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

ENER Lot 29 – Pumps for Private and Public Swimming Pools, Ponds, Fountains, and Aquariums (and clean water pumps larger than those regulated under ENER Lot 11) – Task 4: Technical analysis

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AUTHORS	Mr. Alvaro de Prado Trigo, BIO Intelligence Service Mr. Benoît Tinetti, BIO Intelligence Service Mr. Shailendra Mudgal, BIO Intelligence Service Mr. Sandeep Pahal, BIO Intelligence Service Dr. Hugh Falkner, Atkins Mr. Keeran Jugdoyal, Atkins
KEY CONTACTS	Mr. Alvaro de Prado Trigo adepradotrigo@bio.deloitte.fr Or Mr. Shailendra Mudgal shmudgal@bio.deloitte.fr
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Task 4. Technical Analysis

This chapter presents the technical analysis of pumps for private and public swimming pools, ponds, fountains, and aquariums (and clean water pumps larger than those regulated under ENER Lot 11) covered in the scope of the ENER Lot 29 study. The technical analysis of product categories described in this chapter uses the product definitions presented earlier in the Task 1 report of this study[1] as its basis. Analysis of the environmental impacts of a product requires the examination of its complete life cycle, starting with the amount of raw materials used during the manufacturing phase and ending with the disposal efforts required at its end-of-life stage. The aim of this task is to examine the technical characteristics of the different product categories covered in this study, which is necessary to form a basis for identifying and defining the base cases that will be further developed in Task 5 of this study.

This task is therefore divided into the following subtasks according to the different life-cycle stages of the pumps for pumps for private and public swimming pools, ponds, fountains, and aquariums (and clean water pumps larger than those regulated under ENER Lot 11):

- production phase;
- distribution phase;
- use phase of the product;
- use phase of the extended product; and,
- end-of-life phase

The last sections of this report concern recommendations for possible mandates to be issued by the European Commission and standardisation organisations for ENER Lot 29 products and the main conclusions of this task

4.1 Technical basics

Pumps are available in a wide variety of designs and configurations, which can be split into two distinct categories, positive displacement pumps and rotodynamic pumps. As per the definition stated in Task 1, a positive displacement pump in its simplest (and oldest) form is typified by a bucket lifting water from a well or river. It shows the principle of all pumps of this type; enclosed volumes of liquid are collected at the pump inlet and discharged at the outlet at increased head. In a rotodynamic pump, a continuous flow of liquid passes through a rotating impeller, which imparts energy, is collected (usually by a volute or guide vanes) and discharged against an increased head.

Water is pushed into the pump inlet branch by the pressure acting on the water surface (usually atmospheric pressure) and, where applicable, the height of the water level above the pump. The

[1] Available at http://lot29.ecopumps.eu/

water flow then passes from the inlet branch of the pump to the inlet of the impeller. If the pump is a mixed flow or centrifugal type, the water then has to change direction from axial to (near) radial as it enters the passage between the impeller vanes. In axial flow pumps, there is no change in direction of the water flow. In a well-designed impeller, at best efficiency flow the water will pass smoothly over the vane inlets with little disturbance. The vanes will then start to work on the water as it flows through the impeller, creating an increase in pressure and velocity. In mixed flow and centrifugal type pumps, at best efficiency flow, the water will spiral out of the impeller in a free vortex of constant angle to the tangential direction. In axial flow pumps, the water is pushed in the pump without any change in the radial location of the fluid particles. As the diameter of the volute increases, the flow velocity reduces and pressure is recovered. The volute cutwater angle should be a close match to the spiral angle and will peel off the water to guide it to the outlet branch. The water then leaves the pump with an increased pressure.

