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

## ENER Lot 28– Pumps for private and public wastewater and for fluids with high solids content – Task 8: Scenario, policy, impact and sensitivity analysis

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# Chapter 8: Task 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 will allow achieving reduction of environmental impacts with consideration to energy savings and reduction in Life Cycle Cost (LCC). Some scenarios analyses allow examining and quantifying the energy and LCC 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 a summary of policies that the authors of the report believe to be of use in order to achieve the desired reduction of the environmental impacts of Lot 28 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

In this section on policy analysis, 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 Lot 28 study are detailed in the following sub-sections.

### 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 DG ENER Lot 11 and Lot 29 studies on clean water 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, as required by the European Commission to undertake the cost and environmental impact analysis in Ecodesign preparatory studies.

## 8.2.2 Scope and product definitions

This preparatory study examined a very wide range of pumps commonly used to handle wastewater (WW) and solids. The primary function of ENER Lot 28 pumps is to pump the three main types of WW (urban WW, domestic WW and industrial WW as earlier defined in Task 1). The WW properties are important as the Lot 28 pumps are required to pump fluids with a range of per cent dry solids content, solids sizes, fibre length, hardness of solid, temperature, corrosive chemical content and viscosity.

**As ENER Lot 30 deals with (all) motors (other than the ones already covered by Lot 11 preparatory study), it would be appropriate to cover all the motors used by ENER Lot 28 pumps, including the ones used in submersible pumps within the scope of ENER Lot 30 Implementing Measure.** This would create clear and precise borderlines for the legislative scope of ecodesign of motors thus allowing timely taking into account of energy efficiency issue of submersible sewage pumps, in parallel in ENER Lot 28 study. Such procedure also follows the Extended Product Approach - created by EUROPUMP[1].

The following types of pumps are proposed to be included within the scope of the ENER Lot 28 study (with an upper power limit of 160 kW):

- Centrifugal submersible pumps
    - Radial sewage, mixed flow and axial flow
    - Once a day operation centrifugal submersible pump (shredding, grinding, radial sewage and where volute is part of tank)
    - Domestic drainage < 40 mm passage centrifugal submersible pump
    - Dewatering centrifugal submersible pump
- Centrifugal dry well pumps
    - Radial sewage centrifugal dry well pumps
    - Mixed flow centrifugal dry well pumps
    - Axial pumps centrifugal dry well pumps
- Slurry pumps
    - Light duty slurry pumps
    - Heavy duty slurry pumps

### ▶ Centrifugal submersible pumps

A submersible pump consists of an electric motor and pump, which is sealed into a single unit and submersed in the media being pumped. These pumps are typically found in wastewater networks, as the submersed concept has a small visual impact and allows a narrow and simplified

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[1] It was agreed in the 3rd stakeholder meeting to consider the motors of submersible pumps under the scope of ENER Lot 30 study instead of ENER Lot 28 study. This means that the motors for Lot 28 submersible pumps will need to adhere to the energy efficiency requirements as proposed in ENER Lot 30 study.

pumping station design. As seen in Task 1, standard submersible wastewater pumps are commonly available from very small sizes up to 600-1000 kW and are designed for flow rates from about 4 l/s up to over 2000 l/s. Sizes on the upper end of this type, typically above 160 kW are usually designed as per customer's specifications ("engineered products"). The pumps included in the centrifugal submersible pumps and the centrifugal submersible dewatering pumps that are normally used to empty liquids holding abrasive solids in mines, quarries and construction sites. They are designed to be portable, to include a built in lifting handle to facilitate movement by hand or with a forklift, and to be able to stand alone on the ground with a hose or pipe connected to its discharge.

### Centrifugal dry well pumps (non-submersible)

The centrifugal dry well pumps comprise an easily separable coupled assembly of an electric motor and a pump which is located outside the pumped liquid. The centrifugal dry well pumps are available in similar sizes (up to 600-800 kW and from about 4 l/s up to over 1600 l/s) as the centrifugal submersible pumps. Sizes on the upper end of this type, typically above 160 kW are usually designed as per customer's specifications ("engineered products"). The centrifugal domestic drainage pumps are designed to lift wastewater and drainage into the local sewerage collection network.

### Slurry pumps

Slurry pumps are designed to pump heavy slurries, primarily in mining applications. They are therefore designed to handle high concentrations of fine solids that are often very abrasive. The overwhelming design goal of slurry pumps is to minimise wear. The features for increased efficiency usually drive down reliability. Slurry pumps have a big variety of material options, to cope with the abrasiveness and corrosive behaviour of the pump liquids. Manufacturers are offering more than 100 of these options, to guaranty an optimum performance and wear behaviour. The material options for manufacturing of these pumps are mostly within the range of:

- Steel or cast iron, which may contain high amounts of Chromium
- Ceramics of different kind
- Rubber liners

According to the pumped liquid/solids and conveying process, it is normal that slurry pumps are not selected at BEP (Best Efficiency Point), e.g. for heavy duty applications pumps are selected at 70 to 90% of BEP. Both light and heavy duty slurry pumps are therefore engineered for every duty to choose the optimum pump type, materials and performance.

During this preparatory study, several other pump types that are closely related to ENER Lot 28 pumps but are either not used for their primary functionality or are typically engineered (above 160 kW) were identified. These pump types are not considered for the ecodesign implementing measures proposed in this study. These pump types are listed below:

- **Progressive Cavity Pumps** are basically not designed for wastewater, but for heavy sludge. On this basis, they are excluded from scope.

- **Peristaltic pumps** are only used for sludge applications and very rarely in small number in engineered wastewater applications. These pumps are basically not designed for wastewater, but for heavy sludge. There is a small application overlap with Progressive Cavity pumps.
- **Rotary Lobe pumps** are used for pumping very delicate high viscosity products such as many foodstuffs, and again have design features for different types of product that would make setting a benchmark hard. Other similar positive displacement pumps which are not used for solids handling include **rotary vane pumps** and **gear pumps**.
- **Plunger and Piston pumps** are used for moving high viscosity product. The output of the pumps is not linear as there is nothing being pumped when the plunger/piston is retracting. These pumps are not typically used in the wastewater industry, as progressing cavity pumps provide the same solids handling capability but have a linear (non-pulsating) output.
- **Diaphragm pumps** are either compressed air driven or driven by electric motors, pumping slurries by alternately inflating two membranes. These are inherently inefficient, but are popular for example in the ceramics industry for clay pumping. These are excluded on the basis that they are used predominantly in highly viscous slurry applications, very different from the defined scope of the study.
- In addition, wastewater treatment (WWT) aeration plants have **turbo-blowers** and **surface mixers**, which are not strictly pumps, and so they are excluded from the scope of the study.
- **Tank mixers** are really a form of stirrer, and are used to prevent solids from settling in WWT tanks.
- **Archimedean screw pumps** are engineered products. These pumps have to be designed case by case for each wastewater plant individually. Typically, for these pumps, the screw is welded to sheet metal and the trough is individually formed from concrete in situ. They have a high resistance to blockages and ragging, this makes them very attractive where there is space for them to be installed. The devices are custom manufactured for each application. Their design has to take into account desired flow and given static head. In many cases, space availability at the installation site is a critical factor and determines slope, screw diameter, helix angle and speed. There is no standard product offering for these pumps, not even some kind of a modular system.
- **Paper and Pulp pumps** describe a large and diverse variety of pumps used in the paper manufacturing process. These are specifically designed to handle various stages of the paper making process, and will need to be able to handle hot fluids with varying solids content. These should though be excluded on the basis that the properties of hot paper and pulp fluids are very different from those of wastewater or other high solids content fluids.

## 8.2.3 Specific Ecodesign requirements

### 8.2.3.1 *Scope of specific ecodesign requirements*

The typical users for large submersible and dry well pumps consist of wastewater treatment plants and wastewater pumping stations (as described earlier in Task 3), which are mainly interested in the reliability of the pumps due to large losses incurred when pumps are not operational. This means that stabilised technologies and less complex products are usually preferred to energy saving alternatives, if their reliability has not been asserted. Other non-technical aspects, such as lack of incentives, may also explain why energy efficiency might not directly impact customer behaviour. Only those technologies that achieve improvement in energy efficiency without any loss of reliability are preferred by the pump industry and their customers.

Task 7 of this preparatory study showed that for many types of centrifugal pumps (BC 1, BC 2, BC 5, BC 6 and BC 7), there exists some potential for product level energy savings sold in the EU market. Consequently, Ecodesign Implementing Measures regarding energy efficiency of these types of pumps may be a recommended policy option.

**Table 8-1: Contribution of each Base-Case to the overall "product level" and "extended product level" energy savings potential of ENER Lot 28 pumps (in 2011)**

| Pump Type | Base-Case name | Stock electricity consumption | Pump level electricity savings | BC contribution to overall pump level electricity savings | EPA level electricity savings | BC contribution to overall EPA level electricity savings |
|---|---|---|---|---|---|---|
| | | GWh/year | GWh/year | % | GWh/year | % |
| **BC 1** | Centrifugal submersible pump: Radial sewage pumps 1 to 160 kW | 15 028 | 361 | 52.4% | 1909 | 66.9% |
| **BC 2** | Centrifugal submersible pump: Mixed flow & axial pumps | 858 | 17 | 2.5% | 103 | 3.6% |
| **BC 3** | Centrifugal submersible pump – once a day operation | 70 | 3 | 0.4% | 7 | 0.3% |
| **BC 4** | Centrifugal submersible domestic drainage pump < 40 mm passage | 88 | 9 | 1.3% | 13 | 0.5% |
| **BC 5** | Submersible dewatering pumps | 2 940 | 147 | 21.4% | 294 | 10.3% |
| **BC 6** | Centrifugal dry well pump | 3 267 | 65 | 9.5% | 268 | 9.4% |

| Pump Type | Base-Case name | Stock electricity consumption | Pump level electricity savings | BC contribution to overall pump level electricity savings | EPA level electricity savings | BC contribution to overall EPA level electricity savings |
|---|---|---|---|---|---|---|
| | | GWh/year | GWh/year | % | GWh/year | % |
| **BC 7A** | Slurry Pumps – Light Duty* | 7 800 | 78 | 11.3% | 234 | 8.2% |
| **BC 7B** | Slurry Pumps – Heavy Duty* | 800 | 8 | 1.2% | 24 | 0.8% |
| **TOTAL** | | 30 851 | 688 | 100% | 2 852 | 100% |

** The EPA savings for BC 7 (slurry pumps) only include hydraulic and motor savings but does not include the VSDs as these are not appropriate for slurry pumps (users change speed by changing pulleys).*

Table 8-1 shows that more than 95% of the overall product level energy savings (hydraulic efficiency improvements) for Lot 28 pumps comes from the following five Base-Cases:

- BC 1: Submersible radial sewage pumps 1 to 160 kW
- BC 2: Submersible fixed flow & axial pumps
- BC 5: Submersible dewatering pumps
- BC 6: Dry well radial sewage pumps 1 to 160 kW
- BC 7A: Light duty slurry pumps

Table 8-1 also shows these five Base-Cases also contributes to more 98% of the overall extended product level energy savings (use of VSD , hydraulic and motor efficiency improvements) for Lot 28 pumps. These five Base-Cases are therefore good candidates for considering specific ecodesign requirements.

BC 4 (Centrifugal submersible domestic drainage pump<40mm passage) although only have a small share (less than 2%) to the product level energy savings of Lot 28 pumps, but these pumps comprise the largest share of sales (more than 75% in 2011, as presented in Task 2) of Lot 28 pumps. For this reason, it is important to also consider these pumps for the specific ecodesign requirements.

The remaining Base-Cases (BC 3 and BC 7B), whose contribution to total energy savings of Lot 28 pumps is insignificant (less than 2% at product level and less than 1% at the extended product level) are therefore recommended not to be considered by the scope of specific ecodesign requirements.

### 8.2.3.2 *Timeline of specific ecodesign requirements*

The Ecodesign requirements discussed hereafter are proposed in a provisional timetable consisting in one or several progressive steps: 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 is valid for the pumps in Lot 28 proposed for regulation since the available improvement options are already implemented in some pumps in the market and the redesign cycle of these pumps is relatively short.

The implementation of Ecodesign requirements in the form of tiers takes into account the redesign cycles of around 2 to 4 years 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.

Therefore, a tiered approach in 2-year steps is proposed for establishing specific ecodesign requirements for wastewater pumps. A maximum of three tiers is considered sufficient to introduce ambitious requirements and provide a long term visibility to the manufacturers. The potential benefits in terms of energy savings and the related consumer expenditure estimated for each of the tiers proposed are 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 implementing measure
- **Second tier**: 2018 or four years after the approval of the implementing measure
- **Third tier**: 2020 or six years after the approval of the implementing measure

### 8.2.3.3 *Type of specific ecodesign requirements*

It is recommendable that any regulation on pump types or applications is based on parameters and approaches (MEI, Minimum Efficiency Index and EEI, Energy Efficiency Index) comparable to other pump regulations (e.g. 641/2009 or 547/2012). Manufacturers of Lot 28 pumps very often also produce other pumps (such as clean water pumps covered under Lot 11) for which they have to already perform the MEI and EEI calculations[2]. Therefore, having a similar approach as other pump regulations (e.g. 641/2009 or 547/2012) would allow Lot 28 pump manufacturers to perform energy efficiency calculations with relative ease. Similarly, the users of Lot 28 pumps who are mostly big water management companies also use clean water pumps for their businesses. Having a harmonised approach as other pump regulations (e.g. 641/2009 or 547/2012) would allow the users to easily relate to the more efficient Lot 28 pumps. The choice of MEI/EEI for setting specific ecodesign requirements for Lot 28 pumps could thus speed up the ecodesign legislative process for Lot 28 pumps.

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[2] As an example, the EEI approach and equations used for Circulators (in Regulation 547/2012) is presented in Annex A.

Ideally, the possible MEPS (Minimum Energy Performance Standard) should be based on the Extended Product Approach presented in Task 1 of this preparatory study. This 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.

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 variable speed or two speeds. This EEI index development 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 Lot 28 pumps to be regulated.

**Energy efficiency requirements for motors used by Lot 28 pumps are to be covered by MEPS requirement for motors proposed by Lot 30 study**[3]. This means that the energy efficiency of all motors is regulated through one legislation instead of a situation where the motors used in centrifugal submersible pumps in Lot 28 are regulated separately through the same energy efficiency legislation as for Lot 28 pumps. Regulating all motors in the former way should make it easier for manufacturers to understand and implement these requirements thus leading to a more effective implementation of the legislation.

Another efficiency parameter, the Minimum hydraulic Efficiency Index (MEI), is defined in the Commission Regulation 547/2012 on ecodesign of 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 Lot 28 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.

The policy options presented in this task are based on simply removing the worst "n"% of Lot 28 pumps, corresponding to an MEI value of "0.n"[4]. A number of potential MEPS based on the MEI cut-off criteria for specific Lot 28 pumps (BC 1, BC 2, BC 4, BC 5, BC 6 and BC 7A) are considered, as presented below:

- Option 1: MEI cut-off values as 0.1 as Tier 1 and 0.4 as Tier 2
- Option 2: MEI cut-off values as 0.4 in a single Tier

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[3] Ecodesign of Electric motors (www.eco-motors-drives.eu/Eco/Home.html)

[4] For example, an MEI of 0.4 means that 40% of Lot 28 pumps currently sold would fall below this line and hence could not be placed on the EU market anymore.

- Option 3: MEI cut-off values as 0.1 as Tier 1, 0.4 as Tier 2 and 0.7 as Tier 3
- Option 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

These policy options allows to reflect on the various timelines (just one tier in Option 2, whereas 3 tiers in Option 3 and two tiers in Options 1 and 4) and of different level of ambitions[5] to high energy savings ambition in Option 4 (MEI =1 requirement as final tier) of energy savings for the Lot 28 pumps. The impact of implementation of these policy options on energy savings and consumer expenditure is assessed later in the report (under the scenario analysis, section 8.3).

### 8.2.3.4 *Minimum Efficiency Index*

The method for calculating the MEI is stated in the Commission Regulation 547/2012 (with regard to ecodesign requirement for water pumps), and the method for calculating the EEI value is given in the Commission regulation 641/2009. The specific MEI values are calculated based on the energy savings and market data presented previously in Task 7 report of this study for each of the Lot 28 pumps (BC 1, BC 2, BC 4, BC 5, BC 6 and BC 7A) considered for specific ecodesign requirements. This data is presented in Table 8-2.

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 Lot 28 pumps (up to 25 years), 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)[6] from setting the different MEI requirements, the distribution of Lot 28 pumps is split into 10 discrete bands from 0% (reference, denoted by WP: Worst pump) to 100% cut off, as presented in Table 8-2 and Table 8-3.

**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[7].**

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[5] Relatively low energy savings ambition level in Option 1, MEI = 0.4 requirement as final tier.

[6] 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.

[7] A data collection based on ENER Lot 11 pumps may not be appropriate for ENER Lot 28 pumps as the pump efficiency correlates with pump size and specific speed in a different manner. This fact is a result of requirements for a free passage of certain dimensions and simple and robust clearances. These requirements will limit the attainable efficiency for small pumps in general and especially pumps of low specific speeds. This will lead to difference in slope between the polynomials based on ENER Lot 11 and ENER Lot 28 pumps, which a constant C-value cannot compensate.

Table 8-2: Task 7 data used as the basis of MEI calculation for Lot 28 pumps

| **Improvement option** | | **BAT** | | | | | | **BC** | | | **WP** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Market share** | | 100% | 90% | 80% | 70% | 60% | 50% | 40% | 30% | 20% | 10% |
| **MEI Value** | | 1 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 | 0.4 | 0.3 | 0.2 | 0.1 |
| Difference in purchase cost compared to Base-Case (%) | BC 1 | **1.4%** | 1.17% | 0.93% | 0.70% | 0.47% | 0.23% | **0.0%** | -0.23% | -0.47% | -0.70% |
| | BC 2 | **1.4%** | 1.17% | 0.93% | 0.70% | 0.47% | 0.23% | **0.0%** | -0.23% | -0.47% | -0.70% |
| | BC 4 | **1.4%** | 1.17% | 0.93% | 0.70% | 0.47% | 0.23% | **0.0%** | -0.23% | -0.47% | -0.70% |
| | BC 5 | **1.4%** | 1.17% | 0.93% | 0.70% | 0.47% | 0.23% | **0.0%** | -0.23% | -0.47% | -0.70% |
| | BC 6 | **1.4%** | 1.17% | 0.93% | 0.70% | 0.47% | 0.23% | **0.0%** | -0.23% | -0.47% | -0.70% |
| | BC 7A | **2.0%** | 1.67% | 1.33% | 1.00% | 0.67% | 0.33% | **0.0%** | -0.33% | -0.67% | -1.00% |
| Difference in maintenance cost compared to Base-Case (%) | BC 1 | **-2.0%** | -1.67% | -1.33% | -1.00% | -0.67% | -0.33% | **0.0%** | 0.33% | 0.67% | 1.00% |
| | BC 2 | **-1.9%** | -1.58% | -1.27% | -0.95% | -0.63% | -0.32% | **0.0%** | 0.32% | 0.63% | 0.95% |
| | BC 4 | **-1.9%** | -1.58% | -1.27% | -0.95% | -0.63% | -0.32% | **0.0%** | 0.32% | 0.63% | 0.95% |
| | BC 5 | **-1.9%** | -1.58% | -1.27% | -0.95% | -0.63% | -0.32% | **0.0%** | 0.32% | 0.63% | 0.95% |
| | BC 6 | **-1.9%** | -1.58% | -1.27% | -0.95% | -0.63% | -0.32% | **0.0%** | 0.32% | 0.63% | 0.95% |
| | BC 7A | **1.0%** | 0.83% | 0.67% | 0.50% | 0.33% | 0.17% | **0.0%** | -0.17% | -0.33% | -0.50% |

| **Improvement option** | | **BAT** | | | | | | **BC** | | | **WP** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Market share** | | **100%** | **90%** | **80%** | **70%** | **60%** | **50%** | **40%** | **30%** | **20%** | **10%** |
| **MEI Value** | | **1** | **0.9** | **0.8** | **0.7** | **0.6** | **0.5** | **0.4** | **0.3** | **0.2** | **0.1** |
| Difference in electricity savings compared to Base-Case (%) | BC 1 | **2.4%** | 2.0% | 1.6% | 1.2% | 0.8% | 0.4% | **0%** | -0.4% | -0.8% | -1.2% |
| | BC 2 | **2%** | 1.7% | 1.3% | 1.0% | 0.7% | 0.3% | **0%** | -0.3% | -0.7% | -1.0% |
| | BC 4 | **10%** | 8.3% | 6.7% | 5.0% | 3.3% | 1.7% | **0%** | -1.7% | -3.3% | -5.0% |
| | BC 5 | **5%** | 4.2% | 3.3% | 2.5% | 1.7% | 0.8% | **0%** | -0.8% | -1.7% | -2.5% |
| | BC 6 | **2.0%** | 1.7% | 1.3% | 1.0% | 0.7% | 0.3% | **0%** | -0.3% | -0.7% | -1.0% |
| | BC 7A | **1.0%** | 0.8% | 0.7% | 0.5% | 0.3% | 0.2% | **0%** | -0.2% | -0.3% | -0.5% |

Table 8-3: MEI values to be used for Lot 28 pumps considered for specific ecodesign requirements

| **Improvement option** | | **BAT** | | | | | | **BC** | | | **WP** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Market share** | | **100%** | **90%** | **80%** | **70%** | **60%** | **50%** | **40%** | **30%** | **20%** | **10%** |
| **MEI Value** | | **1** | **0.9** | **0.8** | **0.7** | **0.6** | **0.5** | **0.4** | **0.3** | **0.2** | **0.1** |
| Annual electricity consumption (kWh/unit/year) | BC 1 | 7 781 | 7 813 | 7 844 | 7 876 | 7 908 | 7 940 | **7 972** | 8 004 | 8 036 | 8 068 |
| | BC 2 | 171 500 | 172 083 | 172 667 | 173 250 | 173 833 | 174 417 | **175 000** | 175 583 | 176 167 | 176 750 |
| | BC 4 | 6 | 6.4 | 6.5 | 6.7 | 6.8 | 6.9 | **7.0** | 7.1 | 7.2 | 7.4 |
| | BC 5 | 9 975 | 10 063 | 10 150 | 10 238 | 10 325 | 10 413 | **10 500** | 10 588 | 10 675 | 10 763 |
| | BC 6 | 12 255 | 12 297 | 12 338 | 12 380 | 12 422 | 12 463 | **12 505** | 12 547 | 12 588 | 12 630 |
| | BC 7A | 128 700 | 128 917 | 129 133 | 129 350 | 129 567 | 129 783 | **130 000** | 130 217 | 130 433 | 130 650 |
| Purchase cost (€/unit) | BC 1 | 3 420 | 3 412 | 3 404 | 3 397 | 3 389 | 3 381 | **3 373** | 3 365 | 3 357 | 3 349 |
| | BC 2 | 15 210 | 15 175 | 15 140 | 15 105 | 15 070 | 15 035 | **15 000** | 14 965 | 14 930 | 14 895 |
| | BC 4 | 304 | 304 | 303 | 302 | 301 | 301 | **300** | 299 | 299 | 298 |
| | BC 5 | 5 070 | 5 058 | 5 047 | 5 035 | 5 023 | 5 012 | **5 000** | 4 988 | 4 977 | 4 965 |
| | BC 6 | 3 481 | 3 473 | 3 465 | 3 457 | 3 449 | 3 441 | **3 433** | 3 425 | 3 417 | 3 409 |
| | BC 7A | 20 400 | 20 333 | 20 267 | 20 200 | 20 133 | 20 067 | **20 000** | 19 933 | 19 867 | 19 800 |

| Improvement option | | BAT | | | | | | BC | | | WP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Market share | | 100% | 90% | 80% | 70% | 60% | 50% | 40% | 30% | 20% | 10% |
| MEI Value | | 1 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 | 0.4 | 0.3 | 0.2 | 0.1 |
| Maintenance and repair cost (€/year) | BC 1 | 798 | 795 | 792 | 790 | 787 | 785 | **782** | 779 | 777 | 774 |
| | BC 2 | 968 | 965 | 962 | 959 | 956 | 953 | **950** | 947 | 944 | 941 |
| | BC 4 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | 0 | 0 | 0 |
| | BC 5 | 472 | 470 | 469 | 467 | 466 | 464 | **463** | 462 | 460 | 459 |
| | BC 6 | 822 | 820 | 817 | 815 | 812 | 810 | **807** | 804 | 802 | 799 |
| | BC 7A | 1 288 | 1 286 | 1 284 | 1 281 | 1 279 | 1 277 | **1 275** | 1 273 | 1 271 | 1 269 |

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) calculated by using specific C-values[8] for each of the MEI selected:

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

$$(\eta \text{ PL}) = F_7 \cdot (\eta \text{ BEP})$$

$$(\eta \text{ OL}) = F_8 \cdot (\eta \text{ BEP})$$

*Where,*

$x = \ln(n_s)$;

$y = \ln(Q)$;

*ln = natural logarithm;*

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

$n_s$ *= specific speed in* $[\min^{-1}]$;

*C = specific values calculated for each pump type;*

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

Ecodesign requirements based on MEI (hydraulic efficiency) for wastewater pumps needs to adhere to specific design requirements and technical parameters to avoid making wastewater pumps incapable of pumping wastewater. An independent study (by EUROPUMP and the University of Berlin) is in progress to develop standardised wastewater classes[9]. This could form the basis of further developing the wastewater calibration for the polynomials / efficiency surface shapes, specific factors of the formulae presented above. The outcome of this will be a function factor respecting the influencing constraint in wastewater business. This function factor takes into account the diversity of applications and broad range of capacities covered by the Lot 28 Base-Cases. These function factors are reflected in the figures used for C-values. These function factors allow correction of the hydraulic efficiency of the Lot 28 pumps by adjusting the C-values so that MEI of 0.1 corresponds to banning 10% of the worst performing pumps. A preliminary estimate by the project team of the adjusted (incorporating function factors) C- values for the Lot 28 pumps is presented in Annex B[7].

## 8.2.4 Generic Ecodesign requirements

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.

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[8] C-values is a parameter specific to each type of Lot 28 pump that is used for the calculation of hydraulic efficiency, using the equation presented in this section 8.2.3.4.

[9] Note that a similar categorisation of slurries/solids would be needed to set up the "Function Factor" for the different types of slurry pumps

For all wastewater pumps covered in this preparatory study, 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 information listed above shall be visibly displayed on freely accessible websites and documentation (such as product catalogues and technical manuals) of the water pump manufacturers.

For Lot 28 specific pumps (BC 1, BC 2, BC 4, BC 5, BC 6 and BC 7A) considered in this preparatory study, manufacturers should also provide the following information:

- The MEI of pumps, calculated in accordance with section 8.2.3.4, shall be indicated on the name plate and packaging of the product and in the technical documentation as follows: 'MEI ≥ 0,[##]'
- The following information shall be provided: 'The benchmark for most efficient Lot 28 specific pumps (BC 1, BC 2, BC 4, BC 5, BC 6 and BC 7A) is MEI ≥ 0,[##]

### 8.2.5 Recommendations on standardisation mandates

To achieve a traceable and reliable test procedure for wastewater pumps, following elements still needs to be addressed:

- A test procedure to define the wastewater types (normally more than one);
- Development of function factors; and
- A mathematical algorithm to calculate the C-values and load profiles for the (BC 1, BC 2, BC 4, BC 5 BC 6 and BC 7) pumps proposed to be covered by specific ecodesign requirements in this study.

This can be done by means of a CEN standard. A VDMA[10] Working Group (WG) in collaboration with the Technical University (TU) of Berlin has been carrying out research work in this context since 2012. At present, these preliminary results are being used by a EUROPUMP WG as the basis for the work on definition of wastewater types and the function factors (indicating the fitness of specific pumps to specific applications/wastewater). All this work will be accompanied by conducting of pilot tests on the wastewater types by TU Berlin. EUROPUMP indicated that it may take at least one more year to fix the definition of different wastewater types. Tests to develop function factors for the specific pump types will take another year. To elaborate an algorithm will take another 3-6 month. This means that that the definition for wastewater types and the

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[10] VDMA (Verband Deutscher Maschinen- und Anlagenbau e.V.) is a German engineering association.

requirements for the test rig and test procedure should be fixed by end of 2014, the algorithm for calculation of function factors and adjusted C-values will follow by end of 2015 and finally the corresponding CEN standard will only be available towards the end of 2016. If this timeline is met, then it is recommended that during the next revision of potential MEPS Regulation for Lot 28 pumps, the EC should take into account the EEI approach for Lot 28 MEPS instead of the MEPS proposed in this Task based on MEI approach.

## 8.3 Scenario analysis

### 8.3.1 Type of scenarios considered

This section presents the scenario analysis to evaluate which of the proposed MEPS (the four policy options concerning ecodesign specific measures, identified in section 8.2.3.3) is the most beneficial from the environmental and economic point of view compared to the Business-as-usual (BaU) scenario. The scenario analysis in this section is performed from 2013 (latest year corresponding to the drafting of this report) till 2040. The time duration (28 years) of the scenario analysis is more than the longest lifetime of the Base-Cases considered (BC 7A with a lifetime of 25 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 stock of Lot 28 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 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 considered earlier in section 8.2.3.3, which include:

- BC 1: Submersible radial sewage pumps 1 to 160 kW
- BC2: Submersible fixed flow & axial pumps
- BC 5: Submersible dewatering pumps
- BC 4: Centrifugal submersible domestic drainage pump<40mm passage
- BC 6: Dry well radial sewage pumps 1 to 160 kW
- BC 7A: Light duty slurry pumps

The four scenarios (other than BaU) analysed in this section are presented in Table 8-4. These four policy scenarios compare the potential environmental 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 ENER Lot 11 preparatory study (Commission Regulation (EU) No 547/2012). The Scenario 2 achieves the same level of ambition than Scenario 1 in a shorter period. 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 current EU average would be banned for sale at short term, and the current 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 Lot 28 pumps at EU level.

**Table 8-4: 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 low 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 10% improve to the 30% cut off, and the 10-20% band of 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 10% improve to the 50% cut off, and the 10-20% 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)[11].

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

The assumptions about consumer response to the MEI requirements, banning the share of Lot 28 pumps below the MEI cut-off value for the four policy option scenarios across the three different

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

possibilities (sub-scenarios) are presented in the Table 8-5. 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 four policy options. This allows to in turn calculate the energy and economic inputs for the policy option scenarios (as presented in next section 8.3.2).

**Table 8-5: 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 | - |

### 8.3.2 Inputs to scenario analysis tool

An Excel tool is created to allow the impacts of the different scenarios to be modelled (2013-2040). The tool is 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 (annual growth rate of 2.5% from 2011 until 2040) and stock forecast detailed in Task 2 are used as input.
- 70% of the annual sales are replacement sales (for replacement of the existing installed stock, meaning only 30% of the annual sales for new installations).
- Total 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.

