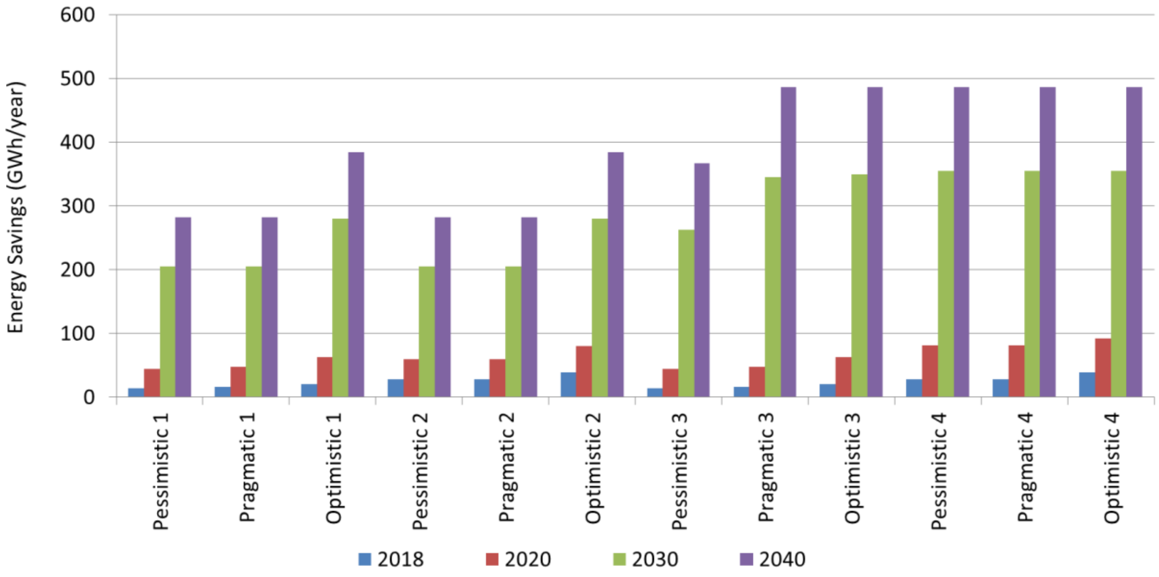

Figure 8-6: Total annual electricity savings at EU level (in GWh) for the selected Base-Cases (BC 1, BC 2) across four key years for the 12 policy option scenarios

The comparison of the total electricity savings achieved by policy implementation on the two Base-Cases included in this analysis shows that the maximum annual savings that could be achieved by 2040 are between 0.29 TWh and 0.49 TWh per year at EU level, depending on the level of ambition of the scenario selected.

There is not much difference between Scenario 1 and Scenario 2. In a similar way, the potential savings of Scenario 3 and Scenario 4 are similar, although the pessimistic sub-scenario 3 achieves notably lower energy savings.

Total consumer expenditure at EU level

The reduction in annual consumer expenditure for each of the Base-Cases for the twelve policy option (sub-)scenarios are calculated by subtracting the overall annual consumer expenditure in the policy option scenarios from those of BaU scenario.

Figure 8-7 to Figure 8-9 present the comparison of annual consumer expenditure reduction for each of the Base-Cases (BC 1 and BC 2) for the twelve different (sub-) scenarios[23].

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[23] Note that the scale of the Y-axis is not always the same in all figures but was chosen each time to allow a comprehensive understanding of the figure. Also, negative values in the figures below represent increase in consumer expenditure.

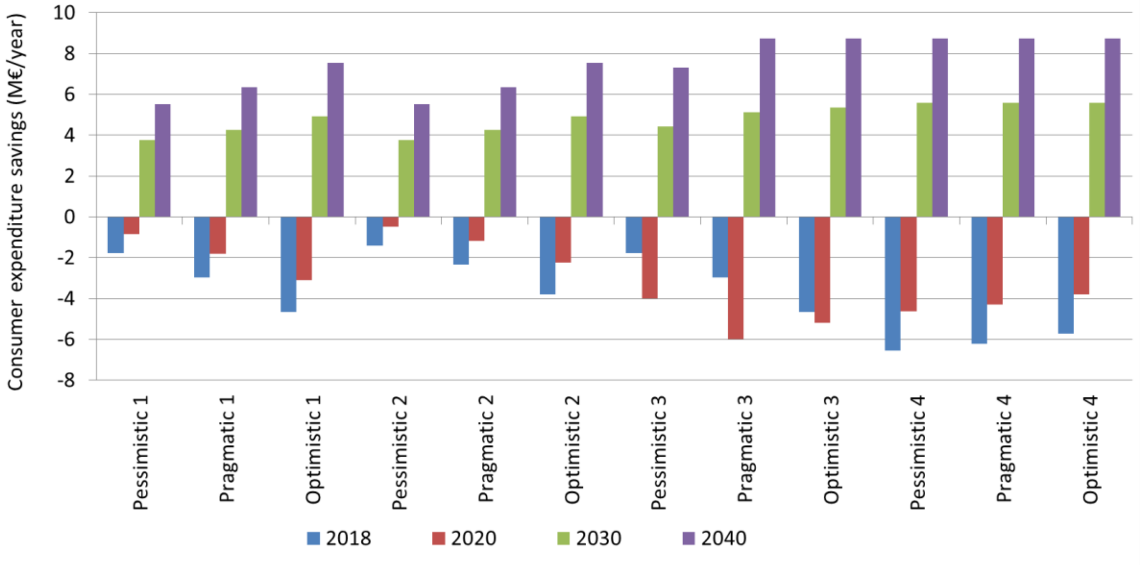

Figure 8-7: Annual consumer expenditure reduction at EU level (in Million Euros) for BC 1 across four key years for the 12 policy option scenarios

For BC 1, the consumer expenditure increases with the enforcement of policy scenarios, up to 6 M€ per year at EU level in 2018 in the pessimistic Scenario 4.

This can be explained on the basis of the very small energy saving potential and high cost increase of the product, which leads to a very long payback time. By 2030, in all the scenarios the consumer expenditure would be lower than in the BaU scenario.

The maximum savings in consumer expenditure at EU level in 2040 would be around 8.5 M€.

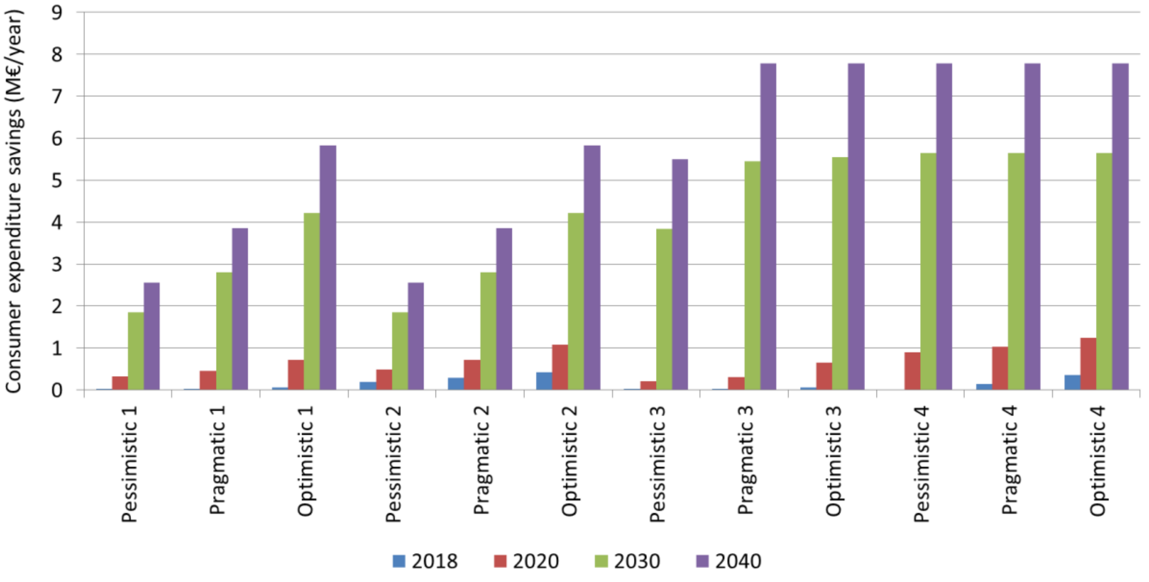

Figure 8-8: Annual consumer expenditure reduction at EU level (in Million Euros) for BC 2 across four key years for the 12 policy option scenarios

There is a reduction in consumer expenditure across all the twelve scenarios considered for BC 2 by as soon as 2018. In one of the most ambitious scenarios (i.e. Scenarios 3 and 4), the maximum reduction in consumer expenditure at EU level in 2040 would be between 5.5 and 7.8 M€.

In the most pessimistic scenario, the total expenditure savings per year at EU level in 2040 would be of 2.5 M€.

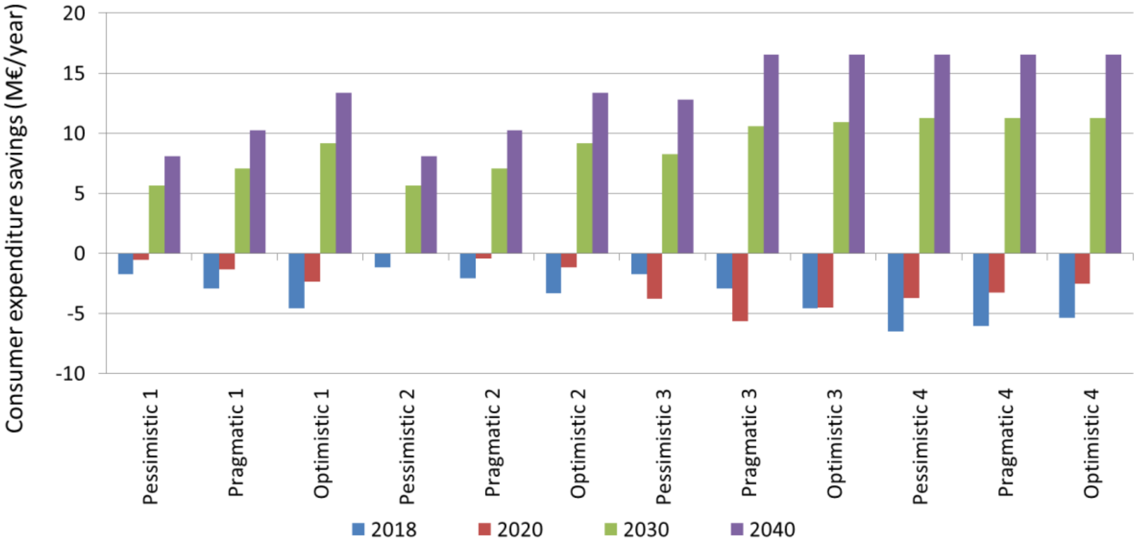

Figure 8-9: Annual consumer expenditure reduction at EU level (in Million Euros) for the selected Base-Cases (BC 1, BC 2) across four key years for the 12 policy option scenarios

The comparison of the total consumer expenditure achieved by policy implementation on all the Base Case included in this analysis shows that the maximum reduction that could be achieved in 2040 are between 8 M€ and over 15 M€ at EU level. There is not much difference between Scenario 1 and Scenario 2; and between Scenario 3 and Scenario 4.

