AEA Energy & Environment
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Appendix 5:
Lot 11 - Water Pumps (in commercial buildings, drinking water pumping, food industry, agriculture).

Report to European Commission

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Executive Summary

The EuP Directive and the Preparatory Studies

The Energy Using Product (EuP) Directive (2005/32/EC) allows the European Commission to develop measures to reduce the eco-impact of energy using products within the EC. Products that do comply with these measures may have the CE mark attached, those which do not could ultimately be prohibited from being traded within the EC.

This Directive provides for the setting of requirements which the energy using products covered by implementing measures must fulfil in order for them to be placed on the market and/or put into service. It contributes to sustainable development by increasing energy efficiency and the level of protection of the environment, while at the same time increasing the security of the energy supply. Furthermore, it goes beyond just energy efficiency considerations, as it also considers whole life cycle costs, including production and disposal costs. It can therefore be thought of as "energy efficiency, but not at any price".

In order to evaluate whether and to which extent a product fulfils certain criteria that make it eligible for implementing measures under the Directive, the MEEUP methodology (Methodology for the Eco-design of Energy Using Products) will be applied in this study. In order to facilitate the environmental impact analysis, the MEEUP methodology provides an Excel form (EuP EcoReport). In the preparatory phase of the study data was collected for inputting to this model, and comprises economic, material and energy use data for different stages of the product's life. This model translates these inputs into quantifiable environmental impacts.

Water Pumps

The study terms of reference set out the scope of the study to include water pumps in the following applications: Commercial Buildings, Drinking Water, Agriculture and the Food Industry**.**

These are regarded as mass produced commodity types of pump, where the user will not spend so long in specifying the optimum type, and so minimum pump efficiency standards of the type considered in this study are seen as being beneficial for reducing the environmental impact of pumps.

The types of pump considered in the study are:

- Single stage close-coupled (end suction close coupled) (ESCC)
- In –Line ESCC pumps (ESCCi)
- Single stage Water (end suction own bearing) (ESOB)
- Submersible multistage well pumps; (4" & 6")
- Vertical Multistage Water Pumps

This study estimates that there are a total of 17M installed pumps of these types in the EU, with sales of 1.5M pa, worth 1,500 Meuros pa.

The Environmental Impact analysis performed by the use of the EC MEEUP model shows that in all cases it is the In use phase that dominates, and so improving the energy performance of the products is key to reducing the lifetime environmental impact. The total energy used by these pumps is estimated at 137TWhpa (electrical), of which the three end suction types account for 73% of the energy consumption.

Pumps are excluded from WEEE and RoHS legislation, but even so, all existing designs appear from our research to be compliant.

Principle Findings and Recommendations

1.) Removing what are currently the worse 40% of pumps from the market is seen as being a reasonable medium term target, which would yield energy savings of c.3.6TWh pa by 2020 at little additional cost to the consumer. Once the full impact of such action is seen, then the energy savings from this measure will be 3.5% (or 5.8TWh pa at 2020 usage), representing a total of 16 TWh in the period 2012 to 2020. The limit to the speed at which this change can be implemented is therefore restricted just by the financial cost to manufacturers and also the number of personnel that they have available for designing and productionising new pump designs. It is suggested that interim targets of raising the cutoffs by 10% every 3 years, starting in 2010, would be reasonable. This relatively slow raising of minimum standards is suggested because of the high claimed cost to industry of 121Meuros for replacing the worst 20% of pumps from the market - any faster might put EU pump manufacturers at a competitive disadvantage.

2.) Life Cycle Costing analysis shows that, for most types of pumps, under typical operating conditions, it is cost effective to the User to select pumps that are within the current top 30% of pumps. If this could be achieved, it would lead to a reduction of 6.4% in pump energy consumption (8.8TWh pa at 2020 levels). There are no technical barriers to this, instead it is just the assumed cost to manufacturers of over 1,000 Meuros for re-designing pumps that is preventing this being proposed as a policy option within the 2020 timeframe of this study.

3.) In most real life applications, pumps will spend much of their time working some way from their design point, and so it is important to take account of this when classifying pump performance. The new "house of efficiency" scheme addresses this issue by setting efficiency criteria for not only 100% flow, but also sets slightly lower efficiency thresholds at 75% and 110% of rated flow that a pump must also exceed. This will avoid pumps passing the simple (rated flow) efficiency threshold, but actually performing very poorly when operated away from this point.

4.) A new methodology for setting the efficiency levels for different types of pumps has been devised, based on a 3-D plane. Although the derivation of this is technically complex, it is easy for manufacturers to use. This is thought to be the first time that a way has been found to compare pumps on a scientifically rigorous basis, and has been fully accepted by the manufacturers during the stakeholder process.

5.) While this methodology could be used as the basis of a "Top runner" or similar labelling scheme, it should be recognised that in general manufacturers will offer a family of pumps that has been developed over a long period of time, and so the efficiencies of individual pumps within a range are likely to be at a wide range of efficiency "cut off" values. Therefore, without considerable additional development work, it is unlikely that any manufacturer would have an entire range of pumps that would meet the efficiency value. This would make marketing the pumps difficult, and might even tempt some buyers to seek an "efficient" pump rather than purchase a correctly sized pump, hence leading to a net increase in energy consumption. However, denoting particularly efficient pumps does have several key advantages that it is felt outweighs these concerns:

- A defined high efficiency value will become a target efficiency value for manufacturers to achieve when designing new pumps. This will then lead to energy savings greater than those shown in points 1.) and 2.).
- It will define a higher efficiency performance standard (HEPs) for programmes that wish to promote "high efficiency" pumps.
- A HEPs is useful in order to get users to think about issue of pump efficiency and pump system efficiency more generally.

It is therefore recommended that a High efficiency performance standard (HEPs) level is defined as those pumps in the current top 20% of products on the market.

6.). The magnitude of allowed tolerances under the current ISO 9906 class 2 test standard compared to the observed spread of efficiencies for each type of pump mean that multi-level efficiency labelling schemes are inappropriate. Instead, just two efficiency lines (and hence three bands) are the most that is practical, corresponding to the mandatory CE/MEPs level and the voluntary label/HEPs level.

This test standard is being revised, and will have several new grades. It should be possible to chose a grade with tolerances tighter than the existing situation.

7.) The technical recommendations apply to the pump only, with separate recommendations for the motor driving it contained within the parallel Lot 11 Motor study.

The detailed analysis showed it is only the energy performance of the product that is critical. With the exception of the requirement to supply test information, there are no other generic design requirements on manufacturers of pumps.

Relative Efficiency	Proposed levels
100%	*Most Efficient Pump*
90%	
80%	HEPS (Labelling scheme level)
70%	
60%	
50%	
40%	MEPS, Mandatory – CE mark
30%	
20%	
10%	
0%	*Least Efficient Pump*

Recommended MEPs and HEPs levels for pumps.

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1 Definition

The study terms of reference (ToR) set out the scope of the study to include pumps in the following applications:
Water pumps used in:

- Commercial Buildings
- Drinking Water
- Agriculture
- Food Industry

The first section defines the product category and defines the system boundaries of the "playing field" for eco-design. This is important for a realistic definition of design options and improvement potential and it is also relevant in the context of technically defending any implementing legislation or voluntary measures that may arise following the study.
The pumps analysed in this study are those used for clean water applications, and will be used not only in the above sectors but also in other sectors which have applications that need this type of pump.

Figure 1-1 End suction own bearings pump supplied on a baseplate complete with motor and coupling, (Flowserve).

1.1 Product category and performance assessment

Existing methods of categorisation:

1.1.1 Prodcom categories (Eurostat)

Prodcom is the official source of EU statistics on EU industrial production, and so is the primary reference used for classification of pumps. There are many categories of pump included, and so for clarity an extract from Prodcom is presented (Table 1-1), this excludes types explicitly not for water pumping. It is unfortunately limited in its usefulness in that it does not differentiate between clean water and other applications (eg 29122413 includes drainage and sewage applications), and it also does not differentiate between different configurations of centrifugal pumps. In terms of user selection, the configuration of pumps is important, consequently this categorisation is inadequate for the purposes of the study.

Prodcom Reference	Description
29122413	Submersible motor, single stage rotodynamic drainage and sewage pumps
29122415	Submersible Motors, multi-stage rotodynamic pump
29122417	Glandless impeller pumps for heating systems and warm water supply
29122420	Rotodynamic pumps <= 15mm discharge
29122430	Centrifugal pumps with a discharge diameter > 15mm, channel impeller pumps, side channel pumps, peripheral pumps and regenerative pumps.
29122451	Centrifugal pumps with a discharge outlet diameter >= 15mm, single stage with a single entry impeller, close coupled
29122453	Centrifugal pumps with a discharge outlet diameter >= 15mm, single stage with a single entry impeller, long coupled
29122455	Centrifugal pumps with a discharge outlet diameter >15mm, single stage double entry impeller.
29122457	Other centrifugal pumps, single-stage

Table 1-1 Prodcom classification of relevant pumps

1.1.2 Categories according to En- or ISO- standards.

The only pertinent technical standard in the classification of pumps is EN 733:1995 "*End-suction centrifugal pumps, rating with 10 bar with bearing bracket. Nominal duty point, main dimensions, designation system*", This contains information (Figure 1-2 and Figure 1-3), which defines the dimensions and nominal performance of end suction centrifugal pumps. Whilst the standard is well accepted within the industry, it is limited in scope to this style of pump only. The definition of product performance is restrictive in that it would not permit changes in physical design of the product, which is in contravention of Article 15 4(e) of the EuP Directive: *"in principle, the setting of an ecodesign requirement shall not have the consequence of imposing proprietary technology on manufacturers."*

Given the large number of pump types in existence, this single standard (which corresponds to some of the "Centrifugal – Single entry volute conventional" pumps in figure 1.1), is inadequate as a means of classifying pump types, and it would certainly be inappropriate to use EN 733:1995 as the basis for any efficiency standards.

For Multistage well pumps, the motor is constructed to standard NEMA dimensions, in this case to suit fixed well diameters (4", 6" and larger). No single En or ISO standard has been identified that relates to all the types of pumps in this study.

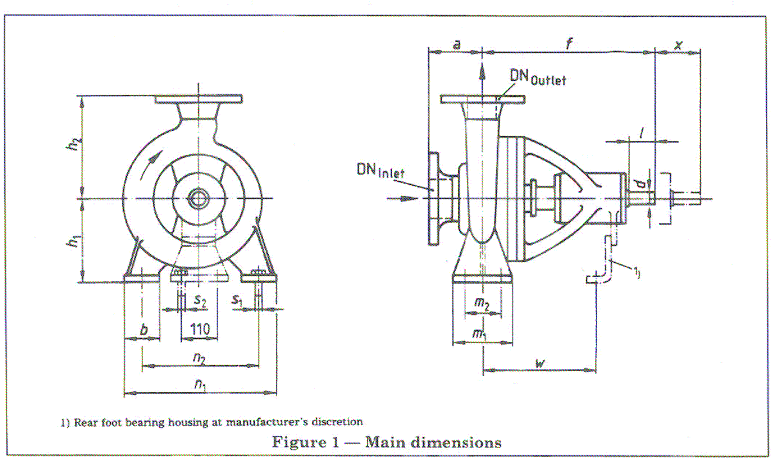


Figure 1 — Main dimensions

Figure 1-2 Extract from EN733 showing the standardised dimensions for pumps built to this standard.

Table 1 — Nominal duty point and main dimensions

Size	Nominal diameter of the impeller	Nominal duty point 1 450 min^{-1} Q	1 450 min^{-1} H^a	2 900 min^{-1} Q	2 900 min^{-1} H^a	Flange mounting dimensions for PN 10[b] DN Inlet	DN Outlet	Pump dimensions (mm) a	f	h_1	h_2	Foot dimensions (mm) b	m_1	m_2	n_1	n_2	s_1 (for bolts)	s_2 (for bolts)	w	Shaft end dimensions (mm) x^c	d	l
	mm	m^3/h (l/s)	m ≈	m^3/h (l/s)	m ≈	mm	mm															
32–125	125	6,3	5	12,5	20	50	32	80	360	112	140	50	100	70	190	140	M 12	M 12	260	100	24	50
32–160	160	(1,75)	8	(3,5)	32					132	160				240	190						
32–200	200		12,5		50					160	180				240	190						
40–125	125	12,5	5	25	20	65	40	80	360	112	140	50	100	70	210	160	M 12	M 12	260	100	24	50
40–160	160	(3,5)	8	(7)	32			80		132	160				240	190						
40–200	200		12,5		50			100		160	180				265	212						
40–250	250		20		80			100		180	225	65	125	95	320	250						
50–125	125	25	5	50	20	65	50	100	360	132	180	50	100	70	240	190	M 12	M 12	260	100	24	50
50–160	160	(7)	8	(14)	32					160	180				265	212						
50–200	200		12,5		50					160	200				265	212						
50–250	250		20		80					180	225	65	125	95	320	250						
65–125	125	50	5	100	20	80	65	100	360	160	180	65	125	95	280	212	M 12	M 12	260	100	24	50
65–160	160	(14)	8	(28)	32					160	200				280	212						
65–200	200		12,5		50					180	225				320	250				140		
65–250	250		20		80				470	200	250	80	160	120	360	280	M 16			140	32	80
65–315	315		32	—	—			125		225	280				400	315			340			
80–160	160	80	8	160	32	100	80	125	360	180	225	65	125	95	320	250	M 12	M 12	260	140	24	50
80–200	200	(22,3)	12,5	(45)	50					180	250				345	280						
80–250	250		20		80				470	200	280	80	160	120	400	315	M 16		340		32	80
80–315	315		32	—	—					250	315											
100–200	200	125 (35)	12,5	250 (70)	50	125	100	125	470	200	280	80	160	120	360	280	M 16	M 12	340	140	32	80
100–250	250		20		80			140		225	280				400	315						
100–315	315		32	—	—					250	315				400	315						
100–400	400		50						530	280	355	100	200	150	500	400	M 20		370	140	42	110
125–250	250		20	—	—	150	125	140	470	250	355	80	160	120	400	315	M 16	M 12	340	140	32	80
125–315	315	200	32						530	280	355	100	200	150	500	400	M 20		370	140	42	110
125–400	400	(56)	50							315	400											
150–315	315	315	32	—	—	200	150	160	530	280	400	100	200	150	550	450	M 20	M 12	370	140	42	110
150–400	400	(87,5)	50							315	450											

[a] The nominal delivery head values indicated for the nominal supply values are approximate values only. The precise values may be found in the manufacturer's literature.

[b] According to ISO 7005-1, ISO 7005-2 and ISO 7005-3 the permitted temperature range may be found in the manufacturer's literature.

[c] Dimension to be considered by the manufacturer in respect of removal of inner parts of the pump. The dimension x must not be identical with the distance between the shafts of the pump and the driving machine. The given dimension considers the use of flexible shaft couplings with spacer sleeve. The gap is necessary for the withdrawal of the rotor toward the driven side.

Figure 1-3 Extract from EN733 showing the complete range of nominal pump dimensions for the EN733 style of pumps

1.1.3 Labelling categories (EU Energy Label or Eco-Label)

There are currently no EU eco labels that can be used as a basis for pump categorisation. The voluntary circulator scheme is a useful reference, in particular in the way that it takes account of operation at reduced flow. However, the flow weighting scheme on which it is based is only feasible because the flow distribution is similar in most systems – which is not the case with the pumps considered in this study because they are used for a very wide range of duties.

1.1.4 The Study classification scheme for pumps

Given the lack of any existing classification scheme adequate for the study purposes, the following categorisation method is adopted[1]. There are other categorising schemes available from other sources, but none of them has obvious merits over any others.

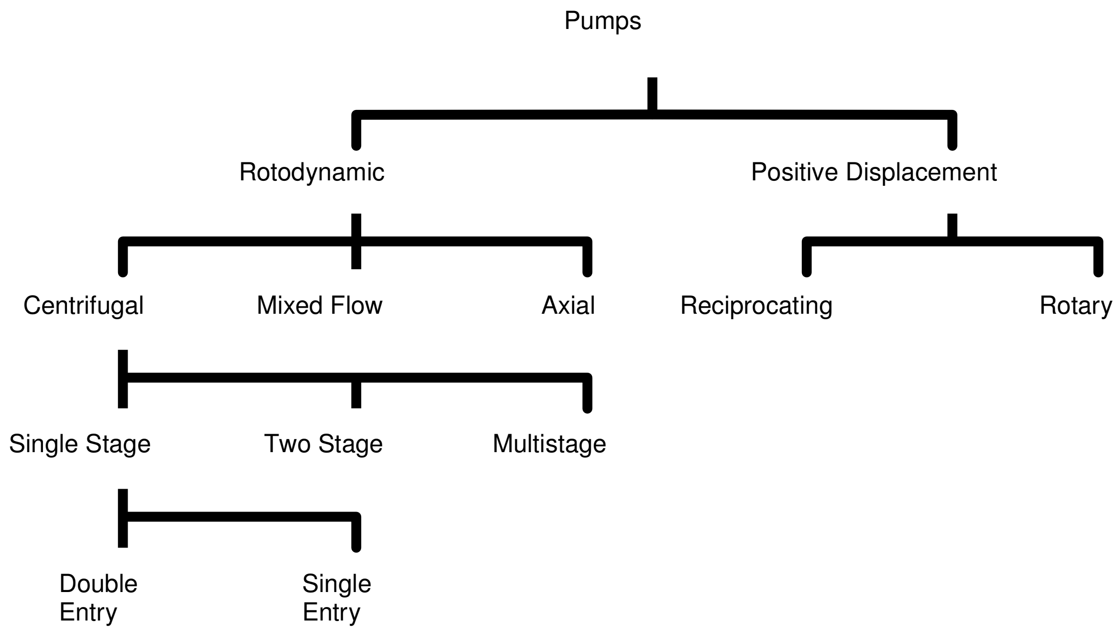


Figure 1-4 Family tree of pumps, showing the main types used for water pumping, by construction

It is acknowledged that this categorisation of type is imprecise, as some types of pumps could be classified in more than one way. However, the impact of this imprecision on the selection and analysis of pumps is only going to be very small, and so is not considered any further. There are in addition some highly specialist types such as jet pumps which work on the venturi principle, liquid ring pumps used for providing a vacuum in for instance the paper industry. Unfortunately there are no sales figures for these, but the specialist nature makes it apparent that sales will be low. However, in terms of our study, the key point is that they are not used for the water pumping applications stated in the ToR, and so they will not be considered any further.

The terms of reference setting out the scope of the study result in the exclusion of pumps which may have special features to cope with the following operating requirements:

- Fluids with particularly high or low temperatures.
- Aggressive fluids, perhaps acidic, flammable or explosive.

[1] UK Guide to the Procurement of Rotodynamic Pumps, David Reeves (Unpublished). Available from the study group or BPMA.

- Matter to be pumped that needs careful handling, eg food processing.
- Precision measurement of fluids
- Pumping of fluids with high solids content, such as Waste Water Treatment.

		Style of Pump	Clean Water?	Mass produced?
ROTODYNAMIC	**Centrifugal**	**Single Entry Volute - Conventional** INCLUDES ***End Suction Own Bearings*** and ***Close Coupled End Suction*** types	X	X
		Single Entry Volute – Solids Handling		
		Single Entry Volute – Non-Clogging		
		Single Entry Volute – In-Line	X	X
		Double Entry Volute	X	
		Two Stage Volute	X	
		Multistage Radial Split INCLUDES ***Vertical Multistage pumps***	X	X
		Multistage Axial Split		
		Multistage Barrel Casing		
		Single Stage Well	X	
		Multistage Well INCLUDES ***Submersible Multistage Well pumps***	X	X
	Mixed Flow	Volute	X	
		Bowl	X	
	Axial Flow	Well	X	
POSITIVE DISPLACEMENT	**Rotary**	Progressing Cavity		
		Sliding Vane		
		Peristaltic		
		Screw		
		Lobe		
		Gear		
	Reciprocating	Diaphragm		
		Plunger		
		Piston		
	Open	Archimedean Screw		

Figure 1-5 The Universe of pumps – categorisation by type.

The two columns on the right are used to show which pumps meet the two key criteria for pump selection that is implied by the terms of reference. The selected pumps are shown in ***italics*** in the third column.

1.1.5 Definition of Primary Functional Parameters

The primary functional parameters (ie "what it does") are: Rated flow ("Q", m^3/hour), pressure or head ("H",m), and the fluid properties. Efficiency is not a primary functional parameter, on the basis that it relates to how a product does something, not what it does. "Fluid properties" are included to make clear that the nature of fluids has a major impact on the selection of product.

The functional unit is the reference value for any pump considered, and is independent of type. It also helps to set the boundaries for comparison of different products. For the pumps in this study, this may be assessed by considering "the quantity of water pumped at the specified head (pressure), (m^3/h, m)".

Although this may seem to be an abstract concept, it is actually a fundamental technical consideration under-pinning this report that will be referred to when later needing to compare physically different pumps which actually perform the same task.

1.1.6 Secondary Functional Parameters

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 policy options. These include;

- **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 (1450rpm) can be cheaper than a two pole motor (2900rpm); 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.

- **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 ($NPSH_R$) 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 $NPSH_R$ 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 $NPSH_R$ 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 $NPSH_A$, 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.

- **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.

- **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.

1.1.7 How the pumps to be studied are derived from the above categorisation

The rationale for the final selection of pumps to be considered in the study is presented here in summary form, but it should be noted that some of the arguments draw on subjects discussed in more detail in later sections of this report. The approach taken is to assume that all pumps are included, unless there are reasons given in clauses within the EuP Directive that mean that they can be excluded. Care has been taken to try to ensure that no pumps are excluded due to the type of technology rather than the duty/service/function.

An important point is that some types of pumps could theoretically be used in many different application categories, but this does not happen for reasons of cost or detailed design features.

In this study we need to reflect real life product usage, and so we are guided by current norms in the way which we consider the products to be considered for each application.

1.1.8 How pumps work

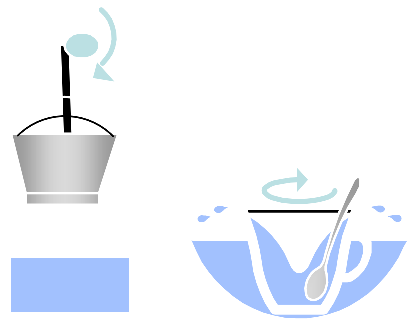


Figure 1-6 above shows the basic differences between a Rotodynamic and a Positive Displacement pump. A Positive Displacement pump in its simplest (and oldest) form is typified by a bucket lifting water from a well or river. It shows the principle of all pumps of this type; enclosed volumes of liquid are collected at the pump inlet and discharged at the outlet at increased head. The basic principle of a Rotodynamic pump is illustrated by the stirring of a cup of tea to the point where the rotating liquid is given sufficient energy to spill into a (rather deep) saucer, where the level (head) is higher than the mean level in the cup. 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.

Contrary to popular belief, a rotodynamic pump cannot suck. 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 water flow then passes from the inlet branch of the pump to the inlet of the impeller. It then has to change direction from axial to (near) radial as it enters the passage between the impeller vanes. 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. At best efficiency flow, the water will spiral out of the impeller in a free vortex of constant angle to the tangential direction. 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 a much increased pressure and usually with a small increase in velocity.

In vertical multistage and submersible multistage well pumps, the volute function is carried out by several vanes which guide the water from the discharge of one impeller to the inlet of the next. Ideally these will be designed for minimum loss but, in small submersible pumps, getting the maximum flow from a fixed borehole diameter may force a reduction in the diameter of the guide vanes or alter their geometry so as to cause a small loss in pump efficiency.

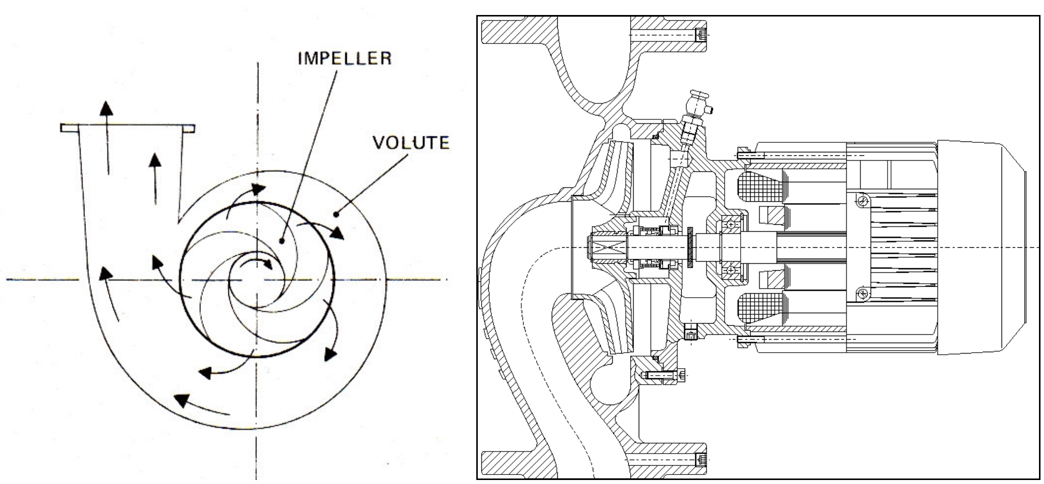


Figure 1-6 How rotodynamic pumps work: flow paths (left) and cutaway of motor-coupled pump (right)

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, and despite their usually better efficiency, are just not currently cost effective for the types of water applications in the ToR.

There are sound reasons for excluding the following types:

Single Entry Volute solids handling and non-clogging: types used in dirty water applications would not be used for these water applications, and so are excluded.

Multi-stage axial split: Mainly large pumps for boiler feed or seawater injection purposes. Excluded on the grounds that there are insufficient volumes sold and that they are not for the applications described in the ToR.

Multi-stage barrel casing: Large pumps primarily for high pressure or temperature liquids. Excluded on the grounds that there are insufficient volumes sold and that they are not for the applications described in the ToR.

Single Stage Well: Pumps mainly for water abstraction, and have very low sales, and hence are outside of the scope of this study. This type is usually surface driven via a long drive shaft.

Double-entry volute: These pumps have the advantage that maintenance is easy because the top of the casing can be removed and the impeller removed without the need for a spacer coupling. Sales of these are very low, and mainly restricted to the UK market. More recently they have become regarded as not worth the additional cost for the ease of maintenance that they enable. They are excluded on the basis of low sales, (there is no precise data on this, but it is estimated to be <<10,000 units pa).

Two stage volute: This is a special design of pump for specific ranges of head and flow; they are at the transition between conventional single stage and multiple stage pumps. Generally there are no equivalents in either of these adjoining sectors, and so it can be regarded as a single type in its own right. On this basis they can be excluded because the annual sales are low.

Mixed Flow and Axial flow: These are specialist (low head) type pumps with only very low annual sales, and so are excluded.

The remaining pump designs are all centrifugal types, and there are various ways that these could be put in to different categories. Generally, if product categories are too tight, then none will exceed the 200,000 pa guideline threshold set out in the ToR to indicate significant sales volume, which is not satisfactory. But if product categories are too broad, then they do not mean much to the user, and any suggested design options would be likely to miss design / application subtleties in the secondary functional parameters and so be flawed.

The argument is always based firstly on the primary functional parameters, which are the flow and head. In these simple terms, within the centrifugal category, different styles are better suited for different head:flow duties. The style alters in a general way with reference to specific speed. While there will always be overlaps between different styles and their suggested range of application, the pragmatic way forward is to use the basic classification shown in the table to split the continuum of styles into manageable groups. Without this, it would be impossible to have a single implementing measure that could sensibly apply to all types.

Taking all these factors into consideration, and by reference to Europump sales statistics, the types shown in bold in 1.1.9 are those that are suggested as being relevant to this study.

1.1.9 Details of the key types of pumps considered in this study

A fuller description of the selected pump styles is given in section 4, but in summary comprises:

- **Single stage Water (end suction own bearing), (includes In-line as a sub-category)**
- **Single stage close-coupled (end suction close coupled),**
- **Submersible multistage well pumps; (4" and 6")**
- **Vertical Multistage Water Pumps**

The End Suction types were included in the earlier SAVE Pumps study[2]

Single Stage Pumps (ESCC and ESOB)
Water pumps of this type are used in many applications. They are commonly used for water supply and pressure boosting in tall buildings, also for cooling water and general service water in industry. They can be used for other applications, but these are outside the scope of this study:

- Fire fighting - but special characteristics are usually required.
- Irrigation (usually with a priming device).
- Pumping from shallow boreholes (using an ejector).
- Small pumps can be used for fountains or swimming pools.

In terms of construction, this category includes close-coupled (ESCC) and end suction own bearings (ESOB) types. Hydraulically they have the same performance, with the difference just being in the way that they are supported. To save cost, smaller pumps are designed in the more compact end suction close coupled (ESCC) construction. Larger pumps will need additional support, and will also have a separate motor, and so are supplied in the end suction own bearing design.

In addition, in-line pumps (ESCCi) are available for use mainly in circulator systems, where this design is particularly convenient to install. Hydraulically they are very similar to end suction types, but have the disadvantage of additional losses due to the additional 90° bend on the inlet side. Figure 1-10 (right) shows such a pump, with the additional bend clearly visible on the left hand side, and the motor mounted on the top. Although sales are lower than that of the standard ESCC type, their per unit life cycle cost is higher because as they are used mainly in heating systems, they have longer average operating hours.

[2] 'SAVE Study on Improving the Efficiency of Pumps', AEAT for the European Commission, February 2001

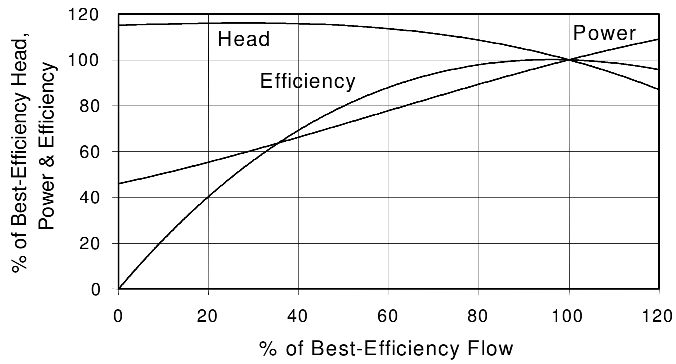


Figure 1-7 Typical Performance of single stage pumps

The Back wear rings associated with integral impeller balance holes (to reduce thrust and gland pressure), cause some efficiency loss. However, the efficiency falls relatively slowly as flow moves away from best-efficiency. A general feature is that smaller pumps tend to be relatively low cost with lower physically attainable efficiencies.

The head may fall with reducing flow (as shown); if so, at reduced flow surging may occur and pumps will not run in parallel at low flows. Power may increase considerably beyond best-efficiency flow, and so to cope with this, larger motors may be needed. The impeller may be mounted on motor shaft, or pump may have its own shaft and bearings with pump driven via a coupling. This important physical characteristic is the defining feature used for separating these into the two classes.

Standard ESOB pumps to ISO 2858 (EN 22858, ex Din 24256) and EN 733, ex DIN 24255, enable back pull-out of rotating element without disturbing pipework and, if using spacer coupling, without disturbing motor. Some pumps have special inlet casings for self-priming.

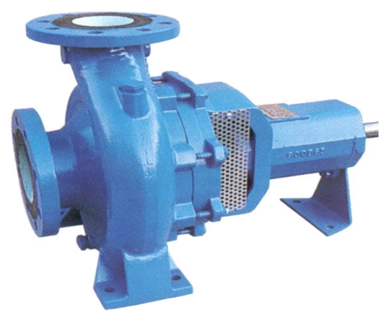


Figure 1-8 End suction own bearings, design of single entry volute pump (Flowserve)

Figure 1-9 End suction close coupled design of single entry volute pump (Flowserve)

Figure 1-10 End suction and in line pumps, with outlet at right angle and in line respectively. The motor is connected to the bottom and top respectively. (Wilo)

Submersible Well and Vertical Multistage pumps are both characterised by being constructed of two or more pump stages being constructed on top of each other, with large stacks consisting of 20 or more stages in order to reach the high head that these applications serve.

Submersible Multistage Well pumps are used mainly for abstraction from wells and boreholes, for potable water supplies or irrigation. They are also used for lowering of groundwater levels, de-watering mines or fire-fighting.

Vertical Multistage pumps are used in potable water supply for relatively high pressure boosting and distribution. They can also be used for irrigation and for feeding small boilers.

Shaft drive from surface mounted motors may be used in wells up to 30m deep, although use in deeper wells may still be economical. However, shaft drive would be very unusual in small diameter wells, and so is not considered in this study.

A submersible motor version is used in deep wells, with motor mounted below pump to aid cooling. The motor is usually water-filled with an integral thrust bearing. Motors are interchangeable between makes since they are connected to the pump by standard NEMA flanges and splined shafts.

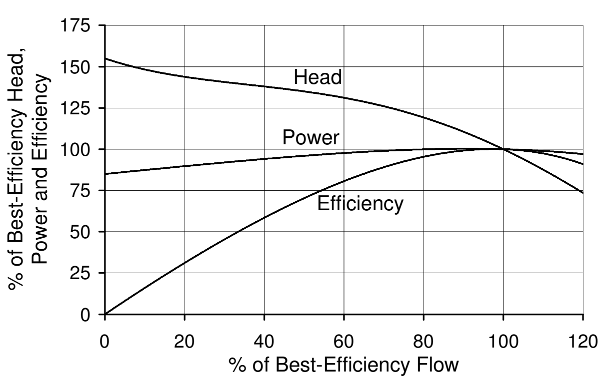


Figure 1-11 Typical Performance of submersible multistage well pumps

- Pump efficiency reasonably good but submersible motor less efficient than conventional motor. Column pipe losses may be significant in deep well.
- Power usually peaks at or near best-efficiency flow.

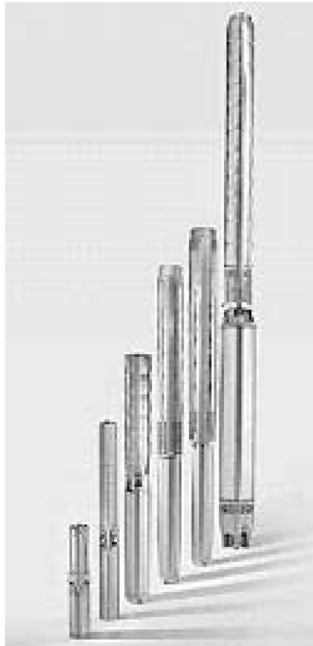



Figure 1-12 (Left) A selection of Submersible Multistage Pumps (Grundfos)

Figure 1-13 (Right) Vertical Multistage Pump (KSB)

1.1.10 Selection of pumps for this study

On the basis of sales statistics, and the applications of pumps specified in the scope of work, the following types of pump are considered relevant to this study:

- **Single stage Water (end suction own bearing), (includes In-line as a sub-category)**
- **Single stage close-coupled (end suction close coupled),**
- **Submersible multistage well pumps; (4” and 6”)**
- **Vertical Multistage Water Pumps**

Small circulator pumps are to be considered within the parallel Circulator report.

The following general points were considered in defining the exact specifications of ranges/types of pumps within each category:

1.) Standard types. The Directive is aimed at commodity types of products, not those designed especially for specialist or niche applications.

2.) When collecting data, manufacturers should not offer their "nearest equivalent" type of pump from a different family that satisfies the required duty, as this would lead to distortions in the results.

3.) As pumps are characterised by hydraulic values rather than power (kW) ratings, it is not possible to directly link them to the ranges in the motor study. However, indicatively it is unlikely that any pumps within the scope of the study will require an electrical motor in excess of 150kW to drive them. 0.75kW (as in the motor study) is about the minimum size to be expected. It is likely that all pumps in the study will be driven by induction motors.

4.) The indicative 200,000 units figure for products to be impacted is only to choose products on the basis of primary functional parameter. It should not be used as the basis for detailed consideration of which particular pump sizes etc are to be considered.

5.) As with many products, sales of those at the extreme of sizes will be very low compared to those in the "centre ground", and in many cases can be considered to be low volume products that are engineered rather than series produced commodity types. We do not have firm data on the proportion of the market that is excluded from the study in this way, and it will vary with the different styles considered, but our best estimate is that it is less than 5% of the total sales of each style, which types are low volume and often for "specialist" applications.

In each case, care must be taken to check that these considerations will not inadvertently allow excluded products from benefiting by being excluded from any policy options.

The following are the selected pump types/sizes that are to be considered to develop the base case reference models. These were carefully selected to represent the manufacturing features that apply to all pumps within each of the categories. To do this adequately, it was found necessary to select both a "small" and "large" model for each type.

Style	**Standard (where applicable)**	**Selected Duties (Q,H,speed)**
End Suction Own Bearings (ESOB)	EN 733:1995, 10 bar rating	1.) 30m^3/h at 30m 2 pole (small) 2.) 125 m^3/h at 32m 4 pole (large)
End Suction Close Coupled (ESCC) And In Line version (ESCCi)	None applicable, and so suggest base duties on EN 733:1995	1.) 25 m^3/h at 32m 2 pole (small) 2.) 125 m^3/h at 32m 4 pole (large)
Submersible Multistage	None applicable, so have based selection on typical available product	1.) 8.5m^3/h at 59.2m 2 pole (small) 2.) 15m^3/h at 88m 2 pole (large)
Vertical Multistage	None applicable, so have based selection on typical available product	1.) 4m^3/h at 45 m 2 pole (small) 2.) 10m^3/h at 42m 2 pole (large)

Table 1-2 Details of the pump types/sizes to be analysed for this study

Figures 1-14 and 1-15 show graphically the limitations on size for 4 and 2 pole speed end suction pumps respectively.

