European Commission

Ecodesign Pump Review

Study of Commission Regulation (EU) No. 547/2012 (Ecodesign requirements for water pumps)

Extended report (final version)

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Energy

Van Holsteijn en Kemna B.V. (VHK)
Rotterdamseweg 386 B-18
2629 HG Delft
The Netherlands
www.vhk.nl

Viegand Maagøe A/S (VM)
Nr. Farimagsgade 37
1364 Copenhagen K
Denmark
viegandmaagoe.dk

Prepared by:

Viegand Maagøe and Van Holsteijn en Kemna B.V.
Study team:
Larisa Maya-Drysdale, Ulrik Vølcker Andersen, Baijia Huang, Annette Gydesen and Jan Viegand (Viegand Maagøe)
Roy van den Boorn, Sanne Aarts, Leo Wierda and René Kemna (Van Holsteijn en Kemna)

Prepared for:

European Commission
DG ENER C.3
Office: DM24 4/149
B-1049 Brussels, Belgium

Contact person: Mr. Ronald Piers de Raveschoot
Email: ronald.piers-de-raveschoot@ec.europa.eu

Project website: www.ecopumpreview.eu

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Executive Summary

The current Regulation 547/2012 establishes ecodesign requirements for 'water pumps', defined in the regulation, Article 2 (1) as "the hydraulic part of a device that moves clean water by physical or mechanical action and that fits one of the following designs":

- End suction own bearing (ESOB)[1],
- End suction close coupled (ESCC)[2],
- End suction close coupled inline (ESCCi)[3],
- Vertical multistage (MS-V)[4],
- Submersible multistage (MSS)[5].

The ecodesign requirements are established based on the water pump's characteristics in terms of nominal speed, impeller size and mechanical shape and flow and hydraulic energy performance. Taking these aspects into account, a minimum efficiency requirement (Minimum Efficiency Index, MEI) is established for the five water pump designs in scope with several tiers, where the last tier is already in place[6] (MEI[7] = 0.4).

In March 2012, the Commission services launched two preparatory studies on pumps not covered by Regulation 547/2012: waste water pumps (Lot 28) and on pumps for private and public swimming pools, ponds, fountains and aquariums and clean water pumps larger than those regulated in Regulation 547/2012 (Lot 29).

Using the opportunity from the mandatory review (aiming at adopting an Extended Product Approach (EPA)), the Commission services proposed - and stakeholders largely concurred - to integrate the preparation of regulatory proposals deriving from the preparatory studies in the review of the existing Regulation 547/2012. This would give time to correctly develop an EPA not only for pumps in scope of the current regulation, but also for those in the preparatory studies (lot 28 and 29) allowing for bigger savings. Furthermore, it would reduce the administrative burden for manufacturers and market surveillance authorities by integrating these pumps into one regulation, rather than having to comply with and verify compliance with requirements in three separate regulations.

Adopting an EPA would mean to set requirements including the motor and any existing control unit to the calculation of energy efficiency (i.e. EEI of a 'pump unit'), while the current regulation 547/2012 sets requirements for the water pumps only (i.e. the 'bare shaft pump').

In current regulation 547/2012, the efficiency is calculated as the Minimum Efficiency

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[1] End suction water pumps mean single stage end suction rotodynamic water pump designed for pressures up to 16 bar, with a specific speed ns between 6 and 80 rpm, a minimum rated flow of 6 m^3/h ($1.667 \cdot 10^{-3}$ m^3/s) with a maximum shaft power of 150 kW, a maximum head of 90 m at nominal speed of 1 450 rpm and a maximum head of 140 m at nominal speed of 2 900 rpm.

[2] Ibid.

[3] Ibid.

[4] Means a glanded multi stage (i > 1) rotodynamic water pump in which the impellers are assembled on a vertical rotating shaft, which is designed for pressures up to 25 bar, with a nominal speed of 2 900 rpm and a maximum flow of 100 m^3 /h ($27.78 \cdot 10^{-3}$ m^3/s).

[5] Means a multi stage (i > 1) rotodynamic water pump with a nominal outer diameter of 4″ (10.16 cm) or 6″ (15.24 cm) designed to be operated in a borehole at nominal speed of 2 900 rpm, at operating temperatures within a range of0 °C and 90 °C.

[6] Ecodesign requirements shall apply from 1 January 2015.

[7] Minimum Efficiency Index (MEI), derived from the pump's best hydraulic efficiency point close to nominal loads

The Extended Product Approach (EPA) methodology for pump units includes components that are typically used together with the bare shaft pump (i.e. motor and VSD) for calculating the pump unit's energy efficiency. The dedicated metric is called the Energy Efficiency Index (EEI), derived from the total efficiency of the pump unit at different loads. The EEI is used for establishment of minimum efficiency requirements for the extended product.

The System Approach focuses on optimising the energy consumption of the pump unit in the actual flow system it is intended to operate (variable or constant flow), and in this way only use the electrical energy necessary to operate in the desired flow profile.

The aim of this review study was thus to propose a new regulatory measure replacing 547/2012 and incorporating if possible an EPA and previous preparatory studies Lot 28 and Lot 29 under the same umbrella of requirements based on analysis of an extension of the scope and analysis of requirements. This included an in-depth analysis of the consequences of EPA for market surveillance.

Scope

The starting point of this review is the '**initial**' scope, which includes the five pump categories defined in the current regulation, eight pump categories from preparatory study Lot 28 and eleven pump categories from preparatory study Lot 29, totalling twenty-four clean water, waste water, solids handling, spa, fountain and swimming pool pumps.

Two screening steps have been performed to define the final proposed scope with only pumps that present important levels of energy consumption and saving potentials, meaning those which show a contribution of more than 0.5% of all the pumps' annual energy consumption and which also present important savings at EPA level. The first screening was based on data from previous preparatory studies (Lot 11, Lot 28 and Lot 29), whose outcome was a preliminary scope used to collect data from industry. The second screening was done using industry data on different operational parameters as well as market data. The outcome of the second screening was the final scope, which was used to calculate the life cycle environmental impacts, life cycle costs, identify designs for improvement and carry out the scenario analysis.

For pumps in the final scope of this review study it has been found that the potential savings when applying EPA are far bigger than those at product level: Estimated savings at product level are about 5 TWh/year based on estimations from data received from industry (see chapter 9, Table 31), while savings when applying EPA are at least 43 TWh/year in 2030. It has also been found that only twelve pump categories out of the twenty-four in the initial scope of the review study account for 95% of the total annual energy consumption. Furthermore, that these twelve pumps represent also the biggest saving potential when applying EPA, i.e. they account for about 90% of the total EPA savings potential of the twenty-four pumps included in the review in the first place.

The final scope of the study has been defined by including these twelve bare shaft pump types, which have been further investigated in the course of this review study and are:

- *End suction own bearing (ESOB) clean water pumps with a maximum shaft power of 150kW*
- *End suction closed coupled (ESCC) clean water pumps with a maximum shaft power of 150 kW*

- *End suction closed coupled in line (ESCCi) clean water pumps with a maximum shaft power of 150 kW*
- *Vertical Multistage (MS-V) clean water pumps designed for pressures up to 25 bar*
- *Vertical Multistage (MS-V) clean water pumps designed for pressures between 25 and 40 bar*
- *Horizontal Multistage (MS-H) clean water pumps designed for pressures up to 25 bar*
- *Horizontal Multistage (MS-H) clean water pumps designed for pressures between 25 and 40 bar*
- *Submersible borehole multistage (MSSB) clean water pumps with a nominal outer diameter of up to 6" (15.24 cm)*
- *Booster-sets for clean water with a maximum shaft power of 150 kW*
- *Swimming pool pumps (SWP) with a maximum shaft power of 2.2 kW*
- *Submersible vortex radial (SVR) pumps for waste water with a maximum shaft power of 160 kW*
- *Submersible channel radial (SCR) pumps for waste water with a maximum shaft power of 160 kW*

The investigation of future policy measures for the above mentioned twelve pumps has been done by extending the scope from the pumps themselves (product level) to the pump units (extended product level as explained in previous page). Furthermore, two different set of requirements have been considered separately, one for constant flow applications and one for variable flow application. This has been done because the potential savings of the whole extended product has been the focus of this study and that pumps in constant flow applications have different hydraulic behaviour (i.e. different flow time profile) than pumps used in variable flow applications.

Energy consumption of water pump units

Based on the investigations of the market and data provided from industry for constant and variable flow applications, the **total annual energy consumption** of all pumps in final scope of the study is **225 TWh/year in 2015**. Of this 166 TWh/year is from pumps covered by the current regulation, and 59 TWh/year is from pumps not covered by the regulation. This means that the majority of the energy consumption (73.8%) is from pumps currently in scope of the regulation.

If **no action** is **taken**, meaning that the current regulation is not revised, the predicted total annual energy consumption will be **253 TWh/year in 2025** and **261 TWh/year in 2030**.

Policy options and potential energy savings of water pump units

The potential energy savings from applying new energy efficiency requirements have been calculated using the Extended Product Approach methodology. However, it goes a bit further into the System Approach by setting different EEI-requirements depending on the flow profile of the system in which the pump units are intended to operate. For pump units operating in variable flow applications, it has been assumed that a transition would occur so by 2021, all pump units will have to be installed with Variable Speed Drives. This would reduce the energy consumption of water pump units, since the motor would only operate at the required speed to deliver the reduced/increased flow and pressure.

To assure this happens, it should be possible for Market Surveillance Authorities to verify that the pump is actually installed with a VSD. The possibility to do that was investigated by consulting with Member State representatives and Market Surveillance Authorities. The results of this analysis show that, within the current framework of the Ecodesign Directive, the Market Surveillance Authorities cannot perform this verification.

On this background two alternative proposals have been developed, which are expected to achieve only a fraction of the initially calculated potential energy savings. The original proposal is called Policy Option 1 (PO1), which brings the largest savings but requires verification at installation, for when the product is put into service. The two alternatives are called Policy Option 2 and 3 (PO2 and PO3). PO2 and PO3 propose ecodesign requirements for when the product is placed on the market. They do not deliver the full savings potential since the verification of the pump units that operate in variable flow systems is not performed, which would ensure they are installed with VSDs.

The three policy options, the proposed requirements and implementation dates are presented in Table 1.

Table 1. Proposed policy options for water pump units.

Policy Option (PO)	Requirements	Applicability of requirements	Implementation dates and EEI ambition levels[8]
BAU - Business As Usual	No proposed requirements		Not relevant
PO1 – MEI and EEI requirements with enforcement when placed on the market and put into service	1. Minimum Efficiency Index (MEI) for all bare shaft pump types as in current regulation 547/2012. 2. Energy Efficiency Index (EEI) and energy efficiency[9] requirements for use of the bare shaft pumps and the pump units in variable and constant flow systems (EEiv and EEIc) with EEIv being more stringent than EEIc. 3. Information requirements on rating plate and in manuals and websites. 4. Information requirement making it mandatory for installer to declare the pump unit's intended use.	1. When bare shaft pumps are placed on the market as such or as part of a pump unit. 2. When placed on the market or put into service. 3. When placed on the market or put into service. 4. When put into service.	• ECO1: Less ambitious EEI levels. 2020 for pump units with an EPA calculation and testing methodology in place and 2021 for pump units without an EPA methodology[10]. • ECO2: More severe EEI levels with two Tiers. Tier 1 in 2020/2021 and same levels as ECO1. Tier 2 in 2023/2024 with more stringent levels. • ECO3: More stringent levels as in Tier 2 of ECO2 are introduced already in 2020/2021.
PO2 – EEI requirements with enforcement when placed on the market	1. Energy Efficiency Index (EEI) and energy efficiency[9] requirements for use of the bare shaft pumps and the pump units in variable and constant flow systems (EEiv and EEIc) with EEIv being more stringent than EEIc. 2. Information requirements on rating plate and in manuals and websites.	1. When bare shaft pumps and pump units are placed on the market. 2. When placed on the market.	• ECO1: Same as ECO1 in PO1. • ECO2: Same as ECO2 in PO1 • ECO3: Same as ECO3 in PO1.

[8] "ECO" scenarios refer to scenarios with different EEI ambition levels at different implementation dates.
[9] Energy efficiency requirements have been developed for pump types where a draft methodology for calculating EEI has not been finalised yet at the time of this study (i.e. multi-stage pumps)
[10] For some pump unit types, an EPA methodology has not yet been been finalised (e.g. multi-stage pump units) or has not been started (e.g. swimming pool pumps and wastewater pumps).

Policy Option (PO)	Requirements	Applicability of requirements	Implementation dates and EEI ambition levels[8]
PO3 – MEI requirements with EEI as information requirement and enforcement when placed on the market	1. Minimum Efficiency Index (MEI) level for all bare shaft pump types as in current regulation 547/2012. 2. Information requirements by manufacturers of bare shaft pumps and pump units on Energy Efficiency Index (EEI) levels, regardless of the intended use (i.e. both in constant and in variable flow systems). 3. Information requirements on rating plate and in manuals and websites.	1. When bare shaft pumps are placed on the market as such or as part of a pump unit. 2. When placed on the market. 3. When placed on the market.	From 2020

The estimated potential energy savings for the different policy options are presented in Table 2. PO2 and PO3 are expected to deliver only a fraction of the PO1 savings because there is no verification that VSDs are installed with pump units operating in variable flow systems. In the case of PO3, the savings are expected to be smaller than those achieved by PO2, because PO3 does not propose minimum efficiency levels for EEI but only information requirements. The exact potential savings are not known at this stage but they will be investigated once these policy options are further evaluated in a future Impact Assessment.

Table 2. Potential energy savings from proposed policy options.

Policy Option (PO)	Potential energy savings for pump units with pump types in current scope of Regulation 547/2012	Potential energy savings for extended scope compared to regulation 547/2012
PO1	• ECO1: 23.2 TWh/year in 2025 and 36.9 TWh/year in 2030 • ECO2: 24.3 TWh/year in 2025 and 39.6 TWh/year in 2030 • ECO3: 25.2 TWh/year in 2025 and 40 TWh/year in 2030	• ECO1: 27.3 TWh/year in 2025 and 42.8 TWh/year in 2030 • ECO2: 29.3 TWh/year in 2025 and 47.3 TWh/year in 2030 • ECO3: 30.6 TWh/year in 2025 and 48 TWh/year in 2030
PO2	Expected to be only a fraction of the savings identified in PO1	
PO3	Expected to be a smaller fraction of the savings identified in PO1	

Table 2 shows that the majority of the savings from PO1 would come from implementing EPA policy measures to pump categories currently in scope of Regulation 547/2012. These account for more than 80% of the total potential savings at EPA level by 2030:

- Eco-scenario 1: 36.9 TWh/year (pumps in current regulation) out of 42.8 TWh/year (pumps in final scope).
- Eco-scenario 2: 39.6 TWh/year (pumps in current regulation) out of 47.3 TWh/year (pumps in final scope).
- Eco-scenario 3: 40 TWh/year (pumps in current regulation) out of 48 TWh/year (pumps in final scope).

Furthermore, it has been found that multistage clean water pumps currently not in scope would contribute with around 11% of the total potential energy savings by 2030, considering any of the three defined policy measures. This means that pumps currently in Regulation 547/2012 plus multistage clean water pumps currently not in scope, represent more than 90% of the total potential savings identified from PO1. PO1 requires that market surveillance is carried out at the putting into service and that it is possible to check wether the pump is installed correctly i.e. in a variable or constant flow system, and with our without a VSD.

PO2 and PO3 have been developed because most of the Market Surveillance Authorities the study team had a dialogue with, concluded that it is very difficult to perform market surveillance at the putting into service and to place the responsibility for ensuring compliance of the assembled pump unit on the installer. This is because MSAs felt that it is not practicable/efficient for market surveillance that compliance becomes installation-dependent (indeed compliance of each pump unit would depend on the specificities of each installation i.e. whether the installation is in constant or variable flow). In addition, according to the Ecodesign Directive verification should be carried out either directly on the product or on the basis of the technical documentation[11]. Some MSAs also mentioned that they don't have the legal powers to make such verifications in individual sites. An other issue mentioned by MSAs is of knowing where and when pumps are installed: MSAs would not know where to look for the newly installed pumps.

It is therefore considerd not practicable/feasible that verification of compliance requires controlling on site whether the pump unit is installed in a variable or in a constant flow system.

PO2 and PO3 address this, and include information requirements to be provided by bare shaft pumps and pump units manufacturers with the view of 'educating' market actors (engineers, installers and users) on the most efficient way to install pump units for variable flow applications in order to secure savings. These requirements are combined with EEI requirements, either as minimum levels or as information provided by manufacturers. This will start educating manufacturers on the use of this metric, and will bring larger savings than those identified by the use of MEI only.

The study team belives that some inconsistencies and ambiguities in the Ecodesign Directive concerning implementing measures for ErPs present a barrier for potential ecodesign requirements of extended products. Should a revision of the Ecodesign Directive take place in the future, several recommendations have been proposed that can be found in section 13.3.

Recommendations

Concerning scope, it is recommended to keep all bare shaft pump types currently in scope of Regulation 547/2012 and additionally integrating multistage clean water pumps currently not in the regulation. Pumps currently in scope bring more than 80% of the potential savings with the most ambitious policy option by 2030, while multistage clean water pumps currently not in scope deliver altogether about 11% of the total savings. However, this is provided that an EPA methodology for measuring and calculating their performance under this approach is completed before the implementation date[12].

It is recommended to integrate Extended Product Approach (EPA) in the revised version of Regulation 547/2012, either as minimum efficiency levels for the pump units (i.e. EEI) or as information requirement. By applying the EPA to pumps in the current regulation and to multistage clean water pumps currently not in the regulation, about 41.61 TWh/year of additional savings would be brought in 2030 (97% of the total potential savings calculated in this study).

Three policy options, PO1, PO2 and PO3, have been presented varying in level of ambition concerning energy efficiency requirements and with different enforcement needs.

PO1 presents three levels of ambition concerning requirement levels and implementation dates (i.e. ECO1, ECO2 and ECO3). Between 8 to 10% additional energy savings were identified from implementing more ambitious EEI levels as potential requirements (i.e. up

[11] Ecodesign Directive 2009/125/EC Article 15 point 7.

[12] Currently, status of standardisation activities is: A draft standard "Pumps — Rotodynamic Pumps - Energy Efficiency Index - Methods of qualification and verification — Part 2 - Testing and calculation of energy efficiency index (EEI) of single pump units" has been developed. This draft standard includes the methodology for the pump categories ESOB, ESCC, ESCCi with both 2-pole and 4-pole motors, and MS-V and MS-H with 2-pole motors. A draft standard also exists for booster-sets "Pumps — Rotodynamic Pumps - Energy Efficiency Index - Methods of qualification and verification — Part 3 - Testing and calculation of energy efficiency index (EEI) of booster sets". There is no date yet to when the standards will be adopted, since it depends partially on the outcomes of this review study.

to 5.2 TWh/year more savings in 2030 from implementing ECO3 compared to ECO1). Due to this relatively small difference, ECO1 appears the most viable so sufficient time is given to adopt EPA calculation methods, both developed and under development, in a revised version of the current regulation.
However, although Policy Option 1 (PO1) brings the largest savings, it is recommended to investigate further the degree to which these savings can be achieved by PO2 and PO3 through a quantitative analysis. In principle, PO2 and PO3 will educate the dealers, installers and users about the importance of installing the pumps with continuous control in variable flow systems, and thereby a large share of the savings potential identified in PO1 could be materialised. Since PO2 proposes EEI levels as potential ecodesign requirements, it is expected that it will achieve a larger share than PO3 of the full saving potential identified in PO1. If this is the case, PO2 could be the recommended policy option for a review of current regulation.

Concerning Market Surveillance, problems with nomenclature and identification of pumps during the market surveillance process were identified along the course of this review study. To solve this, it is recommended to substitute part of the existing product information requirement in Annex II, 2(5) of the regulation. Instead of requiring the 'product type and size identification' to be durably marked on or near the rating plate, the study team proposes to require the marking of an index/coding of the relevant pump category, being these codings defined in the Regulation 547/2012, together with the size identification (rated power and nominal speed). Additionally, it is recommended that the description of this index/coding is stated in the technical documentation and in freely accessible websites provided by the manufacturers.

Furthermore, to facilitate the identification of the pumps by market surveillance authorities who determine whether the pumps are in scope or not, it is recommended to add a product information requirement in Annex, 2, where the manufacturers specify in the technical documentation and in freely accessible websites whether the pump is in scope. If the pump is very similar to the pumps' definitions stated in the regulation but is not in scope due to an exemption, the manufacturers' shall provide a technical justification for the exemption stating clearly that the pump's intended use is not to pump clean water. If this is not stated, it will be assumed that the pump is in scope and therefore not complying with the marking requirement.

When clean water pumps are sold with a nominal speed other than what is specified in the regulation, it is recommended that the pumps are tested in their own nominal speed and use C-values corresponding the closest to those defined in the regulation (1450 min^{-1} and 2900 min^{-1}). Furthermore, with pumps where more than one pump category is applicable, the type of pump casing should determine which C-value has to be taken. Finally, it is recommended to update the definitions in the standard, both for the pumps currently in scope and those suggested to include herein. It is also recommended to include a definition of self-priming pumps to avoid any potential loophole.

Overall, Extended Product Approach (EPA) brings significant potential energy savings, and it is therefore recommended to implement policy measures that bring this approach into place in the next version of the current Regulation 547/2012, since they show significantly more savings than looking only at the product level, considering also that enforceability must be ensured.

Table of contents

List of Tables

List of Figures

1. Introduction

1.1 Scope of the report

This is the draft final report of the Review study of Commission Regulation (EU) No 547/2012 incorporating the preparatory studies on 'Lot 28' and 'Lot 29'. This draft final report follows the MEErP methodology and includes the following tasks according to the Proposal for Services:

- **Task A**: which gives an overview of the impact during the implementation of the current legislation (547/2012) since it entered into force (January 2013).
- **Task B**: which reviews previous preparatory studies before and after the current regulation (Lot 11, Lot 28 and Lot 29); any needs for extending the scope; existing measures and legislations in and outside the European Union (incl. a summary of standardisation bodies' work) and their synergies with existing Regulation (547/2012) and the accuracy, reliability and reproducibility of tests and calculation methods, which could be potentially used for the extended scope.
- **Task C**: which assesses possible inclusion of the Extended Product Approach (EPA) in the regulation, including description of the scope of current EPA standardisation work and its assessment of efficiencies found in the market place.
- **Task D1**: which defines a preliminary scope based on previous reviews, including the merit of extending current scope, together with the definition of water pump categories, system boundaries, any potential loophole and their energy consumption and savings potentials at EU level.
- **Task D2**: which places the water pump product group within the total of EU industry trade and policy and which provides market and costs inputs, insight in the latest market trends and a dataset of prices and rates to be used in the Life Cycle Cost analysis.
- **Task D3**: which quantifies relevant user parameters from the use of the pumps in their lifetimes that are different from those quantified by tests and calculation methods defined in Task B and that influence the pumps' environmental impact.
- **Task D4**: which presents a general technical analysis of existing water pumps in the market including Best Available Technology (BAT) and Best Not Yet Available Technology (BNAT).
- **Final scope for this review study**: where a final scope for this review study is presented, based on the assessments from Tasks D2, D3 and D4 and further input provided from the stakeholders during the consultation process along the development of the study.
- **Task D5**: which presents the definition of the base cases, the economic, energy and material inputs used for the environmental impacts and life cycle cost analyses, and which presents the results of these analyses based on input data using the EcoReport tool.
- **Task D6**: which presents the different design options for improvement; which ranks the options based on a semi-quantitative assessment, and which identifies policy measures and concludes on the preferred one that integrates the design options

and presents the biggest energy savings potentials without resulting in major costs for the manufacturers and market surveillance authorities.

- **Task D7**: which describes the stakeholder consultation process along the review study, describes the policy measures with their opportunities and barriers concluding on the preferred measure, and describes the policy scenarios and the energy and greenhouse gases savings potentials from the different scenarios. Furthermore, this section presents an impact analysis both to industry and consumers and summarizes the main policy recommendations.

- **Market surveillance of water pump units**: which presents the main issues and proposals about the verification of potential ecodesign requirements if Extended Product Approach is to be implemented in the reviewed water pumps regulation 547/2012.

- **Overall conclusions and recommendations**: which presents the main conclusions of the review study and the recommendations for a future amended Regulation 547/2012.

Tasks A, B, C and D1 are an extension of task 1 in the MEErP methodology, due to the need to define a consistent and harmonised scope, which derives from a more thorough quantitative assessment. Particularly since the previous preparatory studies introduced a much wider scope, and a harmonised overview was lacking.

It was therefore necessary to extend the review of the existing legislation and the previous preparatory studies, including the description of EPA and its possibility for adoption in a new regulation. The review part includes three sections in this report (tasks A, B and C) and the definition of a preliminary scope is presented in task D1.

Tasks D2, D3 and D4 follow the MEErP methodology tasks 2, 3 and 4. The final scope is presented, which is derived from the inputs and analyses in tasks D2, D3 and D4. The final scope has been used as the basis for task D5 onwards, which derives into the definition of the base cases followed by presentation of the policy options and performing the scenario analyses in task D7. Tasks D5, D6 and D7 also follow the MEErP methodology of tasks 5, 6 and 7.

Preliminary conclusions and recommendations for a new regulation are presented in the final chapter, which will be discussed with the stakeholders during the Consultation Forum. Table 3 presents an overview of the tasks performed in this review study in comparison with those defined in the MEErP methodology.

Table 3. Comparison of MEErP tasks and those presented in this review study.

Chapter review study	Task review study	Description	Task MEErP methodology
Chapter 1	Introduction to the report	Introduction to the structure and comparison with MEErP	not relevant
Chapter 2	Task A	Experiences from implementation of current regulation	not relevant
Chapter 3	Task B	Review of preparatory studies, existing legislation & schemes, and measurement & calculation standards	Task 1.2: Test standards & Task 1.3: Legislation
Chapter 4	Task C	Assessment of inclusion of EPA	not relevant

Chapter review study	Task review study	Description	Task MEErP methodology
Chapter 5	Task D1	Scope based on review of Preliminary Market analysis	Task 1.1: Product scope
Chapter 6	Task D2	Market analysis to build up stock of preliminary scope using market data	Task 2: Markets
Chapter 7	Task D3	Use of pumps in scope	Task 3: Users (except End of Life behaviour)
Chapter 8	Task D4	Technology assessment	Task 4: Technologies
Chapter 9	Final scope	Final scope after review of markets, users and technologies	End of Tasks 2, 3 & 4 (recommendations)
Chapter 10	Task D5	Definition of base cases and environmental and economic analyses	Task 5: Environment and economics
Chapter 11	Task D6	Identification of design options based on chapter 8 and of policy measures	Task 6: Design options
Chapter 12	Task D7	Description of policy measures, barriers and opportunities, definition of policy scenarios, analyses and results	Task 7: Scenarios
Chapter 13	Market surveillance of water pump units	Limitations and proposals for the verification of water pump units, if ecodesign requirements are included in the reviewed regulation considering an Extended Product Approach	not relevant
Chapter 14	Overall conclusions & recommenda-tions	Conclusions and recommendations for a future regulation repealing 547/2012	Continuation of Task 7 (7.5 – Summary)

2. Task A: Overview of current Regulation 547/2012 and experiences from its implementation

2.1 Ecodesign requirements for water pumps

The Regulation 547/2012 establishes ecodesign requirements for 'water pumps'. Water pumps are defined as the hydraulic part of a device that moves clean water by physical or mechanical action and that fall under one of the following designs:

- End suction own bearing (ESOB)
- End suction close coupled (ESCC)
- End suction close coupled inline (ESCCi)
- Vertical multistage (MS-V)
- Submersible multistage (MSS)

Water pumps specifically excluded are:

- Those designed specifically for pumping clean water at temperatures below – 10 °C or above 120 °C, except with regard to the information requirements of Annex II, points 2(11) to 2(13);
- Designed only for fire-fighting applications;
- Displacement water pumps; and
- Self-priming water pumps.

The ecodesign requirements are established based on the water pumps' characteristics in terms of nominal speed, impeller size and mechanical shape and flow and hydraulic energy performance. Taking these aspects into account, a minimum efficiency threshold is established for the abovementioned five water pump types subdivided in two nominal speeds for the end suction water pumps and one for the multistage pumps.

The minimum efficiency requirements as well as information requirements for rotodynamic water pumps are set out in Annex II of the regulation. The minimum efficiency requirements are set in a way that the worst performing pumps are removed from the market following this timeline:

1. First tier: From 1 January 2013 water pumps shall have a minimum efficiency corrected for the exclusion of 10% cut-off (i.e. the least effective water pumps in the market, represented by the 10% worst performing pumps shall be removed);
2. Second tier: From 1 January 2015, water pumps shall have a minimum efficiency corrected for the exclusion of 40% cut-off (i.e. the least effective water pumps in the market, represented by the 40% worst performing pumps shall be removed);
3. From 1 January 2013, the information on water pumps shall comply with the product information requirements set out in Annex II point 2.

The current regulation only sets minimum requirements for the hydraulic performance of water pumps without the motor, however it covers pumps which are also integrated in other products to achieve the full cost-effective energy-savings potential. The use phase is considered the most and only significant parameter in their life cycle, estimating an annual electricity consumption of 109 TWh (based on 2005 data), and predicting an increase of up to 136 TWh in 2020 if the regulation would have not been established and implemented. Projected saving potentials were calculated as 3.3 TWh/year by 2020 according to the Regulation (EU) 547/2012. Furthermore, projected savings for 2020 with different cut-off criteria were found as 2.5 TWh/year (30% cut-off), 2.8 TWh/year (40% cut-off), 3.2 TWh/year (50% cut-off) and 4.6 TWh/year (70% cut-off)[13]. According to the regulation these improvements should be achieved by applying non-proprietary cost-effective technologies that can reduce the total combined costs of purchase and operation.

The regulation also specifies in article 7 that a revision should be presented no later than four years after its entry into force, both in the light of technological progress and to aim at the adoption of an EPA.

The largest expected saving potentials rely on introducing the concept of EPA to pumps covered by the Lot 11 preparatory study, which is estimated as 35 TWh. Furthermore, the agreed 40% cut-off applied at Tier 2 was based on the understanding that EPA would be integrated in the future regulation to reach higher efficiency levels for water pumps. And by using variable speed drives (VSDs) could reach a level of energy savings of 20-50% (at pump level) or 28% (only in the UK), according to written comments by the UK to the Consultation Forum on pumps[14]. The UK proposed that the use of VSDs could be mandated for applications where the previously mentioned energy savings could be achieved in the majority of circumstances (e.g. building applications). This is because in some cases (in non-variable torque applications) there is a risk of increased energy losses by the use VSDs and therefore this should be limited to applications with variable duty demands.

2.2 Experiences from implementing the regulation

Experiences from implementing the regulation have been collected[15,16,17,18,19] in order to get an overview of the barriers and difficulties encountered, which are summarized in the points below:

- The manufacturers do not use the same categorisation as in the Regulation 547/2012 (i.e. ESOB, ESCC, ESCCi, MS-V and MSS). For Market Surveillance Authorities this makes it difficult to determine whether a pump is within the scope or not and to find the applicable minimum efficiency requirements. Since the nomenclature in the legislation has to be as generic as possible and suitable to all the languages of the countries in the European Union, the study team recommends to substitute part of the existing product information requirement in Annex II, 2(5). Instead of requiring the 'product type and size identification' to be durably marked on or near the rating plate, the study team proposes to require the marking of an index/coding of the relevant pump category, which has been defined in the Regulation 547/2012, together with the size identification (rated power and nominal speed). This means, for example, that the End Suction Own Bearing pumps are marked with 'ESOB' and that the size is clearly marked so that during the verification

[13] Commission staff Working Document – Impact Assessment – Ecodesign requirements for water pumps (2012)
[14] UK comments on motors, pumps, fans and circulators 180608 – Lot 11
[15] Note to the Danish Secretariat for Ecodesign and Energy Labelling of products (SEE) on April 2014 (available by request, in Danish)
[16] Provided by Europump, on the status meeting for pump review study held in Brussels on the 17th of March
[17] Guideline on the application of (EU) N° 547/2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for water pumps
[18] Frequently Asked Questions (FAQ) on the Ecodesign Directive and its Implementing Regulations – Commission Regulation (EC) No. 547/2012
[19] German comments EuP-Lot 11_pumps, on ecodesign requirements for single stage end suction, vertical multistage and submersible multistage pumps, 110608

process the pump category and its ecodesign requirements can be easily identified. The study team suggests that the description of this index/coding is stated in the technical documentation and in freely accessible websites provided by the manufacturers. It is assumed that all the pumps in scope will be marked, but to assure Market Surveillance Authorities can check water pumps not marked if suspected they are in scope the study team proposes to add a product information requirement in Annex 2. Where the manufacturers specify in the technical documentation and in freely accessible websites whether the pump is out of scope and provide a technical justification for the exemption stating clearly that the pump's intended use is not to pump clean water as defined in the regulation (e.g. special design for transport, petrochemicals or pulp and paper and not intended for pumping clean water). If this is not stated it will be assumed the pump is in scope and therefore not complying with the marking requirement. This suggestion will also clarify the confusion of pumps not covered by the regulation as they can pump other fluids apart from clean water. This point departs from the dialogue established with the stakeholders along the consultation process during the course of this study and it is based on pumps' definitions provided partially or fully by industry and/or from information in previous preparatory studies. An overview of the pumps' nomenclature and their application is presented in chapter 9 of this report ('final scope').

- Water pumps designed for some special purposes like pumps for food industry are often misunderstood as exempted from the regulation. In spite of the fact that pumps applied in the food-processing industry have to comply with hygienic requirements, they are obliged to comply with the minimum efficiency requirements if their intended end use is to pump clean water as defined in the regulation and fall within its scope[20].
- There is a misinterpretation within Market Surveillance Authorities that clean water is the same as drinking water. The scope of the regulation (article 1) clearly states that the regulation applies to clean water pumps and the definition in article 2 point 13 explains the characteristics of clean water.
- In Denmark, the Danish Secretariat for Ecodesign and Energy Labelling of products (SEE), which assist the Danish Energy Agency with Market Surveillance, found that the suppliers (manufacturers, importers and retailers) of water pumps do not always deliver all the necessary technical documentation. Therefore, we recommend not to make the technical requirements too long and too difficult as Member States and Market Surveillance Authorities need to check these and manufacturers and retailers need to deliver them. This issue was included as part of the experiences from implementing the water pump Regulation 547/2012.
- When clean water pumps are sold with a nominal speed other than what is specified in the regulation, it is recommended that the pumps are tested in their own nominal speed and use C-values corresponding to the closest to those defined in the regulation (1450 min^{-1} and 2900 min^{-1}). The nominal speed of the pump must be provided as part of the size identification in the product information requirements

[20] Note to the Danish Secretariat for Ecodesign and Energy Labelling of products (SEE) on April 2014 (available by request, in Danish)

(Annex II, 2(5)). Furthermore, with pumps where more than one pump category is applicable the type of pump casing should determine which C-value has to be taken.

- Generally, Europump[21] recommends that the best way for the clean water pump manufacturers to comply with the regulation is to indicate the H-Q curve and at least the three relevant Q-H-η points in Part Load (75% flow at best efficiency point), Best Efficiency Point (100% flow) and Over Load (110% flow at best efficiency point) for full impeller size.

2.3 Identified loopholes in current legislations

The unintended loopholes in the current legislation 547/2012 have been identified as related to the following topics[22]:

- The exclusion of self-priming water pumps and the lack of a definition and justification for this exclusion can create a potential loophole, since some of the currently covered water pumps can also have self-priming functions. A definition would in principle clarify what these pumps are which are in principle exempted. Therefore, the study team suggests that a definition is provided in a future revision of the Regulation 547/2012. The evaluation of its inclusion is discussed in detail in further chapters.
- The absence of multistage horizontal pumps, since a significant number of vertical pumps can be installed horizontally[23] and in this way they can be used for the same purposes as multistage vertical pumps.
- The delimitation of the nominal outer diameter for submersible multistage borehole pumps (for vertical multi-stage pumps).
- Missing wording in article 2 point 7 of the water pump regulation. The wording "end suction" is missing which could lead to misinterpretation as this wording is added to the other end suction pumps.

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[21] Guideline on the application of (EU) N° 547/2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for water pumps

[22] The last three bullet points are based on information provided by Europump.

[23] 'Proposed Scope for Regulation of Multistage Pumps'. Europump position paper issued and dated on the 8th of April, 2016.

3 Task B: Review of preparatory studies and other related existing legislation and measures

The structure of this task starts with the review of **product categorisation** in the previous preparatory studies (Lot 28 and Lot 29), current legislation and Eurostat and gives an overview of other existing categorisations. It also presents the **performance parameters** considered in previous studies and a review of existing **test standards** is shown afterwards, where relevant harmonised methods in and outside the European Union are explained according to current legislation and regulations. An overview of the product performance parameters presented in these standards is also given. Finally, the review of other relevant **legislation** is given, in and outside the European Union, in regards to the product categories and performance discussed previously.

3.1 Review of product categories and performances assessment

This subtask aims to review existing definitions of products in the overall scope taking into account existing categorisations. Secondly, the task aims to identify the functional parameters to be used to define the product group and/or narrow down the product scope.

This task involves three main elements:

1. Describing existing categorisations of products and related product definitions;
2. Presenting other possible definitions of products and scope;
3. Identifying primary and secondary product performance parameters from existing legislation and preparatory studies and the suggested EPA.

3.1.1 Pumps categories in existing legislation

The definition of the pumps defined in the current Regulation (EU) 547/2012 are:

- **End suction own bearing (ESOB) water pumps**: *glanded* single stage end suction rotodynamic water pump[24] with own bearing designed for pressures up to 16 bar, with a specific speed between 6 and 80 rpm, a minimum rated flow of 6 m^3/h, a maximum shaft power of 150 kW, a maximum head of 90 m at nominal speed of 1450 rpm, and a maximum head of 140 m at nominal speed of 2900 rpm.
- **End suction close coupled (ESCC) water pumps:** *glanded* single stage end suction rotodynamic water pump of which the motor shaft is extended to become also the pump shaft, designed for the same levels of pressure, flow, speed and head as the ESOB.
- **End suction close coupled inline (ESCCi)**: *glanded* single stage end suction rotodynamic water pump of which the water inlet of the pump is on the same axis as the water outlet of the pump, designed for the same levels as the ESOB.
- **Vertical multistage pump (MS-V)**: *glanded* multistage (i>1) rotodynamic water pump in which the impellers are assembled on a vertical rotating shaft, designed for pressures up to 25 bar, a nominal speed of 2900 rpm, and a max. flow of 100 m^3/h.
- **Submersible multistage water pump (MSS)**: Multistage (i>1) rotodynamic water pump designed to be operated in a borehole with nominal outer diameters

[24] Water pump is defined in 547/2012 as: the hydraulic part of a device that moves clean water by physical or mechanical action

of 4" or 6", at nominal speed of 2900 rpm at operating temperatures within a range of 0 °C and 90 °C .

Glanded pumps are those having a sealed shaft connection between the impeller in the pump body and the motor. The driving motor connected to glanded pumps remains dry.

The *input power* to these pumps is defined as '*shaft power*', which is the mechanical power transmitted to the pump by the shaft. The energy to the shaft comes from the electric motor, which is powered by electrical energy as input power.

The *output energy* delivered by the pumps is measured as *hydraulic power*, which is the energy per second carried in the fluid in the form of pressure and quantity.

Clean water is specifically defined by the regulation as water with a maximum non-absorbent free solid content of 0.25 kg/m^3 and with a maximum dissolved solids content of 50 kg/m^3, provided that the total gas content of the water does not exceed the saturation volume. Additives that are needed to avoid water freezing down to – 10 °C shall not be taken into account. This definition covers also potable water but it is not limited to it. Any water type that fulfils these specifications is clean water.

3.1.2 Pumps categories in previous preparatory studies

Previous preparatory studies have assessed the importance and potential inclusion of other pumps to the current ecodesign legislation on water pumps. Lot 28 has assessed the inclusion of pumps for private and public *wastewater* management and disposal, and for *fluids with high solids contents*. Lot 29 has assessed the inclusion of larger pumps for *clean water* and of *swimming pools*, ponds, fountains and aquariums water pumps.

The specific pump types assessed and the suggested classification by the Lot 28 are:

- **Centrifugal submersible pumps (radial sewage pumps up to 160 kW)**: Pump sealed into a single unit with motor and submersed in the media being pumped - typically found in wastewater networks; the fluid being pumped is discharged radially, i.e. at right angles to the pump shaft. These type of centrifugal pumps are required in most wastewater applications.
- **Centrifugal submersible pumps (mixed flow & axial pumps)**: Pump sealed into a single unit with motor and submersed in the media being pumped - typically found in wastewater networks; in axial pumps the fluid does not change its radial location since the change in radius at the suction and the discharge is very small, hence the name "axial" pump. In mixed flow pumps the fluid is discharge between an axial and a radial direction (between 0 and 90 degrees from the axial direction).
- **Centrifugal submersible pumps (once a day operation, up to 10 kW)**: Three types of pumps which are used in applications where the pumps have an average operation time of only 30 hours/year: Centrifugal submersible radial sewage pumps once a day operation, centrifugal submersible pumps where the volute is part of a tank, and pumps with shredding or grinding capability.
- **Centrifugal submersible domestic drainage pumps (<40 mm passage)**: Pumps that form a pressure-tight encapsulated unit with the motor, fully flood-proof; for domestic and commercial building flow rates and power supplies, typically sized for flows 1 - 40 l/s at 3 - 15 m head, and power ratings 0.4 - 7.5 kW.

- **Submersible dewatering pumps**: 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; normally used to empty liquids holding abrasive solids in mines, quarries and construction sites.
- **Centrifugal dry well pumps**: Comprise of an electric motor and a pump coupled together (pump and motor are located outside the pumped liquid). The pump is connected to the piping system through flanges on suction and discharge side. Pump and motor are installed on a base frame with a shaft coupling between them. Executions where the motor and the pump are closed coupled are common too. Horizontal installations are possible as well as vertical installations. In some vertical installations the motor is installed separately on the second floor and connected to the pump through a cardanic drive.
- **Slurry pumps (light duty)**: Engineered products tailored for individual applications, matching to the medium to be pumped which typically contains high concentrations of fine very abrasive solids; designed to minimise wear and withstand comparatively moderate loads, use, or stress.
- **Slurry pumps (heavy duty)**: Engineered products tailored for individual applications, matching to the medium to be pumped which typically contains high concentrations of fine very abrasive solids; designed to minimise wear and withstand heavy work.

Wastewater is defined in Lot 28 as any contaminated water resulting from human activities, which may consist of soluble and/or insoluble substances and can be characterised by its aesthetic, chemical and biological quality. A single characterisation cannot be established for all wastewater in the same manner as the Commission Regulation 547/2012 defines clean water since the range of wastewater types vary widely in terms of composition. The Lot 28 calls for a standardised harmonisation of wastewater type definitions, which can be used as a basis for the selection of the appropriate pump technology for a particular type of wastewater. These definitions should include the quantitative specification of important parameters which influence pump selection according to Lot 28, which are: viscosity, rag, grit, chemical properties. Analytical tests and/or sensors for quantifying most of these wastewater characteristics are available, however, the wide range of wastewater types makes it very difficult if not impossible to harmonise these characteristics in one wastewater definition as it is for clean water defined in the Regulation 547/2012.

An alternative to measure these four wastewater characteristics (every time a pump qualifies for the appropriate application) is to establish a scheme to correlate energy efficiency of wastewater pumps with an overall solid content of the wastewater (amongst other pump functionalities)[25]. This approach would establish a function factor related to the wastewater pumps' calculated efficiency, which will depend on the wastewaters' solids content. This approach would only be possible if harmonised definitions of the solids' content of different wastewater types are available. In this way the wastewater treatment plant operators can apply the relevant function factor appropriate to the solids content of the wastewater type they treat in their plants. This approach seems realistic only for wastewater treatment applications where wastewater characteristics are carefully measured and controlled for process optimisation. Wastewater transport and flood control

[25] Communicated by Europump on a FtF meeting (13/08/15), being part of the mandate the EC has given to CEN for standardisation of definition of wastewater types

applications often deal with a wide range of uncontrolled wastewater types containing different types of solids and objects. It is therefore suggested that the relationship between wastewater type and pump efficiency is further assessed from what was originally presented in Lot 28 and the proposed alternative. A suggested classification of wastewater pump applications is presented in chapter 7 (Task D3: Users).

In this regard, Lot 28 provides a qualitative classification based on The Urban Wastewater Treatment Directive (UWTD)[26] as:

- Rainwater (urban wastewater)
- Domestic wastewater
- Industrial wastewater

Two additional wastewater types are specified for water pump applications:

- Commercial wastewater
- Municipal wastewater

The definitions provided in the UWTD are purely qualitative and until today there is no available additional information on the standardisation work or on Europump's work on a standard defining artificial wastewater to be used for testing wastewater pumps' efficiency mentioned in the Lot 28 preparatory study. This is because of the different types of wastewater and the difficulty on harmonising them in a limited number of wastewater categories.

A separate classification of pumps application is specified as *fluids containing high solids*, broken down as *sand water, grit water* and *slurry.* A definition of these types of fluids is lacking, and therefore their definitions are provided herein according to publicly available information:

- *Sand water:* There is not a single definition of sand water publicly available, however, this type of water may be linked to the application of water pumps in mines, quarries and construction sites and be therefore a type of water containing high amounts of sand waste.
- *Grit water:* Grit is generally defined as small residue particles of various types from water pipes, but in this specific study it may refer to water containing residues from grit removal pre-treatment chambers in wastewater treatment plants.
- *Slurry:* Slurry can be any mixture of water and any insoluble abrasive substance or material, but in this specific study it refers primarily to slurry found in mining applications.

Some of the pumps used for wastewater applications are also used for *sludge* applications, particularly for sludge found in wastewater treatment plants. This type of sludge is found at different solids concentration depending on the point of separation in the plant (pre-treatment, primary treatment and secondary treatment), and would therefore be suited for other applications. For the sake of this study, they will only be referred as slurry pumps (light and heavy duty).

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[26] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1991:135:0040:0052:EN:PDF

In a letter communicated to the study team by Europump[27], it is suggested that a similar approach as defined for wastewater categorisation, i.e. with a functional factor depending on solids content, would be needed in order to standardize the effect of the slurry composition on the efficiency of the pumps. Such work does not exist, thus making the calculation of efficiencies very difficult as a wide range of slurry types are used for each of the two slurry pumps categories and therefore a representative efficiency would be impossible to establish.

The pump types assessed by the Lot 29 are:

- **Swimming pool pumps integrated motor+pump with built-in strainer (up to 2.2 kW)**: Small pumps packaged in plastic comprising an integrated unit of motor, pumps and controls typically rated around 1 kW (with built-in strainer); they are sold for residential use.
- **Swimming pool pumps (integrated motor+pump with built-in strainer (over 2.2 kW)**: Pumps packaged in plastic (for domestic use) or made of steel (for commercial use) comprising an integrated unit of motor, pumps and controls with a built-in strainer and rated over 2.2 kW; they are sold for residential use or for smaller commercial pools.
- **Fountain and pond pumps (up to 1 kW)**: Continuously operated pumps built in the same way and differing only for the point of work on the flow/head characteristic curve, working typically at low head and high flow driving water through a filter (pond pumps) and at higher heads with an internal inlet protection filter (fountain pumps).
- **Small aquarium pumps for domestic/small/non-commercial applications (up to 120 W)**: Continuously operated pumps connected to a device, which functions as a filter of substances in the water, which are toxic to the fish; the pumps employed today have permanent magnet synchronous motors that are integrated with the pump with wet rotor.
- **Aquarium power head pumps (up to 120 W)**: Continuously operated pumps which are also connected to a filter having the same permanent synchronous motor technology; power head pumps are circulating pumps which assure continuous flow that enhance avoiding the presence of toxic substances in the water.
- **Spa pumps for domestic and commercial use (0.75 – 3 kW)**: Submersible circulating pumps with nominal speeds of 1450 and 2900 rpm and which either are emptied each time after use (domestic) or where the water is retained and filtered/treated (commercial).
- **Counter-current** pumps: Provide an injection of high pressure flow from outlets on the side of a swimming pool.
- **End suction close coupled pumps (150 kW to 1 MW)**: Single stage end suction rotodynamic water pumps (motor shaft extended to become pump shaft) with the suction side in axial and the water pressure outlet in radial direction.

[27] The Unsuitability of Efficiency Regulation for Slurry Pumps, issued and date July 30th 2015 by John Bower, Europump.

- **End suction coupled inline pumps (150 kW to 1MW)**: Single stage end suction rotodynamic water pump of which the suction side of the pump is in one line with the water pressure outlet of the pump.
- **End suction own bearing pumps (150 kW to 1 MW)**: End suction water pump with own bearings and the suction side in axial and the water pressure outlet in radial direction.
- **Submersible** borehole **pumps**: Multi-stage submersible rotodynamic water pumps, with nominal outer diameters up to 12″ and over 12″, operated in a borehole at nominal speed 2900 rpm, operating temperatures 0 °C to 90 °C.
- **Vertical multistage pumps**: Multi-stage rotodynamic water pumps in which the impellers are assembled on a vertical rotating shaft, designed for pressures between 25 and 40 bar, and also over 40 bar.

Swimming pool water is different from clean water defined in the Commission Regulation 547/2012, since it needs to fulfil special hygienic requirements. Swimming pools require special chemicals for maintaining the disinfected water since the water remains in the same place.

A range of values in terms of water clarity, colour, turbidity, pH, chlorine and other quantitative parameters have been defined in EN 16713 standard on domestic swimming pools[28], which was published on the 10th of February 2016. This set of values could be used as reference to define quantitatively swimming pool water, since it is expected that the performance of the swimming pool pump would be greatly influenced by achieving these values.

3.1.3 Overview of pump types in the regulation and in the preparatory studies

For a complete overview of the pump types included in the regulation and in the studies, please see Table 4.

Table 4. Overview of pump classification in current legislation and preparatory studies.

Pump type	547/2012	Lot 28	Lot 29
End suction own bearing pumps (ESOB, ≤150 kW)	X		
End suction close coupled pumps (ESCC, ≤150 kW)	X		
End suction coupled inline pumps (ESCCi, ≤150 kW)	X		
Vertical multistage pumps (MS-V, ≤25 bar)	X		
Borehole submersible multistage water pump (MSS, 4″ or 6″)	X		
Centrifugal submersible pumps (radial sewage pumps up to 160 kW)		X	
Centrifugal submersible pumps (mixed flow & axial pumps)		X	
Centrifugal submersible pumps (once a day operation, up to 10kW)		X	
Centrifugal submersible domestic drainage pumps (<40 mm passage)		X	
Submersible dewatering pumps		X	

[28] Decision document C06 2015 CEN TC 402 – on the future of FprEN 16713-3:2015 Domestic swimming pools – Water systems – Part 3: Water treatment – Requirements, after CEN Enquiry

Pump type	547/2012	Lot 28	Lot 29
Centrifugal dry well pumps		X	
Slurry pumps (light duty)		X	
Slurry pumps (heavy duty)		X	
Swimming pool integrated motor+pumps with build-in strainer (up to 2.2 kW)			X
Swimming pool integrated motor+pumps with build-in strainer (over 2.2 kW)			X
Fountain and pond pumps (up to 1 kW)			X
Small aquarium pumps for domestic/small/non-commercial applications			X
Aquarium power head pumps (up to 120 kW)			X
Spa pumps for domestic and commercial use			X
Counter current pumps			X
End suction close coupled pumps (ESCC, 150 kW-1 MW)			X
End suction coupled inline pumps (ESCCi, 150 kW-1 MW)			X
End suction own bearing pumps (ESOB, 150 kW-1 MW)			X
Submersible multistage borehole pumps (MSS, 8”, 10”, 12”, 12”+)			X
Vertical multistage pumps (MS-V, >25 bar)			X

3.1.4 Other categorisation

In Figure 1, the pumps have been categorised by the working principle and by the application.

Categories by working principle

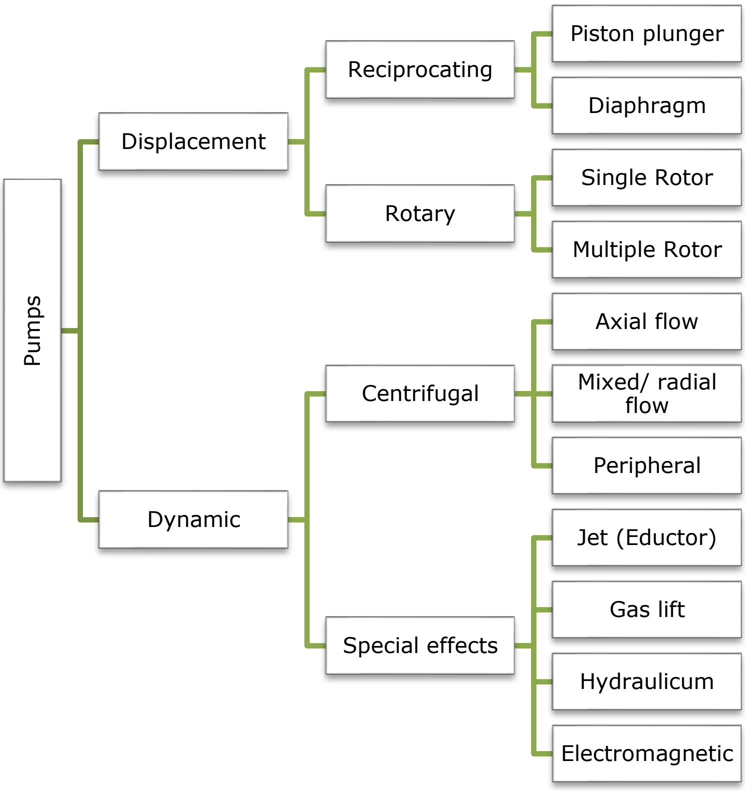

Figure 1. Classification of pumps by working principle according to Europump[29]

Categories by application

Pumps are used for a wealth of applications and there are too many to list them all. To demonstrate an idea of the range, the list below provides some examples. Note: this list is not exhaustive and it is based on a combination of sources[30]:

- Agriculture
- Automotive industry
- Beverage industry
- Biochemical industry
- Biofuel industry
- Commercial Buildings
- District Energy (heating/cooling)
- Domestic, commercial and municipal Wastewater treatment
- Drinking water treatment
- Food industry
- Health care
- HVAC OEM
- Industrial boilers
- Industrial utilities
- Marine
- Metal and equipment manufacturers
- Mining industry

29 http://europump.net/uploads/Classification%20of%20Displacement%20Pumps.pdf
http://europump.net/uploads/Classification%20of%20dynamic%20pumps.pdf
30 Such as the IPPC BREF documents (http://eippcb.jrc.ec.europa.eu/reference/), manufacturers overview of application areas of their products, product brochures, etc.

- Pharmaceutical industry
- Power generation
- Private housing
- Wastewater transport and flood control
- Water distribution

3.2 Overview of product performance parameters

3.2.1 Functional unit

The functional unit is the reference value for any pump considered and is independent of pump type. It also helps to set the boundaries for comparison of different products. For the pumps in this study, the functional unit was defined based on the primary functional parameters identified from Lot 11, Lot 28 and Lot 29 since these parameters define what the water pump does, which is to pump a "quantity of water at the specified head (pressure), (m3/h, m)". Efficiency is not a primary functional parameter since it relates to how a product does something, not what it does. In this understanding, different pumps can be compared based the functional unit which strictly focuses on the function of the pump, and not on how the pump will reach to perform that function (e.g. how effective it performs). Finally, "fluid properties" are included to make clear that the nature of fluids has a major impact on the selection of product, meaning that when two pumps are compared the type of water to be pumped this also defines what the pump has to do.

3.2.2 Overview of secondary functional parameters in Lot 11, Lot 28 and Lot 29

The importance of secondary performance parameters is that they are often instrumental in guiding the specification of a pump and so these must also be considered when considering possible pump categorisation. An overview of the secondary functional parameters previously considered for inclusion in a future amended regulation from previous preparatory studies is presented in the Table 3, including some input provided by industry stakeholders.

Table 5. Overview of secondary functional parameters in previous preparatory studies.

Secondary functional parameters	Lot 11	Lot 28	Lot 29
Pump speed	X	X	X
Fixing dimensions	X	X	
Bearing arrangements	X		X
Net Positive Suction Head (NPSH)	X	X	X
Noise	X		X
Minimum clearances required	X	X	
Expected lifetime of the pump	X	X	
Seal arrangements	X	X	
Efficiency at operating/duty point	X		X
Solids handling capability		X	
Material		X	X
Maintenance needs		X	
Variable speed drives		X	
Shaft power or mechanical power			X
Hydraulic power			X
Electrical power			X
Electricity and primary energy			X
Part load behaviour	X		X

The definitions of these parameters, taken directly from previous preparatory studies and input provided by industry stakeholders, are described below:

- Pump speed content. The rotational speed of the shaft is the most important pump operating variable. Pumps tend to be purchased to operate at the highest speed that the suction conditions (NPSH) will allow, since this usually results in the lowest first cost. Since most pumps are driven by fixed speed induction motors, the speed options tend to be limited. This can be false economy for many reasons, e.g. a four pole motor (1450 rpm) can be cheaper than a two pole motor (2900 rpm); more maintenance will be required since the life of wearing parts (such as impeller/casing wear rings, seals, bearings, couplings) will be reduced. Of the highest importance is the fact that the fastest pump may not be the most efficient option, meaning that the savings in purchase price can be spent in a short time by increased energy costs.
- Fixing dimensions. Depending on whether the pumps are specially designed or mass manufactured, some pumps which are manufactured according to a National or International Standard will usually have their mounting hole positions and sizes, and branch positions, defined by the Standard. This is of particular value when replacing a failed pump.
- Bearing arrangements. Pump impellers must be positively located both radially and axially. The radial bearings must resist radial thrusts and enable the impellers to maintain fine radial running clearances to minimise leakage between the impeller and casing. The axial bearings must resist axial thrusts, maintain the relative positions of the impeller and casing and ensure accurate location of axial seals. End Suction Own Bearings pumps use two anti-friction bearings, usually grease lubricated. End suction Close Coupled pumps use the two grease lubricated anti-friction bearings of the motor. Vertical Multistage pumps use the motor bearings for axial location, radial location being provided partly by the motor and partly by water lubricated plain bearings in the pump. Submersible Multistage Well pumps use the motor thrust bearing to accommodate the hydraulic down thrust and the weight of the pump rotating element, with a small thrust ring in the top of the pump to resist up thrust when starting; radial location is provided by water lubricated plain bearings. Aquarium pumps, pond pumps and fountain pump that use the technology of integrated motor with wet rotor normally do not require shaft bearings because, through a system of internal recirculation, the rotor shaft is constantly lubricated and cooled by the same pumped water.
- Net Positive Suction Head (NPSH). This is the total head at the pump inlet above vapour pressure (corrected to the level of the first stage impeller inlet, if different). Two important values of NPSH are the NPSH required by the pump (NPSH) and the NPSH available to the pump ($NPSH_A$). The $NPSH_R$ is usually that at which the pump (or the first stage impeller if a multistage pump) loses 3% of its generated head due to cavitation. The ($NPSH_A$) must exceed the NPSH by a safety margin. This would rarely be less than 1 m but will usually be greater because of many factors such as pump speed, size and operating range. The NPSH reduces between pump best efficiency flow (BEQ) and about half flow, but increases rapidly above BEQ.
- Noise. A pump of the types covered in this report operating under optimum conditions should be less noisy than its motor. If such a pump is noisy, then it is a fault condition. It could be a mechanical fault, such as failed bearings. However, it

is more likely to be an operational fault. It could be running at too low a flow, which causes noisy cavitation in a volute and sometimes in an impeller, or it could be suffering from inadequate NPSH, which causes noisy cavitation in an impeller. Some exemptions are wastewater pumps with grinding and cutting devices designed for handling wastewater containing large objects, where the level of noise is higher than most of the other pumps and it is not an indication of mechanical or operational failure.

- Minimum clearances required. The radial running clearance between the impeller(s) and the casing is critical, since the leakage through this clearance has an adverse effect on efficiency. In a cold water pump this clearance can be as low as 0.25 mm on diameter. However, if the pump operates away from its best efficiency point there is likely to be contact, wear, and a resulting increase in clearance. Also clearances can be eroded quite quickly by abrasives in the water. This can be a particular problem with sand in boreholes. Swimming pool pumps which are made of plastic cannot achieve these small clearances and the minimum size is approx. 1 mm. This is also necessary to let impurities out of the pool water such as leaves, pine needles and sand and larger gaps are therefore absolutely necessary for trouble-free operation.
- Expected lifetime of the pump. The lifetime of a water pump will rarely be dictated by obsolescence. The pump will usually be replaced when it fails, due to a broken component or an unacceptable drop in output. A pump operating under ideal conditions should work for 20 years with minimum maintenance. Unfortunately, most pumps lose efficiency due to wear in their wear rings, due to operation at part flow, and/or roughening of their cast iron volutes by corrosion products. It is not unusual to lose 10 % of the new efficiency in ten years. In the case of wastewater and solid handling pumps, the lifetime will often be related to the type of solids they are required to pump. In the case of swimming pool pumps, the plastic material and larger clearances prevent this wear.
- Seal arrangements. The pump shaft must be sealed to minimise evaporation of water leaking out between the pump and atmosphere. Some pumps may have packed glands for minimum cost, but most water pumps will have simple mechanical seals consisting of radial faces held together by a spring and lubricated by a very thin film of the pumped water. The faces will usually be carbon running against a metal. These seals are 'leak free', although actually passing a very small flow of water vapour. They do not require cooling or sealing water unless they have to operate below atmospheric pressure. Many wastewater pumps will have mechanical seals consisting of axial faces held together by a spring. The faces will usually be silicon carbide or tungsten carbide.
- Efficiency at operating/duty point. This is a major determinant in lifetime operating costs. It is therefore important that a pump should be chosen which has a high efficiency, and that its best efficiency point (BEP) is as close as possible to the principal duty on site. The efficiency of a pump depends on its basic geometry, fine running clearances and a good surface finish.
- Material. For the duties specified in the scope of work, cast iron is adequate (for other fluids alternative speciality materials may be needed.) The impeller may be in bronze to avoid roughening by corrosion. The cast iron volute can be protected from corrosion by a suitable coating. The need for coating depends on the water hardness and whether aggressive bacteria are present. The hydraulic components

of small Vertical Multistage pumps and small Submersible Multistage Well pumps are usually made from pressed sheet stainless steel or plastic materials. These have a good finish which helps efficiency. In the case of sheet steel, the low thickness further helps efficiency.

- Part load behaviour. At around half flow, a pump can become noisy (see 'Noise' above) due to recirculation of the flow in the impeller and volute. At lower flows this could reduce bearing and seal life. At very low flows a pump can overheat. Low flows should be avoided as far as possible because of loss of efficiency. It is therefore very important to avoid adding unnecessary margins to the required head and flow, which cause the pump to operate at reduced flow under actual site conditions.
- General construction. Ease of maintenance varies with the typical construction of the different pump types. With Vertical Multistage pumps, the top-mounted motor and multiple pump stages make access more difficult, but it is still possible to dismantle the pump without disturbing the pipework. With Submersible Multistage Well pumps the main problem is lifting the rising main to access the pump. However, the pump is then easily removed from the motor by unbolting the standard NEMA flange and sliding the splined shafts apart. With swimming pool pumps it depends on whether they are self-priming or not, however, the biggest effect is not on the maintenance but on the energy efficiency. The pump housing of self-priming pumps, including the pre-filter housing, are generally produced as combined housing reducing the total grade of efficiency. For pumps without self-priming function the choice of materials makes a considerable effect, as plastic in the pumps restrict smaller clearances and impellers cannot be optimised when made of this material by injection moulding. Using alternative construction and materials for swimming pool pumps would affect the easiness to operate them which is important as users are typically not qualified people.
- Solids handling capability. The wastewater pumps considered in this study all need to be able to pump solid materials suspended within the liquid. In many applications the ability to handle fibrous components in the wastewater is of major importance. In order to achieve this, the hydraulics of the pump should be designed to pass solids through the pump.
- Efficiency over operating range/duty point. This is a major determinant in lifetime operating costs. It is therefore important that a pump should be chosen which has maximal efficiency over the range of duties it is expected to pump. Also that its best efficiency point (BEP) is as close as possible to the principal duty on site. The efficiency of a pump depends on its basic geometry, fine running clearances and a good surface finish. Unfortunately, most pumps lose efficiency due to wear in their wear rings, due to operation at part flow, and/or roughening of their cast iron volutes by corrosion products.
- Material. There are very different materials used for volutes and impellers, depending on the application:
    - Volutes may be from cast iron for standard sewage pumps, stainless steel for sewage containing high amount of sulphides or chlorides. They can also be from aluminium for e.g. contractor pumps.

    - Impellers are made from cast iron for standard sewage pumps, but may also be stainless steel, hard metal (for very abrasive water), bronze for water with high chloride content or ever special plastic materials (e.g. for vortex type of pumps)
- Maintenance needs. Ease of maintenance varies with pump type. Larger dry well pumps can be easier to maintain as they are generally mounted in more accessible areas than submersible pumps. However, maintenance of small submersible pumps, is much easier than of small dry mounted pumps plus dry well mounted pumps can have long shafts associated with them and are more likely to suffer from NPSH availability issues. With End Suction Close Coupled pumps, it is possible to access the impeller by removing one set of nuts or screws and removing the full rotating element including the motor without disturbing the pipework. Access to the seal is then possible by removing the impeller. With End Suction Own Bearings pumps, the coupling spacer is removed and the pump rotating element can then be withdrawn without disturbing the motor or the pipework. With progressing cavity pumps the rotor can be withdrawn from the stator without disturbing the pipework.
- Variable speed drives. The implications of using variable speed drives with wastewater pumps need to be explored, since there are issues surrounding their use, which are not present in clean water pumping. In clean water pumps, it is good practice in terms of energy efficiency to match the pump output to the system demand. Doing this with wastewater pumps can potentially result in a reduction the reliability of the pump and the solids handling effectiveness. Wastewater pumps are usually specified to provide a minimum velocity in the pipe to prevent solids from settling within the rising main. It is important that any use of variable speed drives to improve energy efficiency does not compromise the transport of solids. Also, operating a pump at a lower speed may reduce the cutting ability of an impeller and therefore increase the chance of ragging.
- Shaft power or mechanical power: Power transmitted to a pump by the shaft. It is the product of speed and torque.
  $SP = \omega X T$
  where, ω is the angular speed of the shaft. T is the torque transmitted.
- Hydraulic power: Energy per second carried in a fluid, such as water or oil, in the form of pressure and quantity.
  $HP = Q X \Delta p$
  where:
  Q is the flow rate.
  Δp is the change in pressure of the fluid over the pump.
- Electrical power: Power input (in kW) of the pump.
- Electricity and primary energy: Energy consumed by the pump. The primary energy includes the losses due to generation and transport of electricity.

3.3 Overview of test standards (EU, Member States and third country level)

This subtask identifies the relevant test standards for water pumps and provides an overview of the performance parameters they present.

3.3.1 Standard for environmental assessment of power drive systems (EN 50598)

EN 50598 presents a general scheme for setting energy efficiency and environmental indicators of power drive systems. EN 50598 enables Ecodesign requirements to be set for motors and CDM (Complete Drive Module), and part 1 also includes a general methodology for EPA for PDS (Power Drive Systems). The standard provides a method to evaluate EPA for water pumps that are placed on the market without a motor. However, only the evaluations of PDS are considered, the evaluation of water pumps are not included in this standard.

Part 1, EN 50598-1:2014 defines the basic terms required for an Extended Product Approach (EPA) for product units that include PDS. The standard includes a specification of 8 load points for PDS (on a torque-speed curve) that are used for EPA. The standard also includes are Semi-Analytic Model (SAM) which is used for determine the EEI when a PDS is combined with a piece of turbo-machinery (e.g. a pump) to form an EPA. The inputs to the SAM are values for the 8 loads points for PDS as well as measured values for turbo-machinery. The SAM thereby allows a EEI-value to be determined for an EPA without having to measure on the combined product.[31]

Part 2, EN 50598-2:2014, specifies the energy efficiency indicators for power electronics (e.g. complete drive modules and CDM), power drive systems and motor starters, all used for motor-driven equipment in the power range of 0.12 kW up to 1000 kW (100 to 1,000 V)"[32]. It specifies efficiency classes for CDM and PDS.

Part 3, EN 50598-3:2015, specifies a methodology to evaluate the life time environmental impacts of PDS and the aspects that should be included in environmental product declarations.[33]

3.3.2 Test standards

Mandate 498

Mandate to CEN, CENELEC and ETSI for standardisation in the field of pumps.
This mandate relates to Directive 2009/125/EC of the European Parliament and of the Council, and to measures implementing this Directive for which a Harmonised Standard should be developed to cover essential requirements.

In practice this means that the mandate aims to create a harmonized standard, from EN 16480:2016, which covers the minimum required value of efficiency depending on the value of the Minimum Efficiency Index (MEI). This standard also describes how the value of the MEI of a pump size indicated by the manufacturer can be verified by an independent institution (e.g. in the frame of market surveillance).

In the second phase the development of an EPA is required.

CEN TC 197

[31] From the scope of EN 50598-1:2014
[32] From the scope of EN 50598-2:2014
[33] From the scope of EN 50598-3:2015

CEN TC 197 is responsible for the standardization on general process pumps mainly, and handles a portfolio of 29 European standards and 3 technical specifications dealing with safety, testing, performance features among others

This TC consists of 4 working groups[34] shown in Table 6.

Table 6. CEN/TC 197 Subcommittees and Working Groups.

Working group	Title
CEN/TC 197/WG 1	Water pumps efficiency
CEN/TC 197/WG 2	Circulation pumps
CEN/TC 197/WG 3	Test Procedure for Packings for Rotary Applications
CEN/TC 197/WG 4	Liquid pumps and pump units - Noise test code - Grades 2 and 3 of accuracy

CEN TC 197 WG 1 Pumps

CEN/TC 197/ WG 1 "Pumps" is the working group working on the intended harmonized standard that will cover the procedures and methods of measuring the energy efficiency and associated characteristics of water pumps.

Standards developed or under development by this working group[35] and under Mandate 498:

- *EN 16480:2016 "Pumps – Minimum required efficiency or rotodynamic water pumps"*: This European Standard specifies performance requirements (methods and procedures for testing and calculating) for determining the Minimum Efficiency Index (MEI) of rotodynamic glanded water pumps for pumping clean water, including where integrated in other products.
  The pump types and sizes covered by this standard are described in the Annex A. These pumps are designed and produced as duty pumps for pressures up to 16 bar for end suction pumps and up to 25 bar for multistage pumps, temperatures between -10°C and +120°C and 4" or 6" size for submersible multistage pumps at operating temperatures within a range of 0 °C and 90 °C.[36]. This corresponds the pumps in the scope of the regulation No 547/2012 (the current regulation).

- *prEN 17038-1 (WI=00197088)"Development, Validation and Application of a Semi-Analytical Model for the Determination of the Energy Efficiency Index of Single Pump Units - Part 1: General description of the methodology"* and *prEN 17038-2 (WI=00197089) "Development, Validation and Application of a Semi-Analytical Model for the Determination of the Energy Efficiency Index of Single Pump Units Quantification of the energy efficiency of water pump units - Part 2: Single pump units"*: These two standards are still under development and are currently in the Enquiry voting phase, the scope of these two test standards follows the scope mentioned in EN16480:2016 and Mandate 498.

[34] *http://standards.cen.eu/dyn/www/f?p=204:29:0::::FSP_ORG_ID,FSP_LANG_ID:6178,25&cs=106EAE1DD0543C56EA4827C5B1AE921B2#1*

[35] http://standards.cen.eu/dyn/www/f?p=204:22:0::::FSP_ORG_ID,FSP_LANG_ID:759829,25&cs=1C09649B36EF40D0C60761646D2141CC5

[36] http://www.bds-bg.org/en/tc/work_programme.php?national_standard_id=93271

It must be stated that in prEN 17038-2 the submersible borehole pumps are not included. These pumps will be covered in a separate EPA part and will be developed by a separate work group within WG 1 (timeline still to be determined).

Horizontal multistage pumps have been included in prEN 17038-2 and are an addition to the scope of M498 and the current regulation.

Furthermore, booster sets will also be developed as a separate EPA part (anticipating the scope of the current review study).

An overview of published standards under CEN TC 197[37], as well as an overview of those mentioned in Lot 28 and Lot 29 is presented in Annex 1.

3.3.3 Swimming pool standards

According to EUSA Pool Pump Working Group[38], it is necessary to look at the entire pool hydraulic system design when looking at energy reduction measures. This is because it is the hydraulic energy losses throughout the entire pool system which determine the energy losses at the pump level. Specifically mentioned parameters are:

- Minimum flow rate
- Maximum turnover rate
- Clogging cycle/process of the filter

A short description of swimming pool related standards on requirements and tests is provided next. Only for aspects that are related to the hydraulic design of the pool and to the operational side of the swimming pool pumps.

EN 16713-1:2016 on Domestic swimming pools – Water systems - part 1: Filtration systems – Requirements and test methods

This first part of the standard has been prepared by the Technical Committee CEN/TC 402 on "Domestic Pools and Spas" and was published 10 February 2016[39]. It specifies the filtration requirements and test methods of filter elements or media, filtration units or systems designed to be used in domestic swimming pools. The requirements are set for four types of filters which are generally used for swimming pools:

- pre-coat filtration/diatomaceous earth (DE)
- disposable cartridge or filter bag
- graded aggregate (single/multi-layer-filter)
- other filters (e.g. membrane systems)

According to the standard, the velocity at which the water to be filtered passes through the new filter medium shall be adapted to the type of medium used. Furthermore, the filtration flow rate shall be adapted to the nature and surface area of the filter medium used in the filter. Specific maximum water flow velocities for different filter media are defined in this standard. Additionally, the filter's Maximum Operating Pressure (MOP) shall be greater than or equal to the maximum manometric head of the pump of the filtration unit, and the filter must show a reduction efficiency of 50% or greater. Finally, the flow

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[37] http://standards.cen.eu/dyn/www/f?p=204:32:0::::FSP_ORG_ID,FSP_LANG_ID:759829,25&cs=1C09649B36EF40D0C60761646D2141CC5

[38] EUSA Pool Pump Position Paper, Paris, 23/10/2015

[39] https://standards.cen.eu/dyn/www/f?p=204:32:0::::FSP_ORG_ID,FSP_LANG_ID:761125,25&cs=1BECF7719A594A2BB15A601814BAEE67D

rate, duration, pressure and possible backwash disinfection applied depend also on the type of filter and have to be sufficient enough to avoid permanent accumulation of debris especially organic matter (e. g. microorganisms). The standard defines methods to test the different filter abilities which are important for the abovementioned parameters, together with the filter's ability to reduce turbidity and contaminated retained mass as well as its efficiency and retention capacity.

On this basis it can be concluded that the type of filter used influences the minimum flow rate and clogging capacity parameters, which themselves affect the energy losses of the hydraulic system at the swimming pool. It is therefore assumed, that the type of filter will also affect the efficiency of the swimming pool pumps and it is important to assess this when looking at improving the efficiency of swimming pool pumps.

EN 16713-2:2016 on Domestic swimming pools – Water systems -part 2: Circulation systems – Requirements and test methods

This second part of the standard has been prepared by the Technical Committee CEN/TC 402 on "Domestic Pools and Spas" and was published 10 Ferbruary 2016[40]. It specifies requirements and test methods for circulation systems and is applicable to equipment used in domestic swimming pools and designed for the circulation of water (introduction and/or extraction).

The requirements set for circulation systems (i.e. filtration systems) are given for:

- Filtration system design
- Filtration system nominal flow rate
- Extraction of pool water
- Suction devices
- Pool inlets
- Pipe work
- Pumps

The design and the nominal flow rate of the filtration system affect the overflow channels design and skimmers (for the extraction of pool water), suction devices, pool inlets and pipe work. The design and the flow rate of the filtration system depend greatly on the correct selection of the filter pump, which is done based on:

- The flow rate of the pump
- Head loss of filter
- Head loss of pipe and pipefittings
- Head loss of sanitation and heating equipment
- Hydrostatic pressure
- Resistance of materials

Tests are defined, amongst others, to measure the head, power drawn and total efficiency vs. the flow rate of the pump, self-priming performance and running and cyclical endurance.

EN 16713 on Domestic swimming pools – Water systems

En 16713 comprises of 3 parts: EN 16713-1:2016, EN 16713-2:2016 and EN 16713-3 2016. These standards specify requirements and test methods for filtration and circulation

[40] Ibid

systems and requirements for water treatment of domestic swimming pools, with the purpose to ensure a consistently high quality of pool water in terms of hygiene[41]. These standards have been developed by the Technical Committee CEN/TC 402 WG 2 on "Pool water circulation, filtration and treatment" and are available since February 2016.

Of particular relevance concerning the definition of what is 'good' water quality inside the swimming pools, part 3 of this standard defines maximum values for water characteristics of the fill water of the pool (i.e. water used for the initial filling and for topping up), which are used as threshold to require water treatment. Furthermore, indicative values for good quality bathing water parameters are provided, which are relevant mostly to water treated by chlorine.

In order to achieve good quality bathing water, the standard recommends some practices for the use of flocculants/coagulants, disinfectants and pH-adjustment reagents, as well as for keeping the water balance (acidity/alkalinity/precipitation) for dilution and cleaning. Particularly for disinfection, the standard provides indicative results from testing and showing an effective disinfection. Finally, the standard recommends the use of certain disinfectants, including alternative methods such as ozone and UV treatment.

EN 15288:2008 Swimming pools – Part 1: Safety requirements for design and Part 2: Safety requirements and operation

This standard has been prepared by Technical Committee CEN/TC 136 "Sports, playground and other recreation equipment". Both standards define three types of swimming pools:

- Swimming pool type 1: Pool where the water-related activities are the main business (e. g. communal pools, leisure pools, water parks, aqua parks) and whose use is "public" (i.e. use of an installation open to everyone or to a defined group of users, not designated solely for the owner's/proprietor's/operator's family and guests independently from paying an entrance fee).
- Swimming pool type 2: Pool which is an additional service to the main business (e.g. hotel pools, camping pools, club pools, therapeutic pools) and whose use is "public".
- Swimming pool type 3: All pools except for type 1 and 2, and except for pools of "private" use (i.e. use of an installation designated solely for the owner's/proprietor's/operator's family and guests including the use connected with renting houses for family use).

Part 1 of the standard specifies only a few points related to pumps, which are flow circulation (typical flow speed of the water in the return pipes < 1.5 m/s) and a continuous flocculation in particular for swimming pool type 1.

Part 2 of the standard defines a dye test for the water circulation system to make sure the effectiveness of the circulation of the disinfectant, and it indicates a procedure for monitoring water quality.

3.3.4 Other performance/categorisation standards

ISO 9906 "Rotodynamic pumps -- Hydraulic performance acceptance tests -- Grades 1, 2 and 3"

[41] This is to prevent damage to human health, particularly as a result of pathogens, and at the same time account for the well-being of the bathers (e. g. by minimizing the side effects caused by disinfectants)..

This International Standard specifies hydraulic performance tests for customers' acceptance of rotodynamic pumps (centrifugal, mixed flow and axial pumps).

It can be applied to pumps of any size and to any pumped liquids which behave as clean cold water.

The scope of this International Standard, as described on page 1, specifies three levels of acceptance[42]:

- grades 1B, 1E and 1U with tighter tolerance;
- grades 2B and 2U with broader tolerance;
- grade 3B with even broader tolerance.

This International Standard applies either to a pump itself without any fittings or to a combination of a pump associated with all or part of its upstream and/or downstream fittings.

ISO ASME 14414:2015 "Pumping System Energy Assessment"
ISO/ASME 14414:2015 sets the requirements for conducting and reporting the results of a pumping system energy assessment that considers the entire pumping system, from energy inputs to the work performed as the result of these inputs.

The objective of a pumping system energy assessment is to determine the current energy consumption of an existing system and identify ways to improve system efficiency.

3.4 Overview of existing legislation and measures

This subtask presents an inventory and analysis of other existing measures in and outside the European Union.

3.4.1 Legislation and agreements at EU level

Pumps may be addressed, directly or indirectly, by the following EU legislation (non-exhaustive list, in Annex 2 a brief general summary of these EU legislations is given):

- Ecodesign Directive 2009/125/EC, this Directive is relevant for pumps as its implementing measures addresses pumps directly, which is the background for this review study.
- Electric Motors Regulation 640/2009, relevant for pumps as the motor is included in the definition of the EPA; Water Pump Regulation 547/2012, this regulation establishes ecodesign requirements for the placement on the market of rotodynamic water pumps for pumping clean water, including where integrated in other products (see also chapter 2.1). The regulation is being revised currently.
- LVD - Low Voltage Directive 2006/95/EC, the Directive covers electrical equipment with a voltage between 50 and 1000 V for alternating current and between 75 and 1500 V for direct current. For electrical equipment within its scope, the Directive covers all health and safety risks, thus ensuring that electrical equipment is safe in its intended use.
- RoHS 2011/65/EU, is relevant for pumps as this Directive lays down rules on the restriction of the use of hazardous substances in electrical and electronic equipment (EEE) with a view to contributing to the protection of human health and the

[42] ISO 9906:2012 page 1, Scope

environment, including the environmentally sound recovery and disposal of waste EEE.

- MD - Machinery Safety Directive No 2006/42/EC, relevant for pumps as it complies with the definition of Machinery "an assembly, fitted with or intended to be fitted with a drive system other than directly applied human or animal effort, consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application".
- Packaging 94/62/EC (amended by 2004/12/EC, 2005/20/EC and Regulation No 219/2009), covers all packaging placed on the market in the Community and all packaging waste, whether it is used or released at industrial, commercial, office, shop, service, household or any other level, regardless of the material used
- EPBD 2010/31/EU, is relevant for pumps for instance according to Article 2. Point 19[43] when distribution of thermal energy (e.g. hot water) is defined for district heating or district cooling.
- (IED - Industrial Emissions Directive 2010/75/EC) includes former Large Combustion Plant Directive and Integrated Pollution Prevention and Control (IPPC) Directive, in chapter IV article 42 waste water treatment is included which is relevant for this review study as waste water pumps are included in the preliminary scope.
- EMC directive 2004/108/EC, the directive applies to most electrical and electronic apparatus, that is, finished products and systems that include electrical and electronic equipment. Therefore, relevant for pumps. WEEE 2012/19/EU, this Directive on waste electrical and electronic equipment (WEEE) applies to pumps[44] under category 6 and 9 of "Annex I and II"[45].
- Noise by outdoor equipment - Directive 2000/14/EC, pumps are mentioned in the scope of this regulation (ANNEX 1 point 56). Water pump unit: A machine consisting of a water pump itself and the driving system. Water pump means a machine for the raising of water from a lower to a higher energy level.

3.4.2 Legislation and agreements at Member State level

No legislation nor agreements at MS level were found that were significantly relevant for water pumps.

3.4.3 Legislation and agreements at third country level

Energy Conservation Standards for Pumps - United States

The Department of Energy in the US published a final rule for Energy Conservation Standards for Pumps on the 26th of January 2016. Compliance with the new standards established for pumps in this final rule is required on and after 27 January 2020.[46]

[43] district heating' or 'district cooling' means the distribution of thermal energy in the form of steam, hot water or chilled liquids, from a central source of production through a network to multiple buildings or sites, for the use of space or process heating or cooling.

[44] It is not clear whether the complete pump or only its electric/electronic parts are subject to the WEEE Directive.

[45] Category 6: electrical and electronic tools (with the exception of large-scale stationary industrial tools) and category 9: monitoring and control instruments. Subcategory of "Annex IB", for category 6 is: Equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substances by other means and for category 9: other monitoring and control instruments used in industrial installations (e.g. in control panels).

[46] https://www.federalregister.gov/articles/2016/01/26/2016-00324/energy-conservation-program-energy-conservation-standards-for-pumps

The scope in the final rule of this standard is:

- End suction close coupled,
- End suction frame mounted/own bearings,
- In-line,
- Radially split, multi-stage, vertical in-line, diffuser casing diffuser, and
- Submersible turbine.

The DOE proposed to define "clean water pump" as a pump that is designed for use in pumping water with a maximum non-absorbent free solid content of 0.016 pounds per cubic foot (~ 0.25 kg/m^3), and with a maximum dissolved solid content of 3.1 pounds per cubic foot (~ 50 kg/m^3), provided that the total gas content of the water does not exceed the saturation volume, and disregarding any additives necessary to prevent the water from freezing at a minimum of 14°F (-10 °C).
Furthermore, the DOE sets energy conservation standards only for pumps with the following characteristics:

- 25 gallons/minute and greater (at BEP at full impeller diameter); 459 feet of head maximum (at BEP at full impeller diameter and the number of stages specified for testing); Design temperature range from 14 to 248 °F (-10 to 120 °C); Pumps designed to operate with either: (1) a 2- or 4-pole induction motor, or (2) a non-induction motor with a speed of rotation operating range that includes speeds of rotation between 2880 and 4320 revolutions per minute and/or 1440 and 2160 revolutions per minute[47] and in either case, the driver and impeller must rotate at the same speed;For vertical turbine submersible pumps, 6 inch or smaller bowl diameter;

- For end suction close coupled and end suction frame mounted pumps, specific speed less than or equal to 5000 when calculated using U.S. customary units.[48]

Outside the scope of the proposed standard is:

a) Fire pumps;
b) Self-priming pumps;
c) Prime-assist pumps;
d) Magnet driven pumps;
e) Pumps designed to be used in a nuclear facility subject to 10 CFR part 50 - Domestic Licensing of Production and Utilization Facilities; and
f) A pump meeting the design and construction requirements set forth in Military Specification MIL-P-17639F, "Pumps, Centrifugal, Miscellaneous Service, Naval Shipboard Use" (as amended). MIL–P–17881D, ''Pumps, Centrifugal, Boiler Feed, (Multi-Stage)'' (as amended); MIL–P–17840C, ''Pumps, Centrifugal, Close-Coupled, Navy Standard (For Surface Ship Application)'' (as amended); MIL–P–18682D, ''Pump, Centrifugal, Main Condenser Circulating, Naval Shipboard'' (as amended);

[47] The CIP Working Group recommendation specified pumps designed for nominal 3,600 or 1,800 revolutions per minute (rpm) driver speed. However, it was intended that this would include pumps driven by non-induction motors as well. DOE believes that its clarification accomplishes the same intent while excluding niche pumps sold with non-induction motors that may not be able to be tested according to the proposed test procedure. The test procedure final rule contains additional details.
[48] DOE notes that the NOPR included a scope limitation of 1 to 200 hp. In the test procedure final rule, these parameters have been included in the equipment category definitions. Therefore, the limitation is no longer listed separately.

MIL–P–18472G, ‘‘Pumps, Centrifugal, Condensate, Feed Booster, Waste Heat Boiler, And Distilling Plant’’ (as amended).

Pump energy index

The final rule standards are expressed in pump energy index (PEI) values. PEI is defined as the pump efficiency rating (PER) for a given pump model (at full impeller diameter), divided by a calculated minimally compliant PER for the given pump model. PER is defined as a weighted average of the electric input power supplied to the pump over a specified load profile, represented in units of horsepower (hp).

The minimum compliant PER is unique to each pump model and is a function of specific speed (a dimensionless index describing the geometry of the pump) and each pump model's flow at BEP, as well as a specified C-value. A C-value is the translational component of a three-dimensional polynomial equation that describes the attainable hydraulic efficiency of pumps as a function of flow at BEP, specific speed, and C-value. Thus, when a C-value is used to define an efficiency level, that efficiency level can be considered equally attainable across the full scope of flow and specific speed encompassed by this proposed rule.

The C-values proposed by the DOE in Table I.1 correspond to the lower 25th percentile of efficiency for End Suction Close-Coupled (ESCC), End Suction Frame Mounted/Own Bearings (ESFM), In-line (IL). For the submersible turbine (VTS) equipment classes[49] the C-values of 3600 rpm speed pumps correspond to the lower 25th percentile of efficiency, while those of 1800 rpm speed pumps correspond to the baseline efficiency level. The C-values for the Radial Split, Multi-Stage, Vertical In-Line Casing Diffuser (RSV) equipment class harmonize with the standards recently enacted in the European Union[50]. Models in the RSV equipment class are known to be global platforms with no differentiation between products sold into the United States and European Union markets.[51]

Energy star for swimming pool pumps – United States

ENERGY STAR[52] is a US-government-backed symbol for energy efficiency for economic savings and protection of the environment at a national level through energy-efficient products and practices. The US Environmental Protection Agency (EPA) decides which products are part of ENERGY STAR based on a set of criteria which includes, amongst others:

- Products must contribute significant energy savings nationwide
- Certified products must deliver the features and performance demanded by consumers, in addition to increased energy efficiency

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[49] In the test procedure final rule (See EERE–2013– BT–TP–0055), DOE changed the terminology for this equipment class from ‘‘vertical turbine submersible’’ to ‘‘submersible turbine’’ for consistency with the definition of this equipment class. DOE is adopting the acronym ‘‘ST’’ in the regulatory text for long-term consistency with the defined term but has retained the ‘‘VTS’’ abbreviation in the preamble for consistency with the energy conservation standards NOPR and all working Group discussions and recommendations to date (Docket No. EERE–2013–BT–NOC–0039).

[50] Council of the European Union. 2012. Commission Regulation (EU) No 547/2012 of 25 June 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for water pumps. Official Journal of the European Union. L 165, 26 June 2012, pp.28-36.

[51] Market research, limited confidential manufacturer data, and direct input from the CIP working group indicate that RS-V models sold in the United States market are global platforms with hydraulic designs equivalent to those in the European market.

[52] www.energystar.gov

- Energy efficiency can be achieved through broadly available, non-proprietary technologies offered by more than one manufacturer
- Product energy consumption and performance can be measured and verified with testing.

According to ENERGY STAR[53], constant pump speed wastes energy, especially during filtration cycles where half of the flow rate is required for pool vacuuming. In this context ENERGY STAR certified swimming pool pumps are available in variable speeds (either two-speed or variable-speed models). The annual savings established per pump are in the range of 2300-2800 kWh/year for two and variable speed respectively, which translate into around 16.4-18.1 MWh for the whole lifetime (approx.7-10 years). Furthermore, the annual cost savings related to energy use are >50%. ENERGY STAR mentions it is also important to install domestic swimming pool pumps properly (e.g. calculating water volume and determining flow required, as well as calibrating the flow of the new pump to obtain adequate circulation at the lowest possible motor speed). All this information is publicly available and intends to guide domestic users on choosing energy efficient pumps. In addition to guidance and brochures, ENERGY STAR has an open database to compare different types of products available for installation, including swimming pool pumps[54]. Finally, ENERGY STAR works in collaboration with the Association of Pool and Spa Professionals (APSP) to provide certified service on installation and service of the water circulation system.

The key product criteria for evaluating the energy performance of pool pumps is an Energy Factor, which is the volume of water pumped in gallons per watt hour of electric energy consumed by the pump motor (gal/Wh). The minimum threshold for single speed pumps is 3.8 whilst for variable speed (multi-speed, variable speed and variable-flow pumps) is also 3.8 but for the most efficient speed (i.e. the speed with the highest energy factor for a given pump)[55].

APSP has an Appliance Efficiency Pool Pump Database publicly available[56], which was last updated in November 2015 The database shows all energy compliant[57] pumps, showing that from 458 energy efficient pool pumps, only about 8% are single-speed. From the rest, about 48% are dual-speed and 44% are multiple speed.

Australian Standard AS 5102.1:2009 Performance of household electrical appliances – Swimming pool pump-units Part 1: Energy consumption and performance

This series of standards (Part 1 and 2 below) describes the testing and analysis of data required for energy labelling and Minimum Efficiency Performance Standards (MEPS) for single-, two-, multi- and variable-speed swimming pool pumps that:

- Are capable of a flow rate ≥120 l/min
- Have an input power ≤2.5kW
- Are in swimming or spa pools capable of handling > 680 litres of water

[53] https://www.energystar.gov/sites/default/files/asset/document/pool_pump_factsheet_1_0.pdf
[54] https://www.energystar.gov/productfinder/product/certified-pool-pumps/results
[55] https://www.energystar.gov/index.cfm?c=poolpumps.pr_crit_poolpumps
[56] http://apsp.org/resources/energy-efficient-pool-pumps.aspx
[57] Compliant with the ANSI/APSP/ICC-15 2011

The series of standards were developed from the desire of the Australian government to improve the energy efficiency of appliances in households. With swimming pool pumps being one of the appliances and significant users of electricity at home.

The objective of Part 1 standard is to define the tests and measurements to be carried out for the pump to carry a valid energy efficiency label and demonstrate compliance with MEPS.

Specific clean water characteristics are defined for testing, which are very similar to those defined in Regulation (EU) 547/2012, except that the Australian standard goes beyond temperature, kinematic viscosity and density (for testing), defining also values for non-absorbent free solid content and dissolved solid content. Finally, the kinematic viscosity value is defined about 16% higher than that in the EU regulation. The Australian standard defines also test arrangements for calibration of test equipment, test system, pipe and fitting specifications, electrical supply and motor used (a 2-pole induction motor with a minimum Power Factor (PF) at a specific flow rate).

The parameters to be measured from testing are:

- Measurement of flow rate (Q)
- Measurement of pump-unit head (H)
- Measurement of pump-unit power and power factor
- Measurement of sound power

Test procedures are described separately for single-speed pump-units, two-speed and multiple-speed pump units and variable speed units.

The calculations to be done are described for:

- Flow rate intersecting the head (H) – flow (Q) reference curve = Q_D
- Head intersecting the head (H) – flow (Q) reference curve = H_D
- Input power = P_D
- Power Factor = PF_D
- Energy Factor = EF_D
- Average Daily Run Time = DRT_D
- Projected Annual Energy Consumption = $PAEC_D$
- Sound power = L_{WD}

Australian Standard AS 5102.2:2009 Performance of household electrical appliances – Swimming pool pump-units Part 2: Energy labelling and minimum energy performance standard requirements

The objective of Part 2 standard is to specify the energy information disclosure, energy labelling and MEPS requirements for swimming pool pump-units, particularly focusing on the method and calculation of the Star Rating, documentation, format of the label and the procedure for market surveillance (based on testing procedure described in Part 1).

For the determination of the Star Rating, the calculation of the Energy Factor has to be done, which is the volume of water pumped in litres per Wh of electrical energy consumed by the pump motor. The Energy Factor (EF), is calculated from QD and PD as defined in the Part 1 standard. Each unit shall be tested with sufficient test runs to enable valid average values. There are fifteen Star Rating indexes, where half a Star Rating is established from scales 1.0 to 6.0, and one Star Rating can be established from 6.0 to 10.0.

For a summary of other pump related legislation outside the European Union, please see Annex 3.

4 Task C: Extended Product Approach (EPA)

4.1 Introduction

The approach where a product is regarded in several levels from a product level (e.g. a bare shaft pump) to an extended product level (e.g. a pump unit) is called extended product approach[58]. In the existing ecodesign water pumps regulation 547/2012, the Product Approach focuses on the efficiency of the bare shaft pump alone (as in current Regulation 547/2012). The Extended Product Approach (EPA) is focused on the extended product i.e. the pump unit consisting of bare shaft pump, motor and VSD (when applied), considered together. The System Approach focuses on reducing the losses that occur in the system by optimising the pump unit to the desired flow profile. Europump has made a guide[59] to describe how can EPA be applied in implementing measures of water pumps, which was used as starting point for developing this report. The three approaches described above are illustrated in Figure 2.

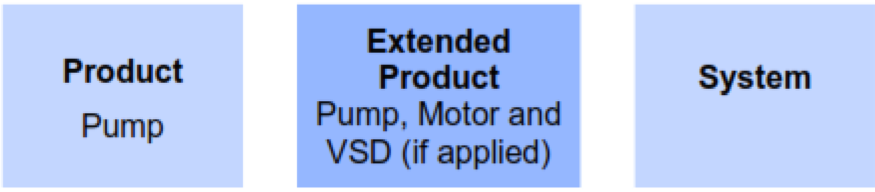

Figure 2. Different approaches of applying energy efficiency for ecodesign implementing measures of water pumps[60].

It is complex to go beyond the Product Approach when defining and implementing energy efficiency policy measures. The more products, sub-assemblies and components are covered under an energy efficiency regulation, the more difficult is to develop reliable methods and measurements to establish the efficiency indicators and to enforce the regulation. According to a report by the International Energy Agency (IEA)[61], many countries find it easier to define and implement product regulations for pumps, fans and compressors above 5 kW. However, regulations for motor driven units[62] offer the potential for greater energy savings.

Already in 2008, the preparatory study Lot 11 on water pumps[63] indicated that three out of the four key areas in which end-users should focus to reduce the energy consumption of a pump are related to how it is fitted to operate within the system. Lot 11 highlighted that optimal pump selection, pump sizing and operating pressures as well as ensuring adequate controls, can lead to energy savings of up to 34%. This fits to the findings from the International Energy Agency, stating that a motor driven unit with energy efficient individual products matched together to meet the required task is able to deliver energy savings of 20%-30%.

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[58] Kemna, R. (2011) Methodology for Ecodesign of Energy-related Products – MEErP 2011. Methodology report Part 1: Methods. Brussels/Delft. 28 November 2011.
[59] Extended Product Approach for pumps. A Europump Guide. 27 October 2014
[60] Adapted from Europump Guide (27 October 2014).
[61] International Energy Agency (2016). Policy guidelines for motor driven units (MDUs). Part 1: Analysis of standards and regulations for pumps, fans and compressors. Energy efficient end-use equipment – International Energy Agency. October 2016.
[62] A motor driven unit (MDU) is an extended product that converts electrical power into rotational mechanical power and may consist of the following individual components: variable speed drive, electric motor, mechanical equipment (gear, belt, clutch, brake, throttle) and a driven application (pump, fan, compressor, transport).
[63] AEA Energy & Environment (2008) Lot 11 - Water Pumps (in commercial buildings, drinking water pumping, food industry, agriculture). ED Number 02287. Issue Number 6. AEA Energy & Environment. April 2008.

In spite of the identified potential energy savings and the importance of the extended product approach, its application has been barely applied at a regulatory level.

4.2 Terminology

The terminology used for products and extended products for water pumps in energy efficiency policy measures is defined by:

- The scope, whether the focus is the pump alone or the motor and other components
- The optimisation of the pump and eventually of other components, to achieve higher levels of energy efficiency
- The enforcement of the measures, and whether this has to be done at a product, extended product or system level. As explained above, the application of extended product and beyond is rarely applied in the EU, although it is found in some product groups like glandless circulators where the evaluation of their energy efficiency considers the motor and the control unit.

Terminology regarding EPA

Product Approach in the case of water pumps refers to the application of energy efficiency measures for the product, i.e. the water pump. According to input from industry, it is called 'Bare shaft pump' because it is placed on market without the base, motor and control system (see Figure 3). Throughout this report, this is referred to as 'pump'.

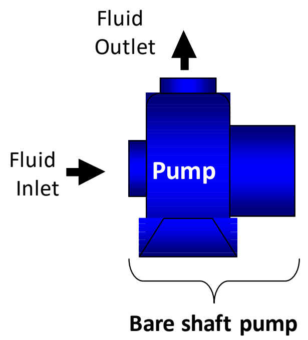


Figure 3. Representation of a bare shaft pump considered in the Product Approach (as it stands in current Regulation 547/2012).

Extended Product Approach refers to the application of energy efficiency measures for the extended product, i.e. the water pump, the coupling, the electric motor and (optionally) the continuous control[64]. According to input from industry, it is called 'Pump unit' because it includes the whole unit that converts electricity power to hydraulic power (see Figure 4).

[64] Continuous control refers to Variable Speed Drives thorough this report

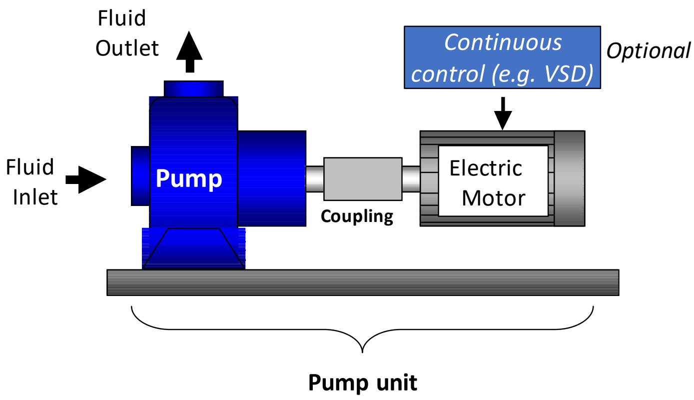


Figure 4. Representation of a pump unit considered in the Extended Product Approach.

System Approach, refers to the use of the pump unit in a specific water supply/water treatment system and its potential for optimising electric power to deliver the desired hydraulic power. Specifically, the EPA for pumps considers whether they are used in constant flow systems or in variable flow systems.

Terminology regarding optimisation and energy efficiency

In the current Regulation 547/2012, the pump is designed for a range of flow in pressure combinations that it will deliver once installed and that are optimised in order to reduce hydraulic losses and achieve higher levels of efficiency at product level. This is done in relation to the use of the mechanical power transmited to the pump and the hydraulic power the pump delivers.

In the extended product approach (EPA), the power of a pump unit can be characterised by (see Figure 5):

- P1: the electric power supplied to the motor (or to the Variable Speed Drive, VSD)
- P2: the mechanical power supplied via the shaft from the motor to the pump (shaft power)
- P_{hyd}: the hydraulic work done by the pump

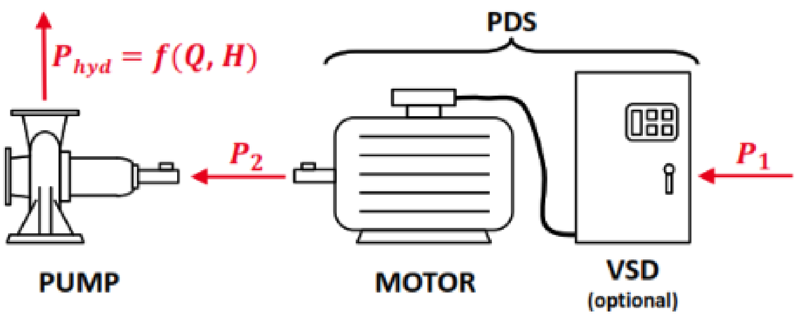


Figure 5. Schematic of the power flow on a pump unit[65].

The relationship between the values at a given load is:

$P_{hyd} = P_2 \cdot \eta_{hyd}$, $P_2 = P_1 \cdot \eta_{motor} \cdot \eta_{VSD}$ or $P_{hyd} = P_1 \cdot \eta_{motor} \cdot \eta_{hyd} \cdot \eta_{VSD}$

[65] Extended Product Approach for Pumps, A Europump Guide, October 2014, Europump.

Here η_{hyd} is the hydraulic efficiency of the pump, η_{motor} is the efficiency of the motor and η_{VSD} is the efficiency of the VSD.

When describing certain characteristics of the performance of the pump unit, the following terms are used with indices:

- Maximum (_max), the design maximum load
- BEP (_BEP), the power at Best Efficiency Point, the point of operation where the pump has the highest hydraulic efficiency
- Average (avg), the average power over time, depends on how the pump is used (variable flow or constant flow)

The overall efficiency of the pump unit is $\eta = \frac{P_{hyd}}{P_1} = \eta_{motor} \cdot \eta_{hyd} \cdot \eta_{VSD}$ and the best efficiency is at BEP:

$$\eta_{BEP} = \frac{P_{hyd,BEP}}{P_{1,BEP}} = \eta_{motor,BEP} \cdot \eta_{hyd,BEP} \cdot \eta_{VSD,BEP}$$

In the Regulation (EU) 547/2012 the categorisation of pump units according to size is normally made using the maximum load of the pump, that is maximum shaft power ($P_{2,max}$), or with other factor such as norminal diameter or design pressure. In this study the size categorisations are made to be similar to those in regulation 547/2012 and in the preparatory studies.

Terminology regarding enforcement

The Ecodesign Directive concerns products that are placed on the market and/or put into service:

- 'Placing on the market' means making a product available for the first time on the Community market with a view to its distribution or use within the Community, whether for reward or free of charge and irrespective of the selling technique;"
- 'Putting into service' means the first use of a product for its intended purpose by an end-user in the Community;"

An Extended Product Approach can be applied for the development and implementation of ecodesign requirements of water pumps and will result in large potential savings. However, this approach brings some challenges because it will be necessary to assess conformity and carry out market surveillance not only for products placed on the market by the manufacturer, but also for products assembled by installers prior to the installation at the end-user's place.

An assessment of different market surveillance approaches is described in chapter 13 of this report, including the main challenges and opportunities from the different approaches.

4.3 Performance parameters

The performance parameters can be determined according to the different approaches explained in previous sections. In a Product Approach the focus is on how the product itself performs. For water pumps the overall performance and energy use is dependent not only on the pump itself but the other components it is coupled with and the system it is placed in. Therefore, the performance of a pump can also be seen from an Extended Product Approach or a System Approach .

If the Product Approach is used for ecodesign regulation, it can be ensured that only energy efficient pumps are placed on the market, but that does not ensure lower energy consumption. The energy consumption of pumps depends on factors such as the rotational speed of the motor and the system curve of the pump system (i.e. its flow and pressure profile). If the pump is connected to a fixed speed motor, the system will only be energy efficient if the pump is used in a constant flow system. With a VSD (or another mean to adjust the speed, i.e. continuous control) the rotational speed of the motor can be adjusted to the demand in a variable flow system. This will reduce energy losses in the motor from operating it constantly at full speed, as well as the losses occurring in the hydraulic circuit when the motor is operated at full speed (without VSD) when only a reduced flow is needed (illustrated in Figure 6). Theses losses typically occur when a valve is used to throttle the flow, as illustrated in Figure 7. Energy consumption is proportional to the pressure; so lower pressure means lower energy consumption[66].

The process for implementing EPA in the EU regulation work progresses in two parallel tracks. Europump has developed a guide to create a common understanding of the subject and to guide the process towards developing actual standards. In parallel the European Commission issued Mandate 498, aiming to create harmonised standards covering an EPA. Currently, two standards have been developed: FprEN 17038-1:2017[67] and FprEN 17038-1:2017[68], and another is on the process of being developed.

In the Europump guide, an EPA is defined as a methodology to calculate the Energy Efficiency Index (EEI) of an Extended Product (EP), which incorporates load profiles and control method for a set of physical components.

Following this, Europump defined the extended pump product as a pump driven by an electric motor with or without variable speed drive with given load profiles (see Figure 6).

[66] Extended Product Approach for Pumps, A Europump Guide, October 2014, Europump..
[67] Pumps - Methods of qualification and verfification of the Energy Efficiency Index for rotodynamic pump units - Part 1: General requirements and procedures for testing and calculation of energy efficiency index (EEI)
[68] Pumps - Methods of qualification and verification of the EnergyEfficiency Index for rotodynamic pump units - Part 2: Testing and calculation of Energy Efficiency Index (EEI) of single pump units

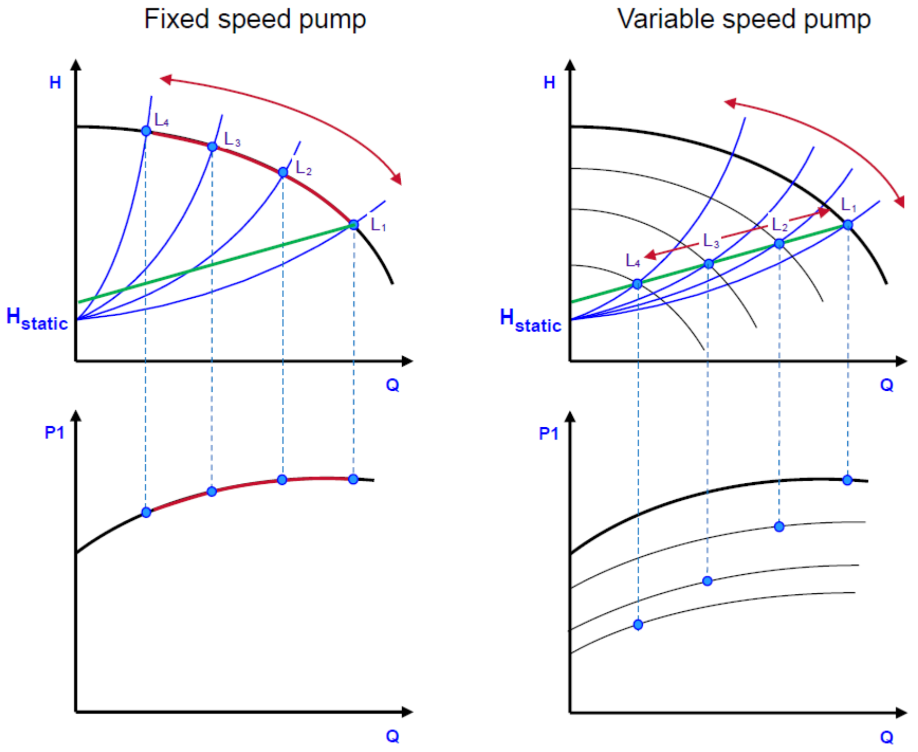


Figure 6. Illustration of operation with fixed speed pump and variable speed pump[69].

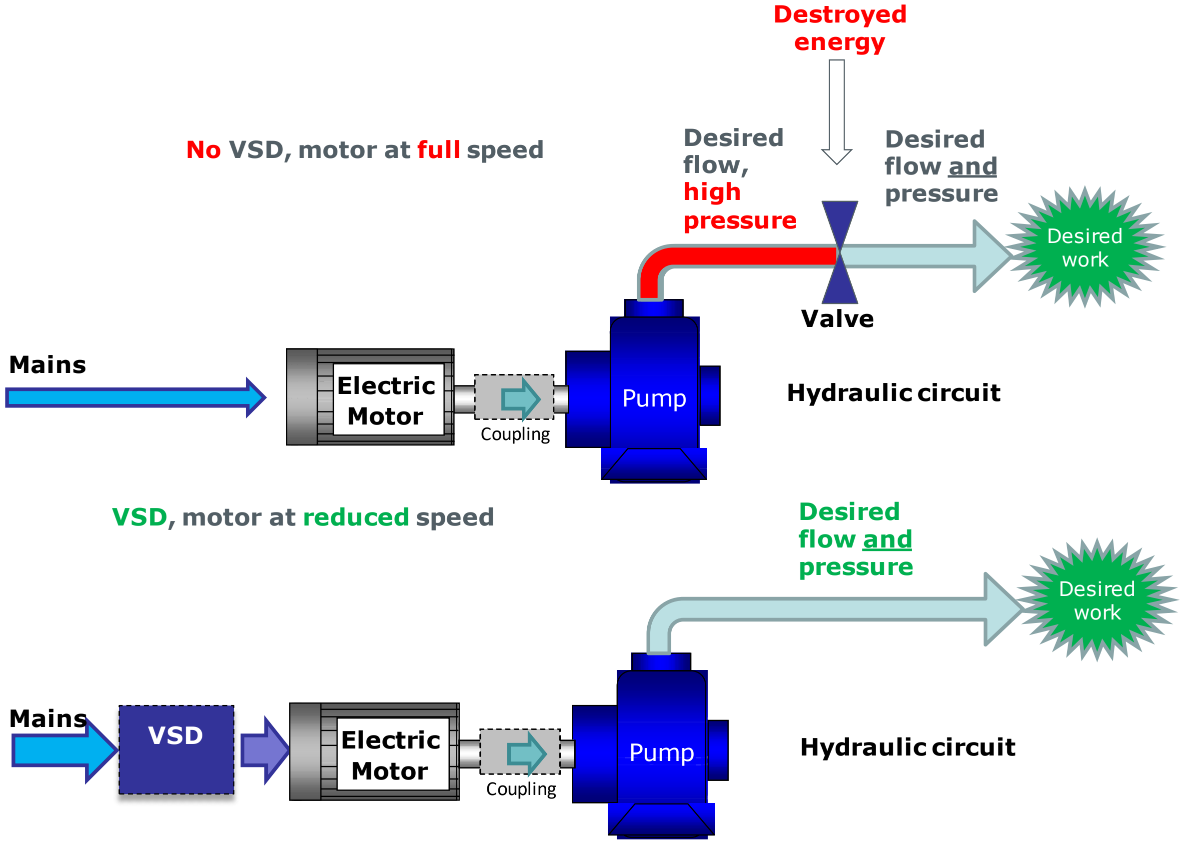


Figure 7. Illustration of system losses and improvement before and after installing a VSD, when low flow is needed.

[69] Extended Product Approach for Pumps, A Europump Guide, October 2014, Europump

Water pumps can be divided into two groups according to the intended system:

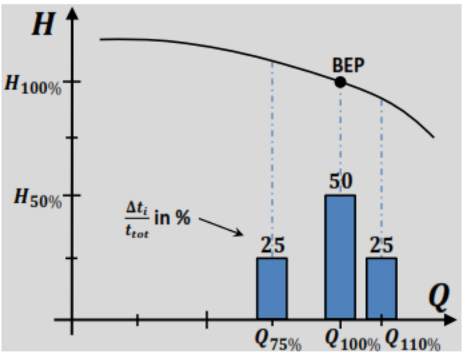
- **Constant flow systems:** where the pump is pumping at best efficiency point (BEP) with slight variations of the flow rate around the nominal value; and
- **Variable flow systems:** where a widely varying demand for flow rate and water pressure or differential pressure has to be generated by the pump.

Note that 'Constant flow system' in this context does not mean that there is no variation in the flowrate, it means that there is no variation in the desired flowrate and therefore there is no need for controls such as a control valve. A typical constant flow system is draining or filling of a reservoir, where there is no need for controlling the flowrate, but the flowrate will fluctuate as the head from the reservoir is changing.

For both types of systems typical and standardized flow-time profiles and reference control curves are defined and used to calculate the corresponding energy efficiency. In section 4.4 this energy efficiency calculation will be explained in more detail. The flow-time profile describes the percentage of time a certain flow is needed in the system. The reference control curve is a standardized control curve, which describes the desired head at the flows defined in the flow–time profile.

Figure 8 and Figure 9 show the flow-time profiles for constant and variable flow systems as they are defined in EPA for Pumps, A Europump Guide, October 2014[70]. Notice that the flow-time profiles are defined as step-functions. It is assumed that the pump has the correct BEP compared to the application, so that in variable flow system the nominal flowrate of the pump is equal to the maximum required flowrate for the application ($Q_{100\%}$). For constant flow applications it is assumed that BEP matches the most frequent operation point ($Q_{100\%}$). This means that for constant flow applications the flowrate varies around BEP being both lower ($Q_{75\%}$) and higher ($Q_{110\%}$).

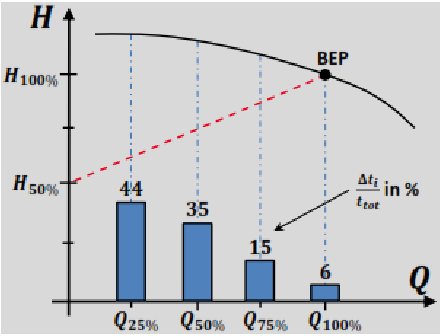
The flow-time profiles are different for constant flow applications and variable flow applications. Setting a clear division for constant and for variable flow requirements makes it possible to compare how well pumps are performing in each application.



	Flow [%]	Time [%]
L_1	110	25
L_2	100	50
L_3	75	25

Figure 8. Flow-time profile for constant flow systems[65].

[70] Ibid.



	Flow [%]	Time [%]
L_1	100	6
L_2	75	15
L_3	50	35
L_4	25	44

Figure 9. Flow-time profile variable flow systems[65].

4.4 Energy Efficiency Index - EEI

To evaluate the energy efficiency according to EPA, the concept of 'Energy Efficiency Index' (EEI) has been developed. An EEI represents the overall energy efficiency of the extended product calculated according to the intended flow-time profile from measured electricity consumption at each operation point. EEI is the average power input calculated on a flow-time profile divided by a reference power input. A graphical presentation of the EEI calculation is shown in Figure 10[71]. The left side shows the calculation of average power input i.e. the numerator of the EEI index. The right side shows how to calculate the reference power i.e. the denominator of the EEI index.

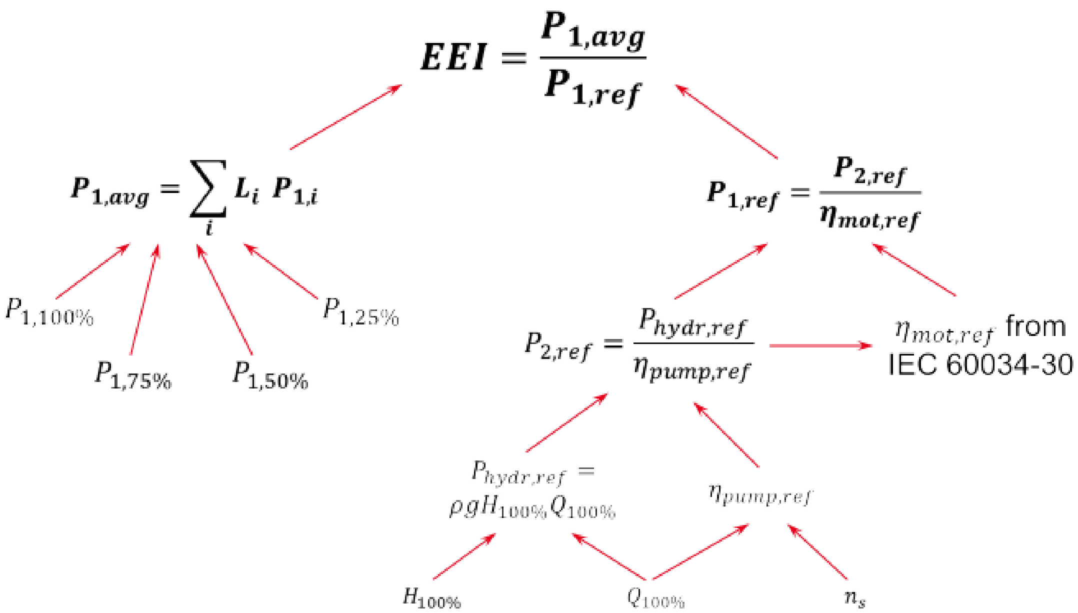


Figure 10. Graphical representation of the Energy Efficiency Index (EEI).

$P_{1,i}$ represents the electricity consumption at the i^{th} load level and is based on measurements of the pump unit (pump + motor + VSD (optional)). L_i represents the share of the time the pump is running at i^{th} load level according to the flow-time profile for variable speed flow systems.

The reference power input ($P_{1,ref}$) is calculated from the reference power input to the pump ($P_{2,ref}$) and the reference motor efficiency ($\eta_{mot,ref}$) from IEC 60034-30. $P_{2,ref}$ is calculated from the reference hydraulic power ($P_{hyd,ref}$) and the reference pump efficiency ($\eta_{pump,ref}$).

[71] Extended Product Approach for Pumps, A Europump Guide, October 2014, Europump

$P_{hyd,ref}$ is derived from the reference flow rate ($Q_{100\%}$) and head of the pump, and $\eta_{pump,ref}$. is calculated as:[72]

$$\eta_{pump,ref} = -11.48 \cdot (ln(n_s))^2 - 0.85 \cdot (ln(Q_{100\%}))^2 - 0.38 \cdot ln(Q_{100\%}) + 88.59 \cdot ln(n_s) + 13.46 \cdot ln(Q_{100\%}) - C$$

Here n_s is the specific speed, which is given as:

$$n_s = n_{100\%} \cdot \frac{\sqrt{Q_{100\%}/3600}}{\left[H_{100\%}/i\right]^{0.75}} \quad [\min^{-1}]$$

4.5 EPA in ecodesign

Europump developed a roadmap for energy efficiency regulation on pumps in the EU as can be seen in Figure 11. This roadmap served as an overview showing the Ecodesign requirements of the extended products which are integrated in the EPA for pumps.

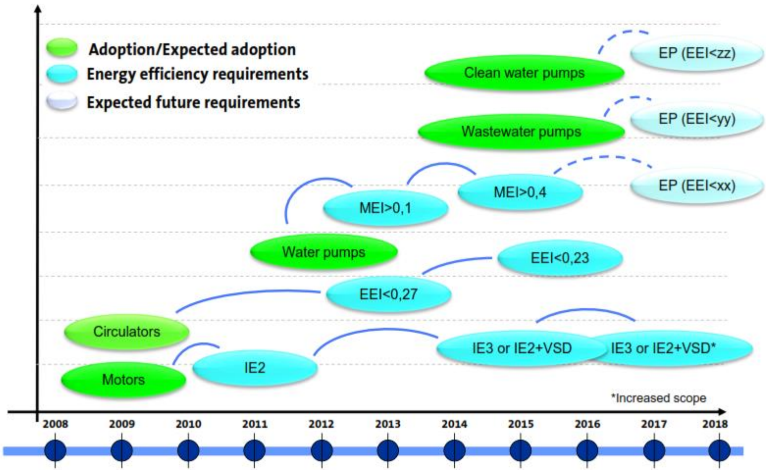


Figure 11. Roadmap for energy efficiency regulations on pumps in EU[73].

The extended product approach (and the corresponding energy efficiency index (EEI)) is currently used for setting Ecodesign requirements for glandless circulators[74]. A glandless circulator is an impeller pump with the shaft of the motor directly coupled to the impeller and the motor immersed in the pumped medium. However, glandless circulators do not require verification at installation since they are placed on the market as pump units.

The product in the EPA methodology comprises in both cases of a motor, a drive and pump for which typical standardised flow time profiles have been created.

Part of Mandate 498 is to create an EPA for the water pump categories that are within the scope of Regulation 547/2012 (clean water pumps)[75]. The working group of CEN has drafted the EPA part 1 (General requirements and procedures for testing and calculation

[72] As given in prEN 17038-2:2016
[73] Extended Product Approach for Pumps, A Europump Guide, October 2014, Europump
[74] COMMISSION REGULATION (EC) No 641/2009
[75] http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=select_attachments.download&doc_id=1406

of energy efficiency index (EEI)) and part 2 (Testing and calculation of energy efficiency index (EEI) of single pump units).

In order to implement EPA in the regulation for pumps it is furthermore necessary to define the minimum allowed EEI values. This requires a thorough investigation of the available technologies on the market. More specifically it is necessary to gain sufficient information to calculate the EEI values of the pumping units available on the market for each flow-time profile separately (variable and constant). Thereby it can be determined the share of the market which can meet the requirements of a given EEI value for a given flow-time profile.

Wastewater pumps are more difficult to evaluate and regulate. Wastewater pumps that are designed for different types of wastewater cannot be compared in energy efficiency directly, since other design requirements can affect the energy efficiency[76]. Furthermore, there are no appropriate test standards for testing the energy efficiency of wastewater pumps. To develop an appropriate test standard for testing wastewater pumps more scientific research is required. The testing of efficiency is not the problem as it can be done with clean water. A classification of the waste water types and a test procedure for the non-clogging behaviour of the pumps is needed. Sources in the industry state that it will take at least 5 years before the necessary test standards are developed. In principle wastewater pumps could be tested under the same procedures as those used for clean water pumps, including using clean water. However, the application of these tests would only be useful to test the pump working ability but data on pumps efficiency would be very different to the real life performance as the fluid properties affect greatly the amount of flow pumped and the head reached which subsequently affect the pump efficiency.

4.6 Energy saving potentials from EPA

A regulation of pumps that includes EPA will rank the pumps according to EEI. The EEI ranking will depend on the intended use of the pumps. A pump designed for variable flow systems will have an EEI according to the variable flow-time profile. This will ensure that pumps for variable flow applications will be ranked according to how suited the applied power drive system (PDS, i.e. motor + VSD) is for these applications. It can be predicted that EPA regulations will lead to a situation where only pumps fitted with the appropriate motor technologies are allowed to be sold. That means that pumps with VSD will gain higher EEI ratings for variable speed applications, but a lower EEI for constant speed systems. Other variations in PDS will also influence the EEI as well as the efficiency of the pump itself.

To estimate the impact of EPA in the regulation, it is assumed that the regulation will lead to a situation, where all pumps for variable speed applications are progressively replaced with pump units fitted with VSD, and all pumps for constant speed applications are replaced with pump units fitted with the most efficient PDS category. The EPA energy savings are those estimated savings that can only be achieved with EPA and not by a normal product approach. Therefore, potential improvements regarding PDS in conjunction with the pump have been considered the focus of this study. It needs to be noted that in some cases it was not possible to use the EPA methodology as this was not yet fully developed for all pump types[77].

[76] Input from representatives of wastewater manufacturers
[77] Some cases where the EPA methodology is not developed into a test standard are: swimming pool pumps, waste water pumps, booster sets (under development), submersible borehole pumps (under development).

For the clean water pumps within the final scope of this study (see chapter 12), the 2015 calculated total energy consumption was 166 TWh/year (see Table 58), of which 91.5 TWh/year were for variable flow applications and 74.5 TWh/year for constant speed applications.

For swimming pool pumps, the 2015 calculated total energy consumption was calculated was 7.3 TWh/year, but all swimming pool pumps were considered to be operating with constant flow (in the EU)[78]. Therefore, the estimated EPA savings potential were calculated between 0.6 to 1.4 TWh/year based purely on improvement of pump and motor technologies.