8.4.5 Additional scenario: potential benefits of speed controls

As discussed in section 8.2.2.4, there is no clear agreement on the potential benefits of Variable Speed Drives for swimming pool pumps. There might be a big difference in the results of the scenario analysis presented above if the Variable Speed Drive technology is considered as BAT for all swimming pool water pumps. However, this option has not been considered the BAT option for all the pumps under study since it would only lead to energy savings in the case of part load operation. Thus, enforcing VSD to all clean water pumps in the market regardless of their load profiles would entail drawbacks for fixed-speed operation, and at the moment there is no indicator for energy efficiency that can take into account the load profiles of different pump applications. This could be done when the Energy Efficiency Index (EEI) calculation method will be available for clean water pumps studied within this preparatory study.

With the aim of assessing the potential energy savings of VSD technology, an additional scenario including the enforcement of VSD in 2020 is modelled for each of the Base-Cases. Table 8-5 shows the inputs used for this additional scenario. The annual consumption and life cycle cost per product are calculated based on the data presented for the Base-Case in Task 5 and the difference in annual energy consumption and purchase cost presented in Task 6 of this preparatory study.

Table 8-5: Electricity consumption in the use phase and economic inputs for Scenario 5

Reference product	VSD	BC
Base-case 1: SPPS (Domestic swimming pool pumps up to 2.2 kW)		
Annual electricity consumption per product (kWh)	1,267	1,440
Difference in annual electricity consumption to Base-Case (%)	-12.0%	-
Difference in purchase cost to Base-Case (%)	204.0%	-
Difference in life cycle cost to Base-Case (%)	8.4%	-
Base-case 2: SPPL (Domestic and commercial swimming pool pumps above 2.2 kW)		
Annual electricity consumption per product (kWh)	11,745	20,250
Difference in annual electricity consumption to Base-Case (%)	-42.0%	-
Difference in purchase cost to Base-Case (%)	104.0%	-
Difference in life cycle cost to Base-Case (%)	-36.4%	-

As the pragmatic option represents most closely the reality, hence it was chosen for the analysis of this Scenario 5 instead of the pessimistic or optimistic options. It is however expected that the order of magnitude of impacts of the parameters assessed in sensitivity analysis would be similar of these other two options (pessimistic and optimistic) as that of pragmatic option.

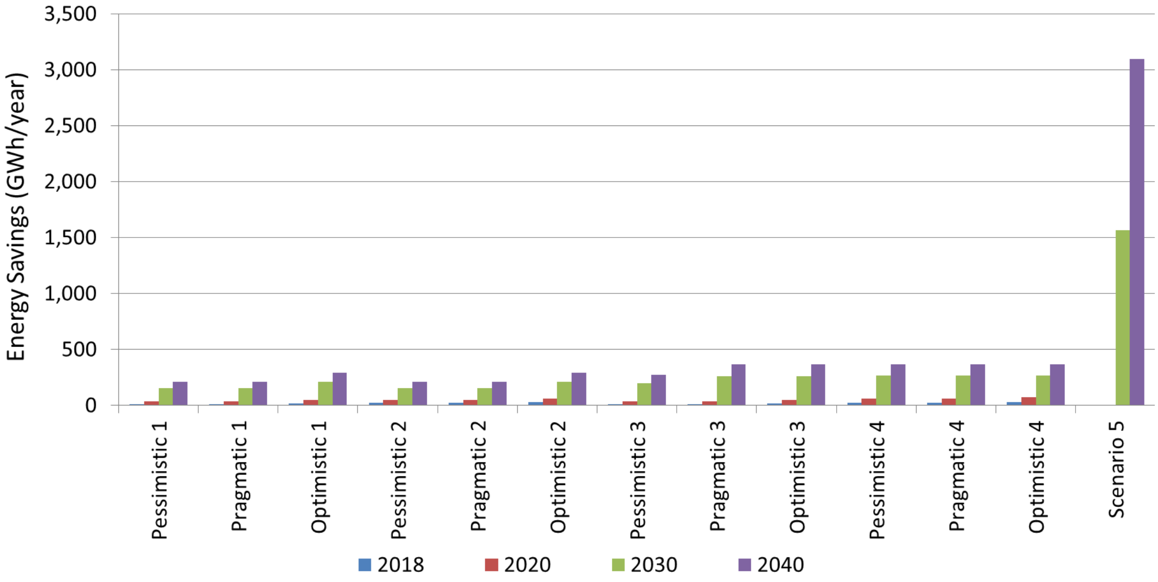

Figure 8-10: Annual electricity savings at EU level (in GWh) for BC 1

For domestic swimming pool pumps under 2.2 kW, the introduction of VSD as the fifth policy scenario would achieve higher electricity savings, around 1.5 TWh per year in 2030 and above 3 TWh per year in 2040.

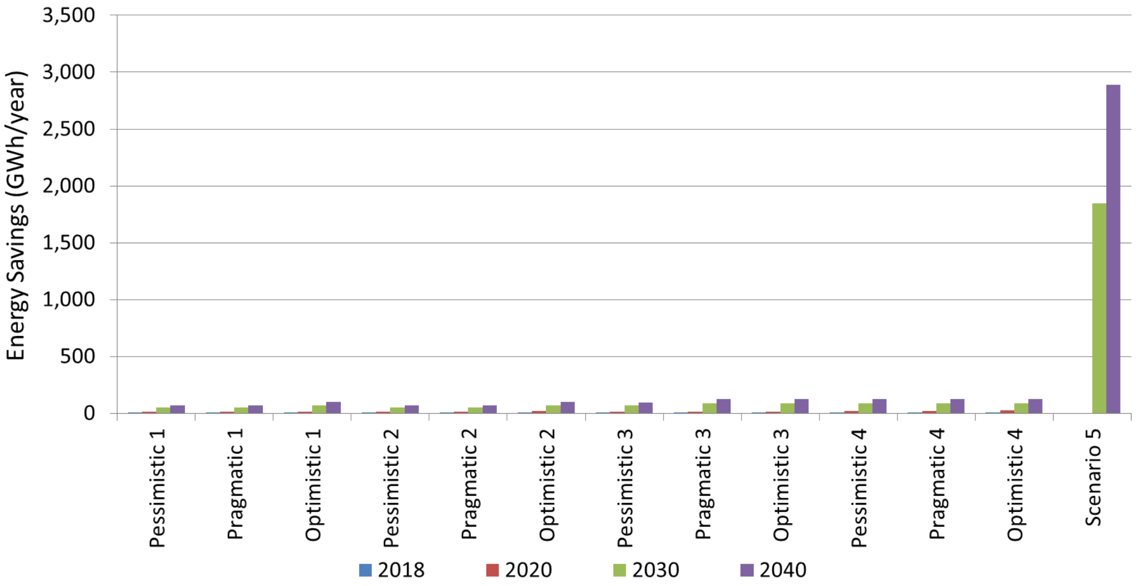

Figure 8-11: Annual electricity savings at EU level (in GWh) for BC 2

The introduction of VSD technology as a policy option in 2020 for swimming pool pumps over 2.2 kW would offer notably higher savings, reaching 2.8 TWh savings per year at EU level in 2040.

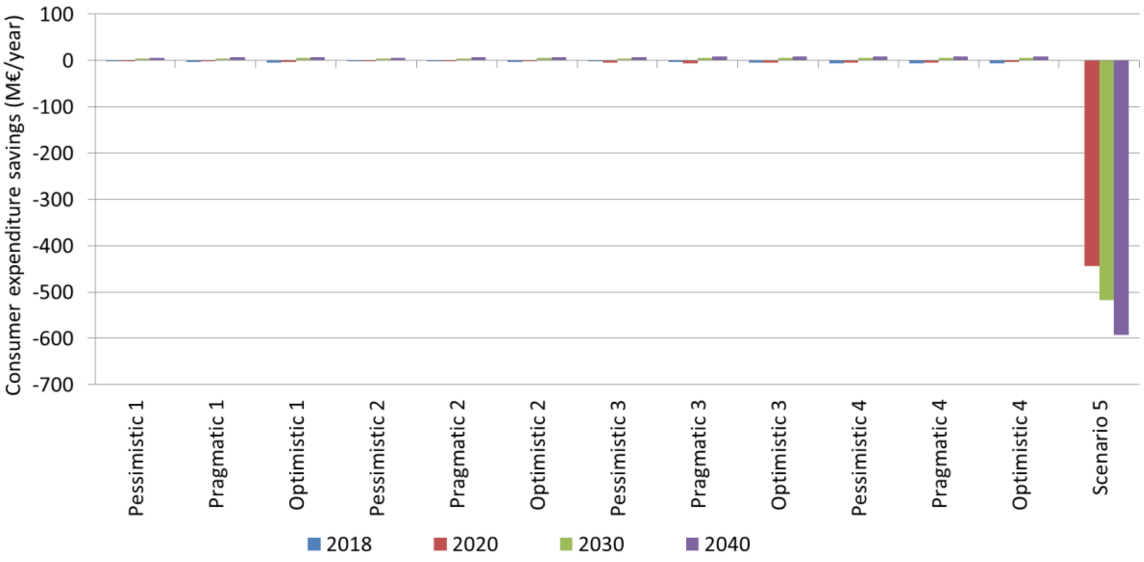

Figure 8-12: Annual consumer expenditure reduction at EU level (in Million €) for BC 1

Regarding the consumer expenditure of domestic swimming pool pumps under 2.2 kW, the introduction of VSD technology as mandatory requirement in 2020 would entail significant increase in expenditure at EU level in 2020, up to 400 M€ higher. This may be due to the high cost increase of this technology (between factor 2 and factor 4 according to some stakeholders), compared to the economic savings achieved by the low reduction in energy consumption.

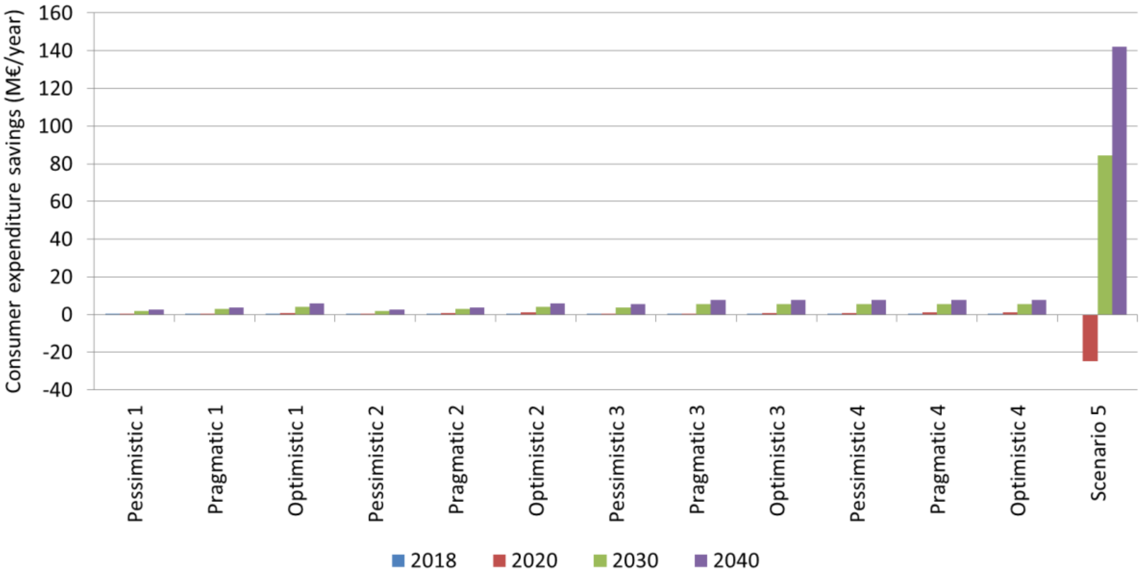

Figure 8-13: Annual consumer expenditure reduction at EU level (in Million €) for BC 2

In the case of swimming pool pumps over 2.2 kW, the introduction of VSD as a fifth scenario policy would lead to a slightly higher consumer expenditure in 2020, but some economic savings in 2030 and 2040, up to 140 M€ per year.