- The total electricity consumption results are not limited to the use phase but also take into account the energy required over the whole lifecycle (including the manufacturing distribution and end-of-life phases). Overall life cycle 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 and install the product (purchase cost), taken into account at the time of purchase, and the operating costs (energy, maintenance and repair), which are spread over the lifecycle of the pump.
- The tool calculates the cost for consumer expenditure in Euros and total electricity in GWh, for the different policy scenarios.

The electricity consumption and economic inputs used for the four policy option scenarios are presented in Table 8-6.

Table 8-6: The energy and economic inputs for the policy option scenarios

| | | MEI = 0.1 | | | MEI = 0.4 | | | MEI = 0.7 | | | MEI =1.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Market response | | Pessimistic (0.2) | Pragmatic (0.4) | Optimistic (1) | Pessimistic (0.5) | Pragmatic (0.7) | Optimistic (1) | Pessimistic (0.8) | Pragmatic (1) | Optimistic (1) | Pragmatic/Pessimistic /Optimistic (1) |
| BC1 | Electricity consumption (kWh/unit/year) | 7 949 | 7 941 | 7 918 | 7 915 | 7 884 | 7 838 | 7 846 | 7 792 | 7 792 | 7 781 |
| BC2 | | 174 580 | 174 440 | 174 020 | 173 950 | 173 390 | 172 550 | 172 690 | 171 710 | 171 710 | 171 500 |
| BC4 | | 6.92 | 6.89 | 6.80 | 6.79 | 6.68 | 6.51 | 6.54 | 6.34 | 6.34 | 6 |
| BC5 | | 10 437 | 10 416 | 10 353 | 10 343 | 10 259 | 10 133 | 10 154 | 10 007 | 10 007 | 9 975 |
| BC6 | | 12 475 | 12 465 | 12 435 | 12 430 | 12 390 | 12 330 | 12 340 | 12 270 | 12 270 | 12 255 |
| BC7A | | 129 844 | 129 792 | 129 636 | 129 610 | 129 402 | 129 090 | 129 142 | 128 778 | 128 778 | 128 700 |
| BC1 | New purchase cost (€/unit) | 3 379 | 3 381 | 3 386 | 3 387 | 3 395 | 3 406 | 3 404 | 3 417 | 3 417 | 3 420 |
| BC2 | | 15 025 | 15 034 | 15 059 | 15 063 | 15 097 | 15 147 | 15 139 | 15 197 | 15 197 | 15 210 |
| BC4 | | 300.5 | 300.7 | 301.2 | 301.3 | 301.9 | 302.9 | 302.8 | 303.9 | 303.9 | 304 |
| BC5 | | 5 008 | 5 011 | 5 020 | 5 021 | 5 032 | 5 049 | 5 046 | 5 066 | 5 066 | 5 070 |
| BC6 | | 3 439 | 3 441 | 3 446 | 3 447 | 3 455 | 3 467 | 3 465 | 3 478 | 3 388 | 3 481 |
| BC7A | | 20 048 | 20 064 | 20 112 | 20 120 | 20 184 | 20 280 | 20 264 | 20 376 | 20 376 | 20 400 |

| | | MEI = 0.1 | | | MEI = 0.4 | | | MEI = 0.7 | | | MEI =1.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Market response | | Pessimistic (0.2) | Pragmatic (0.4) | Optimistic (1) | Pessimistic (0.5) | Pragmatic (0.7) | Optimistic (1) | Pessimistic (0.8) | Pragmatic (1) | Optimistic (1) | Pragmatic/Pessimistic /Optimistic (1) |
| BC1 | New maintenance cost (€/year) | 783.9 | 784.5 | 786.4 | 786.7 | 789.2 | 792.9 | 792.3 | 796.7 | 796.7 | 798 |
| BC2 | | 952.2 | 952.9 | 955.1 | 955.4 | 958.3 | 962.6 | 961.9 | 967.0 | 967.0 | 968 |
| BC4 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BC5 | | 464.1 | 464.4 | 465.5 | 465.6 | 467.0 | 469.2 | 468.8 | 471.3 | 471.3 | 472 |
| BC6 | | 808.8 | 809.5 | 811.3 | 811.6 | 814.1 | 817.7 | 817.1 | 821.4 | 821.4 | 822 |
| BC7A | | 1 277 | 1 277 | 1 279 | 1 279 | 1 281 | 1 284 | 1 283 | 1 287 | 1 263 | 1 288 |

### 8.3.3 Comparison of scenarios

This subsection 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
- Overall consumer expenditure

This comparative analysis is carried out for each of the six Base-Cases (BC 1, BC 2, BC 4, BC 5, BC 6 and BC 7A) recommended for specific ecodesign requirements in section 8.2.3.1. The comparative analysis for these two indicators is presented for the following years:

- 2018
- 2020
- 2030
- 2040

The selection of above 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 (year 2018, 2 years after the first tier of requirements, 2016). Year 2020 corresponds to the EU 2020 headline target set in the Europe 2020 strategy[12]. Year 2030 corresponds to almost half of the EU installed stock of Lot 28 pumps represented by more energy efficient pumps. Lastly, year 2040 corresponds to the time by when most of the EU installed stock of Lot 28 pumps is replenished by more energy efficient pumps (as required under the 12 policy option scenarios).

#### ▶ Total electricity consumption[13]

The savings in annual electricity consumption for each of the six 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 8-1 to Figure 8-7 present the comparison of annual savings in electricity consumption for each of the six Base-Cases (BC 1, BC 2, BC 4, BC 5, BC 6 and BC 7A) for the twelve different sub-scenarios. (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).

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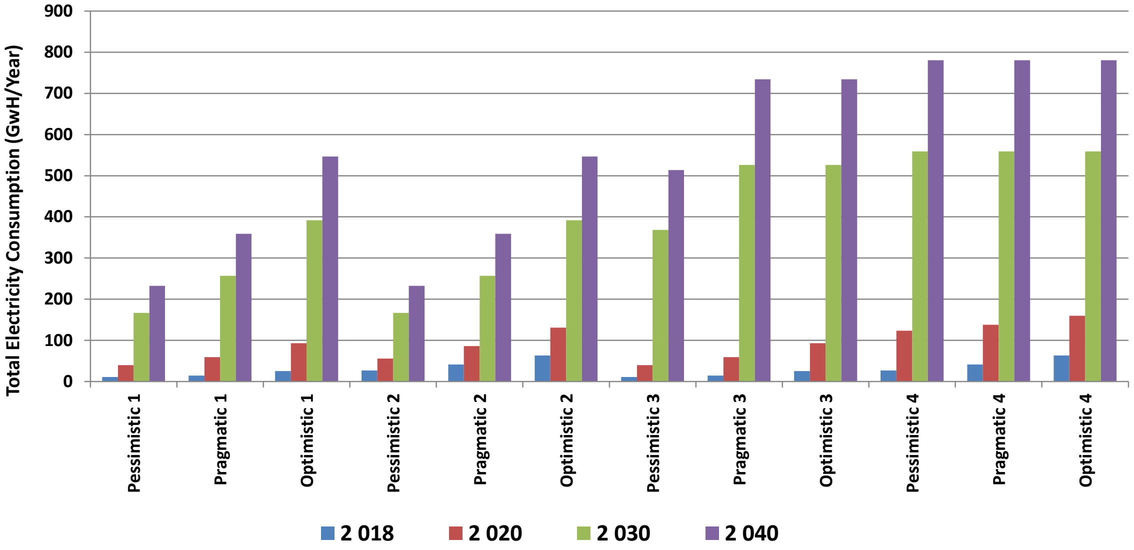
[12] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:2020:FIN:EN:PDF

[13] Total Electricity Consumption over the life cycle of the Base-Case.

Figure 8-1: Total annual electricity consumption savings (in GWh) for BC 1 across four key years for the 12 policy option scenarios

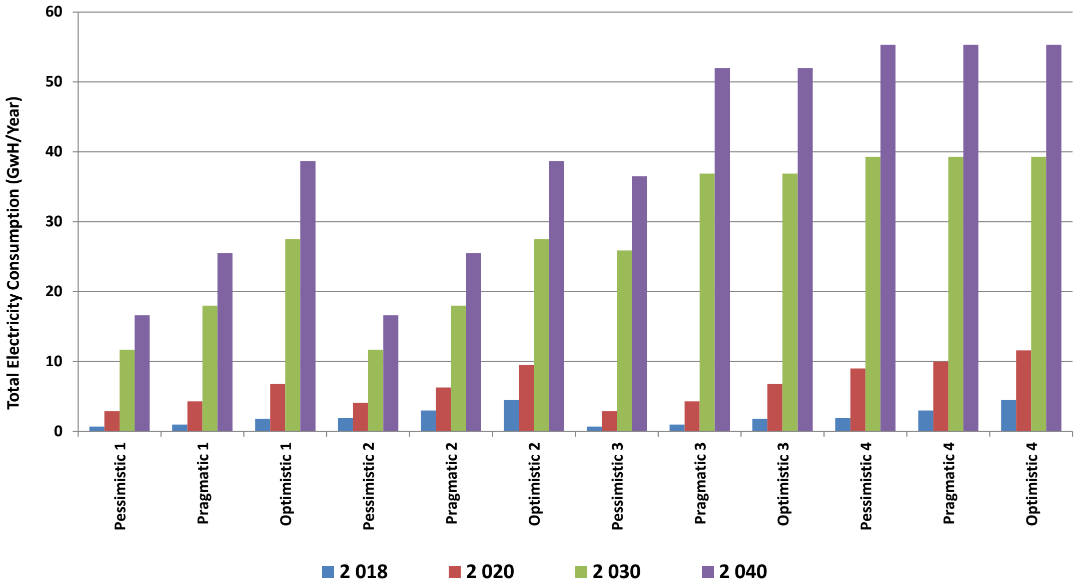


For Base-Case 1, the most ambitious scenario corresponds to Policy Option 4 (cut-offs of 0.4 and 1.0 in 2016 and 2018 respectively), which could save up to 780 GWh per year in 2040 at EU level. In the most modest scenario (i.e. Policy Option 1 and 2), the maximum electricity savings at EU level in the same year would be around 547 GWh.

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

The difference between the maximum potential electricity savings in pragmatic and optimistic scenarios of a cut-off of 0.7 (in Policy Option 3) and 1.0 (Policy Option 4) is also negligible (less than 7% as scenario 3 has electricity savings of 734 GWh as against 780 GWh of scenario 4); except in the case of the pessimistic sub-scenario. Scenario 4 would achieve slightly higher electricity savings faster than scenario 3 (the electricity savings for pessimistic sub-scenario 3 are estimated to be 514 GWh as compared to 780 GWh for pessimistic sub-scenario 4).

Figure 8-2: Total annual electricity consumption savings (in GWh) for BC 2 across four key years for the 12 policy option scenarios

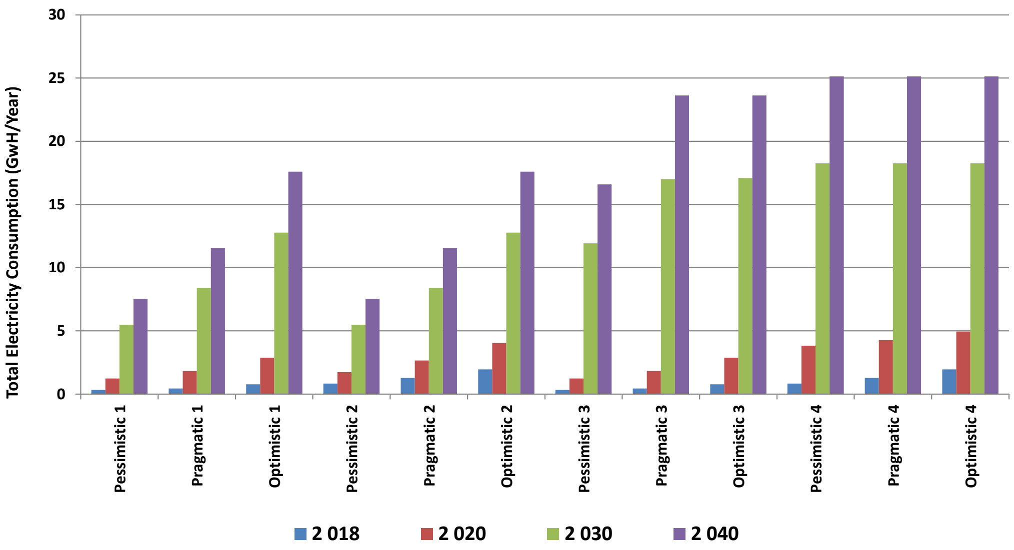


For Base-Case 2, the most ambitious scenario corresponds to Scenario 4, which could save up to 55 GWh per year in 2040 at EU level. In the most modest scenario (i.e Policy Option 1 and 2), the maximum electricity savings at EU level in the same year would be around 39 GWh per year in 2040.

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 electricity savings faster than scenario 3 (the electricity savings for pessimistic sub-scenario 3 are estimated to be 37 GWh as compared to 55 GWh 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 8-3: Total annual electricity consumption savings (in GWh) for BC 4 across four key years for the 12 policy option scenarios

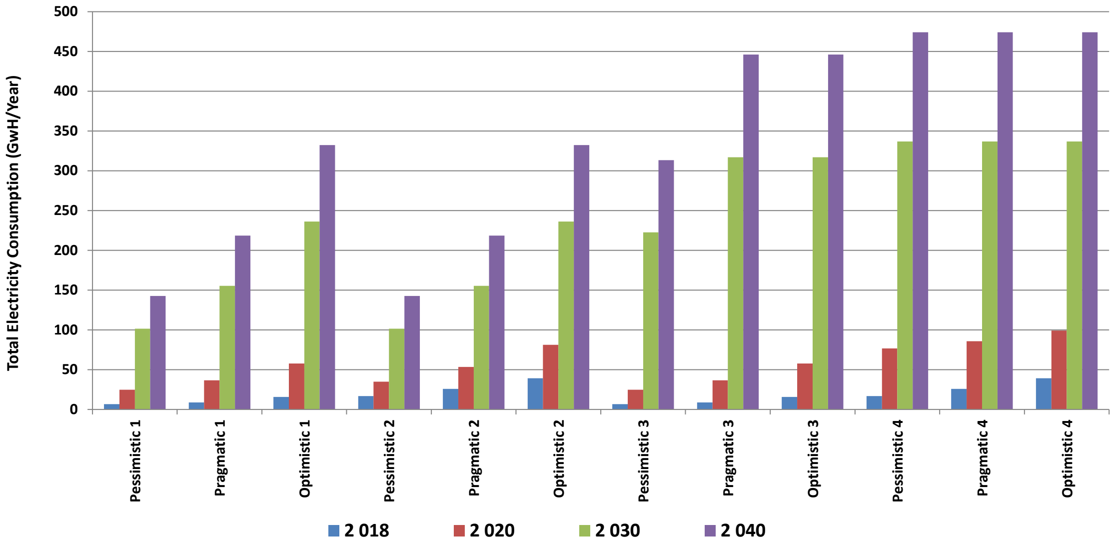


For Base-Case 4, the most ambitious scenario corresponds to Scenario 4. This scenario would save up to 25.1 GWh per year in 2040 at EU level. In the most modest scenario (i.e. Policy Option 1 and 2), the maximum electricity savings at EU level in the same year would be around 17.6 GWh per year in 2040.

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 electricity savings faster than scenario 3 (the electricity savings for pessimistic sub-scenario 3 are estimated to be 16.6 GWh as compared to 25.1 GWh 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.

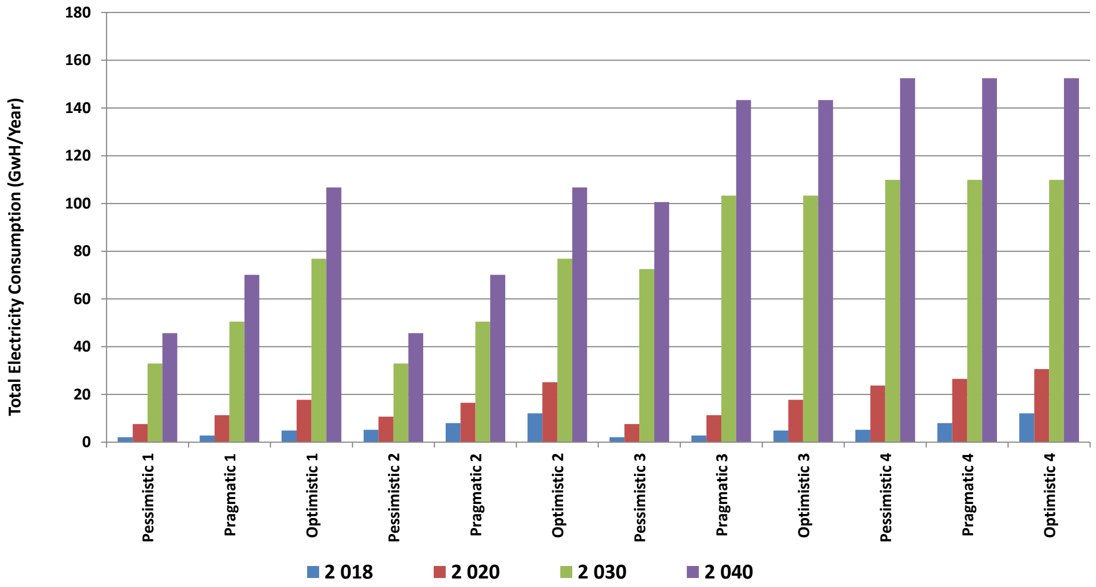
**Figure 8-4: Total annual electricity consumption savings (in GWh) for BC 5 across four key years for the 12 policy option scenarios**



For Base-Case 5, the most ambitious scenario corresponds to Scenario 4 and could save up to 474 GWh per year in 2040 at EU level. In the most modest scenario (i.e. Policy Option 1 and 2), the maximum electricity savings at EU level in the same year would be around 332 GWh. The difference between scenarios 1 and 2 is negligible. In a similar manner, the difference between the maximum potential electricity savings of scenario 3 and scenario 4 is also negligible, except in the case of the pessimistic sub-scenario. Scenario 4 would achieve slightly higher electricity savings faster than scenario 3 (the electricity savings for pessimistic sub-scenario 3 are estimated to be 313 GWh as compared to 474 GWh 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 8-5: Total annual electricity consumption savings (in GWh) for BC 6 across four key years for the 12 policy option scenarios

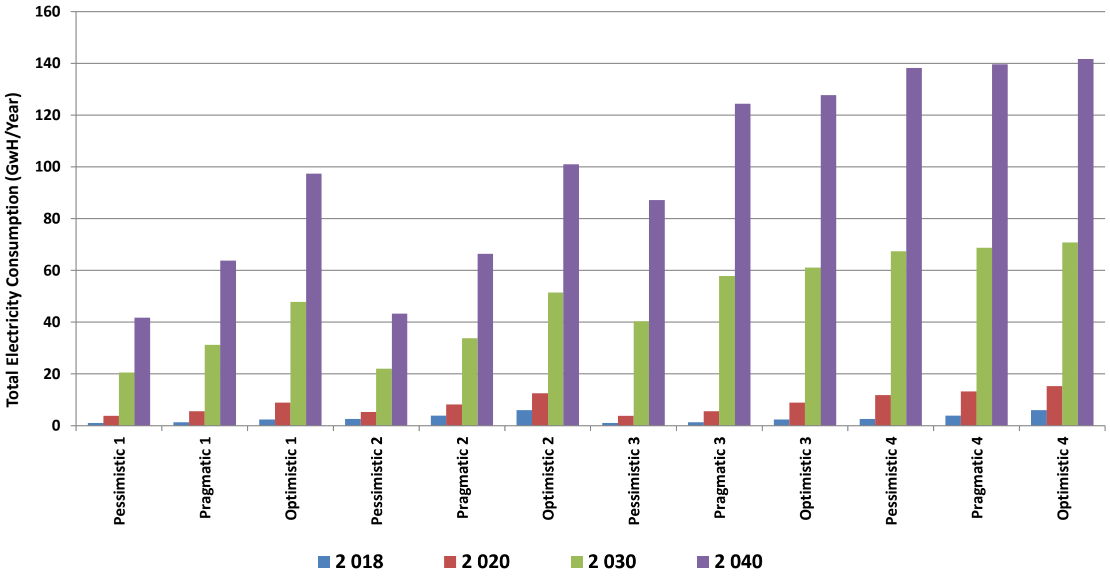


For Base-Case 6, the most ambitious scenario corresponds to Scenario 4 and could save up to 153 GWh per year in 2040 at EU level.

In the most modest scenario (i.e. Policy Option 1 and 2), the maximum electricity savings at EU level in the same year would be around 107 GWh. The difference between scenarios 1 and 2 is negligible. In a similar manner, the difference between the maximum potential electricity savings of scenario 3 and scenario 4 is also negligible, except in the case of the pessimistic sub-scenario. Scenario 4 would achieve slightly higher electricity savings faster than scenario 3 (the electricity savings for pessimistic sub-scenario 3 are estimated to be 101 GWh as compared to 153 GWh for pessimistic sub-scenario 4).

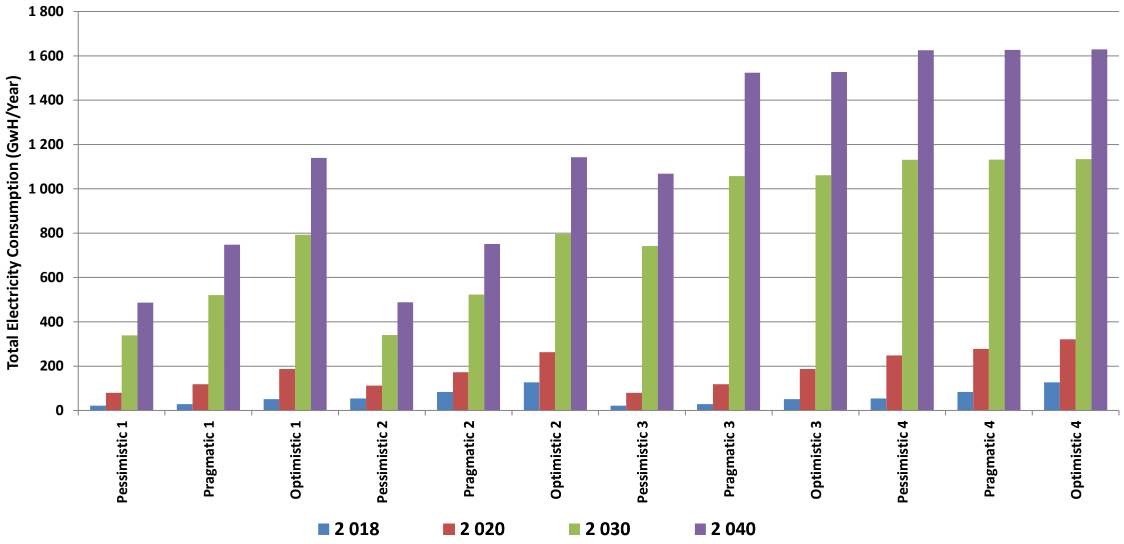
In both cases, Scenario 2 and Scenario 4 could bring electricity savings faster at EU level than Scenario 1 and Scenario 3, respectively.

Figure 8-6: Total annual electricity consumption savings (in GWh) for BC 7A across four key years for the 12 policy option scenarios



For Base-Case 7A the most ambitious scenario is Scenario 4, which could save up to 142 GWh per year in 2040 at EU level. In one of the most modest scenarios (i.e. Policy Option 1 and 2), the maximum electricity savings at EU level in the same year would be around 97 GWh and 101 GWh respectively. The difference between scenarios 1 and 2 is negligible. In a similar manner, the difference between the maximum potential electricity savings of scenario 3 and scenario 4 is also negligible, except in the case of the pessimistic sub-scenario. Scenario 4 would achieve slightly higher electricity savings faster than scenario 3 (the electricity savings for pessimistic sub-scenario 3 are estimated to be 87 GWh as compared to 138 GWh for pessimistic sub-scenario 4).

Figure 8-7: Total annual electricity consumption savings (in GWh) for all selected Base-Cases (BC 1, BC 2, BC 4, BC 5, BC 6 and BC 7A) across four key years for the 12 policy option scenarios



The comparison of the total electricity savings achieved by policy implementation on all the Base-Case included in this analysis shows that the maximum electricity savings per year that could be achieved in 2040 are between 486.6 GWh and 1628.9 GWh 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, which would suggest that regulating waste water pumps in a single cut-off tier would be sufficient and more simple than enforcing a two-tier regulation. In a similar way, the potential savings of Scenario 3 and Scenario 4 are similar, although the pessimistic sub-scenario 3 achieves slightly (less than 7%) lower electricity savings.

### Overall consumer expenditure

The reduction in annual consumer expenditure for each of the six 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 8-8 to Figure 8-14 presents the comparison of annual consumer expenditure reduction for each of the six Base-Cases (BC 1, BC 2, BC 4, BC 5, BC 6 and BC 7A) for the twelve different sub-scenarios.

*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 8-8: Total annual consumer expenditure reduction (in Million Euros) for BC 1 across four key years for the 12 policy option scenarios

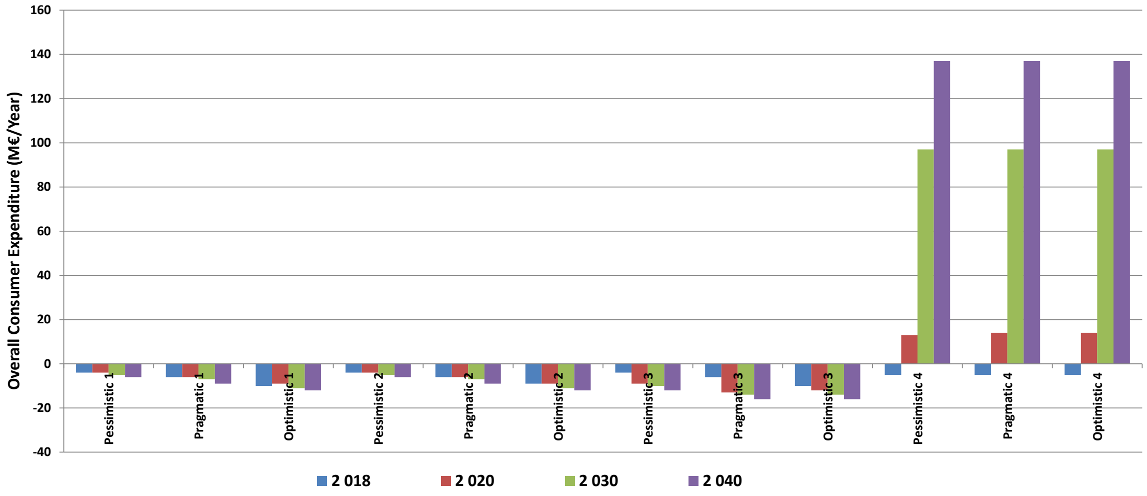


Figure 8-9: Total annual consumer expenditure reduction (in Million Euros) for BC 2 across four key years for the 12 policy option scenarios

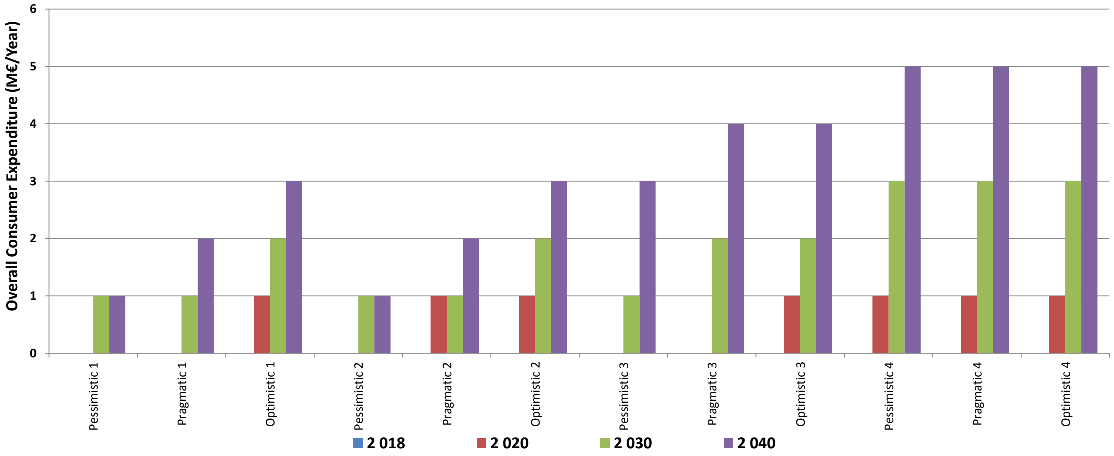


Figure 8-10: Total annual consumer expenditure reduction (in Million Euros) for BC 4 across four key years for the 12 policy option scenarios

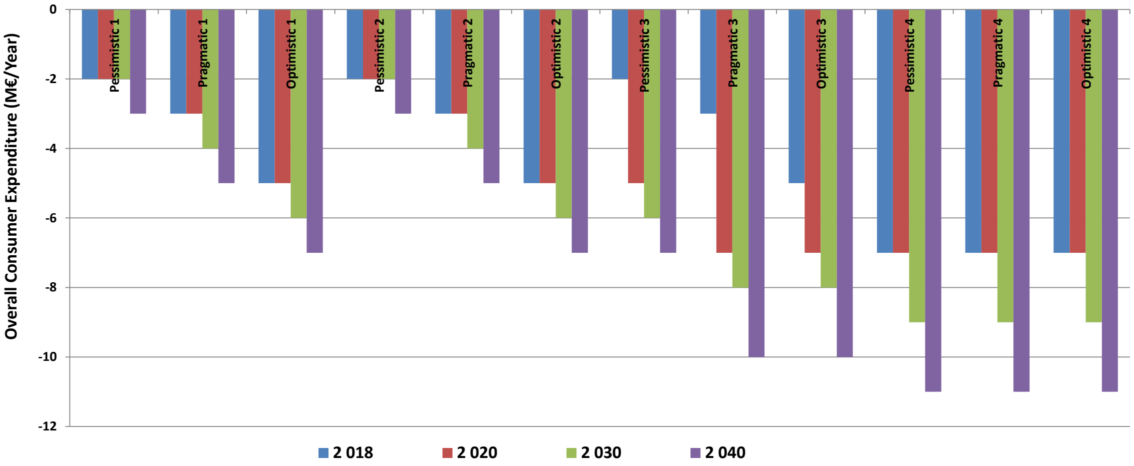


Figure 8-11: Total annual consumer expenditure reduction (in Million Euros) for BC 5 across four key years for the 12 policy option scenarios