For wastewater pumps, the 2015 calculated total energy consumption was 19 TWh/year, of which only 1 TWh/year were from variable flow applications and 18 TWh/year were from constant flow applications.

According to input from industry, all wastewater pumps used in variable flow systems have VSD. However, some wastewater pumps such as vortex and channel are not perceived to be reliable by utilities when operated in variable flow and thus only about 5% to 7% of their total EU-28 stock are used that way. According to input from utilities and industry, more wastewater pumps could be operated in variable flow, if the utilities knew more about the advantages and technical feasibility of using these pumps in variable flow. Additional potential savings could come from increasing the share of wastewater pumps operating in variable flow applications (see Table 20 which indicates that the majority of wastewater pumps are used in constant flow applications). Slurry pumps are often used with belt drives for speed regulation. Although this form of speed regulation might not be as energy efficient as a frequency converter, belt drives are often preferable in slurry pumping since it functions as a safety mechanism that protects the pump against sudden increase in load. It is therefore expected that the efficiency of slurry pumps cannot be improved by changing the power drive system.

Overall it is shown that there is a very significant energy saving potential for applying EPA regulation for clean water pumps, while the potential is much smaller for swimming pool pumps and wastewater pumps. However, this is only based on the assumptions that there is no additional potential for inclusion of variable flow applications which will be evaluated further in the subsequent tasks.

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[78] According to the Working Group of EUSA to the "Review study of ecodesign and energy labelling for pumps", 13/11-2015

5 Task D1: Discussion of proposed preliminary scope of study

This section discusses the preliminary scope, which is based only on the review of previous preparatory studies and current legislation, as well as a couple of remarks from stakeholders and loopholes identified in the current Regulation (EU) 547/2012. The preliminary scope was defined based on (i) relevant experiences from current legislation, (ii) ambiguities identified in current regulation and previous preparatory studies, and on (iii) technical aspects that were considered relevant to define the pumps' categorisation. The selection of pumps in the 'preliminary scope' was made quantitatively, in order to make sure that the pumps studied in further tasks presented a certain level of savings potentials and/or had an important contribution to the overall energy consumption at EU level of all the pumps assessed. The 'preliminary scope' has formed the basis for early discussions with industry stakeholders about the pumps that shall be included in the final scope. A final scope is presented at the end of this report, which is a refinement from the preliminary scope based on input data and information from tasks D2, D3 and D4.

The preliminary scope is shown in Annex 4.

5.1 Main findings related to scope from current legislation and preparatory studies

5.1.1 Third countries legislation

The reviewed legislation in countries outside the EU shows a less comprehensive scope for most of the mandatory/voluntary schemes found. In several cases the scope is very much aligned with the scope of EC Regulation 547/2012, but in some others the schemes cover a wider range of water pumps. This is the case for the Comparative Label in Argentina which covers all centrifugal pumps (mandatory), the schemes in Bangladesh which cover all types of water pumps over 2 HP (voluntary), the Endorsement Label in Brazil which covers all centrifugal pumps (voluntary), the schemes in Iran covering centrifugal, mixed flow and axial pumps (mandatory) and the MEPS in the United States covering industrial and commercial pumps (mandatory). Other pumps covered by third countries regulations are swimming pool pump units (Australia), glandless circulators (Jordan, Switzerland & Turkey), vertical turbine pumps (Mexico) and deep water well pumping systems (Mexico).

As it is noticed, most of the more comprehensive schemes are voluntary, with the exception of the schemes from Argentina, Iran and the United States. However, concerning the legislation in the United States, there are obvious similarities in scope and requirements with the current EU regulation in water pumps but at the same time providing more ambiguous definitions of the pumps in scope. An adoption of these requirements in the current EU regulation would introduce more ambiguities with the scope whilst not making significant changes in terms of requirements. Argentina and Iran legislation focus more on pump technologies than on functionality, which may create future loopholes if technologies change in the future for the same applications. It is therefore not suggested to adapt the scope and requirements in the EU regulation to accommodate the wider scope found in third country legislation. However, individual elements from third country legislation and voluntary agreements may be used as inspiration to clarify present ambiguities and provide a basis for future legislation of pumps not currently included in EU Regulation 547/2012.

5.1.2 Lot 28 & Lot 29

Ambiguities in previous preparatory studies have also been identified by Europump[79] and during the execution of this study. These are related to the following topics:

- Definition of swimming pools pumps is ambiguous, particularly as they can overlap with the end suction pumps categories for big size pumps.
- Definition of submersible borehole pumps stands for specific nominal outer diameters of 8″, 10″ and 12″ in the lower range, which may leave out pumps with other diameters; furthermore, smaller diameters included in the 547/2012 Regulation are also limited to 4″ or 6″ leaving out borehole pumps with diameters of 3″ and 5″.
- The exclusion of horizontal multistage water pumps is not justified anywhere, therefore an unknown potential of energy savings is withdrawn, as these pumps are used widely both in building and industrial applications.
- The lack of distinction between slurry pumps light duty and heavy duty, as no operational parameters are mentioned nor any qualitative description.

5.2 Suggested preliminary scope of the study

5.2.1 Suggested functional unit

As described in section 3.2, the functional unit is the reference value for any water pump to be compared, and for this review study it has been defined based on the primary functional parameters identified from Lot 11, Lot 28 and Lot 29. The functional unit is, therefore:

- The "**quantity** (m^3 or kg) **of a specific type of water** to be pumped at the **specified head** (m) and **flow** (m^3/h, m)"

The quantity (flow) and head (pressure) are to be defined by the water pump users, depending on the specific pumping application. Furthermore, it is important that the type of water to be pumped is also a part of the functional unit (i.e. as "fluid properties"), as pumps for clean water applications will have very different performance than those for wastewater applications. Once these values are defined, the pump users can choose between different pump types taking also into account the pumps' efficiencies.

The type of water defines the application of the pump, assures a function-based clustering of products, and brings the importance of defining and harmonising water types/classes. Fluid properties are a parameter that cannot be established quantitatively to all the pump types identified from previous preparatory studies. This is due to the lack of harmonisation and a scientific definition of water for swimming pools, wastewater, sand water, grit water and slurry as discussed previously. An overview of the current status and problems with water and wastewater characterisation is presented in Table 7.

Clean water is defined in the current regulation, article 2 (13), as "water with a maximum non-absorbent free solid content of 0.25 kg/m^3, and with a maximum dissolved solid content of 50 kg/m^3, provided that the total gas content of the water does not exceed the saturation volume. Any additives that are needed to avoid water freezing down to – 10 °C

[79] 'Follow-up of our meeting on 17 March 2015'. Letter sent by Europump to Viegand Maagøe, dated on the 22 April, 2015

shall not be taken into account". The same definition cannot be applied to swimming pool water nor to wastewater, sand water, grit water and slurry.

Swimming pool water is treated to maintain certain chemical, physical, bacteriological and biological standards[80], and it is submitted to chemical treatment for disinfection. The parameters used to characterise swimming pool water are different to those use to characterise clean water . This is because the water is recirculated and reused and it requires to be filtered and treated in order to keep the hygienic levels required. Since the water has a residence time in the pool, it needs to be assured that it remains at these levels while in the pool and that when it is recirculated and filtrated it comes back to the pool with at least the same levels. Furthermore, the water needs to keep a certain level of clarity, colour and turbidity so the user of the pool feels comfortable while swimming in it. All these requirements are different to clean water, and in spite both types of water are in direct contact with humans, the fact that swimming pool water is reused and stored in a pool where people remain for a certain amount of time, demands other characterisation that cannot be measured the same way as clean water.

The characteristics of wastewater, sand water, grit water and slurry are even more different to clean water, and it is evident that the clean water definition cannot be used to characterise them.

In order to promote technological innovation to reduce the environmental impacts in the European Union and remove energy related products representing low environmental performance, the application of the products is meant to be the basis for comparison and that is why it is important to define a Functional Unit[81]. It is therefore the intention to maintain the classification of pump types categories based on their application. Instead or removing the possibility of doing so, it is decided to keep the pump application categorisation and study further these possibilities along the course of this study.

Table 7. Water types relevant for pumps in scope and their potentials and barriers for characterisation.

Water type	Quantitative definition	Harmonised definition	Typical characterisation parameters	Source
Clean water	Yes	Yes	Non-absorbent free solid content, dissolved solids content, total gas content	547/2012
Swimming pool water	Maybe possible	Maybe possible	Water clarity, colour of water, turbidity, nitrate, TOC, redox potential, pH, chlorine, cyanuric acid	EN 16713-3:2015
Wastewater	Maybe possible	Maybe possible	Viscosity, rag, grit, organic matter, suspended solids, nitrogen, Person Equivalent	Lot 28 (based on UWTD[82]) and other scientific material on ww characterisation[83]

[80] EUSA Pool pump working group position paper #2. Paris, 21/03/2016

[81] According to MEErP methodology: "the clustering products - should be a quantifiable "functional unit", which should be the yardstick for clustering products in one preparatory study and apply specific Ecodesign measures that are technology-neutral. For instance, all products that serve domestic preservation of perishable foods should be brought into one cluster.'

[82] Urban Wastewater Treatment Directive

[83] Different scientific material can be found available regarding wastewater characterisation. An example is Henze, M. & Comeau, Y. (2008). Wastewater Characterization. Biological Wastewater Treatment: Principles Modelling and Design. Edited by M. Henze, M.C.M. van Loosdrecht, G.A. Ekama and D. Brdjanovic. ISBN: 9781843391883. Published by IWA Publishing, London, UK.

Water type	Quantitative definition	Harmonised definition	Typical characterisation parameters	Source
Sand water (high solids content water)	No	No	Suspended solids? Sediments?	Lot 28
Grit water (high solids content water)	No	No	Suspended solids? Sediments?	Lot 28
Slurry	No	No	Suspended solids? Sediments?	Lot 28

5.2.2 Suggested secondary performance parameters

According to the review of the regulation and of preparatory studies, additional performance parameters must also be considered when developing policy options, as they offer instrumental guidance on the specification of a water pump since they have a direct influence on the performance of the pump and, in this particular case, on the efficiency of the pump. A list of secondary parameters has been consolidated from all the preparatory studies and further input from stakeholders. A selection is presented below, considering their relevance to the evaluation of the pumps' energetic performance, their design and their lifetime:

Relevant to all pumps:

- *Pumping application*: Characteristic of the pump application (i.e. wastewater, clean water, swimming pool water or pressure boosting).
- *Stage (i)*: the number of series impellers in the water pump
- *Pump specific speed (n_s)*: dimensional number characterising the impeller type (radial, semi-axial, axial) of rotodynamic pumps by calculating the flow, head, and rotational speed at Best Efficiency Point (BEP).
- *Hydraulic pump efficiency (η)*: calculated from the ratio between the mechanical power transferred to the liquid during its passage through the water pump (hydraulic power), and the mechanical input power transmitted to the pump at its shaft (shaft power).
- *Head (H)*: hydraulic pressure produced by the pump measured in meter water column (m) at the operation points, Best Efficiency Point (BEP), Part Load (PL) and Over Load (OL). For swimming pool pumps, the total head takes into account the head loss of passing the swimming pool water through the filter (i.e. the filter head loss).
- *Flow rate (Q)*: Rate of volume of water displaced by the pump measure in m3/h at the operation points, Best Efficiency Point (BEP), Part Load (PL) and Over Load (OL).
- *Minimum Efficiency Index (MEI)*: the dimensionless scale unit for hydraulic pump efficiency at BEP, PL and OL.
- *Expected lifetime of the pump*: explained previously.
- *Use of Variable Speed Drives (VSD)*: explained previously.

Relevant only to swimming pool pumps:

- *Minimum flow rate*: the minimum amount of water volume that circulates through a swimming pool's filtration system to maintain the pool water clean and only relevant for swimming pool pumps.

- *Maximum turnover rate*: the maximum amount of time the pool water takes to circulate once through the filtration system in order to keep the pool water clean and only relevant for swimming pool pumps.
- *Noise*: explained previously and only relevant for swimming pool pumps.
- *Material requirements*: explained previously and mainly relevant for swimming pool pumps where the decision on pumps' materials can affect the performance and cost of the pump.

Relevant only to wastewater, sand water, grit water and slurry pumps:

- *Clog resistance capability*: the ability of the pump to avoid clogging from solids in wastewater, making the pump more able to handle fluids with higher and/or large solids content and only relevant for wastewater and solids handling pumps.
- *Wear resistance capability*: the ability of the pump to avoid wear from abrasive materials contained in wastewater and only relevant for wastewater and solids handling pumps.

5.2.3 Pumps definition and classification

The suggested pump types and classification for the preliminary scope of this review study have been identified based on at least one of the next criteria:

a. They are included in the current Regulation (547/2012).

b. Based on pumps defined in previous preparatory studies: The pumps represent an important share of the total energy consumption of pumps in the EU[84] (those contributing less than 0.5% of the total energy consumption of pumps have been excluded). This is an arbitrary level which had to be defined by the study team to make a quantitative screening of pumps to be excluded from the 'preliminary scope', in order to limit the scope to the pumps that are considered important. This was taken into account together with the energy savings potential in an individual manner, due to the absence of a harmonised method in previous preparatory studies to quantify these savings.

c. Based on energy savings potentials calculated in previous preparatory studies: The pumps' potential energy savings are significant in the EU, at product level and/or at EPA level.

d. Booster-sets which have not been discussed in the previous preparatory studies have been added to the preliminary scope of this study: Booster-sets are per definition an extended product of a multi-stage pump. It is expected, according to some stakeholders, that this type of pumps present large savings potential when applying the EPA.

e. Self-priming water pumps which were excluded in the preparatory studies but have been added to the preliminary scope of this study: Reliable estimates on energy consumption and energy saving potential are missing at this stage.

f. Horizontal multi-stage water pumps which were outside the scope of the preparatory studies have been added to the preliminary scope of this study: Europump is concerned that by not including this category it can become an

[84] Lot 11 used data from 2007, and Lot 28 & Lot 29 used data from 2011

important loophole in relation to vertical multi-stage water pumps and also booster-sets, if they are included in a further regulation.

The grouping of the presented pump types has been made according to fluid type. It is expected this will avoid confusions by manufacturers and those who have to apply the regulation. For swimming pool pumps this was not possible, and therefore the grouping was made purely from the fact that no definition for swimming pool water is yet publicly available and the fact that the application of these pumps is different to that of clean water pumps.

The borehole MSS pumps for clean water at the different ranges have been merged in three groups to include other diameters than those specifically mentioned in the regulation and in the preparatory study.

End-suction own bearing (ESOB) pumps, submersible bore-hole pumps and vertical multi-stage pumps with sizes larger than what mentioned in Lot 11 have also been included. Europump specifically requested exclusion for these larger pump sizes.

It is understood that they may be engineered products and therefore more difficult to regulate, but at this stage of the review study it is suggested to include them and a further evaluation of their inclusion will be made after data has been analysed in subsequent tasks of this review study.

The excluded pumps are listed below, together with their relative contribution to the total estimated energy consumption (a detailed explanation of the method to estimate this consumption is presented in the next section):

- **Centrifugal submersible wastewater pumps operated once a day**: 0.04% of the estimated total;
- **Centrifugal submersible domestic drainage pumps (<40mm passage)**: 0.05% of the estimated total;
- **Centrifugal mixed flow and axial dry well wastewater pumps**: 0.05% of the total;
- **Fountain and pond pumps up to 1kW**: 0.12% of the estimated total;
- **Aquarium pumps (non-commercial & head, up to 120kW)**: 0.2% of the estimated total;
- **Spa pumps for domestic and commercial use**: 0.01% of the estimated total;
- **Counter-current pumps**: 0.03% of the estimated total;
- **End suction close coupled, 150kW - 1MW**: 0.3% of the estimated total;
- **End suction close coupled inline, 150kW – 1MW**: 0.3% of the estimated total.

5.3 Suggested pump types and categorisation based on previous preparatory studies

Thirteen pump types intended for clean water have been identified for the preliminary scope. Five of them already exist in the current Regulation (547/2012), four were included in Lot 29 and four have been identified from discussions with stakeholders. All have been included on the basis of their estimated or communicated[85] significance in terms of energy

[85] From discussions with Europump

consumption and savings potentials. Considering the data used in Lot 29 is from 2011, the basis for excluding the other pumps is expected to be still relevant.

Two swimming pool pumps types have been identified from previous preparatory study Lot 29, and they have been included on the basis of their estimated significance in terms of energy consumption and savings potential.

Three pump types intended for wastewater management have also been identified from previous preparatory studies for the preliminary scope of this review study, plus one pump intended for high solids content water and two intended for slurry pumps. None exist in the current regulation and all were included in Lot 28. In spite of the uncertainty about the application of comparable ecodesign measures for pumps handling high content of solids, these have been included at this stage of the study due to the significance of their relative energy consumption and savings potentials which are comparable to other water pumps that have also been included. The appropriateness of their inclusion will be further evaluated in the subsequent tasks.

A total of 21 pump types will be further analysed in the next subsequent tasks of this study.

Some of these pumps are expected to be engineered products and therefore difficult to harmonise in certain categories, but due to their significance in terms of energy consumption and saving potentials according to previous studies, they have been included. This will be kept in mind when collecting data from manufacturers and some of the recommendations made by the market surveillance will be considered for re-evaluating their inclusion in this present review.

5.3.1 Total energy consumption at EU level

The annual energy consumption shown at EU level is calculated slightly different in the three preparatory studies, but they all reflect the total installed energy consumption in 2007 (Lot 11) and 2011 (Lot 28 & Lot 29).

Lot 11 calculated the energy consumption separately for each pump category. For each pump type the average energy consumption is estimated as well as the average motor efficiency. These figures were then multiplied with the estimated stock[86].

In Lot 28 the average hydraulic power, the operation time and a relative load factor were estimated for each pump category (the estimates were provided by Europump). The energy consumption for each category was calculated by multiplying these figures with the estimated installed stock[87]. It was not clear from Lot 28 whether the motor efficiency was taken into account in the calculation of the energy consumption. A footnote to table 5-1 (Lot 28) mentions an additional 20% added to the hydraulic power, however, when cross-checking the annual energy consumption for the total installed capacity in the EU, an evident underestimation of around 17% was found.

The additional 20% was also mentioned in table 5-1 of Lot 29 but here it was added to the calculation of annual energy consumption for the total installed capacity in the EU: "Calculated as ((Hydraulic pump power * Annual operating hours) +20%) * EU Stock in 2011". Furthermore, no reference to the additional 20% was found in Lot 28 while in Lot 29 the additional 20% is defined as the motor absorbed power (suggested by stakeholders). Following Lot 29 reasoning, the study team recalculated the total installed

[86] Lot 11, table 2-10
[87] Lot 28, tables 1-3, 4-5 & 5-1

capacity's annual energy consumption for Lot 28 pumps by adding this 20% value to the energy consumption per unit, which was established by multiplying hydraulic power with the load factor and the operation time. By multiplying the energy per unit + motor loss with the stock (as done in Lot 29), the study team realized that most of the values were underestimated by 17%, according to table 5-1 of Lot 28. So the recalculated energy consumption by the study team for EU's installed capacity was used instead and was included in the preliminary scope (see Annex 4 for details).

In Lot 29 the hydraulic pump power was established for each pump category from load profiles and calculated shaft power using pump specific parameters (flow, head, efficiency), together with its relationship with pump's mean lifetime efficiency[88]. According to Lot 29, this was due to the absence of test standard conditions. The energy consumption per unit was then estimated for each pump category according to the pump's operating hours and the installed energy consumption, which was calculated by multiplying these figures with the estimated installed stock and adding 20% for motor losses[89].

In this study and at the time of establishing the final scope, the calculation of total energy consumption was done based on the units' average electrical energy consumption and the calculated stock of the units. Furthermore, the calculation took into account the share of electrical consumption on constant and variable flow applications. The calculated stock will be discussed in task D2, the average electrical energy consumption of the units are presented in Table 29 in task D4 and a detailed explanation of the methodology for calculating total energy consumption at EU level is presented at the last chapter of this report (i.e. final scope).

5.3.2 Estimated energy savings potentials

The methods for estimating the energy saving potentials are also slightly different in each study.

In Lot 11 the energy saving potentials have been quantified according to various cut-off strategies for the established base-case scenarios in Task 8, and the figures identified as those related to potential energy savings at product level are those corresponding to a 70% cut-off[90] (maximum energy efficiency projected by 2015[91]). The calculations in Lot 11 do not take into account the time needed for the existing pumps in use to be replaced by new efficient pumps. The potential energy saving is based on how much the energy consumption is reduced if all pumps with lower efficiency are replaced.

In Lot 28 the energy saving potentials has been estimated from improving the pump itself and from an EPA[92]. The energy saving potentials from improving the pump is estimated based on average values for energy consumption per unit for each pump base case compared to similar values for improved pumps[93]. These calculations do not take into account the time needed for the existing pumps in use to be replaced by new efficient pumps. It is not clear how the energy saving potentials from EPA is calculated in Lot 28. Several scenarios have been established and the energy savings from each scenario have

[88] Lot 29 task 4, section 4.4.1
[89] Lot 29, table 1-3
[90] Lot 11, table 8-7
[91] Commission staff Working Document – Impact Assessment – Ecodesign requirements for water pumps (2012)
[92] Lot 28, table 8-1
[93] Lot 28, table 7-1 to 7-8

been calculated for several key years[94]. In these calculations the slow replacement of old pumps with efficient pumps is taken into account, however it is assumed that the estimates of the energy saving potentials are more comparable with estimates from Lot 11 than the scenario base calculations, due to similar assumptions.

In Lot 29 the energy saving potentials were estimated based on data provided by Europump[95]. For each pump category a certain percentage value was assumed for improvement potential and for potential energy saving from implementing EPA on the regulation. The potential energy saving is the multiplication of these percentage values and the estimated annual energy consumption. As in Lot 28, several scenarios have been established and the energy savings from each scenario have been calculated for several key years[96]. In these calculations the slow replacement of old pumps with efficient pumps is taken into account, however it is assumed that the estimates of the energy saving potentials are more comparable with estimates from Lot 11 than the scenario base calculations, due to similar assumptions.

In this study and at the time of establishing the final scope, the calculation of savings potential at product level was done based on estimations from Lot 11, 28 and 29, as the difference between MEI 0.4 and MEI 0.7 (for Lot 11 related clean water pumps). For the rest of the water pump types, the figures are from Lot 28 and Lot 29. This was done as no further information was provided by industry and quantitative levels could not be set.

Concerning the calculation of savings potential at EPA level, this was done based on the difference of electrical energy consumption at product level using standard motor technology with the electrical energy consumption when using the best identified motor technology and using VSDs.

All these figures were then multiplied with the present stock (discussed in task D2 in this report). The different levels of electrical energy consumption are presented in Table 29 in task D4 and a detailed explanation of the methodology for calculating saving potentials at EU level is presented in chapter 9 (i.e. Final scope).

5.3.3 Definition of pump types

The pump categorisations for this study are divided into five main groups:

1. Water pumps for clean water
2. Pumps for swimming pools
3. Wastewater pumps
4. Pumps for high solids content water
5. Slurry pumps

The definitions of different types of water which are relevant to this categorisation have been described in section 2.3, as well as the definition of pump types which were also included in previous preparatory studies (incl. those defined in existing legislation, defined in sections 2.2 and 2.3).

[94] Lot 28, figure 8-1 to 8-7
[95] Lot 29, table 5-1
[96] Lot 29, figure 8-4 to 8-6 + figure 8-10 to 8-11

6 Task D2: Markets

The purpose of this task is to present the economic and market analysis of the products covered in the current Review study of Commission Regulation (EU) No 547/2012 incorporating the preparatory studies on 'Lot 28' and 'Lot 29'. The report includes:

- Generic economic data
- Market and stock data
- Market trends
- Consumer expenditure base data
- Recommendations

The main objectives of this chapter are to:

1. Place the pumps in scope of this study[97] within the total context of EU industry and trade
2. Initiate dialogue with stakeholders on defined preliminary scope and adjust according to information provided
3. Provide market (sales and installed stock) and product lifetime and costs inputs that will be used in the subsequent tasks for the assessment of EU-wide environmental impacts of the pumps in scope
4. Provide insights into the latest market trends, indicating the market structures and ongoing trends in product design. This will serve as an input for the subsequent tasks such as improvement potentials
5. Provide the data on consumer prices and rates that will be used in the study for Life Cycle Cost (LCC) calculations in subsequent tasks

6.1 Generic economic data

The PRODCOM statistics have the advantage of being the official European Union (EU) source. It is based on products whose definitions are standardised across the European Union thus guaranteeing comparability between Member States. It is used and referenced in other EU policy documents regarding trade and economic policy, and therefore often referred to in preparatory studies.

However, the PRODCOM statistics have some limitations and are often not as reliable, since some data points are confidential or not reported by some countries, and therefore not available or inaccurate. In this study, PRODCOM statistics would be mostly used for quality assurance purpose.

EU sales and trade is derived by using the following formula:

EU sales and trade = production + import - export

EU production, import and export of pumps in units are obtained from the PRODCOM database and reported by Member States to Eurostat. See Table 8 and

Figure **14** for the EU sales and trade from 2005 to 2013. Please note that where no data is supplied, a negative result was obtained after applying the formula above. Please see Figure 12 and Figure 13 below for the total production, import and export in quantity and in value (EUR) of pumps in scope of the study.

[97] The categories of this study have been slightly changed compared to chapter 5: Task D1. The modification is shown in Table 9 and explained in page 50.

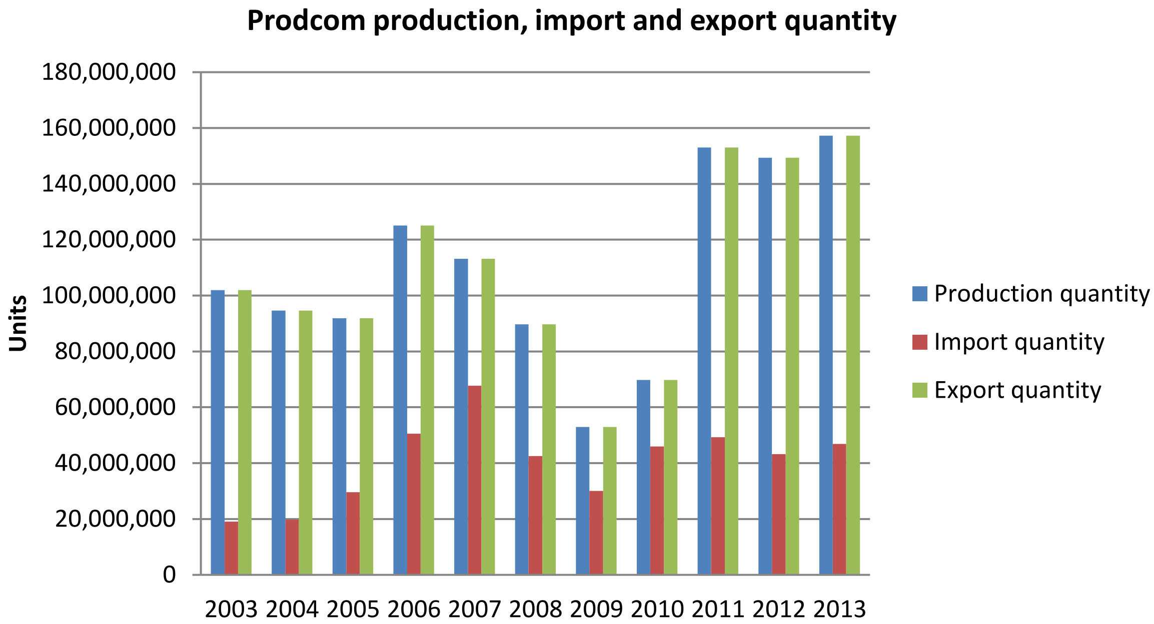


Figure 12. Total production, import and export quantity of pumps in scope 2003 -2013.

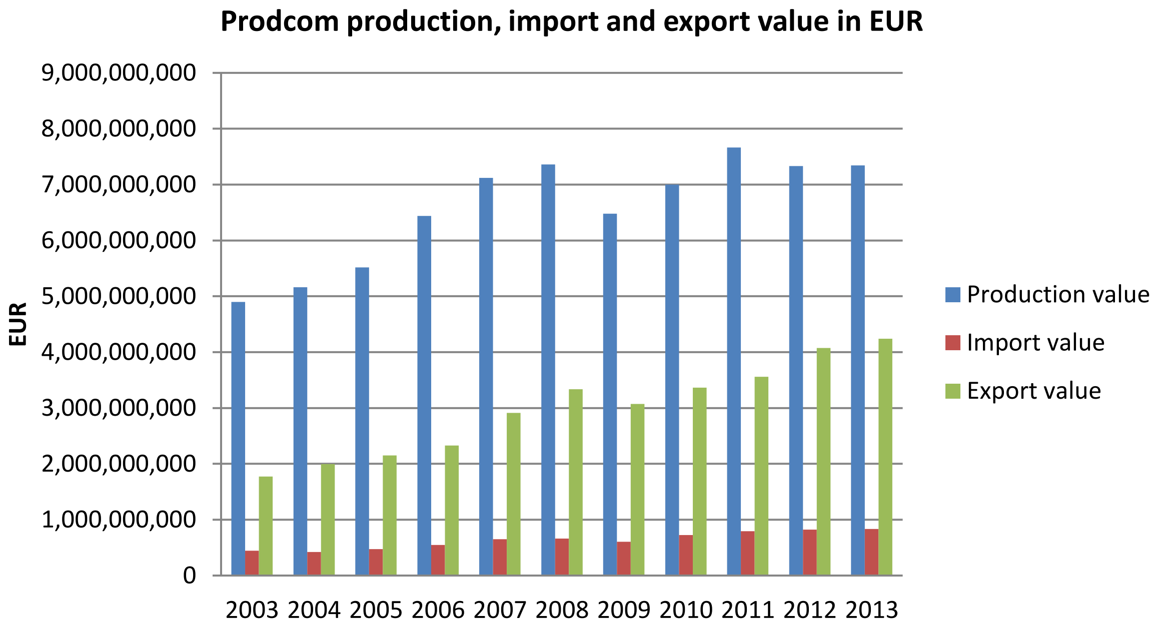


Figure 13. Total production, import and export value in EUR of pumps in scope 2003-2013.

Table 8. EU sales and trade of pumps in scope for EU-28, 2005 – 2013 from Prodcom (units).

Prodcom Code	Description	2005	2008	2010	2013
28131413	Submersible motor, single-stage rotodynamic drainage and sewage pumps	4,065,123	3,431,522	4,616,582	4,651,807
28131415	Submersible motor, multi-stage rotodynamic pumps	1,548,562	1,998,008	1,314,402	2,024,122
28131417	Glandless impeller pumps for heating systems and warm water supply	14,994,050	11,252,699		
28131420	Rotodynamic pumps ≤ 15 mm discharge	619,172	2,005,594	2,246,832	101,546,394 [98]
28131430	Centrifugal pumps with a discharge outlet diameter > 15 mm, channel impeller pumps, side channel pumps, peripheral pumps and regenerative pumps	424,033	424,829	621,245	935,219
28131451	Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with a single entry impeller, close coupled	757,339	184,699	-	1,922,480
28131453	Centrifugal pumps with a discharge outlet diameter > 15 mm, single stage with a single entry impeller, long coupled	1,168,344	764,035	1,117,875	2,302,894
28131455	Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with double entry impeller	-	-	-	-
28131460	Centrifugal pumps with a discharge outlet diameter > 15 mm, multi-stage (including self-priming)	2,549,003	638,721	1,212,782	348,504
28131471	Rotodynamic single-stage mixed flow or axial pumps	4,935,536	4,912,780	4,377,221	5,298,935
28131475	Rotodynamic multi-stage mixed flow or axial pumps	-	-	-	3,723
28131480	Other liquid pumps, liquid elevators	25,738,590	62,236,686	23,016,763	16,922,853
Total		**56,788,752**	**87,849,573**	**56,266,672**	**148,919,469**

[98] The apparent consumption between 2010 and 2013 increases by a factor of 50. The study team cannot explain this sudden increase. Therefor the values are used for quality assurance purpose only.

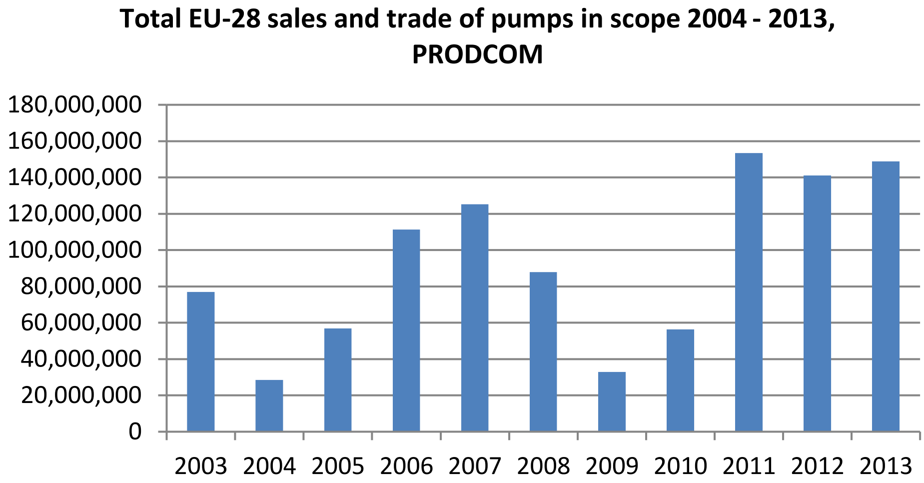


Figure 14. Total EU-28 sales and trade of pumps in scope 2005 – 2013 retrieved from PRODCOM database (without negative sales and trade figures).

The Europump Working Group for wastewater pumps found that the categorisation used in previous preparatory study Lot 28 (and used in preliminary scope defined in Task D1) was not specific enough and would therefore create confusion when selecting pump categories. New pump categories were defined by the working group and the study team, which are shown in Table 9.

Table 9. New categorisation of wastewater pumps according to Europump WG on wastewater pumps.

Lot 28 categories	New categories
Centrifugal submersible wastewater pumps, radial	Submersible vortex radial pumps for wastewater
	Submersible channel radial pumps for wastewater
Centrifugal submersible wastewater pumps, mixed flow and axial flow	Submersible pumps for storm and effluent water, mixed flow and axial
	Submersible pumps for activated sludge, axial
Centrifugal dry well pumps, radial	Dry well vortex pumps for wastewater
	Dry well channel pumps for wastewater
Centrifugal dry well pumps, Mixed flow & axial	Dry well pumps for storm water, mixed flow and axial

The radial pumps for wastewater have been divided into vortex and channel pumps. This is a response to the fact that vortex pumps in general have a much lower energy efficiency than channel pumps. If vortex and channel pumps were to be ranked by energy efficiency the vortex pumps would have a much lower ranking than the channel pumps. But vortex pumps are still very relevant for specific types of applications where clogging would be a problem for a channel pump. It was therefore decided that these types of pumps need to be treated as separate categories.

Submersible pumps with axial flow can be used for different purposes such as transporting effluent water or recirculating activated sludge, however the requirements for the pumps are very different for these purposes. A pump made for recirculating activated sludge is far less energy efficient compared to a pump designed for transporting effluent water, even though both pumps can be categorised as submersible pumps with axial flow. There is therefore a need to specify the purpose of the pumps when ranking the energy efficiency.

PRODCOM data shows a high total sales and trade figure for all pumps that are in scope of the study, however as Table 10 below shows, it is very difficult to match the pump types defined in Task D1 and the new wastewater pump categories into the PRODCOM categories. This shows it is very challenging to use PRODCOM for extrapolating future sales and stock.

Table 10. Matching pump types in current study scope to the PRODCOM categories.

Prodcom Code	Description	How does it match pumps in scope of this study
28131413	Submersible motor, single-stage rotodynamic drainage and sewage pumps	• Submersible vortex radial pumps for wastewater • Submersible channel radial pumps for wastewater • Submersible pumps for activated sludge, axial Submersible dewatering pumps
28131415	Submersible motor, multi-stage rotodynamic pumps	• Submersible vortex radial pumps for wastewater • Submersible channel radial pumps for wastewater • Submersible pumps for activated sludge, axial • Submersible dewatering pumps
28131420	Rotodynamic pumps ≤ 15 mm discharge	• Not possible to match
28131430	Centrifugal pumps with a discharge outlet diameter > 15 mm, channel impeller pumps, side channel pumps, peripheral pumps and regenerative pumps	• Dry well channel pumps for wastewater • ESCCi pumps
28131451	Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with a single entry impeller, close coupled	• ESCC pumps
28131453	Centrifugal pumps with a discharge outlet diameter > 15 mm, single stage with a single entry impeller, long coupled	• ESOB pumps
28131455	Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with double entry impeller	Not possible to match
28131460	Centrifugal pumps with a discharge outlet diameter > 15 mm, multi-stage (including self-priming)	• Self-priming pumps • Vertical Multistage pumps • Horizontal Multistage pumps
28131471	Rotodynamic single-stage mixed flow or axial pumps	• Dry well pumps for storm water, mixed flow and axial
28131475	Rotodynamic multi-stage mixed flow or axial pumps	• Dry well pumps for storm water, mixed flow and axial
28131480	Other liquid pumps, liquid elevators	Not possible to match

6.2 Market and stock data

This subtask presents market and stock data for each of the categories within the scope as defined in Task D1. As shown in Section 1, it is very difficult to match the proposed pump types into the official NACE codes used in PRODCOM, therefore the data presented in this section relies mostly on information provided directly by industry to the current study, or collected earlier for Lot 11, Lot 28 and Lot 29 preparatory studies.

The Europump Association assisted in establishing the figures for this review study. Three working groups were organised by the Europump Association for this task, one for clean water pumps, one for waste water pumps and one for swimming pool pumps, the latter being in collaboration with the European Union of Swimming pool and SPA Association (EUSA) working group. The working groups provided estimated sales numbers and energy consumption data for each subcategory of pumps.

When Europump performed the data collection, member companies had in view the total market of the European Union (EU28) and reported this accordingly. This means that the figures represent the entire EU28 market and not just the market share of the representative in the working groups.

Europump represents the majority of pump manufacturers as well as the pump market within Europe (i.e. 92 % market share[99]). The figures provided by Europump Association for this review study can be considered representative of the EU market as it can be assumed that the representatives of Europump have a firm idea of approximate size of the total market. Europump represents 14 national organisations from EU and 3 non-EU national organisations (Switzerland, Russia and Turkey). The 14 national organisations represent the EU countries with the largest pump manufacturing companies in EU.

In the swimming pool pumps Working Group, members from the European Union of Swimming pool and SPA Association (EUSA) provided data for these pumps. This working group is estimated to represent about 85 % of the European market for swimming pool pumps[100].

6.2.1 Annual sales growth rate

Findings from previous preparatory studies, the impact assessment (Lot 11)[101] and a recent report by the European Industrial Forecasting (EIF) on the world's pump market[102] (provided by Europump) have been consulted.

According to preparatory studies, the market for ESOB, ESCC and smaller submersible borehole and multistage pumps for clean water had significant growth in sales around 2007. However, it was anticipated that the sales would decrease and that possibly around present time to 2020 they would recover[103]. For the rest of clean water pumps in the scope of this project, the market was anticipated to have an annual growth rate of 3% from 2013 to 2040 according to preparatory study Lot 29 [104]. For wastewater and sewage pumps, the market was estimated to have a growth of 2-3% from 2012 to 2015, expecting to grow to 4-5% from 2015 to 2017 according to preparatory study Lot 28[105]. Lot 11 impact

[99] The market share of the represented countries is stated in Lot 28 and Lot 29
[100] Information provided by EUSA Working Group
[101] Commission staff working document – Impact Assessment. Brussels 25.6.2012 SWD(2012) 178 final.
[102] European Industrial Forecasting Ltd (2015). The World Pump Market 2015-2020. Volume I.
[103] Lot 11 preparatory study on water pumps
[104] Lot 29 preparatory study on clean water pumps
[105] Lot 28 preparatory study on wastewater pumps

assessment[106101] shows a constant increase in sales for all categories of pumps from 1990 to 2020. The estimated average growth rate per year from 1990 to 2000 is approximately 1.73%.

According to the German Federal Statistical Office, the production of liquid pumps (without hydro pumps) in 2013 reached €4.7 bn, which corresponds to slight growth (+3.3%) over the previous year. Rotary pump manufacturers took the biggest piece of the cake with more than 40%, while manufacturers of oscillating or rotating displacement pumps accounted for 10% each. In the first three quarters of 2014, production generated €3.5 bn. This is an increase of 1% compared to the same period in the previous year. The volume for the whole year 2014 is estimated once again at €4.7 bn.

The EIF report[107102] on pump market provides the estimated forecasts for 2015-2020 in terms of market growth by end-use, which are based on (i) the fixed investment and analysis of requirements by each end-use sector, and (ii) the apparent consumption of pumps based on EU trade data. These forecasts have been used to revise the abovementioned growth rates from preparatory studies and impact assessment, as according to input from industry those used in preparatory studies were rather high.

The growth rate used in this study and presented by the impact assessment shows a growth rate (1.73% as average from 1990 to 2000), the European Industrial Forecasting report[108102] estimates 1.26% - 1.64% growth for wastewater pumps in 2016-2020 and for clean water pumps the growth reduce from 2.01% in 2016 to 1% by 2020. Beyond 2020, the sales are expected to follow the trend of electric motors growth rate, although with a less drastic decline, where the growth rate will steadily reduce down to 0% by 2030.

The report did not provide information on swimming pool pumps and therefore growth rates from preparatory study Lot 29 have been used for estimating annual sales. Beyond 2020 the growth rates are difficult to predict, however the impact assessment of electric motors have expected that the growth will slow down reaching 0% by 2025. Due to the fact that pumps are usually operated with electric motors and often they are sold together, it can be expected that pumps would also follow the trend. However, since it was considered by the study team that slowing down to 0% by 2025 was rather drastic, it was assumed that growth will be slowing down from 2020 reaching 0% by 2030. The method for estimating the growth rates is detailed below.

6.2.2 Method for estimating growth rates

The estimation of growth rates was done using the EIF report, using data only from relevant end-uses (municipal water, municipal wastewater, industrial building and residential building). Data from industrial water/wastewater end-uses was not considered to estimate the growth rate, as no breakdown to water/wastewater applications in industry was available in the report nor in the excel file.

The data used to estimate the growth were the estimated 2015-2020 market growth forecasts in the EU by end-use provided in this report. Assuming growth rates for 2000 all

[106] Commission staff working document – Impact Assessment. Brussels 25.6.2012 SWD(2012) 178 final.
[107] European Industrial Forecasting Ltd (2015). The World Pump Market 2015-2020. Volume I.
[108] Ibid.

the way back to 1990 were a constant of 1.73% growth per year[109101], an interpolation is applied between 2000 and 2016 to establish the growth rates from 2001 to 2015.

Separate growth rates were established for clean water and wastewater, according to the applications provided in the report (industrial building, municipal water, wastewater and residential building – see explanation of end-uses below[110102]). The estimated forecasts for these applications on a global scale are used to find the market share of wastewater and clean water within each application and then weighted and averaged to find the growth rates of wastewater and clean water pumps for 2001 to 2020.

Municipal water and wastewater

Water and wastewater is a large market for pumps, with radically different market drivers for the advanced industrial countries compared with the developing countries. In the case of the industrial countries there are two major factors: (i) the importance of environmental legislation in recent years, and (ii) the trend towards privatisation of municipal utilities. The latter has also led to growing horizontal integration of privately owned gas, electricity and water companies.

Residential building

Residential buildings are all buildings with living accommodation excluding hospitals. However, not all the applications of pumps in these buildings are to pump water or wastewater. Based on the world's breakdown of market applications for water and wastewater in residential buildings (water supply intake, water supply boosting, water treatment, wastewater transport), the EU market's expected growth was estimated based on EU figures for the whole residential building sector.

Industrial building

Industrial buildings are all non-residential buildings, incl. commercial, hospitals and public sector. However, as for residential buildings, not all the applications of pumps in these buildings are to pumps for water or wastewater. Based on the world's breakdown of market applications for water and wastewater in industrial buildings (water supply intake, water supply boosting, water treatment, wastewater transport), the EU market's expected growth was estimated based on EU figures for the whole residential building sector. The use of these pumps in industrial processes was not included in this estimation, due to lack of breakdown data for each end-use industry application for pumping water and wastewater. This was done at a global level, but only for the whole industry (industrial process as one single end-use) and without reporting the industry sectors included. Therefore, no specific market growth data could be allocated to the specific industry sectors.

Growth rates for 2020 to 2030 are assumed to follow the trend of electric motors, and an interpolation was done from the estimated 2020 growth rate to a zero growth rate 2030. In this way, a gradual decline on sales was modelled.

All these estimations were done for water and wastewater handling pumps applications, and the exception is therefore the swimming pool pumps. For these pumps, an annual growth rate of 3% was used from 2001-2020[111104]. For the period 2020-2030, the same trend as described above was followed.

[109] Commission staff working document – Impact Assessment. Brussels 25.6.2012 SWD(2012) 178 final.
[110] European Industrial Forecasting Ltd (2015). The World Pump Market 2015-2020. Volume I.
[111] Lot 29 preparatory study on clean water pumps

6.2.3 Annual total sales/real EU-consumption

The current sales are obtained from the industry for 2014, using the growth rates identified and assumptions presented above, the annual sales are then projected up to 2030.

Based on the abovementioned assumptions, Table 11 presents an overview of the estimated annual total sales (i.e. for new and replacement markets). Due to the estimated annual growth for each pump category, the annual total sales in the European Union in 2030 are estimated to be about 21% higher than those given in 2014. This is based on a constant growth that lasts for three different periods of time (i.e. 1990-2000, 2000-2020 and 2020-2030). Constant growth may not be always happening during these three periods, but considering the available data it is believed to represent the market properly, especially considering the four points in time of estimated sales presented in Table 11. .

Table 11. Annual total sales estimate of pumps in scope for EU-28, 2014 -2030.

Water pump category	Size division	2014[112]	2020	2025	2030
ESOB pumps for clean water	Rated power ≤ 22 kW	225,000	249,195	259,282	263,178
	Rated power 22 - 150 kW	25,000	27,688	28,809	29,242
	Rated power > 150 kW	1,000	1,108	1,152	1,170
ESCC pumps for clean water	Rated power ≤ 22 kW	225,000	249,195	259,282	263,178
	Rated power 22 - 150 kW	25,000	27,688	28,809	29,242
ESCCi pumps for clean water	Rated power ≤ 22 kW	90,000	99,678	103,713	105,271
	Rated power 22 - 150 kW	10,000	11,075	11,524	11,697
Submersible borehole pumps for clean water	Nominal outer diameter ≤ 6"	700,000	775,274	806,655	818,775
	Nominal outer diameter 6" - 12"	12,000	13,290	13,828	14,036
	Nominal outer diameter > 12"	450	498	519	526
Vertical multistage pumps for clean water	Maximum design pressure ≤ 25 bar	250,000	276,884	288,091	292,420
	Maximum design pressure 25 - 40 bar	2,900	3,212	3,342	3,392
Horizontal multistage pumps for clean water	Maximum design pressure ≤ 25 bar	595,000	658,983	685,656	695,959
	Maximum design pressure 25 - 40 bar	10,500	11,629	12,100	12,282
	Rated power ≤ 22 kW	-	-	-	-

[112] These sales figures were provided by Europump and EUSA Working Group based on their estimates for 2014.

Water pump category	Size division	2014[112]	2020	2025	2030
Self-priming waterpumps for clean water	Rated power 22 - 150 kW	-	-	-	-
	Rated power >150 kW	-	-	-	-
Booster-sets for clean water	Rated power ≤ 150 kW	40,000	44,301	46,095	46,787
Swimming pool pumps (for filtration and circulation)	Rated power ≤ 2.2 kW	508,000	606,579	682,917	714,175
	Rated power > 2.2 kW	11,501	13,732	15,461	16,168
Submersible vortex radial pumps for wastewater	Rated power ≤ 10 kW	80,000	86,744	92,602	94,909
	Rated power 10 - 160 kW	2,400	2,602	2,778	2,847
Submersible channel radial pumps for wastewater	Rated power ≤ 10 kW	80,000	86,744	92,602	94,909
	Rated power 10 - 25 kW	9,600	10,409	11,112	11,389
	Rated power 25 - 160 kW	5,000	5,421	5,788	5,932
Submersible pumps for activated sludge, axial	Rated power < 160 kW	420	455	486	498
Submersible pumps for storm and effluent water, mixed flow and axial	Rated power < 160 kW	280	304	324	332
Dry well pumps for storm water, mixed flow and axial	Rated power < 160 kW	100	108	116	119
Dry well vortex pumps for wastewater	Rated power ≤ 10 kW	10,000	10,843	11,575	11,864
	Rated power 10 - 160 kW	1,000	1,084	1,158	1,186
Dry well channel pumps for wastewater	Rated power ≤ 10 kW	10,000	10,843	11,575	11,864
	Rated power 10 - 25 kW	4,000	4,337	4,630	4,745
	Rated power 25 - 160 kW	1,000	1,084	1,158	1,186
Submersible dewatering pumps (for water containing sand and grit)	Rated power < 160 kW	40,000	43,372	46,301	47,454

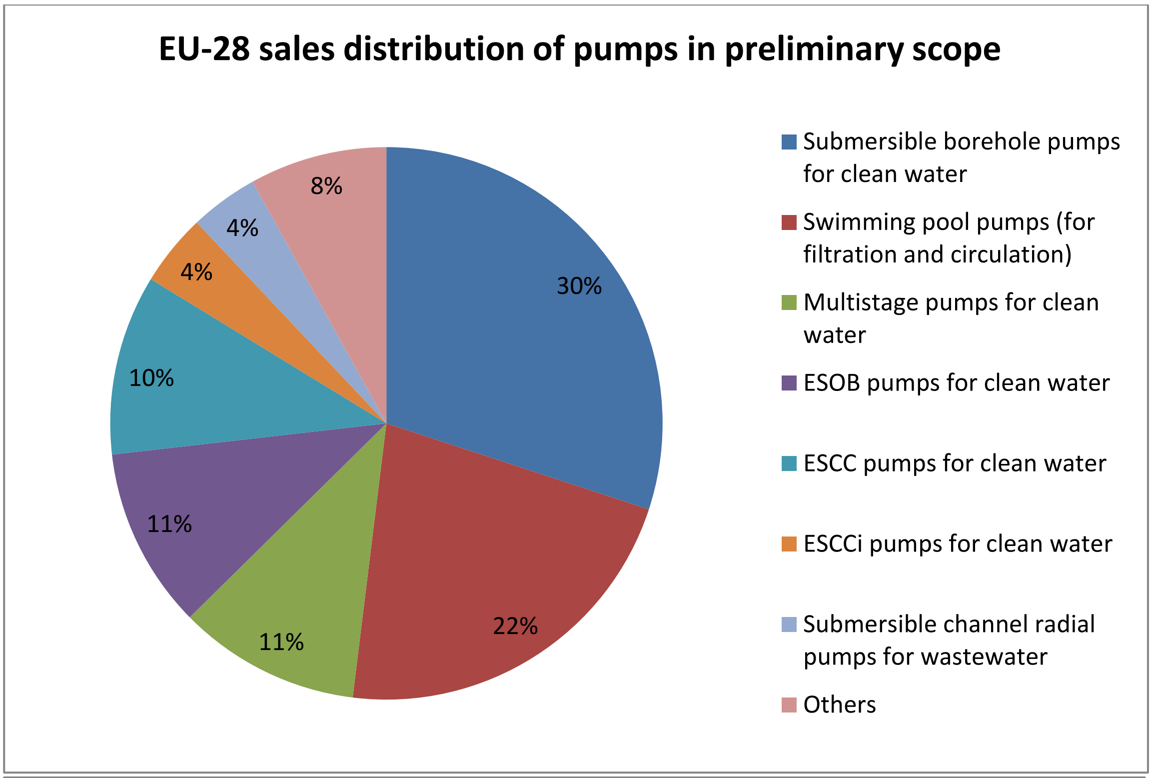
Water pump category	Size division	2014[112]	2020	2025	2030
Slurry pumps, light duty	Rated power < 160 kW	1,500	1,626	1,736	1,780
Slurry pumps, heavy duty	Rated power < 160 kW	300	325	347	356
Total preliminary scope		**2,976,951**	**3,336,316**	**3,531,524**	**3,608,866**

Sales of products are a combination of new sales, which increase the installed stock, and replacement sales. Replacement sales are included in the total sales estimates, as the data obtained for some categories of pumps are not differentiated between new sales and replacement sales. It is necessary to assume a proportion of replacement sales to carry on with the stock estimation.

According to preparatory studies Lot 28 and Lot 29, the pumps sales in the EU-28 market are mainly for the replacement of old units. It is stated that in general 30% of the sales in the EU market are for new installations and 70% are for the replacement. In those EU countries that have a mature water system infrastructure, the sales for new installation and replacement are 10% and 90%, respectively. The water pump market for new installation is higher in those EU countries that have a high need for improvement in their water systems. In such countries, the share of sales is 50% for new sales and the other half constitutes replacement sales.

It is assumed that all pumps sold would be replaced after the product lifetime e.g. 10 years. New sales in the model account for approx. 20% of the total sales up to 2020 and reduce from 2020–2030 due to the growth rate slowing down.

From Figure 15 below, it is clear that the market is currently dominated, in terms of units sold, by submersible borehole pumps for clean water (30%), swimming pool pumps for filtration and circulation (22%), multistage pumps and ESOB pumps for clean water (each 11%), ESCC pumps for clean water (10%), ESCCi pumps for clean water (4%) and submersible channel radial pumps for wastewater (4%) covering 92% of the total EU-28 market. Other pump types representing less than 4% are grouped as ‘others’ and in the second part of the figure it can be seen what these other pumps are.



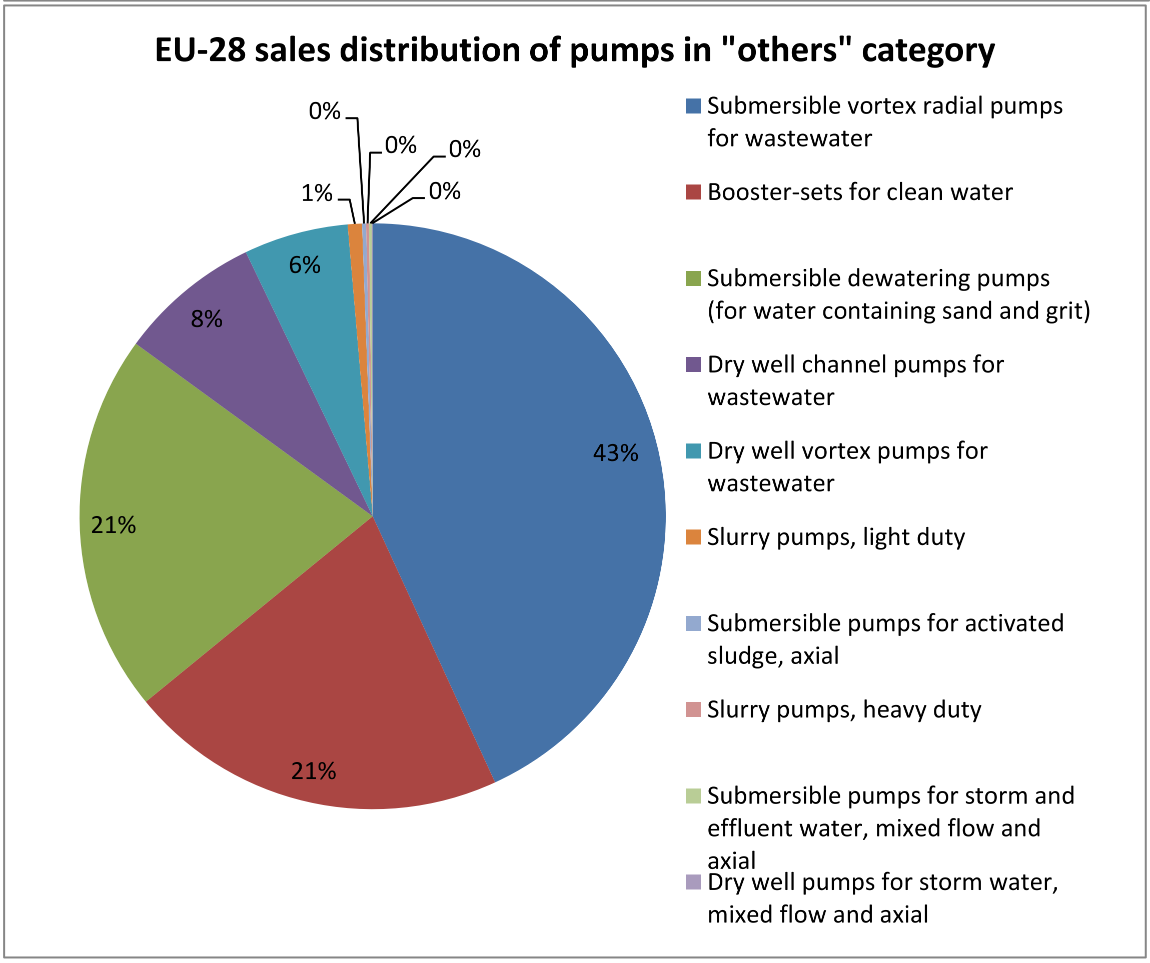


Figure 15. EU - 28 sales distribution of pumps in scope, 2014.

The predicted economic life in service has been obtained from the industry (see Table 12). All pumps have a life time of between 10-25 years depending on the applications. Product lifetime for self-priming water pumps for clean water was not obtained from the industry, it is assumed 10 years in line with most of clean water pump categories. The predicted economic lifetime in service will aid predicting current and future stocks of pumps in the scope of current study, see Table 13 for stocks.

Table 12. Predicted economic lifetime (in years) in service (Source: Europump and EUSA WG).

Water pump category	Product lifetime, years
ESOB pumps for clean water	10
ESCC pumps for clean water	10
ESCCi pumps for clean water	10
Submersible borehole pumps for clean water	10
Multistage pumps for clean water	10
Horizontal multistage pumps for clean water	10
Self-priming water pumps for clean water	10
Booster-sets for clean water	10
Swimming pool pumps (for filtration and circulation)	10
Submersible vortex radial pumps for wastewater	10
Submersible channel radial pumps for wastewater	10
Submersible pumps for activated sludge, axial	10
Submersible pumps for storm and effluent water, mixed flow and axial	10
Dry well pumps for storm water, mixed flow and axial	20
Dry well vortex pumps for wastewater	15
Dry well channel pumps for wastewater	15
Submersible dewatering pumps (for water containing sand and grit)	10
Slurry pumps, light duty	25
Slurry pumps, heavy duty	25

6.2.4 Installed base ("stock")

The stock is calculated using a simplified stock model, where the sales of a pump category in a number of past years that correspond to the predicted economic lifetime is summed up to give the stock. For example, ESOB pumps for clean water stock for 2014 is calculated by summing the annual sales from 2005 to 2014, and stock for 2015 by summing the annual sales from 2006 to 2015 and so on, based on the corresponding product lifetime of each pump category.

The stock from 1990 to 2013 is calculated based on the estimated stock for 2014 and the growth rates presented previously. See Figure 16 for the development the stock and sales from 1990 to 2030. In 1990, the estimated total stock of pumps in scope is approximately 21 million units and it is predicted to increase to 34 million by 2030.

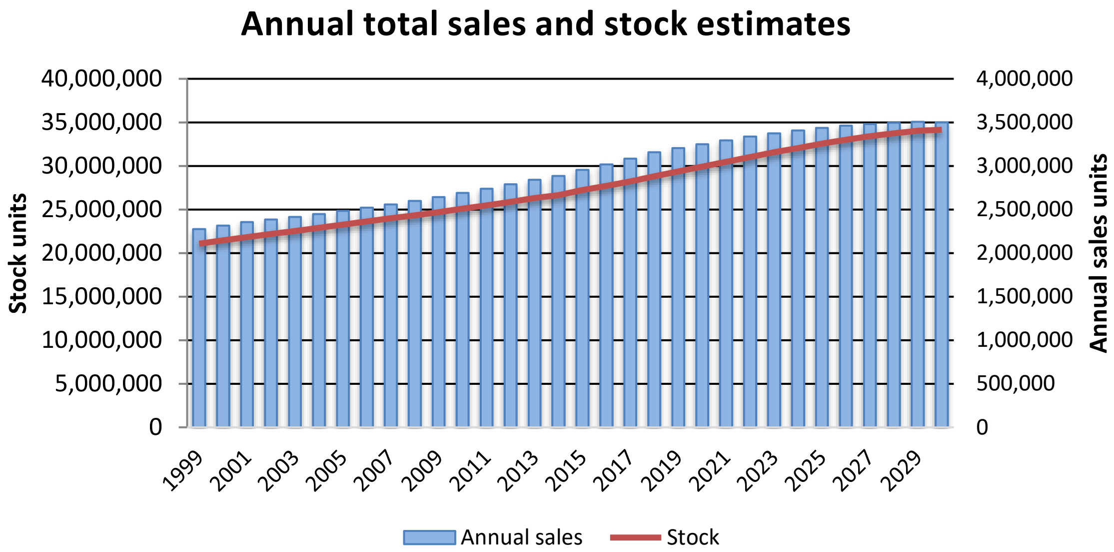


Figure 16. Estimated and projected annual total sales and stock from 1990 – 2030.

The total installed base is different in comparison with the sum of that from previous preparatory studies, which was calculated as 49.4 million units. This is because the current scope is different than what was presented in the previous preparatory studies and the stock shown here is based on 2014 annual sales data. There is a steady and gradual increase in sales which slows down towards 2030 due to the annual growth rate presented in previous sections. The growth rate presented by the impact assessment shows 1.73% as an average from 1990 to 2000. An interpolation was done between 2000 to 2016, based on this average (1.73%) and on the European Industrial Forecasting report[113102] which estimates 1.26% - 1.64% growth for wastewater pumps in 2016-2020 and 2.01% in 2016 to 1% by 2020 for clean water pumps.

Table 13. Estimated EU-28 installed base (stock) in 2014.

Water pump category	Size division	2014[114112]	2020	2025	2030
ESOB pumps for clean water	Rated power ≤ 22 kW	2,096,014	2,318,460	2,490,813	2,589,262
	Rated power 22 - 150 kW	232,890	257,607	276,757	287,696
	Rated power > 150 kW	9,316	10,304	11,070	11,508
ESCC pumps for clean water	Rated power ≤ 22 kW	2,096,014	2,318,460	2,490,813	2,589,262
	Rated power 22 - 150 kW	232,890	257,607	276,757	287,696
ESCCi pumps for clean water	Rated power ≤ 22 kW	838,405	927,384	996,325	1,035,705
	Rated power 22 - 150 kW	93,156	103,043	110,703	115,078

[113] European Industrial Forecasting Ltd (2015). The World Pump Market 2015-2020. Volume I.
[114] These sales figures were provided by Europump and EUSA Working Group based on their estimates for 2014.

Water pump category	Size division	2014[114112]	2020	2025	2030
Submersible borehole pumps for clean water	Nominal outer diameter ≤ 6"	6,520,931	7,212,987	7,749,198	8,055,482
	Nominal outer diameter 6" - 12"	111,787	123,651	132,843	138,094
	Nominal outer diameter > 12"	4,192	4,637	4,982	5,179
Vertical multistage pumps for clean water	Maximum design pressure ≤ 25 bar	2,328,904	2,576,067	2,767,571	2,876,958
	Maximum design pressure 25 - 40 bar	27,015	29,882	32,104	33,373
Horizontal multistage pumps for clean water	Maximum design pressure ≤ 25 bar	5,542,792	6,131,039	6,586,818	6,847,160
	Maximum design pressure 25 - 40 bar	97,814	108,195	116,238	120,832
Self-priming water pumps for clean water	Rated power ≤ 22 kW	-	-	-	-
	Rated power 22 - 150 kW	-	-	-	-
	Rated power >150 kW	-	-	-	-
Booster-sets for clean water	Rated power ≤ 150 kW	372,625	412,171	442,811	460,313
Swimming pool pumps (for filtration and circulation)	Rated power ≤ 2.2 kW	4,463,343	5,329,465	6,138,516	6,805,872
	Rated power > 2.2 kW	101,047	120,655	138,971	154,080
Submersible vortex radial pumps for wastewater	Rated power ≤ 10 kW	762,781	816,861	873,875	924,047
	Rated power 10 - 160 kW	22,883	24,506	26,216	27,721
Submersible channel radial pumps for wastewater	Rated power ≤ 10 kW	762,781	816,861	873,875	924,047
	Rated power 10 -25 kW	91,534	98,023	104,865	110,886
	Rated power 25 - 160 kW	47,674	51,054	54,617	57,753
Submersible pumps for	Rated power < 160 kW	4,005	4,289	4,588	4,851

Water pump category	Size division	2014[114112]	2020	2025	2030
activated sludge, axial					
Submersible pumps for storm and effluent water, mixed flow and axial	Rated power < 160 kW	2,670	2,859	3,059	3,234
Dry well pumps for storm water, mixed flow and axial	Rated power < 160 kW	1,810	1,939	2,056	2,176
Dry well vortex pumps for wastewater	Rated power ≤ 10 kW	139,750	149,008	158,683	168,165
	Rated power 10 - 160 kW	13,975	14,901	15,868	16,817
Dry well channel pumps for wastewater	Rated power ≤ 10 kW	139,750	149,008	158,683	168,165
	Rated power 10 -25 kW	55,900	59,603	63,473	67,266
	Rated power 25 - 160 kW	13,975	14,901	15,868	16,817
Submersible dewatering pumps (for water containing sand and grit)	Rated power < 160 kW	381,390	408,431	436,937	462,023
Slurry pumps, light duty	Rated power < 160 kW	32,817	35,367	37,564	39,677
Slurry pumps, heavy duty	Rated power < 160 kW	6,563	7,073	7,513	7,935
Total preliminary scope		**27,649,392**	**30,896,297**	**33,601,030**	**35,415,129**

6.3 Market trends

This section presents market structure and channels, recent evolution and expected orientation of the market, as well as a review of the parameters, which are likely to influence product sales and design in the future. It is important to understand such trends to identify products, which might represent a significant or marginal market in the near future.

6.3.1 General market trends

The value of the global pump market in 2011 was estimated at approx. 36 billion EUR covering pumps and prime movers (e.g. electric motors). From these, a wide range of pumps applications exist, and depending on the application, pumps can be standard, engineered or special pumps[115102]. Pumps can have more than one application, but generally they are either standard pumps, engineered pumps or special purpose pumps for all their applications (if more than one).

Standard pumps are those produced in large quantities at relatively low unit cost, which performance ranges are very wide.

Engineered pumps are generally of large size and built to high specification and higher price. Most of these pumps are used in other applications that are not clean water or wastewater pumping, but in some cases end uses require these types (quantities of demand are generally smaller).

Special purpose pumps are those required where both standard and engineered pumps cannot provide the desired outcomes through a pumping solution. They are produced in relatively small numbers and can be highly customised and command a price premium over standard pumps.

The European Industrial Forecasting estimated that by 2015[116102] the world's market distribution according to this classification was 59% standard, 15% engineered and 26% for special purposes.

The scope of this study focuses mainly on standard pumps due to their predominance in the market for clean water and wastewater applications. However, in some of the pump categories such as the multistage pumps 25-40 bar, engineered pumps are also assessed within the scope of this study due to their importance in terms of energy consumption and saving potentials at EU level (see chapter 9).

6.3.2 Market channels and production structure

The pump industry in the EU is mainly comprised of a few large manufacturers and a number of SMEs. These manufacturers are well represented by industry associations at Member State and EU level, these mainly include:

- Europump (an umbrella organisation for European pump manufactures), member organisations are[117]:
    - FMS FMM – Machinery & Metalware: An organization of the Austrian Federal Economic Chamber
    - Agoria – Belgian federation of the technology industry
    - SWISSMEM – Swiss association on mechanical and electrical engineering industry & associated technology
    - CPMA CZ - Czech Pump Manufacturers' Association
    - Verband Deutscher Maschinen- und Anlagenbau VDMA
    - DK Pumps - Association of Danish pump manufacturers
    - The Federation of Finnish Technology Industries
    - PROFLUID - Association française des pompes et agitateurs, des compresseurs et de la robinetterie
    - Union of Greek Metal Industries

[115] European Industrial Forecasting Ltd (2015). The World Pump Market 2015-2020. Volume I.
[116] Ibid.
[117] http://europump.net/menu-top/membership

- ANIMA - Federation of National Associations of Mechanical and Engineering Industries
  - FME - Holland Pomp Groep
  - STOWARZYSZENIE PRODUCENTÓW POMP
  - RO APPR
  - Russian Pump Manufacturers' Association
  - Teknikföretagens Branschgrupper AB
  - POMSAD – Turkish pump and valve manufacturers' association
  - BPMA - British Pump Manufacturers Association
- European Union of Swimming pool and SPA Association (an umbrella of the swimming pool and spa businesses in Europe), member organisations are[118]:
  - Association of Greek Enterprises of Pool and Hydromassage (SEEPY
  - Associação Portuguesa de Piscinas (APP)
  - Associazione Italiana Costruttori Piscine (Assopiscine)
  - British Swimming Pool Federation Limited (BSPF)
  - Bundesverband Schwimmbad & Wellness e.V. (bsw)
  - Federación de Asociaciones de Fabricantes de Equipos y Constructores de Piscinas, Saunas y Spas (FAPS)
  - Fédération des Professionnels de la Piscine (FPP)
  - Magyar Uszodatechnikai Egyesület (MUE)
  - Österreichischer Verband der Schwimmbad- und Saunawirtschaft (ÖVS)
  - Svenska Badbranschen (SBB)
  - Swiss Association of Water and Swimming Pool Technology
  - Romanian Swimming Pool and Wellness Association (APPW)

The pump market is led by the few multinational companies, who have worldwide manufacturing facilities. Medium-sized water pumps for swimming pools might be either EU-produced or imported. Production in Europe is cost effective for higher-priced commodity pumps, very large and engineered pumps which may be tailored in some way for end users, and speciality low volume pumps. Companies that have invested heavily in automation are also able to make high volume pumps at competitive prices in Europe.

Depending on their final application, pumps are sold to the end user through a variety of channels such as directly from manufacturers, via wholesalers, via distributors or via installer. The product distribution channels of water pumps, wastewater and sewage pumps are mostly business-to-business, these products usually require experience and engineering knowledge for proper mounting of the pump, and therefore need professional installation. Some aquarium water pumps, or pumps included within other products, and smaller domestic drainage pumps, < 40 mm passage, that do not require installation, might be directly purchased from the retailers, and the market for all pumps directly sold to the consumers is likely to be very small.

The top 23 pump companies accounting for around 50% of the world's pump market in 2015 are[119][102]:

- Alfa laval
- Colfax
- Ebara
- Flowserve
- FMC Technologies
- GE Oil & Gas

[118] http://www.eusaswim.eu/Countries-Members/index.php
[119] European Industrial Forecasting Ltd (2015). The World Pump Market 2015-2020. Volume I.

- Grundfos
- HMS Group
- IDEX
- ITT Industrial Process
- Kirloskar Brothers
- KSB Pump
- Kubota
- National Oilwell Varco
- Pentair
- Roper Industries
- Spirax Sarco
- SPX Flow Technology
- Sulzer
- Toroshima
- WEIR Group
- Wilo
- Xylem

The main manufactures of swimming pool pumps in the EU include:

- Procopi
- ACIS
- Desjoyaux Pools
- Fluidram
- Schmalenberger
- Hayward
- ESPA
- Fluidra
- SPECK Pumpen

The market for swimming pool pumps is mainly distributed between companies mentioned above and many other smaller companies.

Water and sewage is a large market for pumps in the world[120]. Different market drivers are observed in the advanced industrial countries compared with the developing countries. For the industrial countries the two major drivers are the environmental legislation and the trend towards privatisation of municipal utilities.

Germany was the third largest market for water and sewage pumps in 2006, worth about 241 million EUR. For the whole Western Europe, the market was worth about 880 million EUR (based on 2003 prices)[121][120]. Western Europe was the second largest market at that time (average predicted for the period 2006-2008), where water pumps accounted for about 40% of the size of the water and sewage pumps market, whilst sewage pumps accounted for about 60% of it[122][120].

Concerning market channels, it is expected that the majority of the clean water pumps investigated within the scope of this study are sold Business-to-Business (B2B), as these products usually need professional installation in buildings or are bought directly by industry[123]. This is expected to be the same for wastewater and slurry pumps and large swimming pool pumps. The only exception is domestic swimming pool pumps (not sold for

[120] European Industrial Forecasting Ltd (2006). The World Market for Pumps – The Pump Market by End Use Industry 2006-2012. Available at: http://pumpsystemsmatter.org/uploadedFiles/Pumps/Membership/Member_Services/Economic_Report_Services/EIFvolume1.pdf

[121] Ibid.

[122] Ibid.

[123] Lot 28, page 20

commercial installations, mainly for above ground pools), which are often purchased by household end-users and are therefore sold as Business-to-Consumers (B2C).

6.3.3 Trends in product design and features

Several positive trends are noted for ESOB, ESCC and smaller submersible borehole and multistage pumps for clean water, particularly applying to mass produced pumps and pump sets for building applications:

- Greater sales of pumps with pressed stainless steel or plastic impellers
- Variable speed control incorporated in integrated packages
- Optimization of motor design, particular in regards to part-load energy efficiency
- Pumps with built-in condition monitoring are now available, although sales are low so far
- Some larger pumps will have friction reducing coatings on the cast iron volute
- Larger variety of pump sizes and flow rates, allow the costumer to choose pumps with the needed flow rate
- Focus on making installation and replacement easier

The main developments in water pumps in general concern advances in motors equipped with VSDs and controls for regulation of the water flow. Several large companies are selling their pumps with high efficient motors and offer to fit the pumps with VSDs and advanced monitoring systems. Pump control systems are also in focus. For vertical multistage and end suction – the larger end of the market is engineered to high specification (e.g. used in power plants for cooling). Often there are financial penalties set out in contracts if these pumps do not meet their pre-specified efficiencies. Xylem has a patented pump regulation method for submersible pumps. Emphasis is put into designing pumps so that they are easy to install and maintain. The pump is designed to make it easy to dismantle and replace parts that usually are worn out faster, such as bearing brackets. Furthermore, Xylem has developed new designs of multistage and other centrifugal pumps with better hydraulic efficiencies and wider range coverage to make them comply with the second tier of the regulation.

For waste water and sewage pumps, the main developments in this area concern advances in impeller design. Additional developments concern the use of VSD controls for both flow regulation, and de-ragging initiated by a sequence of forward and counter rotations. Other innovations for wastewater pumps include internal monitoring systems to replace float switches or electrodes as means of control. Self-cleaning impellers are also a new innovation on the wastewater market. It is particular robustness and reliability that are the focus for new innovations on the wastewater market.

Sewage varies hugely in terms of its solid content, particularly when comparing domestic to industrial discharges. The greater number of products (that do not disintegrate adequately in water) flushed into the sewage system also requires the use of pumps with a higher solid handling capacity. Higher effluent discharges also encourage more companies to undertake initial screening and de-watering, thus discharging a lower volume but with higher solid content.

The trends for swimming pool pumps in the EU are different from that in the USA and Australia. In the EU there is a focus on limiting the amount of disinfection chemicals in swimming pools, particularly chlorine. The limited amounts of chlorine in the water increase the demands for circulation and filtration for health reasons. Australia and the USA are ahead of EU in advancing energy efficient swimming pool pumps and energy efficient use of swimming pool pumps. The trend in Australia is towards lower flow rates with longer running times. In the US the trend is to reduce the number of domestic swimming pool pumps operated at single-speed and increase pumps with dual, multiple and variable speed (see section 3.4). In the EU there exists several national laws regulating water quality and necessary flow rates and turnover rates[124], and it is generally viewed not feasible to reduce flow rates or operation times. As possible options for reducing energy consumption of swimming pools in EU, it is suggested by the EUSA Pool Pump working group supplemented by additional comments from industry stakeholders, to consider:

- The entire pool hydraulic system design: This must be taken into account in the planning phase.
- Wet end part design: Particularly in relation to minimizing the clearances which will imply different designs and/or materials used in the pump or impeller.
- Hydraulic working point: Where the most fitting pump must be selected depending on the unit resistance.

However, some of these aspects are already considered by the Australian standards and the ENERGY STAR programme in the US.

6.4 Consumer expenditure base data

This section presents purchase prices, installation, repair and maintenance costs as well as applicable rates for running costs (e.g. electricity, water) and other financial parameters (e.g. taxes, rates of interest, inflation rates). These data will form an input for later tasks where Life Cycle Costing for new products will be calculated.

6.4.1 Electricity and water prices

Electricity and water prices are presented in the MEErP methodology. Recently updated rates for electricity were found for 2014, and are presented in Table 14 below. An average for 2014 and an average annual price increase were established[125] . Water rate incl. sewage tax is estimated at 4.45 Euro/m^3 in 2015, taken for the domestic market incl. VAT and a growth rate per year is 3%[126].

Table 14. Household and industry electricity cost.

EU country	Household electricity price, €/kWh	Annual household price increase, %/a	Industry electricity price, €/kWh	Annual industry price increase, %/a
Belgium	0.2097	-3%	0.0916	0%
Bulgaria	0.0832	-10%	0.0736	-8%
Czech Republic	0.1283	-16%	0.0819	-19%
Denmark	0.3042	1%	0.0934	4%
Germany	0.2981	2%	0.0844	-2%
Estonia	0.1307	-3%	0.0794	-6%
Ireland	0.2407	5%	0.1303	-2%
Greece	0.1767	13%	0.109	5%
Spain	0.2165	-3%	0.1185	2%
France	0.1585	4%	0.0743	-5%
Croatia	0.1312	-4%	0.0903	-4%
Italy	0.2446	7%	0.108	-4%
Cyprus	0.2291	-17%	0.1672	-16%
Latvia	0.1365	-1%	0.0903	-5%

[124] EUSA Pool Pump Working Group Position paper, 23/10 2015
[125] Source: Eurostat, assessed December 2015
[126] VHK (2014). Ecodesign Impact Accounting. Part 1 – Status Nov. 2013

EU country	Household electricity price, €/kWh	Annual household price increase, %/a	Industry electricity price, €/kWh	Annual industry price increase, %/a
Lithuania	0.133	-3%	0.0958	0%
Luxembourg	0.1738	4%	0.0949	1%
Hungary	0.1202	-14%	0.0836	-8%
Malta	0.1474	-11%	0.177	-1%
Netherlands	0.1821	-5%	0.0771	-2%
Austria	0.2021	-3%	0.0827	-5%
Poland	0.1421	-4%	0.0777	-12%
Portugal	0.2175	5%	0.1029	1%
Romania	0.129	-2%	0.0753	-17%
Slovenia	0.163	1%	0.0754	-10%
Slovakia	0.1507	-11%	0.1107	-11%
Finland	0.1563	-1%	0.0664	-2%
Sweden	0.1967	-6%	0.0702	-12%
United Kingdom	0.1918	10%	0.1246	11%
EU (28 countries)	**0.2038**	**2%**	**0.0917**	**-2%**

6.4.2 Purchase price

As no new information was supplied by industry, purchase prices of clean water, wastewater and sewage pumps have been collected from preparatory studies Lot 11, Lot 28 and Lot 29 combined with price checks via an internet search. An overview of the purchase price ranges (in EUR) is given in Table 15[127].

Table 15. Estimated purchase price of pumps in scope.

Water pump category	Size division	Average price (EUR)
ESOB pumps for clean water	Maximum shaft power ≤ 22 kW	2,828.0
	Maximum shaft power 22 - 150 kW	4,172.3
	Maximum shaft power > 150 kW	n.a.
ESCC pumps for clean water	Maximum shaft power ≤ 22 kW	1,668.7
	Maximum shaft power 22 - 150 kW	6,076.4
ESCCi pumps for clean water	Maximum shaft power ≤ 22 kW	2,045.6
		5,440.0

[127] Sources: preparatory studies Lot 11, Lot 28 and Lot 29, internet research and prices catalogues in the period from December 2015 to May 2016 and additional input from stakeholders (comments from stakeholders' meeting).

Water pump category	Size division	Average price (EUR)
	Maximum shaft power 22 - 150 kW	
Submersible borehole pumps for clean water	Nominal outer diameter ≤ 6"	1,275.7
	Nominal outer diameter 6" - 12"	11,550.7
Vertical multistage pumps for clean water	Maximum design pressure ≤ 25 bar	1,427.4
	Maximum design pressure 25 - 40 bar	13,135.8
Horizontal multistage pumps for clean water	Maximum design pressure ≤ 25 bar	608.0
	Maximum design pressure 25 - 40 bar	5,595.4
Self-priming pumps	Maximum shaft power ≤ 150 kW	n.a.
	Maximum shaft power > 150 kW	n.a.
Booster-sets for clean water	Maximum shaft power ≤ 150 kW	5,697.6
Swimming pool pumps	Maximum shaft power ≤ 2.2 kW	442.6
	Maximum shaft power > 2.2 kW	n.a.
Submersible vortex radial pumps for wastewater	Maximum shaft power ≤ 10 kW	2,427.5
	Maximum shaft power 10 - 160 kW	6,287.0
Submersible channel radial pumps for wastewater	Maximum shaft power ≤ 10 kW	2,974.2
	Maximum shaft power 10 -25 kW	7,422.8
		38,374.6

Water pump category	Size division	Average price (EUR)
	Maximum shaft power 25 - 160 kW	
Submersible pumps for activated sludge, axial	Maximum shaft power ≤ 160 kW	15,000.0
Submersible pumps for storm and effluent water, mixed flow and axial	Maximum shaft power ≤ 160 kW	15,000.0
Dry well pumps for storm water, mixed flow and axial	Maximum shaft power < 160 kW	2,125 – 21,250
Dry well vortex pumps for wastewater	Maximum shaft power ≤ 10 kW	3,000 – 29,000
	Maximum shaft power 10 - 160 kW	
Dry well channel pumps for wastewater	Maximum shaft power ≤ 10 kW	3,000 – 29,000
	Maximum shaft power 10 -25 kW	
	Maximum shaft power 25 - 160 kW	
Submersible dewatering pumps (for water containing sand and grit)	Maximum shaft power < 160 kW	2,000 – 8,000
Slurry pumps, light duty	Maximum shaft power < 160 kW	20,000
Slurry pumps, heavy duty	Maximum shaft power < 160 kW	20,000

n.a. = data not available

6.4.3 Installation costs, repair and maintenance costs

As no new information was supplied by industry, installation costs, repair and maintenance costs of clean water, wastewater and sewage pumps have been collected from preparatory studies Lot 11, Lot 28 and Lot 29. An overview of the estimated costs ranges is shown in Table 16[128127].

Table 16. Estimated installation costs, repair and maintenance costs.

Water pump category	Size division	Average installation costs, EUR	Average repair & maintenance costs, EUR/year
ESOB pumps for clean water	Maximum shaft power ≤ 22 kW	720	300
	Maximum shaft power 22 - 150 kW		
	Maximum shaft power > 150 kW	2,000	500

[128] Sources: preparatory studies Lot 11, Lot 28 and Lot 29, internet research and prices catalogues in the period from December 2015 to May 2016 and additional input from stakeholders (comments from stakeholders' meeting).

Water pump category	Size division	Average installation costs, EUR	Average repair & maintenance costs, EUR/year
ESCC pumps for clean water	Maximum shaft power ≤ 22 kW Maximum shaft power 22 - 150 kW	2,100	800
ESCCi pumps for clean water	Maximum shaft power ≤ 22 kW Maximum shaft power 22 - 150 kW	2,100	800
Submersible borehole pumps for clean water	Nominal outer diameter ≤ 6"	955	750
	Nominal outer diameter 6" - 12"	3,000	2,167
	Nominal outer diameter > 12"	4,000	3,000
Vertical multistage pumps for clean water	Maximum design pressure ≤ 25 bar	1,000	525
	Maximum design pressure 25 - 40 bar	2,000	1,000
Horizontal multistage pumps for clean water	Maximum design pressure ≤ 25 bar	1,000	525
	Maximum design pressure 25 - 40 bar	2,000	1,000
Self-priming water pumps for clean water	Maximum shaft power ≤ 22 kW	n.a.	n.a.
	Maximum shaft power 22 - 150 kW	n.a.	n.a.
	Maximum shaft power >150 kW	n.a.	n.a.
Booster-sets for clean water	Maximum shaft power ≤ 150 kW	2,000	1,050
Swimming pool pumps (for filtration and circulation)	Maximum shaft power ≤ 2.2 kW	250	4.4
	Maximum shaft power > 2.2 kW	500	50
Submersible vortex radial pumps for wastewater	Maximum shaft power ≤ 10 kW	1,250	750
	Maximum shaft power 10 - 160 kW	3,958	1,600
Submersible channel radial pumps for wastewater	Maximum shaft power ≤ 10 kW	1,250	750
	Maximum shaft power 10 -25 kW	4,063	1,752
	Maximum shaft power 25 - 160 kW	6,250	3,200
Submersible pumps for activated sludge, axial	Maximum shaft power < 160 kW	3,750	1,425

Water pump category	Size division	Average installation costs, EUR	Average repair & maintenance costs, EUR/year
Submersible pumps for storm and effluent water, mixed flow and axial	Maximum shaft power < 160 kW	3,750	1,425
Dry well pumps for storm water, mixed flow and axial	Maximum shaft power < 160 kW	3,750	450
Dry well vortex pumps for wastewater	Maximum shaft power ≤ 10 kW	1,250 – 6,250	375 – 850
	Maximum shaft power 10 - 160 kW		
Dry well channel pumps for wastewater	Maximum shaft power ≤ 10 kW	1,250 – 6,250	375 – 850
	Maximum shaft power 10 -25 kW		
	Maximum shaft power 25 - 160 kW		
Submersible dewatering pumps (for water containing sand and grit)	Maximum shaft power < 160 kW	250	150
Slurry pumps, light duty	Maximum shaft power < 160 kW	5,000	650
Slurry pumps, heavy duty	Maximum shaft power < 160 kW	5,000	650

6.4.4 Disposal tariffs/ taxes

There are no tariffs or tax especially for pumps to the author's knowledge at the time of writing the report. Pumps in scope are mostly constructed of metals, and they are valuable scraps at the end of their life. There is sufficient incentive to recycle old pumps without the need for a financial measure to encourage recycling. It is therefore assumed that there are no incurred disposal costs for pumps at the end of life. However, cleaning and removal of pathogens is required prior to their delivery to the scrap yard.

6.4.5 Interest, inflation and discount rates

The generic interest and inflation rates in the EU-28 are presented in Table 17 below. In principle the discount rate is interest rate minus inflation rate, which gives for domestic and non-domestic values of 5.5% and 4.4%, respectively. However, the European Commission recommends a discount rate of 4%[129].

Table 17. Generic interest and inflation rates in the EU-28[130].

	Domestic	Non-domestic
Interest rate (%)	7.7	6.5
Inflation rate (%)	2.1	
Discount rate (%)	4	

[129] http://ec.europa.eu/smart-regulation/guidelines/tool_54_en.htm
[130] VHK(2011), MEErP 2011 METHODOLOGY PART 1.

6.5 Conclusions and recommendations

The categories in the PRODCOM database do not fit well with the identified pump categories (both in Task D1 and the new wastewater pump categories). In addition, the sales and trade figures from PRODCOM seem high while their market shares of pump types do not fit with the sales data collected from the industry. It is recommended to use the industry data for further analyses in the subsequent tasks.

The categorisation established in Task D1 on the basis of the previous preparatory studies has been updated due to comments from the industry regarding some of the wastewater pumps. It is realised that the categorisation from Lot 28 was too crude to accommodate a meaningful ranking of wastewater pumps according to their intended use and their wide disparity on energy efficiency. The categorisation for these pumps has therefore been modified.

The annual sales of pumps have been on a general growth, starting with a 1.73% average annual growth from 1990 to 2000 based on the past impact assessment, and based on market growth forecasts from the European Industrial Forecasting it is predicted that in the period of 2016 to 2020 the market will grow annually by 1.26% - 1.64% for wastewater pumps and that it will reduce from 2.01% in 2016 to 1% by 2020 for clean water pumps. Growth rates for 2000-2016 have been interpolated based on these two time periods where data was available. Beyond 2020, the sales are expected to follow the growth rate trend of electric motors, although with a less drastic decline, where the growth rate will steadily reduce down to 0% by 2030. The total annual sales (i.e. new and replacement sales) of pumps in scope is approx. 2.9 million for 2014 and it is estimated to increase to approx. 3.5 million by 2030. The market is dominated by submersible borehole pumps for clean water, swimming pool pumps for filtration and circulation, ESOB, ESCC and multistage pumps for clean water. Product lifetime, estimated sales and stock, electricity prices, water prices, interest, inflate, and discount rates have been presented in this chapter which can be used for LCC analysis in the later tasks.

In the recent years the development towards more energy efficient design is notable. The Regulation (EU) 547/2012 can be seen as part of the motivation. For clean water pumps the largest energy savings in the future will not only come from improvement of hydraulic design improvements, but also from a more holistic approach where the components attached to the pumps are considered. Already it is apparent that there is an increasing focus on motor design, VSD and monitoring systems for pumps, all of which contribute to lower energy consumptions. Besides energy consumption, the industry is focusing on improving design to ease installation and maintenance and to increase reliability of the pump.

The industry is positive about the prospect for a revision to the ecodesign regulation by introducing energy savings indicators at an EPA perspective where the most savings can be gained, but there is also some concern that the regulation has a potential of becoming counter-productive if not handled correctly, in particular as the water pump market is very diverse with numerous applications and functional requirements for the pumps. To accommodate this diversity, it is necessary to have a diversity of pump designs available. A new regulation may have to differentiate the requirement for energy efficiency between various designs and/or applications if it is to be successful.

7. Task D3: Users

The purpose of this task is to identify relevant user parameters that influence the environmental impact during the use of the pumps and that are different from standard test conditions (as described in task B).

Specific aspects that have been investigated are:

- Identifying and describing differences on the use of clean water, swimming pool, wastewater and slurry pumps concerning:
    - Load efficiency
    - Frequency and characteristic of use
    - Power management
    - Temperature and/or timer settings
- Identifying and describing differences on the use of these pumps when looking strictly at the product scope (i.e. only at the pump-unit) in comparison to looking at the EPA
- Identifying and describing the impact of local infrastructures on the use of the pumps, particularly any barriers and opportunities

Conclusions and recommendations are presented in relation to the possibility to refine the scope from the perspective of consumer behaviour and local infrastructure, as well as the barriers and opportunities that these present.

7.1 System aspects – use phase

In general, the pumps efficiencies are affected by how the system they operate is designed and its behaviour during their use. Depending on the application of the pump, the system can be carefully controlled in some cases (e.g. water distribution networks and wastewater treatment plants) whilst in others this is difficult to achieve (e.g. wastewater transport and flood control). It is thus not possible to describe the factors affecting the pumps efficiencies without describing the system they operate.

There are some factors affecting the energy consumption of the pumps which are relevant for all the pumps within the scope of this study, and others which apply only to certain types of pumps. Overall, the user defined parameters at a system level which are crucial for the energy consumption of the pump are:

- Specification and design of the system in which the pump is installed: Meaning the configuration of the system affecting the system hydraulics which in turn affect the hydraulics of the pump.
- Correct selection of pump according to application: Meaning in terms of size, duty point, flow rate and pressure and type of fluid they are meant to pump.
- Operation time: Meaning how many hours/day and days/year the pump is meant to operate (i.e. the product service lifetime).
- Control method: Meaning the type of system applied to control the pump flow and/or pressure. This can be throttling, bypassing or a simple on/off timer to pump constant flow, or a VSD that adjusts the flow[131].

7.1.1 Common characteristics of water pumps

The real life efficiency of pumps differs from those tested in standard conditions. The factors that contribute to this fact are:

- Part-load, away from the pump's Best Efficiency Point (BEP) and fluctuating loads

[131] http://electrical-engineering-portal.com/comparison-of-4-different-flow-control-methods-of-pumps

- Wear of impeller, bearings and seals

Part load characteristics of water pumps

This relates to the typical efficiency of the pump as installed, rather than the nominal or catalogue efficiency at the BEP. Designers will specify a pump with a safety margin to indicate in the company catalogues slightly more flow or head than what originally calculated. This allows for any difference in system characteristics from what is planned. This means that the average pump will work lower than what is specified as BEP, and hence below its nominal rated efficiency.

Not only the energy efficiency of the pump is reduced when the pump does not work in its BEP, but other several damaging effects can occur if the pump operates in a duty point far from its design. Some examples are:

- Premature failure of components such as bearings, wear rings, bushes, couplings and seals
- Risk of damage to pump components due to cavitation
- Noise and vibrations induced to the system

Taking into account both the wear and the fact that the operation of the pump is away from the BEP, stakeholders agreed with the Lot 11 study suggestion that, for pumps within the scope of that study, the average pump operates 10-20% (15% average) below the catalogue efficiency (i.e. 15% below BEP). However, this was only for clean water pumps covered in that study. No similar information existed before data was collected for the rest of the pumps in scope of this study.

Wear and maintenance

The energy efficiency of pumps is not constant over its lifetime. Usually the energy efficiency is reduced as the pump wears down. Proper maintenance can keep the pump running at higher efficiency at longer periods, but the pump will in any case be worn down eventually. Figure 17 illustrates how the energy efficiency of a pump is typically reduced over time with and without proper maintenance.

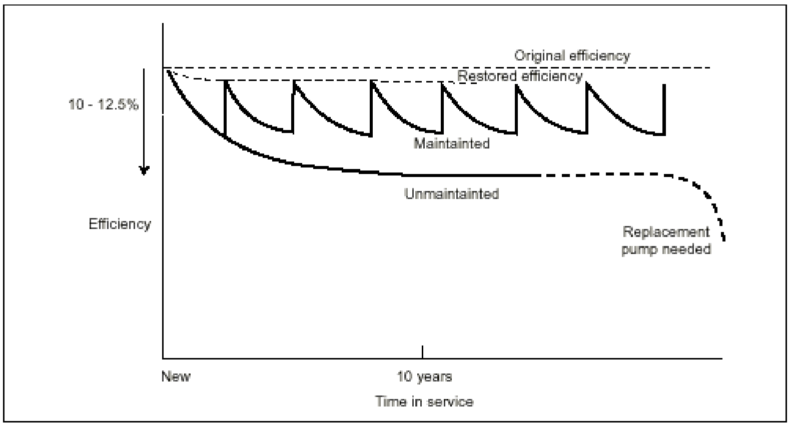


Figure 17. Illustration of how the energy efficiency of a typical pump is reduced over time due to wear[132].

Over the course of a pump's lifetime, maintenance activities will consume the following:

- Lubricant (grease) for bearings
- Replacement seals

[132] Lot 11 page 68 (figure 3-5)

- New bearing
- New wear rings
- New impeller
- New diffuser

7.1.2 Clean water pumps

The clean water pumps which were selected for the 'preliminary scope' were those who are already regulated by Regulation (EU) 547/2012, submersible multistage borehole pumps other than 4" and 6" and bigger pumps such as ESOB 150kW-1MW, submersible multistage borehole pumps 6-12", vertical multistage pumps 25-40 bar and horizontal multistage pumps up to 40 bar. Some of these pumps were screened out once data from industry was received and used to define the final scope (see chapter 9 for more details).

These pumps are used in a wide range of applications both in industry, utilities and in residential buildings and housing. Small pumps (i.e. those in scope of current regulation) are usually standard pumps, meaning they are manufactured in large scale and used in agriculture (water supply and circulation), for water supply, circulation and cooling in industrial processes, for water supply to industrial and residential buildings, and in water distribution by utility companies[133102]. Engineered pumps, which are generally of large size and built to a high specification, are used for water extraction by utilities and for high pressure feed in industrial processes[134102]. Special purpose pumps, which are required where standard and engineered pumps cannot provide an efficient solution and are produced in relatively small numbers by specialist companies, are used in agriculture (irrigation), in industrial and residential buildings as well as by municipal utilities for water treatment, in industrial processes for cooling and hygienic applications as well as for water treatment.

According to Lot 11[135], most significant energy savings come from attention to the way in which the system is designed and controlled. This is by means of optimal pump selection and pump sizing (e.g. standard, special or engineered pump according to desired duty point), optimising operating pressures and ensuring adequate controls, which can lead to energy savings of up to 34%. For smaller pump systems (5-10 kW), the designer is unlikely to have sufficient time to optimise the complete hydraulic system, so there is a clear advantage of using these pumps with integrated controls (typically Variable Speed Drives - VSDs) for achieving energy savings. For bigger pumps, it is more common to optimise the hydraulic system, including by using VSDs, but it is still seen nowadays that many of these pumps are used in constant flow applications and/or without the use of speed control.

Although there are many applications for clean water pumps, some product features remain similar for all of them, due to the fact that the pump media is clean water (water with no significant amount of solids or solvents). Impellers for clean water pumps have fine clearances to minimise backflow and to maximise hydraulic efficiency. Besides impeller design clean water pumps are optimised by their inlet and outlet connection to the piping system by optimising vacuum properties that create less friction, which helps on maintaining hydraulic efficiency. Operation close to the BEP is obviously important for these

[133] European Industrial Forecasting Ltd (2015). The World Pump Market 2015-2020. Volume I.
[134] Ibid.
[135] Lot 11, page 63

pumps, however, the importance of a better installation and maintenance only gives limited savings (3%)[136135].

Extended Product Approach (EPA)

Many clean water pumps are used in variable flow applications (see Table 18). For these applications VSDs are very suitable. Therefore, several large clean water pumps are sold as pumping units which are fitted with VSDs. But despite this development in the very recent years it is still a small minority of the pumping units that are sold with VSDs (see Table 18). From consumers there is a limited awareness of the considerably large energy saving potential from applying VSDs to water pumps. For many costumers the purchase price is a very significant parameter when choosing which pump to buy, even though the lifetime cost can be much higher for the cheaper pumping unit. It is estimated that only by a wider use of VSDs for clean water pumps, the energy savings would be significant (see Final Scope chapter). It is therefore crucial for the success of the revision of the regulations that EPA for clean water pumps is included.

Booster-sets

A new category for this study that is not included in either of the previous preparatory studies and the existing regulation is booster-sets. Booster-sets can be one or more pumps added together to one unit with the purpose of increasing the flow rate to a water circulation system. In a booster-set with more than one pump, the pumps are connected in parallel to vary flow. Booster-sets are used in booster stations in buildings where the central water supply is unreliable as it cannot ensure the minimum flow pressure at the taps[137]. For this reason, the booster stations have to be sized for the maximum flow taking into account concurrency taps and maximum head, and therefore the partial load operation is not taken into account. However, due to the high electrical driving power of booster stations, the efficiency evaluation of these systems is becoming increasingly important where partial load plays an important role leading to a weighted energy demand and subsequent energy savings. The efficiency of real booster stations depends on the ability to follow the partial load operation and to guarantee in this way a demand oriented operation. This partial load can be segmented in many different load profiles which are not harmonised yet.

The demand for increasing the pressure in a system varies a lot over time and therefore all booster-set applications should use VSDs to target the variable flow applications. In variable flow applications the use of VSDs are often very beneficial, however only 50% of booster-sets are currently used with VSDs (see Table 18).

Table 18. Overview of share of constant/variable flow applications and use of VSDs for clean water pumps and booster-sets.

Category	Size division	Variable flow applications (%)	Constant flow applications (%)	Share of pumps with VSDs in variable flow applications (%)
ESOB	Rated power ≤ 22 kW	50%	50%	8%
	Rated power 22 - 150 kW	30%	70%	13%

[136] Lot 11, page 63
[137] 'Efficiency evaluation of booster stations using load profile and control curve'. Prof. Dr. –Ing. Rainer Hirschberg VDI, Wiesbaden.

Category	Size division	Variable flow applications (%)	Constant flow applications (%)	Share of pumps with VSDs in variable flow applications (%)
	Rated power > 150 kW	10%	90%	0%
ESCC	Rated power ≤ 22 kW	50%	50%	10%
	Rated power 22 - 150 kW	50%	50%	10%
ESCCi	Rated power ≤ 22 kW	90%	10%	33%
	Rated power 22 - 150 kW	90%	10%	33%
MSSB	Nominal outer diameter ≤ 6"	20%	80%	5%
	Nominal outer diameter 6" - 12"	20%	80%	50%
	Nominal outer diameter > 12"	10%	90%	0%
MS-V	Maximum design pressure ≤ 25 bar	50%	50%	16%
	Maximum design pressure 25 - 40 bar	50%	50%	70%
MS-H	Maximum design pressure ≤ 25 bar	50%	50%	27%
	Maximum design pressure 25 - 40 bar	50%	50%	43%
Booster-set	Rated power ≤ 150 kW	100%	0%	50%

Operation time

Information provided by Europump on annual operational time of clean water pumps has been used to establish the using times for each clean water pump category. An overview of the average operational times can be seen in Table 19.

Table 19. Overview of average operational times for clean water pumps.

Category	Operation time (hours/year), variable flow applications	Operation time (hours/year), constant flow applications
ESOB	5,000	2,250
ESCC	5,000	2,250
ESCCi	5,000	2,250
MSS	2,880	2,880
MS-V	5,000	2,250
MS-H	5,000	2,250
Booster-set	2,000	Not applicable

7.1.3 Wastewater pumps

While energy efficiency is important for wastewater pumps, there is a vital trade off with the ability to pass solids and resist clogging or ragging. “Rag” is a term used to describe the fibrous solid matter found in wastewater. The ability to resist wear is also crucial for wastewater pumps, so that their efficiency is maintained over the pump’s lifetime.

By way of comparison, the hydraulic efficiency of channel wastewater pumps for constant flow applications in the range of 15-25 kW rated power is about 50-55% whilst that of an end-suction clean water pump also for constant flow applications of about the same size range is about 60-65%. End users traditionally accept this efficiency penalty as long as the pumps do not regularly block and fail, according to information from industry during the stakeholder consultation process of this review and what stated in previous preparatory studies.

Submersible centrifugal wastewater pumps can be used in different application systems:

- Wastewater transport and flood control
- Wastewater treatment

Wastewater transport and flood control

Wastewater is typically collected and transported from urban areas, either from (i) far areas where wastewater is not so polluted with solids, or from (ii) cities and/or near wastewater treatment facilities where wastewater contains different types of solids and objects, some of them being abrasive and creating clogging which damages the hydraulics of the pump.

The variation in flow the pumps need to handle can be great, and these are due to amount of rain and storms but also droughts and/or water preservation practices. For example, there are cases in Germany[138] where the municipalities have to add clean water to the sewers to lower the concentration of solid matter in the wastewater.

In cities, the quality of the wastewater can also vary significantly, depending on the amount of suspended solids and their size, which can be small solid particles such as sand and dirt or big objects such as clothes, cans, toys, sanitary towels, etc. The habits of people can be very different from one region to another within the same country and/or within Europe which define the amount and type of objects that are thrown in the toilets and in the sewer.

Wastewater treatment

Once the wastewater arrives to the treatment plant after collection, transport and flood control, it comes highly concentrated with solids. It arrives first to the inlet pumping station where a screen removal is located to screen out all the big solids, the sand and the grit and grease which affect all the treatment process and which are later collected and disposed as solid waste. In some countries of the EU these screen removals are located in the city as part of the wastewater transport and flood control, whilst in others this happens only at the wastewater treatment plant.

Once the big solids are removed, the wastewater enters the treatment plant typically with a high content of suspended solids which are biodegraded in the activated sludge process or reduced in the chemical treatment. The wastewater is pumped through the different treatment steps where the amount of solids is decreased the closer it gets to the effluent discharge. Most of the wastewater utilities in Europe control the wastewater quality throughout the process and optimize the degradation and/or reduction treatment by pumping wastewater through the different tanks and by letting the wastewater react with the bacteria and/or the treatment chemicals. For this reason, the pumping is very controlled and the wastewater characteristics are too, in order to optimize the treatment process. Finally, the wastewater is discharged back to water channels or to the sea, where

[138] From Hesse, Germany, and from Veolia

pumping also occurs and where the wastewater characteristics are strictly controlled to comply with wastewater discharge limits.

An example of the points where pumping stations are located for both wastewater transport and flood control applications and for wastewater treatment applications are given in Figure 18. From dialogues with wastewater pumps' manufacturers, it was observed these two main applications define the variation in flow rate and the variation in solid content in wastewater systems, which affect the hydraulic performance of wastewater pumps. It is thus important to identify the application of the pumps (i.e. used in wastewater transport & flood control or used in wastewater treatment), to determine the type of pump used and what the expected efficiency will be.

Figure 18. Wastewater pumps' applications and location of pumping stations in cities and wastewater treatment plants. Example presented by Grundfos at IFAT 2016.

To be able to cope with peak flow rates there are several strategies:

- Use of large pumps that can handle peak loads (can be combined with VSD). According to some utilities' engineers[139], it is only about 5% of the total time when the pumps need to handle peak loads in wastewater treatment facilities (though this may change in the future as more floodings occur), therefore pumps tend to be oversized consuming more energy than needed. They argued that it is preferable to control the speed of the pumps with VSDs, in order to deal with flow differences and to optimize the process, and in this case pumps do not need to be much oversized.
- Use of extra pumps that are employed in peak situations, where bigger pumps can be put in place when it is needed, or where several pumps in a row are used to create an increased ability to deal with higher flow rates.
- Use tank buffer to even out the load over time. This was the preferred option in the past, but due to increased amount of peak flow rates and lack of space, this strategy is not applied as often as it used to.
- Use of axial pumps, which are most suitable for heavy rainfalls or floods. These pumps are used also in big wastewater treatment plants.

To be able to cope with high amount of solids there are also several strategies:

- Installation of screens at pumping stations which can be removed by the municipalities to dispose the solids as waste.

[139] From Hesse, Germany, and from Veolia

- Installation of filters, sand traps and solids separation systems both at wastewater transport and flood control systems as well as at wastewater treatment plants.
- Better pump hydraulics designs that can cope with different types and amounts of solids and gases.

The impellers in centrifugal wastewater treatment pumps are designed to allow solids or gases to pass through the pumps without clogging it up, and so have a very different appearance. Therefore, they are less energy efficient. The optimal impeller design for a wastewater pump depends on the characteristics of the wastewater it is pumping, e.g. size and hardness of solid content, viscosity of water/sludge, etc. Through careful selection of the impeller, it is possible to achieve the best efficiency with an acceptable (if any) likelihood of blockage from ragging. One application might require a very specific design with a low energy efficiency to avoid blockage, whilst for other applications a more energy efficient design could be used. Otherwise, it is necessary to replace impellers often (even a few times per year) and this becomes an expensive repair activity.

Three common impeller types are used in wastewater treatment:

- Open channel impellers: Which have large spaces between vanes and the fluid enters the eye being added energy through the turning vanes and directed to the discharge nozzle. Depending on the amount of channels, these impellers can reach efficiencies as high as 80-90%[140]
- Closed channel impellers: Which have two plates enclosing the vanes and the fluid enters the eye being directed to the discharge nozzle. Depending on the amount of channels, these impellers can reach efficiencies as high as 90%[141140].
- Vortex: Which creates a vortex within the pump bowl preventing the solids from coming into contact with the impeller These impellers are usually low in efficiency (20-30%[140]), as their vortex functionality is a trade-off with efficiency.
- Special impellers with grinding and/or shredding capabilities to break up big solids allowing them to pass through the pump with greater ease. These impellers show a maximum efficiency of 47%[142].
- Axial impellers: Which are designed for high flow rates and which are highly efficient (>90%[143140]).

Wastewater characteristics by pump application

Due to the difficulties on characterizing wastewater quantitatively a more simplified characterisation approach must be developed for wastewater pumps applications. Especially since characteristics can vary a lot and therefore it would be either impossible to harmonize (for wastewater transport and flood control applications), or, even if the characteristics can be tracked, there is no warranty the quantitative parameters are always the same at the same pumping points (for wastewater treatment applications).

Extended Product Approach

As with other pump types, the energy efficiency of wastewater pumps depends on the system it is included in, the motor that is applied to it and the control method.

Wastewater pumps are almost exclusive B2B products and the custumers are either utility companies or industries, which even though are expected to know the technical details and

[140] Communication at IFAT 2016 fair.
[141] Ibid.
[142] Ibid
[143] Ibid.

best fitting applications of the products they need, they are also resistant to use other more efficient technologies as they want to ensure their pumps cope well with peak flow rates and high contents of solids. Input from Europump suggests that in all wastewater pump applications where VSD would be beneficial, it is expected that it would be applied to the pump. However, most of the utilities operate wastewater pump units in constant flow (see Table 20). Many utilities' operators believe that in many cases, it is not possible to operate wastewater pump units in variable flow as the settling of solids at low flow velocities will clog the impellers of the pumps. But according to input from some wastewater utilities and manufacturers[144], it is possible to switch more pumps to variable flow operations if the right pump type is purchased (see section 8.2.3 for different wastewater pumps technologies), In this case, the potential energy savings for EPA regulations would be much larger because pumps would switch from constant flow operation to variable flow.

However, it seems reasonable to consider that not all wastewater pumping systems are as energy optimised as possible, given the available technology. The range of possible energy optimisations for wastewater systems is large, and it is likely that designers often do not consider alternatives to the traditional wastewater system designs. By using variable flowrates rather than on/off control systems, greater energy savings might be possible. But alternative forms of control lead to alternative requirements to the system design. Therefore, such energy savings cannot be achieved solely by EPA, but require also a system approach.

Table 20 shows that all pumps used back in 2014 in variable flow applications used VSDs[145]. However, as it appears from input from some wastewater pump manufacturers and some utilities[220], more wastewater pumps could be operated at variable flow with VSD if the end-users would know that it will not compromise other essential aspects like non-clogging, as explained before. This could unlock a higher share of variable flow applications, which could in principle mean lower energy consumption since pump units would not be operating at full speed all the time. If these pump units would continue operating with a VSD, high efficiency would be also secured. Improvement potentials at product level are so far found more limited than those arising from variable flow applications using VSDs (to be discussed more in detail in following chapters).

Table 20. Overview of share of constant/variable flow applications and use of VSDs for wastewater pumps[146].

Category	Size division	Constant flow applications (%)	Variable flow applications (%)	Share of pumps in variable flow applications used with VSDs (%)
Submersible vortex radial	Rated power ≤ 10 kW	95%	5%	100%
	Rated power 10 - 160 kW	93%	7%	100%
Submersible channel radial	Rated power ≤ 10 kW	95%	5%	100%

[144] Provided at IFAT 2016 (http://www.ifat.de/index-2.html)
[145] Input from Europump in 2015
[146] Europump is currently revising these tables in order to update the values. Information will be available for the Impact Assessment.

Category	Size division	Constant flow applications (%)	Variable flow applications (%)	Share of pumps in variable flow applications used with VSDs (%)
	Rated power 10 -25 kW	93%	7%	100%
	Rated power 25 - 160 kW	80%	20%	100%
Submersible pumps for activated sludge, axial	Rated power < 160 kW	76%	24%	100%
Submersible pumps for storm and effluent water, mixed flow and axial	Rated power < 160 kW	76%	24%	100%
Dry well pumps for storm water, mixed flow and axial	Rated power < 160 kW	100%	0%	0%
Dry well vortex pumps for wastewater	Rated power ≤ 10 kW	95%	5%	100%
	Rated power 10 - 160 kW	93%	7%	100%
Dry well channel pumps for wastewater	Rated power ≤ 10 kW	87.5%	12.5%	100%
	Rated power 10 -25 kW	93%	7%	100%
	Rated power 25 - 160 kW	80%	20%	100%
Submersible dewatering pumps	Rated power < 160 kW	100%	0%	0%

Operation time

Information provided by Europump on annual average operation times for each wastewater pump category[148] has been used to establish their annual use time. An overview can be seen in Table 21.

Table 21. Overview of average operational times for wastewater pumps[147].

Category	Operation time (hours/year), all applications
Submersible vortex radial pumps (SVR) < 10 kW	1,000
Submersible vortex radial pumps (SVR) 10 - 160 kW	1,500
Submersible channel radial pumps (SCR) < 10 kW	1,000
Submersible channel radial (SCR) pumps 10 - 25 kW	1,500
Submersible channel radial pumps (SCR) 25 - 160 kW	2,000
Submersible axial pumps (SA) for activated sludge	5,000
Submersible pumps (SMFA) for storm and effluent water, mixed flow and axial	5,000

[147] Europump is currently revising these tables in order to update the values. Information will be available for the Impact Assessment.

Category	Operation time (hours/year), all applications
Dry well pumps (DW) for storm water, mixed flow and axial	250
Dry well vortex pumps (DWV) for wastewater < 10 kW	1,000
Dry well vortex pumps (DWV) for wastewater 10 - 160 kW	1,500
Dry well channel pumps (DWC) for wastewater < 10 kW	1,000
Dry well channel pumps (DWC) for wastewater 10 -25 kW	1,500
Dry well channel pumps (DWC) for wastewater 25 - 160 kW	2,000
Submersible dewatering pumps (SD)	2,000

7.1.4 Swimming pool pumps

Swimming pool pumps can be used to pump water through filters, heaters, and chemical dosing systems. The number of changes of water required per day is the subject of regional recommendations, which can vary considerably. The national laws in different countries deal with water quality standards and necessary flow rates, and turnover rates with respect to different types of pools (e.g. in France, Belgium, Austria).

The operation of swimming pool pumps is ruled by different system demands. These are described in the next sections, as well as their potential for energy efficiency improvement at extended product level.

Self-priming pumps

Swimming pool pumps can be self-priming, and this capability is necessary when[148]:

- Pool pumps are installed above the pool water level
- Pool pumps are installed above the balance tank water level
- Both manual or automatic suction cleaners are used
- Above ground pools are installed without integrated suction inlets
- Restarting the pump after cleaning the strainer basket

According to EUSA Working Group[149,148], self-priming pool pumps represents the majority of the pumps which are equipped in the permanently installed pools. The capability to reprime itself during normal operation can be qualified with the standardized test method of EN 16713-2[150], as part of the three standard series on requirements and test methods on domestic swimming pools water systems. When swimming pool pumps are self-priming, it can be expected that the efficiency of the pumps is reduced as their ability to handle air and be self-priming is at the sacrifice of efficiency[151]. However, it is expected that the priming functionality in swimming pool pumps is only a small fraction of its running time, but due to lack of available data and of input from industry, no distinction was made between self-priming and non self-priming pumps when presenting use data for swimming pool pumps. Nor distinction was made between efficiencies between non priming and priming functions (i.e. efficiency data was collected overall concerning all pumps in the EU market).

[148] EUSA Pool Pump Working Group Position paper #2, dated on the 21st of March, 2016
[149] Ibid.
[150] FprEN 16713-2. Domestic swimming pools – Water systems – Part 2: Circulation systems – Requirements and test methods. September 2015.
[151] "Unsuitability of some pump types for regulation and problems to be solved for others". Europump position paper, final issue 1. February 16th, 2016.

Physical and sanitation treatments in swimming pool pumps

EUSA Working Group[152148] differentiates between physical and sanitation treatments in swimming pools. The physical treatment is to remove the suspended matter from the pool water by passing the water through a suitable medium contained in a filter body[153], whilst the sanitation treatment is achieved by using chemicals to disinfect the pool water. According to input from stakeholders, the reason why the relationship between the filtration and sanitation systems is key on identifying the potential for energy savings of swimming pool pumps, is that the removal of pollution and achievement of clarity in swimming pools is achieved by both of these means.

The physical treatment in a swimming pool is made by the filtration and the circulation systems. The filtration system is to remove the suspended matter from the pool water by passing the water through a suitable medium contained in a filter body[154153] whilst the circulation system[155] will ensure the greatest possible mixing of the water in the pool basin in order to provide a uniform distribution of chemical treatment and heat, making sure fine debris are kept in suspension as long as possible so it can be removed by the filtration system, assuring there are no 'dead areas' where water movement is zero[156].

The sanitation treatment is not defined in the stakeholders position papers nor in the EN standards, but it is assumed to be the complementary step to disinfect the pool water by using chemicals such as chlorine and ozone.

The filtration system of the physical treatment shall have a sufficient nominal flow rate to allow the total volume of water contained in the pool to be recycled in the most appropriate time in order to protect the user health by removing solid organic particles from the water[157,148]. This is what is defined as 'maximum turnover rate' (MTR), which in Europe is recommended to be no longer than 8h in comparison to 12h in the USA (according to the NSF 50)[158,148]. Differences in MTR will give a significant decrease of nominal flow rate which it is assumed to affect the quality of pool water.

EUSA Working Group points out that if a proper circulation is not achieved, the risk of accumulation of free chlorine in the bottom of the pool and organic pollutants (e.g. skin fats, body oils, saliva, mucus) at the top is greater. Furthermore, they point out at the differences between water quality recommendations in the USA and in Europe for free chlorine (see Figure 19), as free chlorine residues give an indication on the amount of disinfectants allowed for use by the sanitation treatment. EUSA Working Group concludes that, if more chlorine residues are allowed in the USA, less circulation is required by the physical treatment and thus there are differences in the recommended maximum turnover rates. However, in spite EUSA Working Group only refers to free active chlorine levels without cyanuric acid pointed out by Fpr EN 16713-3:2015, it is not clear why free chlorine levels in combination with cyanuric acid are not used for comparison. The latter being not as different to the USAs requirements as the levels of free active chlorine. Furthermore, it

[152] EUSA Pool Pump Working Group Position paper #2, dated on the 21st of March, 2016
[153] FprEN 16713-1:2015
[154] Ibid.
[155] According to EUSA Pool Pump Working Group Position paper #2, dated on the 21st of March, 2016, a circulation system is: "All equipment which has separate functions, but when connected to each other by piping, perform as a coordinated system for the purpose of maintaining pool water in a clear and sanitary condition. This equipment may be, but not limited to, categories of pumps, hair and lint strainers, filters, valves, gauges, meters, heaters, surface skimmers, inlet/outlet fittings, and chemical feeding devices."
[156] FprEN 16713-2:2015
[157] EUSA Pool Pump Working Group Position paper #2, dated on the 21st of March, 2016
[158] Ibid.

is not clear whether only one or the other or a combination of both can be used for comparison with the free chlorine levels presented by the ANSI/APSP/ICC-15 2011 Standard.

A. Sanitizer Levels				
1. Sanitizer Residual A residual of an EPA-registered sanitizer shall be present at all times and in all areas of the pool or spa. One of the following EPA-registered sanitizer systems shall be used: Chlorine; or Bromine; or PHMB; or Metal-based systems.				
1. Free Chlorine, ppm				
Standard	Minimum	Ideal	Maximum	Comments
APSP-1 APSP-4 APSP-5 APSP-9 APSP-11	1.0	2.0–4.0	The U.S. EPA has established a maximum chlorine level of 4.0 ppm for re-entry of swimmers into the water. However, state or local health codes may allow or require the use of chlorine levels above 4.0 ppm.	Hot water/heavy use may require operation at or near maximum levels. • Test kits are available for a variety of free chlorine ranges. • Free chlorine test color (DPD) may be completely or partially bleached by chlorine levels greater than 5 ppm to give a false low reading. For appropriate test kit, consult pool professional or test kit manufacturer. Regular oxidation is recommended and remedial practices may be necessary.

Parameter	Value
Water clarity	clear view of the pool bottom
Colour of the water	no colour should be observed[e, f]
Turbidity in FNU/NTU	max 1,5 (preferably less than 0,5)
Nitrate concentration above that of fill water in mg/l	max 20
Total organic carbon (TOC) in mg/l[a]	max 4,0
Redox potential against Ag/AgCI 3,5 m KCl in mV	min 650
pH value[c, d]	6,8 to 7,6
Free active chlorine (without cyanuric acid) in mg/l	0,3 to 1,5
Free chlorine used in combination with cyanuric acid in mg/l	1,0 to 3,0
Cyanuric acid in mg/l	max 100[b]
Combined chlorine in mg/l	max 0,5 (preferably close to 0,0 mg/l)
When using alternative/additional disinfectants other appropriate parameters may be considered.	

Figure 19. Comparison of free chlorine recommendations in swimming pool water between the USA (above) and the EU (below). Data sources: ANSI/APSP/ICC-15 2011 Standard (taken from EUSA WG Position paper #2) and FprEN 16713-3:2015.

System approach

In spite of the difficulties of identifying areas for potential energy savings by EUSA Working Group, they recommend[159,148] to look at a System Approach instead as the pump technologies alone cannot be assessed as isolated factors for achieving energy efficiency in swimming pool systems. They suggest to look at the whole physical treatment system (i.e. the filtration and circulation systems) together with the pool design and the sanitation treatment when investigating alternatives for reducing energy consumption.

[159] EUSA Pool Pump Working Group Position paper #2, dated on the 21st of March, 2016

The fact that the market of swimming pool pumps is unlike that of other water pumps in this study, which is dominated by many smaller manufacturers and manufacturers that produce a wide range of products for swimming pools, makes it more challenging to bring swimming pool pumps into the scope of the regulation. The lack of awareness on energy consumption by consumers influences the manufactures, defining a market which does not have the same focus on improving the energy efficiency of the pumps. It is therefore assumed that there are potential energy savings to be gained from improving the operation of the pumps , but by making sure this does not compromise the hygiene of the swimming pool.

Furthermore, the fact that the pumps perform as circulation systems brings opportunities to reduce energy consumption by fitting the actual flow rate to lower levels at some points of the day where the circulation system does not need to operate at its highest. An example in the UK has been identified by the study team[160], where the pump can be adjusted to different speeds depending on the time of the day and application needs (see Figure 20). This pump allows motor speed reductions to different pump operation modes such as night filtration, suction cleaning, heating, or a normal filtration cycle. In spite that the pump's purchase price is about 3.5 times more expensive than an average swimming pool pump, the manufacturer claims that by adapting the speed to different purposes, the annual savings in terms of energy would allow a payback period of about 5 years for a 1 HP pump, and it would reduce the noise significantly as this is an important secondary performance parameter for domestic swimming pool pumps.

Figure 20. Example of a variable speed pump in the EU market which can be fitted to different applications (IntelliFlo™)[161].

[160] http://poolstore.co.uk/blog/the-intelliflo-pump-and-why-it-might-be-worth-1200/
[161] http://poolstore.co.uk/upload/photo/cms/file/pdfs/IntelliFloVS-VF%20Brochure.pdf

Extended Product Approach

In the USA and in Australia the use of VSD for swimming pool pumps is becoming more prevalent because there are energy savings to be made by regulating the flow rate of the pumps instead of simply using on/off control. However, in the EU and based on data provided by EUSA, a small share of pumps are used with VSDs but only in constant flow applications for controlling different on/off settings (see Table 22). The use of VSDs is mostly favourable when the pumps operate at lower flows and/or pressures, thus farer from their BEP than when operating at the duty point the whole time. Thus, the use of VSDs in constant flow applications does not bring the higher efficiency levels and reduced energy consumption that some examples in the USA and Australia suggest.

Table 22. Overview of share of constant/variable flow applications and use of VSDs for swimming pool pumps.

Category	Size division	Variable flow applications (%)	Constant flow applications (%)	Share of pumps with VSDs in constant flow applications (%)
Swimming pool pumps	Rated power ≤ 2.2 kW	0%	100%	2.9%
	Rated power > 2.2 kW	0%	100%	2.9%

It should be noted that it is the opinion of the stakeholders represented by EUSA that: "Adjustments regarding reduced flow rates, reduced turnover times in order of energy saving aspects have to be avoided under any circumstances." Lower flow-rates might lead to accumulation of suspended solids and potential for bacterial growth, especially at the bottom of the swimming pool. According to EUSA in USA and Australia chlorine and disinfectants are used in a higher extent as the concentration limits of these chemicals in the swimming pool pumps are allowed to be higher.However, no concrete input from stakeholders was provided on these limits. Only recommendations were found by the study team (see Figure 19).

Moreover, stakeholders commented during the consultation process that the USA tends to use larger pumps than what needed (i.e. delivering nominal flow rates larger than what needed to circulate the water). Therefore, reducing the flow does not affect the required water circulation through the pool so it would affect the water quality. However, stakeholders did not provide concrete examples of such cases when requested.

A desktop analysis with two concrete examples of swimming pool pumps found in the US database of pool pumps[162] was made, considering operational recommendations both in the US and in the EU. This analysis was done to identify any energy savings potential that could be used to confirm/reinforce industry's statement about the limitations of using the same operational conditions in the US when using swimming pool pumps in the EU.

In order to perform this analysis, the operational parameters that define the potential for using a VSD were identified. These are classified as independent meaning those which are fixed, recommended and selected by the user, and as dependent meaning those which rely on the first ones (see Table 23). The two examples from the desktop analysis depart from

[162] APSP Appliance Efficiency Pool Pump Database available at: http://apsp.org/resources/energy-efficient-pool-pumps

two different parameter configuration using different assumptions (see Table 24 and Table 26).

Table 23. Operational parameters relevant when applying EPA to swimming pool pumps.

Independent parameter		Dependent parameter
Fixed	Pool volume	Pool water flow Energy consumption of pump unit Energy efficiency of pump
Recommended	Maximum Turnover Rate (MTR)	
Decided by user	Operational time per day Swimming pool pump size Swimming pool pump speed	

Example 1 – Fixed Maximum Turnover Rate (MTR) recommended by EUSA

The first example considers a fixed MTR according to what is recommended by EUSA (i.e. 8 hours)[163].