8.5 Sensitivity analysis

The objective of the sensitivity analysis is to examine the accuracy of the results of the study and to see how susceptible they are to unreliable data. Parameters included in the sensitivity analysis are in accordance with the Annex II of the Ecodesign Directive. The parameters that are considered the most relevant for this sensitivity analysis (because of their importance and uncertainty) in the case of lot 29 pumps are:

- Product lifetime; and
- Annual sales growth rate.

The sensitivity analysis is carried out for each of the two Base-Cases (BC 1, BC 2) around the pragmatic scenarios[24] of the four policy options:

- Pragmatic Scenario 1: MEI cut-off values as 0.1 as Tier 1 and 0.4 as Tier 2;
- Pragmatic Scenario 2: MEI cut-off values as 0.4 in a single Tier;
- Pragmatic Scenario 3: MEI cut-off values as 0.1 as Tier 1, 0.4 as Tier 2 and 0.7 as Tier 3; and

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[24] As the pragmatic option represents most closely the reality, hence it was chosen for the sensitivity analysis instead of the pessimistic or optimistic options. It is however expected that the order of magnitude of impacts of the parameters assessed in sensitivity analysis would be similar of these other two options (pessimistic and optimistic) as that of pragmatic option.

- Pragmatic Scenario 4: MEI cut-off values at the level of the Base-Case (MEI = 0.4) as Tier 1 and BAT (MEI = 1) as Tier 2.

The sensitivity analysis allows checking if any of the results change significantly with different data. This helps to determine how robust and reliable the findings of this study are.

The sensitivity analysis graphs provides a comparison of the change in energy savings or expenditure reduction for each of the four scenarios for a particular a Base-Case by varying the values of the two parameters selected, one by one. As an example for BC 1, if:

- BaU EC 2020 = Energy consumption of BC 1 stock in 2020 in Business as Usual scenario;
- PS1 EC 2020 = Energy consumption of BC 1 stock in 2020 in pragmatic Scenario 1
- PS2 EC 2020 = Energy consumption of BC 1 stock in 2020 in pragmatic Scenario 2;
- PS3 EC 2020 = Energy consumption of BC 1 stock in 2020 in pragmatic Scenario 3;
- PS4 EC 2020 = Energy consumption of BC 1 stock in 2020 in pragmatic Scenario 4;
- LL PS1 EC 2020 = Energy consumption of BC 1 stock in 2020 in pragmatic Scenario 1 for a Lower value of lifetime;
- LL PS2 EC 2020 = Energy consumption of BC 1 stock in 2020 in pragmatic Scenario 2 for a Lower value of lifetime;
- LL PS3 EC 2020 = Energy consumption of BC 1 stock in 2020 in pragmatic Scenario 3 for a Lower value of lifetime;
- LL PS4 EC 2020 = Energy consumption of BC 1 stock in 2020 in pragmatic Scenario 4 for a Lower value of lifetime;
- UL PS1 EC 2020 = Energy consumption of BC 1 stock in 2020 in pragmatic Scenario 1 for a Upper value of lifetime;
- UL PS2 EC 2020 = Energy consumption of BC 1 stock in 2020 in pragmatic Scenario 2 for a Upper value of lifetime;
- UL PS3 EC 2020 = Energy consumption of BC 1 stock in 2020 in pragmatic Scenario 3 for a Upper value of lifetime; and
- UL PS4 EC 2020 = Energy consumption of BC 1 stock in 2020 in pragmatic Scenario 4 for a Upper value of lifetime.

Then, the sensitivity analysis assesses for an increase in lifetime for each of the four scenarios the following value (percentage change in energy savings):

$$[(\text{UL PS1 EC 2020} - \text{PS1 EC 2020}) / \text{BaU EC 2020}] \times 100$$

Similarly, the sensitivity analysis also assesses for a decrease in lifetime for each of the four scenarios the following value (percentage change in energy savings):

[(LL PS1 EC 2020 – PS1 EC 2020)/ BaU EC 2020] x 100

The background data used for the sensitivity analysis graphs presented in this section is presented in Annex III.

8.5.1 Assumptions related to the product lifetime

Average lifetimes are used in the EcoReport tool to assess environmental and LCC of the Base-Cases. However, some products can have a shorter or a longer lifetime. Such extreme values, are considered for two scenarios (presented below) used in this sensitivity analysis to assess the impact of this parameter on the LCC of the Base-Cases and their energy consumption during the use phase.

Variation in product lifetime (in years):

- An increase of 25% (upper limit); and
- A decrease of -25% (lower limit).

This analysis shows the influence of the product lifetime on the total energy consumption (TEC) and life-cycle costs at EU level of the different scenarios analysed in section 8.4.

As seen in Figure 8-13 to Figure 8-18, for all situations, the lifetime of the product has little influence on the total energy consumption (less than 0.25% variation for the total stock of swimming pool pumps). The life cycle costs of swimming pool pumps at EU level varies between -13% and +6% if the lifetime of the pumps is changed.