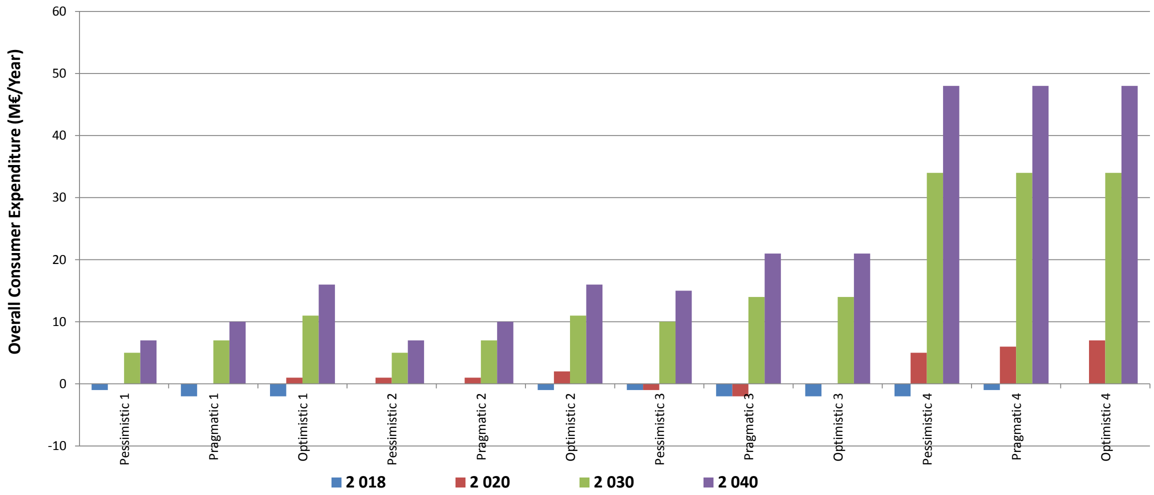


Figure 8-12: Total annual consumer expenditure reduction (in Million Euros) for BC 6 across four key years for the 12 policy option scenarios

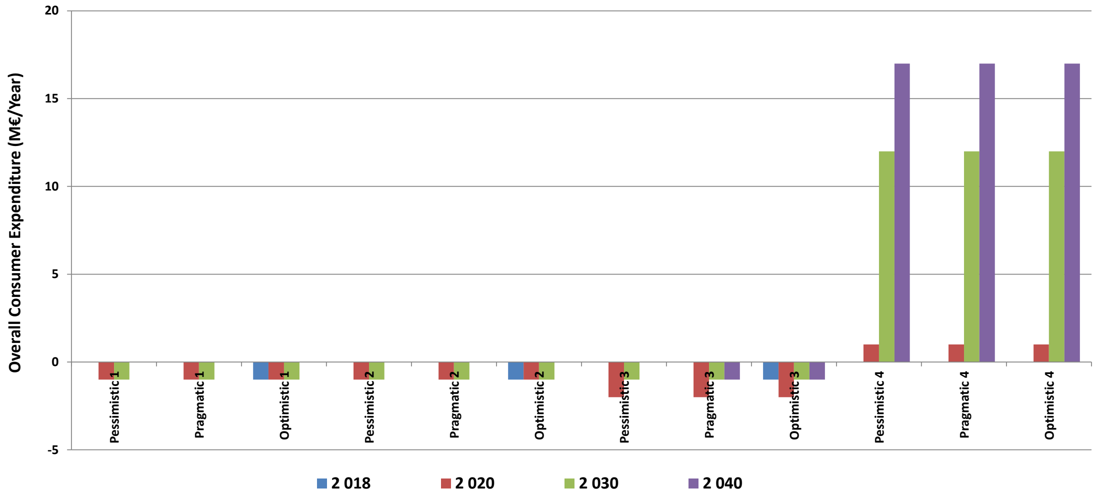


Figure 8-13: Total annual consumer expenditure reduction (in Million Euros) for BC 7A across four key years for the 12 policy option scenarios

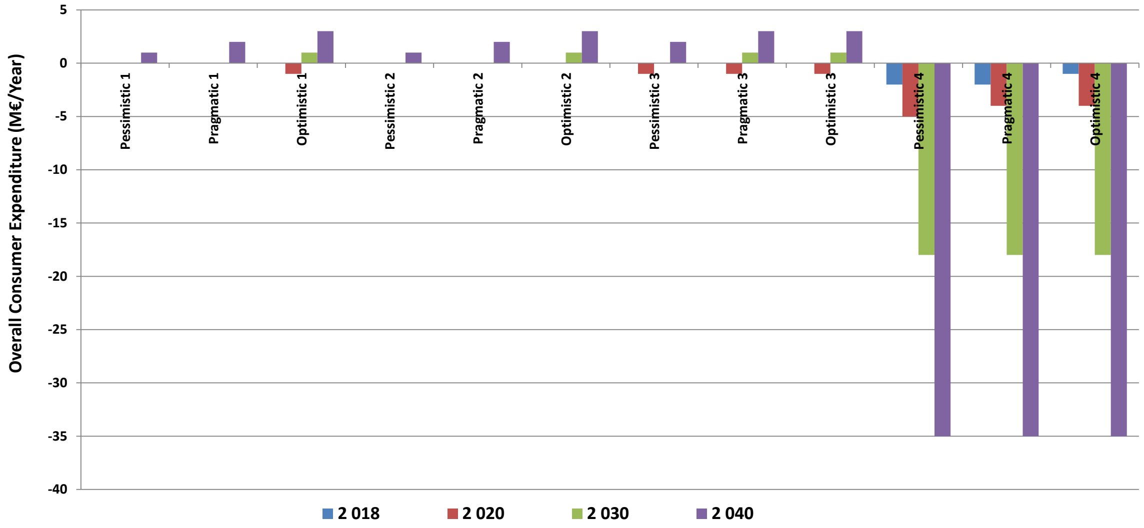
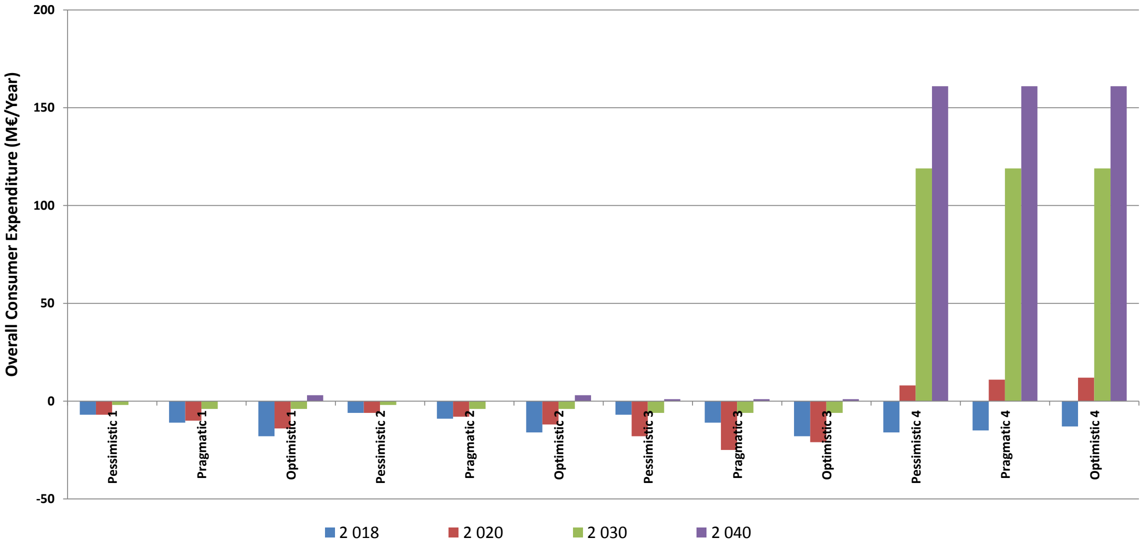


Figure 8-14: Total annual consumer expenditure reduction (in Million Euros) for all selected Base-Cases (BC 1, BC 2, BC 4, BC 5, BC 6 and BC 7A) across four key years for the 12 policy option scenarios



There is a reduction in consumer expenditure is across all the twelve scenarios considered for BC 2 and BC 5 by as soon as 2020. For BC 2, in one of the most ambitious scenarios (i.e. Policy Option 3 and 4), the maximum reduction in consumer expenditure at EU level in 2040 would be around 4 Million Euros and 5 Million Euros respectively.  For BC 5, in one of the most ambitious scenarios (i.e. Policy Option 3 and 4), the maximum reduction in consumer expenditure at EU level in 2040 would be around 21 Million Euros and 48 Million Euros respectively.

The For BC 4, the consumer expenditure increases with time for all the twelve scenarios, which can be explained on the basis of their very small number of annual operating hours. In one of the most modest scenarios (i.e. Policy Option 3 and 4), the maximum increase in consumer expenditure at EU level in 2040 would be around 10 Million Euros and 11 Million Euros respectively.

There is a slight increase in consumer expenditure for BC 1 and BC 6 for three scenarios (Policy Options 1, 2 and 3). As the sales of more efficient pumps replaces the existing stock, by 2040, there is almost negligible (less than a Million Euros) impact on consumer expenditure of BC 6 for the first 3 scenarios (scenario 1, 2 and 3). However, scenario 4 leads to some reduction in consumer expenditure for these Base-Cases in 2040 (137 Million Euros for BC 1 and 17 Million Euros for BC 6).

For BC 7A, there is slight reduction in consumer expenditure (around 3 Million Euros) in 2040 for the three scenarios (Policy Options 1, 2 and 3). However, scenario 4 leads to some increase in consumer expenditure for BC 7A in 2040 (35 Million Euros).

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 Zero (in Pragmatic Scenario 1) and 161 Million Euros (in Pragmatic Scenario 4) at EU level. There is not much difference between Scenario 1, Scenario 2 and Scenario 3.

## 8.4 Impact analysis

As mentioned in the Ecodesign Directive, any 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. This will be studied in detail in an Impact Assessment commissioned by the European Commission at a later stage in the policy-making process but a first analysis is provided here. In this section, the following impacts are assessed:

- Impacts on manufacturers of wastewater pumps and competition
- Impacts on consumers
- Impacts on innovation and development
- Social impacts

### 8.4.1 Impacts on manufacturer 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 Lot 28. However, the data collected and presented in Task 2 can give a rough economic overview of the sector of wastewater 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 wastewater pump sales in the EU are replacement of old pumps (assumption of 70% in the scenario analysis, see section 8.3.2), and only a small part are new pump installations. This means that the wastewater 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 MEPS 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 MEPS is technically achievable although it may require an economical effort from the manufacturers. While the improvement technologies are already used in some wastewater pumps, not all the manufacturers include them in their designs, and the launching of new products will require product redesign (such as patterns and tooling). Product redesign for hydraulic improvement in slurry pumps would be particular expensive to manufacturers because they have different pump designs i.e. metal, ceramic and rubber lined and the metal pumps are made in many different materials. Each of these needs different patterns/moulds. Manufacturers also have a large number of hydraulic sizes because of the importance of selecting the pumps at the right operating point on the head flow curve to maximise pump life and reliability. So the implementation of MEPS might require investment 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 MEPS adopted 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 wastewater 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 Lot 28 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.

The test standard development, as described earlier in section 8.2.5, is expected to be completed by end of 2016. If this timeline is met ,then it is recommended that during the next revision of potential MEPS Regulation for Lot 28 pumps, the EC should take into account the EEI approach for Lot 28 MEPS instead of the MEPS proposed in this Task based on MEI approach.

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 Lot 28 pumps. If MEPS are set, it is believed that they should all be able to keep up with the market requirements, as most of these manufacturers already claim to produce highly efficient pumps. Therefore, the implementation of MEPS is not expected to significantly hamper the economic development of these manufacturers in the EU. However, the European market of slurry pumps is quite small on a global scale (as communicated by Europump). The main markets for the slurry pumps are countries with intensive mining activities outside EU, e.g. Australia, South Africa, Chile, Russia. Therefore, the annual sales of these pumps in EU are generally decreasing. There is a concern amongst European manufacturers (as communicated by Europump) that they may be disadvantaged in the world market of slurry pumps where reliability is the main criteria for purchase decision instead of energy efficiency[14].

## 8.4.2 Impact on consumers

In the case of any additional costs to manufacturers, these could be passed on to the customers, and even though this could be seen as a downside, 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 5 for most of the policy options considered in this Task whereas for BC 1 and BC 6, reduction in consumer expenditure occurs but only for policy option 4 (high energy efficiency requirements).

## 8.4.3 Impacts on innovation and development

The proposed policy options will remove inefficient wastewater pumps from the market in a first tier, thus achieving energy savings at EU level in a short time lapse. The introduction of second and third tiers with more ambitious targets would push manufacturers to design more efficient products and achieve higher energy savings in the long term, 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 as a small share of the products in the market. However, a shift can be expected towards more efficient models with intelligent controls within the EU although, such controls have no such big impacts on the design of the pump itself.

The standardisation of new energy efficiency indexes such as MEI and EEI 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 waste 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 MEPS 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.

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[14] This is in line with the payback time calculation for slurry pumps carried out in Task 7 which showed that the hydraulic improvement options for these pumps do not pay back the users.

### 8.4.4 Social impacts

Most of the manufacturers of wastewater 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 Ecodesign requirements 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[15]. In addition, the ecodesign improvement options 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 nor the EU industries disadvantaged.

## 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/or uncertainty) in the case of wastewater pumps are listed below:

- Product lifetime
- Maintenance and repair cost
- Product price
- Annual sales growth rate

The sensitivity analysis is carried out for each of the six Base-Cases (BC 1, BC 2, BC 4, BC 5, BC 6 and BC 7A) around the pragmatic scenarios[16] 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
- 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

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[15] Europump however raised the concern that if the Ecodesign requirements were to result in need for manufacturing extensive new patterns and castings, the pump industry may take it as an opportunity to consider lower cost overseas even if the parts are currently made in the EU. This can pose a risk to pump industry jobs in EU.

Particularly for slurry pumps, with the small market size in the EU, there is a concern amongst manufacturers (as communicated by Europump) mining and process industries may move to areas of lower labour cost and lower operating costs to avoid EU energy efficiency regulations imposed on these business.

[16] 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.

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 four parameters selected, one by one. As an example for BC 1, if:

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

[(UL PS1 EC 2020 – PS1 EC 2020)/ BaU EC 2020] x 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

### 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 electricity consumption during the use phase.

Variation in product lifetime (in years):

- An increase of 50% (upper limit)
- A decrease of -25% (lower limit)

The following figures (Figure 8-15 to Figure 8-28) show the influence of the product lifetime on the total electricity consumption and life-cycle costs of the different Base-Cases and associated improvement options. For all situations, despite the expected variations in absolute values, the ranking of the different improvement options remains the same whether the minimum or maximum parameter is used[17].

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[17] The background data used for the sensitivity analysis graphs presented in this section is presented in Annex C.

Figure 8-15: Sensitivity analysis of total electricity consumption[18] to product lifetime for BC 1

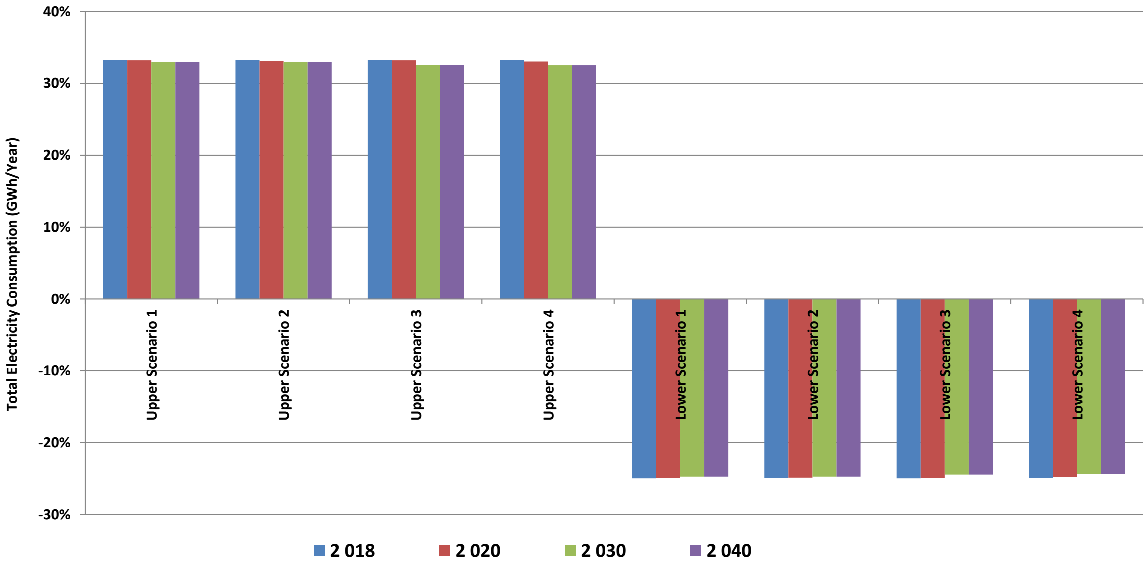
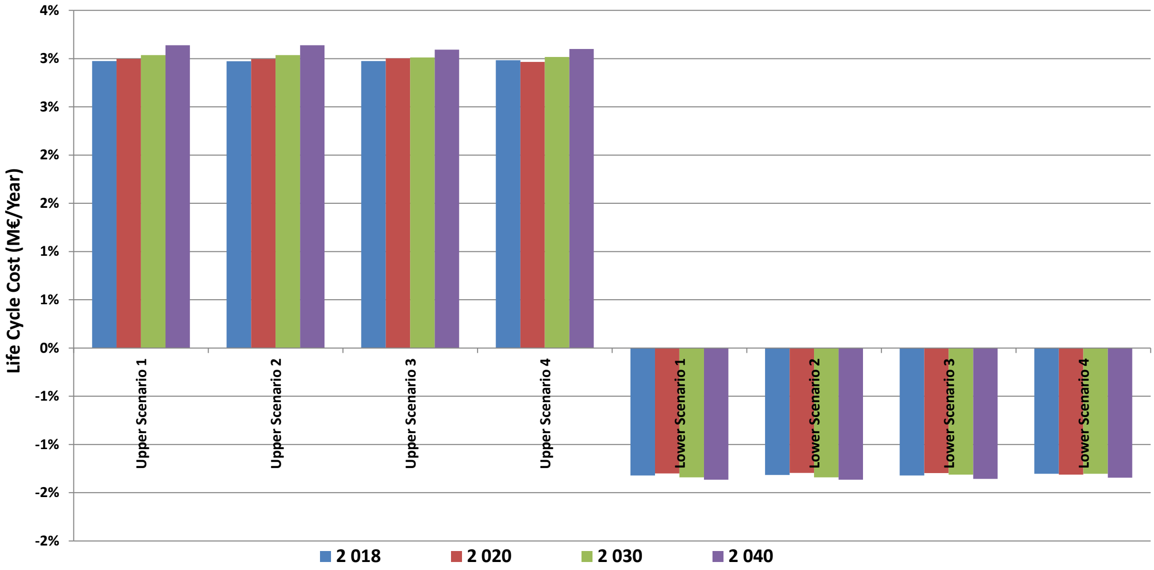


Figure 8-16: Sensitivity analysis of life cycle cost to product lifetime for BC 1



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[18] Total Electricity Consumption over the life cycle of the Base-Case

Figure 8-17: Sensitivity analysis of total electricity consumption to product lifetime for BC 2

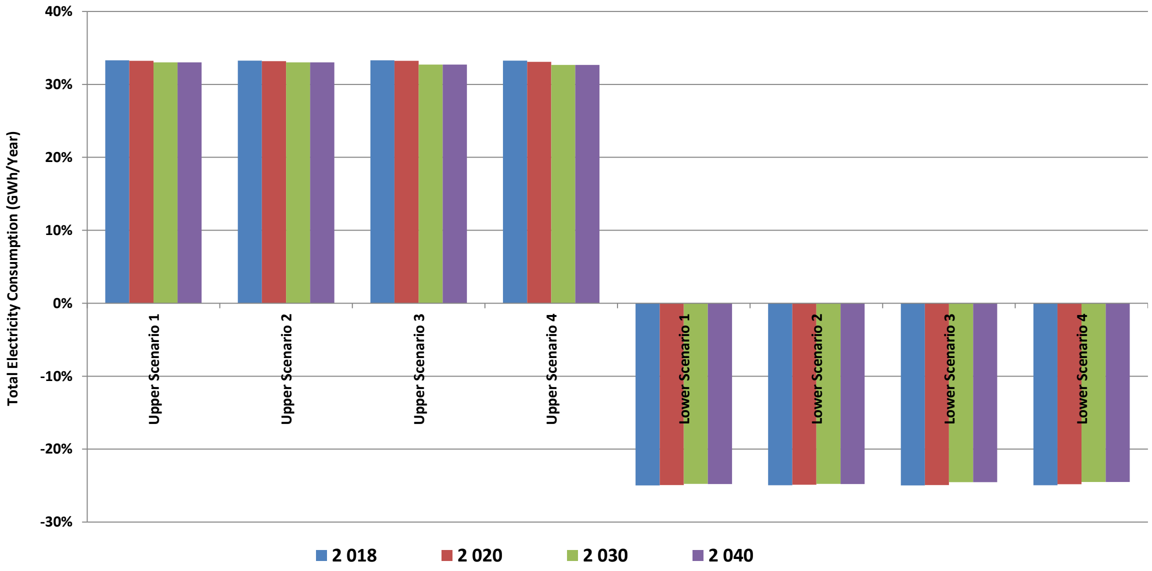


Figure 8-18: Sensitivity analysis of life cycle cost to product lifetime for BC 2

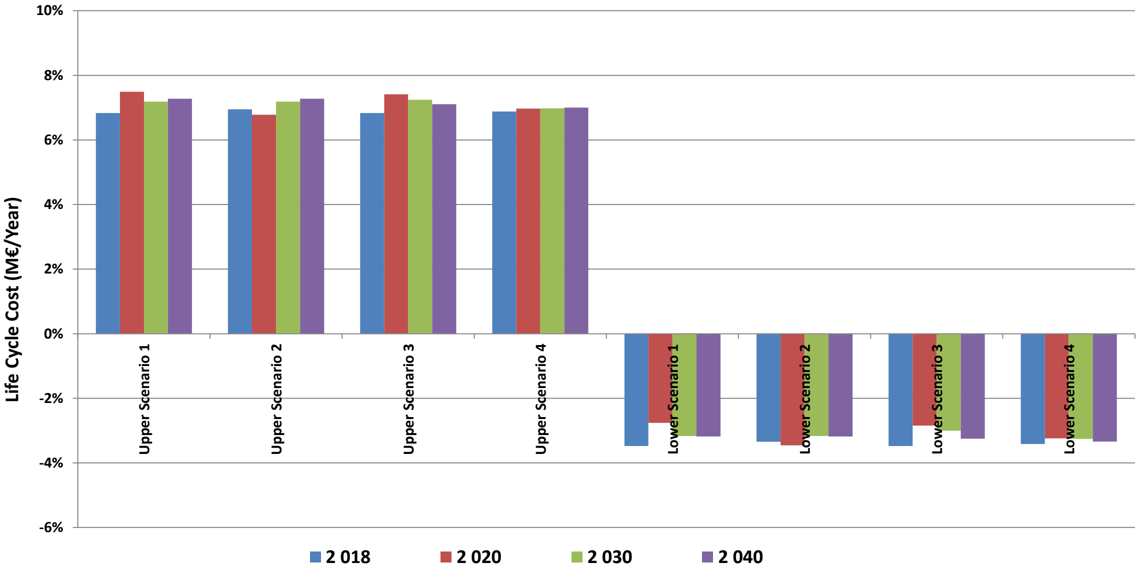


Figure 8-19: Sensitivity analysis of total electricity consumption to product lifetime for BC 4

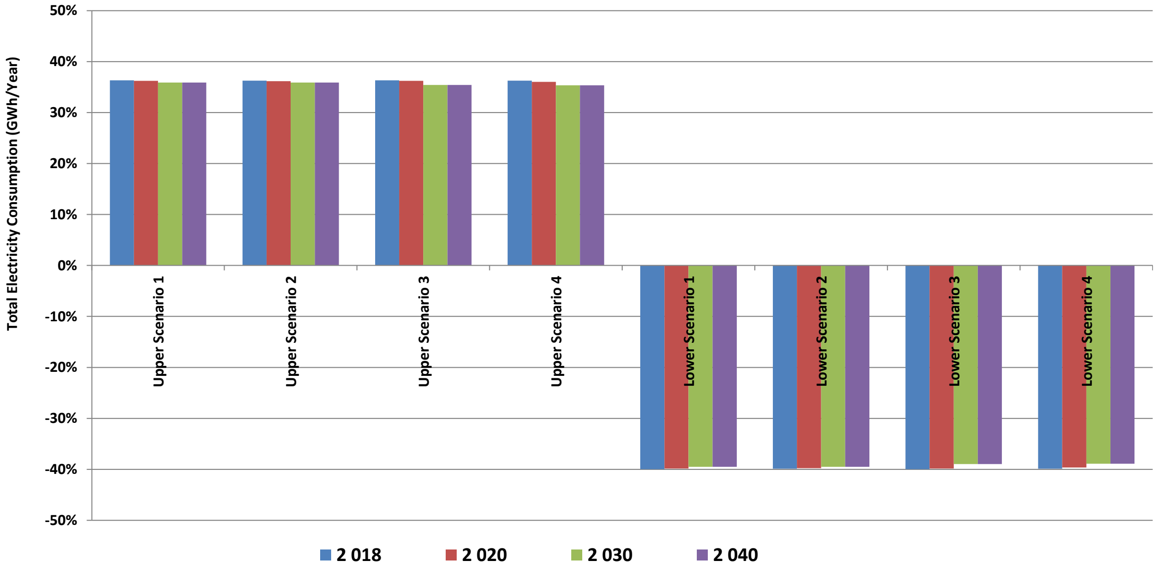


Figure 8-20: Sensitivity analysis of life cycle cost to product lifetime for BC 4

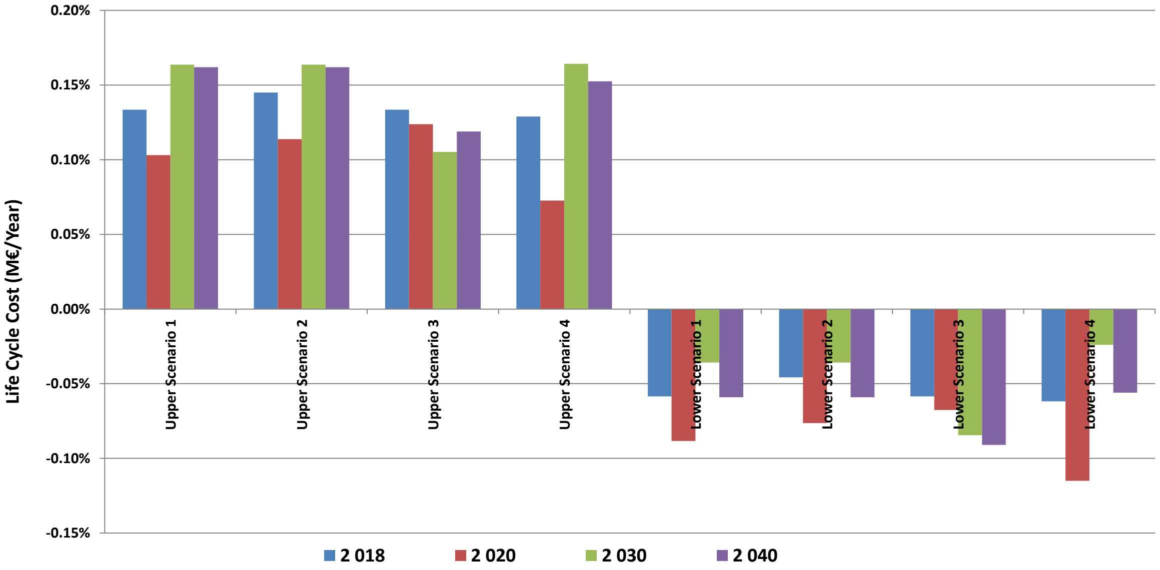


Figure 8-21: Sensitivity analysis of total electricity consumption to product lifetime for BC 5

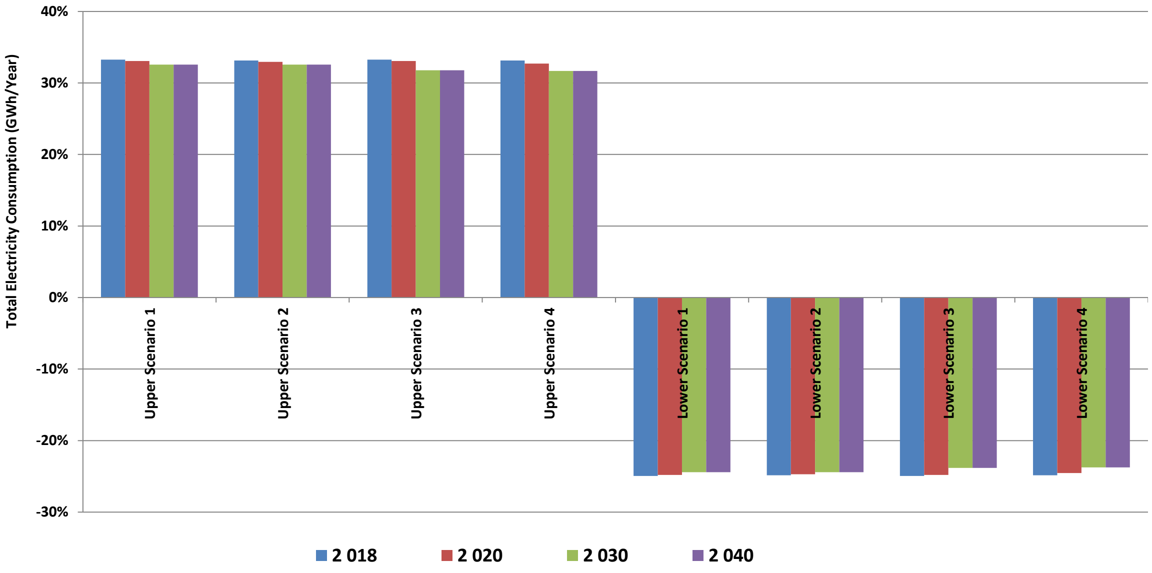


Figure 8-22: Sensitivity analysis of life cycle cost to product lifetime for BC 5