Table 24. Parameter values & dependencies in example 1.

Parameter	Value
Pool Volume	4 m x 8 m x 1.9 m = 60.8 m^3
Maximum Turnover Rate (MTR)	8 hours
Operational time per day	24 hours
Swimming pool pump efficiency	Depends on pump, see Table 25.
Swimming pool pump size	Depends on pump, see Table 25.
Swimming pool pump speed	Depends on pump, see Table 25.

The savings related to using a VSD with swimming pool pump units is obtained through adjusting the flow exactly to the recommended MTR.

Choosing a proper size of swimming pool pump is essential to the economy of the system. The affinity laws that govern the operation of a pump[164] state that reducing the flow by just 5% will yield a 14.3% reduction in energy consumption. This is for a perfect system and the change in efficiency of the pump should, in principle, be taken into consideration as well.

For a swimming pool system, the flow conditions can be considered fixed in the way that a certain size pool will need a certain flow that satisfies the Maximum Turnover Rate (MTR), which is the maximum time it takes for all the pool water volume to circulate through the filter. Exceeding this flow will yield better but unnecessary filtration at an increased energy consumption. A turnover time of 8 hours is the recommendation in the EU by EUSA. Choosing an arbitrary pool size (see Table 24), an example calculation is carried out.

Using the recommended MTR, a 7.6 m3/h flow becomes the minimum required:

$$Q = \frac{Volume}{MTR} = 7.6\mathrm{m}^3/\mathrm{h}$$

To properly chose a pump a pool system curve describing the interdependency of pressure loss and flow is used. The curve originates from the American APSP-15 (originally from ANSI/HI 1.6-2000). The curve describes the expected relation for pressure loss and flow

[163] EUSA Pool Pump Working Group Position paper #2, dated on the 21st of March, 2016

[164] See for example: https://www.introtopumps.com/pump-terms/affinity-laws/

in a 2-inch piping system in pools less than 17000 gallons (64.4 m^3). The head is proportional to the flow squared as stated in the affinity laws.

$$Head = 0.0167 \cdot Flow^2$$

In this equation head is in feet water column and flow in gallon per minutes.

Now considering a database[165] with 36 different swimming pool pumps a couple of suitable pumps are chosen.

The two single speed pumps and the dual speed pump are chosen to match the design flow as close as possible given the stated system curve. The IntelliPro pump is chosen because the pump data are available and are very close to the design flow yielding less uncertainty when using the affinity laws.

A shaft speed of 1725 RPM by the IntelliPro pump corresponds to a flow of 8.2 m^3/h according to the pool system curve, which is exactly identical to that of the single speed pumps. This enables a direct comparison between the pumps before the variable speed benefit is evaluated.

Table 25. Technical data for the four pumps.

	Speck A91R[166]	Hayward SP2305X7EESP[167]	Badu EcoM2/433-V*[168]	IntelliPro VS-3050[169]
Type	Single Speed	Single Speed	Dual Speed	Variable Speed
Rated Power [HP]	0.75	0.75	0.75 / 1.5	3
Flow [m3/h]	8.2	8.2	7.9	8.2
Power [kWh/day][170]	12.9	12.3	9.3	9.4
Head [kPa]	64.7	64.7	61.1	64.7
Speed [% of max]	100%	100%	50%	50%
Efficiency[171]	27%	29%	35%	38%

Since no efficiency curves for IntelliPro are available, the loss of pump efficiency at a reduced speed (*N*) is not accounted for. This will have an influence on energy consumption but since the RPM is only decreased by 7%, it is assumed this would be small:

$$\frac{N_{Design,flow}}{1725\ RPM} = \frac{Q_{Design,flow}}{Q_{1725\ RPM}} = \frac{7{,}6}{8{,}2} = 93\%$$

Once the flow reduction is found directly from the affinity laws (calculated above) and the energy consumption at 1725RPM is known ($P_{1725,RPM}$), the energy consumption must be scaled down to the reduced flow $Q_{Design,Flow}$. This is carried out in the following way:

$$\frac{P_1}{P_2} = \left(\frac{Q_1}{Q_2}\right)^3 \rightarrow P_{Design,Flow} = P_{1725,RPM} \cdot \left(\frac{Q_{Design,Flow}}{Q_{1725,RPM}}\right)^3 = 9{,}4 \cdot \left(\frac{7{,}6}{8{,}2}\right)^3 = 7.5\text{kWh/day}$$

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165 APSP Appliance Efficiency Pool Pump Database (Last Revised: November 5, 2015)
166 http://usa.speck-pumps.com/wp-content/uploads/2017/07/Brochure_Model-A91.pdf
167 https://hayward-pool-assets.com/assets/documents/pools/pdf/manuals/MaxfloXL-IS2300.pdf?fromCDN=true
168 Manual can be found here https://usa.speck-pumps.com/downloads-pool/
169 https://www.royalswimmingpools.com/IntelliFloVS-Manual.pdf
170 Calculated based on the wattage of the pump and the operational time
171 Calculated from the pump curves giving hyrulic power, and rated power

Hayward to Intellipro Comparison:

The total energy savings of switching from a single speed pump (Howard) to a variable speed pump (Intellipro) are found by comparing the power consumption by reducing the flow (see calculation above), which is 7.5 kWh/day to that of the Hayward pump shown in Table 25 which is 12.9 kWh/day: a 39% energy saving.
The operating savings can be split into two aspects:

- Saving due to a more efficient pump: **23.7%**
- Saving due to flow reduction: **15.0%**

The 23.7% savings are found by calculating the pump power consumption at the identical flow of $8.2\ m^3/h$ (see Table 25).

$$Saving_{pump,efficiency} = \frac{P_{Hayward} - P_{intellipro,1725,RPM}}{P_{Hayward}} = \frac{12{,}4\,\frac{\text{kWh}}{\text{day}} - 9{,}4\,\frac{\text{kWh}}{\text{day}}}{12{,}4\,\frac{\text{kWh}}{\text{day}}} = 23{,}7\%$$

The 15% savings were found by comparing the power consumption of the intellipro at reduced flow to the Hayward and subtracting the amount related to pump efficiency.

$$Saving_{total} = \frac{P_{Hayward} - P_{intellipro,Design,Flow}}{P_{Hayward}} = \frac{12{,}4\,\frac{\text{kWh}}{\text{day}} - 7{,}5\,\frac{\text{kWh}}{\text{day}}}{12{,}4\,\frac{\text{kWh}}{\text{day}}} = 38{,}7\%$$

$$Saving_{reduced,speed} = Saving_{total} - Saving_{pump,efficiency} = 38{,}7\% - 23{,}7\% = 15\%$$

Badu dual speed to Intellipro Comparison:

The total energy savings of switching from a dual speed pump (Badu) to a variable speed pump (Intellipro) are found by comparing their power consumption: 7.5 kWh/day (intellipro consumption) to 9.3 kWh/day (Badu consumption in Table 25). This gives a 19% energy saving.

The operating savings can also be split into two aspects, the calculation procedure is that same as carried out for the Hayward & Intellipro comparison:

- Saving due to a more efficient pump: **7.2%**
- Saving due to flow reduction: **11.7%**

The pump efficiencies can again be compared in Table 25. It is important to note that these savings are assuming that the optimal flow, in this case 7.6 m^3/h, can be matched exactly. Also it is assumed that the pumps are running 24 h/day. The savings percentage will however hold true for any time period.

Sizing the pump is not an easy task for swimming pool users. With fixed speed pumps, oversizing the pump will result in higher flow rates than necessary and increased energy consumption. Having a VSD on the pump gives room to the user to choose a large pump but reduce the flow speed filtration needs. The VSD will thus permit a pump to be fitted to the specific filtration and circulation needs of the pool. This will however require careful installation to obtain the desirable flow.

Example 2 – Fixed Maximum Turnover Rate recommended by filter manufacturer

The second example takes a different approach using a different MTR lower than what recommended by EUSA but still recommended by a filter manufacturer in the USA[174].

Table 26: Parameter values and dependencies in example 2.

Parameter	Value
Pool Volume	4 m x 8 m x 1.9 m = 60.8 m^3
Maximum Turnover Rate (MTR)	24 Hours
Operational time per day	Variable
Swimming pool pump efficiency	Depends on pump and operating point
Swimming pool pump size	Depends on pump
Swimming pool pump speed	Depends on pump and operating hours

In an american standard[172] it is stated that:

"For maximum energy efficiency, pool filtration should be operated at the lowest possible flow rate for a time period that provides sufficient water turnover for clarity and sanitation."

The exact time period is however not stated. In an EU standard[173] it is recommended that the filter manuals should state the minimum daily filtration operating time. In a Hayward[174] filter manual the following statements were found:

"Your filter system is designed for continuous operation. However, this is not necessary for most swimming pools. You can determine your filter operation schedule based on your pool size and usage. Be sure to operate your filtration system long enough each day to obtain at least one complete turnover of your pool water."

Using the assumption that only one complete turnover is necessary per day, and given that most filtration systems are designed to sustain a MTR of 8 hours (EUSA recommendation[175] & online recommendation guides[176,177,178,179]), this will amount to an operating pattern of 8 hours filtration and 16 hours of off time which is not energy efficient.

Using the pool and pumps examples presented in *Example 1,* the energy consumption of one turnover as a function of operating hours are calculated in order to find the optimal operational time of the filter system. Data is known for the Intellipro pump at four different rotation speeds. The three relevant speeds corresponding to operating hours of 8 hours, 15 hours and 24 hours (to complete 1 turnover) are shown in Figure 21. For the single speed pumps only one speed is available, thus the operating hours to complete one

[172] "APSP-15 Standard for Energy Efficiency for Residential Inground Swimming Pools, and Spas", The association of Pool & Spa professionals.
[173] EU standard: FprEN 16713-1:2015 E
[174] Hayward ProSeries High Rate Sand Filter Owners Manual.
Link: https://hayward-pool-assets.com/assets/documents/pools/pdf/manuals/IS210T.pdf?fromCDN=true
[175] EUSA Pool Pump Working Group Position paper #2, dated on the 21st of March, 2016
[176] 6-8 Hours: http://www.havuz.org/pool_pool/pool_maintenance/filtration.htm
[177] 6-12 Hours: https://www.inyopools.com/Blog/how-long-should-i-run-my-pool-pump/
[178] 4-8 Hours: https://thepoolrenovators.com.au/swimming-pool-filters-filtration-process/
[179] 6-8 Hours: http://homeguides.sfgate.com/many-hours-should-swimming-pool-pump-run-94574.html

turnover will be fixed. For the dual speed pump two points will be available, only one is shown in Figure 21.

For a fixed MTR, the higher the rotation speed of a pump the lower the operating time. However as the rotation speed is increased and as the operating time lowers the energy consumption increases, as can be seen on Figure 21.

From Figure 21 it can be seen that the single speed pumps who are operated in a start/stop configuration will spend ~8 hours to complete the turnover and use around 4 kWh/day in doing so. The intellipro pump has to run at increased hours when the flow is lowered. This in order to still complete the full turnover.

It should be noted that in this example the energy consumption can be reduced by over 60% by running for 15 hours and then shutting off for the remainder of the time. A slight increase in the daily energy consumption is experienced as the operating hours are increased further. This is a result of moving gradually farther away from the best efficiency point of this specific pump. Since the best efficiency point is dependant on both system and pump the slope of the curve will vary from case to case.

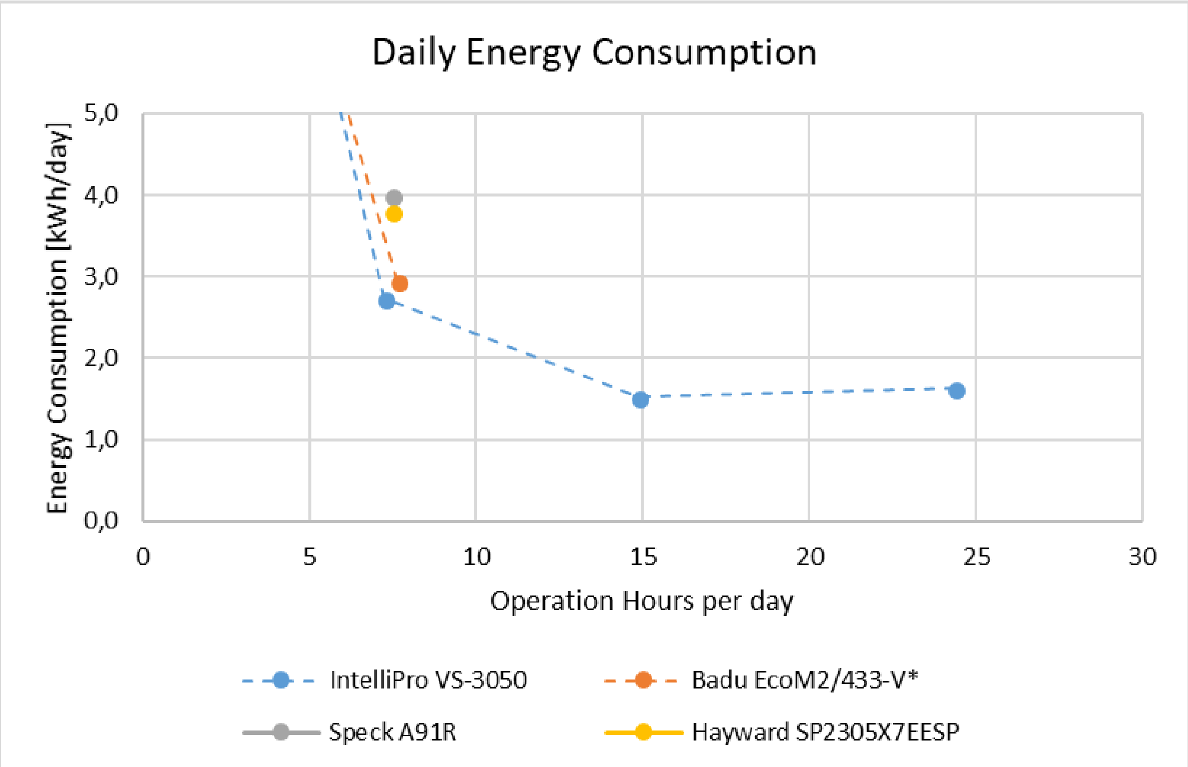

Figure 21. Pump energy consumption to complete one full turnover per day as a function of operating hours.

Reducing the MTR is probably only adviseable during times of low pool attendance such as nights or no-use days. It is, however, uncertain the extent of the impact to the water quality when the flow is lowered for extended periods of low-use time. Stakeholders have notified this impacts water quality but whether this happens at thresholds over what is recommended (see Figure 19) is not known, This uncertainty derives from the absence of of EU harmonised hygienic requirements for domestic swimming pools.

Conclusion on Extended Product Approach

In the USA and in Australia the use of VSD for swimming pool pumps is becoming more prevalent. There are large energy savings to be made by reducing the flow rate of the pumps instead of simply using on/off control. Example 2 adressed these savings, instead of having 8 operation hours a day with one turnover, the potential in running with lower flow rates for longer hours was investigated. It was found that the energy consumption per day could be reduced by at least 60% for the example case.

As shown in example 1 there is, however, still some savings related to tuning in the correct MTR, if practically possible. It was found that for the example case the flow reduction could save 12-15% of the total energy consumption. Exact savings will however be very case dependent. If a severely oversized pump is to be replaced there will be large savings. The better the fixed speed pump is chosen for the physical and chemical sanitation systems of the pool, the less the potential savings from utilising a VSD. The piping, filter type and pump selection will all determine the pump efficiency. Depending on how close the best efficiency point is matched savings will vary.

Operation time

Information provided by EUSA Working Group on annual average operation times for swimming pool pumps[180] has been used to estimate their annual use time. An overview can be seen in Table 27. However, these are based on seasonal variation and thus do not reflect the average hours/day that a swimming pool pump is used. According to input from industry, large variations exist between summer and winter, so conclusions about optimal use in regards to lowering speed with a VSD cannot be established.

Table 27. Overview of average operational time for swimming pool pumps.

Category	Operation time (hours/year), all applications
Swimming pool pumps < 2.2 kW	1,540
Swimming pool pumps > 2.2 kW	3,375

7.1.5 Slurry pumps

The main difference between slurry pumps and wastewater pumps is that while the purpose of wastewater pumps is to move water that happens to have a solid content, the purpose of slurry pumps is to move solids which are mixed with water to ease to movement. It is the opinion of Europump that this difference places slurry pumps outside the scope of water pumps and therefore it should not be covered in this study[18127]. Slurry has some properties that differentiate it from water and even wastewater. When there are solid particles in a flowing slurry, water flows faster than the solids because the solids are moved along only when drag forces, generated by the faster water, overcome gravity forces[18227]

Slurry pumps are designed to pump heavy slurries, primarily in mining applications[183]. These pumps are therefore designed to handle high concentrations of fine solids that are often very abrasive and that cause wear. The overwhelming slurry pump design goal is

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[180] EUSA pool pump position paper. Parisa, 23/10/2015.

[181] The Unsuitability of Efficiency Regulation for Slurry Pumps, issued and date July 30th 2015 by John Bower, Europump.

[182] Ibid.

[183] "Unsuitability of some pump types for regulation and problems to be solved for others". Europump position paper, final issue 1. February 16th, 2016.

thus to minimise wear, and it is therefore that they are usually designed with a big variety of material options to cope with abrasiveness and sometimes corrosive behaviour of the slurry[184151]. So slurry pump manufacturers often offer a wide diversity of engineered products tailored for individual applications, for example, the materials for impeller and volute/volute cladding have to be chosen individually, matching to the medium to be pumped. The components commonly used in slurry pumps often require special bolting and assembly arrangements, and are normally thicker and shaft and bearings are often larger, than those for water pumps. Slurry pumps require larger impeller diameters to produce the same head because they usually run slower than water pumps to keep the wear within reasonable limits[18527]. The pumps are designed to have parts replaced, as they wear down much faster than those from water pumps. Slurry pumps are also designed to move the slurry at low speeds, as higher speeds create more wear on the components.

The counterpart of designing these often tailored products in the conditions described above is the trade-off on efficiency which cannot be avoided. Furthermore, as the hydraulic components of the pumps wear significantly in the course of time, the tested efficiency at the point of sale will be very different to the actual efficiency during the pumps' operation and will decrease significantly soon after it was tested. Finally, the pumps are intentionally selected away from BEP to improve solids handling, and that cannot be avoided as flow rate and pressure are not the decisive parameters to select these kind of pumps.

Some manufactures are improving the hydraulic efficiency of slurry pumps by reducing friction. Friction is not only a source of energy loss it also influences the amount of wear. However, to harmonise slurry pumps designs to increase hydraulic efficiency would be a very difficult task due to the tailored nature of these pumps in terms of sizes, designs and materials[18627].

Extended Product Approach

The data received from Europump show that there are only 3% of the slurry pumps that are used in variable flow applications. Similarly, these data show that none of the slurry pumps are currently being sold with VSD. The energy saving potential from EPA consists mainly in the possibility of using high efficient motors (permanent magnet motors) with slurry pumps. Furthermore, according to Europump[187151], VSDs are not appropriate for most slurry applications because of the settling of solids at low flow velocity.

Operation time

Information provided by Europump on annual average operation times for slurry pumps has been used to establish their annual use time. An overview can be seen in Table 28.

Table 28. Overview of average operational time for slurry pumps

Category	Operation time (hours/year), all applications
Slurry pumps, light duty	2,600
Slurry pumps, heavy duty	2,000

[184] Ibid.
[185] Ibid.
[186] The Unsuitability of Efficiency Regulation for Slurry Pumps, issued and date July 30th 2015 by John Bower, Europump.
[187] "Unsuitability of some pump types for regulation and problems to be solved for others". Europump position paper, final issue 1. February 16th, 2016.

7.2 End of Life behaviour

This section is presented in task D4: Technologies.

7.3 Local infrastructure

This section identifies and describes the barriers and opportunities relating to the local infrastructure. According to the MEErP methodology, this includes consideration of energy, water, installation skills and physical environment where it applies. Based on previous preparatory studies, many of the mentioned local infrastructure issues in the MEErP methodology do not apply to pumps, especially water use, telecom and installation skills. General issues related to technology reliability and end-user's limitations which present barriers to ecodesign regulations are presented next, identified for groups of pumps.

Clean water pumps

For most of the end suction pumps, submersible borehole pumps and multistage pumps in scope of this study, the local infrastructure does not pose any issues, however electrical demand can still be reduced through a more efficient pump operation. The end user is a crucial factor concerning the environmental impacts of pumps.

Large water pumps

These pumps will draw a high electrical power, and so may need an appropriate Medium Voltage electrical connection. When there is a shortage in budget, the decision may be taken to refurbish rather than replacing pumps, hence delaying the impact of any regulations, as these pumps are costly to replace.

Swimming pool pumps

There are not thought to be any significant infrastructure constraints on the adoption of improved products, as there is no new information about the local infrastructure issues relating to these pumps. Most of the issues presenting barriers for improved products are related to keeping a high water quality and therefore influencing the pumps' operation cycles and speeds by the need of a constant water circulation system.

Wastewater pumps

There are no identified issues regarding local infrastructure. However, with the purpose of these pumps being transporting water from A to B, which contains high amounts of solids of many kinds, sizes and properties which in some cases are corrosive, this limits the selection of the pumps to certain types and materials which may hinder the users to choose from the most efficient pump. These pumps require a more regular maintenance than clean water pumps.

Pumps for fluids with high solids content

The local infrastructure does not pose particular issues for these pumps either, but the purposes of these pumps hinder as well the users to choose the most efficient pumps. These pumps are especially designed to pump solids and resist clogging which reduces their real life efficiency, and therefore users have accepted that there is an efficiency penalty for ensuring a more reliable operation of these pumps. One major factor is the impellers used. Although there are a number of impellers options for the users to choose from, the most efficient impellers may not be the most appropriate when they are looking for reliable operation. These pumps also require regular maintenance to ensure continued efficient operation over their lifetime.

7.3.1 Energy: Reliability, availability and nature

Pump technologies do not function without the reliable input of electrical energy and this is an important consideration for local infrastructure. The pumps will be utilised in the European context and in Europe today, where the electrical energy supply is reliable. The electrical energy system in all EU countries has been reliable for numerous years, and has reached a point where it is unlikely that there will be a shortage of electrical energy. In addition, the quality of electrical energy is high. The transition towards renewable energy sources demands a specific effort to ensure this quality is sustained. The creation of the Energy Union is a reaction to this transition as a guarantee that the quality of the electrical energy supply is sustained.

7.3.2 Use of water

Pumps do not utilise water for their operation, but rather their function is to transport water. Thus there are no specific water infrastructure requirements for the pumps, except for transport of wastewater and solids handling applications, where water may be added to decrease the solids concentration and increase the fluid velocity. It is assumed this will be negligible compared to the use of electricity to make pumps function, and it was thus decided not to assess water consumption.

7.3.3 Installation

Pumps are important components within the systems that they form part of, therefore there is a need to have skilful experts to supply and install the pumps in Europe. Most of the largest pump manufacturers have teams of experts in most of the EU countries with the largest market share for pumps. These skilled experts are trained and have experience in handling a range of installation challenges and circumstances. In terms of providing appropriate spare parts and lubricants for the pumps, these consumables are readily available in the markets and there is likely to be no shortage for the continued operation of the pumps.

7.3.4 Physical environment

There are minimal physical environment infrastructure considerations for pumps. Pumps can usually be installed in the locations in which they are needed. Appropriate services can be utilised (e.g. planning) to ensure the pumps are installed in the required locations.

7.3.5 Other barriers to eco-design

In practice, many barriers to ecodesign may come from the supply chain rules. For example, investment-related questions may be directly involved: Often the more energy-efficient the product is, the more expensive purchase price is. Some other barriers are presented below:

- **Preference for stabilised technologies:** Technology changes often generate a temporary increase in breakdown rates, if the end-users are not properly trained on using the new technologies or due to a necessary learning period.
- **Fear of complexity:** As an example, components of complex systems with many connections to the other components and replacing one of these components may necessitate global adaptations of the whole system.
- **Lack of knowledge and/or understanding:** E.g., relevant information is not available to users of pumps in the scope of the study, lack of understanding of using variable speed to control the pumps' operation.
- Other **non-technical barriers** (lack of internal incentives, e.g. reduction of budget for subsequent years).

7.4 Conclusions and recommendations

For clean water pumps there is little doubt that large energy savings can be achieved from integrating an EPA to the use of the pumps, encouraging the use of VSDs where it is suitable. The reason why VSDs are rarely used today, even for applications where the energy savings could be high (up to about 35%), is that end users often pay too much emphasis on the purchase price rather than the lifecycle costs.

It is assumed that for wastewater pumps the situation is different, since most consumers are utility companies with a better knowledge of their pumping system and in some cases already have implement strategies to improve the pumps efficiencies. However, despite they may have known this, they may still be challenged with the situation of decreasing the performance of other important parameters during the use of the pumps (e.g. avoiding clogging or ragging). It is therefore believed that it is possible to improve the energy efficiency of wastewater pumping if anti-clogging technologies that can be operated at higher efficiencies are available or if a system approach is adopted.

For swimming pool pumps it is clear that this is a field where the EU is behind when it comes to regulating and encouraging energy efficient products, as no energy efficiency program is operating such as in the case of the USA and Australia. They have set up regulatory schemes for labelling swimming pool pumps according to energy efficiency, and there is a lot to be gained from being inspired by these schemes. But at the same time it is necessary to understand the differences between managing of swimming pools inside and outside the EU, particularly the levels of use of chemicals to hinder bacterial growth and the frequency the swimming pool water that is circulated throughout the filtration system (i.e. the turnover rate). In the USA, it is assumed by EU industry stakeholders, that the concentration levels of chlorine and disinfectants are higher (though this has not yet been proven), and the turnover rate is 50% longer in the USA, increasing the possibility of bacterial growth if no more chemicals are added into the pool.

Concerning local infrastructure, most of the potential barriers mentioned in the MEErP methodology do not apply to pumps. Energy supply security is currently being carefully managed through research, development and investment to avoid becoming an issue in the European Union, as an ongoing transition towards other sources apart from fossil fuels is occurring. This does not mean, however, that an approach towards energy conservation is not relevant. Measures like this regulation are appropriate to control the energy demand and to avoid huge energy wastages.

Most of the potential barriers towards an extended scope and inclusion of an EPA to improve water, swimming pool, wastewater and slurry pumps efficiencies is the lack of understanding of using variable speed to control the pumps' operation. This is either due to a focus on the purchase price or to a lack of understanding of the optimal trade-offs with other important user parameters. In order to understand better these trade-offs, it is important to understand the relationship between the pump efficiency and its EPA system or even the swimming pool/wastewater treatment system.

8. Task D4: Technologies

The purpose of this task is to entail a general technical analysis of pumps defined in the scope of this study, incorporating a description of the existing technologies in the market, including their production, distribution and end of life. This will provide general inputs for the definition of the Base Cases for task D5. Furthermore, this task aims also at identifying Best Available Technologies (BAT) and Best Not Yet Available Technologies (BNAT) so the definition of improvement potentials and policy scenarios can be established in tasks D6 and D7.

Specific aspects that have been investigated are:

- Technical product description of Base Cases, BAT and BNAT with data on performance, price and sources of potential environmental impacts (resources/emissions)
- The description of the pumps value chain from the production and distribution to their end of life

Conclusions and recommendations are presented in relation to the possibility to refine the scope from a technical application point of view, as well as the barriers and opportunities that these present.

8.1 Technical product description

8.1.1 Existing products

As part of the investigation of the current state of the pumps within the scope of this study, qualitative and quantitative information have been collected on the existing products available on the market. The qualitative information has been presented and discussed in section 7.1, Task D3. The quantitative will be presented in this section. The quantitative information were acquired together with the sales data with input from Europump and EUSA as explained in Task D2. The data collection included average technical data for the products currently on the market. In this way a pump categorisation was established which is shown in Table 29, and each category is divided into sub-categories according to power driving systems technologies attached to the pumps. This was done in order to calculate saving potentials at EPA level, as it was identified these could be established from moving either to use of VSDs or to that combined with the use of more efficient motors. Five categories of power drive systems were identified:

- Induction motor (asynchronous motor)
- Induction motor with VSD
- Permanent magnet motor
- Permanent magnet motor with VSD
- Other motor technologies

Permanent magnet motors are regarded as a technology that is only used for smaller units and the categories are therefore only used for the size-categories that include pumps with at maximum shaft power of less than 22 kW.

The data[188] for clean water, swimming pool, wastewater and slurry pumps considered for the preliminary scope of this study are presented in Table 29, with maximum shaft power

[188] Data on average shaft power consumption and average electrical power consumption for variable and constant flow applications was provided by Europump.

(BEP level) and average electric power consumption for variable and constant flow applications.

Due to the many different interpretations of what self-priming pumps are, it was not possible to engage in a further data collection for this pump category. However, it is acknowledged that they are used for pumping clean water, amongst many other fluids, and they are therefore currently exempted in the current regulation. The need for establishing a harmonised definition is important and in this way potential loopholes can be prevented. In paragraph 8.2.2, the technologies and types of self-priming pumps by some of the actors in industry are described, which are used as a basis to develop a harmonized definition. However, self-priming pumps will not be assessed further as base case in this report as it was not possible to arrive to a harmonised definition with the help of stakeholders at the time of writing this report.

Table 29. Overview of pump categories and average electric power consumption[189][188] based on data and information collected.

Water pump category	Size division [190]	Power drive system	Pump size (shaft power BEP)	Average electric power consumption (variable flow)	Average electric power consumption (constant flow)
			kW	kW	kW
ESOB pumps for clean water	Maximum shaft power ≤ 22 kW	Induction motor	4.8	4.9	5.4
		Induction motor with VSD		3.1	5.6
		PM motor		4.7	5.2
		PM motor with VSD		2.6	5.2
		Other power drive system		2.8	5.6
	Maximum shaft power 22 - 150 kW	Induction motor	25.5	24.6	27.4
		Induction motor with VSD		15.5	28.2
		Other power drive system		14.1	28.2
	Maximum shaft power > 150 kW	Induction motor	200	188	209
		Induction motor with VSD		113	215
		Other power drive system		108	215
ESCC pumps for clean water	Maximum shaft power ≤ 22 kW	Induction motor	4.1	4.2	4.6
		Induction motor with VSD		2.6	4.8
		PM motor		4.1	4.5
		PM motor with VSD		2.0	4.5
		Other power drive system		2.4	4.8
	Maximum shaft power 22 - 150 kW	Induction motor	26.1	25.2	28.0
		Induction motor with VSD		15.9	28.9
		Other power drive system		14.5	28.9
ESCCi pumps for clean water	Maximum shaft power ≤ 22 kW	Induction motor	3.3	3.4	3.8
		Induction motor with VSD		2.2	3.9
		PM motor		3.3	3.7
		PM motor with VSD		1.9	3.7
		Other power drive system		2.0	3.9
	Maximum shaft power 22 - 150 kW	Induction motor	25.4	24.6	27.3
		Induction motor with VSD		15.6	28.1
		Other power drive system		14.1	28.1
Submersible borehole	Nominal outer	Induction motor	1.5	1.6	1.7
		Induction motor with VSD		1.0	1.8

[189] Data on average shaft power consumption and average electrical power consumption for variable and constant flow applications was provided by Europump.
[190] The term "maximum shaft power" is explained in section 4.1

Water pump category	Size division 190	Power drive system	Pump size (shaft power BEP) kW	Average electric power consumption (variable flow) kW	Average electric power consumption (constant flow) kW
pumps for clean water	diameter ≤ 6"	PM motor		1.5	1.7
		PM motor with VSD		1.1	1.7
		Other power drive system		1.2	3.9
	Nominal outer diameter 6" - 12"	Induction motor	52.6	50.2	55.8
		Induction motor with VSD		40.3	57.5
		PM motor		48.7	54.1
		PM motor with VSD		35.2	54.1
		Other power drive system		37.4	57.5
	Nominal outer diameter > 12"	Induction motor	288	270	300
		Induction motor with VSD		216	309
		Other power drive system		201	309
Vertical multistage pumps for clean water	Maximum design pressure ≤ 25 bar	Induction motor	3.2	3.3	3.7
		Induction motor with VSD		2.1	3.8
		PM motor		3.2	3.6
		PM motor with VSD		1.8	3.6
		Other power drive system		1.9	3.8
	Maximum design pressure 25 - 40 bar	Induction motor	68	64.7	71.9
		Induction motor with VSD		40.7	74.1
		PM motor		62.7	69.7
		PM motor with VSD		34.9	69.7
		Other power drive system		37.0	74.1
Horizontal multistage pumps for clean water	Maximum design pressure ≤ 25 bar	Induction motor	1.0	1.1	1.2
		Induction motor with VSD		0.7	1.3
		PM motor		1.1	1.2
		PM motor with VSD		0.6	1.2
		Other power drive system		0.6	1.3
	Maximum design pressure 25 - 40 bar	Induction motor	30	28.9.	32.1
		Induction motor with VSD		18.2	33.1
		PM motor		28.1	31.2
		PM motor with VSD		15.6	31.2
		Other power drive system		16.6	33.1
Booster-sets for clean water	Maximum shaft power ≤ 150 kW	Multiple pumps without VSD	9.2	5.0	not relevant
		Multiple pumps with one VSD		3.6	not relevant
		Multiple pumps with multiple VSD		3.4	not relevant
Swimming pool pumps	Maximum shaft	Induction motor	0.8	not relevant	1.0
		Induction motor with VSD	0.8	not relevant	1.0

Water pump category	Size division [190]	Power drive system	Pump size (shaft power BEP) kW	Average electric power consumption (variable flow) kW	Average electric power consumption (constant flow) kW
	power ≤ 2.2 kW	PM motor	0.8	not relevant	1.0
		PM motor with VSD	0.8	not relevant	1.0
		Other power drive system	0.8	not relevant	1.0
	Maximum shaft power > 2.2 kW	Induction motor	5	not relevant	6.0
		Induction motor with VSD	5	not relevant	6.2
		Other power drive system	5	not relevant	6.0
Submersible radial vortex pumps for wastewater	Maximum shaft power ≤ 10 kW	Induction motor	4	4.3	4.8
		Induction motor with VSD	4	2.7	5.0
		PM motor	4	4.0	4.5
		PM motor with VSD	4	2.2	4.5
		Other power drive system	4	2.3	4.6
	Maximum shaft power 10 - 160 kW	Induction motor	15	15.2	17.0
		Induction motor with VSD	15	9.6	17.4
		Other power drive system	15	14.1	15.7
Submersible radial channel pumps for wastewater	Maximum shaft power ≤ 10 kW	Induction motor	4	4.3	4.8
		Induction motor with VSD	4	2.7	5.0
		PM motor	4	4.0	4.5
		PM motor with VSD	4	2.2	4.5
		Other power drive system	4	2.3	4.6
	Maximum shaft power 10 -25 kW	Induction motor	15	15.2	17.0
		Induction motor with VSD	15	9.6	17.4
		PM motor	15	14.2	15.7
		PM motor with VSD	15	7.9	15.7
		Other power drive system	15	8.1	16.2
	Maximum shaft power 25 - 160 kW	Induction motor	75	72.8	80.9
		Induction motor with VSD	75	45.9	83.4
		Other power drive system	75	67.7	75.3
Submersible pumps for activated sludge, axial	Maximum shaft power ≤ 160 kW	Induction motor	10	10.3	11.5
		Induction motor with VSD	10	6.5	11.8
		PM motor	10	9.6	10.7
		PM motor with VSD	10	5.3	10.7
		Other power drive system	10	5.5	11.0
Submersible pumps for storm and	Maximum shaft	Induction motor	100	96.6	107.4
		Induction motor with VSD	100	60.9	110.7
		PM motor	100	89.9	99.8

Water pump category	Size division [190]	Power drive system	Pump size (shaft power BEP)	Average electric power consumption (variable flow)	Average electric power consumption (constant flow)
			kW	kW	kW
effluent water, mixed flow and axial	power ≤ 160 kW	PM motor with VSD	100	49.9	99.8
		Other power drive system	100	51.5	103
Dry well pumps for storm water, mixed flow and axial	Maximum shaft power ≤ 160 kW	Induction motor	150	144	160
		Induction motor with VSD	150	90.8	165
		PM motor	150	134	149
		PM motor with VSD	150	74.4	149
		Other power drive system	150	76.8	154
Dry well vortex pumps for wastewater	Maximum shaft power ≤ 10 kW	Induction motor	6	6.3	7.0
		Induction motor with VSD	6	4.0	7.3
		PM motor	6	5.9	6.6
		PM motor with VSD	6	3.3	6.6
		Other power drive system	6	3.4	6.8
	Maximum shaft power 10 - 160 kW	Induction motor	15	15.2	17.0
		Induction motor with VSD	15	9.6	17.4
		Other power drive system	15	14.2	15.7
Dry well channel pumps for wastewater	Maximum shaft power ≤ 10 kW	Induction motor	6	6.3	7.0
		Induction motor with VSD	6	4.0	7.3
		PM motor	6	5.9	6.6
		PM motor with VSD	6	3.3	6.6
		Other power drive system	6	3.4	6.8
	Maximum shaft power 10 -25 kW	Induction motor	15	15.2	16.9
		Induction motor with VSD	15	9.6	17.4
		PM motor	15	14.2	15.7
		PM motor with VSD	15	7.9	15.7
		Other power drive system	15	8.1	16.2
	Maximum shaft power 25 - 160 kW	Induction motor	75	72.8	80.9
		Induction motor with VSD	75	45.9	83.4
		Other power drive system	75	67.7	75.3
Submersible dewatering pumps (for water containing sand and grit)	Maximum shaft power ≤ 160 kW	Induction motor	7	7.3	8.2
		Induction motor with VSD	7	4.6	8.4
		PM motor	7	6.8	7.6
		PM motor with VSD	7	3.8	7.6
		Other power drive system	7	3.9	7.8

Water pump category	Size division [190]	Power drive system	Pump size (shaft power BEP)	Average electric power consumption (variable flow)	Average electric power consumption (constant flow)
			kW	kW	kW
Slurry pumps, light duty	Maximum shaft power ≤ 160 kW	Induction motor	50	49.0	54.4
		Induction motor with VSD	50	30.8	56.1
		PM motor	50	45.5	50.6
		PM motor with VSD	50	25.3	50.6
		Other power drive system	50	26.1	52.2
Slurry pumps, heavy duty	Maximum shaft power ≤ 160 kW	Induction motor	37	36.5	40.6
		Induction motor with VSD	37	23.0	41.8
		PM motor	37	33.9	37.7
		PM motor with VSD	37	18.9	37.7
		Other power drive system	37	19.5	38.9

The splitting of pump sizes into power drive system technologies is presented only to illustrate the differences of average electric power consumption when different power rive systems are used without and with VSDs, however, this splitting is not part of the final categorisation of pumps.

8.2 Best Available Technology (BAT)

The best available technology can be identified according to the best component technology available, meaning technology on:

- Impellers
- Casing
- Wear rings
- Bearings
- Motor and control (power drive system, extended product)

8.2.1 Clean water pumps

Clean water pumps are generally very similar in terms of design options. With clean water there is little risk of clogging or blockage, therefore there is no reason for having a high clearing between the blades. Since a low clearance gives the highest energy efficiency, clean water pumps are almost exclusively designed with a low clearance and a high number of channels. As such, there is no differentiation between most of the standard designs of clean water pumps between manufactures. However, minor improvements in design are archived with minor design modifications. Some of the most energy efficient designs come at a compromise with other parameters such as head, pressure and net positive suction head required (NPSHR) against flow. For these reason, it is possible to find similar water pumps where one pump has slightly higher energy efficiency than the other. In the preparatory study for the current regulation[191] this was also observed:

“With many years of feedback, an established manufacturer should have arrived at close to the optimum impeller vane number, vane shape, impeller inlet diameter, impeller cross-

[191] Lot 11, page 134

sectional profile, and casing geometry. This should produce an effective compromise between the various curve shapes for head, power, efficiency, and NPSHR against flow.

However, in most cases efficiency could be improved by sacrificing one or both of the ideals of head stability at low flows (e.g. by using a smaller diameter impeller), or NPSHR at best efficiency flow (e.g. by using a smaller impeller inlet diameter)."

For clean water pumps, which are subject to the Regulation 547/2012, the product efficiency is ranked according to MEI (Minimum Efficiency Index). In Regulation 547/2012, a MEI = 0.7 is defined as a benchmark value, which means that the pumps that have a MEI > 0.7 are considered to have the best possible pump design. Several pump manufactures are marketing their high efficient water pumps as being MEI > 0.7 compliant[192]. The difference between MEI = 0.4 and MEI = 0.7 is about 3.5 %-points in energy efficiency[193].

In order to arrive at even higher energy efficiencies, the surface roughness of the pumps has to be improved. The surface roughness of the pump depends on the casting method and if the surface is polishing or coated.

Standard pumps are often produced by sand casting of metal (cast iron, bronze, steel, etc.), which is a cost efficient production method and therefore widely used in pump production. Sand casting does, however, result in products with a higher roughness than products made using other types of casting. A reduced roughness of the impeller and the volute can increase the energy efficiency[194]; however most manufactures find that increased cost of investment casting does not outweigh the benefits.

Only in cases where hygiene is important (food or pharmaceutical industry), manufactures use investment casting to reduce the surface roughness, because smooth surfaces prevent the formation of deposits and thereby easy cleaning. When roughness is important, manufactures often include polishing in the final production stages of the pumps to further reduce the roughness, but polishing can further increase the cost. One manufacturer estimates that the increased cost coming from other types of casting than sand casting and hand-polishing is between 5% and 15% of the total cost of the pump.

For most manufactures, it is possible to increase the energy efficiency of the pumps, but any larger improvement requires a change in the production method and an increase in the total cost of the pump. Most manufactures choose not to do so, because they do not believe that benefits will be higher than the increase in the cost.

Corrosion and erosion are common problems for water pumps. Corrosion is occurring when there is direct contact between metal and water. Corrosion is most severe in cast iron impeller that pumps cold water. Stainless steel is often used instead of cast iron due to its resistance to corrosion. Stainless steel is protected against corrosion by a protective

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[192] For example the Wilo-Stratos GIGA and the new Sulzer SNS
http://productfinder.wilo.com/en/COM/product/00000026000219d40002003a/fc_product_datasheet
https://www.sulzer.com/de/Newsroom/Business-News/2015/150916-Sulzer-Launches-the-New-SNS-Process-Pump-Range?type=blank,

[193] http://europump.net/uploads/Fingerprints.pdf

[194] SAVE study on improving the efficiency of pumps, AEAT for European Commission, 2001, page 37-40.

passivation layer. Provided this passive film stays undamaged, corrosion rate will be very low. If the film is damaged, localised corrosion can still occur. [195,196]

Erosion can occur when substrates in the water meet the surface with high velocity. In clean water the amount of substrates are in general low, but erosion can also occur as cavitation. Cavitation is a result of a pressure difference in the fluid and is most commonly observed on the impeller, in particular at the low pressure surfaces.[197]

A method to both reduce surface roughness and protect the metal against corrosion and erosion is to coat the surface of the impeller and the casing interior with a smooth resin. There are several coating materials that can be used including PTFE, FBE, rubber linings, glass flakes, epoxy etc. One type of solvent-free epoxy coating, Belzona®1341 Supermetalglide, has been thoroughly test on water pumps.[198] This is shown in Figure 22, where the difference on efficiency from coating is relatively small compared to the total efficiency, and where difference on performance (i.e. head) is observed minimal.

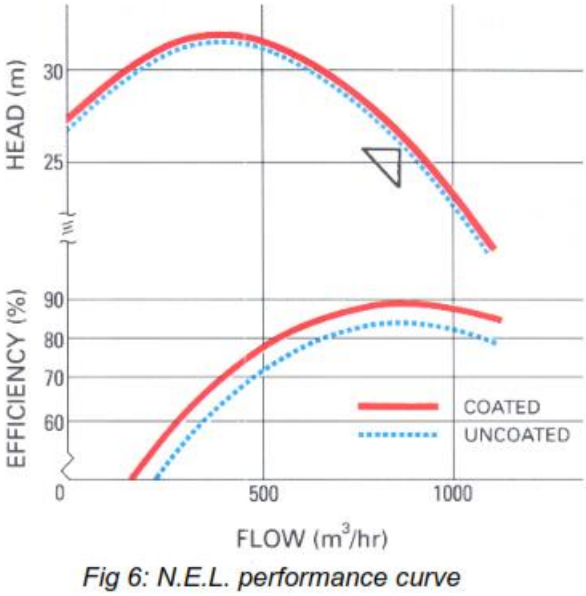

Figure 22. Influence of coating (Belzona®1341 Supermetalglide) on efficiency and performance[199].

Pump efficiency could be improved by reducing the leakage at the wear rings when reducing the clearance. This would require most or all of the following, which would increase costs:

- Tighter manufacturing tolerances
- Increased shaft diameter to minimise contact and wear at reduced or increased flow, which would also require fitting of larger bearings and seals
- Very hard but compatible wear ring materials (e.g. Tungsten carbide).[200]

[195] Lot 11, page 135
[196] Coating technology increases pump performance. Maillard, J. (2008). Belzona Polymerics Ltd. www.belzona.com.
[197] Ibid.
[198] Ibid.
[199] Ibid.
[200] Lot 11,

Specific options for multi-stage clean water pumps[201]

The efficiency of each impeller in a multistage pump tends to depend on the width of the stage, where a wider stage correlate with a higher efficiency. Furthermore, a higher number of stages will normally mean a higher efficiency for the same duty point. However, manufactures tend to limit both width and number of stages to reduce cost and size of the pumps.

Individual stage efficiency could be improved by using outward flow or outward/inward flow diffusers. This also means stage numbers would increase and therefore the size of the pump.

Extended Product Approach

Motor technologies and the application of power drive systems (i.e. motors + VSDs) are more important to increase the energy efficiency of the pumps when looking at the extended product. However, still most pump manufacturers only choose operating motors according to minimum requirements (i.e. IE3) and without VSDs. A few manufacturers are advancing to high efficient motors (i.e. IE4) for their pumps or using their IE2 or IE3 motors in combination with VSDs. Best available technology for motors can be considered to be IE4 motors such as the KSB "SuPremE" motor[202]. But when looking at BAT for clean water pumps, it is the use of VSDs for variable flow applications which could be already an advantage without having to buy more efficient motors. In spite this is not affected directly by the pump's design, the effect the power drive systems have on clean water pumps provide great opportunities for energy savings.

The use of VSD with clean water pumps is still not a standard practice, even though about half of the clean water pumps could reduce their energy consumption significantly if applied with a VSD. But some manufacturers[203] routinely sell clean water pumps with VSD and it is definitely possible to acquire a pump with VSD. As it could be seen in section 7.1, many clean water pumps are not yet taking advantage of using VSDs in variable flow applications.

8.2.2 Self-priming pumps

Self-priming pumps are able to operate when the pump case is not filled completely with fluid but contains some air, or air slugs, and they have the function of overcoming the air-bind problem (where air stops the pump from being able to pump the fluid). Three main types of self-priming pumps include liquid recirculation chamber types, compressed air and vacuum self-priming pumps[204]. The most common is liquid self-priming pumps. These pumps overcome the air-bind problem by creating a vacuum effect, using the impeller, in the chamber that sucks fluid through the suction line into the chamber of the pump case. Once fully primed, and with no air in the chamber, the fluid is pumped [205]. This is shown in Figure 23 where on the left side, the self-priming centrifugal pump is in priming mode with a mixture of air and fluid circulating and creating a vacuum which pulls fluid into the

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[201] Based on information provided in previous preparatory studies Lot 11, Lot 28 and Lot 29.

[202] http://www.ksb.com/SuPremE
[203] For example Grundfos CME and Xylem VFLO
http://www.grundfos.com/products/find-product/cm-cme.html
http://www.xylemflowcontrol.com/marine-and-rv/flojet-water-pressure-pumps/sensor-vsd-pumps/42755-series-vflo-50-gpm-19-lpm-water-pressure-pumps.htm
[204] http://www.waterworld.com/articles/print/volume-28/issue-10/departments/pump-tips-techniques/considerations-for-centrifugal-pump-priming.html
[205] http://www.gongol.net/knowledgebase/selfpriming/

chamber of the case. On the right, in pumping mode only fluid is pumped once the pump is fully primed and no air is in the circuit.

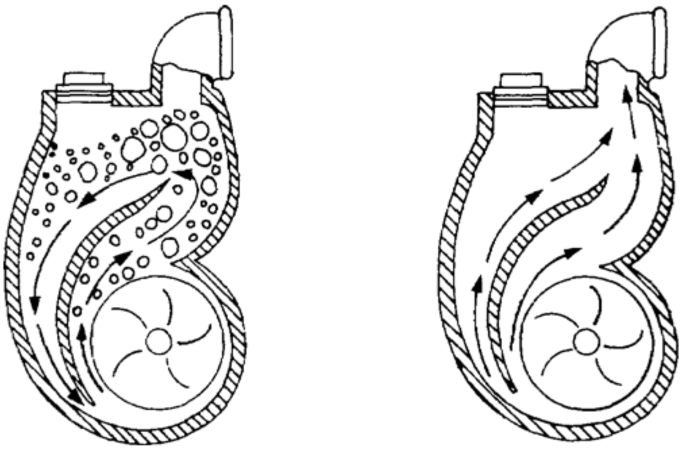

Figure 23. Self-priming centrifugal pump in self-priming mode (left) and pumping mode (right)[206].

Self-priming pumps are designed slightly differently than non self-priming pumps. For example, in the most common liquid self-priming pumps they often have a priming chamber and air separation chamber in the casing (see Figure 23 at the top of the chamber) in order to make the self-priming work, and air must be able to be released from the pump, e.g. through a valve[207]. Furthermore, the self-priming pumps will have the suction centreline above the centreline of the impeller (see Figure 23 which shows the impeller at the bottom).

Self-priming pumps generally have a lower efficiency than non self-priming pumps due to doing more liquid turns during pumping and the close clearance between the impeller and the casing volute tongue in a water-primed self-priming pump[208]. The close clearance is required in order to achieve the self-priming function effectively. Furthermore, the recirculation self-priming pumps have a swan neck on the suction to retain liquid around the impeller which also introduces hydraulic losses and lowers the efficiency of the pump. Overall, self-priming pumps are designed and purchased for the self-priming functionality and have a narrow application, e.g. emptying a water tank. They are often utilised for relatively short usage periods. Self-priming is the most important aspect, even if the efficiency of the pumping is lower, since they are used in situations where fluids are being pumped upwards where priming failures cannot be tolerated.

Self-priming pumps can pump many types of fluids in different location including clean water and swimming pool water but they can also pump fluids with solids and be primed with different methods[209]. Ideally one should subtract the priming function to establish the efficiency when it only pumps fluids however because the self-priming function is applicable to a wide range of centrifugal pump types and in situations where there is a diverse range of self-priming types, including liquid recirculation chamber types and compressed air and vacuum self-priming pump. Different self-priming pumps have different self-priming capabilities and efficiencies, and categorization by application or technology would lead to

[206] http://www.fao.org/docrep/010/ah810e/AH810E07.htm
[207] http://www.acdrive.in/difference-between-self-priming-and-centrifugal-pump-589158.html
[208] http://www.waterworld.com/articles/print/volume-28/issue-10/departments/pump-tips-techniques/considerations-for-centrifugal-pump-priming.html
[209] http://www.pacificliquid.com/selfprimer.pdf

multiple categories and this would lead to a complex analysis. It would be very difficult to determine an average fluid/air mixture or to determine the average pump flow time. This means that it would be very difficult to determine an average energy efficiency during priming and pumping. In addition, self-priming pumps are often utilised in short time periods for special purposes.

It can be concluded that there is no harmonised definition and design of self-priming pumps since they are often designed and purchased for specific usage and many manufacturers have their own designs which differ from each other. Furthermore, the pattern on how long and when the pump performs the priming function is widely diverse. This affects their efficiencies as well.

It is therefore difficult to categorise them into one category. To achieve this two main aspects would have to be harmonised: 1) types and designs and 2) how they operate in their self-priming and pumping function.

8.2.3 Wastewater pumps

- In order to fit wastewater application, industry has developed a variety of closed and open channel impellers, as well as vortex and special impellers which can fit the pumping needs. The most widely used are listed in the next paragraphs.

Multi-channel impellers

These impellers are used for two purposes[210140]:

- Collection and transport of wastewater from far areas when wastewater is not so polluted.
- Activated sludge where wastewater characteristics are carefully controlled for process optimisation where wastewater does not have big objects and its composition is quite homogeneous.

Multi-channel impellers can be open or closed and are usually for handling wastewater with no big objects nor highly abrasive solids and are usually very efficient being the most efficient closed multi-channel impellers. These impellers can manage high flow rates, and according to a simplified classification provided by industry stakeholders, they could be defined as for '*Light duty wastewater applications*' (see Table 30). 'Light duty', according to information provided by KSB, refers to handling wastewater with suspended solids but not big objects such as clothes, cans, plastic bottles, wood or metal parts. A concrete definition is missing, but according to information provided by KSB, the definition is an ongoing discussion by the Lot 28 working group at Europump. Some examples of multi-channel impellers are shown in Figure 24.

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[210] Communication at IFAT 2016 fair.

Figure 24. Examples of multi-channel impellers[211]. Source: presentation and exhibition at IFAT 2016[212].

Single channel impellers

These impellers can be open or closed and are used for wastewater types containing big solids (depending on the pump's passage) and/or abrasive materials such as fat or other solids containing corrosive substances. Furthermore, other impellers are designed to handle gases (in the liquid), which disturb the hydraulics of the impeller making the pump less efficient. These impellers can manage moderate to high flow rates, and according to a simplified classification provided by industry stakeholders, they could be defined as for '*Heavy duty wastewater applications*' (see Table 30). Some examples of multi-channel impellers are shown in Figure 25.

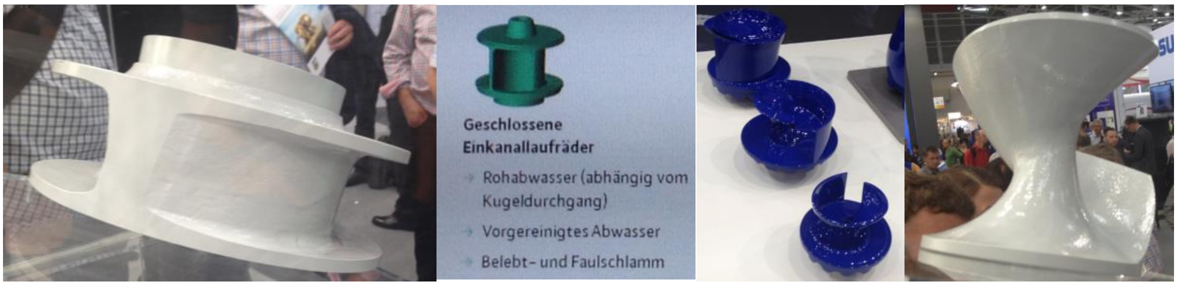

Figure 25. Examples of single channel impellers[213]. Source: presentation and exhibition at IFAT 2016[214212].

Vortex impellers

These impellers are used for lower flow rates but for wastewater that has high content of suspended solids (although not big objects). These impellers have a functionality that creates a vortex in the water avoiding direct contact with most of the abrasive or damaging materials to the impeller. Vortex impellers are usually less exposed to wear so they maintain their functionality (including set energy efficiency levels) longer without the need for replacement. The applications of these impellers is slightly different to that for 'Heavy-duty applications', as these impellers cannot manage high flow rates but prevent more clogging. Therefore, they could be defined for '*Special heavy-duty applications*' (see Table 30). Some examples of vortex impellers are shown in Figure 26.

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[211] Impeller at the left is an example of a closed multichannel impeller for pre-filtered wastewater and for activated and digested sludge.
[212] http://www.ifat.de/index-2.html
[213] The second impeller from the left is an example of a single channel impeller for the same applications as multi-channel impellers, but with the possibility to handle raw wastewater (depending on the pump's passage).
[214] http://www.ifat.de/index-2.html

Figure 26. Examples of vortex impellers[215]. Source: presentation and exhibition at IFAT 2016[216][212].

Axial flow impellers

These impellers are designed for very high flow rates which most commonly have a poor ability avoid clogging. They are therefore mainly suitable for relatively clean wastewater at big treatment plants or rain water catchments before the water collects many solids. See an example in Figure 27.

Figure 27. Example of axial flow impeller. Source: presentation and exhibition at IFAT 2016[217][212].

Special impellers for high solids contents and/or big objects

These are typically channel impellers with special functionalities such as grinding and/or shredding, which can have this functionality already integrated in the impeller, and are therefore sold as one unit, or can be sold as separate unit. These impellers could be defined for '*Special heavy-duty applications*' (see Table 30). The impeller itself will typically have the same energy efficiency of a normal channel impeller, but the grinding capability is very energy consuming and can be as high as twice the pump's energy consumption and will therefore drastically reduce its overall efficiency. In some cases, the use of a vortex pump would be a more energy efficient solution.

Other parameters that influence pump performance for improving it to higher levels, in particular:

- Energy consumption
- Reliability
- Ease of maintenance

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[215] The last impeller to the right is an example of a vortex impeller for the same applications as channel impellers, but with the possibility to handle all types of raw wastewater , slop wastewater and wastewater with coarse particles.
[216] http://www.ifat.de/index-2.html
[217] Ibid.

- Clog resistance
- Wear resistance

Often the optimal design is a compromise between these factors, and a wastewater pump's efficiency depends on its reliability and maintenance. Wear decreases the energy efficiency and reliability of the pump over time, while proper maintenance reduces the effect of wear. Clogging and other failures have a high impact on the life cycle cost as they reduce the availability of the pumps and could potentially be dangerous in some systems. Therefore, reliability is always a fundamental design parameter for wastewater pumps, while energy efficiency is secondary. Reliability (seen as the degree on which the pump is able to stay fully functional) is important because of the cost of sending out a maintenance crew (including energy cost for transportation) and the cost of interruption of the operation.

In Lot 28 it was found that the best energy efficiency for wastewater pumps with channel impeller are 88.7 % and for pumps with vortex impeller are 63%. This however does not mean that the best available technology for wastewater pumps are pumps with an energy efficiency of 88.7%, since the best design depends on the application (see Table 30).

Other technologies for improving energy efficiency

Usually the choice of impeller type depends on the wastewater type. There is usually a trade-off between the reliability of the pump and the energy efficiency (see Figure 28), where vortex pumps are considered the most reliable but have the lowest energy efficiency. Multichannel impellers are in the other end of the spectrum with double channel and single channel impellers and intermediate steps.

Reliability (seen as the degree on which the pump is able to stay fully functional) is important for several reasons:

- Cost of sending out a maintenance crew (including energy cost for transportation)
- Cost of interruption of the operation

In order to improve energy efficiency of wastewater pumps, several measures have been identified:

- Correct sizing or switching pumps according to flow rates variation
- Screen away solid contamination
- Variable speed for reduced flow rates (although there is a limit depending on the amount and size of solids)
- Use of multi-channel or other speciality impellers
- Optimised pump design

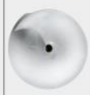
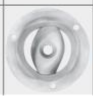
Type			Fluids	Solids Size	Best efficiency point	Gas Content [Vol. %]	Sand Content [g/l]	Dry Substance Content [%]
F-max		Free-flow, Vortex	▪ Raw sewage ▪ Activated sludge ▪ Raw and digested sludge ▪ Mixed water	+++	+	+++	+++	++
E-max		Closed single vane	▪ Raw sewage ▪ Recirculated and heated Sludge ▪ Mixed water ▪ Activated sludge	++	++	+	++	++
K-max		Closed Multivane	▪ Recirculated sludge ▪ Activated sludge ▪ Industrial effluent ▪ Storm water	+	+++	+	+++	+
D		Open Single Vane, Screw	▪ Raw sewage ▪ Mixed water ▪ Raw and digested sludge ▪ Activated sludge ▪ Re-circulated and heated sludget	+	++	++	++	+++
S		Cutter, Grinder	▪ Domestic sewage ▪ Waste water ▪ Effluents	+	+	++	+	+

Figure 28. Optimal impeller selection in handling difficult fluids – relationship between pump's efficiency and clogging[218]. Source: Presentation and exhibition at IFAT 2016[219][212].

Wastewater pumps and wastewater characterisation

KSB together with the Lot 28 Working Group within Europump suggest a grouping of wastewater types according to pumping applications[220][140], which they have observed follows pump and impeller application (see Table 30). This classification is simplified to three groups without a quantitative definition, however, it fits well with impeller designs as it was described in the previous paragraphs. This could be the starting point to separate wastewater types and impeller types to establish different levels of efficiency.

Table 30. Wastewater classification (light-duty, heavy-duty and special) according to application of the pumps. Source: KSB/Lot 28 WG.

Type of waste water	Wastewater application	Activities	Additional criteria
Light-duty waste water	Wastewater treatment	Waste water treatment plant intake with fine screen	none
		Activated sludge (recirculation pumps)	Low fibre content
		Centrate	none
		Sewer overflow	Optimised design
		Filter reverse flow flushing pump	none
	Wastewater transport	Mechanically treated waste water	Fine screen, coarse screen, high flow rates
		Rainwater/storm water	Not containing coarse particles
Heavy-duty wastewater	Wastewater treatment	Waste water treatment plant intake with coarse screen	High flow rates

218 https://www.ksb.com/ksb-en/Products_and_Services/waste-water/waste-water-pumps/
219 http://www.ifat.de/index-2.html
220 Communication at IFAT 2016 fair.

Type of waste water	Wastewater application	Activities	Additional criteria
		Waste water treatment plant intake without coarse screen	High flow rates
		Primary sludge	High flow rates
		Activated sludge (recirculation pumps)	High fibre cement
		Heating sludge	none
		Digester circulation	High flow rates
		Storm water retention applications	High flow rates
	Wastewater transport	Raw waste water (municipal waste water)	High flow rates
		Mechanically treated waste water	Coarse screen, low flow rates
		Multiple dwelling/blocks of flats	High flow rates
		Housing development area (village, borough, city district)	High flow rates
		Rainwater/storm water	Containing coarse particles
Vortex impeller and special heavy-duty wastewater	Wastewater treatment	Waste water treatment plant intake with coarse screen	Low flow rates
		Waste water treatment plant intake without coarse screen	Low flow rates
		Sand trap	none
		Primary sludge	Low flow rates
		Digester circulation	Low flow rates
		Storm water retention applications	Low flow rates
		Purification	none
		Sewer overflow	Problematic design
	Wastewater transport	Raw waste water (municipal waste water)	Low flow rates
		Detached houses	none
		Multiple dwellings/blocks of flats	Low flow rates
		Housing development area (village, borough, city district)	Low flow rates

Special design impellers for energy efficiency

Other examples of impellers designed to avoid clogging or a more effective handling of solids are:

- An open channel impeller which can maintain its energy efficiency despite wear. The pump plate can be adjusted from the outside of the pump to fit the impeller as it wears down, so in this way it acts as closed impeller. See Figure 29.
- A channel impeller that creates a rotating 180ºC movement of the water directing solids to a special channel in the fitting part, where the solids come out. The design ensures that contamination is not trapped inside the impeller where there is a risk of clogging. See Figure 30.
- A channel impeller which can move up and down and can therefore bring space to the big solids to pass through without losing hydraulic flow and/or pressure. See Figure 31.

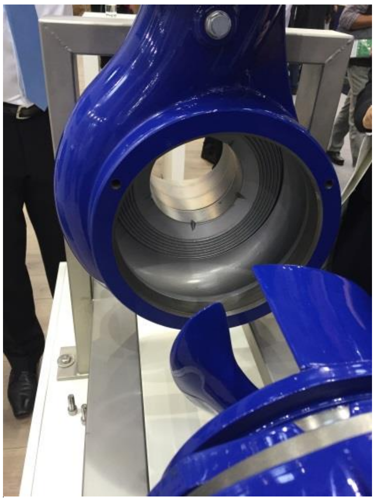


Figure 29. Example of an improved channel impeller to increase energy efficiency despite wear. Source: Presentation and exhibition at IFAT 2016[221212].

Figure 30. Example of an improved rotating channel impeller to increase energy efficiency avoiding clogging. Source: Presentation and exhibition at IFAT 2016[222212].

Figure 31. Example of an improved rotating channel impeller to increase energy efficiency avoiding clogging. Source: Presentation and exhibition at IFAT 2016[223212].

8.2.4 Swimming pool pumps

The design of swimming pool pumps differs for domestic applications (most of the pumps with a maximum shaft power ≤ 2.2 kW) than for commercial applications (most of the pumps with a maximum shaft power > 2.2 kW). Many pumps for domestic applications are above-ground pumps, which in many cases have a self-priming capability. Pumps for commercial applications (i.e. for big public swimming pools) are in-ground pumps which do not need this capability. Most of the pumps for commercial applications are end suction

[221] http://www.ifat.de/index-2.html
[222] Ibid.
[223] Ibid.

pumps of the type already covered in the current regulation, differently to pumps for domestic applications. Pumps for commercial applications are typically made of steel for wear resistance and longevity, while pumps for domestic applications are made of plastic[224]. Since most of the pumps made for commercial applications are similar to clean water pumps, this section focuses on pumps for domestic applications.

Pumps for domestic applications are mostly built on plastic, that helps increasing smoothness and can be made with tight tolerances on the size of the parts. This increases the efficiency of the pumps[225224,226]. However, when having a self-priming capability, the efficiency is reduced which is an inherent feature of self-priming pumps. To avoid blockage, the pumps are installed with a strainer, which means that a simple impeller design can be used (unlike wastewater pumps). For this reason the impeller types are mostly similar to those for clean water pumps, which are closed multi-channel impellers. However the clearance has to be large enough to handle any contamination that may pass through the strainers. Swimming pool pumps for domestic applications are typically sold with the motor and a built-in strainer (some examples are shown in Figure 32). In these examples the inlet is located to the left side of the pumps where the water enters into the strainer, then moving into the impeller and finally expelled through outlet located at the top. A schematic representation can be found at Figure 33.

Most of the improvements for swimming pool pumps found available at the point of sale are related to: (i) improvements of the motor operation and technology, (ii) better fitting of the pump to the swimming pool system demands, and (iii) a more efficient operation of the pump at reduced speeds.

Figure 32. Swimming pool pumps for domestic applications[227].

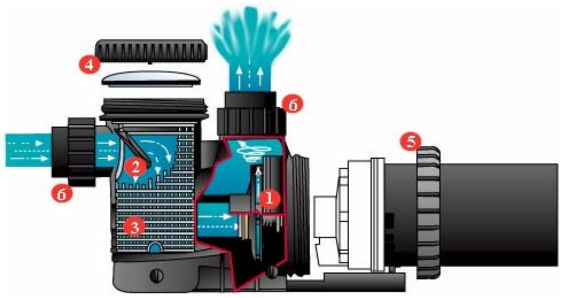


Figure 33. Schematic representation of swimming pool pumps. 1=impeller, 2=input flow to strainer, 3=strainer, 4=strainer lid, 5=motor, 6=inlet and outlet[228].

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224 Information from task 1 report, Lot 29
225 Ibid.
226 Information from task 6 report, Lot 29
227 Pentair IntelliFlo® pump, Zodiac Titan Series Pool Pump and IntelliFlo® UltraFlow® VS pump.
228 Taken from poolcenter.com (http://www.poolcenter.com/pumpsMotors)

Motor operation and technology

Some pump manufacturers have incorporated motor technology improvements in order to increase the efficiency so less power is lost at the motor unit or more power is available to the shaft which drives the centrifugal pump.

Some new technologies allow capacitors to store energy into storage units called dielectrics until the power is needed. The stored energy can be utilised when the motor needs it thus boosting the energy transferred to the impeller. These technologies claim to save up to 85% compared to traditional motors used in pool pumps[229]. Other swimming pool pumps are sold with permanent magnet motors that reduce noise and vibration which in turn reduce energy transmission losses to the pump's shaft and increase pump's lifetime[230]. Finally, other motor technologies can reduce energy consumption by incorporating totally enclosed fan cooled technologies (TEFC) that reduce the need of temperature cooling[231230].

Better fitting to swimming pool system demands

Because most uses of swimming pool pumps are private consumers, they are unaware of what is the best-fitted pump according to their swimming pool system, meaning according to the pool's hydraulics. Therefore it is common that they do not know which pump size they need. The result is that lot of energy is wasted on running pumps that are too large for their purpose.

This is clearly seen in the USA and Australia, where many governmental and consumer-oriented websites are found where the consumers are advised on the best-fitted pump according to their pool.

According to the US Energy Department, about 40% of a swimming pool's energy savings can be achieved by replacing a pump to the correct size (i.e. downsizing), where the annual power bill can be reduced from 3000 kWh to 1800 kWh[232]. This was, however, only based on a study of 120 pools in the state of Florida, where, according to the study, the absolute savings are higher as the pool season is longer. According to the US Department of Energy, the same study found that pumps up to 0.75 HP are generally sufficient size for residential pools, and they even advice on practices to reduce the pool circulation system hydraulic resistance so there is no need to use bigger pumps than what strictly needed.

More efficient operation at reduced speeds

Another potential improvement is to adapt the speed of the pump according to the different operation tasks of the filtration and circulation systems in the pool. These can be, e.g.. circulation, filter backwashing, filtration and heating, instead of operating at a fixed speed. However, some EU industry stakeholders claim[233235] that 99% of the time the pool systems are operating at filtration and it does not make sense to operate at different speeds. The US Department of Energy claims, based on the same study in Florida, that about 60% of pump energy consumption can be saved by operating the pump at different speeds at different times according to the pool's needs[234232]. What the UK supplier shows is that different speeds can be fitted for different times of the day, especially since it is assumed

229 http://www.ecopoolpumps.com/energy-efficient-pool-pumps.htm
230 http://www.swimmingpool.com/inground-pools/pool-features/energy-efficiency
231 Ibid.
232 http://energy.gov/energysaver/installing-and-operating-efficient-swimming-pool-pump
233 Information provided by industry stakeholders at stakeholders meeting on February 2016.
234 http://energy.gov/energysaver/installing-and-operating-efficient-swimming-pool-pump

a domestic pool pump does not need to service people for long periods of time during the day.

However, it is not an easy task to determine the optimal filtration cycle as well as an optimal balance between this cycle and maintaining the pool hygienics, as it has been previously discussed in section 7.1.5. Another risk is to program the cycles so to avoid too much debris is accumulated in the strain and thus affecting negatively the efficiency of the pump. In this point it is important to emphasize that the recommended pump's maximum turnover rate in the EU is 8 hours compared to 12 hours in the USA, which means that the cycle for turning the whole pool's volume is 50% longer in the USA compared to the EU, where the water needs to be recirculated more.

However, in information collected from Australian and USA markets, it was identified that swimming pool pumps can be operated at reduced speeds when carrying out circulation/filtration cycles. Since this is about 99% of the time the pumps operate in this mode[235], there is potential for improvement in terms of reduction in energy consumption. According to Lot 29[236], significant energy savings can be made in swimming pool systems that use variable speed drives to match the flow rate to the requirements of the various water treatment systems within the pool. However, adding VSDs to these domestic pool pumps may not provide any tangible energy savings and the investment cost is high. Information gathered from one UK supplier of swimming pool pumps shows that it would be about 5-7 years payback period, considering the much higher price of buying this BAT pump. Alternatively, using two speed controllers (full speed and half speed) could also provide savings. The BAT pump shows that it is possible to regulate the speed of the pump and operate at lower speeds even in constant flow operations.

Extended Product Approach

As it can be seen in Table 27, no swimming pool pumps are used in variable flow applications in the EU. However, VSDs are used in a small share of the market (2.9%) in constant flow applications and, in the particular case of domestic swimming pool pumps, more VSDs could be used to reduce speeds to lower constant flows to fit different operational/circulation/filtration cycles during the day. However, it is not known with certainty if increasing the use of VSDs in constant flow applications would save important amounts of energy. According to data from Europump[237286], it is not the case for end-suction clean water pumps and in the absence of any data for swimming pool pumps, it is assumed the same. Therefore, most of the savings are assumed to come from choosing the right size of pump.

In spite of this, it is important to understand better the hydraulic system where the pumps operate, in order to determine whether this is realistic. Considering this is out of the scope of this study (i.e. looking at system's approach), potential increase in efficiency can be looked at only at EPA level for establishing policy measures, which could be achieved by a higher use of VSDs.

8.2.5 Slurry pumps

Similar to wastewater pumps, for slurry pumps the best pump is application dependent. Wear is a very important issue for slurry pumps. Therefore, slurry pumps are most of all designed for robustness and easy replaceable wear parts. It is still possible, however, to

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[235] Information provided by industry stakeholders at stakeholders meeting on February 2016.
[236] Lot 29, Task 6 report.
[237] Oral communication from Europump at video-conference meeting on the 27th of May, 2016.

reach a high hydraulic energy efficiency with some very large light duty slurry pumps with an efficiency of 82 % and very large heavy duty slurry pumps with an efficiency of up 77 % (Lot 28). However, these are assumed out of the scope of this study.

8.3 Best Not Yet Available Technology (BNAT)

The water pump is a long established technology, and even though very significant improvements have been realised to pump designs within the past decade, the technology is very similar, in particular for clean water pumps. The major changes in the use of technology for pumps are regarding impeller design for avoiding clogging (only wastewater pumps) and the application of power drive systems for variable speeds (motors and VSDs). Some improvements have also been made with hydraulic design. In the past decade improved computer technology has made more sophisticated CFD simulations possible, which in turn allows close to optimal hydraulic design. It might be possible to advance pump design in the future, although in some cases the current BAT present energy efficiencies of well above 80 % (e.g. some centrifugal clean water pumps as discussed previously).

The energy efficiency of motors and VSDs has been improved significantly within the past decade, particular with the introduction of IE2, IE3 and IE4 motors categorisation. The use of VSDs and sophisticated monitoring and control systems is a relatively new thing in the market for water pumps. It can be expected that when these technologies become more common the energy efficiency of water pumps will be coupled with the development of improved control systems. To achieve near optimal energy usage for water pumps it will be necessary to be able to adapt the water pumps and the pumping systems to each other. With better control systems it might be feasible in the future to efficiently adapt a new pump to an existing pumping system.

8.4 Production, distribution, maintenance and end of life

8.3.1 Production and distribution

An overview of the Bill of Materials is presented in Table 39 (in MEErP nomenclature), which is presented in chapter 10 after the definition of the base cases is presented. The table includes the packaging materials, the pump weight with and without packaging the end life routes. The Bill of Materials data presented here have been collected from previous preparatory studies, and following comments from stakeholders. The end of life data has been calculated on the presented analysis in the End of Life section.

For distribution it is assumed that 70% of the packaged pumps will be transported by truck and 30% by ship considering most of the pumps are still produced within Europe (i.e. transported by truck) and the rest produced outside Europe and therefore transported by ship. For pumps transported by ship, it is assumed a transport distance of 10,000 km and for pumps transported by truck, it is assumed a transport distance of about 3,400 km (conservative assumptions considering the many transport scenarios).

The materials identified for all the pumps within the scope and shown below, coded according to the Ecodesign EcoReport tool v.2014 as it follows:

1-BULK PLASTICS

- Low-density polyethylene: 1-LDPE
- High-density polyethylene: 2-HDPE
- Polypropylene: 4-PP
- Polyvinyl chloride: 8-PVC

- Acrylonitrile butadiene styrene: 11-ABS

2-TECHNICAL PLASTICS

- Nylon PA 6: 12- PA 6
- Polyurethane: 16-Rigid PUR

3-FERRO MATERIALS

- Stainless steel coil: 26-Stainless 18/8 coil
- Steel tube/profile: 23-St tube/profile
- Cast iron: 24-Cast iron

4-NON-FERRO MATERIALS

- Aluminium die caste: 28-Alu die cast
- Copper winding wire: 29-Cu winding wire

5-COATING MATERIALS

- Powder coating: 40-Powder coating

6-ELECTRONICS

- Integrated circuit: 47 -IC's avg., 5% Si, Au
- Surface-mounted device light-emitting diode: 49 -SMD/ LED's avg.

Printed wiring board: 50-PWB 1/2 lay 3.75kg/m27-MISCELLANEOUS MATERIALS

- Paper: 58-Office paper
- Cardboard: 57-Cardboard

8.3.2 Repair and maintenance

Pump equipment will need repair and maintenance during its lifetime. Some of the largest pump manufacturers provide onsite repair and workshop repair services[238,239,240,241,242]. Services can include, for example, machining and repair welding, upgrades, retrofits or scheduled analysis and maintenance. This can, for example, be through a paid service, in the form of a product care-package that is paid regularly in order to receive immediate service when the pump requires it. Refurbishment services are also provided when pumps effectiveness is too low and to ensure appropriate efficiency through the life of the pump. From these same large companies, a service can be provided with transportation and spare parts for the pumps, and expert teams are available to provide the service. Service options can be provided onsite or in a company workshop.

It is also common that the largest pump manufacturers provide pump auditing or scheduled maintenance services which can be carried out on a regular basis (e.g. once a year) in order to ensure the pump is operating most efficiently. Repair and maintenance will be done on the basis of the result of an audit to improve efficiency, or when a pump breaks down.

As explained in the previous preparatory studies for important pump sets, carrying out regular on line measurement of differential pressure (and even flow) and electrical consumption helps to identify change in performance and this helps to identify the optimum time for refurbishment. However, this can be expensive and it is certainly not economic for

[238] http://www.xylemwatersolutions.com/scs/eastern-europe/en-us/Sparepartsandservice/Pages/default.aspx
[239] http://www.flowserve.com/Services-and-Solutions/Aftermarket-Parts-and-Services
[240] https://www.grundfos.com/service-support/service-portfolios.html
[241] https://www.sulzer.com/en/Products-and-Services/Pumps-Services
[242] http://www.ksb.com/ksb-en/Products_and_Services/service-and-spare-parts/

the bulk of pumps in this study.[243] For some pumps the economic viability of repair and maintenance needs to be determined, for example for sewage pumping stations. Sometimes it will be more economical to replace pumps rather than repair them.

Due to cost of removal of clogging from wastewater pumps, the maintenance schedule is often based on a risk analysis considering, for example, historic frequency of breakdown; and the impact if the pump breaks down[244]. Maintenance activities include condition inspections, security checks, electrical tests and jetting. Statistically, a wastewater pump in a small pumping station will be replaced 5-6 times over a system's 60-year life.

Re-conditioning of pumps may consist of the following;

- Renewal of wear rings
- Renewal of impeller

Regular maintenance actions for pumps may include:

- Bearing replacement / greasing.
- Seal replacement
- Application of coatings

8.3.3 End of Life

As explained in the previous preparatory studies, most pumps are heavy items and have a positive scrap value, since they are mostly made from ferrous and non-ferrous metals with some recyclable plastics. In addition, the pumps can include rare earth elements (REE) within the magnets of the motors. Thus there is little reason to send them to landfill and more reason to recycle them. However not all pumps are high metal content with some being mostly plastic. In addition, it is unknown what happens to different types of pumps once they are disused. Therefore, more information would be needed to determine precisely how each pump is treated at the end of life.

Information about the disposal methods for pumps can be sourced from the pump manufacturers themselves and from the consumer side for waste disposal. The different perspectives on the disposal of pumps for industry and consumers are presented below. Based on these perspectives the end of life treatment assumptions of the pumps is determined.

Rare earth elements

The main rare earths (REE) contained in magnets are Sm, Dy and Nd and recycling could have a significant impact on these most critical elements. Due to the criticality of the rare earths used in permanent magnets, as well as the potential value of the waste stream, the future demand, the concentration of rare earths, the size of the sector, the difficulty in finding substitutes, and whether there are any remaining technical challenges to recycling, permanent magnets that contain REE are the number one priority for future recycling, according to a report on rare elements[245].

It is unknown how much REE can be recovered from the magnets since recovery of these elements is in its early development stages[246][245]. In this report, the industry suggests a mandatory and standardised marking/label to better dismantle motors with rare earth materials, which can ease the recycling of products containing REE magnets above a certain

[243] Lot 11 preparatory report, pg. 67
[244] Preparatory study Lot 28 Task 3, pg. 14
[245]http://reinhardbuetikofer.eu/wp-content/uploads/2015/03/ERECON_Report_v05.pdf
[246] http://reinhardbuetikofer.eu/wp-content/uploads/2015/03/ERECON_Report_v05.pdf

minimum weight. This could facilitate future recycling practices. It is believed that a marking giving information on the presence of rare earth magnets as well as information on the applied type (e.g. SmCo, FeNdB) can positively influence the establishment of a European circular economy for rare earth elements. These issues have been discussed in Germany at a stakeholder meeting for the motor regulation where some manufacturers stated they name (label) already the rare earth materials on the name plate of the product. In order to understand the full implications and recovery rates for REEs this would require further assessment.

Industry perspective

The pump manufacturers usually state that their pumps should be recycled at their end of life since in most cases the pumps consist of a high content of ferrous and non-ferrous metals and other recyclable materials. In terms of the recyclability of the pumps, this varies by pump type and its BOM. The BOMs for each pump type, together with the respective motor or motor and VSD in scope of this study are shown in Table 39.

As shown in Table 39, the pumps consist of large amount of recyclable materials, e.g. ferrous metals, plastics. If it is assumed that only the metal component of the pumps is recyclable, then the percentage of recyclability of the pump materials ranges from approximately 99% (mostly metal clean water pump) to approximately 70% (swimming pool pump with high content of plastic).

Xylem, one of the world's largest pump manufacturers, has carried out numerous Environmental Product Declarations (EPDs) for some of its pumps and this provides useful information about the recyclability of the different pumps. One example is the pump type "3085.183", designed mainly for operation in pump sumps, i.e. sewage pumping in pumping stations and/or sewage treatment plants. The pump has a hydraulic power of 1.29 kW. The weight varies from around 50 kg to about 100 kg, and the average weight of the pump is 74 kg, depending on the model of pump casing, impeller, stator and rotor.

According to the Xylem Flygt recovery schedule for Life Cycle Assessment, 10% of the pump material weight goes to landfill during end-of-life treatment. At a weight of 74 kg, this represents a weight of 7.4 kg that goes to landfill. The remaining material of the pump is assumed to be recycled.[247] "

The recycle percentage of a typical Grundfos pump is between 90% and 98%, and the rest can be incinerated[248] (some eco-designed Grundfos pumps have a recyclability of around 94% and incineration of material of 5% with 1% for landfill[249]). Grundfos set up a take-back scheme in Denmark where plumbing companies have organised to collect the disused pumps which are then sent for recycling[250].

In the previous preparatory studies, it was assumed that it is the norm for pumps to be sent for scrap and all the metallic materials in the pumps are recycled and none of the non-metallic materials are recycled.

Consumer perspective

It is difficult to estimate the actual collection and disposal rates by material fraction for pumps based on a consumer perspective. This would require a detailed study into

[247] http://gryphon.environdec.com/data/files/6/7230/epd62_3.1.pdf
[248] http://vbn.aau.dk/files/13401334/workingpaper202007.pdf
[249] http://ostfoldforskning.no/uploads/dokumenter/NorLCA/Presentasjon/NorLCA_Thrane_Remmen.pdf
[250] https://dk.grundfos.com/recycling.html

consumer behaviour including surveys and analysis. It is difficult because the pumps are utilised in numerous locations for numerous purposes and over a relatively long lifetime.

In order to get a better understanding of the proportion of pumps treated and the proportion of materials sent to recycling, landfill or incineration, high level Eurostat waste data was utilised.

Eurostat provide waste data for a category called 'discarded equipment'. Based on all 30 categories defined for waste in the legislation of the European Parliament and of the Council on waste statistics- "*(EC) No. 2150/2002, amended by Commission Regulation (EU) No. 849/2010*"[251] this category is assumed to include disposed pumps because there is no other category in which the pumps could be included. The definition of discarded equipment is defined in the regulation on waste statistics, and it includes all equipment (except discarded vehicles and batteries and accumulators) with the main relevant categories being electrical and electronic equipment, including major hazardous/non-hazardous household equipment and discarded hazardous/non-hazardous machines and equipment components.

Even though disused pumps would account for only a fraction of this waste category, the data on those are the best available data to determine the waste treatment pathways for pumps from a consumer perspective.

Although pumps are made mostly from ferrous/non-ferrous metal it is reasonable to assume that pumps would not be included in the metallic wastes definition since pumps are defined as complex mechanical equipment and they include other material, therefore it is not included as a material input, it is included as an equipment input containing not only metal.

Although waste data from Eurostat is the best available data for waste for discarded equipment, the data contains numerous uncertainties. For example, the amount of reported waste may be lower than reality since it is common that discarded equipment can be disposed in illegal ways, e.g. by illegal dumping (landfilling) which is not reported. This would mean that the reported waste sent to landfill could be higher. In addition, discarded equipment can be mixed with other waste types and thus it is not recorded in the discarded equipment category. Despite this, the Eurostat data is the best available data to use at present.

Although Eurostat provide data for the generation of discarded equipment waste and the treatment of this waste, the generated waste includes imported waste and therefore this increases the waste value, thus it is not directly comparable to the treated waste data. Therefore, only the treated waste data and landfilled waste data is utilised here.

Treated waste means incinerated or recycled waste. Thus all waste treatment pathways are included in the data presented here, landfill, recycling and incineration. In the latest year where data is provided which was 2012, the amount of treated discarded equipment waste was 99%[252]. This means it was either recycled or incinerated. The discarded equipment that was landfilled was much lower at 1%, or 20,000 tonnes. The amount of treated waste is very high and there may be instances where discarded pumps are not

[251] Available at http://faolex.fao.org/docs/pdf/eur97704.pdf
[252] http://tinyurl.com/q8omu6h

reported or they remain as untreated waste at a waste collection premise but it is not possible to determine this in this study.

Based on the data above it is assumed that the materials within the pumps are separated into four disposal routes:

- Recycling: Steel, iron and aluminium at 70%, copper winding wire at 60%, and office paper and cardboard at 80%.
- Incineration with energy recovery: 30% of the rest of the materials fractions.
- Incineration: 40% of the rest of the materials fractions.
- Landfill: 30% of the rest of the material fractions.

These fractions are used for all pump types. This includes small pumps which have been found that they are disposed as iron metal scrap, meaning that it is introduced into electric arc furnaces without previous dismantling.

The amount of metals for recycling is not 100% due to devaluing factors, for example during shredding and liberation and contaminants such as the mixture of metals and other materials. This reduces the recyclability of the metals and therefore it is not 100% of the metals that can be recycled. In addition, the devaluation of iron metal fraction due to copper content can occur and devaluing from the plastic content in secondary metal production, and the presence of copper catalysing dioxin formation[253] can occur.

In the UNEP metal recycling report detailed research was done on the amount of recycling and recovery of metals and this was utilised to determine the actual recycling potential of the metals.[254]

For copper recycling this was based on the report The Life Cycle of Copper, its Co-Products and By-Products Copper recycling. Copper recycling is lower which was determined by taking the average recycling rates for copper[255]. Therefore, the following disposal rates were established: Recycling- 70% of ferrous metals as well as aluminium are recycled; 60% of copper wire is recycled and 80% of paper and cardboard is recycled.

For the remaining materials that are not recycled: 30% are sent to incineration with energy recovery; 40% sent to incineration and 30% sent to landfill. No plastics are recycled as it is assumed that it is bounded to other scrap materials and therefore lost in the Electric Arc Furnace. If several recycling possibilities exist, the manufacturer could provide information about the optimal route according to the design of products.

Overall there needs to be specific design for dismantling high quality metal fractions to follow the Commission's Circular Economy Strategy.

Packaging waste

It is assumed that for the packaging waste, all the paper and cardboard is recycled and incinerated according to the same ratio presented above for municipal waste, where 53% is sent for recycling, and 47% for incineration. Any other packaging such as soft plastic packaging is assumed to be incinerated.

[253]http://www.unep.org/resourcepanel-old/Portals/24102/PDFs/Metal_Recycling-Full_Report_150dpi_130919.pdf
[254] (http://www.unep.org/resourcepanel-old/Portals/24102/PDFs/Metal_Recycling-Full_Report_150dpi_130919.pdf)
[255] http://pubs.iied.org/pdfs/G00740.pdf

Summary

Using the assumptions described above, the waste disposal routes for the different types of pumps were calculated. In summary all pumps have a high metal content (over 90% by weight approximately), except for domestic swimming pool pumps which have a higher plastic content.

8.3.4 Estimated second hand use

As mentioned in the previous preparatory studies, it is unlikely that parts from the pumps would be removed and used in another pump since it is not cost effective or feasible. Pumps need to run as efficiently as possible and it is highly unlikely that a pump would utilise a second hand part due to the risk of failure and the high costs associated with this. It is more cost effective to invest more capital into maintaining the pump to achieve the highest level of quality. In general, second-hand pumps are not very common since most large companies repair or update the pumps through aftermarket services by supplying appropriate parts and services. This is done to extend the lifetime of the pumps rather than replacing them.

8.3.5 Best practice in sustainable use

In regards to best practice an important consideration is to select the appropriate pump for the purpose. The correct selection of pump is at least as important as the selection of pump by highest BEP[256].

This will ensure that the pump being utilised is able to meet the demands that is put on it in terms of utilisation rate, purpose and longevity. For example, the lifetime of sewage pumps may be impacted by the solids they have to pump.

As explained in the preparatory studies the most significant energy savings come from attention to the way in which the pumping system is designed and controlled. Improving the approach to pump system design would include measures such as optimal pump selection and pipework sizing, minimising velocities and reducing friction losses, optimising operating pressures, and ensuring adequate controls will realise significant energy savings within the complete pumping system. The SAVE study presented in the preparatory study identified energy savings associated with these measures as follows: [257]

- Selecting better sized pump: 4%
- Better installation / maintenance: 3%
- Better System Design: 10%
- Better System Control: 20%

The use of Variable Speed Drives to adjust the flow to match the actual system requirements can make energy savings in some systems. The most efficient control method depends on the specific application needs[258].

When selecting a pump, a manufacturer will use "tombstone" curves, which show their ranges of pumps to cover a range of duties. Ideally, the duty you want will be roughly 20% below the maximum flow shown on the tombstone, which corresponds to the BEP of the selected pump (each tombstone is built up from individual pumps). But for economic reasons they have to restrict the number of pumps that they offer. This means that even

[256] Preparatory study Lot 11, pg. 69
[257] Preparatory study Lot 29 Task 3, pg. 12
[258] Preparatory study Lot 28 Task 3

a manufacturer of particularly efficient pumps may lose out, when quoting efficiencies in competition with less efficient pumps where the BEP just happens to be nearer the requested performance[259].

As mentioned above, appropriate servicing, maintenance and repair and refurbishment from qualified experts ensure best practice in operating pumps. In addition, for optimal pump operation, best practice involves appropriate installation and start-up in accordance with the pump manufacturer's guidelines.

8.5 Conclusions and recommendations

The definition of product categories for the pumps considered in this review study have been presented in this chapter, together with their Bill of Materials, distribution and end of life routes. Repair and maintenance practices have also been identified, as well as best practices in sustainable use.

Most of the pumps defined in the product categories have been split in different sizes according to the pump capacity, and they have been categorised according to the type of water they are used for in the different applications. This categorisation and size subdivision has been made according to the functional unit defined in chapter 5, section 5.2.

The end of life routes identified have been based both on an industry and consumer perspective to identify more realistic scenarios.

These data and information will be used to perform the subsequent tasks, to perform the environmental impacts assessment of the pumps within the scope of this study. Furthermore, they will be used as the Base Cases for this study.

[259] Preparatory study Lot 11 pg. 70

9. Final scope

9.1 Energy consumption and potential savings

Industry provided market and technical data for this stage of the study. The study team used the data to check the preliminary scope previously defined based on data from the preparatory studies. This was the basis to refine the scope into a final scope, which followed the criteria below for checking pump categories to be studied further in the subsequent tasks of the review study:

- The individual pump types' energy consumption in relation to the total EU consumption for products in preliminary scope, combined with their share of potential energy savings in relation to the total EU potential for products in preliminary scope.
- Ambiguities about parameters influencing the calculation of savings potential and/or about product categorisation.

The estimations to calculate energy consumption and energy saving potentials were done based on average market and technical data, either provided by Europump and EUSA Working Groups or in the absence of these, based on data from preparatory studies. The data has already been described in chapter 7 (task D3) and in chapter 8 (task D4) and the calculations that led to the energy consumption and energy saving potentials are discussed in the next paragraphs. The results are presented in Table 33. Based on these results the final list of pump categories to be included in this review study are presented in section 9.2.

This final scope is what has been assessed further in the next chapters of this report. Considering the final scope, the overall conclusions and recommendations on what to include and exclude in a future reviewed regulation are made considering the established base cases in chapter 10, the design options for potential improvement in chapter 11, the potential impacts on industry and consumers for the selected policy options in chapter 12, and the issues and proposals identified and developed for market surveillance in chapter 13.

9.1.1 Total energy consumption estimates

The total energy consumption is calculated based on values collected by the Europump and EUSA Working Groups. There are some notable differences between these values and the values presented in the preliminary scope in Annex 4, which were based on values from previous preparatory studies. First, the average energy consumption data provided by industry for each pump category is divided into constant flow and variable flow applications, as well as the operational time which in some cases is different. These data have been used to establish the annual energy consumption. Second, the energy consumption for vertical multistage pumps is found to be much larger than the values estimated in Lot 11. The difference comes from the average operation time, which is assumed to be 1500 hours/year as in Lot 11, while the new data collection shows it to be 5000 and 2250 hours/year for variable and constant flow application, respectively. Also, the energy consumption for slurry pumps (both light duty and heavy duty) shows a significant difference. Here the difference is the estimated stock. Although the input sales numbers are the same as in Lot 28, the stock calculated in Lot 28 is almost twice than that calculated in this study. In Lot 28 the stock was assumed to be 40-50 times the yearly sales number.

The yearly energy consumption is calculated for each pump category as follows:

$$E = Stock \cdot (Share_{var} \cdot P1_{avg,var} \cdot Op\_T_{avg,var} + Share_{const} \cdot P1_{avg,const} \cdot Op\_T_{avg,const})$$

For each pump category, pump size and motor technology (see Table 29), the share of pumps that are used in variable flow applications ($Share_{var}$) as well as the share of pumps that are used in constant flow applications ($Share_{const}$) is defined. This is based on the share of applications used in variable/constant flow systems. The share used for variable flow applications does not only apply to pumps used with VSDs, but overall to all pumps considered to be used in variable flow systems. However, the share for constant flow applications applies only to pumps used with motors without VSD (with the exception of swimming pool pumps where VSDs are used for constant flow applications)[260].

Similarly, the average power consumption during operation for variable and constant flow operations were provided by the Europump and EUSA Working Groups ($P1_{avg,var}$ and $P1_{avg,const}$). Both of these average power consumption values have been used with the current pump stock with induction motors to calculate annual average electricity consumption (E), since this is considered to be the standard motor technology. The average operation time per year has also been defined for variable and constant flow applications ($Op\_T_{avg,var}$ and $Op\_T_{avg,const}$).

The smaller end suction clean water pumps have been merged into one category (≤150 kW), in contrary to what is presented in Table 29. This is because there is no difference from a regulatory perspective within the two sizes, ≤22 kW and 22-150 kW. In addition, the scope of this study has been greatly extended so categories were merged to simplify the presentation of the results for the final scope.

9.1.2 Potential savings at product level

According to information from industry, the savings' potential at product level is limited, since there are no possibilities for changing the pumps' designs radically to achieve significant savings. This has been the basis for the discussions to focus this review study on the assessment of potential energy savings at the extended product level (i.e. pump + motor + control device mechanism such as variable speed drives). Based on this, industry did not provide any data that indicated there were potential savings at product level, and the study team thus aimed to estimate them only to compare savings at product level with those at extended product level (as discussed in chapter 5, task D1 preliminary scope). The estimations were done based on data from Lot 11 for water pumps in current scope of the regulation, and from Lot 28 and Lot 29 for the other water pumps which are in the preliminary scope.

Concerning water pumps in current scope of the regulation, it was assumed that the potential energy savings at product level could be calculated by assuming that the energy savings calculated in Lot 11 for MEI≥0.7 can be achieved[261]. Since the current regulation has already achieved the energy savings for MEI≥0.4, the savings potential was estimated as the difference between the energy savings potentials, taken from Lot 11, for MEI≥0.7 and MEI≥0.4. These values are shown in Table 31. For the sake of comparison, the estimated potential energy savings at extended product level are also shown. Be aware that, at that point in time when writing the report, the methodology for calculating the EPA energy indexes was not fully developed, and therefore several preliminary assumptions

[260] Information provided by Europump and EUSA Working Groups.
[261] Since MEI≥0.7 is the indicative benchmark value in the current regulation

were made in order to estimate potential savings at EPA level that could be used for this comparison.

Table 31. Potential energy savings at product level calculated from Lot 11 and potential energy savings at EPA level calculated from data provided from stakeholders.

Pump type	Estimated annual energy savings potential at product level in EU (2014) TWh/year	Estimated annual energy savings potential at EPA level in EU (2014) TWh/year
End suction pumps for clean water		
ESOB (≤150 kW)	1.12	11.4 – 14.6
ESCC (≤150 kW)	0.92	12.2 – 15.4
ESCCi (≤150 kW)	0.72	5.7 - 7.5
Submersible borehole pumps for clean water		
Borehole MSS (≤6")	0.67	0.9 – 1.9
Vertical and horizontal multistage pumps for clean water		
MS-V (≤25 bar)	0.16	6.0 – 8.0

However, according to input from Europump[262], a cut off at MEI = 0.7 is not realistic and would have severe impacts on pump manufacturers, especially SME's. They claimed that the relatively low energy savings cannot justify losses in jobs due to cost for redevelopment, and that the SMEs will not have the resources to do so. Therefore, they encouraged to focus the assessment on estimating the potential savings from applying an EPA."[263] Furthermore, later input from stakeholders suggested that because water pumps are designed for many different purposes, some water pumps are subject to design limitations that compromise the energy efficiency, which makes it impossible to reach the MEI=0.7 level efficiency for all water pumps.[264] Therefore, it was not realistic to calculate potential savings at product level based on the MEI value since the MEI cannot be further improved to an MEI=0.7.

Furthermore, stakeholders (both manufactures and academia) have consistently stated that, there is little room for improvements of the existing product design of water pumps. There is a general agreement that the water pumps have already a well optimised technology with no large improvement potential on the product itself. Minor design optimisations are still possible, but the improvement potential is very low compared to that of EPA.[265] Based on this input, the potential savings at product level were considered to be insignificant and were not assessed further to define the final scope.

The potential energy savings at product level for the pumps not included in the current regulation but that were selected as part of the preliminary scope were estimated based on data from Lot 28 (for waste water pumps) and from Lot 29 (for large clean water pumps and swimming pool pumps). These values are shown in Table 32 together with the estimate potential energy savings at extended product level. The estimated savings potential for these pumps were derived from data from Europump, and it was indicative at the point of

[262] in connection with stakeholder meeting the 11th of February 2016
[263] Official comments on Study Report by Europump, 1st of February 2016
[264] Input from manufacturers
[265] Communication via email, phone interview and meetings.

defining the final scope since a EPA methodology was not existing for these pumps[266]. However, based on operational data considering the share of variable/constant flow, operational time, power demand and motor use (see next section for details), the savings at EPA were estimated. From Table 32 it can be seen that great variations exist, which are due to the uncertainties from these estimations at that point in time. However, the numbers presented at product level were also estimates based on data available from Lot 28 and Lot 29. These data also presented uncertainties as described in section 5.3.2. Furthermore, input provided by industry was the same as for clean water pumps, indicating limited room for improvement at product level. Considering these, and in order to keep consistency with the assessment of the other water pumps in scope, the focus continued being the potential savings at EPA level and this study did not continue assessing those at product level.

Table 32. Potential energy savings at product level estimated in Lot 28 and Lot 29 and potential energy savings at EPA level calculated from data provided from stakeholders.

Pump type	Intended use	Estimated energy savings potential at product level	Estimated energy savings potential EPA level
		TWh/year	TWh/year
ESOB (150kW – 1MW)	pump clean water	0.06	0.32
Borehole MSS (>6" and ≤12")		0.42	0.3 – 0.9
Borehole MSS (>12")		0.07	0.04 - 0.1
MS-V (25-40 bar)		0.13	0.5 – 0.8
MS-H (≤25 bar)		Not available.	Not available
Booster-sets pumps		Not available.	Not available
Small swimming pool pumps (≤2.2 kW)	pump swimming pool water	0.14	0 - 0.21
Large swimming pool pumps (>2.2 kW)		0.05	0 – 0 06
Radial vortex pumps (≤ 10 kW)	pump industrial, commercial & municipal wastewater	0.06	0 – 0.3
Radial vortex pumps (10 - 160 kW)		0.01	0 - 0.04
Radial channel pumps (≤10 kW)		0.06	0 - 0.3
Radial channel pumps (10 - 25 kW)		0.06	0 – 0.2
Radial channel pumps (25 - 160 kW)		0.18	0 - 0.4
Mixed flow & axial pumps (≤160 kW)	pump rainwater, storm and effluent water	0.015	0 - 0.10
Dry well pumps (≤160 kW)	pump rain water, domestic/industrial/ commercial/m	0.083	0 – 0.43

[266] As of 31st of July, 2017, the methodology for end suction, multistage vertical and multistage horizontal clean water pumps is finalised and is described in draft standards prEN 17038-1 and prEN 17038-2. The methodology for booster sets is almost ready (according to Europump's input) and it will be in a future draft standard (part 3), while the methodology for multistage submersible borehole pumps is on early stages (part 4).

Pump type	Intended use	Estimated energy savings potential at product level	Estimated energy savings potential EPA level
		TWh/year	TWh/year
	unicipal wastewater, sand water, grit water, raw/primary/secondary/activated/tertiary sludge		
Submersible dewatering pumps	pump sand water & grit water	0.15	0 - 0.4
Slurry pumps – light duty	pump slurry	0.08	0.05 - 0.4
Slurry pumps – heavy duty		0.01	0.01 - 0.04

9.1.3 Estimates of potential savings at Extended Product Approach (EPA) level

The potential energy savings from EPA were estimated using data from Europump and were calculated as follows:

$$E_{EPA\,save} = Stock \cdot (Share_{var} \cdot [P1_{avg,var} - P1_{avg,var,improved}] \cdot Op\_T_{avg,var} + Share_{const} \cdot [P1_{avg,const} - P1_{avg,const,improved}] \cdot Op\_T_{avg,const})$$

Based on two scenarios:

a. Applying VSD for variable flow applications, or,
b. Applying the best available motor technology in all cases, including the use of VSD for variable flow applications.

In the first option (a), the average power consumption with improved motor technology for variable flow applications $P1_{avg,var,improved}$ is the value for induction motor with VSD and, $P1_{avg,const,improved}$ is the same as $P1_{avg,const}$ (i.e. no savings for constant flow applications). This is because induction motor is considered to be the standard motor technology and because according to information from stakeholders, pumps in constant flow applications do not use VSD during their operation (except swimming pool pumps).

In the second option (b), the average power consumption with improved motor technology for variable flow applications $P1_{avg,var,improved}$ is the value for permanent magnet motor with VSD and, $P1_{avg,const,improved}$ is the value for the best available motor technology for constant flow application. The savings are therefore calculated by considering that all the current pump stock would switch from being used with induction motor (current standard motor technology) to permanent motor with VSD or to the best available motor technology.

In Table 33 a range is thus presented, which shows the estimates for potential energy savings at EPA level with the lowest potential savings based on option (a), and the highest based on option (b).

Option (a), which is to apply VSD for all pumps in variable flow application, can be translated into to an EEI_V requirement. This is possible for single stage pumps because it is observed that EEI_V for pump units without VSD is above 0.57 and for pump units with

VSD it is below 0.52. For other pump categories this is also possible as soon as a viable method for determine EEI is ready. Option (b) assumes all applications would use the best available motor technology which is a not realistic possibility, and thus this cannot be used to estimate an EEI_V.

In the particular case of domestic swimming pool pumps the potential savings at EPA level are based on figures provided by the EUSA Working Group, which shows no variable flow applications and only a minor share of use of VSDs in constant flow applications (i.e. 2.9%). This is contradictory to the market trends in the USA and Australia where a crescent share of the use of VSDs is observed (as discussed in previous chapters). To observe any differences on potential savings at EPA levels, the share of VSD use could be increased in subsequent tasks, not only for swimming pool pumps but also for other pumps that present a low share (i.e. some wastewater pumps and slurry pumps). This is also the case for large swimming pool pumps where no new data has been received, therefore the data from Lot 29 is presented. Finally, as an alternative method for calculating the potential energy savings for swimming pool pumps it is possible to use data from the USA ENERGY STAR database[56]. For each pump in the database there are energy factors (pumped volume per energy use) which are calculated for three different load curves.

Table 33. Pump types and classification based on the preliminary scope of this study, incl. based on data provided by industry[267] and/or preparatory studies.

Pump type	Intended use	Annual average total energy consumption in EU (2014)		Estimated annual energy savings potential at EPA level in EU (2014)	
		TWh/ year	% of total in EU **	TWh/year	% of total in EU**
End suction pumps for clean water					
ESOB (≤150 kW)	clean water	*55.7*	*19 %*	*11.4 – 14.6*	*24 - 26 %*
ESOB (150kW – 1MW)		4.8	2 %	0.32	0.5 - 0.7 %
ESCC (≤150 kW)		*53.6*	*18 %*	*12.2 – 15.4*	*25 - 28 %*
ESCCi (≤150 kW)		*21.7*	*7 %*	*5.7 - 7.5*	*12 - 13 %*
Submersible borehole pumps for clean water					
Borehole MSS (≤6")	clean water	*24.9*	*9 %*	*0.9 – 1.9*	*2 - 3%*
Borehole MSS (>6" and ≤12")		17.3	6 %	0.3 – 0.9	1 - 2%
Borehole MSS (>12")		4.1	1 %	0.04 - 0.1	0.9 - 1%
Vertical and horizontal multistage pumps for clean water					
MS-V (≤25 bar)	clean water	*27.8*	*9 %*	*6.0 – 8.0*	*13 - 14 %*
MS-V (25-40 bar)		5.4	2 %	0.5 – 0.8	1.1 – 1.3 %
MS-H (≤25 bar)		21,2	7 %	4.1 – 5.7	9.4 – 9.5 %.
MS-H (25-40 bar)		9.5	3 %	1.5 – 2.1	3.3 – 3.5 %
Other pumps for clean water					
Booster-sets pumps (≤150 kW)	clean water	3.2	1 %	0.5 – 0.7	1.1 – 1.2 %
Pumps for swimming pools					
Small swimming pool pumps (≤2.2 kW)	swimming pool water	6.9	2 %	0 - 0.21	0 - 0.3 %
Large swimming pool pumps (>2.2 kW)		0.9	0.3 %	0 – 0 06	0 – 0.1 %
Submersible pumps for wastewater					

[267] Europump and EUSA Working Groups

Pump type	Intended use	Annual average total energy consumption in EU (2014)		Estimated annual energy savings potential at EPA level in EU (2014)	
		TWh/ year	% of total in EU **	TWh/year	% of total in EU**
Radial vortex pumps (≤ 10 kW)	industrial, commercial & municipal wastewater	3.6	1 %	0 – 0.3	0 - 0.4 %
Radial vortex pumps (10 - 160 kW)	industrial, commercial & municipal wastewater	0.6	0.2 %	0 - 0.04	0 - 0.1%
Radial channel pumps (≤10 kW)	industrial, commercial & municipal wastewater	3.6	1 %	0 - 0.3	0 - 0.4 %
Radial channel pumps (10 - 25 kW)	industrial, commercial & municipal wastewater	2.3	1 %	0 – 0.2	0.3 %
Radial channel pumps (25 - 160 kW)	industrial, commercial & municipal wastewater	7.0	2 %	0 - 0.4	0 - 1 %
Axial pumps (≤160 kW)	activated sludge	0.2	0.1 %	0 - 0.02	0 - 0.03%
Mixed flow & axial pumps (≤160 kW)	Rainwater, storm and effluent water	1.3	0.4 %	0 - 0.10	0 - 0.2%
Dry well pumps for wastewater					
Mixed flow & axial pumps (≤160 kW)	Rainwater, storm and effluent water	0.1	0.02 %	0 - 0.01	0 - 0.01%
Radial vortex pumps (≤10 kW)		1.0	0.3 %	0 – 0.1	0 - 0.1 %
Radial vortex pumps (10 - 160 kW)	rain water, domestic/industrial/ commercial/municipal wastewater, sand water, grit water, raw/primary/secondary/ activated/tertiary sludge	0.3	0.1%	0 - 0.02	0 - 0.04%
Radial channel pumps (≤10 kW)	rain water, domestic/industrial/ commercial/municipal wastewater, sand water, grit water, raw/primary/secondary/ activated/tertiary sludge	1.0	0.3 %	0 – 0.1	0 - 0.1 %
Radial channel pumps (10 - 25 kW)	rain water, domestic/industrial/ commercial/municipal wastewater, sand	1.4	0.5 %	0 – 0.1	0 - 0.2 %

Pump type	Intended use	Annual average total energy consumption in EU (2014)		Estimated annual energy savings potential at EPA level in EU (2014)	
		TWh/ year	% of total in EU **	TWh/year	% of total in EU**
	water, grit water, raw/primary/secondary/ activated/tertiary sludge				
Radial channel pumps (25 - 160 kW)	rain water, domestic/industrial/ commercial/municipal wastewater, sand water, grit water, raw/primary/secondary/ activated/tertiary sludge	2.1	1 %	0 - 0.1	0 - 0.2%
High solids content water pumps					
Submersible dewatering pumps	sand water & grit water	6.2	2 %	0 - 0.4	0 - 1 %
Slurry pumps					
Slurry pumps – light duty	Slurry	4.6	2 %	0.05 - 0.4	0 - 0.6 %
Slurry pumps – heavy duty		0.5	0.2 %	0.01 - 0.04	0 - 0.1 %
Total energy consumption/savings potentials for all water pumps included in Lot 11, Lot 28 & Lot 29		**292.8**	**100%**	**43 – 61**	**100%**

Pumps in italic are those covered by present Regulation (EU) 547/2012

*Estimated energy savings potential at product level are based on estimations from Lot 11, 28 and 29. Those figures in *italic are from Lot 11* (2007), the savings are the difference between MEI 0.4 and MEI 0.7; for the rest of the water pump types, the figures are from Lot 28 and Lot 29 and from 2011.

**From the total sum of water pumps included, except those with no data (self-priming pumps).

***From the total sum of water pumps included in Lot 11, 28 & 29 studies.

****The categories from Lot 28 have been split into the categories in this table. The values from Lot 28 are therefore the split on to these categories based on proportionality of annual energy consumption.

9.2 Pump categories in final scope of this review study

9.2.1 Extended Product Approach

The estimated potential for energy savings from this chapter onwards is only presented at EPA level. However, energy consumption is also shown in order to place pump categories in perspective in terms of the energetic demand in the whole European Union. It is important to note that at this point of the study both the energy consumption and the potential energy savings are only estimates used to refine the product into the final scope. The final calculations for energy consumption and energy saving potentials are shown in chapter 12.

9.2.2 Clean water pumps

The clean water pumps included in the final scope are:

- End suction own bearing (ESOB) pumps with a maximum shaft power of 150 kW
- End suction closed coupled (ESCC) pumps with a maximum shaft power of 150 kW
- End suction closed coupled in line (ESCCi) pumps with a maximum shaft power of 150 kW
- Submersible borehole multistage clean water pumps (MSSB) with a nominal outer diameter of up to 6" (15.24 cm)
- Vertical Multistage (MS-V) clean water pumps which are designed for pressures up to 40 bar
- Horizontal Multistage (MS-H) clean water pumps which are designed for pressures up to 40 bar
- Booster-sets for clean water with a maximum shaft power of 150 kW

The pump categories **ESOB, ESCC, ESCCi, MSS (up to 6") and MS-V (up to 25 bar and 100m3/h)** are already covered by the existing regulation.

Larger horizontal multistage water pumps (which are designed for pressures between 25 and 40 bar) are included since they present important energy savings according to estimates in potential energy savings (1.5–2.1 TWh/year). The study team are aware of the difficulties brought up by Europump[268] on regulating these pumps since they are engineered and would have difficulties on attaining a harmonized requirement. Furthermore, Europump has also mentioned they would present problems for Market Surveillance due to their size which may make testing difficult. However, this was discussed by some Member States who said that other large products can be verified, such as in the Transformers Regulation 548/2012. Finally, they stated that users are already aware of efficiency and of the advantage of using VSDs. However, data provided by Europump confirms that about 29% of the pumps used in variable flow applications use VSD, bringing an important opportunity considering the reduction of average electricity consumption from about 29 kW without VSD to 18 kW with VSD. Furthermore, the calculated potential shows that not as many users are aware of efficiency and the use of VSDs, as Europump stated[269268]. Larger vertical multistage water pumps (designed for pressures between 25 and 40 bar) are also included since this will increase the energy savings and because, as suspected by the study team, that to neglect regulating larger vertical multistage water

[268] 'Proposed scope for regulation of multistage pumps' position paper. Issued by Europump on the 8th of April, 2016.
[269] Ibid.

pumps could lead to the same loophole stated by Europump for smaller horizontal multistage pumps of up to 25 bars[270].

Booster-sets are also included, since according to industry[271], this will bring into scope the mass produced horizontal pumps with a smaller flow and head range which are used in booster sets.

Larger borehole submersible multistage water pumps (with a nominal outer diameter from 6" to 12") have been excluded after receiving new data from Europump on the use of VSDs, which shows that little savings can be achieved since many of the pumps used in variable flow applications already use VSDs (0.3 TWh/year as shown in Table 33). Furthermore, most of the savings in the highest range (0.9 TWh/year) come from switching to improved motor technologies, which is a decision not directly dependent on the review of the Pump regulation 547/2012.

In spite of the large electrical power consumption per unit, the estimated stock of **large ESOB pumps (rated power >150 kW)** is limited (about 9000 units). The estimated energy saving potentials is about 0.3 TWh/year and this is based on the assumption that 10% of these pumps are used in the variable flow applications and therefore could save electricity by applying VSD. The assumption of 10% pumps operating in variable flow application might differ slightly from the reality, but even if it is 20% the potential energy savings would not be higher than 0.7 TWh/year. Assuming a higher share of variable flow applications is unrealistic since they are often selected for a specific duty with no opportunities to vary the flow/head[272151], according to investigations conducted by the study team and information provided by stakeholders. It is therefore concluded that this energy saving potential would not pay off the additional costs these pumps would imply on market surveillance and verification procedures. The study team has therefore decided to exclude these pumps from the next tasks of the review study.

According to information from stakeholders and from desktop research, **self-priming pumps** present a diverse range of pump types with different capabilities which need to be identified before even starting with the data collection. These have not been discussed in previous chapters due to the lack of information on the relevance to the specific pump categories assessed in this review study. This is because self-priming pumps cover a wide range of applications and there is no single definition for them, which makes their characterisation impossible without having a proper harmonized definition first. Furthermore, the type of fluids they pump is not only water but also air and it is not sure how many of the existing self-priming pumps are used for clean water applications. Since there is no available information on the number of self-priming pumps in use or sold, and no reliable information about their average size or operation time, it is not possible to estimate the overall energy consumption nor energy saving potentials. It has been discussed whether the exclusion of self-priming pumps presents a potential loophole. Inputs from stakeholders indicate that it is very unlikely that anyone would buy a self-priming pump if the self-priming function is not needed, therefore the exclusion can only present a loophole if the definition for self-priming pumps is unclear. A definition is presented in section 9.3.

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[270] 'Proposed scope for regulation of multistage pumps' position paper. Issued by Europump on the 8th of April, 2016.
[271] Ibid.
[272] "Unsuitability of some pump types for regulation and problems to be solved for others". Europump position paper, final issue 1. February 16th, 2016.

Borehole MSS (>12") for clean water presents very little savings potential and have therefore been excluded.

9.2.3 Swimming pool pumps

Only **small swimming pool pumps (up to 2.2 kW rated power)** have been included in the final scope.

In spite of the small potential savings at EPA level (0-0.21 TWh/year), small swimming pool pumps present important ambiguities on the parameters that greatly influence the calculation of savings potentials:

- It is considered that all pumps operate under constant flow and that only a small part of the European market uses variable speed drives (2.9%). There are no doubts about this figure and its representation of the market, however, there is an indication that variable speed drive can be beneficial for the energy consumption of swimming pool pumps (e.g. in the USA and Australia, where the share of variable speed applications can go up to 92%, and in the UK where a pump using VSD can be reduced to half of the annual energy consumption of a 1HP pump). This would bring the energy savings from 0.21 TWh/year to 3.4 TWh/year, considering only the manufacturer's information. The savings would come from switching to variable flow and therefore opening the possibility of using VSDs and achieving a potential saving. Despite this is based only on one manufacturer's information, it points out at the unexploited potential of switching to variable flow which is also discussed by the ENERGY STAR program in Australia and the energy efficiency standard in the USA as discussed in previous chapters.
- Despite that the study team is aware of the differences on use of disinfectants between the USA and Australia, there does not seem to be specific requirements which show the chlorine (or other disinfectant) levels that must be kept under a certain limit. What is stated as chlorine levels by stakeholders[273][148] are not required limits but are recommended levels in swimming pool standards both in the USA and in the EU. Furthermore, this comparison does not show clearly whether the levels are very different or more or less equal.
- The differences on maximum turnover rate between the USA and the EU have been made clear but it is not clear whether a different system design can maintain this and at the same time reduce the energy consumption by the pump.
- The example in the UK shows different speed modes for different operation cycles, arguing that the filtration system does not need to run full speed all the time, e.g. during the night time. This puts in doubt the fact of whether the maximum turnover rate must be fixed for the different times of the day.
- According to data provided by industry, the fact that no small swimming pool pumps are operated in variable flow applications reduces the savings potential at EPA level nearly to zero. If, for example, the amount of variable flow applications would increase to 50%, the potential savings would be at least 1.1 TWh/year. The fact that the use of variable speed is not currently promoted in the EU domestic swimming pool market, slows down the possibility to increase the amount of variable flow applications. In a circulation/filtration system, this is an evident possibility which should be explored.

[273] EUSA Pool Pump Working Group Position paper #2, dated on the 21st of March, 2016

Larger swimming pool pumps (rated power > 2.2 kW) have been excluded, since they present very small saving potentials. Furthermore, it is assumed that these pumps are used in commercial settings, where the possibility to increase the use of VSDs thus turning them into more variable flow applications are limited.

9.2.4 Wastewater pumps

The wastewater pumps included in the final scope are:

- **Submersible vortex radial (SVR) pumps for wastewater ≤ 160 kW**
- **Submersible channel radial (SCR) pumps for wastewater ≤ 160 kW**

In spite of the very little potential savings, max. 0.34 TWh/year for vortex radial pumps and max. 0.9 TWh/year for channel radial pumps, these pumps have been included in the final scope. This is because by the time of the decision on the final scope, these pumps presented many ambiguities in terms of categorisation.

Although vortex pumps appear to have have different uses than channel pumps[274], one of the wastewater pump manufacturers is not using vortex pumps any longer and appears to have substituted them by improved channel pumps. However, further input from industry[275] clarified that a significant number of wastewater pumping applications still require vortex pumps for a reliable operation. This input was received after the final scope was identified, so it was left as it is.

Axial flow pumps have been excluded from the review study since they have been clearly identified for applications that differ from channel radial and vortex radial pumps (i.e. for high flows and low heads, contrary to all the vortex and most of the channel pumps). Furthermore, the stock of these pumps is rather small (2000-3000 units) and their potential savings are max. 0.02-0.10 TWh/year, since they already show a high use of VSDs (100% of all the variable flow applications, which is 24% of all the applications in the EU market).

The estimated potential energy savings for all the **dry well wastewater pumps** is max. 0.4 TWh/year, and considering the complexity in defining and categorising wastewater pumps and the effort required for market surveillance, the study team concludes to exclude all dry well wastewater pumps from the next tasks of the review study.

9.2.5 Solids handling pumps

None of these pumps have been included in the final scope of this review study.

In spite of the significant total electricity consumption at EU level (5.8 TWh/year) of **submersible dewatering pumps** and the comparable savings potential of some submersible wastewater pumps (0 – 0.4 TWh/year), the potential to increase the amount of pumps dedicated to variable applications to much higher levels and thus increasing savings potential is not realistically possible. The nature of their mobile applications makes it difficult to couple them with VSDs and high efficient motors, according to information from stakeholders and in Lot 28. Furthermore, the type of fluid they pump is quite diverse, not only composed of sand and grit water (specified in Lot 28), but varying from pool water to wastewater and solids, according to information from Europump. This diversity demands a further categorization based on the type of fluid they pump, and this task is not possible

[274] Dialogue with manufacturers at IFAT 2016
[275] Europump response published the 31st May 2018 to document elaborated by study team: "EXTRACT NO.2 FROM DRAFT FINAL REPORT ON WASTEWATER PUMPS", sent to Europump on the 15th May 2018.

at this point in time since the wide range of applications also presents a wide range of water and wastewater mixtures that cannot be categorized at this stage in time. The study team therefore sees no reason to keep assessing this pump category and it is therefore excluded from the next tasks of the review study.

The estimated potential energy savings for **slurry pumps (light and heavy duty)** are less than 0.5 TWh/year. Slurry pumps are exposed to extreme wear, which influence the energy efficiency. The energy efficiency of a new pump is less relevant than the energy efficiency after the pump has been exposed to wear for some time. Therefore, normal testing procedures, where new pumps are tested, would not give a correct indication of which pumps are most energy efficient during their lifetime. Considering the complexity of testing slurry pumps and the effort required for market surveillance, the study team concludes to exclude slurry pumps from the next tasks of the review study.

9.3 Pump definitions in final scope of this review study

The above described pump categories can be grouped in thirteen pump types and are defined as follows:

- **End suction own bearing pumps (ESOB):** A glanded single stage end suction rotodynamic water pump with own bearing designed for a maximum shaft power up to 150 kW, which does not have a self-priming function and which its intended use is pumping clean water.
- **End suction close coupled pumps (ESCC):** A glanded single stage end suction rotodynamic water pump of which the motor shaft is extended to also become the pump shaft, designed for a maximum shaft power up to 150 kW, which does not have a self-priming function and which its intended use is pumping clean water.
- **End suction close coupled inline pumps (ESCCi):** A glanded single stage end suction rotodynamic water pump of which the water inlet of the pump is on the same axis as the water outlet of the pump, which does not have a self-priming function and which its intended use is pumping clean water.
- **Submersible borehole multistage pumps (MSSB):** A multi stage ($i > 1$) rotodynamic water pump, designed to be operated in a borehole at operating temperatures within a range of 0-90 degrees C, designed with a nominal outer diameter up to 6” which does not have a self-priming function and which its intended use is pumping clean water.
- **Vertical multi-stage pumps:** A glanded vertical multistage ($i > 1$) rotodynamic water pump in which the impellers are assembled on a rotating shaft, which is designed for pressures up to 40 bar, which does not have a self-priming function and which its intended use is pumping clean water.
- **Horizontal multi-stage pumps:** A glanded horizontal multistage ($i > 1$) rotodynamic water pump in which the impellers are assembled on a rotating shaft, which is designed for pressures up to 40 bar, which does not have a self-priming function and which its intended use is pumping clean water.
- **Self-priming water pump:** A pump that moves clean water and which can start and/or operate also when only partly filled with water and which its intended use is pumping clean water.
- **Booster-set:** A booster-set is either a single pump or an assembly of parallel connected pump units with a maximum shaft power of 150 kW to be operated with backflow prevention and additional components influencing hydraulic performance and components necessary to control pressure in open loops inside buildings and

which is placed on the market and/or put into service as one single product and its intended use is to pump clean water.[276]

- **Swimming pool pumps:** A small pump packaged in plastic comprising an integrated unit of motor, pumps and controls typically with a maximum shaft power of 2.2 kW (with built-in strainer) and designed specifically for pumping swimming pool water for circulation and filtration.
- **Centrifugal submersible radial vortex wastewater pumps:** A rotodynamic water pump that has a radial inflow and a vortex impeller and it is designed to operate under water with a maximum shaft power of 160 kW, and which its intended use is to pump wastewater. A vortex impeller is an impeller that drives the flow by creating a whirlpool.
- **Centrifugal submersible channel radial wastewater pumps**: A rotodynamic water pump that has a radial flow and an impeller inside the flow channel with a maximum shaft power of 160 kW and it is designed to operate under water, and which its intended use is to pump wastewater.

[276] Definition provided by Europump

10 Task D5: Definition of Base Cases: Environment & Economics

10.1 Product-specific inputs

This section describes the inputs for the base cases that form the reference for the environmental, technical and economical improvements to be identified in Task 6 and 7.

According to the MEErP[277], Task 5 requires that one or more average EU product(s) are defined or that a representative product category is identified for the whole of the EU-28 ("base-case"). In this review study the following base-cases have been identified.