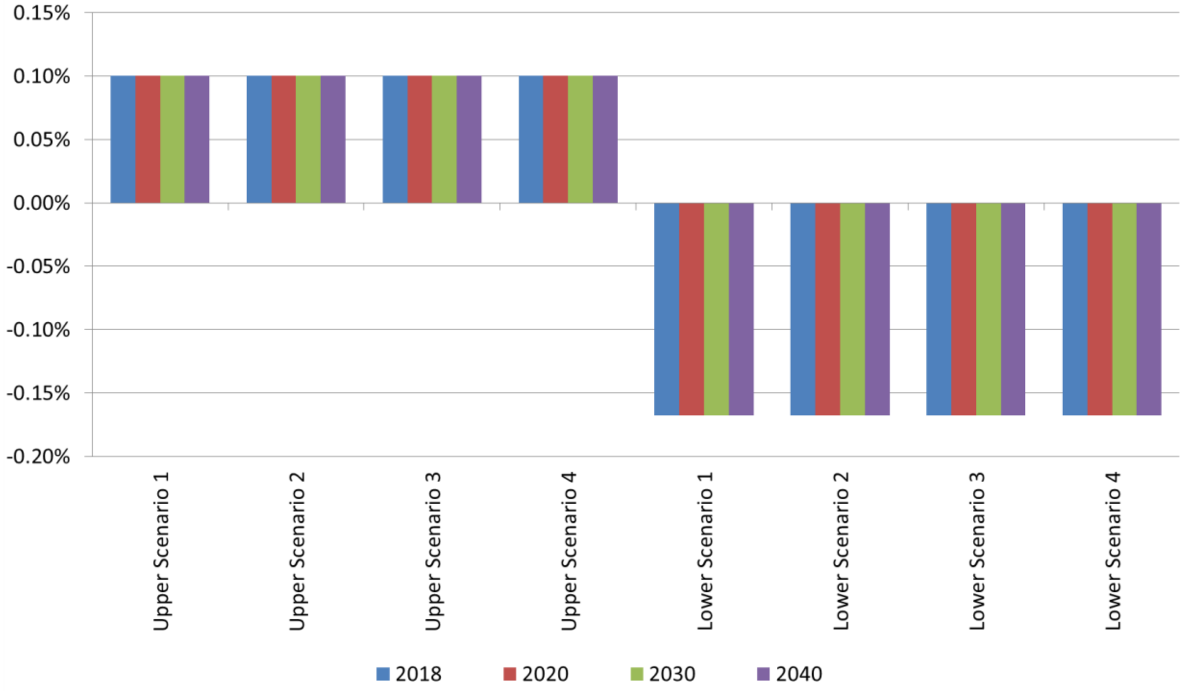

Figure 8-14: Sensitivity to product lifetime for BC 1 Total Energy Consumption

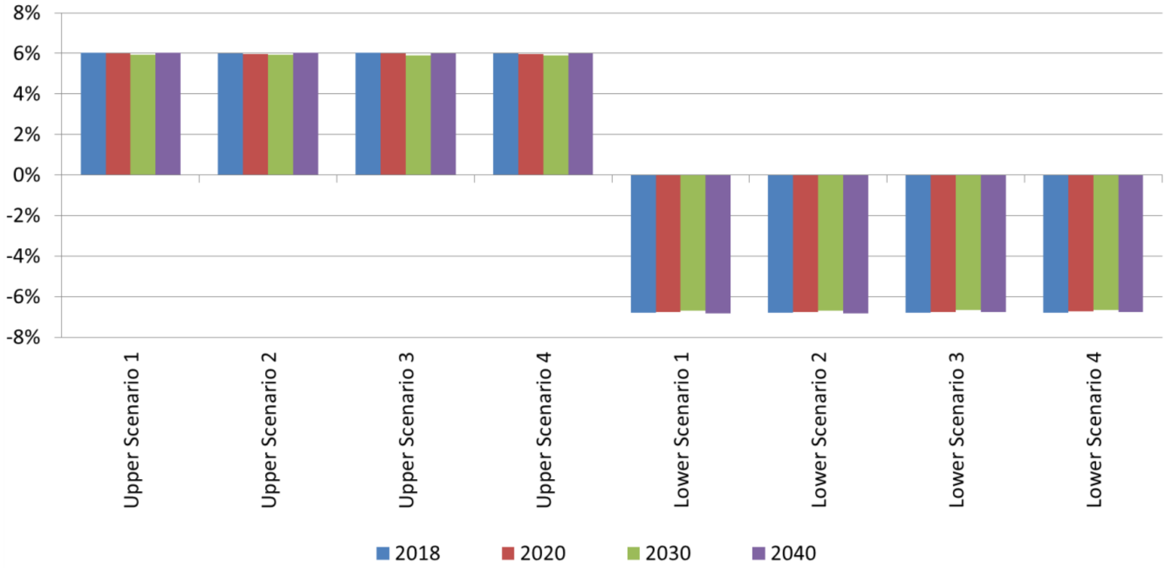

Figure 8-15: Sensitivity to product lifetime for BC 1 Life Cycle Cost

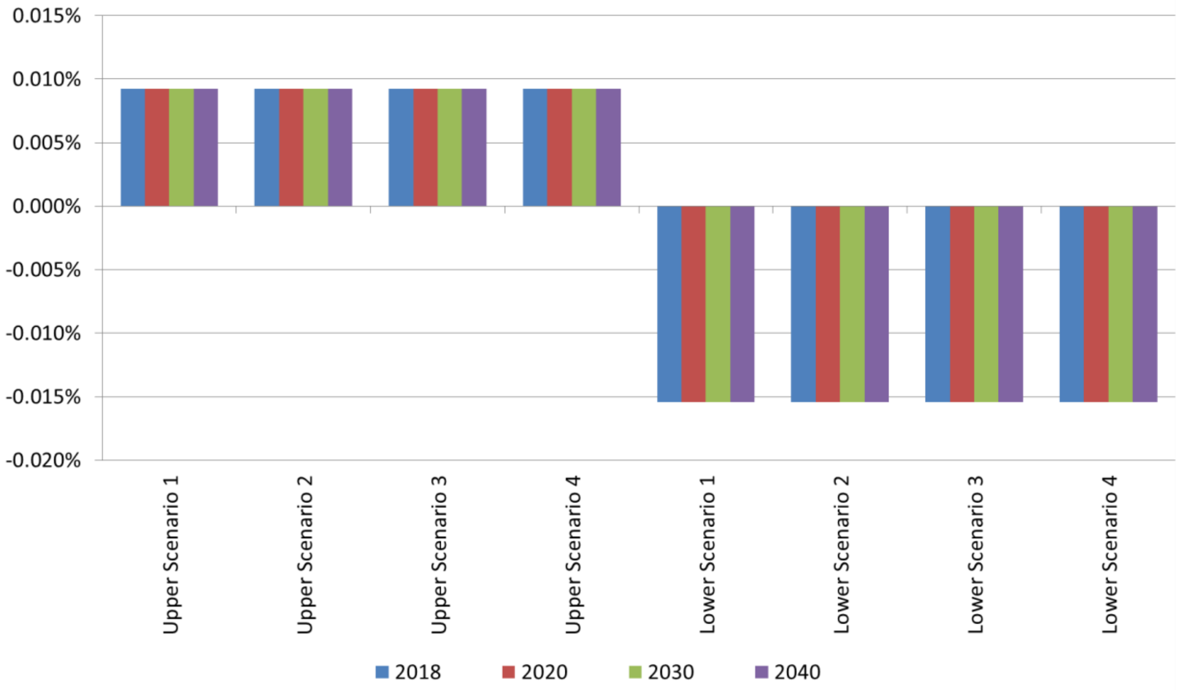

Figure 8-16: Sensitivity to product lifetime for BC 2 Total Energy Consumption

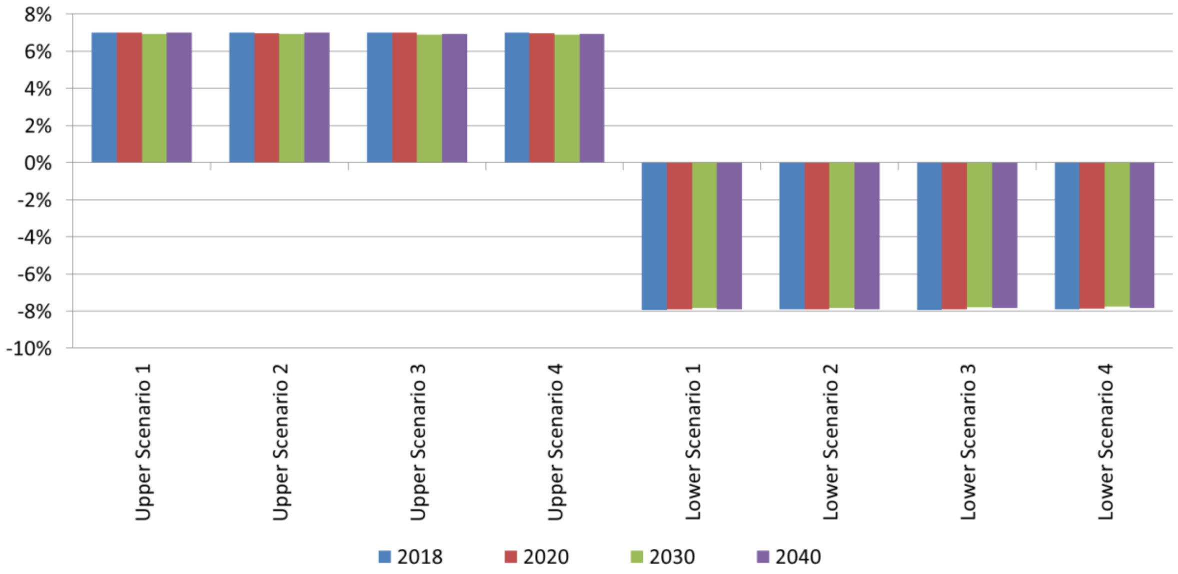

Figure 8-17: Sensitivity to product lifetime for BC 2 Life Cycle Cost

8.5.2 **Assumptions related to the annual sales growth rate**

Estimating the stock of Lot 29 pumps in EU was not an easy task due to the fragmented nature of the market and limited availability of corresponding market data particularly concerning sales growth rate.

In Task 2, stock for 2011 was defined based on available information and inputs provided by stakeholders. Sales growth rate was estimated to be 3% until 2017 by industry stakeholders. The same growth rate was assumed by project team to be applicable until 2040.

Variation in sales growth rate:

- An increase to 5%; and
- A decrease to 0%.

The following figures show the influence of the sales growth rate on the total energy consumption (TEC) and life-cycle costs at EU level of the different scenarios analysed in section 8.4.

The sales growth rate influences significantly the potential energy savings of the proposed scenarios (between -35% to +22% variation), and also the consumer expenditure at EU level (between -15% to +7%).