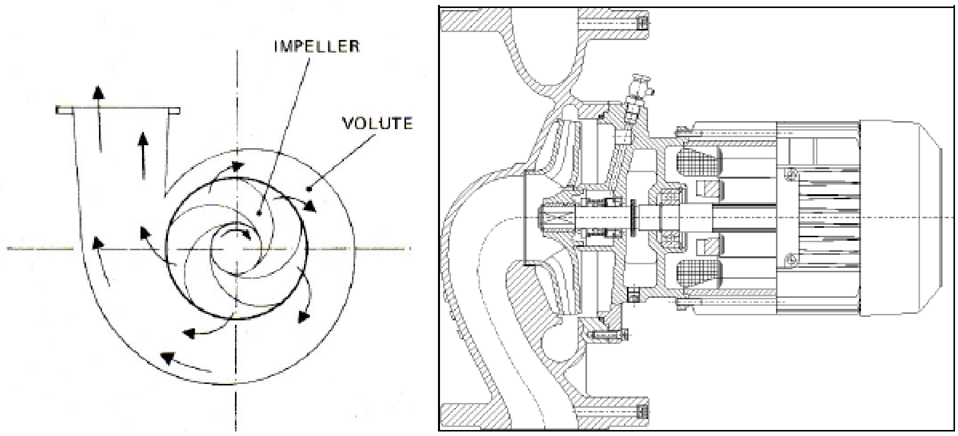

Figure 1 – How rotodynamic pumps work: flow paths (left) and cutaway of motor-coupled pump (right) (Source: ENER Lot 11 preparatory study on ecodesign of motors)

Rotodynamic types are generally cheaper and more robust, and so account for the bulk (>90%) of sales. Positive Displacement types are more sophisticated and highly engineered. They are generally suited to higher pressure pumping applications than are used for rotodynamic pumping applications and for very viscous liquids.

Task 1 Sections 1.0.2 to 1.0.3 contains further details on pump systems and the basic pump laws.

4.1.1 Fluid flow concepts

The flow rate of fluid into a pump is always the same as the flow of fluid out of a pump when measured in terms of mass or weight. The volume of the flow is also the same as long as there are no changes in density. Pressure, velocity and height are the three main forms of energy found within a pump system. The energy in the pump system can change from one form to another.

As liquid flows through a pipe it gives rise to friction. This in turn is a source of energy loss in the liquid as the pump overcomes the friction in the form of pressure losses. The amount of pressure loss depends on the following factors:

- Flow rate
- Pipe length

- Pipe diameter
- Pipe surface roughness
- Piping design
- Viscosity of liquid
- Density of liquid

The flow within a pipe can be either turbulent or laminar depending on the viscosity of the liquid and the design velocity used for the system. The losses associated with laminar flow are dramatically different to those associated with turbulent flow. In laminar flow the layers of liquid slide smoothly over the each other as it travels down the pipe. Laminar flows tend to occur in liquids with a high viscosity when pumped at a low velocity. In turbulent flows the individual particles in the liquid take erratic flow patterns along the pipe, with eddies and local vortices. Most of the flow from rotodynamic pumps is turbulent. The flow within the pumps considered in this study is predominantly turbulent.

Pump pipework systems are made up of components such as valves, tees, bends and filters in addition to the simple pipes. These components all contribute to the friction in the system and therefore the losses.

4.1.2 Common products and technologies

The products involved in this study are described in detail in Task 1, section 1.3.1.

There are number of factors that contribute to the overall efficiency of a pump. A detailed discussion of these factors is provided in the 'SAVE Study on Improving the Efficiency of Pumps'[2] for the European Commission and issued in February 2001. Task 5 of that study supported by Darmstadt University, who emphasise that the main intention of this work was to identify, respectively quantify the various design factors affecting the efficiency of centrifugal pumps in a fundamental and exemplary manner. The main focus of the evaluation was on single stage standard industrial pumps of an overall size, which is typical for this type of pumps.

Regarding an appreciable improvement of the efficiency of centrifugal pumps one has always to consider that the possible gain of efficiency, which can be achieved, e.g. by the reduction of the gap width or additional surface treatments, strongly depends on the initial state of these parts as well as the absolute size of the pump. Other aspects, which also limit the potential of a possible efficiency increase, are requirements arising from operating reliability.

Besides the issue of operating reliability there are many other technical requirements such as production, assembly or system aspects, which determine, respectively dominate the design process of centrifugal pumps. It is therefore not always reasonable or even possible to apply all the design features and recommendations discussed in the SAVE Study.

[2] ETSU, AEAT PLC (2001) Study on Improving the Efficiency of Pumps. Available at http://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/files/documents/save_pumps_final_report_june_2003.pdf

Impellers

Impellers have a key role in contributing towards the efficiency and performance of pumps. This is because their primary function is to transfer the energy from the pump to the water, and so a poorly designed impeller can be a significant source of losses in the system. Impellor should be designed to minimise leakage from the discharge side back to the suction side. Wear rings can be provided which assist with minimising leakage.