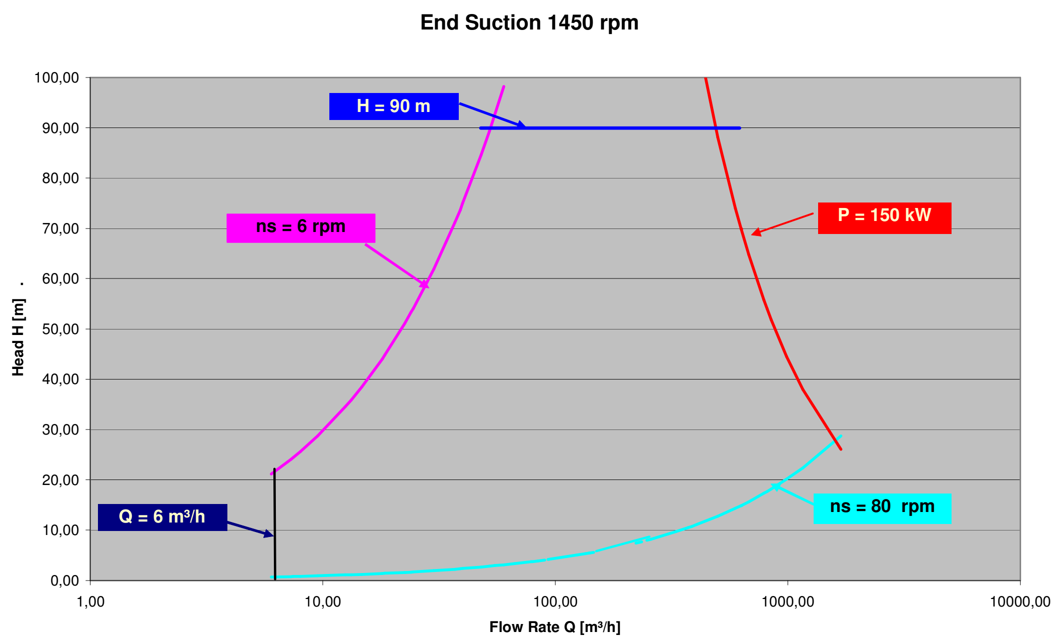


Figure 1-14 Duty limitations for 4-pole speed end suction pumps

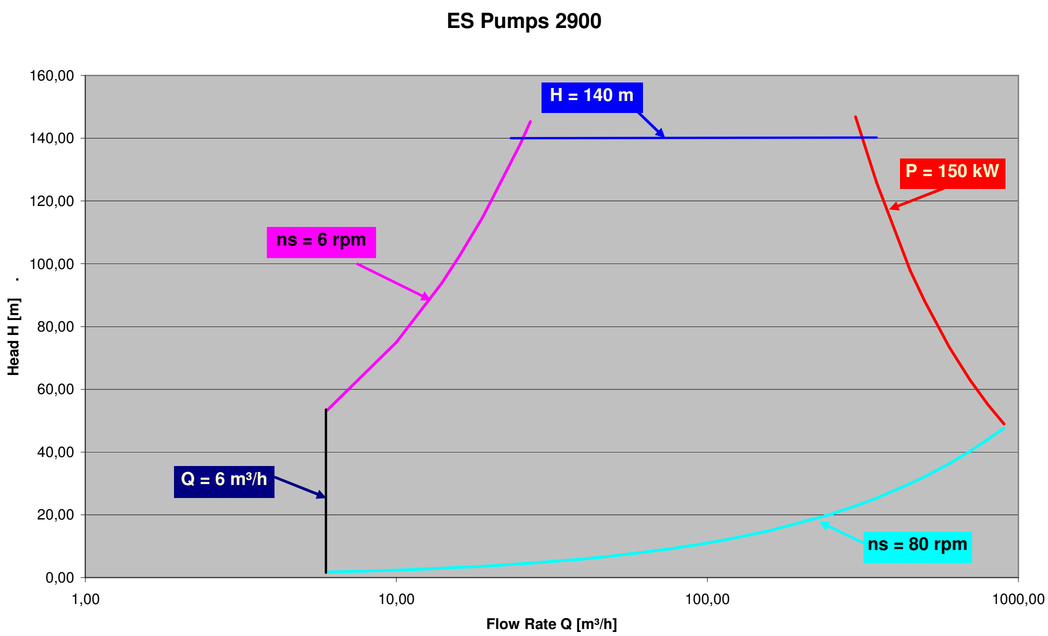


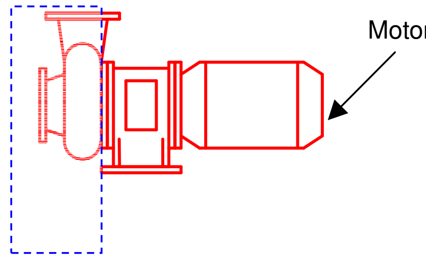
Figure 1-15 Duty limitations for 2-pole speed end suction pumps

1.1.11 Boundaries of the system

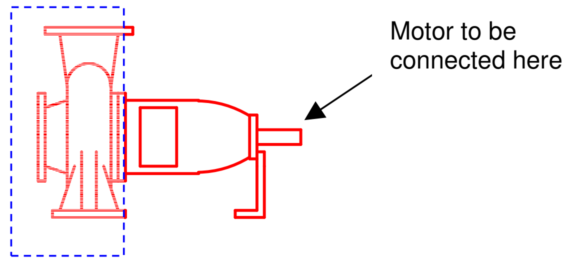
The boundaries for each product were decided on a product by product basis, in particular taking account of the market conditions applying to each product.

All pump performance data and subsequent analysis considers the pump shaft power only, (known sometimes as P2). It is only converted into electrical power (P1) in order to estimate the environmental impact of the pumps. This is done by assuming that the motor is on the Eff2 border, where $P1 = P2 / \eta_{mot}$, where η_{mot} is the assumed motor efficiency (at full load).

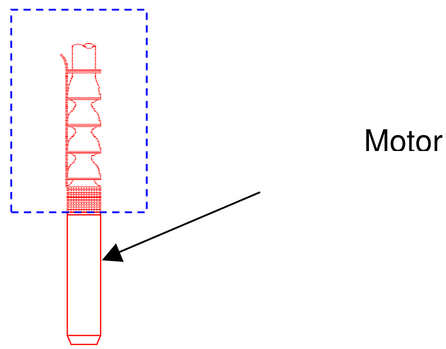
End suction close coupled pump



End suction own bearings pump



Multistage submersible pump



Vertical multistage pump

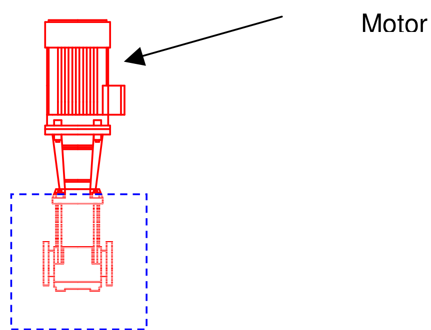


Figure 1-16 Boundaries of the system for each of the types of pump considered, (pump shown in blue dashed box)

End Suction Own Bearing pumps

These pumps are constructed as standalone products, that may be traded either as standalone products or with a motor attached by the manufacturer. The choice of motor will often not be known at the time of manufacture, and particularly on larger pumps may be dictated by the end User. While it is more usual for the product to be traded with a motor and associated mounting components, it was felt that the results would be more useful if this study analysed the pump alone.

End Suction Close Coupled Pumps

These are always supplied with the pump attached to the motor, as the impeller is supported by a special shaft. This is because if it was supplied separately, the impeller would be loose until such time as it was attached to a motor, which is clearly impractical. So there is an argument for considering the whole motor:pump unit as the product. However, because the motor is likely to be a standard induction motor in all respects apart from the shaft, it will be analysed as a pump only.

Submersible Multistage Well pumps,
These products are always sold as a combined pump and motor. However, the motors used have a standard NEMA mechanical connection, and are inter-changeable.[3]

Vertical Multistage pumps
As with End Suction Own Bearing pumps; these may have any motor attached to them although it is more usual for the manufacturer to supply this. But because they can clearly be split, this is the approach that has been taken.

In all cases the above thinking applies to the analysis only, this does not necessarily exclude policy options being based on the combined motor and pump unit.

1.1.12 The pump system

A pump will be described in a catalogue in terms of head, flow and, usually, power. In order to include a power curve, a specific gravity of unity is used (i.e. a density of 1000 kg/m^3), in other words the catalogue shows the power absorbed when pumping clean cold water. The actual mechanical power consumption is calculated as P_{mech} = Q x H x density x g / pump efficiency. This means that it is not possible to give standard curves of power consumption against duty for all liquids, as generally the power consumption varies with fluid properties – although for this study because we are only considering clean water this is not a problem. In addition, the same pump can be used with different motor speeds and impeller sizes, which adds additional variation.

Because a pump will on average spend most of its life operating below its Best Efficiency Flow, part flow operation is usually more critical from an energy perspective. Furthermore, pumps can be designed to have different trade-offs between full and part flow efficiency. It is therefore important that performance at part flow is taken account of in the analysis.

There is no “standard” flow distribution pattern for the types of pumps that are being considered in this study, and so an assumed pattern has been used in the analysis of energy consumption.

The concept of head is very useful and fairly easy to understand in a system such as that shown in Figure 1.17 below. The pump has to produce a head to overcome the static difference in water levels plus the equivalent head of the friction losses in the pipework. The beauty of using head is that the pump will deliver the same flow in the system shown no matter what liquid is being pumped (assuming its viscosity is low, clearly a centrifugal pump would not generate much head if trying to pump treacle). Confusion arises when the significance of head is not understood. Put simply, head is the effective work done on, or energy received by, the liquid per unit of mass, divided by g (the gravitational constant). This can be shown dimensionally:

A column of liquid of height (or head) H exerts a force F on its base of area A equal to its weight, i.e. F = mass x g = H x A x density x g

Thus, $H = F / (A \times \text{density} \times g) = N / (m^2 \times kg/m^3 \times g) = Nm / (kg \times g)$

i.e. <u>Head = Work per unit mass / g</u> <u>in units of</u> $[kg \times m/s^2 / (m^2 \times kg/m^3 \times m/s^2)] = \underline{m}$

Irrespective of the liquid pumped, a given pump at a given flow and speed does the same amount of effective work on each unit mass of liquid (and therefore generates the same head). This assumes that viscosity is low and that g varies very little on earth. (In space, a pump will generate an infinite head.) Pressure and power will vary with liquid density.

[3] Franklin motors for example specialise in the manufacture of these motors, and supply them both to OEM pump manufacturers and as spares for many different brands of pump.

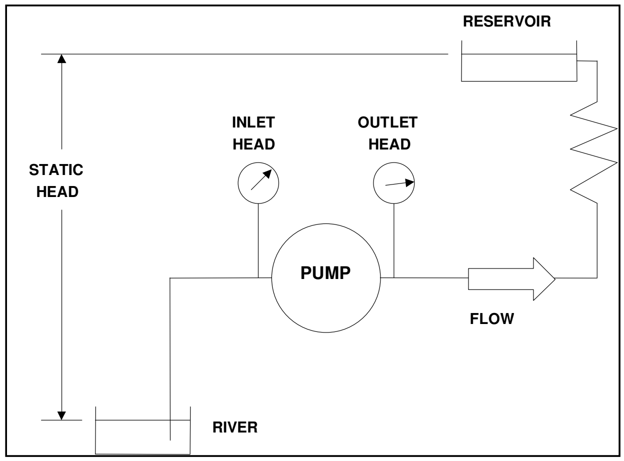


Figure 1-17 Illustration of an open pumping system

In this figure, Pump head = (outlet head – inlet head) = (static head + friction head)

1.1.13 Basic pump laws[4]

The fundamental similarity (scaling) laws applying to rotodynamic pumps are:

$$\frac{Y_{P2}}{Y_{P1}} = \frac{H_{P2}}{H_{P1}} = \left(\frac{n_{P2}}{n_{P1}}\right)^2 \cdot \left(\frac{D_{P2}}{D_{P1}}\right)^2$$

(equation 1)

where: Y= Specific hydraulic work (i.e. work done per unit of mass), D= Impeller diameter, n =Pump speed and H= Head

$$\frac{Q_{P2}}{Q_{P1}} = \frac{n_{P2}}{n_{P1}} \cdot \left(\frac{D_{P2}}{D_{P1}}\right)^3$$

(equation 2)

where Q = flow.

This shows, for example, that for two pumps which are exact scaled models, the power consumption (proportional to Q x H) is proportional to the impeller diameter to the fifth power at constant speed, or to speed cubed at constant diameter .

Resolving equation 1 and 2 results in

$$n_{P1} = n_{P2} \cdot \frac{(Q_{P2}/Q_{P1})^{1/2}}{(H_{P2}/H_{P1})^{3/4}}$$

(equation 3)

[4] Section 1.1.11 copied (with some modifications) from Europump EEMODS 2007 draft paper '*Energy Efficiency Evaluation of Pumps in Europe - Europumps proactive approach to the Energy Using Products Directive'*

With a Q_{P1} = 1m³/s, H_{P1} = 1m and Pump 2 at best efficiency point equation 3 leads to the specific speed n_s (usually used in literature for n_{P1})

Specific speed $n_s = n.(Q_{opt})^{1/2}/(H_{opt})^{3/4}$ (equation 4)

where n is speed in rotations per minute (rpm), Q_{opt} is flowrate in m^3/s, and H_{opt} is total head across pump in m, all at best efficiency point. It is conventional to refer to n_s in units of rpm, although this is not strictly correct.

The specific speed is the most important similarity parameter in hydrodynamic pump technology. It has central focus throughout pump literature. It characterises the impeller shape, is suited to compare different impeller types and consequently pump types on a common basis.

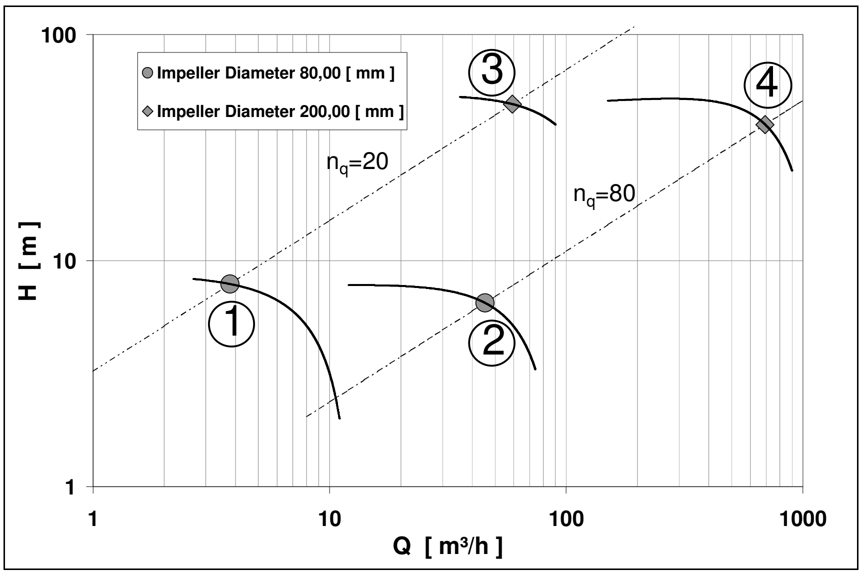


Figure 1-18 Duty points of pumps of different sizes but same specific speed

Figure 1-18 illustrates four different pump cases of two different pump types in a H-Q-Diagram. The two pump types are characterised by the specific speed. Though the pump sizes of for example No.1 and No.3 are completely different (more than a magnitude difference in flow) their geometrical ratio is similar and therefore they have also the same specific speed.

The same four cases are shown in figure 1-19 in more detail. The impeller diameter of pumps with the same specific speed are different and hence their flow rate at best efficiency point also. The pump is designed for a system in which it has to be implemented (heating / cooling systems, open pump systems etc.). All these different systems mean different requirements to the pump itself and subsequently the hydraulic design. Hence there is a requirement within industry for a large variety of pump sizes to service the European market. This allows pump manufacturers to optimize pump efficiency for each design. For example usually a bigger sized impeller with the same specific speed has a better efficiency than the geometrically similar smaller version. To say “the bigger the better“ is however not necessarily correct because of the large amount of energy dissipated by operating points which may not match to the system. The choice of a pump for a specific application is also dependent on the NPSH-figure, noise, dirt etc.

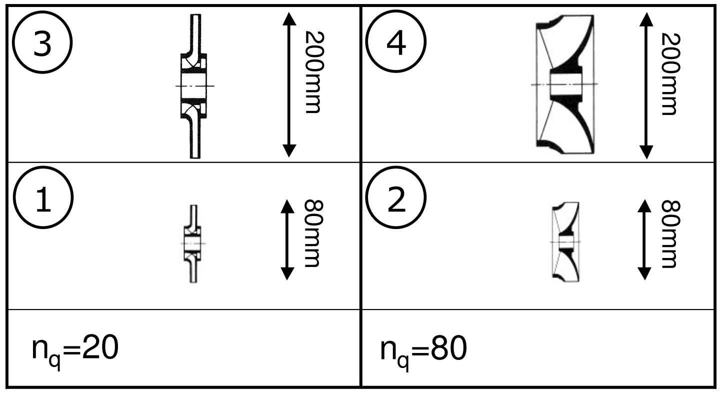


Figure 1-19 Principle impeller designs for typical pump sizes and specific speed

As induction motors are only available in fixed speeds, trimming the impeller is a common way to adjust the output of a pump to suit a particular application. The User therefore has an almost infinite range of pump options, which makes analysis difficult. But because the pump will be designed for best efficiency at full impeller, it is most appropriate to only consider performance at full impeller, as this is indicative of performance at all impeller diameters. As the EuP Directive is aimed at improving pump design, this was seen as being the most appropriate impeller diameter to consider.

1.1.14 Importance of inlet pressure

Unlike a fan, a pump requires a minimum pressure at its inlet branch if it is to produce any flow at all. This is because at low pressures the water vaporises at the impeller inlet and the impeller is then unable to produce the pressure rise necessary to overcome the system resistance it is intended to work against.

The net positive suction head (NPSH) required by the pump (NPSHR) is defined above. To operate normally the pump will usually be arranged in the system such that the NPSH available at the pump inlet (NPSHA) is at least 1.5m greater than the NPSHR throughout the intended flow range.

If the NPSHA is close to or less than the NPSHR, the head produced by the pump and the pump efficiency will both fall. It is therefore essential to provide adequate suction pressure to the pump if its optimum performance is to be achieved.

If the pressure at the pump suction is below atmospheric pressure, the pump performance can also deteriorate if air leaks into the pipework or through the pump seal. Even a very small leakage of air can reduce the pump head and efficiency significantly, so close attention to sealing is essential. In the case of Submersible Multistage Well pumps, if the water level in the well is too low air can be drawn into the pump through a vortex and again the performance will be adversely affected.

1.1.15 Variable speed operation and Integrated Variable Speed Pumpsets

It should be noted that the part flow performance of the same pump will differ greatly depending on the characteristics of the hydraulic system that it is driving. The extremes of a pumping system would be represented by a circulator system where there is a steep reduction in power consumption as speed falls, and a water raising system where the system will simply not work if speed is reduced (the required pressure may not be achieved). For fixed speed pumping systems, which is the focus of this study, this variation in characteristics does not matter. But for variable speed pumping systems, this is an issue.

This means that in order to define the operating conditions under which part flow measurement will be undertaken, a single system resistance must be defined that is in some way representative of all the systems that the pump may be driving.

While in terms of the Directive Integrated Variable Speed Pumpsets are clearly within scope regarding the definition of a product, the view is that this would be a mistake on two grounds:

Sales of integrated variable speed pumpsets are very low compared to fixed speed equivalents, and so would not be a separate product category.

The pumps used in integrated variable speed pumpsets are the same as those sold as pumps without any driver, and hence the results of this study will also apply to pumps incorporated into variable speed units. In practical terms, it is important from the manufacturers perspective that the same design considerations apply to all pumps of the same type, irrespective of how they are sold. Differences in the performance of the driver (control electronics) between models will be negligible compared to the energy savings that they can deliver.

What we therefore suggest is that we make an estimate of the system energy and environmental savings possible from the use of variable speed operation, but not look at the additional costs of the variable speed control unit. This is in line with us not considering the impact on the pump or pump system of using a more efficient motor. From a policy perspective there is some sense in this in that we would not want to discriminate against users who obtain the same benefits by using a separately mounted variable speed drive (VSD).

Europump estimate (May 2007) that the proportion of each class of pump sold with integral VSD control is:

End Suction Own Bearings	4%
End Suction Close Coupled	5%
End Suction Close Coupled in line	30%
Multistage water	8%
Multistage submersible	1%

A separate section on the benefits of variable speed control is included as an annex to the parallel Motors report.

Figure 1-20 Variable speed pumpset (KSB)

1.2 Test Standards

This section identifies the relevant test standards and procedures.

1.2.1 Harmonised test standards

Performance testing of pumps is to one of two ISO grades, Grade 1 (most accurate) or Grade 2 (least accurate) to EN ISO 9906-1999, (currently being revised). The tolerance on efficiency for Grade 2, which is the norm for mass produced pumps of the type with which this study is most closely concerned, is 5% of the value.

For larger pumps, a user may request a test of the actual pump to Grade 1, but this costs additional money, and so will not be done unless specifically requested.

Smaller pumps produced in series (mass produced) tend to be sold (usually) without test and instead use the efficiencies shown on catalogue curves, with the efficiencies to the tolerances shown in Annex A of ISO EN 9906-1999.

With any efficiency ranking scheme, it is important that there is a level playing field, with no manufacturer seeking to exaggerate the efficiency of their products.

These factors mean that quoted efficiencies may not be sufficiently reliable indicators of actual performance, which makes selection of specific pump by the specifier on the basis of efficiency hard. Furthermore, the wide tolerances currently allowed on performance testing / efficiency quotation could make classification of pumps on the basis of efficiency difficult. *The implication of this is that a multi-level labelling scheme for pumps is not very practical.*

Pump Efficiency Tolerances per EN ISO 9906:1999

The following is the study group's interpretation of these allowed tolerances:
Tolerances are applicable when comparing a Test efficiency with a Guaranteed efficiency. The highest relevant Tolerance factor listed below should be used.

A. General.

Grade 1 Test: The Test efficiency shall not be below the Guaranteed efficiency by more than (3% x Guaranteed efficiency).

Grade 2 Test: The Test efficiency shall not be below the Guaranteed efficiency by more than (5% x Guaranteed efficiency).

B. Pumps produced in series with selection made from typical performance curves.

Grade 2 Test: The Test efficiency shall not be below the Guaranteed efficiency by more than (7% x Guaranteed efficiency).

C. Pumps with a driver power input less than 10 kW but greater than 1 kW.

Grade 2 Test: The Test efficiency shall not be below the Guaranteed efficiency by more than (T% x Guaranteed efficiency)

where T = [17 – (Maximum driver power input in kW over the range of operation)]

[A tolerance is allowed on driver power input of $(49+T^2)^{½}$ %]

D. Pumps with a driver power input less than 1 kW.
Grade 2 Test: Another special agreement may be made between the parties.

1.2.2 Sector-specific directions for product-testing

There are no sector-specific directions for product testing for the selected products.

1.3 Existing Legislation

1.3.3 Legislation and Agreements at European Community Level

1.3.3.1 Health and Safety

ISO EN 809:1998 (Common safety requirements) is the most relevant document for general mechanical construction.

The American Petroleum Institute (API) imposes standards for pumps used in the oil industry. These are driven by safety requirements, which often result in reduced efficiency through demanding for instance larger clearances. *It is understood that these standards do not impact on the design of water pumps for the European market.*

The Pressure Equipment Directive: The view of Europump is that pumps and pump units are not relevant to this directive.5 This needs to be independently verified by the study group.

1.3.3.2 Overview of the WEEE (Waste Electrical and Electronic Equipment) Directive 2002/96/EC

The WEEE Directive is one of a small number of European Directives that implement the principle of "extended producer responsibility". Under this principle, producers are expected to take responsibility for the environmental impact of their products, especially when they become waste. The WEEE Directive applies this in relation to electrical and electronic equipment (EEE).

The broad aims of the WEEE Directive are to address the environmental impacts of electrical and electronic equipment and to encourage its separate collection, and subsequent treatment, reuse, recovery, recycling and environmentally sound disposal.

The WEEE Directive seeks to improve the environmental performance of all operators involved in the lifecycle of EEE, especially those dealing with W of EEE. Accordingly it sets certain requirements relating to the separate collection of W of EEE, standards for its treatment at permitted facilities, and requires its recycling and recovery to target levels. It makes producers responsible for financing the majority of these activities. Distributors have responsibilities in terms of the provision of facilities to enable the free take-back of W of EEE by consumers and also the provision of certain information to consumers of EEE.

Options for EuP measures might include those that contribute to the WEEE implementation in contributing to waste prevention in reducing materials use, when possible, and in introducing e.g. easier disassembly, which will make reuse and recycling of energy using products easier

1.3.3.3 Verification of efficiency values

It is important that the actual efficiencies of products placed on the market comply with any claimed energy performance class. Manufacturers currently use a statistical approach such that all of their pumps (except for a small statistical proportion) will exceed the declared efficiency value after allowing for the permitted test tolerance. They will test typically to ISO 9906:1999 Grade 2, which allows for a -5% tolerance (or more, see para 1.2.1 above) on quoted efficiency. (Acceptance) testing is generally done at the manufacturer's own test facility, and may be witnessed by a representative of the purchaser. For larger pumps, a user may request a test of the actual pump to Grade 1, but this costs additional money, and so will not be done unless specifically requested.

Although ISO 9906 does also publish the measurement uncertainties for different measurement techniques, manufacturers will not normally make any specific allowance during acceptance testing for the uncertainties inherent in their test methods, since these uncertainties will usually be less than the permitted tolerance.

Manufacturers will take a statistical risk in how they position the declared and mean production values of efficiency. Those who control production to give a tighter spread may choose either to produce pumps with a lower mean efficiency and reap any cost savings, or quote a higher efficiency.

It is often the case that only a small percentage of each pump size included in this report will actually be tested by the manufacturer, either for customers or for quality control purposes.

[5] http://www.europump.org/pdf/EP_PosPap_PED.PDF

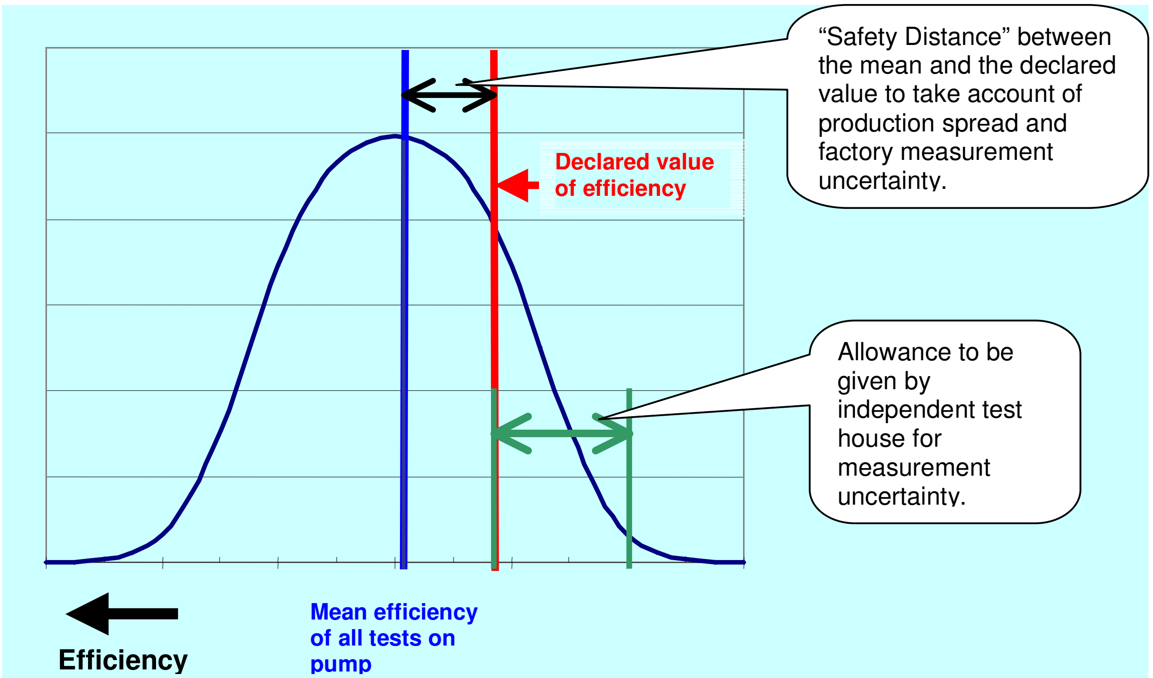


Figure 1-21 Testing and verification of pumps (only relevant to testing of products by an external test house)

If an independent testing body is asked to measure the performance of a pump, it is in their interests to use a test method with a small uncertainty. This will not only give a more accurate indication of the true efficiency, but will also minimise the efficiency "allowance" to take account of measurement uncertainties that needs to be given to the pump being tested (see Figure 1-21).

1.3.3.4 Criteria for identifying products covered under the WEEE legislation

The product must meet the following three criteria:

- Main power source is electricity (including batteries)
- Less than 1,000v AC or 1,500v DC
- Electricity is needed for primary function

It must be one of the following categories of EEE / WEEE specified in Annex A1 of the WEEE Directive:
1) Large household appliances
2) Small household appliances
3) IT & telecommunications equipment
4) Consumer equipment
5) Lighting equipment
6) Electrical and electronic tools
7) Toys leisure and sports equipment
8) Medical devices
9) Monitoring and control instruments
10) Automatic dispensers

Even if a pump is sold without a motor, it will usually be powered by an electric motor. For the pumps in the power range considered in this study, this will be less than 1,000v AC. The pump would therefore pass the first three criteria.

The pump cannot though be considered to fall within any of the categories specified in Annex !A of the Directive. *We therefore consider that the pumps of the type considered in this study are not covered by the WEEE Directive.* This argument was proposed at the second stakeholder meeting and there were no objections to this viewpoint.

In addition, the MEEUP modelling and analysis will show if any products do contain any of the above substances, in which case a discussion to justify the continued use or phasing out of these substances will be developed.

1.3.3.5 RoHS (Restriction of Hazardous Substance Directive) 2002/95/EC

The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2006 (“the RoHS Regulations”) implement the provisions of the European Parliament and Council Directive on the Restrictions of the use of certain Hazardous Substances in electrical and electronic equipment (“the RoHS Directive”), as amended.

The RoHS Regulations ban the putting on the EU market of new Electrical and Electronic Equipment (EEE) containing more than the permitted levels of the following:

- lead
- mercury;
- cadmium;
- hexavalent chromium;
- polybrominated biphenyls (PBBs); or
- polybrominated diphenyl ethers (PBDEs).

In order to put products on the market in the EU, manufacturers need to ensure that their products and product components comply with the requirements of the Regulations.

Given that the scope of the RoHS Directive is drawn from that of the WEEE Directive it is assumed that certain provisions in the WEEE Directive may apply to EEE within the RoHS Directive so as to limit its scope. There is, however, no express provision in the RoHS Directive to this effect.

Pumps are excluded from the RoHS Directive on the same grounds that they are excluded from the WEEE Directive, but from our research they are anyway compliant.

1.3.3.6 Existing self-regulation

The most significant voluntary scheme to date is the Europump/SAVE circulator voluntary labelling scheme. This is discussed in the parallel EuP Circulator report. It should be noted that this scheme is only possible because the product is used in defined systems with defined (or typical) duty patterns, and so it is not easily extendable to other classes of pump operating in systems with greatly varying characteristics. As an example, circulators will operate in a central heating system with fairly similar annual operating hours, and similar static/friction heads. The variability (eg different running hours according to climate or control method) can be dealt with in a quantitive way by defining different sub-groups of product application types. But general “water pumps” can have a duty that varies greatly from low hours (eg fire pumps) to high hours (constant water supply pressurisation), and from no head circulation systems to high head boost systems. It is therefore not possible to identify different sub-sectors of the market in the same way, and hence impractical to simply extend this methodology to other pumps in the same way.

Although not a regulatory measure, the **Europump/SAVE pump efficiency selection guide**[6] gives procurement advice on the efficiency that can be expected for End Suction close coupled and own bearing pumps. Of particular relevance to this study, it includes guidance on close coupled and end suction own bearing sub-categories of pump, which represents 50 % of the total energy use of pumps in the EC[7].

6 The guide “European Guide to Pump efficiency for Single Stage Centrifugal Pumps” is shown in Appendix 3, and is also available as a free downloadable pdf document from www.europump.org, under “Europump Guides”.
7 Ref Europump data (as shown in appendix). This figure is still to be ratified, but shows the importance of these types.

The purpose of the European Guide was to help purchasers choose pumps of good efficiency. It shows six plots of pump efficiency against flow, for End Suction Close Coupled, End Suction Own Bearings and Double entry Split Casing pumps, running at two and four pole speeds. To produce the plots, hundreds of pump efficiencies were obtained from maker's catalogues. From these, two lines were derived for each plot. The upper line represents the mean of the catalogue best efficiencies and is ideally the efficiency a user should aspire to for his pump main duty. However, since it is not always possible to source the ideal pump, another line was added, five to ten points below the upper line, to cover efficient pumps for which the required duty is away from the best efficiency point. Selection below the lower line was considered unacceptable unless there were exceptional circumstances.

It was felt that the concept of Specific Speed was too complicated to explain to the average pump buyer, so it was eliminated by using its effect in a novel way. A relationship was derived between pump Specific Speed and the efficiency drop from that at the optimum Specific Speed. This single relationship was felt to adequately satisfy the limited range of pump types being considered. It allowed correction curves for head to be applied to the plots of efficiency against flow. Thus a pump user can now enter the curves for the pump type he has chosen with his desired head, flow and speed and determine the efficiency levels against which he can judge the adequacy of the pump efficiency he is being offered by a supplier. (This method involves a small approximation which makes it fine for pump selection, but probably inappropriate for legislation).

The Guide also includes notes on minimising the loss of pump efficiency with time, other costs involved in the total operating system, and shows a comparison between a curve taken from the Guide and curves from four other sources.

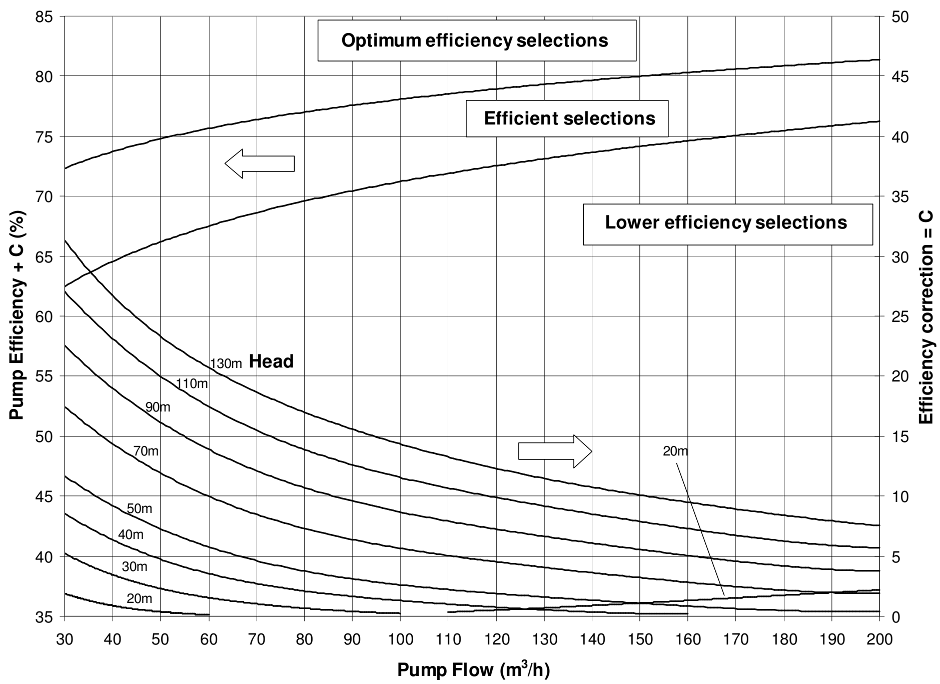


Figure 1-22 Typical plot from the European Guide (End Suction Own Bearings Pumps)

Worked example (ref figure 1.22):

Chosen pump type:	End suction with own bearings.
Chosen duty for maximum efficiency:	80 m^3/h at 110 m.
Quoted pump performance:	60% efficiency at 2900 rev/min.

(Check materials, suction performance, etc, are satisfactory)

From graph:	'C' = 14.
Plot on graph:	'Pump Efficiency + C' = 60 + 14 = 74%.

The graph suggests that an additional 3 points of efficiency or more is possible.

1.3.4 Legislation at Member State Level

There is no relevant legislation at member state level.

1.3.5 Third Country Legislation

There are two pump efficiency schemes, one in Korea and the other in China. Given the importance of Far East markets for European and other manufacturers, these are of particular interest to the study. If any EC schemes were able to be devised on the same or similar basis to these existing national schemes, then it would make it easier for users to evaluate pumps from any supplier on the same basis. An important aspect of this study will be to determine the "best" method, with comparisons made with these existing schemes in section 8.

1.3.5.2 Korea

Official information on this scheme is not available, but the study group's understanding is summarised below.
The scheme is aimed at the voluntary certification of pump efficiency, with the objective of encouraging the development of new efficient pumps. It is devised by the Korea Energy Management Corporation (KEMCO).
The pumps targeted are centrifugal water supply pumps of the single stage and multistage types with discharge branches from 25 to 200mm bore, running at 2 pole and 4 pole speeds.
The requirements of the scheme are:

- The Flow at Best Efficiency must be within a 'specified range' for each discharge branch bore (different flow ranges for single stage and multistage).
- The Best Efficiency value must exceed a figure shown on a plot of efficiency against flow, designated the 'A' efficiency.
- The efficiency at all flows within the 'specified range' for a pump's discharge bore must exceed a figure shown on another plot of efficiency against flow, designated the 'B' efficiency (about 12 points of efficiency below the Best Efficiency value). This is intended to encourage 'broad' high efficiency curves.

Perceived problems inherent in this scheme include:

- There is, in effect, a tie-in between efficiency and discharge branch bore.
- The same target efficiencies are given for single stage and multistage pumps.
- The all-important effect of Specific Speed (and therefore pump generated head) appears to be ignored.
- A pump whose Best Efficiency flow is near the bottom end of the 'specified range' for its discharge branch bore has little hope of satisfying the 'B' efficiency at the top end of the 'specified range'.

1.3.5.3 China

GBT13007 –1991

This is a standard of <u>recommended</u> efficiencies that was devised by the Chinese pump manufacturers. It is believed that it is currently only available in Chinese.

The scheme gives a graph of efficiency against specific flow for each of the types of pump included in the scheme:

- Single stage centrifugal pumpsfor freshwater pumping (5 – 10,000m3/h).
- Multiple stage pumps for clean water, (5 – 3,000m3/h).
- Petrochemical pumps (5 – 3,000m3/h).

There is also a correction factor (or efficiency allowance) that is added to the actual pump efficiency, which takes account of the actual head and flow – ie it takes account of the limitations of specific speed on pump efficiency.

There are two lines, for ns = (20 – 130) and (210 – 300).

For each pump, it must meet or exceed minimum efficiency criteria:
- The ‘A’ point, which is at rated (100%) flow.
- The ‘B’ points, which are at 50/60% (mans can chose) and 120% rated flow. The pump must exceed the B allowance at both of these points.

This therefore takes account of both peak and off-peak efficiency.

A mandatory National Standard of the People’s Republic of China came into effect in December 2005.

Although using a very similar methodology to that of GBT13007-1991, the levels are, as a result of lobbying by manufacturers, much lower.

The pumps covered are for clear water and are of the types:
- Single Stage (single and double suction)
- Multistage
- Multistage Well

Mandatory minimum values of best efficiency are specified for the first time. The efficiency for each pump type is first derived from plots of best efficiency against flow and then corrected for Specific Speed, using the same correction curve for all pump types. This correction is very similar to that chosen for the EC SAVE study. This gives a ‘Minimum Allowable’ efficiency level which is quite low, and which is intended to eliminate the worst 15% of pumps from the market. Because of the details of the method, there is a “jump” in at ns = 300 – 600.

There is also an ‘Evaluating’ efficiency. Pumps achieving this level are allowed to be classed as ‘Energy Conservation pumps’.

A new Standard is currently being proposed which includes a ‘Target Minimum Allowable’ efficiency level, which is expected to come into effect in 2010. This ‘Target’ is set at a level which would eliminate 90% of the 6000 pumps which have been analysed.

The comment is made by the author that the correction factor is actually more generous than the US ANSI/SP, and in practice Chinese pumps are considerably less efficient than US or European pumps.

Table 1.3 is a summary of the scope of each of the schemes;

Pump Type	SAVE / Europump	Kemco (Korea)	China
ESOB	X	X	X
ESCC	X	X	X
Multistage Water	-	X	X
Multistage Well	-	-	X

Table 1-3 Scope of existing international schemes

1.4 Summary

ISO9906 (currently under revision) is the accepted international test standard for measuring the performance of pumps, which allows various specified tolerances to be used. However, there is no agreement on what tolerance should be used for performance schemes.

While pumps are actually excluded from RoHS and WEEE legislation, manufacturers do in any case comply with these directives.

The earlier SAVE scheme to select pumps by efficiency is described, but this was not intended to be the basis of a pump labelling MEPS scheme. It is therefore not appropriate for this study.

China is also proposing a method that take account of performance at both peak and low and high flows. It is recommended there is an attempt to harmonise:

- The flows at which low and high flow are assessed.
- The values of the reduced efficiency allowed at the low and high flow points.

A key part of the methodology is the value of the correction factor for specific speed. It is also recommended that it is attempted to harmonise this factor.