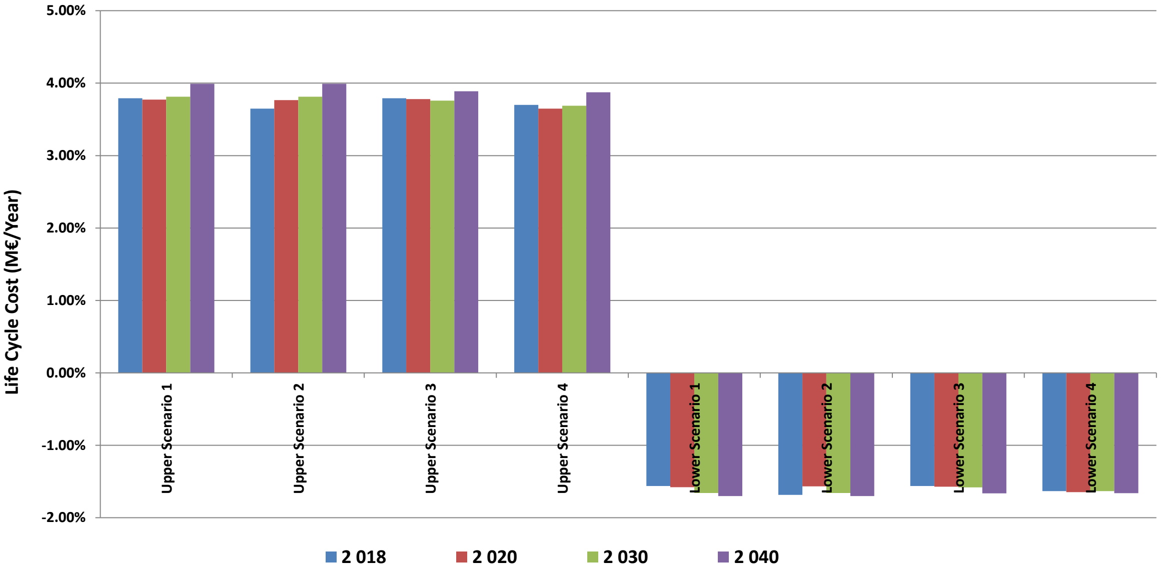


Figure 8-23: Sensitivity analysis of total electricity consumption to product lifetime for BC 6

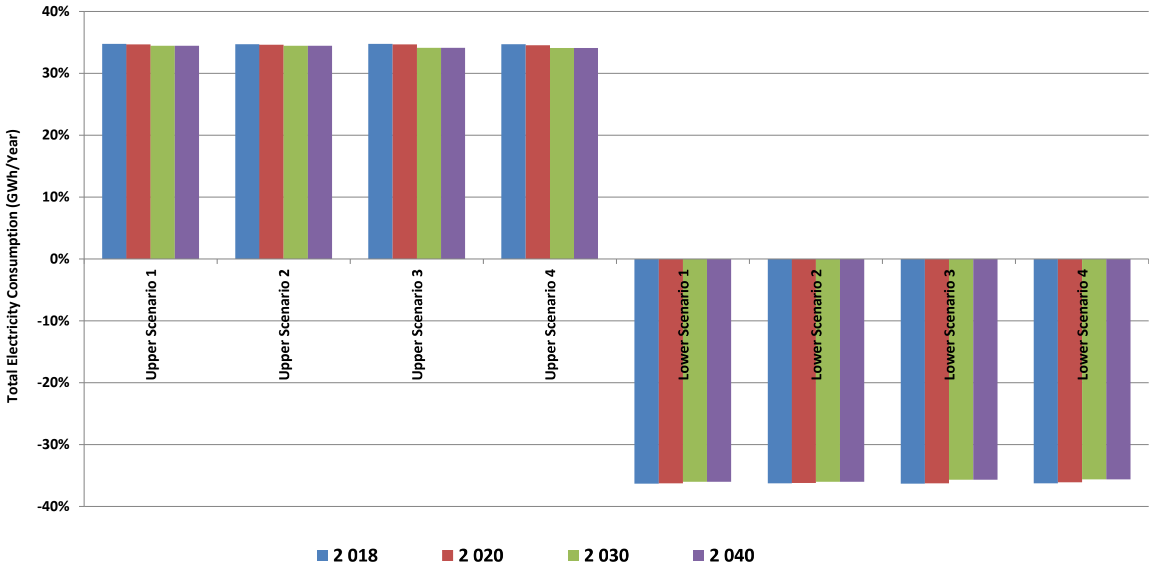


Figure 8-24: Sensitivity analysis of life cycle cost to product lifetime for BC 6

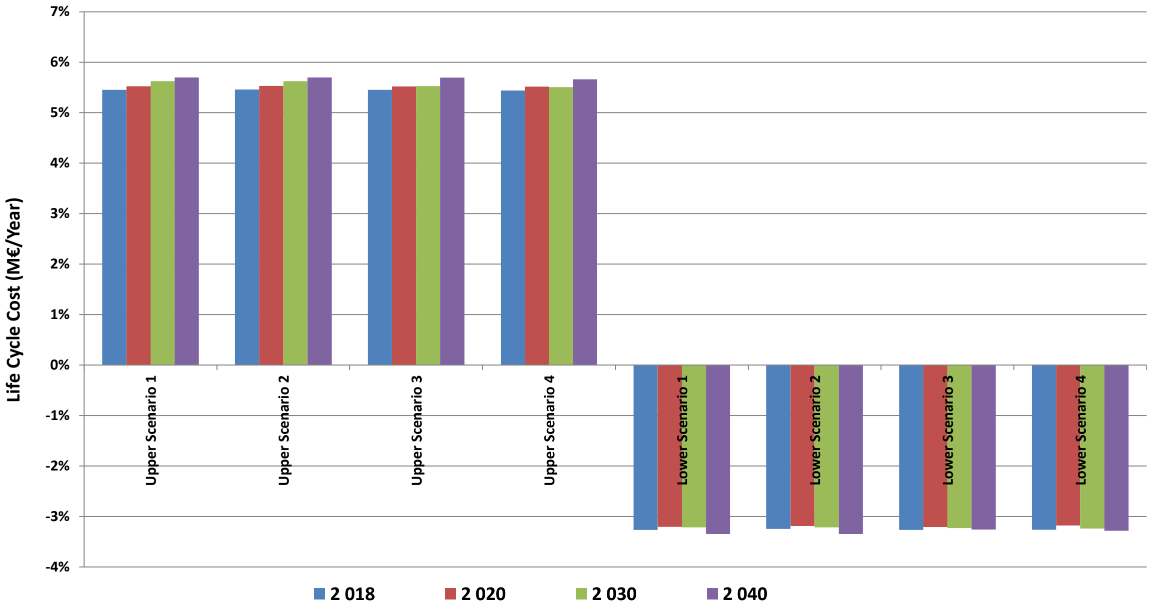


Figure 8-25: Sensitivity analysis of total electricity consumption to product lifetime for BC 7A

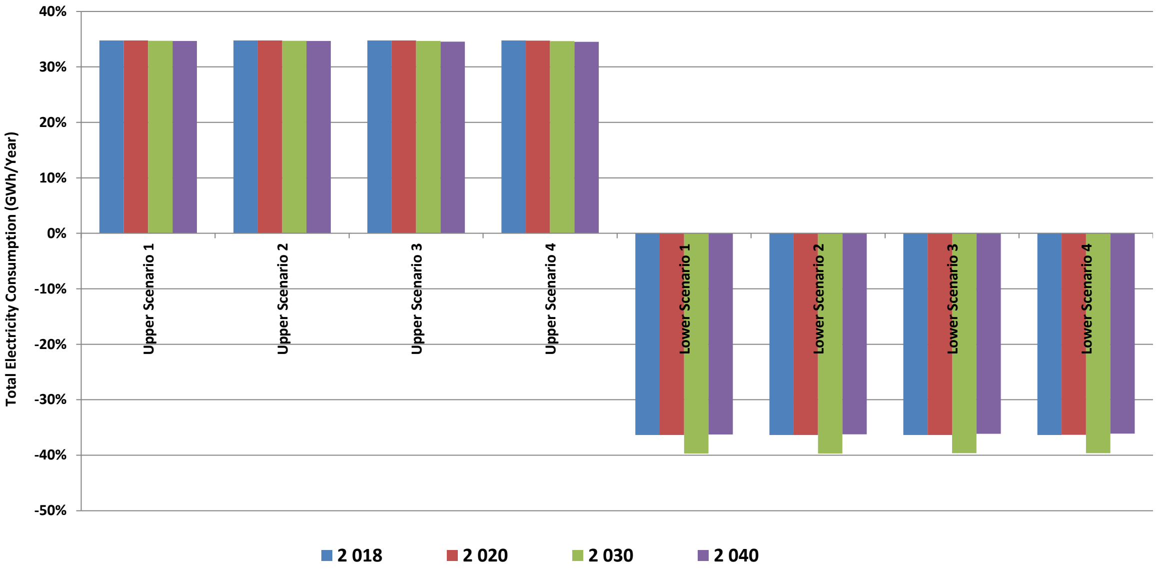


Figure 8-26: Sensitivity analysis of life cycle cost to product lifetime for BC 7A

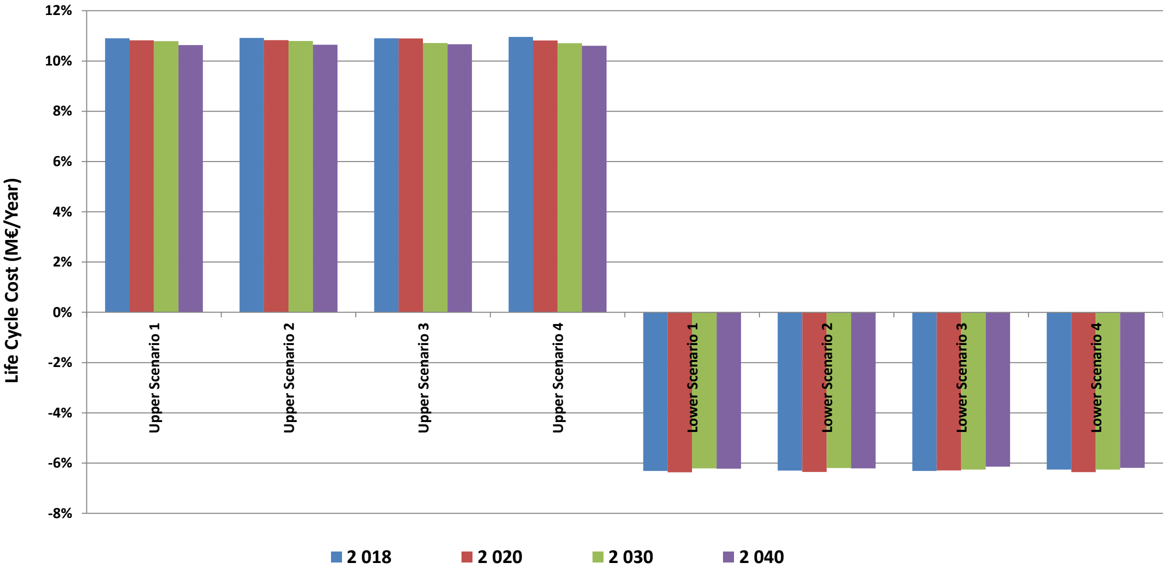


Figure 8-27: Sensitivity analysis of total electricity consumption to product lifetime for All BCs

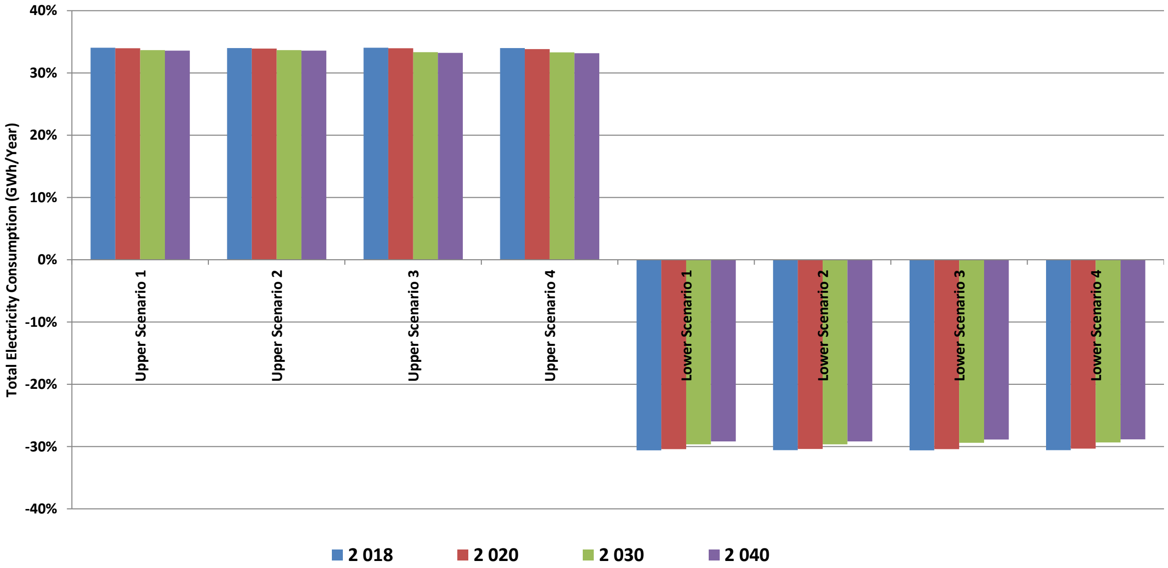
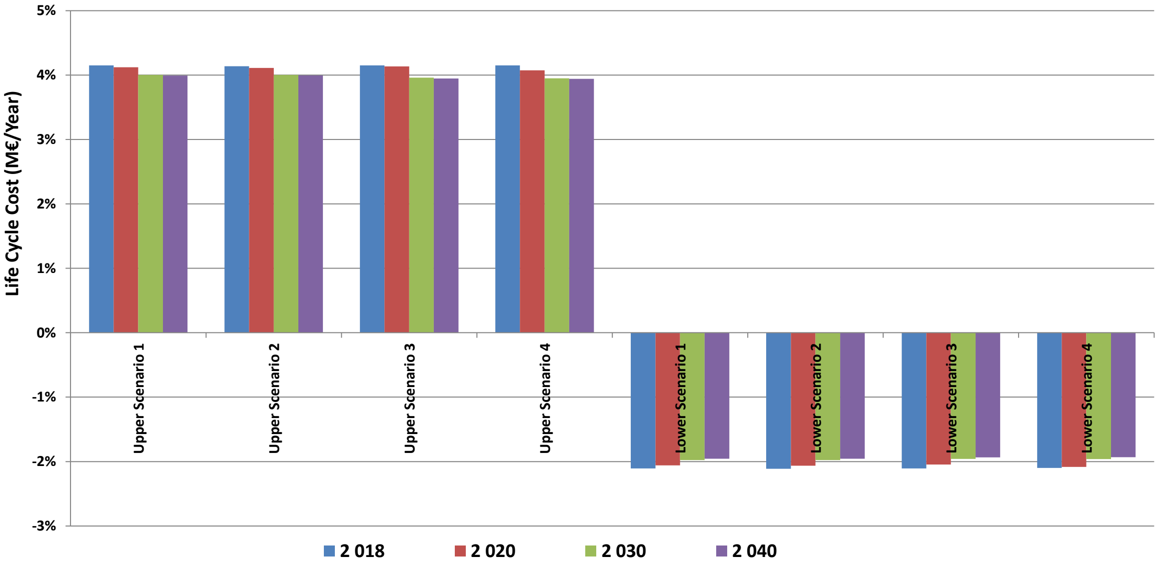


Figure 8-28: Sensitivity analysis of life cycle cost to product lifetime for All BCs



## 8.5.2 Assumptions related to the product price

The ranges of Lot 28 pumps covered by each of the product groups (Base-Cases) are very wide. Lot 28 pumps with a variety of characteristics, applications and different purchase prices exist on the EU market.

Therefore, compared to the product price defined for Base-Cases, two scenarios are defined, to take into account the fact that on the one hand, the price may be underestimated and on the other that it is overestimated.

Variation in product price:

- An increase of 25% (upper limit)
- A decrease of - 50% (lower limit)

The following figures (Figure 8-29 to Figure 8-35) show the influence of the product price on the life-cycle costs of the different base-cases and associated improvement options. For all situations, despite the expected variations in absolute values, the ranking of the different improvement options remains the same whether the minimum or maximum parameter is used[17].

Figure 8-29: Sensitivity analysis of life cycle cost to product price for BC 1

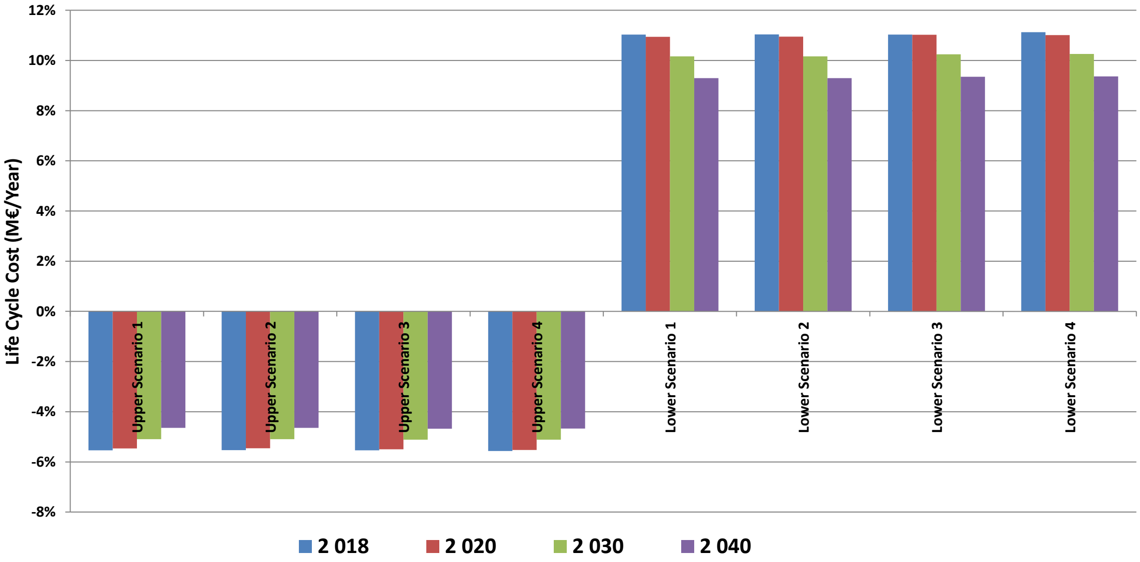


Figure 8-30: Sensitivity analysis of life cycle cost to product price for BC 2

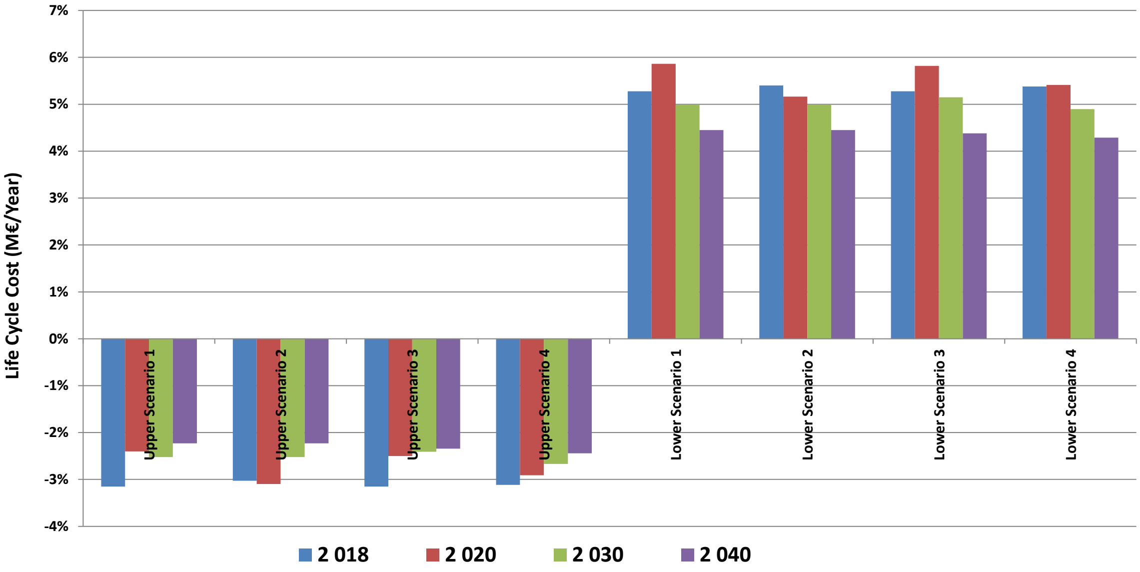


Figure 8-31: Sensitivity analysis of life cycle cost to product price for BC 4

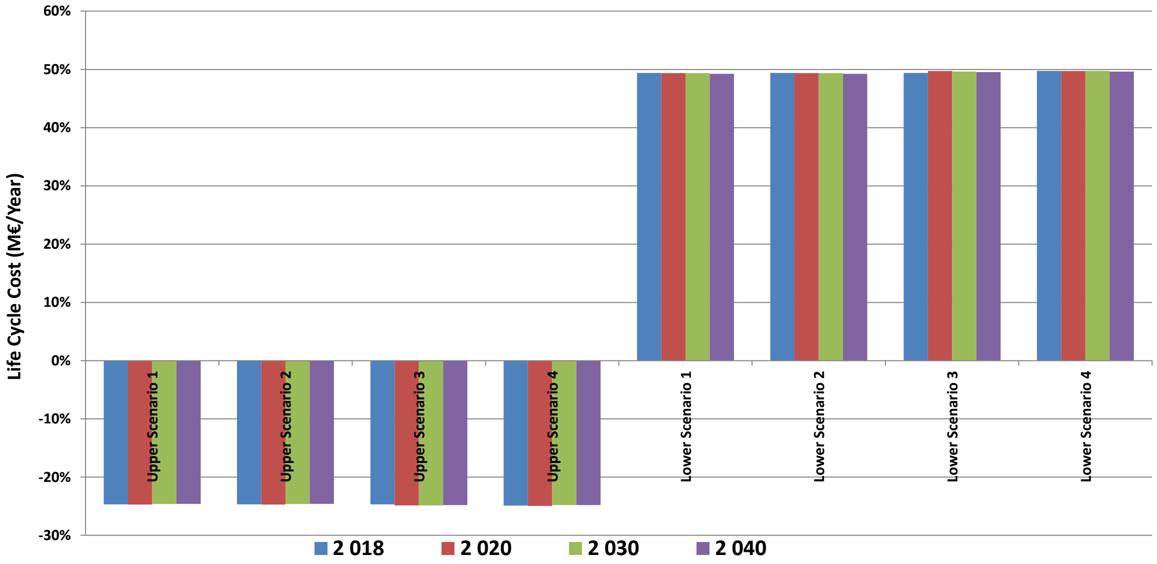


Figure 8-32: Sensitivity analysis of life cycle cost to product price for BC 5

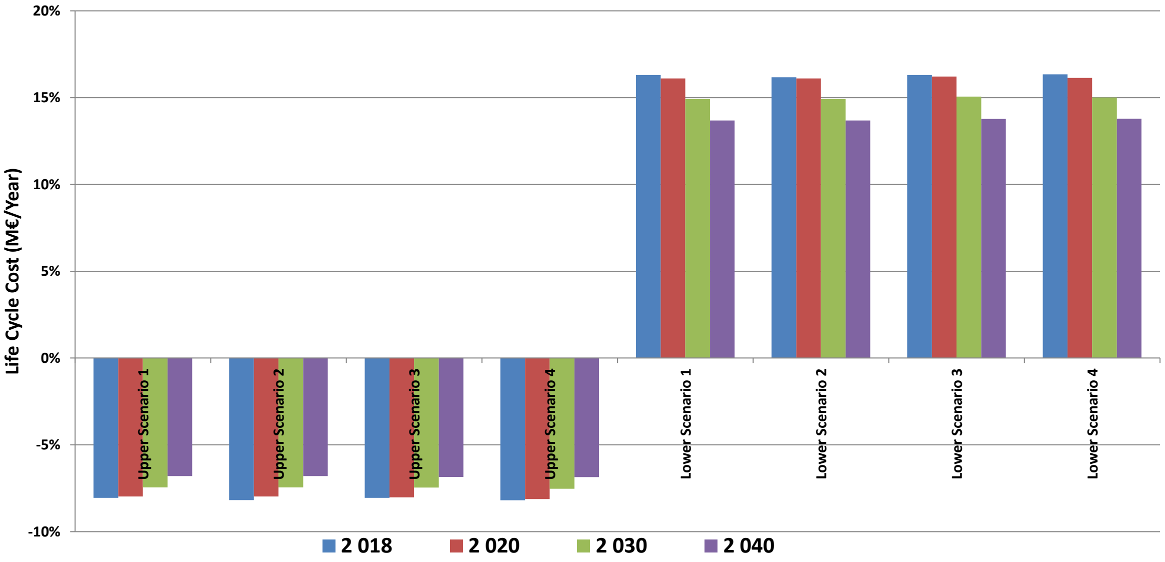


Figure 8-33: Sensitivity analysis of life cycle cost to product price for BC 6

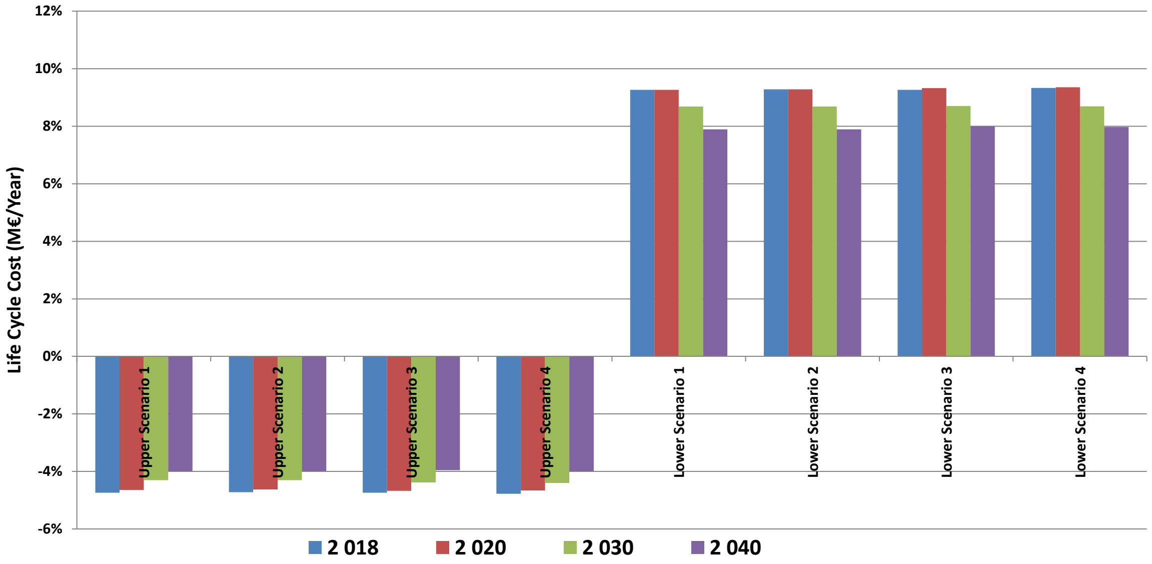


Figure 8-34: Sensitivity analysis of life cycle cost to product price for BC 7A

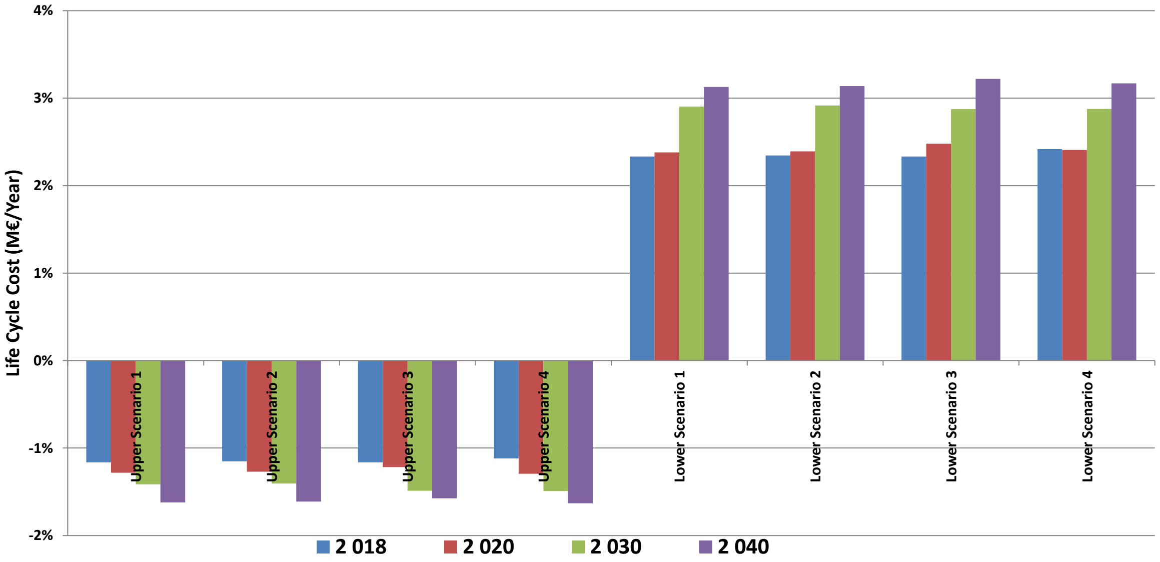
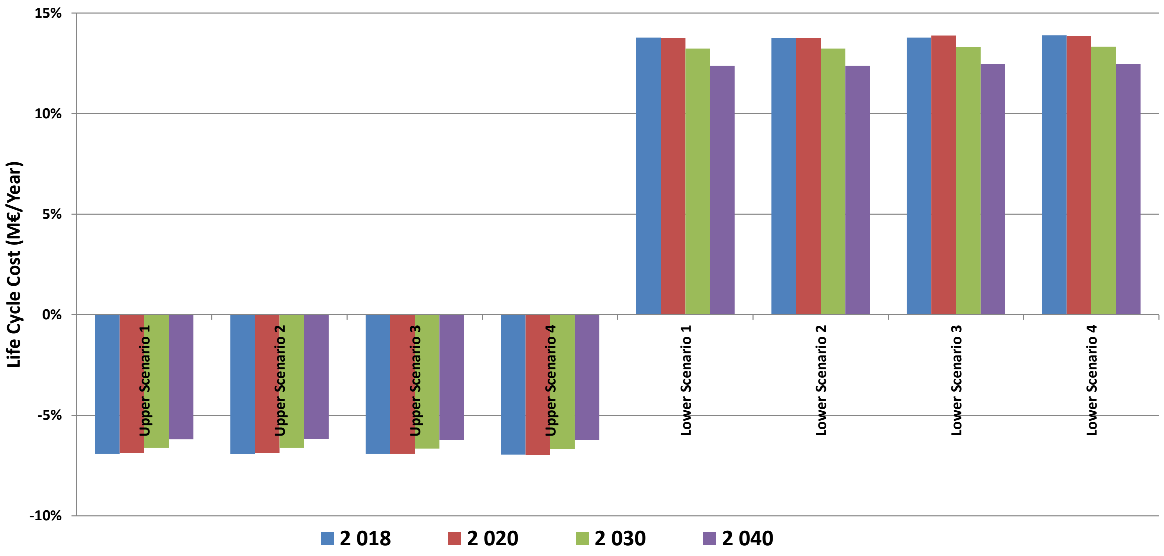


Figure 8-35: Sensitivity analysis of life cycle cost to product price for All BCs



### 8.5.3 Assumptions related to the sales growth rate

Estimating the stock of Lot 28 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 2.5% till 2017 by industry stakeholders. The same growth rate was assumed by project team to be applicable till 2040.