Pump manufacturers provide pumps with a range a range of impeller sizes to cater for the wide range of duties required. The diameter of an impeller has the following effects on pump performance:

- Flow is directly proportional to impeller diameter
- Head is proportional to the square of the impeller diameter
- Power is proportional to the cube of the impeller diameter

Impellers can be trimmed to ensure that their output matches the required duty. However, users who buy pumps with trimmed impellers should be aware that pumps are designed for maximum efficiency with the impeller at full diameter.

Motors

Many of the pumps in the study are likely to be used in conjunction with AC electric induction motors. AC motors are rotating electric machines designed to operate from an AC power source. Like other motors, an AC motor has a fixed portion, called the stator and a rotor that spins with a carefully engineered air gap between the two.

Induction Motors

In an AC induction motor, one set of electromagnets in the form of a rotating magnetic field is formed in the stator when an AC supply connected to the stator windings. The rotating magnetic field induces an Electromagnetic Force (EMF) in the rotor as per Lenz's law, thus generating another set of electromagnets; hence the name – induction motor.

Interaction between the rotating magnetic field and the rotor field generates the motor torque. As a result, the motor rotates in the direction of the resultant torque. One way to produce a rotating magnetic field in the stator of an AC motor is to use a three-phase power supply to feed 3 sets of stator coils, which are a distributed at 120 degrees intervals.

The speed of the rotating magnetic field (synchronous speed) in an induction motor depends on the frequency of the supply voltage and on the number of poles in the motor.

$$Sychronous\ speed\ (rpm) = \frac{frequency\ of\ the\ applied\ voltage\ (Hz) \times 60}{number\ of\ pole\ pairs}$$

For example, when a 4-pole motor is supplied with 50 Hz supply, the synchronous speed will be 1500 rpm. Motors with 2, 4 and 6 poles represent the vast majority of the motor market. The rotor speed is slightly lower (a few percent at full power) than the synchronous speed and therefore the induction motor is also called asynchronous motor. The rotor slip increases in a linear manner as the load increases, being almost zero at no-load.

There are two types of three-phase induction motors classified by the type of rotor used: wound or squirrel cage, the latter representing the large majority of them.

Main characteristics:

- Low construction complexity,
- High reliability (no brush wear), even at very high achievable speeds
- Medium efficiency at low power (below 2.2. kW), high efficiency at high power
- Driven directly by the grid or by multi-phase Inverter controllers
- Low Electromagnetic Interference (EMI)
- Sensorless speed control possible
- Lowest cost per kW among different motor technologies

Induction motors are by far the most widely used motor in the power range under consideration, using over 90% of the electricity consumed by all motors in that range. Induction motors are robust, inexpensive when compared with other technologies and their efficiency ranges from fair (around 70% for small motors) to very high (over 95% for large motors) depending on the power level and on the design.

General-purpose induction motors are a commodity type of motor constituting a large majority of the market (they represent 80-85% of the 3-phase induction motor market), whose main characteristics are standardised. This standardisation allows motors to be easily exchanged around the world, by motors made by different manufacturers meeting the same requirements. There is a huge variety of special purpose induction motors, generally custom made for specific applications. In some applications, these motors may have to comply with strict requirements (e.g. fireproof motors) in which safety is an overriding concern.

▷ **Single-Phase Induction motors**

As the name suggests, Single-Phase Induction motors operate with a single-phase power supply. In single-phase induction motors, there is a stator main winding and an auxiliary winding for starting purposes. The rotor is of the squirrel cage type.

When the motor is connected to a single-phase power supply, the main winding carries an alternating current. This current produces a pulsating magnetic field. Due to induction, the rotor is energized. As the main magnetic field is pulsating, the torque necessary for the motor rotation is not generated. This will cause the rotor to vibrate, but not to rotate. Hence, the single-phase induction motor is required to have a starting mechanism that can provide the starting kick for the motor to rotate. This is accomplished by the auxiliary stator winding, which normally is connected in series with a capacitor. The combination of the two windings creates a rotating field and the motor torque is generated in the rotor like in a 3-phase induction motor. After starting, a centrifugal switch may be used to disconnect the auxiliary winding.