It should be noted that this study considers the pump only; it excludes the motor, coupling, baseplate and any other ancillary items.

2 Economics and Market Analysis

The objectives of this chapter are to present the following information:

- Generic economic data - places circulators (the product group) within the total of EU industry and trade policy
- Market and stock data - provides market and cost inputs for the EU wide environmental impact of circulators
- Market trends - identifies the latest market trends so as to indicate the market structures and ongoing trends in product design
- Consumer expenditure base data - provides a practical dataset of prices and rates to be used in a Life Cycle Cost (LCC) calculation

The primary data source is Eurostats. This is selected so that all policies at an EC level (both EuP and other initiatives) are from the same data source.

2.1 Generic Economic data

The primary data source for this is Eurostats. This is selected so that all policies at an EC level (both EuP and other initiatives) are from the same data source, and it remains the most complete data set for our work. However, this data has insufficient resolution for this study, as it does not categorise pumps in the same way or in the detail that we require.

In anticipation of this study, Europump has generated its own more detailed data, using a variety of public and private sources. No other adequately detailed surveys of EC pump sales have been identified during this stage of the study.

The original data presented by Europump was identified as having some inconsistencies, and so the exercise was repeated at the request of the study team and some Europump members. The method adopted was for each manufacturer to submit their estimates of their market share for each type of pump and country to an independent administrator. Such market shares are thought to be fairly well known by the larger manufacturers, and so this method was seen as being reasonable. The data was then compiled, inconsistencies identified and addressed, and then the final results circulated for approval.

Year: 2005									
Product Code	29122413 - Submersible motor, single-stage rotodynamic drainage and sewage pumps	29122415 - Submersible motor, multi-stage rotodynamic pumps	29122417 - Glandless impeller pumps for heating systems and warm water supply	29122420 - Rotodynamic pumps <= 15mm discharge	29122430 - Centrifugal pumps with a discharge outlet diameter > 15 mm, channel impeller pumps, side channel pumps, peripheral pumps and regenerative pumps	29122451 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with a single entry impeller, close coupled	29122453 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single stage with a single entry impeller, long coupled	29122455 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with double entry impeller	29122460 - Centrifugal pumps with a discharge outlet diameter > 15 mm, multi-stage (including self-priming)
Country	**Apparent Consumption (Quantity)**								
Austria	124471	12941	181772	29437	2402	10374	12634	12	11963
Belgium	13983	4465	178229	12782	-13289	532	5575	62	44147
Bulgaria	6562	4395	57001	6973	136	4775	4367	18	3752
Cyprus	8599	4698	18311	2087	423	159	1299	13	346
Czech Republic	101739	41245	174067	-4622203	16146	38620	-77	4820	14258
Denmark	82384	33520	225812	3007	725	3615	128222	6	-5614
Estonia	4659	1027	13273	937	239	86	572	2	3421
Finland	58371	7356	19808	5075	849	1670	8799	465	1492
France	515776	155971	11598	314805	22424	165103	49207	-25971	-987792
Germany	1489172	275624	3656720	2361302	48074	2200437	306492	-1440	52029
Greece	20024	139169	220725	2778	16	6470	73114	471	18360
Hungary	54739	6638	98361	10963	363	-20254	35539	76	2844
Ireland	-51294	5299	-128178	296	1948	2921	1646	47	4064
Italy	154630	708644	2986621	613222	11407	-1468831	580039	-12	406569
Latvia	8694	1911	20424	492	26	172	2192	8	3167
Lituania	4143	228	41467	-173	109	6439	597	1	2200
Luxemburg	-139710799	159	10210	526106	122	14437	806	0	177
Malta	3406	1828	466	321	759	239	0	243	14
Netherlands	684224	27311	505198	12105	59478	13413	21856	56	6807
Poland	98686	2752	742165	5587	1159	51271	-601	38	5159
Portugal	89966	84035	147688	5110	37	3380	-13452	33	16051
Romania	89855	43272	0	-11831	2266	-2887	11580	752	2734
Slovakia	34103	2254	187825	423	10293	-2391541	29328	-1	1363
Slovenia	29311	599	-105556	-917335	908	91321	-177	19	-170
Spain	163556	97724	244168	959665	137146	75713	22432	6210	56429
Sweden	106862	22935	330165	10324	92	96231	7625	3825	21023
United Kingdom	543043	53878	2861404	71278	847	28633	559755	-2784	209682
EU15TOTALS	-139,222,880	-369,348	-2,847,720	4,502,744	889	736,800	127,036	-27,088	2,460,992
EU25TOTALS	-138,949,782	1,557,612	14,780,768	-394,749	396,471	1,006,321	1,123,075	-26,307	2,550,591
EU27TOTALS	-138,896,642	1,595,225	-1,500,532	-380,828	17,970	1,023,919	151,808	-26,287	2,559,113

Table 2-1A Eurostats data on EC pump consumption – by quantity, 2005. Source data for this is shown in Appendix 1

Year: 2005									
Product Code	29122413 - Submersible motor, single-stage rotodynamic drainage and sewage pumps	29122415 - Submersible motor, multi-stage rotodynamic pumps	29122417 - Glandless impeller pumps for heating systems and warm water supply	29122420 - Rotodynamic pumps <= 15mm discharge	29122430 - Centrifugal pumps with a discharge outlet diameter > 15 mm, channel impeller pumps, side channel pumps, peripheral pumps and regenerative pumps	29122451 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with a single entry impeller, close coupled	29122453 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single stage with a single entry impeller, long coupled	29122455 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with double entry impeller	29122460 - Centrifugal pumps with a discharge outlet diameter > 15 mm, multi-stage (including self-priming)
Country	**Apparent Consumption (Value)**								
Austria	2484760	4358460	11980140	578250	165660	1971610	1213310	93230	2571770
Belgium	5692720	1489910	10741160	349470	-2166800	-2041040	5917390	114090	10761840
Bulgaria	1333410	719615	3995661	92280	270538	934702	2155324	1130400	1121177
Cyprus	1009410	505920	1261370	126290	61310	11240	163020	1430	33980
Czech Republic	6731150	2746410	9524130	-12589590	-165730	3199860	2779000	121090	3478270
Denmark	8433206	2695315	11223277	12680	190170	2804528	26868986	144794	7064956
Estonia	646120	202660	1580500	10210	30210	-24490	965100	1310	631570
Finland	-14384424	2884900	982930	164540	753010	716070	32920660	714000	1017830
France	56670800	52290420	49618440	3628890	22226540	52696310	52439250	-6224780	75901810
Germany	92305331	58128027	245885881	-1677954	46649969	46123791	117479297	-27828130	63703059
Greece	2573310	3416940	10571660	194390	31730	-2984810	-278560	13620	1969210
Hungary	4480190	1468811	3398880	-898020	387810	-12085030	24186076	39140	943640
Ireland	-32955010	869190	-3672960	82230	177490	540230	596940	20290	1282970
Italy	70332010	71714890	87734810	44429590	10064230	-9234680	93220490	267500	41937950
Latvia	23200	324420	1107560	15060	22900	84460	335660	59250	821610
Lituania	1032040	768200	1858410	-56050	44680	474980	917950	900	783878
Luxemburg	-6510130	56780	3096650	71380	37310	88320	399120	0	111150
Malta	250220	194120	38140	32270	15400	20140	0	1040	11720
Netherlands	19788510	1914330	20326310	334600	2596610	4041560	3245700	53760	4682250
Poland	7131490	2652820	23353560	138050	682270	4795390	10436505	15310	3505540
Portugal	5363196	15171899	4385710	89450	311660	403580	-384610	25450	4844084
Romania	7024710	6016454	9788470	-1324800	627850	2675204	1489010	86230	2519600
Slovakia	3337100	704800	6098390	92690	410790	119280	1479380	0	823260
Slovenia	867680	330210	-2011390	-3854050	470290	1212930	735940	40980	640100
Spain	20667360	27042655	15660800	1579920	6323474	9313981	13693623	-1640	19485208
Sweden	82410164	4994260	11358960	72070	523400	12508260	3066220	-279420	6944250
United Kingdom	31999294	57908902	145852922	220300	47278087	34718638	5055436	13264995	92655521
EU15TOTALS	-223,967,110	-89,838,030	-152,691,870	8,002,490	-25,598,240	200,924,100	-156,069,250	-33,547,940	-143,214,690
EU25TOTALS	-202,366,860	297,615,399	709,575,498	51,659,088	167,573,305	201,334,196	520,051,896	37,964,652	-132,219,730
EU27TOTALS	-196,821,330	303,490,998	-95,027,660	-5,468,600	-23,322,340	204,448,232	-147,526,410	39,337,452	-129,635,800

Table 2-2B Eurostats data on EC pump consumption – by value (Euros), 2005. Source data for this is shown in Appendix 1

Segment	Number
Heating Circulators: Boiler Integrated Standalone TOTAL	 7,500,000 6,500,000 14,000,000
DN < 15mm	16,000,000
Domestic Drainage (Submersible)	3,000,000
Residential Sewage (Submersible < 2kW)	600,000
Total	33,600,000

Table 2-3 Europump data on annual sales (mass produced pumps), published April 2005, for EU-25.

Style of pump	**Number**	**(Annual running hours)**
Single Stage close-coupled (SAVE) + **In Line**	250,000 100,000	2,250 4,000
Single stage Water (SAVE)	250,000	2,250
Portable Drainage	100,000	
Municipal / Industrial Sewage Submersible 2 – 70 kW	100,000	
Submersible Multistage 4" & 6" [8]	700,000	1,000
Multistage Water	250,000	1,500
Chemical Process	40,000	
Refining Process OH2	10,000	
Total of pumps within the scope of the study	**1,550,000**	
Total	1,800,000	

Table 2-4 Europump data on annual sales and suggested linked running hours (standard and engineered pumps), January 2007, for EU-25. Styles of pump shown in blue are those being considered in this study.

[8] This is split roughly 80% 4inch and 20% 6inch

2.1.1 Consistency of data

This section presents a short discussion on the consistency of Figure 2.3 (Europump sales data) with Motor sales data quoted in the Motors report.

The underlying assumption in this analysis is that all new pumps are fitted with a new motor. This is not quite true, as there will be instances when an old motor will be fitted to a new pump. But certainly for smaller ESCC pumps and submersible pumps, they will invariably be supplied with a new motor. These types alone represent two thirds of the pumps sold within the scope of the study, so this assumption will not give a significant error in terms of total pump energy consumption.

Most of these pumps by sales are in the 0.75 – 37kW power range category shown in the Motor report annual sales figures. There are some pumps sold that are above 37kW, but they will only be a low proportion by number of units.

Power range	**EU 15 sales in Mio. units**	share	**Capacity in Giga Watt**	share
0,75 - 7,5kW	**7.2**	79%	22.5	28%
7,5 - 37 kW	**1.5**	16%	30.0	38%
37 - 75 kW	**0.3**	3.3%	15.6	20%
75 - 200 kW	**0.1**	1.2%	11.6	15%
Total	**9.1**	100%	79.7	100%

Table 2-5 Copy of table in Motors report showing annual EC sales[9] of all motors.

Of the 8.7M motors sold pa in the 0.75 – 37kW power range (Motors study), 1.8M are pumps (Europump data). This represents 21% of sales, which is in line with the 21% proportion of motor energy estimated to be consumed by pumps in the Motors study. (This data shows industry using 21% of energy in pumps, and the tertiary sector 16% of energy used by pumps.)

2.1.1.1 Running hours

Section 4.3 of the Motors report gives annual running hours for motors in each of the above size ranges for industrial and tertiary use, with an extract shown in Table 2.5 below.

Motor power range	**Industrial (hours pa)**	**Tertiary (hours pa)**
0.75 - 4 kW	2,800	1,800
4 – 10 kW	2,700	1,300
10 – 30 kW	2,800	1,100
30 – 70 kW	4,700	1,500
70 – 130 kW	6,200	1,700

Table 2-6 Annual running hours, by motor size and power range, (for <u>all</u> motor applications)

[9] Although this table only shows data for EU 15 sales rather than EU27 sales, this does not matter as it is only the proportions of sales that are of interest.

Given that the Motors report does not discriminate between the annual running hours of different types of pump, the slightly differing energy use suggested by the two studies is not a cause of concern.

There is no direct link between the styles of pump and motor size, and so direct comparisons are not possible between the above data and that in the motor study.

2.1.1.2 Consistency of Figure 2.3 (Europump sales data) with Eurostats data.

Section 1.1.4 contains a discussion about the many different ways of classifying pumps, with the differences between these two main sources of data showing the apparent inconsistencies that can arise when different classification systems are used. Unfortunately, it was not possible to directly match the two different statistics. There are various possible reasons for errors in both Eurostats and Europump which account for this:

- Some production data from smaller countries is deliberately suppressed as it would be traceable to a single manufacturer.
- Age of data: It can take several years for information to be collected and presented in the database.
- Missing countries: Only some countries have reported, with new member states in particular not having filed returns for these early years.
- Definitions and categories:
  - Abrupt changes can result from the re-definition of product categories.
  - Categories may be interpreted differently by different countries, reflecting their individual methods of collecting data.
  - Distortion due to auxiliary components or spares being inadvertently counted as pumps.

It should be noted that the Europump data is derived largely from the EIF (European Industrial Forecasting (EIF) World Pump Market Report[10]) statistics, with changes made to ensure that it relates to consumption rather than just sales. EIF reports are regarded by industry as being the most accurate data existing, and so the Europump data is in turn regarded as being reasonable.

2.1.1.3 Summary of data sources

In broad terms, the EIF-based Europump data fits with the data in the Motors report. But for some pumps, this data is quite different to that in Eurostats, with the error at this level of detail being ascribed to differences in the classification of pumps by manufacturers. For consistency with the other studies in Lot 11, it is decided to adopt the Europump data as that to be used in the remainder of this study.

In the later analysis, these differences will be mentioned, as these differences will impact the apparent energy saving potential of multistage, ESCC and ESOB pumps.

2.1.1.4 New Member States

Eurostats and Europump data does not include information on New Member States (NMS) In the event of the absence of suitable data from Eurostats, Europump or other, we assumed that a similar proportion of energy is used in pumps in the NMS as with the EC average. For consistency, we will use the data that will be generated within the Motors study.

For the 2000 data used in the motor study, table 2.6 show pumps using the following proportions of motor energy in EU-25 states:

[10] http://www.eif4cast.com/pump4cast/specfile/wrldpu20.htm

Sector	Total motor energy consumption (TWh pa)	Motor energy consumption due to pumps (TWh pa)	Proportion of electricity used by pumps (%)
Industrial	650	136	21
Tertiary	210	33	16
Combined	860	169	**20**

Table 2-7 EU 25 total pump energy consumption (2000) – extract from the motor study.

The 20% of motor electricity consumption used by pumps fits well with studies in many different countries, and so this 169 TWhpa figure is regarded as being correct. The difference between the 136TWhpa calculated for the pumps in this report and the figure from the motors report can be accounted for by all the types of pumps that are regarded as being out of scope.

2.1.1.5 Breakdown of production and consumption by style of pump

The MEEUP Methodology requires the following data, for each type of pump:

- EU Production
- Extra-EU trade
- Intra-EU trade
- Apparent EU-consumption

2.1.1.6 EU Production & Consumption

Eurostats gives figures for imports, exports and production, which are shown in appendix 1. Tables 2-1a/b are derived from this, where Apparent EU-consumption (by country) = Pump production + Pump imports – Pump exports. However, as discussed elsewhere, Europump figures will be used in order to be consistent with the rest of the statistics.

2.1.1.7 Extra- and Intra- EU trade

This is defined as trade between different EU member states.

Given the global nature of the pumps industry, there are large volumes of products traded between different countries. Industry consolidation means that there has been a progressive trend towards fewer but larger companies and plants. Rather than talking about inter-country trade, it is therefore more useful to think in terms of exports from particular manufacturing plants.

Figure 2-1 and Figure 2-2 from the 2006 Europump survey present data on imports and exports of pumps, by country. This data is based on returns from member states and Eurostats. Such data needs to be treated with care, as both pumps and pump parts may be re-exported as part of larger equipment.

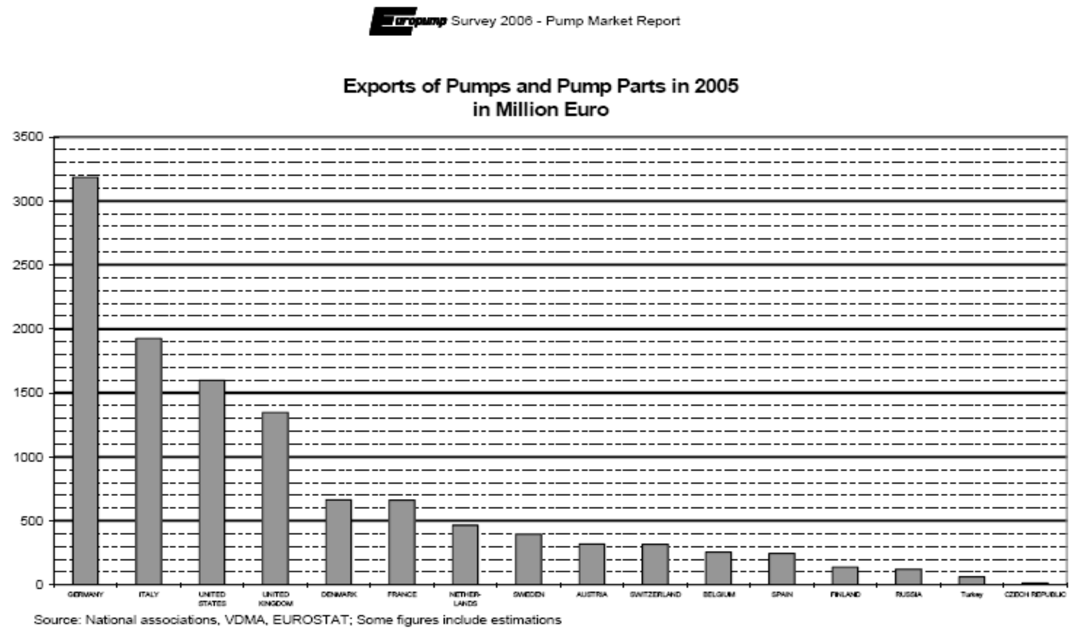


Figure 2-1 Exports of pumps and pump parts by member state and USA.

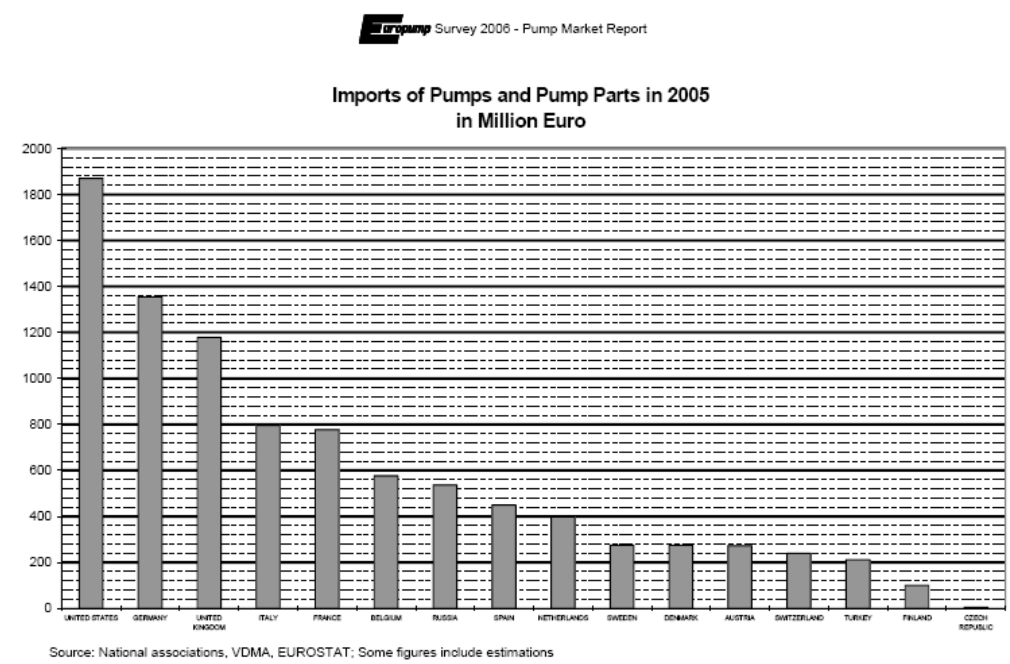


Figure 2-2 Imports of pumps and pump parts by member state and USA.

2.2 Market and stock data

2.2.1 Overview of this section

This section presents the following market data:

- Installed base ("stock") and penetration rate
- Annual sales growth rate (% or physical units)
- Average Product life (in years), differentiated in overall time and time in service, and a rough indication of the spread (eg standard deviations)
- Total sales/real EU-consumption, (also in euros, when available)
- Replacement sales (derived)
- New sales (derived)

It is calculated for 2007, and then estimates made of sales for past and future years.

2.2.2 Installed base ("stock") and penetration rate

In the sense that all industrial processes that need pumps will already have them, penetration can be considered to be complete. There will though be growth in some markets such as air conditioning and orehole pumps as demand for these increases.

A key factor in determining stock projections is a consideration of historic sales. Manufacturers can point to past years where sales of particular types exceeded or did not meet historic trends, but given the changing proportions of EU imports/exports and tolerances on production and sales statistics, it is not thought that these differences could be seen within the statistical tolerances.

The implication of this for the study is that a simple stock model can be assumed where the stock is calculated by multiplying the annual sales by the average half-life (defined as that time by which half the pumps installed in a particular year will be disposed of). This is in fact the method used in the MEEUP spreadsheet.

2.2.3 Annual sales growth rate

Pump manufacturers are currently seeing a significant growth in sales in the tertiary sector, but sales to the industrial sector are weakening, with many manufacturers reporting very buoyant conditions at present. Looking forward, there are many factors that might influence the market, but it is assumed that the market will fall and then recover by 2020 to a similar level as at present.

2.2.4 Average product life

Pump life can be reduced by many factors:
- Mis-matching to the system
- High running hours or
- Poor maintenance
- Poor installation
- Chemical impurities in the water
- Entrained particles in the water

Pump life can be extended by the following;
- Use of duty/standby systems to reduce the load per pump
- Variable speed controls can reduce duty and hence hydraulic wear

Estimating "average" lifetime is difficult, with the Europump figures based on the collective views of suppliers. For pumps operating under normal conditions, it is thought that these numbers are indeed reasonable, but there are sometimes exceptional circumstances which shorten this "natural" lifetime:

- Misuse of a pump. Mis-application of the pump, for example running it such that it has excessive cavitation will rapidly destroy a pump.
- Damaging fluids. Entrained particulates or chemical impurities will accelerate wear on a pump.

Note that these effects are much more important with pumps than with motors or fans.

- The equipment to which a pump is fitted may be scrapped before the end of the pump life, in which case the pump will probably be disposed of while it still actually has some useful life.

Taking account of all of these factors, the following table is presented as the average lifetimes and operating hours of the pumps considered in this study:

Type of pump	Basecase size	Sales adj to EU-25	Pump Life (years)	Stock (Nos)	Operating hours pa
End Suction Own Bearings (ESOB)	Small	200000	11	2200000	2250
	Large	50000	11	550000	2250
End Suction Close Coupled (ESCC)	Small	200000	11	2200000	2250
	Large	50000	11	550000	2250
End Suction Close Coupled Inline (ESCCi)	Small	80000	11	880000	4000
	Large	20000	11	220000	4000
Submersible Multistage	Small	560000	11	6160000	1000
	Large	140000	11	1540000	1000
Vertical Multistage	Small	200000	11	2200000	1500
	Large	50000	11	550000	1500
			Total	17,050,000	

Table 2-8 Average lifetimes and actual time in operation

Note that for example that the sales of all large ESCC pumps are less than the 200,000 units pa threshold specified in the EUP Directive, but taken together the total sales of this class do exceed this value and hence are included. ESCCi pumps are similarly regarded as a sub-category of ESCC pumps, and hence are also included.

2.2.5 Total sales/real EU-consumption

Total sales (units) are shown in table 2.8.

The value of this in euros is calculated by multiplying this number by the average price for each. Note that these prices are for the pump as defined by the boundary as discussed in figure 1.15 – care must be taken when comparing this with other data sources to check that the boundaries are the same.

Electrical energy consumption is calculated on the assumption that a fully loaded class Eff2 motor is used.

Type of pump	Basecase size	Average Purchase price (euros)	Annual sales of pump (No.)	Total sales value of pumps in EU (euros pa)
End Suction Own Bearings (ESOB)	Small	440	200,000	88,000,000
	Large	1,000	50,000	50,000,000
End Suction Close Coupled (ESCC)	Small	900	200,000	180,000,000
	Large	3,300	50,000	165,000,000
End Suction Close Coupled Inline (ESCCi)	Small	900	80,000	72,000,000
	Large	3,300	20,000	66,000,000
Submersible Multistage	Small	910	560,000	509,600,000
	Large	1,000	140,000	140,000,000
Vertical Multistage	Small	1,000	200,000	200,000,000
	Large	1,000	50,000	50,000,000
			Total	1,520,600,000

Table 2-9 EU Sales of pumps (in the scope of this study) by number and value, 2007

Type of pump	Basecase size	Total annual energy consumption of stock (P2) (GWh pa)	Related motor efficiency (%)	Primary energy consumption of stock (P1) (GWhpa) by type, size	Total Primary energy consumption of stock (P1) (GWh pa)
End Suction Own Bearings (ESOB)	Small	18,988	84.2	22,551	
	Large	17,923	90.0	19,915	42,466
End Suction Close Coupled (ESCC)	Small	16,040	84.2	19,050	
	Large	17,936	90.0	19,928	38,978
End Suction Close Coupled Inline (ESCCi)	Small	9,597	84.2	11,398	
	Large	11,732	90.0	13,035	24,433
Submersible Multistage	Small	13,189	82.6	15,967	
	Large	7,632	87.0	8,773	24,739
Vertical Multistage	Small	2,983	76.2	3,915	
	Large	1,691	81.0	2,087	6,002
		117,711		**Total**	**136,620**

Table 2-10 Total EU 25 energy consumption of the types of pumps in this study.

2.2.6 Historical and projected future sales

It has not been possible to gain a consensus on the change in efficiency of pumps sold since 1990. If anything it is imagined that efficiencies will have improved slightly, but there is no firm evidence for this. This is certainly countered by the earlier SAVE II study that found that pump efficiency had not changed significantly in the preceding 10 years or more. It is therefore assumed for the purposes of this study that efficiencies have remained the same since 1990.

2.2.7 Replacement and New sales (derived)

To calculate the split of replacement and new sales, it is necessary to have knowledge regarding the typical lifetime of the installations into which pumps are sold – but the stakeholders consulted were unable to offer firm information on this question. However, given that the market is overall only growing slowly, this split will not significantly alter the rate at which stock can be changed. Replacement sales are influenced by many factors:

- Value of the pump. For the smaller mass produced pumps considered in this study, it is unlikely to be worthwhile repairing them, and so they will be replaced rather than repaired.
- Motor failure. Similarly, if the motor fails, it may be more sensible to replace the whole pumpset.
- Life of the installation. If a site or item of equipment is no longer used, then it is unlikely that these smaller pumps would be re-used, hence shortening the average life.

2.3 Market trends

Several positive trends are noted, particularly as applied to mass produced pumps and pumpsets for building applications:

- Greater sales of pumps with pressed stainless steel or plastic impellers.
- Variable speed control incorporated in integrated packages.
- Pumps available with built-in condition monitoring, although sales so far are poor.
- Some larger pumps will have friction reducing coatings on the cast iron volute.

The commodity pump market is led by a few multinational companies, who have worldwide manufacturing facilities, but with a trend towards production in regions with a lower cost of labour. Production in Europe is cost effective for higher-priced commodity pumps, 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.

2.4 Consumer expenditure base data

(Rates, tariffs, prices, multiplier product costs/consumer prices.)
This data is important primarily so that we can calculate the purchase, installation and running costs of improved products. It will ultimately allow us to understand how far it is possible to reduce the eco-impact of products without incurring excessive costs to the consumer. This is discussed in later sections, but key inputs for the MEEUP model are presented here:

Style	Basecase	Average Purchase price (euros)	Average installation cost (euros)	Average total acquisition[11] costs (Euros)	Average cost of repair and maintenance (euros)
End Suction Own Bearings (ESOB)	Small Large	*440* *1,000*	*440* *1,000*	**880** **2,000**	**1,000** **1,000**
End Suction Close Coupled (ESCC & ESCCi)	Small Large	*900* *3,300*	*900* *3,300*	**1,800** **6,600**	**400** **1,200**
Submersible Multistage	Small Large	*910* *1,000*	*910* *1,000*	**1,820** **2,000**	**0** **10,000**
Vertical Multistage	Small Large	*1,000* *1,000*	*1,000* *1,000*	**2,000** **2,000**	**10,000** **10,000**

Table 2-11 Summary of basecase product financial information

[11] Acquisition cost = Purchase + installation cost

2.4.1 Electricity rates

The following data is the most recent information published by Eurostats, split by domestic and commercial users, (table 2.11).

The following data is the most recent information published by Eurostats, split by domestic and commercial users.

Domestic[12]:
The electricity prices presented are charged to final domestic consumers, which are defined as follows: annual consumption of 3 500 kWh of which 1 300 kWh is overnight (standard dwelling of 90m²). Prices are given in Euro (without taxes) per kWh corresponding to prices applicable on 1 January 2006. For the purposes of the Life Cycle Costing calculations, the EU25 prices of 0.11 euro/kWh are considered as the base price.

Industrial
The electricity prices presented are charged to final industrial consumers, which are defined as follows: annual consumption of 2 000 MWh, maximum demand of 500 kW and annual load of 4 000 hours. Prices are given in Euro (without taxes) per kWh corresponding to prices applicable on 1 January 2006. For the purposes of the Life Cycle Costing calculations, the EU25 prices of 0.075 euro/kWh are considered as the base price.

However, taxation and tiered pricing strategies mean that in practice the actual prices paid by end users will be higher than this. **Therefore, 0.075 euros/kWh is taken as being more typical for industrial users, and 0.135 euros/kWh for domestic users.**[13] As there is a large variation in prices between countries, in the sensitivity analysis in Chapter 8 the cost effectiveness for different policy options is re-calculated for 0.05 and 0.15 euros/kW (commercial). (For comparison, the range for industrial users assumed in other studies is 0.035 to 0.11 euros.)

There is though a large variation of prices across the EU, ranging from 7 eurocents/kWh (including taxes) in Estonia to 24 eurocents/kWh in Denmark for domestic users, (Eurostats , July 2006). Accordingly, the key results from the study will be re-calculated at these two extremes of rates.

Country	Industry	Domestic
EU25	7.37	13.45
EU15	7.54	13.74
BE	7.73	13.78
CZ	5.71	7.87
DK		22.31
DE	8.97	16.96
EE	3.78	6.97
EL	5.60	8.11
ES	6.39	10.52
FR	5.00	11.62
IE	9.14	13.46
IT	10.90	20.00
CY	10.74	14.17
LV	3.28	6.68
LT	4.82	7.34
LU	-	14.61
HU	5.84	11.12

[12] Domestic prices will apply to some users of small submersible multistage pumps.
[13] In order to ensure consistency between these two linked reports, we have used the same figures as in the ecoboiler study.

MT	5.72	12.01
NL	6.31	20.54
AT	7.20	12.78
PL	5.33	11.64
PT	7.30	12.60
SI	5.60	9.40
SK	7.20	11.04
FI	5.31	9.10
SE	5.17	13.23
UK	7.15	10.31

Table 2-12 EU Electricity Prices, 2006[14] [15]

A **discount rate of 2%** is taken as being typical of EU-25 and is used in the LCC analysis.

2.4.2 Repair and maintenance costs

For each of the basecase model pumps, both direct labour and parts costs, and the car mileage associated with these visits is calculated. For some types of pumps, the total weight of spares over the years can be considerable, and in some cases may be of a material that has an eco-peak. In order that this detail is not lost, the convention used in completing the Bill of Materials in section 4 is that all consumables are listed as a separate item.

Unfortunately, the MEEUP already has a default a 1% by total weight default for consumables, which cannot be over-written. Given that this only represents an error of 1% in the total weight of each component, this is not regarded as a significant concern, as the benefit from our approach of itemising consumables separately will outweigh this small error. The runs of the MEEUP model later showed that material content is not the major driver in reducing the total eco-impact of pumps.

Type of pump	Average lifetime repair and maintenance costs of a pump (Euros)	
	Small basecase	Large basecase
ESOB	1,000	1,000
ESCC	400	1,200
Multistage Water	1,500	2,000
Submersible Multistage	2,000	3,000

Table 2-13 Average lifetime repair and maintenance costs of a pump.

Type of pump	Average lifetime mileage driven per pump for repair and maintenance work, (km)	
	Small basecase	Large basecase
ESOB	300	100
ESCC	150	300
Multistage Water	1,000	1,000
Submersible Multistage	1,000	1,000

Table 2-14 Average lifetime mileage driven per pump for repair and maintenance work.

[14] http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1334,49092079,1334_49092794&_dad=portal&_schema=PORTAL
[15] Eurostat press release 93/2006, July 2006.

2.4.3 Installation costs

These are detailed in the MEEUP input sheet for each product.

Type of pump	Average installation cost (euros)	
	Small basecase	Large basecase
ESOB	440	1,000
ESCC	900	3,300
Multistage Water	1,000	1,000
Submersible Multistage	910	1,000

Table 2-15 Average installation costs of pumps

The industry uses as a rough guide the rule of thumb that "the installation cost is equal to the purchase cost of the pump." In practice it is very site specific, but as no better averages could be offered by any stakeholders, it was agreed to use this simple formula as the basis for these costs.

2.4.4 Disposal tariffs/taxes

We are not aware of any tariffs/taxes specifically for these products. Given the value of the products as scrap, there is sufficient incentive to recycle old pumps without the need for additional financial measures. (By comparison, disposal of products that do fall within the scope of the WEEE Directive 2002/96/EC would be charged at the rate of around 0.30 Euros/kg, but this varies between states)[16]

2.4.5 Interest and inflation rates.

The following table shows national inflation and interest rates for the EU-25 as published by Eurostat and the European Central Bank (ECB).

Member State	Inflation rate [(a)] (%)	Interest rate [(b)] (%)
Austria (AT)	1.6	3.4
Belgium (BE)	2.8	3.4
Cyprus (CY)	1.4	5.2
Czech Republic (CZ)	1.9	
Denmark (DK)	2.2	3.4
Estonia (EE)	3.6	
Finland (FI)	1.1	3.4
France (FR)	1.8	3.4
Germany (DE)	2.1	3.4
Greece (EL)	3.5	3.6
Hungary (HU)	3.3	6.6
Ireland (IE)	2.2	3.3
Italy (IT)	2.1	3.6
Latvia (LV)	7.1	3.5
Lithuania (LT)	3	3.7
Luxembourg (LU)	3.4	
Malta (MT)	3.4	4.6
Poland (PL)	0.8	5.2
Portugal (PT)	2.5	3.4
Slovak Republic (SK)	3.9	3.5
Slovenia (SI)	2.4	3.8

[16] Synthesis report: Gather, process and summarise information of the waste electric an electronic equipment directive (2002/96/EC), for DG ENV, European Commission.

Spain (ES)	3.7	3.4
Sweden (SE)	1.3	3.4
The Netherlands (NL)	2.1	3.4
United Kingdom (UK)	2	4.5
EU-15 Average	2.2	3.4 (c)
EU-25 Average	2.1	3.9

(a) Annual inflation (%) in December 2005 Eurostat "Euro-indictors", 7/2006 – 19 January 2006.
(b) ECB long-term interest rates; 10-year government bond yields, secondary market. Annual average (%), 2005.(c) Euro zone.

Table 2-16 Interest and inflation rates for EU-25

2.4.6 Summary

This section has reviewed several sources of data in order to come to a conclusion on pump sales, stock and lifetime. In each case the market has been split into "large" and "small", as it is important that technical and economic differences are not lost when considering the cost effectiveness of different design options.

By making assumptions on the price to the user of basecase pumps, a total annual EU sales value of 1,500 M euros has been calculated.

Purchase, installation and maintenance costs of the different types of pumps have also been estimated for each type and size of basecase design.

Even for the commodity type (mass produced) pumps that are the subject of this study, most are manufactured within the EU.

There are several developments in pump technology that will lead to a reduction in energy consumption:

- Greater sales of pumps with pressed stainless steel or plastic impellers that lead to reduced friction.
- Variable speed control incorporated in integrated packages to give large energy savings in for examples many building services applications.
- Pumps available with built-in condition monitoring, although sales so far are poor.
- Some larger pumps will have friction reducing coatings on the cast iron volute.

3 Consumer Behaviour and Local Infrastructure

Consumer behaviour can – in part – be influenced by product design, but certainly for pumps it is an important input for the assessment of the environmental impact and the life cycle costs of a product. A key aim is to identify barriers and restrictions to possible eco-design measures, due to social, cultural or infra-structural factors. A second aim is to quantify relevant user-parameters that influence the environmental impact during product life and that are different from the standard test conditions as described in subtask 1.2.

3.0 Reducing pump system energy consumption

The applications of the pumps in this study is so wide that it is difficult to discuss in any other than general terms the impacts of consumer behaviour on pump use and hence eco-impact.

The key areas in which consumer behaviour can influence pump eco-impact are:

Correct specification and design of the system in which the pump is installed.

An analysis of system losses are beyond the scope of this study, but key points to consider include:

- What is the system trying to achieve – ie what flow rate, pressure or cooling effect is actually required?
- Controlling the pump (or group of pumps) to match this actual demand, with measures that might include on/off or variable speed control. Existing pumps may be altered by fitting smaller impellers or the addition of small jockey pumps for use at times of low demand.
- Attention to pipework design can substantially reduce system friction and hence pressure drop.

Effective maintenance of the pump.

The repair and maintenance of pumps is an important business in its own right, with sales of spares and servicing typically being one of the most lucrative part of a manufacturers business. Maintenance and end of life considerations are therefore particularly important for pumps. Related to this is the importance of a pump being used in the correct way – as if not used as intended the lifetime and efficiency can be severely impaired.

More so than fans, pumps are very sensitive to operation far from their design point, with many problems being avoided by avoiding running at very low or high flows:

- The pump should run smoothly with minimum internal disturbing forces, thereby saving on maintenance costs due to premature failure of components such as bearings, wear rings, bushes, couplings and seals.
- The risk of damage to pump components due to cavitation should be reduced.
- Vibration should be minimised, benefiting other equipment.
- Noise should be minimised, improving the environment.

Pressure pulsations should also be minimised, reducing the risk of problems in the pumping system as a whole.

Larger pumps will require some basic consumables and replacement parts, including lubricant (grease) for bearings, replacement seals, new bearings and new wear rings. Coatings may also be applied to both reduce friction (and hence hydraulic losses) and also reduce corrosion, which can be used both from new and for in service refurbishment. For smaller pumps, it will not be economic to change these parts, and so they will instead be replaced with new pumps.

By contrast, the cost of removing a submersible pump for maintenance will be very high, due to the need for a specialist crane or other lifting apparatus. In these applications, quality of the pump and motor is of particular importance.

Condition monitoring is used on important installations to detect problems such as worn bearings or cavitation before it causes excessive energy loss or risk of failure. This is very much to be encouraged, but uptake is limited by cost.

Although not considered in the MEEUP model, the costs of downtime in terms of lost or spoiled production can be huge, and so attention to pump maintenance can reduce the eco-impact of unplanned plant outages.