10.1.1 Overview of base cases

The base cases for this review study derive from the pump categories in final scope as defined in sections 9.2 and 9.3 of chapter 9. However, based on the fact that the focus of this study is on tackling potential savings at EPA level, it became evident the relevance of assessing potential energy saving measures for each pump category at constant and variable flow applications separately. This is because the hydraulic behaviour of constant flow systems is rather different to that of variable flow, thus influencing the pump efficiencies in different ways. Furthermore, the application of VSDs is mainly relevant for variable flow applications, since when applied to constant flow applications it may not be beneficial in terms of energy consumption because of the energy loss in the VSD. For example, according to data provided by industry stakeholders, swimming pool pumps using VSDs use more energy in constant flow applications than when not using VSDs. This is because no current variable flow applications are registered within EUSA members[278100,279124] and thus no benefits are identified from using VSDs in variable flow applications. On the contrary, ESOB pumps present very little savings (about 3%) for constant flow applications, while the rest is from variable flow applications which comes, to a great extent, from using VSDs.

To investigate requirements at EPA level it has therefore been decided to assess these separately: (i) requirements for constant flow applications, and (ii) requirements for variable flow applications.

Constant flow applications

In a constant flow application, the pump operates according to the reference flow time profile for constant flow operation. The reference flow time profile for constant flow operation is either at 'Part load (PL)', 'Best Efficiency Point (BEP)' and Over load (OL)'[280] (see Table 34 below).

[277] See http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/methodology/index_en.htm
[278] Information provided by EUSA Working Group
[279] EUSA Pool Pump Working Group Position paper, 23/10 2015
[280] Commission Regulation (EU) No. 547/2012

Table 34. Reference flow time profile for constant flow applications[65].

Flow Q in % of $Q_{100\%}$	75	100	110
Time Δt in % of total operating time	25	50	25

Variable flow applications

In a variable flow application, the pump operates according to the reference flow time profile for variable flow operation. The reference flow time profile for variable flow operation is shown in Table 35.

Table 35. Reference flow time profile for variable flow applications[65].

Flow Q in % of $Q_{100\%}$	25	50	75	100
Time Δt in % of total operating time	44	35	15	6

For more details about differences between constant and variable flow, please refer to chapter 4 (Task C: Extended Product Approach).

Based on this, the base cases are presented in Table 36. An additional remark is that the base cases for clean water pumps have been disaggregated in the two size categories defined in Lot 11, as it was observed in that study that their applications and also their efficiencies were different and it was therefore of interest to investigate whether these were still valid. This does not apply to booster-sets nor to borehole multistage submersible pumps (MSSB) as there is only one size range in the final scope. Additionally, it was found not relevant to disaggregate wastewater pump units according to size categories. Industry initially provided two and three sub-categories for submersible vortex and channel pumps, respectively. However, no clear reasoning for this division was provided except that the majority of these pumps were sold in sizes not bigger than 10 kW. In order to be consistent with the base cases identified in preparatory study Lot 28, it was decided by the study team to aggregate them as one category for each pump type. Finally, since large swimming pool pumps have been excluded from final scope there is also only one size category for these pumps which are intended mostly for domestic use according to information from Europump and EUSA working groups.

Table 36. Overview of base cases, their application, size sub-division and predicted economic lifetime.

Base case #	Abbreviation	Water pump category	Size sub-division	Use	Application	Predicted economic lifetime (years)
1	ESOBs cons	End Suction Own Bearing pumps	Rated power ≤ 22 kW	Pumping of clean water	Constant flow	10
2	ESOBs var				Variable flow	
3	ESOBm cons		Rated power 22-150 kW		Constant flow	
4	ESOBm var				Variable flow	
5	ESCCs cons	End Suction Closed Coupled pumps	Rated power ≤ 22 kW		Constant flow	10
6	ESCCs var				Variable flow	
7	ESCCm cons		Rated power 22-150 kW		Constant flow	
8	ESCCm var				Variable flow	
9	ESCCis cons	End Suction Closed Coupled inline pumps	Rated power ≤ 22 kW		Constant flow	10
10	ESCCis var				Variable flow	
11	ESCCim cons		Rated power 22-150 kW		Constant flow	
12	ESCCim var				Variable flow	
13	MSSBs cons	Borehole multistage submersible pumps	Nominal outer diameter ≤ 6"		Constant flow	10
14	MSSBs var				Variable flow	
15	MS-Vs cons	Vertical multistage pumps	Maximum design pressure ≤ 25 bar		Constant flow	10
16	MS-Vs var				Variable flow	
17	MS-Vm cons		Maximum design pressure 25 - 40 bar		Constant flow	10
18	MS-Vm var				Variable flow	
19	MS-Hs cons	Horizontal multistage pumps	Maximum design pressure ≤ 25 bar		Constant flow	10
20	MS-Hs var				Variable flow	
21	MS-Hm cons		Maximum design pressure 25 - 40 bar		Constant flow	10
22	MS-Hm var				Variable flow	
23	Booster-sets	Booster-sets pumps	Rated power ≤ 150 kW	Boosting of clean water	Variable flow	10
24	SWP cons	Swimming pool pumps	Rated power ≤ 2.2 kW	Filtration and circulation of swimming pool water	Constant flow	10
25	SVR cons	Submersible vortex radial pumps	Rated power ≤ 160 kW	Pumping of wastewater	Constant flow	10
26	SVR var				Variable flow	
27	SCR cons	Submersible channel radial pumps	Rated power ≤ 160 kW		Constant flow	10
28	SCR var				Variable flow	

10.1.2 Summary of relevant standards for performance

As explained in chapters 3 and 4, there are several performance standards for quantification and testing of energy efficiency that are relevant for the pumps in scope of this review study. However, as the focus of this review is on developing efficiency requirements at EPA level, the only relevant standard for performance is the *prEN 17038-1: Development, Validation an Application of a Semi-Analytical Model for the Determination of the Energy Efficiency Index of Single Pump Units - Part 1: General description of the methodology,* and *prEN 17038-2: Development, Validation and Application of a Semi-Analytical Model for the Determination of the Energy Efficiency Index of Single Pump Units Quantification of the energy efficiency of water pump units - Part 2: Single pump units.*

However, these standards are not applicable to all the pump categories in the final scope of this study. The standards are only relevant for end suction clean water pumps (base cases 1 to 12, see Table 36), since it is not possible for both vertical and horizontal multistage clean water pumps (base cases 15 to 22, see Table 36) to establish P1ref[281] values. Therefore, the EEI value cannot be estimated[282]. Furthermore, a correction factor must still be established in order to make multistage pumps comparable independently of their number of stages. Moreover, the borehole submersible multistage pumps (base cases 13 and 14, see Table 36) are not part of these standards and separate sub-working groups within the CEN TC 197 Working Group 1 will be formed to develop a separate methodology[283]. Finally, there is no C-value for other pumps than end suction and vertical multistage pumps (up to 25 bar), making the calculation of the reference pump efficiency nor P1ref possible for these pumps.

At the start of this project and thorough the review study[284] there was no methodology nor a performance standard to calculate EEI of 14 out of the 28 base cases in this study. Therefore, several assumptions were made to calculate energy saving potentials which are explained in chapter 12 (Task 7). However, due to changes in timeline for the review study, the current status of the standard indicates that 21 out of 28 base cases have or will soon have a methodology to calculate their EEI[285]. MSSB clean water pumps, swimming pool pumps and wastewater pumps have not yet a foreseen methodology, but an attempt to develop a transitional method to be included in the future amended regulation will be done after assessing further the opportunities and barriers of including these pumps in the regulation.

it is important to emphasize the importance of a harmonised methodology (i.e. a standard) to quantify the energy efficiency of the pump categories in scope at an EPA level, if they are to be included in a review of Regulation 547/2012. This is due to the fact that EPA is the focus for a future amended regulation.

10.1.3 Overview of market data for base cases

An overview of market data collected in previous tasks and used for establishing the environmental and economic assessment in these tasks is shown in Table 37. The base cases for variable flow applications are sub-divided in two sub-categories: with and without VSDs. This is because no information was provided on the share of VSDs used in constant

281 Reference power input to the pump, see Figure 10
282 Information provided by Europump.
283 Information provided by standardisation group.
284 This was up to the date of the writing of the draft final report which was accepted on August 2016.
285 This was notified by Europump on the 13th of June 2017. The draft standard is the prEN 17038.

flow applications and it was therefore assumed by the study team that the share of VSD use for each pump category relates only to variable flow applications. Furthermore, preliminary information from industry about the application of the EPA methodology on the distribution of EEI levels for end suction clean water pumps in the EU market[286], showed that EEI_c is practically independent of whether a VSD is included in the pump unit. For this reason, it makes no sense to aim for using more VSDs in constant flow applications. On the other hand, pump units in variable flow clearly benefit from using variable speed controllers, showing EEI reductions up to 50%. The share of pumps using VSDs in variable flow applications in 2014 has been provided by Europump. The use of VSDs increases efficiency of the pumps and the motors when looking at the EPA, so this indicator shows whether there is an opportunity for improvement. This is further evaluated in chapter 12 (Task 7).

An interest rate of 4% p.a. has been used for all base cases as stated in chapter 6, section 6.4. Industry electricity prices were applied for all pump categories except swimming pool pumps which are used at households. Despite that many of the clean water pumps are also used in residential buildings, it is not known what percentage of base cases is used for industrial or residential purpose in the EU. Furthermore, it is likely that they are charged electricity prices for the service sector when used by building management services organisations and/or building management boards, since for apartment buildings it is usually them purchasing pumps and paying for their operation. It has therefore been assumed that all pumps that are B2B are charged industry electricity prices and those that are B2C are charged household electricity prices (assuming household prices and prices for the service sector are close to each other).

[286] Oral communication from Europump at video-conference meeting on the 27th of May, 2016.

Table 37. Overview of market data used in the environmental and economic assessment.

Base case #	Abbrevia-tion	Use of VSD[287][288]	Variable flow application[288]	Average purchase price (EUR)[289]	Weighted average purchase price (EUR)[290]	Average installa-tion costs (EUR/ year)	Average repair & maintenance costs (EUR/year)	Industry electricity price (EUR/ kWh)	Household electricity price (EUR/ kWh)	2014 Sales (units)	2014 Stock (units)
1	ESOBs cons	No	*n.r.*	3,000.5		720	300	0.0917	*n.r.*	112,500	1,046,805
2	ESOBs var	8% of total var. apps.	ESOBs var m	3,000.5	3,021.1					112,500	97,136
			ESOBs var vsd	3,258.0							
3	ESOBm cons	No	*n.r.*	4,862.3						17,500	162,836
4	ESOBm var	13% of total var. apps.	ESOBm var m	4,862.3	4,997.5					7,500	6,476
			ESOBm var vsd	5,902.3							
5	ESCCs cons	No	*n.r.*	1,841.2		2,100	800			112,500	1,046,805
6	ESCCs var	10% of total var.apps.	ESCCs var m	1,841.2	1,866.9					112,500	97,136
			ESCCs var vsd	2,098.7							
7	ESCCm cons	No	*n.r.*	6,766.4						12,500	116,312
8	ESCCm var	10% of total var. apps.	ESCCm var m	6,766.4	6,870.4					12,500	10,793
			ESCCm var vsd	7,806.4							
9	ESCCis cons	No	*n.r.*	2,218.1		2,100	800			9,000	83,744
10	ESCCis var	33% of total var. apps.	ESCCis var m	2,218.1	2,303.1					81,000	69,938
			ESCCis var vsd	2,475.6							
11	ESCCim cons	No	*n.r.*	6,130.0						1,000	9,305
12	ESCCim var	33% of total var. apps.	ESCCim var m	6,130.0	6,473.2					9,000	7,754
			ESCCim var vsd	7,170.0							
13	MSSBs cons	No	*n.r.*	1,855.7		955	750			560,000	5,210,764
14	MSSBs var	5% of total var. apps.	MSSBs var m	1,855.7	1,909.2					140,000	120,881
			MSSBs var vsd	2,925.7							
15	MS-Vs cons	No	*n.r.*	1,599.9		1,000	525			125,000	1,163,117

287 Pumps used for variable flow applications can be used with or without VSD. In this table these are referred as: Pumps used with only motor (m) and pumps used with motor and vsd (vsd). The percentages are calculated based on 2014 data provided by industry.

288 Ibid.

289 Prices of constant and variable applications without VSD (m) are the same, as in both cases the price includes the pump and the correspondant IE3 motor in terms of size. Prices of variable applications with VSD (vsd) are different, considering the price of the pump, an IE2 motor and an IE1 VSD, which follows requirements in the draft Motor Regulation.

290 The average purchase prices have been weighted according to the share of VSD in variable flow applications (Use of VSDs column). For swimming pool pumps (base case#24), this was done according to the share of VSD in constant flow applications.

Base case #	Abbrevia-tion	Use of VSD[287][288]	Variable flow application[288]	Average purchase price (EUR)[289]	Weighted average purchase price (EUR)[290]	Average installa-tion costs (EUR/ year)	Average repair & maintenance costs (EUR/year)	Industry electricity price (EUR/ kWh)	Household electricity price (EUR/ kWh)	2014 Sales (units)	2014 Stock (units)
16	MS-Vs var	16% of total var. apps.	MS-Vs var m	1,599.9	1,641.1					125,000	107,929
			MS-Vs var vsd	1,857.4							
17	MS-Vm cons	No	*n.r.*	13,825.8		2,000	1,000			1,450	13,492
18	MS-Vm var	70% of total var. apps.	MS-Vm var m	13,825.8	14,553.8					1,450	1,252
			MS-Vm var vsd	14,865.8							
19	MS-Hs cons	No	*n.r.*	780.5		1,000	525			297,500	2,768,219
20	MS-Hs var	27% of total var. apps.	MS-Hs var m	780.5	850.1					297,500	256,871
			MS-Hs var vsd	1,038.0							
21	MS-Hm cons	No	*n.r.*	6,285.4		2,000	1,000			5,250	48,851
22	MS-Hm var	43% of total var. apps.	MS-Hm var m	6,285.4	6,732.6					5,250	4,533
			MS-Hm var vsd	7,325.4							
23	Booster-sets	50% of total var. apps.	Booster-sets vsd	6,315.1		2,000	1,050			40,000	372,197
24	SWP con	2,9% of total con. apps.	SWP con m[291]	615.1	622.5	250	4.4	*n.r.*	0.2038	508,000	374,611
			SWP con vsd	872.6							
25	SVR con	No	*n.r.*	3,163.5		1,329	775	0,0917	*n.r.*	78,232	745,541
26	SVR var	100% of total var. apps.	SVR var m	3,163.5	3,403.8					4,168	3,768
			SVR var vsd	3,403.8							
27	SCR con	No	*n.r.*	5,992.0		1,800	981			88,928	847,473
28	SCR var	100% of total var. apps.	SCR var m	5,992.0	6,331.2					5,672	5,128
			SCR var vsd	6,331.2							

n.r. = not relevant

[291] In the case of swimming pools, the VSDs are used for constant applications according to EUSA Working Group. According to them, there are no variable applications within their members.

10.1.4 Overview of energy data for base cases

An overview of the energy data on average user load of the pumps in the base cases is shown in Table 38. These data were used for establishing the environmental and economic assessment in this task. The use of water and other consumables are considered negligible and are therefore not shown.

Table 38. Overview of data on average energy use patterns for the environmental and economic assessment (numbers given per pump unit).

Base case #	Abbreviation	Average annual electrical energy consumption (kWh/year)	Operating hours (hours/ year)	Average annual user demand (P1avg, kW)	Average annual load (P3avg, kW)	Average load factor (P3avg/ P3 BEP)	Average efficiency (P3avg/ P1avg)
1	ESOBs cons	12,150	2,250	5.40	3.38	97%	63%
2	ESOBs var	18,794	5,000	3.76	1.80	52%	48%
3	ESOBm cons	61,650	2,250	27.40	18.51	97%	68%
4	ESOBm var	89,517	5,000	17.90	9.52	50%	53%
5	ESCCs cons	10,350	2,250	4.60	2.85	97%	62%
6	ESCCs var	15,916	5,000	3.18	1.51	51%	47%
7	ESCCm cons	63,000	2,250	28.00	18.92	97%	68%
8	ESCCm var	92,535	5,000	18.51	9.83	50%	53%
9	ESCCis cons	8,550	2,250	3.80	2.31	97%	61%
10	ESCCis var	11,914	5,000	2.38	1.13	47%	47%
11	ESCCim cons	54,449	2,250	24.20	16.35	97%	68%
12	ESCCim var	73,395	5,000	14.68	7.86	47%	54%
13	MSSBs cons	3,825	2,250	1.70	0.82	97%	48%
14	MSSBs var	3,256	2,250	1.45	0.52	61%	36%
15	MS-Vs cons	8,325	2,250	3.70	2.34	97%	63%
16	MS-Vs var	13,720	5,000	2.74	1.25	52%	46%
17	MS-Vm cons	161,775	2,250	71.90	53.33	97%	74%
18	MS-Vm var	199,278	5,000	39.86	22.87	42%	57%
19	MS-Hs cons	2,209	2,250	0.98	0.41	97%	42%
20	MS-Hs var	3,560	5,000	0.71	0.22	52%	31%
21	MS-Hm cons	66,436	2,250	29.53	16.09	97%	55%
22	MS-Hm var	91,217	5,000	18.24	7.38	45%	40%
23	Booster-sets	21,050	2,000	4.21	1.71	41%	41%
24	SWP cons	1,538	1,540	1.00	0.41	97%	41%
25	SVR cons	5,403	1,048	5.16	1.34	98%	26%
26	SVR var	2,536	1,046	2.43	0.49	36%	20%
27	SCR cons	15,351	1,511	10.16	5.51	97%	54%

Base case #	Abbreviation	Average annual electrical energy consumption (kWh/year)	Operating hours (hours/year)	Average annual user demand (P1avg, kW)	Average annual load (P3avg, kW)	Average load factor (P3avg/ P3 BEP)	Average efficiency (P3avg/ P1avg)
28	SCR var	9,398	1,493	6.30	2.69	47%	43%

10.1.5 Overview of materials use for base cases

An overview of the materials used for the base cases is shown in Table 39. These data were used for establishing the environmental and economic assessment in this task, and it includes the materials for the motors (for constant and variable applications) and for the VSDs (for variable applications).

Table 39. Overview of data on material use for the environmental and economic assessment (numbers given per pump + PDS unit).

Base case #	26 Stainless steel (kg)	23 Steel prof. (kg)	24 Cast iron (kg)	30 Copp wire (kg)	28 Alu (kg)	12 PA 6 (kg)	4 PP (kg)	2 HDPE (kg)	11 ABS (kg)	40 Coa-ting (kg)	58 Pap (kg)	57 Card (kg)	1 LDPE (kg)	16 PUR (kg)	8 PVC (kg)	50 PWB (kg)	49 SMD (kg)	47 IC (kg)	Pro-duct weight (kg)	Total packaged pro-duct (kg)
1	10.8	5.94	32.7	1.36	1.87	0	0	0	0	0.16	0.10	5.10	0.50	0.06	0	0	0	0	**52.9**	**58.6**
2	10.8	5.96	32.7	1.36	1.96	0	0	0	0	0.16	0.10	5.10	0.50	0.06	0.03	0.02	0.02	0	**53.1**	**58.8**
3	22.7	39.6	178	7.04	9.90	0	0	0	0	0.65	0.10	16.9	1.00	0.22	0	0.00	0	0	**258**	**276**
4	22.7	39.8	178	7.04	10.2	0	0	0	0	0.65	0.10	16.9	1.00	0.22	0.07	0.04	0.1	0.03	**259**	**277**
5	2.85	5.94	16.7	1.36	1.87	0	0	0	0	0.21	0.10	5.10	1.00	0.06	0	0	0	0	**29.0**	**35.2**
6	2.85	6.00	16.7	1.36	1.98	0	0	0	0	0.21	0.10	5.10	1.00	0.06	0.03	0.02	0.02	0.01	**29.3**	**35.5**
7	17	39.6	116	7.04	9.90	0	0	0	0	0.75	0.10	16.9	3.00	0.22	0	0	0	0	**191**	**211**
8	17	39.8	116	7.04	10.0	0	0	0	0	0.75	0.10	16.9	3.00	0.22	0.06	0.03	0.08	0.02	**192**	**212**
9	2.85	5.9	16.7	1.36	1.87	0	0	0	0	0.21	0.10	5.10	1.00	0.06	0	0	0	0	**29.0**	**35.2**
10	2.85	6.12	16.7	1.36	2.24	0	0	0	0	0.21	0.10	5.10	1.00	0.06	0.11	0.07	0.07	0.02	**29.9**	**36.1**
11	17	39.6	116	7.04	9.90	0	0	0	0	0.75	0.10	16.9	3.00	0.22	0	0	0	0	**191**	**211**
12	17	40.2	116	7.04	10.7	0	0	0	0	0.75	0.10	16.9	3.00	0.22	0.18	0.11	0.26	0.07	**193**	**213**
13	8.7	10.9	3.85	2.15	2.89	0	0	0	0	0.24	0.10	3.50	0.10	0.18	0	0	0	0	**28.9**	**32.6**
14	8.7	10.9	3.85	2.15	2.94	0	0	0	0	0.24	0.10	3.50	0.10	0.18	0.02	0.01	0.01	0	**29.0**	**32.7**
15	5.35	5.9	6.45	1.36	1.87	0	0	0	0	0.11	0.10	2.10	0.10	0.16	0	0	0	0	**21.2**	**23.5**
16	5.35	6.03	6.45	1.36	2.05	0	0	0	0	0.11	0.10	2.10	0.10	0.16	0.04	0.04	0.04	0.01	**21.6**	**23.9**
17	55.7	226	59.6	9.87	9.90	3.87	0	0	0	0.55	0	18.2	0	0.22	0	0	0	0	**366**	**384**
18	55.7	227	59.6	9.87	11.6	3.87	0	0	0	0.55	0	18.2	0	0.22	0.39	0.23	0.54	0.15	**370**	**389**
19	5.35	5.94	6.45	1.36	1.87	0	0	0	0	0.11	0.10	2.10	0.10	0.16	0	0	0	0	**21.2**	**23.5**
20	5.35	6.09	6.45	1.36	2.17	0	0	0	0	0.11	0.10	2.10	0.10	0.16	0.09	0.06	0.06	0.01	**21.9**	**24.2**
21	55.7	226	59.6	9.87	9.90	3.87	0	0	0	0.55	0	18.25	0	0.22	0	0	0	0	**366**	**384**

Base case #	26 Stainless steel (kg)	23 Steel prof. (kg)	24 Cast iron (kg)	30 Copp wire (kg)	28 Alu (kg)	12 PA 6 (kg)	4 PP (kg)	2 HDPE (kg)	11 ABS (kg)	40 Coa-ting (kg)	58 Pap (kg)	57 Card (kg)	1 LDPE (kg)	16 PUR (kg)	8 PVC (kg)	50 PWB (kg)	49 SMD (kg)	47 IC (kg)	Pro-duct weight (kg)	Total packaged pro-duct (kg)
22	55.7	227	59.6	9.87	10.9	3.87	0	0	0	0.55	0	18.2	0	0.22	0.24	0.14	0.33	0.09	**369**	**387**
23	5.83	9.18	6.93	1.40	4.07	0.04	0	0	0	0.11	0.10	2.18	0.10	0.15	0.33	0.22	0.22	0.06	**28.5**	**30.9**
24	7.81	5.94	2.75	4.86	1.87	0.92	1.38	1.38	0.46	0.11	0	2.27	0	0	0	0	0	0	**27.5**	**29.7**
25	15.1	82.5	16.7	13.8	5.45	0.95	0	0	0	0.41	0	4.28	0	0.14	0	0	0	0	**135**	**139**
26	15.1	83.1	16.7	13.8	6.55	0.95	0	0	0	0.41	0	4.28	0	0.14	0.33	0.22	0.22	0.06	**138**	**142**
27	18.1	96.6	22.2	16.3	9.90	0.95	0	0	0	0.55	0	7.48	0	0.22	0	0	0	0	**165**	**172**
28	18.1	98.4	22.2	16.3	12.3	0.95	0	0	0	0.55	0	7.48	0	0.22	0.55	0.33	0.77	0.22	**171**	**179**

Material codes are: 26= Stainless steel 18/8 coil; 23=Steel tube/profile; 24=Cast iron; 30=Copper winding wire; 28= Aluminium die cast; 12=Nylon Polyamide 6; 4=Polypropylene; 2=High Density Polyethylene; 11=ABS; 40=Powder coating; 58=Office paper; 57=Cardboard; 1=Low density Polyethylene; 16= Rigid Polyurethane; 8=Polyvinylchloride; 50=Printed Wiring Board 1/lay, 3.75 kg/m2; 49=Surface Mounted Device/LED average (electronics small); 47=Integrated Circuits average 5% Si, AU (electronics big).

10.2 Base-case Environmental Impact Assessment

This section presents the results of the Life Cycle Assessment (LCA) analysis for all the base cases identified above, using the EcoReport Tool[292]. In this analysis, all life cycle stages of a pump unit are considered, these include:

- Production
  - Material production
  - Product manufacturing
- Distribution
- Use over product service life (10 years)
- End-of-life
  - Disposal
  - Recycling
  - Incineration
  - Stock

The results of the analysis serve as reference to compare the total environmental impacts of the different base cases.

The results are presented per base case (per pump unit) throughout their product service life which in all base cases is 10 years, and as annual environmental impacts calculated for 2014 as the reference year considering stock of that year. For calculating the environmental impacts, the mass of materials in product and in stock is considered, and also the fractions of the product sent to end-of-life disposal, incineration, recycling and stock. Stock is the surplus (or deficit) of mass in stock (in use or stored with consumer) due to growth (or decline) of the unit sales or the share of the materials fraction over a period that equals the product life.

The environmental impact categories are split into three main categories

- Resources and waste
  - Total Energy (Gross Energy Requirement - GER)
  - Electricity (in primary MJ)
  - Water (process)
  - Water (cooling)
  - Waste, non-hazardous/landfill
  - Waste, hazardous/incinerated
- Emissions (air)
  - Greenhouse gases in GWP100
  - Acidification, emissions
  - Volatile Organic Compounds (VOC)
  - Persistent Organic Pollutants (POP)
  - Heavy Metals
  - PAHs
  - Particulate Matter (PM dust)
- Emissions (water)
  - Heavy Metals
  - Eutrophication

Overall the largest environmental impact of the products is from the use phase followed by the production phase. Recycling credits are achieved by the products due to the recycling of disposed materials such as metals.

Four of the environmental impact categories are presented in the next four sections (total energy, Global Warming Potential, Acidification and Non-hazardous waste) for all the base cases, and the remaining impact results are presented in Annex 7.

10.2.1 Total energy (Gross energy requirement-GER)

The total energy for each life cycle stage for each base case is presented in Table 40. It is evident that the use phase is the dominant stage for all base cases with some base cases having a use phase impact almost 1000 times greater than the production stage.

The base case 18 (vertical multistage pumps in variable flow applications with a max. design pressure of 25 to 40 bar) has the highest total energy, whilst base case 24 (domestic swimming pool pump units) has the lowest. This is not only due to the lower use of energy during the use phase, but due to the lower gross energy requirement from the production in spite of the higher credits from recycling (which comes mainly from recycling the metals).

For most of the clean water pump units, the total energy demand is greater when used in variable flow applications, except for the borehole multistage submersible pump units (base cases 13 & 14). This is mainly due to the lower gross energy requirement at the use phase. The reason why all the clean water end suction pump units for variable flow applications present higher total energy is because they consume more electricity as they have lower efficiencies (see Table 38). This is because these pump units operate at lower levels from their BEP compared to pump units for constant flow applications.

For wastewater pump units, the total energy demand is lower when used in variable flow applications. This is because of their lower total energy during use phase.

10.2.2 Greenhouse gas emissions

Table 41 presents the greenhouse gas emissions for each life cycle stage for each base. The same picture is observed, where the use phase is the major source of greenhouse gases presenting much higher levels of emissions than the production stage which is the second highest.

The base case 18 (vertical multistage pumps in variable flow applications with a max. design pressure of 25 to 40 bar) has also the highest greenhouse gas emissions, whilst the base case 24 (Swimming pool pumps) has the lowest. The trend in greenhouse gas emissions is the same as for total energy, which is the use of total energy in the use phase and gross energy requirements from the production stage.

The greenhouse gas emissions have the same trend as observed for total energy between variable and constant flow applications.

10.2.3 Acidification, emissions

The acidification emissions for each life cycle stage for each base case is presented in Table 42. The same trend as for total energy and greenhouse gas emissions is observed, where the use phase is dominant followed, to a much lower extent, by the production stage.

The same base cases present the highest (base case 18) and the lowest (base case 24) source of acidifying emissions. This is due to the consumption of fossil fuels in electricity production during the use phase. In addition, base case 18 presents a high source of acidifying emissions in comparison to the other base cases in the production stage due to the materials used and their manufacturing processes (mainly from metals melting and casting).

The same trend for acidification is observed between variable and constant flow applications as for total energy and Greenhouse gases.

10.2.4 Waste, non-hazardous

Table 43 presents the non-hazardous waste for each life cycle stage for each base case. The same trend is observed as for the other impact categories where the use phase is dominant, although in some cases the contribution of non-hazardous waste from the production stage is proportionally larger (e.g. 15% for domestic swimming pool pump units and 10-36% for wastewater pumps, even when considering the credit for recycling).

The same base cases show the highest and the lowest amount of non-hazardous waste generation (base case 18 and base case 24), due to the high and low amount of non-hazardous waste generated during the use phase from fossil fuel extraction for electricity production plants.

The same trend for waste is observed between variable and constant flow applications as for total energy, Greenhouse gases and Acidifying emissions.

Table 40. Total energy (Gross energy requirement-GER) for each life cycle stage for each base case in MJ.

Life Cycle phases	PRODUCTION			DISTRIBUTION	USE	END-OF-LIFE		TOTAL
Base Case	Material	Manufacture-ring	Total			Disposal	Recycling	
BC1	1,598	302	**1,899**	136	1,093,516	20	-380	**1,095,191**
BC2	1,697	308	**2,005**	136	1,692,017	24	-389	**1,693,794**
BC3	5,562	916	**6,478**	234	5,548,556	71	-1,319	**5,554,020**
BC4	6,566	944	**7,510**	234	8,055,066	97	-1,491	**8,061,416**
BC5	1,007	144	**1,151**	125	931,510	14	-225	**932,575**
BC6	1,131	151	**1,282**	125	1,431,011	19	-236	**1,432,202**
BC7	5,223	760	**5,984**	202	5,670,052	69	-1,208	**5,675,099**
BC8	5,657	781	**6,438**	202	8,329,557	87	-1,244	**8,335,039**
BC9	1,007	144	**1,151**	125	769,510	14	-225	**770,575**
BC10	1,422	172	**1,594**	125	1,071,014	30	-260	**1,072,503**
BC11	5,223	760	**5,984**	202	4,900,552	69	-1,206	**4,905,600**
BC12	6,669	829	**7,498**	203	6,606,067	127	-1,325	**6,612,569**
BC13	1,382	196	**1,579**	125	344,264	17	-334	**345,651**
BC14	1,444	201	**1,645**	125	293,639	20	-339	**295,090**
BC15	882	134	**1,016**	120	749,259	11	-211	**750,195**
BC16	1,081	147	**1,228**	121	1,233,011	19	-228	**1,234,151**
BC17	10,682	1,372	**12,055**	286	14,559,857	143	-2,528	**14,569,811**
BC18	13,718	1,518	**15,236**	287	17,937,137	263	-2,780	**17,950,144**
BC19	882	134	**1,016**	120	198,459	11	-211	**199,395**
BC20	1,216	156	**1,373**	121	319,512	24	-239	**320,791**
BC21	10,682	1,372	**12,055**	286	5,979,932	143	-2,528	**5,989,886**
BC22	12,539	1,461	**14,000**	287	8,208,125	216	-2,682	**8,219,947**
BC23	2,277	236	**2,513**	124	757,823	62	-352	**760,046**
BC24	1,742	329	**2,071**	124	138,617	27	-279	**140,436**
BC25	4,778	391	**5,169**	175	486,739	65	-1,194	**490,954**
BC26	6,025	475	**6,500**	175	228,820	116	-1,304	**234,308**
BC27	5,932	490	**6,422**	190	1,381,718	79	-1,489	**1,386,920**
BC28	10,270	697	**10,967**	190	846,634	260	-1,865	**856,185**

Table 41. Greenhouse gases in GWP100 for each life cycle stage for each base case in kg CO_2 eq.

Life Ccycle phases	PRODUCTION			DISTRIBUTION	USE	END-OF-LIFE		TOTAL
Base Case	Material	Manufacturing	Total			Disposal	Recycling	
BC1	132	17	**149**	10	46,679	0	-32	**46,807**
BC2	138	18	**156**	10	72,227	0	-32	**72,361**
BC3	478	52	**530**	16	236,851	0	-115	**237,283**
BC4	523	53	**576**	16	343,846	1	-121	**344,318**
BC5	68	8	**76**	9	39,763	0	-16	**39,833**
BC6	76	9	**84**	9	61,085	0	-17	**61,162**
BC7	394	43	**437**	14	242,037	0	-94	**242,394**
BC8	419	44	**464**	14	355,562	0	-96	**355,944**
BC9	68	8	**76**	9	32,848	0	-16	**32,918**
BC10	92	10	**102**	9	45,718	0	-18	**45,812**
BC11	394	43	**437**	14	209,190	0	-94	**209,547**
BC12	479	47	**527**	14	281,992	1	-101	**282,433**
BC13	104	11	**116**	9	14,696	0	-25	**14,796**
BC14	108	11	**119**	9	12,535	0	-25	**12,638**
BC15	68	8	**75**	9	31,984	0	-16	**32,052**
BC16	79	8	**88**	9	52,633	0	-17	**52,713**
BC17	873	78	**951**	20	621,515	1	-206	**622,280**
BC18	1,052	88	**1,140**	20	765,680	1	-221	**766,620**
BC19	68	8	**75**	9	8,472	0	-16	**8,540**
BC20	685	42	**727**	14	36,142	1	-130	**36,754**
BC21	873	78	**951**	20	255,267	1	-206	**256,033**
BC22	983	84	**1,067**	20	350,381	1	-215	**351,254**
BC23	152	14	**166**	9	32,349	0	-25	**32,490**
BC24	114	19	**133**	9	5,918	0	-21	**6,030**
BC25	349	22	**372**	13	20,779	0	-87	**21,076**
BC26	422	28	**450**	13	9,769	1	-94	**10,138**
BC27	429	28	**457**	14	58,983	0	-107	**59,346**
BC28	685	42	**727**	14	36,142	1	-130	**36,754**

Table 42. Acidification, emissions for each life cycle stage for each base case in kg SO_2 eq.

Life Ccycle phases	PRODUCTION			DISTRIBUTION	USE	END-OF-LIFE		TOTAL
Base Case	Material	Manufacturing	**Total**			Disposal	Recycling	
BC1	1.2	0.1	**1.3**	0.0	207	0.0	-0.3	**208**
BC2	1.2	0.1	**1.3**	0.0	320	0.0	-0.3	**321**
BC3	4.3	0.2	**4.5**	0.0	1,048	0.0	-1.0	**1,052**
BC4	4.5	0.2	**4.8**	0.0	1,522	0.0	-1.1	**1,525**
BC5	0.7	0.0	**0.7**	0.0	176	0.0	-0.2	**177**
BC6	0.7	0.0	**0.8**	0.0	270	0.0	-0.2	**271**
BC7	3.8	0.2	**4.0**	0.0	1,071	0.0	-0.9	**1,074**
BC8	4.0	0.2	**4.2**	0.0	1,573	0.0	-0.9	**1,577**
BC9	0.7	0.0	**0.7**	0.0	145	0.0	-0.2	**146**
BC10	0.9	0.0	**0.9**	0.0	202	0.0	-0.2	**203**
BC11	3.8	0.2	**4.0**	0.0	926	0.0	-0.9	**929**
BC12	4.4	0.2	**4.7**	0.0	1,248	0.0	-1.0	**1,252**
BC13	1.2	0.0	**1.3**	0.0	65	0.0	-0.3	**66**
BC14	1.3	0.1	**1.3**	0.0	55	0.0	-0.3	**57**
BC15	0.8	0.0	**0.8**	0.0	142	0.0	-0.2	**142**
BC16	0.9	0.0	**0.9**	0.0	233	0.0	-0.2	**234**
BC17	7.4	0.3	**7.7**	0.1	2,750	0.0	-1.8	**2,756**
BC18	8.8	0.4	**9.2**	0.1	3,388	0.0	-1.9	**3,396**
BC19	0.8	0.0	**0.8**	0.0	37	0.0	-0.2	**38**
BC20	0.9	0.0	**1.0**	0.0	60	0.0	-0.2	**61**
BC21	7.4	0.3	**7.7**	0.1	1,130	0.0	-1.8	**1,136**
BC22	8.2	0.4	**8.6**	0.1	1,550	0.0	-1.8	**1,557**
BC23	1.4	0.1	**1.5**	0.0	143	0.0	-0.3	**144**
BC24	2.0	0.1	**2.1**	0.0	26	0.0	-0.4	**28**
BC25	5.4	0.1	**5.5**	0.0	92	0.0	-1.4	**96**
BC26	6.0	0.1	**6.1**	0.0	43	0.0	-1.4	**48**
BC27	6.4	0.1	**6.6**	0.0	261	0.0	-1.6	**266**
BC28	8.4	0.2	**8.6**	0.0	160	0.0	-1.8	**167**

Table 43. Waste, non-hazardous for each life cycle stage for each base case in kg.

Life Ccycle phases	PRODUCTION			DISTRIBUTION	USE	END-OF-LIFE		TOTAL
Base Case	Material	Manufacturing	Total			Disposal	Recycling	
BC1	27	1	**28**	0.1	564	0	-6	**586**
BC2	27	1	**28**	0.1	872	0	-6	**894**
BC3	113	4	**116**	0.2	2,860	2	-27	**2,952**
BC4	114	4	**118**	0.2	4,152	2	-28	**4,245**
BC5	14	1	**14**	0.1	480	0	-3	**491**
BC6	14	1	**14**	0.1	738	0	-3	**749**
BC7	88	3	**91**	0.2	2,923	2	-21	**2,995**
BC8	89	3	**92**	0.2	4,293	2	-21	**4,366**
BC9	14	1	**14**	0.1	397	0	-3	**408**
BC10	14	1	**15**	0.1	552	0	-3	**564**
BC11	88	3	**91**	0.2	2,526	2	-21	**2,598**
BC12	91	3	**94**	0.2	3,405	2	-22	**3,479**
BC13	19	1	**20**	0.1	178	0	-5	**194**
BC14	20	1	**21**	0.1	152	0	-5	**168**
BC15	13	1	**13**	0.1	386	0	-3	**397**
BC16	13	1	**14**	0.1	636	0	-3	**646**
BC17	259	6	**266**	0.2	7,506	5	-63	**7,714**
BC18	264	6	**271**	0.2	9,246	5	-63	**9,459**
BC19	13	1	**13**	0.1	102	0	-3	**113**
BC20	13	1	**14**	0.1	165	0	-3	**176**
BC21	259	6	**266**	0.2	3,084	5	-63	**3,292**
BC22	262	6	**269**	0.2	4,232	5	-63	**4,443**
BC23	18	1	**19**	0.1	391	0	-4	**406**
BC24	14	1	**16**	0.1	72	0	-3	**84**
BC25	88	2	**90**	0.1	252	2	-22	**321**
BC26	90	2	**92**	0.1	119	2	-23	**190**
BC27	105	2	**107**	0.1	713	2	-27	**796**
BC28	112	2	**114**	0.1	437	2	-27	**527**

10.2.5 Life-cycle environmental impact at EU-28 level

The total environmental impact of the EU stock in the year 2014 for the range of pump units in the base cases, both in-use and discarded, is presented in Table 44. The impacts are quantified using market data for 2014. The results are for a single year (2014) as opposed to the entire lifetime of the products.

Looking at total energy and greenhouse gas emissions, base cases 2, 6, 13 and 16 present the highest impacts due to stock (small ESOB, ESCC and MS-V clean water pump units in variable flow applications and small borehole multistage submersible pump units in constant flow applications). Total energy and greenhouse gas emissions are closely related to the use of energy in the use phase but also in the manufacturing processes of the materials and components used in pump units. The same trend applies to acidifying emissions, as this environmental impact category is also closely related to electricity production. Base cases 9, 11, 26 and 28 present the lowest values due to a combination of lower stock and low energy use (small and medium ESCCi clean water pump units in constant flow applications and submersible vortex and channel wastewater pump units in variable flow applications), particularly for the clean water pump units.

The same trend follows for the amount of non-hazardous and hazardous waste, and other presented environmental impact indicators.

It is possible to identify the same difference between pump units in constant and variable flow applications, where most of the clean water pumps perform better in constant flow applications and MSSB and wastewater pump units perform better in variable flow applications. This is not applicable to booster-sets and swimming pool pump units, since booster-sets only operate in variable flow and swimming pool pump units in constant flow.

Table 44. EU total impact of stock of products in reference year 2014 (produced, in use, discarded).

	Other Resources & Waste						Emissions (Air)							Emissions (Water)	
	Total Energy (GER)	*of which, electricity (in primary PJ)*	Water (process)	Water (cooling)	Waste, non-haz./ landfill	Waste, hazardous/ incinerated	Greenhouse Gases in GWP100	Acidification, emissions	Volatile Organic Compounds	Persistent Organic Pollutants (POP)	Heavy Metals	PAHs	Particulate Matter (PM, dust)	Heavy Metals	Eutrophication
Unit	PJ	*PJ*	mln. m^3	mln. m^3	kt	kt	Mt CO_2 eq.	kt SO_2 eq.	kt	g i-Teq	ton Ni eq.	ton Ni eq.	kt	ton Hg/20	kt PO_4
BC1	115	*115*	0.1	5	62	2	5	22	3	0.3	1	0.3	0.5	0.6	0.02
BC2	177	*177*	0.1	8	94	3	8	34	4	0.5	2	0.4	0.8	0.9	0.04
BC3	90	*90*	0.04	4	49	1	4	17	2	0.2	1	0.2	0.4	0.4	0.02
BC4	56	*56*	0.02	3	30	1	2	11	1	0.1	1	0.1	0.2	0.3	0.01
BC5	98	*98*	0.03	4	52	2	4	19	2	0.3	1	0.2	0.4	0.5	0.02
BC6	150	*150*	0.03	7	79	2	6	28	3	0.4	2	0.4	0.6	0.7	0.03
BC7	66	*66*	0.02	3	35	1	3	13	1	0.2	1	0.2	0.3	0.3	0.01
BC8	97	*97*	0.02	4	51	2	4	18	2	0.2	1	0.2	0.4	0.4	0.02
BC9	6	*6*	0.002	0	3	0.1	0	1	0.1	0.0	0.1	0.02	0.03	0.03	0.001
BC10	81	*81*	0.03	4	43	1	3	15	2	0.2	1	0.2	0.4	0.4	0.02
BC11	5	*5*	0.001	0	2	0.1	0.2	1	0.1	0.0	0.05	0.01	0.02	0.02	0.001
BC12	55	*55*	0.02	2	29	1	2	10	1	0.1	1	0.1	0.2	0.3	0.01
BC13	180	*180*	0.4	8	104	3	8	35	4	0.6	3	0.5	0.8	1.3	0.05
BC14	38	*38*	0.1	2	23	1	2	7	1	0.1	1	0.1	0.2	0.3	0.01
BC15	87	*87*	0.1	4	47	1	4	17	2	0.2	1	0.2	0.4	0.5	0.02
BC16	144	*143*	0.1	6	76	2	6	27	3	0.4	2	0.3	0.6	0.7	0.03
BC17	20	*20*	0.01	1	11	0.3	1	4	0.4	0.1	0.2	0.05	0.1	0.1	0.004
BC18	24	*24*	0.01	1	13	0.4	1	5	1	0.1	0.3	0.1	0.1	0.1	0.005
BC19	55	*55*	0.1	3	32	1	2	11	1	0.2	1	0.1	0.3	0.4	0.02
BC20	89	*89*	0.1	4	50	1	4	17	2	0.3	1	0.2	0.4	0.6	0.02
BC21	29	*29*	0.02	1	16	0.5	1	6	1	0.1	0.3	0.1	0.1	0.2	0.01
BC22	40	*40*	0.03	2	22	1	2	8	1	0.1	0.5	0.1	0.2	0.2	0.01
BC23	28	*28*	0.03	1	15	0.5	1	5	1	0.1	0.3	0.1	0.1	0.2	0.01
BC24	63	*62*	0.3	3	40	1	3	13	1	0.3	1	0.2	0.3	0.9	0.02
BC25	37	*36*	0.1	2	26	1	2	7	1	0.2	1	0.1	0.2	0.4	0.01
BC26	1	*1*	0.01	0	1	0.02	0.04	0.2	0.02	0.0	0.02	0.0	0.01	0.02	0.0004
BC27	118	*117*	0.1	5	70	2	5	23	3	0.4	2	0.3	0.5	0.8	0.03
BC28	5	*5*	0.01	0	3	0.1	0.2	1	0.1	0.02	0.1	0.01	0.02	0.04	0.001

10.3 Base-case Life Cycle Costs for consumer

This section presents the results of the Life Cycle Costs (LCC) analysis which was done using the EcoReport Tool[292]. The LCC was done for each of the base cases per product throughout their product service life, and the total EU-28 was also established for the annual life cycle costs in the reference year 2014.

In this analysis, all consumer expenditures throughout the life of the product are considered, these include:

- Average purchase cost of the base cases in Euro
- Average installation costs in Euro
- Average repair and maintenance costs in Euro
- Average electricity rate in Euro/kWh
- Average lifetime of the base cases in years
- Average annual energy consumption (only on-mode consumption in kWh is relevant)

The results of the analysis serve to identify where in the life cycle of the pump units[293] the highest costs arise and to compare the total expenditure of the different base cases.

The life cycle costs in the EcoReport Tool are calculated as follows:

$$LCC = PP + PWF \times OE + EoL$$

Where, in this case, 'PP' is the average purchase cost and installation cost, 'OE' is the operating expense resulting from the average annual energy consumption and the average electricity rate, 'EoL' is the End-of-life costs which in this review study have not been quantified and 'PWF' is the present worth factor, calculated as follows:

$$PWF = 1 - \frac{(1+e)}{(d+e)} \cdot \left[1 - \left(\frac{1+e}{1+d}\right)^N\right] \qquad if\ (d \neq e)$$

$$PWF = N \qquad if\ (d = e)$$

Where 'N' is the product life in years, 'd' is the discount rate and 'e' is the escalation rate. The escalation rate is the annual growth rate of running costs, such as energy and water. This growth rate allows energy price projections to be taken into account. In this review study, the discount rate is assumed at 4% as presented in task 2 and the escalation rate is assumed as default value of 4%. In this case, PWF equal the product life time, i.e. 10 years, so by replacing PWF with N, the LCC can be simplified to:

$$LCC = PP + N \times OE + EoL$$

This section will present the results of the LCC analysis based on the above equations for each base case, as well as the societal LCC which includes the external damages caused

[292] Version 3.06 VHK for European Commission 2011, modified by IZM 2014. Copyright ©Van Holsteijn en Kemna BV 2005-2011. Distribution rights European Commission 2005-2011.

[293] Pump unit is defined in prEN 17038-2 either as (i) the electric motor + the pump for fixed speed systems or as (ii) the Complete Drive Module (CDM) + electric motor, which both are defined as the Power Drive System + the pump for variable speed systems. For purposes of our study, pump unit refers either as motor + pump, or as motor + Power Drive System.

by emissions from industrial and power plants according to the MEErP methodology[294] and a study from European Environmental Agency[295].

10.3.1 Base cases 1 to 12–End Suction pumps for clean water

Life Cycle Costs per product

Table 45 shows the total life cycle costs per pump unit for all the end suction clean water pumps, including the costs for external damages from emissions, provided by value (EUR) and by contribution (%) to the total societal life cycle costs. It is evident that the highest costs come from the use of electricity which varies between 45% (for small end suction close coupled inline pump units used in constant flow applications) to 81% (for medium end suction own bearing pump units in variable flow applications). For all these base cases, the product price is not higher than 12%, even for those using Power Drive Systems. The repair and maintenance costs are as low as 2% of the total and as high as 31%, whilst the installation costs are generally low in comparison to the total life cycle cost. The external damage costs, coming mainly from greenhouse gases and acidifying emissions from industrial and power plants are significant, varying from 7% to 13% of the total life cycle cost, increasing with the share of electricity costs.

The base case with the highest LCC is base case 8, end closed couple pump units for variable flow applications with rated power of 22 kW–150 kW. This pump unit presents a high annual electricity cost in relation to the other base cases. The base case with the lowest LCC is base case 1, end suction own bearing pump units for constant flow applications with rated power ≤ 22 kW. This pump unit presents a lower purchase price in relation to the other end suction pump units, but especially a lower annual electricity cost which creates a lower external damage cost. The reason why all the clean water end suction pump units for variable flow applications present higher life cycle costs is because they consume more electricity as they have lower efficiencies (see Table 38).

Life Cycle Costs at EU level

Table 45 presents the total annual consumer expenditure at EU28 level for the pump units considered in constant and variable flow applications for base cases 1 to 12. The results show the same picture as per product level, where a large proportion of the annual life cycle costs (44% to 81%) are from the electricity consumption. Because of this, the external damage costs are also significant in most of the base cases. However, the repair and maintenance price takes a slightly higher importance when looking at the whole EU stock of these pump units.

When looking at the whole EU stock, the base case with the highest total societal LCC is base case 6 (end suction closed coupled pump units for variable flow applications with rated power ≤ 22 kW) instead of base case 8 at the product level and this is due to higher stock. Whilst base case 11 (end suction closed coupled inline pump units for constant flow applications with rated power of 22 kW–150 kW) shows the lowest total societal LCC, which is due to low stock.

[294] MEErP 2011. Methodology for Ecodesign of Energy-related Products. Methodology Report. Part 1: Methods. René Kemna, 2011.
[295] EEA, Revealing the costs of air pollution, Technical Report No. 15/2011, Copenhagen, Nov. 2011.

Table 45. Total Life Cycle Costs per pump unit including external societal costs for base cases 1 to 12.

Base case #	Abbre-viation	Product price[296]	Installation	Electricity	Repair & maintenance costs	Total LCC	External damages costs	Total societal LCC
1	ESOBs cons	€ 3 090	€ 720	€ 16 294	€ 3 000	**€ 23 105**	€ 2 531	**€ 25 636**
		12%	*3%*	*64%*	*12%*	***90%***	*10%*	***100%***
2	ESOBs var	€ 3 113	€ 720	€ 25 232	€ 3 000	**€ 32 065**	€ 3 901	**€ 35 966**
		9%	*2%*	*70%*	*8%*	***89%***	*11%*	***100%***
3	ESOBm cons	€ 5 008	€ 720	€ 81 951	€ 3 000	**€ 90 679**	€ 12 814	**€ 103 493**
		5%	*1%*	*79%*	*3%*	***88%***	*12%*	***100%***
4	ESOBm var	€ 5 162	€ 720	€ 119 247	€ 3 000	**€ 128 129**	€ 18 553	**€ 146 682**
		4%	*0%*	*81%*	*2%*	***87%***	*13%*	***100%***
5	ESCCs cons	€ 1 896	€ 2 100	€ 13 889	€ 8 000	**€ 25 885**	€ 2 147	**€ 28 032**
		7%	*7%*	*50%*	*29%*	***92%***	*8%*	***100%***
6	ESCCs var	€ 1 925	€ 2 100	€ 21 393	€ 8 000	**€ 33 418**	€ 3 291	**€ 36 709**
		5%	*6%*	*58%*	*22%*	***91%***	*9%*	***100%***
7	ESCCm cons	€ 6 968	€ 2 100	€ 83 624	€ 8 000	**€ 100 693**	€ 13 066	**€ 113 758**
		6%	*2%*	*74%*	*7%*	***89%***	*11%*	***100%***
8	ESCCm var	€ 7 084	€ 2 100	€ 123 326	€ 8 000	**€ 140 511**	€ 19 153	**€ 159 664**
		4%	*1%*	*77%*	*5%*	***88%***	*12%*	***100%***
9	ESCCis cons	€ 2 285	€ 2 100	€ 11 494	€ 8 000	**€ 23 879**	€ 1 776	**€ 25 655**
		9%	*8%*	*45%*	*31%*	***93%***	*7%*	***100%***
10	ESCCis var	€ 2 381	€ 2 100	€ 16 111	€ 8 000	**€ 28 591**	€ 2 469	**€ 31 060**
		8%	*7%*	*52%*	*26%*	***92%***	*8%*	***100%***
11	ESCCim cons	€ 6 968	€ 2 100	€ 72 377	€ 8 000	**€ 89 445**	€ 11 305	**€ 100 750**
		7%	*2%*	*72%*	*8%*	***89%***	*11%*	***100%***
12	ESCCim var	€ 7 355	€ 2 100	€ 98 256	€ 8 000	**€ 115 712**	€ 15 216	**€ 130 927**
		6%	*2%*	*75%*	*6%*	***88%***	*12%*	***100%***
Total		**€ 53 236**	**€ 19 680**	**€ 683 196**	**€ 76 000**	**€ 832 111**	**€ 106 221**	**€ 938 332**
		6%	***2%***	***73%***	***8%***	***89%***	***11%***	***100%***

[296] Purchase price are the only acquisition costs considered in the Life Cycle Costs calculations

Table 46. Total annual consumer expenditure in EU-28 considering the LCC of all pump units in stock in 2014 for base cases 1 to 12.

Base case #	Abbre-viation	Unit	Product price	Installation	Electricity	Repair & maintenance costs	Total LCC	External damages total	Total societal LCC
1	ESOBs cons	mln. €	348	81	1 708	314	**2 451**	265	**2 716**
		%	*13%*	*3%*	*63%*	*12%*	***90%***	*10%*	***100%***
2	ESOBs var	mln. €	350	81	2 644	314	**3 390**	409	**3 799**
		%	*9%*	*2%*	*70%*	*8%*	***89%***	*11%*	***100%***
3	ESOBm cons	mln. €	88	13	1 336	49	**1 485**	209	**1 694**
		%	*5%*	*1%*	*79%*	*3%*	***88%***	*12%*	***100%***
4	ESOBm var	mln. €	39	5	833	21	**898**	130	**1 028**
		%	*4%*	*1%*	*81%*	*2%*	***87%***	*13%*	***100%***
5	ESCCs cons	mln. €	213	236	1 456	838	**2 744**	225	**2 969**
		%	*7%*	*8%*	*49%*	*28%*	***92%***	*8%*	***100%***
6	ESCCs var	mln. €	217	236	2 242	838	**3 533**	345	**3 878**
		%	*6%*	*6%*	*58%*	*22%*	***91%***	*9%*	***100%***
7	ESCCm cons	mln. €	87	26	974	93	**1 180**	152	**1 332**
		%	*7%*	*2%*	*73%*	*7%*	***89%***	*11%*	***100%***
8	ESCCm var	mln. €	89	26	1 436	93	**1 644**	223	**1 867**
		%	*5%*	*1%*	*77%*	*5%*	***88%***	*12%*	***100%***
9	ESCCis cons	mln. €	21	19	96	67	**203**	15	**218**
		%	*9%*	*9%*	*44%*	*31%*	***93%***	*7%*	***100%***
10	ESCCis var	mln. €	193	170	1 216	604	**2 182**	186	**2 369**
		%	*8%*	*7%*	*51%*	*25%*	***92%***	*8%*	***100%***
11	ESCCim cons	mln. €	7	2	67	7	**84**	11	**94**
		%	*7%*	*2%*	*71%*	*8%*	***89%***	*11%*	***100%***
12	ESCCim var	mln. €	66	19	824	67	**976**	128	**1 104**
		%	*6%*	*2%*	*75%*	*6%*	***88%***	*12%*	***100%***
Total		**mln. €**	**1 716**	**915**	**14 832**	**3 307**	**20 770**	**2 297**	**23 067**
		%	***7%***	***4%***	***64%***	***14%***	***90%***	***10%***	***100%***

10.3.2 Base cases 13 to 23 – Multistage pumps for clean water

Life Cycle Costs per product

Table 47 shows the total life cycle costs per pump unit for all the multistage clean water pumps, including the costs for external damages from emissions, presented by value (EUR) and by contribution (%) to the total societal life cycle costs. The highest costs come from the use of electricity, however the variation is large of between 26% (for borehole multistage submersible pump units in variable flow applications with a nominal outer diameter ≤ 6”) to 80% (for medium vertical multistage pump units in variable flow applications designed for maximum pressures between 25 and 40 bar). This variation is also seen in the contribution from product price to the total life cycle costs, where vertical multistage pump units show lower purchase costs in comparison to other life cycle costs and borehole multistage submersible pumps as well as booster-sets show higher purchase costs. Installation costs are generally the smallest contributor to the LCC. The repair and maintenance costs are generally lower than for end suction pumps, although it accounts for 40-50% of the LCC in some of the pumps (such as base case 13 & 14). The external damage costs which are still important, are not as high as the electricity or the maintenance costs from using the pumps.

The base case with the highest LCC is base case 18, vertical multistage pump units for variable flow applications with maximum design pressure of 25-40 bar. This pump unit presents a high annual electricity cost in relation to the other base cases. The base case with the lowest LCC is base case 19, horizontal multistage pump units for constant flow applications with maximum design pressure of ≤ 25 bar. This pump unit presents a lower average purchase price in relation to the other multistage pump units, and a lower annual electricity cost creating a lower external damage cost. For multistage clean water pump units, the variable flow applications also present higher life cycle costs due to higher electricity costs, but the difference compared to constant flow applications is not as large as it is for end suction pump clean water pump units. This is due to a relatively lower amount of operating hours in the variable flow conditions decreasing the electricity consumption.

Life Cycle Costs at EU level

Table 48 presents the total annual consumer expenditure at EU28 level for the pump units considered in constant and variable flow applications for base cases 13 to 23. The results show the same picture as per product level, where an important part of the annual life cycle costs (26% to 80%) are from the electricity consumption. The purchase price is also important in some base cases (for borehole multistage submersible pumps and for booster-sets) and becomes a higher cost than the external damages costs from pollution.

The base case with the highest total societal LCC is base case 13 (borehole multistage submersible pump units for constant flow applications with a nominal outer diameter ≤ 6”) instead of base case 18 at the product level, due to higher stock. Whilst base case 17 becomes the pump unit with the lowest total societal LCC, due to low stock.

Table 47. Total Life Cycle Costs per pump unit including external societal costs for base cases 13 to 23.

Base case #	Abbre-viation	Product price	Installation	Electricity	Repair & maintenance costs	Total LCC	External damages total	Total societal LCC
13	MSSBs cons	€ 1 911	€ 955	€ 5 182	€ 7 500	€ 15 548	€ 808	€ 16 356
		12%	6%	32%	46%	95%	5%	100%
14	MSSBs var	€ 2 003	€ 955	€ 3 894	€ 7 500	€ 14 352	€ 692	€ 15 045
		13%	6%	26%	50%	95%	5%	100%
15	MS-Vs cons	€ 1 648	€ 1 000	€ 11 196	€ 5 250	€ 19 094	€ 1 728	€ 20 823
		8%	5%	54%	25%	92%	8%	100%
16	MS-Vs var	€ 1 694	€ 1 000	€ 18 522	€ 5 250	€ 26 466	€ 2 836	€ 29 302
		6%	3%	63%	18%	90%	10%	100%
17	MS-Vm cons	€ 14 239	€ 2 000	€ 214 587	€ 10 000	€ 240 826	€ 33 455	€ 274 281
		5%	1%	78%	4%	88%	12%	100%
18	MS-Vm var	€ 15 053	€ 2 000	€ 270 305	€ 10 000	€ 297 358	€ 41 199	€ 338 558
		4%	1%	80%	3%	88%	12%	100%
19	MS-Hs cons	€ 804	€ 1 000	€ 2 993	€ 5 250	€ 10 047	€ 468	€ 10 515
		8%	10%	28%	50%	96%	4%	100%
20	MS-Hs var	€ 881	€ 1 000	€ 4 867	€ 5 250	€ 11 998	€ 747	€ 12 746
		7%	8%	38%	41%	94%	6%	100%
21	MS-Hm cons	€ 6 473	€ 2 000	€ 88 881	€ 10 000	€ 107 354	€ 13 823	€ 121 177
		5%	2%	73%	8%	89%	11%	100%
22	MS-Hm var	€ 6 972	€ 2 000	€ 123 426	€ 10 000	€ 142 398	€ 18 932	€ 161 330
		4%	1%	77%	6%	88%	12%	100%
23	Booster-sets	€ 6 301	€ 2 000	€ 11 377	€ 10 500	€ 30 177	€ 1 756	€ 31 933
		20%	6%	36%	33%	95%	5%	100%
Total		€ 57 979	€ 15 910	€ 755 230	€ 86 500	€ 915 619	€ 116 446	€ 1 032 065
		6%	2%	73%	8%	89%	11%	100%

Table 48. Total annual consumer expenditure in EU-28 considering the LCC of all pump units in stock in 2014 for base cases 13 to 23.

Base case #	Abbre-viation	Unit	Product price	Installation	Electricity	Repair & maintenance costs	Total LCC	External damages total	Total societal LCC
13	MSSBs cons	mln. €	1 070	535	2 703	3 913	**8 221**	421	**8 642**
		%	*12%*	*6%*	*31%*	*45%*	***95%***	*5%*	***100%***
14	MSSBs var	mln. €	280	134	508	978	**1 900**	90	**1 990**
		%	*14%*	*7%*	*26%*	*49%*	***95%***	*5%*	***100%***
15	MS-Vs cons	mln. €	206	125	1 304	611	**2 246**	201	**2 447**
		%	*8%*	*5%*	*53%*	*25%*	***92%***	*8%*	***100%***
16	MS-Vs var	mln. €	212	125	2 157	611	**3 105**	330	**3 435**
		%	*6%*	*4%*	*63%*	*18%*	***90%***	*10%*	***100%***
17	MS-Vm cons	mln. €	21	3	290	14	**327**	45	**372**
		%	*6%*	*1%*	*78%*	*4%*	***88%***	*12%*	***100%***
18	MS-Vm var	mln. €	22	3	365	14	**403**	56	**459**
		%	*5%*	*1%*	*80%*	*3%*	***88%***	*12%*	***100%***
19	MS-Hs cons	mln. €	239	298	830	1 455	**2 821**	130	**2 951**
		%	*8%*	*10%*	*28%*	*49%*	***96%***	*4%*	***100%***
20	MS-Hs var	mln. €	262	298	1 349	1 455	**3 364**	207	**3 571**
		%	*7%*	*8%*	*38%*	*41%*	***94%***	*6%*	***100%***
21	MS-Hm cons	mln. €	34	11	435	49	**528**	68	**596**
		%	*6%*	*2%*	*73%*	*8%*	***89%***	*11%*	***100%***
22	MS-Hm var	mln. €	37	11	604	49	**700**	93	**792**
		%	*5%*	*1%*	*76%*	*6%*	***88%***	*12%*	***100%***
23	Booster-sets	mln. €	252	80	424	391	**1 147**	65	**1 213**
		%	*21%*	*7%*	*35%*	*32%*	***95%***	*5%*	***100%***
Total		**mln. €**	**2 635**	**1 620**	**10 967**	**9 539**	**24 762**	**1 707**	**26 468**
		%	***10%***	***6%***	***41%***	***36%***	***94%***	***6%***	***100%***

10.3.3 Base case 24 – Domestic swimming pool pumps

Life Cycle Costs per product

Table 49 shows the total life cycle costs per pump unit for domestic swimming pool pumps, including the costs for external damages from emissions, presented by value (EUR) and by contribution (%) to the total societal life cycle costs. The highest costs come from the use of electricity (70%), while purchase price and installation costs are still important summing up to 22% of the total annual life cycle costs. Even though electricity costs are dominant, the external damage costs are not (8%). This is due to the greater importance of the purchase and installation costs.

Life Cycle Costs at EU level

Table 50 presents the total annual consumer expenditure at EU28 level for domestic swimming pool pump units considered in constant and variable flow applications. The results show the same picture as per product level, where an important part of the annual life cycle costs (68%) are from the electricity consumption. Because of the high stock of domestic swimming pool pump units, the average annual electricity costs for 2014 stock is higher than many of the multistage clean water pump units (see Table 48) and then many of the end suction clean water pump units (see Table 46).

Table 49. Total Life Cycle Costs per pump unit including external societal costs for base case 24.

Base case #	Abbre-viation	Product price	Installation	Electricity	Repair & maintenance costs	Total LCC	External damages total	Total societal LCC
24	SWP cons	€ 735	€ 250	€ 3 140	€ 44	**€ 4 169**	€ 344	**€ 4 513**
		16%	*6%*	*70%*	*1%*	***92%***	*8%*	***100%***

Table 50. Total annual consumer expenditure in EU-28 considering the LCC of all pump units in stock in 2014 for base case 24.

Base case #	Abbre-viation	Unit	Product price	Installation	Electricity	Repair & maintenance costs	Total LCC	External damages total	Total societal LCC
24	SWP cons	mln. €	373	127	1 402	20	**1 922**	153	**2 075**
		%	*18%*	*6%*	*68%*	*1%*	***93%***	*7%*	***100%***

10.3.4 Wastewater pumps

Life Cycle Costs per product

Table 51 shows the total life cycle costs per pump unit for all the wastewater pumps, including the costs for external damages from emissions, presented by value (EUR) and by contribution (%) to the total societal life cycle costs. The highest costs come from the use of electricity, which show a variation between 21% of the total annual life cycle costs (for submersible vortex radial pump units for variable flow applications) to 52% (for submersible channel radial pumps for constant flow applications). Purchase costs are percentwise similar for both radial and vortex pumps. The punp units installed in variable flow applications are in both cases more expensive at 21-23% of the LCC because of the additional cost of the continuous controls. Repair and maintenance costs are also important for all wastewater pumps. Generally the purchase price of the wastewater pumps represents a larger amount of the LCC than for the end suction pumps and the multistage pumps for clean water.

The base case with the highest LCC is base case 28, submersible channel pumps for variable flow applications. This pump unit presents a higher purchase price and larger maintenance cost in relation to the other base cases. The base case with the lowest LCC is base case 26, submersible vortex pumps in variable flow applications. This pump unit presents a lower annual electricity cost which creates a lower external damage cost.

Life Cycle Costs at EU level

Table 52 presents the total annual consumer expenditure at EU28 level for the pump units considered in constant and variable flow applications for base cases 25 to 28. The results show the same picture as per product level, where an important part of the annual life cycle costs (21% to 51%) are from the electricity consumption. Although, the purchase price and the maintenance costs are also important.

When looking at the whole EU stock, the base case with the highest total societal LCC is base case 27, due to high stock. Whilst base case 26 is again the pump unit with the lowest total societal LCC, due to low stock.

Table 51. Annual Life Cycle Costs per pump unit including external societal costs for base cased 25 to 28.

Base case #	Abbre-viation	Product price	Installation	Electricity	Repair & maintenance costs	Total LCC	External damages total	Total societal LCC
25	SVR cons	€ 3 280	€ 1 327	€ 7 410	€ 7 743	**€ 19 759**	€ 1 194	**€ 20 953**
		16%	*6%*	*35%*	*37%*	***94%***	*6%*	***100%***
26	SVR var	€ 3 672	€ 1 359	€ 3 641	€ 7 843	**€ 16 515**	€ 611	**€ 17 125**
		21%	*8%*	*21%*	*46%*	***96%***	*4%*	***100%***
27	SCR cons	€ 5 906	€ 1 757	€ 21 832	€ 9 608	**€ 39 104**	€ 3 258	**€ 42 362**
		14%	*4%*	*52%*	*23%*	***92%***	*8%*	***100%***
28	SCR var	€ 11 666	€ 2 465	€ 21 709	€ 13 007	**€ 48 846**	€ 2 059	**€ 50 905**
		23%	*5%*	*43%*	*26%*	***96%***	*4%*	***100%***
Total		**€ 24 524**	**€ 6 909**	**€ 54 591**	**€ 38 200**	**€ 124 224**	**€ 7 121**	**€ 131 345**
		19%	***5%***	***42%***	***29%***	***95%***	***5%***	***100%***

Table 52. Total annual consumer expenditure in EU-28 considering the LCC of all pump units in stock in 2014 for base cases 25 to 28.

Base case #	Abbre-viation	Unit	Product price	Installation	Electricity	Repair & maintenance costs	Total LCC	External damages total	Total societal LCC
25	SVR cons	mln. €	257	104	553	578	**1 491**	89	**1 580**
		%	*16%*	*7%*	*35%*	*37%*	***94%***	*6%*	***100%***
26	SVR var	mln. €	15	6	14	31	**67**	2	**69**
		%	*22%*	*8%*	*21%*	*45%*	***96%***	*4%*	***100%***
27	SCR cons	mln. €	525	156	1 851	815	**3 347**	276	**3 624**
		%	*14%*	*4%*	*51%*	*22%*	***92%***	*8%*	***100%***
28	SCR var	mln. €	66	14	117	70	**268**	11	**279**
		%	*24%*	*5%*	*42%*	*25%*	***96%***	*4%*	***100%***
Total		mln. €	**863**	**280**	**2 536**	**1 494**	**5 173**	**379**	**5551**
		%	***16%***	***5%***	***46%***	***27%***	***93%***	***7%***	***100%***

10.4 Conclusions and recommendations

The base cases defined for the further tasks of this review study have been presented, including their inputs used in the environmental and economic assessments which, for some of them, are also used in the scenario analysis in task 7. The main differences from the pump categorisation presented in chapter 9 (final scope) is: (i) the split of sizes for clean water pumps (except MSSB and booster-sets) in order to observe differences in efficiencies in this task but also differences in savings potentials in task 7, and, (ii) the split of pump categories in constant and variable flow applications, as it was identified that these applications present different hydraulic performance and therefore require different levels of requirements.

It was indeed observed that different sizes of clean water pumps present different efficiencies (see Table 38), although the differences for end suction clean water pump units were about 6-7% whilst for multistage clean water pump units were about 9-13%. Furthermore, it was observed that there are differences in life cycle environmental impacts and life cycle costs between constant and variable flow applications. This is mainly because for most of the clean water pump units the use of electricity during the use phase is higher in variable flow applications whereas for borehole submersible multistage clean water pump units and wastewater pump units is lower.

For all base cases the total societal LCC sums to 57 billion euros at the whole EU level, of which 52% comes from electricity costs, 10% from product purchase price, and 8% from external damage costs. Installation and maintenance costs account for 5% and 25%, respectively (see Table 53). The external damage costs are the costs from mitigating the effect of certain emissions released throughout the whole life cycle of the pumps, including indirect emissions (e.g. those released at the power plants that generates the electricity used by the pumps)[297].

In most cases (except base cases 13, 14, 19, 20, 25 and 26), the electricity cost accounts for the largest share of the LCC and total societal LCC. The second highest share of LCC varies.

Table 53. EU total annual LCC and societal LCC including external societal costs for all base cases (in millions of Euros).

Unit	Product price	Installation	Electricity	Repair & maintenance costs	Total LCC	External damages total	Total societal LCC
mln. €	5 588	2 942	29 736	14 360	**52 626**	4 536	**57 162**
%	*10%*	*5%*	*52%*	*25%*	***92%***	*8%*	***100%***

[297] The emissions are greenhouse gases, acidifying substances related to acidification potential, volatile organic compounds, persistent organic pollutants, heavy metals, polyaromatic hydrocarbons and particulate matter, all quantified by the EcoReport tool, 2011. The rates of external marginal costs to society are specified in the EcoReport tool.

11 Task D6: Design options

This task identifies the design options that have the potential for improvement and ranks them according to their costs and benefits. According to the MEErP methodology[298130], the identification of the design option with the Least Life Cycle Cost (LLCC) for the consumer and its relationship with the BAT is crucial for each base case. This is because the LLCC is used to identify the base case minimum targets in terms of ecodesign requirements and its distance to the BAT shows how much it costs to achieve the most efficient levels. This gives an indication of the price elasticity between minimum and maximum levels.

In this review study it was not possible to identify and rank the design options for each base case in a purely quantitative manner, since:

(i) the design improvements for each base case required a quantification of their improvements on efficiency at EPA level, and to establish this it was necessary to calculate first P1 avg, which in this case was possible only through a desktop research[299] from a limited amount of manufacturers' publicly available data in websites and product catalogues. And then P1ref to come up with current and improved EEI levels which was not possible for all the pumps in final scope since no C-values, flow-time profiles nor methodology to calculate it exist yet;

(ii) it was not possible to establish a spectrum of LCC for each design option since, at this point in time, mostly improvement possibilities at a pump unit level (i.e. from the use of VSDs) are being explored –wastewater and swimming pool pump units are mostly operated in constant flow applications, thus the use of VSDs is not a mature design improvement due to other risks (e.g. clogging[300] or hygienic[301]) .

The selection of the policy measures for the scenario analyses in task D7 was therefore done mostly considering only estimated saving potentials in comparison to optimal levels provided by industry[302,286] and information based on dialogue with wastewater pump manufacturers or desktop research of swimming pool manufacturers. The process to arrive at the selected policy measures is described in the next sections.

11.1 Options

The design options identified in chapters 8 (task D4) and 10 (task D5) which apply to the pump units in final scope are:

- Use of VSD in variable flow
- Energy efficient design of pumps
- Energy efficient design of pump systems
- Use of full impeller pumps
- Correct sizing of pumps
- Self-cleaning impellers
- Use of energy efficient impeller type

[298] VHK(2011), MEErP 2011 METHODOLOGY PART 1.
[299] Information about the effect on P1 for individual design improvements was only gathered from pump manufacturers' websites and public catalogues due to missing information from industry
[300] 'Understanding Sustained Efficiency in Non-Clog Pumps'. White paper – SUSTAINED EFFICIENCY – February 2011.
[301] For swimming pool pumps, variable flow applications are perceived incompatible with keeping the hygienic requirements in swimming pools
[302] Oral communication from Europump at video-conference meeting on the 27th of May, 2016.

Some of these options are relevant for all pump units while others are only relevant to some.

11.1.1 Design options for all pump units

Use of VSD in variable flow

Use of VSDs in variable flow will reduce the energy consumption significantly, as shown in chapter 9 (final scope). It was estimated at this point of the study, based on preliminary information from industry used in chapter 9, that about at least 43 TWh/year could be saved mostly by using VSD, an in a minor degree by using a more efficient motor technology. However, the savings from using VSD are only from clean water pumps, since wastewater pumps in variable flow are already equipped with VSD and swimming pool pumps normally operate with constant flow.

However, if more swimming pool pump units and wastewater pump units would switch to variable flow operation, potential savings could be calculated. This could be possible according to desktop research and dialogue with one wastewater manufacturer. E.g. a UK swimming pool manufacturer argues the use of VSDs can achieve savings at 50% bringing an additional 3.4 TWh/year, while a wastewater pump manufacturer[303] has indicated that 30% reduction in energy consumption can be achieved with intelligent control units that operate at different flow rates according to water volume flowing into the pump.

If more wastewater pumps would switch to variable flow, by understanding that clogging can be avoided by more intelligent control systems, this would bring additional savings of 5.1 TWh/year considering the annual electricity consumption of wastewater pumps is 17.1 TWh/year (see Table 33 in chapter 9). The total saving potential from using VSDs in variable flow would accumulate to 51.5 TWh/year for all the pump units in final scope. However, it is important to note that these are preliminary figures, as the real potential savings are calculated and presented in chapter 12. This alternative, though, was not included in the scenario analysis in chapter 12 because no further evidence, apart from these two EU manufacturers, was collected to demonstrate that these two pump groups can indeed be used more widely in variable flow operation.

Energy efficient design of the pumps

For all pump types there is a small potential to increase the energy efficiency without increasing the cost of the pumps significantly. It is estimated[304] that the potential is in the range of 1.5-3% with a potential energy saving of 4-7.4 TWh/year, considering that the estimates of total annual energy consumption for all pumps in final scope is 247 TWh/year (see Table 33 in chapter 9).

The savings allocated to the different pump groups (i.e. clean water pumps, swimming pool pumps and wastewater pumps in final scope) were estimated based on information available from preparatory studies, shown in Table 31 and Table 32 (i.e. 3.72 TWh/year from improvements in clean water pumps and 0.51 TWh/year in swimming pool and wastewater pumps). However, consultation with stakeholders showed no further evidence of efficiency improvement at product level, in particular for clean water pumps in scope of this study. Concerning swimming pool pumps and wastewater pumps, the savings were estimated based on improvement percentages defined in the preparatory studies (Lot 28 and Lot 29), which were not supported by industry. According to EUSA, any improvement

[303] From information provided by Xylem Water Solutions Global Services AB
[304] From information found on public catalogues and manufacturers' websites during desktop research

for swimming pool pumps would only come from an optimal fit of the pumps to the filtration and circulation systems and thus not from improving the design of the pumps. According to Europump and desktop research in this study, improvements for wastewater pumps are possible (e.g. more efficient impellers), but a harmonised methodology to quantify wastewater pumps' efficiency is not yet developed and thus it is not possible to confirm the improvements reported in Lot 28.

Energy efficient design of pump systems

Energy efficient design of pump systems can lead to large reductions in the energy consumption. It has not been estimated how much energy savings can be achieved in this manner as it is beyond the scope of the study, since this study does not focus on a Systems Approach.

11.1.2 Design options for clean water pumps

Use of full impeller pumps

A pump with a trimmed impeller has a lower energy efficiency compared to a pump using a full impeller, although lower energy consumption compared to an oversized impeller. To compensate for oversized impellers, most end suction pumps manufacturers offer trimmed impellers which are impellers that are under-sized, compared to the volute. Instead of producing only a short range of volute sizes for each pump design and a broader range of impeller sizes for each volute size, the manufacturers could offer a broader range of volute sizes. In this way the average energy efficiency of the pumps would be higher. It is estimated[305,304] that the average energy efficiency of trimmed impeller pumps is about 5% lower than the corresponding full impeller pumps. Since trimmed impellers are not always used, the impact is estimated to be about 1-3% for ESOB, ESCC and ESCCi pumps under final scope giving potential savings of 1.3-3.9 TWh/year, considering that the estimated annual energy consumption for these pumps at final scope chapter is 131 TWh/year (see Table 33 in chapter 9).

11.1.3 Design options for swimming pool pump units

Correct sizing of pumps

Correct sizing of pumps is important since large pumps consume more energy. Desktop research and information from stakeholders[306] indicate that swimming pool pumps are often oversized, but it has not been possible to quantify how often. However, it is assumed[307,304] that about 10% of the energy consumption from swimming pool pumps could be saved if all swimming pool pumps are used with the correct size, giving an estimation of total savings potential of 0.58 TWh/year.

11.1.4 Design options for wastewater pump units

Self-cleaning impellers

Self-cleaning impellers are most often used in wastewater applications and it is a design strategy to aim to have contamination removed from the impeller continuously during normal operation. Having contamination accumulated in the impeller normally leads to clogging of the pump, often without actually stopping the pump but simply reducing its performance. A wastewater manufacturer[308,303] indicates that pumps lose about 50% of

[305] From information found on public catalogues and manufacturers' websites during desktop research
[306] From stakeholders meeting, 11th of February 2016.
[307] From information found on public catalogues and manufacturers' websites during desktop research
[308] From information provided by Xylem Water Solutions Global Services AB

their energy efficiency due to partial clogging when the water contains rags, and they have estimated that about 10% of the energy consumption of wastewater pumps can be saved by using self-cleaning impellers, which would give estimated potential savings of about 1.7 TWh/year.

Use of energy efficient impeller type

Wastewater pumps must be reliable, since the clogging of a pump due to the presence of large and/or high concentrations of solids and/or large volumes can be very expensive in terms of time used to de-clog the pump and the risks of sickness and errors when staff needs to get involved. It is best to minimize human contact with wastewater. A general rule of thumb in wastewater pumping is that the better the wastewater handling capabilities the worse the energy efficiency. For example, vortex pumps are considered very reliable but they have the worst energy efficiency.

Use of energy efficient impeller types means that the most energy efficient impeller is used which is suitable for the application. According to some wastewater pump manufacturers[309], vortex impellers in some cases are used when channel impellers could be just as reliable with much higher energy efficiency. Going from a vortex impeller to a proper non-clogging channel impeller saves about 40-50%[310],[303] of the energy. If 25% of the vortex impellers could be replaced by appropriate non-clogging channel impellers, 0.5 TWh/year could be saved. (see Table 33).

For a summary of the design options, see Table 54. It is important to notice that the energy savings estimates are only preliminary, as the real savings for the preferred design option is shown in chapter 12. The relevance of each design option is also shown in Table 54, together with a qualitative ranking. Their ranking is related to the positive and negative impacts of each design option. Finally, policy measures have been identified, which support the realization of the positive impacts and prevents some or all of the negative impacts.

The positive and negative effects of the identified policy measures were mostly done at a qualitative level (except for the energy savings estimates) due to the lack of LCC data for the different design options and other identified risks to consumers. Overall, the positive effects are very important but some verification mechanisms should be in place in order to avoid some of the risks mentioned herein.

[309] Dialogue with manufacturers at IFAT 2016
[310] From information provided by Xylem Water Solutions Global Services AB

Table 54. Summary of design options, their main application and impacts and identified policy measure.

Rank	Design option	Main application	Relevance of design option	Impacts of measure (quantitative & qualitative)	Additional costs identified	Negative side effects	Identified policy measure
1	**Use of VSD in variable flow**	All pumps, most relevant for clean water pumps	High (clean water pumps) Medium (swimming pool & wastewater pumps)	Potential energy savings: 51.5 TWh/year Focus on optimisation of pump unit.	Purchasing VSDs for variable flow applications	Pump units may get declared for constant flow by the manufacturers but be used at variable flow	**Energy efficiency requirements at EPA level**
2	**Use of full impeller pumps**	End-suction clean water pumps	Low (multistage clean water pumps & wastewater pumps) Medium (end-suction clean water pumps & swimming pool pumps)	Potential energy savings: 1.3 – 3.9 TWh/year. More efficient pumps.	Manufacturing more volute sizes	Potential increase in purchase price from increased manufacturing costs	**Energy efficiency requirements at EPA level only for full impeller pumps**
3	**Energy efficient design of clean and swimming pool pumps**	Clean water pumps & swimming pool pumps	Low	Potential energy savings: 3 - 5 TWh/year. More efficient pumps.	Developing new pump technologies which aren't foreseen to be in future market	Relatively smaller savings compared to pump unit optimisation with no technologies forseen available	**Strengthen MEI requirements for water pumps (MEI)**
4	**Correct sizing of pumps**	Swimming pool pumps	High (swimming pool pumps)	Potential energy savings: 0.58 TWh/year. Increased consumer awareness on energy efficiency.	Development of metric and labelling scheme	Potential higher costs for purchase and installation to end-users	**Labelling scheme**
5	**Self-cleaning impellers**	Wastewater pumps	High (only wastewater pumps)	Potential energy savings: 1.7 TWh/year.	Developing more efficient impellers	No harmonised standard to measure efficiency and reliability	**Standardised test for wastewater pumps efficiency &**

Rank	Design option	Main application	Relevance of design option	Impacts of measure (quantitative & qualitative)	Additional costs identified	Negative side effects	Identified policy measure
				Improved reliability of pumps when used by utilities & municipalities.			**solid handling capabilities**
6	**Use of energy efficient impeller type**	Wastewater pumps	Medium (only in some wastewater pumping applications)	Potential energy savings: 0.5 TWh/year. Improved reliability of pumps when used by utilities & municipalities.	Developing more efficient impellers	No harmonised standard to measure efficiency and reliability	**Standardised test for wastewater pumps efficiency & solid handling capabilities**
7	**Energy efficient design of pump systems**	All pumps, most relevant for swimming pool pumps	Out of scope of this study	Potential energy savings: ~4 TWh/year.	n.a.	Out of scope of this study	**Out of scope of ecodesign**

11.1.5 Policy measures

The policy measures identified are:

- Energy efficiency requirements at EPA level (EEI)
- Streengthening MEI requirements to 0.7
- Standardised test for wastewater pumps' energy efficiency and solid handling capabilities
- Labelling scheme or a voluntary scheme for swimming pool pumps

The energy efficient design of pump systems is an option which is out of scope in ecodesign, since it goes beyond the product and extended product approach.

Energy efficiency requirements at EPA level promote the optimisation of the whole pump unit concerning energy efficiency, while maintaining the same level of efficiency for water pumps in the EU market. If EPA is introduced, the use of VSD can be a side effect because VSDs reduce the energy consumption for pumps in variable flow applications. If the pump operates at constant flow, a VSD will not be a benefit and could in fact reduce the overall energy efficiency because of the energy loss in the VSD. For this reason, it is necessary to target the energy efficiency requirements to specific conditions of operation. Therefore, two modes of operation are defined; constant flow operation and variable flow operation (see chapter 4: Task C).

Strengthening MEI requirements to 0.7 will improve the efficiency of clean water pumps and swimming pool pumps. The technological improvements of these pumps, according to input presented by industry and discussed in previous chapters, are not foreseen in the future. Industry claims technological improvements have already taken place and it is not foreseen clean water pumps will reach benchmark efficiency levels. Moreover, their focus has been on optimising the pump unit, where the potential energy savings are much higher.

Standardised test for wastewater pumps efficiency and solid handling capabilities will provide a tool for wastewater pump manufactures to prove the capability and efficiency of their pumps in a manner that can convince costumers about the pumping reliability. This will make it easier to choose the most energy efficient pump for a specific application without the fear of clogging.

If done correctly, a **labelling scheme** for swimming pool pumps can help costumers of domestic swimming pool pumps buy the correct size of pump, and can also promote the use of variable flow by introducing energy efficiency levels which can only be achieved by the use of VSDs. Furthermore, it can also promote the design of more energy efficient pumps and systems. A label could for example, classify which size of a swimming pool the pump is designed for. However, the industry has informed the study team and the European Commission[311] that they have formed a Working Group to specifically target the development of harmonised methodologies for calculating energy efficiency of swimming pool pumps. Their work is planned to culminate on the development of a standard and a potential voluntary agreement. In order to do so, the Working Group has to follow the Commission Recommendations on guidelines for self-regulation measures[312], which was communicated to industry by the study team. The Guidelines address in particular the list

[311] EUSA Pool Pump Working Group: Plan for future study. Paris 06/09/2017. Version 1.
[312] Concluded by industry under Directive 2009/125/EC of the European Parliament and of the Council. Brussels, 30.11.2016, C(2016) 7770 final.

of indicative criteria in Annex VIII to Directive 2009/125/EC which may be used by the Commission to assess the admissibility of a self-regulatory initiative as an alternative to implementing measures and which refer to openness of participation, added value, representativeness, quantified and staged objectives, involvement of civil society, monitoring and reporting, cost-effectiveness of administering a self-regulatory initiative, sustainability and incentive compatibility. It is not clear, according to further input from industry[313], whether they fulfil these criteria. However, it appears that the focus of the Working Group is to first develop a harmonised methodology for quantifying energy efficiency of swimming pool pumps which currently does not exist.

11.1.6 Ranking of policy measures

From the four identified policy measures, it is the energy efficiency requirements at EPA level which stand out as the measure which is estimated to have the most positive effects and the least risks. However, quantitative LCCs will be established in chapter 12, to find out whether the potential energy savings justify the additional costs.

It is necessary to develop new standards, for three of the four measures:

- To introduce EPA for clean water pumps the methodology for measuring EEI needs to be in place.
- For introducing a labelling scheme for swimming pool pumps there is a need for classifying and standardising the capabilities of swimming pool pumps in relation to harmonised hygienic requirements.
- A standardised test for wastewater pumps' efficiency and solid handling capabilities still don't exist, and requires harmonised definitions of wastewater types.

Of these three measures, only the methodology for measuring EEI has been initiated and there is a standard under development.

Concerning wastewater pumps, utilities have to understand the properties of the wastewater to choose the most energy efficient pump that can handle it with high reliability. For this reason, there are many types of wastewater pumps, with advantages and disadvantages, each suitable for different purposes.

Since there are no generally accepted standards or guidelines on wastewater pumping, most utilities choose pumps according to experience. The fact that local utilities rely on local experience explains why there is a high degree of conservatism in the sector and why it can be difficult to introduce new technology in the market. One example of this is the fact that some utilities insist on using vortex pumps even though modern channel impeller pumps are often just as reliable. It is difficult to prove how reliable a wastewater pump is, since there is no standardised test.

Considering that the positive and negative effects of these measures and the fact that a standard is already under development, the study team has selected to investigate further only the energy efficiency requirements for EPA.

11.1.7 BNAT

The study has not found any examples of pump technologies under development that are not already fully available on the market, except for wastewater pumps. In the wastewater business there is a strong focus on developing channel impeller pumps that can operate

[313] Discussed by telephone with EUSA

reliably when pumping all kinds of wastewater. There is focus to improve the mechanical design to make the impeller flexible so that it temporarily adjusts the clearance when larger pieces of materials pass through. Another upcoming design is to use control algorithms that can detect clogging and can reverse the pump rotation to automatically solve the clogging situation. However, these technologies have already been launched, and they are therefore expected to be commercially available in the next future (industry has not disclosed a date yet).

11.2 Conclusions and recommendations

Seven design options for improving energy efficiency and four policy measures have been identified.

It is clear from the semi-quantitative assessment that the policy measure for establishing energy efficiency requirements at EPA level is the most attractive, since it represents by far the highest estimated energy saving potentials and the development of a test standard is already ongoing. Although, this is only for clean water pumps, since for swimming pool pumps and wastewater pumps present other challenges which must be solved before an EPA methodology is to be developed.

It is because of these challenges that two alternative policy measures for swimming pool pumps and wastewater pumps have been identified, which can support the process of standardisation towards an EPA methodology. However, these measures present much lower estimated saving potentials and other risks. It is for this reason, that for the next task on Scenario analyses, only one of the policy measures has been explored (efficiency requirements at EPA level).

12 Task D7: Scenario analysis

12.1 Policy analysis

12.1.1 Stakeholders consultation

The policy analysis is based on data obtained from three sources:

- Previous preparatory studies (Lot 11, 28 and 29)
- Independent research by the study team (using publicly available materials)
- Input from stakeholders, mainly from manufacturers and manufacturers' interest organisations

During the entire project, the study team maintained a productive dialog with manufacturers, mainly represented by Europump and EUSA as described in previous chapters of this report. During the first six months of the study, Europump organised working groups who provided required input by the study team and who estimated data for each pump category. The input data collected included:

- Input to study team's pump categorisation
- Sales numbers, including the share of pumps sold with VSD
- Share of pumps that are used for variable flow operation
- Average motor sizes
- Average power consumption dependent on power drive system and operation mode (constant flow or variable flow)

Files with input data for the analyses were received by the study team from the stakeholders on these dates:

- 12/10/2015: Pumps for clean water (Lot 11 pumps + large pumps from Lot 29 + Booster-sets)
- 5/11/2015: Wastewater pumps and slurry pumps (Lot 28 pumps)
- 13/11/2015: Swimming pool pumps
- 7/12/2015: Horizontal multistage pumps

Data gaps on some pump categories, especially those where there were disagreements on scope, were gathered from previous preparatory studies, such as product life, operational hours and bill of materials. Furthermore, some mistakes on sales data and share of pumps sold with VSD were corrected along the course of the review study, up until May 2016.

EUSA also organized a working group in the fall of 2015 and provided 2014 sales, average power consumption, share of VSD under constant flow, operational time, predicted economic lifetime and product weight data in their position paper dated from the 13th of November 2015[314].

These inputs were used to determine the overall energy consumption and energy saving potentials for each pump category that were the basis to define the final scope (see chapter 9). The pump categories that showed small overall energy saving potentials were removed, however, for those pump categories where it was suspected that there might be some flaws in the assumptions behind the calculation of the energy saving potentials, further

[314] 'Contribution of the Working Group of EUSA to the review study of ecodesign and energy labelling for pumps'. Paris 13/11/2015.

investigations were conducted and were therefore left as part of the final scope. This was the case for swimming pool pumps and wastewater pumps.

For swimming pool pumps, the issue concerned the use of Variable Speed Drives. In some non-EU countries (USA and Australia) the use of VSDs with swimming pool pumps are promoted as an energy saving measure, whereas European stakeholder input suggests that VSDs are not beneficial in terms of energy consumption (assuming that the sizing of the pump is correct). Further investigation into the swimming pool pump market suggests that wrong pump sizing is an issue in the sector, where private households are the main customers. Advertisements for swimming pool pumps with a VSD in the USA use oversized pumps with constant speed to show high energy saving potentials, however, one UK manufacturer shows also high savings for a 1HP pump unit, which represents 26% of the European market[315314], following 0.75 HP pump units that represent 32%. The conclusion of the investigation is that there is a large energy saving potential for swimming pool pumps, but it is mainly from (i) changing to variable flow applications and using VSD, as well as from (ii) the pump sizing and the system design. The former is a parameter the study team was careful to change, as the share of variable/constant flow applications does not depend entirely on the manufacturers but on the users' demand and it poses high risks to define an ecodesign policy measure if it is not known if users will change from constant to variable flow operation. The latter is outside the scope of EPA.

For wastewater pumps the issue concerned the categorisation. The study team started out by using the categorisation that was used in Lot 28 and then received input during the data collection from Europump that suggested a further subdivision of some categories. With a high number of different categories, most of these represent only small energy saving potentials. Considering each of these categories separately would mean that most should be removed from the study due to their insignificance. But considering the fact that even the experts from Europump are in doubt when it comes to how to classify wastewater pumps, it seemed unreasonable to exclude wastewater pump categories at an early stage of the study. However, not all categories were included in the final scope as it became clear at a later stage of the study that dry well pumps and axial pumps are used for separate applications. Since their stocks and savings potentials are much lower than centrifugal submersible radial pumps' stock, it became evident that there was no reason to investigate these pumps further.

In addition to the initial data collection, Europump has provided the study team with information about how some pump categories would be difficult to regulate within the scope of ecodesign.

In December 2015 the study team published a progress report, covering a review of current relevant legislation and standardisation work on EPA and including tasks 1to 4 of the MEErP. This report was discussed with stakeholders during the meeting of 11th February 2016. The minutes of this meeting are included in Annex 5, however, it is important to notice that the study team has not received input from the Commission and the version attached is therefore not yet approved. The comments on the progress report, received from stakeholders during the meeting and in successive written form, have been used during the revision of the Task 1-4 report, and have been integrated in this draft final report. Europump and EUSA Working Groups provided an official document with all of their

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[315] 'Contribution of the Working Group of EUSA to the review study of ecodesign and energy labelling for pumps'. Paris 13/11/2015.

comments and have asked the study team to reply to these comments. They have thus been attached, including answers from the study team (see Table 78 and Table 79 in Annex 6 and Annex 7, where the view of the team is presented).

The position of Europump and EUSA, as expressed during the meeting and through position papers sent to the study team, can be summarised as:

- Europump wants to include an EPA in a revision of the legislation and believes there is a saving potential of about 35 TWh from the pumps already in the scope of regulation 547/2012.
- Europump and EUSA are not in favour of including swimming pool pumps in the revision of the regulation, since the energy saving potential from these, according to data provided by Europump and EUSA working groups, is very low and the required standardisation work will be a distraction from the work needed for regulating other pump categories with much higher energy saving potentials.
- According to information provided by Europump, the development of EPA methodologies for multistage borehole pumps (MSS) up to 12" nominal diameter and for booster-sets is under development. For this review study it means that no methodology currently exists for these pumps, but that it will be developed in the future, which will serve as the basis to revise EEI levels estimated in this study.
- Europump wants to include horizontal multistage pumps (MS-H) into the scope to avoid a potential loophole from these in relation to vertical multistage pumps. However, Europump is also mindful of the fact that horizontal multistage pumps are a large and complex range of products of which not all are suitable to be regulated.
- Europump does not want to include large horizontal or vertical multistage pumps (above the current limit of 25 bar and 100 m^3/h) for various reasons, but mainly because verification procedures for these are not developed yet and it would be complex to do so due to the fact that these pumps often include custom features.
- Europump wants to bring submersible wastewater pumps into the scope, in spite of the difficulties with wastewater characterisation and pump categorisation: Europump is aware it may be too early to regulate them, but it is willing to invest more efforts on developing a standardisation first for wastewater characterisation and then for development of test methods.
- Europump thinks that slurry and submersible dewatering pumps should be out of the scope of a revised regulation on water pumps, as "these pumps are designed to transport the "solids" (like gravel, potatoes, apples or even live fish) with water as a transport medium rather than to transport a pumped fluid." The exclusion of these pumps from the final scope has been already communicated to Europump by the study team.

12.1.2 Opportunities and barriers

Opportunity: Establish Extended Product Approach requirements[316]

When Lot 11 preparatory study was first completed, it was assessed by the European Commission and its consultants that only some 5 TWh of energy saving would be available from the products in scope at that time.

[316] The contents of this paragraph is largely based on: Europump position paper on the review of "Regulation (EU) No 547/2012", September 2015, available at: http://europump.net/uploads/Europump%20position%20paper%20LOT%2011%20review.pdf

Europump persisted on introducing the concept of an EPA[317], where they estimated that for Lot 11 some 60 TWh of savings could exist by applying EPA. Eventually Europump and the Commission worked together to bring into effect regulation 547/2012 for water pumps with a 0.4 MEI[318] cut-off, designed to remove the worst performing pumps. This agreed maximum product cut-off was made on the understanding that Europump would investigate the potential of applying EPA to water pumps which would be used during a future review study.

In the meantime, the EPA has been implemented for circulators, with an estimated saving covering 24 TWh of the 60 TWh mentioned above. In the past years' industry (Europump) has invested in developing standards and preparing performance standards based on EPA also for water pumps. Completion of the EPA is therefore one of the main aims (and opportunities) of the review of Regulation 547/2012.

The potential energy savings from introducing EPA for water pumps were estimated by Europump as 35 TWh[319316] (remaining part of the 60 TWh mentioned above). However, based on preliminary calculations by the study team to perform the screening that was the basis for determining the final scope, including additional pump categories not considered in Lot 11, the potential savings are in the range of 43 – 61 TWh. One of the tasks of the scenario analysis in this report is to verify these quantities.

Opportunity: Increase use of VSDs in variable flow applications

For many uses of water pumps the energy consumption is connected to the use of speed control by using VSDs. This gives the pumps the ability to control the speed which can significantly reduce the energy consumption. In general, VSDs have a positive impact on the energy consumption if the flow demand of a pump is variating. If there is a constant or near constant flow demand from the pump, the VSD is not beneficial if the pump has the correct size. However, VSDs can also reduce the power consumption of an oversized pump.

The review of Regulation 547/2012, combined with the introduction of EPA, offers the opportunity to set minimum energy efficiency requirements on the combination of pump + motor+ control system (both motor and control system referred as power drive system and altogether referred as pump unit). This strongly stimulates the use of VSDs in variable flow applications. This is the major opportunity for energy savings on clean water pumps, which also presents an opportunity for wastewater and swimming pool pump units as described in chapter 11 (task D6) but that provides lower saving potentials in comparison to most of the clean water pumps. Motor regulation 640/2009 also promotes the use of VSDs with associated energy savings. In this analysis, the Business as Usual (BAU) scenario already takes into account the effects of the Motor Regulation by considering motors' levels of efficiency suggested in the conclusions of the Impact Assessment study. Therefore, no savings are accounted from the motors, and in that way double counting is avoided.

[317] Regulation 547/2012 only considers the hydraulic efficiency of the pumps themselves. The EPA considers the combination of the pump, the motor, and the drive/control. Introduction of the EPA is essential to stimulate users to apply the correct combination of the three components, and in particular to stimulate users to apply VSDs in variable flow applications.

[318] MEI = Minimum Efficiency Index, as defined in regulation 547/2012

[319] The contents of this paragraph is largely based on: Europump position paper on the review of "Regulation (EU) No 547/2012", September 2015, available at: http://europump.net/uploads/Europump%20position%20paper%20LOT%2011%20review.pdf

Opportunity: Close loopholes

The existing regulation has introduced several loopholes. E.g. multi-stage submersible water pumps (MSS) are only covered by regulation 547/2012 if they have a nominal outer diameter of 4" or 6". This has induced some suppliers to start marketing pumps with slightly different diameters to avoid having to meet the requirements, thus undermining the regulation. In addition, there have been loophole issues regarding the difference between multi-stage vertical (MS-V) pumps (in the scope of the regulation) and multi-stage horizontal (MS-H) pumps (out-of-scope of the regulation). Another example is the avoidance of meeting ecodesign requirements by claiming a clean water pump covered by the regulation is self-priming pump. Since there is no definition, any manufacturer can claim their pump is self-priming.

The review of regulation 547/2012 is an opportunity to close the observed loopholes[320].

Opportunity: Extension of scope

The review of Regulation 547/2012 is an opportunity to expand the scope. One of the aims of the review study is to explore the possibility to include pumps assessed in previous preparatory studies Lot 28 and Lot 29. A final scope has been recommended and communicated to the Commission and to industry stakeholders by the study team[321] and further refinements were done due to sales data corrections provided by Europump in latter stages of the study. Therefore, a final scope has been the subject of further investigations throughout tasks D5 and D6 (tasks 5 & 6 in MEErP) and are assessed in this chapter. The exact scope has been discussed between stakeholders, study team and the Commission, along the progress of this review study. The results of the scenario analysis presented in this report are expected to contribute to reaching a final decision, because they indicate for which pump types the energy savings are worthwhile.

Opportunity: Cover oversized pumps with trimmed impellers

The pump manufacturers usually offer a limited number of pump sizes in order to save on manufacturing costs. This means that customers often have to select a volute that is too large (oversized) for their application, also, because of the fear of not having a pump that can handle peak loads, which is especially relevant for wastewater pumps used for wastewater transport and flood control. To compensate for this, most manufacturers offer trimmed impellers, which are impellers that are undersized compared to the volute. A pump with a trimmed impeller has a lower energy efficiency compared to one with a full impeller, although lower energy consumption compared to an oversized pump with a full impeller. Simply removing trimmed impellers from the market would not be a good solution if the trimmed impeller pumps are replaced by oversized pumps with higher energy consumption. Therefore, any energy saving measure has to be balanced, since the range of available products affects the energy consumption of new pumps. The current Regulation 547/2012 handles this issue by not applying the energy efficiency requirements to pumps with trimmed impellers. This, however, means that there is little motivation for manufacturers to increase the number of volutes in their portfolio.

Recent updates from industry indicate that it has been accounted for the loss of efficiency for trimmed impellers by introducing a compensation factor in the calculation of the EEI. At the time of this review, the methodology hadn't been fully developed for all water pumps in final scope of this study, so it was not possible to specifically explain how this factor

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[320] Definitions proposed in section 9.3 are those recommended in order to close these loopholes

[321] 'Recommendation of scope for revision of regulation', dated on the 16th of February, 2016, and 'Recommendation of scope for revision of regulation – Part II', dated on the 22nd of February, 2016.

would be applied to EPA requirements. However, the development of EPA requirements provided with the opportunity to compare fairly the energy efficiency of water pumps with and without trimmed impellers and to stimulate suppliers to increase the number of volutes in their portfolio.

Barrier: State of development of EPA performance standards

The methodology for calculating the Energy Efficiency Index (EEI)-values that are used in EPA is given in the draft standard "Pumps — Rotodynamic Pumps - Energy Efficiency Index - Methods of qualification and verification — Part 2 - Testing and calculation of energy efficiency index (EEI) of single pump units". This draft standard includes the methodology for the pump categories ESOB, ESCC, ESCCi with both 2-pole and 4-pole motors, and MS-V and MS-H with 2-pole motors. A draft standard also exists for booster-sets "Pumps — Rotodynamic Pumps - Energy Efficiency Index - Methods of qualification and verification — Part 3 - Testing and calculation of energy efficiency index (EEI) of booster sets".

This issue also influences the timing of the introduction of new measures: for ESOB, ESCC and ESCCi it is believed that the first tier of requirements can be put into action in 2020, while for the other pump categories it will not be sooner than in 2021.

There are currently no methodologies developed for swimming pool pumps and vortex and channel impeller wastewater pumps.

Barrier: Reliability vs efficiency

Wastewater pumps must be reliable, since the clogging of a pump due to the presence of large solids, high concentra-tions of solids and/or high flows can be very expensive in terms of time used to de-clog the pump and the risks of sick-ness and errors when staff needs to get involved. It is best to minimize human contact with wastewater. A general rule of thumb in wastewater pumping is that the better the wastewater handling capabilities the worse the energy efficiency. For example, vortex pumps are considered very reliable but they have the worst energy efficiency.

Observations regarding swimming pool pumps

Swimming pool pumps are mostly used in private households and the customers are most likely not technical experts. Therefore, it is not uncommon that the customers buy oversized pumps and do not know how to operate the pump optimally. This also means that the energy efficiencies of the pumps on the market are relatively low compared to other pumps. Proper, reliable and standardised labelling could help customers to choose the right pump size and promote higher energy efficiencies. Within the EU there are various national regulations on how to operate swimming pools. Therefore, a labelling strategy would have to take into consideration all the national requirements.

Observations regarding clean water pumps

A large part of the clean water pump applications is for variable flow, but the number of pumps installed with VSD is much lower. Therefore, there is a significant energy saving potential if VSDs are used in all applications with variable flow.

Clean water pumps are already subject to energy efficiency requirements in the current regulation. These requirements are only for the pump itself and only pumps with full (non-trimmed) impeller are subject to the requirements. Furthermore, for multistage pumps, only MS-V pumps with 3 stages and MSS with 9 stages are tested against the requirements. This means that there are many pumps with energy efficiencies below the requirements. On the other side of the spectrum there are many pumps on the market that comply with

MEI≥0.7, that is about 3-4%-points better than the current MEI=0.4 requirement. This indicates the possibility to push the pump development towards slightly higher energy efficiencies. However, the potential energy savings from increasing the pump efficiency are low compared to those that can be gained by applying VSDs in variable flow.

12.1.3 Possible policy measures

The following policy options have been considered for the policy scenarios:

- No action ('Business-as-Usual', BAU)
- Self-regulation
- Energy labelling
- Ecodesign measures

No action (BAU)

If no new action is taken, the existing Regulation 547/2012 for water pumps remains in force, leading to the previously estimated 5 TWh energy savings, due to improvements in the hydraulic efficiency of the pumps themselves.

Additional savings can be expected from the effects of Regulation 640/2009[322] on electric motors (including those applied to pumps). From 1 January 2015, this regulation requires electric motors from 7.5 to 375 kW to be of efficiency class IE3 or to be of efficiency class IE2 if equipped with a VSD. From 1 January 2017 this requirement is extended to motors with powers down to 0.75 kW. This motor regulation is currently being reviewed and scope extensions have been proposed, but no final decision on a new motor regulation has been taken yet (June 2018).

Not taking any action would mean wasted time and effort put by industry in developing the EPA for pumps. It would also not reap the potential additional energy savings that can be obtained from introducing the EPA. Loopholes in the existing regulation would continue to exist. None of the stakeholders is in favour of taking 'no action'.

Consequently, 'no action' is not presented as a policy option, but the corresponding scenario has been taken into account as the Business-As-usual (BAU) scenario, that will serve as a reference to compute the savings of the ECO-scenarios introduced below. The BAU scenario assumes that the current pump Regulation 547/2012 remains in force, and it also includes the effects of motor regulation 640/2009 on the motors (and VSDs) used for pumps. This ensures that any savings on pumps that are purely due to the motor regulation are not included in the savings calculated in this report for the pump ECO scenarios, thus avoiding double counting.

Self-regulation

In Art. 15.3 b) of the Ecodesign Directive 2009/125/EC self-regulation, including voluntary agreements offered as unilateral commitments by industry, is indicated as a preferred

[322] COMMISSION REGULATION (EC) No 640/2009 of 22 July 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for electric motors, OJ L 191/26, 23.7.2009,
as amended by:
COMMISSION REGULATION (EU) No 4/2014 of 6 January 2014 amending Regulation (EC) No 640/2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for electric motors, OJ L 2/1, 7.1.2014

option. However, this is subject to certain conditions stipulated in Article 17 and Annex VIII to the Directive (e.g. market coverage by signatories, ambition level, etc.).

These conditions are not fulfilled for clean water pumps and wastewater pumps: none of the relevant stakeholders expressed interest in self-regulationand the minimum market coverage will not be met because the risk of 'free-riders'.

According to EUSA[323], there is an interest in the swimming pool manufacturing industry in Europe to develop a voluntary scheme. However, this is still in early stages and it is conditioned to the outcomes of this review study and the data availability EUSA will need from members in order to collect data that supports this policy measure. The data availability will also clarify whether the participation of the industry is enough, since a minimum market coverage has to be assured in order to develop a self-regulation. Overall, this is still in premature stages and at this point it can be concluded that no self-regulation is foreseen in the near future for swimming pool pumps.

Consequently, self-regulation has not further been considered as policy option.

Energy labelling

In the impact assessment[32413] accompanying the introduction of Regulation 547/2012, energy labelling of pumps under the European energy labelling directive 2010/30/EU is discarded for the following reasons:

- Pumps in the scope of this impact assessment are not household appliances, and are therefore not covered by the labelling requirements set under the Energy Labelling Framework Directive 2010/30/EU.
- The actual operating point of a water pump is rarely at the specified "Best Efficiency Point" quoted in datasheets. Instead it will usually be at a reduced flow point, where the pump will have a reduced efficiency (compared to its BEP). The correct sizing of a pump is therefore critical for minimising energy costs. The use of a label to denote an "efficient" pump could lead the less educated specifier to select such an "efficient" pump in preference to a correctly sized pump. In many cases this "efficient" pump would actually use more energy than the correctly sized pump that had a lower headline efficiency indicated in a label.
- Labelling of pumps based on lower than BEP efficiency does not make sense either, as the end-user should not be encouraged to use pumps beyond the BEP, when possible. Labelling for pumps is therefore potentially misleading and might encourage the selection of inappropriate pumps. After the implementation of the minimum efficiency requirements it would be difficult to distinguish seven energy efficiency classes above the proposed cut-off levels (only three realistic levels left).

The first reason reported in the impact assessment is not fully correct. Directive 2010/30/EU applies to all energy-related products and not only to household appliances, although in practice energy labels are mainly being used for household products. Anyway, excepting the smaller sized swimming pool pumps that are mainly sold in the residential sector, it is estimated that maximum 15-20% of the water pumps is sold in the residential sector, so the large majority of users is in the tertiary sector, industry and agriculture. For

[323] EUSA Pool Pump Working Group. Plan for furture study. Paris 06/09/2017. Version 1.
[324] Commission staff Working Document – Impact Assessment – Ecodesign requirements for water pumps (2012)

these users an energy label is judged less useful, and ecodesign information requirements are deemed sufficient.

The second reason reported above, i.e. choosing the right size being even more important than choosing the highest efficiency, and an energy label being potentially misleading, is still valid.

The third reason, i.e. the difficulty to distinguish seven energy efficiency classes above the minimum efficiency imposed by ecodesign, is also retained to be still valid. The introduction of EPA further complicates an introduction of energy labelling.

Considering the reasons above, and considering that none of the stakeholders has expressed the desire to introduce an energy labelling for water, wastewater and swimming pool pumps, this option has not been taken into account any further.

The study team signals a potential benefit of introducing energy labelling for swimming pool pumps (see chapter 11), but for the moment this is only presented as a topic for further discussion and has not been included in the scenario analysis.

Ecodesign measures

This policy measure involves the substitution of Regulation 547/2012 by a new regulation that is based on the EPA, and that specifies energy efficiency requirements in terms of maximum allowed Energy Efficiency Index (EEI)-values. According to the points presented in the previous sections, this is considered the most viable option.

12.1.4 Policy scenarios

In order to define policy scenarios, the study team has identified two strategies based on information and data provided by stakeholders: One is to promote a switch towards the use of VSDs in variable flow operations, the other is to promote higher energy efficiency of the water pumps by using more efficient pumps in relation to their hydraulic efficiency.

The first strategy is implemented by applying maximum EEI-requirements for variable flow pumps that can only be met by pumps with VSD, meaning that every pump unit used in variable flow applications would have to be equipped with a VSD. It is assumed a large cut-off as a consequence of this, but it is not an issue as manufacturers, retailers or installers can 'simply' equip pumps with VSDs to meet the requirements.

The second strategy is implemented by applying maximum EEI-requirements both for variable and constant flow pumps that will remove pumps with lowest hydraulic efficiency from the market. With this strategy it is important to ensure that the cut-off is not too high, since it will take time and money for the manufacturers to replace the pump models that are going to be removed from the market, and the fewer pump models on the market, the larger the chances that customers are forced to buy oversized pumps.

These strategies imply that compliance of the extended product depends on the installation in which it is installed (i.e. in constant or in variable flow application). This is the most ambitious scenario, since it would ensure that the installed pump units bring the estimated savings, but it also raises challenges for verification and enforcement. The viability of this approach is assessed in detail in chapter 13. This section presents the policy scenarios considering this approach is viable, and chapter 12 further presents the results from this approach in terms of energy savings, GHG emissions, consumer expenditure and revenue and jobs.

For each pump two EEI-values have been establised, one for variable flow operation and one for constant flow operation[325]. The two types of flow are defined by the respective flow-time profiles defined in the standard[326,156], even if in real life applications the flow-time profiles might be different for each application.

In regards to the development status of the standard that defines the calculation and testing methodologies for the EEI's, see section 12.1.2.

Currently, the EEI-calculation is not fully defined for all pump types in the scope of the study. In these cases, in order to enable a preliminary calculation of the potential energy savings, the study team made an estimate of the average energy efficiency percentages[327], or of the share of variable flow applications using VSD, that would be expected to result from future EEI-requirements.

For each base case (pump type, size, flow-type) two levels of energy efficiency requirements are proposed (a less severe one and a more severe one), combined with three different time-scales for their introduction:

- ECO1: Introduction of less severe requirement in 2020
- ECO2: ECO1 + introduction of more severe requirement in 2023
- ECO3: Introduction of more severe requirement in 2020

For those pump types where the EEI-methodology is not yet fully defined in the draft standard, the introduction of the requirements shifts by 1 year, to 2021 and 2024 respectively.

Table 55 provides an overview of the Eco-scenarios in comparison to BAU, and implicitly also defines the scope of the proposed measures.

Table 55. Overview of BAU and ecodesign policy options selected for analysis (EEIc refers to requirements in constant flow applications; EEIv in variable flow applications).

Base cases			BAU	Eco1	Eco2	Eco3
ESOB, ESCC, ESCCi	Constant flow	(all sizes ≤ 150 kW)	EEIc,max = 0.991 0.995 0.965	EEIc,max = 0.988 from 1/1 2020	Eco1 + EEIc,max = 0.96 from 1/1 2023	EEIc,max = 0.96 from 1/1 2020
	Variable flow	(all sizes ≤ 150 kW)	EEIv,max = 0.712 0.717 0.698	EEIv,max = 0.62 from 1/1 2020	Eco1 + EEIv,max = 0.57 from 1/1 2023	EEIv,max = 0.57 from 1/1 2020
MS-V	Constant flow	(≤ 25 bar)	Avg. eff. = 63.6% in 2021	Avg. eff. = 64.8% from 1/1 2021	Eco1 + Avg. eff. = 66.3% from 1/1 2024	Avg. eff. = 66.3% from 1/1 2021

[325] Except for Booster-sets, which are considered to operate with an alternative variable flow-time profile, and swimming pool pumps which always operate as constant flow.
[326] FprEN 16713-1:2015
[327] Based on limited data received from industry on efficiency levels, only hydraulic efficiency was considered and an average level was defined.

Base cases		BAU	Eco1	Eco2	Eco3
	Constant flow (25 < p ≤ 40 bar)	Avg. eff. = 74.5% in 2021	Avg. eff. = 75.7% from 1/1 2021	Eco1 + Avg. eff. = 77.2% from 1/1 2024	Avg. eff. = 77.2% from 1/1 2021
	Variable flow (all sizes ≤ 40 bar)	Avg. eff. = 51.3% in 2021	Avg. eff. = 51.8% from 1/1 2021		
MS-H	Constant flow (≤ 25 bar)	Avg. eff. = 42.1 in 2021	Avg. eff. = 45.9% from 1/1 2021	Eco1 + Avg. eff. = 48.9% from 1/1 2024	Avg. eff. = 48.9% from 1/1 2021
	Constant flow (25 < p ≤ 40 bar)	Avg. eff. = 54.8% in 2021	Avg. eff. = 56.0% from 1/1 2021	Eco1 + Avg. eff. = 57.5% from 1/1 2024	Avg. eff. = 57.5% from 1/1 2021
	Variable flow (all sizes ≤ 40 bar)	Avg. eff. = 34.8% in 2021	Avg. eff. = 38.4% from 1/1 2021		
MSSB	Constant flow (≤ 6" diameter)	Avg. eff. = 48.7% in 2021	Avg. eff. = 52.4% from 1/1 2021	Eco1 + Avg. eff. = 55.4% from 1/1 2024	Avg. eff. = 55.4% from 1/1 2021
	Variable flow (≤ 6" diameter)	Avg. eff. = 36% in 2021	Avg. eff. = 37.6% from 1/1 2021 Avg. eff. = 37.6% from 1/1 2021		
Booster-sets	Variable flow (all sizes ≤ 150 kW)	Avg. eff. = 41.6% in 2021	Avg. eff. = 42% from 1/1 2021		
SWP	Constant flow (all sizes ≤ 2.2 kW)	EEIc,max = 1.16	EEIc,max = 1.10 from 1/1 2021	Eco1 + EEIc,max = 0.988 from 1/1 2024	EEIc,max = 0.988 from 1/1 2021
SVR	Constant flow (≤ 10 kW)	Avg. eff. = 25.9% in 2021	Avg. eff. = 27.3% from 1/1 2021	Eco1 + Avg. eff. = 28.8% from 1/1 2024	Avg. eff. = 28.8% from 1/1 2021
	Constant flow (10 - 160 kW)	Avg. eff. = 28.4% in 2021	Avg. eff. = 29.7% from 1/1 2021	Eco1 + Avg. eff. = 31.2% from 1/1 2024	Avg. eff. = 31.2% from 1/1 2021
	Variable flow (≤ 10 kW)	Avg. eff. = 20.1% in 2021	Avg. eff. = 21.5%	Eco1 + Avg. eff. = 23.0%	Avg. eff. = 23.0%

Base cases		BAU	Eco1	Eco2	Eco3
			from 1/1 2021	from 1/1 2024	from 1/1 2021
	Variable flow (10 - 160 kW)	Avg. eff. = 23.1% in 2021	Avg. eff. = 24.5% from 1/1 2021	Eco1 + Avg. eff. = 26.0% from 1/1 2024	Avg. eff. = 26.0% from 1/1 2021
SCR	Constant flow (≤ 10 kW)	Avg. eff. = 48.3% in 2021	Avg. eff. = 49.6% from 1/1 2021	Eco1 + Avg. eff. = 51.1% from 1/1 2024	Avg. eff. = 51.1% from 1/1 2021
	Constant flow (10 -25 kW)	Avg. eff. = 56.3% in 2021	Avg. eff. = 57.5% from 1/1 2021	Eco1 + Avg. eff. = 59.0% from 1/1 2024	Avg. eff. = 59.0% from 1/1 2021
	Constant flow (25 - 160 kW)	Avg. eff. = 60.9% in 2021	Avg. eff. = 62.1% from 1/1 2021	Eco1 + Avg. eff. = 63.6% from 1/1 2024	Avg. eff. = 63.6% from 1/1 2021
	Variable flow (≤ 10 kW)	Avg. eff. = 36.1% in 2021	Avg. eff. = 37.4% from 1/1 2021	Eco1 + Avg. eff. = 38.9% from 1/1 2024	Avg. eff. = 38.9% from 1/1 2021
	Variable flow (10 - 25 kW)	Avg. eff. = 45.9% in 2021	Avg. eff. = 47.2% from 1/1 2021	Eco1 + Avg. eff. = 48.7% from 1/1 2024	Avg. eff. = 48.7% from 1/1 2021
	Variable flow (25 - 160 kW)	Avg. eff. = 49.6% in 2021	Avg. eff. = 50.9% from 1/1 2021	Eco1 + Avg. eff. = 52.4% from 1/1 2024	Avg. eff. = 52.4% from 1/1 2021

EEI,max = requirement set in regulation. Avg. eff. = estimated average efficiency of pumps on the market after future introduction of an EEI requirement, for the extended product including the whole pump unit.

ESOB, ESCC and ESCCi for constant flow

The EEIc ≤ 0.988 requirement is expected to correspond to keeping on the market all pumps with MEI ≥ 0.4 operating on an IE3 efficiency motor. The current regulation only applies to pumps with full impellers, while trimmed impellers are allowed on the market regardless of their MEI (e.g. if their MEI < 0.4), if the corresponding full impeller model has MEI ≥ 0.4. By removing the distinction of trimmed and full impeller pumps, all pumps with trimmed impellers which are MEI<0.4 will no longer be compliant. This is estimated to affect 40% of the pumps currently on the market.

In the context of the work for prEN 17038 by Technical Committee CEN/TC 197 “Pumps”, the committee has agreed on a correction factor for pumps with trimmed impellers in order to reduce the number of pump that would be phased out with the future amended regulation.[328]

The EEI ≤ 0.96 requirement is expected to phase-out around 55% of the pumps currently on the market.

ESOB, ESCC and ESCCi for variable flow

The EEIv ≤ 0.62 requirement is expected to maintain on the market all pumps now marketed with VSD while >99% of the pumps operating without VSD would be phased-out for variable flow applications. Lowering the requirement to 0.57 would phase-out also 5% of the worst performing pumps with VSDs.

In practice this means that in both options all pumps for variable flow will have to use a VSD. The slight difference between the two options would lie in the average efficiency of the pumps with VSDs, but at this stage, this has been neglected for the purposes of scenario analysis. This implies that all three Eco-options lead to the same savings for these pumps.

MS-V for constant flow

It was assessed that most MS-V pumps are of a highly efficient design, therefore only a minor cut-off of 20% is suggested. This is estimated to increase the average efficiency to 64.8% (small size) and 75.7% (medium size).

For the more severe requirements with a cut-off of 40% the average efficiency will be increased to 66.3% (small) and 77.2% (large)..

MS-V for variable flow

For both the small and medium size pumps it is proposed to set requirements that imply the need to use VSDs. For small pumps (≤ 25 bar) this increases the VSD share in variable flow applications from around 20% to 100%. However, for the medium size pumps (25-40 bar) it is expected that 100% VSD use will also be obtained in the BAU scenario from 2021 onwards (due to general trend and due to the motor regulation), so the ECO-requirement will not lead to additional savings for these pumps.

MS-H for constant flow

MS-H pumps are currently not regulated, therefore there are more pumps on the market with less efficient design, and therefore a cut-off of 30% is suggested.

This is estimated to increase the average efficiency to 45.9% (small size) and 56.0% (medium size).

For the more severe requirements with a phase-out of 50% the average efficiency will be increased to 48.9% (small) and 57.5% (large).

MS-H for variable flow

For both the small and medium size pumps it is proposed to set requirements that imply the need to use VSDs. For small pumps (≤ 25 bar) this increases the VSD share in variable flow applications from around 40% in BAU to 100% in ECO. For the medium size pumps (25-40 bar) the VSD share increases from around 60% in BAU to 100% in ECO.

328 Information from meeting with Europump 13th of June 2017

MSSB for constant flow:

Although MSSB pumps are currently regulated, the pumps data collected showed lower efficiencies and thus more room for improvement, and therefore a phase out of 30% is suggested. This is estimated to increase the average efficiency to 52.4%.

For the more severe requirements with a phase-out of 50% the average efficiency will be increased to 55.4%.

MSSB for variable flow

It is proposed to set requirements that imply the need to use VSDs.

Booster sets (assumed to be all for variable flow)

Table 56 further clarifies the shift towards the use of VSDs that has been assumed in the scenario analyses for booster sets. Under the less severe requirements, all pumps have to use a VSD, but the share of applications using multiple-VSDs (one per pump) is only around 15%. Under the more severe requirements 100% of the applications uses multiple VSDs.

Table 56. Shift towards use of VSDs in booster-sets.

	BAU			Eco1			Eco2			Eco3		
Share of booster -sets	No VSD	With VSD	With multiple VSD	No VSD	With VSD	With multiple VSD	No VSD	With VSD	With multiple VSD	No VSD	With VSD	With multiple VSD
2016	44 %	50%	6%	44 %	50%	6%	44 %	50%	6%	44 %	50%	6%
2021	25 %	65%	11%	0%	86%	14%	0%	75%	25%	0%	0%	100%
2024	10 %	75%	15%	0%	84%	16%	0%	0%	100%	0%	0%	100%

SWP (Swimming pool pumps) (assumed to be all for constant flow)

SWP are currently not regulated, therefore there are more pumps on the market with less efficient design. However, it is a business with several small producers, meaning that severe requirements could result in significant impact on the concerned SMEs. Therefore a phase out of 25% is suggested.

A EEI ≤ 1.1 requirement is expected to phase-out around 25% of the pumps currently on the market. Under the EEI ≤ 0.988 requirement this is expected to increase to around 50%. This requirement was established assuming that swimming pool pumps have very similar construction than ESOB pumps, and that the efficiency levels on the market are similar to those of ESOB clean water pumps. However, the level was set less ambitious considering swimming pool pumps would have a more difficult transition towards higher efficiency levels.

SVR and SCR (Wastewater pumps) for constant and variable flow

It was assessed that most wastewater pumps are of a highly efficient design, therefore only a minor phase-out of 20% is suggested. Alternative a phase-out of 40% is chosen for a severe scenario.

For all pump sizes and both for constant and for variable flow, the lowest average efficiencies are expected to correspond to requirements that phase-out 20% of existing pumps on the market. The highest average efficiencies correspond to a phase-out of 40%.