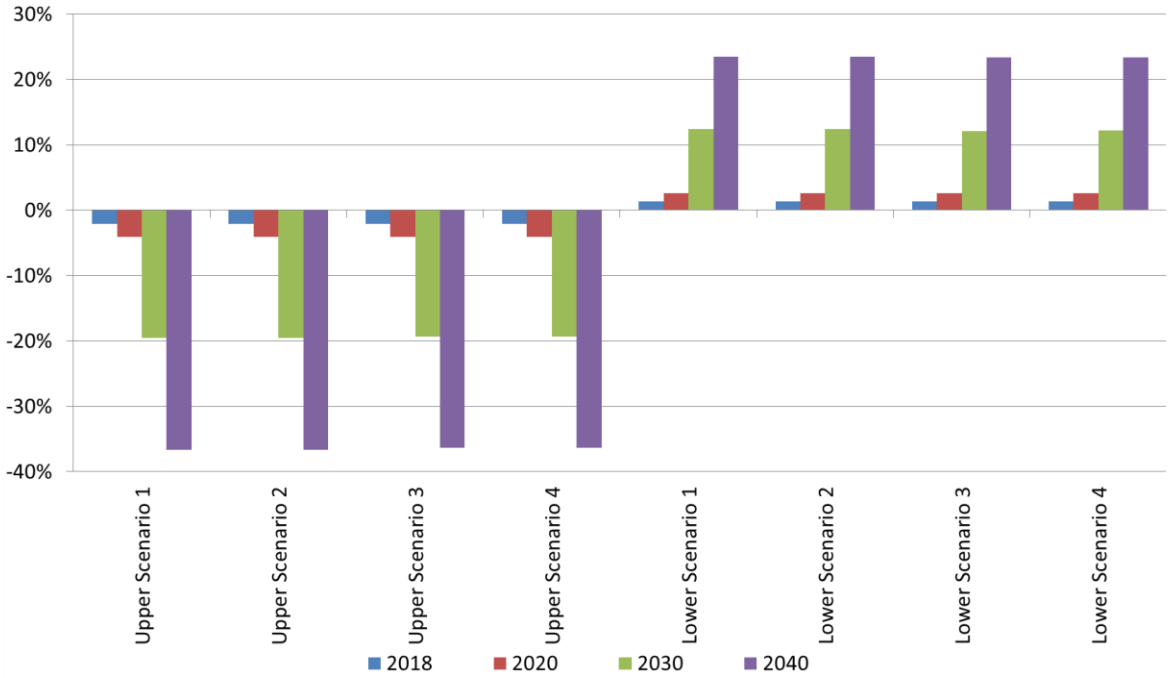

Figure 8-18: Sensitivity to sales growth rate for BC 1 Total Energy Consumption

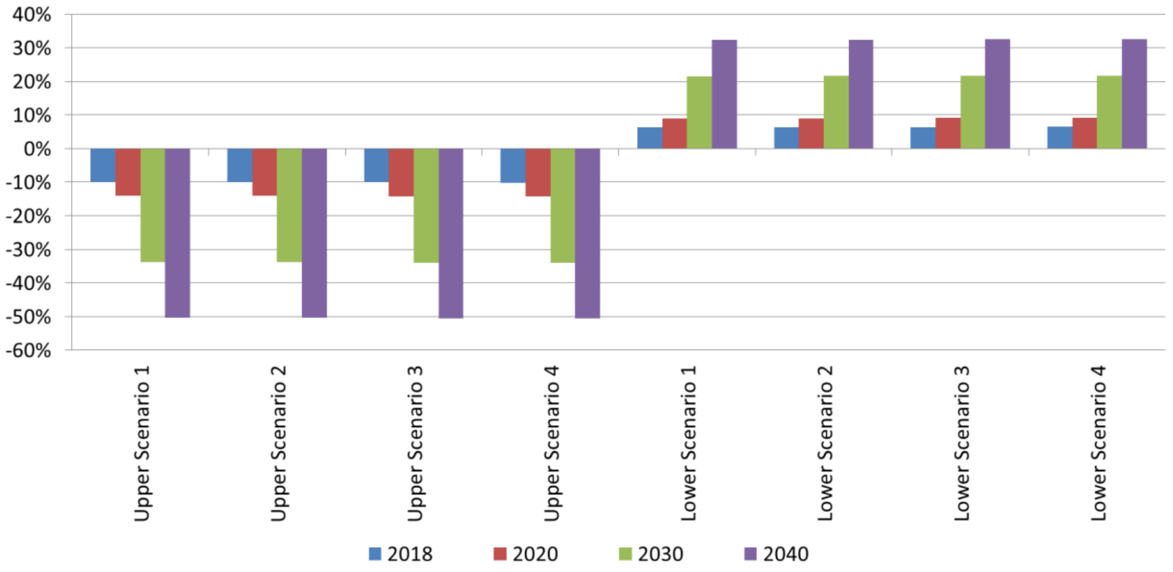

Figure 8-19: Sensitivity to sales growth rate for BC 1 Life Cycle Cost

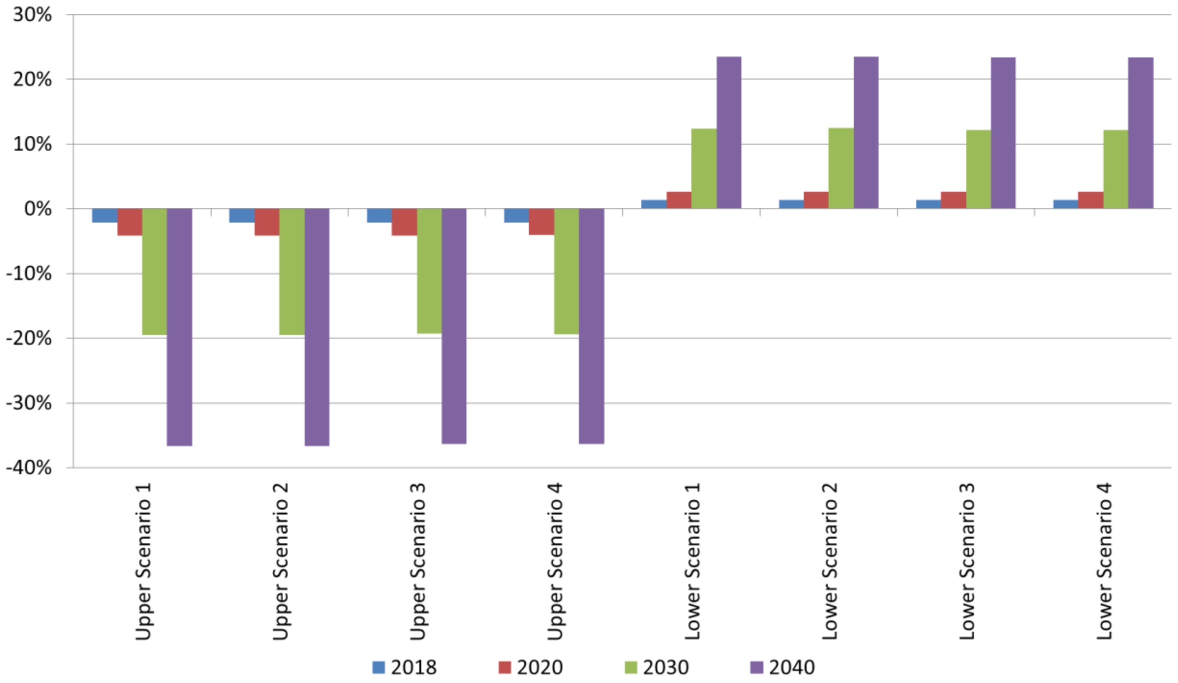

Figure 8-20: Sensitivity to sales growth rate for BC 2 Total Energy Consumption

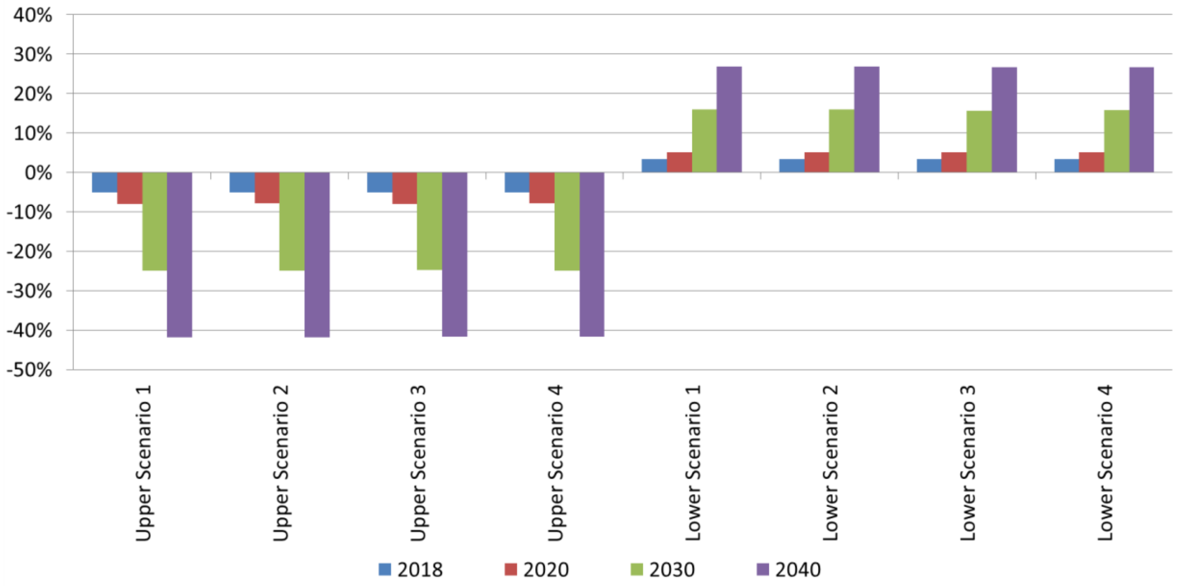

Figure 8-21: Sensitivity to sales growth rate for BC 2 Life Cycle Cost

8.5.3 Conclusions of the sensitivity analysis

The product lifetime and the annual sales growth rate have different influence on the total energy consumption and consumer expenditure at EU level. Whilst the influence of the lifetime on the total energy consumption is negligible, the consumer expenditure can vary from -13 to +6%. This is normal if we take into account that the comparison is made between energy consumption per year and consumer expenditure per year, which are not highly influenced by the lifetime of the product.

On the other hand, the sales growth rate of swimming pool pumps in Europe influences the number of pumps used, and therefore the variations of -35% to +22% potential energy savings are not surprising.

In any case, when varying the input data on the parameters: product lifetime and sales growth rate, the evolution of the four different pragmatic scenarios relative to the business as usual is similar to that presented in section 8.4: the maximum energy and economic savings are achieved in 2040 in all the scenarios, whilst the consumer expenditure would be penalised in 2020 and 2030. This observation strengthens the reliability of the outcomes presented in previous sections.

8.6 Impact analysis

The Ecodesign requirements should not entail excessive costs nor undermine the competitiveness of European enterprises and should not have a significant negative impact on consumers or others users. In this section, the following impacts are assessed:

- Impacts on manufacturers and competition;
- Impacts on consumers;
- Impacts on innovation and development; and
- Social impacts.

8.6.1 Impacts on manufacturers and competition

As presented in Task 2, the PRODCOM statistics are the official EU source for economic data, but it has some limitations as pump products are classified into wide range of categories that do not match exactly the classification proposed for pumps in ENER Lot 29. However, the data collected and presented in Task 2 can give a rough economic overview of the sector of clean water pumps in the EU.

According to that, the sector presents a minor growth trend in recent years and the same small growth is forecasted for the coming years. Most of the pump sales in the EU are replacement of old pumps (around 70%), and only a small part are new pump installations. This means that the pump market in the EU is close to saturation, and the introduction of new pumps and technologies in the market would take time. Because of that, the return of investment on new launches of products by manufacturers would be small over a long period.

The timeline to implement the measures should take into account the development of test standards, product redesign cycle and adaptation of production lines. All the technologies described in this study and considered as improvement options in the scenarios are already available on the market. As a result, the implementation of measures is technically achievable although it will require an economical effort from the manufacturers (e.g. need to invest in new patterns and tooling). The investment needed would vary depending on the ambition of the policies implemented.

While the improvement technologies are already used in some water pumps in the EU, not all the manufacturers include them in their designs, and the launching of new products will require some redesign work. Therefore, the implementation of measures would require investments in technology and product development or in adapting their production lines to offer the required more efficient products. The impact of these investments would depend on the level of ambition of the policies proposed and on the energy performance of models proposed by each manufacturer.

The redesign time varies depending on the type of product and extent of desired change. As seen in Task 2, the redesign cycles of water pumps are between 2 to 4 years, including all the time necessary to launch a new product.

As the considered design improvement options are already available in the market, it is estimated that the redesign of pumps would be on the lower part of this range. Therefore, a lapse of around 24 months should be sufficient for all the manufacturers to redesign their products, adapt the production lines and develop test methods to verify the compliance with the legal requirements[25].

The ongoing work on the development of a methodology for calculating the Energy Efficiency Index of clean water pumps is expected to be continued over 2015. After this task is accomplished, it is recommended that during the next revision of any Ecodesign Regulation for ENER Lot 29 pumps, the European Commission should take into account the EEI approach for ENER Lot 29 MEPS instead of the MEI approach presented in this preparatory study. The standardisation of EEI calculation method would facilitate the benchmark of pumps per application, and therefore the inclusion of the benefits of variable flow for those pumps applications that can benefit from it.

Most of the pump production is done inside the EU and there are some imports of different products, but these quantities are not as representative as the ones produced inside the EU. Few big manufacturers dominate the European market of pumps. Most of these manufacturers already claim to produce highly efficient pumps. They should all be able to keep up with the market requirements if mandatory policy measures are set. The implementation of MEPS could potentially affect more seriously the medium and small pump manufacturers in the EU.

8.6.2 Impacts on customers

For the improvement options presented in Task 6, the functional unit and the quality service given by the improved product remains the same as with the Base-Cases.

In the case of any additional costs to manufacturers, these could be reflected in a higher purchase price for customers. However, the lower energy consumption during the use phase would compensate the higher purchase price of the pump. This would also mean that more capital to purchase the more efficient products would be required. The scenario analysis already shows some of the expected monetary impacts for users.

The higher price of a more efficient pump could be paid back by the savings in energy consumed during the use phase. This seems to be the case for BC 2 and BC 11 for most of the policy options considered in this Task whereas for BC 1, reduction in consumer expenditure occurs but only for the most optimistic policy options.

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[25] One manufacturer stated that the redesign cycles of end suction pumps, submersible bore-hole pumps and vertical multi-stage pumps is of around 10 years.

8.6.3 Impacts on innovation and development

The proposed policy options will remove inefficient water pumps from the market but it is unlikely to lead to big technological changes. This happens mainly because the products with the improvement options identified in this study already exist in the market. However, a shift can be expected towards more efficient models with intelligent controls within the EU. However, such controls have no such big impacts on the design of the pump itself.

The proposed policy measures can be seen as an opportunity for manufacturers to search for innovative and efficient technological solutions. As mentioned, it seems that with the current trend of research and development activities in EU manufacturing companies, it should be feasible that manufacturers can meet the proposed requirements.

The standardisation of new energy efficiency indexes such as MEI, EEI or the Energy Star scheme would have a positive impact on the innovation and competitiveness of the EU market of pumps. If these indexes are widely used by manufacturers and communicated to installers and users, this will help create awareness in the market of the different technologies available and their corresponding benefits. This could also drive the customer's choice towards more energy-efficient products. The manufacturers can also provide recommendations on the installation and concerning efficient use of clean water pumps, which could help optimise the energy efficiency of pumping systems further than the pump itself, even though the systems are not directly regulated.

The proposed policy measures can be seen as an opportunity for manufacturers to search for innovative and efficient technological solutions. As mentioned, it seems that with the current trend of research and development activities in EU manufacturing companies, it should be feasible that manufacturers can meet the requirements considered in this report.

8.6.4 Social impacts

Most of the manufacturers of water pumps have production plants within the EU. Upgrading or changing production lines in the EU is often viewed as an opportunity to decide whether to relocate the production plant to another country – within or outside the EU – or not. If performance standards were set, they are not thought to have a detrimental impact on the number of jobs or the well-being of the EU manufacturers' employees.