Main characteristics:

- Medium construction complexity due to extra capacitor and centrifugal switch
- Higher cost than 3-phase induction motors

- High reliability (no brushes)
- Lower efficiency than 3-phase induction motors
- Low EMI
- Driven directly from AC line or from Variable Frequency controllers

Single-phase motors are more expensive and less efficient than equivalent 3 phase motors, being mainly used in residential appliances, and rarely exceeding a few kW. The most relevant electric home appliances are the subject of efficiency assessment regulation in which the efficiency of the whole equipment is regulated. Other integral single-phase motors can be found, mostly in the residential sector, in applications such as submersible pumps and machine tools. In general, terms single-phase motors are used when a three-phase supply is unavailable.

- **Brushless Permanent Magnet DC or AC Motor**

Brushless permanent magnet AC motors (BLAC) are used in smaller pumps such as aquarium and fountain pumps. BLAC motors are synchronous motors with use permanent magnets rather than windings in the rotor. The brushless permanent magnet DC motor (BLDC) is a brushless AC motor with integrated inverter and rectifier, sensor and inverter control electronics. They are fed through a DC link with power originating from an AC source. The DC power is then inverted back to AC, which feeds the motor. Strictly speaking, they are AC motors but historically they have been classified as DC.

Brushless Permanent Magnet (BPM) Motors are rapidly becoming one of the most popular motor types. They differ from Brushed Permanent magnet motors in that the magnets are in the rotor instead of the stator, and in the commutation method, which is controlled electronically. BPM Motors, therefore, avoid use of a commutator and brushes.

Main characteristics:

- Medium construction complexity
- Moderate to high cost depending on magnet materials
- High reliability (no brush and commutator wear), even at very high achievable speeds
- High efficiency
- Low EMI
- Driven by multi-phase Inverter controllers
- Sensorless speed control possible

These motors are still highly customized without suitable standards (e.g. dimensions, mounting, power, torque specifications, etc.) to allow a commodity market to develop. Because of mass production for specialized applications, their cost has been decreasing and may become a key player particularly in the low power range. They are often used in conjunction with aquarium, pond and swimming pool pumps.

Controls

Pumps are available with a variety of controls to suit a range of pumping operation, such as intermittent batch pumping and variable flow system. The types of controls available are discussed in the following section.

Time switches

As the name suggests time switches are used to control the operation of pumps based on times. These types of controls can commonly be found on swimming pool pumps or pond pumps and are based on pre-set on and off operation times.

Time switches are relatively simple to operate and are available as simple once per day timers, to very complex multiple event, multiple day timer that allow the user to specify different times of operation on different days.

Level controls

Level controls are commonly used in wet well type pumping operations. They are used to switch the pumps on when the amount of water in a wet well reaches a pre-set high level, and switch them off once the water level reaches a pre-set low level. Level controls can be used to provide variable flow control in pumping stations with more than one pump, by running a single pump during periods of low flow into the station and multiple pumps during high flow periods.

Process based controls

Certain pumps such as those pumps used for specific process operations like borehole pumping in water treatment work. The speed of the pumps, as well as the running times, can be managed by process-based controls. For example if there is a high demand for water, the pumps will be operated at full speed; however they might be operated at half speed during periods of low demand.

Pressure controls

Pressure controls are used to vary the speed of pumps in order to maintain a constant outlet pressure and flow rate in the pumping system. These types of controls are commonly used in water supply network, and in filtering processes. In water supply networks, these controls ensure that a constant flow rate is supplied to all users of a water network, and in filtering processes ensure that a consistent volume of water is filtered, even when the filter starts to clog.

Sensors

Level and pressure sensors tend to be most commonly used water pumping. Level sensors are typically found in the form of pressure transmitters, ultrasonic sensors, level probes and float switches.

Pressure transmitters

Pressure transmitters are suspended in the water of the wet well, in a protective enclosure, and they use the pressure measured to determine the water level. Pressure transmitters can provide continuous accurate level readings.

▷ Ultrasonic sensor

Ultrasonic sensors are placed in wet wells above the water level. They measure water level by emitting an ultrasonic sound waves at the water and measuring the time it take for the ultrasound echo to return to the sensor. The longer it takes the echo to return the lower the water level in the wet well.

A key benefit of these types of sensor is that they are never in contact with the water.

▷ Level probes

The principle of operation of is that there are two electrodes placed within the wet well. One on the well wall and one in the level probe. A low voltage is applied between the wall electrode and the level probe. When the waste water level in the wet well reaches the height of the probe, an electrical connection in made between the two electrodes, and this is used as a signal be the controls to turn the pumps on or off.