Correct Selection of Pump

A critical issue in determining efficiency and lifetime is the correct selection of pump. While specifiers are often at fault for not having an accurate idea of the real duty requirements, the limited number of models in a manufacturers' range may mean that the "nearest" pump is actually a long way from the actual duty point. Supplying pumps with a variety of impeller sizes does help, but at the cost of reduced efficiency. Ideally a manufacturer would have a very large range of pumps to cater for a range of duties, but the costs make this prohibitive, and so this is a source of energy loss. Theoretically specifiers could often do better by "shopping around", but because they usually order all pumps for a new installation from a single supplier, this does not happen.

It is considered that because pumps are made wholly or almost entirely of easily recyclable metals, and that they are handled by professionals who are aware of their value, they will all be recycled. The market for second hand pumps is only very small.

Given that these products are used mainly by industry or commerce, rather than consumers, it is hard to identify how social or cultural factors will impact patterns of use. Similarly, no infra-structure related barriers could be identified, except for some submersible pumps where improved conventional water supplies would mean they were no longer needed.

However, although beyond the scope of this report, measures to reduce water consumption would reduce the operating duties of pumps, and ultimately reduce the number of pumps needed, with a consequent reduction of eco-impact.

System Energy Savings

This report concerns solely the energy savings that can be achieved by using a more efficient pump – but in terms of the overall savings that can be found in a pumping system these savings represent only a small proportion of the total system loss.

Considering the entire pump system ("electricity to water"), it is found that on average, most significant energy savings come from attention to the way in which the 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 whole pumping system. The SAVE study[17] identified energy savings associated with these measures as follows:

- Selecting better sized pump: 4%
- Better installation / maintenance: 3%
- Better System Design: 10%
- Better System Control: 20%

In particular, the use of Variable Speed Drives to adjust the flow to match the actual system requirements can make energy savings of over 50% in some systems, and so is something to be encouraged. Many suppliers already offer pumps with built in variable speed control, although the price premium means that sales so far are only small.

For smaller pump systems, indicatively less than 5-10kW, the designer is unlikely to have sufficient time to optimise the complete hydraulic system. Hence the use of pumps with integrated controls (typically

[17] SAVE study on improving the efficiency of pumps, AEAT for European Commission, 2001.

variable speed) represents a useful way to achieve energy savings, even if the entire system is not "fully optimised."

3.1 Real load efficiency (vs. nominal)

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 provide slightly more flow or head than calculated to allow for any difference in system characteristics from that planned. This means that the average pump will work to the left of the BEP, and hence below its nominal rated efficiency.

Pumps may consume the following during their lifetime:

- Lubricant (grease) for bearings
- Replacement seals
- New bearing
- New wear rings

For many mass produced pumps it can be assumed that they will receive no maintenance, and so are replaced when they fail. It is assumed that in most applications these quantities are insignificant. We need to understand which categories of pumps consume the above, and how much.

3.1.1 Part load characteristics of pumps

Pumps are always defined by the basic Pump characteristics below (figure 3.1). They show the relationship between head, power and efficiency against flow. It is important to see just how "peaky" the efficiency might be, showing that running at a duty (head and/or flow) below rated duty is likely to lead to a significant reduction in pump efficiency. The Best Efficiency Point (BEP) of a pump is ideally at the rated duty point. The peak power consumption will not necessarily be at the BEP.

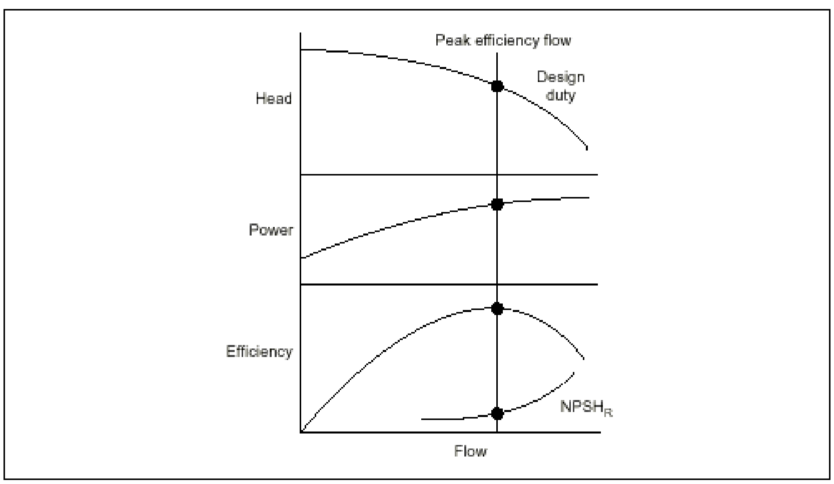


Figure 3-1 Centrifugal pump characteristics

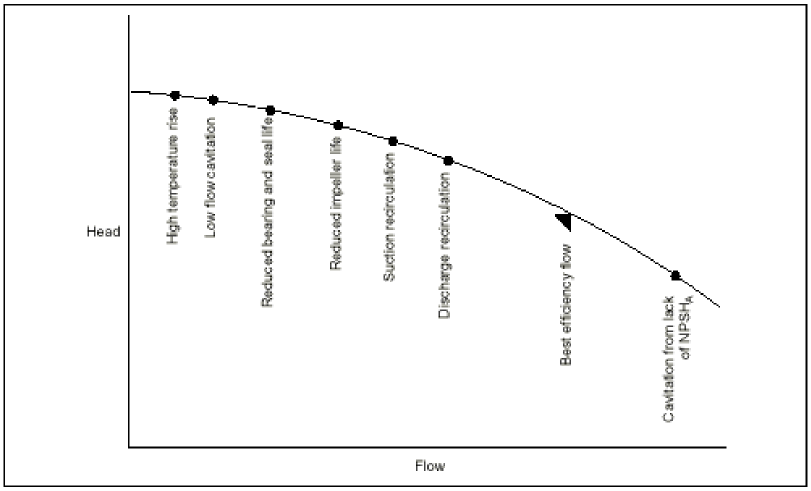


Figure 3-2 Onset of adverse effects when operating a pump away from its peak efficiency flow

The importance of selecting a pump to operate as closely as possible to its BEP cannot be over-emphasised. Not only should this save on energy costs, it will have several other benefits:

- The pump should run smoothly with minimum internal disturbing forces, thereby saving on maintenance costs due to premature failure of components such as bearings, wear rings, bushes, couplings and seals.
- The risk of damage to pump components due to cavitation should be reduced.
- Vibration should be minimised, benefiting other equipment.
- Noise should be minimised, improving the environment.
- Pressure pulsations should also be minimised, reducing the risk of problems in the pumping system as a whole.

Figure 3-3 indicates some of the problems which can result from operating away from BEP. Some of these problems may not be serious in small pumps, but they increase in severity as pump power increases, and should therefore be discussed with the pump supplier.

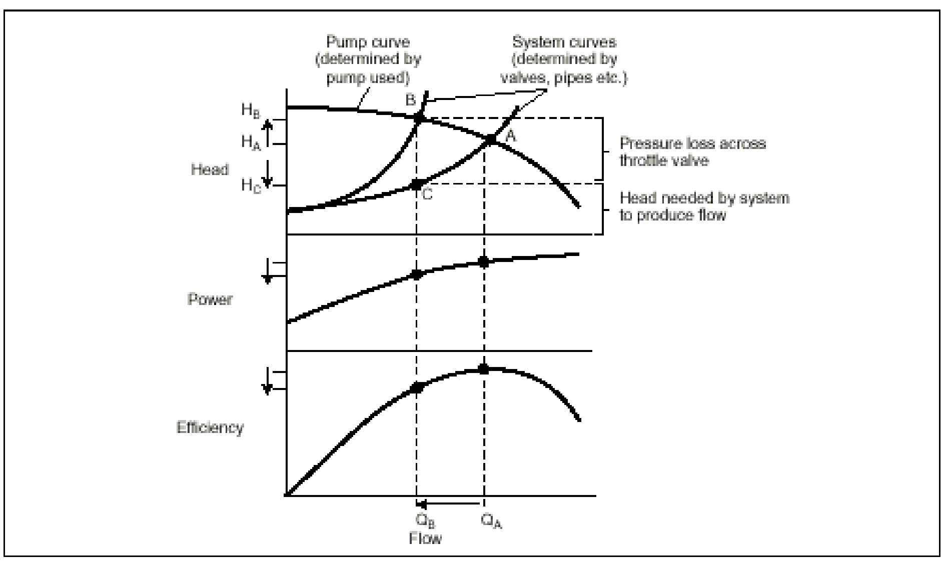


Figure 3-3 Illustration of the effect on efficiency of throttling a pump

Taking account of both the wear, and the fact that operation is away from the BEP, stakeholders agreed with the study team's suggestion that the average pump of the types included in this study is operating 10-20% (15% average) below the catalogue efficiency.

3.2 End of life behaviour

3.2.1 Economical Product Life (=in practice)

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 could 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 absence of other definitive information, a standard 11 year life was assumed for all pumps.

Repair and Maintenance Practice

Maintenance of the pump to reduce the deterioration in efficiency over time is important to minimise the eco impact. Even for water pumps this can be significant. Pumps do wear over time (3-4), but their efficiency can be maintained by refurbishment (3-5).

For critical pumpsets, on line measurement of differential pressure (and even flow), and electrical consumption is useful for trending changes in performance and hence the optimum time for refurbishment. This is costly and certainly not economic for the bulk of pumps in this study.

Re-conditioning may consist of the following;
- Renewal of wear rings
- Renewal of impeller

Regular maintainance actions may include:
- Bearing replacement / greasing.
- Seal replacement.

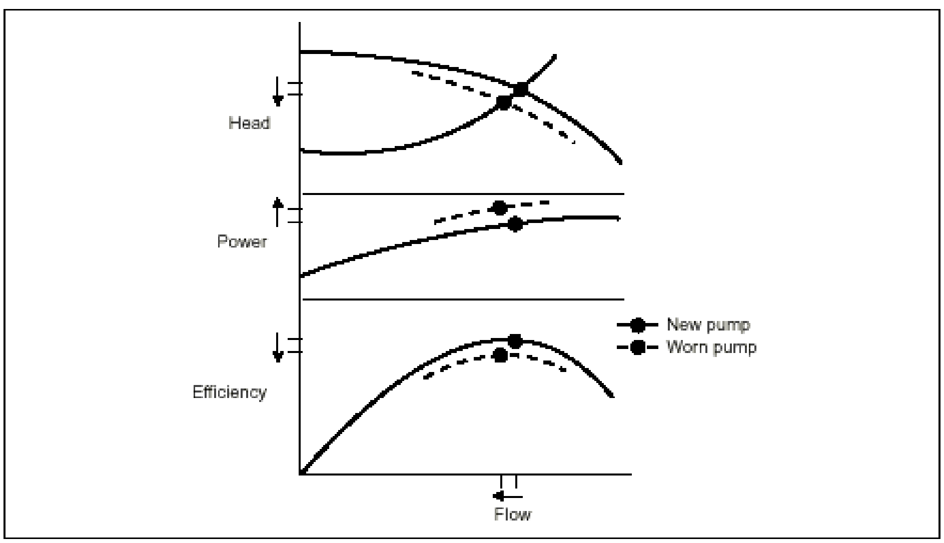


Figure 3-4 Effect of wear on pump characteristics

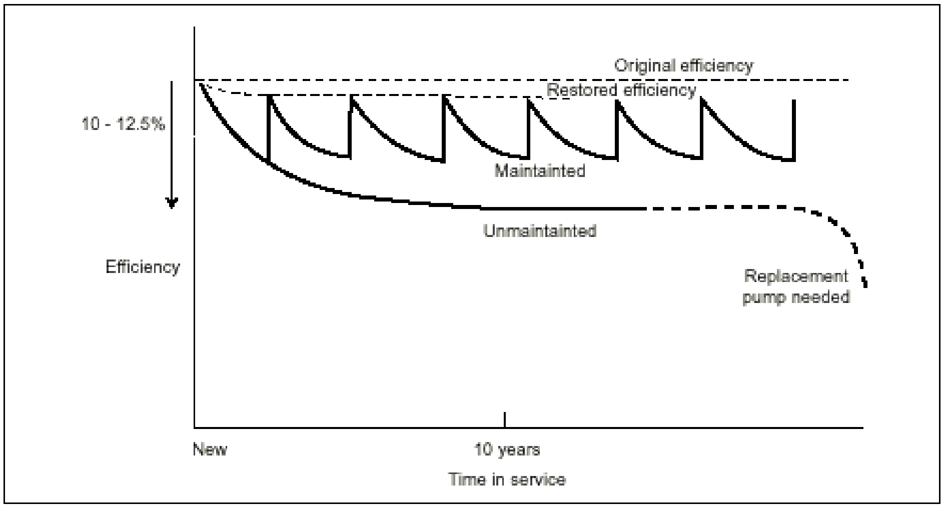


Figure 3-5 Average wear trends for maintained and unmaintained pumps

Figure 3-6 Worn pump inlet before and after repair and coating with low friction protective coating, (courtesy Corrocoat, Leeds, UK).

3.2.2 Present fractions to recycling, re-use and disposal

The BOMs for the pumps in the study show the proportion of non-metallic components by weight as varying from 4.4% in the larger ESOB pump to 25% on the smaller ESCC pumps. Pumps are heavy items, and have both a positive scrap value and an avoided disposal cost, and so it is to a company's advantage to send old pumps for scrap. In practice it is the norm for pumps to be sent for scrap. To a good approximation it is assumed that all of the metallic and none of the non-metallic components are recycled.

The following table shows the weight of pumps split by metallic and non-metallic components:

Pump	Total weight of metal components (g)	Total weight of non-metallic components (g)	Percentage of non-metalic components
ESCC Small	15,200	5,200	25
ESCC Large	108,600	10,300	8.7
ESOB Small	39,100	4,650	10.6
In Line Small	36,840	4,695	11.3
ESOB Large	176,200	8,200	4.4
Multistage small (6 stages)	6,050	1,300	18
Multistage big (5 stages)	8,750	1,300	12.9
Multistage submersible SP17	15,336	0	0
Multistage submersible SP8	5,215	1,350	21

Table 3-1 Proportion of non-metallic components in the pumps considered in the study.

Re-use in the context of this study refers to parts that can be removed from a product and re-used in a new product. There are in practical terms no such parts on pumps. (Motors on pumpsets could well be re-used, but these are beyond the boundaries of the definition of the pump in this study).

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 MEEUP model is therefore thought to be too high. However, as the MEEUP model showed that materials are not responsible for much of the total eco-impact, this does not represent a significant error, and so is not investigated any further.

3.2.3 Estimated second hand use, fraction of total and estimated second product life (in practice)

There is some use of second hand pumps, but is not a significant factor in the market. There is no developed second hand pump market as there is with some other consumer or industrial equipment, rather it is as the result of the occasional factory closure or where a pump is incorporated into a larger item of plant that is sold. Therefore, in terms of this study, this second hand life is included in the total lifetime of the product referred to in 3.2.1, and so this lack of definitive data does not affect the analysis.

3.2.4 Best Practice in Sustainable product use

Following from the earlier discussion on part load operation, it is clear that the correct selection of pump is at least as important as the selection of pump by highest BEP. The following text explains how manufacturers design a range of pumps to suit all duties within a range, and the compromises that this means in terms of being able to select a pump for a particular duty.

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 efficiencies in competition with less efficient pumps whose BEP just happens to be nearer the requested performance. The worked example following makes this clearer.

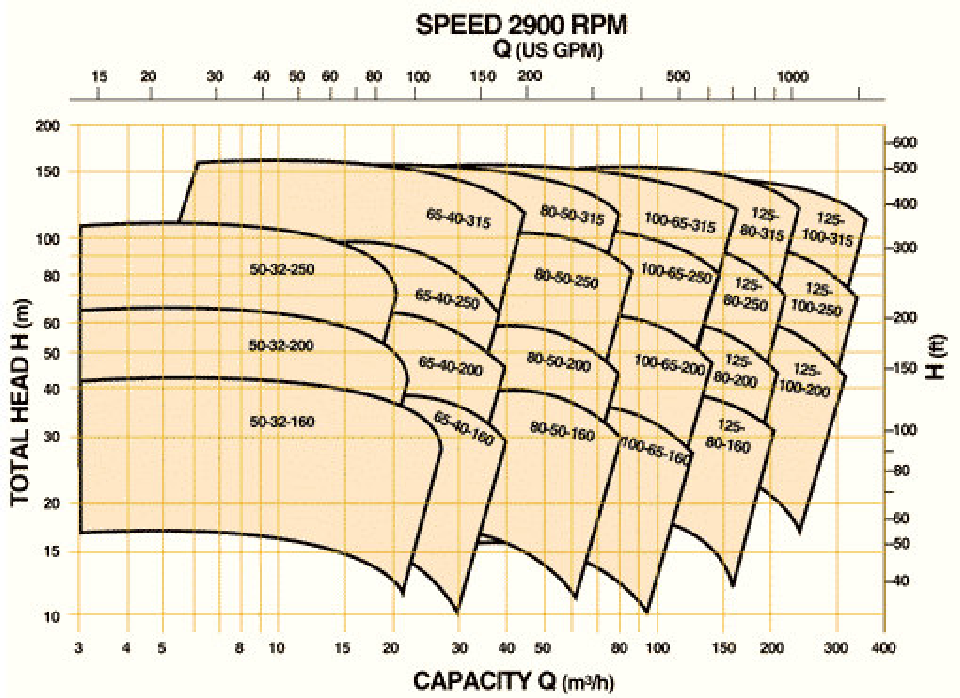
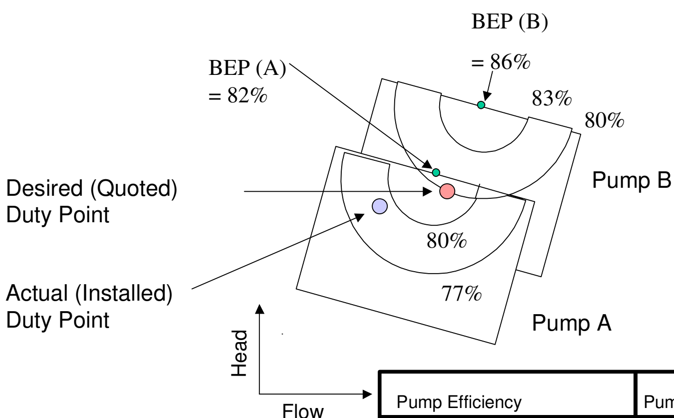


Figure 3-7 "Tombstone" curves for the selection of pumps by duty.



Pump Efficiency	Pump A	Pump B
Peak (BEP)	82%	86%
At desired (quoted) duty point	81.5%	80%
At actual (installed) duty point	79%	<77%

Figure 3-8 Worked example showing the importance of correct selection of a pump

A user requests quotes for a pump at a particular desired duty. Manufacturers A and B offer the pumps shown, which are the best that they can offer from the ranges that they have.

There are two important points:

While pump B has a higher BEP, at the desired duty, pump A actually has a higher efficiency than pump B.

Over-specifying the duty means that at the actual installed duty, the efficiency of the pump will be considerably less than quoted. (In this particular case it would be better to use a reduced diameter impeller, or perhaps a quite different pump to either of those quoted for.)

3.2.4.1 System energy losses

Beyond the pump itself, large energy savings are to be found by looking at the system:

- What is the system trying to achieve – ie what flow rate, pressure or cooling effect is actually required?
- Controlling the pump (or group of pumps) to match this actual demand, with measures that might include on/off or variable speed control. Existing pumps may be altered by fitting smaller impellers or the addition of small jockey pumps for use at times of low demand.
- Attention to pipework design can substantially reduce system friction and hence pressure drop.

3.2.4.2 Condition monitoring

Condition Monitoring of pumps, either with permanent or portable equipment represents best practice in identifying pumps before they fail catastrophically. This can save energy and other costs in many ways[18]:

Effect of unplanned breakdown	Related energy cost
Temporary reduction of output during breakdowns	Background energy used to maintain essential services is spread across less product, so specific energy consumption rises
Start-up losses	Energy is lost during the warm-up phase of high-temperature processes
Using alternative methods to regain production	Less efficient production methods may be used, possibly relying on older equipment or involving extra transport costs
Loss of production during warm-up phase	Some processes result in scrapped product while they are warming up
Energy lost in part-processing a product	Energy may have been expended in getting a product close to the end of a production line. This will be wasted.
Disposal of damaged products	There may be energy costs involved in disposing of scrapped products
Emergency repairs made to restart plant	Because of the urgent need to get a plant running again, speed may take priority over getting the best quality repair or looking for the most efficient replacement parts.
Rework costs	Extra energy is needed to rework spoiled products
Time lost for less urgent work	Time that could have been spent on cutting energy consumption is lost.

Table 3-2 The energy costs of unplanned outages

3.3 Local infrastructure (energy, water, telecom, physical distribution, etc)

[18] From Falkner and Gaisford, Proc EEMODs 2005.

Local infrastructure issues do not apply to pumps, except for reduced electrical demand through more efficient pump operation. Hence no further consideration of this is made in this report.

3.3 Summary

The energy savings from the optimum sizing of a pump can be equal to or larger than those from picking a higher efficiency pump. This is because the efficiency of a standard centrifugal pump will fall off much more rapidly than for a comparably sized motor. Wear of the pump will also be accelerated if operated away from the rated point, leading to a reduction in lifetime operating efficiency and also reduced lifetime.

Design of the system and controls can yield energy savings that will usually exceed that from the selection of a more efficient pump. The use of variable speed or intelligent controls for saving energy is outside the scope of this study, but is to be encouraged.

4 Technical Analysis Existing Products

This chapter contains all the technical inputs for the MEEUP model for each of the pump types in this study. This comprises the production phase (materials), distribution, In use phase (energy and maintenance costs) and end of life phase.

4.1 Data on the production phase

The detailed Bill of Material (BOM) data lists all materials, by weight, for each basecase pump. The basecase is seen as being representative of current “best sellers”. The method of derivation varies for each type, but is generally based on a single real model, with some parameters adjusted in consultation with industry to be more widely representative of all models.

In all cases, the selection of the basecase model was derived from expert opinions. The subsequent analysis will verify the accuracy of this choice. But even if it is shown that this is not quite correct, it should not matter, providing that it is clear where in the performance range of all pumps it belongs. The importance of having “real” small and large basecase models is that it is easy to identify the practical impact of design options – something which might be lost if just using the single virtual basecase.

When there was any doubt, the model BOM was assigned a material content at the higher end of the range of estimates. This was to make sure that any emissions from the production phase are if anything exaggerated. This is because on an initial exploratory run of the model it was clear that the production phase was actually only of minor impact.

It is noted that wood, widely used for packaging crates, is absent from this list. However, consultation with in-house eco-analysis experts is that wood is a fairly benign product, and so this omission is not important in terms of the overall eco-impact.

4.1.1 Bill of Materials for Single Stage Close-coupled (end suction close coupled) and in line version

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Impeller	2000.0	3-Ferro	23-Cast iron
2	Casing	8000.0	3-Ferro	23-Cast iron
3	Adapter/bearing housing/feet	4000.0	3-Ferro	23-Cast iron
4	Shaft (part of motor)	0.0	3-Ferro	25-Stainless 18/8 coil
5	Metal fixings, seals, bearings	1000.0	3-Ferro	25-Stainless 18/8 coil
6	Paint	100.0	5-Coating	39-powder coating
7	User instruction manual	100.0	7-Misc.	57-Office paper
8	Pallet	4000.0	7-Misc.	56-Cardboard
9	Protective covering	1000.0	1-BlkPlastics	1-LDPE
10	CONSUMABLES - Seal - 2 assumed at 100g each	200.0	3-Ferro	25-Stainless 18/8 coil

Figure 4-1 BOM ESCC Small (25m^3/h, 25m)

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Impeller	12000.0	3-Ferro	23-Cast iron
2	Casing	55000.0	3-Ferro	23-Cast iron
3	Adapter/bearing housing/feet	35000.0	3-Ferro	23-Cast iron
4	Shaft	4000.0	3-Ferro	25-Stainless 18/8 coil
5	Metal fixings, seals, bearings	2000.0	3-Ferro	25-Stainless 18/8 coil
6	Paint	200.0	5-Coating	39-powder coating
7	User instruction manual	100.0	7-Misc.	57-Office paper
8	Pallet	7000.0	7-Misc.	56-Cardboard
9	Protective covering	3000.0	1-BlkPlastics	1-LDPE
10	CONSUMABLES - Seals - 3 assumed at 200g each	600.0	3-Ferro	25-Stainless 18/8 coil
11	CONSUMABLES - lubricant over life (no field for grease)	0.0	7-Misc.	57-Office paper

Figure 4-2 BOM ESCC Large (125m^3/h, 25m)

4.1.2 Bill of Materials for Single Stage Close-coupled (end suction own bearings)

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Impeller	2000.0	3-Ferro	23-Cast iron
2	Casing	8000.0	3-Ferro	23-Cast iron
3	Adapter/bearing housing/feet	20000.0	3-Ferro	23-Cast iron
4	Shaft	4000.0	3-Ferro	25-Stainless 18/8 coil
5	Metal fixings, seals, bearings	3000.0	3-Ferro	25-Stainless 18/8 coil
6	Paint	50.0	5-Coating	39-powder coating
7	User instruction manual	100.0	7-Misc.	57-Office paper
8	Pallet	4000.0	7-Misc.	56-Cardboard
9	Protective covering	500.0	1-BlkPlastics	1-LDPE
10	CONSUMABLES - Bearings - 3 assumed at 600g each	1800.0	3-Ferro	25-Stainless 18/8 coil
11	CONSUMABLES - Seal - 3 assumed at 100g each	300.0	3-Ferro	25-Stainless 18/8 coil

Figure 4-3 BOM ESOB Small (25m^3/h, 32m)

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Impeller	12000.0	3-Ferro	23-Cast iron
2	Casing	55000.0	3-Ferro	23-Cast iron
3	Adapter/bearing housing/feet	97000.0	3-Ferro	23-Cast iron
4	Shaft	8000.0	3-Ferro	25-Stainless 18/8 coil
5	Metal fixings, seals, bearings	600.0	3-Ferro	25-Stainless 18/8 coil
6	Paint	100.0	5-Coating	39-powder coating
7	User instruction manual	100.0	7-Misc.	57-Office paper
8	Pallet	7000.0	7-Misc.	56-Cardboard
9	Protective covering	1000.0	1-BlkPlastics	1-LDPE
10	CONSUMABLES - Bearings - 3 assumed at 1000g each	3000.0	3-Ferro	25-Stainless 18/8 coil
11	CONSUMABLES - Seal - 3 assumed at 200g each	600.0	3-Ferro	25-Stainless 18/8 coil

Figure 4-4 BOM ESOB Large (125m^3/h , 32m)

4.1.3 Bill of Materials for Submersible multistage well pumps

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Suction interconnector	800.0	3-Ferro	25-Stainless 18/8 coil
2	Impeller	550.0	3-Ferro	25-Stainless 18/8 coil
3	Lower chamber	240.0	3-Ferro	25-Stainless 18/8 coil
4	Chamber int.	1160.0	3-Ferro	25-Stainless 18/8 coil
5	Chamber upper	180.0	3-Ferro	25-Stainless 18/8 coil
6	Shaft kp.	385.0	3-Ferro	25-Stainless 18/8 coil
7	Metal fixings (screws)	50.0	3-Ferro	25-Stainless 18/8 coil
8	Valve casing	560.0	3-Ferro	25-Stainless 18/8 coil
9	Strap	1180.0	3-Ferro	25-Stainless 18/8 coil
10	Cable guard	110.0	3-Ferro	25-Stainless 18/8 coil
11	Packaging materials	1350.0	7-Misc.	56-Cardboard
12			3-Ferro	25-Stainless 18/8 coil

Figure 4-5 BOM Small (8.5m^3/h at 59m, 2 pole) ,

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Impeller	600.0	3-Ferro	25-Stainless 18/8 coil
2	Casing	3500.0	3-Ferro	25-Stainless 18/8 coil
3	Stage casing	1900.0	3-Ferro	25-Stainless 18/8 coil
4	Shaft (part of motor)	500.0	3-Ferro	25-Stainless 18/8 coil
5	Metal fixings (screws)	500.0	3-Ferro	25-Stainless 18/8 coil
6	Paint	0.0	5-Coating	39-powder coating
7	User instruction manual	100.0	7-Misc.	57-Office paper
8	Pallet	1000.0	7-Misc.	56-Cardboard
9	Protective covering	100.0	1-BlkPlastics	1-LDPE
10	Static seals	100.0	2-TecPlastics	16-Flex PUR
11	CONSUMABLES - mechanical seals (5 x 50g)	250.0	3-Ferro	25-Stainless 18/8 coil
12	CONSUMABLES - Bearings (5 x 300??)	1500.0	3-Ferro	25-Stainless 18/8 coil

Figure 4-6 BOM Large (15m^3/h at 88m, 2 pole) ,

4.1.4 Bill of Materials for Vertical multistage pumps

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Impeller	600.0	3-Ferro	25-Stainless 18/8 coil
2	Casing	1600.0	3-Ferro	25-Stainless 18/8 coil
3	Stage casing	1100.0	3-Ferro	25-Stainless 18/8 coil
4	Shaft (part of motor)	500.0	3-Ferro	25-Stainless 18/8 coil
5	Metal fixings (screws)	500.0	3-Ferro	25-Stainless 18/8 coil
6	Paint	0.0	5-Coating	39-powder coating
7	User instruction manual	100.0	7-Misc.	57-Office paper
8	Pallet	1000.0	7-Misc.	56-Cardboard
9	Protective covering	100.0	1-BlkPlastics	1-LDPE
10	Static seals	100.0	2-TecPlastics	16-Flex PUR
11	CONSUMABLES - mechanical seals (5 x 50g)	250.0	3-Ferro	25-Stainless 18/8 coil
12	CONSUMABLES - Bearings (5 x300??)	1500.0	3-Ferro	25-Stainless 18/8 coil

Figure 4-7 BOM Vertical multistage (small) (4m^3/h at 45m, 2 pole) ,

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Impeller	600.0	3-Ferro	25-Stainless 18/8 coil
2	Casing	3500.0	3-Ferro	25-Stainless 18/8 coil
3	Stage casing	1900.0	3-Ferro	25-Stainless 18/8 coil
4	Shaft (part of motor)	500.0	3-Ferro	25-Stainless 18/8 coil
5	Metal fixings (screws)	500.0	3-Ferro	25-Stainless 18/8 coil
6	Paint	0.0	5-Coating	39-powder coating
7	User instruction manual	100.0	7-Misc.	57-Office paper
8	Pallet	1000.0	7-Misc.	56-Cardboard
9	Protective covering	100.0	1-BlkPlastics	1-LDPE
10	Static seals	100.0	2-TecPlastics	16-Flex PUR
11	CONSUMABLES - mechanical seals (5 x 50g)	250.0	3-Ferro	25-Stainless 18/8 coil
12	CONSUMABLES - Bearings (5 x300??)	1500.0	3-Ferro	25-Stainless 18/8 coil

Figure 4-8 BOM Vertical multistage (Big) (10m^3/h at 42m, 2 pole) ,

4.2 Data on the distribution phase

No definitive data exists on this, and so in consultation with stakeholders the following was agreed upon as representing the mileage incurred in the distribution of each product. It was found that this was actually hard to estimate, as the actual mileage varies tremendously according to location of the pump and nearest service agent, the pump duty and the servicing policy of the site. However, because it was found not to be a very significant factor, no further work was done on this, as any greater refinement of data will not greatly affect the outcomes.

Style	Basecase	Average distance for maintenance (km)
End Suction Own Bearings (ESOB)	Small Large	300 100
End Suction Close Coupled (ESCC)	Small Large	150 300
Submersible Multistage	Small Large	0 1000
Vertical Multistage	Small Large	1000 1000

Table 4-1 Average distance for maintenance by pump type

The differences between pumps are large, and are accounted for by the following factors:

Actual distances vary, as it is a function of the number of times maintenance is required and the assumed number of repairs tolerated before a pump is scrapped.

Multistage pumps need regular specialist maintenance, and hence the distance is high.

The only exception to this is the small submersible multistage pump that would usually be replaced rather than repaired.

The model actually assumes a fixed distance of 200km from factory to distribution centre and 20km from there to the consumer. However, the results of the analysis show that eco impact of the distribution is insignificant compared to other factors, and so this discrepancy does not alter significantly the results of this analysis.

4.3 Use phase (product)

4.3.1 Calculation of the energy used by the basecase pump

The MEEUP model states that this should be calculated based on actual and test standard conditions. However, there is currently no test standard condition, and so in order to derive the basecase model, an assumed flow profile was used, based on the experience of the study team, (table 4-2).

% of BEP flow	% of time at this flow
50	25
75	50
100	20
125*	5

*(Note that as shown in section 3.1, it is permissible to use many types of pumps "beyond" their rated flow point, providing that for example the NPSH is still adequate and that the motor has adequate power.)

Table 4-2 Proportion of time the pump is assumed to operate at each flow.

The energy performance of each pump was then calculated using a new worksheet added to the MEEUP spreadsheet. This was calculated by summing the annual energy consumed at each of the above duty points, which will most importantly include the efficiency at each point.
As an example, consider a small End Suction Close Coupled pump (as shown in Fig 4.3).

- Look up the rated efficiency at the 4 selected flow points. *Eg At 75%, this is 61%.*
- Subtract a nominal amount (here 3%) to allow for lifetime decrease in efficiency. *(61 – 3)% = 58%.*
- Calculate the power consumption at each flow point. Ie Power = Flow (m^3/s) x head (m) x relative density of fluid x gravity / (efficiency (%) x 3600).

(25 x 0.75) x 38 x 1.0 x 9.8 / 0.58 x 3,600 = 3.34kW.

- For each flow point, multiply the power by the number of hours pa. This is calculated as a percentage of time spent operating pa. This gives the total energy consumption for each flow point.

3.34 x (0.25 x 2,250) = 1,675 kWh pa

- This is repeated for each of the four flow points, and totalled to give total annual energy consumption for the pump under assumed operating conditions.

1,675 + 3,762 + 1,581 + 273 = 7,291 kWh pa

4.3.2 Calculation of the average efficiency of the basecase and other pumps

For the standard commodity pumps considered in this study, there is technologically little difference between the pumps of different efficiency. The basecase pumps were selected as being roughly at the average efficiency of the products on the market, and as shown in chapter seven the actual choice of basecase does not impact the results of the study. All the MEEUP model analysis have been calculated on this basis, as this was the best information available when the study commenced.

Table 4-3 shows the actual scatter of efficiencies derived from the much later (Summer 2007) market survey of over 2,500 pumps described in Annex 3. These are different from the initial estimates made of average pump efficiencies. The "cut off" term shown here and used in the later analysis can be regarded as the "percentile".

The error from the assumption that the spread of efficiencies is based on the estimated basecase rather than the actual statistical (50% cutoff) average is shown in table 4-4. The impact of this error will in most cases be only small, the main impact being a small under-estimation of the current energy use and hence also of the projected energy savings.

Cut off (%)	ESCC S	ESCC L	ESOB S	ESOB L	MSS S	MSS L	MS S	MS L	ESCCi S	ESCCi L
80	68.48	79.15	69.68	79.78	72.44	75.51	51.26	65	66.88	75.92
70	67.27	77.76	67.96	77.87	70.65	73.72	48.64	63.45	65.19	74.24
60	66.22	76.65	66.9	76.62	69.27	72.34	47.14	61.71	63.68	72.9
50	65.16	75.84	65.84	75.75	67.22	70.29	45.58	58.89	62.37	72.22
40	64.25	74.76	64.75	74.65	65.7	68.77	45.06	58.55	61.33	70.92
30	62.79	73.45	63.41	73.37	63.55	66.62	44.12	56.53	60.11	69.78
20	61.2	72.02	61.59	72.04	62.06	65.13	43.6	55.96	58.49	68.62
10	59.09	70.48	59.42	70.14	60.18	63.25	40.82	54.48	55.57	66.55

Table 4-3 Actual statistical spread of efficiencies for each type/size of pump

Type of pump	Basecase size	Assumed basecase efficiency (%)	Actual Statistical mean efficiency (%)	Deviation of assumed from actual efficiency (% points)
End Suction Own Bearings (ESOB)	Small	65	65.84	-0.84
	Large	72	75.75	-3.75
End Suction Close Coupled (ESCC)	Small	65	65.16	-0.16
	Large	73	75.84	-2.84
End Suction Close Coupled Inline (ESCCi)	Small	62	65.16	-3.16
	Large	70	72.22	-2.22
Submersible Multistage	Small	63	67.22	-4.22
	Large	73.4	70.3	3.1
Vertical Multistage	Small	60	45.58	14.42
	Large	65	58.89	6.11
			Average	**0.644**

Table 4-4 Comparison of estimated basecase efficiencies and actual statistical efficiencies of each size/type of pump

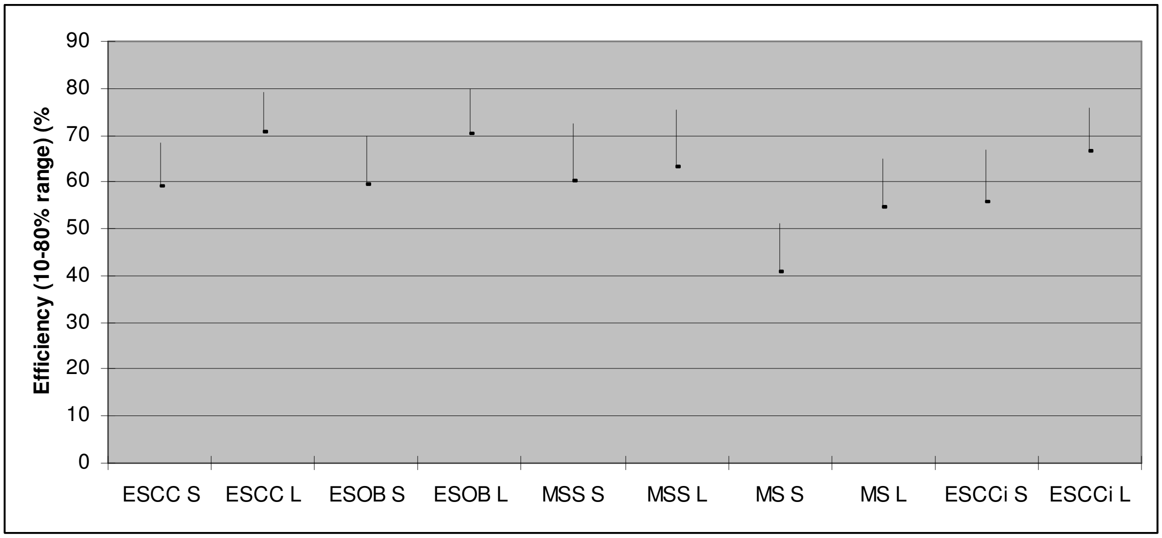


Figure 4-9 Spread of actual efficiencies (BEP) for each style of pump

Note on Multistage submersible pumps

The final stakeholder view was that it is most sensible to have just one efficiency line for 3", 4" and 6" multistage submersible pumps. The justification for this is that there is in practice little overlap of the duties served by the different sizes, and so it is easier to just have one line that includes both types. While the study group do see this as being a workable solution, a more convincing case would be made if the different types were able to be analysed separately in order that the impact of this approximation can be understood.

