European Commission

Ecodesign Pump Review

Study of Commission Regulation (EU) No. 547/2012 incorporating the preparatory studies on 'Lot 28' and 'Lot 29' (Pumps)

Final Progress report

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Energy

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1. Introduction to progress report

1.1 Scope of the report

This is the progress report of the Review study of Commission Regulation (EU) No 547/2012 incorporating the preparatory studies on 'Lot 28' and 'Lot 29'. This progress report follows the MEErP methodology and includes the next 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 came into force (January 2013).
- **Task B**, which reviews previous preparatory studies before and after the legislation (Lot 11, Lot 28 & Lot 29) and any needs for extending their 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 whether Extended Product Approach (EPA) shall be part of the Regulation or not, including 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 by Regulation 547/2012, 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 pumps product group within the total of EU industry trade and policy and to provide 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 up to Best Available Technology (BAT) and Best Not yet Available Technology (BNAT).
- **Final scope for this study**, where a 'final' presentation of the scope for this review study is presented, based on the assessments from Tasks D2, D3 and D4.

Tasks A, B, C and D1 are an extension of task 1 in the MEErP methodology, due to the need of defining a scope which is more consistent, harmonised and 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 on the reviews of existing legislation and previous preparatory studies, including the description of Extended Product Approach and its possibility for adoption in a newer version of the Regulation (EU) 547/2012 according to Article 7 (Revision). 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 at the end of this report. It is called 'final', as it is derived from the inputs and analyses in tasks D2, D3 and D4. The 'final' scope will be used in further tasks, and the differences with the preliminary scope are presented in this report.

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 a scope of 'water pumps'. Water pumps are defined 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)
- 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;
- Self-priming water pumps.

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 threshold is established for the five water pump types abovementioned 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 the next 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 up to 136 TWh in 2020 if the Regulation would have not been established and implemented. Projected savings 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)[1]. 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 Extended Product Approach (EPA).

The impact of the Regulation in terms of energy savings has not yet been made available publicly or yet assessed, but according to Europump[2], the greatest expected saving potentials rely on introducing the concept of Extended Product Approach (EPA) to pumps covered by Lot 11 preparatory study, estimated as 35 TWh. Furthermore, the agreed 40% cut-off applied at Tier 2 was on the understanding that EPA would be integrated in the future Regulation to reach higher efficiency levels for water pumps, and 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[3]. The inclusion on this present review is primordial to assess whether higher potential savings could be achieved, apart from extending the scope of the present Regulation. 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 from Denmark[4] and the EU[5,6,7,8] 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, it is suggested to specifically request in the Annex IV of the Regulation that the manufacturers provide the verification information (requested in Annex IV) categorised in the same way as the Regulation and make this obligatory. The

[1] Commission staff Working Document – Impact Assessment – Ecodesign requirements for water pumps (2012)
[2] Europump position papaer on the review of Regulation (EU) No. 547/2012, available at: http://europump.net/uploads/Europump%20position%20paper%20LOT%2011%20review.pdf
[3] UK comments on motors, pumps, fans and circulators 180608 – Lot 11
[4] Note to the Danish Secretariat for Ecodesign and Energy Labelling of products (SEE) on April 2014 (available by request, in Danish)
[5] Provided by Europump, on the status meeting for pump review study held in Brussels on the 17th of March
[6] 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
[7] Frequently Asked Questions (FAQ) on the Ecodesign Directive and its Implementing Regulations – Commission Regulation (EC) No. 547/2012
[8] German comments EuP-Lot 11_pumps, on ecodesign requirements for single stage end suction, vertical multistage and submersible multistage pumps, 110608

compliance with this requirement should also be checked by Market Surveillance Authorities. In this case it is necessary to establish a dialogue with the manufacturers already in this review study, to consult the application of the suggested nomenclature with them. Furthermore, it is suggested to encourage them to provide the categorisation of their pumps on their websites, to make this information readily available. An overview of the pumps' nomenclature and their application is presented in the last section of this report ('final scope'). This will be discussed with the stakeholders and an overview of the common names used by manufacturers will be gathered. This will aim to make a list which the Market Surveillance Authorities can use to ensure they identify properly the pumps and their nomenclature at the time they check for this requirement.

- For big water pumps which are often custom made (i.e. 'engineered products') and catalogues and websites only are dealing with major groups (product families) and types of pumps, it is usually difficult to make an unambiguous identification of the individual pump model for market surveillance purposes. To identify the individual pump model it is necessary to find its product number which provides the unique identification. The product number can only be determined when the pump is dimensioned from the pump's flow and pressure (head). In these cases it is necessary to establish contact with the pump's supplier to obtain this information, or to use a dimensioning tool for establishing the pump's dimensions.
- In some of the collected experiences it was difficult for the manufacturers to understand the fact that, if their pumps have other applications besides pumping clean water, the pumps shall still comply with the relevant requirements in the Regulation (EC) 547/2012. Misunderstandings related the use of clean water pumps to also pump chemicals, drinking water and other type of fluids. In the case that a particular pump is designed only for one purpose which is excluded from the scope of the Regulation (e.g. use in ships as means of transport or pumps specially designed for petrochemical or pulp and paper applications), it is suggested that this should be stated on the packaging and in the technical documentation of the pump to avoid misunderstandings.
- Water pumps designed for some special purposes like pumps for off-shore and 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[6], if they are pumping clean water as defined in the Regulation and fall within its scope, they are obliged to comply with the minimum efficiency requirements.
- 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.
- It is important to make additional efforts to make sure that the suppliers of water pumps deliver all the necessary technical documentation, as it has been observed in Denmark that this is not always the case. This includes not only manufacturers, but also importers.
- When pumps are sold as integrated products in other machinery and are therefore obliged to comply with other legislation (e.g. Machinery Directive 2006/64/EC), it is recommended that a complete declaration of conformity according to the Ecodesign Directive is issued by the pump manufacturer, separately from a declaration of incorporation for the integrated pump for other relevant legislation.
- When clean water pumps are sold with a nominal speed other than what declared in the Regulation, it is recommended that the pumps are either 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}), or just tested at the Regulation's values and not at their own. 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[6] 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[8] 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.

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:

- 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.
- The absence of multistage horizontal pumps, as horizontal multistage pumps can be used for the same purposes as multistage vertical pumps.
- The delimitation of the nominal outer diameter for submersible multistage borehole pumps and of range (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.

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 previous preparatory studies, 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 performance 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 Extended Product Approach.

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[9] 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

[9] 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 itself 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 drink water but it is not limited to it. Any water type that fulfils these specifications is clean water.

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 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.
- **Centrifugal submersible pumps (mixed flow & axial pumps)**: same sealed submersible unit as previous pump, also 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 applications.
- **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. 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.
- **Centrifugal submersible domestic drainage pumps (<40 mm passage)**: pumps that form a pressure-tight encapsulated unit with the motor, fully flood-proof, with motor housing constructed from corrosion resistant material, and the outer jacket and impeller of durable plastics; 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, as 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.

An alternative to measure these four wastewater characteristics every time a pump is to be chosen is to establish a scheme to correlate energy efficiency of wastewater pumps with an overall solid content of the wastewater (amongst other pump functionalities)[10]. 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 be only possible if harmonised definitions of the solids' content of different wastewater types are available, so 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.

In this regard, Lot 28 provides a qualitative classification based on The Urban Wastewater Treatment Directive (UWTD)[11] as:

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

Two additional wastewater types are specified for water pump applications:

- Commercial wastewater

[10] 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

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

- Municipal wastewater

The definitions provided in the UWTD are purely qualitative and until today no 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 Lot 28 preparatory study are available.

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 information publicly available:

- *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).

In a letter communicated to the study team by Europump[12], it is suggested that a similar approach as that 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, 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 specific pump types assessed and suggested classification 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 or to about 3 kW (with built-in strainer); they are sold for residential use (commercial premises use standard water large pumps) which can also be used for Jacuzzis.
- **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

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

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**: submersible circulating pumps which are emptied each time after use.
- **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.
- **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, as it needs to fulfil special hygienic requirements. Swimming pools require special chemicals for maintaining the water disinfected providing it remains recirculating in the same place and it may therefore not be enough with defining swimming pool water by specific levels of absorbance and dissolved solids as for clean water.

A range of values in terms of water clarity, colour, turbidity, pH, chlorine and other quantitative parameters have been defined for the future EN standard on domestic swimming pools[13], which is expected to be available in March 2016. This set of values could be used as reference to define quantitatively swimming pool water, as it is expected that the performance of the swimming pool pump would be greatly influenced

[13] 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

by the achievement of these swimming water characteristics, as for these systems water quality is of extreme importance.

For a complete overview of the pump types included in the Regulation and in the studies, please see Table 1.

Table 1: 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	
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

Other categorisation

Categories by working principle

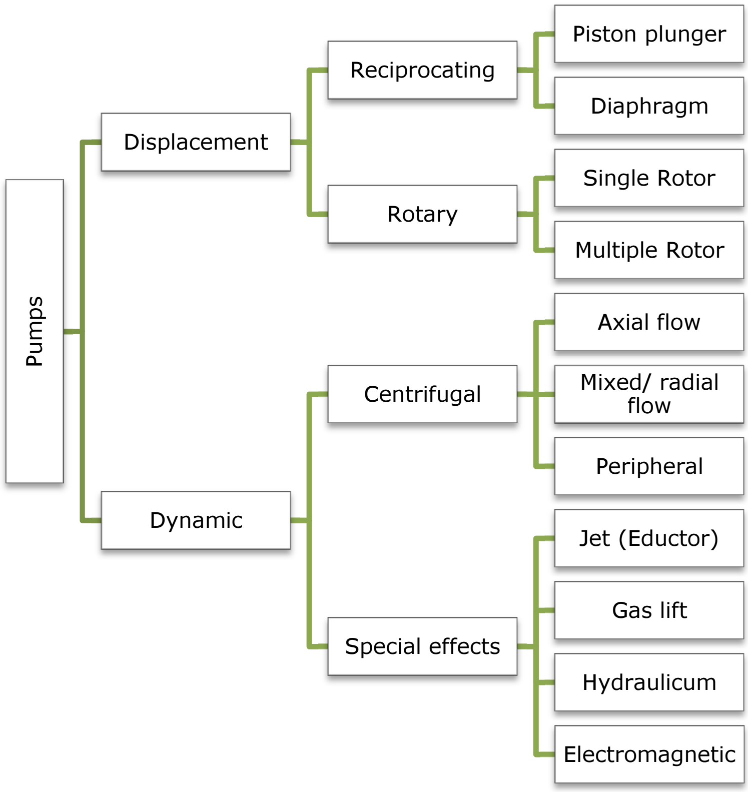

Figure 1: Classification of pumps by working principle according to Europump[14]

Categories by application

Pumps are used for a wealth of applications, too many to list them all. Just to give an idea of the range, the list below gives some examples. Note: this list is not exhaustive, and it is based on a combination of sources[15]:

- Agriculture
- Automotive industry
- Beverage industry
- Biochemicals
- 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
- Pharmaceutical industry
- Power generation

[14] http://europump.net/uploads/Classification%20of%20Displacement%20Pumps.pdf
http://europump.net/uploads/Classification%20of%20dynamic%20pumps.pdf

[15] Such as the IPPC BREF documents (http://eippcb.jrc.ec.europa.eu/reference/), manufacturers overview of application areas of their products, product brochures, etc.

- Private housing
- Wastewater transport and flood control
- Water distribution

In Denmark, the energy consumption for pumps in each sector has been estimated[16]. Using these data as an example, the relative importance of each sector can be shown (see Figure 2). It should be noted that pumping usages include circulators (covered by Regulation 622/2012) and the pumping of other liquids than water. This estimation shows that industrial pumping usages are the most important application in Denmark, in terms of energy consumption. A reliable source for establishing a quantitative estimation at EU level was not found, however, it is assumed that there are minor differencies between Denmark and EU regarding consumption patterns, for example, concerning industrialised agriculture where the relative share may be larger in Denmark (the share of agriculture in the GDP is 1.5 % for Denmark and 1.2 % for EU-2717). For manufacturing the difference is smaller, it stands for 25 % of the Danish non-finacial business economy, while it is about 28 % of the EU non-finacial business economy18. Based on these limited indicators it is assumed that Denmark compares to EU in so far that energy consumption for pumping is mostly used in the industry and secondly in agriculture, private housing, and utilities.

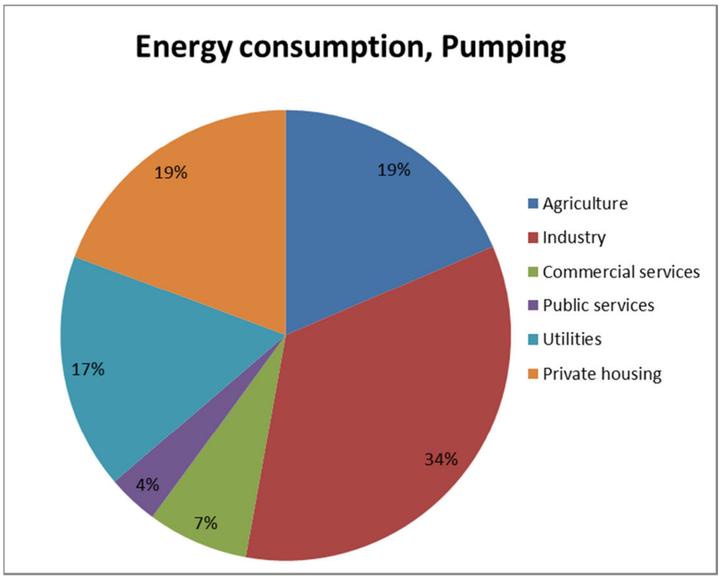

Figure 2: Overview of energy consumption for Denmark by pumps and circulators of liquids (incl. water)

3.2 Overview of product performance parameters

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

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[16] Kortlægning af Energiforbrug i Virksomheder (Mapping of energy consumption in companies), The Danish Energy Agency (2015)

[17] From page 5 in the document available at: http://ec.europa.eu/agriculture/statistics/agricultural/2013/pdf/b0-1-2_en.pdf

[18] From page 56 in the document available at: http://ec.europa.eu/eurostat/documents/3930297/5967534/KS-ET-11-001-EN.PDF/81dfdd85-c028-41f9-bbf0-a9d8ef5134c5

parameters identified from Lot 11, Lot 28 and Lot 29 as these parameters define what the water pump does, which is to pump a "quantity of water at the specified head (pressure), (m^3/h, m)". Efficiency is not a primary functional parameter as 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 is also defining what the pump has to do.

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 considered for inclusion in a future Regulation from previous preparatory studies is presented in the Table 2.

Table 2: 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		
Bearing arrangements	X		X
Net Positive Suction Head (NPSH)	X	X	X
Noise	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	
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

The definitions of these parameters are described below.

- Pump speed. 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, so that the initial price advantage can be lost in a short time by increased energy costs.

- Fixing dimensions. Pumps which are manufactured 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 downthrust and the weight of the pump rotating element, with a small thrust ring in the top of the pump to resist upthrust 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 1m 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.

- 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.

- 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.

- Seal arrangements. The pump shaft must be sealed to minimise leakage 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. However, 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 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 Bearings pumps, the coupling spacer is removed and the pump rotating element can then be withdrawn without disturbing the motor or the pipework. 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.

- 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. In order to achieve this, the impeller should be suitably sized to allow solids to pass between the gaps between the vanes. Some pumps will have the ability to cut larger solids into smaller pieces, which can fit through the impeller.

- 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 pump 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, as 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.
  $SP = \omega \times T$
  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.
  $HP = Q \times \Delta p$
  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.

- Part load behaviour. Throttled down to around half flow, a fixed speed pump can become noisy (see 'Noise' below) 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. However, 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.

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

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

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 prEN 16480:2012, 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 extended product approach is required.

CEN TC 197

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 3 working groups[19] shown in Table 3.

Table 3. 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 1 Pumps

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

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

Standards under development by this working group[20] and under Mandate 498:

- *FprEN 16480 (WI 00197087) "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.[21].
- *(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 (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 in the drafting phase, the scope of these two test standards will follow the scope mentioned in prEN16480 and it therefore follows Mandate 498.

An overview of published standards under CEN TC 197[22], as well as an overview of those mentioned in Lot 28 and Lot 29 is presented in Annex 1.

Swimming pool standards

According to EUSA Pool Pump Working Group[23], 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
- Minimum turnover times (i.e. 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.

FprEN 16713 (Decision C04/2015) 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 is expected to be available in March 2016. 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

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

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

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

23 EUSA Pool Pump Position Paper, Paris, 23/10/2015

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 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.

FprEN 16713 (Decision C04/2015) 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 is expected to be available also in March 2016. 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.