▷ Float switches

Float switches are typically made of plastic and are lightweight balls or boxes filled with air and therefore are able to float on water. There is an electrical switch within the float, which turns on and off depending on the orientation of the float. As shown in Figure 4-2, when the float-switch is submerged in the water it turns upside-down and the switch is turned on and the control system is sent a signal.

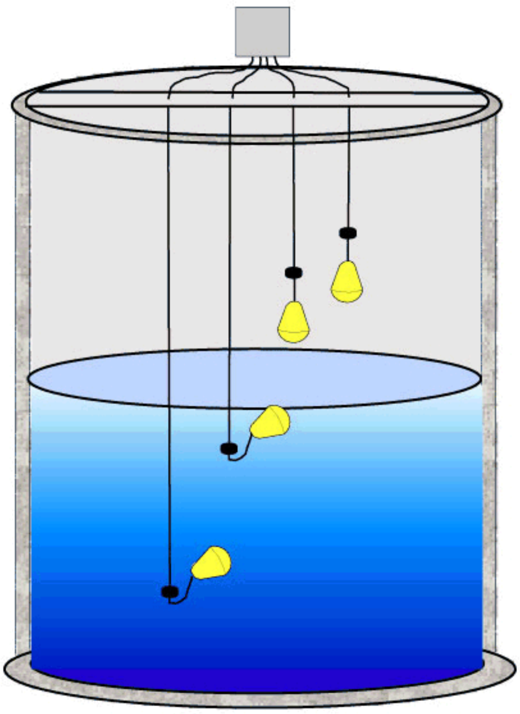

Figure 4-2: Example of a wet well with float switches

▷ Pressure sensors

Pressure sensors are typically made of piezoelectric materials, which convert any force exerted onto it into an electrical signal. The pressure sensor is installed into the pump system and the electrical signal is fed back to the pump controller. Pressure sensors are relatively cheap and easy to install, and require little maintenance. Table 4-1 listed the components present or available for pumps in the study.

Table 4-1: Components present or included for pumps in the study

		Motors			Controls				Sensors				
	Impellers	Three phase Induction motors	Single-Phase Induction motors	Brushless Permanent Magnet Motor	Time switches	Level controls	Process based controls	Pressure controls	Pressure transmitters	Ultrasonic sensor	Level probes	Float switches	Pressure sensors
Swimming Pool pumps (integrated motor+pump)													
Domestic with built in strainer up to 2.2 kW	✓	✓	✓	○	○	×	×	×	×	×	×	×	○
Domestic/commercial with built in strainer over 2.2 kW	✓	✓		○	○	×	×	×	×	×	×	×	○
Fountain and pond pumps to 1 kW	✓			✓	○		×	×	×	×	×	×	×
Aquarium pumps (domestic/small aquarium - non-commercial) to 120 W	✓			✓	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Aquarium power head (separate study for life cycle data only) to 120W	✓			✓	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
Spa pumps for domestic & commercial spa's (where the water is retained and filtered)	✓	✓	✓		×	×	×	×	×	×	×	×	×
Counter-Current Pumps	✓	✓	✓		○	×	×	×	×	×	×	×	×
End Suction water pumps (over 150kW-P2)													
ES Close Coupled from 150 kW to 1 MW	✓	○			×	×	×	×	×	×	×	×	×
ES Close Coupled Inline from 150 kW to 1 MW	✓	○			×	×	×	×	×	×	×	×	×
ES Own Bearing from 150 kW to 1 MW	✓	○			×	×	×	×	×	×	×	×	×
8" Submersible bore-hole pumps	✓	○			×	×	×	×	×	×	×	×	×
10" Submersible bore-hole pumps	✓	○			×	×	×	×	×	×	×	×	×
12" Submersible bore-hole pumps	✓	○			×	×	×	×	×	×	×	×	×
Submersible bore-hole pumps larger than 12"	✓	○			×	×	×	×	×	×	×	×	×
Vertical multi-stage pump (25 to 40 bar and/or 100 to 180 m3/hr)	✓	○			×	×	×	×	×	×	×	×	×
Vertical multi-stage pump (>40 bar and/or >180 m3/hr)	✓	○			×	×	×	×	×	×	×	×	×

✓: Included ○: Optional Δ: to be avoided ×: Not commonly included

4.2 Production phase

4.2.1 Bill of Materials (BoM)

In order to calculate the environmental impacts and costs of materials and production processes, 'bill of materials' (BoM) of typical pumps for pumps for private and public swimming pools, ponds, fountains, and aquariums (and clean water pumps larger than those regulated under ENER Lot 11) needs to be gathered from manufacturers. BoMs list all the types and quantities of materials and components used to produce one product unit.