In addition, the technologies to fulfil the proposed Ecodesign requirements presented do not require any specific material that might be difficult to obtain within the EU so that the supply would not be unduly affected not EU industries disadvantaged.

8.7 Conclusions

This Task report brings together the finding of the previous tasks of the preparatory study for Ecodesign requirements of pumps for public and private swimming pools, ponds, fountains and aquariums. It looked at the possibility for proposing suitable Ecodesign requirements for swimming pool pumps to achieve environmental and economic improvements at EU level.

Due to the diversity of pump types, sizes and uses included in this preparatory study, the policy options are assessed independently for each of the different product groups. The applications and sizes covered within this preparatory study are from <1 kW to engineered pumps of >1000 kW. Any possible regulation would need different methodology, testing, market surveillance and standards.

Swimming pool pumps

For swimming pool pumps, it is recommended to regulate the provision of mandatory information by manufacturers within the pump brochures and technical specifications. This measure would spread the awareness about the energy efficiency of pumps and the possibilities for energy and economic savings.

Manufacturers should also provide with benchmarks, guidance and recommendations on how to design and install the pool water pumping system to optimise the efficiency of the pump. The information on energy efficiency of the pump and the benchmarks could be done in efficiency (η) at Best Efficiency Point, at Part Load and at Over Load.

The US Energy Star can be a quick-win solution to spread awareness between installers and users about the potential energy and cost savings of pumps. The generalisation of this voluntary labelling scheme could drive professional and domestic purchases towards more efficient pumps, and help manufacturers differentiate from competitors in the market.

It is also recommended to implement mandatory use of time controls in all swimming pool pumps in the EU, as this is a simple improvement option that may allow users reduce the energy consumption of pumps at a low cost.

The study team analysed the possible scope to set Minimum Energy Performance Standards (MEPS) for swimming pool pumps, taking the approach of the Minimum Efficiency Index introduced in the Ecodesign Regulation on water pumps[26]. The estimation of MEI values for swimming pool pumps presented in this report has been done as an example, and is based on a linear distribution of the efficiencies of pumps in the EU market. If any regulation is to be set on swimming pool pumps using MEI, a statistical analysis of the EU market of pumps would be necessary in order to calculate the accurate MEI values and potential savings.

Scenarios representing the implementation of MEPS in swimming pool pumps in the EU were projected over the period 2013-2040 to quantify the total potential of improvements that can be achieved with respect to a Business-as-Usual (BAU) scenario if MEPS were enforced from 2017.

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[26] Commission Regulation (EU) No 547/2012

For domestic swimming pool pumps up to 2.2 kW, the potential electricity savings vary from 0.20 to 0.36 TWh per year in 2040, but the consumer expenditure at EU level would increase slightly after the introduction of the regulation between 0.5 to 6.5 M€ per year. The consumer expenditure would only decrease to the level before regulation after the year 2030, and would achieve a maximum of 8.5 M€ savings per year in 2040.

For domestic and commercial swimming pool pumps over 2.2 kW, the potential electricity savings at EU level of the policy options studied are between 0.07 and 0.12 TWh per year in 2040, with a consumer expenditure savings of between 2.5 to 7.8 M€ per year.

If Variable Speed Drive technology is considered as a BAT option for policy implementation, the electricity savings of swimming pool pumps would be notably higher (i.e. up to 6 TWh in 2040 for all swimming pool pumps), but the economic impacts on customers would also be affected. The consumer expenditure of swimming pool pumps less than 2.2 kW would increase without possibility of payback during the lifetime of the product. This would definitely prevent from implementing speed controls in small domestic swimming pool pumps. For swimming pool pumps over 2.2 kW, the consumer expenditure would increase up to 20 M€ by 2020, but decrease by in 2030 and 2040, up to 140 M€ per year. This shows the potential of speed control for commercial swimming pool pumps, although it would be necessary to fully develop an Extended Product Approach and EEI calculation method in order to apply any regulation that could achieve these savings across different pump applications.

If Ecodesign Implementing Measures in the form of Minimum Energy Performance Standards are to be set for swimming pool pumps, these should follow the MEI proposed in the intermediate scenario presented in Table 8-6.

Table 8-6: Most beneficial cut-off scenario

	MEI		
	Tier 1: 2016	**Tier 2: 2018**	**Tier 3: 2020**
Scenario 3	0.1	0.4	0.7

This policy scenario achieves some energy and economic savings at EU level (e.g. a total of between 0.27 and 0.48 TWh and between 8 to 16 M€ per year in 2040, depending on the consumer market response to the potential Implementing Measures explained in section 8.4.2).

In a future revision of the proposed regulation, the Extended Product Approach and the Energy Efficiency Index method could be included in order to develop a more ambitious regulation for clean water pumps in the EU, which could potentially save up to 6 TWh per year in 2040. The possible drawbacks should be carefully assessed in order to avoid possible economic burden on manufacturers or consumers.

Table 8-7 shows a summary of the potential energy savings of the different policy options analysed for swimming pool pumps.

Table 8-7: Summary of Policy Options considered for Swimming Pool pumps

Policy Option	Average energy savings per product (%)	Estimated annual electricity savings (TWh) in 2040 at EU level		
		Swimming pool pumps <2.2 kW	Swimming pool pumps >2.2 kW	Total
Mandatory Information requirements / Energy labelling[27]	N/A	N/A	N/A	N/A
Mandatory use of speed controls[28]	12% for pumps <2.2 kW 42% for pumps <2.2 kW	3.1	2.9	6.0
Mandatory use of time controls[29]	7.5%	1.2	0.4	1.6
Mandatory MEPS[30]	2%	0.20 to 0.36	0.07 to 0.12	0.27 to 0.48
Voluntary use of correct sized pipes[31]	10%	1.6	0.6	2.2

It should be noted that for VSDs this is the average saving from all swimming pool pumps, savings on individual pumps where good savings can be made will be larger. However, as described in Task 6 and 7 these numbers are best estimates based on little industry data.

The impact of information requirements and energy labelling cannot be estimated due to the difficulty of predicting the purchase decisions of consumers. The US Energy Star present some estimation of potential economic savings if all swimming pool pumps were certified, but it is not clear if those assumptions can be extrapolated to the EU market.

In practice, the total energy savings will be less than the sum of the individual policy options listed in Table 8-7, as some measures are not "mathematically" additive; but because the savings attributable to the individual policy options are if anything understated, this gives a fair idea of the total realistic energy saving potential.

Fountain, pond, aquarium, spa and counter current pumps

The improvement potential of fountain and pond pumps, aquarium pumps, spa pumps and counter current pumps is not very high. These pumps, except some aquarium pumps, usually require professional engineers and technicians to dimension and design the systems. Aquarium pumps may be sold in do-it-yourself markets, but as seen in previous task of this study, the difference in energy efficiency between the best and the worst product is not very big. Thus, relevant product information requirements are thought to be more effective than complex

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[27] As described in section 8.2.2.1.

[28] As described in section 8.2.2.2 and calculated in section 8.4.5.

[29] As described in section 8.2.2.3. Calculated as 7.5% of the electricity consumption at EU level in 2040.

[30] As described in section 8.2.2.4 and calculated in section 8.4.

[31] As described in section 8.2.2.5. Calculated as 10% of the electricity consumption at EU level in 2040.

energy labels. The provision of information by manufacturers would make installers and users aware of the energy efficiency of these pumps and the possibilities for energy and cost savings.

End suction, bore-hole and vertical multistage pumps

End suction pumps, bore-hole pumps and vertical multistage pumps usually require professional engineers and technicians to dimension and design the systems. The hydraulic efficiency of these big pumps is usually a major concern of users, and these pumps are usually tailor-made, specifically designed to meet the client’s criteria. The use of Variable Speed Drives in these pumps is only beneficial when the pump application in which they are used requires it.

In any case, the provision of information by manufacturers would spread the awareness about the energy efficiency of pumps and the possibilities for optimisation its use and maintenance. Furthermore, the provision of benchmarks, guidance and recommendations on how to design and install the pumping system to optimise the efficiency of the pump may help increasing the energy efficiency of the installed stock in the EU.

Annex I: Energy Efficiency Index

Existing regulations for the Pump product (only) are based on MEPs for a particular pump size, which are defined with reference to a Minimum Efficiency Index or "MEI" value. The Extended Product Approach energy consumption is distinguished from this by being defined in terms of the Energy Efficiency Index or "EEI" value.

The term EEI comes from the Ecodesign Regulation on circulators[32], where the annual energy consumption is based on the energy used by pump + motor + VSD control over a typical annual operating profile. The advantage of this EEI method is that it considers the real life operating profile of the extended product, and so gives the best representation of the actual costs of using that product.

Creating load profiles that are representative of the different types of application that will be powered by the pumps in scope is critical. The load profiles give the proportion of the time that is spent at each load point, with the actual annual operating time for each application being used to establish energy consumption.

The following factors are needed for calculating the EEI:

- Pump efficiency at different load points;
- Motor efficiency at different load points;
- VSD efficiency at different load points in as far as VSD is applicable;
- Applicable load profile; and
- Efficiency of controls (contactors) is neglected, because this is less than 0.1 % of the motor losses.

The EEI is calculated as following:

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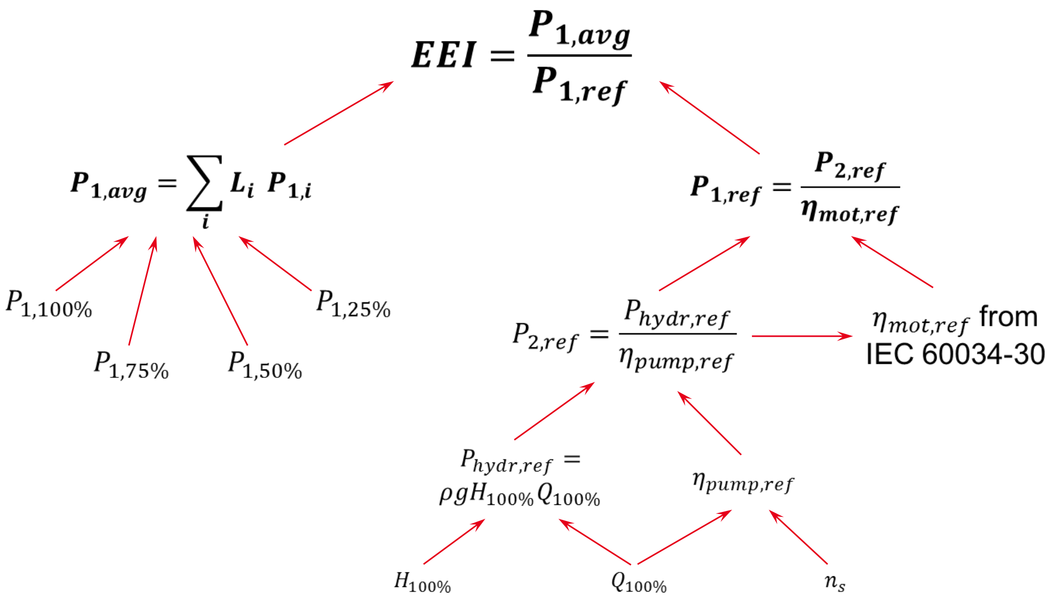
[32] Commission Regulation (EC) No 641/2009 of 22 July 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products



Where:

P1,i is the electrical power input from the grid in each of the profiles

P2,i is the mechanical power from the motor shaft in each of the profiles

P_{hydr} is the hydraulic power produced by the pump

$P_{L,avg}$ is the weighted average power of a pump equipped with variable speed or two speeds

P_{ref} is the reference power of the pump (i.e. the relation between hydraulic power and power consumption of a pump)

The power input values *P1,i* can be measured, but this is not possible in most cases especially not for separated units. The *P1,i* values will then be calculated from Semi Analytical Models. Based on actual measurements of the pump, the head and the flow, the best efficiency point (*H100%*, *Q100%*) is determined and from that the specific speed (n_s) is calculated. Based on the hydraulic power and the efficiency, the reference shaft power *P2,ref* is calculated, which can via the IEC 600034-30 for motors be converted onto a reference power input. The reference efficiency of the VSD is set to 100% by definition. The actual efficiency of the specific VSD is captured by the power input values *P1,i* as is the case for pump and motor.