FprEN 16713 (Decision C04/2015) on Domestic swimming pools – Water systems (part 3: Circulation systems – Requirements)

This third part of the standard has been prepared by the Technical Committee CEN/TC 402 on "Domestic Pools and Spas" and is expected to be available also in March 2016. It specifies requirements and test methods for equipment and means of pool water treatment utilised in domestic swimming pools, with the purpose to ensure a consistently high quality of pool water in terms of hygiene. 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).

Maximum values for water characteristics of the fill water of the pool (i.e. water used for the initial filling and for topping up) are defined, 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 monitor water quality.

Other performance/categorisation standards

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

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.

This International Standard specifies three levels of acceptance:

- 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.

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 extended product approach; Water Pump Regulation 547/2012, 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 (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 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[24] 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[25] under category 6 and 9 of "Annex I and II"[26]
- 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

Legislation and agreements at Member State level

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

Legislation and agreements at third country level

Energy Conservation Standards for Pumps - United States

The Department of Energy in the US published a proposal for Energy Conservation Standards for Pumps on 18 March 2015. DOE is scheduled to publish a final rule by the end of 2015, and the standards would take effect late 2019.

The proposed scope of this standard[27] is:

- End suction close coupled,
- end suction frame mounted/own bearings,

[24] 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.

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

[26] 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).

[27] http://www.Regulations.gov/#!docketDetail;dct=FR%252BPR%252BN%252BSR;rpp=10;po=0;D=EERE-2011-BT-STD-0031

- in-line,
- radially split, multi-stage, vertical in-line, diffuser casing diffuser, and
- vertical turbine submersible.

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 0.25 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, and disregarding any additives necessary to prevent the water from freezing at a minimum of -10 °C.
Furthermore, DOE proposes to set energy conservation standards only for pumps with the following characteristics:

- 1-200 hp (shaft power at BEP at full impeller diameter for the number of stages required for testing to the standard);
- 25 gallons/minute and greater (at BEP at full impeller diameter);
- 459 feet of head maximum (at BEP at full impeller diameter);
- Design temperature range from -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 2,880 and 4,320 revolutions per minute and/or 1,440 and 2,160 revolutions per minute[28;] and
- 6 inch or smaller bowl diameter (VT-S/HI VS0).

Outside the scope of the proposed standard is:

a) fire pumps;
b) self-priming pumps;
c) prime-assist pumps;
d) sealless 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).

Pump energy index
DOE's proposals consists of 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 minimally 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 best efficiency point (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.

[28] The CIP Working Group recommendation specified pumps designed for nominal 3600 or 1800 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 NOPR contains additional details.

The C-values proposed by 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), and Vertical Turbine Submersible (VT-S) equipment classes. The C-values for the Radial Split Multi-Stage Vertical In-Line Casing Diffuser (RS-V) equipment class were targeted to harmonize with the standards recently enacted in the European Union[29], as models in the RS-V equipment class are known to be global platforms with no differentiation between products sold into the United States and European Union markets.[30]

Energy star for swimming pool pumps – United States

ENERGY STAR[31] is a trusted, US-government-backed symbol for energy efficiency helping save money and protect 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
- 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[32], 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[33]. 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)[34].

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[29] 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.

[30] 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.

[31] www.energystar.gov

[32] https://www.energystar.gov/sites/default/files/asset/document/pool_pump_factsheet_1_0.pdf

[33] https://www.energystar.gov/productfinder/product/certified-pool-pumps/results

[34] https://www.energystar.gov/index.cfm?c=poolpumps.pr_crit_poolpumps

APSP has an Appliance Efficiency Pool Pump Database publicly available[35], which was last updated in November 2015. The database shows all energy compliant[36] 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

The series of standards were developed from the desire of the Australian government to improve the energy efficiency of appliances in households, being swimming pool pumps 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}

[35] http://apsp.org/resources/energy-efficient-pool-pumps.aspx
[36] Compliant with the ANSI/APSP/ICC-15 2011

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

4.1 Terminology (power)

The power of a pump unit can be described either as (see Figure 3):

- P1, the electric power supplied to the motor (or to the 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

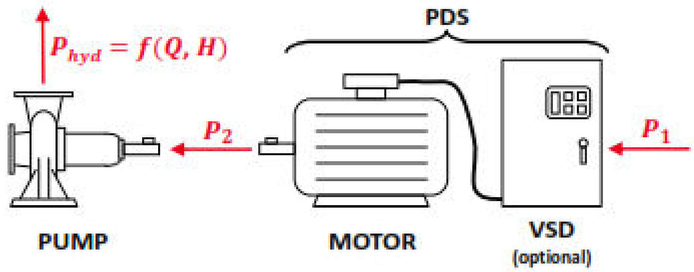


Figure 3. Schematic of the power flow on a pump unit

The relationship between the values at a given load is:
$P_{hyd} = P_2 \cdot \eta_{hyd}$, $P_2 = P_1 \cdot \eta_{motor}$ or $P_{hyd} = P_1 \cdot \eta_{motor} \cdot \eta_{hyd}$

Here η_{hyd} is the hydraulic efficiency of the pump and η_{motor} is the efficiency of the motor (or motor with 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 have 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 $\eta = \frac{P_{hyd}}{P_1} = \eta_{motor} \cdot \eta_{hyd}$ and the best efficiency is at BEP:

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

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.

4.2 Performance parameters

The performance parameters can be determined from different approaches. In a normal approach the focus is on how the product itself performs, this is the product approach. For water pumps the overall performance 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 a system approach or an extended product approach. In general there are three approaches[37]:

- The Product Approach focuses on the efficiency of the pump alone
- The Extended Product Approach is focused on the extended product i.e. pump, motor and VSD (when applied)
- The System Approach focuses on optimising the pumping system

If the product approach is used for Ecodesign regulations, the regulation can ensure that only energy efficient pumps are put on the marked, but that does not ensure lowest 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. If the pump is connected to a fix speed motor, the pump 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) the rotational speed of the motor can be adjusted to the demand in a variable flow system and thereby have a lower energy consumption (illustrated in Figure 4). Energy consumption is proportional with the pressure, so lower pressure means lower energy consumption[35].

The Ecodesign regulation targets the products that are place at the marked and not directly how they are used, therefore a system approach is not viable for the Ecodesign regulation. However, since water pumps are normally sold together with a motor, with or without speed control, it feasible to implement an extended product approach in the regulation.

In the process for implementing EPA in the EU regulation work is progressing in two parallel tracks. Europump has initiated the development of a guide, which is a helpful tool to create a common understanding of the subject and guide the process towards developing actual standards. In parallel the European Commission has issued Mandate 498 which aims to create harmonised standards covering an extended product approach.

In the Europumps guide, an Extended Product Approach (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.

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

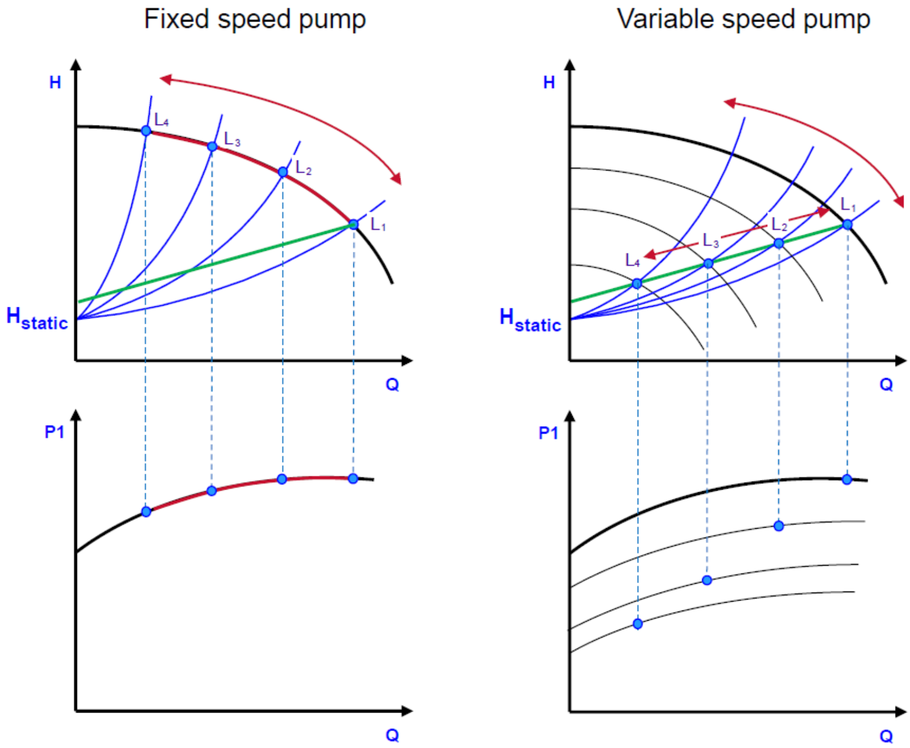


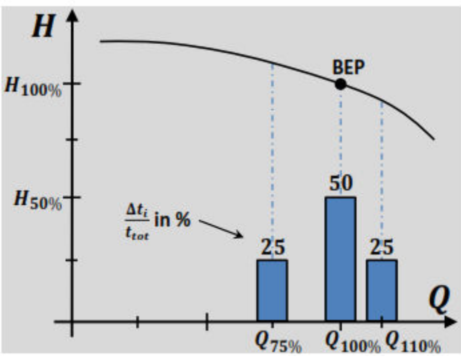
Figure 4: Illustration of operation with fixed speed pump and variable speed pump.

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.

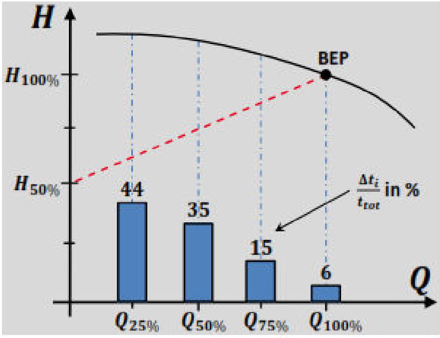
For both type of systems typical, standardized flow-time profiles and reference control curves are defined and used to calculate the corresponding EEI. The flow-time profile describes the percentage of time a certain flow is needed in the system. The reference control curve is a standardized control curve, which describes the desired head at the flows defined in the flow–time profile.

Table 5 and Figure 6 show the flow-time profiles for constant and variable flow systems as they are defined in Extended Product Approach for Pumps, A Europump Guide, October 2014[37]. Notice that the flow-time profiles are defined as step-functions with in these cases either three or four steps.



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

Figure 5: Flow-time profile for constant flow systems.



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

Figure 6: Flow-time profile variable flow systems.

4.3 Energy Efficiency Index - EEI

To evaluate the energy efficiency according to EPA, the concept of 'Energy efficiency index' (EEI) has been developed. EEI represent the overall energy efficiency of the extended product calculated according to the intended flow-time profile. 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 7[37]. 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.

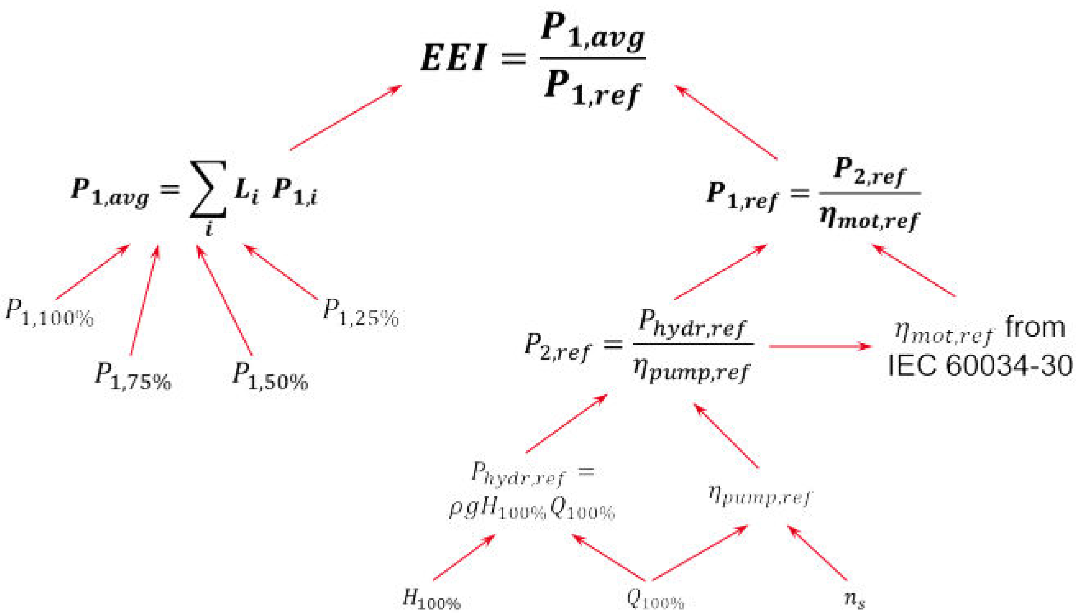


Figure 7: Graphical representation of the Energy Efficiency Index (EEI).

$P_{1,i}$ represent the power input at the i^{th} load level. L_i represent 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 ($\eta_{pump,ref}$). $P_{hyd,ref}$ is derived from the reference flow rate ($Q_{100\%}$) and head of the pump, and $\eta_{pump,ref}$ from the reference flow rate and the nominal speed of the pump (n_s).

4.4 EPA in ecodesign

Figure 8 below shows the road map for ecodesign requirements for pumps as imagined by Europump. The steps regarding EEI for circulators and MEI for water pumps represent the present situation.

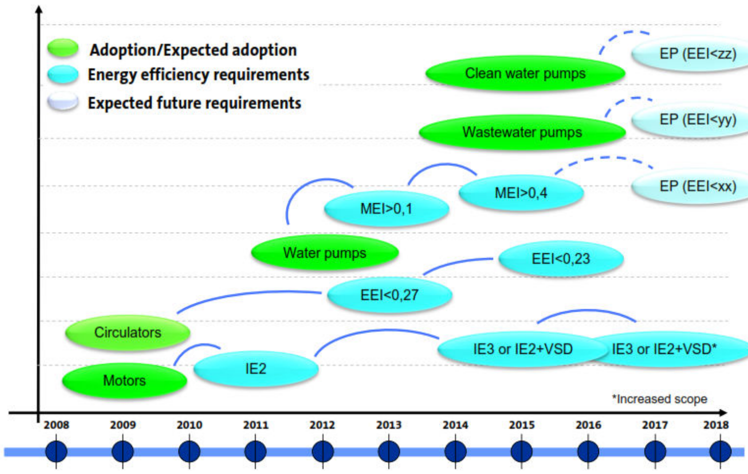


Figure 8: Roadmap for eco-design requirements on pumps in EU.

As with circulators it is feasible to apply EEI requirements for water pumps. Water pumps are used for many different purposes with different requirements and loading patterns and therefore more complicated to evaluate.

As discussed above there are defined different flow-time profiles which are used to evaluate pumps that are either used in constant flow application or variable flow applications. With this division it is possible to compare how well pumps are performing in each application with EEI. Thereby EEI will be an appropriate comparison method for clean water pumps.

Part of Mandate 498 is to create an extended product approach for the water pump categories that are within the scope of Regulation 547/2012 (clean water pumps)[38]. The Working Group of CEN is working on the draft EPA part 1 (General requirements and procedures for testing and calculation of energy efficiency index (EEI)) and part 2 (Testing and calculation of energy efficiency index (EEI) of single pump units). These standards are expected to be publicly available in 2017 (as the last forcasted voting date is October 2016)[39]. It is therefore expected that they can be implemented in a future regulation in 2018.

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 necessary to gain sufficient information to calculate the EEI values of the pumping units available on the market. Thereby it can be determined how large a share of the market which can meet the requirements of a given EEI value.

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[38] http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=select_attachments.download&doc_id=1406

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

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[40]. 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. 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 pumps' 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 pumps' efficiency.

4.5 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 speed systems will have an EEI according to the variable speed flow-time profile. This will ensure that pumps for variable speed applications will be ranked according to how suited the applied motor technology is for variable speed 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 a higher EEI ratings for variable speed applications, but a lower EEI for constant speed systems. Other variations in motor technology 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 replaced with pumps that are fitted with VSD and all pumps for constant speed applications are replaced with pumps fitted with the most efficient motor technology category. The EPA energy savings that are estimated are those savings that can only be achieved with EPA and not by a normal product approach. Therefore only potential improvement regarding motor technology is considered while potential improvements on the pump itself is not considered here.

For the clean water pumps within the scope of this study, the total energy consumption is estimated at 216 TWh/year, of which 121 TWh/year is for variable flow applications and only 95 TWh/year is for constant speed applications (i.e. by switching to the best motor technologies, see chapter 9 on Final Scope).

For swimming pool pumps the estimated energy consumption is 8.9 TWh/year, but the potential energy savings is much smaller, since most swimming pool pumps are considered to be operating with constant flow (in the EU)[41]. Therefore the estimated EPA savings potential are estimated to be 0.41 TWh/year (see Final Scope chapter).