For these pumps it is assumed that 100% of the variable flow applications use a VSD already in the BAU-scenario, so there are no savings from a shift towards VSDs in the ECO-scenarios: the only savings are from improvements in efficiency.

12.2 Scenario analysis

12.2.1 Introduction to scenario analysis

For the scenario analysis the study team developed a stock model for pumps that will be referred to as MAESP (Model for Analysis of Ecodesign Scenarios for Pumps). The model consists of an Excel file that follows the calculation methodology used in the Ecodesign Impact Accounting[329], with some specific additions for pumps.

The input data for this model are those derived in the previous Tasks 1-6 and include:

- Subdivision in base cases (scope of the study)
- Pump sales quantities in 2014
- Annual growth percentages for pump sales
- Shares of pumps sold for constant flow and for variable flow
- Shares of pumps for variable flow using a VSD
- Average useful pump lifetimes
- Average load (user demand for pump output: output power x operating hours)
- Average energy efficiencies of new sold products in a given year
- Relation between energy consumption and CO_2-emissions (GWP100)
- Purchase-, Installation- and Maintenance costs for pumps
- Electricity rates (euros/kWh)
- Sector composition of purchase cost (industry-, retail-, wholesale-, tax-shares)
- Relation between sector revenues and number of jobs involved

The output of the model covers the period 1990-2030 and includes (for each scenario):

- Quantity of pumps installed in EU-28 (stock)
- Total EU-28 pump load (total demand for pump output)
- Average energy efficiency of the stock
- Total EU-28 energy consumption for pumps (primary energy and electricity)
- Total EU-28 greenhouse gas emission related to this energy consumption
- Total EU-28 consumer expenses for pump acquisition and operation
- Total EU-28 sector revenues from pump sales and related jobs

The input data that vary depending on the scenario (BAU, ECO1, ECO2, ECO3, see par. 1.3.4 and 1.4) are the shares of pumps for variable flow using a VSD, and the average energy efficiencies of new sold products.

Energy savings for variable flow pump applications mainly derive from a shift in sales from pumps without VSD (lower energy efficiency) to pumps with VSD (higher energy efficiency).

Energy savings for constant flow pump applications only derive from an increase in the average energy efficiency of new sold pumps.

[329] See e.g.
https://ec.europa.eu/energy/sites/ener/files/documents/2014_06_ecodesign_impact_accounting_part1.pdf

Annex 9 explains details of the calculations performed by the model and clarifies the input data for the BAU- and ECO-scenarios. Some selected results are also presented in this Annex, with a focus on those for the BAU-scenario.

Section 12.3 concentrates on the differences in model results between the BAU- and ECO-scenarios, i.e. on the savings and on impact reduction due to the Ecodesign measures.

12.2.2 Business-As-Usual (BAU) scenario

The BAU-scenario represents the condition where no new ecodesign measures will be taken. This means that regulation 547/2012 remains in force as it is, and that pumps in the scope of this regulation must have a MEI ≥ 0.4 starting from 1 January 2015.

The BAU-scenario also considers that the motors used for the pumps have to meet the requirements from regulation 640/2009 (if they are in the scope of that regulation). From 1 January 2015, this regulation requires electric motors from 7.5 to 375 kW to be of efficiency class IE3, or to be of efficiency class IE2 and to be equipped with a VSD. From 1 January 2017 this requirement is extended to motors with powers down to 0.75 kW. Consequently, in the BAU scenario, IE3 motor efficiency has been assumed for pumps without VSD, and IE2 efficiency for pumps with VSD. The development over time of motor efficiencies and VSD-shares assumed in the most recent Impact Assessment study for electric motors[330] has inspired the BAU-development of efficiency and VSD-shares for pumps (as extended product). For a detailed explanation of the share of pumps using VSD from 1990 to 2030, see Annex 9 (section 9.4) and Table 109. For a detailed explanation of the efficiencies assumed up to 2030, see Annex 9, section 9.7.

This implies that the BAU-scenario is not a freeze scenario of the 2015 situation: it includes the improvements in efficiency and the increases in VSD shares that are assumed to occur also in the absence of new regulations, see details in Annex 9.

The BAU-scenario serves as a reference for the ECO-scenarios. In particular, the savings obtained by an ECO scenario (an Ecodesign measure) are computed as the difference between the BAU- and the ECO-scenario. As the BAU-scenario already takes into account the effects of motor regulation 640/2009, there is no double counting of savings with that regulation.

The BAU- and ECO-scenarios can be compared only if they cover the same products, i.e. if they have the same scope. Considering that the ECO-scenarios have a scope that is wider than that of regulation 547/2012, the BAU-scenario also has to use this wider scope. However, the results for the current scope of regulation 547/2012 can also be of interest, and the MAESP is therefore split in:

- Current scope (of regulation 547/2012)
- Scope extension = additional pumps not included in current scope
- Extended scope = current scope + scope extension

For details on the input- and output-data for the BAU-scenario see Annex B. Some selected data follow below.

Sales (BAU)

In 2015 the number of pump units sold in EU-28 was 2.94 million, of which 1.58 million for pumps in scope of regulation 547/2012 and 1.36 million for additional pumps in the

[330] not publicly available yet

scope of this study. Based on the assumed growth rates (Annex 9.3) the sales are projected to increase to 3.23 million in 2020 and 3.50 million in 2030.

The quantity of pumps sold for constant flow in 2015 was 1.97 million (73.5%). The remainder, 0.97 million units (26.5%) were for variable flow applications, of which 0.25 million were sold with a VSD (25.6%). For the VSD-shares in variable flow assumed for each pump type, see Annex 9.4.

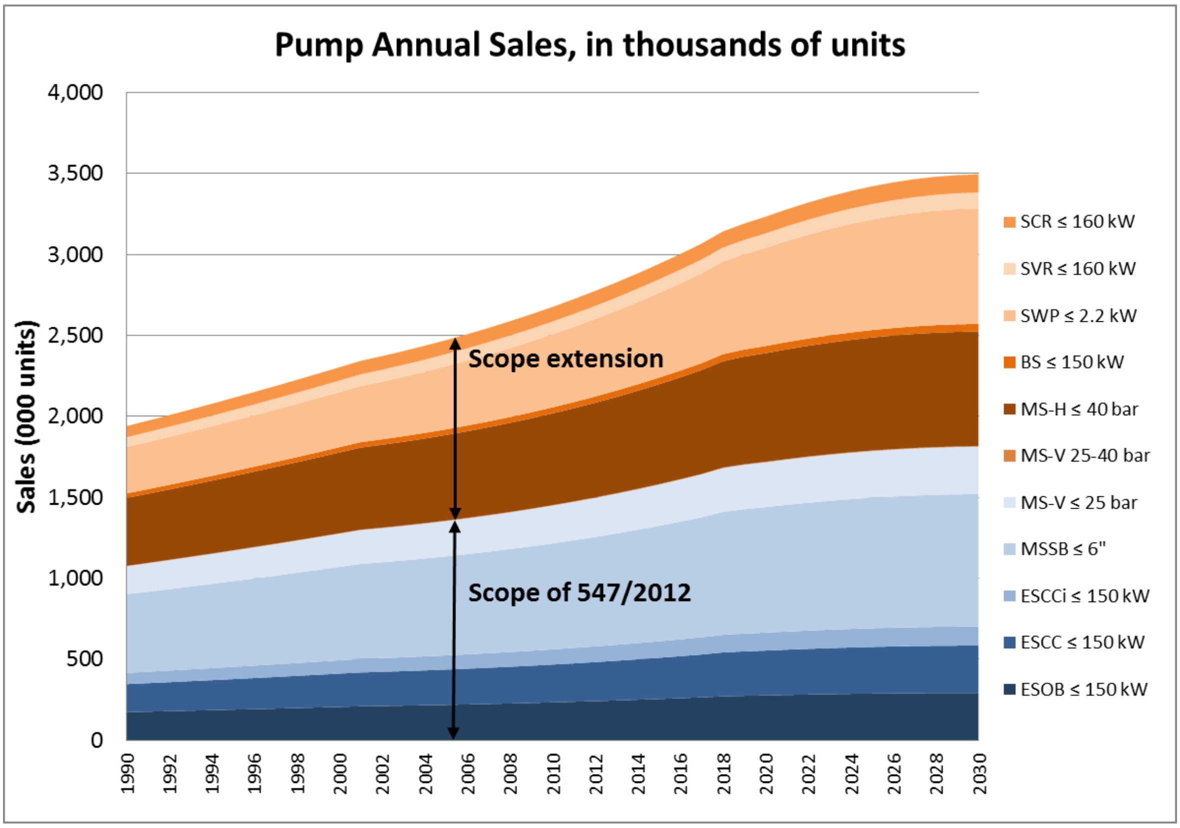


Figure 34. Annual pump sales in thousands of units (source: MAESP).

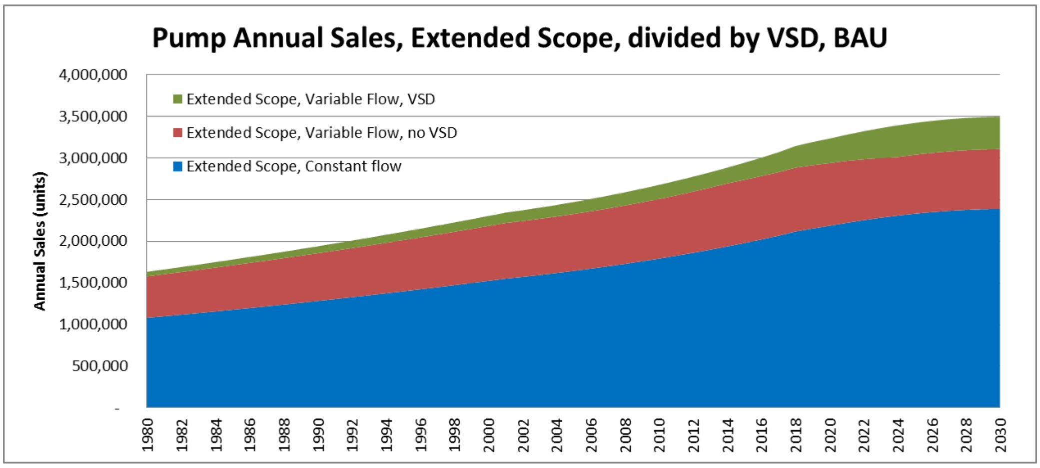


Figure 35. Sales for pumps for constant flow, and sales for pumps with variable flow split in those without and with VSD (BAU-scenario).

Installed Stock (BAU)

For all pump types in the scope of the study, an average useful lifetime of 10 years has been assumed. In 2015 this leads to an installed stock of pumps in the EU-28 of 27.1

million units, of which 16.6 million for pumps in scope of regulation 547/2012 and 12.4 million for additional pumps in the scope of this study. The installed stock is expected to increase to 29.8 million in 2020 and 34.1 million in 2030. See Annex 9.5 for further details.

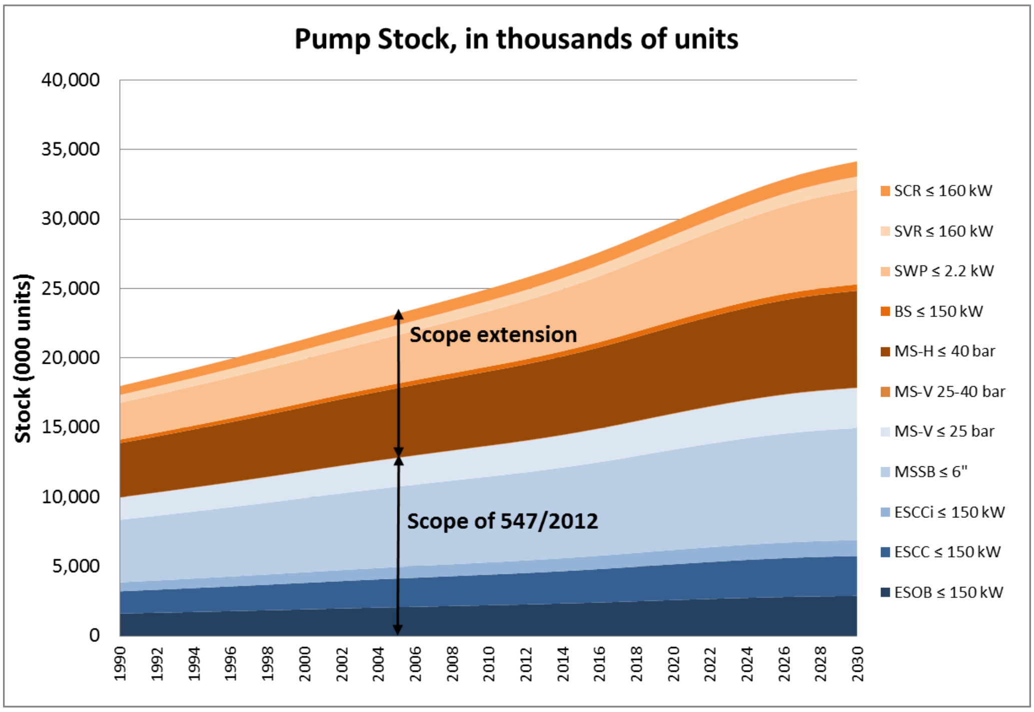


Figure 36. Pump installed stock in thousands of units (source: MAESP).

Total EU-28 Pump Load (BAU)

In the scenario modelling, the load represents the annual user demand for pump output in kWh/a. It is calculated for each base case unit as the product of the average pump output power (P3 in kW) and the average annual operating hours (h/a). The unit loads are assumed to remain constant over the years.

The unit loads are multiplied by the stock of installed pumps to obtain the total EU-28 pump load shown in Figure 37. In 2015 the pump output load requested by users is 114 TWh/a and is expected to increase to 124 TWh/a in 2020 and 137 TWh/a in 2030.

For further details on output powers, operating hours and loads, see Annex 9.6.

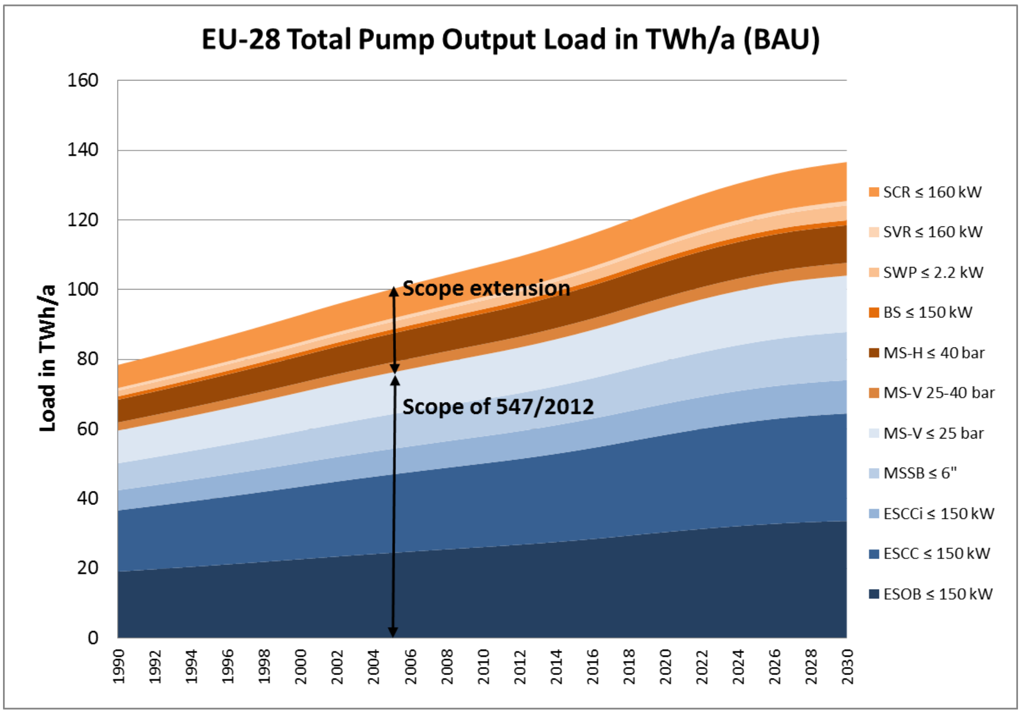


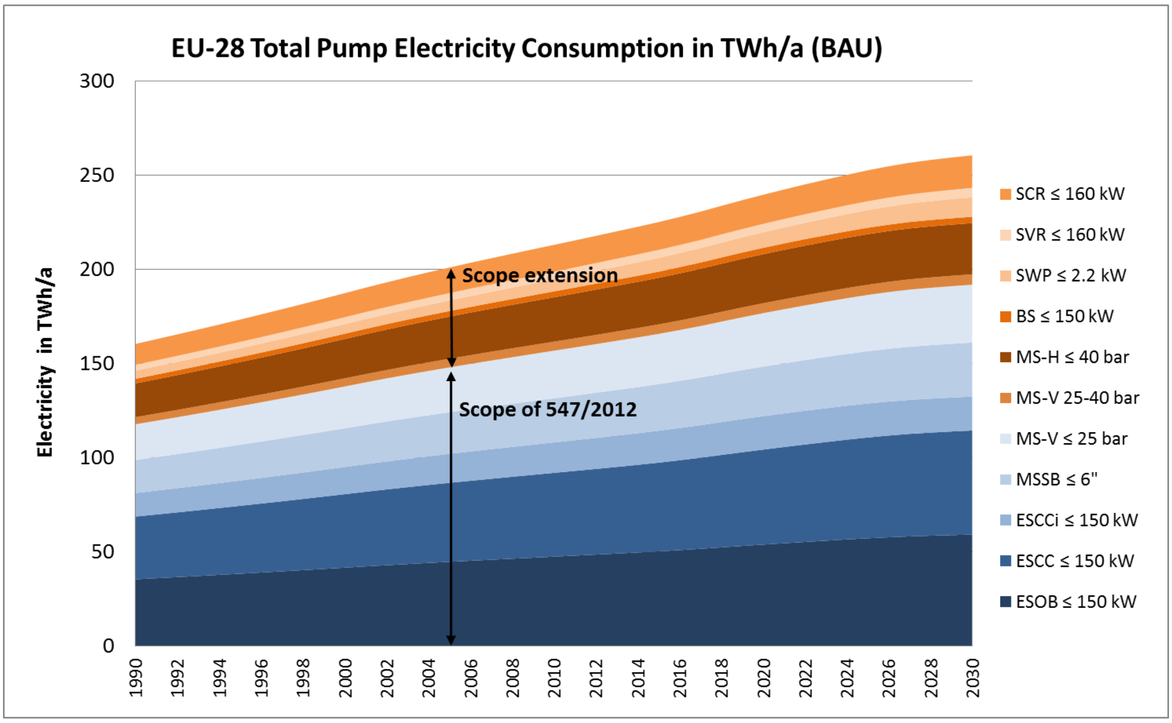
Figure 37. EU-28 total load of pumps in the scope of the study. The pump load represents the annual user demand for pump output and is computed as the product of the average output power (P3, in kWh) times the average annual operating hours (h/a) times the installed stock of pumps.

Electricity consumption by pumps (BAU)

The annual electricity (kWh/a) consumed by a pump to provide the demanded output load is computed by dividing the Load (kWh/a) by the energy efficiency of the pump (as extended product). The efficiencies (%) and Energy Efficiency Index (EEI) values assumed for each pump type are reported in Annex 9.7.

In 2015 the total EU-28 electricity consumption for pumps in the scope of the study was 225 TWh/a, of which 166 TWh/a (74%) for pumps in scope of regulation 547/2012 and 59 TWh (26%) for other pumps in the scope of the study. In the BAU-scenario the total energy consumption is expected to increase to 240 TWh in 2020 and 261 TWh in 2030.

In 2015, 112 TWh (50%) was consumed by pumps for constant flow applications and 113 TWh (50%) by pumps for variable flow applications. Of the latter, approximately 97 TWh (86% of variable flow) was consumed by pumps without VSD.



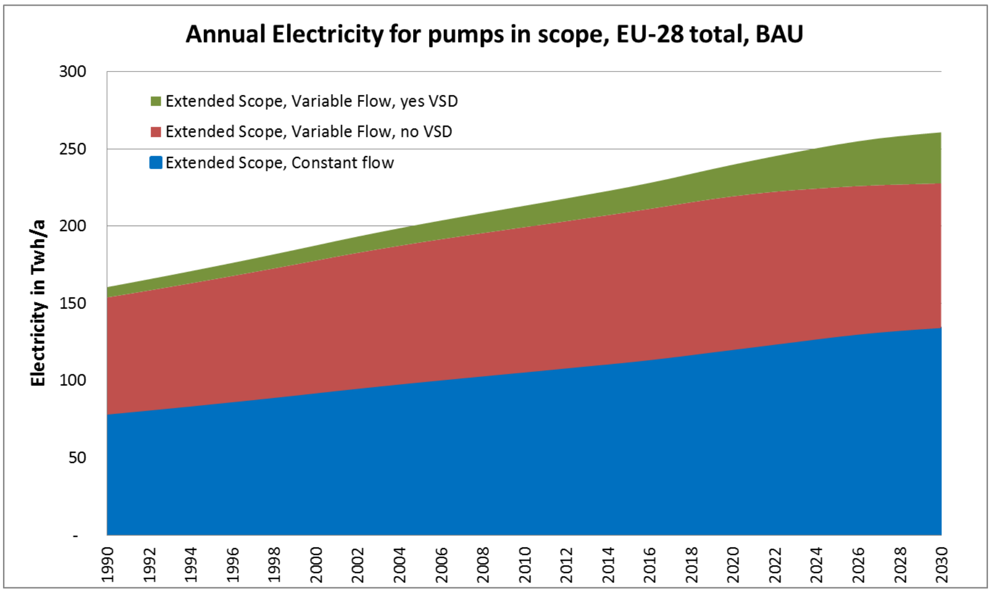


Figure 38. Total EU-28 annual electricity consumption in TWh/a for pumps in the scope of the study, for the BAU-scenario.

Greenhouse gas emissions due to pump operation (BAU)

The greenhouse gas emissions are derived from the electricity consumption by multiplying the latter by the Global Warming Potential for electricity (GWPel), expressed in kg CO_2 equivalent emitted per kWh electricity consumed. As specified in Annex 9.9, the GWPel decreases over the years, from 0.5 in 1990 to 0.395 in 2015 and 0.34 in 2030.

In 2015 the total EU-28 GHG-emission due to the electricity consumption by pumps is estimated as 89 Mt CO_2 eq./a, and without further action (BAU-scenario) this is expected to remain approximately constant up to 2030. The reason for this is that although electricity consumption increases, the GWP is projected to go down, and the two effects more or less compensate each other in the BAU-scenario.

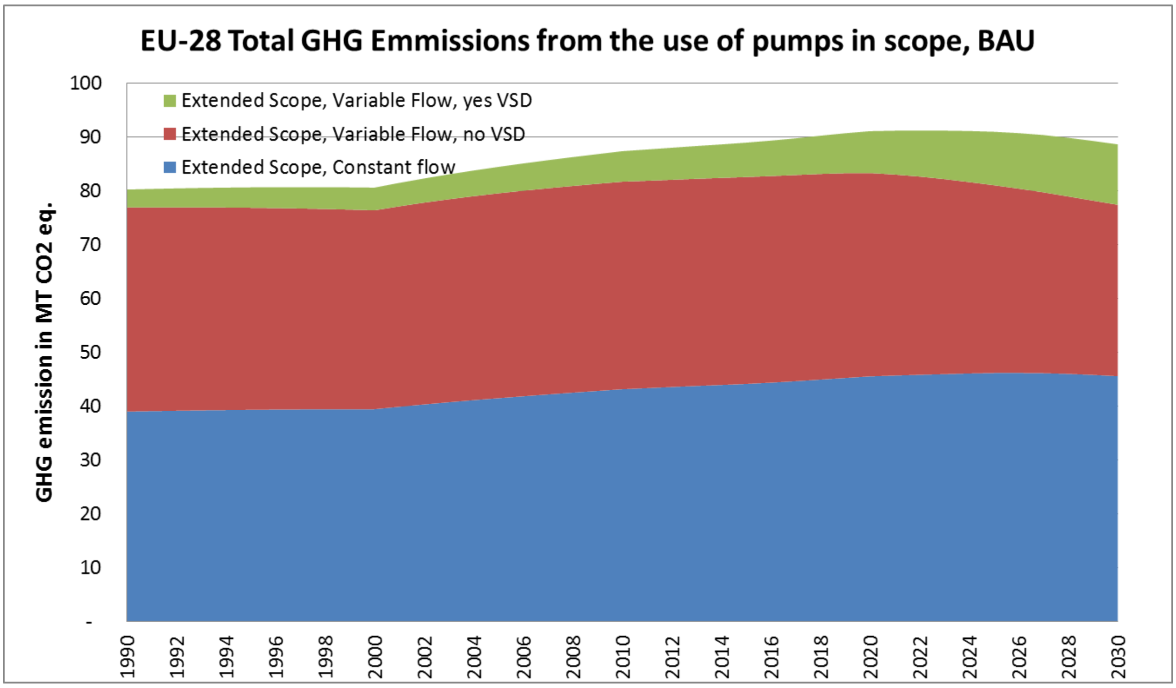


Figure 39. EU-28 Total annual greenhouse gas emissions due to the electricity consumed by pumps in the scope of the study, in Mt CO2 eq./a, for the BAU-scenario.

Total EU-28 Consumer Expense for pumps (BAU)

The consumer expenses related to pumps consist in acquisition costs, installation costs, electricity costs and maintenance costs.

As regards the acquisition costs, details on the prices used for each pump type are reported in Annex 9.10. The prices are for the extended product (pump + motor + VSD where present) and include 20% VAT for the estimated share of (residential) users that effectively pay this tax (effectively this implies that 3-4% of the price is VAT).

As explained in more detail in the Annex, a price-elasticity has been created in the model, where prices depend on energy efficiency. The price for a product in a given year is then determined in function of the energy efficiency of new sold products in that year. For 2015, the price is based on a pump with MEI=0.4 using an IE3 motor or an IE2 motor with VSD of IE1 efficiency.

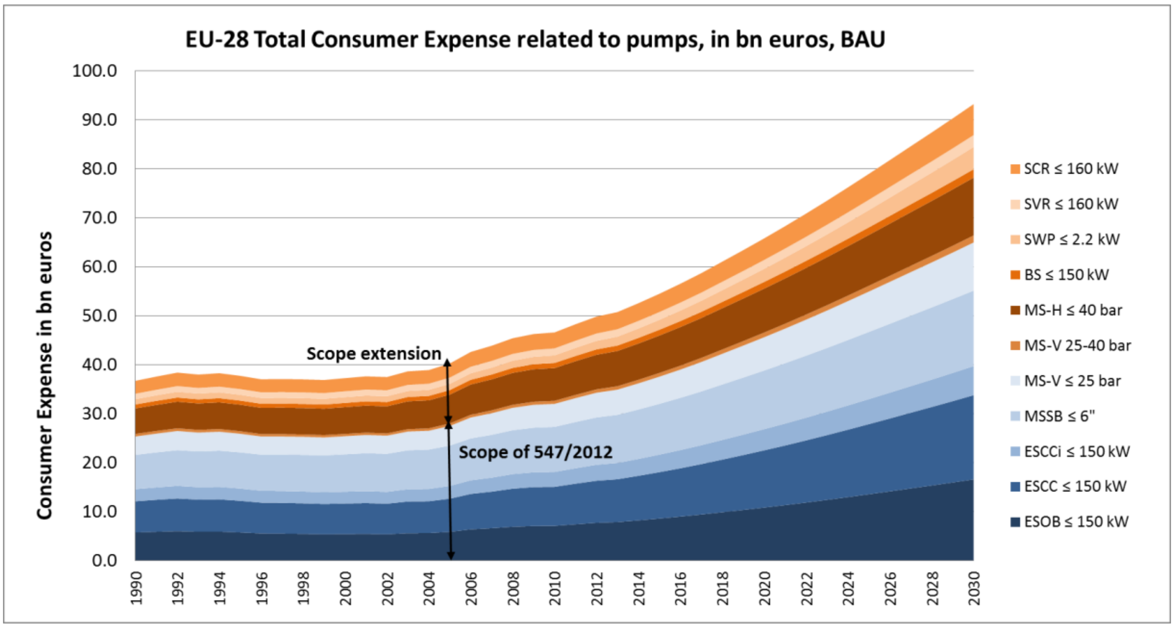
As regards energy costs, the electricity rates are reported in Annex 9.12. Separate rates are distinguished for residential and non-residential use, and in general an increase in the rates (above that of the inflation) has been implemented. E.g. the residential rates increase from 0.205 €/kWh in 2015 to 0.369 €/kWh in 2030.

All prices and costs are reported in fixed 2010 euros.

Details on the four cost components (acquisition, installation, electricity, maintenance) can be found in Annex 9.11-14. The figure below reports the EU-28 total consumer expense, i.e. the sum of all costs.

In 2015 the EU-28 total consumer expense related to pumps in the scope of the study is 54.5 billion euros, of which 5.6 for acquisition, 3.0 for installation, 31.3 for electricity and 14.6 for maintenance. Note that running costs (electricity and maintenance) represent 84% of the total cost.

Without further action (BAU-scenario) the expense is projected to increase to 65.8 billion euros in 2020 and 93.3 billion in 2030. This increase is due mainly to the growth in annual sales (and hence in stock and in electricity consumption) and to the increase of the electricity rate.



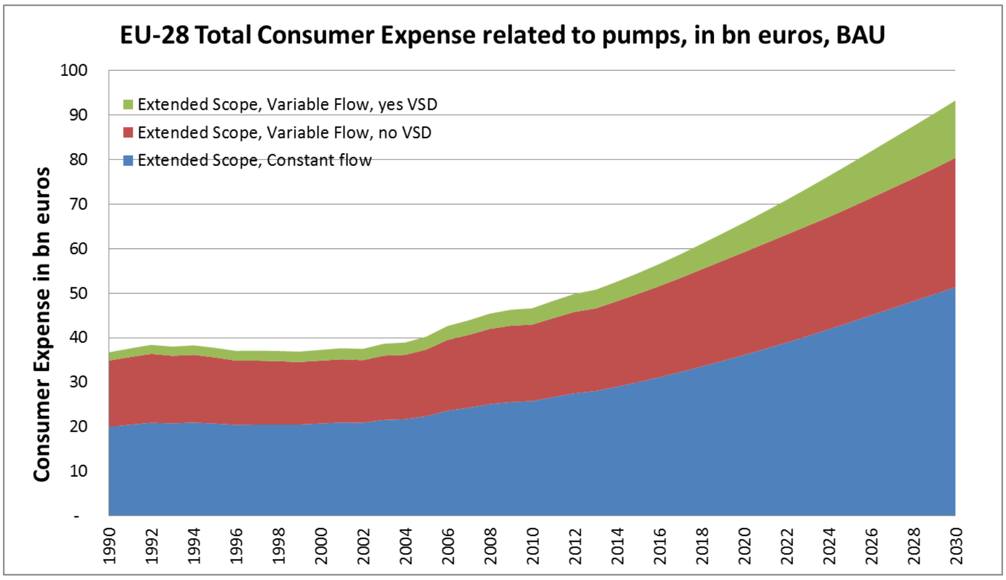


Figure 40. Total EU-28 Consumer Expense for acquiring, installing, operating and maintaining pumps in scope of the study, in billion euros, fixed euros 2010, BAU- and ECO3-scenarios.

12.3 Impacts on industry and consumers

In this chapter the impacts of the proposed Eco-design measures are evaluated by comparing the results for the three ECO scenarios with those for the BAU scenario.

The Eco-design measures have been introduced and lead to an increase in average energy efficiency for constant flow pumps and to a shift from pumps without VSD to pumps with VSD for variable flow applications, starting from 2020.

The model assumes that pump manufacturers will anticipate the measures, including some higher efficiency pumps and some additional pumps equipped with VSD in their portfolios already in 2019. Consequently, the eco-design measures already have some effects also in 2020.

The comparison is made for electricity consumption, greenhouse gas emissions, total consumer expenses and revenues and related jobs for the pump business sectors.

12.3.1 Electricity savings

Figure 41 and Table 57 show the EU-28 total annual electricity consumption for pumps in the scope of the study. Until 2019 the consumption is identical to that of the BAU-scenario. In later years the savings obtained in the ECO-scenarios gradually increase as a larger part of the installed stock of pumps is being replaced by higher efficiency pumps and/or by variable flow pumps with VSD. It takes approximately 10 years (the assumed useful lifetime of the pumps) before the entire stock has been replaced, so the maximum savings of the measures introduced in 2020 are obtained in 2030.

In that year the BAU electricity consumption is 261 TWh, against 218 TWh for ECO1 and 213 TWh for both ECO2 and ECO3. The corresponding electricity savings (Table 57, ECO vs BAU) are respectively 42.8, 47.3 and 48.0 TWh in 2030, i.e. 16-18% of the BAU electricity. This is a significant saving.

The difference in saving between the three ECO-scenarios is relatively small. This is mainly due to the fact that all three scenarios assume the same shift to variable flow pumps with VSD. The differences between the ECO-scenarios derive only from differences in average energy efficiency, and the corresponding savings are small compared to those from the shift to VSDs.

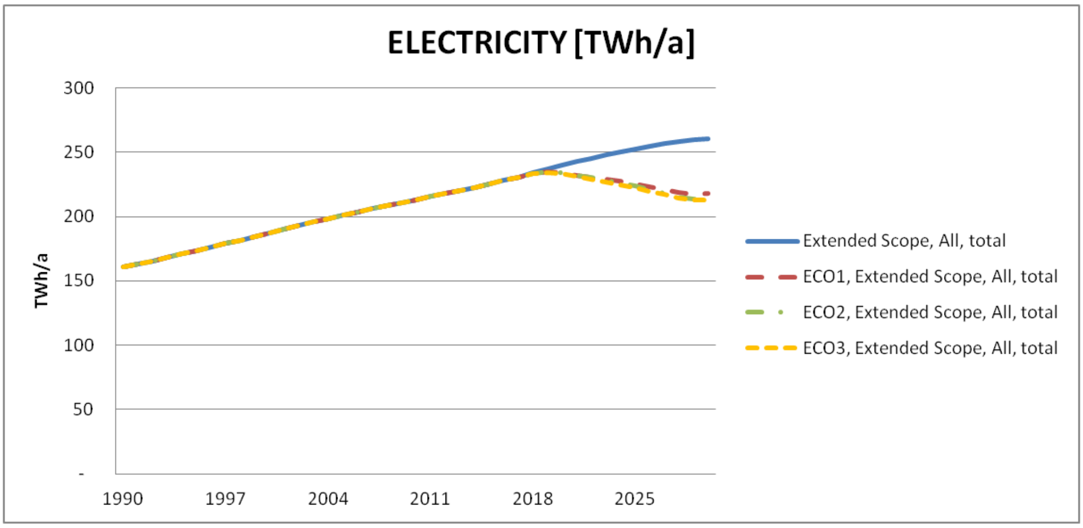


Figure 41. EU-28 Total Electricity consumption of pumps in the scope of the study, in TWh/a, comparison of the BAU-scenario with the three ECO-scenarios.

Table 57. EU-28 total annual Electricity consumption and savings ECO vs. BAU (in TWh/a).

ELECTRICITY	UNIT	2015	2020	2025	2030
ABSOLUTE					
BAU	TWh/a	225	240	253	261
ECO1	TWh/a	225	234	225	218
ECO2	TWh/a	225	234	223	213
ECO3	TWh/a	225	233	222	213
SAVINGS					
BAU	TWh/a				
ECO1	TWh/a	0.0	5.8	27.3	42.8
ECO2	TWh/a	0.0	5.9	29.3	47.3
ECO3	TWh/a	0.0	6.5	30.6	48.0

Electricity consumption by scope range

Figure 42 shows the contributions to the overall electricity consumption for pumps in the scope of the regulation 547/2012 (current scope) and those for other pumps in the scope of the study (scope extension). Scope extension does not include pumps in current scope, so it is possible to distinguish the annual energy consumption from the pumps in current scope to those which would be added by extending it (i.e. scope extension). Furthermore, it is possible to compare their potential savings when implementing the different policy measures. This figure clarifies that pumps in the scope of 547/2012 are dominant as regards electricity use and the savings obtained by the Ecodesign measures. This is further clarified by Figure 43 that provides the savings per scope-range in the three ECO-scenarios.

In 2020, the scope extension accounts for approximately 20% of the total savings. This share drops to 14-17% (depending on the Eco-scenario) in 2030.

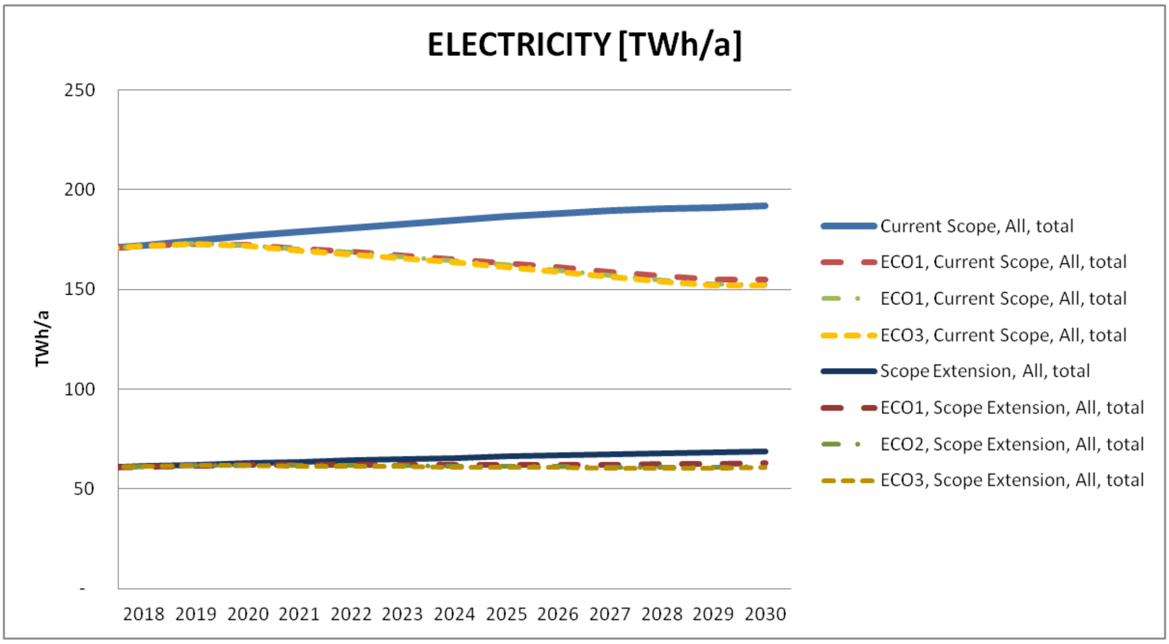


Figure 42. Contributions to the electricity consumption for pumps in the scope of Regulation 547/2012 (current scope) and for other pumps in the scope of the study (scope extension).

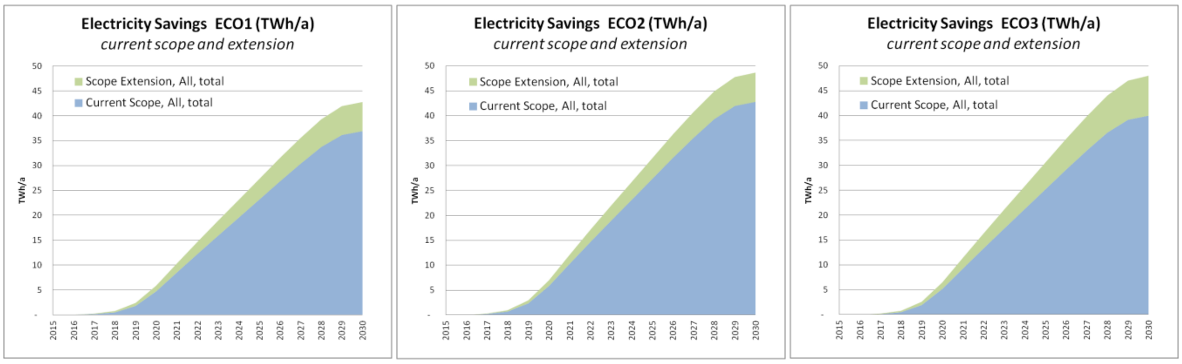


Figure 43. Electricity savings current scope vs scope extension.

Table 58. Contributions to the Electricity consumption for pumps in the scope of regulation 547/2012 (current scope) and for other pumps in the scope of the study (scope extension).

ELECTRICITY	UNIT	2015	2020	2025	2030
SAVINGS					
ORIGINAL SCOPE					
BAU	TWh/a	166	177	187	192
ECO1	TWh/a	0.0	4.7	23.2	36.9
ECO2	TWh/a	0.0	4.7	24.3	39.6
ECO3	TWh/a	0.0	5.1	25.2	40.0
SCOPE EXTENSION					
BAU	TWh/a	59	63	66	69
ECO1	TWh/a	0.0	1.1	4.2	5.9
ECO2	TWh/a	0.0	1.2	4.9	7.7
ECO3	TWh/a	0.0	1.3	5.4	8.0

Electricity savings per pump category

Figure 44 and Table 59 show the electricity savings per pump category. The major contributions come from the ESOB <22kW pumps (9.9 TWh/a in 2030, 21%) and ESCC <22kW (8.3 TWh/a, 17%).

In 2030, 92% of the savings is related to only half of the base cases: the ESOB, ESCC, ESCCi (all sizes), the MSSB, and the MS-V and MS-H both <25bar.

The wastewater pumps (SCR and SVR) cover only 2.6% of the 2030 savings.

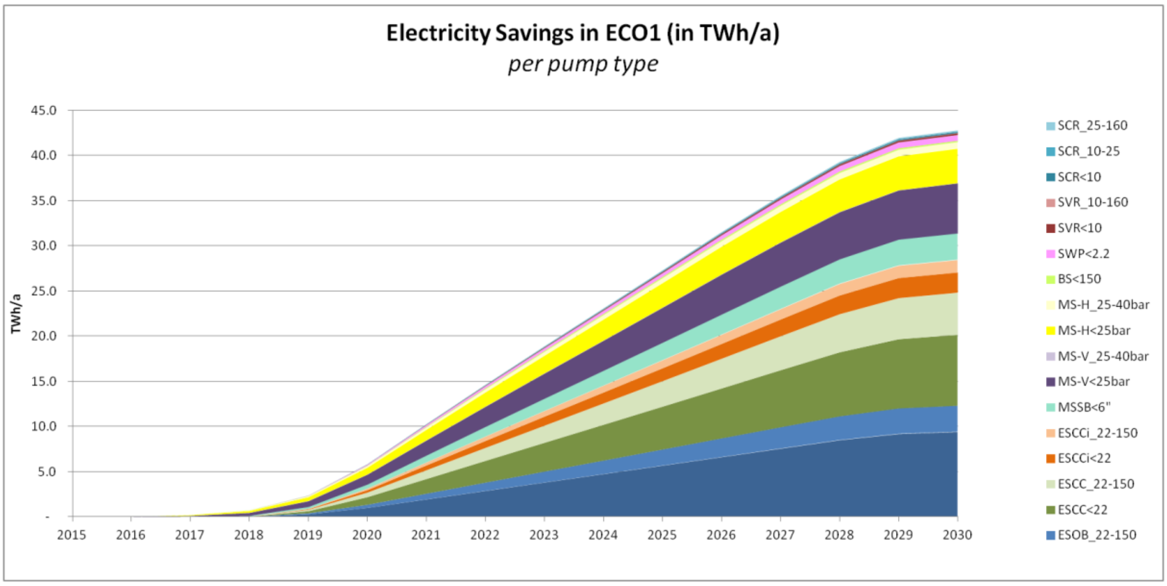


Figure 44. Annual electricity savings (TWh/a) per pump category (BAU-ECO1).

Table 59. Annual electricity savings (TWh/a) per pump category for the Eco-scenarios.

		2020			2025			2030		
		ECO1	ECO2	ECO3	ECO1	ECO2	ECO3	ECO1	ECO2	ECO3
ESOB<22	TWh/a	1.00	1.00	1.10	5.68	5.88	6.01	9.43	9.86	9.91
ESOB_22-150	TWh/a	0.35	0.35	0.42	1.78	1.94	2.05	2.89	3.22	3.26
ESCC<22	TWh/a	0.84	0.84	0.93	4.75	4.92	5.04	7.86	8.23	8.26
ESCC_22-150	TWh/a	0.50	0.50	0.56	2.81	2.93	3.01	4.65	4.89	4.92
ESCCi<22	TWh/a	0.27	0.27	0.28	1.43	1.44	1.45	2.24	2.27	2.27
ESCCi_22-150	TWh/a	017	0.17	0.17	0.88	0.89	0.89	1.38	1.40	1.40
MSSB<6"	TWh/a	0.46	0.50	0.57	1.96	2.40	2.72	2.95	3.95	4.18
MS-V<25bar	TWh/a	1.10	1.10	1.12	3.87	3.96	4.03	5.54	5.76	5.81
MS-V_25-40bar	TWh/a	0.00	0.01	0.01	0.02	0.04	0.05	0.03	0.07	0.08
MS-H<25bar	TWh/a	0.75	0.76	0.79	2.69	2.84	2.95	3.81	4.16	4.24
MS-H_25-40bar	TWh/a	0.17	0.17	0.18	0.54	0.58	0.60	0.69	0.77	0.79
BS<150	TWh/a	0.06	0.06	0.09	0.16	0.13	0.27	0.17	0.21	0.32
SWP<2.2	TWh/a	0.09	0.11	0.11	0.39	0.76	0.76	0.62	1.37	1.37
SVR<10	TWh/a	0.02	0.03	0.05	0.13	0.20	0.26	0.21	0.38	0.42
SVR_10-160	TWh/a	0.00	0.00	0.01	0.02	0.03	0.04	0.03	0.05	0.06
SCR<10	TWh/a	0.02	0.02	0.04	0.09	0.15	0.20	0.13	0.28	0.32
SCR_10-25	TWh/a	0.01	0.01	0.01	0.03	0.05	0.07	0.04	0.10	0.11
SCR_25-160	TWh/a	0.02	0.02	0.04	0.08	0.15	0.20	0.13	0.29	0.33
TOTAL	**TWh/a**	**5.84**	**5.94**	**6.47**	**27.32**	**29.27**	**30.59**	**42.81**	**47.27**	**48.05**

Electricity savings per flow type

Figure 45 and Figure 46 show the electricity consumption and the savings subdivided per scope-range and per flow type.

The majority of the savings derive from the Ecodesign measurements on variable flow applications (i.e. mainly due to the shift towards VSD use). In ECO1 the share of variable flow in the savings is 86%, in ECO2 78% and in ECO3 82%).

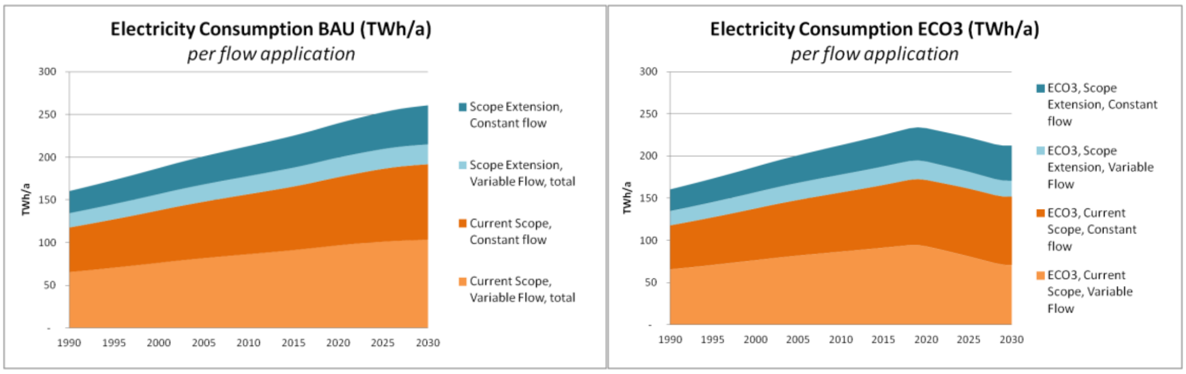


Figure 45. Electricity consumption per scope-range and per flow type.

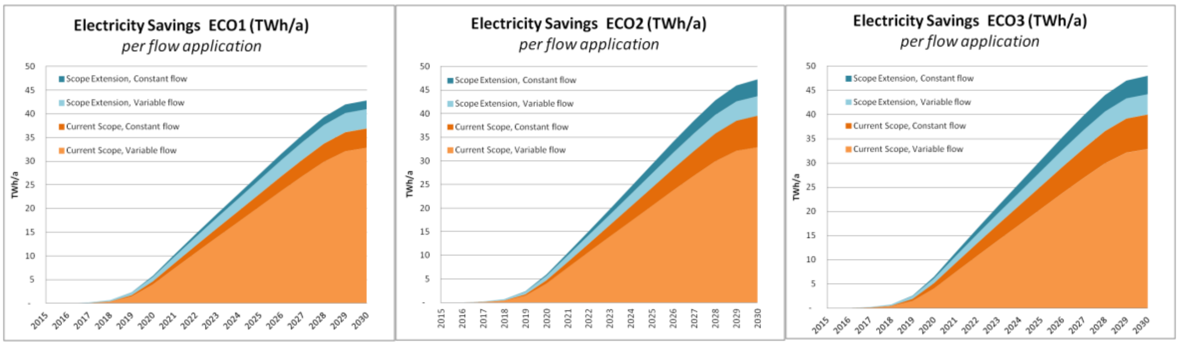


Figure 46. Electricity savings per scope-range and per flow type.

12.3.2 Greenhouse gas emission savings

Figure 47 and Table 60 show the annual greenhouse gas emissions in Mt CO_2 eq./a for the BAU- and ECO-scenarios. Previously shown in the BAU-scenario these emissions remain more or less constant around 90 Mt CO_2 eq./a over the period 2015-2030 because the increasing electricity consumption is compensated by a decreasing GWPel.

The annual emission savings vary from 14.6 (ECO1) to 16.1 (ECO2) to 16.3 Mt CO_2 eq/a for ECO3.

Table 60. Total EU-28 greenhouse gas emissions in Mt CO2 eq./a, for the BAU-scenario and for the ECO-scenarios, and savings ECO vs. BAU.

EMISSIONS	UNIT	2015	2020	2025	2030
ABSOLUTE					
BAU	$MtCO_2$ eq/a	89	91	91	89
ECO1	MtCO2 eq/a	89	89	81	74
ECO2	MtCO2 eq/a	89	89	80	73
ECO3	MtCO2 eq/a	89	89	80	72
SAVINGS					
BAU	MtCO2 eq/a				
ECO1	MtCO2 eq/a	0.0	2.2	9.8	14.6
ECO2	MtCO2 eq/a	0.0	2.3	10.5	16.1
ECO3	MtCO2 eq/a	0.0	2.5	11.0	16.3

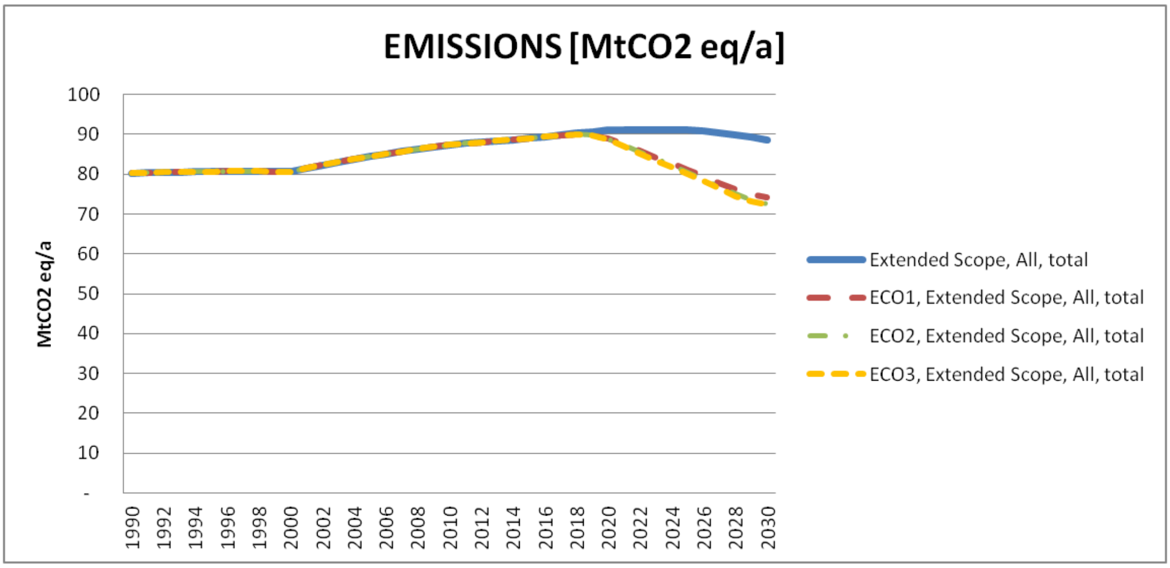


Figure 47. Total EU-28 greenhouse gas emissions in Mt CO_2 eq./a, for the BAU-scenario and for the ECO-scenarios.

12.3.3 Life cycle costs (LCC) for consumer

By introducing new ecodesign requirements, the life cycle costs (LCC) for the consumer will be affected, in particular the purchase price, due to improvements in the pump unit, and the use phase, due to the potential savings from lower electricity consumption. The other costs, i.e. installation and repair & maintenance costs, are not affected and will therefore remain constant.

Because the new ecodesign requirements consider the whole extended product, i.e. the pump unit, the LCC have to consider the additional costs from purchasing a more efficient motor and/or purchasing a VSD (for variable flow applications). Therefore, the LCC presented herein considers the costs from purchasing, installing and maintaining the whole pump unit. End-of-life costs are assumed to be zero as disposal costs are covered by the manufacturers, and ultimately partly or totally absorbed by the consumer in the purchase price.

For BAU, the LCC considers the relevant motor types and motor efficiencies which are typically installed with the bare shaft pumps, and the use of VSDs in the case of variable flow applications. These considerations are based on current market development according to input received from industry throughout the whole review study.

For the ECO scenarios, the LCC considers improved bare shaft pumps as well as motor types and efficiencies so the pump units can comply with the proposed EEI requirements, together with the use of VSDs for all the variable flow applications.

In the below sections the increase in purchase costs and decrease in electricity costs (due to energy savings) are explained[331].

[331] Potential increase of installation and maintenance costs in this assessment was assumed negiglible according to input from industry. However, this could turn to be significant considering installers would require special knowledge on the installation of VSDs. Moreover, the end-users may also require special training for maintaining the pump units with a VSD. This shall be further investigated by establishing a dialogue with installers, which will also be needed for quantification of potential savings and impacts from implementing PO2 and PO3 (as described in chapters 13 and 14).

Only LCC from ECO1 and ECO2 are shown in relation to BAU, since only these two policy scenarios involve changes in requirements and the implementation of the EPA. ECO3 introduces additional changes only concerning implementation dates. Moreover, the LCC is presented separately for constant flow applications and variable flow applications for each base case to observe any difference. In order to simplify the presentation of results and improve their interpretation, base cases for different bare shaft pump sizes have been aggregated based on sales numbers. For variable flow applications, a sales-weighted aggregation was also done considering pump units operating with and without VSDs. So the LCC of each base case represent the average product on the market and the additional costs/savings from implementing reviewed ecodesign requirements.

Consumer purchase price costs

The costs for consumer when purchasing pump units include:

- For constant flow applications: the price of a bare shaft pump and the price of an electric motor
- For variable flow applications: the price of a bare shaft pump, of an electric motor and of a VSD, in the case a pump unit is operated with a VSD

For BAU, the purchase price of the base cases used in constant flow applications has been estimated based on their combined efficiency. This is the actual efficiency of the bare shaft pump and electric motor together, data which was provided by industry based on market trends up to 2030. Average market prices of electric motors and bare shaft pumps were used as reference, as well as the theoretical combined efficiency using a bare shaft pump with the three different levels of motor efficiency (i.e. IE2, IE3 and IE4). Any difference between theoretical and actual efficiencies was attributed to using a lower or higher efficiency motor class. Price difference from switching to better/worse motor efficiency class could then be established, and used to adjust the pump unit's purchase price to its actual efficiency.

For the base cases used in variable flow applications, the BAU purchase price has been estimated including the average market price of a VSD IE1, adapting the pump unit's purchase price to its actual efficiency as done for pump units used in constant flow applications.

For ECO1 and ECO2 scenarios, the purchase prices of the base cases were also estimated by adjusting the efficiencies. However, instead of an actual efficiency, a predicted efficiency was used based on the proposed ecodesign requirements presented in section 12.14. The predicted efficiency was estimated up to 2030 considering a shift towards more efficient pump units after implementation date of the proposed requirements.

For more details on the underlying data please see Annex 9, section 9.10.

Increases in the bases cases' purchase prices up to 2030 were then estimated. An overview to these is presented in Table 61.

Table 61. Increase in pump units' purchase price (EUR) from 2020 to 2030 for all the base cases[332]. Comparison is done in reference to BAU 2020 price.

BASE CASE	ECO1	ECO2
ESOB constant	1	1

[332] 2020 was used as reference year as this is the first implementation date of the proposed requirements.

BASE CASE	ECO1	ECO2
ESOB variable	299	299
ESCC constant	1	1
ESCC variable	323	323
ESCCi constant	0	1
ESCCi variable	198	198
MSSB constant	2	3
MSSB variable	175	175
MS-V constant	0	0
MS-V variable	221	221
MS-H constant	1	1
MS-H variable	183	183
Booster-sets	169	473
SWP constant	0	0
SVR constant	2	4
SVR variable	2	5
SCR constant	18	39
SCR variable	60	157

Table 61 shows that price increase of pump units used in constant flow applications is much lower than pump units in variable flow applications. This is because the combined efficiency achieved by pump units operating in constant flow systems, according to current market trends, is limited so the proposed energy efficiency requirements can be achieved by a relatively small additional cost. However, for variable flow applications the increase comes mainly from purchasing VSDs in variable flow applications. In order to achieve the proposed ecodesign requirements, all pump units used in variable flow applications will have a VSD by 2021.

Electricity costs for the consumer during use of the pump units

The costs of the pump units using electricity both in constant and variable flow applications were calculated based on:

- Actual and predicted energy efficiencies, same used for estimating the pump units' purchase prices. These were used to calculate the actual and predicted energy consumption of the whole pump unit (P1). Same were used to calculate the electricity savings in section 12.3.1.
- Forecasted electricity prices from Primes[333] up to 2030.
- The lifetime of the pump units.
- An annual discount rate of 4%.

An overview of the differences in electricity costs compared to those in BAU is presented in Table 62.

Table 62. Increase in electricity costs (EUR) from 2020 to 2030 for all the base cases[334]. Comparison is done in reference to BAU 2020 costs. Negative values are savings.

BASE CASE	ECO1	ECO2
ESOB constant	-395	-916
ESOB variable	-7930	-7930

[333] PRIMES 2016, provided by European Commission, DG ENER A4

[334] 2020 was used as reference year as this is the first implementation date of the proposed requirements.

BASE CASE	ECO1	ECO2
ESCC constant	-351	-783
ESCC variable	-7902	-7902
ESCCi constant	156	-221
ESCCi variable	-4049	-4049
MSSB constant	-215	-374
MSSB variable	-879	-879
MS-V constant	-1	-179
MS-V variable	-3714	-3714
MS-H constant	-152	-276
MS-H variable	-1262	-1262
Booster-sets	-673	-1005
SWP constant	-81	-192
SVR constant	-185	-402
SVR variable	-128	-259
SCR constant	-45	-380
SCR variable	-41	-126

Results

Figure 48 shows the total LCC for the BAU scenario in 2030, with the contributions from purchasing cost, installation cost, repair and maintenance cost, and cost of electricity for each base case throughout their lifetime. Electricity costs are dominant for six of the base cases, while repair and maintenance cost is an important contributor in most of the base cases due to the high average costs per year (for the underlying data please see section 6.4.3).

The LCCs are higher for variable flow applications in all the end suction base cases (i.e. ESOB, ESCC, ESCCi) and multi-stage vertical and horizontal base cases, where the same pump type is used in both constant and variable flow applications. This is primarily due to the larger electricity cost, as the market share of VSD use in these applications for these pump types is low (see Table 109). Use of pump units in variable flow applications without VSD makes them less efficient and thus more costly.

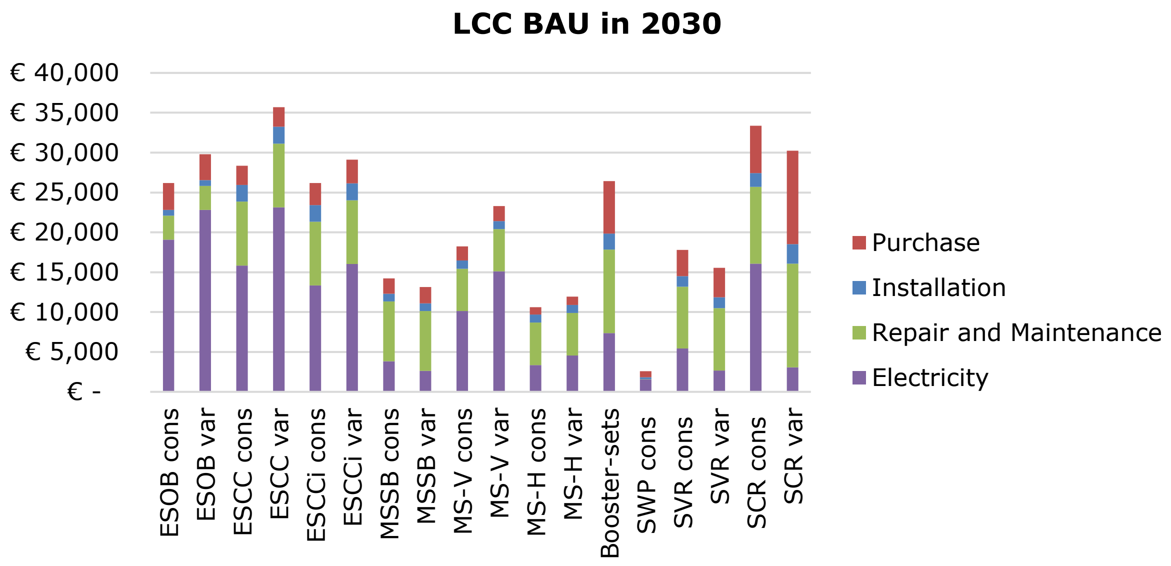


Figure 48. LCC for the BAU scenario divided into purchase, installation, repair and maintanance cost and electricity costs.

Figure 49 shows the total LCC for the BAU, ECO1, and ECO2 scenarios. For some base cases, specially those used in variable flow applications, the difference between BAU and ECO1/ECO2 is large. However, the difference between ECO1 and ECO2 is marginal for all base cases disregardless of the application. The largest savings originate from pumps used in variable flow applications, in particular due to the use of VSDs. Base cases already with a high use of VSDs in variable flow applications, present small LCC savings.

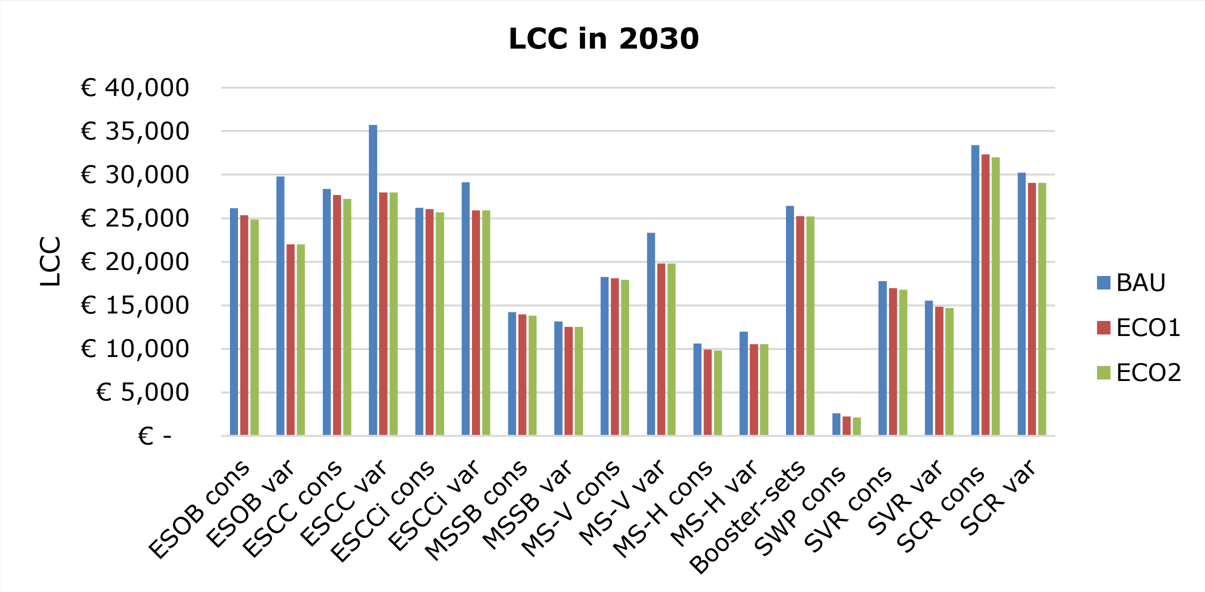


Figure 49. Total LCC for BAU, ECO1, and ECO2 scenarios.

Table 63 lists the additional costs/savings when comparing the ECO scenarios to BAU. These are shown only for purchase, electricity and total costs. Since the installation and repair and maintenance costs are assumed to be equal between the three scenarios, the difference in total costs is equal to the difference in purchase and electricity costs.

Overall, the additional costs per product from purchasing will be counteracted by costs savings from electricity in 2030.

Table 63. Additional costs/Savings for ECO1 and ECO2 in 2030, when comparing to BAU in 2030. All values in EUR. Negative values are savings.

Basecase	ECO1			ECO2		
	Purchase cost	Electricity cost	Total	Purchase cost	Electricity cost	Total
ESOB cons	1	-828	**-827**	1	-1349	**-1348**
ESOB var	288	-8108	**-7820**	288	-8108	**-7820**
ESCC cons	1	-709	**-708**	1	-1141	**-1140**
ESCC var	310	-8064	**-7754**	310	-8064	**-7754**
ESCCi cons	0	-142	**-142**	1	-519	**-518**
ESCCi var	152	-3379	**-3227**	152	-3379	**-3227**
MSSB cons	2	-259	**-258**	3	-418	**-415**
MSSB var	150	-795	**-645**	150	-795	**-645**
MS-V cons	0	-142	**-142**	0	-320	**-319**
MS-V var	204	-3701	**-3497**	204	-3701	**-3497**
MS-H cons	1	-194	**-193**	1	-318	**-317**
MS-H var	152	-1075	**-923**	152	-1075	**-923**
Booster-sets	58	-296	**-237**	362	-628	**-265**
SWP cons	0	-92	**-92**	0	-204	**-204**
SVR cons	2	-256	**-254**	3	-473	**-470**
SVR var	2	-159	**-157**	4	-290	**-286**
SCR cons	13	-284	**-271**	34	-618	**-585**
SCR var	60	-84	**-24**	156	-169	**-12**

12.3.4 Consumer expenditure savings

The total consumer expenditure related to acquisition, installation, operation and maintenance of the pumps in the scope of the study were 55 bn euros in 2015, increasing up to 93 bn euros in 2030 (see Table 64). These consumer expenditure costs are related to the acquisition, installation, operation and maintenance of the pumps in the case where no amendments to the Water Pump Regulation 547/2012 take place (BAU-scenario). Table 64 shows these costs and the additional costs or savings that can be obtained if any of the energy efficiency requirements defined in the policy scenarios section are implemented (i.e. ECO-scenarios). The additional costs and savings are presented for the whole EU28 stock.

Concerning the additional acquisition costs from implementing the ecodesign requirements, these originate from installing a VSD on the pump unit when operating at variable flow applications (see Table 64). On average, these better performing products entail slightly higher acquisition costs for the consumers (+0.2 bn euros), but this is more than compensated by savings on the electricity costs, ranging from 10.6 to 12 billion euros in 2030, depending on the scenario chosen. Additional installation and maintenance costs have not been quantified but are assumed negiglible compared to the acquisition costs.

The overall results are savings on total consumer expenditure of 10.4 to 11.7 billion euros in 2030, depending on the scenario chosen. These are savings of more than 10%, which can be seen in Figure 50. The figure shows the total consumer expenditure from 1990-2030 for the four different scenarios.

Table 64. Overview of EU-28 annual consumer expenditure, in billion euros[335] incl. VAT for residential buyers (negative values are savings).

		2015	2020	2025	2030
ACQUISITION COSTS in bn euros/a					
BAU	absolute	6	6.2	6.5	6.6
ECO1	additional costs		0.2	0.2	0.2
ECO2	additional costs		0.2	0.2	0.2
ECO3	additional costs		0.2	0.2	0.2
ELECTRICITY COSTS in bn euros/a					
BAU	absolute	31	40.6	52.1	65.4
ECO1	additional costs		-1.0	-5.6	-10.6
ECO2	additional costs		-1.0	-6.0	-11.8
ECO3	additional costs		-1.1	-6.3	-12.0
INSTALLATION COSTS in bn euros/a					
BAU	absolute	3.0	3.2	3.4	3.5
ECO1	additional costs		0.0	0.0	0.0
ECO2	additional costs		0.0	0.0	0.0
ECO3	additional costs		0.0	0.0	0.0
MAINTENANCE in bn euros/a					
BAU	absolute	15	15.8	17.0	17.7
ECO1	additional costs		0.0	0.0	0.0
ECO2	additional costs		0.0	0.0	0.0
ECO3	additional costs		0.0	0.0	0.0
TOTAL EXPENSE in bn euros/a					
BAU	**absolute**	**55**	**65.8**	**79**	**93.3**
ECO1	**additional costs**		**-0.8**	**-5.3**	**-10.4**
ECO2	**additional costs**		**-0.8**	**-5.8**	**-11.6**
ECO3	**additional costs**		**-0.9**	**-6.0**	**-11.7**

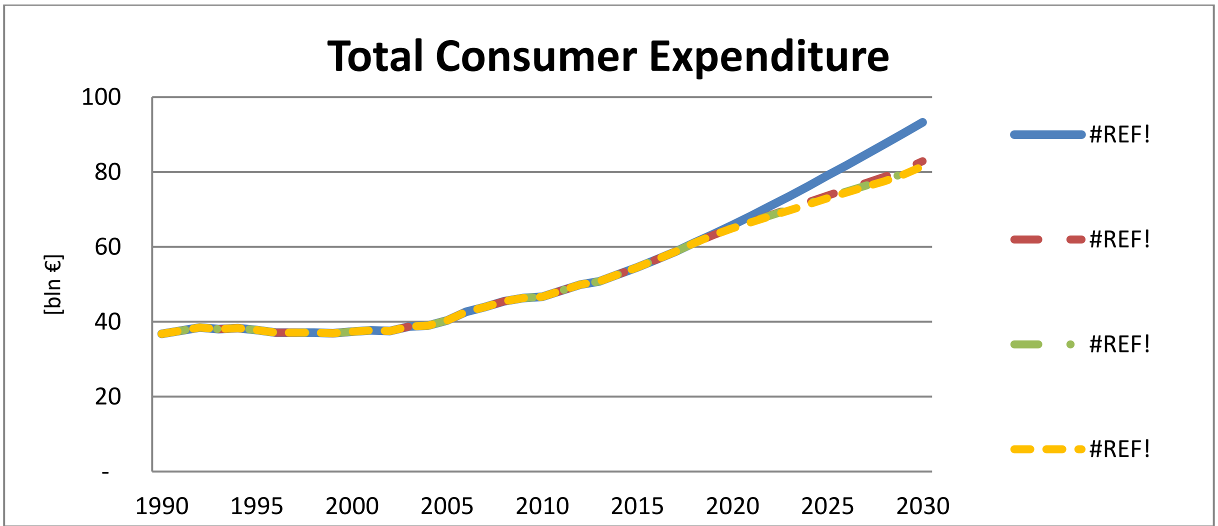


Figure 50. Total EU-28 consumer costs for all scenarios related to pumps in the scope of the study.

The annual EU28 consumer expenditure shown in Table 64 are broken down per pump type and can be seen in Table 65 to Table 69. The breakdown by 2030 is shown in Figure

[335] Fixed rate 2010

51 to Figure 53. It is apparent from Table 65 & Figure 51 that the main additional acquisition costs are found in the ESOB, ESCC & ESCCi pumps (~46% of acquisition costs) but also in the MS-H < 25 category (~23% of total).

Both installation and maintenance costs show no difference between the BAU and ECO scenarios, see Table 66 & Table 67.

The main reason for the total net savings are the electricity savings, see Table 68 & Figure 52. Again the main savings originate from ESOB, ESCC & ESCCi pumps (~65% of electricity costs savings) but there is also a significant contribution from MS-V < 25 & MS-H < 25 (~20% of total).

Five pump types account for ~85% of the total net savings, see Table 68 & Figure 53. That is the end suction pumps (ESOB, ESCC & ESCi) & the low pressure multistage pumps (MS-V <25 & MS-H <25). The remainder is primarily related to MSSB & SWP.

Table 65. Overview of EU-28 annual acquisition costs, in billion euros[335] incl. VAT for residential buyers.

Acquisition [bln €]	BAU Total Cost				ECO 1 Additional Costs			ECO 2 Additional Costs			ECO 3 Additional Costs		
	2015	2020	2025	2030	2020	2025	2030	2020	2025	2030	2020	2025	2030
ESOB	0.84	0.91	0.95	0.96	0.03	0.04	0.04	0.03	0.04	0.04	0.03	0.04	0.04
ESCC	0.62	0.67	0.70	0.71	0.03	0.04	0.05	0.03	0.04	0.05	0.03	0.04	0.05
ESCCi	0.29	0.32	0.34	0.34	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.02
MS-V <25	0.43	0.46	0.48	0.49	0.02	0.03	0.03	0.02	0.03	0.03	0.02	0.03	0.03
MS-V 25-40	0.04	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MS-H <25	0.51	0.56	0.59	0.60	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
MS-H 25-40	0.07	0.08	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSSB	1.38	1.49	1.55	1.56	0.02	0.02	0.03	0.02	0.03	0.03	0.02	0.03	0.03
Booster-Sets	0.26	0.28	0.30	0.31	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.02
SWP	0.38	0.44	0.50	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SVR	0.27	0.29	0.31	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCR	0.60	0.64	0.68	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**5.69**	**6.20**	**6.53**	**6.63**	**0.18**	**0.21**	**0.21**	**0.18**	**0.23**	**0.23**	**0.19**	**0.23**	**0.23**

Table 66. Overview of EU-28 annual installation costs, in billion euros[335] incl. VAT for residential buyers.

Installation [bln €]	BAU Total Cost				ECO 1 Additional Costs			ECO 2 Additional Costs			ECO 3 Additional Costs		
	2015	2020	2025	2030	2020	2025	2030	2020	2025	2030	2020	2025	2030
ESOB	0.18	0.20	0.21	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ESCC	0.53	0.58	0.60	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ESCCi	0.21	0.23	0.24	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MS-V <25	0.25	0.28	0.29	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MS-V 25-40	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MS-H <25	0.61	0.66	0.69	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MS-H 25-40	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSSB	0.68	0.74	0.77	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Booster-Sets	0.08	0.09	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWP	0.13	0.15	0.17	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SVR	0.11	0.12	0.13	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCR	0.17	0.18	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TOTAL	3.00	3.26	3.42	3.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 67. Overview of EU-28 annual maintenance costs, in billion euros[335] incl. VAT for residential buyers.

Maintenance [bln €]	BAU Total Cost				ECO 1 Additional Costs			ECO 2 Additional Costs			ECO 3 Additional Costs		
	2015	2020	2025	2030	2020	2025	2030	2020	2025	2030	2020	2025	2030
ESOB	0.71	0.77	0.83	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ESCC	1.89	2.06	2.21	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ESCCi	0.76	0.82	0.89	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MS-V <25	1.24	1.35	1.45	1.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MS-V 25-40	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MS-H <25	2.96	3.22	3.46	3.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MS-H 25-40	0.10	0.11	0.12	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSSB	4.97	5.41	5.81	6.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Booster-Sets	0.40	0.43	0.46	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWP	0.02	0.02	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SVR	0.62	0.65	0.70	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SCR	0.89	0.95	1.01	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	14.58	15.83	17.00	17.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 68. Overview of EU-28 annual electricity costs, in billion euros[335] incl. VAT for residential buyers (negative values are savings).

Electricity [bln €]	BAU Total Cost				ECO 1 Additional Costs			ECO 2 Additional Costs			ECO 3 Additional Costs		
	2015	2020	2025	2030	2020	2025	2030	2020	2025	2030	2020	2025	2030
ESOB	6.86	8.95	11.56	14.55	-0.22	-1.51	-3.03	-0.22	-1.58	-3.21	-0.25	-1.63	-3.23
ESCC	6.43	8.38	10.81	13.59	-0.22	-1.53	-3.07	-0.22	-1.58	-3.22	-0.25	-1.62	-3.24
ESCCi	2.31	2.95	3.64	4.43	-0.07	-0.47	-0.89	-0.07	-0.47	-0.90	-0.07	-0.47	-0.90
MS-V <25	3.64	4.71	6.03	7.55	-0.18	-0.78	-1.36	-0.18	-0.80	-1.41	-0.19	-0.81	-1.43
MS-V 25-40	0.69	0.88	1.09	1.36	0.00	0.00	-0.01	0.00	-0.01	-0.02	0.00	-0.01	-0.02
MS-H <25	2.29	2.92	3.67	4.54	-0.12	-0.54	-0.94	-0.13	-0.57	-1.02	-0.13	-0.60	-1.04
MS-H 25-40	1.09	1.40	1.75	2.15	-0.03	-0.11	-0.17	-0.03	-0.12	-0.19	-0.03	-0.12	-0.19
MSSB	3.37	4.37	5.61	7.04	-0.08	-0.40	-0.72	-0.08	-0.48	-0.97	-0.09	-0.55	-1.03
Booster-Sets	0.45	0.56	0.69	0.83	-0.01	-0.03	-0.04	-0.01	-0.03	-0.05	-0.01	-0.05	-0.08
SWP	1.49	2.06	2.84	3.82	-0.02	-0.12	-0.23	-0.03	-0.23	-0.50	-0.03	-0.23	-0.50
SVR	0.59	0.75	0.97	1.25	0.00	-0.03	-0.06	-0.01	-0.05	-0.11	-0.01	-0.06	-0.12
SCR	2.06	2.63	3.40	4.35	-0.01	-0.04	-0.08	-0.01	-0.07	-0.17	-0.01	-0.10	-0.19
TOTAL	31.28	40.55	52.08	65.45	-0.98	-5.56	-10.59	-1.00	-5.99	-11.78	-1.08	-6.26	-11.98

Table 69 Overview of EU-28 annual costs for consumers, in billion euros[335] incl. VAT for residential buyers (negative values are savings).

Total Additonal Costs [bln €]	BAU Total Cost				ECO 1 Additional Costs			ECO 2 Additional Costs			ECO 3 Additional Costs		
	2015	2020	2025	2030	2020	2025	2030	2020	2025	2030	2020	2025	2030
ESOB	8.60	10.83	13.55	16.59	-0.19	-1.47	-2.99	-0.19	-1.54	-3.17	-0.22	-1.59	-3.19
ESCC	9.47	11.69	14.33	17.21	-0.19	-1.48	-3.03	-0.19	-1.54	-3.18	-0.21	-1.58	-3.19
ESCCi	3.58	4.32	5.11	5.94	-0.06	-0.45	-0.87	-0.06	-0.45	-0.88	-0.06	-0.46	-0.89
MS-V <25	5.56	6.80	8.26	9.84	-0.16	-0.75	-1.33	-0.16	-0.77	-1.38	-0.16	-0.78	-1.40
MS-V 25-40	0.76	0.96	1.18	1.45	0.00	0.00	-0.01	0.00	-0.01	-0.02	0.00	-0.01	-0.02
MS-H <25	6.36	7.36	8.41	9.43	-0.08	-0.49	-0.89	-0.08	-0.52	-0.97	-0.09	-0.55	-0.99
MS-H 25-40	1.28	1.61	1.97	2.37	-0.03	-0.11	-0.17	-0.03	-0.11	-0.19	-0.03	-0.12	-0.19

Total Additonal Costs [bln €]	BAU Total Cost				ECO 1 Additional Costs			ECO 2 Additional Costs			ECO 3 Additional Costs		
	2015	2020	2025	2030	2020	2025	2030	2020	2025	2030	2020	2025	2030
MSSB	10.40	12.01	13.74	15.43	-0.05	-0.37	-0.70	-0.06	-0.46	-0.94	-0.07	-0.52	-1.00
Booster-Sets	1.18	1.37	1.55	1.71	-0.01	-0.03	-0.04	0.00	-0.01	-0.03	0.00	-0.04	-0.06
SWP	2.03	2.68	3.54	4.54	-0.02	-0.12	-0.23	-0.03	-0.23	-0.50	-0.03	-0.23	-0.50
SVR	1.60	1.82	2.11	2.43	0.00	-0.03	-0.06	-0.01	-0.05	-0.11	-0.01	-0.06	-0.12
SCR	3.73	4.40	5.29	6.32	-0.01	-0.04	-0.08	-0.01	-0.07	-0.17	-0.01	-0.09	-0.19
TOTAL	**54.54**	**65.85**	**79.03**	**93.27**	**-0.80**	**-5.35**	**-10.38**	**-0.82**	**-5.76**	**-11.55**	**-0.89**	**-6.03**	**-11.75**

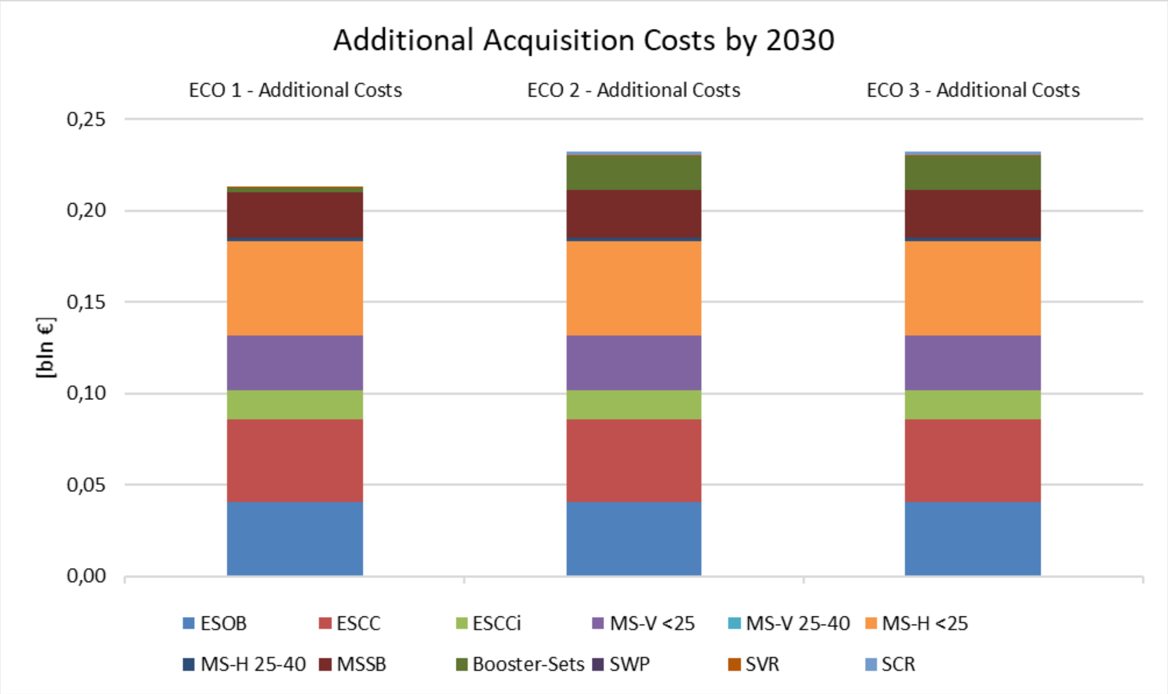


Figure 51. Additional acquistion costs by pump type from implementing the three ECO scenarios for the extended scope.

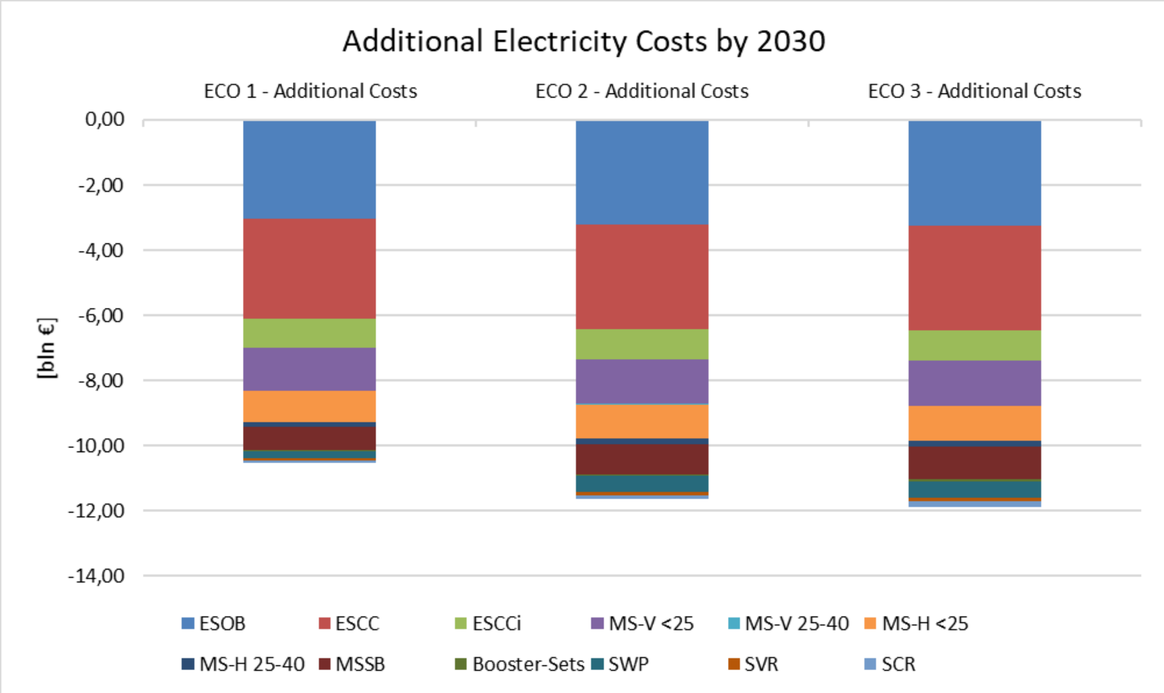


Figure 52. Net electricity savings by pump type from implementing the three ECO scenarios for the extended scope (negative values are savings).

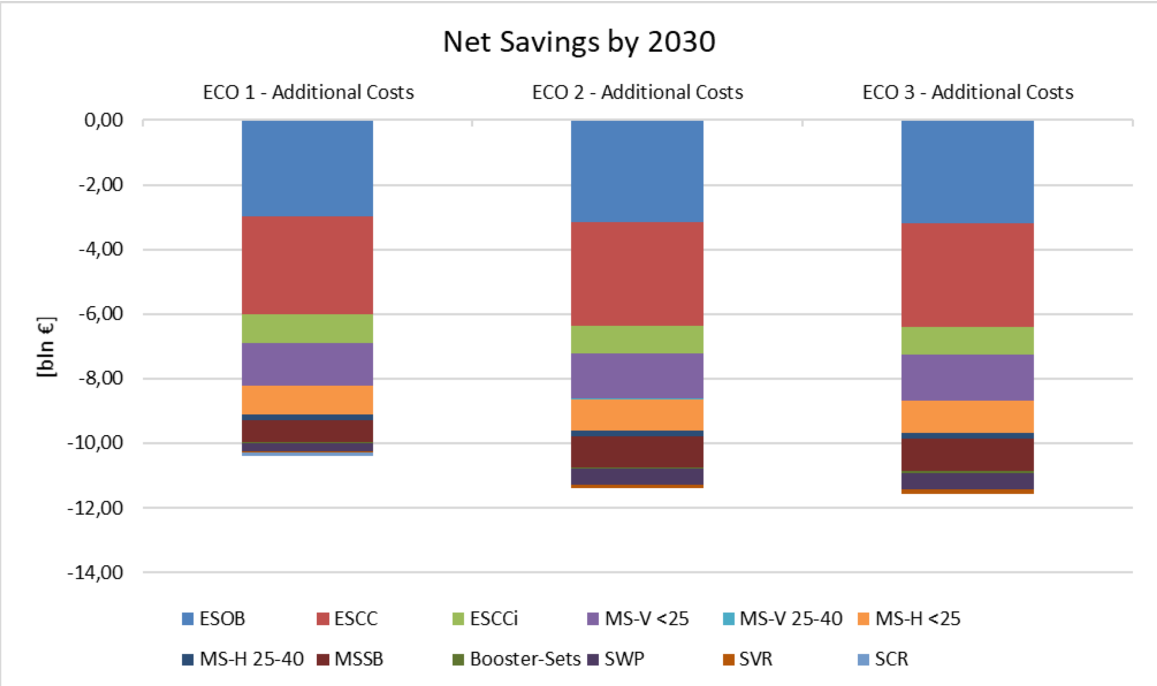


Figure 53. Net total consumer expenditure savings by pump type from implementing the three ECO scenarios for the extended scope (negative values are savings).

12.3.5 Revenues and jobs

The shares of the purchase prices that form revenue for industry, wholesalers and retailers are defined in Annex 9.10.

Table 70 shows the EU-28 total revenues for these sectors for the BAU-scenario and the increases in revenue in the ECO-scenarios, due to the higher average acquisition costs.

The highest increase in (combined) revenue is obtained in the ECO3 scenario in 2030: 155+46+23 = 224 mln euros extra on a total revenue of 6338 mln euros, an increase of 3.5%.

For installers and maintenance, the model does not include any differences in costs and consequently there are no additional revenues.

Table 70. Revenues for industry, wholesale and retail (in million Euros).

		2015	2020	2025	2030
INDUSTRY REVENUE					
BAU	absolute mln €	3,738	4,072	4,280	4,348
ECO1	increase [mln €]		118	140	142
ECO2	increase [mln €]		120	154	155
ECO3	increase [mln €]		128	154	155
WHOLESALE REVENUE					
BAU	absolute	1,100	1,196	1,256	1,275
ECO1	increase [mln €]		35	42	43
ECO2	increase [mln €]		36	46	46
ECO3	increase [mln €]		39	46	46
RETAIL REVENUE					
BAU	absolute	607	665	702	715
ECO1	increase [mln €]		18	21	21
ECO2	increase [mln €]		18	23	23
ECO3	increase [mln €]		19	23	23

The sector revenues are related to jobs by means of constant factors, as explained in Annex 9.16. The results are shown in Table 71 and show a total of 3 700 newly created jobs in the ECO3 scenario in 2030, on a total of 104 000 jobs in BAU.

Table 71. Jobs (in thousands) related to the manufacturing and trading of pumps in the scope of the study for industry, wholesale and retail (not necessarily all inside EU-28).

INDUSTRY JOBS*1000		2015	2020	2025	2030
BAU	absolute	75	81	86	87
ECO1	increase	0	2.4	2.8	2.8
ECO2	increase	0	2.4	3.1	3.1
ECO3	increase	0	2.6	3.1	3.1
WHOLESALE JOBS * 1000					
BAU	absolute	4	5	5	5
ECO1	increase	0	0.1	0.2	0.2
ECO2	increase	0	0.1	0.2	0.2
ECO3	increase	0	0.2	0.2	0.2
RETAIL JOBS *1000					
BAU	absolute	10	11	12	12
ECO1	increase	0	0.3	0.4	0.4
ECO2	increase	0	0.3	0.4	0.4
ECO3	increase	0	0.3	0.4	0.4

13 Market surveillance

In chapter 4 (Task C: Extended Product Approach - EPA), it is mentioned that an appropriate market surveillance approach needs to be developed if EPA is to be implemented in the reviewed water pumps regulation 547/2012. In this chapter, two proposals are presented, including an introduction to the main issues related to the verification of the requirements in the regulation and the methodological aspects used to develop this proposal.

13.1 Introduction

In chapter 4 it is described how water pumps can be either placed on the market as as bare shaft pumps, pump units with only bare shaft pump and motor and pump units with continuous control equipment (e.g. a Variable Speed Drive, VSD). Throughout this chapter, we thus refer to these products as:

- Bare shaft pump[336] placed on the market as separate product by one manufacturer. In this case, motor and, optionally, the continuous control equipment are placed on the market separately by the same manufacturer or by others. Bare shaft pump, motor and continuous control will be later put together at the time of the installation.
- Pump unit without a continuous control piece of equipment (e.g. a VSD), i.e. pump and motor, placed on the market by one manufacturer or assembled by a third party who buys both pump and motor separately and assembles them together before placing the pump unit on the market.
- Pump unit with a continuous control piece of equipment (e.g. a VSD), placed on the market by one manufacturer or assembled by a third party who buys them separately and assembles them together before placing the pump unit on the market.

For a visual representation, please see Figure 54.

To achieve the largest share of potential electricity savings mentioned in chapter 12 (see Figure 46), the reviewed regulation should include ecodesign requirements that, to the largest possible extent, could ensure that the pump units are installed with continuous control, in particular when used in variable flow applications (see chapter 4 for explanation of these flow systems). It was therefore investigated through consultation with Market Surveillance Authorities whether market surveillance could be also performed at installation, i.e. once the pump unit is put into service. To make it happen, appropriate requirements would have to be defined in a reviewed Regulation 547/2012.

Furthermore, it would require that clear definitions distinguishing constant from variable flow applications are developed for verification and surveillance which do not currently exist. These definitions are essential to implement and verify installation requirements.

This analysis is presented in the subsequent sections, together with a conclusion at the end of this chapter.

[336] Without the base and motor, or without the base, motor and VSD. Throughout this report, this has been referred to as 'pump'.

13.1.1 Placing on the market and putting into service

According to the Ecodesign Directive, placing on the market and putting into service refer to two different moments in the process of bringing a product on the market[337]. Furthermore, product compliance for the entry into the market, providing it complies with requirements for CE marking, is required only once (i.e. when the product is placed on the market or when is put into service)[338].

In the Blue Guide on the implementation of the Ecodesign Directive, demonstrating compliance when products are 'put into service' is only applicable for those that have not previously been placed on the market. However, compliance is also applicable to 'products' which have not been placed on the market prior to their putting into service or which can be used only after assembly, installation, etc[339]. This is applicable to pump units, since they have become a new product if not placed on the market as such and cannot be used before installation (see Figure 54).

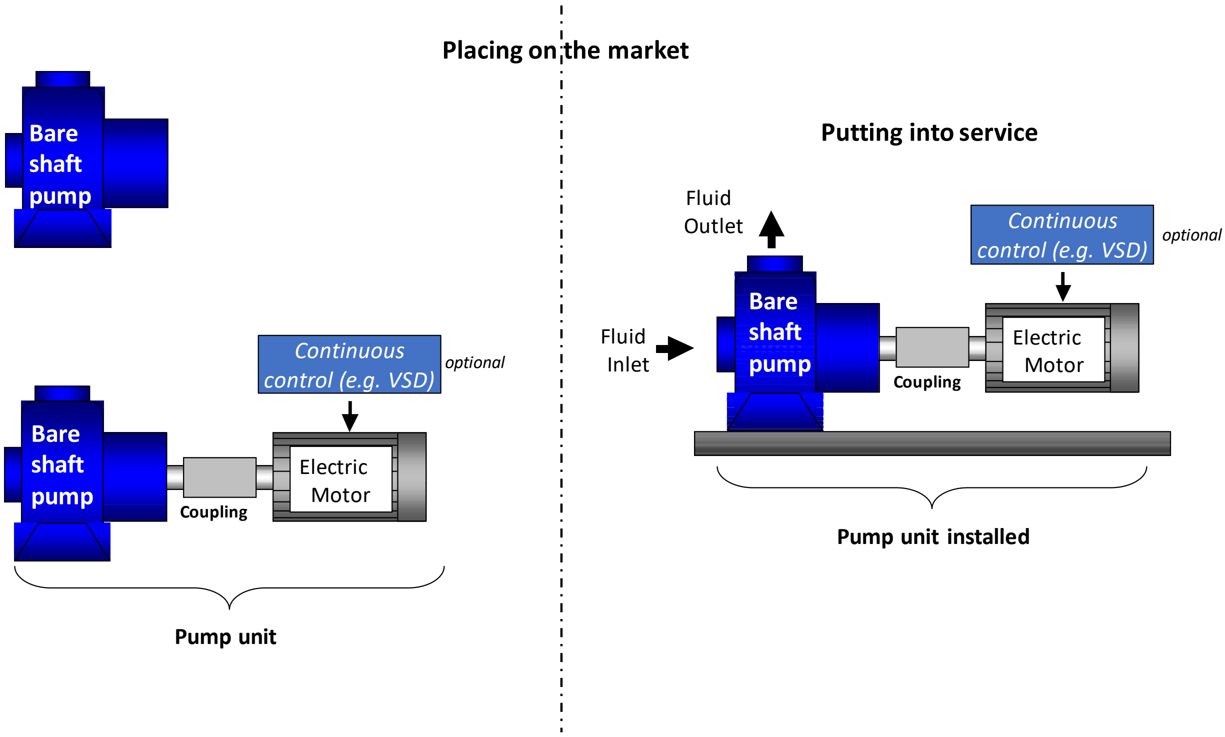


Figure 54. Schematic representation of bare shaft pump and pump unit when placed on the market (left side) and of the extended product when put into service (right side)[340].

13.1.2 Responsibility of compliance

Typically, compliance of products covered by ecodesign requirements are verified once they are placed on the market. The responsibilities of the manufacturer are defined in the product regulations, and only a few of these assign responsibilities of compliance to the

[337] '**Placing on the market**' means making a product available for the first time on the Community market with a view to its distribution or use within the Community, whether for reward or free of charge and irrespective of the selling technique; '**Putting into service**' means the first use of a product for its intended purpose by an end-user in the Community.
[338] Frequently Asked Questions (FAQ) on the Ecodesign Directive 2009/125/EC establishing a framework for the setting of ecodesign requirements for energy-related products and its Implementing Regulations
[339] From the Blue Guide: *"Demonstration of compliance of products when put into service and when installed, maintained and used for the intended purpose should be limited to products which have not been placed on the market prior to their putting into service or which can be used only after an assembly, an installation or other manipulation has been carried out"*
[340] Adapted based on input from Europump

installers when the product is been put into service[341]. In these cases, installers are held accountable for compliance, which is not a common practice in Ecodesign. Furthermore, the boundaries of the product may change once the product is put into service, in the case the pump unit is assembled only after it is placed on the market and thus becoming a new product as such(see Figure 54). According to the Blue Guide, when a combination of different products and parts which each comply with applicable legislation are designed or put together by the same person, this assembly is considered a 'finished product' which has to comply with legislation as such. The Blue Guide provides guidance concerning the following responsibilities of the installer as the manufacturer of the assembly:

- Verifying on a case-by-case basis whether the combination of parts has to be considered as one finished product in relation to the scope of the legislation
- Selecting suitable products to make up and put the combination together so it complies with the provisions of the laws concerned[342]
- Fulfilling all the requirements of the legislation in relation to the assembly ensuring the appropriate conformity assessment procedure has been carried out
- Fulfilling the EU declaration of conformity and CE marking, eventhough the parts are already CE marked[343]

According to the guide, the natural or legal person who puts the product into service has the same responsibilities as a manufacturer who places a product on the market.

13.1.3 Verification by Market Surveillance Authorities (MSAs)

In order to secure the large energy savings potential for the extended product, the ecodesign requirement would have to cover the installation of the product and MSAs would have to verify compliance also when products are put into service. In order to get an overview of what the MSAs think of this approach, interviews with 8 MSAs were carried out by the study team. Additional input was collected on experience with market surveillance of other products that present a similar problematic. The detailed outcomes of these interviews are shown in Annex 10. Furthermore, a meeting with representatives from different Member States and MSAs as well as with industry[344] took place in order to find an agreement on whether this verification approach would be possible. The main conclusions from the meeting are shown in Annex 12. Input from these stakeholders made it clear that most of them don't consider possible to carry out market surveillance when pump units are put into service because:

- Requirements should only address the product and not the installation, in particular since surveillance would concern a myriad of individual installations, which reduce effectiveness and increase the costs.
- MSAs do not have the legal power to carry out the related inspections and have no means to identify where and when pump units are installed.
- Burden of compliance and documentation of conformity for installers would be problematic.

[341] For Ecodesign requlations on hot water storage tanks (Regulation 814/2013) and ventilation units (1253/2014). See Annex 11 for more details.

[342] From the Blue Guide: *"Manufacturers must choose componente and parts in such a way that the finished product itself complies"*

[343] From the Blue Guide: *"The fact that components or parts are CE marked does not automatically guarantee that the finished product also complies"*

[344] Representatives from Europump

- Some MS representatives and MSAs find that verification of installed products is outside the scope of the Ecodesign Directive because of Article 15 (explained in previous section).
- Doubts about the technial ability of MSAs to make the on-site verification (e.g., determine whether the installation is constant or variable flow, determine whether a VSD is present).

Additional input from some Member States representatives and MSAs indicated that the Article 15 in the Ecodesign Directive prevents this verification approach, since the market surveillance can either be achieved directly on the product or on the basis of the technical documentation. Various Member States believe this prevents establishment of requirements and market surveillance activities which take into account the system in which the product is installed.

Annex VII of the Ecodesign Directive describes the content of implementing measures. Point 4 of this annex states that the implementing measure must specify among others the requirements on installation of the product where it has a direct relevance to the product's environmental performance.

Whether Article 15 and information in Annex VII of the Ecodesign Directive contradict each other is subject to interpretation. However, Annex VII seems to give the possibility for installation requirements if relevant from an environmental perspective which is the case of pump units. However, input from Member State representatives and MSAs was clear that implementation of this would be too difficult (see Annex 10 and Annex 12).

The information presented in this introduction, together with the input received from stakeholders during the interviews, the meeting and input provided during this review study have been used to draw the proposals shown in section 13.2.

During the development of these proposal, a dialogue was held with the European Commission based on the input provided from Member State representatives and Market Surveillance Authorities. During this dialogue, industry also provided considerable input until establishing the draft proposal.

13.2 Proposals for the verification of bare shaft pumps and pump units

A proposal was drafted after input was received from Member State representatives and Market Surveillance Authorities, which is shown in Figure 55.

Member State representatives and Market Surveillance Authorities also proposed to keep EEI as efficiency metric for the whole pump unit. They also proposed to keep MEI as a MEPS for the bare shaft pump, to be used as a supplement to the EEI metric for the whole pump unit. They proposed to use information requirements in ways they aren't typically used in Ecodesign. These proposals are reflected in what is shown in Figure 55, however, the idea was to keep an installation information requirement to ensure installers woud use continuous controls in variable flow applications, counting on the premise that installers can be made responsible of compliance (as described in section 13.1.2).

After further discussions with the European Commission and industry, two alternative proposals were developed which are presented in the next two sections. These alternatives were developed with the aim to remove responsibilities from the installers, and thus removing requirements when products are put into service.

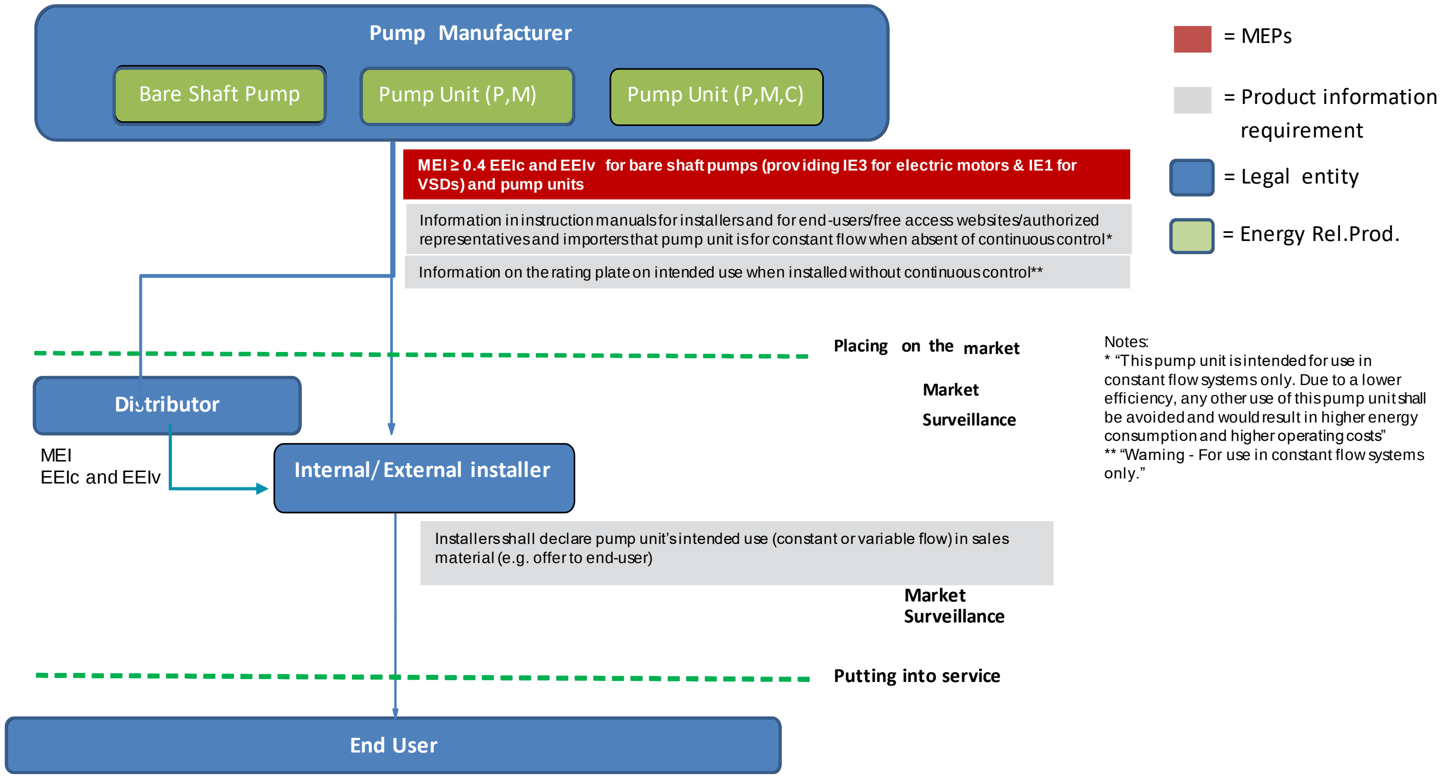


Figure 55. Preliminary proposal drafted after discussions with MS representatives and MSAs: Placing on the market and putting into service.

13.2.1 Proposal 1: MEI as MEPS + EEI as information requirement

The ecodesign requirements for bare shaft pumps and pump units could be verified once these have been placed on the market. An overview of this proposal is shown in Figure 56.

MEI as MEPS would ensure at least the same energy efficiency levels of bare shaft pumps as required in existing regulation.

EEI as information requirement would give the manufacturers the possibility to get familiar with the EPA methodology for calculating this metric. Providing different EEI values for constant (EEIc) and variable flow applications (EEIv) would allow that manufacturers get also familiar with both calculation methodologies in the EN standards. Manufacturers of bare shaft pumps and pump units without continuous control would have to declare both values (EEIc and EEIv) on every pump, using default values for motor or continuous control efficiency. This would add additional burdens to these manufacturers from testing a bare shaft pump in both variable and constant flow profiles, in comparison to testing only at one of these time-profiles. Manufacturers of pump units with continuous control would only have to declare EEIv. According to input from industry, it is very unlikely that pump units equipped with continuous control are installed in constant flow applications due to the additional costs.

MEI and EEI values on the rating plate of the bare shaft pump would provide information to the installers on the efficiency of the bare shaft pump and of the pump unit, when provided with a motor and eventually a VSD. A special warning has been proposed, also on the rating plate, to prevent installers to use pump units without continuous control in variable flow applications.

Information requirement regarding instruction manuals for installers and end users, as well as information on free access websites of manufacturers and authorized representatives and importers would also educate the installers on the importance of using continuous control when installing pump units for variable flow applications. A disclaimer has been additionally proposed as a warning to emphasize that EEIv is only valid in the presence of continuous controls in the pump unit.

These proposed ecodesign requirementsfit within the current framework of ecodesign and market surveillance, applied to water pumps.

Industry has emphasized[345] that this proposal does not deliver the predicted savings calculated and presented in chapter 12. During the meeting with Member State representatives and MSAs, it was discussed that other legal mechanisms such as the Energy Performance Building Directive (EPBD) could be exploited to ensure the installation of pump units with continuous control in variable flow applications. This would release some of the missed energy savings.

There is still one technological inconsistency between MEI and EEI which is the adjustment factor for trimmed impellers. Furthermore, industry claims[344] that in reality the calculation of EEI_v for bare shaft pumps used in variable flow applications would present some uncertainties. This is because in this calculation, MEPS levels for motors and VSDs that comply with ecodesign requirements are used to establish their EEI_v. However, motors and VSDs efficiencies are established at nominal (not partial) loads. Industry proposes to use

[345] Europump position regarding Extended Product Approach for Water Pumps. EUROPUMP CONCLUSIONS REGARDING EXTENDED PRODUCT APPROACH FOR WATER PUMPS. Sent to study team on the 18th of May, 2018.

instead the IEC 61800-9 standard which describes a methodology for establishing efficiencies at part load behaviour for Power Drive Systems which in this case are motors and VSDs. Due to the late input of this proposal, it has not been considered but this has to be checked once the Impact Assessment is carried out.

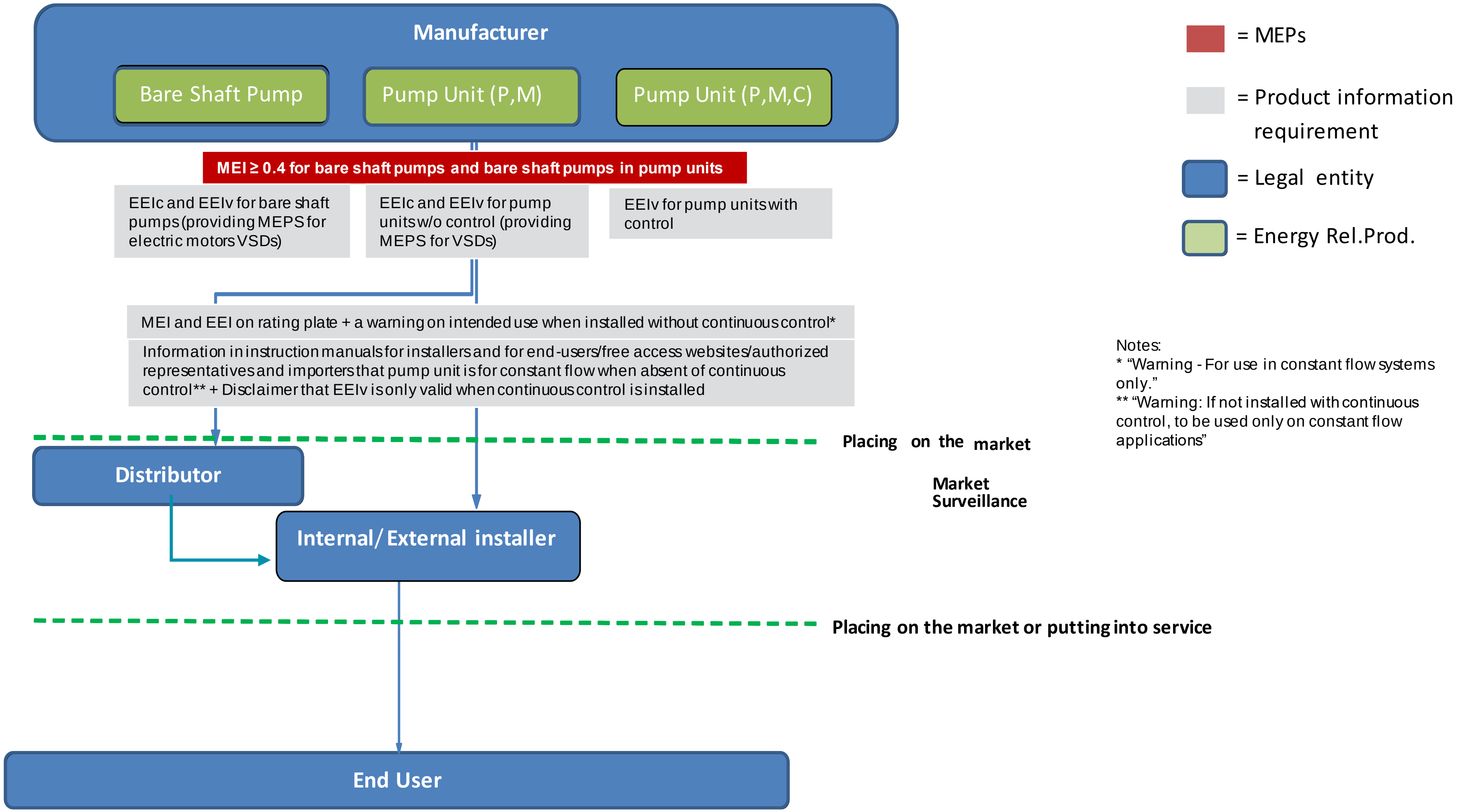


Figure 56. First proposal after further discussions with stakeholders.

13.2.2 Proposal 2: EEI as MEPS

The ecodesign requirements for bare shaft pumps and pump units could be verified once these have been placed on the market as for proposal 1. An overview of the second proposal is shown in Figure 57.

The second proposal suggests to discontinue the use of MEI and introduce EEI as MEPS. This would be a more drastic measure which may secure more of the savings identified in chapter 12, although still without the possibility of setting requirement for putting into service.

Both EEIc and EEIv would have to be declared by manufacturers of bare shaft pumps and pump units without continuous control. Manufacturers of pump units equipped with continuous control, would only have to report EEIv.

By having EEI as the only MEPS, the inconsistency of methodology for bare shaft pumps with trimmed impellers would be solved since this has already been taken care of in the EEI methodology. However, there is the risk that by discontinuing MEI as MEPS would disincentivize bare shaft pump manufacturers to keep focus on energy efficiency.

The information requirements are proposed to be the same for both proposals, in order to keep the focus on delivering information to the installers on the most energy efficient installation of pump units both for constant and for variable flow applications.

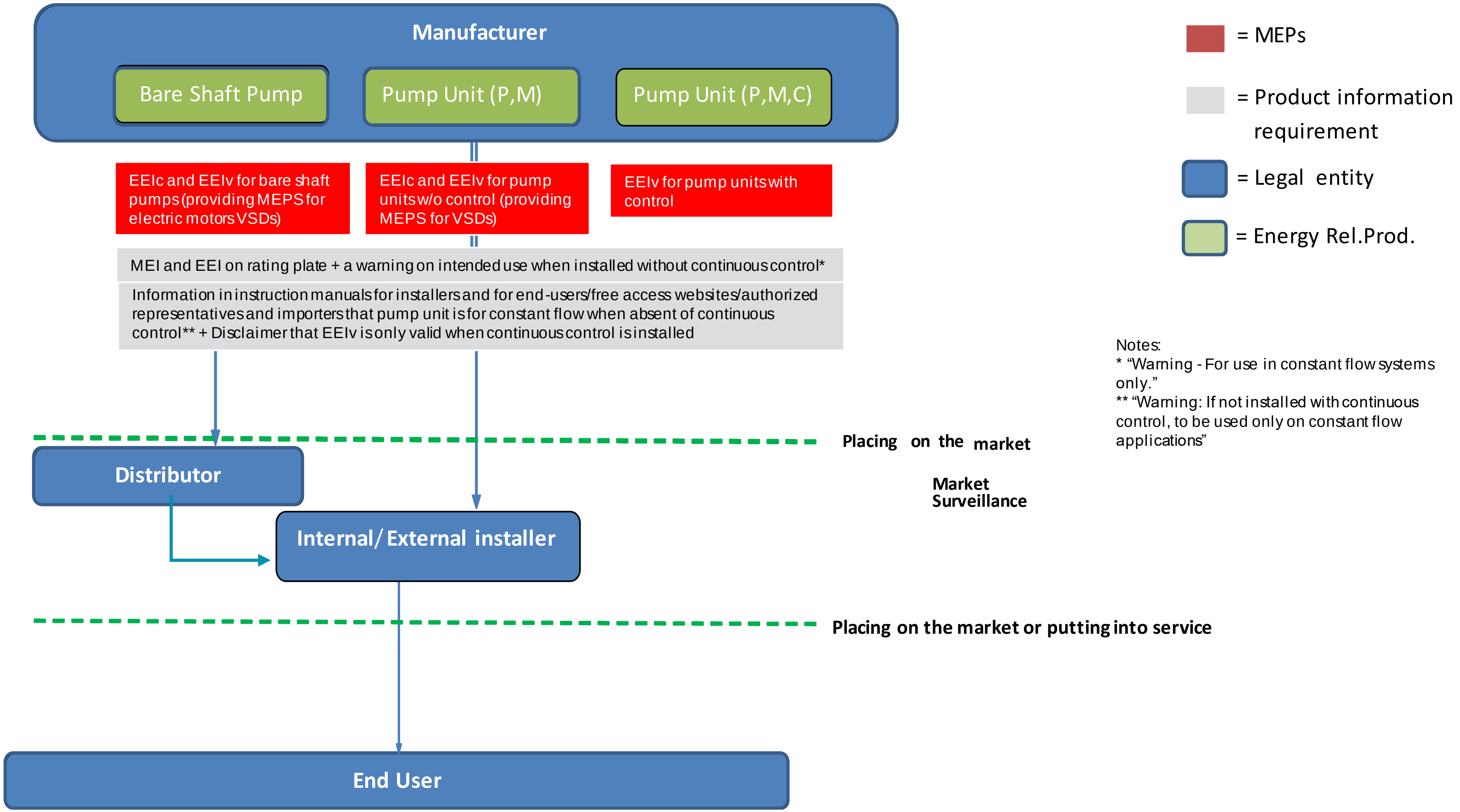


Figure 57. Second proposal after further discussions with stakeholders.

13.3 Conclusion

Both proposals have been developed after extensive discussions with Member State representatives, Market Surveillance Authorities, industry and the European Commission. In spite these is not expected to achieve all of the large potential savings identified in chapter 12, the market surveillance assessment indicated clearly that verification at putting into service would not be a realistic approach at this point in time.

It has therefore been proposed to include several information requirements to be provided by bare shaft pumps and pump units manufacturers, which will very likely arrive to the installers and may educate them on the most efficient way to install pump units for variable flow applications. Furthermore, by introducing EEI requirements by applying the extended product approach, either as information requirement or as MEPS, will start educating manufacturers on the use of this metric which brings considerable larger savings than those identified by the use of MEI.

Additional burdens for manufacturers as well as a couple of technical issues have been identified and thus Europump has recently proposed[345] that a single EEI requirement level for both constant and variable flow applications may simplify these proposals (see Annex 13. Single EEI value for all pumps in scope (under preparation, foreseen publishing date mid-January 2019).). This is based on the assumption that all pump systems could benefit from speed controls in terms of energy savings. This is, somehow, contradictory to previous discussions where Europump has stated that the use of VSDs is counteractive in constant flow applications due to the energy losses and the absence of benefits by operating at partial loads when using VSDs in pump units for constant flow. However, Europump has argued that energy savings would still be greater since many pumps are actually oversized. This topic should be further investigated during the Impact Assessment to assess potential savings considering the whole life cycle costs.

Member State representatives and MSAs suggested that other public mechanisms could also be used for verification of the compliance of pump units on-site. However, this possibility could not be included in an ecodesign regulation for pumps because it is dependent on other policy instruments. But Member States who want to carry out inspection of the compliance of the pump unit on-site could do that in combination with other surveillance activities for instance inspection of safety on workplaces, the energy performance certificate of buildings and energy management schemes. However, this will have to be worked out at national level.

Finally, inconsistencies and ambiguities in the Ecodesign Directive concerning implementing measures for ErPs present a barrier for potential ecodesign requirements of extended products. Should a revision of the Ecodesign Directive take place in the future, it is recommended that:

- Inconsistencies between Article 15, point 7, and Annex VII are resolved, in order to make inspections possible for installed products according to the instructions from the manufacturer. This could require the possibility to take into account information regarding the system into which the product is installed.
- Responsibilities of compliance are clarified for products that are to fulfill requirements at puting into service. Specific text from Blue Guide mentioned in previous sections could be used in the revised Directive. To facilitate this, product-specific regulations should require that manufacturers provide information related to their installation/put into service, which is delivered to the installarers, so they

can assess conformity without having to make expensive tests and/or complicated calculations.

- It could be specified that implementing measures could include information to be available at the point of sale/installation. Installers could be obliged to provide information to their customers at this point (for instance in offers) and be required to deliver a copy of the information to the Market Surveillance Authorities in case the product is selected for inspection.

14 Overall conclusions and recommendations

The overall conclusions and recommendations of this review study are presented in this chapter, based on the previous thirteen chapters.

The conclusions and recommendations are presented in five sections:

1. Final scope of the review study, including their definitions.
2. Energy consumption for pumps included in final scope.
3. Proposed policy measures and potential energy savings, based on the policy scenarios assessed in chapter 12 as well as the proposals developed in chapter 13 considering the results of the market surveillance assessment.
4. Recommendations for review of current regulation.

14.1 Scope of review study

The initial scope during this review study was based on current water pumps Regulation 547/2012 and pump types within the final scope of preparatory studies Lot 28 and Lot 29. Using this as a starting point, the following pump categories were identified as those presenting significant energy consumption and in most cases potential savings:

- *End suction own bearing (ESOB) clean water pumps with a maximum shaft power of 150 kW*
- *End suction closed coupled (ESCC) clean water pumps with a maximum shaft power of 150 kW*
- *End suction closed coupled in line (ESCCi) clean water pumps with a maximum shaft power of 150 kW*
- *Vertical Multistage (MS-V) clean water pumps designed for pressures up to 25 bar*
- *Vertical Multistage (MS-V) clean water pumps designed for pressures between 25 and 40 bar*
- *Horizontal Multistage (MS-H) clean water pumps designed for pressures up to 25 bar*
- *Horizontal Multistage (MS-H) clean water pumps designed for pressures between 25 and 40 bar*
- *Submersible borehole multistage (MSSB) clean water pumps with a nominal outer diameter of up to 6" (15.24 cm)*
- *Booster-sets (which are also multistage pumps but configured differently and intended to be used only at variable flow applications) for clean water with a maximum shaft power of 150 kW*
- *Swimming pool pumps (SWP) with a maximum shaft power of 2.2 kW*
- *Submersible vortex radial (SVR) pumps for wastewater with a maximum shaft power of 160 kW*
- *Submersible channel radial (SCR) pumps for wastewater with a maximum shaft power of 160 kW*

The significance of the energy consumption of these pumps was based on data and information presented in preparatory studies, on industry data, and on important identified ambiguities concerning parameters influencing their consumption and potential savings. The inclusion of these pumps in a future reviewed water pump regulation 547/2012 is assessed for each water pump type in section 14.3 of this chapter.

The sub-division in sizes through the study served only as a basis to identify any difference in terms of potential energy savings. In the case of multistage clean water pumps, the size sub-division remains to differentiate pumps in scope of current regulation to those not in scope.

14.2 Energy consumption

Based on the investigations of the market for constant and variable flow applications and data provided from industry, the total annual energy consumption of all pumps in final scope of the study is **225 TWh by 2015**. From this, **166 TWh/year** are for **pumps** currently **in scope of the regulation**, and **59 TWh/year** are from **pumps not covered by the regulation**. This means that the majority of the energy consumption (73.8%) is from pumps currently in scope of the regulation.

If no action is taken (i.e. BAU), meaning that no changes in current regulation takes place, the **predicted total annual energy consumption in 2025** will be **253 TWh/year** and **in 2030** it will be **261 TWh/year**, with the majority of the consumption still coming from pumps in scope of current regulation.

14.3 Policy measures and potential effects

The investigation of future policy measures was done considering extending the scope from pumps to pumps driven with an electric motor with or without a VSD also known as pump unit or extended product and by taking the Extended Product Approach (EPA).

Several measures were investigated, including no action (i.e. Business as Usual – BAU), self-regulation (e.g. voluntary agreements offered as unilateral commitments by industry), energy labelling and ecodesign measures. No action was not considered feasible. No action prevents a significant amount of energy savings to be achieved by implementing new measures considering the extended product (37-48 TWh/year by 2030), in comparison to the estimated savings from having implemented the current regulation (5 TWh/year). The conditions for self-regulation were not met for most of the pumps categories, since none in the industry had interest in such a measure. Although there is interest by some swimming pool manufacturers, it is not certain yet whether they fulfil the conditions of market representation since a potential self-regulation is only at the first stage of discussions. Energy labelling was not considered relevant as most of these pumps are sold Business to Business. Ecodesign measures, in the contrary, present significant opportunities from applying the Extended Product Approach and a methodology for quantifying energy efficiency of water pump units is in an advanced stage of development.