4.3.3 Data on Use Phase for End suction close coupled pumps (ESCC)

Quantity	Units	
Operating efficiency of the pump selected at the requested duty point	63	%
Average end of life efficiency decrease due to wear	5	%
End of life efficiency to average life efficiency conversion	0.6	
Mean lifetime efficiency decrease	3	%
Head at BEP	32	m
Flow at BEP	25	m3/h
Flow at BEP (l/s)	6.9	l/s
Head at 50% BEP flow	42	m
Head at 75% BEP flow	38	m
Head at 125% BEP flow	16	m
Density of water	1,000	kg/m3
Gravity	10	m/s2
Hydraulic power output at BEP flow	2.2	kW
Mechanical (shaft power) at BEP flow	3.4	kW
Annual running hours	2,250	hrs pa

Key
Fixed values
User entered values
Calculated values

% Rated (100%) Flow	Efficiency (at full impeller) (%)	Average lifetime efficiency (%)	Power consumption at this flow (kW)	Proportion of running hours at this flow (%)	Annual energy consumption at this flow (kWh pa)
50	51	48	3.0	25	1,675
75	61	58	3.3	50	3,762
100	65	62	3.5	20	1,581
125	59	56	2.4	5	273
		Total annual energy consumption			**7,291**

Figure 4-10 Energy data - End suction close coupled (small)

Quantity	Units	
Operating efficiency of the pump selected at the requested duty point	72	%
Average end of life efficiency decrease due to wear	5	%
End of life efficiency to average life efficiency conversion	0.6	
Mean lifetime efficiency decrease	3	%
Head at BEP	31	m
Flow at BEP	132	m3/h
Flow at BEP (l/s)	36.7	l/s
Head at 50% BEP flow	42	m
Head at 75% BEP flow	38	m
Head at 125% BEP flow	16	m
Density of water	1,000	kg/m3
Gravity	10	m/s2
Hydraulic power output at BEP flow	11.1	kW
Mechanical (shaft power) at BEP flow	15.3	kW
Annual running hours	2,250	hrs pa

Key
Fixed values
User entered values
Calculated values

% Rated (100%) Flow	Efficiency (at full impeller) (%)	Average lifetime efficiency (%)	Power consumption at this flow (kW)	Proportion of running hours at this flow (%)	Annual energy consumption at this flow (kWh pa)
50	59	56	13.5	25	7,580
75	72	69	14.8	50	16,697
100	73	70	15.9	20	7,161
125	72	69	10.4	5	1,172
		Total annual energy consumption			**32,610**

Figure 4-11 Energy data - End suction close coupled (large)

4.3.4 Data on Use Phase for in line End suction close coupled pumps (ESCCi)

Quantity	Units	
Operating efficiency of the pump selected at the requested duty point	63	%
Average end of life efficiency decrease due to wear	5	%
End of life efficiency to average life efficiency conversion	0.6	
Mean lifetime efficiency decrease	3	%
Head at BEP	32	m
Flow at BEP	25	m3/h
Flow at BEP (l/s)	6.9	l/s
Head at 50% BEP flow	42	m
Head at 75% BEP flow	38	m
Head at 125% BEP flow	16	m
Density of water	1,000	kg/m3
Gravity	10	m/s2
Hydraulic power output at BEP flow	2.2	kW
Mechanical (shaft power) at BEP flow	3.8	kW
Annual running hours	4,000	hrs pa

Key
Fixed values
User entered values
Calculated values

% Rated (100%) Flow	Efficiency (at full impeller) (%)	Average lifetime efficiency (%)	Power consumption at this flow (kW)	Proportion of running hours at this flow (%)	Annual energy consumption at this flow (kWh pa)
25	30	27	2.6	44	4,658
50	48	45	2.9	35	4,023
75	58	55	3.0	15	1,782
100	62	59	1.8	6	443
		Total annual energy consumption			**10,906**

Figure 4-12 Energy data - End suction in line close coupled (small)

Quantity	Units	
Operating efficiency of the pump selected at the requested duty point	72	%
Average end of life efficiency decrease due to wear	5	%
End of life efficiency to average life efficiency conversion	0.6	
Mean lifetime efficiency decrease	3	%
Head at BEP	31	m
Flow at BEP	132	m3/h
Flow at BEP (l/s)	36.7	l/s
Head at 50% BEP flow	42	m
Head at 75% BEP flow	38	m
Head at 25% BEP flow	44	m
Density of water	1,000	kg/m3
Gravity	10	m/s2
Hydraulic power output at BEP flow	11.1	kW
Mechanical (shaft power) at BEP flow	15.9	kW
Annual running hours	4,000	hrs pa

Key
Fixed values
User entered values
Calculated values

% Rated (100%) Flow	Efficiency (at full impeller) (%)	Average lifetime efficiency (%)	Power consumption at this flow (kW)	Proportion of running hours at this flow (%)	Annual energy consumption at this flow (kWh pa)
25	37	34.0	11.6	44	20,461
50	57	54.0	14.0	35	19,564
75	69	66.0	15.5	15	9,310
100	70	67.0	16.6	6	3,990
		Total annual energy consumption			**53,325**

Figure 4-13 Energy data - End suction in line close coupled (large)

Note that for ESCCi pumps, these are used mainly in heating applications, and hence the Blauer Engel flow distribution[19] is assumed. This includes some time at 25% flow, but none over 100% flow.

[19] This is discussed in Appendix 1 of the EUP Lot 11 Circulator report.

4.3.5 Data on Use phase for End suction own bearings pumps

Quantity	Value	Units	Key
Operating efficiency of the pump selected at the requested duty point	63	%	Fixed values
Average end of life efficiency decrease due to wear	5	%	User entered values
End of life efficiency to average life efficiency conversion	0.6		Calculated values
Mean lifetime efficiency decrease	3	%	
Head at BEP	30	m	
Flow at BEP	30	m3/h	
Flow at BEP (l/s)	8.3	l/s	
Head at 50% BEP flow	42	m	
Head at 75% BEP flow	38	m	
Head at 125% BEP flow	16	m	
Density of water	1,000	kg/m3	
Gravity	10	m/s2	
Hydraulic power output at BEP flow	2.5	kW	
Mechanical (shaft power) at BEP flow	3.8	kW	
Annual running hours	2,250	hrs pa	

% Rated (100%) Flow	Efficiency (at full impeller) (%)	Average lifetime efficiency (%)	Power consumption at this flow (kW)	Proportion of running hours at this flow (%)	Annual energy consumption at this flow (kWh pa)
50	51	48	3.6	25	2,010
75	61	58	4.0	50	4,515
100	65	62	4.0	20	1,778
125	59	56	2.9	5	328
		Total annual energy consumption			**8,631**

Figure 4-14 Energy data - End suction own bearing pump (small)

Quantity	Value	Units	Key
Operating efficiency of the pump selected at the requested duty point	72	%	Fixed values
Average end of life efficiency decrease due to wear	10	%	User entered values
End of life efficiency to average life efficiency conversion	0.6		Calculated values
Mean lifetime efficiency decrease	6	%	
Head at BEP	32	m	
Flow at BEP	125	m3/h	
Flow at BEP (l/s)	34.7	l/s	
Head at 50% BEP flow	42	m	
Head at 75% BEP flow	38	m	
Head at 125% BEP flow	16	m	
Density of water	1,000	kg/m3	
Gravity	10	m/s2	
Hydraulic power output at BEP flow	10.9	kW	
Mechanical (shaft power) at BEP flow	14.9	kW	
Annual running hours	2,250	hrs pa	

% Rated (100%) Flow	Efficiency (at full impeller) (%)	Average lifetime efficiency (%)	Power consumption at this flow (kW)	Proportion of running hours at this flow (%)	Annual energy consumption at this flow (kWh pa)
50	59	53	13.5	25	7,584
75	72	66	14.7	50	16,531
100	73	67	16.3	20	7,313
125	72	66	10.3	5	1,160
		Total annual energy consumption			**32,588**

Figure 4-15 Energy data - End suction own bearings (large)

4.3.6 Data on Use phase for submersible multistage pumps

Quantity	Units	
Operating efficiency of the pump selected at the requested duty point	63.1	%
Average end of life efficiency decrease due to wear	5	%
End of life efficiency to average life efficiency conversion	0.6	
Mean lifetime efficiency decrease	3	%
Head at BEP	59.2	m
Flow at BEP	8.5	m3/h
Flow at BEP (l/s)	2.4	l/s
Head at 50% BEP flow	80	m
Head at 75% BEP flow	70	m
Head at 125% BEP flow	45	m
Density of water	1,000	kg/m3
Gravity	10	m/s2
Hydraulic power output at BEP flow	1.4	kW
Mechanical (shaft power) at BEP flow	2.2	kW
Annual running hours	1,000	hrs pa

Key
Fixed values
User entered values
Calculated values

% Rated (100%) Flow	Efficiency (at full impeller) (%)	Average lifetime efficiency (%)	Power consumption at this flow (kW)	Proportion of running hours at this flow (%)	Annual energy consumption at this flow (kWh pa)
50	53	50	1.9	25	463
75	58	55	2.2	50	1,104
100	63.1	60.1	2.3	20	456
125	58	55	2.4	5	118
		Total annual energy consumption			**2,141**

Figure 4-16 Energy data - Submersible multistage (small) SP8

Quantity	Units	
Operating efficiency of the pump selected at the requested duty point	73.4	%
Average end of life efficiency decrease due to wear	3	%
End of life efficiency to average life efficiency conversion	0.6	
Mean lifetime efficiency decrease	1.8	%
Head at BEP	88	m
Flow at BEP	15	m3/h
Flow at BEP (l/s)	4.2	l/s
Head at 50% BEP flow	130	m
Head at 75% BEP flow	110	m
Head at 125% BEP flow	75	m
Density of water	1,000	kg/m3
Gravity	10	m/s2
Hydraulic power output at BEP flow	3.6	kW
Mechanical (shaft power) at BEP flow	4.9	kW
Annual running hours	1,000	hrs pa

Key
Fixed values
User entered values
Calculated values

% Rated (100%) Flow	Efficiency (at full impeller) (%)	Average lifetime efficiency (%)	Power consumption at this flow (kW)	Proportion of running hours at this flow (%)	Annual energy consumption at this flow (kWh pa)
50	57	55.2	4.8	25	1,202
75	70	68.2	4.9	50	2,470
100	73.4	71.6	5.0	20	1,004
125	70	68.2	5.6	5	281
		Total annual energy consumption			**4,956**

Figure 4-17 Energy data - Submersible multistage (big) SP17

4.3.7 Data on Use phase for vertical multistage pumps

Quantity	Units		Key
Operating efficiency of the pump selected at the requested duty point	65	%	Fixed values
Average end of life efficiency decrease due to wear	3	%	User entered values
End of life efficiency to average life efficiency conversion	0.6		Calculated values
Mean lifetime efficiency decrease	1.8	%	
Head at BEP	42	m	
Flow at BEP	10	m3/h	
Flow at BEP (l/s)	2.8	l/s	
Head at 50% BEP flow	75	m	
Head at 75% BEP flow	60	m	
Head at 125% BEP flow	30	m	
Density of water	1,000	kg/m3	
Gravity	10	m/s2	
Hydraulic power output at BEP flow	1.1	kW	
Mechanical (shaft power) at BEP flow	1.8	kW	
Annual running hours	1,500	hrs pa	

% Rated (100%) Flow	Efficiency (at full impeller) (%)	Average lifetime efficiency (%)	Power consumption at this flow (kW)	Proportion of running hours at this flow (%)	Annual energy consumption at this flow (kWh pa)
50	50	48.2	2.1	25	794
75	60	58.2	2.1	50	1,579
100	65	63.2	1.8	20	543
125	50	48.2	2.1	5	159
		Total annual energy consumption			**3,074**

Figure 4-18 Energy data - Multistage pump (Small)

Quantity	Units		Key
Operating efficiency of the pump selected at the requested duty point	60	%	Fixed values
Average end of life efficiency decrease due to wear	3	%	User entered values
End of life efficiency to average life efficiency conversion	0.6		Calculated values
Mean lifetime efficiency decrease	1.8	%	
Head at BEP	45	m	
Flow at BEP	4	m3/h	
Flow at BEP (l/s)	1.1	l/s	
Head at 50% BEP flow	75	m	
Head at 75% BEP flow	60	m	
Head at 125% BEP flow	30	m	
Density of water	1,000	kg/m3	
Gravity	10	m/s2	
Hydraulic power output at BEP flow	0.5	kW	
Mechanical (shaft power) at BEP flow	0.8	kW	
Annual running hours	1,500	hrs pa	

% Rated (100%) Flow	Efficiency (at full impeller) (%)	Average lifetime efficiency (%)	Power consumption at this flow (kW)	Proportion of running hours at this flow (%)	Annual energy consumption at this flow (kWh pa)
50	45	43.2	0.9	25	354
75	55	53.2	0.9	50	691
100	60	58.2	0.8	20	253
125	54	52.2	0.8	5	59
		Total annual energy consumption			**1,356**

Figure 4-19 Energy data - Multistage pump (Big)

4.4 Use phase (system)

It is important here to understand the interactions of the product with the system that it is operating in. These aspects are discussed elsewhere, but in summary comprise:

- Impact of the system design and use on pump wear and maintenance requirements.
- The maintenance (ie reduced wear) benefits of working close to the BEP.
- The energy saving benefits of variable speed operation.

The impacts of these interactions in terms of data entered into the model comprise:

- Better maintenance will both reduce wear and reduce the time between maintenance when it is working at lower efficiency due to degradation of pump performance.
- Better maintenance will reduce the likelihood of unplanned failure and the attendant financial consequences.
- Variable speed control means that the pump will operate at nearer its best efficiency point when operating at reduced flow.
- When operating at reduced flow, the head will be reduced, and so there will be significant additional energy savings.

4.5 End of Life phase

The default values adopted are those discussed and presented in section 3.

4.6 Summary

This section presents the technical inputs (materials and energy performance) needed as inputs to the MEEUP model.

Because in real life pumps are likely to work for all or part of their time at flows away from the rated flow point, it is important that the energy analysis takes account of this. An additional worksheet has therefore been added to the MEEUP model that derives a single energy use figure based on operation under typical flow profiles. It is this figure that is then entered into the proper MEEUP model as a single total energy consumption figure. Note that all the calculations in this chapter are in terms of mechanical power, and so in order to calculate the environmental impact (due to electrical energy) in the following section, use of a Class Eff2 motor is assumed.

Because of the big differences in design of the small and large basecase models, the analysis is run for both types separately, with the total impacts of each type of pump by adding the two basecase EIAs together.

5 Definition of base case

This chapter presents the results of the Environmental Impact Assessment performed on the three basecase models using the MEEUP model. The environmental impact is split into the following catagories:

- Materials
- Other resources and waste
- Emissions to air
- Emissions to water

The results show the total environmental impact in the following phases of product life:
- Production phase
- Distribution phase
- In Use phase
- End of life phase

In addition, economic information is provided to enable detailed LCC analysis to be undertaken as the basis of devising policy options.

Because there is no significant design change in pumps as the efficiency changes, the concept of Best Available and Best Next Available Technology don’t strictly apply, and therefore the approach we have taken differs from that in the proscribed MEEUP methodology.

5.1 Product Specific Inputs

This section presents information on disposal and recycling for the different types of pumps considered in this study.

5.1.1 End Suction Close Coupled Pumps

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	1632	8%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	900	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	100	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	10	1%	4
235	Plastics: Materials Recycling (please edit% only)	90	9%	4
236	Plastics: Thermal Recycling (please edit% only)	900	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	18430		fixed

Table 5-1 ESCC Small pump (25m^3/h at 32m, 2 pole) – Disposal and Recycling

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	9512	8%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	2700	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	300	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	30	1%	4
235	Plastics: Materials Recycling (please edit% only)	270	9%	4
236	Plastics: Thermal Recycling (please edit% only)	2700	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	110105		fixed

Table 5-2 ESCC Large pump (125m^3/h at 32m, 4 pole) – Disposal and Recycling

5.1.2 End Suction Own Bearing Pumps

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	3500	8%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	450	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	50	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	5	1%	4
235	Plastics: Materials Recycling (please edit% only)	45	9%	4
236	Plastics: Thermal Recycling (please edit% only)	450	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	41088		fixed

Table 5-3 ESOB Small pump (30m^3/h at 30m, 2 pole) – Disposal and Recycling

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	14752	8%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	900	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	100	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	10	1%	4
235	Plastics: Materials Recycling (please edit% only)	90	9%	4
236	Plastics: Thermal Recycling (please edit% only)	900	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	174230		fixed

Table 5-4 ESOB Large pump (125m^3/h at 32m, 4 pole) – Disposal and Recycling

5.1.3 End Suction Close Coupled In line Pumps

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	1632	8%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	900	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	100	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	10	1%	4
235	Plastics: Materials Recycling (please edit% only)	90	9%	4
236	Plastics: Thermal Recycling (please edit% only)	900	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	18430		fixed

Table 5-5End Suction Close Coupled In Line pumps Small (25m^3/h at 32m, 2 pole) – Disposal and Recycling

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	9512	8%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	2700	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	300	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	30	1%	4
235	Plastics: Materials Recycling (please edit% only)	270	9%	4
236	Plastics: Thermal Recycling (please edit% only)	2700	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	110105		fixed

Table 5-6 End Suction Close Coupled In Line pumps Large (25m^3/h at 32m, 4 pole) – Disposal and Recycling

5.1.4 Submersible Multistage Pumps

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	525	8%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	0	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	0	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	0	1%	4
235	Plastics: Materials Recycling (please edit% only)	0	9%	4
236	Plastics: Thermal Recycling (please edit% only)	0	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	6237		fixed

Table 5-7 Submersible Multistage Small pump (8.5m^3/h at 59m, 2 pole) – Disposal and Recycling

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	804	8%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	180	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	20	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	2	1%	4
235	Plastics: Materials Recycling (please edit% only)	18	9%	4
236	Plastics: Thermal Recycling (please edit% only)	180	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	9358		fixed

Table 5-8 Submersible Multistage Large pump (15m^3/h at 88m, 2 pole) – Disposal and Recycling

5.1.5 Vertical Multistage Pumps

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	588	8%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	180	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	20	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	2	1%	4
235	Plastics: Materials Recycling (please edit% only)	18	9%	4
236	Plastics: Thermal Recycling (please edit% only)	180	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	6793		fixed

Table 5-9 Vertical Multistage Small pump (4m^3/h at 45m, 2 pole) – Disposal and Recycling

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	804	8%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	180	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	20	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	2	1%	4
235	Plastics: Materials Recycling (please edit% only)	18	9%	4
236	Plastics: Thermal Recycling (please edit% only)	180	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	9358		fixed

Table 5-10 Vertical Multistage Large pump (10m^3/h at 42m, 2 pole) – Disposal and Recycling

5.2 Base-case Environmental Impact Assessment

This section presents the outputs from the Environmental Impact Analysis for all of the base-case pumps. This shows the environmental impact of each input, split into production, distribution and use phase.
The results are shown for the following types, in both small and large sizes, both in terms of per product and of the impact of all pumps sold in 2006[20].

- End Suction close coupled
- End Suction close coupled in line
- End Suction own bearings
- Submersible Multistage
- Vertical Multistage

[20] Note that several of the output tables from the MEEUP model have lots of zeroes. This is because of the scaling used in the model, which does not show quantities which are extremely low.

5.2.1 EIA for End Suction Close Coupled Pumps

Nr	Life cycle Impact per product:							Date	Author		
0	ESCC 25 m3/h at 32m Model A							38968	HWF		
	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**1000**			900	100	**1000**	**0**
2	TecPlastics	g			**0**			0	0	**0**	**0**
3	Ferro	g			**15200**			1216	13984	**15200**	**0**
4	Non-ferro	g			**0**			0	0	**0**	**0**
5	Coating	g			**100**			8	92	**100**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**4100**			328	3772	**4100**	**0**
	Total weight	g			**20400**			2452	17948	**20400**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	444	90	**534**	**309**	**1089174**	173	119	**54**	**1090071**
9	of which, electricity (in primary MJ)	MJ	42	54	**96**	**1**	**1088809**	0	0	**0**	**1088905**
10	Water (process)	ltr	150	1	**151**	**0**	**72589**	0	0	**0**	**72739**
11	Water (cooling)	ltr	145	25	**170**	**0**	**2903490**	0	2	**-2**	**2903658**
12	Waste, non-haz./ landfill	g	5924	283	**6208**	**176**	**1262473**	2001	1	**2000**	**1270856**
13	Waste, hazardous/ incinerated	g	7	0	**7**	**3**	**25089**	900	0	**900**	**25999**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	29	5	**34**	**20**	**47543**	13	9	**4**	**47601**
15	Ozone Depletion, emissions	mg R-11 eq.					negligible				
16	Acidification, emissions	g SO2 eq.	131	22	**152**	**59**	**280397**	26	11	**15**	**280623**
17	Volatile Organic Compounds (VOC)	g	2	0	**2**	**4**	**416**	1	0	**0**	**423**
18	Persistent Organic Pollutants (POP)	ng i-Teq	93	0	**93**	**1**	**7138**	14	0	**14**	**7246**
19	Heavy Metals	mg Ni eq.	206	0	**206**	**9**	**18760**	49	0	**49**	**19024**
	PAHs	mg Ni eq.	0	0	**0**	**11**	**2223**	0	0	**0**	**2234**
20	Particulate Matter (PM, dust)	g	208	3	**211**	**650**	**7314**	224	0	**224**	**8399**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	116	0	**116**	**0**	**7021**	14	0	**14**	**7153**
22	Eutrophication	g PO4	5	0	**5**	**0**	**34**	1	0	**1**	**39**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Table 5-11 EIA per product for End Suction Close Coupled Pump (Small), (25m^3/h at 32m, 2 pole), 2250 hrs pa

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	ESCC 25 m3/h at 32m Model A	38968	HWF

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**0**			0	0	**0**	**0**
2	TecPlastics	kt			**0**			0	0	**0**	**0**
3	Ferro	kt			**3**			0	3	**3**	**0**
4	Non-ferro	kt			**0**			0	0	**0**	**0**
5	Coating	kt			**0**			0	0	**0**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**1**			0	1	**1**	**0**
	Total weight	kt			**4**			0	4	**4**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	0	0	**0**	**0**	**204**	0	0	**0**	**204**
9	of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**204**	0	0	**0**	**204**
10	Water (process)	mln. m3	0	0	**0**	**0**	**14**	0	0	**0**	**14**
11	Water (cooling)	mln. m3	0	0	0	0	544	0	0	0	544
12	Waste, non-haz./ landfill	kt	1	0	**1**	**0**	**236**	0	0	**0**	**238**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**5**	0	0	**0**	**5**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**9**	0	0	**0**	**9**
15	Ozone Depletion, emissions	t R-11eq.					negligible				
16	Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**53**	0	0	**0**	**53**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**1**	0	0	**0**	**1**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**4**	0	0	**0**	**4**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**1**	0	0	**0**	**2**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**1**	0	0	**0**	**1**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq					negligible				

Table 5-12 EIA of 2006 production of End Suction Close Coupled Pumps (Small) (25m^3/h at 32m, 2 pole), 2250 hrs pa.

Nr	Life cycle Impact per product:	Date	Author
0	ESCC 125 m3/h at 32m Model A	38966	HWF

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**3000**			2700	300	**3000**	**0**
2	TecPlastics	g			**0**			0	0	**0**	**0**
3	Ferro	g			**108600**			8688	99912	**108600**	**0**
4	Non-ferro	g			**0**			0	0	**0**	**0**
5	Coating	g			**200**			16	184	**200**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**7100**			568	6532	**7100**	**0**
	Total weight	g			**118900**			11972	106928	**118900**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	1934	447	**2381**	**839**	**4185657**	834	284	**550**	**4189427**
9	of which, electricity (in primary MJ)	MJ	144	269	**414**	**2**	**4184916**	0	1	**-1**	**4185330**
10	Water (process)	ltr	702	4	**706**	**0**	**279001**	0	1	**-1**	**279707**
11	Water (cooling)	ltr	641	127	**768**	**0**	**11159772**	0	6	**-6**	**11160533**
12	Waste, non-haz./ landfill	g	39370	1411	**40781**	**431**	**4852575**	11662	4	**11658**	**4905444**
13	Waste, hazardous/ incinerated	g	18	0	**18**	**9**	**96433**	2700	1	**2699**	**99159**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	163	25	**188**	**51**	**182685**	62	20	**42**	**182965**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	742	107	**849**	**155**	**1077679**	123	26	**97**	**1078780**
17	Volatile Organic Compounds (VOC)	g	14	0	**14**	**12**	**1588**	3	0	**3**	**1617**
18	Persistent Organic Pollutants (POP)	ng i-Teq	663	1	**664**	**2**	**27437**	80	0	**80**	**28183**
19	Heavy Metals	mg Ni eq.	1182	2	**1183**	**22**	**71965**	239	0	**239**	**73410**
	PAHs	mg Ni eq.	2	0	**2**	**28**	**8400**	0	0	**0**	**8431**
20	Particulate Matter (PM, dust)	g	1486	17	**1503**	**1983**	**25678**	1084	1	**1083**	**30248**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	663	0	**663**	**1**	**26990**	69	0	**69**	**27723**
22	Eutrophication	g PO4	21	0	**21**	**0**	**129**	4	0	**4**	**154**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Table 5-13 EIA per product for End Suction Close Coupled Pump (Large) ($125m^3/h$ at 32m, 4 pole) 2250 hrs pa.

Nr	EU Impact of New Models sold 2005 over their lifetime:		Date	Author
0	ESCC 125 m3/h at 32m Model A		38966	HWF

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**0**			0	0	**0**	**0**
2	TecPlastics	kt			**0**			0	0	**0**	**0**
3	Ferro	kt			**5**			0	5	**5**	**0**
4	Non-ferro	kt			**0**			0	0	**0**	**0**
5	Coating	kt			**0**			0	0	**0**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**0**			0	0	**0**	**0**
	Total weight	kt			**6**			1	5	**6**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	0	0	**0**	**0**	**188**	0	0	**0**	**189**
9	of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**188**	0	0	**0**	**188**
10	Water (process)	mln. m3	0	0	**0**	**0**	**13**	0	0	**0**	**13**
11	Water (cooling)	mln. m3	0	0	**0**	**0**	**502**	0	0	**0**	**502**
12	Waste, non-haz./ landfill	kt	2	0	**2**	**0**	**218**	1	0	**1**	**221**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**4**	0	0	**0**	**4**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**8**	0	0	**0**	**8**
15	Ozone Depletion, emissions	t R-11 eq.					negligible				
16	Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**48**	0	0	**0**	**49**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**1**	0	0	**0**	**1**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**3**	0	0	**0**	**3**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**1**	0	0	**0**	**1**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq					negligible				

Table 5-14 EIA of 2006 production of End Suction Close Coupled Pumps (Large) (125m^3/h at 32m, 4 pole), 2250 hrs pa

5.2.2 EIA for End Suction In Line Close Coupled Pumps

Nr	Life cycle Impact per product:	Date	Author
0	ESCC 25 m3/h at 32m Model A	38968	HWF

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**1000**			900	100	**1000**	**0**
2	TecPlastics	g			**0**			0	0	**0**	**0**
3	Ferro	g			**15200**			1216	13984	**15200**	**0**
4	Non-ferro	g			**0**			0	0	**0**	**0**
5	Coating	g			**100**			8	92	**100**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**4100**			328	3772	**4100**	**0**
	Total weight	g			**20400**			2452	17948	**20400**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	444	90	**534**	**309**	**1496322**	173	119	**54**	**1497219**
9	of which, electricity (in primary MJ)	MJ	42	54	**96**	**1**	**1495957**	0	0	**0**	**1496053**
10	Water (process)	ltr	150	1	**151**	**0**	**99732**	0	0	**0**	**99882**
11	Water (cooling)	ltr	145	25	**170**	**0**	**3989218**	0	2	**-2**	**3989386**
12	Waste, non-haz./ landfill	g	5924	283	**6208**	**176**	**1734538**	2001	1	**2000**	**1742921**
13	Waste, hazardous/ incinerated	g	7	0	**7**	**3**	**34471**	900	0	**900**	**35381**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	29	5	**34**	**20**	**65311**	13	9	**4**	**65369**
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	131	22	**152**	**59**	**385238**	26	11	**15**	**385464**
17	Volatile Organic Compounds (VOC)	g	2	0	**2**	**4**	**569**	1	0	**0**	**576**
18	Persistent Organic Pollutants (POP)	ng i-Teq	93	0	**93**	**1**	**9806**	14	0	**14**	**9915**
19	Heavy Metals	mg Ni eq.	206	0	**206**	**9**	**25745**	49	0	**49**	**26009**
	PAHs	mg Ni eq.	0	0	**0**	**11**	**3025**	0	0	**0**	**3036**
20	Particulate Matter (PM, dust)	g	208	3	**211**	**650**	**9553**	224	0	**224**	**10638**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	116	0	**116**	**0**	**9647**	14	0	**14**	**9778**
22	Eutrophication	g PO4	5	0	**5**	**0**	**46**	1	0	**1**	**52**
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Table 5-15 EIA per product for End Suction Close Coupled In line Pump (Small) (25m^3/h at 32m, 2 pole) , 4000 hrs pa

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	ESCC 25 m3/h at 32m Model A	38968	HWF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			0			0	0	0	0
2	TecPlastics	kt			0			0	0	0	0
3	Ferro	kt			1			0	1	1	0
4	Non-ferro	kt			0			0	0	0	0
5	Coating	kt			0			0	0	0	0
6	Electronics	kt			0			0	0	0	0
7	Misc.	kt			0			0	0	0	0
	Total weight	kt			2			0	1	2	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	0	0	0	0	120	0	0	0	120
9	of which, electricity (in primary PJ)	PJ	0	0	0	0	120	0	0	0	120
10	Water (process)	mln. m3	0	0	0	0	8	0	0	0	8
11	Water (cooling)	mln. m3	0	0	0	0	319	0	0	0	319
12	Waste, non-haz./ landfill	kt	0	0	0	0	139	0	0	0	139
13	Waste, hazardous/ incinerated	kt	0	0	0	0	3	0	0	0	3
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	0	0	5	0	0	0	5
15	Ozone Depletion, emissions	t R-11 eq.					negligible				
16	Acidification, emissions	kt SO2 eq.	0	0	0	0	31	0	0	0	31
17	Volatile Organic Compounds (VOC)	kt	0	0	0	0	0	0	0	0	0
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	0	0	1	0	0	0	1
19	Heavy Metals	ton Ni eq.	0	0	0	0	2	0	0	0	2
	PAHs	ton Ni eq.	0	0	0	0	0	0	0	0	0
20	Particulate Matter (PM, dust)	kt	0	0	0	0	1	0	0	0	1
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	0	0	1	0	0	0	1
22	Eutrophication	kt PO4	0	0	0	0	0	0	0	0	0
23	Persistent Organic Pollutants (POP)	g i-Teq					negligible				

Table 5-16 EIA for 2006 production of End Suction Close Coupled In line Pump (Small) (25m^3/h at 32m, 2 pole) 4000 hrs pa.

Nr	Life cycle Impact per product:	Date	Author
0	ESCC 125 m3/h at 32m Model A	38966	HWF

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**3000**			2700	300	**3000**	**0**
2	TecPlastics	g			**0**			0	0	**0**	**0**
3	Ferro	g			**108600**			8688	99912	**108600**	**0**
4	Non-ferro	g			**0**			0	0	**0**	**0**
5	Coating	g			**200**			16	184	**200**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**7100**			568	6532	**7100**	**0**
	Total weight	g			**118900**			11972	106928	**118900**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	1934	447	**2381**	**839**	**6844121**	834	284	**550**	**6847891**
9	of which, electricity (in primary MJ)	MJ	144	269	**414**	**2**	**6843379**	0	1	**-1**	**6843793**
10	Water (process)	ltr	702	4	**706**	**0**	**456232**	0	1	**-1**	**456938**
11	Water (cooling)	ltr	641	127	**768**	**0**	**18249008**	0	6	**-6**	**18249769**
12	Waste, non-haz./ landfill	g	39370	1411	**40781**	**431**	**7934913**	11662	4	**11658**	**7987782**
13	Waste, hazardous/ incinerated	g	18	0	**18**	**9**	**157692**	2700	1	**2699**	**160417**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	163	25	**188**	**51**	**298699**	62	20	**42**	**298979**
15	Ozone Depletion, emissions	mg R-11 eq					negligible				
16	Acidification, emissions	g SO2 eq.	742	107	**849**	**155**	**1762233**	123	26	**97**	**1763334**
17	Volatile Organic Compounds (VOC)	g	14	0	**14**	**12**	**2589**	3	0	**3**	**2619**
18	Persistent Organic Pollutants (POP)	ng i-Teq	663	1	**664**	**2**	**44862**	80	0	**80**	**45609**
19	Heavy Metals	mg Ni eq.	1182	2	**1183**	**22**	**117574**	239	0	**239**	**119019**
	PAHs	mg Ni eq.	2	0	**2**	**28**	**13638**	0	0	**0**	**13668**
20	Particulate Matter (PM, dust)	g	1486	17	**1503**	**1983**	**40300**	1084	1	**1083**	**44869**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	663	0	**663**	**1**	**44131**	69	0	**69**	**44864**
22	Eutrophication	g PO4	21	0	**21**	**0**	**211**	4	0	**4**	**236**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

Table 5-17 EIA per product for End Suction Close Coupled In line Pump (Large) (125m^3/h at 32m, 4 pole) 4000 hrs pa.

Table . EU Total Impact of NEW ESCC 125 m3/h at 32m Model A produced in 2005 (over their lifetime)

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	ESCC 125 m3/h at 32m Model A	38966	HWF

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**0**			0	0	**0**	**0**
2	TecPlastics	kt			**0**			0	0	**0**	**0**
3	Ferro	kt			**2**			0	2	**2**	**0**
4	Non-ferro	kt			**0**			0	0	**0**	**0**
5	Coating	kt			**0**			0	0	**0**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**0**			0	0	**0**	**0**
	Total weight	kt			**2**			0	2	**2**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	0	0	**0**	**0**	**137**	0	0	**0**	**137**
9	of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**137**	0	0	**0**	**137**
10	Water (process)	mln. m3	0	0	**0**	**0**	**9**	0	0	**0**	**9**
11	Water (cooling)	mln. m3	0	0	**0**	**0**	**365**	0	0	**0**	**365**
12	Waste, non-haz./ landfill	kt	1	0	**1**	**0**	**159**	0	0	**0**	**160**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**3**	0	0	**0**	**3**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**6**	0	0	**0**	**6**
15	Ozone Depletion, emissions	t R-11 eq.				negligible					
16	Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**35**	0	0	**0**	**35**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**1**	0	0	**0**	**1**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**2**	0	0	**0**	**2**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**1**	0	0	**0**	**1**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq				negligible					

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

***=Note: mt= megatonnes (metric)= 10^9 kg; kt= kilotonnes (metric)= 10^9 g; ton(metric)= 10^9 g; g=gram= 10^9 ng ; mln. M3 = million cubic metres= 10^9 litres; PJ= petaJoules= 10^9 MJ (megajoules) = 10^{15} Joules.**

Table 5-18 EIA for 2006 production of End Suction Close Coupled In line Pump (Large) (125m^3/h at 32m, 4 pole) 4000 hrs pa

5.2.3 EIA per product for End Suction Own Bearings Pumps

Nr	Life cycle Impact per product:							Date	Author		
0	ESOB 25 m3/h at 32m Model A							38966	HWF		
	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			500			450	50	500	0
2	TecPlastics	g			0			0	0	0	0
3	Ferro	g			39100			3128	35972	39100	0
4	Non-ferro	g			0			0	0	0	0
5	Coating	g			50			4	46	50	0
6	Electronics	g			0			0	0	0	0
7	Misc.	g			4100			328	3772	4100	0
	Total weight	g			43750			3910	39840	43750	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	1037	225	1262	174	580755	270	119	151	582341
9	of which, electricity (in primary MJ)	MJ	111	135	246	0	580022	0	0	0	580268
10	Water (process)	ltr	766	2	768	0	38676	0	0	0	39444
11	Water (cooling)	ltr	228	64	292	0	1546723	0	1	-1	1547014
12	Waste, non-haz./ landfill	g	18823	718	19542	110	672696	4291	1	4290	696638
13	Waste, hazardous/ incinerated	g	3	0	3	2	13365	450	0	450	13821
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	93	13	105	12	25369	20	9	11	25497
15	Ozone Depletion, emissions	mg R-11 eq.					negligible				
16	Acidification, emissions	g SO2 eq.	618	54	672	34	149418	40	11	29	150153
17	Volatile Organic Compounds (VOC)	g	5	0	5	2	230	1	0	1	238
18	Persistent Organic Pollutants (POP)	ng i-Teq	250	1	251	1	3804	30	0	30	4086
19	Heavy Metals	mg Ni eq.	1409	2	1412	6	10121	78	0	78	11616
	PAHs	mg Ni eq.	1	0	1	7	1299	0	0	0	1306
20	Particulate Matter (PM, dust)	g	493	8	502	308	5841	351	0	351	7002
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	813	0	813	0	3748	22	0	22	4584
22	Eutrophication	g PO4	23	0	23	0	18	1	0	1	43
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Table 5-19 EIA per product for End Suction Own Bearings Pump (Small) (30m^3/h at 30m, 2 pole) 2250 hrs pa.

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	ESOB 25 m3/h at 32m Model A	38966	HWF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			0			0	0	0	0
2	TecPlastics	kt			0			0	0	0	0
3	Ferro	kt			8			1	7	8	0
4	Non-ferro	kt			0			0	0	0	0
5	Coating	kt			0			0	0	0	0
6	Electronics	kt			0			0	0	0	0
7	Misc.	kt			1			0	1	1	0
	Total weight	kt			9			1	8	9	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	0	0	0	0	237	0	0	0	237
9	of which, electricity (in primary PJ)	PJ	0	0	0	0	237	0	0	0	237
10	Water (process)	mln. m3	0	0	0	0	16	0	0	0	16
11	Water (cooling)	mln. m3	0	0	0	0	631	0	0	0	632
12	Waste, non-haz./ landfill	kt	4	0	4	0	275	1	0	1	279
13	Waste, hazardous/ incinerated	kt	0	0	0	0	5	0	0	0	6
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	0	0	10	0	0	0	10
15	Ozone Depletion, emissions	t R-11 eq.					negligible				
16	Acidification, emissions	kt SO2 eq.	0	0	0	0	61	0	0	0	61
17	Volatile Organic Compounds (VOC)	kt	0	0	0	0	0	0	0	0	0
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	0	0	2	0	0	0	2
19	Heavy Metals	ton Ni eq.	0	0	0	0	4	0	0	0	4
	PAHs	ton Ni eq.	0	0	0	0	0	0	0	0	0
20	Particulate Matter (PM, dust)	kt	0	0	0	0	2	0	0	0	2
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	0	0	2	0	0	0	2
22	Eutrophication	kt PO4	0	0	0	0	0	0	0	0	0
23	Persistent Organic Pollutants (POP)	g i-Teq					negligible				

Table 5-20 EIA for 2006 production of End Suction Own Bearings Pumps (Small) ($30m^3$/h at 30m, 2 pole) 2250 hrs pa.

5.2.3.1

Nr	Life cycle Impact per product: ESOB 125 m3/h at 32m Model A							Date	Author		
0								38966	HWF		
	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			1000			900	100	1000	0
2	TecPlastics	g			0			0	0	0	0
3	Ferro	g			176200			14096	162104	176200	0
4	Non-ferro	g			0			0	0	0	0
5	Coating	g			100			8	92	100	0
6	Electronics	g			0			0	0	0	0
7	Misc.	g			7100			568	6532	7100	0
	Total weight	g			184400			15572	168828	184400	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	2710	587	3297	391	5353426	1069	194	875	5357989
9	of which, electricity (in primary MJ)	MJ	174	353	527	1	5353157	0	0	0	5353685
10	Water (process)	ltr	1199	5	1204	0	356889	0	0	0	358093
11	Water (cooling)	ltr	787	166	953	0	14275082	0	2	-2	14276032
12	Waste, non-haz./ landfill	g	64385	1857	66241	215	6207338	18085	1	18084	6291879
13	Waste, hazardous/ incinerated	g	7	0	7	4	123352	900	0	900	124263
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	258	33	290	25	233630	80	14	66	234010
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	1235	141	1376	74	1378469	157	18	139	1380057
17	Volatile Organic Compounds (VOC)	g	22	0	22	5	2020	4	0	4	2051
18	Persistent Organic Pollutants (POP)	ng i-Teq	1078	1	1079	1	35098	124	0	124	36304
19	Heavy Metals	mg Ni eq.	2135	3	2138	11	91913	311	0	311	94374
	PAHs	mg Ni eq.	3	0	3	14	10598	0	0	0	10614
20	Particulate Matter (PM, dust)	g	2395	22	2417	855	30349	1392	0	1391	35012
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	1203	0	1203	0	34528	89	0	89	35820
22	Eutrophication	g PO4	35	0	35	0	165	5	0	5	205
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Table 5-21 EIA per product for End Suction Own Bearings Pump (Large) (125m^3/h at 32m, 4 pole) 2250 hrs pa.