For wastewater pumps (including slurry pumps) the total energy consumption is estimated to 33 TWh/year, of which only 1.83 TWh/year are from variable flow applications and 31.9 TWh/year are from constant flow applications. The industry have

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[40] Input from representatives of wastewater manufacturers
[41] According to the WG of EUSA to the "Review study of ecodesign and energy labelling for pumps", 13/11-2015

assessed that all wastewater pumps besides slurry pumps have VSD when applied in variable flow applications and therefore there no additional potential savings.

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 somewhat 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.

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 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

Third countries legislation

The reviewed legislation in third countries (i.e. 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 Label Comparative in Argentina which covers all centrifugal pumps (mandatory), the schemes in Bangladesh which cover all types of water pumps over 2 HP (voluntary), the Label Endorsement 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), water source heat pumps (China), 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.

Lot 28 & Lot 29

Ambiguities in previous preparatory studies have also been identified by Europump[42] and during the execution of this study. These are related to the following topics:

[42] Letter sent to Viegand Maagøe, dated on the 17th March, 2015

- 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 particularly in large industrial applications.
- The lack of distinction between 'wastewater' and 'high solids fluids', as the centrifugal dry well pumps are used for both and the submersible dewatering pumps and slurry pumps are used only for 'high solids fluids'. This may lead to the question on what is 'solid' and what is 'liquid' (the Regulation only applies to water pumps). 'High solids fluids' include sand water, grit water and slurry.
- 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

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 of a specific type of water** to be pumped at the **specified head** (pressure) 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.

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. In spite of this, it is suggested to group the pump types according to the water types the pumps are handling.

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. A list of secondary parameters has been consolidated from all the preparatory studies. From this a selection is presented below, considering their relevance to the evaluation of the pumps' energetic performance, their design and their lifetime:

- *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).
- *Best Efficiency Point (BEP),* the operating point of the water pump at which it is at the maximum hydraulic pump efficiency measured with clean cold water of characteristics defined in the EC Regulation 547/2012.
- *Pump Part load (PL)*, the operating point of the water pump at 75% of the flow at BEP.
- *Pump Over load (OL),* the operating point of the water pump at 110% of the flow at BEP.
- *Minimum Efficiency Index (MEI),* the dimensionless scale unit for hydraulic pump efficiency at BEP, PL and OL.
- *Expected lifetime of the pump,* explained previously.
- *Variable Speed Drive (VSD),* explained previously.
- *Material requirements,* explained previously.
- *Maintenance needs,* explained previously.

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 a significant share of the total energy consumption of pumps in the EU[43] (those contributing less than 0.5% of the total energy consumption of pumps have been excluded);

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 were excluded in the preparatory studies, have been added to the 'preliminary' scope of this study. 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 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

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

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 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[44] significance in terms of energy 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.

[44] From discussions with Europump

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 ʼpreliminaryʼ 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.

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[45].

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[46]. 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 capacity's annual energy consumption for Lot 28 pumps by adding this 20% value to the

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

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 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[47]. 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[48].

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. 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 units' average electrical energy consumption are presented at Table 19 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).

Estimated energy savings potentials

The methods of 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[49] (maximum energy efficiency projected by 2015[1]). 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 less efficiency are replaced.

In Lot 28 the energy saving potentials has been estimated from improving the pump itself and from an extended product approach[50]. 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[51]. 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 been calculated for several key years[52]. In these

[47] Lot 29 task 4, section 4.4.1
[48] Lot 29, table 1-3
[49] Lot 11, table 8-7
[50] Lot 28, table 8-1
[51] Lot 28, table 7-1 to 7-8
[52] Lot 28, figure 8-1 to 8-7

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[53]. For each pump category a certain percentage values was assumed as improvement potential and as potential energy saving from implementing EPA on the Regulation. The potential energy savings 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[54]. 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 based on potential improvements information at pump level found in the literature.

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 Variable Speed Drives (VSDs).

All these figures were then multiplied with present stock (discussed in task D2 in this report). The different levels of electrical energy consumption are presented at Table 19 in task D4 and a detailed explanation of the methodology for calculating savings potentials at EU level is presented at the last chapter of this report (i.e. Final scope).

[53] Lot 29, table 5-1
[54] Lot 29, figure 8-4 to 8-6 + figure 8-10 to 8-11

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).

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:

1. To place the pumps in scope of this study[55] within the total context of EU industry and trade.
2. To 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.
3. To 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.
4. To 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, as 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 PRODCOM database and reported by Member States to Eurostat. See Figure 10 and table 4 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 9 and Figure 10 below for the total production, import and export in quanitity and in value (EUR) of pumps in scope of the study.

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

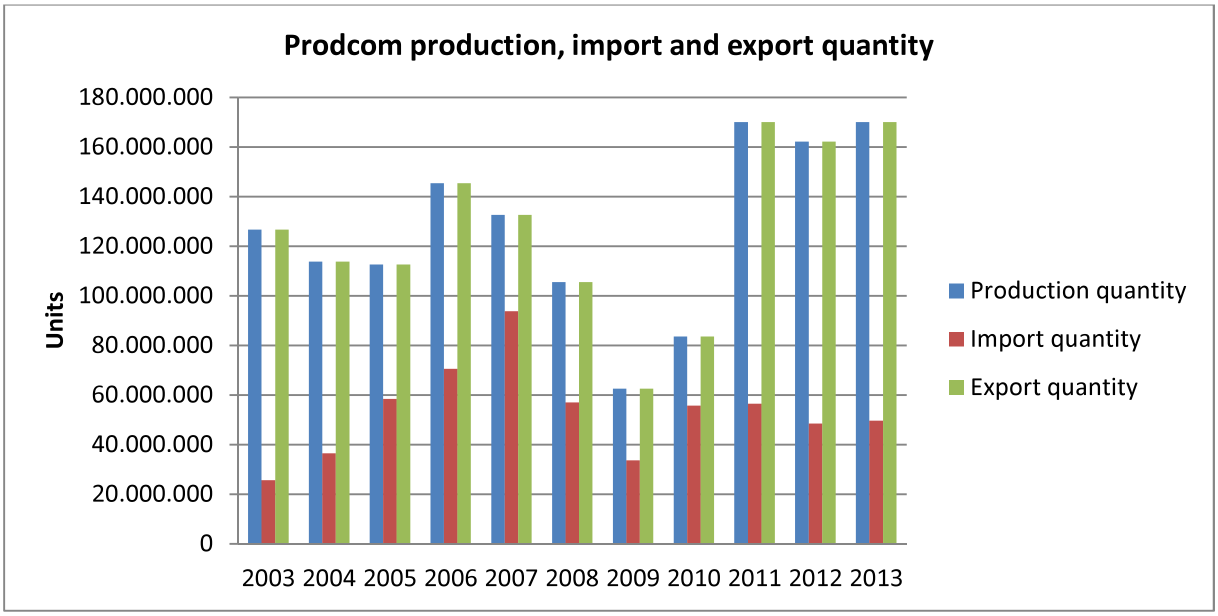

Figure 9. Total production, import and export quantity of pumps in scope 2003 -2013.

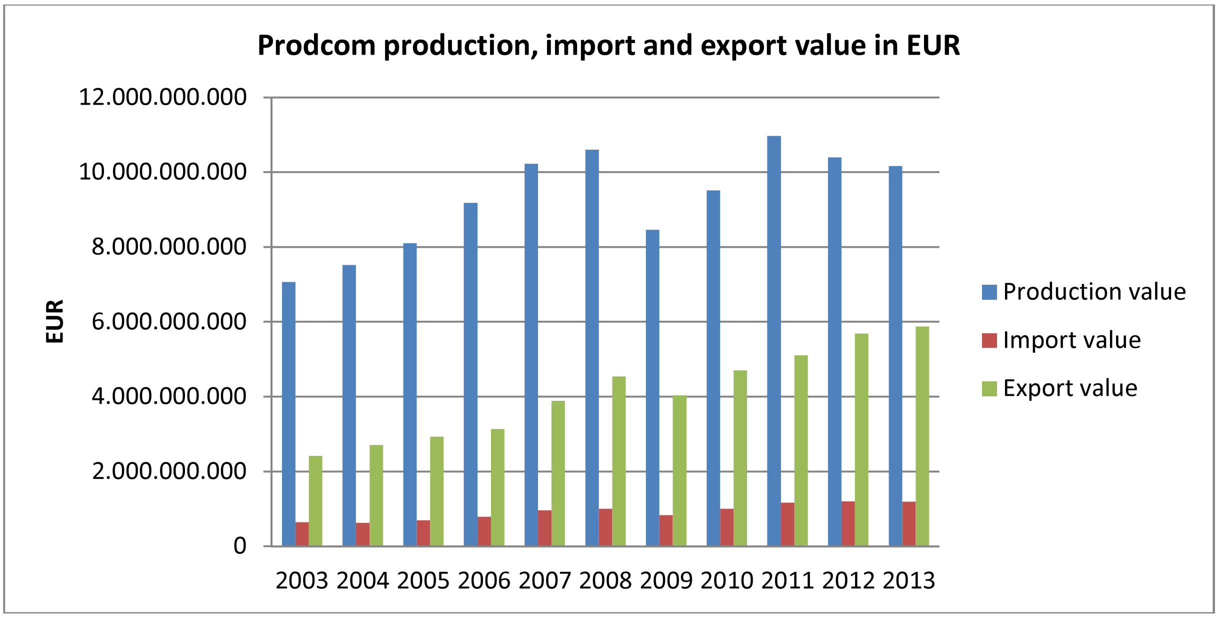

Figure 10. Total production, import and export value in EUR of pumps in scope 2003-2013.

Table 4 EU sales and trade of pumps in scope for EU-27, 2005 – 2013 from Prodcom (units)

Prodcom Code	Description	2005	2008	2010	2013
28121320	Hydraulic pumps (radial piston)	1,735,664	2,629,945	2,726,373	2,558,244
28121350	Hydraulic pumps (gear)	12,226,250	5,080,378	4,098,146	3,130,061
28121380	Hydraulic pumps (vane)	32,178,307	15,963,933	8,859,509	1,942,641
28121530	Hydraulic pumps (axial piston)	87,050	113,006	53,889	101,233
28121580	Hydraulic pumps (excluding axial, radial, gear, vane)	27,636	280,072	145,417	546,722
28131250	In-line reciprocating piston pumps	-	-	249,456	1,174,020
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
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		103,054,659	111,916,907	72,399,462	158,372,390

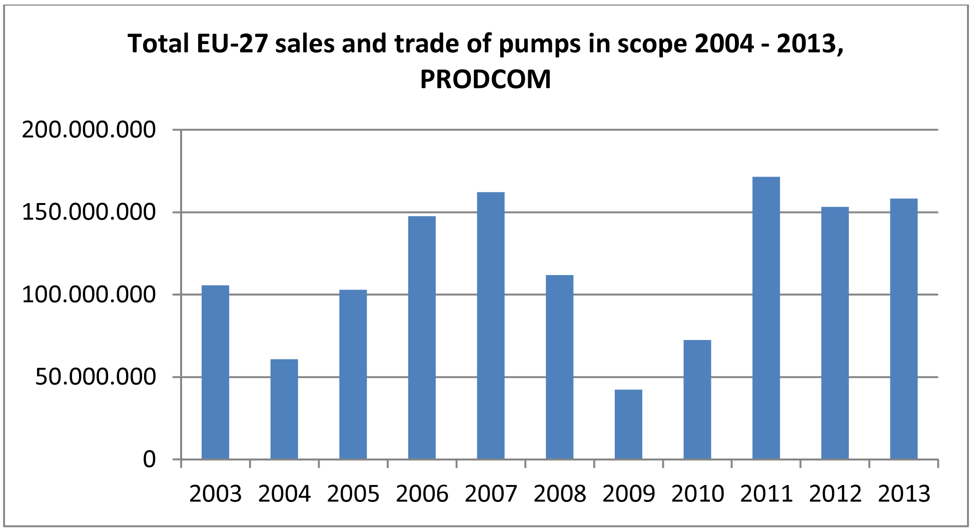

Figure 11 Total EU-27 sales and trade of pumps in scope 2005 – 2013 retrieved from PRODCOM database (without negative sales and trade figures)

The Europump Working Group (WG) 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 confusions when selecting pump categories. New pump categories were defined by the WG and the study team, which are shown in Table 5.

Table 5. 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 where to be rank 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 to 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 6 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 6. Matching pump types in current study scope to the PRODCOM categories.

Prodcom Code	Description	How does it match pumps in scope of this study
28121320	Hydraulic pumps (radial piston)	Not possible to match
28121350	Hydraulic pumps (gear)	Not possible to match
28121380	Hydraulic pumps (vane)	Not possible to match
28121530	Hydraulic pumps (axial piston)	Not possible to match
28121580	Hydraulic pumps (excluding axial, radial, gear, vane)	Not possible to match
28131250	In-line reciprocating piston pumps	Not possible to match
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	• Dry well pumps for storm water, mixed flow and axial • Dry well channel pumps for wastewater • Dry well vortex pumps for wastewater • ESOB pumps • ESCC pumps • ESCCi pumps • Vertical Multistage pumps • Horizontal Multistage pumps
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	Not possible to match

Prodcom Code	Description	How does it match pumps in scope of this study
	mm, single-stage with double entry impeller	
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 present 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. Members from the European Union of Swimming pool and SPA Association (EUSA) also provided data. The working groups provided estimated the sales numbers and energy consumption data for each subcategory of pumps.

When Europump performed the data collection member companies had the total market of the European Union (EU28) in view and reported 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[56]). 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 represent 14 national organisation from EU and 3 non-EU national organisations (Switzerland, Russia and Turkey). The 14 national organisation represent the EU countries with the largeste pump manufaturing companies in EU.

In the swimming pool pumps Working Group (WG), members from the European Union of Swimming pool and SPA Association (EUSA) provided data for these pumps. This WG is estimated to represent about 85 % of the European market for swimming pool pumps[57].

Annual sales growth rate

New information on annual sales growth rate was not supplied by the industry in this study, therefore the findings from preparatory studies on pumps (Lot 11, Lot 28 and Lot 29), the impact assessment (Lot 11) and a report by the European Industrial Forecasting on the world's pump market[61] have been consulted.

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[56] The market share of the represented countries is stated in Lot 28 and Lot 29
[57] Information provided by EUSA WG

The market for ESOB, ESCC and smaller submersible borehole and multistage pumps for clean water had significant growth in sales around 2007 but it was anticipated that the sales would decrease and that possibly around present time to 2020 it will recover to a similar level as in 2007[58]. For the rest of clean water pumps in the scope of this project, the market is anticipated to have an annual growth rate of 3% from 2013 to 2040 for each of the pump categories [59]. For wastewater and sewerage pumps, the market is estimated to have a growth of 2-3% from 2012 to 2015 and this is expected to grow to 4-5% from 2015 to 2017 for each of the pump categories[60]. The report on pump market by the European Industrial Forecasting[61] shows that most Western European countries largely represented by the EU countries have increased sales in water and sewage pumps from 2006 to 2011 with an annual average growth rate of 2.21%. Lot 11 impact assessment shows a constant increase in sales for all categories of pumps from 1990 to 2020. The estimated growth rate per year from 1990 to 2006 is approximately 1.75%.

Based on the above findings, the calculation of sales and stock was done based on the next assumptions:

- From 1990 to 2006, all pumps in scope are modelled with a annual growth rate of 1.75%
- From 2006 to 2010, all pumps in scope are modelled with an annual growth rate of 2.21%
- From 2011 to 2030, an annual growth of 3% is modelled for clean water pumps and 4% for wastewater and slurry pumps

Annual total sales/real EU-consumption

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

Based on the abovementioned assumptions, Table 7 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 69% higher than those given in 2014. This is based on a constant growth which may not represent the market truly, but it is based on information provided in previous preparatory studies which was confirmed by Europump WGs (data on swimming pool pumps was not available and therefore the growth rate given in Lot 29 was used).

Table 7. Annual total sales estimate of pumps in scope for EU-27, 2014 -2030.

Water pump category	Size division	2014[62]	2020	2025	2030
ESOB pumps for clean water	Maximum shaft power ≤ 22 kW	225,000	268,662	311,453	361,059
	Maximum shaft power 22 - 150 kW	25,000	29,851	34,606	40,118
	Maximum shaft power > 150 kW	1,000	1,194	1,384	1,605

[58] Lot 11 preparatory study on water pumps
[59] Lot 29 preparatory study on clean water pumps
[60] Lot 28 preparatory study on wastewater pumps
[61] European Industrial Forecasting Ltd (2006), The World Pump Market 2006 – 2011 Volume I. Available at: http://pumpsystemsmatter.org/uploadedFiles/Pumps/Membership/Member_Services/Economic_Report_Services/EIFvolume1.pdf
[62] These sales figures are provided by Europump and EUSA Working Group based on their estimates for 2014.