The most suitable policy measure was therefore considered as the ecodesign measure. The policy measures are based on the EPA that specifies energy efficiency requirements in terms of maximum allowed Energy Efficiency Index (EEI)-values for the pump unit.

For each pump two EEI-requirement levels have been established, one for variable flow operation (EETv) and one for constant flow operation (EEIc)[346], except for those pumps when one of the flow applications was not relevant. The two types of flow are defined by the respective flow-time profiles defined in the standards[153,156]. Each pump will have to comply with both (except when one of them is not relevant), and relevant information should be provided (for more details on requirements see Table 72). This is providing that

[346] Except for Booster-sets, which are considered to operate with an alternative variable flow-time profile, and swimming pool pumps which always operate as constant flow.

EPA methodology is fully developed by the implementation date of a reviewed regulation for all pump types.

The intention of the first policy option assessed (PO1) is to ensure that pump units in variable flow appicaitons would all have to operate with Variable Speed Drives from 2021 - with an implementation date in 2020. This will reduce the energy consumption of pump units operating in variable flow systems, since the motor would only operate at the required speed to deliver the reduced/increased flow.

To assure this happens, pump units for variable flow applications would have to be installed with Variable Speed Drives and this would have to be verified by Market Surveillance Authorities at installation. This was investigated by consulting with Member State representatives and Market Surveillance Authorities. The results of this analysis show that, within the current framework of the Ecodesign Framework Directive, the Market Surveillance Authorities cannot perform this verification.

On this background two alternative proposals have been developed, which are expected to achieve only a fraction of the initially calculated potential energy savings. The original proposal is called Policy Option 1 (PO1), which brings the largest savings but requires verification at installation, and the two alternatives are called Policy Option 2 and 3 (PO2 and PO3). PO2 and PO3 propose ecodesign requirements for when the product is placed on the market. They do not deliver the full savings potential since the verification of the pump units that operate in variable flow systems is not performed, which would ensure they are installed with VSDs.

The three policy options, the proposed requirements and implementation dates are presented in Table 72.

Table 72. Proposed policy options and requirements for water pump units in final scope.

Policy Option (PO)	Requirements	Applicability of requirements	Implementation dates and EEI ambition levels[347]
BAU - Business As Usual	No proposed requirements		Not relevant
PO1 – MEI and EEI requirements with enforcement when placed on the market and put into service	1. Minimum Efficiency Index (MEI) for all bare shaft pump types as in current regulation 547/2012. 2. Energy Efficiency Index (EEI) and energy efficiency[348] requirements for use of the bare shaft pumps and the pump units in variable and constant flow systems (EEiv and EEIc) with EEIv being more stringent than EEIc. 3. Information requirements on rating plate and in manuals and websites. 4. Information requirement making it mandatory for installer to declare the pump unit's intended use.	1. When bare shaft pumps are placed on the market as such or as part of a pump unit. 2. When placed on the market or put into service. 3. When placed on the market or put into service. 4. When put into service.	• ECO1: Less ambitious EEI levels. 2020 for pump units with an EPA calculation and testing methodology in place and 2021 for pump units without an EPA methodology[349]. • ECO2: More severe EEI levels with two Tiers. Tier 1 in 2020/2021 and same levels as ECO1. Tier 2 in 2023/2024 with more stringent levels. • ECO3: More stringent levels as in Tier 2 of ECO2 are introduced already in 2020/2021.
PO2 – EEI requirements with enforcement when placed on the market	1. Energy Efficiency Index (EEI) and energy efficiency[9] requirements for use of the bare shaft pumps and the pump units in variable and constant flow systems (EEiv and EEIc) with EEIv being more stringent than EEIc. 2. Information requirements on rating plate and in manuals and websites.	1. When bare shaft pumps and pump units are placed on the market. 2. When placed on the market.	• ECO1: Same as ECO1 in PO1. • ECO2: Same as ECO2 in PO1 • ECO3: Same as ECO3 in PO1.

347 "ECO" scenarios refer to scenarios with different EEI ambition levels at different implementation dates
348 Energy efficiency requirements have been developed for pump types where a draft methodology for calculating EEI has not been finalised yet at the time of this study (i.e. multi-stage pumps)
349 For some pump unit types, an EPA methodology has not yet been been finalised (e.g. multi-stage pump units) or has not been started (e.g. swimming pool pumps and wastewater pumps).

Policy Option (PO)	Requirements	Applicability of requirements	Implementation dates and EEI ambition levels[347]
PO3 – MEI requirements with EEI as information requirement and enforcement when placed on the market	1. Minimum Efficiency Index (MEI) level for all bare shaft pump types as in current regulation 547/2012. 2. Information requirements by manufacturers of bare shaft pumps and pump units on Energy Efficiency Index (EEI) levels, regardless of the intended use (i.e. both in constant and in variable flow systems). 3. Information requirements on rating plate and in manuals and websites.	1. When bare shaft pumps are placed on the market as such or as part of a pump unit. 2. When placed on the market. 3. When placed on the market.	From 2020

Actual savings were only calculated for PO1, as this was the original proposal considering enforcement of the installation of pump units with variable speed drives in variable flow systems. PO2 and PO3 are expected to achieve only a fraction of these savings, with PO3 being the least ambitious providing the smallest fraction of the savings. The actual savings will among others depend on the functioning of the information requirements and how well they are able to educate manufacturers and installers and create awareness.

Potential energy savings of PO1

End suction clean water pumps

The different levels of ambition for the potential policy measures assessed concerning all end suction clean water pumps, presents three different outcomes, when compared to the BAU scenario:

- Based on the *less severe policy measure (ECO1)*, the potential annual energy savings would be *17.4 TWh/year in 2025 and 28.4 TWh/year in 2030*.
- Based on the *more severe policy measure (ECO2)*, the potential energy savings would be *17.9 TWh/year in 2025 and 29.9 TWh/year in 2030*.
- Based on the *most severe policy measure (ECO3)*, the potential energy savings would be *18.3 TWh by 2025 and 30.1 TWh by 2030*.

These scenarios have been presented in detail in chapter 12.

Multistage clean water pumps

For multi-stage clean water pumps, the policy measures identified were different, since for some of these pumps, an EPA methodology for measuring and testing pumps is already ongoing (multistage pumps up to 25 bar) whilst for the rest it is not. Therefore, their requirements were set based on their observed average efficiency on the current market and the levels that would be achieved counting on a future EPA methodology in place (for those with no existing EPA methodology).

For these pumps, three different levels of ambition were also identified and defined in the same way as for end suction pumps (least ambitious – Eco1 to most ambitious – Eco3).

Multistage clean water pumps currently in scope

Looking first at the pumps currently in scope, the saving potentials, when compared to the BAU scenario, are:

- Based on the *less severe policy measure (ECO1)*, the potential energy savings would be *5.9 TWh/year in 2025 and 8.4 TWh/year in 2030*.
- Based on the *more severe policy measure (ECO2)*, the potential energy savings would be *6.4 TWh/year in 2025 and 9.7 TWh/year in 2030*.
- Based on the *most severe policy measure (ECO3)*, the potential energy savings would be *6.7 TWh/year in 2025 and 10 TWh/year in 2030*.

It is important to notice that borehole submersible multistage pumps with nominal outer diameter other than 4” and 6” are not included in the current scope of the regulation, which means that some of the savings stated above come from pumps currently not in scope.

Multistage clean water pumps currently not in scope

Looking then at the pumps currently not in scope, the saving potentials, when compared to the BAU scenario, are:

- Based on the *less severe policy measure (ECO1)*, the potential energy savings would be *3.4 TWh/year in 2025 and 4.7 TWh/year in 2030*.
- Based on the *more severe policy measure (ECO2)*, the potential energy savings would be *3.5 TWh/year in 2025 and 5.3 TWh/year in 2030*.
- Based on the *most severe policy measure (ECO3)*, the potential energy savings would be *4 TWh/year in 2025 and 5.4 TWh/year in 2030*.

About 75-80% of these savings come from including only horizontal multistage pumps up to 25 bar, while the rest mainly comes from horizontal multistage pumps from 25 to 40 bar and booster-sets.

Swimming pool pumps

The policy measures evaluated for swimming pool pumps had very little room for improvement. This is because, according to information from stakeholders, all of these pumps operate under constant flow, and as discussed throughout the report, the use of variable speed drives does not favour the operation of pumps in constant flow applications, unless pumps are oversized and if they could operate for longer turnover rates at reduced flows.

The policy measures were set in three different ambition levels, as for the previous pump categories. The main results, when compared to the BAU scenario, are:

- Based on the *less severe policy measure (ECO1)*, the potential energy savings would be *0.4 TWh/year in 2025 and 0.6 TWh/year in 2030*.
- Based on the *more severe policy measure (ECO2)*, the potential energy savings would be *0.8 TWh/year in 2025 and 1.4 TWh/year in 2030*.
- Based on the *most severe policy measure (ECO3)*, the potential energy savings would be *0.8 TWh/year in 2025 and 1.4 TWh/year in 2030*.

Larger savings could be achieved as presented throughout the report, but they are subject to different assumptions concerning the use of the swimming pool pumps. These assumptions are uncertain as there apparently exist some limitations to use the pumps at reduced flows as it risks the hygienic conditions of the pool. Therefore, a harmonised methodology to quantify energy efficiency needs first to be developed to make these calculations more reliable and comparable.

Wastewater pumps

In the absence of a methodology to measure the performance of wastewater pumps at EPA level, the defined levels of requirements for the three policy measures for wastewater pumps were based on minimum average efficiencies based on performance data of relevant wastewater pumps in the market and information from manufacturers. However, due to the fact that all wastewater pumps in variable flow applications already operate on variable speed (i.e. using variable speed drives), according to data from industry, the room for improvement is also very small. However, at this point in time, it is unknown whether more wastewater pumps could switch to operating in variable flow applications, as explained in previous chapters.

Based on this information, the policy measures were also set in three different ambition levels. The main results, when compared to the BAU scenario, are:

- Based on the *less severe policy measure (ECO1)*, the potential energy savings would be *0.3 TWh/year in 2025 and 0.4 TWh/year in 2030*.

- Based on the *more severe policy measure (ECO2)*, the potential energy savings would be *0.5 TWh/year in 2025 and 1.2 TWh/year in 2030*.
- Based on the *most severe policy measure (ECO3)*, the potential energy savings would be *0.8 TWh/year in 2025 and 1.2 TWh/year in 2030*.

Potential energy savings – current scope

The overall potential energy savings for implementing the policy measures for pumps in the current scope, when compared to the BAU scenario, are:

- Based on the less severe policy measure (ECO1), the potential energy savings would be **23.2 TWh/year in 2025** and **36.9 TWh/year in 2030**.
- Based on the more severe policy measure (ECO2), the potential energy savings would be **24.3 TWh/year in 2025** and **39.6 TWh/year in 2030**.
- Based on the most severe policy measure (ECO3), the potential energy savings would be **25.2 TWh/year in 2025** and **40 TWh/year in 2030**.

Potential energy savings – extended scope

The overall potential energy savings for implementing the policy measures and extending the scope, when comparing to the BAU scenario, are:

- Based on the less severe policy measure (ECO1), the potential energy savings would be **27.3 TWh/year in 2025** and **42.5 TWh/year in 2030**.
- Based on the more severe policy measure (ECO2), the potential energy savings would be **29.3 TWh/year in 2025** and **47.3 TWh/year in 2030**.
- Based on the most severe policy measure (ECO3), the potential energy savings would be **30.6 TWh/year in 2025** and **48 TWh/year in 2030**.

From information presented previously, it can be concluded that the majority of the savings will be achieved from implementing EPA in a reviewed ecodesign regulation for pump categories currently in scope. These account for more than 80% of the total potential savings in 2030.

Greenhouse gas emissions, costs, revenues and jobs of PO1

By achieving the abovementioned potential energy savings, derived reductions of CO_2 emissions are:

- Based on the least ambitious policy measure (ECO1), the potential reduction of CO_2 emissions would be **9.8 Mt $CO_{2\text{-eq.}}$/year in 2025** and **14.6 Mt $CO_{2\text{-eq.}}$/year in 2030**.
- Based on the middle ambitious policy measure (ECO2), the potential reduction of CO_2 emissions would be **10.5 Mt $CO_{2\text{-eq.}}$/year in 2025** and **16.1 Mt $CO_{2\text{-eq.}}$/year in 2030**.
- Based on the most ambitious policy measure (ECO3), the potential reduction of CO_2 emissions would be **11 Mt $CO_{2\text{-eq.}}$/year in 2025** and **16.3 Mt $CO_{2\text{-eq.}}$/year in 2030**.

Based on increased purchase prices from buying pumps with power drive systems, and increased installation costs, the **total acquisition costs** would be very similar for the three different levels of ambition for the policy measures. These range **from 213 to 232 million Euros/year in 2030**, starting with the least ambitious policy measure to the most ambitious.

However, by reducing the consumption of energy during the use of the pumps, the **total savings for expenses to consumers** would be from **10.6 billion Euros/year** by implementing the least ambitious policy measure to **12 billion Euros/year** by implementing the most ambitious measure, all **in 2030**.

The increase in (combined) **revenue** ranges from **206 mln Euros to 224 mln Euros** in 2030. The sector revenues are related to jobs by means of constant factors, as explained in Annex 9.16. The results range from **3 400 to 3 700 newly created jobs** by 2030.

Potential effects of PO2 and PO3

Policy options 2 and 3 (PO2 and PO3) will make the manufacturers become used to apply the calculation methods in the standards for both EEIc and EEIv. In addition, the dealers, installers or users will continuously be informed about the energy efficiency of pumps units for constant and variable flow systems (i.e. EEIc and EEIv) respectively and they will be made aware that pump units without continuous control should not be used in variable flow systems.

The intention and the hope is that MEPS and information requirements, either in combination (in PO2) or purely as information requirements (in PO3), will educate the installers about the importance of installing the pumps with continuous control in variable flow systems, and thereby a large share of the savings potential identified in PO1 will be utilized.

14.4 Recommendations for review of regulation

Based on the conclusions mentioned above, the recommendations are grouped in the next sections.

Scope

- Pumps currently in scope bring more than 80% of the potential savings with the most ambitious policy option, and it is therefore recommended to keep these pumps in the next version of the regulation, incorporating Extended Product Aproach.

- Multistage clean water pumps currently not in scope deliver altogether about 11% of the total savings by 2030 in case of implementation of the most ambitious policy option (i.e. PO1, see next section for explanation of policy options). It is therefore recommended that they are brought into the scope of the regulation. However, this is provided that an EPA methodology for measuring their performance under this approach is completed before the implementation date.

- Because of their low contribution to the overall potential energy savings and the uncertainties in these calculations due to the absence of an EPA methodology, it is not recommended to bring swimming pool pumps and submersible vortex and channel radial wastewater pumps into the scope of the regulation. However, it is important to note that the calculation of their savings was done considering that they have very small room for improvement, since swimming pool pumps do not operate in variable flow and all wastewater pumps doing so have VSDs. It was shown along the course of this report that there is a strong resistance to operate these pumps in variable flow applications since the consumers fear this will lead to non-compliance with hygienic needs or non-clogging needs. However, some manufacturers in the EU market claim there is technology to avoid these problems.

It is therefore recommended to perform an additional research on the possibilities to increase the amount of variable flow applications for these pumps. Furthermore, it is also recommended to establish harmonised requirements for testing performance of swimming pool pumps at established hygienic requirements and for submersible vortex and channel wastewater pumps' solids handling capabilities.

Policy options

- EPA requirements can be implemented either as minimum efficiency levels for the pump unit and/or as information requirements. In this study, three policy options have been presented varying in level of ambition concerning energy efficiency requirements and enforcement needs.

- PO1 presents three levels of ambition concerning requirement levels and implementation dates (i.e. ECO1, ECO2 and ECO3). Between 8 to 10% additional energy savings were identified from implementing more ambitious EEI levels as potential requirements (i.e. up to 5.2 TWh/year more savings in 2030 from implementing ECO3 compared to ECO1). Due to this relatively small difference, ECO1 appears the most viable so sufficient time is given to adopt EPA calculation methods, both developed and under development, in a revised version of the current regulation.

- However, although Policy Option 1 (PO1) brings the largest savings, it is recommended to investigate further the degree to which these savings can be also (partially) achieved by PO2 and PO3 through a quantitative analysis. In principle, PO2 and PO3 will educate the dealers, installers and users about the importance of installing the pumps with continuous control in variable flow systems, and thereby a large share of the savings potential identified in PO1 will be utilized. Since PO2 proposes EEI levels as potential ecodesign requirements, it is expected that it will achieve a larger share than PO3. If this is the case, PO2 could be the recommended policy option for a review of current regulation.

Other aspects related to market surveillance and enforcement

- To solve the problems with nomenclature and identification of pumps during the market surveillance process, it is recommended to substitute part of the existing product information requirement in Annex II, 2(5) of the regulation. Instead of requiring the 'product type and size identification' to be durably marked on or near the rating plate, the study team proposes to require the marking of an index/coding of the relevant pump category, being these codings defined in the Regulation 547/2012, together with the size identification (rated power and nominal speed). Additionally, it is recommended that the description of this index/coding is stated in the technical documentation and in freely accessible websites provided by the manufacturers.
- To facilitate the identification of the pumps by market surveillance authorities who determine whether the pumps are in scope or not, it is recommended to add a product information requirement in Annex, 2, where the manufacturers specify in the technical documentation and in freely accessible websites whether the pump is in scope. If the pump is very similar to the pumps' definitions stated in the regulation but is not in scope due to an exemption, the manufacturers' shall provide a technical justification for the exemption stating clearly that the pump's intended

use is not to pump clean water. If this is not stated, it will be assumed that the pump is in scope and therefore not complying with the marking requirement.

- When clean water pumps are sold with a nominal speed other than what is specified in the regulation, it is recommended that the pumps are tested in their own nominal speed and use C-values corresponding the closest to those defined in the regulation (1450 min^{-1} and 2900 min^{-1}). Furthermore, with pumps where more than one pump category is applicable, the type of pump casing should determine which C-value has to be taken.Finally, it is recommended to update the definitions in the standard, both for the pumps currently in scope and those suggested to include herein. It is also recommended to include a definition of self-priming pumps to avoid any potential loophole.

Overall, Extended Product Approach (EPA) brings significant potential energy savings, and it is therefore recommended to implement policy measures that bring this approach into place in the next version of the current Regulation 547/2012, since they show significantly more savings than looking only at the product level.

Annex 1. Overview of published standards under CEN TC 197.

Table 73 gives an overview of the published standards under CEN TC 197 as of 8-6-2016 and published on the website[350].

Table 73. Overview of the published standards under CEN TC 197.

Reference	Title
EN 1829-1:2010	High pressure water jet machines - Safety requirements - Part 1: Machines
EN ISO 15783:2003/A1:2008	Seal-less rotodynamic pumps - Class II - Specification - Amendment 1 (ISO 15783:2003/Amd 1:2008)
EN ISO 9905:1997/AC:2006	Technical specifications for centrifugal pumps - Class I (ISO 9905:1994)
EN ISO 9906:2012	Rotodynamic pumps - Hydraulic performance acceptance tests - Grades 1, 2 and 3 (ISO 9906:2012)
EN ISO 15783:2003	Seal-less rotodynamic pumps - Class II - Specification (ISO 15783:2002)
EN ISO 5198:1998	Centrifugal, mixed flow and axial pumps - Code for hydraulic performance tests - Precision class (ISO 5198:1987)
EN ISO 5199:2002	Technical specifications for centrifugal pumps - Class II (ISO 5199:2002)
EN ISO 9905:1997	Technical specifications for centrifugal pumps - Class I (ISO 9905:1994)
EN ISO 9908:1997	Technical specifications for centrifugal pumps - Class III (ISO 9908:1993)
EN ISO 14847:1999	Rotary positive displacement pumps - Technical requirements (ISO 14847:1999)
EN ISO 16330:2003	Reciprocating positive displacement pumps and pump units - Technical requirements (ISO 16330:2003)
EN 14343:2005/AC:2008	Rotary positive displacement pumps - Performance tests for acceptance
CEN/TR 13930:2009	Rotodynamic pumps - Design of pump intakes - Recommendations for installation of pumps
CEN/TR 13931:2009	Rotodynamic pumps - Forces and moments on flanges - Centrifugal, mixed flow and axial flow horizontal and vertical shafts pumps
CEN/TR 13932:2009	Rotodynamic pumps - Recommendations for fitting of inlet and outlet on piping
EN ISO 3661:2010	End-suction centrifugal pumps - Baseplate and installation dimensions (ISO 3661:1977)
EN ISO 2858:2010	End-suction centrifugal pumps (rating 16 bar) - Designation, nominal duty point and dimensions (ISO 2858:1975)
EN ISO 14414:2015	Pump system energy assessment (ISO/ASME 14414:2015)
EN ISO 17769-2:2012	Liquid pumps and installation - General terms, definitions, quantities, letter symbols and units - Part 2: Pumping System (ISO 17769-2:2012)
EN ISO 17769-1:2012	Liquid pumps and installation - General terms, definitions, quantities, letter symbols and units - Part 1: Liquid pumps (ISO 17769-1:2012)

350 https://standards.cen.eu/dyn/www/f?p=204:32:0::::FSP_ORG_ID,FSP_LANG_ID:6178,25&cs=106EAE1DD0543C56EA4827C5B1AE921B2

Reference	Title
EN 809:1998+A1:2009/AC:2010	Pumps and pump units for liquids - Common safety requirements
EN 16297-1:2012	Pumps - Rotodynamic pumps - Glandless circulators - Part 1: General requirements and procedures for testing and calculation of energy efficiency index (EEI)
EN 16297-2:2012	Pumps - Rotodynamic pumps - Glandless circulators - Part 2: Calculation of energy efficiency index (EEI) for standalone circulators
EN 16297-3:2012	Pumps - Rotodynamic pumps - Glandless circulators - Part 3: Energy efficiency index (EEI) for circulators integrated in products
EN 16644:2014	Pumps - Rotodynamic pumps - Glandless circulators having a rated power input not exceeding 200 W for heating installations and domestic hot water installations - Noise test code (vibro-acoustics) for measuring structure- and fluid-borne noise
CEN/TR 13930:2009/AC:2010	Rotodynamic pumps - Design of pump intakes - Recommendation for installation of pumps
CEN/TR 13931:2009/AC:2010	Rotodynamic pumps - Forces and moments on flanges - Centrifugal, mixed flow and axial flow horizontal and vertical shafts pumps
EN ISO 9905:1997/A1:2011	Technical specifications for centrifugal pumps - Class I - Amendment 1 (ISO 9905:1994/AMD 1:2011)
EN ISO 9908:1997/A1:2011	Technical specifications for centrifugal pumps - Class III - Amendment 1 (ISO 9908:1993/AMD 1:2011)
EN 1829-2:2008/AC:2011	High-pressure water jet machines - Safety requirements - Part 2: Hoses, hose lines and connectors
EN 13951:2012	Liquid pumps - Safety requirements - Agrifoodstuffs equipment; Design rules to ensure hygiene in use
EN 809:1998+A1:2009	Pumps and pump units for liquids - Common safety requirements
EN 1829-2:2008	High-pressure water jet machines - Safety requirements - Part 2: Hoses, hose lines and connectors
EN 12162:2001+A1:2009	Liquid pumps - Safety requirements - Procedure for hydrostatic testing
EN 16752:2015	Centrifugal pumps - Test procedure for seal packings
EN 16480:2016	Pumps - Minimum required efficiency of rotodynamic water pumps
EN ISO 20361:2015	Liquid pumps and pump units - Noise test code - Grades 2 and 3 of accuracy (ISO 20361:2015)
EN ISO 14414:2015/A1:2016	Pump system energy assessment - Amendment 1 (ISO/ASME 14414:2015/Amd 1:2016)
EN 12262:1998	Rotodynamic pumps - Technical documents - Terms, delivery range, layout
EN 14343:2005	Rotary positive displacement pumps - Performance tests for acceptance
EN 733:1995	End-suction centrifugal pumps, rating with 10 bar with bearing bracket - Nominal duty point, main dimensions, designation system
EN 734:1995	Side channel pumps PN 40 - Nominal duty point, main dimensions, designation system
EN 735:1995	Overall dimensions of rotodynamic pumps - Tolerances
EN 12157:1999	Rotodynamic pumps - Coolant pumps units for machine tools - Nominal flow rate, dimensions

Reference	Title
EN 12483:1999	Liquid pumps - Pump units with frequency inverters - Guarantee and compatibility tests
EN 12756:2000	Mechanical seals - Principal dimensions, designation and material codes

Table 74. Test standards mentioned in Lot 28.

EN 1092-2	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Cast iron flanges
EN 12723	Liquid pumps. General terms for pumps and installations. Definitions, quantities, letter symbols and units.
EN 13463-1	Non-electrical equipment for potentially explosive atmospheres. Basic method and requirements.
EN 60034	Rotating electrical machines
EN 12050	Wastewater lifting plants for buildings and sights – principles of construction and testing
EN 12056	Gravity drainage systems inside buildings

Table 75. Test standards mentioned in Lot 29.

EN 60335-2-41	Household and similar electrical appliances – Safety – Part 2-41: Particular requirements for pumps
EN 60335-2-55	Household and similar electrical appliances - Safety - Part 2-55: Particular requirements for electrical appliances for use with aquariums and garden ponds
EN 13451-1 part 1	Pool with public use / swimming pool equipment: general safety requirements and test methods
EN 13451-3 part 3	Pool with public use / additional specific safety requirements and test methods for pool fittings for water treatment purposes

Annex 2. Overview of legislations and agreements at EU level

This Annex gives a general overview of legislation that might be applicable to pumps in general. It is not possible due to the diversity of pump types to specify which legislation is applicable to every pump type.

Ecodesign Directive 2009/125/EC

This Directive provides for the setting of requirements which the energy-related products covered by implementing measures must fulfil in order to be placed on the market and/or put into service.

The Ecodesign Directive is relevant for pumps as its implementing measures may address pumps directly or indirectly.

Electric motors Regulation 640/2009

The Electric motor regulation is relevant for pumps as the motor may be included in the definition of the EPA. A new regulation to repeal the existing regulation is currently under Impact Assessment, which will extend the scope and update the requirements.

In Regulation 640/2009 the definition of the electric motor is:

'Motor' means an electric single speed, three-phase 50 Hz or 50/60 Hz, squirrel cage induction motor that:

- has 2 to 6 poles,
- has a rated voltage of U_N up to 1 000 V,
- has a rated output P_N between 0.75 kW and 375 kW,
- is rated on the basis of continuous duty operation.

Excluded are motors that:

- motors designed to operate wholly immersed in a liquid;
- motors completely integrated into a product (for example gear, pump, fan or compressor) of which the energy performance cannot be tested independently from the product;
- motors specifically designed to operate in non-standard ambient conditions (see regulation for more specific descriptions of these conditions);
- brake motors.

The ecodesign requirements address the energy efficiency of the motor, expressed in IE levels of efficiency. The ecodesign requirements apply in accordance with the following timetable:

1. from 16 June 2011, all motors placed on the market shall not be less efficient than the IE2 efficiency level (IE levels defined in Annex I, point 1);
2. from 1 January 2015: motors with a rated output of 7,5-375 kW shall not be less efficient than the IE3 efficiency level or meet the IE2 efficiency level and be equipped with a variable speed drive.

3. from 1 January 2017: all motors with a rated output of 0,75-375 kW shall not be less efficient than the IE3 efficiency level, or meet the IE2 efficiency level and be equipped with a variable speed drive.

LVD - Low Voltage Directive 2006/95/EC

The Low Voltage Directive (LVD) 2006/95/EC is one of the oldest Single Market Directives adopted before the "New" or "Global" Approach. However, it does characterise both with a conformity assessment procedure applied to equipment before placing on the Market and with Essential Health and Safety Requirements (EHSRs) which such equipment must meet either directly or by means of harmonised standards. The LVD ensures that electrical equipment within certain voltage limits both provides a high level of protection for European citizens and enjoys a Single Market in the European Union.

The Directive covers electrical equipment with a voltage between 50 and 1000 V for alternating current and between 75 and 1500 V for direct current. It should be noted that these voltage ratings refer to the voltage of the electrical input or output, not to voltages that may appear inside the equipment. For most electrical equipment, the health aspects of emissions of Electromagnetic Fields are also under the domain of the Low Voltage Directive.

For electrical equipment within its scope, the Directive covers all health and safety risks, thus ensuring that electrical equipment is safe in its intended use. Guidelines on application and Recommendations are available - including LVD Administrative Co-operation Working Group (LVD ADCO) documents and recommendations - as well as European Commission opinions within framework of the Directive.

In respect of conformity assessment, there is no third party intervention, as the manufacturer undertakes the conformity assessment. There are "Notified Bodies" which may be used to provide reports in response to a challenge by a national authority as to the conformity of the equipment. Note that this Directive is a codified version of the original Directive (73/23/EEC) which was published for the purpose of clarity following numerous amendments.

RoHS - Restriction of the Use of Certain Hazardous Substances

The RoHS Directive, in tandem with the WEEE Directive prevents the use of certain hazardous materials in new electrical and electronic equipment (EEE) placed on the market. This limits the impact of the EEE at the end of its life and it also ensures harmonisation of legislation on the use of hazardous materials in EEE across all Member States.

In Annex II of the RoHS directive a list of restricted substances for Electrical and Electronic Equipment is given[351]. These substances are:

- Lead
- Mercury
- Cadmium
- Hexavalent chromium
- Polybrominated biphenyls (PBB)

[351] DIRECTIVE 2011/65/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment

- Polybrominated diphenyl ethers (PBDE)

There are exemptions and limit values listed in the Annex to the Directive for some equipment where it is understood that one or more these substances is required for their functioning and no economically viable alternatives exist in sufficient quantity at present. Therefore, some of these substances may still be found in some electrical and electronic equipment.

The Annex has been revised on a number of occasions, altering the list of exclusions and limit values.

Other hazardous substances, as indicated by environmental organisations

According a coalition of environmental and health NGO's the following other substances are to be regulated under this Directive.[352]

PVC and other chlorinated polymers

Chlorinated polymers such as PVC are commonly present in conjunction with brominated materials, primarily brominated flame retardants. The combination of these two groups of materials can result in emissions of mixed chlorinated-brominated dioxins/furans when combusting, possibly during end of life processing. These chemicals could constitute a significant fraction of the total halogenated dioxin/furan burden from use of such materials, and the mixed chlorinated-brominated dioxins/furans may be as toxic, than the more well-known chlorinated dioxins/furans.[353352]

Areas of use of PVC[354]s:

- External cabling and wire
- Internal cabling and wires (including ribbon cables)
- Housing
- Packaging
- Plastic coated/encased electrical connectors
- Home cinema sets, DVD players/ recorders, lighting equipment, PC's.

Brominated flame retardants (BFRs)

The RoHS directive currently allows an exemption for one chemical of the PBDE group, namely deca-BDE. Studies have demonstrated the potential for environmental contamination with persistent, bio accumulative and toxic chemicals that can be produced during the processing of materials containing organic-bound bromine (which include all BFRs), as well as organic-bound chlorine (which includes the plastic PVC)[355].

The data from these studies relating to halogenated dioxins/furans

(polychlorinated dibenzo-dioxins and –furans), include;

- chlorinated dioxins/furans arising from chlorinated materials (e.g. PVC)

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352 http://www.greenpeace.org/raw/content/international/assets/binaries/ngo-rohs-submission.pdf
353 Ibid.
354 http://www.greenpeace.org/international/Global/international/planet-2/report/2009/1/green-electronics-survey-2.pdf
355 http://www.greenpeace.org/raw/content/international/assets/binaries/ngo-rohs-submission.pdf

- brominated dioxins/furans from brominated materials (e.g. all BFRs)
- mixed chlorinated-brominated dioxins/furans arising from mixtures of chlorinated and brominated materials (e.g. PVC and BFRs in the same source)[356352,357354,358355,359360].

Areas of use of BFRs[360]:

- Laminates of printed wiring boards, including flexible circuit boards.
- Battery, including casing and components
- Housing (including for periphery equipment, e.g. transformer)
- Fan and fan housing
- Ribbon cables
- Electrical insulation sheet
- Plastic coated/encased electrical connectors

Phthalate esters (phthalates)
Subsequent to this submission, studies have been released that demonstrate the widespread use of phthalates in some classes of EEE; laptop computers and mobile phones. These studies demonstrate the use of numerous phthalates, primarily as plasticisers (softeners) in materials manufactured from PVC and other polymers.

Due to concerns over human exposure to toxic and potentially toxic chemicals, the use of certain phthalates is banned in toys and childcare articles.[361]

Areas of use of phthalates:

- Polyvinylchloride (PVC)

Beryllium
Beryllium is primarily used as a hardening agent in alloys, notably beryllium copper. Beryllium, beryllium alloys and beryllium compounds are used in for instance connectors or as a component in heat sink. Beryllium has been used in the past in the form of beryllium copper in connectors of various kinds. Certain manufacturers have phases out the use of Beryllium voluntarily and their products are now beryllium-free.

Antimony
Antimony is mainly used in combination with BFRs to increase fire protective properties. Certain manufacturers have already phased out antimony voluntarily and antimony trioxide is no longer used in any major part. There are also other applications for antimony such as moisture protection and in varistors. For moisture protection, alternatives have been developed and replacement is well on the way, but for varistors no alternatives have been

356 http://www.greenpeace.org/raw/content/international/assets/binaries/ngo-rohs-submission.pdf
357 http://www.greenpeace.org/international/Global/international/planet-2/report/2009/1/green-electronics-survey-2.pdf
358 http://www.greenpeace.org/raw/content/international/assets/binaries/ngo-rohs-submission.pdf
359 Ibid.
360 http://www.greenpeace.org/international/Global/international/planet-2/report/2009/1/green-electronics-survey-2.pdf
361 http://europa.eu/rapid/pressReleasesAction.do?reference=IP/99/829&format=HTML&aged=1&language=EN&guiLanguage=en

identified and this use is exempted from the phase-out plan until replacement materials have been identified.

Also Nickel-compounds and Bismuth are considered hazardous by these organisations.

MD - Machinery Safety Directive No 2006/42/EC

The Machinery Directive 2006/42/EC provides the regulatory basis for the harmonisation of the essential health and safety requirements for machinery at European Union level. Machinery can be described as "an assembly, fitted with or intended to be fitted with a drive system other than directly applied human or animal effort, consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application".

The essential requirements related to environmental aspects may address noise, vibrations, radiation, emissions of hazardous materials and substances (Annex 1, item 1.5).

The Machinery Safety Directive 2006/42/EC was published on 9th June 2006 and it is applicable from 29th December 2009, replacing the Machinery Directive 98/37/EC.

ATEX directive 94/9/EC

Directive 94/9/EC of the European Parliament and the Council of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres (OJ L 100, 19.4.1994)

This directive applies to equipment used in hazardous areas (potential for an explosion) including equipment designed to prevent explosions[362]. The safety of workers is covered by a separate directive. The directive only applies to equipment that introduces energy, electrically or mechanically, into a potentially explosive atmosphere.

Packaging - Directive on Packaging and Packaging Waste

The Directive 94/62/EC (amended by 2004/12/EC, 2005/20/EC and Regulation No 219/2009) covers all packaging placed on the market in the Community and all packaging waste, whether it is used or released at industrial, commercial, office, shop, service, household or any other level, regardless of the material used.

The EC Packaging Directive seeks to reduce the impact of packaging and packaging waste on the environment by introducing recovery and recycling targets for packaging waste, and by encouraging minimisation and reuse of packaging[363]. A scheme of symbols, currently voluntary, has been prepared through Commission Decision 97/129/EC[364]. These can be used by manufacturers on their packaging so that different materials can be identified to assist end-of-life recycling.

Member States should take measures to prevent the formation of packaging waste, and to develop packaging reuse systems reducing their impact on the environment. The Member States must introduce systems for the return and/or collection of used packaging to attain the following targets:

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[362] http://www.conformance.co.uk/adirectives/doku.php?id=atex
[363] OJ L 365 , 31.12.1994 P. 10-23, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31994L0062:EN:HTML
[364] OJ L 050, 20.02.1997 P. 28 – 31, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31997D0129:EN:HTML

a) by no later than 30 June 2001, between 50 and 65% by weight of packaging waste to be recovered or incinerated at waste incineration plants with energy recovery;
b) by no later than 31 December 2008, at least 60% by weight of packaging waste to be recovered or incinerated at waste incineration plants with energy recovery;
c) by no later than 30 June 2001, between 25 and 45% by weight of the totality of packaging materials contained in packaging waste to be recycled (with a minimum of 15% by weight for each packaging material);
d) by no later than 31 December 2008, between 55 and 80% by weight of packaging waste to be recycled;
e) no later than 31 December 2008 the following targets for materials contained in packaging waste must be attained:
    - 60% for glass, paper and board;
    - 50% for metals;
    - 22.5% for plastics and;
    - 15% for wood.

The 2006 Report on the implementation of Directive 94/62/EC on packaging and packaging waste concluded that almost half of the Member States held derogations applying until 2015. Nevertheless, the objectives set for 2008 in Directive 2004/12/EC were to remain valid, even after 2008.

The incineration of waste at plants with energy recovery is regarded as contributing to the realisation of these objectives.

Member States must ensure that packaging placed on the market complies with the essential requirements of Annex II:

- to limit the weight and volume of packaging to a minimum in order meet the required level of safety, hygiene and acceptability for consumers;
- to reduce the content of hazardous substances and materials in the packaging material and its components;
- to design reusable or recoverable packaging.

Member States should develop information systems (databases) on packaging and packaging waste so that realisation of the targets of this Directive can be monitored. The data they hold must be sent to the Commission in the formats laid down in Annex III.

Energy Performance of Buildings Directive 2010/31/EU

On 19 May 2010, a recast of the Energy Performance of Buildings Directive was adopted by the European Parliament and the Council of the European Union in order to strengthen the energy performance requirements and to clarify and streamline some of the provisions from the 2002 Directive (2002/91/EC) it replaces. In November 2008, the Commission adopted the proposal for a recast of the Energy Performance of Buildings Directive. Throughout 2009, the proposal went through the approval process of the European Parliament and Council and a political agreement was achieved 17 November 2009. The recast proposal confirms the importance of effective implementation at the Member State level, the importance of Community-wide co-operation and the strong long-term commitment and role of the Commission itself to support such effective implementation. As the November 2008 Commission Communication for the original proposal states, buildings have significant untapped potential for cost effective energy savings "which, if realised, would mean that in 2020 the EU will consume 11 % less final energy." The magnitude of the potential savings is such that every effort must be made to achieve it.

IED - Industrial Emissions Directive 2010/75/EC

Industrial production processes account for a considerable share of the overall pollution in Europe (for emissions of greenhouse gases and acidifying substances, wastewater emissions and waste). In order to take further steps to reduce emissions from such installations, the Commission adopted its proposal for a Directive on industrial emissions on 21 December 2007. The Industrial Emissions

Directive 2010/75/EC (IED) entered into force on 6 January 2011 and has to be transposed into national legislation by Member States by 7 January 2013.

The Directive on industrial emissions recasts seven existing Directives related to industrial emissions into a single clear and coherent legislative instrument. The recast includes:

- The IPPC Directive (Directive 96/61/EC, replaced by Directive 2008/1/EC concerning integrated pollution prevention and control - the IPPC Directive)
- the Large Combustion Plants Directive (Directive 2001/80/EC on pollutants emitted by large combustion plants);
- the Waste Incineration Directive (Directive 2000/76/EC on the incineration of waste);
- the Solvents Emissions Directive (Directive 1999/13/EC on volatile organic compounds) and;
- three Directives on Titanium Dioxide (Directives 78/176/EEC, 82/883/EEC and 92/112/EEC on waste and discards from the titanium dioxide industry).

This integrated approach to issuing permits to industrial installations should allow major progress to be made in the field of atmospheric pollution. The central element of this approach is the implementation of Best Available Techniques (BAT).

The IED is the successor of the IPPC Directive and in essence, it is about minimising pollution from various industrial sources throughout the European Union. Operators of industrial installations operating activities covered by Annex I of the IED are required to obtain an integrated permit from the authorities in the EU countries. About 50 000 installations were covered by the IPPC Directive and the IED will cover some new activities which could mean the number of installations rising slightly.

The IED is based on several principles, namely (1) an integrated approach, (2) best available techniques, (3) flexibility, (4) inspections and (5) public participation.

1. The integrated approach means that the permits must take into account the whole environmental performance of the plant, covering e.g. emissions to air, water and land, generation of waste, use of raw materials, energy efficiency, noise, prevention of accidents, and restoration of the site upon closure. The purpose of the Directive is to ensure a high level of protection of the environment taken as a whole. Should the activity involve the use, production or release of relevant hazardous substances, the IED requires operators to prepare a baseline report before starting an operation of an installation or before a permit is updated having regard to the possibility of soil and groundwater contamination, ensuring the integrated approach.

2. The permit conditions including emission limit values (ELVs) must be based on the Best Available Techniques (BAT), as defined in the IPPC Directive[365]. BAT conclusions (documents containing information on the emission levels associated with the best available techniques) shall be the reference for setting permit conditions. To assist the licensing authorities and companies to determine BAT, the Commission organises an exchange of information between experts from the EU Member States, industry and environmental organisations. This work is co-ordinated by the European IPPC Bureau of the Institute for Prospective Technology Studies at the EU Joint Research Centre in Seville (Spain). This results in the adoption and publication by the Commission of the BAT conclusions and BAT Reference Documents (the so-called BREFs).

3. The IED contains certain elements of flexibility by allowing the licensing authorities to set less strict emission limit values in specific cases. Such measures are only applicable where an assessment shows that the achievement of emission levels associated with BAT as described in the BAT conclusions would lead to disproportionately higher costs compared to the environmental benefits due to:

   a. geographical location or the local environmental conditions or

   b. the technical characteristics of the installation.

   The competent authority shall always document the reasons for the application of the flexibility measures in the permit including the result of the cost-benefit assessment. Moreover, Chapter III on large combustion plants includes certain flexibility instruments (Transitional National Plan, limited lifetime derogation, etc.)

4. The IED contains mandatory requirements on environmental inspections. Member States shall set up a system of environmental inspections and draw up inspection plans accordingly. The IED requires a site visit shall take place at least every 1 to 3 years, using risk-based criteria.

5. The Directive ensures that the public has a right to participate in the decision-making process, and to be informed of its consequences, by having access to:

   a. permit applications in order to give opinions,
   b. permits,
   c. results of the monitoring of releases and
   d. the European Pollutant Release and Transfer Register (E-PRTR). In E-PRTR, emission data reported by Member States are made accessible in a public register, which is intended to provide environmental information on major industrial activities. E-PRTR has replaced the previous EU-wide pollutant inventory, the so-called European Pollutant Emission Register (EPER).

The Commission also formulated an action plan for 2008-2010 to improve the implementation of existing legislation. Under this plan, the Commission will ensure that the legislation on industrial emissions is fully transposed and will assist Member States in cutting unnecessary administrative burdens and in implementing legislation. It will also improve the monitoring of the enforcement of legislation and compliance checking, as well as improving the collection of data on best available techniques, and will create stronger links with the Research Framework Programme.

Also discussed is extending the scope of the IPPC Directive to cover certain activities (e.g. combustion plants between 20 and 50 MW) and clarifying the scope for certain sectors

[365] Note that the IPPC definition of BAT may be different to that used in Ecodesign studies, following the MEEuP, MEErP.

(e.g. waste treatment) to increase consistency and coherence of current permitting practices.

Finally, the Commission discusses the possibility of using flexible instruments such as an emission trading scheme for NO_x and SO_2.

Electromagnetic Compatibility Directive 2004/108/EC

The Electromagnetic Compatibility Directive was adopted on 15th December 2004 and repealed Directive 89/336/EEC. The EMC[366] is in place to ensure that electrical equipment is designed such that it doesn't interfere with or get disturbed by other electrical equipment and thus functions properly.

The main objective of the Directive 2004/108/EC of the European Parliament and of the Council, of 15 December 2004, on the approximation of the Laws of Member States relating to electromagnetic compatibility (EMC) is thus to regulate the compatibility of equipment regarding EMC:

- equipment (apparatus and fixed installations) needs to comply with EMC requirements when it is placed on the market and/or taken into service;
- the application of good engineering practice is required for fixed installations, with the possibility for the competent authorities of Member States to impose measures if non-compliance is established.

The EMC Directive first limits electromagnetic emissions of equipment in order to ensure that, when used as intended, such equipment does not disturb radio and telecommunication as well as other equipment. The Directive also governs the immunity of such equipment to interference and seeks to ensure that this equipment is not disturbed by radio emissions when used as intended.

Before equipment is placed on the market (including both apparatus and fixed installations) they must be shown to meet the requirements set out in the EMC Directive.

Waste Electrical and Electronic Equipment Directive

The European Parliament and the Council Directive 2012/19/EU on waste electrical and electronic equipment (WEEE) apply to pumps[367] under category 6 and 9 of "Annex I and II".[368]

The requirements of the Directive are transposed into national law by individual Member States and it is important to be aware of national take back and recycling schemes and arrangements in specific Member States. The Directive requires electrical and electronic equipment to be taken to a suitable authorised treatment facility at the end of its life so that it can be treated/ dismantled and materials recovered for recycling where possible. The Directive outlines minimum requirements for the treatment and recovery of WEEE.

[366] OJ L 390, 31.12.2004, p. 24–37, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:390:0024:0037:EN:PDF

[367] It is not clear whether the complete pump or only its electric/electronic parts are subject to the WEEE Directive.

[368] Category 6: electrical and electronic tools (with the exception of large-scale stationary industrial tools) and category 9: monitoring and control instruments. Subcategory of "Annex IB", for category 6 is: Equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substances by other means and for category 9: other monitoring and control instruments used in industrial installations (e.g. in control panels).

The WEEE Directive also requires products to be labelled, in order to identify them as EEE, with the aim of minimising the wrong disposal of WEEE. Where it is not feasible to put the label on the actual product it should be included in the documentation accompanying the product.

This Directive therefore deals with many of the end-of-life environmental impacts of electrical and electronic equipment.

For this category Member states shall ensure to reach the following targets:

- the rate of recovery shall be increased to a minimum of 80 % by an average weight per appliance, and component, material and substance reuse and recycling shall be increased to a minimum of 75 % by an average weight per appliance.

Noise by outdoor equipment - Directive 2000/14/EC

As amended by 2005/88/EC, on the noise emission in the environment by equipment for use outdoors defines water pump unit as follows:

A machine consisting of a water pump itself and the driving system. Water pump means a machine for the raising of water from a lower to a higher energy level

The administrative and legal position is given in the Directive 2000/14/EC of the European Parliament and of the Council of 8 May 2000, on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors. Noise emissions of outdoor machinery are regulated by European directive 2000/14/EC. This directive lays down minimal requirements (such as noise marking, noise emission limits) for outdoor machinery that must be respected before equipment can be placed on the European market. It represents a conventional ("command-and-control") regulatory approach. The directive has been amended by the Directive 2005/88/EC of the European Parliament and of the Council of 14 December 2005 and by the Regulation (EC) 219/2009.

Basic noise emission standard EN ISO 3744:1995

Measurement surface/number of microphone positions/measuring distance
Parallelepiped/according to EN ISO 3744:1995 with measurement distance d = 1 m

Operating conditions during test

Mounting of equipment
The water pump unit shall be installed on the reflecting plane; skid-mounted water pump units shall be placed on a support
0,40 m high, unless otherwise required by the manufacturer's conditions of installation

Test under load
The engine must operate at the point of best efficiency given in the manufacturer's instructions

Period of observation
The period of observation shall at least be 15 seconds

National test standards

There are also test standards developed at Member State level such as: DIN 4109 (-1) Sound insulation in buildings - Part 1: Requirements for sound insulation.

Annex 3. Summary of other pump related legislation.

The table below shows an overview of other water pumps legislation outside the European Union.

Table 76. Overview of water pumps legislation outside the EU.

Country	Policy Type	Mandatory/Voluntary	Scope	Policy Status	Test Procedure
Argentina	Comparative Label	Mandatory	Centrifugal pumps.	Development Completed - Pending Implementation	IRAM 62408
Australia	MEPS	Voluntary	This Standard specifies the energy information disclosure, energy labelling and MEPS requirements for swimming pool pump-units. This Standard covers all single phase pump-units intended for use in the operation of residential swimming pools and spa pools, and which are capable of a flow rate equal to or greater than 120 L/min. This Standard applies to single-speed, dual-speed, multi-speed and variable speed pump-units with an input power of less than or equal to 2500 W for any of the available speeds. This Standard covers pump-units for the circulation of water through filters, sanitisation devices, cleaning devices, water heaters (including solar), spa or jet outlets or other features forming part of the pool. This Standard covers pump-units that form part of a complete new pool installation as well as pump-units intended for sale as replacements for existing pools. This Standard covers all water-retaining structures designed for human use - (i) that are capable of holding more than 680 litres of water; and (ii) that incorporate, or are connected to, equipment that is capable of filtering and heating any water contained in it and injecting air bubbles or water into it under pressure so as to cause water turbulence.	Entered into Force	AS 5102.1-2009
	Comparative Label	Voluntary		Entered into Force	AS 5102.1-2009, AS 5102.2-2009
Bangladesh	MEPS	Voluntary	All types of water pumps over 2 horsepower	Under Consideration for Development	
	Comparative Label	Voluntary		Under Development	
Brazil	Comparative Label	Mandatory	Closed, open and semi-open rotor pumps, self-aspiring centrifugal pumps, multi-stage pumps with horizontal or vertical axis, up to 25 HP for three-phase monoblock centrifugal pumps, and up to 15 HP for single phase monoblock centrifugal pumps.	Entered into Force	NBR 626-2, NBR 5383-1, NBR 5383-2
	Endorsement Label	Voluntary	Centrifugal pumps	Entered into Force	NBR 626-2, NBR 5383-1, NBR 5383-2
China (PRC)	MEPS	Mandatory	Applies only to single stage single suction clear water centrifugal pump, single stage double suction clear water centrifugal pump, and multiple stage clear water centrifugal pump.	Entered into Force	GB 19762-2007 GB/T 3216 GB/T 5657 GB/T 7021 GB/T 13006

Country	Policy Type	Mandatory/Voluntary	Scope	Policy Status	Test Procedure
	Endorsement Label	Voluntary		Entered into Force	GB 19762-2007 GB/T 3216 GB/T 5657 GB/T 7021 GB/T 13006
	Endorsement Label	Voluntary	Applies to water source heat pumps using eletro-mechnical compressing system, with water as cold (heat) source. Product could be for home use, commercial and industrial use.	Entered into Force	CQC 3123-2010
India	Comparative Label	Voluntary	This standard specifies the requirements for participating in the energy labeling scheme for pump sets covering electric mono set pumps, submersible pump sets and open well submersible pump sets. The referred Indian Standard are IS 9079 : 2002 for Electric Mono set pumps for clear, cold water and water supply purposes, IS 8034: 2002 for Submersible pump sets, IS 14220: 1994 Open well submersible pump sets and IS 11346:2004 for testing purposes of the above mentioned pump sets.	Entered into Force	IS 9079, IS 8034, IS 14220, IS 11346:2002
Iran	Comparative Label	Mandatory	Centrifugal, mixed flow and axial pumps	Entered into Force	ISO-2548 (Class C)
	MEPS	Mandatory		Entered into Force	ISO-2548 (Class C)
Jordan	MEPS	Mandatory	Glandless standalone circulators and glandless circulators integrated in products. This regulation shall not apply to: (a) drinking water circulators, except as regards information requirements; (b) circulators integrated in products and placed on the market not later than 1 January 2020 as replacement for identical circulators integrated in products and placed on the market no later than 1 August 2015.	Under Development	
Korea (ROK)	Endorsement Label	Voluntary	Pump: Centrifugal pump for feeding water into boilers	Entered into Force	
Mexico	Comparative Label	Mandatory	NOM-004-ENER-2008 applies to clean-water pumps and motor pumps with a power rating of 0.187 kW to 0.746 kW. The standard aims at residential water pumps used to fill rooftop water tanks due to the low water pressure in the water mains; it establishes the minimum energy efficiency levels and the maximum energy consumption levels for residential water pumps and residential water motor pumps (using single-phase squirrel-cage induction motors), respectively, and the test methods for verifying compliance therewith.	Entered into Force	NOM-004-ENER-2008
	MEPS	Mandatory	Standard NOM-001-ENER-2000 applies to vertical turbine pumps with external vertical electric motor for pumping clean water as specified in the standard.	Entered into Force	NOM-001-ENER-2000
	MEPS	Mandatory	Standard NOM-010-ENER-2004 applies to submersible deep well type clean water motor pumps operated by a submersible three-phase electric motor. The standard does not apply to sewage and mud pumps.	Entered into Force	NOM-010-ENER-2004
	MEPS	Mandatory	Standard NOM-004-ENER-2008 applies to clean-water pumps and motor pumps with a power rating of 0.187 kW to 0.746 kW. The standard aims at residential water pumps used to fill rooftop water tanks due to the low water pressure in the water mains; it establishes the minimum energy efficiency levels and the maximum energy consumption levels for residential water pumps and residential water motor pumps (using single-phase squirrel-cage induction motors),	Entered into Force	NOM-004-ENER-2008

Country	Policy Type	Mandatory/Voluntary	Scope	Policy Status	Test Procedure
			respectively, and the test methods for verifying compliance therewith.		
	Endorsement Label	Voluntary	This endorsement label establishes specifications for centrifugal water pumps for residential use, from 0.187kW (1/4HP) to 0.746kW (1HP), with nominal voltage of 115 and 127V, operating at a frequency of 60Hz.	Entered into Force	NOM-004-ENER
	MEPS	Mandatory	Standard NOM-006-ENER-1995 applies to deep well water pumping systems, consisting of vertical centrifugal pump and electric motor (external or submersible), with power output from 5.5 to 261 kW (7.5 to 350 HP).	Entered into Force	NOM-006-ENER-1995
	Endorsement Label	Voluntary	This specification is applicable to: clean water submersible motor pumps from 1HP to 200HP, vertical turbine pumps with external electric motor for pumping clean water from 5HP to 500HP, vertical turbine pumps with external or submersible electric motor for the extraction of deep well water from 7.5HP to 350HP	Entered into Force	NOM-001-ENER; NOM-004-ENER; NOM-006-ENER; NOM-010-ENER
Switzerland	MEPS	Mandatory	This regulation establishes ecodesign requirements for the placing on the market of glandless standalone circulators and glandless circulators integrated in products. This regulation shall not apply to: (a) drinking water circulators, except as regards information requirements; (b) circulators integrated in products and placed on the market not later than 1 January 2020 as replacement for identical circulators integrated in products and placed on the market no later than 1 August 2015.	Entered into Force	
Turkey	MEPS	Mandatory	This regulation establishes ecodesign requirements for the placing on the market of glandless standalone circulators and glandless circulators integrated in products. This regulation shall not apply to: (a) drinking water circulators, except as regards information requirements; (b) circulators integrated in products and placed on the market not later than 1 January 2020 as replacement for identical circulators integrated in products and placed on the market no later than 1 August 2015.	Entered into Force	
	MEPS	Mandatory	This regulation establishes ecodesign requirements for the placing on the market of rotodynamic water pumps for pumping clean water, including where integrated in other products. This regulation shall not apply to: (a) water pumps designed specifically for pumping clean water at temperatures below – 10 °C or above 120 °C, except with regard to the information requirements of Annex II, points 2(11) to 2(13); (b) water pumps designed only for fire-fighting applications; (c) displacement water pumps; (d) self-priming water pumps.	Under Consideration for Development	
United States	MEPS	Mandatory	Industrial and Commercial Pumps	Under Consideration for Development	
	Endorsement Label	Voluntary	This labelling scheme establishes a minimum efficiency threshold which is calculated based on the volume of water pumped in gallons per watt hour of electric energy consumed by the pump motor (gal/Wh). The threshold is defined as 3.8.	Entered into Force	ENERGY START own test requirements

Source: Clasponline

Annex 4. Suggested pump categorisation for preliminary scope.

Table 77. Suggested pump categorisation for preliminary scope (total energy consumption figures based on preparatory studies).

Pump type	Intended use	Total energy consumption in EU	
		TWh/year*	% of total**
End suction pumps for clean water			
ESOB (≤150 kW)	clean water	*42.5*	*18.8%*
ESOB (150kW – 1MW)		6.4	2.8%
ESCC (≤150 kW)		*39.0*	*17.2%*
ESCCi (≤150 kW)		*24.4*	*10.8%*
Submersible borehole pumps for clean water			
Borehole MSS (≤6")	clean water	*24.7* *(only from 4" & 6" pumps)*	*10.9%* *(only from 4" & 6" pumps)*
Borehole MSS (>6" and ≤12")		21.0 (only from 8", 10" & 12" pumps)	9.3% (only from 8", 10" & 12" pumps)
Borehole MSS (>12")		5.2	2.3%
Vertical and horizontal multistage pumps for clean water			
MS-V (≤25 bar)	clean water	*6.0* *(only from vertical MS pumps)*	*2.7%* *(only from vertical MS pumps)*
MS-V (25-40 bar)		6.4 (only from vertical MS pumps)	2.8% (only from vertical MS pumps)
MS-H (≤25 bar)		n.a.	n.a.
MS-H (25-40 bar)		n.a.	n.a.
Other pumps for clean water			
Self-priming pumps	clean water	n.a.	n.a.
Booster-sets pumps		n.a.	n.a.
Pumps for swimming pools			
Small swimming pool pumps (≤2.2 kW)	swimming pool water	6.9	3.1%
Large swimming pool pumps (>2.2 kW)		2.3	1.0%
Centrifugal submersible pumps for wastewater			
Radial pumps (≤160 kW)	industrial, commercial & municipal wastewater	18.0	8.0%
Mixed flow & axial pumps	rainwater & activated sludge	1.0	0.5%
Dry well pumps (≤160 kW)	rain water, domestic/industrial/ commercial/municipal wastewater, sand water, grit water, raw/primary/secondary/ activated/tertiary sludge	3.9	1.7%
High solids content water pumps			
Centrifugal submersible dewatering pumps	sand water & grit water	4.0	1.8%

Slurry pumps			
Slurry pumps – light duty	slurry	9.4	4.1%
Slurry pumps – heavy duty		1.1	0.5%
Total energy consumption for pumps included in preliminary scope		**222.8***	**100%**

n.a. = not applicable as no study have covered this pump type or because the calculation for potential energy savings from EPA was not made in Lot 11.
* For water pump types in *italic (Lot 11 pumps)*, the annual calculated figures are from 2007; for the rest of the water pump types, the annual figures are from 2011.
**From the total sum of water pumps included in Lot 11, Lot 28 & Lot 29 studies, incl. those not mentioned due to their exclusion from this study.

Annex 5. Minutes from stakeholders meeting (draft to the European Commission)

Project:	Review of the review regulation 547/2012
Subject:	Minutes of stakeholders meeting
Date:	11 February 2016
To:	Participants of the meeting
From:	Study Team - Viegand Maagøe & VHK

viegand maagøe
energy people

Viegand Maagøe A/S
Nr. Farimagsgade 37
1364 Copenhagen K
Denmark

Tlf.: +45 33 34 90 00
info@viegandmaagoe.dk
CVR: 29688834

The minutes contain the topics and, when agreed, the conclusions arisen from the discussions on the topics presented at the Stakeholders Meeting. The presentation slides are also available at the project's website for reference.

Meeting participants

- Ruben Kubiak (RK) – Policy Officer at DG ENER, European Commission
- Larisa Maya-Drysdale (LMD) - study team (Viegand Maagøe)
- Ulrik Vølcker Andersen (UVA) - study team (Viegand Maagøe)
- Roy van den Boorn (RVDB) - study team (VHK)
- Jan Viegand (JV) - study team (Viegand Maagøe)
- Julien Aerts - Flowserve
- Niels Bidstrup - Grundfos/EUROPUMP
- Narciso Bolivar Rodriguez - FLUIDRA
- Wim Bonte - PACKO INOX NV
- John Bower - EUROPUMP
- Julien Chalet - PROFLUID / EUROPUMP
- Yeen Chan - ICF International
- Thijs de Wolff - EUROPUMP
- Oriol Falques - FLUIDRA
- Juan Jose Gomez - ESPA 2025, S.L./EUSA WG
- Anders Hallberg - Swedish Energy Agency (SEA)
- Thomas Heng - EUROPUMP
- Armin Herger - Speck Pumpen Verkaufsgesellschaft GmbH
- Markus Holmberg - EUROPUMP
- Pierre Iorio - FPP
- Aksel Jepsen - Danfoss
- Peter Klippel - Franklin Electric
- Friedrich Klütsch - EUROPUMP
- Michael Koenen - EUROPUMP
- Thomas Merkle - Schmalenberger
- Peter Nielsen - Danish Energy Agency (DEA)
- Mike Rimmer – UK Department of Energy and Climate Change (UK DECC)
- Moritz-C. Schlegel – DE BAM Federal Institute for Materials Research and Testing
- Stephen Schofield - EUROPUMP and BPMA
- Fredrik Söderlund – EUROPUMP
- Christian Tebert - OEKOPOL on behalf of ECOS
- Markus Teepe - EUROPUMP

- Samuel Thiollier - FOREZ PISCINES/EUSA WG
- Denis VEDEL - KSB SAS
- Kristof Vervloesem - Baltimore Aircoil International NV
- Sebastian Watolla - Speck Pumpen Verkaufsgesellschaft GmbH

Agenda

1. Welcome by the European Commission
2. Agenda of the day
3. Overview of the project
4. Overview of experiences from implementation of current Regulation 547/2012
5. Overview of current developments of Extended Product Approach (EPA)
6. Presentation of preliminary scope
7. Stock model
8. User characteristics of pump categories in scope
9. Technologies
10. Final scope
11. Next steps & additional Q&A

Aim of the meeting

The meeting focused on presenting a brief overview of the consolidated Regulation, the review study and on establishing an interactive dialogue with the participants on the topics of assessment. The aims of the meeting were:

- to present the aim and scope of the study as well as the methodology of the review,
- to present the methodology and the study team's findings so far, focusing on the aspects where the study team received comments from stakeholders for further clarification and discussion,
- to capture further input from the stakeholders participating in the meeting in order to continue the review study by the study team.

Welcome by European Commission

RK mentioned that this is the 1st and last stakeholder meeting. The report will be submitted before the summer break and the CF will be held probably after the summer break (i.e. around September/October). At the CF it will be evaluated how to best incorporate the review results into the existing legislation. Afterwards it will follow the usual procedure, which is an Impact Assessment, a Consultation and a Regulatory Committee Vote.

Agenda of the day

LMD presented the agenda of the day and emphasized that it is important to agree on the final scope, if not at the meeting, right after, once the study team has collected input from the stakeholders (at the meeting), LMD emphasized the topics discussed are based on comments received from stakeholders, particularly those where there is need for clarification and/or further discussion. The rest of the comments will be handled directly in the report. Additional questions are also welcome.

ECOS asked about deadline for comments as he did not see clear instructions for any deadline. ECOS would appreciate one more stakeholder meeting to discuss the final report. Maybe the conclusion after this meeting is that there is no need for it, but another opportunity to discuss the main conclusions of the final report has proved useful before.

LMD clarified the deadline for written comments is the end of February.

RK answered that indeed there have been more meetings for previous preparatory studies, however as a review study does not start from scratch, a second meeting is not considered necessary. Regarding a final stakeholders meeting at the completion of the study, the Commission has consciously stopped that as it was a duplication of a CF meeting which happens only 2 months later. This slowed the process and the Commission did not see a decline in quality.

Overview of the project

JV presented the aim and scope of the study, indicating that the background for this review is the past Consultation Forum in May 2014 where it was decided to incorporate previous preparatory studies with the scheduled review according to the Regulation 547/2012. JV presented also the methodology and its overlap/differences with MEErP.

ECOS mentioned it was difficult to find some good information in the report, as the chapters are without numbers. It would be preferable to have normal MEErP nomenclature for the chapters, to make it easier to find information. ECOS suggested to merge to a report within the MEErP structure.

JV answered that this may not be doable as some requested tasks by the Commission are outside the MEErP. The study team will assess whether this is possible.

ECOS mentioned it may be difficult as the reader may be expecting MEErP headings.

Overview of experiences from implementation of current Regulation 547/2012

JV presented an overview of these experiences, including the identified problems and recommendations.

ECOS agreed with all issues raised. It is crucial to find a solution for these issues as it is important the Market Surveillance Authorities (MSAs) can do a proper verification. In particular regarding a consistent categorisation, it does not matter whether it is on the nameplate or on the manufacturers' website.

EUROPUMP mentioned it is not a good idea to tag pumps with abbreviations (e.g. ESOB, ESCC): 1) Because EPA will be introduced consisting of a new methodology and new efficiency calculations, 2) Because the existing names are from previous preparatory study (2008), and based on English abbreviations which cannot be understood in non-English speaking countries. If there is a need for a consistent categorisation, it should be in the technical documentation, but there must be a better way than just taking English abbreviations.

Grundfos/EUROPUMP commented that in other regulations the manufacturers must prove their products are exempted from the scope and this could be done for this regulation (e.g. pumps with a special design for transport) to avoid loopholes without the need of clarifying the intended use.

JV answered it may be a challenge to have a common name that represents all languages, but a unit ID could be representative. He mentioned the study team is open for suggestions from EUROPUMP, and a continued dialogue should be established. He emphasized this needs to be solved as it is clear there is an issue with MSAs.

LMD emphasized it is important to establish a common ground for MSAs which they can use to relate the pumps they see and those stated in the regulation. LMD and Grundfos/EUROPUMP discussed further the issue about intended use, and Grundfos/EUROPUMP concluded that by stating the specific exemption by the manufacturer (e.g. special design for transport) should avoid loopholes. As, e.g. transport pumps, also pump clean water.

DEA stated MSAs in Denmark experience numerous problems with motors and pumps, especially with manufacturers trying to evade compliance. They have wasted a lot of time discussing whether pumps are in scope or not. He suggested having an index/coding indicating the pump type and whether it is in/out of scope. Even when specifying what the pump is designed for (suggested by EUROPUMP), this does not assure the pump type is really out of scope, as it is easy for manufacturers to specify their pumps have a special design and are therefore out of scope. Furthermore, the retailers may communicate to customers different uses of the pumps than what specified by the manufacturers, who may not assume responsibility over the retailers' actions. He therefore strongly recommends a common index/coding to make life easier for MSAs. He emphasized this problem was brought in by MSAs from several countries (through the Ecopliant project), and not only Denmark.

EUROPUMP mentioned there is no need for manufacturers to declare their pumps are out of scope. A possible solution would be to specify, only for the exemptions, that the pumps are exempted by the 547/2012 as well as the reason why. Else it should be considered the pumps are in scope.

UK DECC refers to the Standby Regulation, where a technical justification shall be provided if the requirements are inappropriate for the intended use (requirement 9d, Annex II). This is in alignment with what EUROPUMP is saying.

Overview of current developments of Extended Product Approach (EPA)

RVDB presented an overview of the EPA, including its definition, methodology, the background to look at this in the present review, and the test standards currently under development. He mentioned the draft standard FprEN 16840 has recently passed the voting and after some editorial changes a request will be sent to the EC for publication in the Official Journal. He also explained that the test standards EPA part 1 and part 2 are currently under development, and mentioned part 2 covers the current Regulation 547/2012 with the exception of submersible borehole pumps. He mentioned that the standards may be finalised at the end of this year/beginning next year (if everything goes well). Depending on the outcomes of current review study and a future revised Regulation 547/2012, this EPA test standard may extend to parts 3,4, 5, etc., on e.g. wastewater pumps, swimming pool pumps, etc.

No questions or comments were made.

Presentation of preliminary scope

LMD presented the relevance of the preliminary scope, which was established based on previous regulations and preparatory studies. She mentioned it was important to perform a qualitative/quantitative screening, to assess the relevance of all the pump types, not only in the current regulation but also in previous preparatory studies. She also explained the methodology to establish the preliminary scope.

EUROPUMP asked the next questions:

- Classification of wastewater: The classification of wastewater quality in wastewater treatment plants, is for bacterial growth before treatment. The pumped wastewater is different after the treatment. Therefore, the pumped wastewater is qualitatively different than the wastewater characterized.
- Swimming pool pumps: Slide 35 states minimum turnover time, which should probably be maximum turnover time.
- The exclusion criteria of 0.5 % of energy consumption: Is that a suitable criteria for exclusion? If a category with 0.5 % of the consumption can save 100 % of the energy it will be more than 1 TWh of savings.
- In Slide 39, the Lot 11 energy calculation is missing the pump losses.
- Wastewater subclasses: all water that is not clean could be wastewater, therefore EUROPUMP suggests that all water that has solids content is wastewater. EUROPUMP is willing to collaborate to find a definition of wastewater.

LMD answers:

- Wastewater: other chemical parameters than bacterial growth and solids content are measured throughout the plant to quantify organic matter/nutrients removal at the different stages of the treatment. However, EUROPUMP is right on the fact that the wastewater measured may not be the same than the wastewater pumped. She also mentioned EUROPUMP wanted to establish a definition based on a functional factor which could be adapted to different wastewater types and to correct the real efficiency of the pumps. She mentioned this could correct for the difference between wastewater characterised/wastewater pumped.
- The 0.5% was the only parameter that was consistently applied to all pump types for exclusion, as the saving potentials calculation methodologies were so inconsistent in previous preparatory studies (particularly Lot 28 & Lot 29). However, the study team also looked at savings potentials in an individual manner to make sure a pump type with high savings potential (in comparison to the other pump types') was not excluded.
- Regarding wastewater sub-characterisation, there is knowledge and a common scientific/engineering understanding on the different wastewater types (e.g. rain water is different to sewage wastewater which are also different to wastewater effluent), and what the typical benchmark values are as well as the qualitative/quantitative characteristics. Whilst this is not the case for slurry and for high solids content waster. Therefore there is hope for progressing on characterising wastewater in comparison to the other two.
- Regarding the parameter for swimming pool pumps, the study team agrees and this will be corrected in the report.
- Regarding the motor loss, that energy consumption was based on electric energy and therefore includes both motor and pump efficiency.

EUROPUMP asked how the exclusion of pumps from scope should be interpreted at this point in time? LMD answered that these pumps are not assessed further. EUROPUMP asks whether all the large pumps (>150kw) are excluded? LMD answered yes, but we included ESOB because it presented a higher energy consumption/saving potential. She clarified that further data was not collected for the excluded categories. She emphasized that the MEErP asks to refine the scope after each task (2 to 4), therefore in this review two versions of the scope are presented, one before and one after this refinement.

ECOS mentioned that they had requested in previous studies to present a sound methodology for exclusion of certain pump types, so they are glad this was done in this review study. He still questions the relevance of the 0.5% exclusion as some important pumps may have been excluded already. ECOS agrees on the scope we present as well as the methodology for exclusion.

Stock model

LMD presented the stock model and how it was calculated. She explained that other aspects of task 2 (Markets) were not presented since comments were mainly editorial and the study team agrees with them. The presentation focuses only on aspects which the stakeholders asked to get clarification.

EUROPUMP commented that growth rates are usually measured in dollars (value), but this is not relevant for the assessment as, e.g., if the growth rate is 2.2% this could be due to increase in labour cost and does not mean an increase in the number of sold pumps. Here we have pumps in number of pieces. What he suggested were reasonability checks (based on statistical data). Furthermore, pumps are used by people and this should not double over 15 years. Data is available in EIF-report from 2014, where the values have been corrected from 2011 to 2014.

EUROPUMP confirmed the report is available for purchase at the EIF website. LMD confirmed this was previously referred by EUROPUMP but that the price of the report was a couple of thousand pounds. EUROPUMP confirmed they will provide it as they get special price and it was therefore concluded the study team will get it from EUROPUMP. LMD confirmed the predictions until 2030 are based on rates from Lot 28 & Lot 29, so if a better more realistic rate is available in this report, this can be corrected in the stock model.

ECOS mentioned that Prodcom data presents always have this problem that it is based on monetary values. He also indicated that price ranges should be available by industry where product categories show price development vs. number of products. LMD confirmed this was suggested to the study team by industry previously (i.e. to provide price ranges and get a confirmation from industry), so hopefully industry can provide a confirmation on whether these ranges are appropriate and indication on how much they are not, if that is the case.

JV clarified the population in Europe may not always be the best indication, e.g. in wastewater pumps where a change of procedures and/or requirements for wastewater treatment may affect the growth rate. It was mentioned by a stakeholder that as rule of thumb (and accepted by government) is that the installed stock is 10 times the annual sales.

It was agreed that the study team will purchase the report abovementioned, if EUROPUMP can provide it with a discount price.

User characteristics of pump categories in scope

UVA presented the user parameters for the pump types in scope, which are used to calculate the energy consumption and therefore very important. He presented the values and assumptions as well as data sources, and he finally presented how the EPA was applied for calculating savings potentials.

FOREZ PISCINES/EUSA WG mentioned it is not right to mix two data sources for the operation time (EUSA WG for pumps ≤2.2 W & Lot 29 for pumps >2.2 W). He emphasizes pumps >2.2 W are not part of the market and therefore EUSA WG did not provide data on it. 99% of the swimming pool market concerns pumps ≤2.2 W, so operational time data for bigger pumps is not relevant.

UVA answered that 11500 pumps >2.2W were sold in 2011 (Lot 29) and with the average electricity consumption of 5kW, this makes 25% of the total energy consumption for swimming pool pumps. Therefore the study team considered it was still relevant to include at that point. UVA mentioned that EUROPUMP was referred as the data source.

EUROPUMP asked for clarification as clean water pumps are referred both as Lot 11 pumps and as Lot 29 pumps. UVA clarified he refers to both.

ESPA/EUSA WG mentioned they have provided this information (pumps >2.2W represent only 1 % of the market). UVA mentions this will be checked by the study team.

Note: All the sales numbers provided by the EUSA/WG were only covering (smaller) pumps up to 2.2kW. No data was provided for bigger pumps. The 1% provided refers to 2.2kW pumps, which are still covered by the category for smaller pumps.

Technologies

UVA presented the best cases and how their energy consumption was estimated. He also gave an overview of the definitions, as well as a short overview to the identified BAT.

Considering these aspects, UVA asked for feedback from stakeholders and below a summary of this is presented.

Booster-sets

EUROPUMP found a loophole by applying this definition, and it should therefore specify that it is '*to be operated with backflow prevention'*, because it can be assembled on site. EUROPUMP offered their help on providing definitions to avoid loopholes like this.

LMD mentioned it would be good to delimitate the definitions by size, rate power or another quantitative parameter as they have to be at a Working Document level. EUROPUMP said that individual pumps in booster-sets are already regulated but once they would should be regulated differently to achieve higher savings potential and therefore the definition is also different. Furthermore, these are multi-stage pumps which will be already regulated. A comment on this regard was made by ESPA/EUSA WG, stating it would be difficult to control booster-sets once they are built, as they become part of another device (i.e. in buildings). EUROPUMP clarifies they can be regulated as the products are placed in the market and/or put into service according to ecodesign wording, and in the example provided by ESPA, the product would be put into service. He clarified of the extended obligation of those whom put products into service, as the products they sell are also covered by the Regulation.

Horizontal multistage (MS-H) pumps

EUROPUMP mentioned MS-H could include horizontal split chase pumps which are used for feedwater for boilerplant and would therefore be engineered products as they fit into the category of up to 1MW. Serial pumps should be produced identically and in this case the methodology can be applied.

ECOS mentioned some pumps used in power plants are not engineered (e.g. for the washer and the scrubber). EUROPUMP answered that at least for MS–H split case pumps they are engineered as the planning of the whole power is done around the design point of the pump. There is a huge process of engineering and certification before the pump can be switched on. It will never happen that market surveillance can buy such a pump and test it.

EUROPUMP commented that regarding the definition of MS-H pumps, the EPA has to be taken into account. The products might have the same casing but they have big variations as they are selected specifically for an application and have a different motor, seal etc. EUROPUMP has therefore suggested to fit in the definition only the serial types, and therefore include only these in scope (they are also used in the booster-sets). EUROPUMP would like to distinguish between the engineered types and the serial types in the definition. UVA asked whether it is only big pumps which are engineered, EUROPUMP answered that the current size limitation of 150 kW represents largely the split between serial and engineered pumps.

Testing procedures and Market Surveillance

JV mentioned that regarding testing procedure, MSAs can do testing with large products on the installation site/manufacturing site. EUROPUMP commented this could be done for a particular pump, but if it fails the test the current legislation says that three more pumps have to be tested and that does not work for MSA. JV remarked his comment is also about large serial produced pumps, which the MSAs have the possibility to check by testing on-site. EUROPUMP (NB) emphasized that, by using EPA, the putting into service is a key as producers have to test and monitor pumps on-site. Some smaller pumps will have an EEI already when they are placed on the market, but the EPA will still have to be applied when the product is put into service. Therefore it is important to reconsider the whole 1+3 testing scheme in the current Regulation.

UK DECC mentioned the case of the Ventilation Regulation for large ventilation units, only five installations were produced in a year and therefore only one was tested. Another wording for testing could thus be used as inspiration from these other regulations for large products. On the 9th of March the UK DECC is facilitating a seminar on market surveillance of larger products with MSAs and manufactures attending. What we hope is that there will be an understanding between MSA and manufactures on how to deal with larger products.

RK clarified that at any regulation there is freedom to define the verification procedure counting on majority of Member States support. He mentioned also that testing products after they have been put into service can be difficult for MSAs. If most products of a pump category have to be tested like that, he assumes that MSA will not be able to do it. He raised then the question on whether it makes sense to put a requirement into a product that cannot be verified. SEA mentioned an example from the regulation of larger transformers, where MSAs can test these at the manufacturer place before they are put into service.

Conclusion: UVA wrapped-up by saying that in spite there may be issues with market surveillance of some products and even more considering the integration of EPA, ways to define the verification procedure can be elaborated by being creative. This input will be taken into account for the next steps of the review study.

Wastewater pumps

EUROPUMP (NB) mentioned that the current classification is based on technology because EUROPUMP has acknowledged that in a short time is not possible to come up with definition of wastewater which can be used to categorise the pumps. TU in Berlin says that it will take at least 5 years before different wastewater types can be defined. LMD asked whether the biggest problem is to come up with harmonised definitions of different wastewater classes. EUROPUMP answered by giving an example of channel vs. vortex pumps where, due to both treating the same wastewater type but having different efficiencies, one of them would be excluded from the market which would be a mistake as it is needed as one prevents clogging which is necessary in wastewater treatment plants. UVA then asked whether it is possible to have technology as the basis for categorisation in the Regulation. EUROPUMP (NB) answers it is at this stage. EUROPUMP remarked that there is a mix in the report between applications and pump types, and in the case of wastewater and its lack of definition, it is important to have in all of the pumps the technology included in the definition. The pump definition should be as clear as possible and not include applications. EUROPUMP concluded that in the case of wastewater pumps, as there are so many different technologies used for it and due to the lack of definition, it makes sense to categorise them by technologies. LMD emphasized the need to avoid clustering of products by technology, as it is important to encourage to move towards more efficient technologies which deliver the same application. EUROPUMP (NB) agreed with this in principal, but it is simply not feasible on a short timescale for wastewater pumps. He also emphasizes this was done for clean water pumps and it was accepted.

Conclusion: UVA concluded that for the short term and for the next version of this regulation, it is best to move forward with technology based classification in almost all the pumps. He asked industry to provide input to the study team on developing better definitions, as this still has to be done.

Slurry pumps

EUROPUMP mentioned it is not true that slurry pumps solely handle fine abrasive solids, there are other applications. Furthermore, the water is irrelevant and it is therefore the focus of the pump to move solids. He mentioned they developed a definition which will be sent to the study team, including a definition of dewatering pumps.

Swimming pool pumps

FLUIDRA commented that swimming pool pumps are not always operating at BEP and it is needed to operate them at different speeds for the different flows of the swimming pool in order to treat the water. This is why it is feasible to operate with VSDs. He assumed this is the reason why they are focused on this possibility in the USA and Australia. He concluded it is worth to use VSDs not only to adapt to efficiencies but also to users. UVA asked for clarification since he assumed the pump can use a frequency convertor to adapt to the different flow rates, FLUIDRA clarified that these different flow rates are operating 99 % of the time on filtration, and only using different flow rates e.g. when the pump is clogged and needs a higher flow rate. However this is only about once a month, and most of the time the pumps are working on filtration. UVA asked again for clarification, because if the pump is operating at lower flowrates (not BEP) most of the time then it is very beneficial to use VSDs. FLUIDRA answered that for hygienic requirements, a number of circulations/day are needed, and this is achieved by working with the pump for 10-18 hours/day (depending on the swimming pool) on filtration. Once a month for a very short time (3 minutes), a higher flow rate can be used. Most of the time the pump is working at constant flow. UVA asked whether there is a way to boost the flow rate at higher levels at this short times, if the pumps are operated efficiently during filtration. FLUIDRA clarified VSDs can be used in this case but only for 3 minutes/month.

Speckpump mentioned that they produce swimming pool pumps for Germany, USA and Australia, and that he totally agrees that swimming pool pumps have one working point. The reason VSDs are used in USA is that they like bigger pumps and buy pumps too large for the application. Where in USA they will buy a 3 hp pump the Europeans would buy a 1hp pump. EUROPUMP added that swimming pool pumps are multifunctional product; filtration and cleaning. And if the backflushing is not considered in the energy calculations then an important part of the pump's function is missing.

FOREZ PISCINES/EUSA WG added that pumps with VSD only represent less than 3% of the market. When comparing with USA and Australia it is important to take into consideration that there they use 5-10 times as much chloride as in Europe to compensate with the very low flow they are using. Therefore it is not enough argument to claim energy savings with use of VSDs, but also take into account the hygienic requirements.

RK mentioned these comments were still not enough to avoid regulation of the pumps. If the energy savings achieved in the USA and Australia comes from them using too large pumps, the same energy savings could be achieved just by using smaller pumps. The argument about chloride and the need to pump more in Europe does not mean that the technology can't be improved. Technological development has to be looked at, independently from sizes. Speckpumps commented that in the USA they do not look at the system approach as it is done in Europe (e.g. looking at the pipes' dimensions). By looking at the pipes' dimensions more carefully, it is possible to decrease the pressure on the pumps and therefore working with less power. In the USA smaller pipes/bigger pipes are used, whilst in Germany and in Europe the system approach has always been very important. UVA asked whether this implies to find the right size of the pump to the system, and Speckpumps confirmed it is indeed. FLUIDRA emphasized that because in the USA more chemicals are used, less water recirculation is needed. LMD invited the stakeholders to share information about the specific hygienic requirements and addition of chemicals in the different countries in Europe. The study team will investigate this further.

Conclusions: UVA mentioned these pumps will be looked into in more detail and if they are considered within scope, they will be part of the whole assessment during the review study.

Self-priming pumps

EUROPUMP is willing to provide a technological definition of what is/isn't a self-priming pump. EUROPUMP is working on a legal definition which will be sent to the study team by the 2nd week of March.

EUROPUMP added other challenges to regulate these pumps apart from those presented by UVA: (1) Efficiency is a trade-off with self-priming capability, (2) There is a very diverse range of these products in the market: some self-priming pumps can only handle very fine water, they can't even handle 'clean water', whilst others more efficient can handle a higher margin of solids. It would therefore be very difficult to categorise pump types according to type of water/application and even according to technologies. When pumping different types of liquid and mixtures of liquids/solids/gases the power consumption is also different. This is why they were left out of Lot 11 and of the current Regulation. EUROPUMP confirmed that self-priming pumps have short running times as those running for longer hours are less efficient so operators may choose other type of pumps to perform the same functions.

Conclusion: UVA wrapped up by saying the definition would help to resolve the loophole but the study team may find a way to gather or estimate energy consumption/savings potential. LMD emphasized on the importance to include a definition in a revision of the current regulation.

Motor technologies

EUROPUMP mentioned that the field in the data collection with PM without VSD is the energy consumption which it would use if it were running at fixed speed.

EUROPUMP also clarified that part load performance is not only relevant for variable flow applications but also (though at less degree) for constant flow applications. At constant flow application 75 %, 100% and 110% loads are considered. UVA clarified that from the data received from industry it appears that energy consumption is not reduced by applying VSDs to those constant flow applications.

EUROPUMP asked UVA what is the study team's understanding of system's approach and UVA clarified it is beyond EPA. EUROPUMP then clarified they considered that to be still EPA: the product approach is the wet-end, the extended product is still new products put into industry but looking at the entire system as one unit and system's approach is the installed base (i.e. pumps that are already in the market), what EUROPUMP is looking at is at defining the system's demand within the system. Furthermore, EUROPUMP simplified this by saying EPA is what happens between the flanges of the pump (i.e. treated as a product), there is a load profile to describe what happens with that product between the flanges, but EPA doesn't take into account sizing, pipes, which valves and other things one can do in the system to reduce the energy consumption. That is system's approach (not EPA). EPA always measures according to itself (i.e. the starting point is the BEP). JV added the load points for the EPA are kind of proxy for the system, so a simulation of the system is needed to have an understanding of what happens in real life but it is not regulated.

EUROPUMP mentioned some implications concerning motors: (1) PM motors always run with a VSD and the permanent magnets are produced in China. (2) IE4 motor do not have standard frame sizes and are often using permanent magnets- different frame sizes have the disadvantages that the IE4 motor may not be interchangeable between suppliers, (3) IE3 & IE4 motors are currently not regulated with requirements.

UVA clarified that the reason IE4 was presented as BAT is because, in spite it does not present a requirement, it is still the BAT found in the market.

ECOS requested to extend the BAT part of the technologies. Short described, not argumented, not elaborated enough. UVA and LMD clarified this will be done and LMD invited industry to provide further input on this aspect.

Wastewater pumps

EUROPUMP asked to have very clear definitions of vortex pumps and channel pumps as they are used for the same application. Due to channel pumps having lower efficiencies, vortex pumps may be the preferred option. It is therefore important to avoid this from happening.

Swimming pool

FOREZ PISCINES/EUSA WG clarified that, if one of the BAT options presented concerning high motor efficiencies (IE3 or better) concerns all type of motors, this is a wrong assumption as swimming pool pumps are mostly used with single phase motors (95-99%).

End of life

ECOS mentioned a point previously addressed in the motor study and previous pump studies, which is concerning rare earth materials which are not addressed in the report. They should be, ECOS highlighted a study from Siemens and others containing information about recycling. They pointed out that it would be valuable to see whether there are efforts done by the industry to label or better identify and even to better dismantle motors with rare earth materials, which can ease the recycling later on. He asked to reconsider whether all metals in the products are recyclable, the mixture of metals and other materials are disturbing the recyclability of the metals and therefore it is not 100% of the metals that can be recycled. These issues have been discussed in Germany at a stakeholder meeting for the motor regulation where some manufacturers stated they name (label) already the rare earth materials on the name plate of the product, so it may be good to collect these positive examples. Even plastic may not be recycled as it is often bounded to other scrap materials and therefore lost in the Electric Arc Furnace.

Final scope

Slurry pumps

EUROPUMP presented the difficulties of regulating slurry pumps:

1. They transport solids not water
2. The solids they transport are abrasive (fine or large lumps of rock), so the design of the pump is to handle solids not water, therefore testing in water for new pumps is irrelevant
3. Type of solids are very diverse and a potential harmonisation would be very difficult
4. The constructions are very different with very different materials (e.g. rubber-lime, ceramic, metal)
5. The pumps are deliberately designed to run at lower capacities so they operate far from their BEP therefore efficiencies established on BEP are irrelevant
6. Solids settle out and therefore operate at low speed so VSD applications are not relevant either. However, it is recognised that by changing speed energy savings can be achieved by, e.g., using belt drives (as they are often run) but not VSDs. Belt losses are usually around 3%.
7. Motors are not a go for mining applications in the context of EPA.
8. Previous Lot 28 categorisation is too generic
9. Savings potential is too low considering all the technical and categorisation difficulties

EUROPUMP concludes slurry pumps should not be in scope.

ECOS said they are reluctant to skip them too fast as many products may be also serial and the testing problems is not enough reason. There could be, e.g., a request for a test standard. EUROPUMP mentions the savings are rather small and clarifies double counting should be avoided as the motors regulation may already consider motor savings.

Conclusion: The study team concluded that they will write a formal assessment of all these arguments in the report, together with a clear definition of slurry pumps provided by the industry.

Self-priming pumps

Conclusion: UVA emphasized the importance to have a definition where the study team hopes to get assistance from industry.

Large pumps

EUROPUMP added the issues with testing as well as that by only regulating ESOB the market could move towards ESCC as they have the same application. This could create a move on the wrong direction.

Conclusion: LMD and UVA concluded that the issues/potential solutions mentioned in the meeting regarding testing will be further investigated. UVA emphasized that they key issue is to assess more closely the savings potential and counter balance this with the potential barriers by regulating.

Multistage pumps

EUROPUMP said they present the same argument for bigger MS pumps (>180 m3/h), the current and new methodologies do not fit these large pumps. General comments about scoping

EUROPUMP concluded that summing all these 21 small pump categories only add up to 5 TWh savings, while the total EPA savings are about 35 TWh. So the huge amount of work working with these new categories does not correspond with the potential savings. These are too small.

JV asked EUROPUMP where are specifically the additional costs deriving from regulating these new pump categories, for industry. EUROPUMP answered it is a lot of work to be done for continuing developing the EPA methodology for all these additional products. Furthermore, there are many unclarities for standardisation that need to be solved.

LMD emphasized the exclusion of pump categories must be done by ensuring there is no way to increase the savings potential. The study team needs to re-evaluate some parameters from the data, before taking a final decision on exclusions.

EUROPUMP clarifies the effort for them is mostly after the first data collection by the study team is finalised. For the 547/2012 about 4000 data points (per pump type) were collected to establish the polynomials that are in the regulation. For the large pumps the data points may be too few to apply a statistical approach to establish these polynomials. So to conclude, the work for EUROPUMP would come after the first two screenings the study team has done, preliminary and final scope.

LMD asked EUROPUMP whether they would establish these polynomials for other pump types than those EUROPUMP has suggested for exclusion since the beginning of the study. EUROPUMP answered it is something they do not do themselves, but they pay for it to be done.

RK said the consultants are doing what requested by the Commission. If EUROPUMP decides not to provide data, the consultants need to do the work based on estimations. A pump category cannot be excluded on the basis that industry cannot provide data. This is a no go. EUROPUMP (NB) emphasized that the most costly is to get data for setting requirements (i.e. collecting the data points to establish the polynomials to be included as equations and requirements in the Regulation). This exercise takes time and it was the reason why establishing a scope was important since months ago, to proceed with the second data collection by EUROPUMP.

DEA emphasized that from the perspective of MSAs, it is important not to get a regulation with small savings potential (e.g. the Standby Regulation on coffee machines). RK emphasized it is not about pushing products with small savings through the regulation, but to present (by the study team) valid arguments to not include products in the scope. Valid arguments come from good data, but if data cannot be provided then the study team needs to make assumptions.

EUROPUMP asked what is the benchmark value is to define a product as worth to be regulated. For example, in the report is found that some products have 'high' savings potentials therefore EUROPUMP wonders what is high and what is not high.

LMD summarized 3 groups of pump categories:

1. Group 1: Those that should be in scope, according to the agreement that has already taken place from dialogue between the study team and industry
2. Group 2: Those which, with the last input received from stakeholders, will be excluded already from this review study as they present low savings potential and many difficulties to regulate
3. Group 3: Those which will continue to be assessed in this review study and that may be recommended for inclusion in a future revision of the current regulation, once the main conclusions are drawn and when the final report is ready

LMD asked then Europump whether they are waiting for the decision on the final scope to start collecting the data for establishing the polynomials and the EEI indexes. EUROPUMP answered they are waiting indeed to define the direction of the standardisation work and with universities, although they are already working on developing the EPA methodology with some of the clean water pumps from Lot 11 plus others like booster-sets.

LMD asked what is the status of the data collection (for establishing the polynomials and EEI indexes) for the pumps where there is already an agreement (group #1 mentioned above). These pumps have been communicated to EUROPUMP since August 2015. And second she asked if EUROPUMP would collect these data also for some pump categories where EUROPUMP does not agree (group #3).

EUROPUMP answered they are already collecting data for pumps in group #1, but not for all members, they are also analysing the data, checking methodology lacks, etc. The results of these unofficial data collections are going into the standardisation work. He asked how it helps for the study team that this data collection exercise is done for pumps in group #3, how it would help their work.

Next steps & additional Q&A

EUROPUMP mentioned that for pumps already agreed on (group #1), the next step is, e.g. with small ESOB pumps, to cluster for data. He asked when is the study team expecting the clusters for the pumps in scope from EUROPUMP, before or after the CF? LMD answered these should have ideally been delivered before the completion of the study (i.e. before summer holidays), as it is part of the review to suggest more advanced ecodesign requirements including, if possible, EPA. EUROPUMP explained that, when looking at the savings potentials at product and at EPA level, it is obvious EPA give the most of the savings. Considering the study team has already established ranges in these savings, he asked whether it is not enough argument to conclude the study without having to wait for EUROPUMP's outcome from the second data collection. LMD emphasized the data shows there are large savings with EPA, however it does not show any specific ecodesign requirements the pumps can be tested against like the MEI index. EUROPUMP (NB) asked then to clarify whether the study team expects to have the cluster data before the summer. Especially since resolving other issues like characterisation of wastewater, by including these pumps in scope, would delay the work on the data clusters.

LMD asked EUROPUMP to continue working on the categories already agreed (group #1), however EUROPUMP answered it is not possible to work unless a complete package is presented.

Based on the previous discussions and further agreements, the next steps are:

- Communicate clearly the pumps the study team will continue working in (group #1 & group #3)
- Communicate clearly the pumps the study team will not continue assessing (group #2)
- The study team will wait for additional comments from stakeholders (extended to the 10th of March, by request of some stakeholders), and update the report accordingly.
- Written comments will be received once the Draft Final Report is published in the project's website. It will be communicated when about the deadline.
- The study team will upload the document with EUROPUMP's comments, answering only those which were not discussed and where a conclusion was not achieved. Those discussed and concluded during the stakeholders meeting will not be dealt with.

Based on the previous discussions, the agreed information, reports or data to be sent to the study team are:

- EUROPUMP will send the EIF 2014 report if the study team decides to purchase it – *sent*
- EUSA WG will send information on hygienic requirements - *sent*
- EUROPUMP will send definitions on the next pump categories:
    - Slurry pumps – *not sent yet*
    - Booster-sets – *not sent yet*
    - Self-priming pumps (to be sent by second week of March) – *not sent yet*

Others to be discussed along the continuation of the review (e.g. multistage horizontal pumps)

Annex 6. Europump official comments and reply from study team.

Table 78. Europump official comments to study progress report and reply from study team.

EUROPUMP Template for comments and secretariat observations 1 **MB** = Member body / **NC** = National Committee (enter the ISO 3166 two-letter country code, e.g. CN for China; comments from the ISO/CS editing unit are identified by **) 2 **Type of comment:** **ge** = general **te** = technical **ed** = editorial *ISO/IEC/CEN/CENELEC electronic balloting commenting template/version 2012-03*						Date: 19 Jan. 2016 – 20th January 2016 [re-revised up to 28nd Jan,) Reply by study team: 15th June 2016.	Document: **Ecodesign Pump Review, Study of Commission Regulation (EU) No. 547/2012 incorp […] 'Lot 28' and 'Lot 29' (Pumps) - Final Progress Report**		Project: EUROPUMP & EUSA Joint Comments on Review Study
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1	page 6	0	list of figures	Ge	It seems some figures are taken from Europump document	Please mention the sources of figures somewhere in the document		The sources of data for tables and figures, when not based on information and data elaborated by the study team, have been properly referenced in the pages these are presented.	
2	page 7	1.1		Ge	the link between the tasks of this study and the tasks from the MEERP methodology is not very clear	Add a general description of this study including a correspondence table between the study tasks and the MEERP tasks		The general description is already included in the introduction chapter. An overview table has been added in the same chapter.	
3	page 7	1.1	last paragraph	Ge	The objective of defining a "final scope" is not clear. Does it mean that it will be the scope of the policy options that will be recommended at the end of the study? "The final scope will be used in further tasks": what are the further tasks?	Clarify what will be done with the "final scope"		The purpose of the 'final scope' has been discussed and clarified in stakeholders' meeting. An explanation of what 'further' tasks are has been included in this chapter.	
4	page 9	2.2	1st bullet point	Ge	"The manufacturers do not use the same categorisation as in the Regulation": this cannot be surprising. Each brand has its			The study team proposes to harmonise the categorisation by introducing an index/coding which the manufacturers have to follow, according to what provided in the water pump regulation. This has been suggested in the report.	

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					own way to categorise products.			
5	page 9	2.2	1st bullet point	Te	The definition of ESOB, ESCC… could also be applied to pumps out of the scope of the regulation. To add this on website does not help to identify which pumps are covered or not.	Only the declaration of conformity tell if the manufacturer apply Regulation on a particular product. Maybe the MEI value could also be accompanied by the ESOB, ESCC… category (applicability of this proposal on the nameplate should be studied carefully)		This proposed change has been suggested in the report. Please look at section 2.2 for details.
6	Page 9		Paragraph 2.2 1st Bullet	Ge	*"The manufacturers do not use the same categorization as in the Regulation 547/2012 (i.e. ESOB, ESCC, ESCCi, MS-V and MSS). For Market Surveillance Authorities, this makes it difficult to determine whether a pump is within the scope or not and to find the applicable minimum efficiency requirements. Since the nomenclature in the legislation has to be as generic as possible, it is suggested to specifically request in the Annex IV of the Regulation that the*	Somebody who tests a pump should know what he does and therefore knows which pump is under testing. Should a Centrifugal submersible Pump (Once a day Operation) be named as CSP(OADO) in future for all languages?		The people doing the testing are in many cases not those selecting the pumps for verification, and have no technical insight to select the right pumps. It is therefore proposed in the report to add a universal simplified index/coding which is marked near or on the name plate with an accompanying explanation of the coding in the technical documentation.

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					manufacturers provide the verification information (requested in Annex IV) categorized in the same way as the Regulation and make this obligatory."			
7	page 9	2.2	1st bullet point	Ge	When any authority try to verify the conformity of a pump, the identification of ESOB, ESCC, … will be quite easy.			See proposal in section 2.2
8	Page 9	2.2	1st bullet	Ge	The designation is clear and did not cause any problems with Market Surveillance from our knowledge. However, the designations (ESOB etc) are based on English terms and cannot be used with different languages. Listing them will cause confusion.			According to market Surveillance Authorities (MSAs), an index/coding will avoid language confusions. See proposal in section 2.2.
9						DELETE FIRST BULLET POINT		The stakeholders incl. MSAs pointed out the importance of solving this problem, and it was therefore decided to act on it rather than deleting it from the report.
10	Page 9 – 10		3rd bullet	Te	That is not practical. Every pump can pump water (and does so during test in the factory)			This is not related to whether they pump can pump water but to the pump's intended use. The study team has made a proposal in section 2.2 of the report.

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11	Page 9 – 10		4th bullet	Te	Off-shore is not covered in Ecodesign Directive	Delete – Validity of Directives is on-shore		Deleted.
12	Page 9 - 10		4th bullet	Te	We had the discussion of hygienic requirements several times before. It will be impossible to comply to both requirements	EUROPUMP suggests to clearly exempt pumps designed for hygienic purposes to avoid further misunderstandings. Specifically designed hygienic pumps for food processing and pharmaceutical applications falling under Annex I.2 'SUPPLEMENTARY ESSENTIAL HEALTH AND SAFETY REQUIREMENTS FOR CERTAIN CATEGORIES OF MACHINERY' of the 'DIRECTIVE 2006/42/EC of 17 May 2006 on machinery' should be exempted from efficiency requirements of Regulation EU 547/2012. Pumps under EC No. 1935/2004 shall not be in scope also.		This item was discussed during the stakeholders' meeting and the conclusion was the same: that as long as the pumps' intended use is to pump clean water, they are covered by the regulation.
13	Page 9 - 10		6 bullet	Ge	??	EXPLAIN.		Done.
14	Page 9 - 10		7th bullet	Te	We cannot have two declarations of conformity. Legal requirements do not foresee this.	Two declaration of conformity are against European common market principles. Pumps are machines, they do not need a DOI (declaration of incorporation)		Bullet point deleted.

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						Please revise.		
15	Page 9 - 10		8th bullet	Te	Test with actual pump speed	See prEN16480 – Change.		Changed accordingly. See section 2.2 of the report.
16	Page 9 - 10		9th bullet	Te	That is usually done. We should not mix MEI with efficiency again. This will lead to wrong pump selection!!			Part of the sentence has been deleted, excluding the suggestion by Germany to include efficiency information at PL.
17			Paragraph 2.2	Te	*"Generally, Europump recommends that the best way for the clean water pump manufacturers to comply with the Regulation is to indicate the H-Q curve and at least the three relevant Q-H-η points in Part Load (75% flow at BEP), Best Efficiency Point (100% flow) and Over Load (110% flow at BEP) for full impeller size. In this regard Germany has also suggested to provide 'sufficient' efficiency information (e.g. efficiency at part load) on the product documentation sheet, including also information on use of materials for planners and craftsmen."*	It has been discussed numerous times, trying to make clear, that it is the purpose of an Index to eliminate the mistake of oversizing pumps when prioritising efficiency as the primary selection parameter. The decisive and first selection parameter for the pump is the demand, namely Flow and Head, of the pump installation. Therefore it is counterproductive to request efficiency values as a direct parameter of choice. A part load characteristic of a pump is not subject of the legislation 547/2012 as is. It might make sense in the review, but then it has to have the complete installed extended product in mind. The EEI is then the correct value to express the		Part of the sentence has been deleted, excluding the suggestion by Germany to include efficiency information at PL.

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						efficiency also in part load operation		
18 *19* *20*	Page 11	2.3	1st bullet	ge/te	"The exclusion of self-priming water pumps and the lack of justification for this exclusion, as some of the currently covered water pumps can also have self-priming functions." Implies that not including self-priming pumps in 547/2012 was a loop hole. This is not correct. The pumps have lower efficiency, are multiple types, run short times and were deliberately excluded. Self-priming pumps have a different design of impeller and casing to reach the self-priming capability. This has a negative impact on efficiency. If a self-priming device is supplied the pump will not usually run continuous or very long. (All the other bullets of omissions & loopholes were provided by Europump)	Remove		This point must be left as it is creating a potential loophole and in this section the aim is to present the causes. The discussion about scope is presented in other chapters of the report.

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21			2nd bullet	Te	Incorrect, a horizontal and vertical pumps have for example different bearings			Despite they may have different designs they may be used for the same purpose and this has been acknowledged by Europump's position paper. See section 2.3 of the report for more details.
22			3rd bullet	Te	Europump suggests to use <12", later in document this is not used			This section deals with presenting potential loopholes. The discussion about categorisation and scoping is dealt in other chapters of the report.
23			Paragraph 2.3	Te	The exclusion of self-priming water pumps and the lack of justification for this exclusion, as some of the currently covered water pumps can also have self-priming functions.	Self-priming pumps do suffer from the priming functionality in terms of efficiency. Therefore the not given definition of self-priming pumps might be a legislative loophole in 547/2012 but not that these pumps are exempted from the legislation is a loophole. Types are too diverse to be categorised as clean-water pumps. The pumped media is a mixture of a fluid and gas. Therefore it is a special design and application.		This point must be left as it is creating a potential loophole and in this section the aim is to present the causes. The discussion about scope is presented in other chapters of the report.
24	13	3.1		Ed	The text describing the first two pump categories; centrifugal submersible pumps	Change place on row 23 and 28		Corrected

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					(radial…) and centrifugal submersible pumps (mixed flow…), have been interchanged.			
						Reverse headlines !		Corrected
25	Page 13	3.1	par. 10	Te	Materials should generally be treated as secondary when it comes to definitions of product categories. This to avoid unnecessary loop holes. This is also valid for "centrifugal submersible domestic drainage..." even though this product category is concluded exclude.	Text to clarify exclusion of intended products in scope. Material cannot be a limiting factor. EUROPUMP will offer to better define pump types.		Materials excluded. EUROPUMP did not provide alternative definitions and the study team has therefore only used previous preparatory studies as source to present in chapter 3. The study team reminds Europump this chapter is a literature review of preparatory studies, so final definitions are only relevant to pump categorisation in scope which are presented in a later chapter.
26	Page 13	3.1		Te	"Centrifugal submersible pumps (radial sewage pumps up to 160 kW): pump sealed into a single unit with motor and submersed in the media being pumped - typically found in wastewater networks; <u>the fluid does not change its radial location since the change in radius at the suction and the discharge is very small, hence the name "axial" pump."</u>	What shall be said? Please correct or clarify.		Wrong headline, the text is for axial flow and mixed flow pumps. Headline corrected and a description for mixed flow pumps is added. The given description is according to what is written in Lot 28. The purpose of this section is to present the findings of the previous studies

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Date: 19 Jan. 2016 – 20th January 2016 [re-revised up to 28nd Jan,) Reply by study team: 15th June 2016.	Document: **Ecodesign Pump Review, Study of Commission Regulation (EU) No. 547/2012 incorp [...] 'Lot 28' and 'Lot 29' (Pumps) - Final Progress Report**	Project: EUROPUMP & EUSA Joint Comments on Review Study

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27	Page 13	3.1		Te	"Centrifugal submersible pumps (once a day operation, up to 10 kW): typically formed by a water pressure-tight encapsulated fully flood-proof motor and pump forming a compact, robust unit construction which may vary in different technologies in relation to reliability, operational lifetime, pressure, flow and motor power. <u>They have a grinding/shredding system formed with a stationary cutting device in the inlet and a rotating cutting device at the end of the pump/rotor shaft."</u>	Most of them don't have. Remove. <u>This (underlined)</u> is not true.		Description is changed, according to what is given in Lot 28
28	Page 14 Line 11	3.1	Par. 2	Te	Definition of slurry pumps (light duty) is not clear	Europump will supply a more suitable definition. There should only be one definition for slurry pumps. A separation into light and heavy duty is not possible.		This description is from Lot 28, the purpose of this section is to present the findings of the previous studies. The study team never received the definitions from Europump.
29	Page 14	3.1	Par.5	Ge	<u>Clarification regarding functional factor and Europump position:</u> A	Europump offer support on the needed changes.		It is acknowledged by the study team of Europump's efforts on the difficult task of finding a relationship between wastewater type and pump's efficiencies according to a classification on pump's application. The study team has

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					methodology where the functional factor is used for the assessment of true wastewater efficiency and ultimately for pump qualification is very far from being realized. To succeed typical wastewater contents and representative artificial wastewater have to defined as well as reliable and cost effective test methods have to be developed and verified. Before this is realized the functional factor should not be considered at all. Europump position in Lot 28 is to have a regulation based on clean water efficiency (tested according to 9906:2012) supported by defined pump types and wastewater classes. A link between pump types and waste water classes are necessary to get data collections that are taking the secondary functional parameters into account. In this report this is not considered. Instead all types of radial channel pumps are treated as one group and			therefore modified this sentence recognizing the difficulties on doing this, and a proposed classification is presented in chapter 7 (Task D3: Users).

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					vortex pumps are treated separately based on technology.			
30	Page 14	3.1		Te	"Slurry pumps (heavy duty): engineered products tailored for individual applications, matching to the medium to be pumped which typically contains high concentrations of fine very abrasive solids; designed to minimise wear and withstand heavy work." Larger particles and even stones are usually be in the pumped fluid. These are not "fine" solids	Clarification required		This description is from Lot 28, the purpose of this section is to present the findings of the previous studies
31	Page 14	3.1		Te	"These definitions should include the quantitative specification of important parameters which influence pump selection according to Lot 28, which are: viscosity, rag, grit, chemical properties. An alternative to measure these four wastewater	Explain that there is no clear definition for waste water. Describe the need for classification and appropriate tests.		Included, although it is important to emphasize that wastewater in treatment applications can be characterised and it is therefore more feasible to establish a harmonised definition.

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					characteristics every time a pump is to be chosen …” The characteristic of waste water is much more complicated and cannot get described with these 4 parameters.			
32	Page 15	3.1	Penultimate §		The definition of the swimming pool pump is confusing. It shall be rewrite to be clearer and avoid any misunderstanding. Why talking about the 3kw pumps in the pool pump definition up to 2,2kw. It does not make sense. A lot of commercial pool (campsite, hotel ...) use pool pump up to 2,2kw. Therefore, the sentence shall be modified in this way. Finally, Replace Jacuzzis (trade name) by spa or hot tub.	To be modified as follow : **Swimming pool pumps integrated motor + pump with built-in strainer (up to 2.2 kW)**: small pumps packaged in plastic comprising an integrated unit of motor, pumps and controls typically rated around 1 kW (with built-in strainer); they are mainly sold for residential use (commercial premises use sometimes standard water large pumps) which can also be used for spas / hot tubs .		The description is from Lot 29, the purpose of this section is to present the finding of the previous studies. The revised definition for swimming pool pumps has been adapted in section 9.3.
33	Page 15 Also page 45 Also pages 79 and 80		3rd para from end Second paragraph	Te	The report from Europump explaining the serious problems in trying to regulate slurry pumps has been recognised, but the pumps have been left in the study scope	→ Remove Slurry Pumps from Scope of this study		The purpose of this section is to present the findings of the previous studies, and the revision of the scope is dealt until chapter 9.

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34	page 16		bullet point 4	Te	The comment about submersible spa pumps may need to be revised, as they are not used in a spa in the way described In a self-contained portable hot tub, they are housed in the cabinet (as a non self-priming pump) while in other spas, self-priming pumps are used.	Clarification is needed from the author about what they want to include. Definition is unclear. Clarify.		The description has been extended but could not be done more comprehensively as it is from Lot 29, and the purpose of this section is to present the findings of the previous studies
35	Page 19		Fig 2	Te	The Denmark energy breakdown is very different to that found in the UK. Is it typical of Europe, or does it depend on definitions?	EUROPUMP feels that the bottom up extrapolation from Denmark to whole Europe is a misleading way. A UK government study for example says the different. (reference) EUROSTAT Data base and all the preliminary studies for LOT 11 motors and Pumps etc to come to a more reliable estimation.		Example deleted as a reliable data source for the whole EU was not found.
36	Page 20	3.2	Last bullet	Te	Fixing dimensions: The sentence can be read in a way that it is understood that the entire pumps are manufactured following national or international	To modify as follow: Fixing dimensions. Some pumps which are manufactured to a National or International Standard will usually have their mounting hole positions and		Corrected.

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					standards, which is not the case. It is “design restrictive” and shall be modified.	sizes, and branch positions, defined by the Standard. This is of particular value when replacing a failed pump.		
37	Page 20	3.2	table 2	Te	The purpose of table 2 is very unclear and the purpose has to be clarified			The MEErP methodology calls for reviewing secondary functional parameters previously used in other studies. The study team has to review this, and that was the intention on presenting the table. Furthermore, it is a good starting point to discuss the importance of some of these parameters in chapters 7, 8 & 9.
38	Page 20	3.2	Table 2	Te	Where does this come from? The content seems quite arbitrary. Examples Fixing dimensions not relevant for lot 28? Part load behaviour not relevant for lot 11? Noise is very significant parameter in the swimming pool area! The selection of materials for small swimming pool pumps is significant. Most pumps are made from plastic.	Revise or remove		The study team has included the input provided, but the table remains in the report as it is the intention to show what other preparatory studies mention, as it is the aim of this section to present the findings from previous preparatory studies.
39	Page 20		Table 2	te.	The secondary functions should not be so different between different Lots			See previous comment.

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40	Page 20		Table 2 6 explanantions	Ge	"Pump Speed" – Pump speed is limited for fixed speed pumps through the pole number of the electric motors. Therefore it is necessary to switch between speeds to avoid inacceptable low efficiencies of extreme specific speeds.	Change Pump Speed content		Changed.
41		Chapter 3.2				Data is confusing. Please explain ! This data should not be used to draw conclusion.		The study team does not understand what 'data' Europump refers to, but if it is about the information presented, it is important to remind Europump that this is based on what presented in previous preparatory studies and its aim is to give a summarised overview and to use it as starting point for the further chapters.
42				ed.	The wording leakage is misused several times for different things.	Change in appropriate wording.		Text where leakage is mentioned comes from Lot 11, and the study team has assessed is correct in most of places. It has been partially corrected only in one sentence. The study team invites Europump to give specific suggestions to improve the text.
43	Page 21	3.2	bullet point 3 and 4		Noise: For wastewater pumps noise can be caused by cutting devices that sometimes are used. These technical solutions are especially for small pumps of the grinder type but also for cutter pumps used in manure applications. In these cases the sound level from the hydraulics might be higher than from the	Disagreed. Revise text. Noisy pumps in clean water pumping is an indication for something going wrong: . Agreed. But the paragraph needs revision.		Paragraph on noise has been revised accordingly. Paragraph on minimum clearances has been left in as it is a secondary parameter which may be also evaluated for at least selection of other materials as it affects energy efficiency negatively.

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					motor. Customers are used to this today. Minimum clearances are valid for Lot 28 as well as Lot 11 and 29 but is not a functional parameter for selection. Minimum clearances for plastic swimming pool pumps amount to approx. 1 mm. This is due to the manufacturing tolerances and larger gaps are absolutely necessary for trouble-free operation due to impurities such as leaves, pine needles and sand.	Paragraph on minimum clearances need more developments.		
44	Page 22	3.2	5th bullet	ge	General Construction: Part of the text is already mentioned in the 2nd bullet of page 23 (Maintenance). This is not helpful and shall be deleted. General construction of swimming pool pumps for the private area also take into account the fact that it should be user-friendly, simple constructions as the operators	To deleted the following sentences : Ease of maintenance varies with pump type. With End Suction Close Coupled pumps it is possible to access the impeller by removing one set of nuts or screws and removing the full rotating element including the motor without disturbing the pipework. Access to the seal is then possible by removing the impeller. With End Suction Own		Revised.

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					are not pump experts in most cases.	Bearings pumps, the coupling spacer is removed and the pump rotating element can then be withdrawn without disturbing the motor or the pipework Add a sentence about swimming pool pumps		
45	44	3.2 p.22	par. 6	te	Solids handling capability: The text concerning wastewater pumps are misleading. The ability to handle fibrous components is of major importance for most of the pumps in scope of Lot 28. There are several technical solutions to assure reliability and self-cleaning in the relevant applications. These technical solutions are all distinguished by refinement of the geometries and not primarily depending on size.	Change to:…In many applications the ability to handle fibrous components in the wastewater is of major importance. In order to achieve this, the hydraulics of the pump should be designed to pass solids through the pump.		Revised.
46	Page 22	3.2		ge	Solids handling capability. The pumps considered in this study all need to be able to pump solid materials suspended within the liquid. The ability to handle fibrous components in the wastewater is also of importance.	Clarify		Corrected.

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					This is valid for lot 28, **but not** for all pumps considered in the study			
47	Page 23	3.2	4th & 5th bullet	ed	Units are missing	To add units		This section has only a descriptive aim, and we are therefore not providing units in any of the parameters. For consistency reasons both bullets have been left as they are.
48	Page 24 Last bullet			ge	Repetition of Part Load Behaviour (see Page 22)	Delete		Deleted.
49	Page 27	3.3		te	FprEN 16713 part 3 This part concerns only pool water treatment. It specifies only recommendations and does not include test methods.	To modify the text to avoid any misunderstanding.		Corrected.
50	Page 28			ge		Wording of evaluation of tolerances is biased. There are good reasons for these tolerance bands.		Literally the scope of ISO 9906, added to the section in the report.
51	page 34	4.1	figure 3	ed	Source of the figure?	Please cite the source (this comments is applicable to several figure)		Revised.
52	Page 34			te	The overall efficiency of the pump unit is […] and the best efficiency is at BEP Eta VSD is missing.	This section is mostly extracted from Europump Guidelines but the changes/additions have introduced an error which needs to be corrected		Corrected.
53	Page 35			te	The Extended Product Approach is made of pump,			Text described is not relevant to load profile as it only presents the scope in terms of components. But text in

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					motor and optional VSD **and load profiles**.			another paragraph, which is considered more relevant, has been revised.
55		Page 38	Last sentence	te		States that it is necessary to find out what share of the market could meet the chosen EEI mandatory levels. This is OK if is sorting out fixed flow from variable flow and finding that fixed speed pumps are not suitable in their EEI values for variable flow, but EEI is not about introducing further cut-offs of pumps, motors and VFDs.		Revised.
56		Page 38		ed	Footnote 39, link does not work	Revise.		Corrected.
57		4.5 p.39	Par.1	ge	The use of the expression "motor technology" seems to refer to both motor and drive. It should be considered to change this to another wording that is more in line with the EPA. Maybe the term PDS (power drive systems) defined in 4.1 can be used not to confuse the reader when "applied motor technology" also means the inclusion of a VSD.			Corrected

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58	page 39		Penultimate para	ge	The relatively low amount of energy savings for swimming pool pumps does not warrant the money and effort at this stage, as Europump appear to have identified much bigger savings from some of the other pumps.	Defer swimming pool pumps to a later stage, if actually needed at all, so that efficient use of time can be spent to get the biggest savings now.		The intention of this chapter is to put the swimming pool pumps in the perspective of the EPA. The paragraph has not been deleted. Issues of scope are discussed further in the report.
59	Page 39	4.4		te	*"Furthermore,there are no appropriate test standards for testing the energy efficiency of wastewater pumps. To develop an appropriate test standard for testing wastewater pumps more scientific research is required."* The testing of efficiency is not the problem as it can be done with clean water. What we need is a classification of the waste water and a test procedure for the non clogging behaviour of the pumps.	Correct		Corrected.
60	39	4.5		te	"Therefore only potential improvement regarding motor technology is considered while potential improvements on the pump itself are not considered here."	Improvement in pump efficiency means improvement also. Revise.		Text has been modified to make point that improvement of pump's efficiency can also have an influence.

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					This is not true, improvements of pump efficiency will have the same effect on the EEI			
61		4.5, Page 40	First line	te	The report notes that wastewater pumps do not benefit from EPA except slurry pumps. Europump has always stated that slurry pumps have even worse issues with low speed than sewage pumps and they already have belt drives which are used to change speed as the duty changes.			Revised.
62	page 41	5.1	1st paragraph	te	"water source heat pumps" are not similar product to the water pumps in scope of this study	Delete Example		Deleted.
63				ge		Europump questions the whole relevance of chapter 5.1. Revise.		This section must be included according to the MEErP methodology, and it also provides a summary of what presented in previous chapters and the highlights to justify a preliminary scope. It has been left in the report.
64	page 41		Footnote 42	ed		Identify the letter by title please.		Corrected.
66	Page 42	5.1		te	"The lack of distinction between 'wastewater' and 'high solids fluids', as the centrifugal dry well pumps are used for both			Agreed and therefore this was deleted from list of ambiguities.

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					No, these are different pump types.			
67		Page 42	Third bullet	te	The report states: ***The exclusion of horizontal multistage water pumps is not justified anywhere, therefore an unknown potential of energy savings is withdrawn, as these pumps are used widely particularly in large industrial applications*** This very worryingly implies that large industrial pump can be in scope. These are not the type of high volume horizontal pumps Europump wants in scope and we must be very careful with the definition of horizontal pumps	Europump will provide a reasonable definition for horizontal multistage pumps. The pumps which shall be in scope are NOT used in industrial applications but in building service sector. Please Revise accordingly.		Text revised. However, industrial applications was not deleted as these pumps are used both in building and industry. At this stage of the report we still considered the three sizes sub-division of horizontal multi-stage pumps.
68	page 42	5.2	1st bullet point and second paragraph	ed	A "quantity of water" should be expressed in m^3 (or in kg) the flow can be expressed in m^3/h, the head can be expressed in any pressure unit or in meters	correct the functional unit and the following sentence. *"m"* belongs to head.		Revised.
69	Page 42	5.2	3rd paragraph	te	Types of water listed (e.g. grit water ...) is questionable. The sentence:*"In spite of this, it is suggested to group the pump*	The listed 'water classes' are application specific. Most of the listed 'waters' are located in the waste water pumps business.		In order to promote technology innovation, the application of ErPs is meant to be the basis for comparison and that is why it is important to define a Functional unit. The study team acknowledges the difficulties of doing so when

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Date: 19 Jan. 2016 – 20th January 2016 [re-revised up to 28nd Jan,) Reply by study team: 15th June 2016.	Document: **Ecodesign Pump Review, Study of Commission Regulation (EU) No. 547/2012 incorp […] 'Lot 28' and 'Lot 29' (Pumps) - Final Progress Report**	Project: EUROPUMP & EUSA Joint Comments on Review Study

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					types according to the water types the pumps are handling" EUROPUMP is convinced that this is impossible on such a level.	EUROPUMP will suggest reasonable waste water specific classes. According to the European Commission in general we have to talk about pump types instead of application type.		wastewater and swimming pool water do not have an harmonised definition, but at this point of the report it was decided to leave this as the basis of categorisation. The text, however, has been revised and extended to prove the point better.
70	Page 42/43	5.2	Pumps definition and classification	te	The fundamental design is missing as a characteristic: an ESOB pump is something different then a self priming pump or a waste water pump.			General construction was added.
71	Whole doc			ge		The whole document gives evaluated energy savings. What are large energy savings ? What is the benchmark for being 'large'.and 'significant' ? Please use real figures and not biased comments. The selection of 0.5% of overall-consumption to be a qualified product has nothing to do with potential savings which should be the reason for being a pump in scope.		A level for exclusion had to be established in order to limit the study to the pumps that were important. This was looked together with savings potential at individual level. Remember that at this stage of the report the scope is only preliminary. The text has been extended to justify more the study team's point.
72	Page 43	5.2		ge		Booster Sets have never been discussed in preparatory studies it is an Extended Product made		Revised.

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						from pumps plus accessories for which EUROPUMP suggests an own EPA regulation.		
73	20	5.2 p.43		te		Add secondary performance parameters *clog resistance capability* and *wear resistance capability.*		Added.
74	page 43	5.2	4th to 6th bullet point		BEP, PL and OL are not parameters	the parameters should be: head and flow at BEP head at PL head at OL		Corrected.
75	Page 42 & 48			ge	Slurry pumps are not pumps in the meaning of this study. They are meant to transport solids by the means of fluids and not fluids itself	EUROPUMP regularly requested to deal these kind of pumps elsewhere as they are incomparable with all other pumps in scope.		At this point of the report, the slurry pumps were still considered part of the 'preliminary scope'. Look at later chapters for more details about slurry pumps.
76	Page 44	5.2		te	"End suction coupled, 150kW - 1MW: 0.3% of the estimated total;" Does it mean "closed coupled"?	Clarify		Corrected.
77		5.2		ge	EUROPUMP doubts that it is reasonable to exclude or include pumps based on their overall-consumption. It is the purpose the Ecodesign-			The methodology to determine the 'preliminary scope' was already discussed above.

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					Directive to save energy. Where the highest potential for savings exists, these products should be chosen. Here for example ESCC > 150kW – 1MW is out but ESOB 150kW – 1MW is in based on their consumption.			
78				ge	**EUROPUMP refuses to develop EPA further if an increase of MEI is proposed.** **To increase MEI would be enormously costly to the European pump industry, in time, Euros and jobs, for small savings. Europump offered EPA in place of an increase in MEI, to the EC'** **EU 547/2012 Article 7 requests an extended product approach which has been followed up with tremendous effort by EUROPUMP. Turning around the wheel again is counter-productive.**			**It was clarified during the stakeholder meeting that MEI was not used as the only indicator for assessment. It was used as for some pumps (i.e. those in Lot 11), only MEI levels were available. Saving potentials at EPA level have also been looked at.**
79	Page 44-46	5.3		te	This sub-chapter refers to move from energy-savings to energy consumption as a			It has been clarified that energy consumption was not the only parameter the study team has looked at for defining the 'preliminary scope'. See further explanations in our replies above.

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					selection criteria for pumps in scope. EUROPUMP strongly suggests to focus again (see MEErP-Studies) on energy savings to correctly prioritise products in scope.			
80	Page 45	5.3	1st paragraph	ge	The 2 types identify from the preparatory study is a non-sense and do not represent the pool pump market. See the provided data: Pool pumps up to 2.2kw represent 99% of the market. Therefore, there is no need to keep the second type of pool pumps.	To delete, in the entire report, all information coming from the preparatory study and concerning the above 2.2kw pool pumps.		Based on the preliminary assessment, non-domestic swimming pool pumps were still relevant to look at. The study team has therefore not deleted them from the whole report, but rather provide explanations of why they are considered in the 'preliminary scope' (this was done since the progress report) and why not in the final scope (in the draft final report).
81	Page 46	5.3		ge/te	By adding another 20% losses to a wrong figure does not make a wrong figure correct. BIOIS has estimated these values on their own more or less reflecting best estimates from EUROPUMP.	Revise chapter !!!		It is not sure whether BIO made a mistake, but they study team found a consistent error which has been explained and justified. An alternative to this method was not provided by Europump, and the study team therefore decided to stick to this method considering the lack of information in Lot 28.
83	page 48	5.3		te	"*pumps for solids content water*": this type of pumps cannot be found in sections 2.2 and 2.3	add a definition or correct the references		The grouping is used to distinguish applications between pumps for wastewater and pumps for high solids content water. *high solids content water' was introduced to represent all fluids with very high solids content such as

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								slurry or grit. It was a simplification done by the study team to group dewatering and slurry pumps in the same application based on the input from stakeholders.
84	Page 48	5.3		te	Category 4 is a sub-category of type 3.	Review.		It is not, as it was also stated many times by Europump, that pumping wastewater is not the same as pumping fluids with high solids content.
85	Page 51	Chapter 6	Table 4	ge	Prodcom Statistics. 28131420 Rotodynamic pumps ≤ 15 mm discharge 2005: 619,172 2008: 2,005,594 2010: 2,246,832 2013: 101,546,394	An increase of 5000% from 2010 to 2013 is ridiculous. Even if the data is considered to be inconsistent at a later stage in the text, This value should be cross checked if it is not a €uro figure instead of units. Especially this should be done as there is a matching of Prodcom data with defined Pump categories in scope (see table 6). A pump wigth <15mm Discharge for a waste water pump is not known to EUROPUMP. REVISE !		These values are provided in units directly from PRODCOM, and as stated in the text they are shown only for reference and to get an insight of what PRODCOM shows in relation to industry data. The increase is not 5000% but 165% (excluding positive displacement pumps). Finally, the study team aimed to include in this analysis all rotodynamic pumps for clean and wastewater mentioned in PRODCOM. Due to differences in categorisation is difficult to match them all. However, taking in your comment, this category has been set as not matching in the table of matching pump types.
86		Page 51 And Page 53	Table 4 And Table 6	te	Includes Positive Displacement pumps types which have never been in scope	Delete.		Deleted.