Variation in sales growth rate:

- An increase to 5%
- A decrease to 0%

The following figures (Figure 8-36 to Figure 8-49) show the influence of the sales growth rate on the total electricity consumption (TEC) and life-cycle costs of the different base-cases and associated improvement options. For all situations, despite the expected variations in absolute values, the ranking of the different improvement options remains the same whether the minimum or maximum parameter is used[17].

Figure 8-36: Sensitivity analysis of total electricity consumption to sales growth rate for BC 1

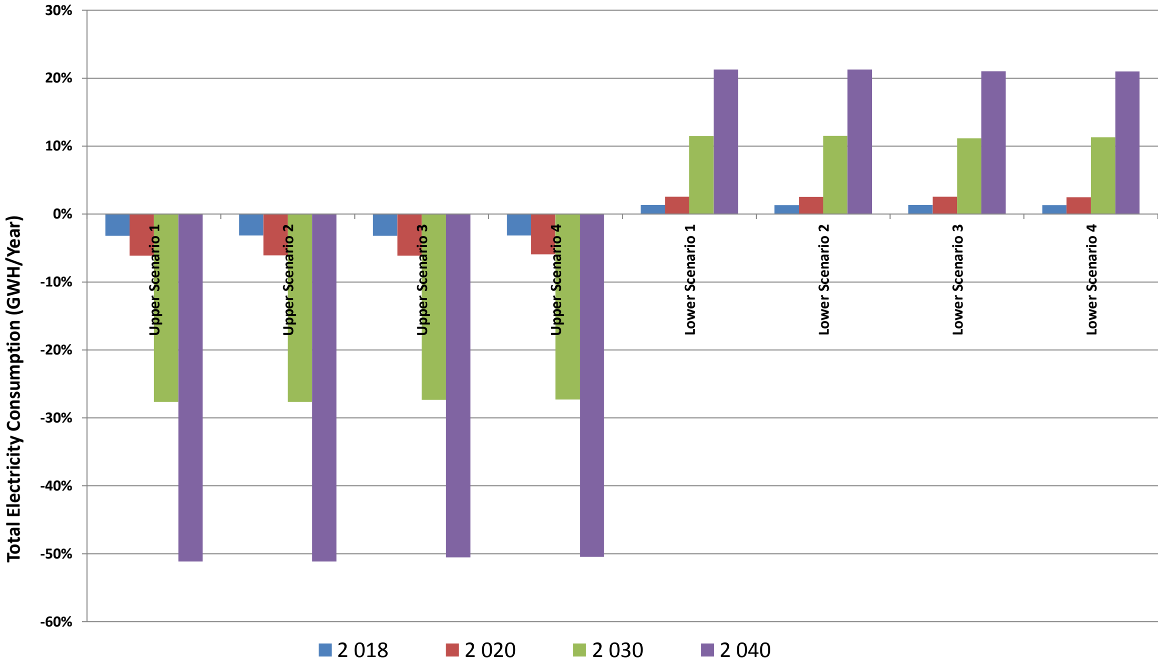


Figure 8-37: Sensitivity analysis of life cycle cost to sales growth rate for BC 1

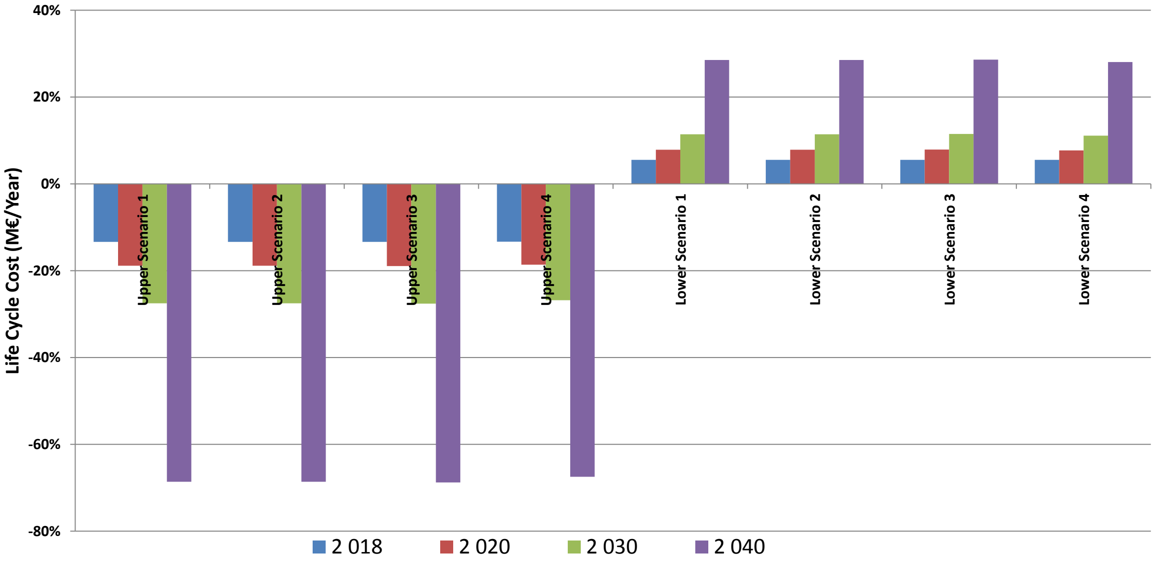


Figure 8-38: Sensitivity analysis of total electricity consumption to sales growth rate for BC 2

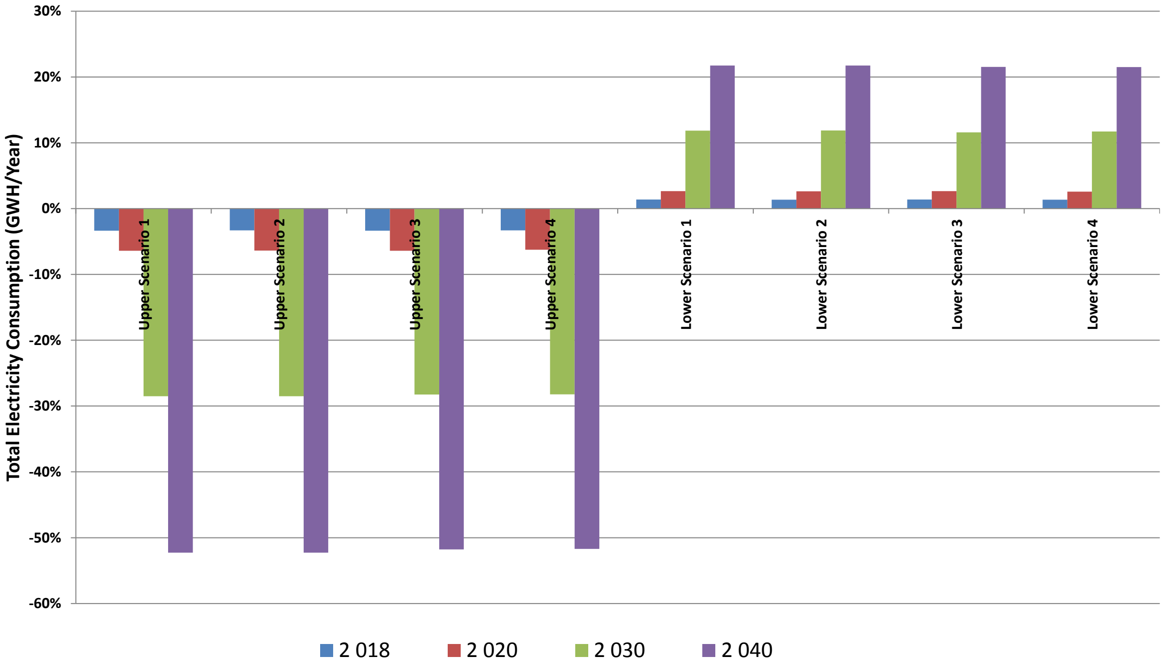


Figure 8-39: Sensitivity analysis of life cycle cost to sales growth rate for BC 2

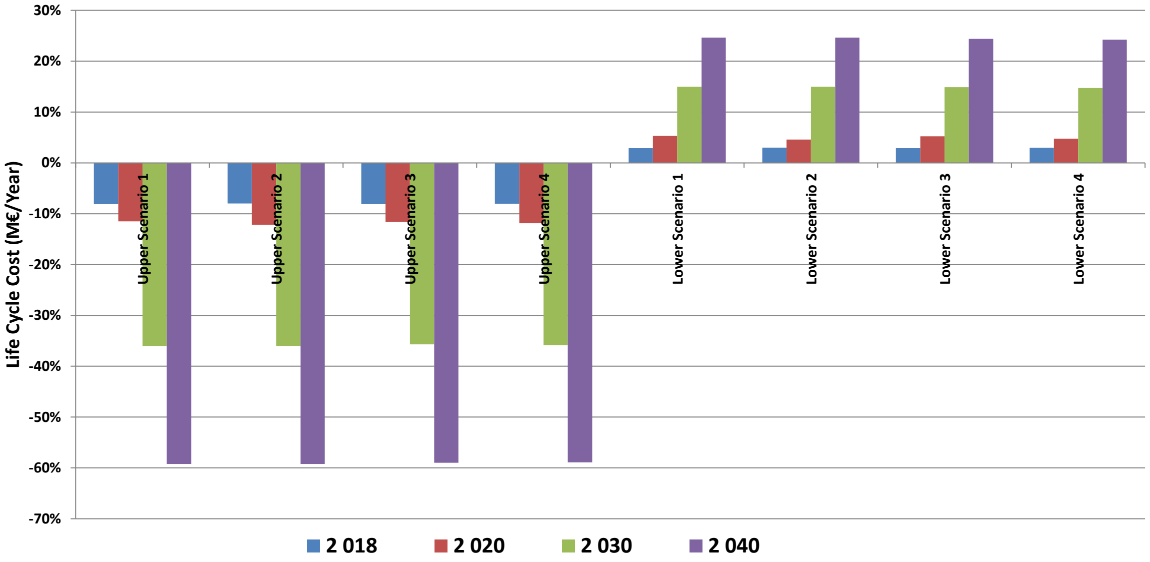


Figure 8-40: Sensitivity analysis of total electricity consumption to sales growth rate for BC 4

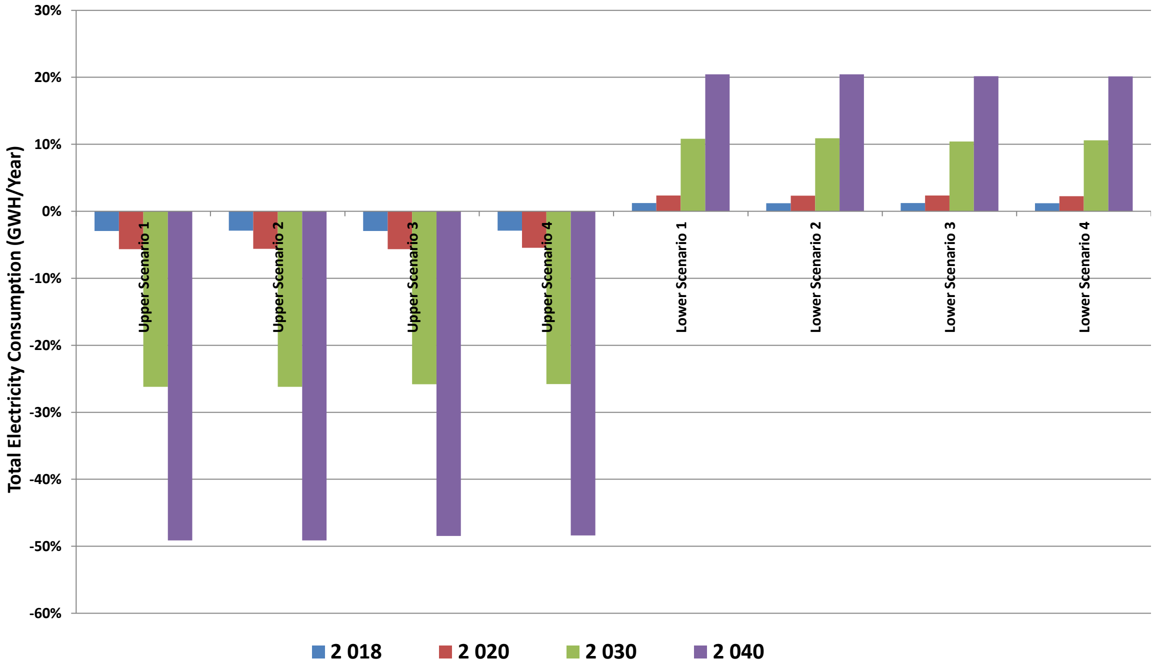


Figure 8-41: Sensitivity analysis of life cycle cost to sales growth rate for BC 4

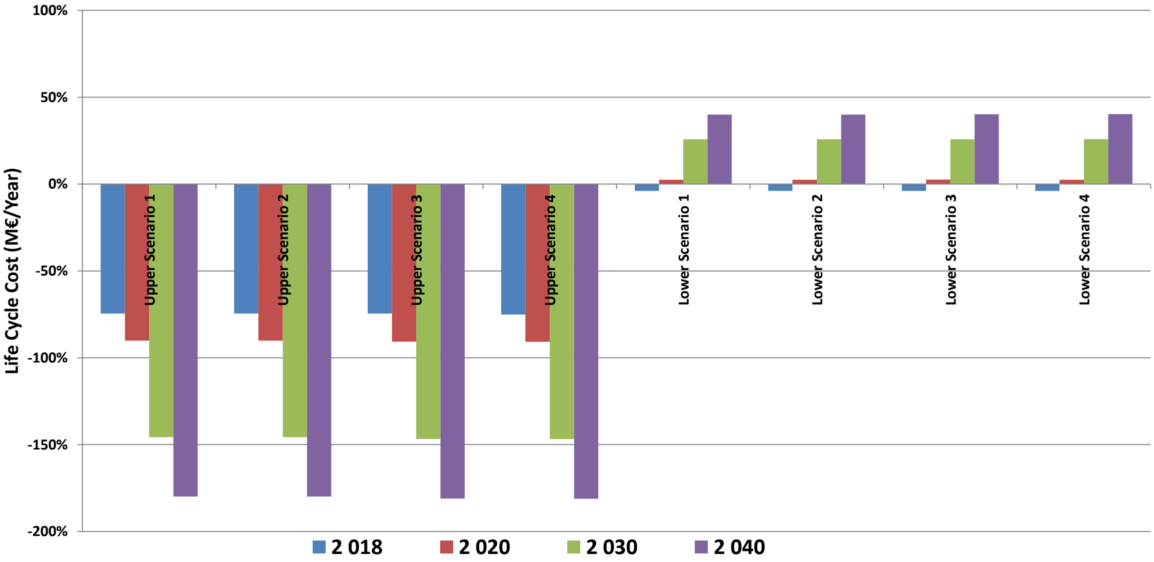


Figure 8-42: Sensitivity analysis of total electricity consumption to sales growth rate for BC 5

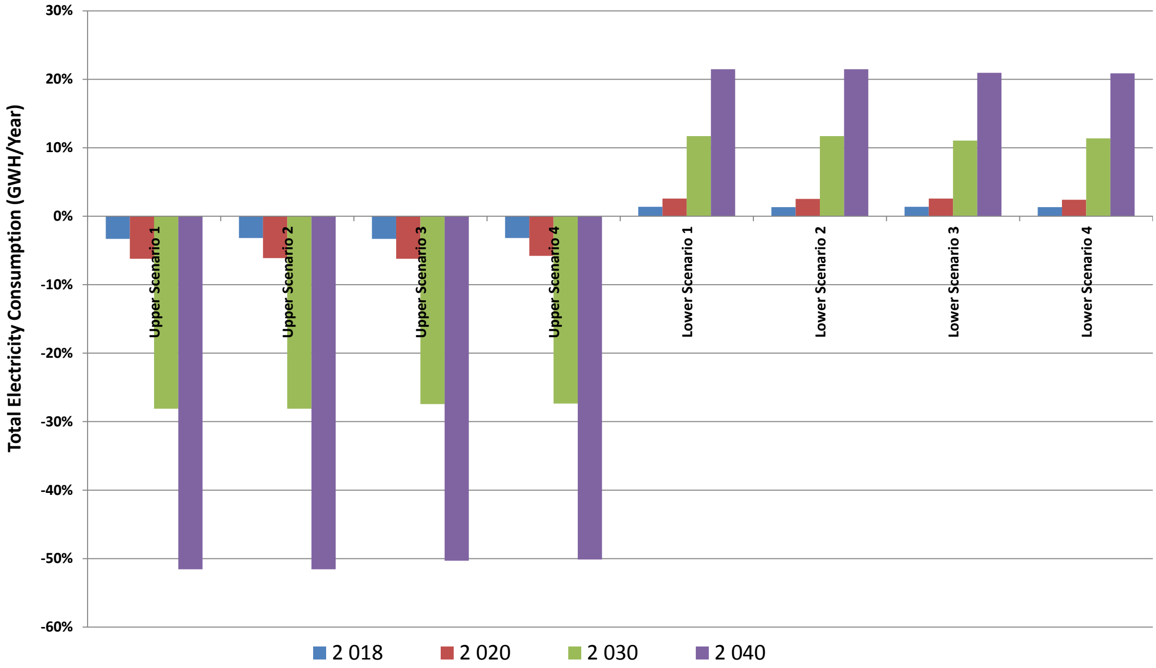


Figure 8-43: Sensitivity analysis of life cycle cost to sales growth rate for BC 5

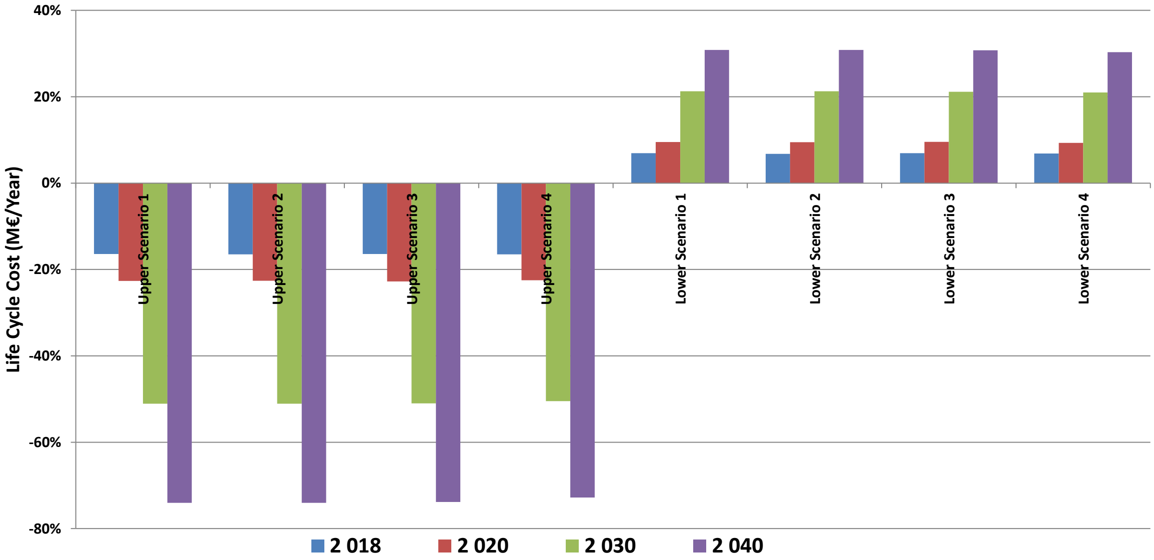


Figure 8-44: Sensitivity analysis of total electricity consumption to sales growth rate for BC 6

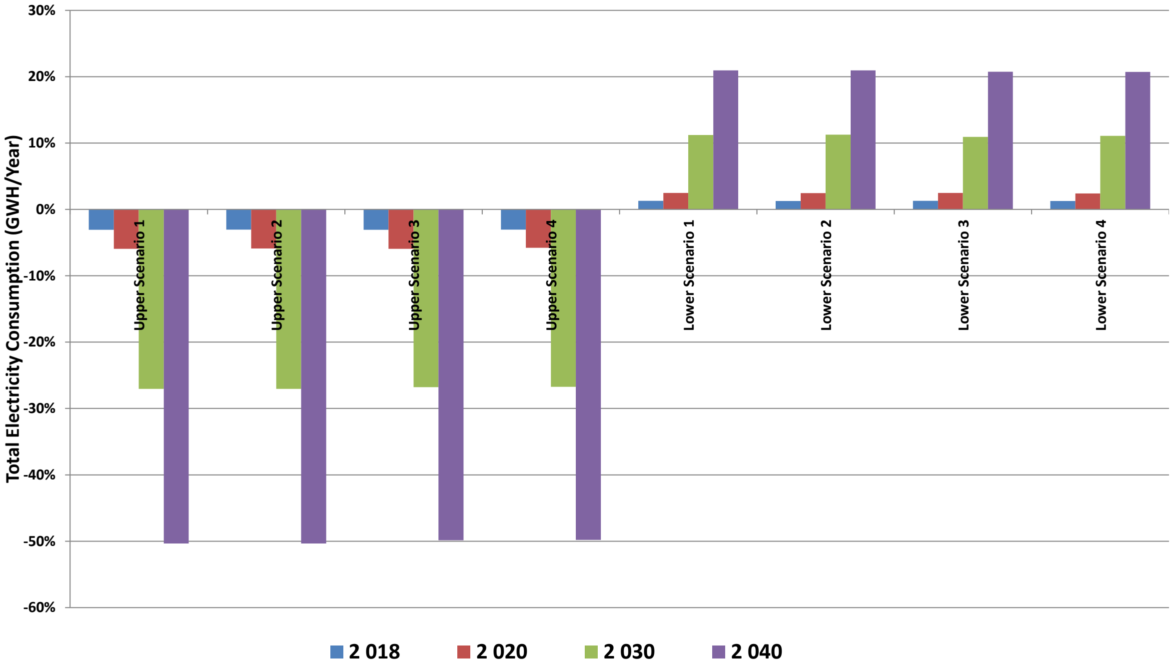


Figure 8-45: Sensitivity analysis of life cycle cost to sales growth rate for BC 6

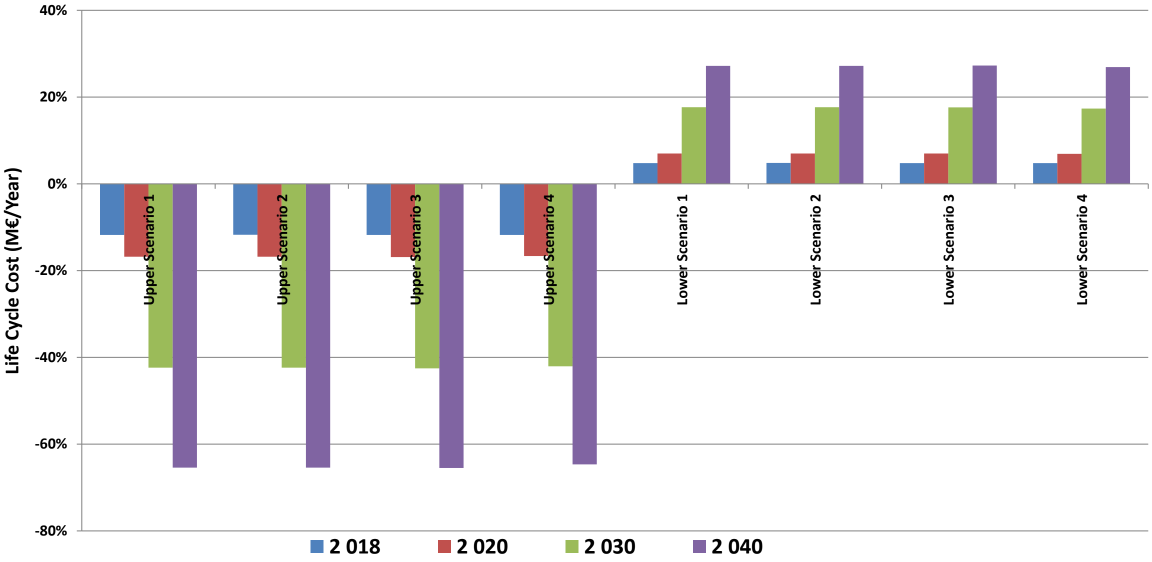


Figure 8-46: Sensitivity analysis of total electricity consumption to sales growth rate for BC 7A

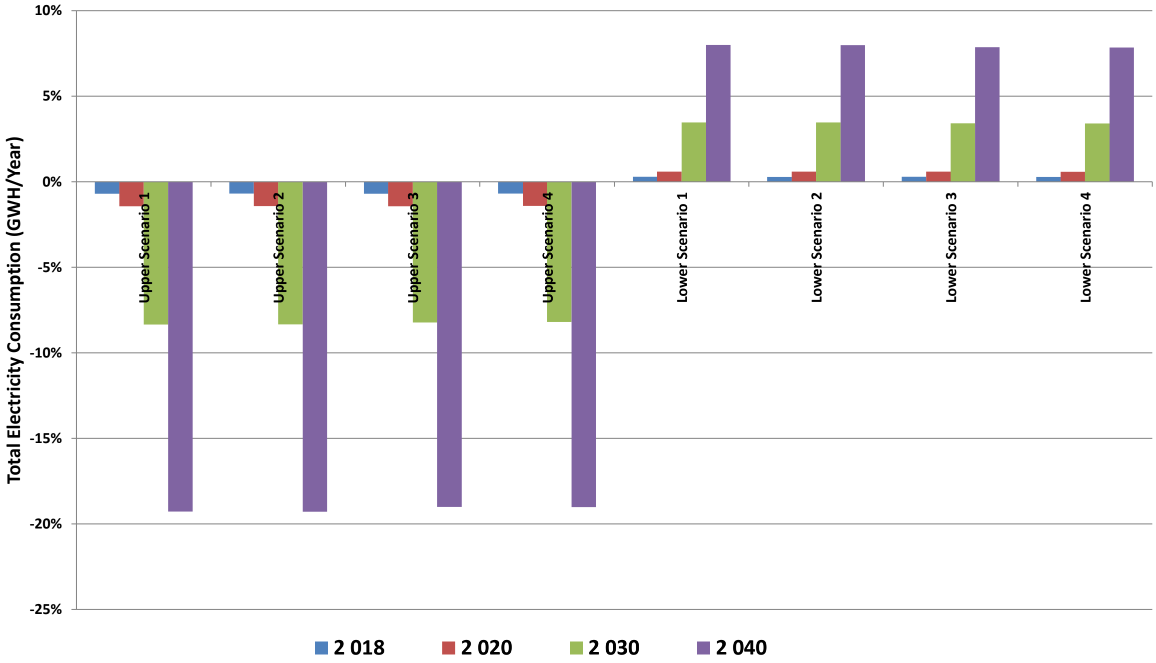


Figure 8-47: Sensitivity analysis of life cycle cost to sales growth rate for BC 7A

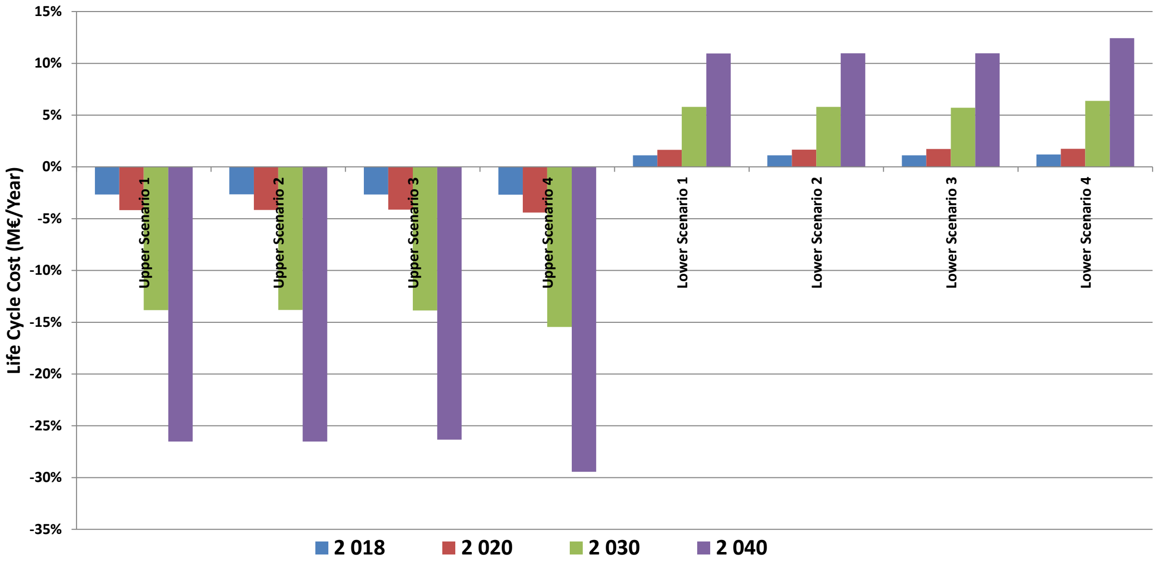


Figure 8-48: Sensitivity analysis of total electricity consumption to sales growth rate for All BCs

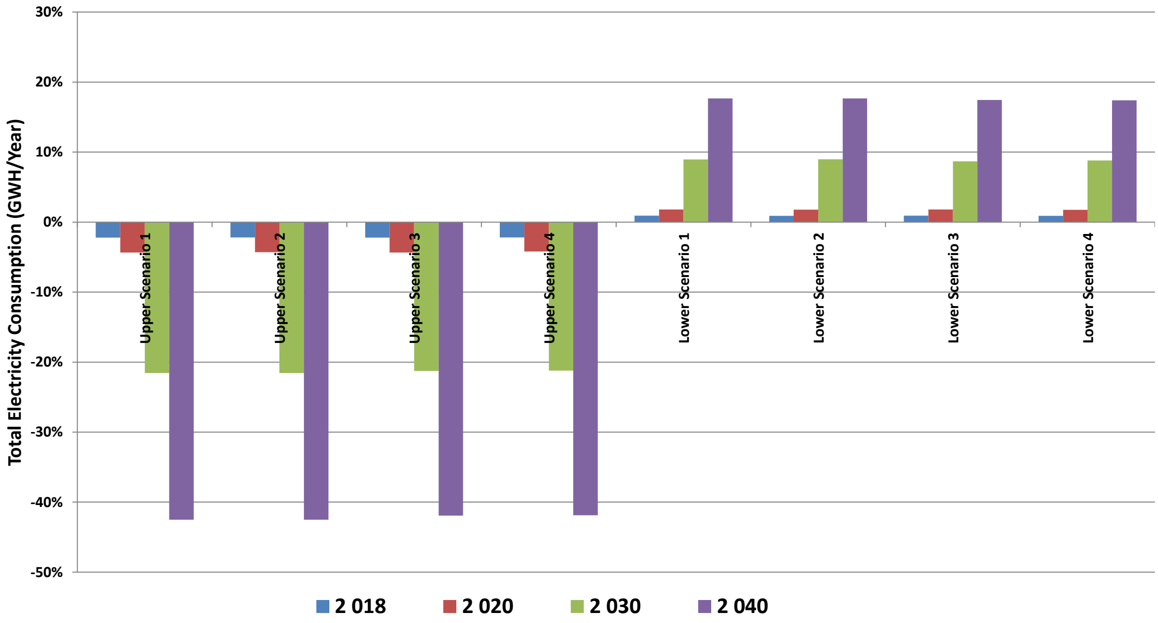
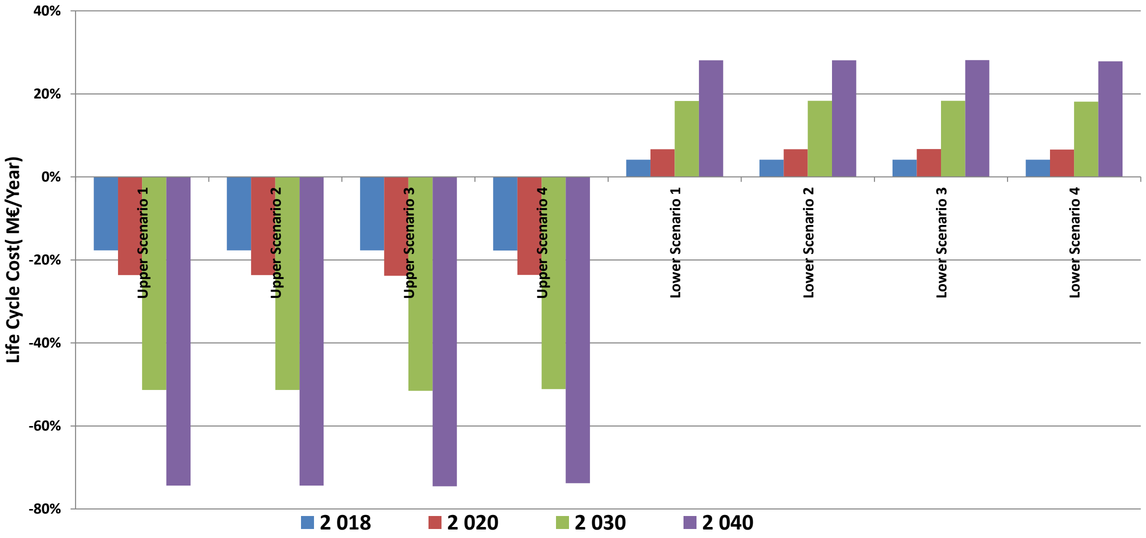


Figure 8-49: Sensitivity analysis of life cycle cost to sales growth rate for All BCs



### 8.5.4 Assumptions related to the maintenance and repair cost

The ranges of Lot 28 pumps covered by each of the product groups (Base-Cases) are very wide. Lot 28 pumps with a variety of characteristics, applications and different maintenance and repair costs exist on the EU market.