Water pump category	Size division	2014[62]	2020	2025	2030
ESCC pumps for clean water	Maximum shaft power ≤ 22 kW	225,000	268,662	311,453	361,059
	Maximum shaft power 22 - 150 kW	25,000	29,851	34,606	40,118
ESCCi pumps for clean water	Maximum shaft power ≤ 22 kW	90,000	107,465	124,581	144,424
	Maximum shaft power 22 - 150 kW	10,000	11,941	13,842	16,047
Submersible borehole pumps for clean water	Nomilar outer diameter ≤ 6"	700,000	835,837	968,964	1,123,295
	Nomilar outer diameter 6" - 12"	12,000	14,329	16,611	19,256
	Nomilar outer diameter > 12"	450	537	623	722
Vertical multistage pumps for clean water	Maximum design pressure ≤ 25 bar	250,000	298,513	346,058	401,177
	Maximum design pressure 25 - 40 bar	2,900	3,463	4,014	4,654
Horizontal multistage pumps for clean water	Maximum design pressure ≤ 25 bar	-	-	-	-
	Maximum design pressure 25 - 40 bar	-	-	-	-
Self-priming waterpumps for clean water	Maximum shaft power ≤ 22 kW	-	-	-	-
	Maximum shaft power 22 - 150 kW	-	-	-	-
	Maximum shaft power >150 kW	-	-	-	-
Booster-sets for clean water	Maximum shaft power ≤ 150 kW	40,000	47,762	55,369	64,188
Swimming pool pumps (for filtration and circulation)	Maximum shaft power ≤ 2.2 kW	508,000	642,782	782,043	951,474
	Maximum shaft power > 2.2 kW	11,501	14,552	17,705	21,541
Submersible vortex radial pumps for wastewater	Maximum shaft power ≤ 10 kW	80,000	101,226	123,156	149,838
	Maximum shaft power 10 - 160 kW	2,400	3,037	3,695	4,495
Submersible channel radial pumps for wastewater	Maximum shaft power ≤ 10 kW	80,000	101,226	123,156	149,838
	Maximum shaft power 10 -25 kW	9,600	12,147	14,779	17,981
	Maximum shaft power 25 - 160 kW	5,000	6,327	7,697	9,365
Submersible pumps for activated sludge, axial	Maximum shaft power ≤ 160 kW	420	531	647	787
Submersible pumps for storm and effluent water, mixed flow and axial	Maximum shaft power ≤ 160 kW	280	354	431	524
Dry well pumps for storm water, mixed	Maximum shaft power ≤ 160 kW	100	127	154	187

Water pump category	Size division	2014[62]	2020	2025	2030
flow and axial					
Dry well vortex pumps for wastewater	Maximum shaft power ≤ 10 kW	10,000	12,653	15,395	18,730
	Maximum shaft power 10 - 160 kW	1,000	1,265	1,539	1,873
Dry well channel pumps for wastewater	Maximum shaft power ≤ 10 kW	10,000	12,653	15,395	18,730
	Maximum shaft power 10 -25 kW	4,000	5,061	6,158	7,492
	Maximum shaft power 25 - 160 kW	1,000	1,265	1,539	1,873
Submersible dewatering pumps (for water containing sand and grit)	Maximum shaft power ≤ 160 kW	40,000	50,613	61,578	74,919
Slurry pumps, light duty	Maximum shaft power ≤ 160 kW	1,500	1,898	2,309	2,809
Slurry pumps, heavy duty	Maximum shaft power < 160 kW	300	380	462	562
Total		**2,371,451**	**2,886,162**	**3,401,402**	**4,010,740**

Replacement sales

Overall, sales of products are combinations 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 sale to carry on with the stock estimation.

According to reparatory studies Lot 28 and Lot 29, the pumps sales in the EU-27 market are mainly for the replacement of old units. It is stated that in general 30% of the sales in 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 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.

For the stock model, all sales before 2014 are included to build up to the installed base of 2014. From 2014 onwards it is only the new sales which increase the size of the stock. 70% replacement sales and 30% new sales will be assumed, unless new information is supplied by industry stakeholders.

From Figure 12 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%), ESOB, ESCC and multistage pumps for clean water (each 11%). Other pump types are also included in total but the market share is very small 1% or less, and some are too small and therefore they have not been labelled in the chart below.

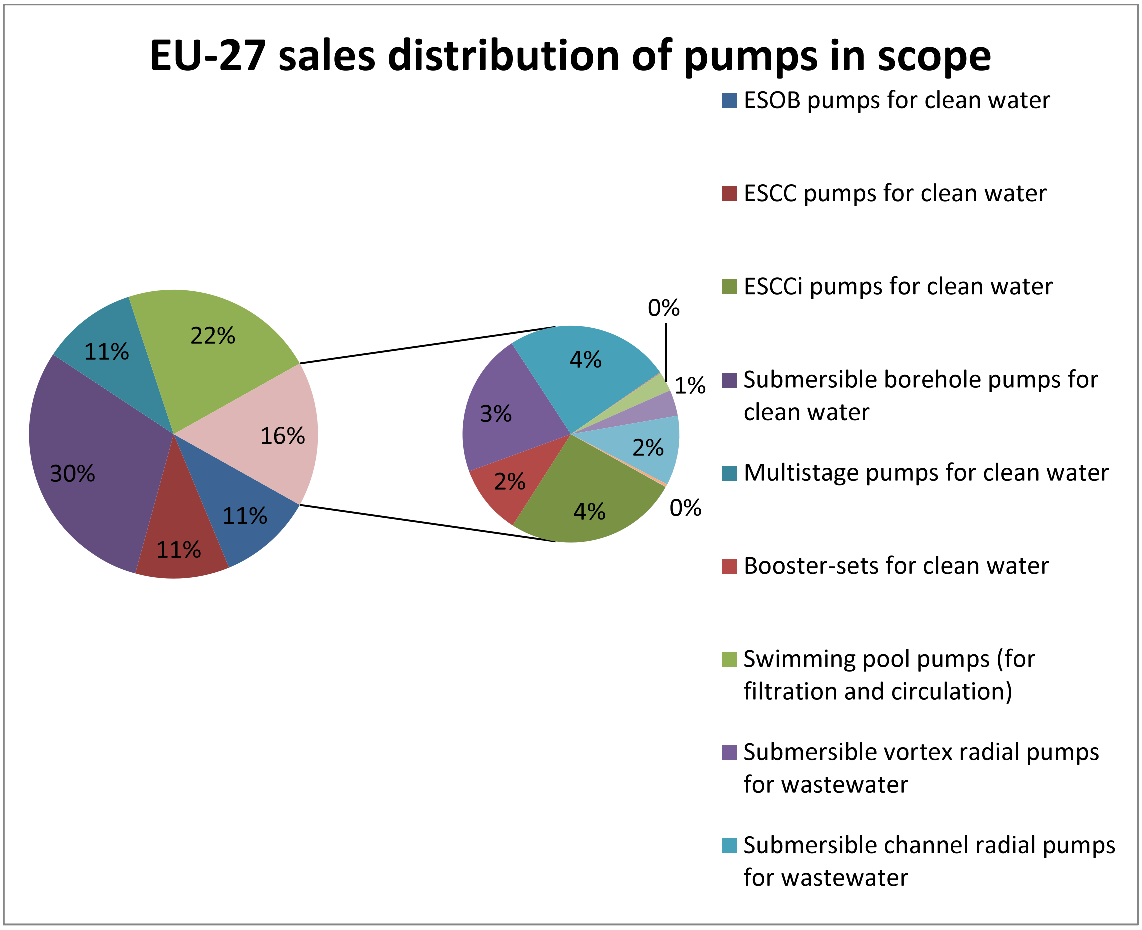

Figure 12. EU - 27 sales distribution of pumps in scope, 2014

The predicted economic life in service has been obtained from the industry. All pumps have a life time of between 10-25 years depending on the applications. Pumps for clean water tend to have shorter life time in service, and dry well pumps and slurry pumps tend to have longer life time. 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 9 for stocks.

Table 8. 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 waterpumps 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	10

Water pump category	Product lifetime, years
wastewater	
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

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, e.g. ESOB pumps for clean water stock for 2014 is calculated by summing the annual sales (excl. replacement units) from 2005 to 2014, and stock for 2015 by summing the annual sales from 2006 to 2015 and so on, based on a product lifetime of 10 years.

The stock from 1990 to 2013 is calculated based on the estimated stock for 2014 and the growth rates presented previously. See Figure 13 for the development the stock and sales from 1990 to 2030. In 1990, the estimated total stock of pumps in scope is approximately 13 million units and it is predicted to increase to 36 million by 2030.

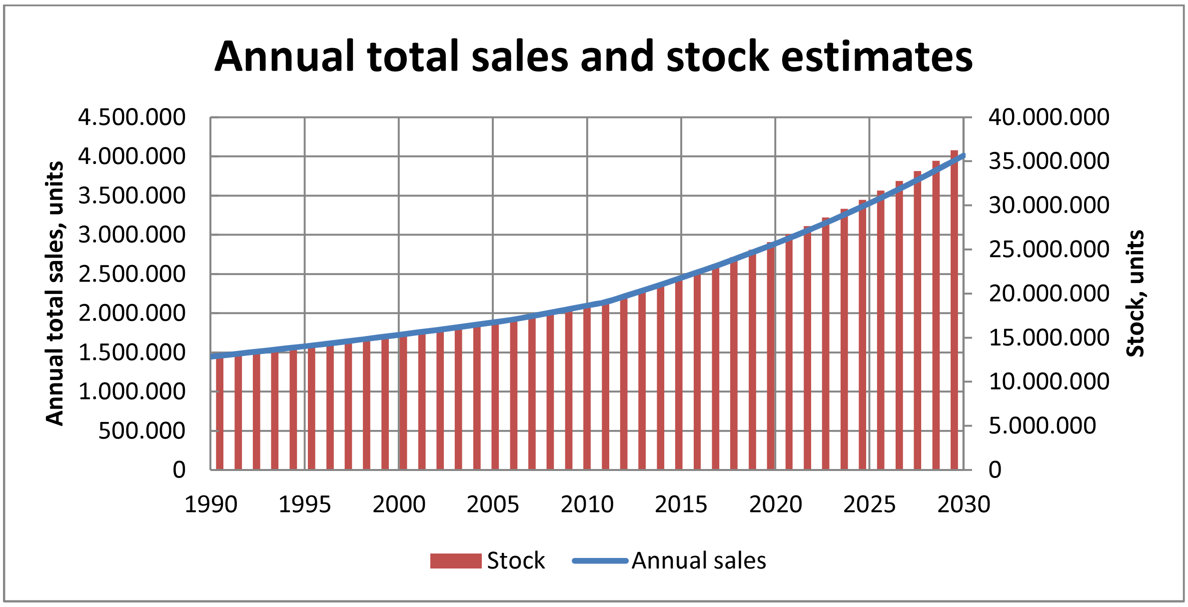

Figure 13. Estimated and projected annual total sales and stock from 1990 – 2030

The total installed base is different in comparison with the sum of that from previous preparatory studies (49.4 million units). This is because the current scope is different than what presented in the previous preparatory studies and the stock shown here is based on 2014 annual sales data. An observed picking-up in 2011 is due to the increased annual growth rate presented in previous sections (from 1.75% -1990 to 2006, to 2.21% -2006 to 2010- to 3-4% -2011 to 2030). Although the growth rate presented by the impact assessment shows a more conservative growth rate (1.75% as average from

1990 to 2006), both the European Industrial Forecasting[61] and previous preparatory studies as well as data confirmed by the Europump WGs have confirmed this growth has been bigger in the later years (based on data from 2006 onwards). The European Industrial Forecasting shows that, in spite of the economic crisis of 2008, the growth rate levels after 2006 are levelised into a slow but steady growth due to higher GDP growth in Eastern Europe and the stabilisation of oil prices at a lower level right after 2008 and until 2011. Finally, the growth rates after 2011, which have been provided by Europump WGs, are at similar levels of what other references report[63,64]. The McIlvaine Company analysis shows a global growth of water pumps' sales of up to 5-6% (being 73% centrifugal pumps)[64], whilst VDMA reports a moderate growth of liquid pumps production only in Germany of 3.3% from 2012 to 2013 (being 40% rotatory pumps), The higher global sales growth rate cannot be used in Europe, as an important part of this growth is presumed to happen in Asia, Brazil and other emerging economies. However, the figures provided by Europump WGs seem to be levelised to the European context, and also considering Germany is one of the main producers and sellers of water pumps in Europe. Furthermore, previous preparatory studies (Lot 28 & 29) have shown that in spite the EU market is close to saturation, a steady growth is still observed from new pumps installations[65]. This explains the current study assumption of a small steady growth until 2030.

Table 9 Estimated EU-27 installed base (stock) in 2014

Water pump category	Size division	Installed base (stock) in 2014
ESOB pumps for clean water	Maximum shaft power ≤ 22 kW	2,001,292
	Maximum shaft power 22 - 150 kW	222,366
	Maximum shaft power > 150 kW	8,895
ESCC pumps for clean water	Maximum shaft power ≤ 22 kW	2,001,292
	Maximum shaft power 22 - 150 kW	222,366
ESCCi pumps for clean water	Maximum shaft power ≤ 22 kW	800,517
	Maximum shaft power 22 - 150 kW	88,946
Submersible borehole pumps for clean water	Nomilar outer diameter ≤ 6"	6,226,241
	Nomilar outer diameter 6" - 12"	106,736
	Nomilar outer diameter > 12"	4,003
Vertical multistage pumps for clean water	Maximum design pressure ≤ 25 bar	2,223,658
	Maximum design pressure	25,794

[63] Pumps and compressors for the world market 2015 (VDMA). Available at: https://pu.vdma.org/documents/105981/801486/2015_PuKo_Englisch_LR.pdf/4a1b25a7-2985-4fba-9201-037767555daa
[64] Water Market Insights from 2012. Available at: http://www.mcilvainecompany.com/Decision_Tree/subscriber/Tree/DescriptionTextLinks/Water%20Market%20Insights%20August%2017,%202012.htm
[65] Lot 28, section 8.4.1 and Lot 29, section 8.6.1

Water pump category	Size division	Installed base (stock) in 2014
	25 - 40 bar	
Horizontal multistage pumps for clean water	0-40 bar	-
Self-priming waterpumps for clean water	Maximum shaft power ≤ 22 kW	-
	Maximum shaft power 22 - 150 kW	-
	Maximum shaft power >150 kW	-
Booster-sets for clean water	Maximum shaft power ≤ 150 kW	355,785
Swimming pool pumps (for filtration and circulation)	Maximum shaft power ≤ 2.2 kW	4,410,541
	Maximum shaft power > 2.2 kW	99,851
Submersible vortex radial pumps for wastewater	Maximum shaft power ≤ 10 kW	694,573
	Maximum shaft power 10 - 160 kW	20,837
Submersible channel radial pumps for wastewater	Maximum shaft power ≤ 10 kW	694,573
	Maximum shaft power 10 - 25 kW	83,349
	Maximum shaft power 25 - 160 kW	43,411
Submersible pumps for activated sludge, axial	Maximum shaft power < 160 kW	3,647
Submersible pumps for storm and effluent water, mixed flow and axial	Maximum shaft power < 160 kW	2,431
Dry well pumps for storm water, mixed flow and axial	Maximum shaft power < 160 kW	1,574
Dry well vortex pumps for wastewater	Maximum shaft power ≤ 10 kW	123,691
	Maximum shaft power 10 - 160 kW	12,369
Dry well channel pumps for wastewater	Maximum shaft power ≤ 10 kW	123,691
	Maximum shaft power 10 - 25 kW	49,476
	Maximum shaft power 25 - 160 kW	12,369
Submersible dewatering pumps (for water containing sand and grit)	Maximum shaft power < 160 kW	347,287
Slurry pumps, light duty	Maximum shaft power < 160 kW	28,252
Slurry pumps, heavy duty	Maximum shaft power < 160 kW	5,650
Total		**21,045,463**

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.

General market trends

The value of the world's pump market in 2011 was estimated at approx. 36 billion EUR covering pumps and prime movers (e.g. electric motors) but excluding parts[66] (data representative for 63 of the most developed countries). From these, a wide range of pumps' applications exist, and depending on the application, pumps can be standard, engineered or special pumps[66]. 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 (mostly in conformity with API 610[67]) and higher price. Most of these pumps are used in oil refinery processes, power generation and oil and gas exploration, but many other end uses have also often requirement for this type (quantities of demand are generally smaller).

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

An overview of the main relevant applications for the water pumps in scope of this study is presented in Table 10. The table is based on information publicly available[68].

Table 10. Overview of end use, application and range of pumps.