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	ESOB 125 m3/h at 32m Model A	38966	HWF

Nr	Life Cycle phases --> / Resources Use and Emissions	unit	PRODUCTION Material	PRODUCTION Manuf.	PRODUCTION Total	DISTRI-BUTION	USE	END-OF-LIFE* Disposal	END-OF-LIFE* Recycl.	END-OF-LIFE* Total	TOTAL
	Materials	**unit**									
1	Bulk Plastics	kt			**0**			0	0	**0**	**0**
2	TecPlastics	kt			**0**			0	0	**0**	**0**
3	Ferro	kt			**9**			1	8	**9**	**0**
4	Non-ferro	kt			**0**			0	0	**0**	**0**
5	Coating	kt			**0**			0	0	**0**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**0**			0	0	**0**	**0**
	Total weight	kt			**9**			1	8	**9**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	0	0	**0**	**0**	**211**	0	0	**0**	**211**
9	of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**211**	0	0	**0**	**211**
10	Water (process)	mln. m3	0	0	**0**	**0**	**14**	0	0	**0**	**14**
11	Water (cooling)	mln. m3	0	0	0	0	**561**	0	0	0	561
12	Waste, non-haz./ landfill	kt	3	0	**3**	**0**	**244**	1	0	**1**	**248**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**5**	0	0	**0**	**5**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**9**	0	0	**0**	**9**
15	Ozone Depletion, emissions	t R-11 eq.					negligible				
16	Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**54**	0	0	**0**	**54**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**1**	0	0	**0**	**1**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**4**	0	0	**0**	**4**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**1**	0	0	**0**	**1**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq					negligible				

Table 5-22 EIA for 2006 production of End Suction Own Bearings Pump (Large) (125m3/h at 32m, 4 pole) 2250 hrs pa.

5.2.4 EIA per product for Submersible Multistage Pumps

Nr	Life cycle Impact per product:	Date	Author
0	Multistage Submerisble SP8	38987	HWF

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0			0	0	0	0
2	TecPlastics	g			0			0	0	0	0
3	Ferro	g			5215			417	4798	5215	0
4	Non-ferro	g			0			0	0	0	0
5	Coating	g			0			0	0	0	0
6	Electronics	g			0			0	0	0	0
7	Misc.	g			1350			108	1242	1350	0
	Total weight	g			6565			525	6040	6565	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	361	80	441	106	370993	36	38	-3	371537
9	of which, electricity (in primary MJ)	MJ	53	48	101	0	370987	0	0	0	371088
10	Water (process)	ltr	404	1	405	0	24736	0	0	0	25142
11	Water (cooling)	ltr	44	22	66	0	989297	0	0	0	989363
12	Waste, non-haz./ landfill	g	5286	257	5542	78	430193	644	0	644	436456
13	Waste, hazardous/ incinerated	g	0	0	0	2	8549	0	0	0	8550
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	33	4	38	8	16190	3	3	0	16235
15	Ozone Depletion, emissions	mg R-11 eq.				negligible					
16	Acidification, emissions	g SO2 eq.	294	19	313	22	95532	5	4	2	95868
17	Volatile Organic Compounds (VOC)	g	1	0	1	1	140	0	0	0	141
18	Persistent Organic Pollutants (POP)	ng i-Teq	40	1	41	0	2432	4	0	4	2478
19	Heavy Metals	mg Ni eq.	773	1	775	4	6373	11	0	11	7162
	PAHs	mg Ni eq.	0	0	0	4	731	0	0	0	736
20	Particulate Matter (PM, dust)	g	41	3	44	137	2050	47	0	47	2278
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	450	0	450	0	2397	3	0	3	2850
22	Eutrophication	g PO4	12	0	12	0	12	0	0	0	24
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Table 5-23 EIA Impact per product for Submersible Multistage Pump (Small) (8.5m^3/h at 59m, 2 pole) 1000 hrs pa.

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	Multistage Submerisble SP8	38987	HWF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**0**			0	0	**0**	**0**
2	TecPlastics	kt			**0**			0	0	**0**	**0**
3	Ferro	kt			**3**			0	3	**3**	**0**
4	Non-ferro	kt			**0**			0	0	**0**	**0**
5	Coating	kt			**0**			0	0	**0**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**1**			0	1	**1**	**0**
	Total weight	kt			**4**			0	3	**4**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	0	0	**0**	**0**	**208**	0	0	**0**	**208**
9	of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**208**	0	0	**0**	**208**
10	Water (process)	mln. m3	0	0	**0**	**0**	**14**	0	0	**0**	**14**
11	Water (cooling)	mln. m3	0	0	**0**	**0**	**554**	0	0	**0**	**554**
12	Waste, non-haz./ landfill	kt	3	0	**3**	**0**	**241**	0	0	**0**	**244**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**5**	0	0	**0**	**5**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**9**	0	0	**0**	**9**
15	Ozone Depletion, emissions	t R-11 eq.					negligible				
16	Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**53**	0	0	**0**	**54**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**1**	0	0	**0**	**1**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**4**	0	0	**0**	**4**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**1**	0	0	**0**	**2**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq					negligible				

Table 5-24 EIA of 2006 production of Submersible Multistage Pumps (Small) (8.5m^3/h at 59m, 2 pole) 1000 hrs pa

Nr	Life cycle Impact per product:	Date	Author
0	Multistage Water Big (5 stages)	38987	HWF

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**100**			90	10	**100**	**0**
2	TecPlastics	g			**100**			90	10	**100**	**0**
3	Ferro	g			**8750**			700	8050	**8750**	**0**
4	Non-ferro	g			**0**			0	0	**0**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**1100**			88	1012	**1100**	**0**
	Total weight	g			**10050**			968	9082	**10050**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	593	142	**735**	**119**	**989362**	67	58	**9**	**990225**
9	of which, electricity (in primary MJ)	MJ	91	85	**176**	**0**	**986949**	0	0	**0**	**987125**
10	Water (process)	ltr	685	1	**686**	**0**	**65803**	0	0	**0**	**66489**
11	Water (cooling)	ltr	108	40	**148**	**0**	**2631861**	0	0	**0**	**2632009**
12	Waste, non-haz./ landfill	g	8868	456	**9325**	**84**	**1144403**	986	0	**985**	**1154797**
13	Waste, hazardous/ incinerated	g	4	0	**4**	**2**	**22742**	180	0	**180**	**22928**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	56	8	**64**	**9**	**43257**	5	4	**1**	**43329**
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	496	34	**530**	**24**	**254330**	10	5	**5**	**254889**
17	Volatile Organic Compounds (VOC)	g	1	0	**1**	**1**	**411**	0	0	**0**	**413**
18	Persistent Organic Pollutants (POP)	ng i-Teq	67	1	**68**	**0**	**6470**	7	0	**7**	**6545**
19	Heavy Metals	mg Ni eq.	1298	2	**1300**	**4**	**17465**	19	0	**19**	**18789**
	PAHs	mg Ni eq.	2	0	**2**	**5**	**2464**	0	0	**0**	**2471**
20	Particulate Matter (PM, dust)	g	70	5	**76**	**171**	**14249**	87	0	**87**	**14583**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	756	0	**756**	**0**	**6371**	6	0	**6**	**7133**
22	Eutrophication	g PO4	22	0	**22**	**0**	**31**	0	0	**0**	**52**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Table 5-25 EIA Impact per product for Submersible Multistage Pump (Large) (15m^3/h at 88m, 2 pole) 1000 hrs pa

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	Multistage Water Big (5 stages)	38987	HWF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**0**			0	0	**0**	**0**
2	TecPlastics	kt			**0**			0	0	**0**	**0**
3	Ferro	kt			**1**			0	1	**1**	**0**
4	Non-ferro	kt			**0**			0	0	**0**	**0**
5	Coating	kt			**0**			0	0	**0**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**0**			0	0	**0**	**0**
	Total weight	kt			**1**			0	1	**1**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	0	0	**0**	**0**	**50**	0	0	**0**	**50**
9	of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**50**	0	0	**0**	**50**
10	Water (process)	mln. m3	0	0	**0**	**0**	**3**	0	0	**0**	**3**
11	Water (cooling)	mln. m3	0	0	**0**	**0**	**133**	0	0	**0**	**133**
12	Waste, non-haz./ landfill	kt	1	0	**1**	**0**	**58**	0	0	**0**	**59**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**2**	0	0	**0**	**2**
15	Ozone Depletion, emissions	t R-11 eq.				negligible					
16	Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**13**	0	0	**0**	**13**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**0**	0	0	**0**	**0**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**2**	0	0	**0**	**2**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**0**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq				negligible					

Table 5-26 EIA of 2006 production of Submersible Multistage Pumps (Large) (15m^3/h at 88m, 2 pole) 1000 hrs pa.

5.2.5 EIA per Product for Vertical Multistage Pumps

Nr	Life cycle Impact per product:	Date	Author
0	Multistage Water Small (6 stages)	38987	HWF

Nr	Life Cycle phases --> / Resources Use and Emissions	unit	PRODUCTION Material	PRODUCTION Manuf.	PRODUCTION Total	DISTRI-BUTION	USE	END-OF-LIFE* Disposal	END-OF-LIFE* Recycl.	END-OF-LIFE* Total	TOTAL
	Materials	**unit**									
1	Bulk Plastics	g			**100**			90	10	**100**	**0**
2	TecPlastics	g			**100**			90	10	**100**	**0**
3	Ferro	g			**6050**			484	5566	**6050**	**0**
4	Non-ferro	g			**0**			0	0	**0**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**1100**			88	1012	**1100**	**0**
	Total weight	g			**7350**			752	6598	**7350**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	426	100	**526**	**119**	**208002**	52	48	**4**	**208652**
9	of which, electricity (in primary MJ)	MJ	64	60	**125**	**0**	**205591**	0	0	**0**	**205716**
10	Water (process)	ltr	480	1	**481**	**0**	**13711**	0	0	**0**	**14192**
11	Water (cooling)	ltr	85	28	**114**	**0**	**548241**	0	0	**0**	**548354**
12	Waste, non-haz./ landfill	g	6168	323	**6492**	**84**	**238435**	721	0	**721**	**245731**
13	Waste, hazardous/ incinerated	g	4	0	**4**	**2**	**4737**	180	0	**180**	**4923**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	39	6	**45**	**9**	**9158**	4	4	**0**	**9212**
15	Ozone Depletion, emissions	mg R-11 eq.					negligible				
16	Acidification, emissions	g SO2 eq.	344	24	**368**	**24**	**53129**	8	4	**3**	**53525**
17	Volatile Organic Compounds (VOC)	g	1	0	**1**	**1**	**116**	0	0	**0**	**118**
18	Persistent Organic Pollutants (POP)	ng i-Teq	47	1	**47**	**0**	**1348**	5	0	**5**	**1401**
19	Heavy Metals	mg Ni eq.	897	2	**899**	**4**	**4056**	15	0	**15**	**4974**
	PAHs	mg Ni eq.	2	0	**2**	**5**	**925**	0	0	**0**	**932**
20	Particulate Matter (PM, dust)	g	49	4	**53**	**171**	**9951**	68	0	**68**	**10243**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	523	0	**523**	**0**	**1331**	4	0	**4**	**1858**
22	Eutrophication	g PO4	15	0	**15**	**0**	**6**	0	0	**0**	**22**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

Table 5-27 EIA per product for Vertical Multistage Pump (Small) ($4m^3/h$ at 45m, 2 pole) 1500 hrs pa.

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	Multistage Water Small (6 stages)	38987	HWF

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**0**			0	0	**0**	**0**
2	TecPlastics	kt			**0**			0	0	**0**	**0**
3	Ferro	kt			**1**			0	1	**1**	**0**
4	Non-ferro	kt			**0**			0	0	**0**	**0**
5	Coating	kt			**0**			0	0	**0**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**0**			0	0	**0**	**0**
	Total weight	kt			**1**			0	1	**1**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	0	0	**0**	**0**	**42**	0	0	**0**	**42**
9	of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**41**	0	0	**0**	**41**
10	Water (process)	mln. m3	0	0	**0**	**0**	**3**	0	0	**0**	**3**
11	Water (cooling)	mln. m3	0	0	**0**	**0**	**110**	0	0	**0**	**110**
12	Waste, non-haz./ landfill	kt	1	0	**1**	**0**	**48**	0	0	**0**	**49**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**2**	0	0	**0**	**2**
15	Ozone Depletion, emissions	t R-11 eq.				negligible					
16	Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**11**	0	0	**0**	**11**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**0**	0	0	**0**	**0**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**2**	0	0	**0**	**2**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**0**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq				negligible					

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

***=Note: mt= megatonnes (metric)= 10^9 kg; kt= kilotonnes (metric)= 10^9g; ton(metric)= 10^9g; g=gram= 10^9 ng ; mln. M3 = million cubic metres= 10^9 litres; PJ= petaJoules= 10^9 MJ (megajoules) = 10^{15} Joules.**

Table 5-28 EIA of 2006 production of Vertical Multistage Pumps (small) (4m^3/h at 45m, 2 pole) 1500 hrs pa.

Nr	Life cycle Impact per product:	Date	Author
0	Multistage Water Big (5 stages)	38987	HWF

Nr	Life Cycle phases --> Resources Use and Emissions		PRODUCTION Material	 Manuf.	 Total	DISTRI- BUTION	USE	END-OF-LIFE* Disposal	 Recycl.	 Total	TOTAL
	Materials	**unit**									
1	Bulk Plastics	g			**100**			90	10	**100**	**0**
2	TecPlastics	g			**100**			90	10	**100**	**0**
3	Ferro	g			**8750**			700	8050	**8750**	**0**
4	Non-ferro	g			**0**			0	0	**0**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**1100**			88	1012	**1100**	**0**
	Total weight	g			**10050**			968	9082	**10050**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	593	142	**735**	**119**	**440737**	67	58	**9**	**441600**
9	of which, electricity (in primary MJ)	MJ	91	85	**176**	**0**	**438324**	0	0	**0**	**438500**
10	Water (process)	ltr	685	1	**686**	**0**	**29228**	0	0	**0**	**29914**
11	Water (cooling)	ltr	108	40	**148**	**0**	**1168861**	0	0	**0**	**1169009**
12	Waste, non-haz./ landfill	g	8868	456	**9325**	**84**	**508303**	986	0	**985**	**518697**
13	Waste, hazardous/ incinerated	g	4	0	**4**	**2**	**10100**	180	0	**180**	**10286**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	56	8	**64**	**9**	**19315**	5	4	**1**	**19388**
15	Ozone Depletion, emissions	mg R-11 eq.					negligible				
16	Acidification, emissions	g SO2 eq.	496	34	**530**	**24**	**113059**	10	5	**5**	**113618**
17	Volatile Organic Compounds (VOC)	g	1	0	**1**	**1**	**204**	0	0	**0**	**207**
18	Persistent Organic Pollutants (POP)	ng i-Teq	67	1	**68**	**0**	**2874**	7	0	**7**	**2949**
19	Heavy Metals	mg Ni eq.	1298	2	**1300**	**4**	**8053**	19	0	**19**	**9377**
	PAHs	mg Ni eq.	2	0	**2**	**5**	**1384**	0	0	**0**	**1391**
20	Particulate Matter (PM, dust)	g	70	5	**76**	**171**	**11232**	87	0	**87**	**11566**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	756	0	**756**	**0**	**2834**	6	0	**6**	**3596**
22	Eutrophication	g PO4	22	0	**22**	**0**	**14**	0	0	**0**	**36**
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

Table 5-29 EIA per product of Vertical Multistage Pumps (Large) (10m^3/h at 42m, 2 pole) 1500 hrs pa.

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	Multistage Water Big (5 stages)	38987	HWF

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**0**			0	0	**0**	**0**
2	TecPlastics	kt			**0**			0	0	**0**	**0**
3	Ferro	kt			**0**			0	0	**0**	**0**
4	Non-ferro	kt			**0**			0	0	**0**	**0**
5	Coating	kt			**0**			0	0	**0**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**0**			0	0	**0**	**0**
	Total weight	kt			**1**			0	0	**1**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	0	0	**0**	**0**	**22**	0	0	**0**	**22**
9	of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**22**	0	0	**0**	**22**
10	Water (process)	mln. m3	0	0	**0**	**0**	**1**	0	0	**0**	**1**
11	Water (cooling)	mln. m3	0	0	**0**	**0**	**58**	0	0	**0**	**58**
12	Waste, non-haz./ landfill	kt	0	0	**0**	**0**	**25**	0	0	**0**	**26**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
15	Ozone Depletion, emissions	t R-11 eq.				negligible					
16	Acidification, emissions	kt SO2 eq.	0	0	**0**	**0**	**6**	0	0	**0**	**6**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**0**	0	0	**0**	**0**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**0**	0	0	**0**	**0**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**1**	0	0	**0**	**1**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**0**	0	0	**0**	**0**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq				negligible					

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

***=Note: mt= megatonnes (metric)= 10^9 kg; kt= kilotonnes (metric)= 10^9g; ton(metric)= 10^9g; g=gram= 10^9 ng ; mln. M3 = million cubic metres= 10^9 litres; PJ= petaJoules= 10^9 MJ (megajoules) = 10^{15} Joules.**

Table 5-30 EIA of 2006 production of Vertical Multistage Pumps (Large) (10m^3/h at 42m, 2 pole) 1500 hrs pa

5.3 Base case Life Cycle costs

This section shows the Life Cycle costs for each product. This provides the basis from which the later economic analysis to justify possible design improvements is calculated.

This analysis uses a 2% discount cash factor. The electricity price used varies according to the likely application, ranging from 0.135 euros/kWh for residential applications (eg small multistage submersible pumps) to 0.075 euros/kWh for industrial applications (eg all ESOB pumps).

5.3.1 Life cycle costs per product and total annual expenditure for End Suction Close Coupled Pumps

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	**11**	years
B	Annual sales	**0.2**	mln. Units/year
C	EU Stock	**2.2**	mln. Units
D	Product price	**900**	Euro/unit
E	Installation/acquisition costs (if any)	**900**	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	**0.075**	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	**400**	Euro/ unit
M	Discount rate (interest minus inflation)	**2.0%**	%
N	Present Worth Factor (PWF) (calculated automatically)	**9.79**	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	**1.00**	

	ESCC 25 m3/h at 32m Model A *Item*	**LCC new product**		**total annual consumer expenditure in EU25**	
D	Product price	900	€	180	mln.€
E	Installation/ acquisition costs (if any)	900	€	180	mln.€
F	Fuel (gas, oil, wood)	0	€	0	mln.€
F	Electricity	7524	€	1691	mln.€
G	Water	0	€	0	mln.€
H	Aux. 1: None	0	€	0	mln.€
I	Aux. 2 :None	0	€	0	mln.€
J	Aux. 3: None	0	€	0	mln.€
K	Repair & maintenance costs	356	€	80	mln.€
	Total	**9680**	€	**2131**	mln.€

Table 5-31 Life cycle costs per product and total annual expenditure for End Suction Close Coupled Pump (Small) (25m^3/h at 32m, 2 pole), 2250 hrs pa

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	**11**	years
B	Annual sales	**0.05**	mln. Units/year
C	EU Stock	**0.55**	mln. Units
D	Product price	**3300**	Euro/unit
E	Installation/acquisition costs (if any)	**3300**	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	**0.075**	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	**1200**	Euro/ unit
M	Discount rate (interest minus inflation)	**2.0%**	%
N	Present Worth Factor (PWF) (calculated automatically)	**9.79**	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	**1.00**	

	ESCC 125 m3/h at 32m Model A *Item*	**LCC new product**		**total annual consumer expenditure in EU25**	
D	Product price	3300	€	165	mln.€
E	Installation/ acquisition costs (if any)	3300	€	165	mln.€
F	Fuel (gas, oil, wood)	0	€	0	mln.€
F	Electricity	26596	€	1495	mln.€
G	Water	0	€	0	mln.€
H	Aux. 1: None	0	€	0	mln.€
I	Aux. 2 :None	0	€	0	mln.€
J	Aux. 3: None	0	€	0	mln.€
K	Repair & maintenance costs	1068	€	60	mln.€
	Total	**34263**	€	**1885**	mln.€

Table 5-32 Life cycle costs per product and total annual expenditure for End Suction Close Coupled Pump (Large) (125m^3/h at 32m, 2 pole) , 2250 hrs pa

5.3.2 Life cycle costs per product and total annual expenditure for End Suction Close Coupled In Line Pumps

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	**11**	years
B	Annual sales	**0.08**	mln. Units/year
C	EU Stock	**0.88**	mln. Units
D	Product price	**900**	Euro/unit
E	Installation/acquisition costs (if any)	**900**	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	**0.1**	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	**400**	Euro/ unit
M	Discount rate (interest minus inflation)	**2.0%**	%
N	Present Worth Factor (PWF) (calculated automatically)	**9.79**	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	**1.00**	

	ESCC 25 m3/h at 32m Model A *Item*	LCC new product		total annual consumer expenditure in EU25	
D	Product price	900	€	72	mln.€
E	Installation/ acquisition costs (if any)	900	€	72	mln.€
F	Fuel (gas, oil, wood)	0	€	0	mln.€
F	Electricity	12676	€	1140	mln.€
G	Water	0	€	0	mln.€
H	Aux. 1: None	0	€	0	mln.€
I	Aux. 2 :None	0	€	0	mln.€
J	Aux. 3: None	0	€	0	mln.€
K	Repair & maintenance costs	356	€	32	mln.€
	Total	**14832**	€	**1316**	mln.€

Table 5-33 Life cycle costs per product and total annual expenditure for End Suction Close Coupled In Line Pump (Small)) (25m^3/h at 32m, 2 pole) , 4000 hrs pa.

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	11	years
B	Annual sales	0.05	mln. Units/year
C	EU Stock	0.55	mln. Units
D	Product price	3300	Euro/unit
E	Installation/acquisition costs (if any)	3300	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.075	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	1200	Euro/ unit
M	Discount rate (interest minus inflation)	2.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	9.79	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

	ESCC 125 m3/h at 32m Model A *Item*	LCC new product	total annual consumer expenditure in EU25
D	Product price	3300 €	165 mln.€
E	Installation/ acquisition costs (if any)	3300 €	165 mln.€
F	Fuel (gas, oil, wood)	0 €	0 mln.€
F	Electricity	26596 €	1495 mln.€
G	Water	0 €	0 mln.€
H	Aux. 1: None	0 €	0 mln.€
I	Aux. 2 :None	0 €	0 mln.€
J	Aux. 3: None	0 €	0 mln.€
K	Repair & maintenance costs	1068 €	60 mln.€
	Total	**34263** €	**1885** mln.€

5-34 Life cycle costs per product and total annual expenditure for End Suction Close Coupled In Line Pump (Large)) (125m^3/h at 32m, 4 pole) 4000 hrs pa.

5.3.3 Life cycle costs per product and total annual expenditure for End Suction Own Bearing Pumps

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	11	years
B	Annual sales	0.2	mln. Units/year
C	EU Stock	2.2	mln. Units
D	Product price	440	Euro/unit
E	Installation/acquisition costs (if any)	440	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.075	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	1000	Euro/ unit
M	Discount rate (interest minus inflation)	2.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	9.79	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

	ESOB 25 m3/h at 32m Model A *Item*	LCC new product		total annual consumer expenditure in EU25	
D	Product price	440	€	88	mln.€
E	Installation/ acquisition costs (if any)	440	€	88	mln.€
F	Fuel (gas, oil, wood)	0	€	0	mln.€
F	Electricity	7524	€	1691	mln.€
G	Water	0	€	0	mln.€
H	Aux. 1: None	0	€	0	mln.€
I	Aux. 2 :None	0	€	0	mln.€
J	Aux. 3: None	0	€	0	mln.€
K	Repair & maintenance costs	890	€	200	mln.€
	Total	9294	€	2067	mln.€

Table 5-35 Life cycle costs per product and total annual expenditure for End Suction Own Bearing Pumps (Small) (30m^3/h at 30m, 2 pole) , 2250 hrs pa.

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	11	years
B	Annual sales	0.05	mln. Units/year
C	EU Stock	0.55	mln. Units
D	Product price	1000	Euro/unit
E	Installation/acquisition costs (if any)	1000	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.075	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	1000	Euro/ unit
M	Discount rate (interest minus inflation)	2.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	9.79	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

	ESOB 125 m3/h at 32m Model A *Item*	LCC new product		total annual consumer expenditure in EU25	
D	Product price	1000	€	50	mln.€
E	Installation/ acquisition costs (if any)	1000	€	50	mln.€
F	Fuel (gas, oil, wood)	0	€	0	mln.€
F	Electricity	26578	€	1494	mln.€
G	Water	0	€	0	mln.€
H	Aux. 1: None	0	€	0	mln.€
I	Aux. 2 :None	0	€	0	mln.€
J	Aux. 3: None	0	€	0	mln.€
K	Repair & maintenance costs	890	€	50	mln.€
	Total	**29468**	€	**1644**	mln.€

Table 5-36 Life cycle costs per product and total annual expenditure for End Suction Own Bearing Pumps (Large) ($125m^3$/h at 32m, 4 pole) , 2250 hrs pa.

5.3.4 Life cycle costs per product and total annual expenditure for Submersible Multistage Pumps

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	11	years
B	Annual sales	0.56	mln. Units/year
C	EU Stock	6.16	mln. Units
D	Product price	910	Euro/unit
E	Installation/acquisition costs (if any)	910	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.135	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	0	Euro/ unit
M	Discount rate (interest minus inflation)	2.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	9.79	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

	Multistage Submerisble SP8 *Item*	LCC new product	total annual consumer expenditure in EU25
D	Product price	910 €	510 mln.€
E	Installation/ acquisition costs (if any)	910 €	510 mln.€
F	Fuel (gas, oil, wood)	0 €	0 mln.€
F	Electricity	3425 €	2156 mln.€
G	Water	0 €	0 mln.€
H	Aux. 1: None	0 €	0 mln.€
I	Aux. 2 :None	0 €	0 mln.€
J	Aux. 3: None	0 €	0 mln.€
K	Repair & maintenance costs	0 €	0 mln.€
	Total	**5245** €	**3175** mln.€

Table 5-37 Life cycle costs per product and total annual expenditure for Submersible Multistage Pumps (Small) (8.5m^3/h at 59m, 2 pole) , 1000 hrs pa.

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	**11**	years
B	Annual sales	**0.14**	mln. Units/year
C	EU Stock	**1.54**	mln. Units
D	Product price	**1000**	Euro/unit
E	Installation/acquisition costs (if any)	**1000**	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	**0.1**	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	**10000**	Euro/ unit
M	Discount rate (interest minus inflation)	**2.0%**	%
N	Present Worth Factor (PWF) (calculated automatically)	**9.79**	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	**1.00**	

	Multistage Water Big (5 stages) *Item*	**LCC new product**	**total annual consumer expenditure in EU25**
D	Product price	1000 €	140 mln.€
E	Installation/ acquisition costs (if any)	1000 €	140 mln.€
F	Fuel (gas, oil, wood)	0 €	0 mln.€
F	Electricity	5576 €	877 mln.€
G	Water	0 €	0 mln.€
H	Aux. 1: None	0 €	0 mln.€
I	Aux. 2 :None	0 €	0 mln.€
J	Aux. 3: None	0 €	0 mln.€
K	Repair & maintenance costs	8897 €	1400 mln.€
	Total	**16473** €	**2557** mln.€

Table 5-38 Life cycle costs per product and total annual expenditure for Submersible Multistage Pumps (Large) (15m^3/h at 8m, 2 pole) , 1000 hrs pa.

5.3.5 Life cycle costs per product and total annual expenditure for Vertical multistage Pumps

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	11	years
B	Annual sales	0.2	mln. Units/year
C	EU Stock	2.2	mln. Units
D	Product price	1000	Euro/unit
E	Installation/acquisition costs (if any)	1000	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.075	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	10000	Euro/ unit
M	Discount rate (interest minus inflation)	2.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	9.79	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

	Multistage Water Small (6 stages) *Item*	LCC new product	total annual consumer expenditure in EU25
D	Product price	1000 €	200 mln.€
E	Installation/ acquisition costs (if any)	1000 €	200 mln.€
F	Fuel (gas, oil, wood)	0 €	0 mln.€
F	Electricity	1307 €	294 mln.€
G	Water	0 €	0 mln.€
H	Aux. 1: None	0 €	0 mln.€
I	Aux. 2 :None	0 €	0 mln.€
J	Aux. 3: None	0 €	0 mln.€
K	Repair & maintenance costs	8897 €	2000 mln.€
	Total	**12204** €	**2694** mln.€

Table 5-39 Life cycle costs per product and total annual expenditure for Vertical Multistage Pumps (Small) ($4m^3$/h at 45m, 2 pole) , 1500 hrs pa.

nr	Description		
A	Product Life	**11**	years
B	Annual sales	**0.05**	mln. Units/year
C	EU Stock	**0.55**	mln. Units
D	Product price	**1000**	Euro/unit
E	Installation/acquisition costs (if any)	**1000**	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	**0.075**	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	**10000**	Euro/ unit
M	Discount rate (interest minus inflation)	**2.0%**	%
N	Present Worth Factor (PWF) (calculated automatically)	**9.79**	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	**1.00**	

	Multistage Water Big (5 stages) *Item*	**LCC new product**	**total annual consumer expenditure in EU25**
D	Product price	1000 €	50 mln.€
E	Installation/ acquisition costs (if any)	1000 €	50 mln.€
F	Fuel (gas, oil, wood)	0 €	0 mln.€
F	Electricity	2786 €	157 mln.€
G	Water	0 €	0 mln.€
H	Aux. 1: None	0 €	0 mln.€
I	Aux. 2 :None	0 €	0 mln.€
J	Aux. 3: None	0 €	0 mln.€
K	Repair & maintenance costs	8897 €	500 mln.€
	Total	**13683** €	**757** mln.€

Table 5-40 Life cycle costs per product and total annual expenditure for Vertical Multistage Pumps (Large) ($10m^3/h$ at 42m, 2 pole) , 1500 hrs pa.

5.4 EU Totals

The following tables show the Environmental Impact Assessment (EIA) of the total stock of each style and size of pump:

- End Suction close coupled
- End Suction Close coupled in line
- End Suction own bearings
- Submersible Multistage
- Vertical Multistage

Note that these tables refer to the impact per annum of the current total stock.

5.4.1 EIA Impact of total stock – ESCC Pumps

main life cycle indicators	value	unit
Total Energy (GER)	**189**	PJ
of which, electricity	17.9	TWh
Water (process)*	**13**	mln.m3
Waste, non-haz./ landfill*	**221**	kton
Waste, hazardous/ incinerated*	**4**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**8**	mt CO2eq.
Acidifying agents (AP)	**49**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**3**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**1**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

Table 5-41 EU EIA of total stock – End Suction close coupled pumps (small) (30m^3/h at 30m, 2 pole) 2250 hrs pa.

main life cycle indicators	value	unit
Total Energy (GER)	**209**	PJ
of which, electricity	19.9	TWh
Water (process)*	**14**	mln.m3
Waste, non-haz./ landfill*	**245**	kton
Waste, hazardous/ incinerated*	**5**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**9**	mt CO2eq.
Acidifying agents (AP)	**54**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**4**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**2**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

Table 5-42 EU EIA of total stock – End Suction close coupled pumps (large) (125m^3/h at 32m, 4 pole) , 2250 hrs pa.

5.4.2 EIA Impact of total stock of End Suction close coupled in line pumps

Table . Summary Environmental Impacts EU-Stock 2005, ESCC 25 m3/h at 32m Model A

main life cycle indicators	value	unit
Total Energy (GER)	**120**	PJ
of which, electricity	11.4	TWh
Water (process)*	**8**	mln.m3
Waste, non-haz./ landfill*	**139**	kton
Waste, hazardous/ incinerated*	**3**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**5**	mt CO2eq.
Acidifying agents (AP)	**31**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**2**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**1**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

Table 5-43 EU EIA of total stock – End Suction close coupled In Line pumps (small)) (25m^3/h at 32m, 2 pole) , 4000 hrs pa.

Table . Summary Environmental Impacts EU-Stock 2005, ESCC 125 m3/h at 32m Model A

main life cycle indicators	value	unit
Total Energy (GER)	**137**	PJ
of which, electricity	13.0	TWh
Water (process)*	**9**	mln.m3
Waste, non-haz./ landfill*	**160**	kton
Waste, hazardous/ incinerated*	**3**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**6**	mt CO2eq.
Acidifying agents (AP)	**35**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**2**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**1**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

Table 5-44 EU EIA of total stock – End Suction close coupled in line pumps (large) (125m^3/h at 32m, 4 pole) , 4000 hrs pa.

EIA of total stock – End Suction Own Bearings pumps

main life cycle indicators	value	unit
Total Energy (GER)	**237**	PJ
of which, electricity	22.6	TWh
Water (process)*	**16**	mln.m3
Waste, non-haz./ landfill*	**279**	kton
Waste, hazardous/ incinerated*	**6**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**10**	mt CO2eq.
Acidifying agents (AP)	**61**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**2**	g i-Teq.
Heavy Metals (HM)	**4**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**2**	kt
Emissions (Water)		
Heavy Metals (HM)	2	ton Hg/20
Eutrophication (EP)	0	kt PO4

Table 5-45 EU EIA of total stock – End Suction own bearings pumps (small) (30m^3/h at 30m, 2 pole), 2250 hrs pa.

Table . Summary Environmental Impacts EU-Stock 2005, ESOB 125 m3/h at 32m Model A

main life cycle indicators	value	unit
Total Energy (GER)	**209**	PJ
of which, electricity	19.9	TWh
Water (process)*	**14**	mln.m3
Waste, non-haz./ landfill*	**247**	kton
Waste, hazardous/ incinerated*	**5**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**9**	mt CO2eq.
Acidifying agents (AP)	**54**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**4**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**1**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

Table 5-46 EU EIA of total stock – End Suction own bearings pumps (large) (125m^3/h at 32m, 4 pole) , 2250 hrs pa.

5.4.3 EIA of total stock –Submersible Multistage pumps

Table . Summary Environmental Impacts EU-Stock 2005, Multistage Submerisble SP8

main life cycle indicators	value	unit
Total Energy (GER)	**252**	PJ
of which, electricity	24.0	TWh
Water (process)*	17	mln.m3
Waste, non-haz./ landfill*	295	kton
Waste, hazardous/ incinerated*	6	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**11**	mt CO2eq.
Acidifying agents (AP)	**65**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**2**	g i-Teq.
Heavy Metals (HM)	**5**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**2**	kt
Emissions (Water)		
Heavy Metals (HM)	2	ton Hg/20
Eutrophication (EP)	0	kt PO4

Table 5-47 EU EIA of total stock – Submersible Multistage pumps (small) (8.5m^3/h at 59m, 2 pole) , 1000 hrs pa.

Table . Summary Environmental Impacts EU-Stock 2005, Multistage Water Big (5 stages)

main life cycle indicators	value	unit
Total Energy (GER)	**93**	PJ
of which, electricity	8.8	TWh
Water (process)*	**6**	mln.m3
Waste, non-haz./ landfill*	**108**	kton
Waste, hazardous/ incinerated*	**2**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**4**	mt CO2eq.
Acidifying agents (AP)	**24**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**2**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**2**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

Table 5-48 EU EIA of total stock – Submersible Multistage pumps (large) (15m^3/h at 88m, 2 pole) , 1000 hrs pa.

5.4.4 EIA of total stock – Vertical Multistage pumps

Table . Summary Environmental Impacts EU-Stock 2005, Multistage Water Small (6 stages)

main life cycle indicators	value	unit
Total Energy (GER)	**28**	PJ
of which, electricity	2.6	TWh
Water (process)*	2	mln.m3
Waste, non-haz./ landfill*	33	kton
Waste, hazardous/ incinerated*	1	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**1**	mt CO2eq.
Acidifying agents (AP)	**7**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**0**	g i-Teq.
Heavy Metals (HM)	**1**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**2**	kt
Emissions (Water)		
Heavy Metals (HM)	0	ton Hg/20
Eutrophication (EP)	0	kt PO4

Table 5-49 EU EIA of total stock – Vertical Multistage pumps (small) (4m^3/h at 45m, 2 pole) 1500 hrs pa

Table . Summary Environmental Impacts EU-Stock 2005, Multistage Water Big (5 stages)

main life cycle indicators	value	unit
Total Energy (GER)	**22**	PJ
of which, electricity	2.1	TWh
Water (process)*	**1**	mln.m3
Waste, non-haz./ landfill*	**26**	kton
Waste, hazardous/ incinerated*	**1**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**1**	mt CO2eq.
Acidifying agents (AP)	**6**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**0**	g i-Teq.
Heavy Metals (HM)	**0**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**1**	kt
Emissions (Water)		
Heavy Metals (HM)	0	ton Hg/20
Eutrophication (EP)	0	kt PO4

Table 5-50 EU EIA of total stock – Vertical Multistage pumps (large) (10m^3/h at 42m, 2 pole) 1500 hrs pa.

5.4.5 Environmental Impact Assessment by phase

The following tables show the relative proportions of the total environmental impact assessment that arise from each stage of the life cycle. These particular basecase pumps were selected as they were estimated to have the lowest ratio of emissions between the Use and other phases.