Annex II: Estimation of C-values for Lot 29 pumps

This Annex contains a description of the methodology proposed for use to estimate the "C-values" for pumps in ENER Lot 29 preparatory study. This section only covers those pumps for which the project team proposed MEPS based on MEI as part of the possible policy options analysed in Task 8 of this preparatory study (i.e. swimming pool pumps).

The concept of "C-values" was first used in the ENER Lot 11 study for clean water pumps. The intention of the ENER Lot 29 study authors is to use the ENER Lot 11 C-value methodology and adapt it for use with the ENER Lot 29 pumps (even if ideally an exhaustive data collection on pumps in the EU market in order to calculate the appropriate C-values should be carried out). The C-values used in the calculation of EEI and those used in the calculation of MEI are not the same.

Setting the efficiency levels is very complicated, as they will differ by type, speed, flow, head and impeller diameter. Achievable efficiency is dependent on pump size and specific speed as well as pump type. To simplify things (and in fact to make any kind of analysis understandable), it is based on maximum impeller. This is reasonable on the basis that the volute will be designed around maximum impeller performance, with a volute that is good at maximum diameter also being relatively good at reduced impeller sizes.

Different types of pumps must have different efficiency criteria. Unfortunately, this still means that there will be different efficiency criteria for the different (flow, head) duties within the range of pumps in each category. In practical terms, it means that a simple chart or 2-D graph is not possible, instead a 3-D plane has to be used to present the data. A 3-D plane was produced in the ENER Lot 11 report using data from Technische Universität Darmstadt in 1998 for an earlier SAVE project led by AEAT. This plane is shown in Figure 8-25.

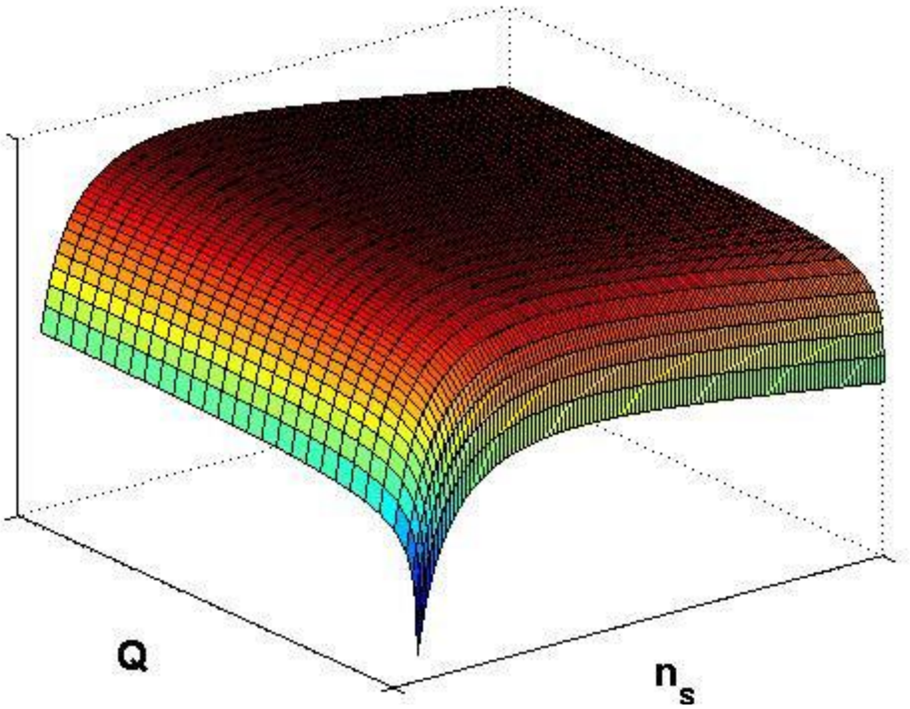


Figure 8-22: 3D plane used in the ENER Lot 11 pump study

Where:

N_s is specific speed (min^{-1})

Q is flow (m^3/h)

η is efficiency

The mathematical description of the plane was obtained by means of a 3-D quadratic polynomial approximation. The equation defining the efficiency plane is:

$$\eta_{Bottom} = -11.48x^2 - 0.85y^2 - 0.38xy + 88.59x + 13.46y - C$$

Where x = ln(n_s) and y = ln(Q)

The numbers of pumps (in percentage of the total data of one pump type) that do not fulfil the minimum efficiency requirements imposed by the plane are lying below the surface and are therefore “cut-off” by the plane.

With C used as a variable for each pump type, it is possible to identify the pumps with the lowest efficiencies for the size and specific speed considered. The plane is shifted downwards vertically according to the value of C, until the chosen quantity cut-off criterion is fulfilled.

C-values calculation procedure used in ENER Lot 11

In ENER Lot 11, the following C-values were used for the pumps in scope:

Table 8-8: ENER Lot 11 C-values

	C value at different cut-offs (%)									
	5	10	15	20	30	40	50	60	70	80
ESOB 1450 (L)	134.38	132.58	131.70	130.68	129.35	128.07	126.97	126.10	124.85	122.94
ESOB 2900 (S)	137.28	135.60	134.54	133.43	131.61	130.27	129.18	128.12	127.06	125.34
ESCC 1450 (L)	134.39	132.74	132.07	131.20	129.77	128.46	127.38	126.57	125.46	124.07
ESCC 2900 (S)	137.32	135.93	134.86	133.92	132.23	130.77	129.86	128.80	127.75	126.54
ESCCi 1450 (L)	138.13	136.67	135.40	134.60	133.40	132.30	131.00	130.03	128.98	127.30
ESCCi 2900 (S)	141.71	139.45	137.73	136.53	134.91	133.69	132.65	131.34	129.83	128.14
MS 1450 (L)	134.83	134.45	133.89	132.97	132.40	130.38	130.04	127.22	125.48	123.93
MS2900 (S)	139.52	138.19	136.95	135.41	134.89	133.95	133.43	131.87	130.37	127.75
MSS 2900 (L)	137.08	134.31	132.89	132.43	130.94	128.79	127.27	125.22	123.84	122.05
MSS 2900 (S)	137.08	134.31	132.89	132.43	130.94	128.79	127.27	125.22	123.84	122.05

The average pump for each pump type considered in ENER Lot 11 was then decided upon and values for the average duty point, specific speed and x and y values were defined as follows:

Table 8-9: ENER Lot 11 Average Pumps

Type of pump (Prep study)	Mean size	Mean Head	Mean flow	Specific Speed	x in MEPS formula	y in MEPS formula
Abbrevn.	kW (Hyd)	m	m3/hr	per min	(ln ns) /min	(ln m^3/hr)
ESOB 1450 (L)	10.9	32	125	20.08	3.00	4.83
ESOB 2900 (S)	2.5	30	30	20.65	3.03	3.40
ESCC 1450 (L)	11.10	31	131	21.05	3.05	4.88
ESCC 2900 (S)	2.2	32	25	17.96	2.89	3.22
ESCCi 1450 (L)	11.1	31	132	21.13	3.05	4.88
ESCCi 2900 (S)	2.2	32	25	17.96	2.89	3.22
MS 1450 (L)	1.1	42	10	15.49	2.74	2.30
MS2900 (S)	0.5	45	4	18.60	2.92	1.39
MSS 2900 (L)	3.6	88	15	54.55	4.00	2.71
MSS 2900 (S)	1.4	59	9	31.49	3.45	2.14

Using the data presented in these two tables it was then possible to calculate the MEPS by different pump sizes at different cut-off values as shown in the table below.

Table 8-10: ENER Lot 11 Pump Cut-off efficiencies

	Min efficiency at different cut-offs (%)									
	5	10	15	20	30	40	50	60	70	80
ESOB 1450 (L)	67.74	69.54	70.42	71.44	72.77	74.05	75.15	76.02	77.27	79.18
ESOB 2900 (S)	57.74	59.42	60.48	61.59	63.41	64.75	65.84	66.90	67.96	69.68
ESCC 1450 (L)	68.74	70.39	71.06	71.93	73.36	74.67	75.75	76.56	77.67	79.06
ESCC 2900 (S)	53.77	55.16	56.23	57.17	58.86	60.32	61.23	62.29	63.34	64.55
ESCCi 1450 (L)	65.09	66.55	67.82	68.62	69.82	70.92	72.22	73.19	74.24	75.92
ESCCi 2900 (S)	49.38	51.64	53.36	54.56	56.18	57.40	58.44	59.75	61.26	62.95
MS 1450 (L)	45.81	46.19	46.75	47.67	48.24	50.26	50.60	53.42	55.16	56.71
MS2900 (S)	36.84	38.17	39.41	40.95	41.47	42.41	42.93	44.49	45.99	48.61
MSS 2900	59.70	62.47	63.89	64.35	65.84	67.99	69.51	71.56	72.94	74.73

▶ Adapting the ENER Lot 11 C-values calculation approach for ENER Lot 29 pumps

For the ENER Lot 29 pumps, the project team has estimated the following minimum, maximum and average efficiencies for each pump type. It is important to note that this method is an approximation made by the study authors and would need an exhaustive data collection on pumps in the EU market in order to calculate the appropriate C-values.

Table 8-11: Efficiency range for ENER Lot 29 Pumps

Pump type		Hydraulic Power	η_{max} %	η_{min} %	η_{av} %
SPPS	Domestic with built in strainer up to 2.2 kW	0.8	74	55	68
SPPL	Domestic/commercial with built in strainer over 2.2 kW	5	76	65	72

From these values, it is possible to put together the efficiency cut-off bands for the pumps in scope. They have been calculated by evenly apportion the efficiency between the maximum and minimum between the 10 bands.

Table 8-12: Efficiencies at different cut-off values

Pump type	10%	20%	30%	40%	50%	60%	80%	90%	100%
SPPS	56.9	58.8	60.7	62.6	64.5	66.4	70.2	72.1	74
SPPL	66.1	67.2	68.3	69.4	70.5	71.6	73.8	74.9	76

Average shaft power values were provided by Europump for each pump type. In order to estimate C-values using the formula described previously, average head and flow values are required. For the purpose of this exercise, the average power values were used as a starting point to estimate the average head and flow for each pump type[33]. The results are shown in the following table.