Industry sector / Pump type	Standard	Engineered	Special type
Chemical	Chemical processes Transport of clear liquids Utilities		Metering/dosing Special purposes
Pulp & paper	Transport of liquid and condensate Utilities		Chemical dosing Special purposes
Metal	Descaling/milling/flushing Water treatment Utilities		Special purposes
Food and drinks	Transport of liquids		Hygienic
Pharmaceuticals	Transport of liquids		Hygienic
Power generation	Auxiliary services (coal, gas and nuclear) Main pumps (hydro) Other pumps (hydro) Auxiliary services	Cooling water Auxiliary services (coal, gas, nuclear) Transport of coolant (nuclear)	
Mineral mining and	Dewatering		Special purposes

66 http://europump.net/industry_profile/Structure
67 Specification for centrifugal pumps, according to the American Petroleum Institute
68 http://europump.net/uploads/End%20Use_Application%20and%20Range%20of%20Pump.pdf

Industry sector / Pump type	Standard	Engineered	Special type
processing	Mine drainage Dredge Slurry		
Water supply	Reservoir Distribution[69]		
Sewerage	Transport of sewerage fluids		
Building services	Water supply[69] Drainage[69] Construction dewatering		
Other industries	Chemical processes		

The table above shows that the greatest majority of relevant applications for water pumps within the scope of this study are standard pumps, which is aligned to what the European Industrial Forecasting estimated by 2006[71], where 68% of the pumps were standard, 20% engineered and 12% special purpose.

Market channels and production structure

The pump industry in the EU is mainly comprised of 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), notable member organisations includes:
    - British Pump Manufacturers Association BPMA
    - Verband Deutscher Maschinen- und Anlagenbau VDMA
    - Association française des pompes et agitateurs, des compresseurs et de la robinetterie, Profluid
- European Union of Swimming pool and SPA Association (an umbrella of the swimming pool and spa businesses in Europe), notable member organisations includes:
    - Fédération des Professionnels de la Piscine, FPP, France
    - The British Swimming Pool Federation, BSPF, UK

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 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

[69] This has been added according to information from preparatory studies

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[58,**Error! Bookmark not defined.**,60].

The main manufactures of pumps in the world are:

- Xylem (USA[70])
- Flowserve (USA)
- Grundfos (Danish, EU)
- Sulzer (Swiss)
- Weir (UK, EU)
- KSB (German, EU)
- Schlumberger (French, EU)
- Ebara (Japan)
- WILO (German, EU)

The main manufacturers of wastewater pumps in the EU include:

- Andritz Ritz
- Ebara
- Grundfos
- Hidrostal
- KSB
- Tsurumi
- Sulzer (ABS)
- Wilo
- Xylem

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

- Procopi
- ACIS
- Desjoyaux Pools
- Fluidram
- Schmalenberger

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

Water and sewerage is a large market for pumps in the world[71]. 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 sewerage 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)[71]. 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 sewerage pumps market, whilst sewerage pumps accounted for about 60% of it[71].

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

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[70] Although Xylem is based in the USA, it is a global company with strong interest in the EU

[71] 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

products usually need professional installation in buildings or are bought directly by industry[72]. 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, which are often purchased by household end-users and are therefore sold as Business-to-Consumers (B2C).

Liquid pumps: 2014 production on previous year's level
According to the 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.

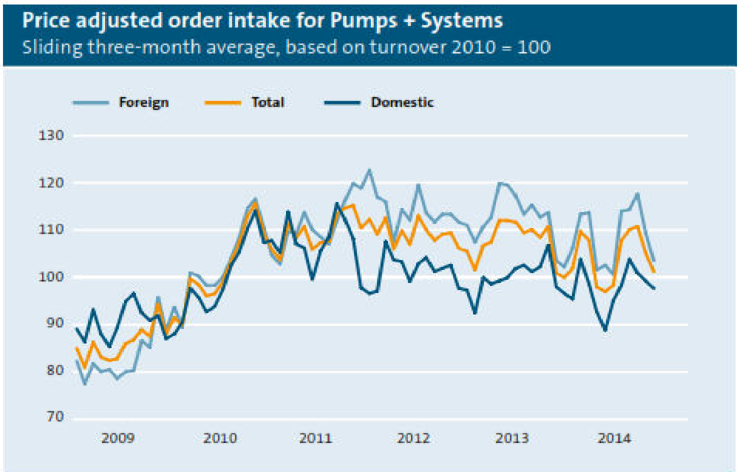

Fig. 1 Source: VDMA

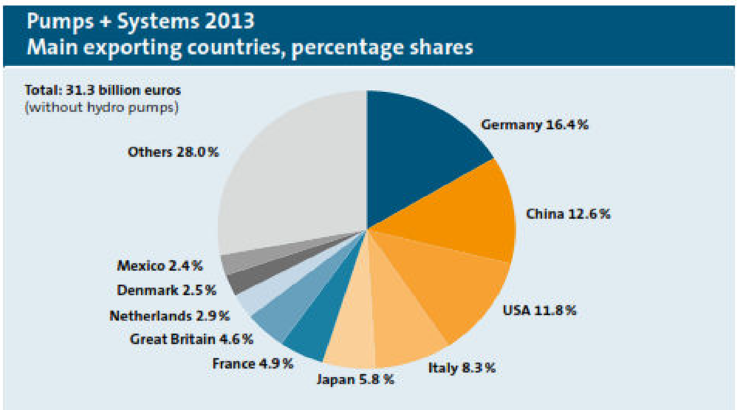

Fig. 2 Source: Federal Department for Statistics / VDMA

[72] Lot 28, page 20

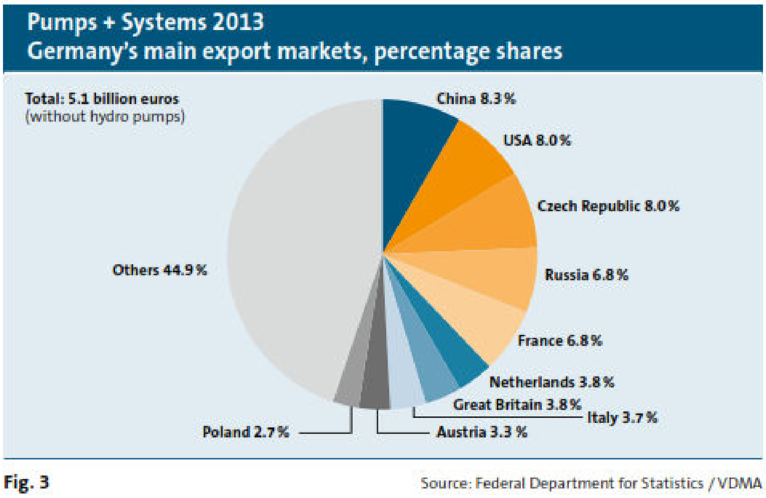

Figure 14. Overview of exporting countries and turnover of Germany (biggest EU's export country)

In January 2015, capacity utilisation, which is a good indicator for the cushion of orders, was in the "medium" range with 88.8 %. Turnover generated in 2014 was also below the previous year's level with a decline of -4 %.

Germany still export world champion

According to the Federal Statistical Office, in 2013 liquid pumps were exported at a value of € 5.1 bn. This value shows good growth (+6 %) compared to the previous year. In 2014, Germany has not seen any essential change for the last two years. By contrast, exports to Africa reached growth of 25 % again in 2013, following a constant decline in recent years. The key purchasing countries for Germany in 2013 were China, the USA, the Czech Republic, Russia and France (see Figure 14).

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 apply 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

Effort to optimize pump hydraulic, both to live up to regulation 547/2012 but also beyond those requirements The main developments in water pumps in general concern advances in motors equipped with variable speed drives (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 are 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 design 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 sewerage 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 is also requiring the use of pumps with a higher solid handling capacity. Higher effluent charges are also encouraging more companies to undertake initial screening and de-watering themselves, so 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 going for lower flow rates with longer running times. In the US is to reduce the number of domestic swimming pool pumps operated single-speed and increasing to dual, multiple and variable speed (see section 3.4). In the EU there exist several national laws regulating water quality and necessary flow rates and turnover rates[73], 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 to consider:

- The entire pool hydraulic system design
- Wet end part design
- Hydraulic working point

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

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) are presented in this section. These data will form an input for later tasks where both Life Cycle Costing for new products will be calculated.

[73] EUSA Pool Pump Working Group Position paper, 23/10 2015

Electricity and water prices

Electricity and water prices are presented in MEErP methodology. Recently updated rates for electricity were found for 2014, and are presented in Table 11 below, for each EU country and as EU-27 average in €/kWh for 2014 and annual price increase in %/a compared with previous year[74] . Water rate incl. sewage tax is estimated at 4.45 Euro/m^3 in 2015, taken for domestic market incl. VAT and a growth rate per year is 3%[75].

Table 11 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%
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 (27 countries)	0.2038	2%	0.0917	-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 internet search. An overview of the purchase price ranges (in EUR) is given in Table 12[76].

Table 12. Estimated purchase price of pumps in scope.

[74] Source: Eurostat, assessed December 2015
[75] VHK (2014). Ecodesign Impact Accounting. Part 1 – Status Nov. 2013
[76] Sources: preparatory studies Lot 11, Lot 28 and Lot 29 and internet research, December 2015

Water pump category	**Size division**	**Purchase price, Euro**
ESOB pumps for clean water	Maximum shaft power ≤ 22 kW	280 - 440
	Maximum shaft power 22 - 150 kW	440 - 3300
	Maximum shaft power > 150 kW	6600 - 8000
ESCC pumps for clean water	Maximum shaft power ≤ 22 kW	900
	Maximum shaft power 22 - 150 kW	3300
ESCCi pumps for clean water	Maximum shaft power ≤ 22 kW	900
	Maximum shaft power 22 - 150 kW	3300
Submersible borehole pumps for clean water	Nomilar outer diameter ≤ 6"	280 – 1000
	Nomilar outer diameter 6" - 12"	6135 - 10000
	Nomilar outer diameter > 12"	12000
Vertical multistage pumps for clean water	Maximum design pressure ≤ 25 bar	1000
	Maximum design pressure 25 - 40 bar	10000
Horizontal multistage pumps for clean water	0-40 bar	600-7000
Self-priming waterpumps for clean water	Maximum shaft power ≤ 22 kW	700 – 8000
	Maximum shaft power 22 - 150 kW	
	Maximum shaft power >150 kW	
Booster-sets for clean water	Maximum shaft power ≤ 150 kW	500 – 6000
Swimming pool pumps (for filtration and circulation)	Maximum shaft power ≤ 2.2 kW	300 - 1500
	Maximum shaft power > 2.2 kW	1300 – 2450
Submersible vortex radial pumps for wastewater	Maximum shaft power ≤ 10 kW	2500 – 29000
	Maximum shaft power 10 - 160 kW	
Submersible channel radial pumps for wastewater	Maximum shaft power ≤ 10 kW	2500 – 29000
	Maximum shaft power 10 - 25 kW	
	Maximum shaft power 25 - 160 kW	
Submersible pumps for activated sludge, axial	Maximum shaft power < 160 kW	3000 – 29000
Submersible pumps for storm and effluent water, mixed flow and axial	Maximum shaft power < 160 kW	3000 – 29000
Dry well pumps for storm water, mixed flow and axial	Maximum shaft power < 160 kW	2125 - 21250

Water pump category	Size division	Purchase price, Euro
Dry well vortex pumps for wastewater	Maximum shaft power ≤ 10 kW	3000 – 29000
	Maximum shaft power 10 - 160 kW	
Dry well channel pumps for wastewater	Maximum shaft power ≤ 10 kW	3000 – 29000
	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	2000 – 8000
Slurry pumps, light duty	Maximum shaft power < 160 kW	20000
Slurry pumps, heavy duty	Maximum shaft power < 160 kW	20000

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 13[76].

Table 13. Estimated installation costs, repair and maintenance costs.

Water pump category	Size division	Installation costs, Euro	Repair and maintenance costs, Euro/year
ESOB pumps for clean water	Maximum shaft power ≤ 22 kW	440 - 1000	100
	Maximum shaft power 22 - 150 kW		
	Maximum shaft power > 150 kW	2000	500
ESCC pumps for clean water	Maximum shaft power ≤ 22 kW	900 – 3300	40 - 120
	Maximum shaft power 22 - 150 kW		
ESCCi pumps for clean water	Maximum shaft power ≤ 22 kW	900 – 3300	40 - 120
	Maximum shaft power 22 - 150 kW		
Submersible borehole pumps for clean water	Nomilar outer diameter ≤ 6"	910 - 1000	200 - 300
	Nomilar outer diameter 6" - 12"	3000	2000 - 2500
	Nomilar outer diameter > 12"	4000	3000
Multistage pumps for clean water	Maximum design pressure ≤ 25 bar	1000	150 – 200
	Maximum design pressure 25 - 40 bar	2000	1000
Horizontal multistage pumps for clean water	0-40 bar	Not yet available	Not yet available

Water pump category	Size division	Installation costs, Euro	Repair and maintenance costs, Euro/year
Self-priming waterpumps for clean water	Maximum shaft power ≤ 22 kW	Not yet available	Not yet available
	Maximum shaft power 22 - 150 kW	Not yet available	Not yet available
	Maximum shaft power >150 kW	Not yet available	Not yet available
Booster-sets for clean water	Maximum shaft power ≤ 150 kW	Not yet available	Not yet available
Swimming pool pumps (for filtration and circulation)	Maximum shaft power ≤ 2.2 kW	250	0
	Maximum shaft power > 2.2 kW	500	50
Submersible vortex radial pumps for wastewater	Maximum shaft power ≤ 10 kW	1250 – 6250	375 – 850
	Maximum shaft power 10 - 160 kW		
Submersible channel radial pumps for wastewater	Maximum shaft power ≤ 10 kW	1250 – 6250	375 – 850
	Maximum shaft power 10 -25 kW		
	Maximum shaft power 25 - 160 kW		
Submersible pumps for activated sludge, axial	Maximum shaft power < 160 kW	3750	450
Submersible pumps for storm and effluent water, mixed flow and axial	Maximum shaft power < 160 kW	3750	450
Dry well pumps for storm water, mixed flow and axial	Maximum shaft power < 160 kW	3750	450
Dry well vortex pumps for wastewater	Maximum shaft power ≤ 10 kW	1250 – 6250	375 – 850
	Maximum shaft power 10 - 160 kW		
Dry well channel pumps for wastewater	Maximum shaft power ≤ 10 kW	1250 – 6250	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	5000	650
Slurry pumps, heavy duty	Maximum shaft power < 160 kW	5000	650

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 is no disposal costs requirement for handling of pumps at the end of life. However, cleaning and removal of pathogens is required prior to their delivery to the scrap yard.

Interest, inflation and discount rates

The generic interest and inflation rates in the EU-27 are presented in below:

Table 14 below:

Table 14. Generic interest and inflation rates in the EU-27[77].

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

6.5 Conclusions and recommendations

The categories in PRODCOM database do not fit very well with the pump categories identified (both in Task D1 and the new wastewater pump categories). In addition, the sales and trade figures from PRODCOM seem very 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 1.75% average annual growth from 1990 to 2006, increasing to 2.21% from 2006 to 2010 and finally with a steady annual growth of 3-4%. The total annual sales (i.e. new and replacement sales) of pumps in scope is approx. 2.4 million for 2014 and it is estimated to increase to approx. 4 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.

[77] VHK(2011), MEErP 2011 METHODOLOGY PART 1.

The industry is positive about the prospect for a revision to the ecodesign regulation with higher ambitions, 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 as well 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 Extended Product Approach
- 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 parameters

In this section, factors that affect the energy consumption are discussed. There are some factors which are relevant for all the pumps within the scope of this study, but there are also factors which apply only to certain types of pumps. Overall, the user defined parameters which are crucial for the energy consumption of the pump are:

- Selection of pump according to application
- Operation time
- Control method
- Specification and design of the system in which the pump is installed

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
- 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 Best Efficiency Point (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 planned. This means that the average pump will work lower than what 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 seral 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)[78]. However, this was only for clean water pumps covered in that study. No similar information exists for the rest of the pumps.

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 15 illustrates how the energy efficiency of a pump is typically reduced over time with and without proper maintenance[78].