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87	Page 54	6.2	2nd paragraph	ge	The Europump swimming pool pump WG and the EUSA swimming pool pump WG are in fact the same WG.	To modify in order to avoid any misinterpretation.		Revised
88		6.2 Page 55		te	Growth rate of 4% continuously seems to be high, particularly for mining/heavy process industries using slurry pumps	Use current data from 2014. Data is available from 2015 by European Industrial Forecasting Ltd. LOT 28 Data estimations for growth are dubious. The growth rate is the dominating factor in the following chapters for stock consumption forecast (in 2030). The choice of this value has tremendous influence on decision later and should be done on a reasonable basis which is EIF report 2015 for example. Growth rate in value (€) and in units is something totally different and shall not be mixed.		A whole section has been introduced in the draft final report, using and describing the method for estimation based on the European Industrial Forecasting Ltd. Report.
89	page 55	6.2	first paragraph of page 55	te	It is not clear in the text if the growth rate is expressed in value or in unit. To our knowledge, EIF study only give growth rates previsions in value (€). But in this report, and	Make the distinction between growth rate in value and growth rate in unit. Explain the method and the assumptions made to calculate growth rate in units.		See reply from previous comment (#88).

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					especially in table 7, growth rates are in number of pumps sold.			
						Annual Growth rates have neither be confirmed nor discussed with Europump with the study writers of previous preparatory studies. They have been estimates by the study writers on which Europump believes does not have any influence on.		Europump has indicated that by using this report (EIF Ltd), the growth rates would be aligned to Europump's practices when looking at market forecasts. Furthermore, it was recommended by Europump during the stakeholder meeting to buy this report to estimate the growth rates. The study team has therefore followed their advice and a methodology has been included in the draft final report.
90	Page 56	6.2	Table 7	ge	Except for the 2014, where do these estimated annual total sales come from?????	Precise the way and calculations used to get the estimated annual total sales. Sources ? Data needs revision.		It is clearly stated in this section that the total annual sales are derived from data provided by Europump and EUSA WGs (2014) and from estimated growth rates. Text has been shortly adapted so it is more clearly referred to the growth rates.
91		6.2 p.58	Figure 12	ed/te	The number of slices in the pie chart does not match the nr of listed pump types	Clarify		The chart has been made bigger to show as many pump categories as possible, but this was not enough to show them all.
92		Page 59	Fig 13	te	Exponential growth of 'stock' seems unlikely. Has allowance been made for stock 'lost' by closed facilities and commercial buildings?	See growth comment above.		Stock has now been recalculated according to refined growth rates, and it does not show exponential growth as it did previously. Allowance for stock 'lost' by closed facilities and commercial buildings has not been included. No data on this was found nor provided.
93		Page 59	Fig 13	te	Stock overcomes the sales rate. It must be the opposite. It	Revise figure 13		Difference between sales and stock was only due to the different scales of the two axis in the chart. This has been set different now to avoid confusion.

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					is contradicting the statement given in the text before. An increase of around 60% in sales and stock over 15 years is exaggerating.			The sales and stock now increase about 21% due to the revision of the growth rates.
94	Page 62			ge	Engineered pumps are generally of large size and built to high specification (mostly in conformity with API 610) and higher price.	We are talking about clean water pumps and waste water pumps, not petrol. Nevertheless also in clean and waste water there are numerous engineered pumps. Correct please !		Revised.
95		Page 62	Table 10	te	It is not recognized that pumps move from standard to Engineered as the size increases. All slurry pumps are shown as standard when in reality they are all engineered, to some degree at least. The text below the table correctly states: ***the greatest majority of relevant applications for water pumps within the scope***	REVISE THE WHOLE TABLE. Europump is offering support to revise the table.		Revised

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					of this study are standard pumps. But slurry pumps are not water pumps! DELETE reference to API 610.			
96		Page 62	Table 10	te	Main relevant applications for water pumps are NOT Chemical, Pulp & Paper, Pharmaceuticals, Power Generation			The table gives an overview of the whole EU pump market, as an insight of this kind is not available for clean water and wastewater pumps. Therefore, these applications have not been removed.
97		Page 62		te	What is a special purpose pump compared to an engineered pump. Pumps are engineered because of special purpose and are NOT generally API 610 pumps.			The categorisation is given according to Europump's reference: http://europump.net/uploads/End%20Use_Application%20and%20Range%20of%20Pump.pdf The study team welcomes Europump's specific input to revise it. However, we need specific suggestions for changes and not only complaining statements.
98	page 63	6.3	1st and second bullet points	ed	A few members are mentioned as "notable". It is not clear why these one are "notable" and not the others.	give a full list of members of EUROPUMP and EUSA or list the European associations. Otherwise it gives a biased wrong picture.		Corrected.
99	Whole doc			ed	"*sewerage pumps*" means "sewage pumps"			Corrected.
100	Page 63			ge	Either all members are listed or none but not "notable" members this is biased and personal view of the author	Correct into a general statement.		Corrected.

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					which might not reflect the thinking of (not listed) associations			
101	page 63	6.3	1st and second bullet points	ed	A few members are mentioned as "notable". It is not clear why these one are "notable" and not the others.	give a full list of members of EUROPUMP and EUSA.		Corrected.
102	page 64	6.3		ed	There is a list of "main" manufacturer. But is the method to make this list is not explained. EIF study could be used to determine a top 10 list of pump manufacturer (in turnover)	WHAT IS THE PURPOSE OF SUCH A LIST? It does not add any information for the purpose of this study. Delete!!! It does not help the report at all.		Revised according to EIF report.
103	page 65	6.3	1st paragraph	te	Only a part of the swimming pool pumps are sold as BtoC (mostly above ground pool)	Clarify this point to avoid any misunderstanding please.		Revised.
104	Page 66			ge	If a decline in Turn over by -4% is listed, why is the assumed growth in Europe around +4%. Even if there is a growth in Africa, it is irrelevant as we are talking about a European regulation here. Changes in requirements in Europe do not affect non-eu countries such as US or Russia etc.	Use other sources. Delete figures. Inappropriate in context with this study. (Recommendation by VDMA itself).		Germany is used as example as it is one of the most important manufacturers of pumps in scope as well as one of the most important markets in the EU. As no similar figures are found available for the EU, the study team has provided Germany as an example. Text and figures about exporting have been deleted to avoid confusion and it was not considered relevant any longer since estimated growth rates have been calculated with more certainty.

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105	page 66			ed	Is the title referring to "Germany still Export World Champion" necessary in this type of EU document?	Modify the heading or better delete the paragraph.		Deleted paragraph.
106	Page 66/67			ed	Delete references to specific companies and their products. All companies have to comply today to the regulation of 547/2012 not only one specific company. Also small companies (and not the big seven only) do offer controlled (vsd) and high efficiency motors according to the law EC 640/2009.	Revise.		The specific reference to Xylem is not provided based on compliance with regulation nor to the use of VSDs. It is provided in the context of ease of repair and maintenance and this information was not found available by other manufacturers. They study team welcomes Europump to provide links to publicly available information in this respect to be added in the report.
107	page 67	6.3	3rd paragraph of page	ge	The trends …. in the EU are different. The amount of disinfection chemicals should never be increased. Because this would not be understandable in a eco-design regulation (pollution with chemicals versus energy savings?). The target must be to select a pump exactly as near as possible to the BEP (Best efficiency point) VSD is reasonable, but only for	Add to the paragraph: The amount of disinfection chemicals should be never increased. Because this would not be understandable in an eco-design regulation (pollution with chemicals versus energy savings?). Pumps should be selected as near as possible to the BEP (Best efficiency point). VSD is reasonable, but only for processes, where the running hours per day exceed e.g. 2 hours.		The amount of chemicals can vary depending on the user behaviour, however, values are recommended in the EN 16713 standard. Therefore stating that 'chemicals should be never increased' is not correct as some users may use more chemicals than others. Therefore this paragraph has not been modified accordingly.

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					processes, where the running hours per day exceed e.g. 2 hours. Australian and US regulation cannot be taken as benchmark.			
108	Page 69	6.4	Table 12	ge	The prices do not seem to be realistic and a range with a factor of sometimes 10 does not give any usable information.	Revise table		Prices have been corrected for most of the pumps, based on an extensive price data search on retailers' online websites and manufacturers' catalogues. Those prices still presented in ranges are for pumps not included in the final scope. For some of the excluded pumps (from final scope), data was not found available.
109				ge	Purchase Prices given in Table 12 are questionable. As the purchase prices directly go into the Least Lifecycle Cost analysis it has a big influence on drawn decision later.	Please correct purchase prices (e.g. a 1MW pump for 8000€ is too low). EUROPUMP cannot give real data (but we can give hints about the (in-)correctness of it)		See previous comment (#108).
110		6.4 p. 70	Table 13	te	Yearly cost for repair and maintenance are generally way too low	EUROPUMP is not allowed to supply purchase price, installation and maintenance cost data. EUROPUMP commented on the old LOT11, 28, 29 reports that given purchase prices were way too low but they have never been corrected.		See previous comment (#108) on prices. Installation, repair and maintenance costs have been corrected for pumps in final scope.

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						Zero Cost for maintenance shall be corrected into maintenance-free if appropriate.		
111	Page 70		Table 13	te	The installation costs for e.g. ESOB Pumps is in the same range as the purchase price. This is unrealistic.	Correct table 12 (see above)		See previous comment (#110).
112	Page 72		Table 14	te		Interest rate is too high for the last 4 years and the upcoming years (~0.5%) CORRECT or give source of information.		The interest rate used is what recommended by the European Commission. See reference in report.
113	page 72	6.5	3rd paragraph	te	"*growth rate of 3-4%" annually*" ?	explain if it is a growth rate in number or in market value Value it-self questionable. 'Domination' needs to be made clear here. It might be in terms of units but not in energy savings.		See comments on growth rates (#88-90).
114	Page 72		Last paragraph.	te	Already it is apparent that there is an increasing focus on motor design, VSD and monitoring systems for pumps, all of which	← THIS IS EPA.		The study team is aware of this, and that is why it was included here, leading to task D3 (task 3 users).

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					contribute to lower energy consumptions. Besides energy consumption, the industry is focusing on improving design to ease installation and maintenance and to increase reliability of the pump.			
115	Page 73			ge	*"The industry is positive about the prospect for a revision to the ecodesign regulation with higher ambitions,"* The higher ambition should focus on the EPA and not simply increasing thresholds of the EU 547/2012 which do not lead to reasonable energy savings.	CHANGE		Revised.
116		7 p.75	Par. 3	te	Impeller and diffuser/volute are wear parts in some of the wastewater pumps. Exchanges of impellers are very common. For submersible dewatering pumps exchanges might be necessary several times each year depending on the	Include according to comment		Included.

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					application and its chemical properties.			
117		p. 75	Last paragraph.	te	Besides impeller design clean water pumps are optimised by their inlet and outlet connection.	Explain in detail what is meant.		It has been briefly described what the study team means.
118		p. 75	Last paragraph.	te	Polishing is not an economic solution to improve pump efficiency sustainably.	Delete.		Deleted.
119				ed	EUROPUMP is well aware of the advantages of VFDs	Delete 'manufacturers' – see Variable Speed Guideline, 2004		Corrected
120	31	7 p.76		te	We cannot say that typical BEP efficiency for a 30 kW waste water pump refers to the given very large efficiency interval.	The interval shall be much more narrow or we give the interval for all pumps instead (w.o the 30kW).		Revised according to own estimations based on market research by the study team.
121					Footnote 78 & 79 are missing	Add footnote/source		Added.
122		Page 76	Booster sets	te	Pumps are generally connected in parallel to vary flow, not in series to vary head	Please correct.		Corrected
123		Page 76	Booster sets		"In variable flow applications the use of VSDs are ~~**always**~~ very beneficial."	Replace 'always' with 'often'.		Corrected
124	3	7 p.77		te	The text states that wastewater pump do not have fine clearance. This is not true. Fine clearances in both open and close channel impellers are important to sustain high clog	Remove sentence.		Removed.

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					resistance capability and pump efficiency.			
125	19	7 p.77		te	Closed impeller types are missing in the list of impeller types for waste water	Add a bullet for closed impeller Add bullet on grinder impeller too.		Added.
126		7 p.78	Table 16	te	Pump types and applications are mixed up in the definition of "submersible pumps for activated sludge" as well as "semi axial and axial pumps for effluent water". This is not in line with the europump view where pump types will be defined separately, In this case an axial flow pump. If a conflict with secondary functional parameters exist it has to be clarified an otherwise it can be checked when the data collection is done and attainable efficiencies are available.	Europump (Lot 28) have to give a clear message about how to proceed with pump types and wastewater classes. Converge the two categories activated sludge and storm and effluent water, mixed flow and axial This category does not comprise storm water → correct please.		The categorisation for wastewater pumps was provided by Europump during stakeholder consultation. The study team never received any alternative, and it was therefore decided to leave it as such.
127	7	p. 78	2nd last paragraph of page 78	ge	"The market for swimming pool pumps is […] dominated by many smaller manufactures […]. These manufactures do not have the same focus on improving the energy efficiency of the pumps" This opinion is questionable. If	remove this sentence.		The comparison with the USA and Australia has been deleted, but the phrase was left in and slightly reformulated to point out both at the lack of awareness by consumers but also the lack of incentive for manufacturers to produce more efficient pumps.

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					there is any lack of focus on improving energy efficiency, this could also be attributed to the lack of focus of the consumers, the low running hours, and the high focus on health and safety.			
128	Page 78	7.1		te	"Pool skimming is important for removing the bulk of the contamination that is found in the top 15cm of the pool, as it reduces the load on the pump filters. Filters should be backwashed at least once a week, or when the pressure drop exceeds 3psi." The accumulation of solids particles on the filtering medium of the filter will result in a progressive increase of the head loss of the hydraulic circuit, so that the filtering medium should be cleaned up according to the indicator recommended by the filter manufacturer. With granular filtering media, which is found on most of the	PSI is not SI-units. Please correct and do not simply copy marketing material especially from US. Value is technically incorrect. Remove or correct with reference to FprEN16713-1		Sentence deleted as it was realized by the study team the lack of significance of the backwash process for reducing speed and therefore energy consumption by the pool pumps.

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					pools, a backwash shall be operated when the cleaning differential pressure is reached (see definition in FprEN 16713-1 "cleaning differential pressure : maximum differential pressure allowed at the terminals of the filter element or the filter to guarantee its efficiency and from which the filter media should be cleaned or replaced").			
129	Page 79	7.1		te	"Slurry pumps are usually designed with replaceable liners …" This is wrong	Correct		Corrected.
130				ed	Footnote 82 - 86 are missing	Add footnotes/sources		Added.
131	page 79	7	table17	te	the running hour for swimming pool pumps <2,2kW, as given by the WG, was 1400hours/year, not 1540 for pumps>2,2kW, the WG did not give value	correct the table (1400 instead of 1540) give the reference for the "3375hours"		EUSA WG provided 1400h/year for outdoor pools (90% market share) and 2800h/year for indoor pools (10% of the market). The weighted average gives 1540 hours/year and that is what it has been used.
132	page 79			ge	The work of Europump and EUSA points out that the whole package is needed to be taken together, otherwise energy savings may have a detrimental	Refer to the comments in the Europump and EUSA position papers.		Statement deleted as a whole section on the more recent position paper from EUSA WG has been introduced and discussed in this section.

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					impact on pool water hygienic quality.			
132bis	Page 81	7.3	1st paragraph	te	"If the fill-in water presents a certain quality, it will not require additional treatment and may therefore not require additional filtration or water circulation cycles. But if it does not, this may influence negatively the efficiency of the pump." Totally wrong. Even if the fill-in water is extremely pure, it will rapidly degrade with the pollution introduced by the swimmers and the surroundings of the pool.	Delete		Deleted.
134		7.3 p.81		te	Definitions of wastewater pumps and pumps for fluid with high solids content is not in line with the work within Europump (Lot28).	Europump (Lot 28) offers support about how to proceed with pump types and wastewater classes.		The reasoning for this classification has been explained already in comment #83.
135		p. 81	2nd paragraph	ed/te	WASTE WATER PUMPS	Delete everything in this paragraph except 1st sentence.		The purpose of this paragraph is to describe what the barriers are for potential ecodesign regulations. It has therefore been left in the report.
136		p. 81	3rd paragraph	te	Purpose is not to define pump types. The chapter is about infrastructure. What is meant	Revise		The purpose of this section is to identify potential barriers for ecodesign regulations. These are related with the

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					with infrastructure? Definitely not efficiency of the product itself….			potential to reduce efficiencies. The paragraph has not been revised.
137		p. 82		te	"Pumps do not utilise water for their operation …"	This not true for slurry pumps. They use the water to transport the solid content. Therefore they should not be in scope.		Revised.
138	Page 83	7.4		ge	"Most of the potential barriers towards an extended scope and inclusion of an EPA to improve water, swimming pool, <u>wastewater and slurry pumps</u> efficiencies is the lack of understanding of using variable speed to control the pumps' operation." Contradiction to page 40: "The industry have assessed that all wastewater pumps besides slurry pumps have VSD when applied in variable flow applications and therefore there no additional potential savings."	Remove waste water and slurry pumps		Paragraph revised. The potential for improvement by using VSDs is different to different pump types. For clean water pumps the potential is bigger than for slurry pumps, for example. Therefore the paragraphs do not contradict themselves. They rather present the differences between different pump types and applications
139	page 83	7.3		ge	"For swimming pool pumps it is clear that this is a field where			Paragraph slightly revised, although it is not clear yet how much the differences limit the potential for energy

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					the EU is behind [US and Australia] [...]. There is a lot to be gained from being inspired by these schemes." This opinion is questionable: an important element of context is given above: 5-10 times less chlorine is used in EU than in US. Is it what the consultant understands as being behind and inspiring?			efficiency improvement. Even the differences in chlorine concentrations is questionable. The paragraph has been left in the report.
140	page 83	7.3		ge	on swimming pool pumps: Page 67, a suggestion to use a system approach is reported. This disappears in the conclusion.	add a sentence such as: "stakeholders believe only system approach would give savings for swimming pool pumps"		Added.
141	page 83			ed	You cannot adopt the Australian Standard or US regulations in the current EU regulatory climate. There are EN-standards under development which will lead to means of control (see report chapter 3.3)	Give reference to regulatory scheme in Australia. Only (voluntary?) standards are given in the report.		The reference to the Australian standard has been given in section 3.4.
142		p. 85	Table 19	ed	Revise headline to what it really is.			Revised.
143		8 p.85	Table 19	te	How have these values been calculated ?	Clarify, give load time profile, Savings calculations. Definition of “other motor technologies”		In several cases ‘other motor technology’ has higher value than PM motor + VSD. This was information provided by Europump during the data collection and it is assumed that

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					Why has "Other motor technologies" so low power consumption? Is an VSD and variable flow systems part of the definitions. What is "other motor technologies" → definition. Source of information			there are other motors performing even better than PM motors. No definition nor details on the technologies for these motors was provided by Europump. Load time profile was also provided by Europump which was used to calculate average P1 values. All these data was provided by Europump. The way these data has been used to calculate potential energy savings is presented in section 9.2. It has been referred in the text as footnote.
144	page 87	8.1	table 19	ed/te	line on swimming pool pumps: WG said that "variable flow application" do not make sense for swimming pool.	one columns of the table should be empty		Corrected.
145	Page 89	8.2		te	"Several pump manufactures are marketing their high efficient water pumps as being MEI > 0.7 compliant. These pumps are designed to have a high hydraulic efficiency and a low level of leakage, and are still serial produced with standard materials. The BAT for clean water pumps considering product design is therefore pumps with MEI > 0.7. " There are principally always several pump types and sizes in	Remove discussion about MEI 0.7. EPA is much more important in terms energy savings.		In spite the majority of the savings come from applying EPA, the study requires to make an assessment of technologies, and since it is also a review of previous preparatory studies, it was considered relevant to present the main improvement alternatives at product level. However, it was made very clearly that these savings are relatively small when looking at the potential by applying at EPA.

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					scope of Eu 547/2012 that reach MEI 0.7. But the impression that this is state of the art for the whole range is wrong.			
146	Page 89	8.2		te	"These pumps are designed to have a high hydraulic efficiency and a low level of leakage …" There should be no leakage at all.	A leaking pump is a broken pump. Revise.		Sentence deleted.
147	page 89	8.2		ed	It is not necessary to give any company name here.	remove reference to brands, keep only references to technology		It is important to give specific references to products in the market else it sounds like it is an invention of the study team. References to products and companies available in the market have been left in the report. The study team welcomes examples provided by Europump on BAT (this has been requested many times but it was never provided).
148	Page 89			te	The average difference between Mei 0.4 and Mei 0.7 is **3.5% points and not 5%** points ! This results directly from the difference of the c-values	Correct accordingly !		Corrected.
149		8.2 p.90		te	Clog resistance and wear resistance capability is an important parameter for waste water pumps	Add bullet for clog resistance and wear resistance.		Section revised.
150	Page 90	8.2		te	"It is still possible, however, to reach a high energy efficiency with some light duty slurry	Correct values.		Sentence revised.

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					pumps with an efficiency of 82 % and heavy duty slurry pumps with an efficiency of up 77 % (lot 28)." These values can be reached with very large pumps (beyond the scope of the regulation) but are far too high for smaller slurry pumps.			
151	page 90	8.2		te	Paragraph on swimming pool pumps: the large differences in consumption given in Wh/liter are explained by system design differences mainly. Reference to Australian and US market as being BAT is misleading, as it does not mean that these kinds of pumps are 'better' pumps. But: the filter process, the pollution by chemicals and that costs must be considered as well.	The best available technology has still to be found. Revise accordingly.		Paragraph revised.
152	Page 90			ed	"The water pump is an ~~old~~ technology [...]"	Replace with 'long established'.		Corrected.
153	Page 90		Footnote	ed		Delete Footnote 92.		Deleted.

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154	Page 91	8.4	Footnote 93	ed	"Europump WGs on clean water and wastewater pumps and EUSA WG on swimming pool pumps"	Change into: EUROPUMP and EUSA Joint Working Group		Changed.
155	Page 93	8.4	Table 20	te	Content of table is totally wrong and contradicting in itself. Examples: There are ESOB > 150 kW in cast iron. Sheet metal pumps are usually not made out of "galvanised steel" Where are casted stainless steel pumps?	Revise table.		The table and materials have been revised according to the re-definition of the base cases and according to comments herein from industry and by looking at pumps' product catalogues. However, it is still largely based on previous preparatory studies, as no other information was available.
156	Page 95	8.4		te	"Due to cost of repairing wastewater pumps the maintenance schedule is often based on a risk analysis considering, for example, historic frequency of breakdown; and the impact if the pump breaks down" Main reason for intervention is not repair of the pumps but removal of clogging.			Revised.

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157	Page 95	8.4		ed	"Some of the largest pump manufacturers (e.g. Xylem, Flowserve, Grundfos, Sulzer, KSB) provide onsite repair and workshop repair services94,95,96,97,98."	Biased. Please revise. Almost all companies selling pumps do offer service also.		No other information is publicly available and no other information was provided by stakeholders. So the names of the companies were deleted but not the references.
158	Page 96		Industry Perspective	ed		Remove direct naming of companies. Instead give source in footnotes if needed.		These are the only data sources available, and it was therefore considered important to give the specific references. The names have not been removed.
159	Page 102	9.1		te	"Further energy savings at product level are still possible by going up to MEI = 0.7 (value defined as benchmark in current Regulation)."	A cut off at MEI = 0.7 is not realistic and would have severe impact on pump manufacturers especially SME's. The relatively low energy savings cannot justify losses in jobs due to cost for redevelopment. SMEs will not have the resources to do so. As previously stated savings are more realistic due to EPA.		The study team has provided an additional explanation on why potential savings at product level were included.
160	page 102	9.1	13th paragraph (last pargraph of the page)	te	The WG said that the market share of variable speed pumps were 2,9%. This does not mean that 2,9% of the application are variable flow.	Replace "variable flow application" by "variable speed pumps" Modify the conclusions accordingly remark: this change the whole meaning of the paragraph and the conclusions.		Replaced. An additional section has been included in the final scope chapter to present the reasons for inclusion in the final scope.

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						As said before, comparison to US and Australia is not appropriate		
161	page 102-103	9.1	6th paragraph of page		The market situation in the USA is different from the situation in Europe. In the USA there are far more chemicals used for disinfection. The "pollution" of the swimming pool" by chemicals must be seen in relation to the filtration process in swimming pools in europe.	add to the paragraph: The market situation in the USA is different from the situation in Europe. In the USA there are chemicals used for disinfection. In Europe the flow rate and recirculation is managing the cleaning of water. The "pollution" of the swimming pool by chemicals must be seen in relation to the filtration process in swimming pools in europe.		The issue about 'pollution' is not yet defined quantitatively and how this affects the maximum turnover rate. Furthermore, a relationship between the chloride content between the USA and the EU is not clear yet. The paragraph suggested was not added as it was found ambiguous, but the issue about disinfectants has been discussed in the report.
162				ge	Table 22 is not consistent with the previous report arguments. EUROPUMP / EUSA does not support table 22. Some products listed shall not be in a final scope list. Please refer to the EUROPUMP / EUSA Position paper.			The study team is aware of the disagreements Europump has, so the study team has further revised the scope after input received from stakeholders meeting. See "Recommendation of scope for revision of regulation" dated on the 16th of February, and "Recommendation of scope for revision of regulation – Part II" dated on the 22dn of February. Furthermore, other pump categories were further excluded considering revised data from Europump on use of VSDs. See chapter 9: Final scope.
163	Page 104		Table 22	ge	Does the "final list of pumps in scope" mean that the expectance of the study writers is that EUROPUMP would collect data for ?	WHAT IS THE DIFFERENCE BETWEEN PRELIMINARY SCOPE (ANNEX 4) and FINAL SCOPE (TABLE 22) ?		The preliminary scope was based on preparatory studies and helped the study writers to focus on pump categories considered relevant from an energy consumption/energy savings point of view. This considering the large initial scope from three separate studies.

EUROPUMP Template for comments and secretariat observations 1 **MB** = Member body / **NC** = National Committee (enter the ISO 3166 two-letter country code, e.g. CN for China; comments from the ISO/CS editing unit are identified by **) 2 **Type of comment:** **ge** = general **te** = technical **ed** = editorial *ISO/IEC/CEN/CENELEC electronic balloting commenting template/version 2012-03*	Date: 19 Jan. 2016 – 20th January 2016 [re-revised up to 28nd Jan,) Reply by study team: 15th June 2016.	Document: **Ecodesign Pump Review, Study of Commission Regulation (EU) No. 547/2012 incorp […] 'Lot 28' and 'Lot 29' (Pumps) - Final Progress Report**	Project: EUROPUMP & EUSA Joint Comments on Review Study

#	Line number/ Page (e.g. 17)	Clause/ Sub-clause (e.g. 3.1)	Paragraph/ Figure/ Table/ (e.g. Table 1)	Type of comment 2	Comments	Proposed change	Observations of the secretariat	Reply from the study team
					This is tremendous money and effort which can't be financed and/or done by EUROPUMP. **Around 50.000€ per pump type.**			The final scope was based, until the extent possible, on data provided by industry and it helped delimitate again the broader scope only to pump categories which were considered relevant. This means in practice that an additional step of scrutiny was used to check whether the pumps in the preliminary scope were indeed relevant, and in this the study team used industry data.
164		Page 104	Table 22 Final scope	te	The exclusion of pumps from in scope in this report has so far only been based on EU energy consumption, not potential energy saving. Eventually those which remain in scope must instead recognise energy saving in relation to the detrimental impact on the pump industry	Data delivered to Viegand & Maagoe which was requested is not represented in table 22. Please explain in detail how the collected data has been used to come to table 22.		The results from the calculations in Table 24 (before Table 22) are mostly based on data provided by Europump. The data provided by Europump was presented in chapters 7 (task D3) and 8 (task D4) and further discussed with stakeholders in stakeholders meeting.
165		9.2 p. 107 / 108		ge	The majority of "Pump definitions in final scope" needs revision	Europump is offering support to revise this list to come to appropriate definitions.		The study team did not receive any further input on definitions, in spite it was requested at the stakeholders' meeting and the final scope communication letters by the study team. Therefore, the same definitions stated in these letters have been used for the report. See "Recommendation of scope for revision of regulation" dated on the 16th of February, and "Recommendation of scope for revision of regulation – Part II" dated on the 22dn of February.
166	Page 107 / 108	9.2		te	"Centrifugal submersible radial vortex wastewater pumps: A rotodynamic water pump, <u>which has a radial inflow</u>, designed to operate	Revise		The definition has been revised.

EUROPUMP Template for comments and secretariat observations

1 **MB** = Member body / **NC** = National Committee (enter the ISO 3166 two-letter country code, e.g. CN for China; comments from the ISO/CS editing unit are identified by **)
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ISO/IEC/CEN/CENELEC electronic balloting commenting template/version 2012-03

Date: 19 Jan. 2016 – 20th January 2016 [re-revised up to 28nd Jan,) Reply by study team: 15th June 2016.	Document: **Ecodesign Pump Review, Study of Commission Regulation (EU) No. 547/2012 incorp […] 'Lot 28' and 'Lot 29' (Pumps) - Final Progress Report**	Project: EUROPUMP & EUSA Joint Comments on Review Study

#	Line number/ Page (e.g. 17)	Clause/ Sub-clause (e.g. 3.1)	Paragraph/ Figure/ Table/ (e.g. Table 1)	Type of comment 2	Comments	Proposed change	Observations of the secretariat	Reply from the study team
					under water, designed to have the flow pass freely through without reaching the impeller, and is specifically designed for pumping wastewater." There are no pumps with radial inflow. And how does it work, if the flow does not reach the impeller?			
167	Page 109	Annex 1		ge	Partly irrelevant, partly outdated partly not correct.	Revise table.		Updated as of 8-6-2016
168	Page 112	Annex 2		ge	Not all directives listed in this chapter are valid for all pump types Example WEEE, Industrial Emission Directive	Match applicable directives with concerned pump categories		Pumps may be addressed, directly or indirectly, by EU legislation and this annex gives a general overview. It is up to the manufacturer to see which is valid for the pumps they produce.
170	Page 126	Annex 4		ge	There's only the total energy consumption listed, but not the achievable savings. Example: Total achievable savings for waste water pumps is 2.215 TWh/year	Display achievable savings (total and/or percentage)		The draft final report has a whole chapter on potential savings, including methodology and results.

Annex 7. SPECK Pumps comments and reply from study team.

Table 79. Comments from SPECK pumps to study progress report and reply from study team.

Chapter	Page	Paragraph / table / figure	Comment	Proposal	Comment study team
Noise	20	Table 2	In the table noise as a secondary functional parameter is listed as not being important for LOT29. On the contrary, noise is very significant in the private swimming pool area! However noise-optimized hydraulics is not always the same as energy-optimized hydraulics. Consider the requirements of DIN 4109 (-1) Sound insulation in buildings - Part 1: Requirements for sound insulation.	Must be taken into account	Included
3.2	20	Table 2	In the table material as a secondary functional parameter is listed as not being important for LOT29. The selection of materials for small swimming pool pumps is significant. Most pumps are made from plastic. Therefore there are restrictions in the constructive implementation of the best grades of efficiency.	Must be taken into account	Included
3.2	21	Chapter: "Minimum clearances required"	Minimum clearances for plastic swimming pool pumps amount to approx. 1 mm. Due to the manufacturing tolerances for the pump components made from plastic, small gaps cannot be realized. The swimming pool water also contains many impurities such as leaves, pine needles and sand. Therefore the larger gaps are absolutely necessary for trouble-free operation. The consequences are increased gap loss.	Must be taken into account	Corrected

Chapter	Page	Paragraph / table / figure	Comment	Proposal	Comment study team
3.2	22	Chapter: "General construction"	The typical construction of a self-priming swimming pool pump is not described in this chapter. For this type of pump the pump housing, including the pre-filter housing, is generally produced as a combined housing. This combination is necessary for the self-priming function, however it considerably reduces the total grade of efficiency. Therefore it would not be possible to fulfil the same MEI values as those defined in the 547/2012 guidelines. Implementing the best grade of efficiency with plastic pumps is generally restricted due to the construction and demoulding: - Small gaps are not possible. The result is high gap loss. - Realising optimal 3D curved impeller blade geometry is only possible to a limited extent with plastic injection moulding. - The flow-optimised geometry of the pump housing parts could only be partly implemented if the housing was split into multiple parts. Swimming pool pumps for the private area should be user-friendly, simple constructions as the operators are unqualified in most cases.	Must be taken into account	Included

Chapter	Page	Paragraph / table / figure	Comment	Proposal	Comment study team
3.2	22	Chapter: "Expected lifetime of the pump"	"Unfortunately, most pumps lose efficiency due to wear in their wear rings, due to operation at part flow, and/or roughening of their cast iron volutes by corrosion products. It is not unusual to lose 10 % of the new efficiency in ten years." Wear to plastic pumps is minimal as the gaps are configured with a minimum of 1 mm from the start. However as a result, the ability to achieve the best grade of efficiency is considerably reduced when compared to metal pumps.	Must be taken into account	Included
6.3	64	Chapter: "The main manufactures of swimming pool pumps"	Some notable companies are missing from the list of swimming pool pump manufacturers.	Please add the following companies: Hayward ESPA Fluidra SPECK Pumpen	Included
6.3	67	Chapter: "pool hydraulic system design"	Pool hydraulic system design - must be taken into account in the planning phase.	Comment	Included
6.3	67	Chapter: "Wet end part design"	Wet end part design – is partly doable. Something can surely be improved hydraulically. However this could also be at the expense of vulnerabilities (smaller gaps).	Comment	Included
6.3	67	Chapter: "Hydraulic working point"	Hydraulic working point – Here the most fitting pump must be selected depending on the unit resistance.	Comment	Included
8.2	90	Chapter: "Swimming pool pumps"	Describing pump flow rates per Wh is incorrect. This quickly disregards the fact that a dynamic head is required and this complies with the unit resistance (filtration/rinsing/partial load operation).	Must be taken into account	Sentence deleted
8.4	91+ 93	Table 20	Some materials that are used as standard in swimming pool technology are missing: PP; ABS; PPE; PVC; PC	Must be taken into account	Included

Chapter	Page	Paragraph / table / figure	Comment	Proposal	Comment study team
9.1	101-103	Final scope	The aim must be to continue to represent that: 1. The eco design guidelines clearly simulate the motor grade of efficiency improvements (up to VSD). 2. The Wet-End construction improvement is only partly possible (also considering the increased selling price). 3. Nothing may influence the operation (running time/volume flow/filter rinsing). 4. The professional selection of the pump is carried out in relation to the relevant unit. 5. The professional planning of the unit is carried out in relation to the resistance minimisation.	Must be taken into account	Some of these aspects are related to a 'system approach' which has been discussed briefly in the report but the discussion has not been as extensive as by assessing the importance of these parameters. This is because the review study focuses on an Extended Product Approach and not a System Approach. However, some of these aspects which are more directly related to the pumps and the power drive system have been discussed in more detail.
Annex 2.	121	Last paragraph of the page	Consideration of DIN 4109 (-1) Sound insulation in buildings - Part 1: Requirements for sound insulation is missing on this page.	Must be taken into account	Included

Annex 8. Detailed life cycle impact assessment data for all the base cases.

Table 80. Base case 1: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRIBUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufac-turing	Total			Disposall	Recycling	Stock	
Total product weight	kg	-	-	59	0	1	11	40	8	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	1,598	302	1,899	136	1,093,516	20	-380	-	1,095,191
of which, electricity (in primary MJ)	MJ	164	175	340	0	1,093,502	0	-38	-	1,093,803
Water (process)	ltr	865	2	867	0	9	0	-208	-	668
Water (cooling)	ltr	313	77	389	0	48,603	0	-65	-	48,927
Waste, non-haz./ landfill	kg	27	1	28	0	564	0	-6	-	586
Waste, hazardous/ incinerated	kg	0	0	0	0	17	0	0	-	17
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	132	17	149	10	46,679	0	-32	-	46,807
Acidification, emissions	kg SO_2 eq.	1	0	1	0	207	0	0	-	208
Volatile Organic Compounds (VOC)	kg	0	0	0	0	24	0	0	-	24
Persistent Organic Pollutants (POP)	ng i-Teq	418	29	447	1	2,556	0	-101	-	2,903
Heavy Metals	mg Ni eq.	1,751	67	1,819	6	11,074	6	-423	-	12,481
PAHs	mg Ni eq.	43	0	43	4	2,552	0	-10	-	2,588
Particulate Matter (PM, dust)	kg	1	0	1	0	4	0	0	-	5
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	1,110	2	1,113	0	4,718	1	-268	-	5,564
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.2	0.0	0.0	-	0.2

Table 81. Base case 2: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	59	0	1	11	41	8	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	1,697	308	2,005	136	1,692,017	24	-389	-	1,693,794
of which, electricity (in primary MJ)	MJ	253	176	429	0	1,692,003	0	-45	-	1,692,387
Water (process)	ltr	884	3	887	0	9	0	-209	-	686
Water (cooling)	ltr	314	78	392	0	75,203	0	-65	-	75,530
Waste, non-haz./ landfill	kg	27	1	28	0	872	0	-6	-	894
Waste, hazardous/ incinerated	kg	0	0	0	0	27	0	0	-	27
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	138	18	156	10	72,227	0	-32	-	72,361
Acidification, emissions	kg SO_2 eq.	1	0	1	0	320	0	0	-	321
Volatile Organic Compounds (VOC)	kg	0	0	0	0	38	0	0	-	38
Persistent Organic Pollutants (POP)	ng i-Teq	422	29	451	1	3,952	0	-102	-	4,302
Heavy Metals	mg Ni eq.	1,762	67	1,829	6	17,126	6	-424	-	18,543
PAHs	mg Ni eq.	44	0	45	4	3,948	0	-10	-	3,986
Particulate Matter (PM, dust)	kg	1	0	1	0	7	0	0	-	7
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	1,129	2	1,132	0	7,295	1	-270	-	8,158
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.3	0.0	0.0	-	0.3

Table 82. Base case 3: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	261	0	3	48	180	36	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	5,562	916	6,478	234	5,548,556	71	-1,319	-	5,554,020
of which, electricity (in primary MJ)	MJ	486	539	1,024	0	5,548,505	0	-113	-	5,549,417
Water (process)	ltr	1,976	8	1,983	0	20	0	-475	-	1,529
Water (cooling)	ltr	1,204	241	1,445	0	246,612	0	-266	-	247,791
Waste, non-haz./ landfill	kg	113	4	116	0	2,860	2	-27	-	2,952
Waste, hazardous/ incinerated	kg	0	0	0	0	88	0	0	-	88
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	478	52	530	16	236,851	0	-115	-	237,283
Acidification, emissions	kg SO_2 eq.	4	0	4	0	1,048	0	-1	-	1,052
Volatile Organic Compounds (VOC)	kg	0	0	0	0	124	0	0	-	124
Persistent Organic Pollutants (POP)	ng i-Teq	2,078	61	2,139	1	12,967	1	-502	-	14,606
Heavy Metals	mg Ni eq.	4,212	142	4,353	9	56,144	14	-1,018	-	59,502
PAHs	mg Ni eq.	222	0	222	7	12,949	0	-53	-	13,125
Particulate Matter (PM, dust)	kg	3	0	3	0	22	0	-1	-	25
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	2,917	5	2,921	0	23,913	3	-704	-	26,134
Eutrophication	kg PO_4	0.1	0.0	0.1	0.0	1.0	0.0	0.0	-	1.1

Table 83. Base case 4: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	277	0	3	50	191	38	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	6,566	944	7,510	234	8,055,066	97	-1,491	-	8,061,416
of which, electricity (in primary MJ)	MJ	1,054	542	1,596	0	8,055,011	0	-163	-	8,056,444
Water (process)	ltr	2,079	10	2,089	0	21	0	-482	-	1,627
Water (cooling)	ltr	1,212	249	1,461	0	358,012	0	-266	-	359,207
Waste, non-haz./ landfill	kg	114	4	118	0	4,152	2	-28	-	4,245
Waste, hazardous/ incinerated	kg	0	0	0	0	127	0	0	-	127
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	523	53	576	16	343,846	1	-121	-	344,318
Acidification, emissions	kg SO_2 eq.	5	0	5	0	1,522	0	-1	-	1,525
Volatile Organic Compounds (VOC)	kg	0	0	0	0	180	0	0	-	180
Persistent Organic Pollutants (POP)	ng i-Teq	2,095	61	2,156	1	18,816	1	-506	-	20,468
Heavy Metals	mg Ni eq.	4,271	142	4,413	9	81,488	15	-1,023	-	84,901
PAHs	mg Ni eq.	229	1	230	7	18,797	0	-54	-	18,980
Particulate Matter (PM, dust)	kg	3	0	3	0	32	0	-1	-	35
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	3,034	5	3,039	0	34,704	3	-713	-	37,033
Eutrophication	kg PO_4	0.1	0.0	0.1	0.0	1.5	0.0	0.0	-	1.6

Table 84. Base case 5: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	35	0	0	7	24	5	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	1,007	144	1,151	125	931,510	14	-225	-	932,575
of which, electricity (in primary MJ)	MJ	95	85	180	0	931,501	0	-19	-	931,662
Water (process)	ltr	248	1	249	0	2	0	-58	-	193
Water (cooling)	ltr	229	38	267	0	41,402	0	-38	-	41,632
Waste, non-haz./ landfill	kg	14	1	14	0	480	0	-3	-	491
Waste, hazardous/ incinerated	kg	0	0	0	0	15	0	0	-	15
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	68	8	76	9	39,763	0	-16	-	39,833
Acidification, emissions	kg SO_2 eq.	1	0	1	0	176	0	0	-	177
Volatile Organic Compounds (VOC)	kg	0	0	0	0	21	0	0	-	21
Persistent Organic Pollutants (POP)	ng i-Teq	262	8	269	1	2,176	0	-63	-	2,383
Heavy Metals	mg Ni eq.	548	18	566	6	9,424	2	-133	-	9,865
PAHs	mg Ni eq.	42	0	42	3	2,174	0	-10	-	2,210
Particulate Matter (PM, dust)	kg	0	0	0	0	4	0	0	-	4
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	414	1	414	0	4,014	0	-100	-	4,329
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.2	0.0	0.0	-	0.2

Table 85. Base case 6: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	35	0	0	7	24	5	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	1,131	151	1,282	125	1,431,011	19	-236	-	1,432,202
of which, electricity (in primary MJ)	MJ	207	86	293	0	1,431,002	0	-28	-	1,431,268
Water (process)	ltr	261	2	263	0	3	0	-59	-	206
Water (cooling)	ltr	232	40	273	0	63,602	0	-38	-	63,837
Waste, non-haz./ landfill	kg	14	1	14	0	738	0	-3	-	749
Waste, hazardous/ incinerated	kg	0	0	0	0	23	0	0	-	23
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	76	9	84	9	61,085	0	-17	-	61,162
Acidification, emissions	kg SO_2 eq.	1	0	1	0	270	0	0	-	271
Volatile Organic Compounds (VOC)	kg	0	0	0	0	32	0	0	-	32
Persistent Organic Pollutants (POP)	ng i-Teq	267	8	274	1	3,342	0	-64	-	3,552
Heavy Metals	mg Ni eq.	558	18	576	6	14,475	2	-133	-	14,925
PAHs	mg Ni eq.	44	0	45	3	3,339	0	-10	-	3,377
Particulate Matter (PM, dust)	kg	0	0	0	0	6	0	0	-	6
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	454	1	454	0	6,164	1	-103	-	6,517
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.3	0.0	0.0	-	0.3

Table 86. Base case 7: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturingg	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	211	0	2	39	145	29	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	5,223	760	5,984	202	5,670,052	69	-1,208	-	5,675,099
of which, electricity (in primary MJ)	MJ	486	448	934	0	5,670,005	0	-106	-	5,670,833
Water (process)	ltr	1,479	6	1,485	0	15	0	-353	-	1,148
Water (cooling)	ltr	1,059	201	1,260	0	252,011	0	-202	-	253,069
Waste, non-haz./ landfill	kg	88	3	91	0	2923	2	-21	-	2995
Waste, hazardous/ incinerated	kg	0	0	0	0	89	0	0	-	89
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	394	43	437	14	242,037	0	-94	-	242,394
Acidification, emissions	kg SO_2 eq.	4	0	4	0	1071	0	-1	-	1074
Volatile Organic Compounds (VOC)	kg	0	0	0	0	127	0	0	-	127
Persistent Organic Pollutants (POP)	ng i-Teq	1,663	46	1,709	1	13,247	1	-402	-	14,555
Heavy Metals	mg Ni eq.	3,259	107	3,366	8	57,363	11	-788	-	59,959
PAHs	mg Ni eq.	221	0	221	6	13,232	0	-53	-	13,407
Particulate Matter (PM, dust)	kg	2	0	2	0	23	0	0	-	24
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	2,377	3	2,380	0	24,431	2	-573	-	26,241
Eutrophication	kg PO_4	0.1	0.0	0.1	0.0	1.1	0.0	0.0	-	1.1

Table 87. Base case 8: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	211	0	2	39	145	29	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	5,657	781	6,438	202	8,329,557	87	-1,244	-	8,335,039
of which, electricity (in primary MJ)	MJ	890	451	1,340	0	8,329,509	0	-137	-	8,330,712
Water (process)	ltr	1,556	8	1,564	0	16	0	-358	-	1,222
Water (cooling)	ltr	1,065	207	1,272	0	370,211	0	-202	-	371,281
Waste, non-haz./ landfill	kg	89	3	92	0	4,293	2	-21	-	4,366
Waste, hazardous/ incinerated	kg	0	0	0	0	131	0	0	-	132
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	419	44	464	14	355,562	0	-96	-	355,944
Acidification, emissions	kg SO_2 eq.	4	0	4	0	1,573	0	-1	-	1,577
Volatile Organic Compounds (VOC)	kg	0	0	0	0	186	0	0	-	186
Persistent Organic Pollutants (POP)	ng i-Teq	1,675	46	1,721	1	19,452	1	-405	-	20,771
Heavy Metals	mg Ni eq.	3,303	107	3,410	8	84,254	12	-791	-	86,891
PAHs	mg Ni eq.	226	1	227	6	19,438	0	-54	-	19,617
Particulate Matter (PM, dust)	kg	2	0	2	0	33	0	0	-	35
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	2,465	3	2,469	0	35,880	3	-580	-	37,771
Eutrophication	kg PO_4	0.1	0.0	0.1	0.0	1.6	0.0	0.0	-	1.6

Table 88. Base case 9: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	35	0	0	7	24	5	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	1,007	144	1,151	125	769,510	14	-225	-	770,575
of which, electricity (in primary MJ)	MJ	95	85	180	0	769,501	0	-19	-	769,662
Water (process)	ltr	248	1	249	0	2	0	-58	-	193
Water (cooling)	ltr	228	38	266	0	34,202	0	-38	-	34,430
Waste, non-haz./ landfill	kg	14	1	14	0	397	0	-3	-	408
Waste, hazardous/ incinerated	kg	0	0	0	0	12	0	0	-	12
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	68	8	76	9	32,848	0	-16	-	32,918
Acidification, emissions	kg SO_2 eq.	1	0	1	0	145	0	0	-	146
Volatile Organic Compounds (VOC)	kg	0	0	0	0	17	0	0	-	17
Persistent Organic Pollutants (POP)	ng i-Teq	262	8	269	1	1,798	0	-63	-	2,005
Heavy Metals	mg Ni eq.	548	18	566	6	7,786	2	-133	-	8,227
PAHs	mg Ni eq.	42	0	42	3	1,796	0	-10	-	1,831
Particulate Matter (PM, dust)	kg	0	0	0	0	3	0	0	-	3
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	414	1	414	0	3,317	0	-100	-	3,632
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-	0.2

Table 89. Base case 10: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	36	0	0	7	25	5	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	1,422	172	1,594	125	1,071,014	30	-260	-	1,072,503
of which, electricity (in primary MJ)	MJ	465	90	555	0	1,071,005	0	-48	-	1,071,512
Water (process)	ltr	329	3	333	0	3	0	-65	-	271
Water (cooling)	ltr	240	46	286	0	47,602	0	-38	-	47,851
Waste, non-haz./ landfill	kg	14	1	15	0	552	0	-3	-	564
Waste, hazardous/ incinerated	kg	0	0	0	0	17	0	0	-	17
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	92	10	102	9	45,718	0	-18	-	45,812
Acidification, emissions	kg SO_2 eq.	1	0	1	0	202	0	0	-	203
Volatile Organic Compounds (VOC)	kg	0	0	0	0	24	0	0	-	24
Persistent Organic Pollutants (POP)	ng i-Teq	278	8	286	1	2,502	0	-67	-	2,722
Heavy Metals	mg Ni eq.	591	18	609	6	10,835	2	-136	-	11,316
PAHs	mg Ni eq.	50	1	50	3	2,499	0	-12	-	2,541
Particulate Matter (PM, dust)	kg	0	0	0	0	4	0	0	-	5
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	492	1	493	0	4,615	1	-106	-	5,003
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.2	0.0	0.0	-	0.2

Table 90. Base case 11: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	211	0	2	39	145	29	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	5,223	760	5,984	202	4,900,552	69	-1,206	-	4,905,600
of which, electricity (in primary MJ)	MJ	486	448	934	0	4,900,505	0	-106	-	4,901,333
Water (process)	ltr	1,479	6	1,485	0	15	0	-352	-	1,148
Water (cooling)	ltr	1,059	201	1,260	0	217,811	0	-202	-	218,869
Waste, non-haz./ landfill	kg	88	3	91	0	2526	2	-21	-	2598
Waste, hazardous/ incinerated	kg	0	0	0	0	77	0	0	-	77
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	394	43	437	14	209,190	0	-94	-	209,547
Acidification, emissions	kg SO_2 eq.	4	0	4	0	926	0	-1	-	929
Volatile Organic Compounds (VOC)	kg	0	0	0	0	109	0	0	-	109
Persistent Organic Pollutants (POP)	ng i-Teq	1,663	46	1,709	1	11,451	1	-401	-	12,760
Heavy Metals	mg Ni eq.	3,259	107	3,366	8	49,582	11	-787	-	52,180
PAHs	mg Ni eq.	221	0	221	6	11,437	0	-53	-	11,612
Particulate Matter (PM, dust)	kg	2	0	2	0	20	0	0	-	21
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	2,377	3	2,380	0	21,118	2	-572	-	22,929
Eutrophication	kg PO_4	0	0	0	0	1	0	0	-	1

Table 91. Base case 12: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	213	0	2	40	146	30	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	6,669	829	7,498	203	6,606,067	127	-1,325	-	6,612,569
of which, electricity (in primary MJ)	MJ	1,831	457	2,288	0	6,606,018	0	-210	-	6,608,096
Water (process)	ltr	1,737	12	1,749	0	17	0	-371	-	1,395
Water (cooling)	ltr	1,079	221	1,299	0	293,611	0	-201	-	294,709
Waste, non-haz./ landfill	kg	91	3	94	0	3405	2	-22	-	3479
Waste, hazardous/ incinerated	kg	0	0	0	0	104	0	0	-	104
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	479	47	527	14	281,992	1	-101	-	282,433
Acidification, emissions	kg SO_2 eq.	4	0	5	0	1248	0	-1	-	1252
Volatile Organic Compounds (VOC)	kg	0	0	0	0	148	0	0	-	148
Persistent Organic Pollutants (POP)	ng i-Teq	1,705	46	1,750	1	15,431	1	-410	-	16,774
Heavy Metals	mg Ni eq.	3,406	107	3,513	8	66,828	13	-798	-	69,564
PAHs	mg Ni eq.	238	2	240	6	15,416	0	-56	-	15,606
Particulate Matter (PM, dust)	kg	2	0	2	0	26	0	0	-	28
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	2,671	3	2,674	0	28,463	3	-596	-	30,545
Eutrophication	kg PO_4	0.1	0.0	0.1	0.0	1.2	0.0	0.0	-	1.3

Table 92. Base case 13: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	33	0	0	6	23	4	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	1,382	196	1,579	125	344,264	17	-334	-	345,651
of which, electricity (in primary MJ)	MJ	162	113	275	0	344,252	0	-38	-	344,488
Water (process)	ltr	680	2	681	0	7	0	-162	-	525
Water (cooling)	ltr	239	48	288	0	15,302	0	-47	-	15,543
Waste, non-haz./ landfill	kg	19	1	20	0	178	0	-5	-	194
Waste, hazardous/ incinerated	kg	0	0	0	0	5	0	0	-	5
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	104	11	116	9	14,696	0	-25	-	14,796
Acidification, emissions	kg SO_2 eq.	1	0	1	0	65	0	0	-	66
Volatile Organic Compounds (VOC)	kg	0	0	0	0	8	0	0	-	8
Persistent Organic Pollutants (POP)	ng i-Teq	326	23	349	1	807	0	-79	-	1,078
Heavy Metals	mg Ni eq.	1,447	54	1,501	6	3,495	5	-350	-	4,657
PAHs	mg Ni eq.	67	0	67	3	804	0	-16	-	859
Particulate Matter (PM, dust)	kg	0	0	0	0	1	0	0	-	2
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	1,001	2	1,003	0	1,492	1	-241	-	2,255
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-	0.1

Table 93. Base case 14: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	33	0	0	6	23	5	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	1,444	201	1,645	125	293,639	20	-339	-	295,090
of which, electricity (in primary MJ)	MJ	217	114	331	0	293,627	0	-43	-	293,915
Water (process)	ltr	692	2	694	0	7	0	-163	-	537
Water (cooling)	ltr	241	50	291	0	13,052	0	-47	-	13,296
Waste, non-haz./ landfill	kg	20	1	21	0	152	0	-5	-	168
Waste, hazardous/ incinerated	kg	0	0	0	0	5	0	0	-	5
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	108	11	119	9	12,535	0	-25	-	12,638
Acidification, emissions	kg SO_2 eq.	1	0	1	0	55	0	0	-	57
Volatile Organic Compounds (VOC)	kg	0	0	0	0	7	0	0	-	7
Persistent Organic Pollutants (POP)	ng i-Teq	328	23	352	1	688	0	-79	-	962
Heavy Metals	mg Ni eq.	1,453	54	1,508	6	2,983	5	-350	-	4,151
PAHs	mg Ni eq.	68	0	68	3	686	0	-16	-	741
Particulate Matter (PM, dust)	kg	0	0	0	0	1	0	0	-	1
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	1,012	2	1,014	0	1,274	1	-242	-	2,048
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-	0.1

Table 94. Base case 15: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	24	0	0	4	16	3	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	882	134	1,016	120	749,259	11	-211	-	750,195
of which, electricity (in primary MJ)	MJ	96	78	173	0	749,251	0	-22	-	749,402
Water (process)	ltr	426	1	427	0	4	0	-101	-	330
Water (cooling)	ltr	164	33	197	0	33,302	0	-30	-	33,469
Waste, non-haz./ landfill	kg	13	1	13	0	386	0	-3	-	397
Waste, hazardous/ incinerated	kg	0	0	0	0	12	0	0	-	12
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	68	8	75	9	31,984	0	-16	-	32,052
Acidification, emissions	kg SO_2 eq.	1	0	1	0	142	0	0	-	142
Volatile Organic Compounds (VOC)	kg	0	0	0	0	17	0	0	-	17
Persistent Organic Pollutants (POP)	ng i-Teq	219	14	233	1	1,750	0	-53	-	1,932
Heavy Metals	mg Ni eq.	898	33	932	6	7,585	3	-217	-	8,308
PAHs	mg Ni eq.	44	0	44	3	1,749	0	-10	-	1,786
Particulate Matter (PM, dust)	kg	0	0	0	0	3	0	0	-	3
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	624	1	625	0	3,231	1	-150	-	3,708
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-	0.2

Table 95. Base case 16: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	24	0	0	4	16	3	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	1,081	147	1,228	121	1,233,011	19	-228	-	1,234,151
of which, electricity (in primary MJ)	MJ	273	80	353	0	1,233,003	0	-36	-	1,233,319
Water (process)	ltr	464	2	466	0	5	0	-104	-	367
Water (cooling)	ltr	168	37	205	0	54,802	0	-30	-	54,977
Waste, non-haz./ landfill	kg	13	1	14	0	636	0	-3	-	646
Waste, hazardous/ incinerated	kg	0	0	0	0	19	0	0	-	20
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	79	8	88	9	52,633	0	-17	-	52,713
Acidification, emissions	kg SO_2 eq.	1	0	1	0	233	0	0	-	234
Volatile Organic Compounds (VOC)	kg	0	0	0	0	28	0	0	-	28
Persistent Organic Pollutants (POP)	ng i-Teq	227	14	241	1	2,879	0	-55	-	3,067
Heavy Metals	mg Ni eq.	919	34	952	6	12,476	3	-219	-	13,219
PAHs	mg Ni eq.	48	0	48	3	2,877	0	-11	-	2,917
Particulate Matter (PM, dust)	kg	0	0	0	0	5	0	0	-	5
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	662	1	663	0	5,314	1	-153	-	5,826
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.2	0.0	0.0	-	0.2

Table 96. Base case 17: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	384	0	4	71	264	53	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	10,682	1,372	12,055	286	14,559,857	143	-2,528	-	14,569,811
of which, electricity (in primary MJ)	MJ	1,716	794	2,510	0	14,559,767	0	-406	-	14,561,871
Water (process)	ltr	4,384	11	4,395	0	44	0	-1,048	-	3,391
Water (cooling)	ltr	1,814	342	2,156	0	647,118	0	-289	-	648,986
Waste, non-haz./ landfill	kg	259	6	266	0	7506	5	-63	-	7714
Waste, hazardous/ incinerated	kg	0	0	0	0	230	0	0	-	230
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	873	78	951	20	621,515	1	-206	-	622,280
Acidification, emissions	kg SO_2 eq.	7	0	8	0	2750	0	-2	-	2756
Volatile Organic Compounds (VOC)	kg	0	0	0	0	325	0	0	-	325
Persistent Organic Pollutants (POP)	ng i-Teq	3,872	150	4,022	1	34,011	3	-936	-	37,101
Heavy Metals	mg Ni eq.	9,522	348	9,870	10	147,310	33	-2,302	-	154,921
PAHs	mg Ni eq.	244	0	244	9	33,975	0	-58	-	34,171
Particulate Matter (PM, dust)	kg	2	0	2	1	58	0	0	-	60
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	6,415	11	6,426	0	62,738	7	-1,518	-	67,653
Eutrophication	kg PO_4	0.2	0.0	0.2	0.0	2.8	0.0	0.0	-	2.9

Table 97. Base case 18: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	389	0	4	72	267	54	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	13,718	1,518	15,236	287	17,937,137	263	-2,780	-	17,950,144
of which, electricity (in primary MJ)	MJ	4,540	813	5,353	0	17,937,045	0	-626	-	17,941,773
Water (process)	ltr	4,926	22	4,948	0	49	0	-1,089	-	3,909
Water (cooling)	ltr	1,856	383	2,239	0	797,219	0	-288	-	799,169
Waste, non-haz./ landfill	kg	264	6	271	0	9246	5	-63	-	9459
Waste, hazardous/ incinerated	kg	1	0	1	0	283	0	0	-	284
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	1,052	88	1,140	20	765,680	1	-221	-	766,620
Acidification, emissions	kg SO_2 eq.	9	0	9	0	3388	0	-2	-	3396
Volatile Organic Compounds (VOC)	kg	0	0	0	0	401	0	0	-	401
Persistent Organic Pollutants (POP)	ng i-Teq	3,960	150	4,110	1	41,893	3	-955	-	45,052
Heavy Metals	mg Ni eq.	9,831	349	10,180	10	181,461	36	-2,327	-	189,360
PAHs	mg Ni eq.	280	3	283	9	41,856	0	-66	-	42,082
Particulate Matter (PM, dust)	kg	2	0	2	1	72	0	0	-	74
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	7,032	11	7,044	0	77,282	9	-1,568	-	82,767
Eutrophication	kg PO_4	0	0	0	0	3	0	0	-	4

Table 98. Base case 19: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	24	0	0	4	16	3	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	882	134	1,016	120	198,459	11	-211	-	199,395
of which, electricity (in primary MJ)	MJ	96	78	173	0	198,451	0	-22	-	198,602
Water (process)	ltr	426	1	427	0	4	0	-101	-	330
Water (cooling)	ltr	164	33	197	0	8,822	0	-30	-	8,989
Waste, non-haz./ landfill	kg	13	1	13	0	102	0	-3	-	113
Waste, hazardous/ incinerated	kg	0	0	0	0	3	0	0	-	3
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	68	8	75	9	8,472	0	-16	-	8,540
Acidification, emissions	kg SO_2 eq.	1	0	1	0	37	0	0	-	38
Volatile Organic Compounds (VOC)	kg	0	0	0	0	4	0	0	-	4
Persistent Organic Pollutants (POP)	ng i-Teq	219	14	233	1	465	0	-53	-	646
Heavy Metals	mg Ni eq.	898	33	932	6	2,016	3	-217	-	2,739
PAHs	mg Ni eq.	44	0	44	3	463	0	-10	-	501
Particulate Matter (PM, dust)	kg	0	0	0	0	1	0	0	-	1
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	625	1	626	0	860	1	-150	-	1,337
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.1

Table 99. Base case 20: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	24	0	0	5	17	3	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	1,216	156	1,373	121	319,512	24	-239	-	320,791
of which, electricity (in primary MJ)	MJ	394	81	476	0	319,504	0	-46	-	319,934
Water (process)	ltr	491	3	494	0	5	0	-106	-	393
Water (cooling)	ltr	172	40	212	0	14,202	0	-30	-	14,384
Waste, non-haz./ landfill	kg	13	1	14	0	165	0	-3	-	176
Waste, hazardous/ incinerated	kg	0	0	0	0	5	0	0	-	5
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	87	9	96	9	13,639	0	-18	-	13,727
Acidification, emissions	kg SO_2 eq.	1	0	1	0	60	0	0	-	61
Volatile Organic Compounds (VOC)	kg	0	0	0	0	7	0	0	-	7
Persistent Organic Pollutants (POP)	ng i-Teq	232	14	247	1	748	0	-56	-	940
Heavy Metals	mg Ni eq.	933	34	966	6	3,240	3	-220	-	3,995
PAHs	mg Ni eq.	50	0	50	3	746	0	-11	-	788
Particulate Matter (PM, dust)	kg	0	0	0	0	1	0	0	-	1
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	688	1	689	0	1,382	1	-155	-	1,917
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-	0.1

Table 100. Base case 21: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	384	0	4	71	264	53	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	10,682	1,372	12,055	286	5,979,932	143	-2,528	-	5,989,886
of which, electricity (in primary MJ)	MJ	1,716	794	2,510	0	5,979,842	0	-406	-	5,981,946
Water (process)	ltr	4,384	11	4,395	0	44	0	-1,047	-	3,391
Water (cooling)	ltr	1,814	342	2,156	0	265,788	0	-289	-	267,656
Waste, non-haz./ landfill	kg	259	6	266	0	3084	5	-63	-	3292
Waste, hazardous/ incinerated	kg	0	0	0	0	94	0	0	-	94
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	873	78	951	20	255,267	1	-206	-	256,033
Acidification, emissions	kg SO_2 eq.	7	0	8	0	1130	0	-2	-	1136
Volatile Organic Compounds (VOC)	kg	0	0	0	0	134	0	0	-	134
Persistent Organic Pollutants (POP)	ng i-Teq	3,872	150	4,022	1	13,992	3	-936	-	17,081
Heavy Metals	mg Ni eq.	9,522	348	9,870	10	60,558	33	-2,302	-	68,168
PAHs	mg Ni eq.	244	0	244	9	13,955	0	-58	-	14,151
Particulate Matter (PM, dust)	kg	2	0	2	1	24	0	0	-	26
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	6,415	11	6,426	0	25,805	7	-1,518	-	30,720
Eutrophication	kg PO_4	0.2	0.0	0.2	0.0	1.1	0.0	0.0	-	1.3

Table 101. Base case 22: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	387	0	4	72	266	53	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	12,539	1,461	14,000	287	8,208,125	216	-2,682	-	8,219,947
of which, electricity (in primary MJ)	MJ	3,443	806	4,249	0	8,208,034	0	-541	-	8,211,743
Water (process)	ltr	4,716	18	4,734	0	47	0	-1,073	-	3,708
Water (cooling)	ltr	1,839	367	2,207	0	364,818	0	-288	-	366,737
Waste, non-haz./ landfill	kg	262	6	269	0	4232	5	-63	-	4443
Waste, hazardous/ incinerated	kg	0	0	0	0	130	0	0	-	130
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	983	84	1,067	20	350,381	1	-215	-	351,254
Acidification, emissions	kg SO_2 eq.	8	0	9	0	1550	0	-2	-	1557
Volatile Organic Compounds (VOC)	kg	0	0	0	0	183	0	0	-	183
Persistent Organic Pollutants (POP)	ng i-Teq	3,926	150	4,076	1	19,191	3	-947	-	22,323
Heavy Metals	mg Ni eq.	9,711	349	10,060	10	83,089	35	-2,317	-	90,876
PAHs	mg Ni eq.	266	2	268	9	19,155	0	-63	-	19,369
Particulate Matter (PM, dust)	kg	2	0	2	1	33	0	0	-	35
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	6,792	11	6,803	0	35,400	8	-1,549	-	40,663
Eutrophication	kg PO_4	0.2	0.0	0.2	0.0	1.6	0.0	0.0	-	1.7

Table 102. Base case 23: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	31	0	0	6	21	4	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	2,277	236	2,513	0	757,823	62	-352	-	760,046
of which, electricity (in primary MJ)	MJ	1,225	102	1,327	0	757,812	0	-113	-	759,026
Water (process)	ltr	707	7	715	0	7	0	-129	-	593
Water (cooling)	ltr	215	62	277	0	33,682	0	-32	-	33,927
Waste, non-haz./ landfill	kg	18	1	19	0	391	0	-4	-	406
Waste, hazardous/ incinerated	kg	0	0	0	0	12	0	0	-	12
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	152	14	166	0	32,349	0	-25	-	32,490
Acidification, emissions	kg SO_2 eq.	1	0	1	0	143	0	0	-	144
Volatile Organic Compounds (VOC)	kg	0	0	0	0	17	0	0	-	17
Persistent Organic Pollutants (POP)	ng i-Teq	345	16	360	0	1,772	0	-82	-	2,050
Heavy Metals	mg Ni eq.	1,107	37	1,144	0	7,673	5	-247	-	8,575
PAHs	mg Ni eq.	86	2	87	0	1,769	0	-20	-	1,837
Particulate Matter (PM, dust)	kg	0	0	0	0	3	0	0	-	3
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	919	1	920	0	3,271	2	-183	-	4,010
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-	0.2

Table 103. Base case 24: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	30	0	0	6	16	8	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	1,742	329	2,071	0	138,617	27	-279	-	140,436
of which, electricity (in primary MJ)	MJ	155	193	349	0	138,602	0	-23	-	138,927
Water (process)	ltr	627	3	630	0	6	0	-123	-	513
Water (cooling)	ltr	494	87	580	0	6,165	0	-26	-	6,719
Waste, non-haz./ landfill	kg	14	1	16	0	72	0	-3	-	84
Waste, hazardous/ incinerated	kg	0	0	0	0	2	0	0	-	2
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	114	19	133	0	5,918	0	-21	-	6,030
Acidification, emissions	kg SO_2 eq.	2	0	2	0	26	0	0	-	28
Volatile Organic Compounds (VOC)	kg	0	0	0	0	3	0	0	-	3
Persistent Organic Pollutants (POP)	ng i-Teq	229	21	250	0	326	0	-47	-	528
Heavy Metals	mg Ni eq.	1,448	49	1,497	0	1,416	4	-299	-	2,618
PAHs	mg Ni eq.	62	0	62	0	324	0	-12	-	374
Particulate Matter (PM, dust)	kg	0	0	0	0	1	0	0	-	1
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	1,202	2	1,203	0	609	1	-242	-	1,572
Eutrophication	kg PO_4	0.02	0.00	0.02	0.00	0.03	0.00	0.00	-	0.05

Table 104. Base case 25: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	139	0	1	27	100	14	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	4,778	391	5,169	175	486,739	65	-1,194	-	490,954
of which, electricity (in primary MJ)	MJ	577	227	804	0	486,697	0	-144	-	487,357
Water (process)	ltr	1,200	3	1,203	0	12	0	-300	-	916
Water (cooling)	ltr	596	98	695	0	21,637	0	-108	-	22,223
Waste, non-haz./ landfill	kg	88	2	90	0	252	2	-22	-	321
Waste, hazardous/ incinerated	kg	0	0	0	0	8	0	0	-	8
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	349	22	372	13	20,779	0	-87	-	21,076
Acidification, emissions	kg SO_2 eq.	5	0	5	0	92	0	-1	-	96
Volatile Organic Compounds (VOC)	kg	0	0	0	0	11	0	0	-	11
Persistent Organic Pollutants (POP)	ng i-Teq	1,441	41	1,482	1	1,150	1	-365	-	2,269
Heavy Metals	mg Ni eq.	3,260	95	3,355	7	4,954	12	-825	-	7,502
PAHs	mg Ni eq.	177	0	178	5	1,137	0	-44	-	1,276
Particulate Matter (PM, dust)	kg	1	0	1	0	2	0	0	-	3
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	2,843	3	2,846	0	2,123	3	-711	-	4,262
Eutrophication	kg PO_4	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-	0.1

Table 105. Base case 26: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	142	0	1	28	102	14	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	6,025	475	6,500	175	228,820	116	-1,304	-	234,308
of which, electricity (in primary MJ)	MJ	1,689	241	1,929	0	228,777	0	-234	-	230,473
Water (process)	ltr	1,445	9	1,454	0	14	0	-319	-	1,150
Water (cooling)	ltr	636	122	758	0	10,173	0	-108	-	10,823
Waste, non-haz./ landfill	kg	90	2	92	0	119	2	-23	-	190
Waste, hazardous/ incinerated	kg	0	0	0	0	4	0	0	-	4
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	422	28	450	13	9,769	1	-94	-	10,138
Acidification, emissions	kg SO_2 eq.	6	0	6	0	43	0	-1	-	48
Volatile Organic Compounds (VOC)	kg	0	0	0	0	5	0	0	-	5
Persistent Organic Pollutants (POP)	ng i-Teq	1,491	41	1,532	1	549	1	-376	-	1,706
Heavy Metals	mg Ni eq.	3,388	95	3,483	7	2,347	13	-836	-	5,014
PAHs	mg Ni eq.	200	2	201	5	536	0	-50	-	693
Particulate Matter (PM, dust)	kg	1	0	1	0	1	0	0	-	2
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	3,080	3	3,083	0	1,016	4	-731	-	3,371
Eutrophication	kg PO_4	0.1	0.0	0.1	0.0	0.0	0.0	0.0	-	0.1

Table 106. Base case 27: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	172	0	2	33	124	17	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	5,932	490	6,422	190	1,381,718	79	-1,489	-	1,386,920
of which, electricity (in primary MJ)	MJ	688	285	972	0	1,381,665	0	-172	-	1,382,466
Water (process)	ltr	1,442	4	1,446	0	14	0	-360	-	1,101
Water (cooling)	ltr	720	124	844	0	61,414	0	-135	-	62,123
Waste, non-haz./ landfill	kg	105	2	107	0	713	2	-27	-	796
Waste, hazardous/ incinerated	kg	0	0	0	0	22	0	0	-	22
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	429	28	457	14	58,983	0	-107	-	59,346
Acidification, emissions	kg SO_2 eq.	6	0	7	0	261	0	-2	-	266
Volatile Organic Compounds (VOC)	kg	0	0	0	0	31	0	0	-	31
Persistent Organic Pollutants (POP)	ng i-Teq	1,826	49	1,875	1	3,242	1	-462	-	4,657
Heavy Metals	mg Ni eq.	3,892	113	4,006	7	14,009	14	-985	-	17,051
PAHs	mg Ni eq.	272	0	272	6	3,227	0	-68	-	3,436
Particulate Matter (PM, dust)	kg	1	0	1	0	6	0	0	-	6
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	3,393	4	3,396	0	5,981	4	-849	-	8,533
Eutrophication	kg PO_4	0.1	0.0	0.1	0.0	0.3	0.0	0.0	-	0.3

Table 107. Base case 28: Contribution of different life cycle stages to the different environmental impacts.

Life Cycle phases		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE			TOTAL
Impact category	Unit	Material	Manufacturing	Total			Disposal	Recycling	Stock	
Total product weight	kg	-	-	178	0	2	35	128	17	0
Other Resources & Waste							debit	credit		
Total Energy (GER)	MJ	10,270	697	10,967	190	846,634	260	-1,865	-	856,185
of which, electricity (in primary MJ)	MJ	4,723	312	5,034	0	846,578	0	-500	-	851,112
Water (process)	ltr	2,217	20	2,237	0	22	0	-422	-	1,837
Water (cooling)	ltr	779	182	961	0	37,631	0	-134	-	38,458
Waste, non-haz./ landfill	kg	112	2	114	0	437	2	-27	-	527
Waste, hazardous/ incinerated	kg	1	0	1	0	13	0	0	-	14
Emissions (Air)							debit	credit		
Greenhouse Gases in GWP100	kg CO_2 eq.	685	42	727	14	36,142	1	-130	-	36,754
Acidification, emissions	kg SO_2 eq.	8	0	9	0	160	0	-2	-	167
Volatile Organic Compounds (VOC)	kg	0	0	0	0	19	0	0	-	19
Persistent Organic Pollutants (POP)	ng i-Teq	1,951	49	2,000	1	1,995	1	-490	-	3,507
Heavy Metals	mg Ni eq.	4,334	115	4,448	7	8,603	19	-1,022	-	12,055
PAHs	mg Ni eq.	322	4	326	6	1,978	0	-79	-	2,231
Particulate Matter (PM, dust)	kg	1	0	1	0	3	0	0	-	4
Emissions (Water)							debit	credit		
Heavy Metals	mg Hg/20	4,275	4	4,278	0	3,687	7	-924	-	7,048
Eutrophication	kg PO_4	0.1	0.0	0.1	0.0	0.2	0.0	0.0	-	0.2

Annex 9. MAESP-model, input data and BAU-results

9.1 Introduction

For the scenario analysis the study team developed a stock model for pumps that will be referred to as MAESP (Model for Analysis of Ecodesign Scenarios for Pumps). The model consists of an Excel file that follows the calculation methodology used in the Ecodesign Impact Accounting 369, with some specific additions for pumps.

The input data for this model are those derived in the previous Tasks 1-6 and include:

- Subdivision in base cases (scope of the study)
- Pump sales quantities in 2014
- Annual growth percentages for pump sales
- Shares of pumps sold for constant flow and for variable flow
- Shares of pumps for variable flow using a VSD
- Average useful pump lifetimes
- Average Load (user demand for pump output: output power x operating hours)
- Average energy efficiencies of new sold products in a given year
- Relation between energy consumption and CO_2-emissions (GWP)
- Purchase-, Installation- and Maintenance costs for pumps
- Electricity rates (euros/kWh)
- Sector composition of purchase cost (industry-, retail-, wholesale-, tax-shares)
- Relation between sector revenues and number of jobs involved

The output of the model covers the period 1990-2030 and includes (for each scenario):

- Quantity of pumps installed in EU-28 (stock)
- Total EU-28 pump load (total demand for pump output)
- Average energy efficiency of the stock
- Total EU-28 energy consumption for pumps (primary energy and electricity)
- Total EU-28 greenhouse gas emission related to this energy consumption
- Total EU-28 consumer expenses for pump acquisition and operation
- Total EU-28 sector revenues from pump sales and related jobs

The input data that vary depending on the scenario (BAU, ECO1, ECO2, ECO3) are the shares of pumps for variable flow using a VSD, and the average energy efficiencies of new sold products.

Energy savings for variable flow pump applications mainly derive from a shift in sales from pumps without VSD (lower energy efficiency) to pumps with VSD (higher energy efficiency).

Energy savings for constant flow pump applications mainly derive from an increase in the average energy efficiency of new sold pumps.

This Annex contains a detailed description of the calculations performed in the model, of the input data used, and of the results obtained for the BAU-scenario.

9.2 Base Cases and General aspects

Each sheet of the MAEPS Excel-file covers one model parameter, e.g. Sales, Stock, Electricity Consumption, Greenhouse gas emission, Price, Energy Costs, Total Consumer Expense, Industry revenue, etc.

[369] See e.g. https://ec.europa.eu/energy/sites/ener/files/documents/2014_06_ecodesign_impact_accounting_part1.pdf

For most parameters there are two sheets, i.e. one for the BAU-scenario and one for all ECO-scenarios together, e.g. SALES_BAU, SALES_ECO, ELEC_BAU, ELEC_ECO.

Most sheets of the Excel model have the same structure, with base cases organized on rows and years organized in columns.

The years cover the period 1990-2030 (some sheets 1980-2030).

The base cases correspond to those that are in the scope of the study. The subdivision is per pump type, per pump size, per type of motor (without or with VSD) and per type of flow (constant, variable). The base cases are divided in two main groups, corresponding to the current scope (of regulation 547/2012) and to the scope extension. Where applicable, totals are computed separately for the current scope, the scope extension, and the extended scope (=total over all pumps).

CURRENT SCOPE					
ESOB pumps for clean water	Rated power ≤ 22 kW	Induction motor	variable	50%	**ESOB<22_VF**
			constant	50%	**ESOB<22_CF**
		Induction motor with VSD	variable	50%	**ESOB<22_VSD-VF**
	Rated power 22 - 150 kW	Induction motor	variable	30%	**ESOB_22-150_VF**
			constant	70%	**ESOB_22-150_CF**
		Induction motor with VSD	variable	30%	**ESOB_22-150_VSD-VF**
ESCC pumps for clean water	Rated power ≤ 22 kW	Induction motor	variable	50%	**ESCC<22_VF**
			constant	50%	**ESCC<22_CF**
		Induction motor with VSD	variable	50%	**ESCC<22_VSD-VF**
	Rated power 22 - 150 kW	Induction motor	variable	50%	**ESCC_22-150_VF**
			constant	50%	**ESCC_22-150_CF**
		Induction motor with VSD	variable	50%	**ESCC_22-150_VSD-VF**
ESCCi pumps for clean water	Rated power ≤ 22 kW	Induction motor	variable	90%	**ESCCi<22_VF**
			constant	10%	**ESCCi<22_CF**
		Induction motor with VSD	variable	90%	**ESCCi<22_VSD-VF**
	Rated power 22 - 150 kW	Induction motor	variable	10%	**ESCCi_22-150_VF**
			constant	90%	**ESCCi_22-150_CF**
		Induction motor with VSD	variable	10%	**ESCCi_22-150_VSD-VF**
Submersible borehole pumps for clean water	Nominal outer diameter ≤ 6"	Induction motor	variable	20%	**SBP<6"_VF**
			constant	80%	**SBP<6"_CF**
		Induction motor with VSD	variable	20%	**SBP<6"_VSD-VF**
Vertical multistage pumps for clean water	Maximum design pressure ≤ 25 bar	Induction motor	variable	50%	**MS-V<25bar_VF**
			constant	50%	**MS-V<25bar_CF**
		Induction motor with VSD	variable	50%	**MS-V<25bar_VSD-VF**

SCOPE EXTENSION					
Vertical multistage pumps for clean water	Maximum design pressure 25 - 40 bar	Induction motor	variable	50%	MS-V_25-40bar_VF
			constant	50%	MS-V_25-40bar_CF
		Induction motor with VSD	variable	50%	MS-V_25-40bar_VSD-VF
Horizontal multistage pumps for clean water	Maximum design pressure ≤ 25 bar	Induction motor	variable	50%	MS-H<25bar_VF
			constant	50%	MS-H<25bar_CF
		Induction motor with VSD	variable	50%	MS-H<25bar_VSD-VF
	Maximum design pressure 25 - 40 bar	Induction motor	variable	50%	MS-H_25-40bar_VF
			constant	50%	MS-H_25-40bar_CF
		Induction motor with VSD	variable	50%	MS-H_25-40bar_VSD-VF
Booster-sets for clean water	Rated power ≤ 150 kW	Induction motor	variable	100%	BS<150_VF
			constant	0%	BS<150_CF
		Induction motor with VSD	variable	100%	BS<150_VSD-VF
Swimming pool pumps	Rated power ≤ 2.2 kW	Induction motor	variable	0%	SWP<2.2_VF
			constant	100%	SWP<2.2_CF
		Induction motor with VSD	variable	0%	SWP<2.2_VSD-VF
Submersible vortex radial pumps for wastewater	Rated power ≤ 10 kW	Induction motor	variable	5%	SVR<10_VF
			constant	95%	SVR<10_CF
		Induction motor with VSD	variable	5%	SVR<10_VSD-VF
	Rated power 10 - 160 kW	Induction motor	variable	7%	SVR_10-160_VF
			constant	93%	SVR_10-160_CF
		Induction motor with VSD	variable	7%	SVR_10-160_VSD-VF
Submersible channel radial pumps for wastewater	Rated power ≤ 10 kW	Induction motor	variable	5%	SCR<10_VF
			constant	95%	SCR<10_CF
		Induction motor with VSD	variable	5%	SCR<10_VSD-VF
	Rated power 10 -25 kW	Induction motor	variable	7%	SCR_10-25_VF
			constant	93%	SCR_10-25_CF
		Induction motor with VSD	variable	7%	SCR_10-25_VSD-VF
	Rated power 25 - 160 kW	Induction motor	variable	20%	SCR_25-160_VF
			constant	80%	SCR_25-160_CF
		Induction motor with VSD	variable	20%	SCR_25-160_VSD-VF

Figure 58. Base Cases used in MAESP: pumps are subdivided per category, power size, use of VSD and type of flow. The base cases are combined in two groups: the current scope (of regulation 547/2012) and the scope extension.

9.3 Sales, total per pump category and size

Point of departure are the total sales per pump category and size in 2014. For other years the sales quantities (in number of units sold) are derived using assumed annual growth rates. There are 3 sets of growth rates: for clean water pumps, swimming pool pumps and wastewater pumps. Before year 2000 the growth rate is 1.73% as in the 2009 Impact Assessment. Between 2000 and 2020 the growth rates have been taken from an EIF report (except that data for swimming pool pumps have been taken from the preparatory study). After 2020, growth rates are assumed to go linearly to zero in 2030; this decrease in growth is similar to what has been assumed in the 2015 Impact Assessment for electric motors.

These computations are performed on the sheet TOTAL_SALES.

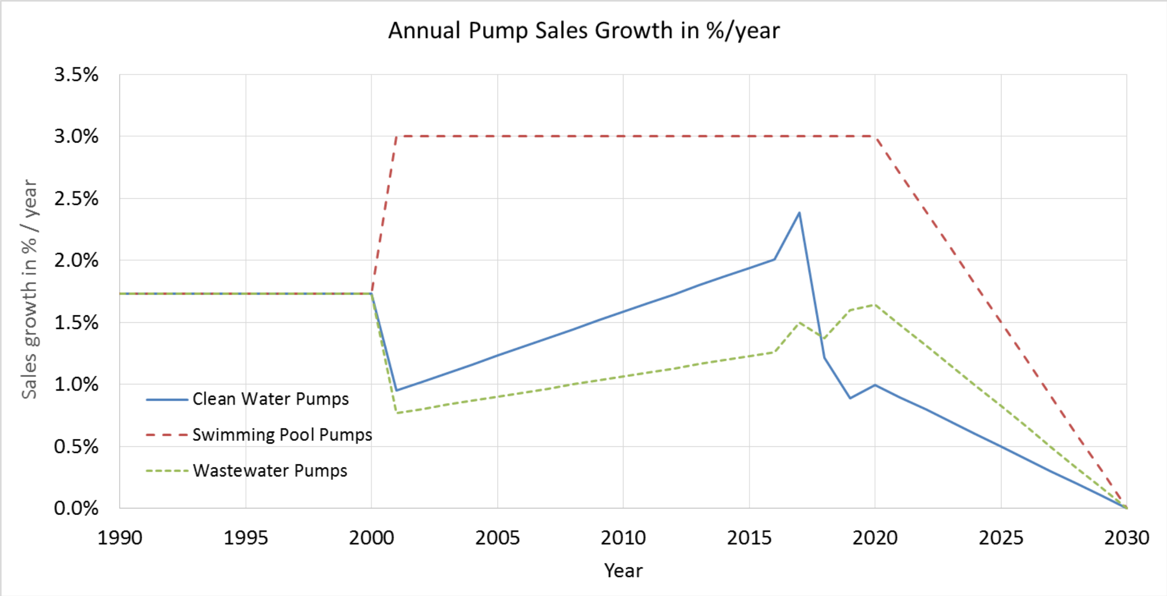


Figure 59. Annual growth rates for pump sales in % per year.

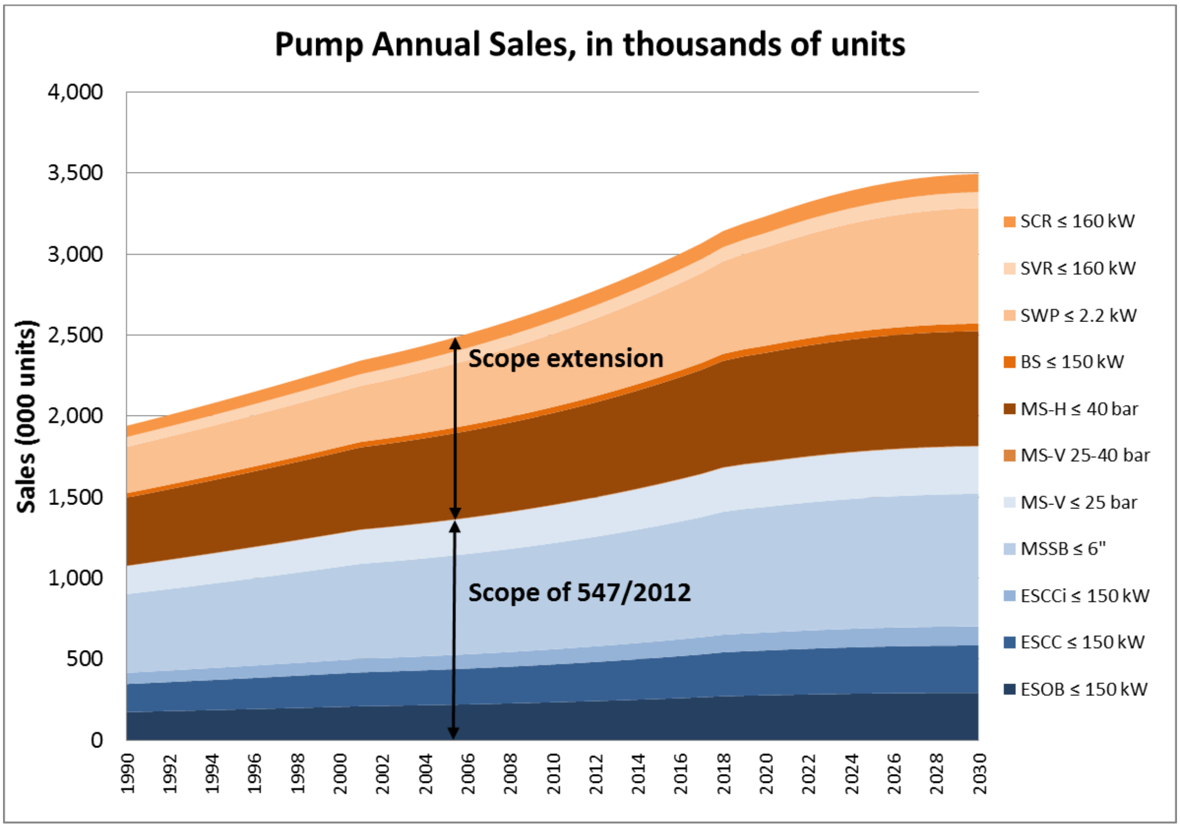


Figure 60. Total sales per pump category.

		1980	1990	2000	2005	2010	2014	2015	2020	2025	2030
SALES CURRENT SCOPE											
ESOB	Rated power ≤ 22 kW	131,361	155,991	185,239	196,528	210,398	225,000	229,204	249,195	259,282	263,178
	Rated power 22 - 150 kW	14,596	17,332	20,582	21,836	23,378	25,000	25,467	27,688	28,809	29,242
ESCC	Rated power ≤ 22 kW	131,361	155,991	185,239	196,528	210,398	225,000	229,204	249,195	259,282	263,178
	Rated power 22 - 150 kW	14,596	17,332	20,582	21,836	23,378	25,000	25,467	27,688	28,809	29,242
ESCCi	Rated power ≤ 22 kW	52,545	62,397	74,096	78,611	84,159	90,000	91,682	99,678	103,713	105,271
	Rated power 22 - 150 kW	5,838	6,933	8,233	8,735	9,351	10,000	10,187	11,075	11,524	11,697
MSSB	Nominal outer diameter ≤ 6"	408,680	485,307	576,300	611,420	654,570	700,000	713,080	775,274	806,655	818,775
MS-V	Maximum design pressure ≤ 25 bar	145,957	173,324	205,822	218,364	233,775	250,000	254,672	276,884	288,091	292,420
Total for scope of 547/2012 (000 units)		**905**	**1,075**	**1,276**	**1,354**	**1,449**	**1,550**	**1,579**	**1,717**	**1,786**	**1,813**
SALES SCOPE EXTENSION											
MS-V	Maximum design pressure 25 - 40 bar	1,693	2,011	2,388	2,533	2,712	2,900	2,954	3,212	3,342	3,392
MS-H	Maximum design pressure ≤ 25 bar	347,378	412,511	489,855	519,707	556,385	595,000	606,118	658,983	685,656	695,959
	Maximum design pressure 25 - 40 bar	6,130	7,280	8,645	9,171	9,819	10,500	10,696	11,629	12,100	12,282
BS	Rated power ≤ 150 kW	23,353	27,732	32,931	34,938	37,404	40,000	40,747	44,301	46,095	46,787
SWP	Rated power ≤ 2.2 kW	241,130	286,341	340,029	389,340	451,351	508,000	523,240	606,579	682,917	714,175
SVR	Rated power ≤ 10 kW	49,220	58,448	69,407	72,949	76,538	80,000	80,955	86,744	92,602	94,909
	Rated power 10 - 160 kW	1,477	1,753	2,082	2,188	2,296	2,400	2,429	2,602	2,778	2,847
SCR	Rated power ≤ 10 kW	49,220	58,448	69,407	72,949	76,538	80,000	80,955	86,744	92,602	94,909
	Rated power 10 -25 kW	5,906	7,014	8,329	8,754	9,185	9,600	9,715	10,409	11,112	11,389
	Rated power 25 - 160 kW	3,076	3,653	4,338	4,559	4,784	5,000	5,060	5,421	5,788	5,932
Total for scope extension (000 units)		**729**	**865**	**1,027**	**1,117**	**1,227**	**1,333**	**1,363**	**1,517**	**1,635**	**1,683**
Total for extended scope (000 units)		**1,634**	**1,940**	**2,304**	**2,471**	**2,676**	**2,883**	**2,942**	**3,233**	**3,421**	**3,496**

Table 108. Total pump sales per category and power size, period 1980-2030.

9.4 Sales, detailed per flow type and VSD use

The sales per pump type of a given size are further split in sales of pumps for constant flow applications and sales of pumps for variable flow applications. This subdivision uses the constant/variable flow shares shown in Figure 58. Note that in this figure the variable flow share is reported twice, but that the two values represent a repetition of the same share and are not additive.

The sales for variable flow are further subdivided in sales of pumps with VSD and without VSD. This is done by means of the share of variable flow pumps that is sold with VSD. This share differs per pump category and is also different for the BAU-scenario and the ECO-scenarios.

In the BAU-scenario the VSD-share is assumed to gradually increase from the 2014-value due to an existing trend and due to the motor regulation 640/2009 that promotes the use of VSDs.

In the ECO-scenarios the VSD-share is typically higher than in the BAU-scenario, and usually set to 100% starting from 2021 or 2022, because the proposed minimum energy efficiency values for variable flow pumps are set in such a way that the requirement can only be met if a VSD is applied.

The change in VSD-share from the BAU to the ECO-scenario implies a sales shift from less efficient pumps (without VSD) to more efficient pumps (with VSD) and consequently is the main driver for energy savings.

VSD shares for 2014 are mainly based on input from industry. The variation of the VSD shares with the years follows the assumptions made in the 2015 motor Impact Assessment for the use of VSDs on electric motors.

For constant flow, no distinction is made between applications with and without VSD: essentially all pumps for constant flow are assumed to work without VSD, in all scenarios.

The assumed shares of pumps for variable flow that are sold with VSD in a given year and scenario are shown in Table 109. For swimming pool pumps (SWP) all pumps are assumed to be for constant flow, so no VSD share has been defined. For wastewater pumps (SCR and SVR) all pumps for variable flow are assumed to be sold with VSD, in all scenarios. For

MS-V 25-40 bar, 100% VSD is already reached in the BAU-scenario from 2021. For all these pump types there are no energy savings due to a shift from pumps without VSD to pumps with VSD.

Note that for all other pump types the shift towards VSDs is identical for the three ECO-scenarios, so that it does not create energy saving differences between these scenarios.

For booster-sets (BS) the situation is more complex, as an additional distinction is made between sets with a single VSD and sets with multiple VSDs.

Table 109. Assumed share of pumps for variable flow that are sold with VSD.

pump category and size	scenario	1990	2000	2010	*2014*	2016	2018	2020	2022	2024	2030
ESOB<22_VSD-VF	BAU	5.1%	6.1%	7.6%	*8.0%*	9.0%	10.2%	11.4%	12.8%	14.3%	14.3%
	ECO1							77.9%	100.0%	100.0%	100.0%
	ECO2							77.9%	100.0%	100.0%	100.0%
	ECO3							77.9%	100.0%	100.0%	100.0%
ESOB_22-150_VSD-VF	BAU	8.5%	10.2%	12.6%	*13.3%*	15.0%	17.0%	19.0%	21.3%	23.9%	23.9%
	ECO1							79.8%	100.0%	100.0%	100.0%
	ECO2							79.8%	100.0%	100.0%	100.0%
	ECO3							79.8%	100.0%	100.0%	100.0%
ESCC<22_VSD-VF	BAU	6.4%	7.7%	9.5%	*10.0%*	11.2%	12.8%	14.3%	16.0%	17.9%	17.9%
	ECO1							78.6%	100.0%	100.0%	100.0%
	ECO2							78.6%	100.0%	100.0%	100.0%
	ECO3							78.6%	100.0%	100.0%	100.0%
ESCC_22-150_VSD-VF	BAU	6.4%	7.7%	9.5%	*10.0%*	11.2%	12.8%	14.3%	16.0%	17.9%	17.9%
	ECO1							78.6%	100.0%	100.0%	100.0%
	ECO2							78.6%	100.0%	100.0%	100.0%
	ECO3							78.6%	100.0%	100.0%	100.0%
ESCCi<22_VSD-VF	BAU	21.4%	25.5%	31.6%	*33.3%*	37.5%	42.5%	47.6%	53.3%	59.7%	59.7%
	ECO1							86.9%	100.0%	100.0%	100.0%
	ECO2							86.9%	100.0%	100.0%	100.0%
	ECO3							86.9%	100.0%	100.0%	100.0%
ESCCi_22-150_VSD-VF	BAU	21.4%	25.5%	31.6%	*33.3%*	37.5%	42.5%	47.6%	53.3%	59.7%	59.7%
	ECO1							86.9%	100.0%	100.0%	100.0%
	ECO2							86.9%	100.0%	100.0%	100.0%
	ECO3							86.9%	100.0%	100.0%	100.0%
MSSB<6"_VSD-VF	BAU	20.6%	24.5%	30.3%	*32.0%*	36.0%	37.8%	39.5%	43.0%	48.2%	48.2%
	ECO1							39.5%	87.0%	100.0%	100.0%
	ECO2							39.5%	87.0%	100.0%	100.0%
	ECO3							39.5%	87.0%	100.0%	100.0%
MS-V<25bar_VSD-VF	BAU	10.3%	12.3%	15.2%	*16.0%*	18.0%	20.4%	22.8%	25.6%	28.7%	28.7%
	ECO1							83.6%	100.0%	100.0%	100.0%
	ECO2							83.6%	100.0%	100.0%	100.0%
	ECO3							83.6%	100.0%	100.0%	100.0%
MS-V_25-40bar_VSD-VF	BAU	45.0%	53.6%	66.3%	*70.0%*	78.7%	87.2%	95.7%	100.0%	100.0%	100.0%
	ECO1							95.7%	100.0%	100.0%	100.0%
	ECO2							95.7%	100.0%	100.0%	100.0%
	ECO3							95.7%	100.0%	100.0%	100.0%
MS-H<25bar_VSD-VF	BAU	17.3%	20.6%	25.5%	*26.9%*	30.2%	34.3%	38.4%	43.0%	48.2%	48.2%
	ECO1							86.0%	100.0%	100.0%	100.0%
	ECO2							86.0%	100.0%	100.0%	100.0%
	ECO3							86.0%	100.0%	100.0%	100.0%
MS-H_25-40bar_VSD-VF	BAU	27.6%	32.9%	40.6%	*42.9%*	48.2%	54.7%	61.2%	68.5%	76.8%	76.8%
	ECO1							89.6%	100.0%	100.0%	100.0%
	ECO2							89.6%	100.0%	100.0%	100.0%
	ECO3							89.6%	100.0%	100.0%	100.0%
BS<150_VSD single-VF	BAU	32.1%	38.3%	47.4%	*50.0%*	50.0%	55.8%	61.7%	68.1%	75.0%	75.0%
	ECO1							78.8%	86.0%	84.0%	84.0%
	ECO2							70.0%	66.0%	0.0%	0.0%
	ECO3							10.0%	0.0%	0.0%	0.0%
BS<150_VSD multi-VF	BAU	0.0%	0.0%	0.0%	*0.0%*	6.2%	8.0%	9.7%	11.9%	14.6%	14.6%
	ECO1							12.4%	14.0%	16.0%	16.0%
	ECO2							21.0%	25.0%	100.0%	100.0%
	ECO3							81.0%	100.0%	100.0%	100.0%

SWP<2.2_VSD-VF	**all**	not applicable, assumed to be all constant flow			
SVR<10_VSD-VF	**all**	40.0%	80.0%	100.0%	assumed 100% VSD already in BAU
SVR_10-160_VSD-VF	**all**	40.0%	80.0%	100.0%	assumed 100% VSD already in BAU
SCR<10_VSD-VF	**all**	40.0%	80.0%	100.0%	assumed 100% VSD already in BAU
SCR_10-25_VSD-VF	**all**	40.0%	80.0%	100.0%	assumed 100% VSD already in BAU
SCR_25-160_VSD-VF	**all**	40.0%	80.0%	100.0%	assumed 100% VSD already in BAU

Table 110 reports the detailed sales quantities subdivided per flow type and per VSD use for variable flow.

In the Excel sheet the corresponding input data and calculations can be found on the sheets SALES_BAU, SALES_ECO and VSD_SHARE_ECO:

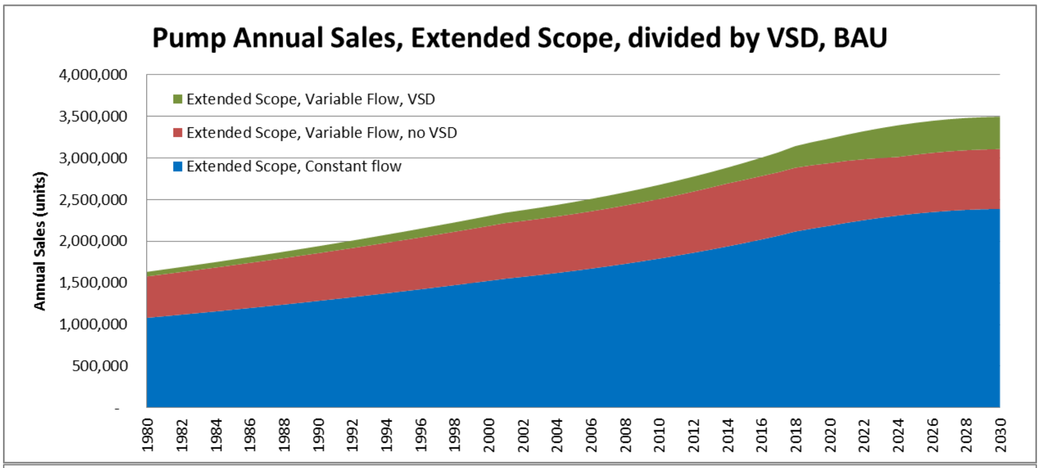
Sales CF	= TOTAL_SALES * % constant flow
Sales VF without VSD	= TOTAL_SALES * % variable flow * % no VSD
Sales VF with VSD	= TOTAL_SALES * % variable flow * % VSD

Table 110. Detailed pump SALES (in thousands of units) per category, size, flow type and VSD use. CF = constant flow; VF = variable flow. For variable flow the part of sales that is with VSD is also indicated, for the BAU scenario and for all ECO-scenarios.

pump category and size	flow	scenario	1990	2000	2010	*2014*	2016	2018	2020	2022	2024	2030
ESOB ≤ 22 kW	**CF**	all	78	93	105	*113*	117	119	125	127	129	132
	VF	all	78	93	105	*113*	117	119	125	127	129	132
	o/w with	BAU	4	6	8	*9*	11	11	14	16	18	19
	VSD	all ECO	4	6	8	*9*	11	11	97	127	129	132
ESOB 22-150 kW	**CF**	all	12	14	16	*18*	18	19	19	20	20	20
	VF	all	5	6	7	*8*	8	8	8	8	9	9
	o/w with	BAU	0	1	1	*1*	1	1	2	2	2	2
	VSD	all ECO	0	1	1	*1*	1	1	7	8	9	9
ESCC ≤ 22 kW	**CF**	all	78	93	105	*113*	117	119	125	127	129	132
	VF	all	78	93	105	*113*	117	119	125	127	129	132
	o/w with	BAU	5	7	10	*11*	13	14	18	20	23	24
	VSD	all ECO	5	7	10	*11*	13	14	98	127	129	132
ESCC 22-150 kW	**CF**	all	9	10	12	*13*	13	13	14	14	14	15
	VF	all	9	10	12	*13*	13	13	14	14	14	15
	o/w with	BAU	1	1	1	*1*	1	2	2	2	3	3
	VSD	all ECO	1	1	1	*1*	1	2	11	14	14	15
ESCCi ≤ 22 kW	**CF**	all	6	7	8	*9*	9	10	10	10	10	11
	VF	all	56.2	66.7	75.7	*81.0*	84.1	85.8	89.7	91.4	92.8	94.7
	o/w with	BAU	12.0	17.0	23.9	*27.0*	31.5	34.3	42.7	48.7	55.4	56.6
	VSD	all ECO	12.0	17.0	23.9	*27.0*	31.5	34.3	78.0	91.4	92.8	94.7
ESCCi 22-150 kW	**CF**	all	6.2	7.4	8.4	*9.0*	9.3	9.5	10.0	10.2	10.3	10.5
	VF	all	0.7	0.8	0.9	*1.0*	1.0	1.1	1.1	1.1	1.1	1.2
	o/w with	BAU	0.1	0.2	0.3	*0.3*	0.4	0.4	0.5	0.6	0.7	0.7
	VSD	all ECO	0.1	0.2	0.3	*0.3*	0.4	0.4	1.0	1.1	1.1	1.2
MSSB ≤ 6"	**CF**	all	388.2	461.0	523.7	*560.0*	581.5	593.2	620.2	632.0	641.5	655.0
	VF	all	97.1	115.3	130.9	*140.0*	145.4	148.3	155.1	158.0	160.4	163.8
	o/w with	BAU	20.0	28.3	39.7	*44.8*	52.3	57.3	61.3	67.9	77.3	78.9
	VSD	all ECO	20.0	28.3	39.7	*44.8*	52.3	72.4	135.2	158.0	160.4	163.8
MS-V ≤ 25 bar	**CF**	all	86.7	102.9	116.9	*125.0*	129.8	132.4	138.4	141.1	143.2	146.2
	VF	all	86.7	102.9	116.9	*125.0*	129.8	132.4	138.4	141.1	143.2	146.2
	o/w with	BAU	8.9	12.6	17.7	*20.0*	23.3	25.4	31.6	36.1	41.0	41.9
	VSD	all ECO	8.9	12.6	17.7	*20.0*	23.3	45.5	115.7	141.1	143.2	146.2
MS-V 25-40 bar	**CF**	all	1.0	1.2	1.4	*1.5*	1.5	1.5	1.6	1.6	1.7	1.7
	VF	all	1.0	1.2	1.4	*1.5*	1.5	1.5	1.6	1.6	1.7	1.7
	o/w with	BAU	0.5	0.6	0.9	*1.0*	1.2	1.3	1.5	1.6	1.7	1.7
	VSD	all ECO	0.5	0.6	0.9	*1.0*	1.2	1.3	1.5	1.6	1.7	1.7
MS-H ≤ 25 bar	**CF**	all	206.3	244.9	278.2	*297.5*	308.9	315.1	329.5	335.8	340.8	348.0
	VF	all	206.3	244.9	278.2	*297.5*	308.9	315.1	329.5	335.8	340.8	348.0
	o/w with	BAU	35.7	50.5	70.9	*80.0*	93.3	101.6	126.5	144.4	164.1	167.6
	VSD	all ECO	35.7	50.5	70.9	*80.0*	93.3	139.2	283.5	335.8	340.8	348.0
MS-H 25-40 bar	**CF**	all	3.6	4.3	4.9	*5.3*	5.5	5.6	5.8	5.9	6.0	6.1
	VF	all	3.6	4.3	4.9	*5.3*	5.5	5.6	5.8	5.9	6.0	6.1

	o/w with	BAU	1.0	1.4	2.0	*2.3*	2.6	2.9	3.6	4.1	4.6	4.7
	VSD	all ECO	1.0	1.4	2.0	*2.3*	2.6	3.3	5.2	5.9	6.0	6.1
BS ≤ 150 kW	**CF**	all	-	-	-	*-*	-	-	-	-	-	-
	VF	all	27.7	32.9	37.4	*40.0*	41.5	42.4	44.3	45.1	45.8	46.8
	o/w with	BAU	8.9	12.6	17.7	*20.0*	23.3	25.4	31.6	36.1	41.0	41.9
	VSD *	all ECO	8.9	12.6	17.7	*20.0*	23.3	27.5	40.4	45.1	45.8	46.8
SWP ≤ 2.2 kW	**CF**	all	286.3	340.0	451.4	*508.0*	538.9	555.1	606.6	641.6	670.8	714.2
	VF	all	-	-	-	*-*	-	-	-	-	-	-
	o/w with	BAU	-	-	-	*-*	-	-	-	-	-	-
	VSD	all ECO	-	-	-	*-*	-	-	-	-	-	-
SVR ≤ 10 kW	**CF**	all	55.5	65.9	72.7	*76.0*	77.9	78.8	82.4	85.0	87.1	90.2
	VF	all	2.9	3.5	3.8	*4.0*	4.1	4.1	4.3	4.5	4.6	4.7
	o/w with	BAU	1.2	2.8	3.8	*4.0*	4.1	4.1	4.3	4.5	4.6	4.7
	VSD	all ECO	1.2	2.8	3.8	*4.0*	4.1	4.1	4.3	4.5	4.6	4.7
SVR 10-160 kW	**CF**	all	1.6	1.9	2.1	*2.2*	2.3	2.3	2.4	2.5	2.6	2.6
	VF	all	0.1	0.1	0.2	*0.2*	0.2	0.2	0.2	0.2	0.2	0.2
	o/w with	BAU	0.0	0.1	0.2	*0.2*	0.2	0.2	0.2	0.2	0.2	0.2
	VSD	all ECO	0.0	0.1	0.2	*0.2*	0.2	0.2	0.2	0.2	0.2	0.2
SCR ≤ 10 kW	**CF**	all	55.5	65.9	72.7	*76.0*	77.9	78.8	82.4	85.0	87.1	90.2
	VF	all	2.9	3.5	3.8	*4.0*	4.1	4.1	4.3	4.5	4.6	4.7
	o/w with	BAU	1.2	2.8	3.8	*4.0*	4.1	4.1	4.3	4.5	4.6	4.7
	VSD	all ECO	1.2	2.8	3.8	*4.0*	4.1	4.1	4.3	4.5	4.6	4.7
SCR 10-25 kW	**CF**	all	6.5	7.7	8.5	*8.9*	9.1	9.3	9.7	10.0	10.2	10.6
	VF	all	0.5	0.6	0.6	*0.7*	0.7	0.7	0.7	0.8	0.8	0.8
	o/w with	BAU	0.2	0.5	0.6	*0.7*	0.7	0.7	0.7	0.8	0.8	0.8
	VSD	all ECO	0.2	0.5	0.6	*0.7*	0.7	0.7	0.7	0.8	0.8	0.8
SCR 25-160 kW	**CF**	all	2.9	3.5	3.8	*4.0*	4.1	4.1	4.3	4.5	4.6	4.7
	VF	all	3.4	3.6	3.8	*4.0*	4.1	4.1	4.3	4.5	4.6	4.7
	o/w with	BAU	2.9	3.5	3.8	*4.0*	4.1	4.1	4.3	4.5	4.6	4.7
	VSD	all ECO	2.9	3.5	3.8	*4.0*	4.1	4.1	4.3	4.5	4.6	4.7

* For booster sets this is the sum for sets with single VSD and sets with multiple VSD



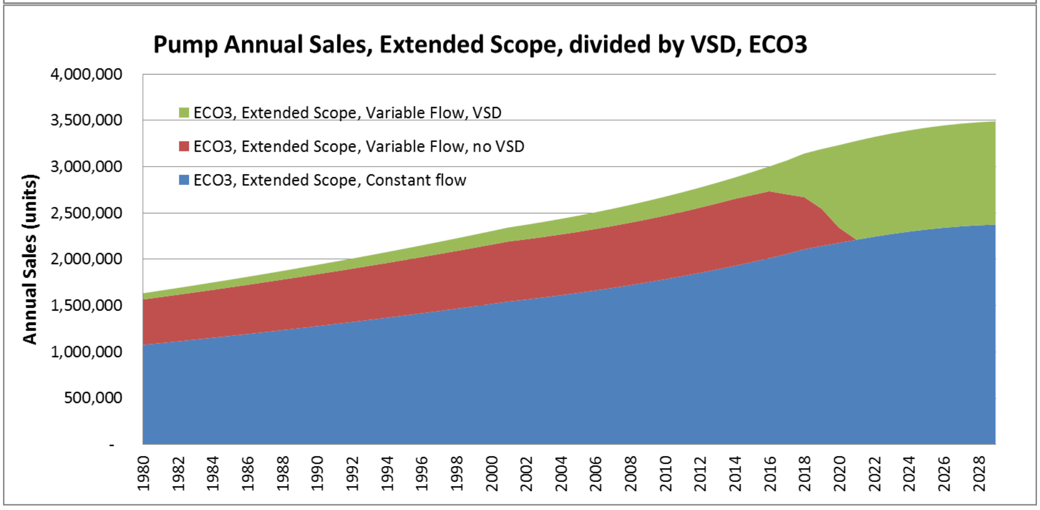


Figure 61. Sales for pumps for constant flow, and sales for pumps with variable flow split in those without and with VSD (top: for BAU-scenario; bottom: for ECO-scenario).

9.5 Lifetimes and Installed Stock

The installed number of pumps in EU-28 (the stock) in a given year is computed by summing the sales over the preceding 'lifetime' years:

$$\sum_{i=(year-lifeINT+1)}^{year} SALES\_BAU_i \quad + SALES\_BAU_{year-lifeINT} * lifeDEC$$

in which:
$SALES\_BAU_i$ = BAU sales quantity in year 'i' for a specific sub-base case
Year= year of the stock calculation
lifeINT = integer part of the lifetime
lifeDEC = decimal part of the lifetime
(and similar for the ECO-scenarios)

The useful lifetime (between acquisition and replacement) of all pumps has been assumed to be 10 years.

The stock calculations are performed on the sheets STOCK_BAU and STOCK_ECO, and the results are shown in Table 111 and following figures.

Table 111. Detailed pump INSTALLED STOCK (in thousands of units) per category, size, flow type and VSD use. CF = constant flow; VF = variable flow. For variable flow the part of sales that is with VSD is also indicated, for the BAU scenario and for all ECO-scenarios.

pump category and size	flow	scenario	1990	2000	2010	2014	2016	2018	2020	2022	2024	2030
ESOB ≤ 22 kW	CF	all	723	858	992	1,048	1,082	1,100	1,159	1,197	1,230	1,295
	VF	all	723	858	992	1,048	1,082	1,100	1,159	1,197	1,230	1,295
	o/w with	BAU	34	49	69	79	85	89	106	121	139	180
	VSD	all ECO	34	49	69	79	85	89	216	453	692	1,295
ESOB 22-150 kW	CF	all	112	134	154	163	168	171	180	186	191	201
	VF	all	48	57	66	70	72	73	77	80	82	86
	o/w with	BAU	4	5	8	9	9	10	12	13	15	20
	VSD	all ECO	4	5	8	9	9	10	19	34	49	86
ESCC ≤ 22 kW	CF	all	723	858	992	1,048	1,082	1,100	1,159	1,197	1,230	1,295
	VF	all	723	858	992	1,048	1,082	1,100	1,159	1,197	1,230	1,295
	o/w with	BAU	43	61	86	98	106	112	133	151	174	225
	VSD	all ECO	43	61	86	98	106	112	240	471	706	1,295
ESCC 22-150 kW	CF	all	80	95	110	116	120	122	129	133	137	144
	VF	all	80	95	110	116	120	122	129	133	137	144
	o/w with	BAU	5	7	10	11	12	12	15	17	19	25
	VSD	all ECO	5	7	10	11	12	12	27	52	78	144
ESCCi ≤ 22 kW	CF	all	58	69	79	84	87	88	93	96	98	104
	VF	all	520	618	714	755	779	792	835	862	886	932
	o/w with	BAU	102	147	206	235	255	268	318	362	417	539
	VSD	all ECO	102	147	206	235	255	268	366	498	630	932
ESCCi 22-150 kW	CF	all	58	69	79	84	87	88	93	96	98	104
	VF	all	6	8	9	9	10	10	10	11	11	12
	o/w with	BAU	1	2	3	3	3	3	4	4	5	7
	VSD	all ECO	1	2	3	3	3	3	5	6	8	12
MSSB ≤ 6"	CF	all	3,598	4,273	4,938	5,217	5,384	5,476	5,770	5,956	6,124	6,444
	VF	all	899	1,068	1,235	1,304	1,346	1,369	1,443	1,489	1,531	1,611
	o/w with	BAU	169	244	342	391	423	462	505	553	615	752
	VSD	all ECO	169	244	342	391	423	516	688	919	1151	1611
MS-V ≤ 25 bar	CF	all	803	954	1,102	1,164	1,202	1,222	1,288	1,329	1,367	1,438
	VF	all	803	954	1,102	1,164	1,202	1,222	1,288	1,329	1,367	1,438
	o/w with	BAU	76	109	153	174	189	198	236	269	309	399
	VSD	all ECO	76	109	153	174	189	218	444	688	934	1,438
MS-V 25-40 bar	CF	all	9	11	13	14	14	14	15	15	16	17
	VF	all	9	11	13	14	14	14	15	15	16	17
	o/w with	BAU	4	6	8	9	10	10	12	13	14	17
	VSD	all ECO	4	6	8	9	10	10	12	13	14	17
MS-H ≤ 25 bar	CF	all	1,911	2,270	2,623	2,771	2,860	2,909	3,066	3,164	3,254	3,424
	VF	all	1,911	2,270	2,623	2,771	2,860	2,909	3,066	3,164	3,254	3,424
	o/w with	BAU	303	435	612	698	756	794	944	1,074	1,235	1,597
	VSD	all ECO	303	435	612	698	756	831	1,332	1,852	2,373	3,424
MS-H 25-40 bar	CF	all	34	40	46	49	50	51	54	56	57	60
	VF	all	34	40	46	49	50	51	54	56	57	60
	o/w with	BAU	9	12	17	20	21	22	27	30	35	45
	VSD	all ECO	9	12	17	20	21	23	31	38	46	60
BS ≤ 150 kW	CF	all	-	-	-	-	-	-	-	-	-	-
	VF	all	257	305	353	373	385	391	412	425	437	460
		BAU	76	109	153	174	189	209	236	268	309	399

	o/w with VSD *	all ECO	76	109	153	*174*	189	209	258	310	362	460
SWP ≤ 2.2 kW	CF	all	2,654	3,151	3,966	*4,463*	4,735	4,877	5,329	5,652	5,979	6,806
	VF	all	-	-	-	*-*	-	-	-	-	-	-
	o/w with	BAU	-	-	-	*-*	-	-	-	-	-	-
	VSD	all ECO	-	-	-	*-*	-	-	-	-	-	-
SVR ≤ 10 kW	CF	all	515	611	697	*725*	740	748	776	797	819	878
	VF	all	27	32	37	*38*	39	39	41	42	43	46
	o/w with	BAU	6	20	35	*38*	39	39	41	42	43	46
	VSD	all ECO	6	20	35	*38*	39	39	41	42	43	46
SVR 10-160 kW	CF	all	15	18	20	*21*	22	22	23	23	24	26
	VF	all	1	1	2	*2*	2	2	2	2	2	2
	o/w with	BAU	0	1	1	*2*	2	2	2	2	2	2
	VSD	all ECO	0	1	1	*2*	2	2	2	2	2	2
SCR ≤ 10 kW	CF	all	515	611	697	*725*	740	748	776	797	819	878
	VF	all	27	32	37	*38*	39	39	41	42	43	46
	o/w with	BAU	6	20	35	*38*	39	39	41	42	43	46
	VSD	all ECO	6	20	35	*38*	39	39	41	42	43	46
SCR 10-25 kW	CF	all	60	72	82	*85*	87	88	91	94	96	103
	VF	all	5	5	6	*6*	7	7	7	7	7	8
	o/w with	BAU	1	3	6	*6*	7	7	7	7	7	8
	VSD	all ECO	1	3	6	*6*	7	7	7	7	7	8
SCR 25-160 kW	CF	all	27	32	37	*38*	39	39	41	42	43	46
	VF	all	32	35	37	*38*	39	39	41	42	43	46
	o/w with	BAU	27	32	37	*38*	39	39	41	42	43	46
	VSD	all ECO	27	32	37	*38*	39	39	41	42	43	46

* For booster sets this is the sum for sets with single VSD and sets with multiple VSD

Table 112. Installed Stock totals (in thousands of units) per scope-range and per flow type.

	1990	2000	2010	2015	2020	2025	2030
CURRENT SCOPE (Regulation 547/2012)							
Constant flow	6,104	7,248	8,377	8,988	9,789	10,517	10,932
Variable Flow, no VSD	3,411	3,940	4,395	4,614	4,822	4,808	4,705
Variable Flow, yes VSD	444	637	896	1,062	1,360	1,834	2,199
Variable Flow, total	3,855	4,578	5,291	5,677	6,183	6,642	6,905
All, total	**9,959**	**11,826**	**13,668**	**14,664**	**15,972**	**17,159**	**17,837**
share with Variable Flow in ALL	38.7%	38.7%	38.7%	38.7%	38.7%	38.7%	38.7%
share with VSD in Variable Flow	11.5%	13.9%	16.9%	18.7%	22.0%	27.6%	31.9%
share with VSD in ALL	4.5%	5.4%	6.6%	7.2%	8.5%	10.7%	12.3%
SCOPE EXTENSION							
Constant flow	5,740	6,816	8,182	9,086	10,171	11,332	12,237
Variable Flow, no VSD	1,872	2,094	2,249	2,321	2,329	2,117	1,903
Variable Flow, yes VSD	406	611	876	1,030	1,318	1,801	2,172
Variable Flow, total	2,278	2,705	3,126	3,351	3,647	3,918	4,075
All, total	**8,018**	**9,521**	**11,307**	**12,437**	**13,818**	**15,250**	**16,312**
share with Variable Flow in ALL	28.4%	28.4%	27.6%	26.9%	26.4%	25.7%	25.0%
share with VSD in Variable Flow	17.8%	22.6%	28.0%	30.7%	36.2%	46.0%	53.3%
share with VSD in ALL	5.1%	6.4%	7.8%	8.3%	9.5%	11.8%	13.3%
EXTENDED SCOPE							
Constant flow	11,843	14,064	16,559	18,074	19,960	21,849	23,170
Variable Flow, no VSD	5,283	6,035	6,644	6,935	7,151	6,925	6,608
Variable Flow, yes VSD	850	1,248	1,773	2,092	2,679	3,635	4,371
Variable Flow, total	6,133	7,283	8,417	9,028	9,830	10,560	10,979
All, total	**17,976**	**21,347**	**24,976**	**27,101**	**29,790**	**32,409**	**34,149**
share with Variable Flow in ALL	28.4%	28.4%	27.6%	26.9%	26.4%	25.7%	25.0%

share with VSD in Variable Flow	17.8%	22.6%	28.0%	30.7%	36.2%	46.0%	53.3%
share with VSD in ALL	5.1%	6.4%	7.8%	8.3%	9.5%	11.8%	13.3%

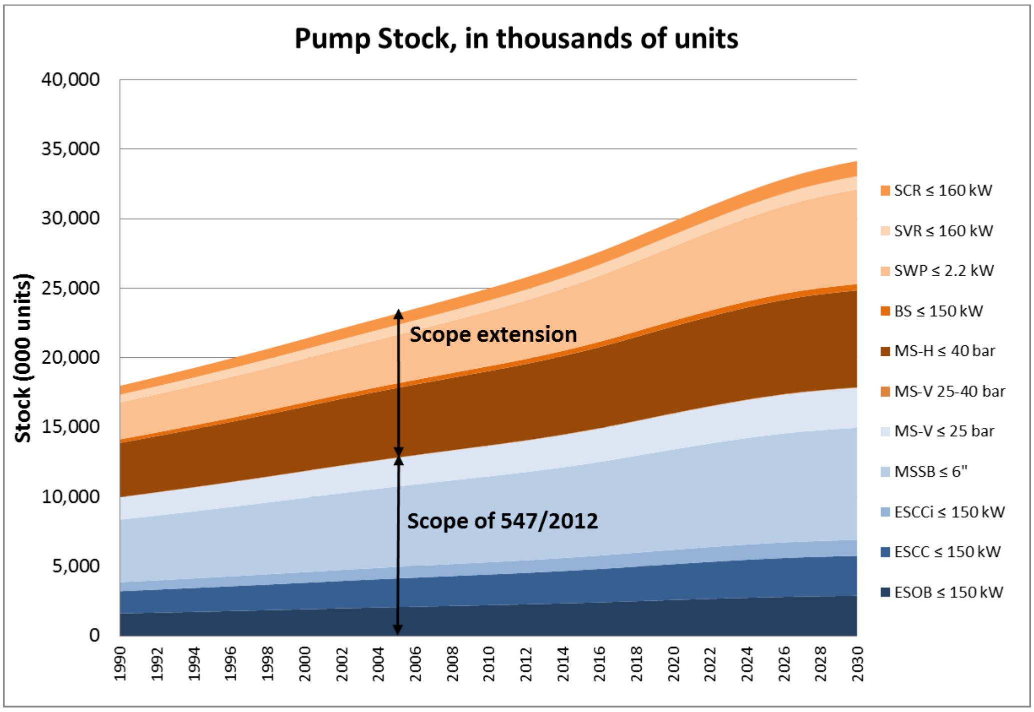
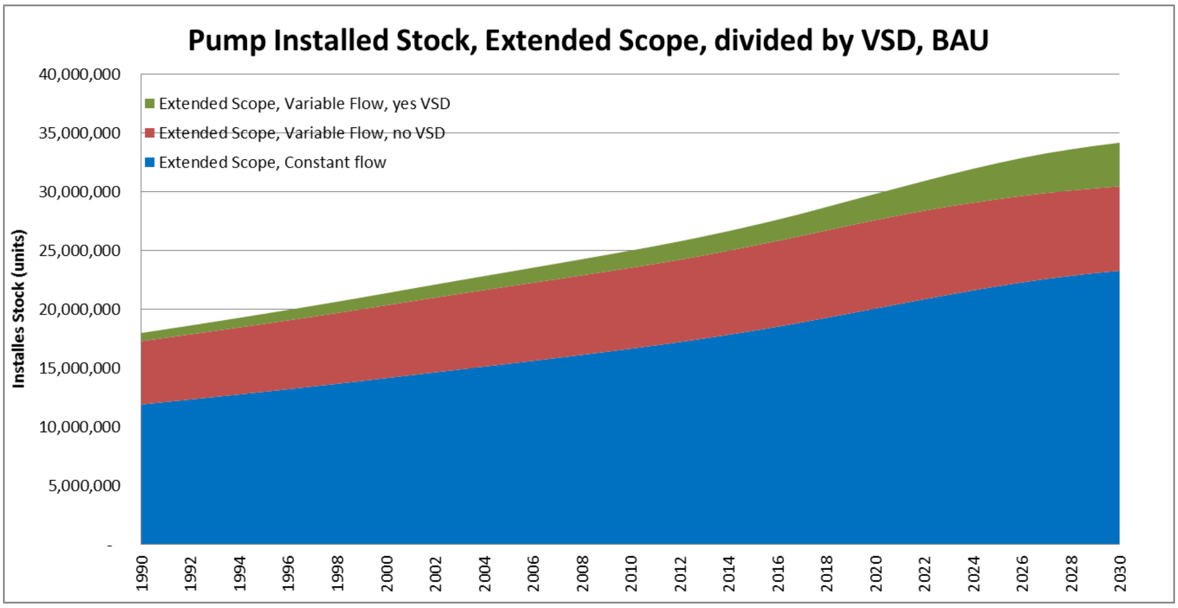


Figure 62. Pump installed stock in thousands of units (source: MAESP).