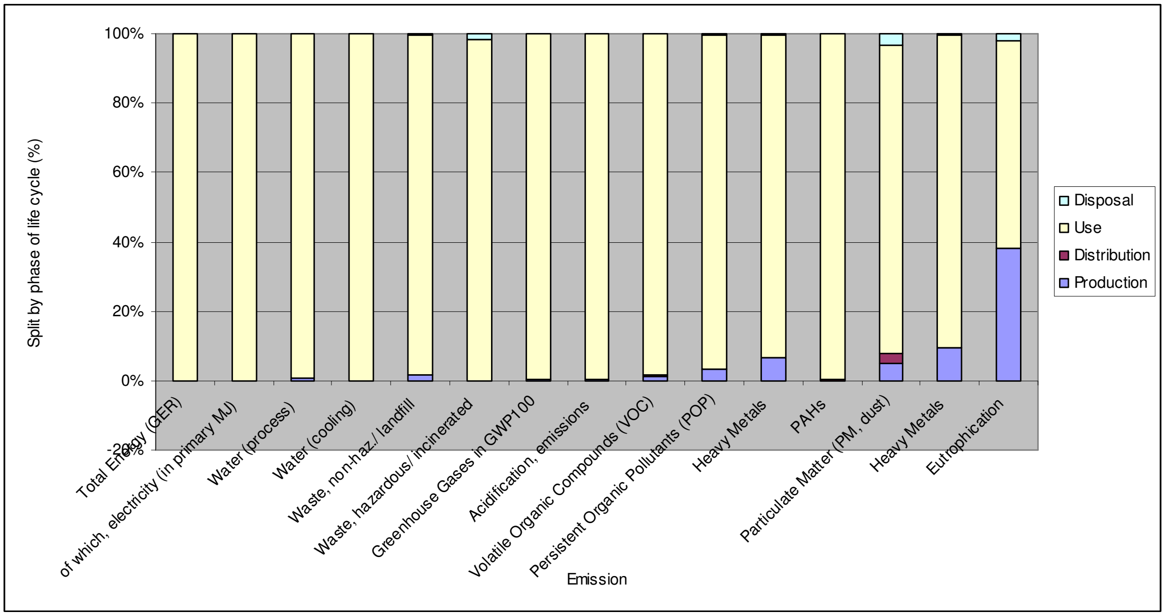


Figure 5-1 Environmental Impact by phase of lifecycle - End Suction own bearings pumps (small)

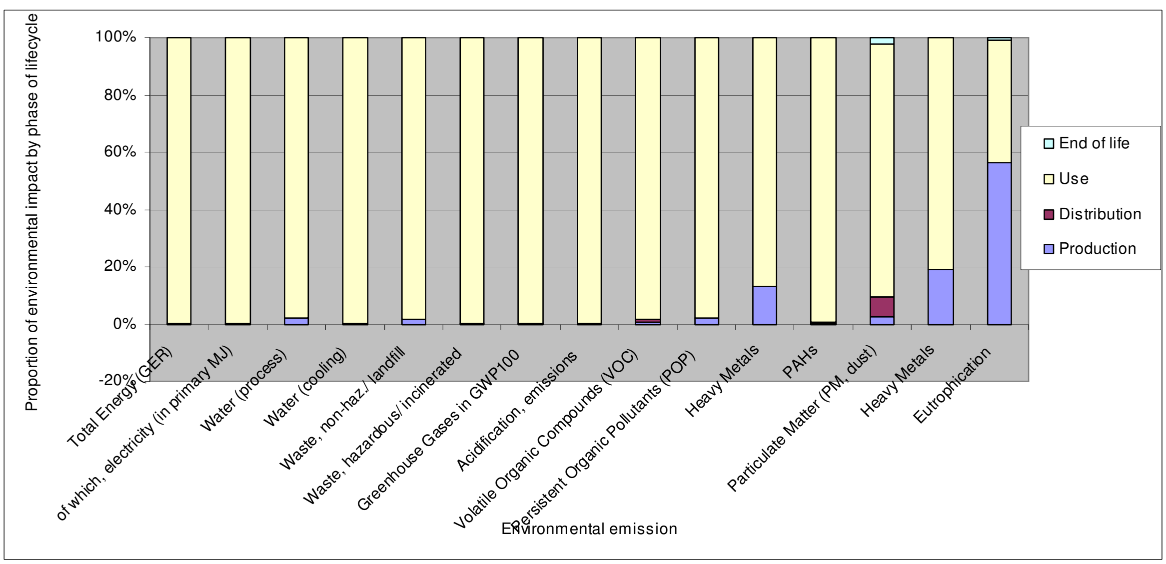


Figure 5-2 Environmental Impact by phase of lifecycle – Submersible multistage pumps (small)

The models showed that for all categories[21], the USE phase dominates the total eco impact. The significance of this is that it verifies the widespread belief that it is the energy and to a much lesser extent the maintenance costs that dominate the total eco impact; hence it is these factors that should be the focus of the study.

However, weight is a key parameter that manufacturers will be striving to reduce anyway as a way of cost reduction. Designs are likely to have been near-optimised already, and so it is thought that there is little scope for reducing weight in any dramatic way.

In principle, policy options could include the setting of weight limits for each duty, but there are some good reasons why this is not thought advisable at this stage:

- It is hard to discern any clear link between product weight and efficiency. The greatest improvements in efficiency are in the design details rather than major changes in dimensions. By far the largest eco gains are from efficiency, and so by asking manufacturers to also make changes to the weight, such an option would impose an additional burden which would have comparatively little gain.

- The reduction in weight of existing products that could be feasible is only very small, say 20% at most, and so the overall change in eco impact even if this was achievable would be extremely modest compared to much smaller gains in efficiency. It would still though be of benefit to the manufacturer to reduce the product weight if it enabled them to reduce production and transportation costs. But this would have little impact on the total lifecycle costs of a product.

[21] The apparent exception to this is eutrophication (acidification) where the factor for stainless steel in the model is unrealistically high compared to more normal accepted values (eg SimaPro). Hence the results for eutrophication are misleading, as the In Use phase should really dominate.

5.5 Summary

This analysis has shown that the eco impacts from the Production, Distribution and End-of-life phases are very small or insignificant compared to the USE phases. This justifies the focus on energy efficiency as the primary means for improving the eco performance of pumps.

Reductions in the weight of the products is something that manufacturers would wish to do anyway, but will not have a significant impact on the overall eco impact of the products.

6 Technical analysis BAT

This section looks beyond products that are currently on the market to consider what products might be available in the future. While the detail of how the efficiency of pumps can be improved is the responsibility of the manufacturer, there are some general techniques that can be applied for improving the efficiency of the different types of pump**. Although they are all theoretically possible, some will be unrealistically expensive to implement. Costing of modifications is not attempted, since the expense will vary with pump type, size, materials and existing individual design details. The examples in this section should not be generalised.**

6.1 State of the art in applied research for the product (prototype level)

6.1.1 Improvements in Centrifugal Pumps

The centrifugal pump is a mature product which has been under development for over 300 years. However, it was not until high speed turbines and electric motors became available in the late 19th century that real improvements became possible. By the 1880's pump efficiencies of 80% were achieved. Today, efficiencies well over 90% are achieved, albeit by larger pumps than those considered here.

6.1.2 End Suction Own Bearings Pumps

The mechanical losses in the two anti-friction bearings and the mechanical seal will be between 2% and 10% of the input power to the pump, depending on the pump size. These are not capable of significant reduction without resorting to very sophisticated (and expensive) solutions, such as water lubricated journal and thrust bearings.

The remaining power losses are looked at theoretically for a specific pump in Appendix 1. These can be viewed as the hydraulic losses due to turbulence and surface friction, plus the leakage losses. These are considered below.

Hydraulic design

The geometry of the impeller and the casing affects the hydraulic losses. Each manufacturer will have their own (confidential) method of choosing this geometry. With many years of feedback, an established manufacturer should have arrived at close to the optimum impeller vane number, vane shape, impeller inlet diameter, impeller cross-sectional profile, and casing geometry. This should produce an effective compromise between the various curve shapes for head, power, efficiency, and NPSHR against flow.

However, in most cases efficiency could be improved by sacrificing one or both of the ideals of head stability at low flows (e.g. by using a smaller diameter impeller), or NPSHR at best efficiency flow (e.g. by using a smaller impeller inlet diameter). The increased sales resulting from higher efficiency would have to be balanced against the loss in sales due to the reductions in performance in the other areas.

One geometric improvement which would raise efficiency without necessarily incurring other disadvantages (apart from cost) would be to replace the cast impellers by ones made from pressed stainless steel, thereby reducing vane and shroud thickness.

Surface friction

a) Impeller

The outer surfaces should be fully machined to a hydraulically smooth finish, but in practice this is rarely done. The inner surfaces should be as smooth as possible. Mechanical methods of smoothing the rough cast interiors of impellers in iron or bronze are time-consuming and not entirely effective due to inaccessibility. Precision casting methods can give a good finish, at a high cost which has never been justified on this type of pump. Cast iron should not be used on cold water pumps unless precautions are taken against corrosion, due to the formation of rough corrosion products. Where good access is possible, a cast iron impeller can be coated with a smooth resin. This is costly and is rarely, if ever, done on pumps of this size. For a good finish, the impeller could be made from plastic or pressed sheet steel, rarely, if ever, done.

b) Casing

The side walls should be fully machined to a hydraulically smooth finish. This is, at best, only partially done at present. The whole casing interior should then be coated with a smooth resin. This is very rarely done on pumps of this size. Not only does this improve efficiency appreciably, but, more importantly, it enables the improvement to be maintained by avoiding the build up of corrosion products. (There have been objections in the past to the use of resin coatings on drinking water pumps, but coatings do now exist which satisfy the regulations. However, a coating is only as good as the operator who applies it, so a reputable supplier is essential.) For an indication, based on many real pump tests, of the effect of coating the inside of a new cast iron pump casing, see Fig. 6-1[22] below. It can be seen that, for the small pumps involved here, the efficiency improvement can be quite substantial.

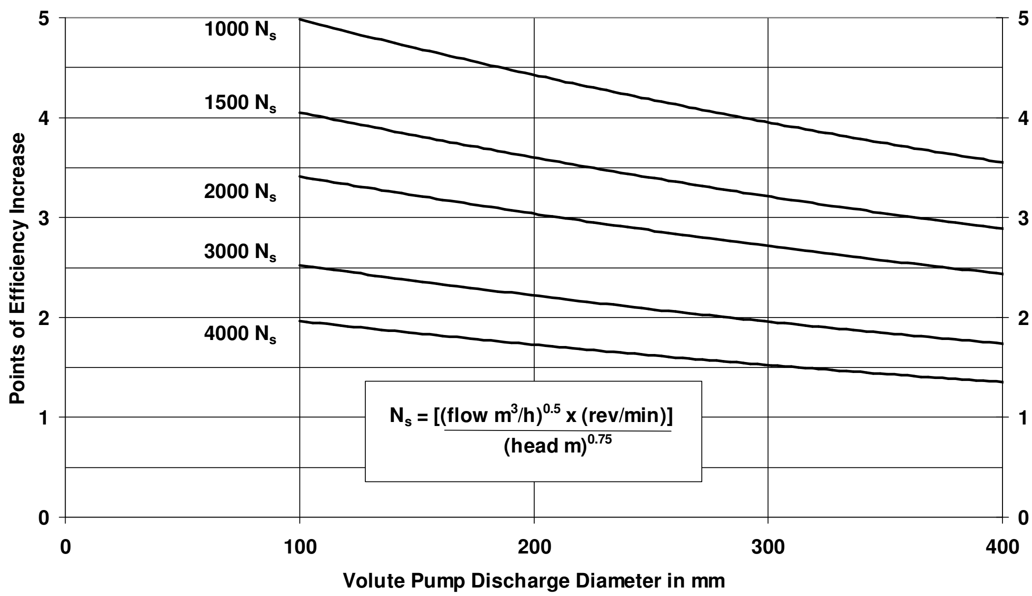


Figure 6-1 Effect on efficiency of coating the inside of a pump casing

Leakage

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

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

[22] Note that in this graph, based on US data, a different definition of specific speed has been used, but the trend shown in the graph is clear.

Alternatively wear ring geometry could be changed, e.g. non-plane surfaces. However, the effect would be small and would be offset by reducing the small but beneficial hydrostatic centring force.

The back wear ring and the associated 'balance holes' could be eliminated to reduce leakage (the thrust bearing size would have to be increased). This may also improve NPSHR.

The bleeding of water from the casing to cool the mechanical seal could be eliminated by using a large conical housing for the seal (already done on some pumps).

6.1.2 End Suction Close Coupled Pumps

The mechanical loss in the seal will be well below 1% for larger pumps, but for the smaller ones of the sizes considered in this study this loss might be much higher. The remaining power losses are considered below.

Hydraulic design

The same comments apply as the previous section. Indeed manufacturers who make both types of pumps will use the same impeller and casing geometries.

Surface friction

a) Impeller - As for End Suction Own Bearings Pumps.

b) Casing - As for End Suction Own Bearings Pumps.

Leakage

c) As for End Suction Own Bearings Pumps, except that:
   - There is not the same opportunity for reducing the wear ring gap by increasing shaft diameter, since the shaft stiffness depends on the motor.
   - The back wear ring and the associated 'balance holes' could rarely be eliminated to reduce leakage, since this could overload the motor thrust bearing.

6.1.3 Submersible Multistage Pumps

The axial thrust from the pump is normally accommodated in the motor. The losses in the water-lubricated journal bearings can be neglected. There are no seal losses.

Hydraulic design

The pump outside diameter is usually restricted by the diameter of the hole it is intended to work in. To reduce cost, for a given duty the number of pump stages tends to be minimised and the stage length reduced. This results in relatively narrow impellers and diffusers. By increasing the number of stages and increasing stage width it would be possible to increase stage efficiency and, in many cases, increase the pump efficiency for a given duty

Some pumps use inward flow diffusers. Stage efficiency could be improved by using outward flow (or outward/inward flow) diffusers, but again stage numbers would increase.

Surface friction

The pump hydraulic components are normally made from plastic and sheet metal, so efficiency improvements by material changes are unlikely.

Leakage

Wear ring (and interstage bush) clearance is mainly dictated by journal bearing clearance. However, very hard but compatible wear ring materials (e.g. Tungsten carbide) may allow reduced clearance. More importantly, hard materials would better resist the wear caused by the abrasive materials found in most wells, which increase leakage. By the same token, hard bearing materials would reduce the risk of wear causing wear ring contact. Rubber bushes and casing wear rings are resistant to wear but to be really effective they need to be run in conjunction with inner hard surfaces.

6.1.4 Vertical Multistage Pumps

The axial thrust from the pump is normally accommodated in the motor but on some pumps there is an external ball thrust bearing. There is little that can be done to reduce these small thrust bearing losses or the small losses in the water-lubricated journal bearings. The loss in the single mechanical seal is negligible.

Hydraulic design

In the smaller pump sizes, for a given duty the number of pump stages tends to be minimised and the stage length reduced. This results in relatively narrow impellers and diffusers. By increasing the number of stages and increasing stage width it would be possible to increase stage efficiency and, in many cases, increase the pump efficiency for a given duty

Some pumps use inward flow diffusers. Efficiency could be improved by using outward flow (or outward/inward flow) diffusers. Pump diameter would increase and, in some cases, so would stage length.

If the pumps become taller, they may need to be made more sturdy.

Surface friction

The pump hydraulic components are normally made from sheet metal, so efficiency improvements by material change are unlikely.

Leakage

Wear ring (and interstage bush) clearance is mainly dictated by bearing clearance. However, in order to reduce these clearances, very hard but and compatible wear ring materials (e.g. Tungsten carbide) could be used. Alternatively, providing the water is clean, PTFE casing wear rings could be used (and sometimes are).

6.1.6 Positive displacement pumps

Although there are many practical reasons why positive displacement pumps are inappropriate for the applications listed in terms of their secondary parameters, they do offer higher efficiencies. They are therefore included here solely as a reference point for what is technically potentially achievable, even though there are practical reasons why they are not a realistic option for most water pumping applications.

Most positive displacement pumps tend to have low internal losses. As long ago as the end of the 19th century, there were large reciprocating pumps with efficiencies of 90%.

Today, there are three basic types of positive displacement pumps; Rotary, Reciprocating, and Open (see Table 2 above). The reciprocating pump is best suited to relatively high heads and small flows. It tends to cause troublesome pressure fluctuations. The rotary pump suits lower heads and small flows, and can maintain a practically continuous flow with low pressure fluctuations against a wide range of heads.

Rotary type

a) Progressing Cavity

These pumps normally comprise a rotating eccentric steel 'screw' running in an elastomeric stator. They are designed principally for pumping viscous/dirty liquids at low speeds. Flows of up to 300 m^3/h are possible and they can pump against heads of up to 100m. They have been used in wells.

b) Sliding vane

These comprise a rotor running eccentrically in a circular casing. Vanes slide in and out of the rotor (or casing) maintaining contact with the casing (or rotor). Because of their construction, heads only go up to about 30m and flows up to 30 m^3/h. This covers only a small area of operation of End Suction and Vertical Multistage pumps, and they would be incapable of fitting into a small diameter well.

c) Peristaltic

These pump by squeezing liquid through a hose. Heads are therefore restricted to around 30m. Flows up to 100 m^3/h are possible.

d) Screw

These consist of axial helical screws meshing together. Heads up to 300m and flows up to 1000 m^3/h are possible. For low viscosity liquids such as water, the screws must be very accurately located without touching by timing gears. This makes the pump expensive.

e) Lobe

These could be viewed as gear pumps, usually with only two or three teeth meshing constantly together. However, unlike gear pumps, they are designed (using timing gears) to avoid the 'teeth' actually coming into contact, and are therefore suitable for low viscosity liquids such as water, clean or contaminated. They are capable of heads up to 120m and flows up to 300 m^3/h. They run at low speed and are therefore relatively large for their duties.

f) Gear

These rely on gear teeth meshing together. They are capable of heads up to 300m and flows up to 300 m^3/h. Because of the metal-to-metal contact, they are normally used for liquids with good lubricating properties, not water.

Reciprocating type

a) Diaphragm

These consist of reciprocating flexible diaphragms with the flow controlled by inlet and outlet valves. They can be driven by a crank or by compressed air. They are capable of flows up to 300 m^3/h. Because of the diaphragms, the heads are restricted.

b) Plunger

These generate pressure by a reciprocating plunger of constant diameter passing through a seal. They are designed for very high pressures, up to 50,000m and low flows,

c) Piston

These generate pressure by a reciprocating piston, the principle could be considered to be the reverse of a car engine. However, in order to limit shock loads, mean piston speeds are very much lower, probably less than 1 m/s when pumping water. Thus the pump is relatively large. Heads up to 200m are possible but pulsations can be high, causing serious system problems. Flow range is almost unlimited.

Open type

The only relevant pump in this category is the Archimedean Screw (invented by the Ancient Egyptians, not Archimedes). This usually consists of a large screw, made from steel plate, inclined at 30 degrees to the horizontal and running with a small clearance in a semi-circular concrete trough. This is very bulky, driven through a gearbox at 20 to 80 rev/min, and only capable of heads below 10m. Compared with other types of positive displacement pumps, its efficiency is low, around 70% at best. It is used for sewage, drainage, and occasionally for irrigation. It could only be viewed as a serious alternative to the End Suction pump on extremely rare occasions, e.g. for land drainage or irrigation. It is unable to achieve the duties of Vertical Multistage or Submersible Well pumps.

6.1.7 Centrifugal Pumps with intelligent controls

Several manufacturers supply pumps with a VSD connected directly to the pumpset. This makes the installation of a variable speed control both easier and often lower cost. Other pumpsets, may be supplied with a VSD connected through cables. By incorporating feedback from whatever parameter is important to control (eg temperature, flow or pressure), energy savings can be achieved. This is discussed in further detail in the section on variable speed control in the Motor study.

Pumps are also available which have built in diagnostics to identify possible causes of detected problems. This is useful in that it can both sound alarms and give maintenance staff ideas of what the technical problems might be. Early warning of problems can save cost and energy through making adjustments or repairs before failure of the pump.

The fitting of intelligent controls to pumps will give improved eco-performance in almost all applications, and so is to be welcomed. However, such controls would have no obvious impact on the design of the pump itself, and so are regarded as being beyond the scope of this study.

6.1.8 Higher speed pumps

The use of electronic controls allows for pumps to be designed for optimal specific speed, without the constraints of conventional 2/4 pole induction motor speeds. This can lead to reduced energy consumption. In many cases this will allow for a physically smaller pump, which will use less material and so will also have a lower eco-impact during the production phase.

6.2 State of the art at component level (prototype, test and field trial level)

The study group is not aware of any developments in this category of products.

6.3 State of the art of best existing product technology outside the EU)

The study group is not aware of any developments in this category of products outside of the EU.

6.4 Summary

This section has discussed the many ways in which efficiency of centrifugal pumps can be increased. Each of the design options has an economic cost, and in some cases may impact adversely on pump lifetime. The detailed decisions on what options are most appropriate for a particular pump will vary from design to design, and so in the LCC analysis in chapter 7 a generic relationship between efficiency and production cost is derived.

Beyond improvements to the actual design of the pump itself, the use of electronic speed controls frees the designer from the specific speed constraints of standard fixed speed induction motors. This enables the efficiency of some pump sizes to be improved by being designed to operate at a more favourable speed and hence specific speed.

The use of speed controls and intelligent controls, although beyond the scope of this study, offer the potential to save even more energy, often actually larger than that from the use of just improving the pump itself, (section 7.6).

7 Improvement Potential

This section reviews the design options that there are for improving the current designs of pumps up to and beyond the basecase reference designs. By considering the total economic lifecycle cost to the user, and comparing this with the environmental impact of each option, the attractiveness of the different options can be compared on an equal basis.

Because the initial MEEUP analysis showed that the environmental impact is dominated by the “In use” phase energy cost, other environmental impacts are not considered further in this section. This means that the different options can be considered purely in terms of cost to the consumer and energy savings.

All analysis is undertaken relative to the basecase reference models used earlier.

Article 12 of the Energy Using Product Directive states that “implementing measures shall not have a negative impact on …(c) the affordability and lifecycle cost to the user”. This analysis will show the lifecycle costs to the user for all products, and will also consider the impact of its interaction with the wider system.

7.1 Options

The limits to efficiency improvements of the types of pumps considered in this study are well known both empirically and from theoretical studies. Appendix 2 and chapter 6 summarise the ways in which improved efficiencies can be achieved, and the impacts on other important secondary parameters of seeking higher efficiencies.

The policy options presented in this report are based on simply removing the worst n% of products from the market. The data supplied by the Technical University Darmstadt (TUD) was submitted in this way, allowing the EC to easily see the impact on the user and the environment of removing different proportions of the worst performing pumps, referred to in this report as “cut off”.

“Cut off” is a term used in this report to discuss the proportion of pumps that would fall below a minimum efficiency line for a particular style/size of pumps. For example, a “30% cutoff” means that 30% of pumps currently sold would fall below this line and hence could not be sold. This is the basis of the LCC costing shown in chapter 7.

It should be stressed that while this method is reasonable for commodity type pumps of the type considered in this report, the importance of other secondary parameters for other engineered types of pumps means that it is unlikely to be usable in its current form for these other types of pumps.

The TUD analysis and methodology on which this section is based is described in section 7.5.

7.2 Impacts

Table 7.1 shows a reducing environmental impact due to a reduction of 2.3 TWhpa (electrical), which is based on all pumps being subject to the “50% cutoff” in scenario 1, the derivation of which is described in 7.5. *(Note that this figure is chosen because it is a useful reference, not because it is a recommended policy option).*

Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
Other Resources & Waste							debet	credit		
Total Energy (GER)	PJ	0	0	**0**	**309**	**24150000**	0	0	**0**	**24150309**
of which, electricity (in primary PJ)	PJ	0	0	**0**	**1**	**24150000**	0	0	**0**	**24150001**
Water (process)	mln. m3	0	0	**0**	**0**	**1610000**	0	0	**0**	**1610000**
Water (cooling)	mln. m3	0	0	**0**	**0**	**64400000**	0	0	**0**	**64400000**
Waste, non-haz./ landfill	kt	0	0	**0**	**176**	**28000555**	0	0	**0**	**28000730**
Waste, hazardous/ incinerated	kt	0	0	**0**	**3**	**556487**	0	0	**0**	**556490**
Emissions (Air)										
Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**20**	**1053892**	0	0	**0**	**1053912**
Ozone Depletion, emissions	t R-11 eq.	negligible								
Acidification, emissions	kt SO2 eq.	0	0	**0**	**59**	**6218625**	0	0	**0**	**6218684**
Volatile Organic Compounds (VOC)	kt	0	0	**0**	**4**	**9095**	0	0	**0**	**9099**
Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**1**	**158293**	0	0	**0**	**158294**
Heavy Metals	ton Ni eq.	0	0	**0**	**9**	**414323**	0	0	**0**	**414332**
PAHs	ton Ni eq.	0	0	**0**	**11**	**47576**	0	0	**0**	**47587**
Particulate Matter (PM, dust)	kt	0	0	**0**	**650**	**132825**	0	0	**0**	**133475**
Emissions (Water)										
Heavy Metals	ton Hg/20	0	0	**0**	**0**	**155712**	0	0	**0**	**155712**
Eutrophication	kt PO4	0	0	**0**	**0**	**743**	0	0	**0**	**743**
Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Table 7-1 Total Environmental Impact from saving 2.3 TWh pa of electrical energy

7.3 Costs

7.3.1 Cost to manufacturers

This cost depends on the specifics of time scales and cut-off values selected, with the table below being submitted by Europump as an indication of these costs. However, this is only approximate and it was not possible to independently verify this.

This is complicated because in addition to the engineering and tooling cost for new designs of pump, there will be implications on the range of pumps. For example, new pump volutes may be needed in order to avoid satisfying some pump duties with much reduced (trimmed) impellers, which will mean making more pump volute sizes than if lower pump efficiencies were allowable. Further, because many of the lower efficiency pumps will just be "odd" designs, it may not make sense to replace them with identical duties – because actually a whole range of pump duties should ideally be altered to minimise the cost of introducing a new range of compliant pumps that satisfy the spread of duties required. It is therefore imperative that manufacturers are given advance warning of any policy options.

Cut off (%)	Development costs of new pumps (Meuros)
10	43.2
20	120.9
50	550.8
80	1,382.4

Table 7-2 Estimated development costs of new pumps to meet different minimum cutoff values, (supplied by Europump)

7.3.2 Cost to users

Table 7-1 shows the annual purchase cost to the consumer of the cutoff being set to various thresholds from 10% to 80%. Although these total increases in cost may appear to be high, these figures should be compared to the estimated total value of the EU pumps market (for new pumps of this type) of 1,500Meuros pa. In addition the consumer will face installation costs of a similar value, and so the value of the increase in cost to the consumer for these increased pumps is proportionately not very significant for lower cut off values.

The cost is calculated by looking at the difference in cost between the current situation and the costs of pumps at the efficiency which they are being moved to. This is then multiplied by the annual sales to get the total additional costs to the user each year.

Cut off (%)	ESCC S	ESCC L	ESOB S	ESOB L	MSS S	MSS L	MS S	MS L	ESCCi S	ESCCi L	Total cost pa (Euros)
80	12,420	11,385	6,072	3,450	35,162	9,660	13,800	3,450	4,968	4,554	**104,921,400**
70	6,120	5,610	2,992	1,700	17,326	4,760	6,800	1,700	2,448	2,244	**51,700,400**
60	2,880	2,640	1,408	800	8,154	2,240	3,200	800	1,152	1,056	**24,329,600**
50	1,080	990	528	300	3,058	840	1,200	300	432	396	**9,123,600**
40	1,080	990	528	300	3,058	840	1,200	300	432	396	**9,123,600**
30	1,080	990	528	300	3,058	840	1,200	300	432	396	**9,123,600**
20	720	660	352	200	2,038	560	800	200	288	264	**6,082,400**
10	0	0	0	0	0	0	0	0	0	0	**0**

Table 7-3 Cost to user (thousand euros pa) of making cutoffs from 10% to 80% the minimum standard

7.4 Analysis LLCC and BAT

The following figures present the LCC analysis and energy savings of selecting differing cutoffs for the different types of pump. The Life Cycle Cost comprises:
Purchase cost
Installation cost
Maintenance and repair cost
Lifetime energy consumption (with discounted cash factor)

7.4.1 Methodology[23]

To calculate the cumulative energy saving from setting the cut off at different points, the distribution of pumps is split into 9 discrete bands from 0% (reference) to 100% cut off, (figure 7.1). (There are 9 rather than 10 bands because there is no split between 80-100%. This is because beyond 80% designs may compromise reliability in order to achieve high efficiencies, and so a cut off at this sort of level would be unreasonable.)

The first column in the top table in 7.4.1 is a copy of the data from annex 3 (TUD)[24], with the relative efficiency denoting the efficiency points below the standard plane of efficiencies. *(It is suggested that the section "Minimum efficiency and requirement and cut-off values" is read so as to understand the derivation of these values).* The second column calculates the actual efficiency points difference relative to the basecase, which is assumed to be that of the basecase examples used in section 4, on the assumption that the basecase is indeed the "average" product sold. The third column finally converts the relative efficiency values into absolute efficiencies.

[23] One manufacturer disagreed with the approach of having a single efficiency standard for both 4" and 6" submersible pumps on the basis that it would be unreasonable for a high flow 4" pump to reach a similar efficiency as a small flow 6" pump. All other members of the Europump group involved in this work do though remain happy with this approximation.
[24] TUD (Technical University Darmstadt)

The results of the MEEUP analysis give the annual energy consumption for each efficiency band (or decile) of pumps, (column 4) based on that of the basecase energy consumption. Column 6 gives the additional purchase price of different options, again relative to the basecase, with the actual price shown in column 7. Finally the total lifetime energy cost and LCC are shown in columns 8 & 9. The second table re-runs this analysis at lower (50%) and higher (200%) of the original running hours so as to show the sensitivity of LCC to this important parameter.

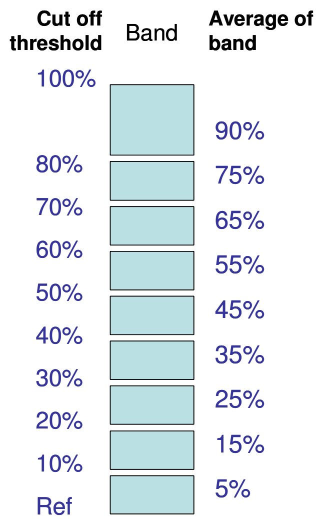


Figure 7-1 Method of splitting the distribution of pumps by efficiency band based on the cutoffs calculated by TUD.

7.4.2 Scenario Analysis

The reference (zero cut off) case is for no change in stock, and so this should give an answer similar to the current mean. This is true for all pumps, with the small differences accounted for by the non-uniform distribution of pumps efficiencies about the mean.

Scenario 1 (third (bottom) tables in 7.4.1)

This assumes that the worst pumps are replaced by those just over the minimum acceptable threshold. This is a very pessimistic scenario, as it is thought that in practice most manufacturers would take the opportunity to replace them with at least those of the mean (50% cutoff) efficiency.

Eg The 10% cut off is calculated by assuming that the worst 10% of pumps are improved to the 10% cut off line. Ie the energy consumption of these falls from the average of the bottom band to that of the cut off line. The 20% cut-off is calculated by assuming that the worst 10% improve to the 20% cut off, and the 10-20% band of pumps improve to the 20% cut off. This is repeated to the 80% cut off line.

Scenario 2

This is calculated in a similar way, but assumes that pumps up to the 40% cutoff will be replaced with those mid-way through the 50-60% band. Above this the scenario is the same as scenario 1.

Both of these scenarios are summarised in figures 7.5.4 – 7.5.7.

In the absence of any other data, and in line with the general findings from the SAVE 2 Pump efficiency study, the business as usual (BAU) case assumes no changes in pump efficiency without external intervention.

Calculations are shown for both electrical and mechanical energy savings, which should make comparisons with the Lot 11 motor report more transparent. (Mechanical savings relate to the energy consumed by the pump ("at the shaft"), whereas electrical savings are those on the input to the motor, assuming a class Eff2 motor).

Commentary on detailed calculations

The following commentary uses the ESOB (Large) as the example.

Relative efficiency (from TUD analysis)	Efficiency difference relative to basecase	Relative energy performance (italics - derived)	Annual energy consumption (kWh pa) from MEEUP	Cut-off (%)
122.94	-4.03000	76.03000	30,861	80
124.85	-2.12000	74.12000	31,656	70
126.1	-0.87000	72.87000	32,199	60
126.97	0.00000	72.00000	32588	**50**
128.07	1.10000	70.90000	33,094	40
129.35	2.38000	69.62000	33,702	30
130.68	3.71000	68.29000	34,358	20
132.58	5.61000	66.39000	35,342	10
134.38	7.41000	64.59000	36,327	5

Column 2 for the 20% cutoff is 130.68 – 126.97 = 3.71 ∆%.

Column 3 for the 20% cutoff is 72.0 – 3.71 = 68.29%.

Column 4 is calculated as the mean (50% cutoff) energy consumption adjusted to the calculated energy consumption at that breakpoint. For example the annual energy consumption at the 20% point is;

32,588 * 72.0/68.29 = 34,358 kWh pa

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	30,861	29,522	*30,593*	*16.826*	1.108	1.316
70	31,656	31,258	*31,189*	*17.154*	0.780	0.926
60	32,199	31,927	*31,542*	*17.348*	0.585	0.695
50	32,588	32,393	*31,756*	*17.466*	0.468	0.556
40	33,094	32,841	*31,984*	*17.591*	0.343	0.407
30	33,702	33,398	*32,197*	*17.708*	0.226	0.268
20	34,358	34,030	*32,361*	*17.799*	0.135	0.161
10	35,342	34,850	*32,508*	*17.880*	0.054	0.064
Base		36,327	*32,607*	*17.934*		

Column 2 is a copy of column 4 from above.

Column 3 is the average of the energy consumption at the bottom and top of this band.
Eg the average energy used by a pump in the 20-30% band is given by;
(34,358 + 33,702)/2 = 34,030 kWh pa..

The average energy used in the 0 – 10% band is taken to be that used at the 5% point (as given by TUD). (Note that the energy savings are particularly sensitive to this value, as there is a marked decrease in efficiency between the 10% and 5% values.)

The value for 90% is also extrapolated from the 70% to 80% values – but this is less critical as such a high cut off is not contemplated in the study.

Column 4 should be read from the bottom up. It starts with the assumption of no change, ie all pumps have average energy consumption (32,607 kWh pa). This is approximately the same value as the 50%

cutoff (32,588 kWh pa), but is slightly difference because the distribution of pumps into deciles is non-linear.

It is calculated by averaging all the values in column 3.

(29,522 + 29,522 + 31,258…….+ 34,030 + 32,508 + 35,834)/ 10 = 32,607 kWh pa.
Note that the 90% value is repeated because it is actually representing the values in the top two deciles.

For scenario 1, it is assumed that the pumps in the 0 – 10% and 10% - 20% bands move to the 20% threshold. The above equation is therefore modified by replacing the last two values with the value at the 20% threshold, (34,358 kWh pa). The equation is now:

(29,522 + 29,522 + 31,258…….+ 34,358 + 34,358)/ 10 = 31,361 kWh pa.

The total energy consumption of the stock at each cutoff is the number of pumps in the total stock x the average energy consumption per pump at that cutoff.

550,000 x 31,361 kWh pa = 17,799 GWh pa.

The total stock energy saving (column 6) is the difference between the new energy consumption and the original energy consumption.

17,934 – 17,799 = 0.135 TWh pa

This is the mechanical energy saving, or that saved “at the shaft”.

To calculate the environmental impact of this saving, the electrical energy needs to be calculated. This is calculated by dividing the mechanical energy by the motor efficiency. A class Eff 2 motor working at full load is assumed.

0.135 / 84.2 = 0.161 TWh pa.

It should be noted that this method is different from that used by TUD in annex 3. This is for several reasons, including that they are able to do the analysis on the actual pump distribution rather than the assumed average that we have used, and because the scenario they have modelled is different.

In the following tables, it should be noted that for clarity the lifetime energy consumption does not pass through zero.