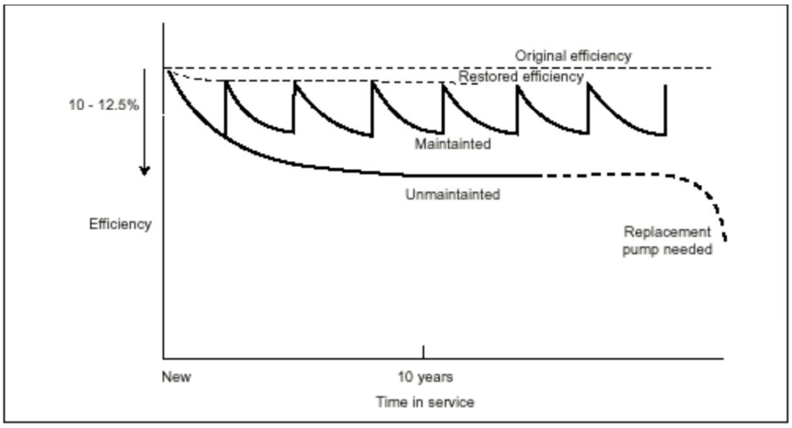

Figure 15. Illustration of how the energy efficiency of a typical pump is reduced over time due to wear

Over the course of a pump's lifetime it will consume the following:
- Lubricant (grease) for bearings
- Replacement seals
- New bearing
- New wear rings

Clean water pumps
The clean water pumps within the scope of this study are those who are already regulated by the Regulation (EU) 547/2012 and a few categories more. These pumps are used in a wide range of applications both in industry, utilities and by private user. Although there are many applications, some 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. For even better hydraulic efficiency the focus in on the smoothness of the surface in pump house and impeller.

Extended Product Approach (EPA)
Many clean water pumps (>50%[79]) are used in variable flow applications. For these applications variable speed drives (VSDs) are very suitable. Therefore several large clean water pump manufactures are selling 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. From both consumers and manufactures there is a limited awareness of the considerable large energy saving potential for 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 adding pressure to a water circulation system. In a booster-set with more than one pump, the pumps are connected in series, so that maximum pressure increase can be achieved. For booster-sets it is the pressure boost that is the primary concern. 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 always very beneficial.

Operation time
Europump has estimated the operation times for each clean water pump category[79]. An overview of the average operational times can be seen in Table 15.

Table 15. Overview of average operational times for clean water pumps.

Category	Operation time, variable flow applications	Operation time (hours/year), constant flow applications
ESOB	5000 hours/year	2250
ESCC	5000 hours/year	2250
ESCCi	5000 hours/year	2250
MSS	2880 hours/year	2880
MS-V	5000 hours/year	2250
MS-H	5000 hours/year	2250
Booster-set	2000 hours/year	Not applicable

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 typical BEP efficiency of a 30 kW wastewater pump is c.30 - 73 %, compared to the typical efficiency of an equivalent duty clean water pump of 65 –

80 %. End users traditionally accept this efficiency penalty as long as the pumps do not regularly block and fail.[80]

The impeller designs for wastewater pumps, unlike clean water pumps, do not have a fine clearance. The impellers in centrifugal wastewater treatment pumps are designed to allow solids to pass through the pumps without clogging it up, and so have a very different appearance. Therefore they are considerably less energy efficient. The optimal impeller design for a wastewater pump depends on the charateristics of the wastewater it is pumping, e.g. size and hardness of solid content, viscocity 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.

Three common impeller types are used in wastewater treatment:

- Open, which have large spaces between vanes, with a maximum efficiency of 87%[80]
- Vortex, which creates a vortex within the pump bowl preventing the solids from coming into contact with the impeller, with a maximum efficiency of 63%[80]
  Grinder impellers, which break up the solids allowing them to pass through the pump with greater ease, with a maximum efficiency of 47%[80]

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 costumers are either utility companies or industries, which can be expected to know in great detail what products they need. Therefore it is the general assumption that costumer normally choose the wastewater pumps that are best for their business and apply the appropriate motor technology. Input from Europump[79] suggests that in all wastewater pump applications where VSD would be beneficial, it is applied to the pump. For this reason the potential energy savings for EPA regulations for wastewater pumps are calculated to be very small. However it seems reasonable to think 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 designer often do not consider alternatives to the traditional wastewater system designs. By using variable flowrates rather than on/off control systems, large 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 a system approach.

Operation time

Europump has estimated the average operation times for each wastewater pumps category[79]. An overview of the average operational times can be seen in Table 16.

[80] From Lot 28

Table 16. Overview of average operational times for wastewater pumps.

Category	Operation time (hours/year), all applications
Submersible vortex radial pumps < 10 kW	1000
Submersible vortex radial pumps 10 - 160 kW	1500
Submersible channel radial pumps < 10 kW	1000
Submersible channel radial pumps 10 - 25 kW	1500
Submersible channel radial pumps 25 - 160 kW	2000
Submersible axial pumps for activated sludge	5000
Submersible pumps for storm and effluent water, mixed flow and axial	5000
Dry well pumps for storm water, mixed flow and axial	250
Dry well vortex pumps for wastewater < 10 kW	1000
Dry well vortex pumps for wastewater 10 - 160 kW	1500
Dry well channel pumps for wastewater < 10 kW	1000
Dry well channel pumps for wastewater 10 -25 kW	1500
Dry well channel pumps for wastewater 25 - 160 kW	2000
Submersible dewatering pumps	2000

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 regulations, which vary considerably. The national laws in different countries are dealing with water quality standards and necessary flow rates, turnover rates with respect to different types of pools (e.g. in France, Belgium, Austria).

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 market for swimming pool pumps is unlike for other water pumps in this study dominated by many smaller manufactures and manufactures that produces a wide range of products for swimming pool. These manufactures do not have the same focus on improving the energy efficiency of the pumps. It is therefore believed that there are potential energy savings to be gain from improving the pumps at product level. In USA and Australia there is a larger focus on energy savings for swimming pool pumps than there is in the EU. It is possible that these markets can be used to inspire the producers and customers in the EU.

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 regulating the flow rate of the pumps instead of simply using on/off control. There are however health reasons to consider when applying such approach. Lower flow-rates might lead to stagnating water and bacterial growth. Therefore 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."[81]

There are some significant differences in how swimming pools are managed in the EU compared to the USA and Australia. Particular the use of chlorine is different, in the USA it is reported to be as much as 5-10 times higher than in the EU[81].

Other methods to reduce the energy consumption for swimming pool pumping would be to consider a system approach when design the swimming pool filtration and circulation system.

Operation time

EUSA WG have estimated the average operation times for swimming pool pumps[79]. An overview of the average operational times can be seen in Table 17.

Table 17. Overview of average operational time for swimming pool pumps.

Category	Operation time (hours/year), all applications
Swimming pool pumps < 2.2 kW	1540 hours/year
Swimming pool pumps > 2.2 kW	3375 hours/year

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 put slurry pumps outside the scope of water pumps and therefore it should not be covered in this study[82]. 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.[83]

Slurry pumps are designed to pump heavy slurries, primarily in mining applications[80]. These pumps are therefore designed to handle high concentrations of fine solids that are often very abrasive. The overwhelming slurry pump design goal is therefore to minimise wear. Slurry pumps are usually designed with replaceable liners and other wear components and often 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[80]. Slurry pumps are constructed of special materials because of the abrasive nature of most slurries, which often require special bolting and assembly arrangements. The components 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.[84]Since slurry pumps are exposed to considerable amount of wear, the focus then designing slurry pumps, is to handle the wear. Therefore slurry pumps often have thick and large components. The pumps are designed to have parts replaced, as they wear down much faster than those

[81] Position paper from EUSA working group

from water pumps. Slurry pumps are also designed to move the slurry at low speeds, as higher speeds create more wear on the components. Some manufactures are moving on hydraulic efficiency of slurry pumps, by reducing friction and therefore improving hydraulic efficiency. Friction is not only a source of energy loss it also influence the amount of wear.

Operation time
Europump[85] have estimated the average operation times for slurry pumps[86]. An overview of the average operational times can be seen in Table 18.

Table 18. Overview of average operational time for slurry pumps

Category	Operation time, all applications
Slurry pumps, light duty	2600 hours/year
Slurry pumps, heavy duty	2000 hours/year

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 very few of the slurry pumps are currently being sold with VSD. The energy savings potential from EPA consists mainly in the possibilty of using high efficient motors (permanent magnet motors) with slurry pumps.

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-users 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. 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. 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.

Wastewater pumps
There are no identified issues regarding local infrastructure. However, 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, limits the selection of the pumps to a certain types and materials which may hinder the users to choose from the most efficient pump. There 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 specially 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.

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, 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. However there is still risk associated with the energy supply in Europe. In recent years the security of supply for natural gas has become less secure due to tensions with Russia. In addition there is now an increased shift towards renewable energy and away from depleting fossil fuels, and therefore there could be a risk that the electrical energy becomes less stable and lower quality as more fluctuating renewable energy penetrates the system. This involves a shift from on-demand power stations to fluctuating renewables such as wind and solar. This transition period demands a specific effort to ensure the transition is successful. Thus this has led to the creation of the Energy Union. There is now an increased push towards making energy (including electrical) supply more independent and secure in Europe. This is through a strong push for renewable energy and for increased energy efficiency on the energy demand side, which decreases the demand for fuel. Despite these uncertainties it is expected that these risks are carefully considered and managed in the future, since a constant supply of quality electrical energy is vital to the sustained economic activity of

Europe, and a large amount of research is going into this transition process to ensure that the electrical energy supply is sustained.

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.

Installation

Pumps are important components within the systems that form part of, therefore there is a need to have skillful 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.

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.

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. Buyers and product distributors are not in charge of the system operation afterwards and thus do not pay the final electricity bill. Following are some other barriers:

- **Preference for stabilised technologies:** technology changes often generate a temporary increase in breakdown rates 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:** E.g., relevant information is not available to users of pumps in the scope of the study.
- 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 thorough knowledge of their pumping system and are therefore expected to have already implemented installation and use strategies to improve the pumps' efficiencies. However, in spite they may have know 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 a system approach is adapted.

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. Both the USA and Australian have set up regulatory schemes for labelling swimming pool pumps according to energy efficiency. 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 the managing of swimming pools inside and outside the EU, particular the use of chemicals to hinder bacterial growth.

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 occuring. 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 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 pump's 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 (ressources/emissions)
- The description of the pumps' value chain from their production, 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

Existing products (Base Cases)

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 have 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 for each category and subcategory of pumps. Each size-category is further divided into categories according the motor technologies attached to the pumps, in order to calculate savings potentials at EPA level. Five categories of motor technologies 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 for clean water, swimming pool, wastewater and slurry pumps considered for the final scope of this study are presented in Table 19, with maximum shaft power (BEP level) and average electric power consumption (variable and constant flows).

Table 19. Overview of pump categories and subcategories considered for the final scope of this study.

Water pump category	Size division [87]	Motor technology	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 motor technology		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 motor technology		14.1	28.2
	Maximum shaft power > 150 kW	Induction motor	200	188	209
		Induction motor with VSD		113	215
		Other motor technology		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 motor technology		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 motor technology		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 motor technology		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 motor technology		14.1	28.1
Submersible borehole pumps for clean water	Nominal outer diameter ≤ 6"	Induction motor	1.5	1.6	1.7
		Induction motor with VSD		1.0	1.8
		PM motor		1.5	1.7
		PM motor with VSD		1.1	1.7
		Other motor technology		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

[87] The term "maximum shaft power" is explained in section 4.1

Water pump category	Size division[87]	Motor technology	Pump size (shaft power BEP)	Average electric power consumption (variable flow)	Average electric power consumption (constant flow)
		Other motor technology		37.4	57.5
	Nominal outer diameter > 12"	Induction motor	288	270	300
		Induction motor with VSD		216	309
		Other motor technology		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 motor technology		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 motor technology		37.0	74.1
Horizontal multistage pumps for clean water	Maximum design pressure ≤ 25 bar	Induction motor	n.a.	n.a.	n.a.
		Induction motor with VSD		n.a.	n.a.
		PM motor		n.a.	n.a.
		PM motor with VSD		n.a.	n.a.
		Other motor technology		n.a.	n.a.
	Maximum design pressure 25 - 40 bar	Induction motor	n.a.	n.a.	n.a.
		Induction motor with VSD		n.a.	n.a.
		PM motor		n.a.	n.a.
		PM motor with VSD		n.a.	n.a.
		Other motor technology		n.a.	n.a.
Self priming pumps for clean water	Maximum shaft power ≤ 22 kW	Induction motor	n.a.	n.a.	n.a.
		Induction motor with VSD		n.a.	n.a.
		PM motor		n.a.	n.a.
		PM motor with VSD		n.a.	n.a.
		Other motor technology		n.a.	n.a.
	Maximum shaft power 22 - 150 kW	Induction motor	n.a.	n.a.	n.a.
		Induction motor with VSD		n.a.	n.a.
		Other motor technology		n.a.	n.a.
	Maximum shaft power > 150 kW	Induction motor	n.a.	n.a.	n.a.
		Induction motor with VSD		n.a.	n.a.
		Other motor technology		n.a.	n.a.
		Pumps not serial produced		n.a.	n.a.
Booster-sets for clean water	Maximum shaft power ≤ 150 kW	Multiple pumps without VSD	n.a.	5.0	not relevant
		Multiple pumps with one VSD		3.6	not relevant
		Multiple pumps with multiple VSD		3.4	not relevant

Water pump category	Size division [87]	Motor technology	Pump size (shaft power BEP)	Average electric power consumption (variable flow)	Average electric power consumption (constant flow)
Swimming pool pumps	Maximum shaft power ≤ 2.2 kW	Induction motor	0.8	0.9	1.0
		Induction motor with VSD	0.8	0.6	1.0
		PM motor	0.8	0.9	1.0
		PM motor with VSD	0.8	0.5	1.0
		Other motor technology	0.8	0.5	1.0
	Maximum shaft power > 2.2 kW	Induction motor	5	5.4	6.0
		Induction motor with VSD	5	3.4	6.2
		Other motor technology	5	5.0	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 motor technology	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 motor technology	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 motor technology	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 motor technology	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 motor technology	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 motor technology	10	5.5	11.0
Submersible pumps for storm and effluent water, mixed flow and axial	Maximum shaft power ≤ 160 kW	Induction motor	100	96.6	107.4
		Induction motor with VSD	100	60.9	110.7
		PM motor	100	89.9	99.8
		PM motor with VSD	100	49.9	99.8
		Other motor technology	100	51.5	103
Dry well	Maximum	Induction motor	150	144	160

Water pump category	Size division [87]	Motor technology	Pump size (shaft power BEP)	Average electric power consumption (variable flow)	Average electric power consumption (constant flow)
pumps for storm water, mixed flow and axial	shaft power ≤ 160 kW	Induction motor with VSD	150	90.8	165
		PM motor	150	134	149
		PM motor with VSD	150	74.4	149
		Other motor technology	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 motor technology	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 motor technology	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 motor technology	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 motor technology	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 motor technology	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 motor technology	7	3.9	7.8
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 motor technology	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 motor technology	37	19.5	38.9

n.a. = data not yet available

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

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 (extended product)
- Control and monitoring (extended product)

Clean water pumps

For clean water pumps, which are subject to the Regulation 547/2012, the product efficiency is ranked accourding 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[88]. 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. The difference between MEI = 0.4 and MEI = 0.7 is about 5 %-points in energy efficiency[89].

Motor technologies are very important for the energy efficiency of the extended product, but still most pump manufactures only choose motors according to the minimum requirements for motors (i.e. IE3). However, a few manufactures are advancing to high efficient motors (i.e. IE4) for their pumps. Best availiable technology for motors can be considered to be IE4 motors such as the KSB "SuPremE" motor[90].

The use of VSD with clean water pumps is still not a standard practice, eventhough about half of the clean water pumps could reduce their energy consumption significally if applied with a VSD. But some manufactures[91] routinely sell clean water pumps with VSD and it is definitely possible to acquire a pump with VSD.

Wastewater pumps

With wastewater pumps there are several parameters that influence pump performance for improving it to higher levels, in particular:

- Energy consumption

[88] 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,
[89] http://europump.net/uploads/Fingerprints.pdf
[90] http://www.ksb.com/SuPremE
[91] 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

- Reliability
- Ease of maintenance

Often the optimal design is a compromise between these three factors, but it is also important to understand that energy consumption depends on reliability and maintenance. The energy consumption of a pump depends also on wear and maintenance of the pump, as the wear decreases the energy efficiency 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. 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 availiable techonology for wastewater pumps are pumps with an energy efficiency of 88.7%, since the best design depends on the application. Since the properties of wastewater circulating through the different points of the wastewater treatment plant where the pumps operate may not be well defined each system can ultimately be considered to be unique and comparioson are therefore difficult.

Slurry pumps
Similar to wastewater pumps, for slurry pumps there does not exist a perfect pump. Which slurry pump is the best depends on the application. Wear is a very important issue for slurry pumps. Therefor slurry pumps are most of all designed for rubustness and easy replaceable wear parts. It is still possible, however, to reach a high energy efficiency with some light duty slurry pumps with an efficiency of 82 % and heavy duty slurry pumps with an efficiency of up 77 % (lot 28).