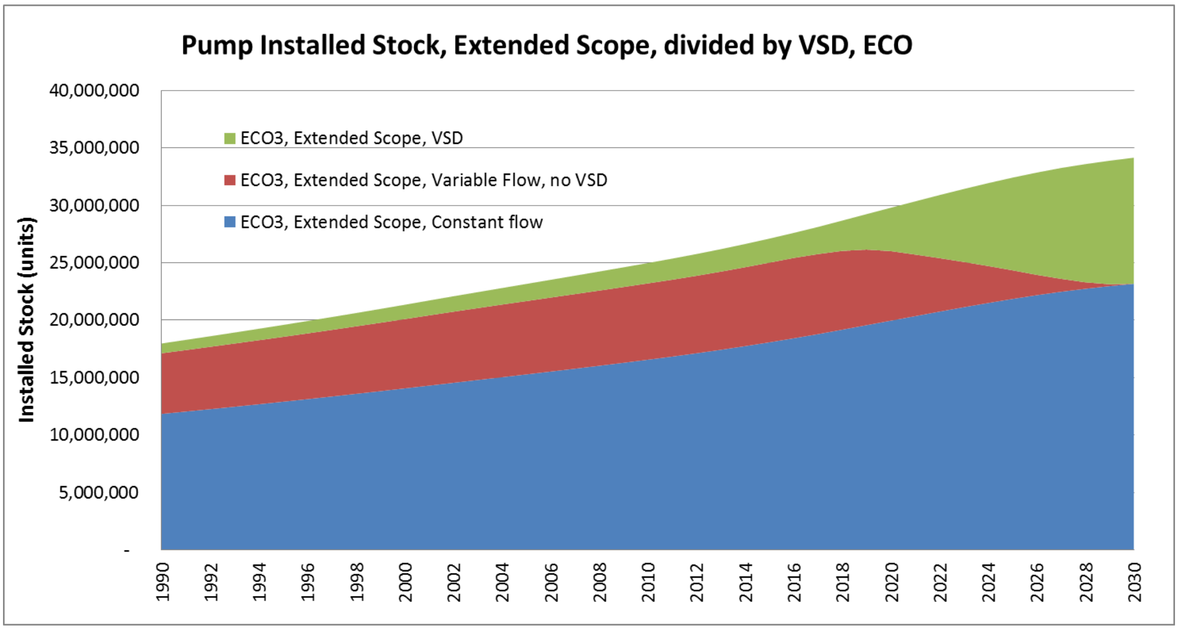


Figure 63. Installed Stock for pumps for constant flow, and for pumps with variable flow split in those without and with VSD (top: for BAU-scenario; bottom: for ECO-scenario).

9.6 Load (demand for pump output)

The 'Load' indicates the annual user demand for pump output. It is calculated per pump unit on the sheet LOAD using:

$$Load\ per\ unit = P3_{avg}[kW] * hours\ [h]$$

In which:
P3avg = the average output power of the pump base case
Hours = average annual operating hours for the pump base case

The load per unit is assumed to stay constant over time.

On the sheet EU_LOAD_BAU the unit loads are multiplied by the installed stock of pumps in EU-28 to obtain the total EU user demand for pump output. As the installed stock varies over time, so does the EU Load.

Note that pumps for variable flow have a different Load for the cases with and without VSD. This is a choice made by the model developers: An alternative would have been to maintain the loads the same and to express the influence of the VSDs on the load factor through the efficiencies. As a consequence of this choice, EU-Loads for variable flow pumps in the ECO-scenario would be lower than those in the BAU-scenario due to the shift from pumps without VSD (higher load) to those with VSD (lower load). This does not mean that the user demand for pump output changes between the scenarios; it only indicates that the installed pumps with VSD better match the real needs of the user.

Table 113 reports for each base case the average pump output powers, the average annual operating hours, the average unit load and the EU-28 total load in 2016.

Table 113. Pump average output power P3 in kW, average annual operating hours in h/a, unit load in kWh/a and EU-28 total load in 2016 in Gwh/a.

Pump Base Case	Pump output power P3 average (kW)	Annual operating hours (h/a)	Unit pump load in kWh/a	EU-28 total pump load in 2016 (GWh/a)
CURRENT SCOPE				
ESOB<22_VF	1.85	5,000	9,230	9,199
ESOB<22_CF	3.38	2,250	7,603	8,224
ESOB<22_VSD-VF	1.25	5,000	6,245	531
ESOB_22-150_VF	9.93	5,000	49,630	3,111
ESOB_22-150_CF	18.51	2,250	41,657	7,009
ESOB_22-150_VSD-VF	6.86	5,000	34,275	323
ESCC<22_VF	1.56	5,000	7,790	7,598
ESCC<22_CF	2.85	2,250	6,408	6,932
ESCC<22_VSD-VF	1.05	5,000	5,260	559
ESCC_22-150_VF	10.14	5,000	50,720	5,497
ESCC_22-150_CF	18.92	2,250	42,570	5,116
ESCC_22-150_VSD-VF	7.01	5,000	35,030	414
ESCCi<22_VF	1.27	5,000	6,345	3,324
ESCCi<22_CF	2.31	2,250	5,207	451
ESCCi<22_VSD-VF	0.86	5,000	4,275	1,090
ESCCi_22-150_VF	8.77	5,000	43,835	284
ESCCi_22-150_CF	16.35	2,250	36,790	3,184
ESCCi_22-150_VSD-VF	6.06	5,000	30,275	95
MSSB<6"_VF	0.53	2,250	1,199	1,535
MSSB<6"_CF	0.82	2,250	1,854	9,983
MSSB<6"_VSD-VF	0.30	2,250	684	45
MS-V<25bar_VF	1.33	5,000	6,635	6,721
MS-V<25bar_CF	2.34	2,250	5,265	6,328
MS-V<25bar_VSD-VF	0.87	5,000	4,325	817
SCOPE EXTENSION				
MS-V_25-40bar_VF	30.30	5,000	151,495	659
MS-V_25-40bar_CF	53.33	2,250	119,995	1,673
MS-V_25-40bar_VSD-VF	19.71	5,000	98,535	945
MS-H<25bar_VF	0.25	5,000	1,230	2,588
MS-H<25bar_CF	0.41	2,250	925	2,645
MS-H<25bar_VSD-VF	0.15	5,000	760	575
MS-H_25-40bar_VF	8.46	5,000	42,305	1,235
MS-H_25-40bar_CF	16.09	2,250	36,207	1,828
MS-H_25-40bar_VSD-VF	5.95	5,000	29,730	633
BS<150_VF	2.03	2,000	4,056	794
BS<150_CF		0	0	0
BS<150_VSD-VF	1.46	2,000	2,920	552
SWP<2.2_VF		1,540	0	0
SWP<2.2_CF	0.409	1,540	630	2,982
SWP<2.2_VSD-VF		1,540	0	0
SVR<10_VF	0.75	1,000	753	0
SVR<10_CF	1.24	1,000	1,237	916
SVR<10_VSD-VF	0.46	1,000	455	18
SVR_10-160_VF	2.98	1,000	2,978	0
SVR_10-160_CF	4.80	1,000	4,799	104
SVR_10-160_VSD-VF	1.76	1,500	2,646	4
SCR<10_VF	1.40	1500	2106	0

SCR<10_CF	4.80	1500	7199	5328
SCR<10_VSD-VF	0.85	1000	853	33
SCR_10-25_VF	5.79	1,000	5,791	0
SCR_10-25_CF	9.52	1,000	9,521	828
SCR_10-25_VSD-VF	3.52	1,500	5,277	35
SCR_25-160_VF	29.81	1,500	44,715	0
SCR_25-160_CF	49.01	1,500	73,514	2,864
SCR_25-160_VSD-VF	18.11	2,000	36,220	353

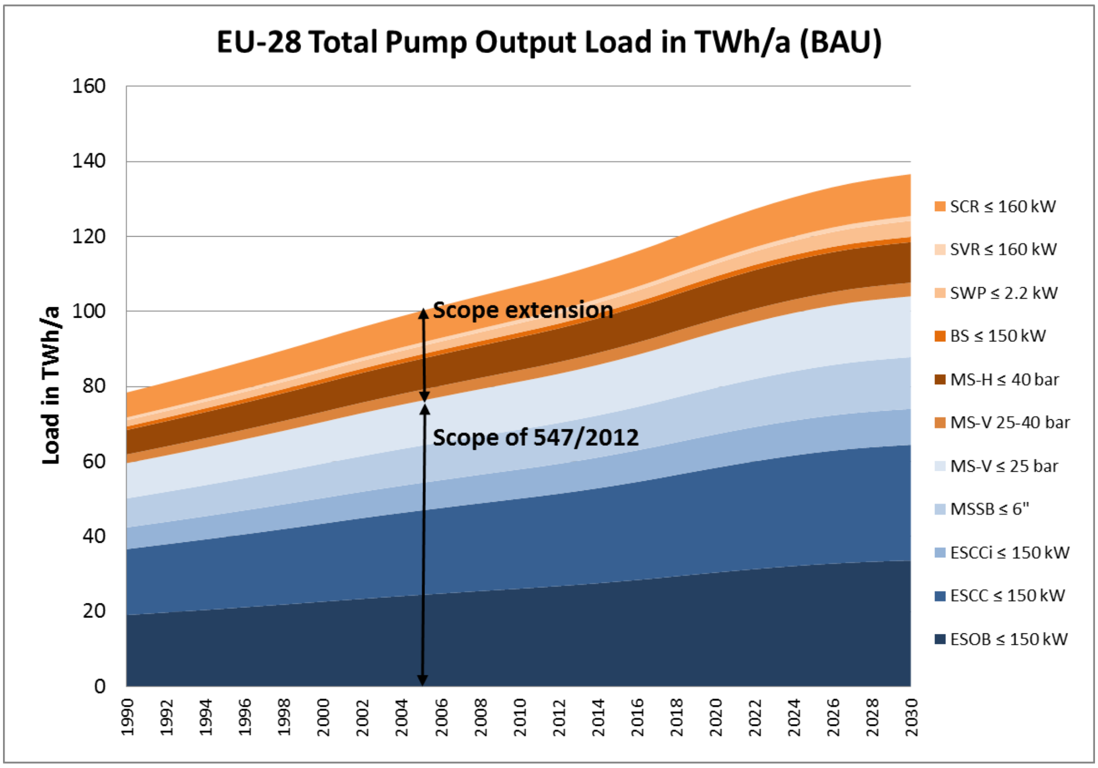


Figure 64. EU-28 total load of pumps in the scope of the study. The pump load represents the annual user demand for pump output and is computes as the product of the average output power (P3, in kWh) times the average annual operating hours (h/a) times the installed stock of pumps.

Table 114. EU-28 Total Pump Load per category, in TWh/a.

	1990	2000	2010	2015	2020	2025	2030
ESOB ≤ 150 kW	19	23	26	28	30	32	34
ESCC ≤ 150 kW	18	21	24	26	28	30	31
ESCCi ≤ 150 kW	6	7	8	9	9	9	9
MSSB ≤ 6"	8	9	10	11	12	13	13
MS-V ≤ 25 bar	9	11	13	14	15	16	16
Total for scope of 547/2012	**60**	**71**	**81**	**87**	**94**	**100**	**104**
MS-V 25-40 bar	2	3	3	3	3	4	4
MS-H ≤ 40 bar	7	8	9	9	10	11	11
BS ≤ 150 kW	1	1	1	1	1	1	1
SWP ≤ 2.2 kW	2	2	2	3	3	4	4
SVR ≤ 160 kW	1	1	1	1	1	1	1
SCR ≤ 160 kW	6	7	7	8	8	9	9
Total for scope extension	**18**	**21**	**24**	**26**	**27**	**29**	**31**
Total for extended scope	**78**	**92**	**105**	**113**	**122**	**130**	**134**

9.7 Energy Efficiencies

The MAEPS has six sheets that regard energy efficiency:

- EFNBAU: Energy efficiency of **N**ew sold products in the BAU-scenario
- EEI_BAU: Energy Efficiency Index of new sold products in the BAU-scenario
- EFSBAU: Energy efficiency of the installed **S**tock in the BAU-scenario
- EFNECO: Energy efficiency of **N**ew sold products in the ECO-scenarios
- EEI_ECO: Energy Efficiency Index of new sold products in the ECO-scenarios
- EFSECO: Energy efficiency of the installed **S**tock in the ECO-scenarios

All values are averages for the base case and regard the extended product of pump + motor + drive (+control where present). Note that the average efficiency will generally be higher than the minimum efficiency proposed for the new regulation.

The energy efficiency values (in %) represent the ratio between the output power (P3) and the electrical input power (P1, to the motor or to the VSD): $\eta = \frac{P3_{avg}}{P1}$. (%)

The EEI-values are computed according to the draft standard as: $EEI = \frac{\frac{P3_{avg}}{\eta}}{Pref} = \frac{P1_{avg}}{P1_{ref}}$.

These EEI values are computed only for the pump types where they are already fully defined (ESOB, ESCC, ESCCi, see also par. In the model the EEI-values are only for reference and information: They are not used in the further computations.

The basic energy efficiency values used for the computations are those on the EFN-sheets (efficiencies for new sold products).

For the period 2011-2016, these efficiencies have been derived from industry input, from the requirements in the current pump regulation 547/2012 (MEI ≥ 0.1 from 2013 MEI ≥ 0.4 from 2015) and from the current motor regulation 640/2009 (efficiency IE2 from 2011; IE3 or IE2 + VSD from 2015, for smaller motors from 2017).

For years before 2011, a general efficiency decrease of 0.1% per year has been applied.

For years following 2016, the efficiencies have been assumed to remain constant, or to slightly increase due to general technological progress, as specified in Table 115.

Note that, except for wastewater pumps, efficiency changes after 2016 have been assumed only for constant flow pumps. For these pumps there is no shift in VSD shares, so that efficiency improvements are the only source of energy savings.

For wastewater pumps, efficiency changes are also assumed for variable flow pumps, but also here there is no shift to VSD as VSd-shares of 100% are already assumed in the BAU-scenario.

New sold products do not instantly replace the entire installed stock of pumps: the replacement of existing (lower efficiency) by new (higher efficiency) pumps is gradual. The average efficiency of the stock therefore lags behind the average efficiency of new sold products in the same year. Consequently an additional average efficiency of the stock is calculated separately on the EFS-sheets, based on the EFN-values of the lifetime preceding years:

$$EFSBAU = \frac{\sum_{i=(year-life)}^{year} EFNBAU_i * SALES_i}{\sum_{i=(year-life)}^{year} SALES_i}$$

These average stock values are the ones used for the energy calculations.

Table 115. Average Efficiencies (EFF in %) and Energy Efficiency Index (EEI) for the BAU- and ECO-scenarios, for each base case, flow condition and VSD use.

pump category and size	P1ref kW	P3 kW	param.	scenario	1990	2000	2010	2014	2016	2018	2020	2022	2024	2030
ESOB ≤ 22 kW CF	5.4	3.4	EFF	BAU	59.7%	60.3%	60.9%	*62.6%*	62.6%	62.6%	62.6%	62.6%	62.6%	62.6%
				ECO1						63.3%	65.3%	65.3%	65.3%	65.3%
				ECO2						63.3%	65.3%	66.7%	67.5%	67.5%
				ECO3						63.7%	67.5%	67.5%	67.5%	67.5%
			EEI	BAU	1.039	1.029	1.019	*0.991*	0.991	0.991	0.991	0.991	0.991	0.991
				ECO1						0.981	0.950	0.950	0.950	0.950
				ECO2						0.981	0.950	0.930	0.920	0.920
				ECO3						0.973	0.920	0.920	0.920	0.920
ESOB ≤ 22 kW VF no VSD	5.4	1.8	EFF	all	45.4%	45.9%	46.3%	*47.6%*	47.6%	47.6%	47.6%	47.6%	47.6%	47.6%
			EEI	all	0.747	0.739	0.732	*0.712*	0.712	0.712	0.712	0.712	0.712	0.712
ESOB ≤ 22 kW VF yes VSD	5.4	1.2	EFF	all	51.7%	52.2%	52.7%	*52.8%*	53.7%	54.2%	54.2%	54.2%	54.2%	54.2%
			EEI	all	0.444	0.439	0.435	*0.434*	0.427	0.423	0.423	0.423	0.423	0.423
ESOB 22-150 kW CF	27.5	18.5	EFF	BAU	65.2%	65.9%	66.5%	*67.6%*	67.6%	67.6%	67.6%	67.6%	67.6%	67.6%
				ECO1						68.4%	70.8%	70.8%	70.8%	70.8%
				ECO2						68.4%	70.8%	72.3%	73.1%	73.1%
				ECO3						68.9%	73.1%	73.1%	73.1%	73.1%
			EEI	BAU	1.032	1.022	1.012	*0.995*	0.995	0.995	0.995	0.995	0.995	0.995
				ECO1						0.984	0.950	0.950	0.950	0.950
				ECO2						0.984	0.950	0.930	0.920	0.920
				ECO3						0.976	0.920	0.920	0.920	0.920
ESOB 22-150 kW VF no VSD	27.5	9.9	EFF	all	50.9%	51.4%	52.0%	*52.8%*	52.8%	52.8%	52.8%	52.8%	52.8%	52.8%
			EEI	all	0.708	0.701	0.694	*0.683*	0.683	0.683	0.683	0.683	0.683	0.683
ESOB 22-150 kW VF yes VSD	27.5	6.9	EFF	all	56.0%	56.6%	57.1%	*57.2%*	57.8%	58.1%	58.1%	58.1%	58.1%	58.1%
			EEI	all	0.445	0.440	0.436	*0.436*	0.431	0.429	0.429	0.429	0.429	0.429

pump category and size	P1ref kW	P3 kW	param.	scenario	1990	2000	2010	2014	2016	2018	2020	2022	2024	2030
ESCC ≤ 22 kW CF	4.6	2.8	EFF	BAU	59.0%	59.6%	60.2%	*61.9%*	61.9%	61.9%	61.9%	61.9%	61.9%	61.9%
				ECO1						62.6%	64.8%	64.8%	64.8%	64.8%
				ECO2						62.6%	64.8%	66.2%	66.9%	66.9%
				ECO3						63.1%	66.9%	66.9%	66.9%	66.9%
			EEI	BAU	1.043	1.033	1.023	*0.995*	0.995	0.995	0.995	0.995	0.995	0.995
				ECO1						0.984	0.950	0.950	0.950	0.950
				ECO2						0.984	0.950	0.930	0.920	0.920
				ECO3						0.976	0.920	0.920	0.920	0.920
ESCC ≤ 22 kW VF no VSD	4.6	1.6	EFF	all	44.8%	45.3%	45.7%	*47.0%*	47.0%	47.0%	47.0%	47.0%	47.0%	47.0%
			EEI	all	0.752	0.744	0.737	*0.717*	0.717	0.717	0.717	0.717	0.717	0.717
ESCC ≤ 22 kW VF yes VSD	4.6	1.1	EFF	all	51.2%	51.7%	52.2%	*52.3%*	53.2%	53.7%	53.7%	53.7%	53.7%	53.7%
			EEI	all	0.444	0.440	0.435	*0.435*	0.427	0.424	0.424	0.424	0.424	0.424
ESCC 22-150 kW CF	28.1	18.9	EFF	BAU	65.3%	65.9%	66.6%	*67.7%*	67.7%	67.7%	67.7%	67.7%	67.7%	67.7%
				ECO1						68.5%	70.8%	70.8%	70.8%	70.8%
				ECO2						68.5%	70.8%	72.3%	73.1%	73.1%
				ECO3						69.0%	73.1%	73.1%	73.1%	73.1%
			EEI	BAU	1.030	1.020	1.010	*0.994*	0.994	0.994	0.994	0.994	0.994	0.994
				ECO1						0.983	0.950	0.950	0.950	0.950
				ECO2						0.983	0.950	0.930	0.920	0.920
				ECO3						0.975	0.920	0.920	0.920	0.920
ESCC 22-150 kW VF no VSD	28.1	10.1	EFF	all	50.9%	51.4%	52.0%	*52.8%*	52.8%	52.8%	52.8%	52.8%	52.8%	52.8%
			EEI	all	0.708	0.701	0.694	*0.683*	0.683	0.683	0.683	0.683	0.683	0.683
ESCC 22-150 kW VF yes VSD	28.1	7.0	EFF	all	56.0%	56.6%	57.1%	*57.2%*	57.8%	58.1%	58.1%	58.1%	58.1%	58.1%
			EEI	all	0.445	0.440	0.436	*0.436*	0.431	0.429	0.429	0.429	0.429	0.429

pump category and size	P1ref kW	P3 kW	param.	scenario	1990	2000	2010	2014	2016	2018	2020	2022	2024	2030
ESCCi ≤ 22 kW CF	3.9	2.3	EFF	BAU	57.9%	58.5%	59.1%	*60.9%*	60.9%	60.9%	60.9%	60.9%	60.9%	60.9%

				ECO1						61.1%	61.9%	61.9%	61.9%	61.9%
				ECO2						61.1%	61.9%	63.2%	63.9%	63.9%
				ECO3						61.6%	63.9%	63.9%	63.9%	63.9%
			EEI	BAU	1.015	1.005	0.995	0.965	0.965	0.965	0.965	0.965	0.965	0.965
				ECO1						0.961	0.950	0.950	0.950	0.950
				ECO2						0.961	0.950	0.930	0.920	0.920
				ECO3						0.954	0.920	0.920	0.920	0.920
ESCCi ≤ 22 kW VF no VSD	3.9	1.3	EFF	all	43.9%	44.4%	44.8%	46.2%	46.2%	46.2%	46.2%	46.2%	46.2%	46.2%
			EEI	all	0.734	0.726	0.719	0.698	0.698	0.698	0.698	0.698	0.698	0.698
ESCCi ≤ 22 kW VF yes VSD	3.9	0.9	EFF	all	50.4%	50.9%	51.4%	51.5%	52.5%	53.0%	53.0%	53.0%	53.0%	53.0%
			EEI	all	0.431	0.426	0.422	0.422	0.414	0.410	0.410	0.410	0.410	0.410
ESCCi 22-150 kW CF	25.4	16.4	EFF	BAU	65.2%	65.9%	66.5%	67.6%	67.6%	67.6%	67.6%	67.6%	67.6%	67.6%
				ECO1						67.7%	67.8%	67.8%	67.8%	67.8%
				ECO2						67.7%	67.8%	69.3%	70.1%	70.1%
				ECO3						68.2%	70.1%	70.1%	70.1%	70.1%
			EEI	BAU	0.989	0.979	0.969	0.953	0.953	0.953	0.953	0.953	0.953	0.953
				ECO1						0.953	0.950	0.950	0.950	0.950
				ECO2						0.953	0.950	0.930	0.920	0.920
				ECO3						0.945	0.920	0.920	0.920	0.920
ESCCi 22-150 kW VF no VSD	25.4	8.8	EFF	all	50.5%	51.0%	51.6%	52.4%	52.4%	52.4%	52.4%	52.4%	52.4%	52.4%
			EEI	all	0.684	0.677	0.670	0.659	0.659	0.659	0.659	0.659	0.659	0.659
ESCCi 22-150 kW VF yes VSD	25.4	6.1	EFF	all	56.0%	56.6%	57.1%	57.2%	57.8%	58.1%	58.1%	58.1%	58.1%	58.1%
			EEI	all	0.426	0.422	0.418	0.417	0.413	0.411	0.411	0.411	0.411	0.411

pump category and size	P1ref kW	P3 kW	param.	scenario	1990	2000	2010	2014	2016	2018	2020	2022	2024	2030
MSSB ≤ 6" CF	1.4	0.8	EFF	BAU	45.8%	46.2%	46.7%	48.4%	48.4%	48.5%	48.6%	48.8%	48.9%	48.9%
				ECO1							51.5%	52.4%	52.4%	52.4%
				ECO2							52.2%	53.4%	55.4%	55.4%
				ECO3							53.7%	55.4%	55.4%	55.4%
MSSB ≤ 6" VF no VSD	1.4	0.5	EFF	all	34.0%	34.4%	34.7%	36.0%	36.0%	36.0%	36.0%	36.0%	36.0%	36.0%
MSSB ≤ 6" VF yes VSD	1.4	0.3	EFF	all	35.5%	35.9%	36.3%	36.3%	37.2%	37.6%	37.6%	37.6%	37.6%	37.6%

pump category and size	P1ref kW	P3 kW	param.	scenario	1990	2000	2010	2014	2016	2018	2020	2022	2024	2030
MS-V ≤ 25 bar CF	4.4	2.3	EFF	BAU	60.2%	60.8%	61.4%	63.3%	63.3%	63.4%	63.5%	63.8%	63.9%	63.9%
				ECO1							64.5%	64.8%	64.8%	64.8%
				ECO2							64.9%	65.3%	66.3%	66.3%
				ECO3							65.6%	66.3%	66.3%	66.3%
			EEI	BAU	0.884	0.875	0.866	0.840	0.840	0.839	0.837	0.834	0.832	0.832
				ECO1							0.825	0.821	0.821	0.821
				ECO2							0.820	0.815	0.802	0.802
				ECO3							0.811	0.802	0.802	0.802
MS-V ≤ 25 bar VF no VSD	4.4	1.3	EFF	all	43.4%	43.8%	44.2%	45.6%	45.6%	45.6%	45.6%	45.6%	45.6%	45.6%
			EEI	all	0.696	0.689	0.682	0.662	0.662	0.662	0.662	0.662	0.662	0.662
MS-V ≤ 25 bar VF yes VSD	4.4	0.9	EFF	all	43.8%	44.3%	44.7%	46.1%	46.1%	46.1%	46.1%	46.1%	46.1%	46.1%
			EEI	all	0.448	0.444	0.440	0.427	0.427	0.427	0.427	0.427	0.427	0.427
MS-V 25-40 bar CF	90.4	53.3	EFF	BAU	71.8%	72.5%	73.3%	74.2%	74.2%	74.3%	74.4%	74.7%	74.9%	74.9%
				ECO1							75.4%	75.7%	75.7%	75.7%
				ECO2							75.8%	76.2%	77.2%	77.2%
				ECO3							76.5%	77.2%	77.2%	77.2%
			EEI	BAU	0.822	0.814	0.806	0.795	0.795	0.794	0.793	0.790	0.788	0.788
				ECO1							0.783	0.780	0.780	0.780
				ECO2							0.779	0.774	0.764	0.764
				ECO3							0.771	0.764	0.764	0.764
MS-V 25-40 bar VF no VSD	90.4	30.3	EFF	all	55.2%	55.7%	56.3%	57.0%	57.0%	57.0%	57.0%	57.0%	57.0%	57.0%
			EEI	all	0.608	0.602	0.596	0.588	0.588	0.588	0.588	0.588	0.588	0.588
MS-V 25-40 bar VF yes VSD	90.4	19.7	EFF	all	55.7%	56.3%	56.9%	57.6%	57.6%	57.6%	57.6%	57.6%	57.6%	57.6%
			EEI	all	0.391	0.387	0.383	0.379	0.379	0.379	0.379	0.379	0.379	0.379

pump category and size	P1ref kW	P3 kW	param.	scenario	1990	2000	2010	2014	2016	2018	2020	2022	2024	2030

MS-H ≤ 25 bar CF	0.8	0.4	EFF	BAU	39.5%	39.9%	40.3%	*41.9%*	41.9%	42.0%	42.1%	42.2%	42.3%	42.3%
				ECO1							44.9%	45.9%	45.9%	45.9%
				ECO2							45.7%	46.9%	48.9%	48.9%
				ECO3							47.2%	48.9%	48.9%	48.9%
			EEI	BAU	1.346	1.333	1.320	*1.269*	1.269	1.267	1.264	1.260	1.257	1.257
				ECO1							1.183	1.158	1.158	1.158
				ECO2							1.164	1.134	1.087	1.087
				ECO3							1.127	1.087	1.087	1.087
MS-H ≤ 25 bar VF no VSD	0.8	0.2	EFF	all	28.7%	29.0%	29.3%	*30.5%*	30.5%	30.5%	30.5%	30.5%	30.5%	30.5%
			EEI	all	1.107	1.096	1.085	*1.043*	1.043	1.043	1.043	1.043	1.043	1.043
MS-H ≤ 25 bar VF yes VSD	0.8	0.2	EFF	all	31.6%	31.9%	32.2%	*33.5%*	33.5%	33.5%	33.5%	33.5%	33.5%	33.5%
			EEI	all	0.623	0.617	0.610	*0.587*	0.587	0.587	0.587	0.587	0.587	0.587
MS-H 25-40 bar CF	27.3	16.1	EFF	BAU	52.2%	52.7%	53.3%	*54.5%*	54.5%	54.6%	54.7%	54.9%	55.0%	55.0%
				ECO1							55.7%	56.0%	56.0%	56.0%
				ECO2							56.1%	56.5%	57.5%	57.5%
				ECO3							56.8%	57.5%	57.5%	57.5%
			EEI	BAU	1.130	1.119	1.108	*1.083*	1.083	1.080	1.078	1.075	1.073	1.073
				ECO1							1.060	1.054	1.054	1.054
				ECO2							1.053	1.044	1.026	1.026
				ECO3							1.039	1.026	1.026	1.026
MS-H 25-40 bar VF no VSD	27.3	8.5	EFF	all	37.5%	37.8%	38.2%	*39.1%*	39.1%	39.1%	39.1%	39.1%	39.1%	39.1%
			EEI	all	0.828	0.820	0.812	*0.794*	0.794	0.794	0.794	0.794	0.794	0.794
MS-H 25-40 bar VF yes VSD	27.3	5.9	EFF	all	41.6%	42.0%	42.4%	*43.4%*	43.4%	43.4%	43.4%	43.4%	43.4%	43.4%
			EEI	all	0.524	0.519	0.514	*0.502*	0.502	0.502	0.502	0.502	0.502	0.502

pump category and size	P1ref kW	P3 kW	param.	scenario	1990	2000	2010	*2014*	2016	2018	2020	2022	2024	2030
BS ≤ 150 kW VF		2.0	EFF	all	39.6%	40.0%	40.4%	*41.6%*	41.6%	41.6%	41.6%	41.6%	41.6%	41.6%
BS ≤ 150 kW VF single VSD		1.5	EFF	all	39.7%	40.1%	40.5%	*40.6%*	41.3%	41.6%	41.6%	41.6%	41.6%	41.6%
BS ≤ 150 kW VF multi VSD		1.4	EFF	all	39.7%	40.1%	40.5%	*40.6%*	41.3%	41.6%	41.6%	41.6%	41.6%	41.6%

pump category and size	P1ref kW	P3 kW	param.	scenario	1990	2000	2010	*2014*	2016	2018	2020	2022	2024	2030
SWP ≤ 2.2 kW CF	0.9	0.4	EFF	BAU	38.5%	38.9%	39.3%	*40.3%*	41.0%	41.1%	41.2%	41.3%	41.4%	41.4%
				ECO1							43.3%	44.0%	44.0%	44.0%
				ECO2							43.3%	45.3%	48.0%	48.0%
				ECO3							46.1%	48.0%	48.0%	48.0%
			EEI	BAU	1.225	1.213	1.201	*1.170*	1.151	1.148	1.146	1.142	1.139	1.139
				ECO1							1.091	1.072	1.072	1.072
				ECO2							1.091	1.042	0.982	0.982
				ECO3							1.023	0.982	0.982	0.982

pump category and size	P1ref kW	P3 kW	param.	scenario	1990	2000	2010	*2014*	2016	2018	2020	2022	2024	2030
SVR ≤ 10 kW CF		1.2	EFF	BAU	24.6%	24.9%	25.1%	*25.5%*	25.8%	25.8%	25.9%	26.0%	26.0%	26.0%
				ECO1							26.9%	27.3%	27.3%	27.3%
				ECO2							27.3%	27.8%	28.8%	28.8%
				ECO3							28.1%	28.8%	28.8%	28.8%
SVR ≤ 10 kW VF no VSD		0.8	EFF	BAU	19.1%	19.3%	19.5%	*19.8%*	20.0%	20.0%	20.1%	20.2%	20.2%	20.2%
				ECO1							21.1%	21.5%	21.5%	21.5%
				ECO2							21.5%	22.0%	23.0%	23.0%
				ECO3							22.3%	23.0%	23.0%	23.0%
SVR ≤ 10 kW VF yes VSD		0.5	EFF	BAU	19.1%	19.3%	19.5%	*19.8%*	20.0%	20.0%	20.1%	20.2%	20.2%	20.2%
				ECO1							21.1%	21.5%	21.5%	21.5%
				ECO2							21.5%	22.0%	23.0%	23.0%
				ECO3							22.3%	23.0%	23.0%	23.0%
SVR 10-160 kW CF		4.8	EFF	BAU	27.1%	27.4%	27.7%	*28.2%*	28.2%	28.3%	28.4%	28.5%	28.5%	28.5%
				ECO1							29.4%	29.7%	29.7%	29.7%
				ECO2							29.7%	30.2%	31.2%	31.2%
				ECO3							30.5%	31.2%	31.2%	31.2%
SVR 10-160 kW VF no VSD		3.0	EFF	BAU	22.1%	22.4%	22.6%	*22.8%*	23.0%	23.0%	23.1%	23.2%	23.2%	23.2%
				ECO1							24.1%	24.5%	24.5%	24.5%

				ECO2							24.5%	25.0%	26.0%	26.0%
				ECO3							25.3%	26.0%	26.0%	26.0%
SVR 10-160 kW VF yes VSD		1.8	EFF	BAU	22.1%	22.4%	22.6%	*22.8%*	23.0%	23.0%	23.1%	23.2%	23.2%	23.2%
				ECO1							24.1%	24.5%	24.5%	24.5%
				ECO2							24.5%	25.0%	26.0%	26.0%
				ECO3							25.3%	26.0%	26.0%	26.0%

pump category and size	P1ref kW	P3 kW	param.	scenario	1990	2000	2010	*2014*	2016	2018	2020	2022	2024	2030
SCR ≤ 10 kW CF	0.0	2.3	EFF	BAU	45.9%	46.3%	46.8%	*48.1%*	48.1%	48.2%	48.3%	48.5%	48.6%	48.6%
				ECO1							49.3%	49.6%	49.6%	49.6%
				ECO2							49.6%	50.1%	51.1%	51.1%
				ECO3							50.4%	51.1%	51.1%	51.1%
SCR ≤ 10 kW VF no VSD	0.0	1.4	EFF	BAU	34.2%	34.6%	34.9%	*35.6%*	35.9%	36.0%	36.1%	36.2%	36.3%	36.3%
				ECO1							37.1%	37.4%	37.4%	37.4%
				ECO2							37.4%	37.9%	38.9%	38.9%
				ECO3							38.2%	38.9%	38.9%	38.9%
SCR ≤ 10 kW VF yes VSD	0.0	0.9	EFF	BAU	34.2%	34.6%	34.9%	*35.9%*	35.9%	36.0%	36.1%	36.2%	36.3%	36.3%
				ECO1							37.1%	37.4%	37.4%	37.4%
				ECO2							37.4%	37.9%	38.9%	38.9%
				ECO3							38.2%	38.9%	38.9%	38.9%
SCR 10-25 kW CF	0.0	9.5	EFF	BAU	53.9%	54.4%	55.0%	*56.0%*	56.0%	56.1%	56.2%	56.5%	56.6%	56.6%
				ECO1							57.2%	57.5%	57.5%	57.5%
				ECO2							57.6%	58.0%	59.0%	59.0%
				ECO3							58.3%	59.0%	59.0%	59.0%
SCR 10-25 kW VF no VSD	0.0	5.8	EFF	BAU	44.0%	44.4%	44.9%	*45.2%*	45.7%	45.8%	45.9%	46.0%	46.1%	46.1%
				ECO1							46.9%	47.2%	47.2%	47.2%
				ECO2							47.2%	47.7%	48.7%	48.7%
				ECO3							48.0%	48.7%	48.7%	48.7%
SCR 10-25 kW VF yes VSD	0.0	3.5	EFF	BAU	44.0%	44.4%	44.9%	*45.7%*	45.7%	45.8%	45.9%	46.0%	46.1%	46.1%
				ECO1							46.9%	47.2%	47.2%	47.2%
				ECO2							47.2%	47.7%	48.7%	48.7%
				ECO3							48.0%	48.7%	48.7%	48.7%
SCR 25-160 kW CF	0.0	49.0	EFF	BAU	58.8%	59.4%	60.0%	*60.6%*	60.6%	60.7%	60.8%	61.1%	61.2%	61.2%
				ECO1							61.8%	62.1%	62.1%	62.1%
				ECO2							62.2%	62.6%	63.6%	63.6%
				ECO3							62.9%	63.6%	63.6%	63.6%
SCR 25-160 kW VF no VSD	0.0	29.8	EFF	BAU	47.9%	48.4%	48.9%	*48.9%*	49.4%	49.5%	49.6%	49.7%	49.8%	49.8%
				ECO1							50.6%	50.9%	50.9%	50.9%
				ECO2							50.9%	51.4%	52.4%	52.4%
				ECO3							51.7%	52.4%	52.4%	52.4%
SCR 25-160 kW VF yes VSD	0.0	18.1	EFF	BAU	47.9%	48.4%	48.9%	*49.4%*	49.4%	49.5%	49.6%	49.7%	49.8%	49.8%
				ECO1							50.6%	50.9%	50.9%	50.9%
				ECO2							50.9%	51.4%	52.4%	52.4%
				ECO3							51.7%	52.4%	52.4%	52.4%

9.8 Primary Energy, Electricity and Savings

The sheets ELECBAU and ELECECO calculate the EU-28 total electricity consumption per base case as:

$ELEC = 10^{-9} * LOAD\ (per\ unit, in\ kWh/a) * STOCK/EFS$ in TWh/a

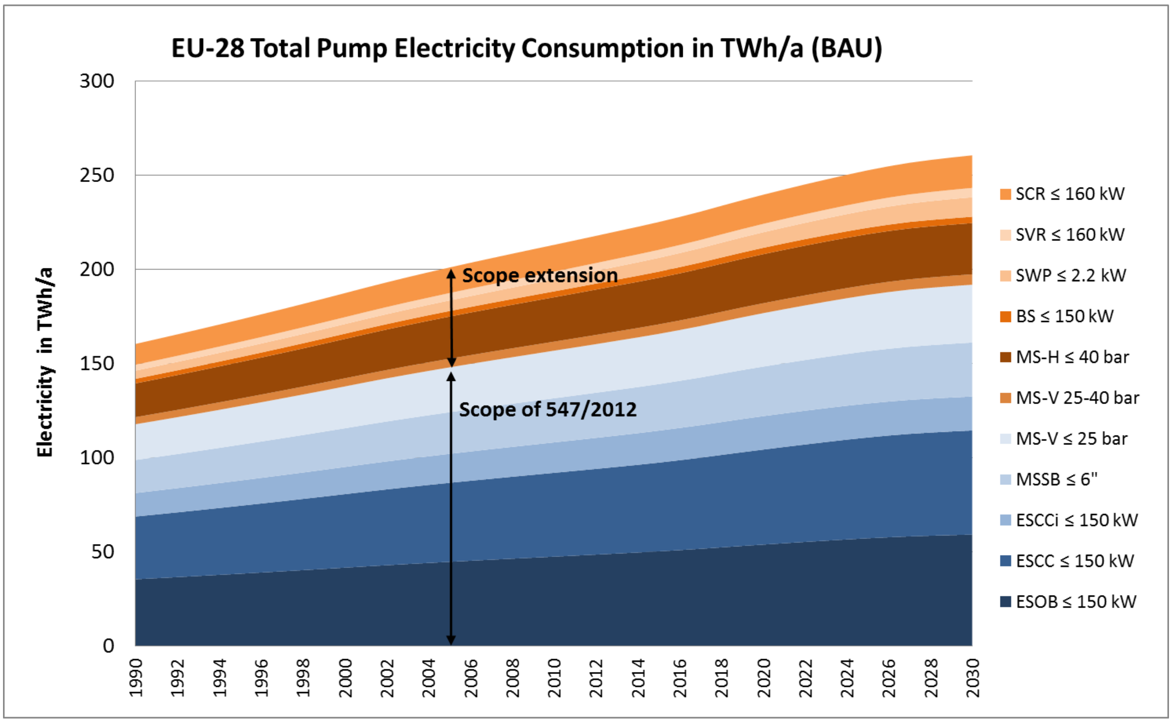
where EFS is the average efficiency of the stock, either EFSBAU or EFSECO.

The sheets NRGBAU and NRGECO calculate the EU-28 total primary energy consumption per base case:
$NRG = ELEC/CC$ in TWh/a

where CC=40% is the agreed average EU-28 efficiency of the generation and distribution of electricity from primary energy sources.

The sheet ELECSAVE provides the difference in electricity consumption between the BAU-scenario and the ECO-scenario, i.e. the electricity savings due to the proposed Ecodesign measures. The savings are available per base case, per pump type, for the scope of regulation 547/2012 and for the scope extension.

The electricity consumption results for the BAU-scenario and the ECO3-scenario are shown in Figure 65 and Figure 66. For the BAU-scenario, results are also shown in Table 116 and Table 117.



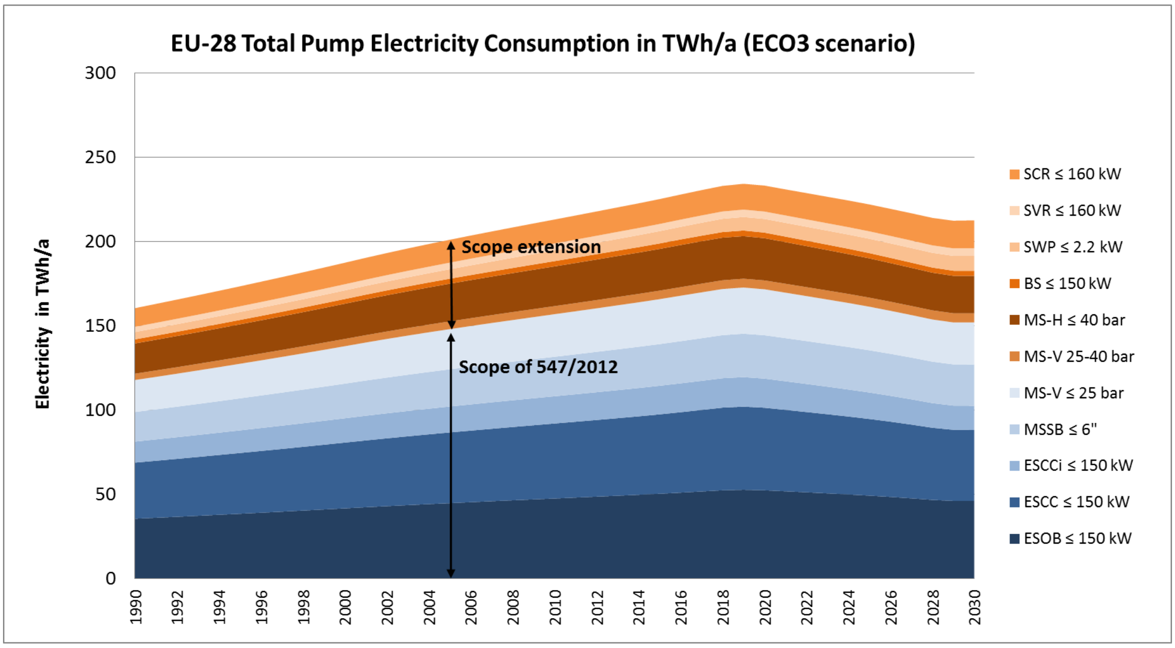
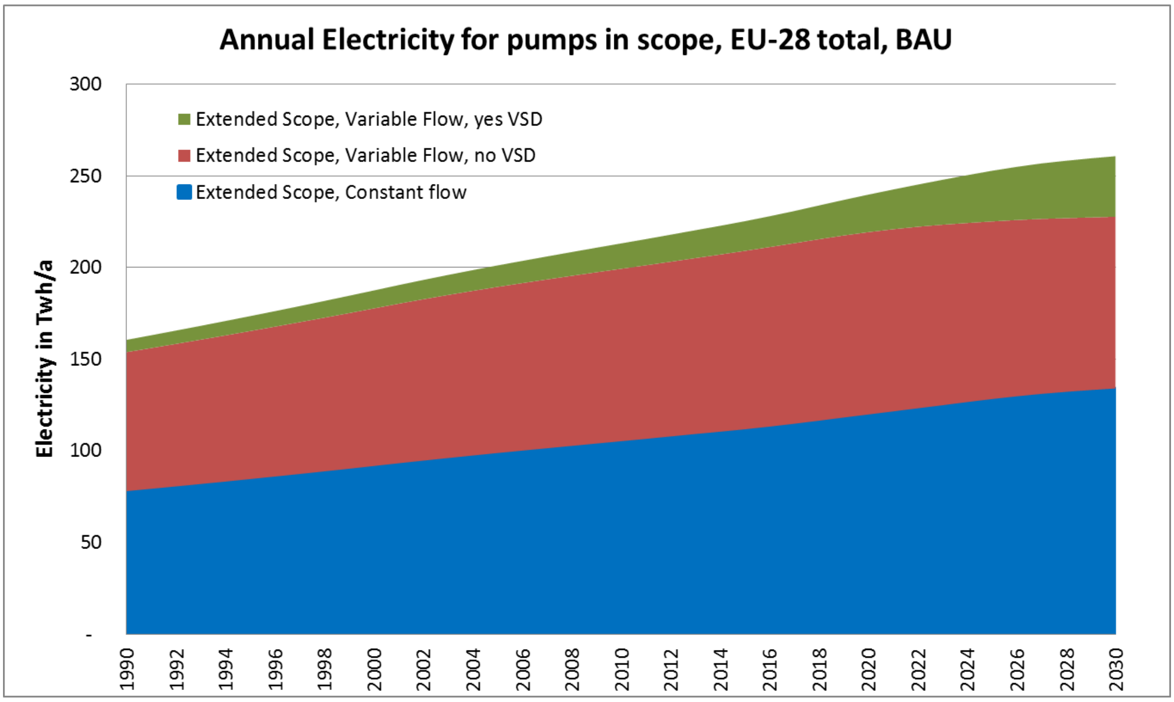


Figure 65. Total EU-28 annual electricity consumption in TWh/a for pumps in the scope of the study, for the BAU-scenario and for the ECO3-scenario.



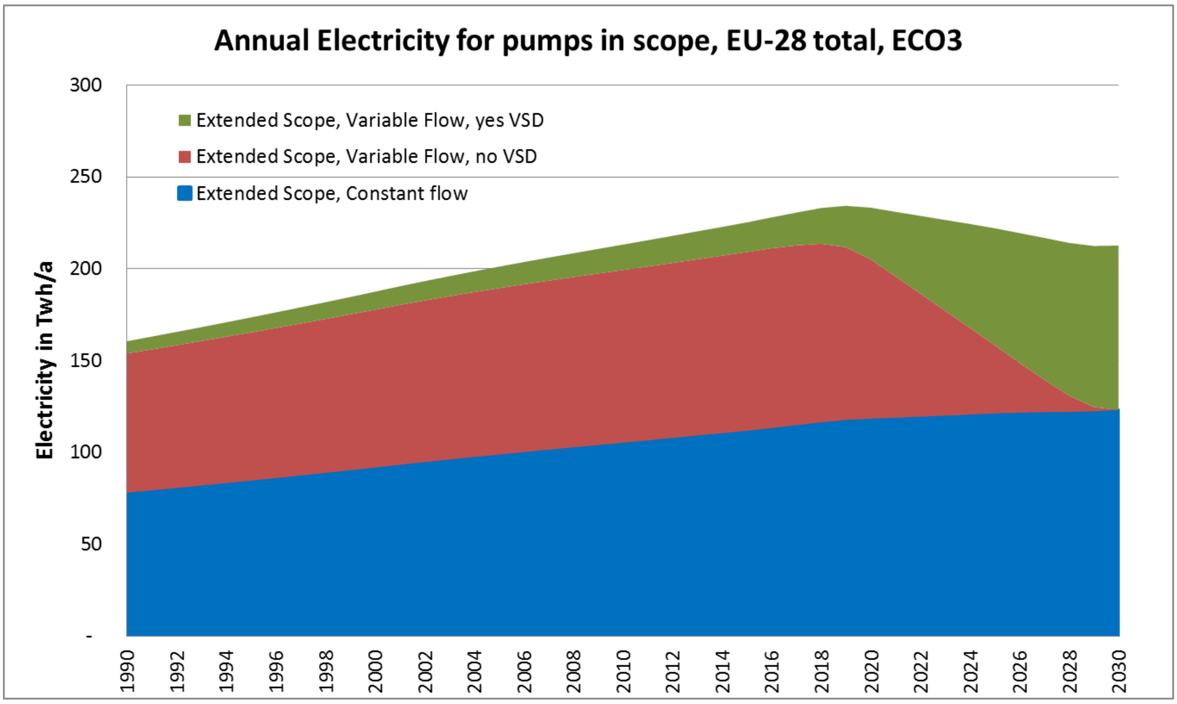


Figure 66. Total EU-28 annual electricity consumption in TWh/a for pumps in the scope of the study, subdivision in constant and variable flow, for the BAU-scenario and for the ECO3-scenario.

Table 116. Total EU-28 annual electricity consumption by pumps in the scope of the study, per pump type, in the BAU-scenario.

EU-28 Pump Electricity TWh/a	1990	2000	2010	2015	2020	2025	2030
ESOB ≤ 150 kW	36	42	48	50	54	57	59
ESCC ≤ 150 kW	33	39	45	47	50	54	55
ESCCi ≤ 150 kW	12	14	16	17	18	18	18
MSSB ≤ 6"	18	21	23	25	26	28	29
MS-V ≤ 25 bar	19	22	25	27	28	30	31
Total for scope of 547/2012	**118**	**138**	**157**	**166**	**177**	**187**	**192**

MS-V 25-40 bar	4	4	5	5	5	5	6
MS-H ≤ 40 bar	18	21	24	25	26	27	27
BS ≤ 150 kW	2	3	3	3	3	3	3
SWP ≤ 2.2 kW	4	5	6	7	8	9	10
SVR ≤ 160 kW	3	4	4	4	4	5	5
SCR ≤ 160 kW	11	13	14	15	15	16	17
Total for scope extension	**43**	**50**	**56**	**59**	**63**	**66**	**69**
Total for extended scope	**161**	**187**	**213**	**225**	**240**	**253**	**261**

Table 117. Total EU-28 annual electricity consumption by pumps in the scope of the study, per base case, flow type and VSD use, in the BAU-scenario.

	1990	2000	2010	2015	2020	2025	2030
CURRENT SCOPE							
ESOB<22_CF	9.2	10.9	12.4	13.2	14.1	15.1	15.7
ESOB<22_VF	14.1	16.4	18.5	19.4	20.5	21.3	21.6
ESOB<22_VSD-VF	0.4	0.6	0.8	1.0	1.2	1.7	2.1
ESOB_22-150_CF	7.2	8.5	9.7	10.3	11.1	11.9	12.4
ESOB_22-150_VF	4.3	5.0	5.6	5.9	6.2	6.3	6.2
ESOB_22-150_VSD-VF	0.2	0.3	0.5	0.5	0.7	1.0	1.2
ESCC<22_CF	7.9	9.3	10.6	11.2	12.1	12.9	13.4
ESCC<22_VF	11.9	13.8	15.5	16.3	17.1	17.6	17.7
ESCC<22_VSD-VF	0.4	0.6	0.9	1.0	1.3	1.8	2.2
ESCC_22-150_CF	5.3	6.2	7.1	7.5	8.1	8.7	9.0
ESCC_22-150_VF	7.6	8.8	9.9	10.4	11.0	11.3	11.4
ESCC_22-150_VSD-VF	0.3	0.4	0.6	0.7	0.9	1.2	1.5
ESCCi<22_CF	0.5	0.6	0.7	0.7	0.8	0.9	0.9
ESCCi<22_VF	6.1	6.8	7.2	7.3	7.1	6.2	5.4
ESCCi<22_VSD-VF	0.9	1.2	1.7	2.0	2.6	3.6	4.3
ESCCi_22-150_CF	0.4	0.4	0.5	0.5	0.6	0.6	0.6
ESCCi_22-150_VF	4.0	4.5	4.8	4.9	4.8	4.2	3.7
ESCCi_22-150_VSD-VF	0.6	0.9	1.2	1.4	1.9	2.6	3.1
MSSB<6"_CF	14.6	17.2	19.7	20.8	22.2	23.6	24.4
MSSB<6"_VF	2.6	2.9	3.1	3.1	3.1	3.0	2.9
MSSB<6"_VSD-VF	0.3	0.5	0.6	0.8	0.9	1.2	1.4
MS-V<25bar_CF	7.1	8.3	9.5	10.1	10.8	11.5	11.9
MS-V<25bar_VF	11.2	12.9	14.3	14.9	15.4	15.4	15.1
MS-V<25bar_VSD-VF	0.7	1.1	1.5	1.7	2.2	3.1	3.7
SCOPE EXTENSION							
MS-V_25-40bar_CF	1.6	1.8	2.1	2.2	2.4	2.6	2.7
MS-V_25-40bar_VF	1.5	1.5	1.4	1.2	0.8	0.3	-
MS-V_25-40bar_VSD-VF	0.7	1.0	1.3	1.6	2.0	2.6	2.9
MS-H<25bar_CF	4.5	5.3	6.0	6.4	6.8	7.2	7.5
MS-H<25bar_VF	6.9	7.8	8.5	8.7	8.6	8.0	7.4
MS-H<25bar_VSD-VF	0.7	1.0	1.4	1.7	2.2	3.0	3.6
MS-H_25-40bar_CF	2.3	2.8	3.2	3.4	3.6	3.8	4.0
MS-H_25-40bar_VF	2.9	3.1	3.2	3.2	3.0	2.3	1.7
MS-H_25-40bar_VSD-VF	0.6	0.9	1.2	1.4	1.8	2.5	3.1
BS<150_CF	-	-	-	-	-	-	-
BS<150_VF	1.9	2.0	2.0	1.96	1.7	1.1	0.6
BS<150_VSD-VF	0.6	0.8	1.1	1.30	1.5	2.0	2.4
BS<150_VSD-VF (multi)	-	-	-	0.01	0.1	0.3	0.4
SWP<2.2_CF	4.4	5.1	6.4	7.3	8.3	9.4	10.4

	1990	2000	2010	2015	2020	2025	2030
SWP<2.2_VF	-	-	-	-	-	-	-
SWP<2.2_VSD-VF	-	-	-	-	-	-	-
SVR<10_CF	2.6	3.1	3.5	3.6	3.7	4.0	4.2
SVR<10_VF	0.1	0.0	0.0	-	-	-	-
SVR<10_VSD-VF	0.0	0.0	0.1	0.1	0.1	0.1	0.1
SVR_10-160_CF	0.4	0.5	0.5	0.6	0.6	0.6	0.7
SVR_10-160_VF	0.0	0.0	0.0	-	-	-	-
SVR_10-160_VSD-VF	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SCR<10_CF	3.9	4.6	5.2	5.4	5.6	5.9	6.3
SCR<10_VF	0.1	0.1	0.0	-	-	-	-
SCR<10_VSD-VF	0.0	0.0	0.1	0.1	0.1	0.1	0.1
SCR_10-25_CF	1.6	1.9	2.1	2.2	2.3	2.5	2.6
SCR_10-25_VF	0.1	0.0	0.0	-	-	-	-
SCR_10-25_VSD-VF	0.0	0.0	0.1	0.1	0.1	0.1	0.1
SCR_25-160_CF	4.5	5.3	6.0	6.3	6.6	7.0	7.4
SCR_25-160_VF	0.7	0.4	0.0	-	-	-	-
SCR_25-160_VSD-VF	0.1	0.4	0.7	0.7	0.7	0.8	0.8

9.9 Emissions

The greenhouse gas emissions are directly related to the electricity use of the stock by means of the Global Warming Potential for electricity (GWPel), expressed in kg CO_2 equivalent emitted per kWh electricity consumed. The same GWP values are used as in the Ecodesign Impact Accounting (Table 118).

The EU-28 total emissions are calculated on sheets EMISBAU and EMISECO by multiplication of the total electricity consumption by the GWPel of the same year, e.g.:

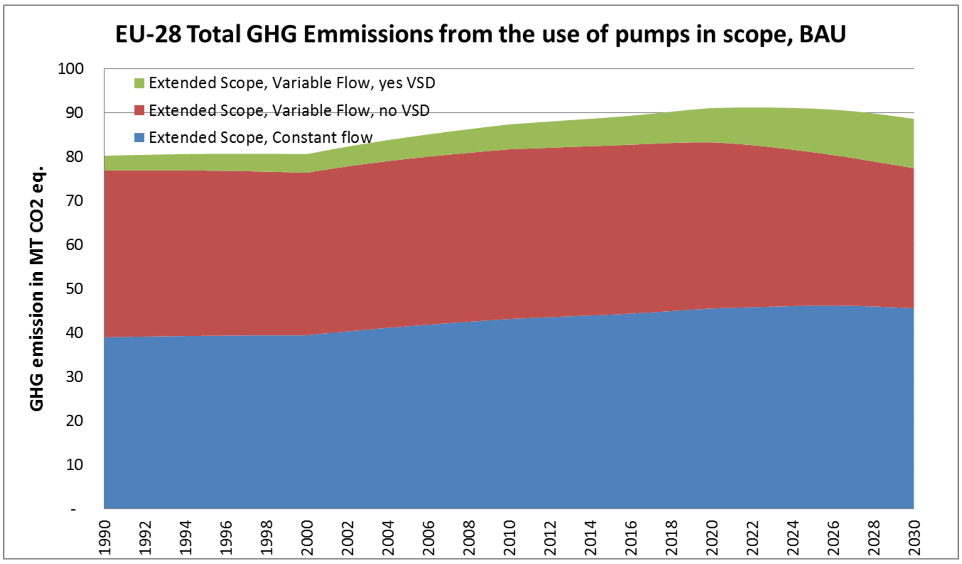
$EMISBAU = ELECBAU * GWPel$ (and similar for ECO)

Since ELEC is expressed in TWh/a, the resulting emissions are in Mton/a.

Table 118. Global Warming Potential for Electricity (GWPel) in kg CO_2 eq./ kWh electricity.

1990	2000	2010	2015	2020	2025	2030
0.500	0.430	0.410	0.395	0.380	0.360	0.340

The following figure provides the total EU-28 annual greenhouse gas emission in Mt CO_2 eq./a for the BAU-scenario and for the ECO3-scenario. Note that, while electricity consumption is lower in earlier years, the GWPel value is higher in those years. As a consequence, the curve is 'flatter' than the electricity consumption curve in Figure 66.



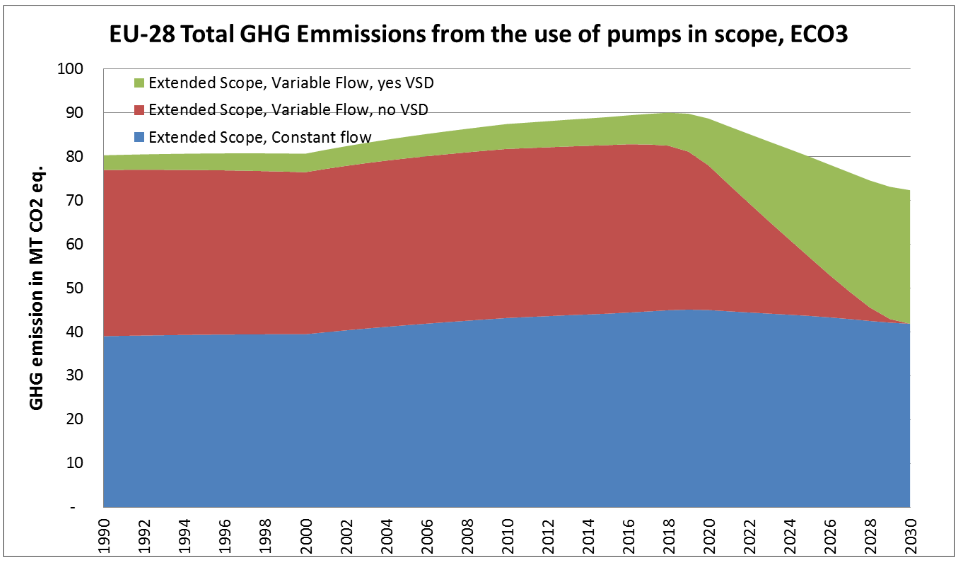


Figure 67. EU-28 Total annual greenhouse gas emissions due to the electricity consumed by pumps in the scope of the study, in MT CO2 eq./a, for the BAU- and the ECO3-scenario.

9.10 Price- and Cost-information

The basic price- and cost-information can be found on the sheet PRICES, that is shown in

Table 119.

The 2nd to 6th column contain the basic price information collected by the study team from various sources for pumps only, motors of IE2, IE3 and IE4 efficiency, and VSDs with IE1 efficiency. These are acquisition costs exclusive VAT and exclusive installation costs.

The central columns, labelled ‘BC’, ‘mid’ and ‘BAT’, give price elasticity data, i.e. the acquisition costs for pump-configurations in function of their (EPA) efficiency.

For the configurations it was chosen to use a IE2 motor for the BC, an IE3 motor for the MID product and an IE4 motor for the BAT. In case of VSD application, in all variants an IE1 VSD was used. These configuration prices include 20% VAT for the share of residential users that is paying these taxes (effectively this implies that 3-4% of the price is VAT).

The prices associated with the BC, MID and BAT have been linked to an efficiency. This was done by linking the configurations to a reference year in the EFNBAU sheet for which this specific configuration was assumed. This means that for the MID case, with an IE3 motor efficiency of the pump configuration, the efficiency from year 2015 was used as a reference. Furthermore, in the EFNBAU sheet, the factors can be found for the efficiency improvement for IE2 to IE3 motors and for IE3 to IE4 motors. These factors (called imp1 and imp2 respectively) are used to calculate the efficiencies matching the other cases.

The columns labelled ‘inst’ and ‘maint’ specify the installation costs (in euros) and the maintenance costs (in euros/a).

The last four columns give the price breakdown over the sectors, i.e. the share of the price that creates revenue for industry, wholesalers, retailers or government (VAT).

The basic price information is used on the sheets PRICEBAU and PRICEECO. In function of the energy efficiency of the sheet EFNBAU or EFNECO for a given year, the model interpolates between the three price-efficiency points of the sheet PRICES to find the configuration price for that year and that scenario.

Table 119. Basic price- and cost information from the sheet PRICES of the MAEPS model.

	PRICE INFORMATION					BC	BC	mid	mid	BAT	BAT	inst	maint	split-up price by party			
	Pumps only	Motor IE2	Motor IE3	Motor IE4	VSD IE1	euro	EF	euro	EF	euro	EF	euro	euro/a	VAT	retail	whole	ind
						BC = Motor IE2 (+VSD1)		BC = Motor IE3 (+VSD1)		BC = Motor IE4 (+VSD1)							
CURRENT SCOPE	**EXCL VAT**					**VAT ADDED**											
ESOB<22_VF						3,079	46%	3,103	48%	3,126	49%	720	300	3.3%	16%	65%	16%
ESOB<22_CF	2828	150.0	172.5	195.0		3,079	61%	3,001	63%	3,126	64%	720	300	3.3%	16%	65%	16%
ESOB<22_VSD-VF					280.0	3,369	53%	3,392	55%	3,415	56%	720	300	3.3%	16%	65%	16%
ESOB_22-150_VF						4,935	52%	5,028	53%	5,121	54%	720	300	3.3%	10%	20%	67%
ESOB_22-150_CF	4,172	600.0	690.0	780.0		4,935	67%	4,862	68%	5,121	69%	720	300	3.3%	10%	20%	67%
ESOB_22-150_VSD-VF					1130.0	6,103	57%	6,196	58%	6,289	59%	720	300	3.3%	10%	20%	67%
ESCC<22_VF						1,881	46%	1,904	47%	1,927	48%	2,100	800	3.3%	10%	20%	67%
ESCC<22_CF	1669	150.0	172.5	195.0		1,881	60%	1,841	62%	1,927	63%	2,100	800	3.3%	10%	20%	67%
ESCC<22_VSD-VF					280.0	2,170	53%	2,193	54%	2,217	55%	2,100	800	3.3%	10%	20%	67%
ESCC_22-150_VF						6,903	52%	6,996	53%	7,089	54%	2,100	800	3.3%	10%	20%	67%
ESCC_22-150_CF	6,076	600.0	690.0	780.0		6,903	67%	6,766	68%	7,089	69%	2,100	800	3.3%	10%	20%	67%
ESCC_22-150_VSD-VF					1130.0	8,071	57%	8,164	58%	8,258	59%	2,100	800	3.3%	10%	20%	67%
ESCCi<22_VF						2,271	45%	2,294	46%	2,317	47%	2,100	800	3.3%	10%	20%	67%
ESCCi<22_CF	2046	150.0	172.5	195.0		2,271	59%	2,219	61%	2,317	62%	2,100	800	3.3%	10%	20%	67%
ESCCi<22_VSD-VF					280.0	2,560	52%	2,583	54%	2,607	55%	2,100	800	3.3%	10%	20%	67%
ESCCi_22-150_VF						6,903	52%	6,996	52%	7,089	53%	2,100	800	3.3%	10%	20%	67%
ESCCi_22-150_CF	6,076	600.0	690.0	780.0		6,903	67%	6,766	68%	7,089	69%	2,100	800	3.3%	10%	20%	67%
ESCCi_22-150_VSD-VF					1130.0	8,071	57%	8,164	58%	8,258	59%	2,100	800	3.3%	10%	20%	67%
MSSB<6"_VF						1,857	35%	1,919	36%	1,981	37%	955	750	3.3%	10%	20%	67%
MSSB<6"_CF	1276	520.0	580.0	640.0		1,857	47%	1,856	49%	1,981	50%	955	750	3.3%	10%	20%	67%
MSSB<6"_VSD-VF					280.0	2,147	37%	2,209	38%	2,271	39%	955	750	3.3%	10%	20%	67%
MS-V<25bar_VF						1,631	44%	1,654	46%	1,678	47%	1,000	525	3.3%	10%	20%	67%
MS-V<25bar_CF	1,427	150.0	172.5	195.0		1,631	62%	1,600	64%	1,678	65%	1,000	525	3.3%	10%	20%	67%
MS-V<25bar_VSD-VF					280.0	1,921	46%	1,944	47%	1,967	49%	1,000	525	3.3%	10%	20%	67%
SCOPE EXTENSION																	
MS-V_25-40bar_VF						14,203	56%	#####	57%	14,389	58%	2,000	1,000	3.3%	10%	20%	67%
MS-V_25-40bar_CF	13136	600.0	690.0	780.0		14,203	74%	#####	74%	14,389	75%	2,000	1,000	3.3%	10%	20%	67%
MS-V_25-40bar_VSD-VF					1130.0	15,371	58%	#####	58%	15,558	59%	2,000	1,000	3.3%	10%	20%	67%
MS-H<25bar_VF						784	29%	807	31%	830	31%	1,000	525	3.3%	10%	20%	67%
MS-H<25bar_CF	608	150.0	172.5	195.0		784	41%	781	42%	830	43%	1,000	525	3.3%	10%	20%	67%
MS-H<25bar_VSD-VF					280.0	1,073	34%	1,097	35%	1,120	36%	1,000	525	3.3%	10%	20%	67%
MS-H_25-40bar_VF						6,406	38%	6,499	39%	6,592	40%	2,000	1,000	3.3%	10%	20%	67%
MS-H_25-40bar_CF	5595	600.0	690.0	780.0		6,406	54%	6,285	55%	6,592	55%	2,000	1,000	3.3%	10%	20%	67%
MS-H_25-40bar_VSD-VF					1130.0	7,574	43%	7,668	44%	7,761	45%	2,000	1,000	3.3%	10%	20%	67%
BS<150_VF	5,698	150.0	172.5	172.5	280.0	6,046	40%	6,070	42%	6,070	42%	2,000	1,050	3.3%	10%	20%	67%
BS<150_CF																	
BS<150_VSD-VF	5,698	337.5	388.1	388.1	280.0	6,530	41%	6,359	42%	6,359	42%	2,000	1,050	3.3%	10%	20%	67%
BS<150_VSD-VF (multi)	5,698	150.0	172.5	172.5	280.0	6,892	41%	6,944	42%	6,944	42%	2,000	1,050	3.3%	10%	20%	67%
SWP<2.2_VF																	
SWP<2.2_CF	443	150.0	172.5	172.5		711	39%	738	41%	738	42%	250	4.4	####	20%	10%	53%
SWP<2.2_VSD-VF					280.0												
SVR<10_VF						3,071	19%	3,134	20%	3,196	20%	1,250	750	4.0%	10%	20%	66%
SVR<10_CF	2,428	520.0	580.0	640.0		3,071	25%	3,008	26%	3,196	26%	1,250	750	4.0%	10%	20%	66%
SVR<10_VSD-VF					280.0	3,363	20%	3,426	20%	3,488	21%	1,250	750	4.0%	10%	20%	66%
SVR_10-160_VF						8,490	23%	8,714	23%	8,937	23%	3,958	1,600	4.0%	10%	20%	66%
SVR_10-160_CF	6287	1860.7	2075.4	2290.1		8,490	28%	8,362	28%	8,937	29%	3,958	1,600	4.0%	10%	20%	66%
SVR_10-160_VSD-VF					1130.0	9,667	23%	9,891	23%	10,115	24%	3,958	1,600	4.0%	10%	20%	66%
SCR<10_VF						3,641	35%	3,703	36%	3,766	37%	1,250	750	4.0%	10%	20%	66%
SCR<10_CF	2,974	520.0	580.0	640.0		3,641	47%	3,554	48%	3,766	49%	1,250	750	4.0%	10%	20%	66%
SCR<10_VSD-VF					280.0	3,933	36%	3,995	37%	4,058	38%	1,250	750	4.0%	10%	20%	66%
SCR_10-25_VF						8,276	45%	8,339	45%	8,401	46%	4,063	1,752	4.0%	10%	20%	66%
SCR_10-25_CF	7423	520.0	580.0	640.0		8,276	55%	8,003	56%	8,401	57%	4,063	1,752	4.0%	10%	20%	66%
SCR_10-25_VSD-VF					1130.0	9,454	46%	9,516	47%	9,579	47%	4,063	1,752	4.0%	10%	20%	66%
SCR_25-160_VF						42,566	49%	#####	49%	59,993	49%	6,250	3,200	4.0%	10%	20%	66%
SCR_25-160_CF	38,375	2475.7	2761.3	#####		42,566	60%	#####	61%	59,993	61%	6,250	3,200	4.0%	10%	20%	66%
SCR_25-160_VSD-VF					1130.0	43,744	49%	#####	50%	61,171	50%	6,250	3,200	4.0%	10%	20%	66%

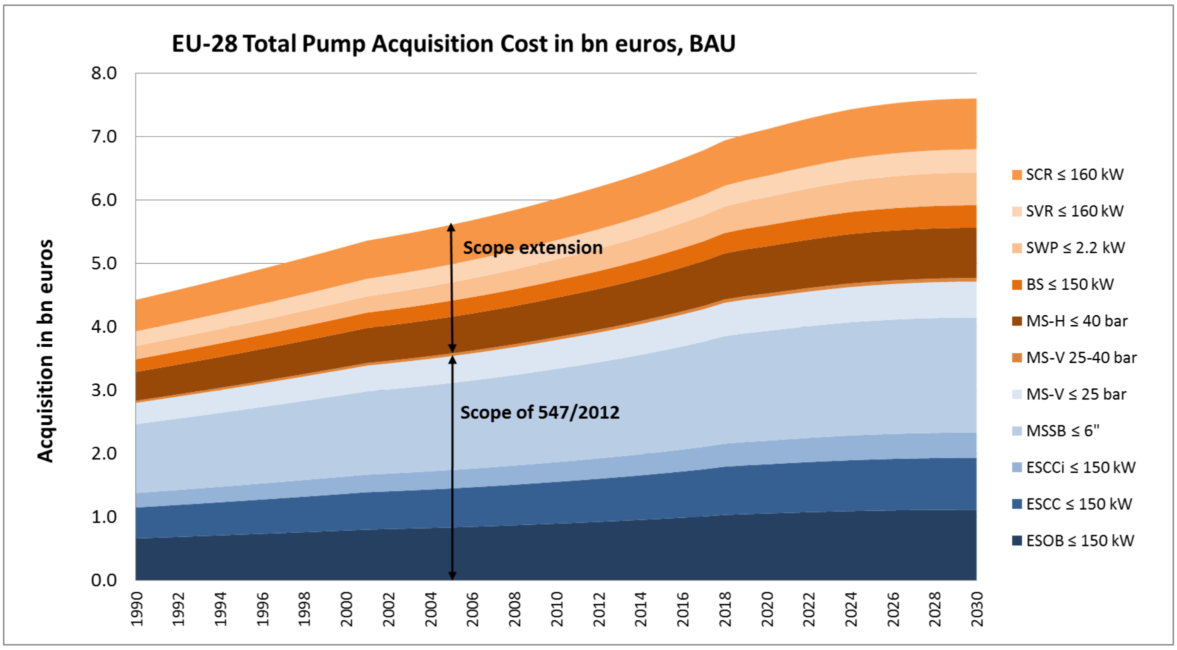
9.11 Acquisition Costs

The sheets ACQBAU and ACQECO compute the total EU-28 acquisition costs for pumps in each year, using the sales quantities from the sheets SALES_BAU and SALES_ECO and the unit prices for the (extended) products of the same year from sheets PRICEBAU and PRICEECO:

$$ACQBAU = SALES\_BAU_x * PRICEBAU_x * 10^{-9}$$

$$ACQECO = SALES\_ECO_x * PRICEECO_x * 10^{-9}$$

which results in acquisition costs in billion Euros. The installation costs are not included in this price. The costs do include VAT for the share of (residential) users that is paying this tax.



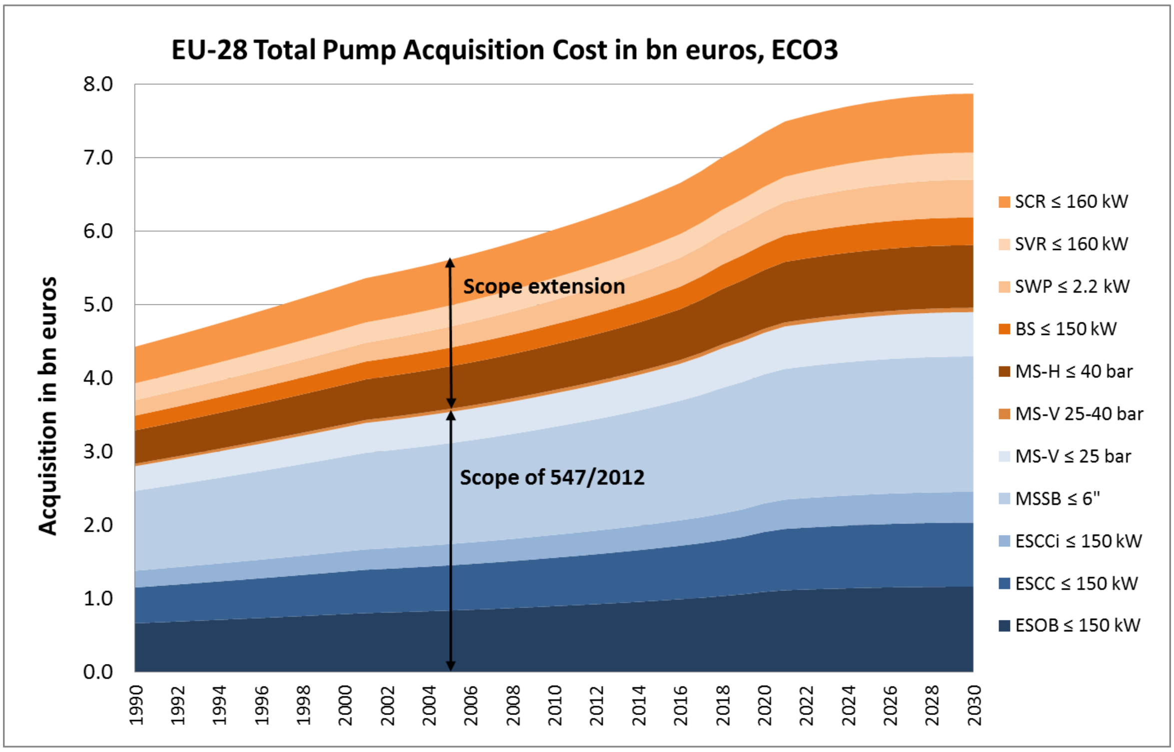
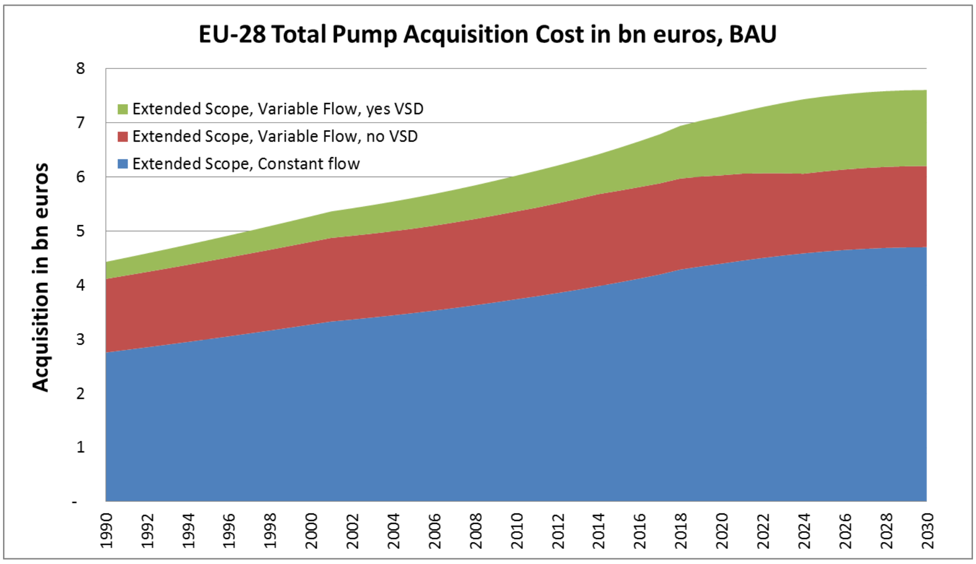


Figure 68. Total EU-28 Acquisition Costs for pumps in scope of the study (as extended products), in billion euros, fixed euros 2010, BAU- and ECO3-scenarios.



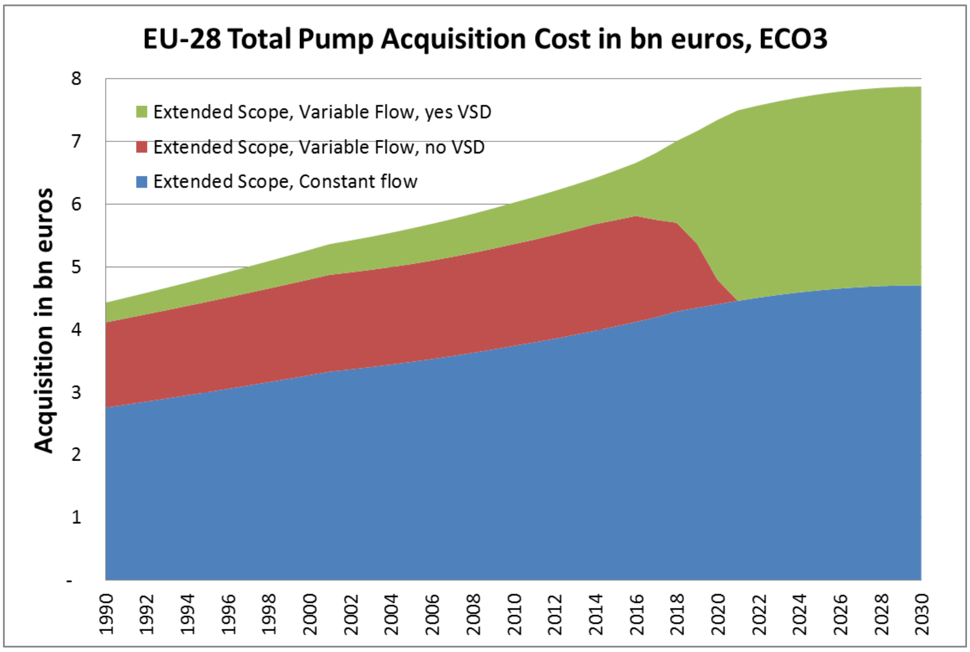


Figure 69. Total EU-28 Acquisition Costs for pumps in scope of the study (as extended products), per flow type and VSD-use, in billion euros, fixed euros 2010, BAU- and ECO3-scenarios.

9.12 Energy Costs and Electricity Rates

Energy costs are calculated on sheets NRGCOSTBAU and NRGCOSTECO, and directly related to the electricity consumption. The electricity from ELECBAU or ELECECO (in TWh/a) is multiplied by the electricity rate in €/kWh. There are two electricity rates available: for residential use and non-residential use. The overall energy costs are calculated as:

$\%_{res} * \mathrm{Rel1} + (1 - \%_{\mathrm{res}}) * \mathrm{Rel2}) * \mathrm{ELEC_x}$ (in billion euros)

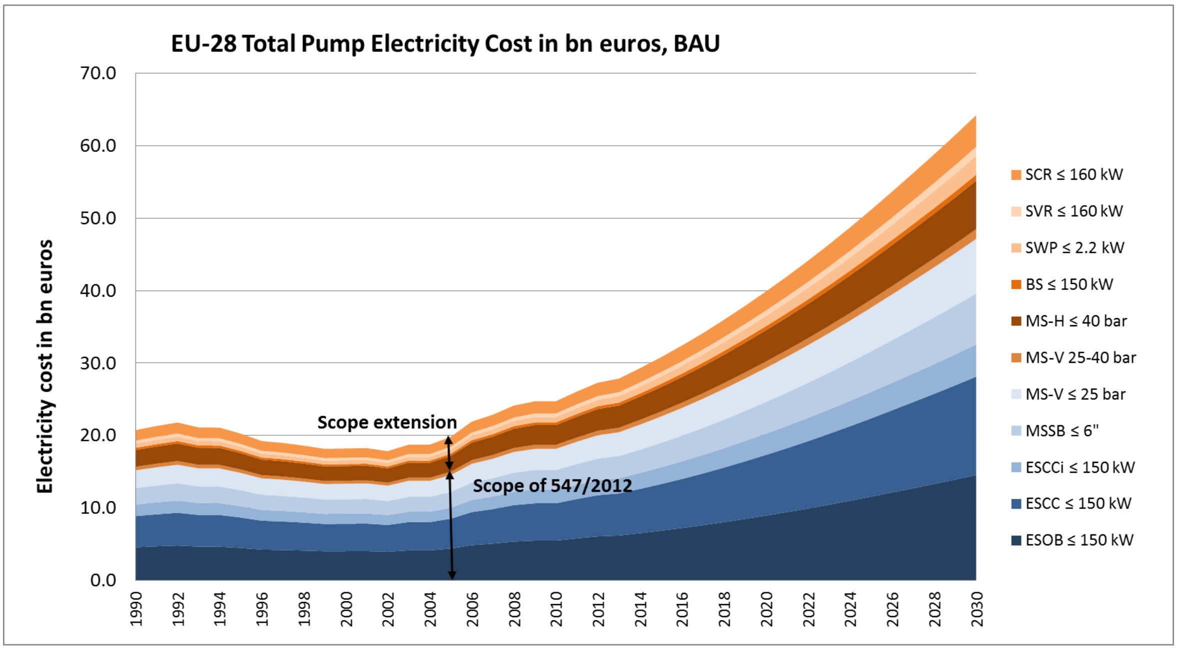
in which:
$\%_{RES}$ = share of residential consumers
Rel1 = electricity rate (€ / kWh) for residential consumers
Rel2 = electricity rate (€ / kWh) for non-residential consumers
$ELEC_X$ = electricity consumption for year x (either BAU or ECO scenario) in TWh
The %res is defined on the sheet PRICES and is identical to the share of users paying VAT.

The electricity rates are the same as used in the Ecodesign Impact Accounting:

Table 120. Electricity rates for residential and non-residential users.

		1990	2000	2010	2015	2020	2025	2030
Rel1 (residential)	€/kwh elec	0.178	0.162	0.170	0.205	0.249	0.303	0.369
Rel2 (non-residential)	€/kwh elec	0.119	0.084	0.105	0.122	0.149	0.181	0.220

See figures below for electricity cost results for the BAU- and ECO3-scenarios.



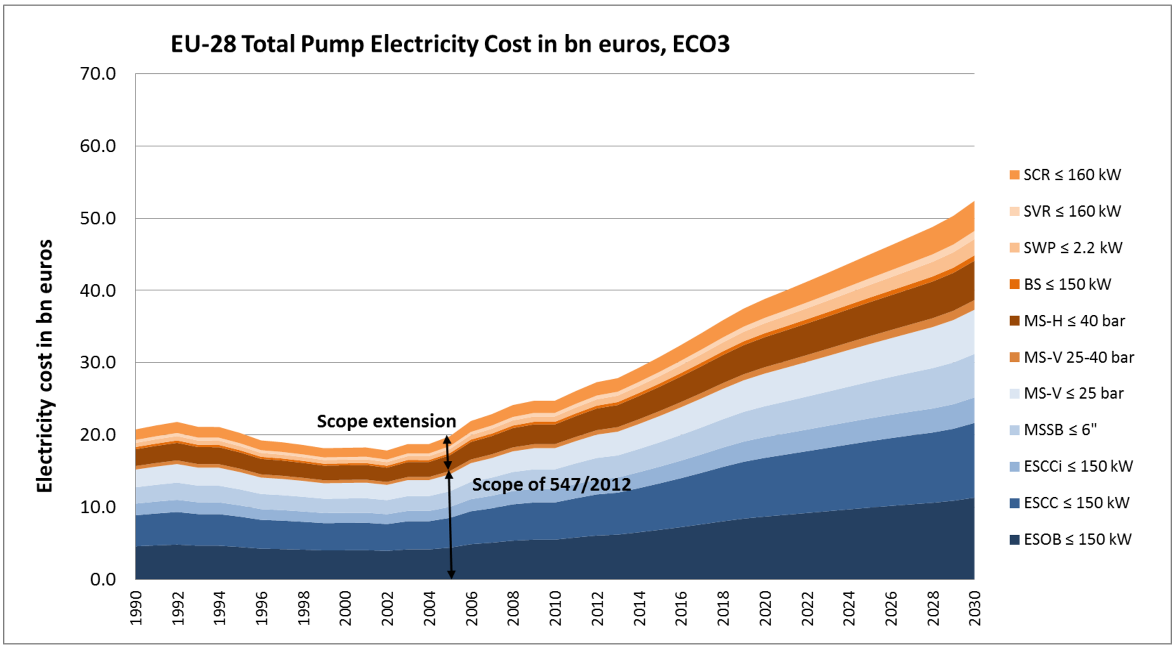
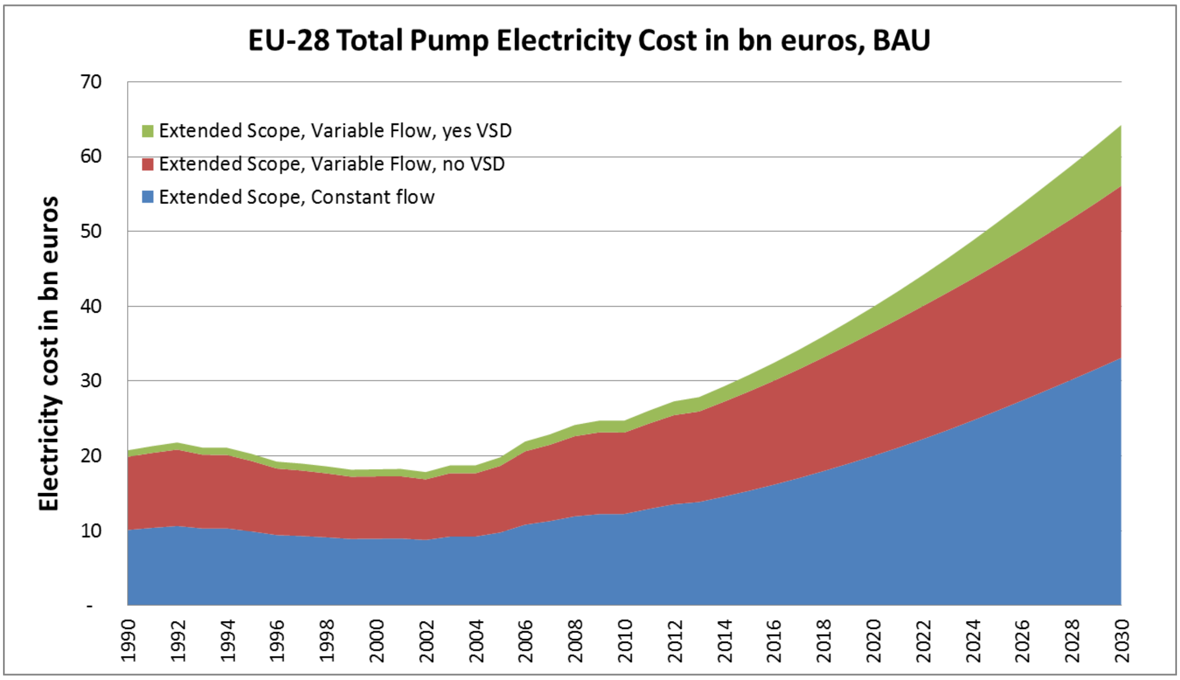


Figure 70. Total EU-28 Electricity Costs for operating pumps in scope of the study, in billion euros, fixed euros 2010, BAU- and ECO3-scenarios.



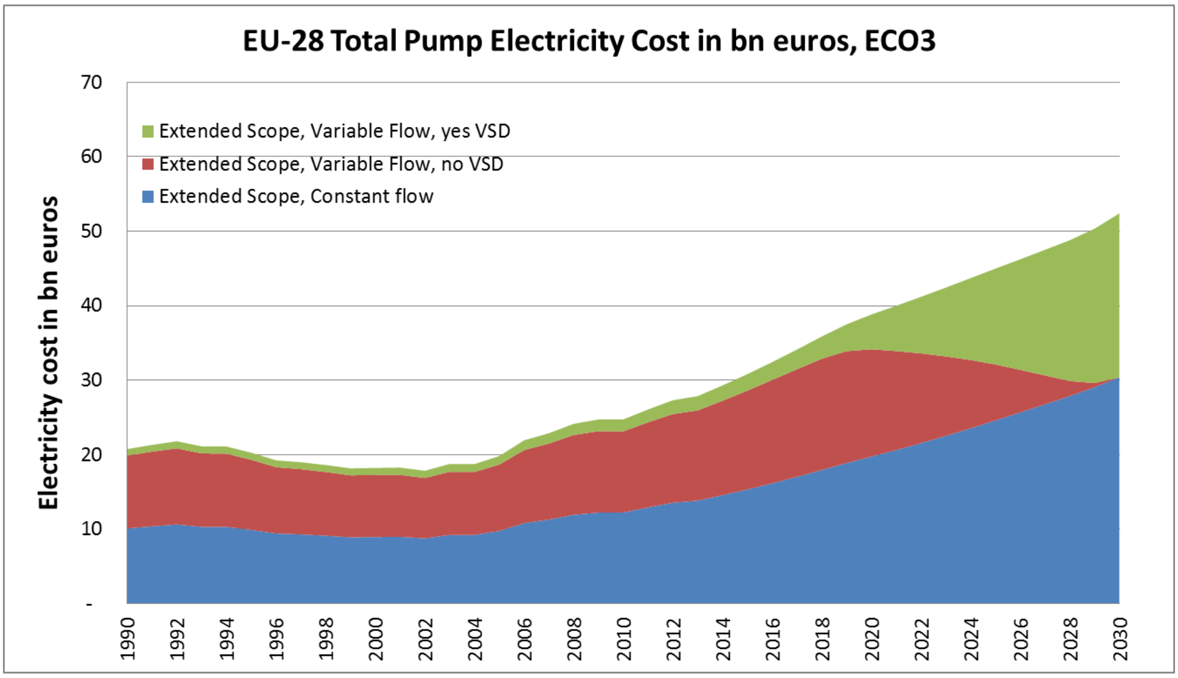


Figure 71. Total EU-28 Electricity Costs for operating pumps in scope of the study, per flow type and VSD use, in billion euros, fixed euros 2010, BAU- and ECO3-scenarios.

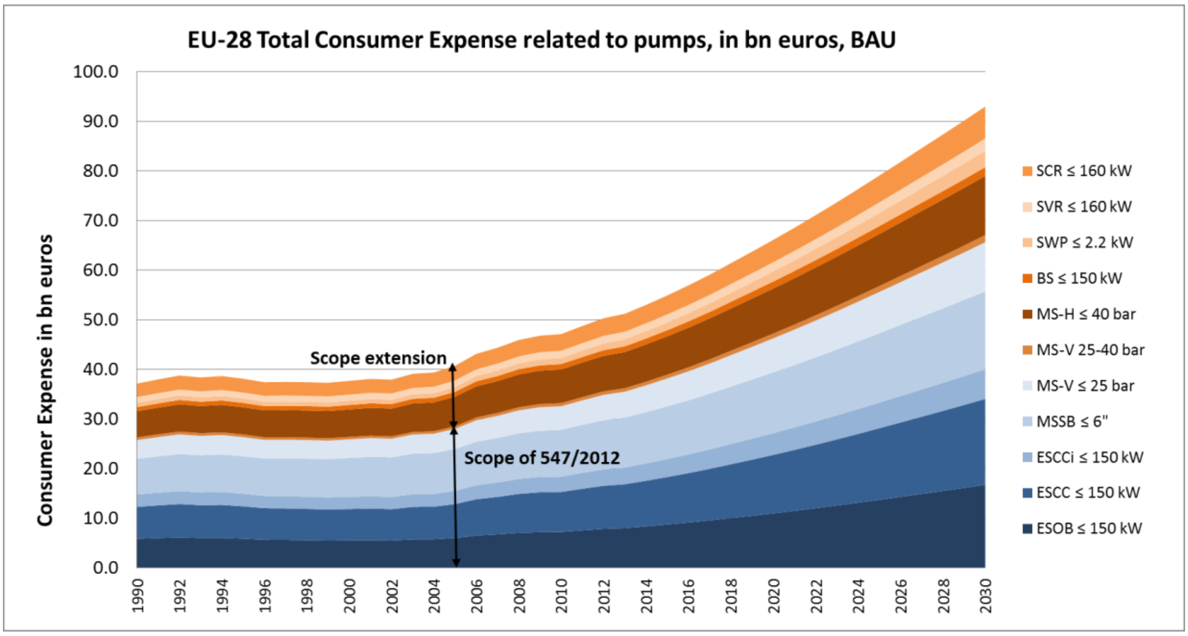
9.13 Installation and Maintenance costs

The unit installation costs are defined on the sheet PRICES (see above). These unit costs are multiplied by the sales quantities from sheet SALES_BAU or SALES_ECO to compute the total EU-28 installation costs on sheets INSTALCOST_BAU and INSTALCOST_ECO.

The annual unit maintenance costs are defined on the sheet PRICES (see above). These unit costs are multiplied by the stock quantities from sheet STOCK_BAU or STOCK_ECO to compute the total EU-28 maintenance costs on sheets MAINT_INCL_BAU and MAINT_INCL_ECO.

9.14 Total Consumer Expense

The EU-28 total annual expense for consumers related to pump acquisition, installation, operation and maintenance is computed on the sheets EXPENSEBAU and EXPENSEECO, as the sum of the cost components explained in preceding paragraphs.



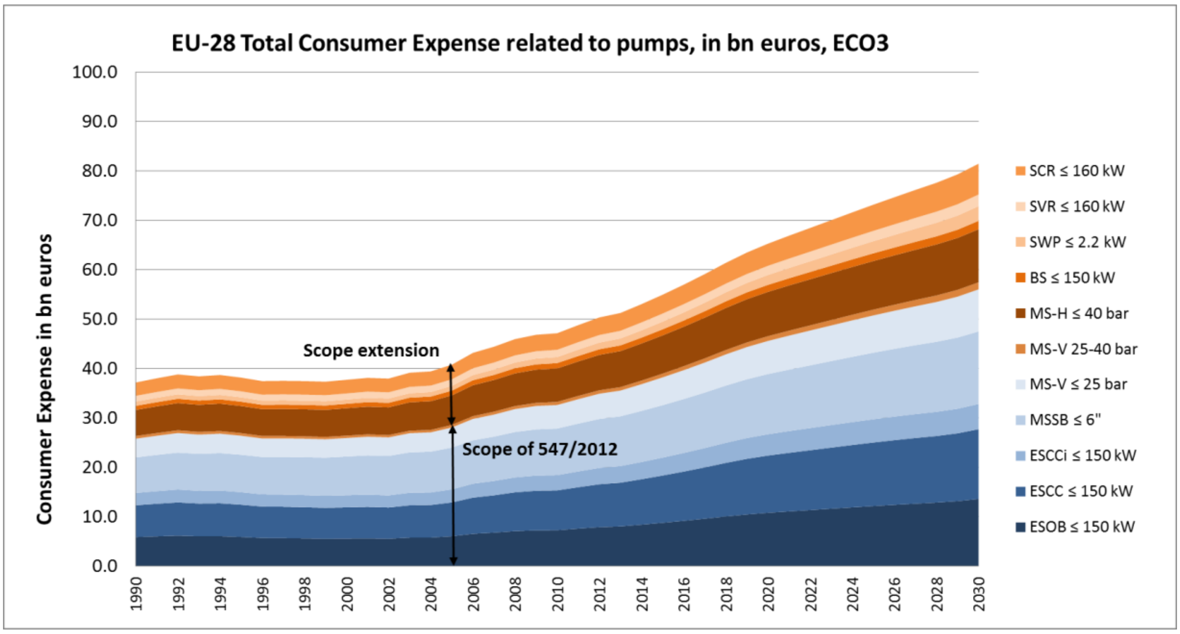
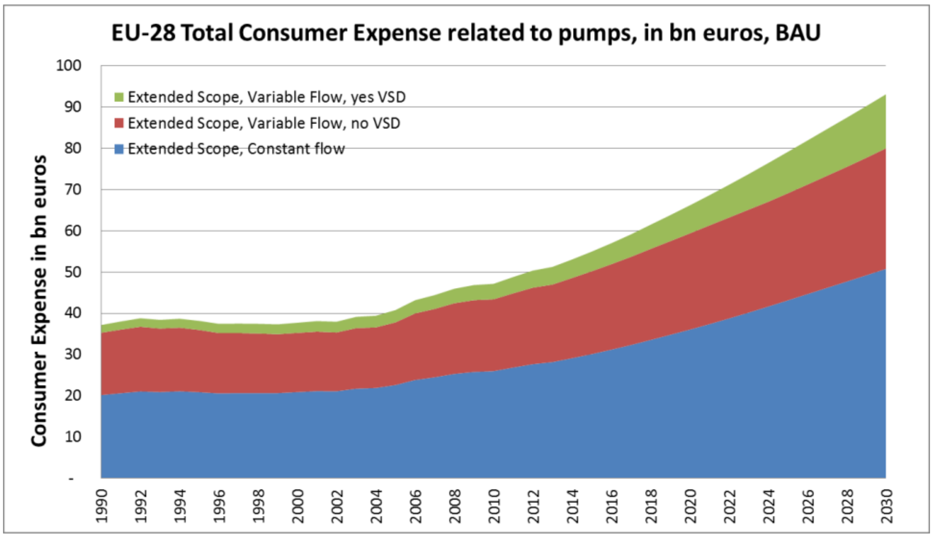


Figure 72. Total EU-28 Consumer Expense for acquiring, installing, operating and maintaining pumps in scope of the study, in billion euros, fixed euros 2010, BAU- and ECO3-scenarios.



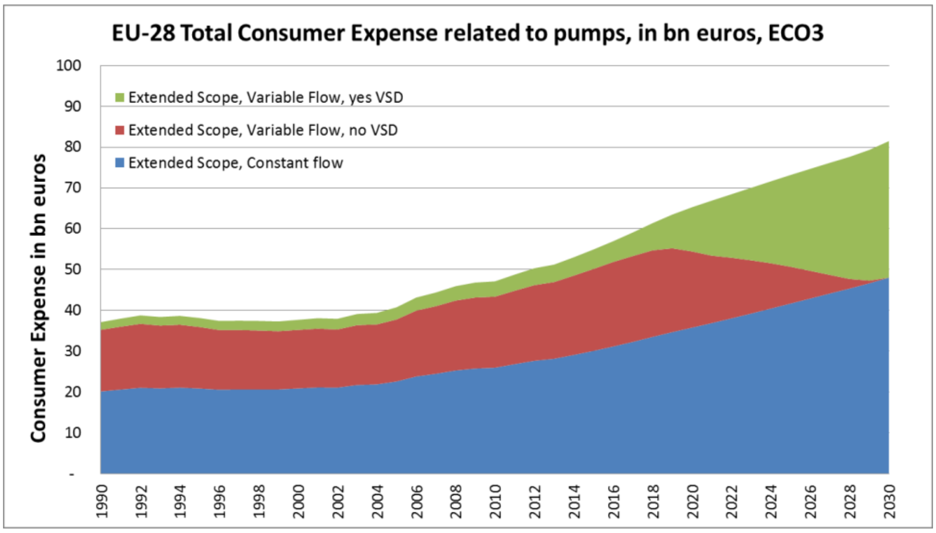


Figure 73. Total EU-28 Consumer Expense for acquiring, installing, operating and maintaining pumps in scope of the study, per flow type and VSD use, in billion euros, fixed euros 2010, BAU- and ECO3-scenarios.

9.15 Revenues per sector of pump business

The total EU-28 revenues deriving from selling, installing and maintaining pumps in the scope of this study are computed for the following sectors: industry, wholesale, retail, installation and maintenance on the sheets REV_xxx_BAU and REV_xxx_ECO:

$$Revenue\ Industry = SALESBAU/ECO_x * \%_{IND} * PRICEBAU/ECO_x * 10^{-6}$$

$$Revenue\ Retail = SALESBAU/ECO_x * \%_{RET} * PRICEBAU/ECO_x * 10^{-6}$$

$$Revenue\ Wholesale = SALESBAU/ECO_x * \%_{WHOLE} * PRICEBAU/ECO_x * 10^{-6}$$

$$Revenue\ Installers = SALESBAU/ECO_x * INST * 10^{-6}$$

$$Revenue\ Maintenance = STOCKBAU/ECO_x * MAINT\_EXCL * 10^{-6}$$

in which:
$SALESBAU/ECO_X$ = sales for year x (either BAU or ECO scenarios)
$STOCKBAU/ECO_X$ = installed stock for year x (either BAU or ECO scenarios)

$PRICEBAU/ECO_X$ = product price for year x (either BAU or ECO scenarios)
$\%_{IND}$ = share of revenue for the industry (from sheet PRICES)
$\%_{RET}$ = share of revenue for retail (from sheet PRICES)
$\%_{WHOLE}$ = share of revenue for wholesale (from sheet PRICES)
Resultant retail revenues are in million Euros.

9.16 Jobs

The direct employment impact of the measures - i.e. the increase of employees in the value-adding chain - is derived from the business revenues in the various sectors, using the following constants. In absence of other data, the same constants ('wages' [370]) have been used as in the Ecodesign Impact Accounting:

- Manufacturer's 'wages': 0.15 m euro/employee ±10%. It is assumed that associated OEM jobs and Service jobs are each of the same order of magnitude. Including also these jobs the 'wage' reduces to 0.05 m euro/employee, which is the quantity used in EIA. Currently no distinction is made if these jobs are inside or outside EU-28.
- Wholesale 'wages': 0.25 m euro/employee ±20%
- Retailer 'wages': 0.06 m euro/employee ±20%
- Installer 'wages': 0.1 m euro/employee ±20%
- Maintenance 'wages': 0.1 m euro/employee ±20%

All constants are in fixed 2010 euros.

[370] These are not actual wages but total company revenue divided by staff.

Annex 10. Input from Market Surveillance Authorities (MSAs)

The MSAs interviewed and their experience with the market surveillance for pumps and electric motors are shown in Table 121.

Table 121. Market Surveillance Authorities (MSAs) interviewed.

Country	Experience with market surveillance	Market surveillance of water pumps (547/2012)	Market surveillance of electric motors (640/2009)
Belgium	Market surveillance and ecodesign expert	none (last priority product from MDUs[371])	Document control and testing
Denmark	Market surveillance coordinator	Document control and occasional testing	Document control and testing
Finland	Market surveillance coordinator	Ongoing dialogue with manufacturers/impor-ters on ecodesign requirements (also when amended) and occasional document control	Ongoing dialogue with manufacturers/import ers on ecodesign requirements (also when amended) and occasional document control
Germany (Baden-Württemberg)	Market surveillance coordinator	none (planned to start next year)	Document control and testing
Italy	Market surveillance and ecodesign expert	none (not part of the priority products)	none (not part of the priority products)
Netherlands	Ecodesign expert and market surveillance coordinator	none (low priority product)	Document control
Rumania	Currently only energy label	none	none
Sweden	Market surveillance coordinator	Document control and occasional testing	Document control and testing

Overall, the interviews showed there is limited experience with market surveillance for water pumps ecodesign requirements in regulation 547/2012 (see Table 121). The main reasons are:

- difficulties of identifying water pumps in scope as trade names aren't the same as categories defined in the regulation
- in most cases water pumps are sold B2B and it is thus difficult for MSAs to identify when the water pumps are placed on the market as they are usually not sold physically by retailers (although they can be checked in product catalogues)
- there are only a few accredited laboratories in the EU offering independent testing

The first point has been discussed through the review study and a potential solution has been proposed by requiring the category name used in the regulation to be included in name plate with a code, according to the acronyms also defined in the regulation (e.g. 'End suction own bearing' pumps as 'ESOB' pumps, see Article 2 in regulation). This proposal

[371] Motor Driven Units

aims to also target the increased complexity of verifying the pump unit and the extended product.

10.1 Experience with verification of motor regulation (EU) 640/2009 with amendment (EU) 4/2014

Overall, MSAs interviewed do not verify whether IE2 motors are actually equipped with a VSD[372]. The main reasons are related to the difficulties of carrying out inspections on-site and who to account responsible for lack of compliance. See below:

- Some MSAs select the motors to be inspected from product catalogues and only focus on IE3. By the use of this procedure it is not possible to check correct installation (whether IE2 motors are actually equipped with VSDs).
- Checking the product after it is 'put into service' (installed) requires certain technical skills by the MSA to identify the motor set-up (with or without a VSD). Consultants may need to be hired to do so. Doing this would be expensive.
- It is the installer who decides whether to put a VSD on a motor. It is he/she who knows what is best for the whole installation and not the manufacturer. It is not possible to take action against a manufacturer, if the installer/end-user decides not to combine the motor with a VSD even if the manufacturer says so.
- It would be difficult to know who to account responsible for lack of compliance, and in the case of installers this would imply MSAs establish contact with them (MSAs are mostly in contact with manufacturers and distributors). However, one MSA pointed out that, if this is where the 'real' savings are, it would be good to place the responsibility at the installers.

10.2 Placing on the market vs. putting into service

During the interviews the two possibilities for verification were discussed (after placing on the market and after putting into service), and generally MSAs felt more uncomfortable with the idea of making verification for products at installation. The arguments presented for the verification of electric motors were very similar to those raised by MSAs on the potential verification of pump units at installation. Some additional potential opportunities and challenges were identified which are presented in the next sections.

Verifying after placing on the market

In the case of verifying products placed on the market, and in the particular case of bare shaft pumps, the interviewed MSAs mentioned that the revised regulation on water pumps should clearly define the 'standard' electric motor (and VSD in the case of variable flow applications) to be used in the pump unit. The 'standard' motor should be defined according to the motor's energy class as stated in the ecodesign motor regulation (IE3 orIE2 equipped with VSD). The 'standard' VSD could be IE1 defined according to EN 50598-2 and IEC 61800-9 standards. Moreover the MSAs proposed, that the manufacturers could recommend which type of extended product set-up works best with a given water pump type.

These preconditions, though, would not solve the challenge of verifying that the bare shaft pump has actually been installed according to its intended use, i.e. in constant or variable flow applications, and in this way that the pump unit complies with the declared EEI level securing the actual energy savings. Furthermore, this would limit the application of the

[372] Ecodesign requirements for electric motors in regulation 640/2009 (incl. amendment (EU) 4/2014) are less stringent (i.e. with an IE2 efficiency class instead of IE3) if they are equipped with a VSD. This requirement can only be controlled if motors are inspected at installation.

bare shaft pump to only one application (either to constant or to variable flow), which is not the case as many bare shaft pumps can be used in both. Alternatively, the manufacturer should declare both EEI values for the bare shaft pump.

Verifying at installation (when the pump has been put into service)

MSAs don't have the means to know where and when pump units are installed. Generally, MSAs only have relationship with manufacturers, not with installers, unless the products have to be safety compliant and the MSAs check both safety and ecodesign/energy labelling requirements. Moreover, in some Member States there are legal constraints to check compliance on-site as MSAs are not allowed to enter a customer's factory (only allowed at the warehouse or on a voluntary basis at the customer's premises). In other Member States this is possible as they are allowed to perform field inspections on-site.

Since verifying installed products is something MSAs are not familiar with (for ecodesign purposes), the verification procedure is something they have difficulties to picture, additional to the legal constraints mentioned in paragraph above. One of the interviewed MSAs suggested that, if the definitions of constant flow and variable flow imply the existence of certain components such as a VSD or a valve, the MSAs could ask the installers for photos of the installation to verify intended use and compliance with a declared EEI instead of travelling to verify on-site. Some of the interviewed MSAs suggested to use other mandatory policy instruments (e.g. national building codes, best practices, voluntary agreements, electrical safety declarations, machine directive) to make sure pumps are installed with VSD and complying with the declared EEI they are intended to.

If the pump unit is not placed on the market before putting it into service, the responsibility for compliance could shift from the manufacturer to the installer. This would mean that the installer would have to collect information on individual products from different manufacturers. Manufacturers would have to provide product information as part of a 'package of information' to the installers, e.g. in an installation manual.

Overall, some of the MSAs don't see water pumps as priority products and thus don't see the point to disrupt common verification practices by verifying installed products. However, some pointed out that if potential savings are substantial that could be a reason to set pump units at a higher ranking of their Market Surveillance priority lists.

Verifying intended use

The proposed ecodesign requirements show that the majority of the energy savings are from operating the pumps at variable flow with the use of VSDs (as shown in section 12.2 of this report). However, some pump units will continue to be installed for operation at constant flow, as according to industry there are specific installations and/or specific countries where pump units are required to operate as such because of, e.g., safety reasons.

It was discussed with the interviewed MSAs, that an exhaustive list of installation types could be listed in the revised regulation of water pumps where pump units are to be operated at constant flow. This could be tied up to specific bare shaft pump types (considering the manufacturers would know the types needed for these installations), and an information requirement could secure that the installers know these pumps have to be installed according to their intended use. For the rest, it would be assumed that they all are to be operated at variable flow (and thus with a VSD).

Industry has later informed that this possibility may be challenging, since it may not be possible to come up with an exhaustive list. Alternatively it would be the manufacturers who would declare the bare shaft pump intended use (i.e. in constant or variable flow). This would require, either or, a clear definition of what these are. Furthermore, since many bare shaft pumps can be operated at both flow applications, if the manufacturers are to declare intended use, it would likely be both.

Summary

The input provided by MSAs indicates that verifying an extended product presents several challenges:

1. To secure the largest savings for operating the pump unit at variable flow, the verification would ideally have to happen after the pump unit is put into service.
2. The usual verification process carried out by MSAs would be largely disrupted, as they would have to build relationships with the installers and end-users and travel on-site to verify the actual use and actual EEI of the pump unit. A semi-analytical model (i.e. SAM) could be used to calculate the actual EEI based on visual inspection of the installation and information from manufacturers. Alternatively, the verification on-site could be tied up to other policy measures such as the national building codes, energy labelling of buildings, energy audits of manufacturing sites, best practices, voluntary agreements, electrical safety declarations, machine directive, etc.
3. The responsibility for compliance of the pump units would shift from the manufacturers to the installers, including issuing the EU declaration of conformity (DoC) and affixing the CE-marking, when the bare shaft pumps are placed separately on the market.
4. Clear definitions of what is constant and what is variable flow shall be elaborated, so MSAs can verify against the relevant EEI requirement.

Annex 11. Verification of products ‘put into service’ - Relevant experiences from other regulations

Alternative approaches for verifying products once they are put into service are used for other products. For instance, for water tanks and motors. See examples in Figure 74 and Figure 75. However, as discussed previously, market surveillance currently is not carried out to verify whether electric motors are equipped with VSDs due to ambiguities on responsibilities and the lack of guidance for MSAs on how to make market surveillance for ErPs once installed.

Answer (1) From the Commissions FAQ on eco-design (hot water storage tanks)

If a tank is placed on the market uninsulated, the manufacturer has to provide the information on how to insulate the tank so that it complies with the requirements when putting it into service. This is specified in Annex II, point 2.2(c) of Regulation 814/2013 in the information requirement of "any specific precautions that shall be taken when the hot water storage tank is assembled, installed or maintained".

Figure 74. Example of water tanks enforcement when putting into service.

Motors which do not meet the IE3 efficiency level need to be equipped with a variable speed drive to comply with the ecodesign regulation for electric motors. To ensure compliance of an IE2 motor the manufacturer must provide information about the obligation of using a VSD in combination with the motor. This information must be visibly displayed on the rating plate or an additional sticker/plate and in the technical documentation of the motor. Examples of the layout of the rating plate that can be used are shown below.

Indication of the necessity to equip IE2 motors with a variable speed drive

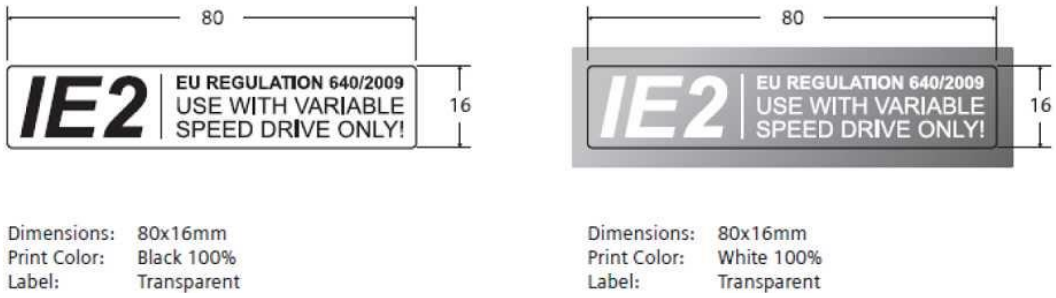


Figure 75. Example of electric motors enforcement when equipped with a VSD.

Table 122 shows different examples about responsibilities for compliance and for CE-marking. Some of the answers are contradictory. However, the example for ventilation units (in **bold font**) seems to be more clear and similar to the proposal herein drafted, where the manufacturer must provide the information on the system they have to be installed, so that they comply with the requirements when they are put into service. The manufacturer must CE-mark the product showing he has complied with all his obligations. The installer is responsible for ensuring that the product is put into service in accordance with the information provided by the manufacturer.

Table 122. Examples from the Commissions FAQ on the Ecodesign Directive[373].

Section about Ecodesign Directive 2009/125/EC	Answer (18) about build to-order products: "An installer or a system integrator selling an assembled product has to be considered responsible for the conformity."
Example regarding ventilation units (Regulation (EU) No 1253/2014)	**Answer (4) about distinction between residential (RVU) and non-residential units (NRVU)** **"Therefore, if a ventilation unit is placed on the market without the "indoor climate control system" or the "motor control system", the manufacturer has to provide the information on which system has to be installed on the ventilation units (cf. Annex IV-1-n), so that it complies with the requirements when putting it into service. The manufacturer has to CE-mark the product showing he has complied with all his obligations. The installer is responsible for ensuring that the product is put into service in accordance with the information provided by the manufacturer pursuant to Annex IV or V."**
Example regarding hot water storage tanks (Regulation (EU) No. 814/2013)	Answer (1) about hot water storage tanks sold uninsulated: "Hot water storage tanks need to comply with ecodesign requirements and have an energy label when placed on the market or put into service. If a tank is placed on the market uninsulated, the manufacturer has to provide the information on how to insulate the tank so that it complies with the requirements when putting it into service."
Example regarding electric motors (Regulation (EC) No 640/2009)	Answer 7 about the meaning of being equipped with a variable speed drive "The motor manufacturer does not have to supply a VSD with every motor sold. The Regulation applies when the product is "placed on the market" or "put into service". In this case, compliance cannot be checked when the product is "placed on the market", so it will need to be checked when the product is "put into service". Nevertheless, if an IE2 motor is placed on the market after 1 January 2015 the following information needs to be provided. Information on the mandatory requirement to equip motors, which do not meet the IE3 efficiency level with a variable speed drive, shall be visibly displayed on the rating plate, technical documentation of the motor: (a) from 1 January 2015 for motors with a rated output of 7,5-375 kW; (b) from 1 January 2017 for motors with a rated output of 0,75-375 kW. When a motor is replaced, it has to be equipped with a VSD, and there are no specific provisions regarding this question."

However, the example of the ventilation units leaves the doubt on who is responsible for affixing the CE-mark to the whole ventilation system.

[373] Commissions Frequently Asked Questions (FAQ) on the Ecodesign Directive and its Implementing Regulations.

Annex 12. Minutes from meeting with Member State representatives and Market Surveillance Authorities (MSAs) on water pumps extended product approach

Project: Water pump extended product approach

Subject: Meeting with Member State representatives and MSAs

Date: 13. marts 2018

To: Ronald Piers de Raveschoot, DG ENERGY

Cc:

From: Viegand Maagøe

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1. Participants

EUROPEAN COMMISSION, DG ENERGY:

Ronald Piers de Raveschoot

CONSULTANTS:

Larisa Maya-Drysdale, Viegand Maagøe

Annette Gydesen, Viegand Maagøe

René Kemna, VHK

INDUSTRY:

Niels Bidstrup, Grundfos & Europump

Markus Teepe, WILO & Europump

Frank Enenbach, Sulzer & Europump

Pierre Lucas, Orgalime & Europump

MEMBER STATE REPRESENTATIVES/MARKET SURVEILLANCE AUTHORITIES:

Milena Presutto, Italy

Floris Akkerman, Germany

Hans Paul Siderius, Netherlands

Carlos Lopes, Swedish Energy Agency

Bram Soenen, Belgium

Bjarke Hansen, Danish Energy Agency

2. Purpose of the meeting

To discuss a proposal for energy efficiency requirements of water pumps following an extended product approach and how the requirements can be verified. The proposal has been developed by Europump in dialogue with the study team and the Commission. The extended product approach is expected to achieve a much larger share of the existing saving potential for water pumps (up to 48 TWh/year by 2030 in comparison to 5 - 7.4 TWh/year).

3. Minutes

The first part of the meeting was a general discussion regarding extended product approach and the background for the proposal. The second part was a discussion of the actual proposal and the third was a discussion of possible requirements.

The minutes include important issues that arose during the general discussion and opinions regarding the presented proposal.

a. Important issues from the general discussion

Without the limit for ecodesign

Some of the participants find that an extended product approach is outside the boundaries of ecodesign in the classical sense, because requirements should only address the product and not the installation and the system.

From a MSA perspective, instead of assessing one product that is representative of thousand other identical products, surveillance would concern a myriad of individual installations, which reduce effectiveness. Some MSAs do not have the legal powers to carry out such inspections. Europump highlights that this might be solved by the upcoming goods proposal. In no way would any MSA remove a product already installed on site for the purpose of sending it to a lab (this comment is somehow void because this was not part of the proposal)

What is in the scope of ecodesign

Anything that is defined as a product is within the scope. Systems are not. A product does not need to be in a simple casing, it can be more (e.g. a pump unit consisting of several products/components). Assembled products are within the scope.

Responsibility of installer

It is important that one can identify the responsible economic actor. In case of assembled products, the person that assembles the product is responsible. In many cases the installer will be the responsible (the installer becomes the manufacturer). According to BE, identification of the person responsible in case of non-compliance is problematic.

SE mentioned an example for floor space heaters with controls, where they consider that the burden on the installer is inappropriate compared to the potential savings. This is too much responsibility for installers.

IT considers that putting the burden of conformity on installers could indeed be problematic: it is a political responsibility to be taken.

Possible to measure

It is important that requirements are measurable and that it is possible to verify the compliance of the product.

Machinery Directive

The machinery directive is mentioned as an example of legislation that includes verification on site. But some participants mentioned that the situation is not the same. The machinery directive deals with safety and the products is built on site. For lifts inspections the verification also includes controls after 3 years of operation. For verification of installations no measurements are required but visual inspection of for instance mounting of required protection shields etc. Within the machinery directive the installer is the responsible (same as with the proposed approach of verifying the extended product).

Identification of products

MSAs do not have any means to identify where and when the products are installed.

Large water pumps

Often, water pumps units do not come in a box. Often, products above 22 kW are separated. For large water pumps installers are specialists.

Enforcement

If the installers are responsible it should also be possible to punish them if they do not full fil the requirements for installation etc. Some regulations already have requirements regarding installation, but they are difficult to verify for compliance. However, according to Europump even if for some regulations there is little or no enforcement, they are still working on achieving the savings potential (to some extent) because the products are made to comply.

b. Opinions on proposed requirements and verification procedure

Most national representatives are not in favor of the proposal. BE, NL, IT, SE and DE find that setting requirements for putting into service is not practical and that verification on site is outside the boundaries of the ecodesign directive.

NL and SE proposed to explore the possibility of using information requirements in ways they aren’t typically used and in combination with other legislations or policy measures.

IT is in favor of information requirements and believes that such requirements will be able to achieve a reasonable share of the savings. Efficient pumps could maybe also be promoted through other incentives and legislation.

DE referred to the content of article 15 point 7 of the ecodesign directive which states that the implementing measure shall specify whether verification can be achieved directly on the product or on the basis of the technical documentation. Various of the participants agree that article 15 point 7 excludes other possibilities for verification of aspects that do not depend directly on the product, such as whether the product is installed in variable or in constant flow systems by visual inspection.

SE does not accept that all water pumps should be installed with continuous control. This will not be the best solution in all cases and will cause unnecessary resource consumption.

DK will not close the door for verification on site and propose that it is considered further. It could be recommended in some situations with big saving potentials.

Europump pointed out that the outcome of the meeting in practice will mean that the extended product approach is dead and that it will not be possible to achieve the largest part of the saving potential. Without requirement for putting into service the requirements will in principle be a hidden MEI. This means that a potential of up to 40-48 TWh will not be utilized.

NL, IT, DK and others find that setting relevant metrics within ecodesign could result in savings elsewhere (through other legislation or incentives).

c. Comments regarding possible requirements

According to the existing legal basis it doesn’t seem possible to control that products are installed to ensure efficient operation as long as this requires inspection on site and it is necessary to take into account issues not related to the product itself (for instance whether the product is installed in a variable or constant flow system).

It is proposed to keep the EEI as a metrics in the context of the regulation. EEI could apply to bare shaft pumps or pump units placed on the market, as mandatory information or as minimum performance requirements (in place or on top of MEI).

It should be considered whether the MEI requirement should be kept for bare shaft pumps. NL thinks that it is a good idea and the rest of the participants agree.

The consultants, together with the European Commission and Europump, will update the proposal according to the input received during this meeting.

Annex 13. Single EEI value for all pumps in scope (under preparation, foreseen publishing date mid-January 2019).