The primarily materials used in pumps depends on their size and use. In the large, clean water pumps steel and non-ferrous metals account for more than 90% of the materials used. This is as expected as they are often used for applications where they need to be robust and withstand high pressures. With the smaller pumps, there is a higher prevalence of plastic materials used, especially for the pump body.

Table 4-2 to Table 4-5 show the BoM for the pumps in the study.

Table 4-2: Detailed bill of materials for VSD

Materials	Rated Power of the pump motor				
	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

bio by Deloitte.

Table 4-3: Bill of Material for smaller clean water pump – Source: Europump and technical experts

Materials	Swimming pool pumps up to 2.2kW*	Swimming pool pumps over 2.2 kW	Fountain and pond pumps up to 1 kW*	Aquarium pumps to 120W*	Aquarium power head	Spa pumps*	Counter-Current Pumps*
Max. power rating [kW]	2.2	25	1	0.12		25	17
Product weight [kg]	14	24.2	4.5	1.2	0.6	25	27.5
Packaging weight [kg]	1.425	5.575	0.39	0.34	0.2	6.5	4.625
Product	**Content [%]**	**Content [%]**	**Content [%]**	**Content [%]**		**Content [%]**	**Content [%]**
Steel	44	49	-	-	-	44	49
Cast Iron	-	-	-	-	-	-	-
Other ferrous metals	-	23	32	17	17	-	11
Non-ferrous metals	25	17	22	17	17	29	17
Plastics	31	11	2	5	17	27	15
Coatings	-	-	-	-	-	-	-
Electronics	-	-	-	-	-	-	-
Other Materials	-	-	27	25	33	-	8
Packaging	**Content [%]**	**Content [%]**	**Content [%]**	**Content [%]**		**Content [%]**	**Content [%]**
Plastics	18	2	3	-	-	-	8
Cardboard	82	44	82	100	100	100	43
Paper	-	-	10	-	-	-	11
Other (Wood, etc.)	-	54	5	-	-	-	38

* Includes pump and motor

Table 4-4: Bill of Material for large clean water pumps – Source: Europump and technical experts

Materials	End suction close coupled from 150 kW to 1 MW	End suction close coupled inline from 150kW to 1MW	End suction own bearing from 150 kW to 1 MW
Max. power rating [kW]	1,000	1,000	1,000
Product weight [kg]	650	650	650
Packaging weight [kg]	10	10	8
Product	**Content [%]**	**Content [%]**	**Content [%]**
Steel	13	13	13
Cast Iron	-	-	-
Other ferrous metals	85	85	85
Non-ferrous metals	2	2	2
Plastics	-	-	-
Coatings	-	-	-
Electronics	-	-	-
Other Materials	-	-	-
Packaging	**Content [%]**	**Content [%]**	**Content [%]**
Plastics	30	30	12.5
Cardboard	70	70	87.5
Paper	-	-	-
Other (Wood, etc.)	-	-	-

Table 4-5: Bill of Material for bore hole pumps and vertical muti-stage – Source: Europump and technical experts

Materials	8" Submersible bore-hole pumps	10" Submersible bore-hole pumps	12" Submersible bore-hole pumps	Submersible bore-hole pumps larger than 12"	Vertical multi-stage pump (25 to 40 bar and/or 100 to 180 m³/hr)	Vertical multi-stage pump (>40 bar and/or >180 m3/hr)
Max. power rating [kW]	110	190	250	400	260	750
Product weight [kg]	191.9	515.1	643.4	2626	283	1,175
Packaging weight [kg]	31.25	53.75	75.5	129.75	34.8	69.3
Product	**Content [%]**	**Content [%]**	**Content [%]**	**Content [%]**	**Content [%]**	**Content [%]**
Steel	49	49	49	49	32	10
Cast Iron	-	-	-	-	-	-
Other ferrous metals	50	50	50	50	66	85
Non-ferrous metals	-	-	-	-	1	5
Plastics	1	1	1	1	1	-
Coatings	-	-	-	-	-	-
Electronics	-	-	-	-	-	-
Other Materials	-	-	-	-	-	-
Packaging	**Content [%]**	**Content [%]**	**Content [%]**	**Content [%]**	**Content [%]**	**Content [%]**
Plastics	6	6	5	5	3	1
Cardboard	17	14	13	10	24	36
Paper	-	-	-	-	-	-
Other (Wood, etc.)	77	80	82	86	73	62

4.3 Distribution phase

There can be wide variations in weight and volume of pumps packed for distribution. Table 4-6 show the weights of pumps, which has been derived through consultation with stakeholders.