Therefore, compared to the maintenance and repair cost defined for Base-Cases, one scenario is defined to take into account the fact the cost may be underestimated.

- Variation in maintenance and repair cost: An increase of 100% (upper limit)

The following figures (Figure 8-50 to Figure 8-56) show the influence of the maintenance and repair cost on the life-cycle costs of the different base-cases and associated improvement options. For all situations, despite the expected variations in absolute values, the ranking of the different improvement options remains the same whether the minimum or maximum parameter is used[17].

Figure 8-50: Sensitivity analysis of life cycle cost to maintenance and repair cost for BC 1

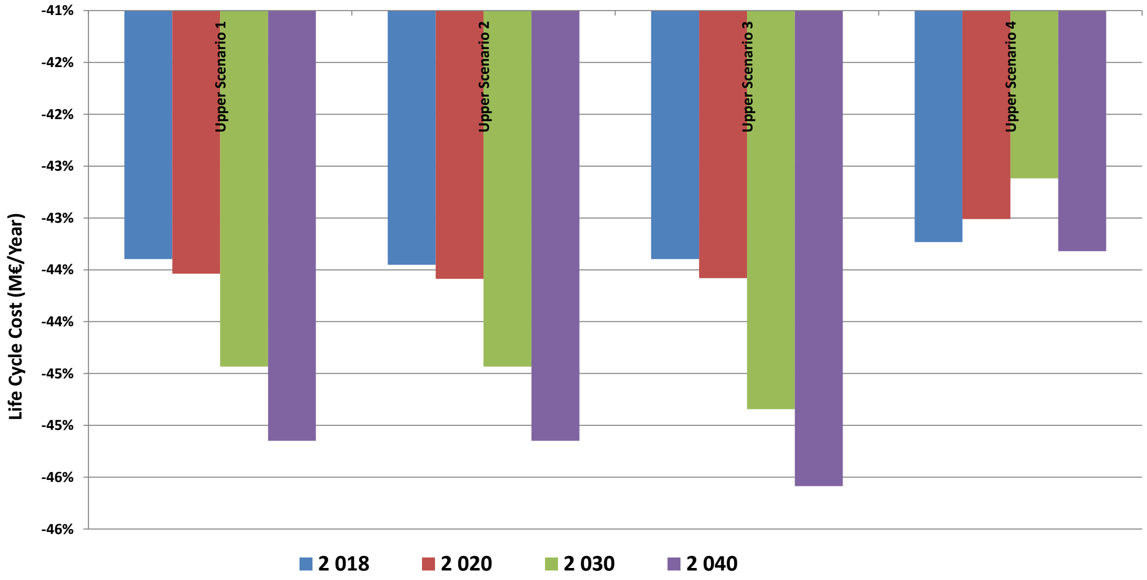


Figure 8-51: Sensitivity analysis of life cycle cost to maintenance and repair cost for BC 2

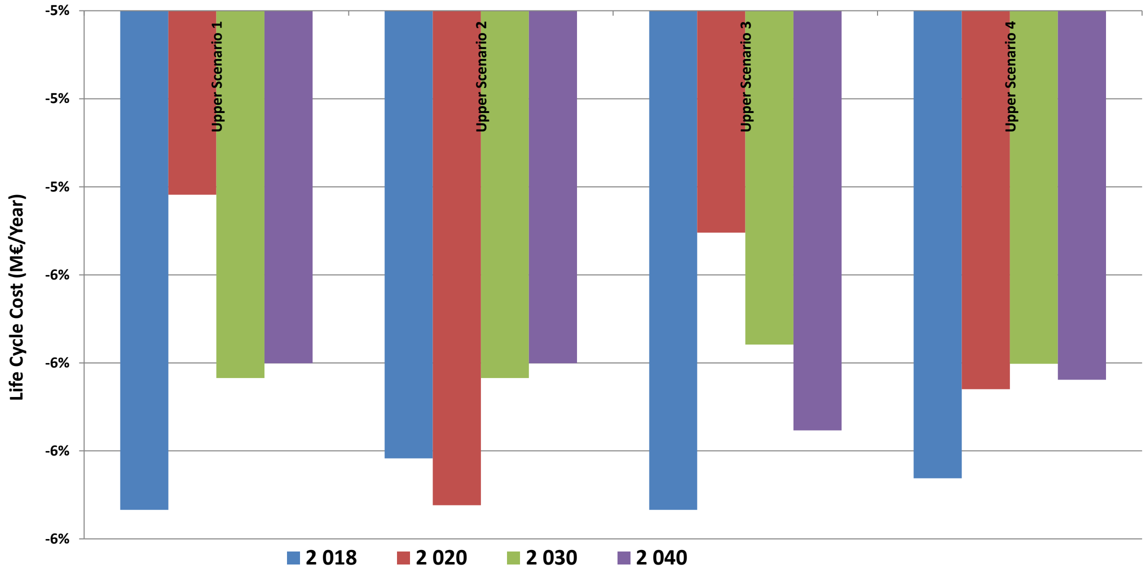


Figure 8-52: Sensitivity analysis of life cycle cost to maintenance and repair cost for BC 4

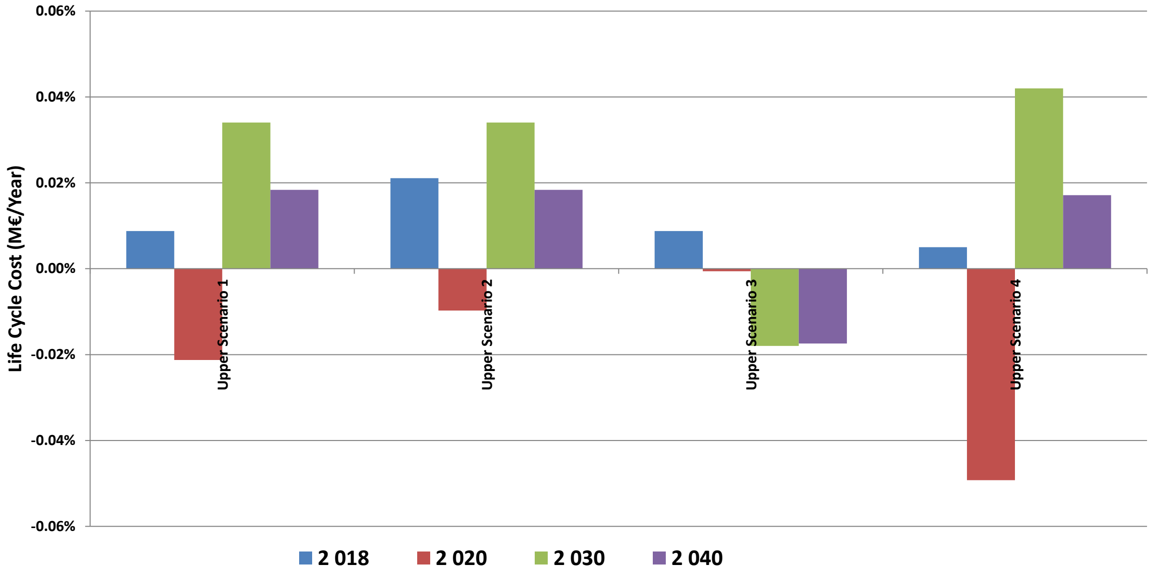


Figure 8-53: Sensitivity analysis of life cycle cost to maintenance and repair cost for BC 5

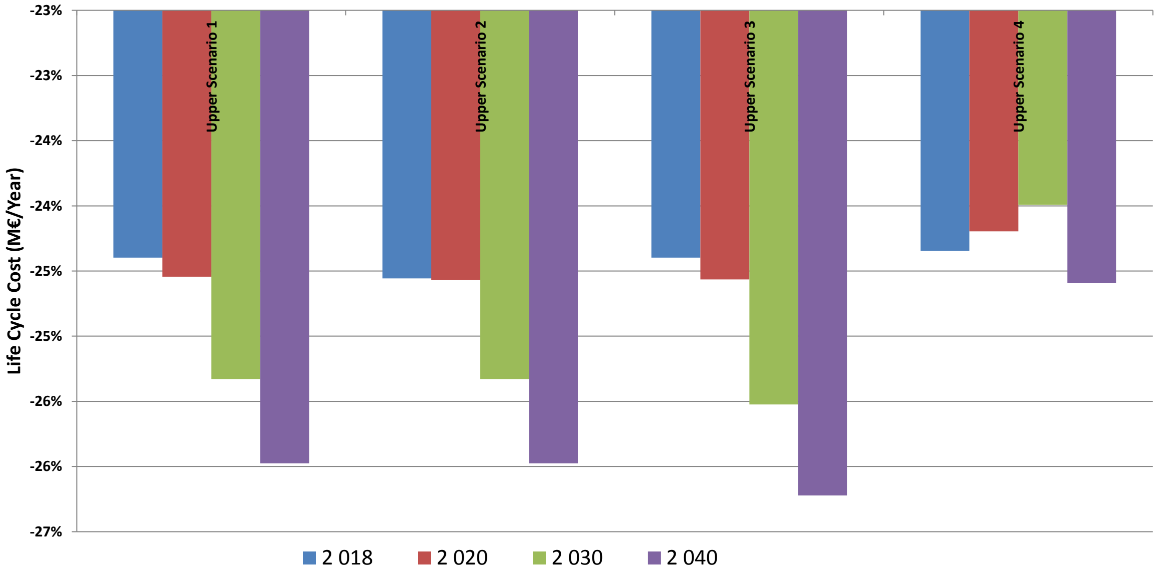


Figure 8-54: Sensitivity analysis of life cycle cost to maintenance and repair cost for BC 6

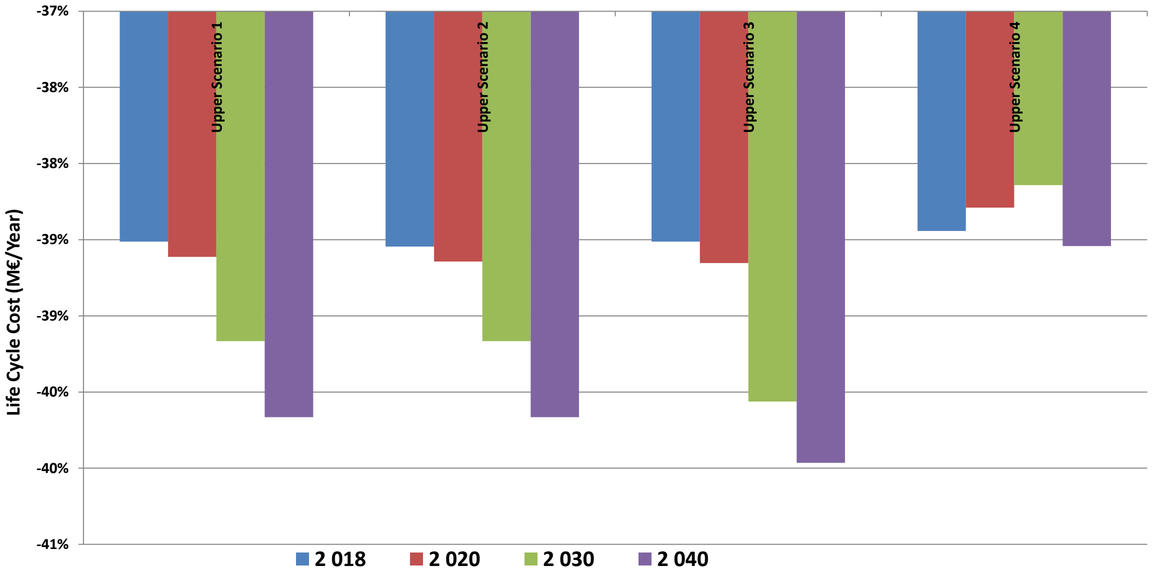


Figure 8-55: Sensitivity analysis of life cycle cost to maintenance and repair cost for BC 7A

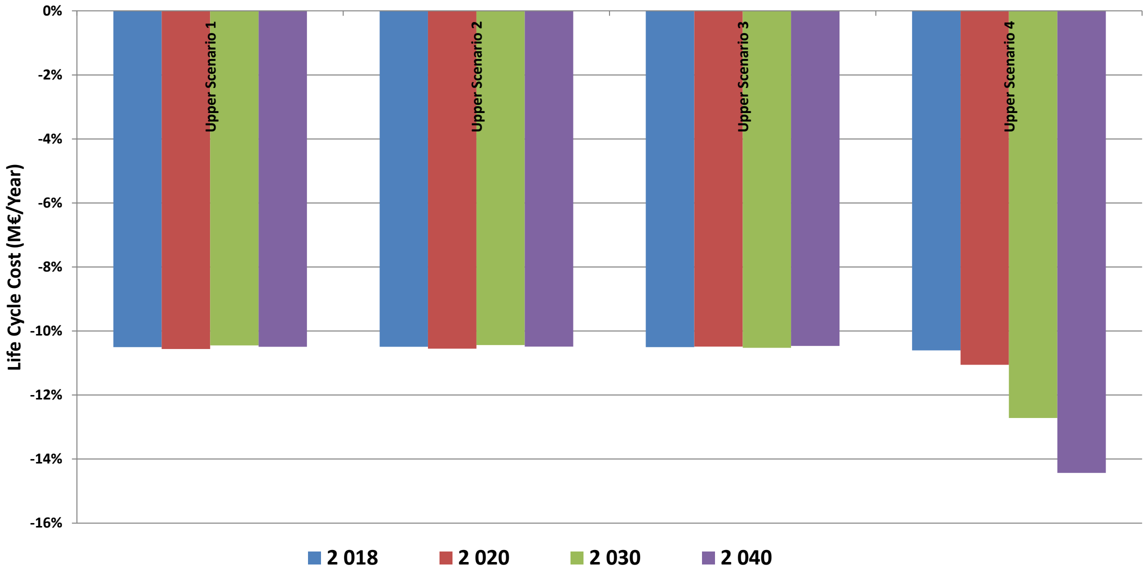
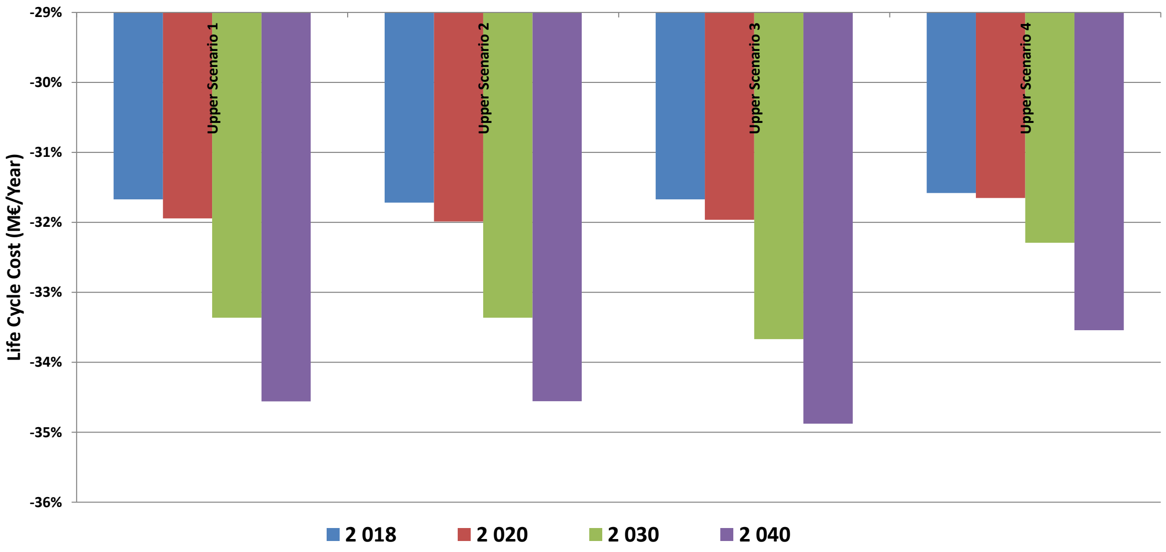


Figure 8-56: Sensitivity analysis of life cycle cost to maintenance and repair cost for All BCs



## 8.5.5 Conclusions of the sensitivity analysis

When varying the input data on 4 parameters: product purchase price, product lifetime, sales growth rate and maintenance and repair costs, the evolution of the four different pragmatic scenarios relative to the BaU is similar to presented in section 8.3: 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 tasks.

## 8.6 Conclusions

This Task report brings together the finding of the previous seven tasks of the Lot 28 preparatory study for Ecodesign requirements of pumps for public and private wastewater and for fluids with high solids content. It looked at the possibility to propose suitable requirements for these Lot 28 pumps to achieve environmental improvements.

Generic ecodesign requirements are recommended for all the Base-Cases considered in Lot 28 study. As pumps usually require professional engineers and technicians to dimension and design the systems, relevant product information requirements were thought to be more effective than energy labelling[19].

Whereas, the possibility to set specific ecodesign requirements was analysed in this report for the following Base-Cases:

- BC 1: Submersible radial sewage pumps 1 to 160 kW
- BC2: Submersible fixed flow & axial pumps
- BC 4: Centrifugal submersible domestic drainage pump<40mm passage
- BC 5: Submersible dewatering pumps
- BC 6: Dry well radial sewage pumps 1 to 160 kW
- BC 7A: Light duty slurry pumps

A number of potential MEPS based on the MEI cut-off criteria for specific Lot 28 pumps (BC 1, BC 2, BC 4, BC 5, BC 6 and BC 7A) are considered, as presented below:

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

Based on the findings of the scenario analysis (performed for the period 2013-2040), it is concluded that whereas there is a significant negative impact on consumer expenditure (around €11 Million/year in 2040) for setting MEI requirements on BC 4, the corresponding electricity savings are rather insignificant (around 25.1 GWh/year in 2040). **Therefore, it is recommended to not consider the pump types corresponding to this Base-Case (BC 4) for any future MEI requirements, but only generic ecodesign requirement.**

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[19] Although BC 4 pumps can be a good candidate for Energy labelling as these pumps are sold in large quantities in EU and not always installed by skilled professionals but also by non-professionals (as available in DIY markets) or low-skilled professionals. However, the energy savings value for these pumps in EU is insignificant to consider any energy labelling requirements. Nonetheless, the concern about the proper installation of these pumps is already addressed via the generic ecodesign requirements proposed for these pumps in this report.

On a similar note, slurry pumps are selected for "tons of solids pumped per hour", not for m³/h or litres per second, as it is normal for all other pumps. Both light and heavy duty slurry pumps are engineered for every duty to choose the optimum pump type, materials and performance. Categorisation of slurry pumps into light and heavy duty is more by application and material handled than by pump type. The VSDs are not appropriate for slurry pumps as the users change speed by changing pulleys. **Therefore, these slurry pumps (BC 7A and 7B) are also not suitable for future MEI requirements**[20].

**The MEI requirements seem to be appropriate for remaining 4 Base-Cases (BC 1, BC 2, BC 5 and BC 6)**. However, if MEI requirements for Lot 28 pumps (BC 1, BC 2, BC 5 and BC 6) are introduced, the methodology for MEI calculation based on ENER Lot 11 pumps may not be appropriate for ENER Lot 28 pumps as the pump efficiency correlates with pump size and specific speed in a different manner. Therefore, a new exhaustive data collection exercise specific Lot 28 pumps (BC 1, BC 2, BC 5 and BC 6) will need to be carried out and along with new standard for MEI compliance testing. In a future revision of the proposed regulation, the Extended Product Approach and the Energy Efficiency Index method could be taken up in order to develop a more ambitious regulation for wastewater pumps in the EU, which could potentially save significantly higher energy compared to regulation based on MEI approach.

The comparison of the total electricity savings achieved by policy implementation on all the Base-Case included in this analysis shows that the **maximum electricity savings per year that could be achieved in 2040 are between around 486.6 GWh and 1628.9 GWh per year at EU level**, depending on the level of ambition of the scenario selected. 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 Zero (in Pragmatic Scenario 1) and 161 Million Euros (in Pragmatic Scenario 4) at EU level**.

Concerning reduction in annual consumer expenditure, there is not much difference in the impact of Scenario 1, Scenario 2 and Scenario 3. The potential savings in electricity consumption of Scenario 3 and Scenario 4 are similar whereas there is not much difference between Scenario 1 and Scenario 2. This would suggest that **regulating Lot 28 pumps using Policy Option 3 (with three cut of tiers) would be more effective than enforcing a single or two-tier regulation.**

The likely economic and social impacts of the policy options were briefly described. The implementation of MEPS might require manufacturers to invest 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 MEPS adopted and on the energy performance of models proposed by each manufacturer.

Finally, a sensitivity analysis was performed to assess the main assumptions used in the study and it was concluded that the findings remain robust and reliable.

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[20] Europump remarked that in the planned energy efficiency regulations in the USA, the Department of Energy is not considering wastewater and slurry pumps (U.S. Department of Energy, Energy Conservation Standards Rulemaking Framework Document for Commercial and Industrial Pumps, January 2013. www.pumps.org/uploadedFiles/Framework_Document_for_Commercial%20_Industrial_Pumps.pdf)

# Annex A: 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 (EC Regulation 547/2012), 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, but work to date suggests that just three profiles will be adequate for ENER Lot 28 pumps:

- Closed loop variable flow;
- Open loop variable flow; and
- Constant flow[21] (open and closed loop).

The profile just gives 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 Lot 28 pumps concern mainly constant flow (open and closed loop).

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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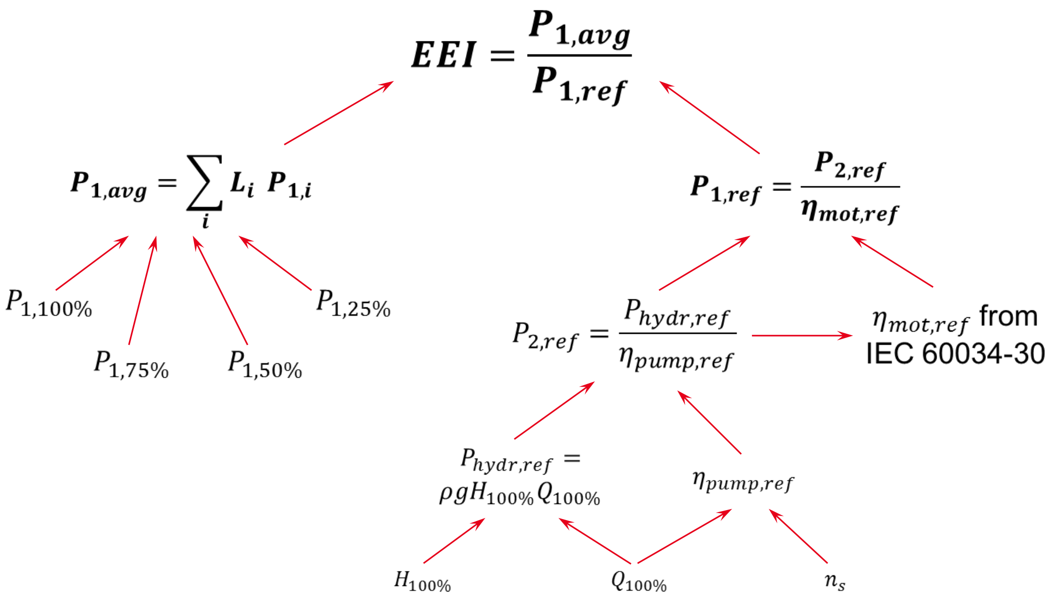
[21] The large majority of waste water pumps follow this profile.



*Where:*

*P1,i is the electrical power input from the grid*

*P2,i is the mechanical power from the motor shaft*

*$P_{hydr}$ 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 B: C-values calculation approach for Lot 28 pumps

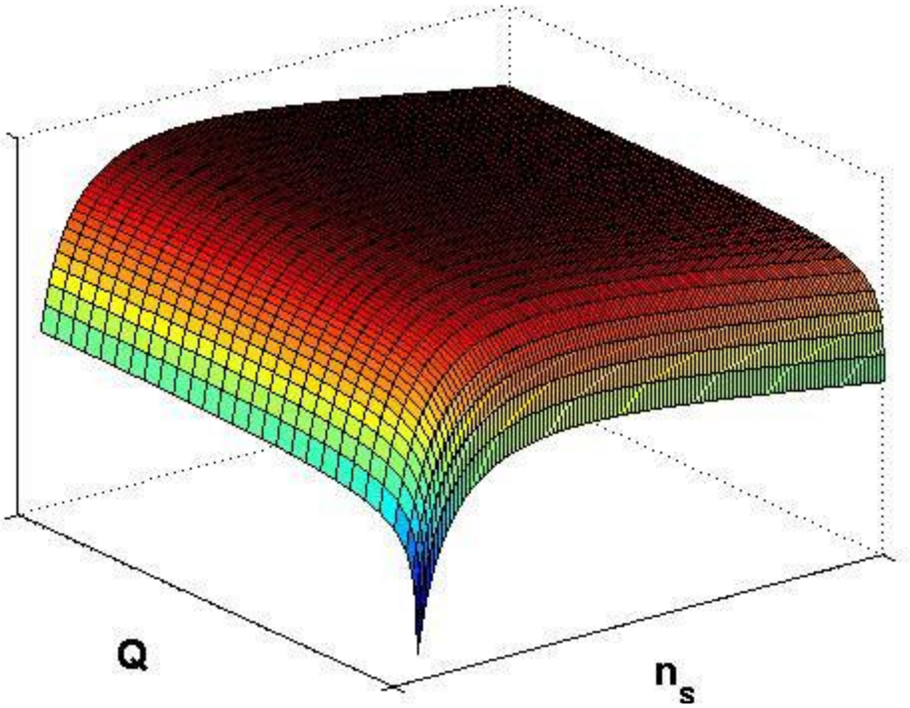
## Introduction

This Annex contains a description of the methodology proposed for use to estimate the "C-values" for the pumps considered in the ENER lot 28 preparatory study. The concept of "C-values" was first used in the ENER Lot 11 study for clean water pumps. The intention of the Lot 28 study authors is to use the ENER Lot 11 C value methodology and adapt it for use with the Lot 28 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).

Setting the efficiency levels is very complicated, as they will differ by type, speed, flow, head and impeller diameter. 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 Lot 11 report using data from Technische Universität Berlin in 1998 for an earlier SAVE project led by AEAT. This plane is shown in Figure B - i.

**Figure B - i: 3D plane used in the Lot 11 pump study**



*Where:*

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

*Q is flow ($m^3/h$)*

*$\eta$ 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 Lot 11

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

Table B - i: 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 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 B - ii : 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 m3/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 Table B - iii.

Table B - iii: 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 Lot 11 C-values calculation approach for Lot 28 pumps

For the Lot 28 pumps, EUROPUMP has provided the following information for 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[7].

Table B - iv: Efficiency range for Lot 28 pumps

| Pump type | Specificity | $\eta_{max}$ | $\eta_{min}$ | $\eta_{av}$ |
|---|---|---|---|---|
| Radial Sewage Pumps 1 to 10kW | vortex | 63 | 26 | 43 |
| Submersible & dry installed | channel | 80 | 39.2 | 71 |
| Radial Sewage Pumps >10 to 25kW | vortex | 58.5 | 38.8 | 45.7 |
| Submersible & dry installed | channel | 87 | 54 | 71.5 |
| Radial Sewage Pumps >25 to 160kW | all types average | 88.7 | 55 | 77.3 |

| | | | | |
|---|---|---|---|---|
| submersible & dry installed | | | | |
| Mixed flow & Axial | Activated sludge recirculation Axial ( H < 2m) | 68.3 | 35.3 | 56.5 |
| | Stormwater & effluent axial and mixed flow | 87.3 | 68 | 82.1 |
| Domestic& commercial buildings | Shredding, grinding pumps | 42 | 22.5 | 32.3 |
| "Once a day operation" | Radial sewage pumps 1 to 10kW | 78 | 26 | 53.5 |
| | Where volute is part of a tank | 71 | 14 | 27.62 |
| | Centrifugal submersible domestic drainage pump < 40 mm passage | 60.8 | 14.5 | 35.2 |
| Dewatering pumps, submersible | | 72 | 46 | 64 |
| Slurry pumps | light | 82 | 45 | 63.5 |
| | heavy | 77 | 35 | 56 |

From these values it is possible to put together the efficiency cut-off bands for the pumps in scope.