Swimming pool pumps
For swimming pool pumps the best availiable technology can be considered to be that used in either the Australian or the USA market. Both have an energy labelling strategy in place. In the Australian labelling scheme the best availiable pump is set to pump 50,000 liters of water per day for a year using 305 kWh (less than half of the worst in the list). In the scheme from USA (Energy Star), the swimming pool pumps are labelled with number of gallons they can pump per Wh (gallons/Wh), according to a head vs. flow-rate curve. Here the best pumps are labelled as being able to pump 29.42 gallons/Wh (111 liters/Wh).

8.3 Best Not yet Available Technology (BNAT)

The water pump is an old technology, and eventhough very significant improvements have been realised to pump designs within the past decade, the technology is very similar[92]. The major changes in the use of technology for pumps are regarding the application of motors and VSDs. However, some improvements have 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).

[92] The most used and most energy efficient water pump technology are variations of the centrifugal pump, which have been used for centuries

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

Production and distribution

An overview of the Bill of Materials is presented in Table20 (according to MEErP methodology), including the packaging materials, the pumps' weight with and without packaging the end life routes. The Bill of Materials data here presented has been collected from previous preparatory studies, as the stakeholders[93] informed these data is still valid as of today. 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 10000 km and for pumps transported by truck, it is assumed a transport distance of about 3400 km (conservative assumptiona considering the many transport scenarios).

The materials identified for all the pumps within the scope and shown in Table 20 are coded according to the Ecodesign EcoReport tool v.2014 as it follows:

1-BULK PLASTICS
- 1-LDPE

2-TECHNICAL PLASTICS
- Nylon PA 6: 12- PA 6
- Polyurethane: 17-Flex PUR

3-FERRO MATERIALS
- Stainless steel coil: 26-Stainless 18/8 coil
- Steel sheet galvanised: 22-St sheet galv
- Steel tube/profile: 23-St tube/profile
- Cast iron: 24-Cast iron

4-NON-FERRO MATERIALS
- Copper wire: 29-Cu winding wire

5-COATING MATERIALS
- Powder coating: 40-Powder coating

7-MISCELLANEOUS MATERIALS
- Paper: 58-Office paper

[93] Europump WGs on clean water and wastewater pumps and EUSA WG on swimming pool pumps

- Cardboard: 57-Cardboard

The Bill of Materials does not include data on VSDs, but if an EPA is meant to be applied, the weight of the VSD materials would have to be included for those pumps where VSDs are used. An overview of the Bill of Materials for different types of VSDs is shown in Table 21.

Table 20. Bill of Materials for pumps in the scope of this study, incl. predicted economic lifetime.

Pump categorisation					Pump materials (kg)						Packaging materials (kg)					End of Life (%)		
Pump application	Pump category	Pump size	Stainless steel coil	Steel sheet galvanised	Steel tube/profile	Cast iron	Copper wire	Nylon PA 6	Powder coating	**Product weight**	Paper	Cardboard	LDPE	PUR	**Total weight (packed product)**	Recycling	Incineration	Landfill
Clean water	ESOB pumps	MSP ≤ 150 kW	21	-	-	194	-	-	0.2	**215**	0.2	11	1.5	-	**228**	99	-	1
		MSP > 150 kW	-	85	553	-	13	1	-	**651**	-	7	-	-	**658**	99	-	1
	ESCC pumps	MSP ≤ 150 kW	8	-	-	116	-	-	0.3	**124**	0.2	11	4	-	**139**	99	-	1
	ESCCi pumps	MSP ≤ 150 kW	8	-	-	116	-	-	0.3	**124**	0.2	11	4	-	**139**	99	-	1
	SB pumps	NOD ≤ 6"	14	-	-	-	-	-	-	**14**	0.1	2	0.1	0.1	**17**	99	-	1
		NOD 6" - 12"	-	662	675	-	-	22	-	**1359**	-	23	-	-	**1382**	97	2	1
		NOD > 12"	-	1287	1313	-	-	33	-	**2632**	-	13	-	-	**2645**	98	1	1
	V-MS pumps	MDP ≤ 25 bar	15	-	-	-	-	-	-	**15**	0.2	2	0.2	0.2	**17**	99	-	1
		MDP 25 - 40 bar	-	91	187	-	3	4	-	**284**	-	8	-	-	**292**	98	1	1
	H-MS pumps	MDP ≤ 25 bar	na	na	na	na	na	na	na	**na**	na	na	na	na	**na**	na	na	na
		MDP 25 - 40 bar	na	na	na	na	na	na	na	**na**	na	na	na	na	**na**	na	na	na
	SP pumps	MSP ≤ 22 kW	na	na	na	na	na	na	na	**na**	na	na	na	na	**na**	na	na	na
		MSP 22 - 150 kW	na	na	na	na	na	na	na	**na**	na	na	na	na	**na**	na	na	na
		MSP >150 kW	na	na	na	na	na	na	na	**na**	na	na	na	na	**na**	na	na	na
	Booster-sets	MSP ≤ 150 kW	na	na	na	na	na	na	na	**na**	na	na	na	na	**na**	na	na	na
Swimming pool	Swimming pool pumps	MSP ≤ 2.2 kW	-	6	-	-	4	5	-	**14**	-	1	-	-	**15**	35	64	1
		MSP > 2.2 kW	-	12	6	-	4	3	-	**24**	-	2	-	-	**27**	88	11	1
Wastewater	SVR pumps (wastewater)	MSP ≤ 10 kW	-	2	5	-	1	0.1	-	**7**	-	0.1	-	-	**7**	98	1	1
		MSP 10 - 160 kW	-	23	70	-	12	1	-	**106**	-	1	-	-	**124**	98	1	1
	SCR pumps (wastewater)	MSP ≤ 10 kW	-	2	5	-	1	-	-	**7**	-	-	-	-	**7**	98	1	1
		MSP 10 -25 kW	-	4	12	-	2	0.2	-	**18**	-	0.1	-	-	**18**	98	1	1

Table 20. Bill of Materials for pumps in the scope of this study, incl. predicted economic lifetime.

Pump categorisation					Pump materials (kg)						Packaging materials (kg)					End of Life (%)		
Pump application	Pump category	Pump size	Stainless steel coil	Steel sheet galvanised	Steel tube/profile	Cast iron	Copper wire	Nylon PA 6	Powder coating	**Product weight**	Paper	Cardboard	LDPE	PUR	**Total weight (packed product)**	Recycling	Incineration	Landfill
		MSP 25 - 160 kW	-	19	59	-	10	1	-	**88**	-	0.5	-	-	**89**	98	1	1
	SA pumps (activated sludge)	MSP ≤ 160 kW	-	100	232	-	60	4	-	**396**	-	-	-	-	**396**	98	1	1
	SMAF pumps (storm & effluent water)	MSP ≤ 160 kW	-	100	232	-	60	4	-	**396**	-	-	-	-	**396**	98	1	1
	DWMAF pumps (storm water)	MSP ≤ 160 kW	-	5	96	-	-	1	-	**102**	-	1	-	-	**103**	98	1	1
	DWV pumps (wastewater)	MSP ≤ 10 kW	-	1	10	-	-	0.1	-	**11**	-	-	-	-	**11**	98	1	1
		MSP 10 - 160 kW	-	5	86	-	-	1	-	**91**	-	0.4	-	-	**92**	98	1	1
	DWC pumps (wastewater)	MSP ≤ 10 kW	-	1	10	-	-	0.1	-	**11**	-	0.1	-	-	**11**	98	1	1
		MSP 10 -25 kW	-	1	16	-	-	0.2	-	**17**	-	0.1	-	-	**17**	98	1	1
		MSP 25 - 160 kW	-	4	70	-	-	1	-	**74**	-	0.4	-	-	**75**	98	1	1
	SWD (high solids fluids)	MSP ≤ 160 kW	-	17	7	-	22	1	-	**47**	-	1	-	-	**48**	97	2	1
Slurry	Slurry pumps, light duty	MSP ≤ 160 kW	-	150	617	-	-	-	-	**767**	-	-	-	-	**767**	99	-	1
	Slurry pumps, heavy duty	MSP ≤ 160 kW	-	133	5732	-	-	-	-	**5865**	-	-	-	-	**5865**	99	-	1

SB = Submersible borehole; V-MS = Vertical Multistage; H-MS = Horizontal Multistage; SP = Self-priming; SVR = Submersible Vortex Radial; SCR = Submersible channel radial; SA = Submersible Axial; SMAF = Submersible Mixed and Axial Flow; DWMAF = Dry Well Mixed Axial Flow pumps; DWV = Dry Well Vortex; DWC = Dry Well Channel; SWD = Submersible Dewatering Pumps
MSP = Maximum Shaft Power; NOD = Nominal Outer Diameter; MDP = Maximum Design Pressure
n.a. = data not yet available

Table 21. Bill of Materials for different types of VSDs (taken from Lot 29).

Materials	Detailed bill of materials for VSD				
	0.37 kW	1.1 kW	11 kW	110 kW	560 kW
Steel (kg/kW)	-	0.5	0.16	0.05	0.045
Aluminium (kg/kW)	1.3	1	0.22	0.01	0.009
PVC Plastic (kg/kW)	0.4	0.3	0.05	0.03	0.027
PWB (kg/kW)	0.26	0.2	0.03	0.01	0.009
Electronics small (SMD, IC,…) (kg/kW)	0.26	0.2	0.07	0.04	0.036
Electronics big (IGBT, Thyristors,…) (kg/kW)	0.065	0.05	0.02	0.03	0.027

Repair and maintenance

Pump equipment will need repair and maintenance during its lifetime. Some of the largest pump manufacturers (e.g. Xylem, Flowserve, Grundfos, Sulzer, KSB) provide onsite repair and workshop repair services[94,95,96,97,98]. 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 the bulk of pumps in this study.[99] 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 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[100]. 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.

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[94] http://www.xylemwatersolutions.com/scs/eastern-europe/en-us/Sparepartsandservice/Pages/default.aspx
[95] http://www.flowserve.com/Services-and-Solutions/Aftermarket-Parts-and-Services
[96] https://www.grundfos.com/service-support/service-portfolios.html
[97] https://www.sulzer.com/en/Products-and-Services/Pumps-Services
[98] http://www.ksb.com/ksb-en/Products_and_Services/service-and-spare-parts/
[99] Lot 11 preparatory rpeort, pg. 67
[100] Preparatory study Lot 28 Task 3, pg. 14

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

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. 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 is presented below. Based on these perspectives the end of life treatment assumptions of the pumps is determined.

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 in this study are shown in Table 20.

As shown in Table 20, 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. On 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.[101] "

The recycle percentage of a typical Grundfos pump is between 90% and 98%, and the rest can be incinerated for energy recovery[102] (some eco-designed Grundfos pumps have a recyclability of around 94% and incineration of material of 5% with 1% for landfill [103]). 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[104].

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 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*"[105] 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.

Although disused pumps would account for only a fraction of this waste category, its data is the best available 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 so it is not included as a material input it is included as an equipment input and 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.

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[101] http://gryphon.environdec.com/data/files/6/7230/epd62_3.1.pdf
[102] http://vbn.aau.dk/files/13401334/workingpaper202007.pdf
[103] http://ostfoldforskning.no/uploads/dokumenter/NorLCA/Presentasjon/NorLCA_Thrane_Remmen.pdf
[104] https://dk.grundfos.com/recycling.html
[105] Available at http://faolex.fao.org/docs/pdf/eur97704.pdf

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%[106]. 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 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 99% of the pumps are treated and only 1% are sent to landfill. Since most pumps are high metal content it is assumed that out of the 99% of treated waste pumps all the high metal content pumps would be sent to recycling. At the recycling facility these pumps would be sorted and disassembled and it is assumed that the metal content is recycled and all other materials are incinerated (e.g. plastics). For all domestic pumps that have high-metal content it is assumed that these pumps are sent to recycling. For domestic pumps that have high plastic content it is assumed that a proportion of these pumps are sent to recycling and a proportion are sent directly to incineration. This is because, it is more likely that high plastic content pumps would be discarded in domestic waste compared to heavier high metal content pumps.

Eurostat provide data on the proportion of all municipal waste that is recycled and incinerated. In 2012 approximately 53% of municipal waste was sent to recycling compared to 47% for incineration[107]. These ratios are applied here for the domestic pumps with high plastic content. For instance using this data, 53% of the plastic pumps will be sent to recycling and the rest to incineration. At the recycling facility the metal parts of the pump will be recycled and the plastic will be incinerated.

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.

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%

[106] http://tinyurl.com/q8omu6h

[107] http://ec.europa.eu/eurostat/statistics-explained/images/8/86/Municipal_waste_landfilled%2C_incinerated%2C_recycled_and_composted_in_the_EU-27%2C_1995_to_2013.png

by weight approximately), except for domestic swimming pool pumps which have a higher plastic content. Please see Table 20 for a detailed overview of the disposal routes for each of the pumps considered for this study (i.e. the Base Cases).

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 rather. This is done to extend the lifetime of the pumps rather than replacing them.

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.108

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: [109]

- 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[110].

When selecting a pump, a manufacturer will use "tombstone" curves, which show their ranges of pumps to cover a range of duties, (Figure 3-7). 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 a manufacturer of particularly efficient pumps may lose out, when quoting

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[108] Preparatory study Lot 11, pg. 69
[109] Preparatory study Lot 29 Task 3, pg. 12
[110] Preparatory study Lot 28 Task 3

efficiencies in competition with less efficient pumps whose BEP just happens to be nearer the requested performance[111].

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 Base Cases 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 selected as Base Cases have been splitted in different sizes according to the pumps' 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. Although, it has been confirmed that in their majority, the pumps are recycled due to their high metal content, except for the domestic (small) swimming pool pumps which have a high content of technical plastics (i.e. nylon PA 6).

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.

[111] Preparatory study Lot 11 pg. 70

9. Final scope

9.1 Final scope

The final scope is presented in Table 22, showing the final list of pump categories to be included in this study, as well as estimated values for total energy consumption and potential energy savings on product level and EPA level for each pump category. The data shown is based, until the extent possible, on new information and data provided by Europump WGs and EUSA WG as it has been described in previous chapters. When data was not available, this was gathered from previous preparatory studies.

Total energy consumption

The total energy consumption is calculated based on values collected by the Europump WGs on clean water pumps and wastewater pumps and the EUSA WG on swimming pool pumps and the estimated stock. There are some notable differences between these values and the values presented in the preliminary scope in Annex 4 based on values from previous preparatory studies. 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, as in Lot 11 it is assumed to be 1500 hours/year, 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 category as:

$$E = Stock \cdot (Share_{var} \cdot P1_{avg,var} \cdot Op\_T_{avg,var} + Share_{const} \cdot P1_{avg,const} \cdot Op\_T_{avg,const})$$

For each pump category, pump size and motor technology (see Table 19), the share of pumps that are used in variable flow applications ($Share_{var}$) is defined as well as the share of pumps that are used in constant flow applications ($Share_{const}$). This is based on data provided by the Europump and EUSA WGs, as the share of pumps that are used in applications that can be considered to be 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[112].

Similarly, the average power consumption during operation for variable and constant flow operations are defined ($P1_{avg,var}$ and $P1_{avg,const}$). Both of these average power consumption values have been calculated using the current pump stock with induction motors, as 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 the contrary to what presented in Table 19. This is because there is no difference from a regulatory perspective where the pumps within the two sizes, ≤22 kW and 22-150 kW, are merged together as it is defined in the current Regulation (EU) 547/2012. This in addition to the fact that the scope of this study has been greatly extended and it was considered irrelevant to split these categories further.

Potential savings at product level

At this stage in the study there are no new data for potential energy savings at product level. The values given in the table for potential energy savings at product level are the values from the preparatory studies (Lot 11, 28 and 29). The pumps covered by Lot 11 (*in italics*) are also covered by Regulation (EU) 547/2012 which requires the pumps to have an energy efficiency of at least corresponding to MEI = 0.4 by this year. Therefore, for the potential energy savings calculated for Lot 11 pumps, an MEI limit at 0.4 is assumed to already being achieved. Further energy savings at product level are still possible by going up to MEI = 0.7 (value defined as benchmark in current Regulation). The potential energy savings for Lot 11 pumps are therefore the difference between the already achieved savings (MEI=0.4) and the benchmarked savings (MEI=0.7).

Potential savings at Extended Product Approach (EPA) level

The potential energy savings from EPA are calculated as:

$$E_{EPA\,save} = Stock \cdot \left(Share_{var} \cdot \left[P1_{avg,var} - P1_{avg,var,improved}\right] \cdot Op\_T_{avg,var} + Share_{const} \cdot \left[P1_{avg,const} - P1_{avg,const,improved}\right] \cdot Op\_T_{avg,const}\right)$$

Based on two scenarios which are determined as:

a. considering applying VSD for variable flow applications, or,
b. applying the best available motor technology in all cases.

With 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 therefore the additional savings would be gained only from applying a VSD.

With 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 motor technology for constant flow application available. The savings are therefore calculated, 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 motor technology available.