Table 4-6: Distribution – Source: technical experts

Pump type		Weight of packaged product [kg]
Swimming Pool pumps (integrated motor+pump)		
	Domestic with built in strainer up to 2.2 kW	15.4
	Domestic/commercial with built in strainer over 2.2 kW	29.8
Fountain and pond pumps to 1 kW		4.9
Aquarium pumps (domestic/small aquarium - non-commercial) to 120 W		1.6
Aquarium power head (separate study for life cycle data only) to 120W		0.8
Spa pumps for domestic & commercial spa's (where the water is retained and filtered)		31.5
Counter-Current Pumps		32.1
End Suction water pumps (over 150kW-P2)		
	ES Close Coupled from 150 kW to 1 MW	660
	ES Close Coupled Inline from 150 kW to 1 MW	660
	ES Own Bearing from 150 kW to 1 MW	658
8" Submersible bore-hole pumps		223.2
10" Submersible bore-hole pumps		568.9
12" Submersible bore-hole pumps		718.9
Submersible bore-hole pumps larger than 12"		2755.8
Vertical multi-stage pump (25 to 40 bar and/or 100 to 180 m3/hr)		317.8
Vertical multi-stage pump (>40 bar and/or >180 m3/hr)		1244.3

4.4 Use phase (product)

4.4.1 Calculation of the Energy Used by the ENER Lot 29 Pumps

The MEEuP Ecodesign general methodology states that the annual resource consumption and the direct emissions produced during the product life should be determined in accordance with the test standards. However, there are currently no test standard condition and so in order to derive the ENER Lot 29 pump models, load profiles for each or the pump types are required. Load profiles give an approximation of how the flow from the pump alters over time. This change in flow could be due to controls in variable flow system. In constant flow systems, this change in flow could potentially be due to changes in the static head or system resistance. An example of a load profile is shown in Table 4-7below.

Table 4-7: Flow profile used for pump modelling – Source ENER Lot 11 Study

% of Best Efficiency Point Flow	% of time at this flow
50	25
75	50
100	20
125	5

The energy performance of each pump is calculated by the following method:

- Look up the rated efficiency at the selected flow points. Subtract a nominal amount to allow to for lifetime decrease in efficiency, and then use this as the basis to determine the average "in service" energy consumption over the lifetime of the pump. Calculate the power consumption at each flow point – i.e.

$$\text{Shaft power (kW)} = \frac{\text{Flow (l/s) x Head (m) x Relative density of fluid (kg/l) x Gravity (m/s}^2\text{)}}{\text{Mean lifetime pump efficiency (\%) x 1,000}}$$

- For each flow point, the power is then multiplied by the annual operating hours associated with this point. This is calculated as a percentage of the time spent at that to get the total annual energy consumption.
- This is repeated for the each of the remaining flow points and totalled to give total annual energy consumption for the pump under assumed operating conditions.
- The conversion between electrical and mechanical (shaft) power is calculated by considering the efficiency of an IE3 induction motor to be used for that pump.

$$Electrical\ Power = \frac{Shaft\ Power}{IE3\ Motor\ Efficiency}$$

- In all cases the data relates to total (electrical) energy consumption, which is what the MEEUP model requires in order to calculate environmental emissions from each pump type. Section 4.3.3 makes these distinctions clear.

Table 4-8 shows the power, operating hours and annual energy consumption for the use phase.

4.4.2 Data on Use Phase for Pumps in Scope

Table 4-8 provides the data on the use phase for pumps in ENER Lot 29.