**Table B - v: Efficiencies at different cut-off values for the Lot 28 pumps**[22]

| Pump type | Specificity | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Radial Sewage Pumps 1 to 10kW | vortex | 29.7 | 33.4 | 37.1 | 40.8 | 44.5 | 48.2 | 51.9 | 55.6 | 59.3 | 63 |
| Submersible & dry installed | channel | 43.28 | 47.36 | 51.44 | 55.52 | 59.6 | 63.68 | 67.76 | 71.84 | 75.92 | 80 |
| Radial Sewage Pumps >10 to 25kW | vortex | 40.77 | 42.74 | 44.71 | 46.68 | 48.65 | 50.62 | 52.59 | 54.56 | 56.53 | 58.5 |
| Submersible & | channel | 57.3 | 60.6 | 63.9 | 67.2 | 70.5 | 73.8 | 77.1 | 80.4 | 83.7 | 87 |

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[22] Please note in the absence of availability of detailed market data, for the values presented in this table the study authors had to assume that the change in energy efficiency of Lot 28 pumps is directly proportional to their market share. However, in reality this may not be true, as the average efficiency pumps may dominate the market share whereas the highly inefficient and highly efficient pumps may only represent a small share of EU market. Therefore, ideally an exhaustive data collection on pumps in the EU market, in order to calculate the appropriate C-values, should be carried out.

| Pump type | Specificity | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| dry installed | | | | | | | | | | | |
| Radial Sewage Pumps >25 to 160kW submersible & dry installed | all types average | 58.37 | 61.74 | 65.11 | 68.48 | 71.85 | 75.22 | 78.59 | 81.96 | 85.33 | 88.7 |
| Mixed flow & Axial | Activated sludge recirculation Axial ( H < 2m) | 38.6 | 41.9 | 45.2 | 48.5 | 51.8 | 55.1 | 58.4 | 61.7 | 65 | 68.3 |
| | Stormwater & effluent axial and mixed flow | 69.93 | 71.86 | 73.79 | 75.72 | 77.65 | 79.58 | 81.51 | 83.44 | 85.37 | 87.3 |
| Domestic& commercial buildings | Shredding, grinding pumps | 24.45 | 26.4 | 28.35 | 30.3 | 32.25 | 34.2 | 36.15 | 38.1 | 40.05 | 42 |
| "Once a day operation" | Radial sewage pumps 1 to 10kW | 31.2 | 36.4 | 41.6 | 46.8 | 52 | 57.2 | 62.4 | 67.6 | 72.8 | 78 |
| | Where volute is part of a tank | 19.7 | 25.4 | 31.1 | 36.8 | 42.5 | 48.2 | 53.9 | 59.6 | 65.3 | 71 |
| | Centrifugal submersible domestic drainage pump < 40 mm passage | 19.13 | 23.76 | 28.39 | 33.02 | 37.65 | 42.28 | 46.91 | 51.54 | 56.17 | 60.8 |
| Dewatering pumps, submersible[23] | | 48.6 | 51.2 | 53.8 | 56.4 | 59 | 61.6 | 64.2 | 66.8 | 69.4 | 72 |
| Slurry pumps | light | 48.7 | 52.4 | 56.1 | 59.8 | 63.5 | 67.2 | 70.9 | 74.6 | 78.3 | 82 |
| | heavy | 39.2 | 43.4 | 47.6 | 51.8 | 56 | 60.2 | 64.4 | 68.6 | 72.8 | 77 |

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

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[23] A distinction between the vortex and channel impellers might be needed for submersible dewatering pumps.

to estimate the average head and flow for each pump type[24]. The results are shown in the following table.

Table B - vi: Estimated average Lot 28 pump duties

| Pump type | Specificity | Shaft power | Head (m) | Flow (m³/h) | Specific Speed | ln ns (/min) | ln Q (m3/hr) |
|---|---|---|---|---|---|---|---|
| Radial Sewage Pumps 1 to 10kW submersible & dry installed | channel | 4 | 10 | 105 | 44.1 | 3.8 | 4.7 |
| Radial Sewage Pumps >10 to 25kW submersible & dry installed | channel | 15 | 20 | 199 | 36.0 | 3.6 | 5.3 |
| Radial Sewage Pumps >25 to 160kW submersible & dry installed | all types average | 75 | 60 | 358 | 21.2 | 3.1 | 5.9 |
| Mixed flow & Axial[25] | Activated sludge recirculation Axial ( H < 2m) | 50 | 4 | 2617 | 220.1 | 5.4 | 7.9 |
| Submersible & dry installed | Stormwater & effluent axial and mixed flow | 150 | 4 | 11410 | 368.2 | 5.9 | 9.3 |
| Domestic& commercial buildings "once a day operation" | Shredding, grinding pumps | 2 | 19 | 12.6 | 18.9 | 2.9 | 2.5 |
| | Radial sewage pumps 1 to 10kW | 2 | 15 | 26 | 32.6 | 3.5 | 3.3 |
| | Where volute is part of a tank | 1.5 | 12 | 12.8 | 26.8 | 3.3 | 2.5 |
| | Centrifugal submersible domestic drainage pump < 40 mm passage | 0.3 | 5 | 7.8 | 40.4 | 3.7 | 2.1 |
| Dewatering pumps, submersible | | 7 | 18 | 92 | 26.6 | 3.3 | 4.5 |
| Slurry pumps[26] | light | 50 | 40 | 294 | 26.1 | 3.3 | 5.7 |
| | heavy | 37 | 40 | 192 | 21.1 | 3.0 | 5.3 |

Using the information in Table B - v and in Table B - vi, combination with the formula previously described, the following C-values are estimated as presented in Table B - vii.

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[24] 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.

[25] Note that the axial flow pumps do not work with the formula shown under "Introduction" of this Annex and therefore it cannot be used to accurately estimate the C-values for these pumps.

[26] Note that the independent data collection for slurry pumps would need to cover probably 6 categories so that the 'C' factor for each type, which allows minimum efficiency to be calculated, could be developed.

Table B - vii: Estimated C-values at different MEPS cut-offs for the Lot 28 pumps

| Pump type | Specificity | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Radial Sewage Pumps 1 to 10kW submersible & dry installed | Channel | 165.1 | 161.0 | 157.0 | 152.9 | 148.8 | 144.7 | 140.6 | 136.6 | 132.5 | 128.4 |
| Radial Sewage Pumps >10 to 25kW submersible & dry installed | Channel | 153.0 | 149.7 | 146.4 | 143.1 | 139.8 | 136.5 | 133.2 | 129.9 | 126.6 | 123.3 |
| Radial Sewage Pumps >25 to 160kW submersible & dry installed | all types average | 148.1 | 144.7 | 141.3 | 137.9 | 134.6 | 131.2 | 127.8 | 124.5 | 121.1 | 117.7 |
| Mixed flow & Axial[27] | Activated sludge recirculation Axial ( H < 2m) | 142.4 | 139.1 | 135.8 | 132.5 | 129.2 | 125.9 | 122.6 | 119.3 | 116.0 | 112.7 |
| | Stormwater & effluent axial and mixed flow[28] | 83.3 | 81.4 | 79.4 | 77.5 | 75.6 | 73.7 | 71.7 | 69.8 | 67.9 | 65.9 |
| Domestic& commercial buildings | Shredding, grinding pumps | 162.5 | 160.6 | 158.6 | 156.7 | 154.7 | 152.8 | 150.8 | 148.9 | 146.9 | 145.0 |
| "Once a day operation" | Radial sewage pumps 1 to 10kW | 168.7 | 163.5 | 158.3 | 153.1 | 147.9 | 142.7 | 137.5 | 132.3 | 127.1 | 121.9 |
| | Where volute is part of a tank | 173.1 | 167.4 | 161.7 | 156.0 | 150.3 | 144.6 | 138.9 | 133.2 | 127.5 | 121.8 |
| | Centrifugal submersible domestic drainage pump < 40 mm passage | 172.7 | 168.1 | 163.4 | 158.8 | 154.2 | 149.5 | 144.9 | 140.3 | 135.7 | 131.0 |

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[27] Note that the axial flow pumps do not work with the formula shown in Section 1 and therefore it cannot be used to accurately estimate the C values for these pumps.

[28] Note as the Lot 11 data collection is not valid for pumps with specific speed above 80, therefore the storm water pumps do not work with the formula shown in Section 1 and therefore it cannot be used to accurately estimate the C values for these pumps.

| Pump type | Specificity | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dewatering pumps, submersible | | 156.3 | 153.7 | 151.1 | 148.5 | 145.9 | 143.3 | 140.7 | 138.1 | 135.5 | 132.9 |
| Slurry pumps | light | 160.1 | 156.4 | 152.7 | 149.0 | 145.3 | 141.6 | 137.9 | 134.2 | 130.5 | 126.8 |
| | heavy | 165.3 | 161.1 | 156.9 | 152.7 | 148.5 | 144.3 | 140.1 | 135.9 | 131.7 | 127.5 |

**It is important to note that this method uses the Lot 11 $\eta_{Bot}$ formula in an unmodified state. This may not be appropriate as it does not account for the fact that the pumps in the Lot28 have to handle solids[7].**

# Annex C: Sensitivity analysis data

## Sensitivity analysis data for lifetime

### Electricity consumption reduction and Overall consumer expenditure data for BC 1

Table C - i: Data used for analysis of life cycle sensitivity to product lifetime for BC1

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | 4 993.70 | 5 011.61 | 4 993.70 | 5 011.61 | -3 719.64 | -3 686.06 | -3 719.64 | -3 686.06 |
| 2020 | GWh/year | 5 428.3 | 5 446.2 | 5 428.3 | 5 480.9 | -3 967.9 | -3 934.4 | -3 967.9 | -3 869.2 |
| 2030 | GWh/year | 7 986.8 | 7 986.8 | 8 166.0 | 8 188.0 | -5 540.1 | -5 540.1 | -5 204.1 | -5 162.8 |
| 2040 | GWh/year | 11 149.9 | 11 149.9 | 11 400.1 | 11 430.9 | -7 734.3 | -7 734.3 | -7 265.3 | -7 207.6 |
| 2018 | % | 33.3% | 33.2% | 33.3% | 33.2% | -25.0% | -24.9% | -25.0% | -24.9% |
| 2020 | % | 33.2% | 33.2% | 33.2% | 33.0% | -24.9% | -24.9% | -24.9% | -24.8% |
| 2030 | % | 33.0% | 33.0% | 32.6% | 32.5% | -57.7% | -57.7% | -57.0% | -56.9% |
| 2040 | % | 33.0% | 33.0% | 32.6% | 32.5% | -24.7% | -24.7% | -24.4% | -24.4% |

Table C - ii: Data used for analysis of life cycle sensitivity to product lifetime for BC 1

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | 91.24 | 91.18 | 91.24 | 92.54 | -49.17 | -48.98 | -49.17 | -47.62 |
| 2020 | M€/year | 99.60 | 99.54 | 92.76 | 118.45 | -51.81 | -51.62 | -58.66 | -32.22 |
| 2030 | M€/year | 144.24 | 144.24 | 135.99 | 247.19 | -73.74 | -73.74 | -79.34 | 32.08 |
| 2040 | M€/year | 203.08 | 203.08 | 192.97 | 346.50 | -101.23 | -101.23 | -107.65 | 46.20 |
| 2018 | % | 3.0% | 3.0% | 3.0% | 3.0% | -4.3% | -4.3% | -4.3% | -4.3% |
| 2020 | % | 3.0% | 3.0% | 3.0% | 3.0% | -4.3% | -4.3% | -4.3% | -4.3% |
| 2030 | % | 3.0% | 3.0% | 3.0% | 3.0% | -4.4% | -4.4% | -4.3% | -4.3% |
| 2040 | % | 3.1% | 3.1% | 3.1% | 3.1% | -4.5% | -4.5% | -4.4% | -4.4% |

- Electricity consumption reduction and Overall consumer expenditure data for BC 2

**Table C - iii: Data used for analysis of life cycle sensitivity to product lifetime for BC2**

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | 411.83 | 413.14 | 411.83 | 413.14 | -307.12 | -304.68 | -307.12 | -304.68 |
| 2020 | GWh/year | 449.0 | 450.3 | 449.0 | 452.9 | -329.2 | -326.8 | -329.2 | -322.1 |
| 2030 | GWh/year | 667.7 | 667.7 | 680.2 | 681.8 | -469.2 | -469.2 | -445.6 | -442.7 |
| 2040 | GWh/year | 939.9 | 939.9 | 957.6 | 959.78 | -660.35 | -660.4 | -627.2 | -623.0 |
| 2018 | % | 33.3% | 33.2% | 33.3% | 33.2% | -25.0% | -24.9% | -25.0% | -24.9% |
| 2020 | % | 33.2% | 33.2% | 33.2% | 33.1% | -24.9% | -24.9% | -24.9% | -24.8% |
| 2030 | % | 33.0% | 33.0% | 32.7% | 32.7% | -57.8% | -57.8% | -57.2% | -57.2% |
| 2040 | % | 33.0% | 33.0% | 32.7% | 32.7% | -24.8% | -24.8% | -24.5% | -24.5% |

**Table C - iv: Data used for analysis of life cycle sensitivity to product lifetime for BC 2**

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | 7.72 | 7.85 | 7.72 | 7.78 | -3.93 | -3.78 | -3.93 | -3.85 |
| 2020 | M€/year | 9.21 | 9.34 | 9.12 | 9.57 | -3.40 | -3.25 | -3.50 | -2.98 |
| 2030 | M€/year | 13.79 | 13.79 | 14.89 | 15.42 | -4.63 | -4.63 | -3.35 | -2.80 |
| 2040 | M€/year | 20.04 | 20.04 | 21.62 | 22.36 | -5.88 | -5.88 | -4.06 | -3.29 |
| 2018 | % | 6.8% | 6.9% | 6.8% | 6.9% | -10.3% | -10.3% | -10.3% | -10.3% |
| 2020 | % | 7.5% | 6.8% | 7.4% | 7.0% | -10.3% | -10.2% | -10.3% | -10.2% |
| 2030 | % | 7.2% | 7.2% | 7.2% | 7.0% | -10.3% | -10.3% | -10.2% | -10.2% |
| 2040 | % | 7.3% | 7.3% | 7.1% | 7.0% | -10.5% | -10.5% | -10.4% | -10.3% |

- Electricity consumption reduction and Overall consumer expenditure data for BC 4

Table C - v: Data used for analysis of life cycle sensitivity to product lifetime for BC4

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | 156.33 | 156.87 | 156.33 | 156.87 | -171.03 | -169.86 | -171.03 | -169.86 |
| 2020 | GWh/year | 168.904 | 169.438 | 168.90 | 170.47 | -181.96 | -180.79 | -181.96 | -178.522 |
| 2030 | GWh/year | 243.116 | 243.116 | 248.59 | 249.39 | -249.79 | -249.79 | -237.74 | -235.978 |
| 2040 | GWh/year | 334.467 | 334.467 | 342.144 | 343.104 | -343.63 | -343.63 | -326.743 | -324.63 |
| 2018 | % | 36.3% | 36.3% | 36.3% | 36.3% | -40.0% | -39.9% | -40.0% | -39.9% |
| 2020 | % | 36.2% | 36.2% | 36.2% | 36.0% | -39.8% | -39.8% | -39.8% | -39.6% |
| 2030 | % | 35.9% | 35.9% | 35.4% | 35.3% | -75.4% | -75.4% | -74.4% | -74.2% |
| 2040 | % | 35.9% | 35.9% | 35.4% | 35.3% | -39.5% | -39.5% | -38.9% | -38.9% |

Table C - vi: Data used for analysis of life cycle sensitivity to product lifetime for BC 4

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -2.26 | -2.20 | -2.26 | -6.29 | -3.32 | -3.25 | -3.32 | -7.34 |
| 2020 | M€/year | -2.39 | -2.33 | -6.27 | -6.57 | -3.52 | -3.45 | -7.40 | -7.68 |
| 2030 | M€/year | -2.73 | -2.73 | -7.19 | -7.73 | -4.28 | -4.28 | -8.65 | -9.19 |
| 2040 | M€/year | -3.44 | -3.44 | -8.86 | -9.53 | -5.57 | -5.57 | -10.87 | -11.54 |
| 2018 | % | 0.1% | 0.1% | 0.1% | 0.1% | -0.2% | -0.2% | -0.2% | -0.2% |
| 2020 | % | 0.1% | 0.1% | 0.1% | 0.1% | -0.2% | -0.2% | -0.2% | -0.2% |
| 2030 | % | 0.2% | 0.2% | 0.1% | 0.2% | -0.2% | -0.2% | -0.2% | -0.2% |
| 2040 | % | 0.2% | 0.2% | 0.1% | 0.2% | -0.2% | -0.2% | -0.2% | -0.2% |

- Electricity consumption reduction and Overall consumer expenditure data for BC 5

Table C - vii: Data used for analysis of life cycle sensitivity to product lifetime for BC5

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | 1 419.89 | 1 431.11 | 1 419.89 | 1 431.11 | -1 049.28 | -1 028.24 | -1 049.28 | -1 028.24 |
| 2020 | GWh/year | 1 558.6 | 1 569.8 | 1 558.6 | 1 591.3 | -1 104.9 | -1 083.9 | -1 104.9 | -1 043.5 |
| 2030 | GWh/year | 2 358.1 | 2 358.1 | 2 465.9 | 2 479.2 | -1 496.8 | -1 496.8 | -1 294.8 | -1 269.9 |
| 2040 | GWh/year | 3 319.2 | 3 319.2 | 3 470.9 | 3 489.6 | -2 107.1 | -2 107.1 | -1 822.6 | -1 787.6 |
| 2018 | % | 33.3% | 33.1% | 33.3% | 33.1% | -24.9% | -24.8% | -24.9% | -24.8% |
| 2020 | % | 33.1% | 32.9% | 33.1% | 32.7% | -24.8% | -24.7% | -24.8% | -24.5% |
| 2030 | % | 32.6% | 32.6% | 31.8% | 31.7% | -57.0% | -57.0% | -55.6% | -55.4% |
| 2040 | % | 32.6% | 32.6% | 31.8% | 31.7% | -24.4% | -24.4% | -23.8% | -23.8% |

Table C - viii: Data used for analysis of life cycle sensitivity to product lifetime for BC 5

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | 26.25 | 27.19 | 26.25 | 26.57 | -13.64 | -12.55 | -13.64 | -13.16 |
| 2020 | M€/year | 30.34 | 31.28 | 28.40 | 35.32 | -12.69 | -11.59 | -14.63 | -7.24 |
| 2030 | M€/year | 50.39 | 50.39 | 56.77 | 75.99 | -11.89 | -11.89 | -3.98 | 15.43 |
| 2040 | M€/year | 71.47 | 71.47 | 80.88 | 107.64 | -16.19 | -16.19 | -4.63 | 22.41 |
| 2018 | % | 3.8% | 3.6% | 3.8% | 3.7% | -5.4% | -5.3% | -5.4% | -5.3% |
| 2020 | % | 3.8% | 3.8% | 3.8% | 3.6% | -5.4% | -5.3% | -5.4% | -5.3% |
| 2030 | % | 3.8% | 3.8% | 3.8% | 3.7% | -5.5% | -5.5% | -5.3% | -5.3% |
| 2040 | % | 4.0% | 4.0% | 3.9% | 3.9% | -5.7% | -5.7% | -5.6% | -5.5% |

- Electricity consumption reduction and Overall consumer expenditure data for BC 6

Table C - ix: Data used for analysis of life cycle sensitivity to product lifetime for BC6

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | 1 240.56 | 1 243.95 | 1 240.56 | 1 243.95 | -1 291.26 | -1 284.18 | -1 291.26 | -1 284.18 |
| 2020 | GWh/year | 1 343.0 | 1 346.4 | 1 343.0 | 1 352.9 | -1 381.0 | -1 373.9 | -1 381.0 | -1 360.3 |
| 2030 | GWh/year | 1 949.2 | 1 949.2 | 1 983.7 | 1 988.0 | -1 934.5 | -1 934.5 | -1 862.5 | -1 853.5 |
| 2040 | GWh/year | 2 702.7 | 2 702.7 | 2 750.4 | 2 756.4 | -2 682.1 | -2 682.1 | -2 582.4 | -2 569.8 |
| 2018 | % | 34.8% | 34.7% | 34.8% | 34.7% | -36.3% | -36.3% | -36.3% | -36.3% |
| 2020 | % | 34.7% | 34.6% | 34.7% | 34.5% | -36.3% | -36.2% | -36.3% | -36.1% |
| 2030 | % | 34.5% | 34.5% | 34.1% | 34.1% | -70.5% | -70.5% | -69.8% | -69.7% |
| 2040 | % | 34.5% | 34.5% | 34.1% | 34.1% | -36.0% | -36.0% | -35.7% | -35.6% |

Table C - x: Data used for analysis of life cycle sensitivity to product lifetime for BC 6

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | 31.51 | 31.55 | 31.51 | 31.44 | -18.88 | -18.76 | -18.88 | -18.87 |
| 2020 | M€/year | 33.30 | 33.34 | 32.28 | 35.26 | -20.91 | -20.80 | -21.93 | -18.73 |
| 2030 | M€/year | 48.17 | 48.17 | 47.30 | 60.12 | -29.12 | -29.12 | -29.24 | -16.33 |
| 2040 | M€/year | 67.51 | 67.51 | 66.51 | 84.10 | -39.65 | -39.65 | -39.62 | -21.89 |
| 2018 | % | 5.5% | 5.5% | 5.5% | 5.4% | -8.7% | -8.7% | -8.7% | -8.7% |
| 2020 | % | 5.5% | 5.5% | 5.5% | 5.5% | -8.7% | -8.7% | -8.7% | -8.7% |
| 2030 | % | 5.6% | 5.6% | 5.5% | 5.5% | -8.8% | -8.8% | -8.8% | -8.7% |
| 2040 | % | 5.7% | 5.7% | 5.7% | 5.7% | -9.0% | -9.0% | -9.0% | -8.9% |

- Electricity consumption reduction and Overall consumer expenditure data for BC 7A

Table C - xi: Data used for analysis of life cycle sensitivity to product lifetime for BC7A

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | 5 495.97 | 5 497.67 | 5 495.97 | 5 497.67 | -5 743.04 | -5 739.49 | -5 743.04 | -5 739.49 |
| 2020 | GWh/year | 5 595.6 | 5 597.2 | 5 595.6 | 5 600.5 | -5 838.4 | -5 834.9 | -5 838.4 | -5 828.1 |
| 2030 | GWh/year | 6 192.2 | 6 193.8 | 6 209.5 | 6 216.7 | -6 409.9 | -6 406.3 | -6 373.5 | -6 358.6 |
| 2040 | GWh/year | 6 953.2 | 6 954.9 | 6 992.8 | 7 002.7 | -7 138.8 | -7 135.3 | -7 056.1 | -7 035.4 |
| 2018 | % | 34.8% | 34.8% | 34.8% | 34.8% | -36.4% | -36.4% | -36.4% | -36.4% |
| 2020 | % | 34.8% | 34.8% | 34.8% | 34.8% | -36.4% | -36.3% | -36.4% | -36.3% |
| 2030 | % | 34.7% | 34.7% | 34.7% | 34.6% | -71.0% | -71.0% | -70.9% | -70.9% |
| 2040 | % | 34.7% | 34.7% | 34.6% | 34.5% | -36.2% | -36.2% | -36.1% | -36.1% |

Table C - xii: Data used for analysis of life cycle sensitivity to product lifetime for BC 7A

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | 85.06 | 85.14 | 85.06 | 83.50 | -49.25 | -49.15 | -49.25 | -50.79 |
| 2020 | M€/year | 86.04 | 86.12 | 85.66 | 82.01 | -50.61 | -50.50 | -50.99 | -54.57 |
| 2030 | M€/year | 95.58 | 95.67 | 95.92 | 76.85 | -55.02 | -54.91 | -54.45 | -73.43 |
| 2040 | M€/year | 108.26 | 108.34 | 109.55 | 70.93 | -60.15 | -60.04 | -58.34 | -96.83 |
| 2018 | % | 10.9% | 10.9% | 10.9% | 11.0% | -17.2% | -17.2% | -17.2% | -17.2% |
| 2020 | % | 10.8% | 10.8% | 10.9% | 10.8% | -17.2% | -17.2% | -17.2% | -17.2% |
| 2030 | % | 10.8% | 10.8% | 10.7% | 10.7% | -17.0% | -17.0% | -17.0% | -17.0% |
| 2040 | % | 10.6% | 10.6% | 10.7% | 10.6% | -16.9% | -16.9% | -16.8% | -16.8% |

- Electricity consumption reduction and Overall consumer expenditure data for All BCs Considered

**Table C - xiii: Data used for analysis of life cycle sensitivity to product lifetime for All BCs**

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | 13718.29 | 13754.34 | 13718.29 | 13754.34 | -12281.37 | -12212.51 | -12281.37 | -12212.51 |
| 2020 | GWh/year | 14543.4 | 14579.4 | 14 543.4 | 14 649.0 | -12803.5 | -12 734.6 | -12803.5 | -12601.6 |
| 2030 | GWh/year | 19397.1 | 19398.8 | 19 753.9 | 19803.0 | -16100.3 | -16096.7 | -15418.3 | -15323.4 |
| 2040 | GWh/year | 25399.4 | 25401.1 | 25 913.9 | 25982.4 | -20666.3 | -20662.8 | -19680.3 | -19548.1 |
| 2018 | % | 34.0% | 34.0% | 34.0% | 34.0% | -30.6% | -30.6% | -30.6% | -30.6% |
| 2020 | % | 34.0% | 33.9% | 34.0% | 33.8% | -30.4% | -30.4% | -30.4% | -30.3% |
| 2030 | % | 33.7% | 33.7% | 33.3% | 33.3% | -63.3% | -63.3% | -62.7% | -62.6% |
| 2040 | % | 33.6% | 33.6% | 33.2% | 33.2% | -29.2% | -29.2% | -28.9% | -28.8% |

**Table C - xiv: Data used for analysis of life cycle sensitivity to product lifetime for All BCs**

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | 239.52 | 240.71 | 239.52 | 235.54 | -138.19 | -136.47 | -138.19 | -141.63 |
| 2020 | M€/year | 256.1 | 257.3 | 241.9 | 274.0 | -142.9 | -141.2 | -157.1 | -123.4 |
| 2030 | M€/year | 349.4 | 349.5 | 343.7 | 467.8 | -178.7 | -178.6 | -179.0 | -54.2 |
| 2040 | M€/year | 466.9 | 467.0 | 462.7 | 622.0 | -228.7 | -228.6 | -225.2 | -64.9 |
| 2018 | % | 4.2% | 4.1% | 4.2% | 4.2% | -6.3% | -6.2% | -6.3% | -6.2% |
| 2020 | % | 4.1% | 4.1% | 4.1% | 4.1% | -6.2% | -6.2% | -6.2% | -6.2% |
| 2030 | % | 4.0% | 4.0% | 4.0% | 4.0% | -6.0% | -6.0% | -5.9% | -5.9% |
| 2040 | % | 4.0% | 4.0% | 3.9% | 3.9% | -6.0% | -6.0% | -5.9% | -5.9% |

### Sensitivity analysis data for product price

#### Overall consumer expenditure reduction

**Table C - xv: Data used for analysis of life cycle sensitivity to product price for BC 1**

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -186.97 | -186.86 | -186.97 | -186.86 | 354.56 | 354.68 | 354.56 | 358.75 |
| 2020 | M€/year | -198.39 | -198.28 | -206.53 | -180.47 | 379.52 | 379.63 | 375.24 | 401.78 |
| 2030 | M€/year | -260.70 | -260.70 | -268.80 | -157.65 | 499.08 | 499.08 | 496.05 | 607.83 |
| 2040 | M€/year | -322.57 | -322.57 | -332.20 | -178.71 | 619.08 | 619.08 | 615.73 | 770.01 |
| 2018 | % | -5.5% | -5.5% | -5.5% | -5.6% | 16.6% | 16.6% | 16.6% | 16.7% |
| 2020 | % | -5.5% | -5.5% | -5.5% | -5.5% | 16.4% | 16.4% | 16.5% | 16.5% |
| 2030 | % | -5.1% | -5.1% | -5.1% | -5.1% | 15.3% | 15.3% | 15.4% | 15.4% |
| 2040 | % | -4.6% | -4.6% | -4.7% | -4.7% | 13.9% | 13.9% | 14.0% | 14.0% |

**Table C - xvi: Data used for analysis of life cycle sensitivity to product price for BC 2**

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -3.56 | -3.42 | -3.56 | -3.52 | 5.96 | 6.10 | 5.96 | 6.08 |
| 2020 | M€/year | -2.95 | -2.81 | -3.07 | -2.58 | 7.21 | 7.35 | 7.16 | 7.66 |
| 2030 | M€/year | -3.49 | -3.49 | -2.29 | -1.75 | 9.88 | 9.88 | 11.17 | 11.72 |
| 2040 | M€/year | -3.53 | -3.53 | -1.81 | -1.05 | 13.04 | 13.04 | 14.86 | 15.63 |
| 2018 | % | -3.2% | -3.0% | -3.2% | -3.1% | 8.4% | 8.4% | 8.4% | 8.5% |
| 2020 | % | -2.4% | -3.1% | -2.5% | -2.9% | 8.3% | 8.3% | 8.3% | 8.3% |
| 2030 | % | -2.5% | -2.5% | -2.4% | -2.7% | 7.5% | 7.5% | 7.6% | 7.6% |
| 2040 | % | -2.2% | -2.2% | -2.3% | -2.4% | 6.7% | 6.7% | 6.7% | 6.7% |

### Table C - xvii: Data used for analysis of life cycle sensitivity to product price for BC 4

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -139.03 | -138.96 | -139.03 | -144.07 | 269.20 | 269.26 | 269.20 | 267.22 |
| 2020 | M€/year | -148.34 | -148.27 | -153.19 | -153.59 | 287.30 | 287.37 | 285.36 | 285.32 |
| 2030 | M€/year | -194.65 | -194.65 | -200.33 | -201.02 | 378.09 | 378.09 | 376.23 | 376.02 |
| 2040 | M€/year | -241.43 | -241.43 | -248.36 | -249.22 | 468.40 | 468.40 | 466.21 | 465.94 |
| 2018 | % | -24.7% | -24.7% | -24.7% | -24.9% | 74.1% | 74.1% | 74.1% | 74.6% |
| 2020 | % | -24.7% | -24.7% | -24.9% | -24.9% | 74.1% | 74.1% | 74.6% | 74.6% |
| 2030 | % | -24.6% | -24.6% | -24.8% | -24.8% | 74.0% | 74.0% | 74.5% | 74.6% |
| 2040 | % | -24.6% | -24.6% | -24.8% | -24.8% | 73.9% | 73.9% | 74.4% | 74.4% |