Table 8-13: Estimated Average Pump Duties

Pump type	Head (m)	Flow (m³/h)	Specific Speed	ln ns (/min)	ln Q (m3/hr)
SPPS	10	29.65	23.40	3.15	3.39
SPPL	15	123.53	35.24	3.56	4.82

Using the information in Table 8-128-10 and in Table 8-138-11 combination with the formula previously described, the following C-values are estimated as presented in Table 8-148-12.

Table 8-14: Estimated C-values at different MEPS cut-offs

Pump type	10%	20%	30%	40%	50%	60%	80%	90%	100%
SPPS	140.1	138.2	136.3	134.4	132.5	130.6	126.8	124.9	123.0
SPPL	142.4	141.3	140.2	139.1	138.0	136.9	134.7	133.6	132.5

Submersible borehole pumps which already have high efficiency and are on the fringe of the MEI methodology limitations. Swimming pool pumps are unlike others with their integral strainers. Re-evaluation of the methodology is required if regulations on these pumps goes ahead.

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[33] Pump data sheets from Sulzer, KSB and Xylem were consulted as part of this exercise, although no single pump was used to represent the "average" pump in any pump type.

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Annex III: Sensitivity analysis data

This section presents the data on total energy consumption and consumer expenditure at EU level of the variations of the scenarios created in the sensitivity analysis. The data is presented in absolute value at EU level and as variation over the Business as Usual scenario used in section 8.4.

Sensitivity analysis data for lifetime

Table 8-15: Analysis of sensitivity on energy consumption to product lifetime for BC 1

		Pragmatic Upper (25 yr)				Pragmatic lower (15 yr)			
Years		Upper Scenario 1	Upper Scenario 2	Upper Scenario 3	Upper Scenario 4	Lower Scenario 1	Lower Scenario 2	Lower Scenario 3	Lower Scenario 4
2018	GWh/year	9,429	9,420	9,429	9,420	9,454	9,445	9,454	9,445
2020	GWh/year	10,035	10,026	10,035	10,009	10,062	10,053	10,062	10,036
2030	GWh/year	13,845	13,845	13,741	13,733	13,883	13,883	13,778	13,771
2040	GWh/year	19,018	19,018	18,865	18,865	19,070	19,070	18,917	18,917
2018	% over BaU	0.1%	0.1%	0.1%	0.1%	-0.2%	-0.2%	-0.2%	-0.2%
2020	% over BaU	0.1%	0.1%	0.1%	0.1%	-0.2%	-0.2%	-0.2%	-0.2%
2030	% over BaU	0.1%	0.1%	0.1%	0.1%	-0.2%	-0.2%	-0.2%	-0.2%
2040	% over BaU	0.1%	0.1%	0.1%	0.1%	-0.2%	-0.2%	-0.2%	-0.2%

Table 8-16: Analysis of sensitivity on Life Cycle Cost to product lifetime for BC 1

		Pragmatic Upper (25 yr)				Pragmatic lower (15 yr)			
Years		Upper Scenario 1	Upper Scenario 2	Upper Scenario 3	Upper Scenario 4	Lower Scenario 1	Lower Scenario 2	Lower Scenario 3	Lower Scenario 4
2018	M€/year	758	757	758	761	861	860	861	864
2020	M€/year	811	810	815	813	920	920	925	923
2030	M€/year	1,121	1,121	1,121	1,120	1,272	1,272	1,271	1,270
2040	M€/year	1,511	1,511	1,509	1,509	1,719	1,719	1,715	1,715
2018	% over BaU	6.0%	6.0%	6.0%	6.0%	-6.8%	-6.8%	-6.8%	-6.8%
2020	% over BaU	6.0%	6.0%	6.0%	6.0%	-6.8%	-6.8%	-6.8%	-6.7%
2030	% over BaU	5.9%	5.9%	5.9%	5.9%	-6.7%	-6.7%	-6.7%	-6.7%
2040	% over BaU	3.4%	3.4%	3.4%	3.4%	-3.8%	-3.8%	-3.8%	-3.8%

Table 8-17: Analysis of sensitivity on energy consumption to product lifetime for BC 2

		Pragmatic Upper (25 yr)				Pragmatic lower (15 yr)			
Years		Upper Scenario 1	Upper Scenario 2	Upper Scenario 3	Upper Scenario 4	Lower Scenario 1	Lower Scenario 2	Lower Scenario 3	Lower Scenario 4
2018	GWh/year	3,165	3,162	3,165	3,162	3,166	3,163	3,166	3,163
2020	GWh/year	3,369	3,366	3,369	3,360	3,370	3,367	3,370	3,361
2030	GWh/year	4,647	4,647	4,612	4,610	4,649	4,649	4,613	4,611
2040	GWh/year	6,384	6,384	6,332	6,332	6,386	6,386	6,334	6,334
2018	% over BaU	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2020	% over BaU	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2030	% over BaU	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2040	% over BaU	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 8-18: Analysis of sensitivity on Life Cycle Costs to product lifetime for BC 2

		Pragmatic Upper (25 yr)				Pragmatic lower (15 yr)			
Years		Upper Scenario 1	Upper Scenario 2	Upper Scenario 3	Upper Scenario 4	Lower Scenario 1	Lower Scenario 2	Lower Scenario 3	Lower Scenario 4
2018	M€/year	216	216	216	216	251	250	251	251
2020	M€/year	230	230	230	230	267	267	267	267
2030	M€/year	318	318	316	316	369	369	366	366
2040	M€/year	434	434	430	430	504	504	500	500
2018	% over BaU	7.0%	7.0%	7.0%	7.0%	-7.9%	-7.9%	-7.9%	-7.9%
2020	% over BaU	7.0%	7.0%	7.0%	7.0%	-7.9%	-7.9%	-7.9%	-7.9%
2030	% over BaU	6.9%	6.9%	6.9%	6.9%	-7.8%	-7.8%	-7.8%	-7.8%
2040	% over BaU	3.9%	3.9%	3.9%	3.9%	-4.4%	-4.4%	-4.4%	-4.4%

Sensitivity analysis data for annual sales growth rate

Table 8-19: Analysis of sensitivity on energy consumption to sales growth for BC 1

		Pragmatic Upper (5% sales growth)				Pragmatic lower (0% sales growth)			
Years		Upper Scenario 1	Upper Scenario 2	Upper Scenario 3	Upper Scenario 4	Lower Scenario 1	Lower Scenario 2	Lower Scenario 3	Lower Scenario 4
2018	GWh/year	9,639	9,628	9,639	9,628	9,310	9,303	9,310	9,303
2020	GWh/year	10,462	10,451	10,462	10,428	9,779	9,771	9,779	9,758
2030	GWh/year	16,596	16,596	16,462	16,462	12,122	12,114	12,057	12,037
2040	GWh/year	26,101	26,101	25,891	25,891	14,509	14,509	14,392	14,392
2018	% over BaU	-2.1%	-2.1%	-2.1%	-2.1%	1.4%	1.3%	1.4%	1.3%
2020	% over BaU	-4.1%	-4.1%	-4.1%	-4.0%	2.6%	2.6%	2.6%	2.6%
2030	% over BaU	-19.5%	-19.5%	-19.3%	-19.4%	12.4%	12.5%	12.1%	12.2%
2040	% over BaU	-36.7%	-36.7%	-36.4%	-36.4%	23.5%	23.5%	23.3%	23.3%

Table 8-20: Analysis of sensitivity on Life Cycle Costs to sales growth for BC 1

		Pragmatic Upper (5% sales growth)				Pragmatic lower (0% sales growth)			
Years		Upper Scenario 1	Upper Scenario 2	Upper Scenario 3	Upper Scenario 4	Lower Scenario 1	Lower Scenario 2	Lower Scenario 3	Lower Scenario 4
2018	M€/year	887	886	887	891	755	754	755	757
2020	M€/year	983	983	989	987	785	784	788	786
2030	M€/year	1,596	1,596	1,597	1,597	934	933	933	932
2040	M€/year	2,423	2,423	2,424	2,424	1,086	1,086	1,082	1,082
2018	% over BaU	-10.0%	-10.0%	-10.0%	-10.1%	6.4%	6.4%	6.4%	6.5%
2020	% over BaU	-14.1%	-14.0%	-14.3%	-14.2%	9.0%	9.0%	9.2%	9.1%
2030	% over BaU	-33.8%	-33.8%	-34.0%	-34.0%	21.6%	21.6%	21.6%	21.6%
2040	% over BaU	-50.4%	-50.4%	-50.6%	-50.6%	32.3%	32.3%	32.5%	32.5%

Table 8-21: Analysis of sensitivity on energy consumption to sales growth for BC 2

		Pragmatic Upper (5% sales growth)				Pragmatic lower (0% sales growth)			
Years		Upper Scenario 1	Upper Scenario 2	Upper Scenario 3	Upper Scenario 4	Lower Scenario 1	Lower Scenario 2	Lower Scenario 3	Lower Scenario 4
2018	GWh/year	3,233	3,229	3,233	3,229	3,122	3,120	3,122	3,120
2020	GWh/year	3,509	3,505	3,509	3,497	3,280	3,277	3,280	3,273
2030	GWh/year	5,566	5,566	5,521	5,521	4,065	4,063	4,043	4,036
2040	GWh/year	8,753	8,753	8,683	8,683	4,866	4,866	4,826	4,826
2018	% over BaU	-2.1%	-2.1%	-2.1%	-2.1%	1.4%	1.3%	1.4%	1.3%
2020	% over BaU	-4.1%	-4.1%	-4.1%	-4.0%	2.6%	2.6%	2.6%	2.6%
2030	% over BaU	-19.5%	-19.5%	-19.3%	-19.4%	12.4%	12.5%	12.1%	12.2%
2040	% over BaU	-36.7%	-36.7%	-36.4%	-36.4%	23.5%	23.5%	23.3%	23.3%

Table 8-22: Analysis of sensitivity on Life Cycle Costs to sales growth for BC 2

		Pragmatic Upper (5% sales growth)				Pragmatic lower (0% sales growth)			
Years		Upper Scenario 1	Upper Scenario 2	Upper Scenario 3	Upper Scenario 4	Lower Scenario 1	Lower Scenario 2	Lower Scenario 3	Lower Scenario 4
2018	M€/year	244	244	244	244	225	224	225	224
2020	M€/year	267	267	268	267	235	235	235	235
2030	M€/year	428	428	425	425	287	287	286	285
2040	M€/year	664	664	659	659	340	340	337	337
2018	% over BaU	-5.2%	-5.1%	-5.2%	-5.1%	3.3%	3.3%	3.3%	3.3%
2020	% over BaU	-8.0%	-7.9%	-8.0%	-7.9%	5.1%	5.1%	5.1%	5.1%
2030	% over BaU	-25.0%	-25.0%	-24.8%	-24.9%	15.9%	16.0%	15.6%	15.7%
2040	% over BaU	-41.9%	-41.9%	-41.7%	-41.7%	26.9%	26.9%	26.7%	26.7%

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