In the table above a range is therefore presented, showing the potential for energy savings at EPA level, being the lowest potential savings based on option (a), and the highest on option (b).

In the particular case of domestic swimming pool pumps, the potential savings at EPA level are based on figures provided by the EUSA WG, showing only a minor share for variable flow applications (i.e. 2.9%). This is contradictory to the market trends in the USA and Australia where a crescent share of these applications is observed (as discussed in previous chapters). The share of variable speed applications could be increased in subsequent tasks to observe any differences on potential savings at EPA levels, 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 the case also for large swimming pool pumps, where no new data have been received, therefore the data from Lot 29 are 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[35]. For each pump in the database there are energy factors (pumped volume per energy use) which are calculated for three different load curves.

Table 22. Suggested pump types and classification for the 'final' scope of this study, incl. energy consumption and saving potentials.

Pump type	Intended use	Total energy consumption in EU		Estimated energy savings potential at product level in EU*		Estimated energy savings potential at EPA level in EU	
		TWh/year	% of total**	TWh/year	% of total in EU***	TWh/year	% of total in EU**
End suction pumps for clean water							
ESOB (≤150 kW)	clean water	*53.7*	*20.8 %*	*1.12*	*21.7 %*	*11.0 – 14.0*	*26.2 %*
ESOB (150kW – 1MW)		4.7	1.8 %	0.06	1.2 %	0.3 – 0.4	0.7 %
ESCC (≤150 kW)		*52.6*	*20.4 %*	*0.92*	*17.9 %*	*12.0 – 16.4*	*28.1 %*
ESCCi (≤150 kW)		*21.3*	*8.3 %*	*0.72*	*14.0 %*	*5.7 - 7.2*	*13.4 %*
Submersible borehole pumps for clean water							
Borehole MSS (≤6")	clean water	*24.5*	*9.5 %*	*0.67*	*13.0 %*	*0.8 – 1.9*	*3.5%*
Borehole MSS (>6" and ≤12")		17.3	6.7 %	0.42	8.1 %	0.6 – 1.4	2.6%
Borehole MSS (>12")		4.1	1.6 %	0.07	1.4 %	0.1	0.2%
Vertical and horizontal multistage pumps for clean water							
MS-V (≤25 bar)	clean water	*27.2*	*10.6 %*	*0.16*	*3.1 %*	*5.9 – 7.6*	*14.2 %*
MS-V (25-40 bar)		6.4	2.5 %	0.13	2.5 %	1.6 – 2.0	3.8 %
MS-H (≤25 bar)		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
MS-H (25-40 bar)		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Other pumps for clean water							
Self-priming pumps (≤22 kW)	clean water	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Self-priming pumps (22 - 150 kW)		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Booster-sets pumps (≤150 kW)		3.7	1.4 %	n.a.	n.a.	1.0 – 1.2	2.2 %
Pumps for swimming pools							
Small swimming pool pumps (≤2.2 kW)	swimming pool water	6.9	2.7 %	0.14	2.7 %	0 - 0.41	0.8 %
Large swimming pool pumps (>2.2 kW)		2.0	0.8 %	0.05	1.0 %	0	0 %
Submersible pumps for wastewater							
Radial vortex pumps (≤ 10 kW)	industrial, commercial & municipal wastewater	3.3	1.3 %	0.06****	1.1 %	0 – 0.24	0.5 %
Radial vortex pumps (10 - 160 kW)	industrial, commercial & municipal wastewater	0.5	0.2 %	0.01****	0.3 %	0 - 0.04	0.1%
Radial channel pumps (≤10 kW)	industrial, commercial & municipal wastewater	3.3	1.3 %	0.06****	1.1 %	0 - 0.24	0.5 %

Pump type	Intended use	Total energy consumption in EU		Estimated energy savings potential at product level in EU*		Estimated energy savings potential at EPA level in EU	
		TWh/year	% of total**	TWh/year	% of total in EU***	TWh/year	% of total in EU**
Radial channel pumps (10 - 25 kW)	industrial, commercial & municipal wastewater	2.1	0.8 %	0.06****	1.1 %	0 – 0.16	0.3 %
Radial channel pumps (25 - 160 kW)	industrial, commercial & municipal wastewater	6.6	2.5 %	0.18****	2.3 %	0 - 0.40	0.7 %
Axial pumps (≤160 kW)	activated sludge	0.2	0.1 %	0.002****	0.0 %	0 - 0.02	0.0%
Mixed flow & axial pumps (≤160 kW)	Rainwater, storm and effluent water	1.2	0.5 %	0.015****	0.3 %	0 - 0.10	0.2%
Dry well pumps for wastewater							
Mixed flow & axial pumps (≤160 kW)	Rainwater, storm and effluent water	0.07	0.0 %	0.001****	0.0 %	0 - 0.005	0.0%
Radial vortex pumps (≤10 kW)		0.9	0.4 %	0.01****	0.2 %	0 – 0.07	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%	0.002****	0.0 %	0 - 0.02	0.04%
Radial channel pumps (≤10 kW)	rain water, domestic/industrial/ commercial/municipal wastewater, sand water, grit water, raw/primary/secondary/ activated/tertiary sludge	0.9	0.4 %	0.01****	0.2 %	0 – 0.07	0.1 %
Radial channel pumps (10 - 25 kW)	rain water, domestic/industrial/ commercial/municipal wastewater, sand water, grit water, raw/primary/secondary/ activated/tertiary sludge	1.3	0.5 %	0.02****	0.4 %	0 – 0.10	0.2 %
Radial channel pumps (25 - 160 kW)	rain water, domestic/industrial/ commercial/municipal wastewater, sand water, grit water, raw/primary/secondary/ activated/tertiary sludge	2.0	0.8 %	0.04****	0.8 %	0 - 0.12	0.2%
High solids content water pumps							
Submersible dewatering pumps	sand water & grit water	5.8	2.2 %	0.15	2.9 %	0 - 0.41	0.9 %
Slurry pumps							
Slurry pumps – light duty	Slurry	4.7	1.8 %	0.08	1.6 %	0.05 - 0.38	0.8 %

Pump type	Intended use	Total energy consumption in EU		Estimated energy savings potential at product level in EU*		Estimated energy savings potential at EPA level in EU	
		TWh/year	% of total**	TWh/year	% of total in EU***	TWh/year	% of total in EU**
Slurry pumps – heavy duty		0.5	0.2 %	0.01	0.2 %	0.01 - 0.04	0.1 %
Total energy consumption/savings potentials for all water pumps included in Lot 11, Lot 28 & Lot 29		**258**	**100%**	**5.15**	**100%**	**39 – 49**	**100%**

Pumps in italic are those covered by present Regulation (EU) 547/2012

n.a. = data not available

*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 (MS-H and self-priming).

***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 definitions in final scope

The above described pump categories can be grouped in thirteen pump types and defined as it 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 1 MW, which does not have a self-priming function and is not designed for pumping other fluids than 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 become also the pump shaft, designed for a maximum shaft power up to 150 kW, which does not have a self-priming function and is not designed specifically for pumping other fluids than 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 is not designed specifically for pumping other fluids than clean water.
- **Borehole submersible multistage pumps (Borehole MSS):** multi stage (i > 1) rotodynamic water pumps, designed to be operated in a borehole at operating temperatures within a range of 0-90 degrees C, not specifically designed for any other fluids than clean water which does not have a self-priming function.
- **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 is not designed specifically for pumping other fluids than 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 is not designed specifically for pumping other fluids than 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 is not designed specifically for pumping other fluids than clean water.
- **Booster-set:** A booster-set is either a single pump or an assembly of clean water parallel connected pump units, together 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.[113]
- **Swimming pool pumps:** A water pump designed specifically for pumping swimming pool water for circulation and filtration.
- **Centrifugal submersible radial vortex wastewater pumps:** A rotodynamic water pump, which has a radial inflow, designed to operate under water, designed to have the flow pass freely through without reaching the impeller, and is specifically designed for pumping wastewater.
- **Centrifugal submersible wastewater pumps, radial:** A rotodynamic water pump, which has a radial inflow, an impeller inside the flow channel, designed to operate under water, and is specifically designed for pumping wastewater.

[113] Definition provided by Europump

- **Centrifugal Submersible pumps for storm and effluent water, mixed flow and axial:** A rotodynamic water pump, which has a mixed or an axial inflow, designed to operate under water and is specifically designed for pumping storm and effluent water.
- **Centrifugal submersible pumps for activated sludge, axial:** A rotodynamic water pump, which has an axial inflow, designed to operate under water and is specifically designed for pumping activated sludge.
- **Centrifugal dry well vortex pumps for wastewater:** A glanded rotodynamic water pump, which is designed to have the flow pass freely through without reaching the impeller, and designed for a maximum shaft power of 160 kW, for handling dirty water/wastewater and is designed for installation in a piping system.
- **Centrifugal dry well channel pumps for wastewater:** A glanded rotodynamic water pump, which has an impeller inside the flow channel, is designed for a maximum shaft power of 160 kW, for handling dirty water/wastewater and is designed for installation in a piping system.
- **Centrifugal submersible dewatering pumps:** A glanded rotodynamic water pump, which is designed for a maximum shaft power of 160 kW, for handling wastewater and is designed for portability.
- **Centrifugal dry well pumps for storm water, mixed flow and axial:** A glanded rotodynamic water pump, which has a mixed or an axial inflow is designed for a maximum shaft power of 160 kW, for handling storm water and is designed for installation in a piping system.
- **Slurry pumps:** 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 and heavy loads, use, or stress.

Annex 1. Overview of published standards under CEN TC 197.

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 1151-2:2006	Pumps - Rotodynamic pumps - Circulation pumps having a rated power input not exceeding 200 W for heating installations and domestic hot water installations - Part 2: Noise test code (vibro-acoustics) for measuring structure- and fluid- borne noise
EN 809:1998+A1:2009	Pumps and pump units for liquids - Common safety requirements
EN 809:1998+A1:2009/ AC:2010	Pumps and pump units for liquids - Common safety requirements
EN 1829-1:2010	High pressure water jet machines - Safety requirements - Part 1: Machines
EN 1829-2:2008	High-pressure water jet machines - Safety requirements - Part 2: Hoses, hose lines and connectors
EN 1829-2:2008/AC:2011	High-pressure water jet machines - Safety requirements - Part 2: Hoses, hose lines and connectors
EN 1151-2:2006/AC:2007	Pumps - Rotodynamic pumps - Circulation pumps having a rated power input not exceeding 200 W for heating installations and domestic hot water installations - Part 2: Noise test code (vibro-acoustics) for measuring structure- and fluid-borne noise
EN 12157:1999	Rotodynamic pumps - Coolant pumps units for machine tools - Nominal flow rate, dimensions
EN 12162:2001+A1:2009	Liquid pumps - Safety requirements - Procedure for hydrostatic testing
EN 12262:1998	Rotodynamic pumps - Technical documents - Terms, delivery range, layout
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
EN 13951:2012	Liquid pumps - Safety requirements - Agrifoodstuffs equipment; Design rules to ensure hygiene in use
EN 14343:2005	Rotary positive displacement pumps - Performance tests for acceptance
EN 14343:2005/AC:2008	Rotary positive displacement pumps - Performance tests for acceptance
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
CEN/TR 13930:2009	Rotodynamic pumps - Design of pump intakes -

	Recommendations for installation of pumps
CEN/TR 13930:2009/AC:2010	Rotodynamic pumps - Design of pump intakes - Recommendation 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 13931:2009/AC:2010	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 5198:1998	Centrifugal, mixed flow and axial pumps - Code for hydraulic performance tests - Precision class (ISO 5198:1987)
EN ISO 2858:2010	End-suction centrifugal pumps (rating 16 bar) - Designation, nominal duty point and dimensions (ISO 2858:1975)
EN ISO 3661:2010	End-suction centrifugal pumps - Baseplate and installation dimensions (ISO 3661:1977) 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 9905:1997/A1:2011	Technical specifications for centrifugal pumps - Class I - Amendment 1 (ISO 9905:1994/AMD 1:2011)
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 9908:1997 Technical specifications for centrifugal pumps - Class III (ISO 9908:1993)
EN ISO 9908:1997/A1:2011	Technical specifications for centrifugal pumps - Class III - Amendment 1 (ISO 9908:1993/AMD 1:2011)
EN ISO 14847:1999	Rotary positive displacement pumps - Technical requirements (ISO 14847:1999)
EN ISO 15783:2003/A1:2008	Seal-less rotodynamic pumps - Class II - Specification - Amendment 1 (ISO 15783:2003/Amd 1:2008)
EN ISO 15783:2003	Seal-less rotodynamic pumps - Class II - Specification (ISO 15783:2002)
EN ISO 16330:2003	Reciprocating positive displacement pumps and pump units - Technical requirements (ISO 16330:2003)
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)
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 20361:2009	Liquid pumps and pump units - Noise test code - Grades 2 and 3 of accuracy (ISO 20361:2007)
EN ISO 20361:2009/AC:2010	Liquid pumps and pump units - Noise test code - Grades 2 and 3 of accuracy (ISO 20361:2007)

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

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.

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 extended product approach. 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[114]. These substances are:

- Lead
- Mercury
- Cadmium
- Hexavalent chromium
- Polybrominated biphenyls (PBB)
- 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

[114] 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

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.[115]

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.[115]

Areas of use of PVC[116]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)[117].

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)
- 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)[115,116,117,118].

[115] http://www.greenpeace.org/raw/content/international/assets/binaries/ngo-rohs-submission.pdf
[116] http://www.greenpeace.org/international/Global/international/planet-2/report/2009/1/green-electronics-survey-2.pdf
[117] http://www.greenpeace.org/raw/content/international/assets/binaries/ngo-rohs-submission.pdf

Areas of use of BFRs[118]:

- 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.[119]

Areas of use of phthalates:

- Polyvinylchloride (PVC)[120]

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[119,120]. 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 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

[118] http://www.greenpeace.org/international/Global/international/planet-2/report/2009/1/green-electronics-survey-2.pdf
[119] http://europa.eu/rapid/pressReleasesAction.do?reference=IP/99/829&format=HTML&aged=1&language=EN&guiLanguage=en
[120] http://www.sonyericsson.com/cws/download/1/308/336/1193062465/SE_Environmental_Policy_local.pdf

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[121]. 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[122]. A scheme of symbols, currently voluntary, has been prepared through Commission Decision 97/129/EC[123]. 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:

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);

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[121] http://www.conformance.co.uk/adirectives/doku.php?id=atex
[122] OJ L 365 , 31.12.1994 P. 10-23, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31994L0062:EN:HTML
[123] OJ L 050, 20.02.1997 P. 28 – 31, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31997D0129:EN:HTML

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[124]. BAT conclusions (documents containing information on the emission levels associated with the best available techniques) shall be the reference for setting permit

[124] Note that the IPPC definition of BAT may be different to that used in Ecodesign studies, following the MEEuP, MEErP.

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 (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[125] 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[126] under category 6 and 9 of "Annex I and II".[127]

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.

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.

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[125] 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
[126] It is not clear whether the complete pump or only its electric/electronic parts are subject to the WEEE Directive.
[127] 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).

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

Annex 3. Summary of other pump related legislation.

The table below shows an overview of other water pumps legislation outside the European Union.

Table 23: Overview of water pumps legislation outside the EU.

Country	Policy Type	Mandatory/ Voluntary	Scope	Policy Status	Test Procedure
Argentina	Label Comparative	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
	Label Comparative	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	
	Label Comparative	Voluntary		Under Development	
Brazil	Label Comparative	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
	Label Endorsement	Voluntary	Centrifugal pumps	Entered into Force	NBR 626-2, NBR 5383-1, NBR

Country	Policy Type	Mandatory/ Voluntary	Scope	Policy Status	Test Procedure
					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
	Label Endorsement	Voluntary		Entered into Force	GB 19762-2007 GB/T 3216 GB/T 5657 GB/T 7021 GB/T 13006
	Label Endorsement	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	Label Comparative	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	Label Comparative	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)	Label Endorsement	Voluntary	Pump: Centrifugal pump for feeding water into boilers	Entered into Force	
Mexico	Label Comparative	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	Entered into Force	NOM-010-ENER-2004

Country	Policy Type	Mandatory/ Voluntary	Scope	Policy Status	Test Procedure
			motor pumps operated by a submersible three-phase electric motor. The standard does not apply to sewage and mud pumps.		
	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), respectively, and the test methods for verifying compliance therewith.	Entered into Force	NOM-004-ENER-2008
	Label Endorsement	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
	Label Endorsement	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	Under Consideration for Development	

Country	Policy Type	Mandatory/ Voluntary	Scope	Policy Status	Test Procedure
			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.		
United States	MEPS	Mandatory	Industrial and Commercial Pumps	Under Consideration for Development	
	Label Endorsement	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

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/savings potentials for all water pumps included in Lot 11, Lot 28 & Lot 29		**226.2***	**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.