### Table C - xviii: Data used for analysis of life cycle sensitivity to product price for BC 5

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -61.99 | -60.95 | -61.99 | -62.02 | 119.44 | 120.48 | 119.44 | 120.78 |
| 2020 | M€/year | -64.15 | -63.10 | -66.53 | -59.33 | 129.47 | 130.51 | 128.38 | 135.74 |
| 2030 | M€/year | -77.81 | -77.81 | -70.93 | -51.65 | 176.74 | 176.74 | 185.32 | 204.81 |
| 2040 | M€/year | -94.71 | -94.71 | -84.50 | -57.64 | 220.77 | 220.77 | 233.08 | 260.21 |
| 2018 | % | -8.1% | -8.2% | -8.1% | -8.2% | 24.4% | 24.4% | 24.4% | 24.5% |
| 2020 | % | -8.0% | -8.0% | -8.0% | -8.1% | 24.1% | 24.1% | 24.2% | 24.3% |
| 2030 | % | -7.5% | -7.5% | -7.5% | -7.5% | 22.4% | 22.4% | 22.5% | 22.5% |
| 2040 | % | -6.8% | -6.8% | -6.9% | -6.9% | 20.5% | 20.5% | 20.6% | 20.6% |

### Table C - xix: Data used for analysis of life cycle sensitivity to product price for BC 6

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -27.38 | -27.29 | -27.38 | -27.60 | 53.57 | 53.65 | 53.57 | 53.95 |
| 2020 | M€/year | -29.83 | -29.74 | -31.03 | -27.94 | 56.56 | 56.64 | 55.93 | 59.09 |
| 2030 | M€/year | -38.63 | -38.63 | -39.27 | -26.43 | 74.94 | 74.94 | 75.05 | 87.99 |
| 2040 | M€/year | -47.26 | -47.26 | -47.93 | -30.29 | 93.49 | 93.49 | 93.77 | 111.52 |
| 2018 | % | -4.7% | -4.7% | -4.7% | -4.8% | 14.0% | 14.0% | 14.0% | 14.1% |
| 2020 | % | -4.6% | -4.6% | -4.7% | -4.7% | 13.9% | 13.9% | 14.0% | 14.0% |
| 2030 | % | -4.3% | -4.3% | -4.4% | -4.4% | 13.0% | 13.0% | 13.1% | 13.1% |
| 2040 | % | -4.0% | -4.0% | -4.0% | -4.0% | 11.9% | 11.9% | 12.0% | 12.0% |

### Table C - xx: Data used for analysis of life cycle sensitivity to product price for BC 7A

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -9.09 | -8.99 | -9.09 | -10.73 | 18.20 | 18.30 | 18.20 | 16.85 |
| 2020 | M€/year | -10.20 | -10.10 | -10.67 | -14.29 | 18.92 | 19.02 | 18.73 | 15.14 |
| 2030 | M€/year | -12.54 | -12.45 | -12.18 | -31.21 | 25.74 | 25.84 | 26.47 | 7.49 |
| 2040 | M€/year | -14.20 | -14.10 | -12.73 | -51.29 | 33.25 | 33.35 | 35.17 | -3.33 |
| 2018 | % | -1.2% | -1.2% | -1.2% | -1.1% | 3.5% | 3.5% | 3.5% | 3.5% |
| 2020 | % | -1.3% | -1.3% | -1.2% | -1.3% | 3.7% | 3.7% | 3.7% | 3.7% |
| 2030 | % | -1.4% | -1.4% | -1.5% | -1.5% | 4.3% | 4.3% | 4.4% | 4.4% |
| 2040 | % | -1.6% | -1.6% | -1.6% | -1.6% | 4.7% | 4.7% | 4.8% | 4.8% |

**Table C - xxi: Data used for analysis of life cycle sensitivity to product price for All BCs**

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -428.02 | -426.47 | -428.02 | -434.79 | 820.93 | 822.48 | 820.93 | 823.63 |
| 2020 | M€/year | -453.9 | -452.3 | -471.0 | -438.2 | 879.0 | 880.5 | 870.8 | 904.7 |
| 2030 | M€/year | -587.8 | -587.7 | -593.8 | -469.7 | 1 164.5 | 1 164.6 | 1 170.3 | 1 295.9 |
| 2040 | M€/year | -723.7 | -723.6 | -727.5 | -568.2 | 1 448.0 | 1 448.1 | 1 458.8 | 1 620.0 |
| 2018 | % | -6.9% | -6.9% | -6.9% | -7.0% | 20.7% | 20.7% | 20.7% | 20.9% |
| 2020 | % | -6.9% | -6.9% | -6.9% | -7.0% | 20.7% | 20.7% | 20.8% | 20.8% |
| 2030 | % | -6.6% | -6.6% | -6.7% | -6.7% | 19.8% | 19.8% | 20.0% | 20.0% |
| 2040 | % | -6.2% | -6.2% | -6.2% | -6.2% | 18.6% | 18.6% | 18.7% | 18.7% |

- Sensitivity analysis data for Sales Growth
  - Electricity consumption reduction and Overall consumer expenditure data for BC 1

**Table C - xxii: Data used for analysis of life cycle sensitivity to product Sales growth for BC1**

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -463.13 | -428.28 | -463.13 | -428.28 | 213.50 | 237.04 | 213.50 | 237.04 |
| 2020 | GWh/year | -929.7 | -894.9 | -929.7 | -820.0 | 470.5 | 494.1 | 470.5 | 536.7 |
| 2030 | GWh/year | -6 227.8 | -6 227.8 | -5 883.9 | -5 841.6 | 2 950.3 | 2 956.2 | 3 140.3 | 3 212.2 |
| 2040 | GWh/year | -16 378.1 | -16 378.1 | -15 808.8 | -15 738.8 | 7 324.8 | 7 324.8 | 7 619.3 | 7 655.6 |
| 2018 | % | -3.2% | -3.1% | -3.2% | -3.1% | 4.5% | 4.4% | 4.5% | 4.4% |
| 2020 | % | -6.1% | -6.1% | -6.1% | -5.9% | 8.7% | 8.6% | 8.7% | 8.4% |
| 2030 | % | -27.7% | -27.7% | -27.3% | -27.3% | 39.1% | 39.2% | 38.5% | 38.6% |
| 2040 | % | -51.1% | -51.1% | -50.5% | -50.5% | 72.4% | 72.4% | 71.6% | 71.5% |

Table C - xxiii: Data used for analysis of life cycle sensitivity to product Sales growth for BC 1

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -442.42 | -442.28 | -442.42 | -440.37 | 174.94 | 175.03 | 174.94 | 176.17 |
| 2020 | M€/year | -669.81 | -669.67 | -680.29 | -641.88 | 270.57 | 270.67 | 265.23 | 286.37 |
| 2030 | M€/year | -1 374.88 | -1 374.88 | -1 386.97 | -1 271.96 | 563.66 | 563.76 | 559.24 | 615.88 |
| 2040 | M€/year | -4 645.57 | -4 645.57 | -4 665.22 | -4 422.03 | 1 921.10 | 1 921.10 | 1 918.60 | 2 035.12 |
| 2018 | % | -13.4% | -13.3% | -13.4% | -13.3% | 18.9% | 18.9% | 18.9% | 18.9% |
| 2020 | % | -18.8% | -18.8% | -18.9% | -18.6% | 26.7% | 26.7% | 26.8% | 26.4% |
| 2030 | % | -27.5% | -27.5% | -27.6% | -26.8% | 38.9% | 38.9% | 39.1% | 37.9% |
| 2040 | % | -68.6% | -68.6% | -68.8% | -67.5% | 97.2% | 97.2% | 97.4% | 95.6% |

- Electricity consumption reduction and Overall consumer expenditure datafor BC 2

Table C - xxiv: Data used for analysis of life cycle sensitivity to product Sales growth for BC2

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -40.32 | -37.78 | -40.32 | -37.78 | 18.20 | 19.91 | 18.20 | 19.91 |
| 2020 | GWh/year | -81.4 | -78.9 | -81.4 | -73.4 | 40.0 | 41.7 | 40.0 | 44.8 |
| 2030 | GWh/year | -542.9 | -542.9 | -518.6 | -515.6 | 251.4 | 251.5 | 265.1 | 270.0 |
| 2040 | GWh/year | -1 422.2 | -1 422.2 | -1 381.7 | -1 376.6 | 628.0 | 628.0 | 648.7 | 651.3 |
| 2018 | % | -3.3% | -3.3% | -3.3% | -3.3% | 4.7% | 4.7% | 4.7% | 4.7% |
| 2020 | % | -6.4% | -6.4% | -6.4% | -6.2% | 9.1% | 9.0% | 9.1% | 8.8% |
| 2030 | % | -28.5% | -28.5% | -28.2% | -28.2% | 40.4% | 40.4% | 39.8% | 39.9% |
| 2040 | % | -52.3% | -52.3% | -51.8% | -51.7% | 74.0% | 74.0% | 73.3% | 73.2% |

Table C - xxv: Data used for analysis of life cycle sensitivity to product Sales growth for BC 2

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -9.19 | -9.00 | -9.19 | -9.11 | 3.27 | 3.40 | 3.27 | 3.34 |
| 2020 | M€/year | -14.15 | -13.97 | -14.30 | -13.61 | 6.51 | 6.63 | 6.43 | 6.84 |
| 2030 | M€/year | -63.06 | -63.06 | -61.57 | -60.85 | 27.61 | 27.62 | 28.52 | 29.19 |
| 2040 | M€/year | -144.86 | -144.86 | -142.30 | -141.11 | 63.12 | 63.12 | 64.53 | 65.12 |
| 2018 | % | -8.1% | -8.0% | -8.1% | -8.1% | 11.0% | 11.0% | 11.0% | 11.0% |
| 2020 | % | -11.5% | -12.2% | -11.6% | -11.9% | 16.8% | 16.7% | 16.9% | 16.6% |
| 2030 | % | -36.0% | -36.0% | -35.7% | -35.9% | 50.9% | 50.9% | 50.6% | 50.6% |
| 2040 | % | -59.2% | -59.2% | -59.0% | -58.9% | 83.9% | 83.9% | 83.4% | 83.2% |

- Electricity consumption reduction and Overall consumer expenditure data for BC 4

Table C - xxvi: Data used for analysis of life cycle sensitivity to product Sales growth for BC4

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -12.18 | -11.09 | -12.18 | -11.09 | 5.70 | 6.43 | 5.70 | 6.43 |
| 2020 | GWh/year | -24.226 | -23.138 | -24.226 | -20.816 | 12.669 | 13.404 | 12.669 | 14.727 |
| 2030 | GWh/year | -162.846 | -162.846 | -151.750 | -150.363 | 79.206 | 79.671 | 85.086 | 87.609 |
| 2040 | GWh/year | -430.401 | -430.401 | -412.333 | -410.074 | 195.507 | 195.507 | 205.072 | 206.268 |
| 2018 | % | -2.9% | -2.9% | -2.9% | -2.9% | 4.2% | 4.1% | 4.2% | 4.1% |
| 2020 | % | -5.6% | -5.6% | -5.6% | -5.4% | 8.0% | 7.9% | 8.0% | 7.7% |
| 2030 | % | -26.2% | -26.2% | -25.8% | -25.8% | 37.0% | 37.1% | 36.2% | 36.4% |
| 2040 | % | -49.1% | -49.1% | -48.5% | -48.4% | 69.6% | 69.6% | 68.6% | 68.5% |

Table C - xxvii: Data used for analysis of life cycle sensitivity to product Sales growth for BC 4

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -413.80 | -413.71 | -413.80 | -420.88 | -24.66 | -24.60 | -24.66 | -28.86 |
| 2020 | M€/year | -533.18 | -533.09 | -540.59 | -541.25 | 11.83 | 11.89 | 8.05 | 7.75 |
| 2030 | M€/year | -1 131.68 | -1 131.68 | -1 143.39 | -1 144.85 | 195.31 | 195.34 | 192.00 | 191.73 |
| 2040 | M€/year | -1 733.37 | -1 733.37 | -1 749.70 | -1 751.74 | 379.51 | 379.51 | 376.50 | 376.13 |
| 2018 | % | -74.6% | -74.5% | -74.6% | -75.1% | 70.6% | 70.6% | 70.6% | 71.1% |
| 2020 | % | -90.2% | -90.2% | -90.7% | -90.9% | 92.7% | 92.7% | 93.3% | 93.4% |
| 2030 | % | -145.7% | -145.7% | -146.7% | -146.8% | 171.4% | 171.4% | 172.5% | 172.7% |
| 2040 | % | -179.9% | -179.9% | -181.0% | -181.1% | 219.9% | 219.9% | 221.2% | 221.4% |

- Electricity consumption reduction and Overall consumer expenditure data for BC 5

Table C - xxviii: Data used for analysis of life cycle sensitivity to product Sales growth for BC5

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -131.55 | -109.71 | -131.55 | -109.71 | 67.40 | 82.15 | 67.40 | 82.15 |
| 2020 | GWh/year | -249.3 | -227.5 | -249.3 | -181.1 | 155.6 | 170.3 | 155.6 | 196.7 |
| 2030 | GWh/year | -1 746.8 | -1 746.8 | -1 538.6 | -1 513.0 | 946.2 | 946.9 | 1 063.8 | 1 105.4 |
| 2040 | GWh/year | -4 690.5 | -4 690.5 | -4 342.8 | -4 300.1 | 2 261.6 | 2 261.6 | 2 439.2 | 2 461.0 |
| 2018 | % | -3.3% | -3.2% | -3.3% | -3.2% | 4.7% | 4.5% | 4.7% | 4.5% |
| 2020 | % | -6.2% | -6.1% | -6.2% | -5.8% | 8.8% | 8.6% | 8.8% | 8.2% |
| 2030 | % | -28.1% | -28.1% | -27.4% | -27.3% | 39.8% | 39.8% | 38.5% | 38.7% |
| 2040 | % | -51.6% | -51.6% | -50.3% | -50.1% | 73.0% | 73.0% | 71.2% | 71.0% |

Table C - xxix: Data used for analysis of life cycle sensitivity to product Sales growth for BC 5

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -124.30 | -122.94 | -124.30 | -123.80 | 49.58 | 50.50 | 49.58 | 49.99 |
| 2020 | M€/year | -182.22 | -180.87 | -185.20 | -174.81 | 76.39 | 77.31 | 74.88 | 80.82 |
| 2030 | M€/year | -574.35 | -574.35 | -566.53 | -540.44 | 248.97 | 249.02 | 254.73 | 272.65 |
| 2040 | M€/year | -1 130.09 | -1 130.09 | -1 115.72 | -1 073.03 | 485.15 | 485.15 | 494.61 | 515.01 |
| 2018 | % | -16.4% | -16.5% | -16.4% | -16.5% | 23.3% | 23.3% | 23.3% | 23.3% |
| 2020 | % | -22.7% | -22.6% | -22.8% | -22.5% | 32.2% | 32.1% | 32.3% | 31.8% |
| 2030 | % | -51.1% | -51.1% | -51.0% | -50.5% | 72.3% | 72.4% | 72.2% | 71.4% |
| 2040 | % | -74.0% | -74.0% | -73.8% | -72.8% | 104.9% | 104.9% | 104.6% | 103.1% |

- Electricity consumption reduction and Overall consumer expenditure data for BC 6

Table C - xxx: Data used for analysis of life cycle sensitivity to product Sales growth for BC6

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -106.95 | -100.22 | -106.95 | -100.22 | 48.46 | 53.01 | 48.46 | 53.01 |
| 2020 | GWh/year | -216.4 | -209.6 | -216.4 | -195.2 | 106.0 | 110.6 | 106.0 | 118.8 |
| 2030 | GWh/year | -1 439.3 | -1 439.3 | -1 372.1 | -1 363.7 | 668.7 | 670.6 | 705.1 | 719.8 |
| 2040 | GWh/year | -3 775.0 | -3 775.0 | -3 664.7 | -3 650.8 | 1 670.5 | 1 670.5 | 1 728.2 | 1 735.4 |
| 2018 | % | -3.1% | -3.0% | -3.1% | -3.0% | 4.4% | 4.3% | 4.4% | 4.3% |
| 2020 | % | -5.9% | -5.9% | -5.9% | -5.8% | 8.4% | 8.3% | 8.4% | 8.2% |
| 2030 | % | -27.0% | -27.0% | -26.8% | -26.7% | 38.3% | 38.3% | 37.7% | 37.8% |
| 2040 | % | -50.3% | -50.3% | -49.9% | -49.8% | 71.3% | 71.3% | 70.6% | 70.5% |

**Table C - xxxi: Data used for analysis of life cycle sensitivity to product Sales growth for BC 6**

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -68.02 | -67.91 | -68.02 | -68.06 | 27.75 | 27.82 | 27.75 | 27.73 |
| 2020 | M€/year | -105.32 | -105.21 | -106.87 | -102.32 | 42.37 | 42.45 | 41.58 | 44.10 |
| 2030 | M€/year | -371.43 | -371.43 | -372.87 | -355.65 | 153.47 | 153.50 | 153.32 | 163.86 |
| 2040 | M€/year | -775.33 | -775.33 | -777.08 | -749.34 | 322.20 | 322.20 | 322.44 | 335.92 |
| 2018 | % | -11.8% | -11.7% | -11.8% | -11.8% | 16.6% | 16.6% | 16.6% | 16.6% |
| 2020 | % | -16.8% | -16.8% | -16.9% | -16.6% | 23.8% | 23.8% | 23.9% | 23.6% |
| 2030 | % | -42.4% | -42.4% | -42.5% | -42.1% | 60.1% | 60.1% | 60.2% | 59.4% |
| 2040 | % | -65.4% | -65.4% | -65.5% | -64.7% | 92.6% | 92.6% | 92.8% | 91.6% |

- Electricity consumption reduction and Overall consumer expenditure data for BC 7A

**Table C - xxxii: Data used for analysis of life cycle sensitivity to product Sales growth for BC7A**

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -108.67 | -105.30 | -108.67 | -105.30 | 47.14 | 49.41 | 47.14 | 49.41 |
| 2020 | GWh/year | -224.0 | -220.7 | -224.0 | -213.5 | 101.2 | 103.5 | 101.2 | 107.5 |
| 2030 | GWh/year | -1 448.9 | -1 445.6 | -1 402.0 | -1 385.6 | 647.2 | 649.5 | 665.4 | 674.0 |
| 2040 | GWh/year | -3 766.9 | -3 766.9 | -3 653.0 | -3 638.8 | 1 652.8 | 1 655.1 | 1 689.2 | 1 700.1 |
| 2018 | % | -0.7% | -0.7% | -0.7% | -0.7% | 1.0% | 1.0% | 1.0% | 1.0% |
| 2020 | % | -1.4% | -1.4% | -1.4% | -1.4% | 2.0% | 2.0% | 2.0% | 2.0% |
| 2030 | % | -8.3% | -8.3% | -8.2% | -8.2% | 11.8% | 11.8% | 11.7% | 11.6% |
| 2040 | % | -19.3% | -19.3% | -19.0% | -19.0% | 27.3% | 27.3% | 26.9% | 26.9% |

Table C - xxxiii: Data used for analysis of life cycle sensitivity to product Sales growth for BC 7A

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -20.77 | -20.64 | -20.77 | -22.95 | 8.66 | 8.74 | 8.66 | 7.38 |
| 2020 | M€/year | -33.15 | -33.02 | -33.73 | -39.05 | 13.10 | 13.18 | 12.80 | 9.91 |
| 2030 | M€/year | -122.53 | -122.41 | -121.79 | -154.96 | 51.31 | 51.39 | 51.68 | 38.56 |
| 2040 | M€/year | -262.90 | -262.90 | -260.09 | -329.09 | 111.51 | 111.60 | 112.56 | 89.22 |
| 2018 | % | -2.7% | -2.6% | -2.7% | -2.7% | 3.8% | 3.8% | 3.8% | 3.9% |
| 2020 | % | -4.2% | -4.2% | -4.1% | -4.4% | 5.8% | 5.8% | 5.9% | 6.2% |
| 2030 | % | -13.8% | -13.8% | -13.9% | -15.5% | 19.6% | 19.6% | 19.6% | 21.8% |
| 2040 | % | -26.5% | -26.5% | -26.3% | -29.4% | 37.5% | 37.5% | 37.3% | 41.9% |

- Electricity consumption reduction and Overall consumer expenditure data for All BCs

Table C - xxxiv: Data used for analysis of life cycle sensitivity to product Sales growth for All BCs

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -862.79 | -792.37 | -862.79 | -792.37 | 400.39 | 447.95 | 400.39 | 447.95 |
| 2020 | GWh/year | -1 725.0 | -1 654.6 | -1 725.0 | -1 504.0 | 885.9 | 933.5 | 885.9 | 1 019.3 |
| 2030 | GWh/year | -11 568.6 | -11 565.2 | -10 867.0 | -10 769.7 | 5 542.9 | 5 554.3 | 5 924.7 | 6 069.1 |
| 2040 | GWh/year | -30 463.1 | -30 463.1 | -29 263.4 | -29 115.1 | 13 733.2 | 13 735.5 | 14 329.6 | 14 409.7 |
| 2018 | % | -2.2% | -2.2% | -2.2% | -2.2% | 3.1% | 3.1% | 3.1% | 3.1% |
| 2020 | % | -4.3% | -4.3% | -4.3% | -4.2% | 6.1% | 6.1% | 6.1% | 5.9% |
| 2030 | % | -21.6% | -21.6% | -21.3% | -21.2% | 30.5% | 30.5% | 29.9% | 30.0% |
| 2040 | % | -42.5% | -42.5% | -41.9% | -41.9% | 60.2% | 60.2% | 59.4% | 59.3% |

Table C - xxxv: Data used for analysis of life cycle sensitivity to product Sales growth for BC 7A

| Years | Units | Pragmatic Upper | | | | Pragmatic Lower | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | -1 078.50 | -1 076.49 | -1 078.50 | -1 085.17 | 239.54 | 240.89 | 239.54 | 235.75 |
| 2020 | M€/year | -1 537.8 | -1 535.8 | -1 561.0 | -1 512.9 | 420.8 | 422.1 | 409.0 | 435.8 |
| 2030 | M€/year | -4 536.7 | -4 536.6 | -4 554.3 | -4 394.8 | 1 612.3 | 1 612.6 | 1 612.4 | 1 720.2 |
| 2040 | M€/year | -8 692.1 | -8 692.1 | -8 710.1 | -8 466.3 | 3 282.6 | 3 282.7 | 3 289.2 | 3 416.5 |
| 2018 | % | -17.7% | -17.7% | -17.7% | -17.7% | 21.8% | 21.8% | 21.8% | 21.9% |
| 2020 | % | -23.7% | -23.7% | -23.8% | -23.6% | 30.4% | 30.3% | 30.5% | 30.2% |
| 2030 | % | -51.3% | -51.3% | -51.5% | -51.1% | 69.6% | 69.6% | 69.8% | 69.3% |
| 2040 | % | -74.4% | -74.4% | -74.5% | -73.8% | 102.4% | 102.4% | 102.6% | 101.6% |

- Sensitivity analysis data for Maintenance & Repair (M & R) costs
    - Overall consumer expenditure reduction

Table C - xxxvi: Data used for analysis of life cycle sensitivity to M & R costs for BC 1

| Years | Units | Pragmatic Upper | | | |
|---|---|---|---|---|---|
| | | Upper Scenario 1 | Upper Scenario 2 | Upper Scenario 3 | Upper Scenario 4 |
| 2018 | M€/year | -1 424.19 | -1 425.97 | -1 424.19 | -1 417.82 |
| 2020 | M€/year | -1 539.36 | -1 541.14 | -1 547.91 | -1 500.85 |
| 2030 | M€/year | -2 219.31 | -2 219.31 | -2 246.74 | -2 024.96 |
| 2040 | M€/year | -3 059.66 | -3 059.66 | -3 096.20 | -2 790.13 |
| 2018 | % | -43.4% | -43.5% | -43.4% | -43.2% |
| 2020 | % | -43.5% | -43.6% | -43.6% | -43.0% |
| 2030 | % | -44.4% | -44.4% | -44.8% | -42.6% |
| 2040 | % | -45.1% | -45.1% | -45.6% | -43.3% |

**Table C - xxxvii: Data used for analysis of life cycle sensitivity to M & R costs for BC 2**

| Years | Units | Pragmatic Upper | | | |
|---|---|---|---|---|---|
| | | Upper Scenario 1 | Upper Scenario 2 | Upper Scenario 3 | Upper Scenario 4 |
| 2018 | M€/year | -6.93 | -6.80 | -6.93 | -6.85 |
| 2020 | M€/year | -6.66 | -6.53 | -6.77 | -6.21 |
| 2030 | M€/year | -9.39 | -9.39 | -8.25 | -7.33 |
| 2040 | M€/year | -12.39 | -12.39 | -10.76 | -9.48 |
| 2018 | % | -6.1% | -6.0% | -6.1% | -6.1% |
| 2020 | % | -5.4% | -6.1% | -5.5% | -5.9% |
| 2030 | % | -5.8% | -5.8% | -5.8% | -5.8% |
| 2040 | % | -5.8% | -5.8% | -6.0% | -5.8% |

**Table C - xxxviii: Data used for analysis of life cycle sensitivity to M & R costs for BC 4**

| Years | Units | Pragmatic Upper | | | |
|---|---|---|---|---|---|
| | | Upper Scenario 1 | Upper Scenario 2 | Upper Scenario 3 | Upper Scenario 4 |
| 2018 | M€/year | -2.95 | -2.88 | -2.95 | -6.97 |
| 2020 | M€/year | -3.12 | -3.06 | -7.00 | -7.29 |
| 2030 | M€/year | -3.74 | -3.74 | -8.14 | -8.67 |
| 2040 | M€/year | -4.82 | -4.82 | -10.17 | -10.84 |
| 2018 | % | 0.0% | 0.0% | 0.0% | 0.0% |
| 2020 | % | 0.0% | 0.0% | 0.0% | 0.0% |
| 2030 | % | 0.0% | 0.0% | 0.0% | 0.0% |
| 2040 | % | 0.0% | 0.0% | 0.0% | 0.0% |

**Table C - xxxix: Data used for analysis of life cycle sensitivity to M & R costs for BC 5**

| Years | Units | Pragmatic Upper | | | |
|---|---|---|---|---|---|
| | | Upper Scenario 1 | Upper Scenario 2 | Upper Scenario 3 | Upper Scenario 4 |

| Years | Units | Pragmatic Upper | | | |
|---|---|---|---|---|---|
| | | Upper Scenario 1 | Upper Scenario 2 | Upper Scenario 3 | Upper Scenario 4 |
| 2018 | M€/year | -183.76 | -182.95 | -183.76 | -182.36 |
| 2020 | M€/year | -197.33 | -196.52 | -199.49 | -188.53 |
| 2030 | M€/year | -281.24 | -281.24 | -276.46 | -239.02 |
| 2040 | M€/year | -390.04 | -390.04 | -382.82 | -330.74 |
| 2018 | % | -24.4% | -24.6% | -24.4% | -24.3% |
| 2020 | % | -24.5% | -24.6% | -24.6% | -24.2% |
| 2030 | % | -25.3% | -25.3% | -25.5% | -24.0% |
| 2040 | % | -26.0% | -26.0% | -26.2% | -24.6% |

Table C - xl: Data used for analysis of life cycle sensitivity to M & R costs for BC 6

| Years | Units | Pragmatic Upper | | | |
|---|---|---|---|---|---|
| | | Upper Scenario 1 | Upper Scenario 2 | Upper Scenario 3 | Upper Scenario 4 |
| 2018 | M€/year | -222.60 | -222.79 | -222.60 | -222.20 |
| 2020 | M€/year | -240.78 | -240.97 | -242.04 | -236.78 |
| 2030 | M€/year | -343.31 | -343.31 | -346.77 | -321.36 |
| 2040 | M€/year | -470.03 | -470.03 | -474.59 | -439.72 |
| 2018 | % | -38.5% | -38.5% | -38.5% | -38.4% |
| 2020 | % | -38.6% | -38.6% | -38.7% | -38.3% |
| 2030 | % | -39.2% | -39.2% | -39.6% | -38.1% |
| 2040 | % | -39.7% | -39.7% | -40.0% | -38.5% |

Table C - xli: Data used for analysis of life cycle sensitivity to product price for BC 7A

| Years | Units | Pragmatic Upper | | | |
|---|---|---|---|---|---|
| | | Upper Scenario 1 | Upper Scenario 2 | Upper Scenario 3 | Upper Scenario 4 |
| 2018 | M€/year | -81.91 | -81.82 | -81.91 | -84.72 |

| Years | Units | Pragmatic Upper | | | |
|---|---|---|---|---|---|
| | | Upper Scenario 1 | Upper Scenario 2 | Upper Scenario 3 | Upper Scenario 4 |
| 2020 | M€/year | -83.99 | -83.90 | -84.38 | -91.87 |
| 2030 | M€/year | -92.58 | -92.50 | -92.25 | -130.67 |
| 2040 | M€/year | -102.84 | -102.76 | -101.55 | -179.18 |
| 2018 | % | -10.5% | -10.5% | -10.5% | -10.6% |
| 2020 | % | -10.6% | -10.6% | -10.5% | -11.1% |
| 2030 | % | -10.4% | -10.4% | -10.5% | -12.7% |
| 2040 | % | -10.5% | -10.5% | -10.5% | -14.4% |

**Table C - xlii: Data used for analysis of life cycle sensitivity to product price for All BCs**

| Years | Units | Pragmatic Upper | | | |
|---|---|---|---|---|---|
| | | Upper Scenario 1 | Upper Scenario 2 | Upper Scenario 3 | Upper Scenario 4 |
| 2018 | M€/year | -1 922.34 | -1 923.22 | -1 922.34 | -1 920.92 |
| 2020 | M€/year | -2 071.2 | -2 072.1 | -2 087.6 | -2 031.5 |
| 2030 | M€/year | -2 949.6 | -2 949.5 | -2 978.6 | -2 732.0 |
| 2040 | M€/year | -4 039.8 | -4 039.7 | -4 076.1 | -3 760.1 |
| 2018 | % | -31.7% | -31.7% | -31.7% | -31.6% |
| 2020 | % | -31.9% | -32.0% | -32.0% | -31.7% |
| 2030 | % | -33.4% | -33.4% | -33.7% | -32.3% |
| 2040 | % | -34.6% | -34.6% | -34.9% | -33.5% |

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