Table 4-8: Data on use phase for pumps in scope – Scope: Europump

Pump Type		Hydraulic Pump Power	Annual operating hours	Annual energy consumption
		kW	Hours	GWh
Swimming Pool pumps (integrated motor + pump)				
	Domestic with built in strainer up to 2.2 kW	0.8	1,500	6,912
	Domestic/commercial with built in strainer > 2.2 kW	5	3,375	2,329
Fountain and pond pumps to 1 kW		0.02	6,000	266
Aquarium pumps to 120 W		0.005	8,720	421
Aquarium power head to 120W		0.005	8,720	18
Spa pumps for domestic & commercial spa's		1.1	350	19
Counter-Current Pumps		3	20	72
End Suction water pumps (over 150kW-P2)				
	ES Close Coupled from 150 kW to 1 MW	150	3,600	648
	ES Close Coupled Inline from 150 kW to 1 MW	150	3,600	648
	ES Own Bearing from 150 kW to 1 MW	325	3,000	6,435
8" Submersible bore-hole pumps		33	2,565	7,415
10" Submersible bore-hole pumps		65	2,725	6,731
12" Submersible bore-hole pumps		121	3,114	6,855
Submersible bore-hole pumps larger than 12"		288	3,352	5,213
Vertical multi-stage pump (25 to 40 bar and/or 100 to 180 m3/hr)		68	2,700	6,389
Vertical multi-stage pump (>40 bar and/or >180 m3/hr)		125	3,450	1,488

4.5 End-of-life phase

▶ Large water pumps

These pumps are likely to be returned to factory for refurbishment when their performance deteriorates too far. Pump manufacturers often make more from spares and maintenance than they do from selling new parts. Routine maintenance will be performed in the field.

When these pumps reach the end of their life, as they are all metal they will be sent for scrap. There is little market for second hand pumps.

▶ Swimming pool, spa and counter current pumps

Given the cost of these pumps, at failure they are more likely to be repaired. Spare motors are for example readily advertised. The second hard market is only small, as consumers are unlikely to upgrade unless their pump fails.

▶ Fountain, pond and aquarium pumps

Given the low value of these, they are likely to be disposed of when they fail, not repaired. The motor contains valuable metal, and the plastic pump and case is can be recycled.

It should be noted that 100% separation of the main metal fractions from the pump is difficult and is not actually achieved during scrap treatment leading to, for example, lower iron recycling quality due to its remaining copper content.

The smaller domestic pumps in the study are typically disposed of in the municipal waste collection and not via separate WEEE collection.

Unlike products that are used by domestic consumers where most goods end up as landfill, the professional market that is responsible for disposing of old pumps is used to sending metal products for scrap. The 8% landfill figure set in the EcoReport (the simplified life cycle assessment tool that will be used to assess environmental impacts and life cycle costs in tasks 5 and 7) is therefore thought to be too high. However, as the EcoReport model carried out in the screening in Task 1 showed that materials are not responsible for much of the total environmental impact; this does not represent a significant error, and so is not investigated any further.

4.6 Recommendations on mandates

The pumps in the study may be appropriate for regulating as extended products. To facilitate this methodology for calculating an Energy Efficiency Index such as that used in the regulation of circulator pumps. It is recommended that a standardised methodology for calculation this is mandated.

4.7 Conclusion

All the pumps in this study are centrifugal pumps. These pumps impart energy to the water via a rotating impeller. Pump impellers are available in a range of dimensions to allow a wide range of duties to be achieved. Impellers can be physically trimmed to meet the exact required duty; however, pumps are designed to achieve their maximum efficiency with a full sized impeller.

The efficiency of pumping operation relies on all the components within it, not just the pump. Using the appropriate combination of motors, controls and sensors with a pump can have as much of an impact on the overall efficiency of a pumping operation as the design of the pump itself.

The smallest pump in the study is the aquarium pump up to 120W. Almost half of the components within this pump are made of plastic, with the remained of the components from metals. As the other end of the size range the clean water pumps have almost 100 % of their components made of metal, with 85% of the materials being classified as 'other ferrous metals'. The pumps in the middle, such as swimming pool pumps and spa pumps are predominantly made of metal, with plastic components accounting for between 15 – 31% of the materials.

In terms of the end life, the larger pumps tend to be refurbished as their performance degrades, and are sent for scrap on failure. Their high metal content ensures that they are recycled. The swimming pool, spa and counter-current pumps are frequently repaired at failure, and sent for scrap at the end of life. The smaller pumps tend to be replaced on failure owing to their low cost. The motors in these smaller pumps are often recycled due to their high metal content, however the plastic components may not be.

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185 avenue de Charles de Gaulle
92200 Neuilly sur Seine
France
biois.com