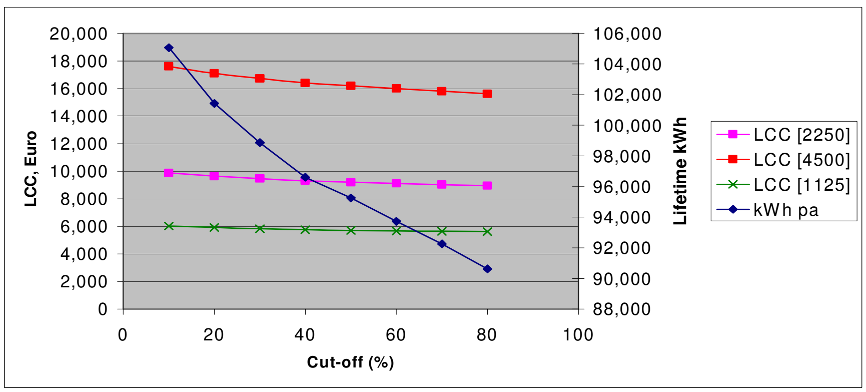
7.4.1 LCC Analysis ESCC Small pumps (25m^3/h at 32m, 2 pole)

ESCC_small **Mean (2250) hours pa**

Relative efficiency (from TUD analysis)	Efficiency difference relative to basecase	Relative energy performance (italics - derived)	Annual energy consumption (kWh pa) from MEEUP	Cut-off (%)	Relative cost (Additional % relative to basecase)	Calculated actual cost (Euros)	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)	
126.54	-3.32000	68.32000	6,937	80	10	990	90,622	8,951	
127.75	-2.11000	67.11000	7,062	70	5	945	92,256	9,026	
128.8	-1.06000	66.06000	7,174	60	2	918	93,722	9,107	
129.86	**0.00000**	**65.00000**	**7291**	**50**	**0**	**900**	**95,251**	**9,201**	basecase
130.77	0.91000	64.09000	7,395	40	**0**	900	96,603	9,300	
132.23	2.37000	62.63000	7,567	30	**0**	900	98,855	9,466	
133.82	3.96000	61.04000	7,764	20	-1	891	101,430	9,646	
135.93	6.07000	58.93000	8,042	10	-5	855	105,062	9,877	
137.32	7.46000	57.54000	8,236	5					

	High (4500) hours pa			Low (1125) hours pa		
Cut-off (%)	Annual energy consumption (kWh pa) from MEEUP	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)	Annual energy consumption (kWh pa) from MEEUP	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
80	13,873	181,244	15,611	3,468	45,311	5,620
70	14,124	184,512	15,807	3,531	46,128	5,635
60	14,348	187,444	15,995	3,587	46,861	5,662
50	14,582	190,501	16,202	3,646	47,625	5,700
40	14,789	193,206	16,401	3,697	48,302	5,750
30	15,134	197,710	16,732	3,783	49,427	5,833
20	15,528	202,860	17,101	3,882	50,715	5,919
10	16,084	210,123	17,599	4,021	52,531	6,016

Life (Years)	11
DCF	0.98000
Electricity (euros/kWh)	0.075
Assumed motor efficiency (%)	84.2
Maintenance etc (euros)	400
Purchase price (Euro)	900
stock	2200000



Scenario 2- Pumps below the cut off move to the minimum allowable value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	6,937	6,716	*6,893*	*15.164*	0.965	1.146
70	7,062	6,999	*6,986*	*15.370*	0.759	0.901
60	7,174	7,118	*7,059*	*15.531*	0.598	0.711
50	7,291	7,233	*7,124*	*15.672*	0.457	0.542
40	7,395	7,343	*7,170*	*15.775*	0.354	0.421
30	7,567	7,481	*7,231*	*15.907*	0.222	0.263
20	7,764	7,665	*7,280*	*16.016*	0.113	0.134
10	8,042	7,903	*7,322*	*16.108*	0.021	0.025
Base	8,236	8,139	*7,331*	*16.129*		

Scenario 2 - Pumps below the cut off line move to the 55% cut off value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	6,937	6,716				
70	7,062	6,999				
60	7,174	7,118	*6,917*	*15.217*	0.912	1.083
50	7,291	7,233	*6,978*	*15.351*	0.778	0.924
40	7,395	7,343	*7,037*	*15.482*	0.647	0.768
30	7,567	7,481	*7,096*	*15.611*	0.518	0.615
20	7,764	7,665	*7,162*	*15.756*	0.373	0.443
10	8,042	7,903	*7,241*	*15.929*	0.199	0.237
Base	8,236	8,139	*7,331*	*16.129*		

7.4.2 LCC Analysis ESCC Large Pumps (125m3/h at 32m, 2 pole)

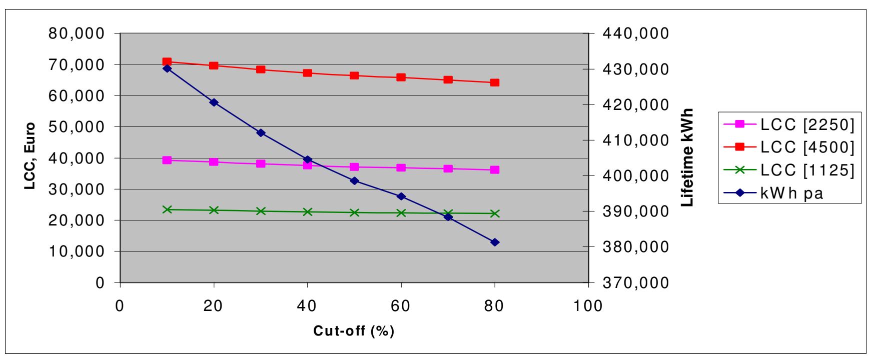
ESCC_large

Mean (2250) hours pa

Relative efficiency (from TUD analysis)	Efficiency difference relative to basecase	Relative energy performance (italics - derived)	Annual energy consumption (kWh pa) from MEEUP	Cut-off (%)	Relative cost (Additional % relative to basecase)	Calculated actual cost (Euros)	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
124.07	-3.31000	76.31000	31,196	80	10	3630	381,279	36,154
125.46	-1.92000	74.92000	31,774	70	5	3465	388,352	36,509
126.57	-0.81000	73.81000	32,252	60	2	3366	394,193	36,839
127.38	0.00000	73.00000	32610	**50**	**0**	**3300**	**398,567**	37,095
128.46	1.08000	71.92000	33,100	**40**	**0**	3300	**404,552**	37,535
129.77	2.39000	70.61000	33,714	**30**	**0**	3300	**412,057**	38,086
131.2	3.82000	69.18000	34,411	20	-1	3267	420,575	38,679
132.74	5.36000	67.64000	35,194	10	-5	3135	430,150	39,251
134.39	7.01000	65.99000	36,074	**5**				

	High (4500) hours pa			Low (1125) hours pa		
Cut-off (%)	**Annual energy consumption (kWh pa) from MEEUP**	**Lifetime electricity consumption (P1, kWh)**	**Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)**	**Annual energy consumption (kWh pa) from MEEUP**	**Lifetime electricity consumption (P1, kWh)**	**Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)**
80	62,391	762,557	64,178	15,598	190,639	22,142
70	63,549	776,705	65,053	15,887	194,176	22,237
60	64,504	788,385	65,812	16,126	197,096	22,353
50	65,220	797,133	66,389	16,305	199,283	22,447
40	66,199	809,104	67,269	16,550	202,276	22,667
30	67,428	824,115	68,372	16,857	206,029	22,943
20	68,821	841,150	69,591	17,205	210,287	23,223
10	70,388	860,301	70,867	17,597	215,075	23,443

Life (Years)	11
DCF	0.98000
Electricity (euros/kWh)	0.075
Assumed motor efficiency (%)	90
Maintenance etc (euros)	1200
Purchase price (Euro)	3300
Stock	550000



Scenario 1 - Pumps below the cut off line move to the minimum allowed value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	31,196	30,984	*31,153*	*17.134*	0.942	1.047
70	31,774	31,485	*31,587*	*17.373*	0.703	0.781
60	32,252	32,013	*31,898*	*17.544*	0.532	0.591
50	32,610	32,431	*32,095*	*17.652*	0.424	0.471
40	33,100	32,855	*32,315*	*17.773*	0.303	0.337
30	33,714	33,407	*32,530*	*17.891*	0.185	0.205
20	34,411	34,062	*32,704*	*17.987*	0.089	0.099
10	35,194	34,802	*32,822*	*18.052*	0.024	0.027
Base	36,074	35,634	*32,866*	*18.076*		

Scenario 2 - Pumps below the cut off line move to the 55% cut off value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	31,196	30,984				
70	31,774	31,485				
60	32,252	32,013	*31,264*	*17.195*	0.881	0.979
50	32,610	32,431	*31,532*	*17.343*	0.733	0.815
40	33,100	32,855	*31,785*	*17.482*	0.594	0.661
30	33,714	33,407	*32,020*	*17.611*	0.465	0.517
20	34,411	34,062	*32,272*	*17.750*	0.326	0.363
10	35,194	34,802	*32,545*	*17.900*	0.176	0.196
Base	36,074	35,634	*32,866*	*18.076*		

7.4.3 LCC Analysis ESCCi Small Pumps (25m^3/h at 32m, 2 pole)

escci_small

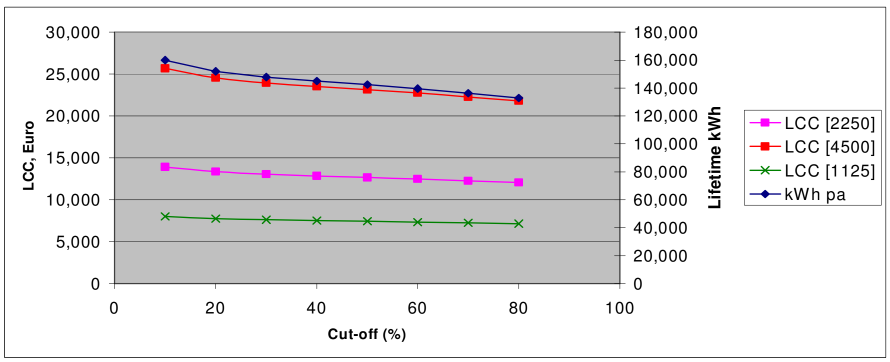
Mean (4000) hours pa

Relative efficiency (from TUD analysis)	Efficiency difference relative to basecase	Relative energy performance (italics - derived)	Annual energy consumption (kWh pa) from MEEUP	Cut-off (%)	Relative cost (Additional % relative to basecase)	Calculated actual cost (Euros)	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
128.14	-4.51000	66.51000	10,166	80	10	990	132,816	12,052
129.83	-2.82000	64.82000	10,432	70	5	945	136,279	12,262
131.34	-1.31000	63.31000	10,680	60	2	918	139,529	12,473
132.65	0.00000	62.00000	10906	50	0	900	142,477	12,672
133.69	1.04000	60.96000	11,092	40	0	900	144,908	12,851
134.91	2.26000	59.74000	11,319	30	0	900	147,867	13,068
136.53	3.88000	58.12000	11,634	20	-1	891	151,989	13,362
139.45	6.80000	55.20000	12,249	10	-5	855	160,029	13,917
141.75	9.10000	52.90000	12,782	5				

High (8000) hours pa / **Low (2000) hours pa**

Cut-off (%)	High: Annual energy consumption (kWh pa) from MEEUP	High: Lifetime electricity consumption (P1, kWh)	High: Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)	Low: Annual energy consumption (kWh pa) from MEEUP	Low: Lifetime electricity consumption (P1, kWh)	Low: Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
80	20,333	265,632	21,814	5,083	66,408	7,171
70	20,863	272,558	22,278	5,216	68,139	7,253
60	21,361	279,059	22,729	5,340	69,765	7,346
50	21,812	284,955	23,144	5,453	71,239	7,436
40	22,184	289,816	23,501	5,546	72,454	7,525
30	22,637	295,735	23,937	5,659	73,934	7,634
20	23,268	303,978	24,533	5,817	75,995	7,777
10	24,499	320,058	25,679	6,125	80,015	8,036

Life (Years)	11
DCF	0.98000
Electricity (euros/kWh)	0.075
Assumed motor efficiency (%)	84.2
Maintenance etc (euros)	400
Purchase price (Euro)	900
Stock	880000



Scenario 1 - Pumps below the cut off line move to the minimum allowed value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	10,166	10,064	*10,146*	*8.928*	0.744	0.884
70	10,432	10,299	*10,345*	*9.103*	0.569	0.676
60	10,680	10,556	*10,506*	*9.246*	0.427	0.507
50	10,906	10,793	*10,631*	*9.355*	0.318	0.377
40	11,092	10,999	*10,714*	*9.429*	0.244	0.290
30	11,319	11,205	*10,794*	*9.498*	0.174	0.207
20	11,634	11,476	*10,872*	*9.568*	0.105	0.124
10	12,249	11,942	*10,965*	*9.649*	0.023	0.028
Base	12,782	12,516	*10,991*	*9.672*		

Scenario 2 - Pumps below the cut off line move to the 55% cut off value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	10,166	10,064				
70	10,432	10,299				
60	10,680	10,556	*10,198*	*8.974*	0.698	0.829
50	10,906	10,793	*10,327*	*9.088*	0.585	0.694
40	11,092	10,999	*10,450*	*9.196*	0.476	0.566
30	11,319	11,205	*10,565*	*9.297*	0.375	0.446
20	11,634	11,476	*10,682*	*9.400*	0.273	0.324
10	12,249	11,942	*10,819*	*9.521*	0.152	0.180
Base	12,782	12,516	*10,991*	*9.672*		

7.4.4 LCC Analysis ESCCi Large Pumps (125m^3/h at 32m, 4 pole)

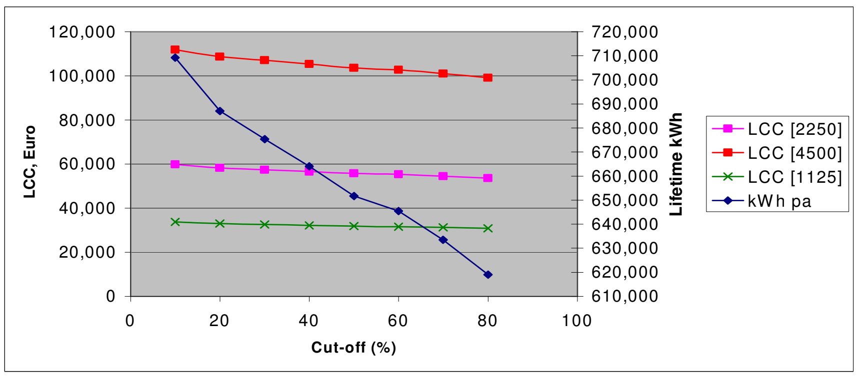
escci_large

Mean (4000) hours pa

Relative efficiency (from TUD analysis)	Efficiency difference relative to basecase	Relative energy performance (italics - derived)	Annual energy consumption (kWh pa) from MEEUP	Cut-off (%)	Relative cost (Additional % relative to basecase)	Calculated actual cost (Euros)	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
127.3	-3.70000	73.70000	50,648	80	10	3630	619,030	53,629
128.98	-2.02000	72.02000	51,829	70	5	3465	633,470	54,525
130.32	-0.68000	70.68000	52,812	60	2	3366	645,480	55,309
131	0.00000	70.00000	53325	**50**	**0**	**3300**	**651,750**	55,704
132.3	1.30000	68.70000	54,334	**40**	**0**	3300	664,083	56,610
133.44	2.44000	67.56000	55,251	**30**	**0**	3300	675,289	57,434
134.6	3.60000	66.40000	56,216	20	-1	3267	687,086	58,268
136.67	5.67000	64.33000	58,025	10	-5	3135	709,195	59,761
138.13	7.13000	62.87000	59,373	**5**				

Cut-off (%)	High (8000) hours pa: Annual energy consumption (kWh pa) from MEEUP	High (8000) hours pa: Lifetime electricity consumption (P1, kWh)	High (8000) hours pa: Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)	Low (2000) hours pa: Annual energy consumption (kWh pa) from MEEUP	Low (2000) hours pa: Lifetime electricity consumption (P1, kWh)	Low (2000) hours pa: Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
80	101,296	1,238,060	99,127	25,324	309,515	30,879
70	103,659	1,266,940	101,085	25,915	316,735	31,245
60	105,624	1,290,959	102,752	26,406	322,740	31,587
50	106,650	1,303,500	103,607	26,663	325,875	31,752
40	108,668	1,328,166	105,420	27,167	332,041	32,205
30	110,502	1,350,577	107,067	27,625	337,644	32,617
20	112,432	1,374,172	108,769	28,108	343,543	33,017
10	116,050	1,418,390	111,887	29,013	354,597	33,698

Life (Years)	11
DCF	0.98000
Electricity (euros/kWh)	0.075
Assumed motor efficiency (%)	90
Maintenance etc (euros)	1200
Purchase price (Euro)	3300
Stock	220000



Scenario 1- Pumps below the cut off move to the minimum allowed value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	50,648	50,267	*50,572*	*11.126*	0.696	0.773
70	51,829	51,239	*51,458*	*11.321*	0.501	0.556
60	52,812	52,321	*52,097*	*11.461*	0.360	0.400
50	53,325	53,068	*52,379*	*11.523*	0.298	0.331
40	54,334	53,830	*52,833*	*11.623*	0.198	0.220
30	55,251	54,792	*53,154*	*11.694*	0.128	0.142
20	56,216	55,734	*53,395*	*11.747*	0.075	0.083
10	58,025	57,121	*53,666*	*11.807*	0.015	0.016
Base	59,373	58,699	*53,734*	*11.821*		

Scenario 2 - Pumps below the cut off line move to the 55% cut off value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	50,648	50,267				
70	51,829	51,239				
60	52,812	52,321	*50,798*	*11.176*	0.646	0.718
50	53,325	53,068	*51,336*	*11.294*	0.528	0.586
40	54,334	53,830	*51,831*	*11.403*	0.419	0.465
30	55,251	54,792	*52,275*	*11.500*	0.321	0.357
20	56,216	55,734	*52,714*	*11.597*	0.224	0.249
10	58,025	57,121	*53,171*	*11.698*	0.124	0.138
Base	59,373	58,699	*53,734*	*11.821*		

7.4.5 LCC Analysis ESOB Small Pumps (30m^3/h at 30m, 2 pole)

Mean (2250) hours pa

Efficiency difference relative to basecase	Relative energy performance (italics - derived)	Annual energy consumption (kWh pa) from MEEUP	Cut-off (%)	Relative cost (Additional % relative to basecase)	Calculated actual cost (Euros)	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
-3.84000	68.84000	8,150	80	10	484	106,467	9,749
-2.12000	67.12000	8,358	70	5	462	109,195	9,928
-1.06000	66.06000	8,493	60	2	448.8	110,947	10,043
0.00000	65.00000	8631	**50**	**0**	**440**	**112,757**	10,168
1.09000	63.91000	8,778	40	0	440	114,680	10,309
2.43000	62.57000	8,966	30	0	440	117,136	10,489
4.25000	60.75000	9,235	20	-1	435.6	120,645	10,743
6.42000	58.58000	9,577	10	-5	418	125,114	11,054
8.10000	56.90000	9,860	5				

	High (4500) hours pa			Low (1125) hours pa		
Cut-off (%)	Annual energy consumption (kWh pa) from MEEUP	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)	Annual energy consumption (kWh pa) from MEEUP	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
80	16,299	212,934	17,575	4,075	53,233	5,837
70	16,717	218,390	17,954	4,179	54,598	5,915
60	16,985	221,894	18,198	4,246	55,474	5,966
50	17,262	225,513	18,455	4,316	56,378	6,024
40	17,556	229,359	18,738	4,389	57,340	6,094
30	17,932	234,271	19,099	4,483	58,568	6,185
20	18,470	241,290	19,610	4,617	60,322	6,309
10	19,154	250,228	20,250	4,788	62,557	6,456

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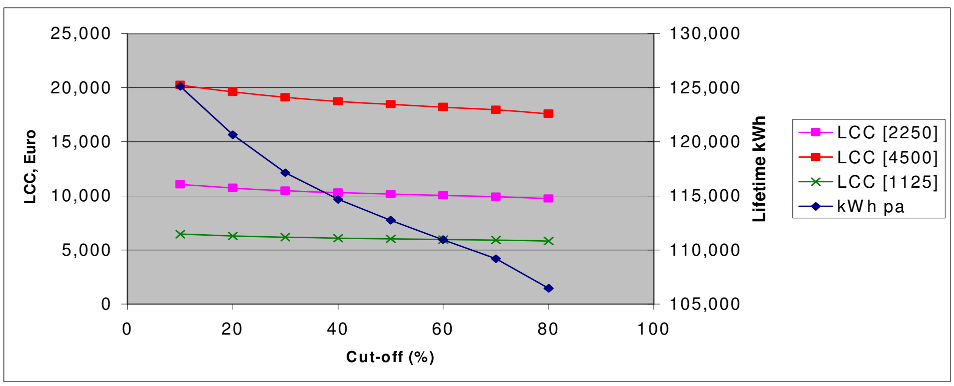


Scenario 1 - Pumps below the cut off move to the minimum allowable value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	8,150	7,864	*8,092*	*17.803*	1.317	1.564
70	8,358	8,254	*8,249*	*18.148*	0.973	1.155
60	8,493	8,425	*8,336*	*18.340*	0.781	0.927
50	8,631	8,562	*8,412*	*18.507*	0.613	0.728
40	8,778	8,705	*8,479*	*18.653*	0.468	0.555
30	8,966	8,872	*8,544*	*18.798*	0.323	0.383
20	9,235	9,101	*8,612*	*18.945*	0.175	0.208
10	9,577	9,406	*8,663*	*19.058*	0.062	0.074
Base		9,860	*8,691*	*19.121*		

Scenario 2 - Pumps below the cut off line move to the 55% cut off value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	8,150	7,864	*8,092*			
70	8,358	8,254	*7,989*			
60	8,493	8,425	*8,130*	*17.887*	1.234	1.465
50	8,631	8,562	*8,224*	*18.093*	1.028	1.221
40	8,778	8,705	*8,311*	*18.284*	0.837	0.994
30	8,966	8,872	*8,382*	*18.441*	0.680	0.807
20	9,235	9,101	*8,463*	*18.619*	0.502	0.596
10	9,577	9,406	*8,561*	*18.835*	0.286	0.339
Base	0	9,860	*8,691*	*19.121*		

7.4.6 LCC Analysis ESOB Large Pumps (125m3/h at 32m, 4 pole)

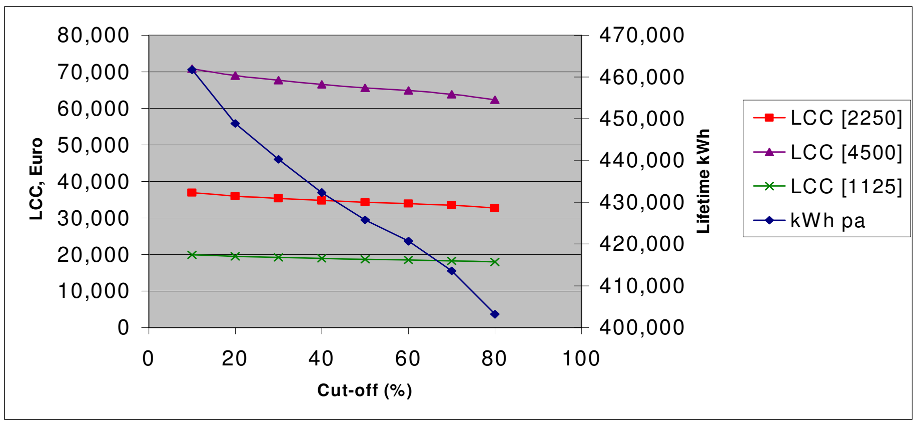
ESOB_large

Mean (2250) Hours pa

Relative efficiency (from TUD analysis)	Efficiency difference relative to basecase	Relative energy performance (italics - derived)	Annual energy consumption (kWh pa) from MEEUP	Cut-off (%)	Relative cost (Additional % relative to basecase)	Calculated actual cost (Euros)	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
122.94	-4.03000	76.03000	30,861	80	10	1100	403,168	32,733
124.85	-2.12000	74.12000	31,656	70	5	1050	413,557	33,446
126.1	-0.87000	72.87000	32,199	60	2	1020	420,651	33,938
126.97	0.00000	72.00000	32588	**50**	**0**	**1000**	**425,734**	34,291
128.07	1.10000	70.90000	33,094	40	0	1000	432,339	34,777
129.35	2.38000	69.62000	33,702	30	0	1000	440,288	35,361
130.68	3.71000	68.29000	34,358	20	-1	990	448,863	35,981
132.58	5.61000	66.39000	35,342	10	-5	950	461,709	36,886
134.38	7.41000	64.59000	36,327	5				

	High (4500) Hours pa			**Low (1125) Hours pa**		
Cut-off (%)	Annual energy consumption (kWh pa) from MEEUP	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity)	Annual energy consumption (kWh pa) from MEEUP	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
80	61,721	806,336	62,366	15,430	201,584	17,916
70	63,312	827,114	63,843	15,828	206,779	18,248
60	64,398	841,302	64,856	16,099	210,326	18,479
50	65,176	851,468	65,583	16,294	212,867	18,646
40	66,187	864,678	66,554	16,547	216,170	18,888
30	67,404	880,576	67,722	16,851	220,144	19,181
20	68,717	897,726	68,973	17,179	224,431	19,486
10	70,683	923,418	70,821	17,671	230,854	19,918

Life (Years)	11
DCF	0.98000
Electricity (euros/kWh)	0.075
Assumed motor efficiency (%)	84.2
Maintenance etc (euros)	1000
Purchase price (Euro)	1000
Pump efficiency (%)	72
Stock	550000



Scenario 1 - Pumps below the line move to the minimum allowed value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	30,861	29,522	*30,593*	*16.826*	1.108	1.316
70	31,656	31,258	*31,189*	*17.154*	0.780	0.926
60	32,199	31,927	*31,542*	*17.348*	0.585	0.695
50	32,588	32,393	*31,756*	*17.466*	0.468	0.556
40	33,094	32,841	*31,984*	*17.591*	0.343	0.407
30	33,702	33,398	*32,197*	*17.708*	0.226	0.268
20	34,358	34,030	*32,361*	*17.799*	0.135	0.161
10	35,342	34,850	*32,508*	*17.880*	0.054	0.064
Base		36,327	*32,607*	*17.934*		

Scenario 2 - Pumps below the cut off line move to the 55% cut off value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	30,861	29,522				
70	31,656	31,258				
60	32,199	31,927	*30,739*	*16.907*	1.027	1.220
50	32,588	32,393	*31,092*	*17.100*	0.833	0.990
40	33,094	32,841	*31,409*	*17.275*	0.659	0.783
30	33,702	33,398	*31,664*	*17.415*	0.518	0.616
20	34,358	34,030	*31,929*	*17.561*	0.373	0.443
10	35,342	34,850	*32,214*	*17.717*	0.216	0.257
Base		36,327	*32,607*	*17.934*		

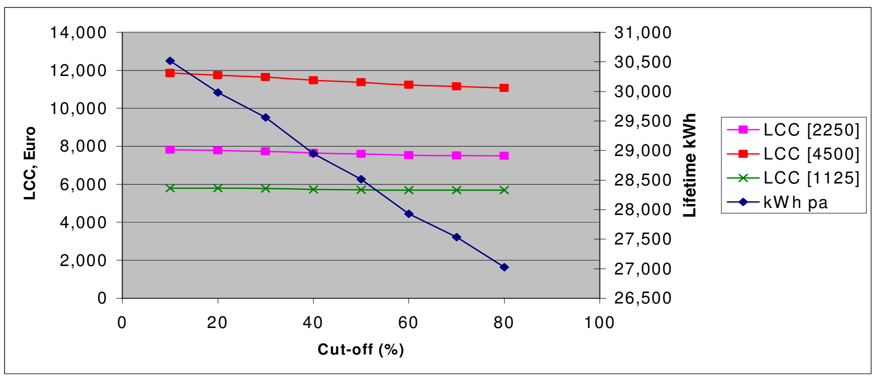
7.4.7 LCC Analysis Submersible Multistage Small Pumps (8.5m^3/hr at 59m, 2 pole)

mss_small | **Mean (1000) hours pa**

Relative efficiency (from TUD analysis)	Efficiency difference relative to basecase	Relative energy performance (italics - derived)	Annual energy consumption (kWh pa) from MEEUP	Cut-off (%)	Relative cost (Additional % relative to basecase)	Calculated actual cost (Euros)	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
122.05	-5.22000	68.22000	2,029	80	10	1001	27,024	7,486
123.84	-3.43000	66.43000	2,068	70	5	955.5	27,534	7,508
125.22	-2.05000	65.05000	2,097	60	2	928.2	27,928	7,533
127.27	0.00000	63.00000	2141	**50**	**0**	**910**	**28,512**	7,592
128.79	1.52000	61.48000	2,174	40	**0**	910	28,945	7,649
130.94	3.67000	59.33000	2,220	30	**0**	910	29,559	7,731
132.43	5.16000	57.84000	2,251	20	-1	900.9	29,983	7,778
134.31	7.04000	55.96000	2,292	10	-5	864.5	30,519	7,812
137.08	9.81000	53.19000	2,351	5				

	High (2000) hours pa			**Low (500) hours pa**		
Cut-off (%)	Annual energy consumption (kWh pa) from MEEUP	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)	Annual energy consumption (kWh pa) from MEEUP	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
80	4,058	54,048	11,061	1,015	13,512	5,699
70	4,135	55,068	11,151	1,034	13,767	5,687
60	4,194	55,855	11,228	1,049	13,964	5,686
50	4,282	57,024	11,364	1,071	14,256	5,706
40	4,347	57,891	11,479	1,087	14,473	5,735
30	4,439	59,117	11,641	1,110	14,779	5,775
20	4,503	59,967	11,744	1,126	14,992	5,794
10	4,583	61,039	11,850	1,146	15,260	5,793

Life (Years)	11
DCF	0.98000
Electricity (euros/kWh)	0.135
Assumed motor efficiency (%)	82.6
Maintenance etc (euros)	2000
Purchase price (Euro)	910
Stock	6160000



Scenario 1 - All move to the minimum allowed value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	2,029	2,010	*2,025*	*12.477*	0.738	0.894
70	2,068	2,048	*2,054*	*12.654*	0.561	0.679
60	2,097	2,082	*2,073*	*12.772*	0.443	0.536
50	2,141	2,119	*2,098*	*12.921*	0.294	0.356
40	2,174	2,157	*2,112*	*13.011*	0.204	0.247
30	2,220	2,197	*2,128*	*13.110*	0.105	0.127
20	2,251	2,236	*2,136*	*13.159*	0.055	0.067
10	2,292	2,272	*2,142*	*13.196*	0.018	0.022
Base	2,351	2,321	*2,145*	*13.215*		

Scenario 2 - Pumps below the cut off line move to the 55% cut off value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	2,029	2,010				
70	2,068	2,048				
60	2,097	2,082	*2,033*	*12.521*	0.694	0.840
50	2,141	2,119	*2,051*	*12.635*	0.579	0.701
40	2,174	2,157	*2,070*	*12.750*	0.465	0.563
30	2,220	2,197	*2,087*	*12.856*	0.358	0.434
20	2,251	2,236	*2,105*	*12.969*	0.246	0.297
10	2,292	2,272	*2,125*	*13.090*	0.125	0.151
Base	2,351	2,321	*2,145*	*13.215*		

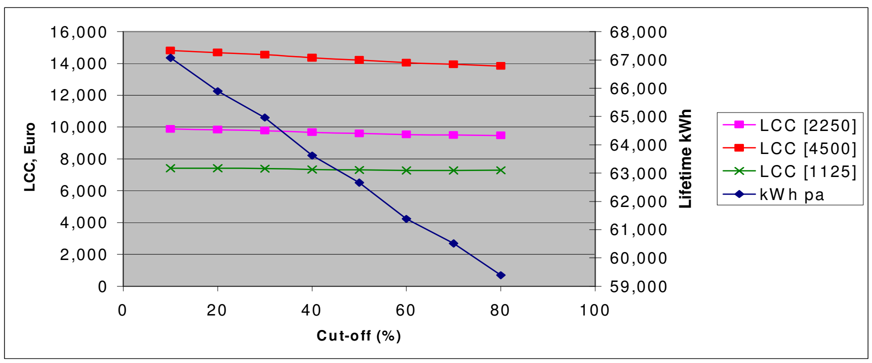
7.4.8 LCC Analysis Submersible Multistage Large Pumps (15m3/h at 88m, 2 pole)

mss_large **Mean (1000) hours pa**

Relative efficiency (from TUD analysis)	Efficiency difference relative to basecase	Relative energy performance (italics - derived)	Annual energy consumption (kWh pa) from MEEUP	Cut-off (%)	Relative cost (Additional % relative to basecase)	Calculated actual cost (Euros)	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
122.05	-5.22000	77.22000	4,697	80	10	1100	59,391	9,465
123.84	-3.43000	75.43000	4,786	70	5	1050	60,513	9,498
125.22	-2.05000	74.05000	4,854	60	2	1020	61,377	9,531
127.27	0.00000	72.00000	4956	**50**	**0**	**1000**	**62,662**	9,606
128.79	1.52000	70.48000	5,031	40	0	1000	63,615	9,676
130.94	3.67000	68.33000	5,138	30	0	1000	64,962	9,775
132.43	5.16000	66.84000	5,212	20	-1	990	65,895	9,833
134.31	7.04000	64.96000	5,305	10	-5	950	67,073	9,880
137.08	9.81000	62.19000	5,442	5				

	High (2000) hours pa			Low (500) hours pa		
Cut-off (%)	Annual energy consumption (kWh pa) from MEEUP	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)	Annual energy consumption (kWh pa) from MEEUP	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
80	9,395	118,782	13,830	2,349	29,696	7,283
70	9,572	121,026	13,945	2,393	30,256	7,274
60	9,709	122,755	14,042	2,427	30,689	7,276
50	9,912	125,324	14,211	2,478	31,331	7,303
40	10,063	127,229	14,351	2,516	31,807	7,338
30	10,276	129,924	14,549	2,569	32,481	7,387
20	10,423	131,791	14,677	2,606	32,948	7,412
10	10,610	134,147	14,810	2,652	33,537	7,415

Life (Years)	11
DCF	0.98000
Electricity (euros/kWh)	0.075
Assumed motor efficiency (%)	87
Maintenance etc (euros)	3000
Purchase price (Euro)	1000
Stock	1540000



Scenario 1 - Pumps below the line move to the minimum allowed value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	4,697	4,653	*4,688*	*7.220*	0.427	0.491
70	4,786	4,742	*4,755*	*7.323*	0.325	0.373
60	4,854	4,820	*4,799*	*7.391*	0.256	0.294
50	4,956	4,905	*4,855*	*7.477*	0.170	0.196
40	5,031	4,994	*4,889*	*7.529*	0.118	0.136
30	5,138	5,085	*4,927*	*7.587*	0.061	0.070
20	5,212	5,175	*4,945*	*7.615*	0.032	0.037
10	5,305	5,258	*4,959*	*7.637*	0.011	0.012
Base	5,442	5,374	*4,966*	*7.647*		

Scenario 2 - Pumps below the cut off line move to the 55% cut off value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	4,697	4,653				
70	4,786	4,742				
60	4,854	4,820	*4,705*	*7.246*	0.401	0.461
50	4,956	4,905	*4,748*	*7.312*	0.335	0.385
40	5,031	4,994	*4,791*	*7.378*	0.269	0.309
30	5,138	5,085	*4,831*	*7.440*	0.207	0.238
20	5,212	5,175	*4,874*	*7.505*	0.142	0.163
10	5,305	5,258	*4,919*	*7.575*	0.072	0.083
Base	5,442	5,374	*4,966*	*7.647*		

7.4.9 LCC Analysis Vertical Multistage Small Pumps (4m^3/h at 45m, 2 pole)

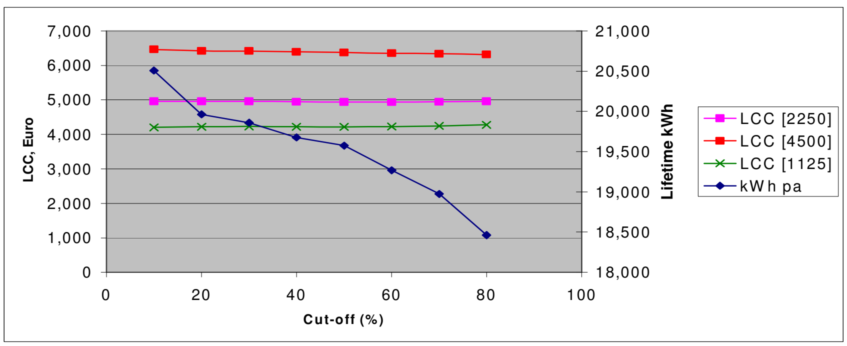
ms_small

Mean (1500) hours pa

Relative efficiency (from TUD analysis)	Efficiency difference relative to basecase	Relative energy performance (italics - derived)	Annual energy consumption (kWh pa) from MEEUP	Cut-off (%)	Relative cost (Additional % relative to basecase)	Calculated actual cost (Euros)	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
127.75	-5.68000	70.68000	1,279	80	10	1100	18,463	4,957
130.37	-3.06000	68.06000	1,315	70	5	1050	18,976	4,945
131.87	-1.56000	66.56000	1,335	60	2	1020	19,269	4,936
133.43	0.00000	65.00000	1356	50	0	1000	19,575	4,939
133.95	0.52000	64.48000	1,363	40	0	1000	19,677	4,946
134.89	1.46000	63.54000	1,376	30	0	1000	19,861	4,960
135.41	1.98000	63.02000	1,383	20	-1	990	19,962	4,957
138.19	4.76000	60.24000	1,421	10	-5	950	20,507	4,957
139.52	6.09000	58.91000	1,439	5				

	High (3000) hours pa			Low (750) hours pa		
Cut-off (%)	Annual energy consumption (kWh pa) from MEEUP	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)	Annual energy consumption (kWh pa) from MEEUP	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
80	2,558	36,926	6,314	639	9,231	4,279
70	2,629	37,952	6,339	657	9,488	4,247
60	2,670	38,539	6,353	667	9,635	4,228
50	2,712	39,150	6,377	678	9,787	4,219
40	2,726	39,353	6,392	682	9,838	4,223
30	2,752	39,721	6,420	688	9,930	4,230
20	2,766	39,925	6,424	691	9,981	4,224
10	2,841	41,013	6,464	710	10,253	4,204

Life (Years)	11
DCF	0.98000
Electricity (euros/kWh)	0.075
Assumed motor efficiency (%)	76.2
Maintenance etc (euros)	1500
Purchase price (Euro)	1000
Stock	2200000



Scenario 1 - Pumps below the line move to the minimum allowed value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	1,279	1,272	*1,278*	*2.811*	0.148	0.195
70	1,315	1,297	*1,304*	*2.869*	0.090	0.118
60	1,335	1,325	*1,317*	*2.898*	0.061	0.080
50	1,356	1,345	*1,329*	*2.924*	0.035	0.046
40	1,363	1,360	*1,332*	*2.931*	0.028	0.037
30	1,376	1,369	*1,337*	*2.941*	0.018	0.024
20	1,383	1,379	*1,338*	*2.945*	0.014	0.019
10	1,421	1,402	*1,344*	*2.957*	0.002	0.003
Base	1,439	1,430	*1,345*	*2.959*		

Scenario 2 - Pumps below the cut off line move to the 55% cut off value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	1,279	1,272				
70	1,315	1,297				
60	1,335	1,325	*1,284*	*2.825*	0.134	0.176
50	1,356	1,345	*1,299*	*2.859*	0.100	0.132
40	1,363	1,360	*1,313*	*2.888*	0.071	0.093
30	1,376	1,369	*1,321*	*2.907*	0.052	0.068
20	1,383	1,379	*1,329*	*2.924*	0.036	0.047
10	1,421	1,402	*1,337*	*2.941*	0.019	0.024
Base	1,439	1,430	*1,345*	*2.959*		

7.4.10 LCC Analysis Vertical Multistage Large Pumps (10m3/h at 42m, 2 pole)

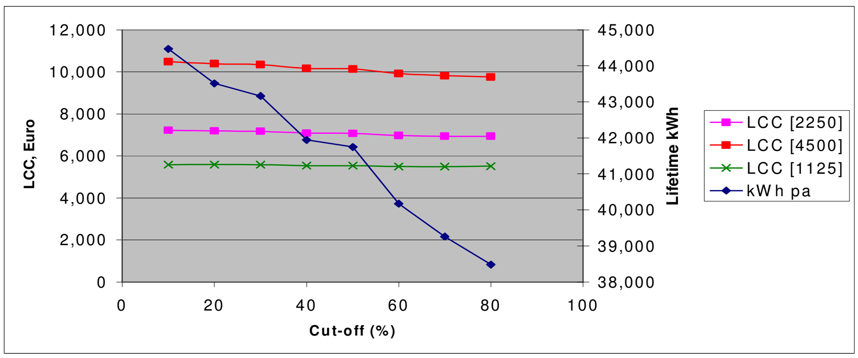
ms_large

Mean (1500) hours pa

Relative efficiency (from TUD analysis)	Efficiency difference relative to basecase	Relative energy performance (italics - derived)	Annual energy consumption (kWh pa) from MEEUP	Cut-off (%)	Relative cost (Additional % relative to basecase)	Calculated actual cost (Euros)	Lifetime electricity consumption (P1, kWh)	Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
123.93	-6.11000	78.11000	2,834	80	10	1100	38,480	6,928
125.48	-4.56000	76.56000	2,891	70	5	1050	39,259	6,936
127.22	-2.82000	74.82000	2,958	60	2	1020	40,172	6,973
130.04	0.00000	72.00000	3074	**50**	**0**	**1000**	**41,746**	7,068
130.38	0.34000	71.66000	3,089	**40**	**0**	1000	**41,944**	7,083
132.4	2.36000	69.64000	3,178	**30**	**0**	1000	**43,160**	7,172
132.97	2.93000	69.07000	3,204	20	-1	990	43,517	7,188
134.45	4.41000	67.59000	3,275	10	-5	950	44,469	7,219
134.83	4.79000	67.21000	3,293	**5**				

Cut-off (%)	High (3000) hours pa: Annual energy consumption (kWh pa) from MEEUP	High (3000) hours pa: Lifetime electricity consumption (P1, kWh)	High (3000) hours pa: Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)	Low (750) hours pa: Annual energy consumption (kWh pa) from MEEUP	Low (750) hours pa: Lifetime electricity consumption (P1, kWh)	Low (750) hours pa: Lifecycle cost (Purchase, Acquisition, Main & Electricity) (Euros)
80	5,667	76,960	9,757	1,417	19,240	5,514
70	5,782	78,519	9,821	1,445	19,630	5,493
60	5,916	80,345	9,925	1,479	20,086	5,496
50	6,148	83,491	10,137	1,537	20,873	5,534
40	6,177	83,887	10,166	1,544	20,972	5,541
30	6,356	86,321	10,345	1,589	21,580	5,586
20	6,409	87,033	10,387	1,602	21,758	5,589
10	6,549	88,939	10,487	1,637	22,235	5,584

Life (Years)	11
DCF	0.98000
Electricity (euros/kWh)	0.075
Assumed motor efficiency (%)	81
Maintenance etc (euros)	2000
Purchase price (Euro)	1000
Stock	550000



Scenario 1 - Pumps below the line move to the minimum allowed value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	2,834	2,801	*2,827*	*1.555*	0.114	0.140
70	2,891	2,862	*2,870*	*1.579*	0.090	0.111
60	2,958	2,925	*2,914*	*1.603*	0.066	0.081
50	3,074	3,016	*2,977*	*1.638*	0.031	0.038
40	3,089	3,081	*2,984*	*1.641*	0.027	0.034
30	3,178	3,133	*3,015*	*1.658*	0.010	0.012
20	3,204	3,191	*3,022*	*1.662*	0.006	0.008
10	3,275	3,239	*3,032*	*1.668*	0.001	0.001
Base	3,293	3,284	*3,033*	*1.668*		

Scenario 2 - Pumps below the cut off line move to the 55% cut off value

Cut-off (%)	Energy used at threshold of "band" (kWh pa)	Average energy used at mid-point of "band"* (kWh pa)	*Mean energy use if pumps with cutoff applied (kWh pa)*	*Total energy consumption of stock (TWh pa)*	Total energy savings - mechanical (TWh pa)	Total energy savings - electrical (TWh pa)
80	2,834	2,801				
70	2,891	2,862				
60	2,958	2,925	*2,839*	*1.561*	0.107	0.132
50	3,074	3,016	*2,872*	*1.579*	0.089	0.110
40	3,089	3,081	*2,905*	*1.598*	0.071	0.087
30	3,178	3,133	*2,939*	*1.617*	0.052	0.064
20	3,204	3,191	*2,973*	*1.635*	0.033	0.041
10	3,275	3,239	*3,007*	*1.654*	0.015	0.018
Base	3,293	3,284	*3,033*	*1.668*		

7.5 Calculation of energy savings

7.5.7 Estimation of energy savings – Manufacturer reaction Scenario 1: Moving worst pumps to minimum allowable efficiency

Tables 7-4 and 7-5 summarise the energy savings calculated for each type of pump at different cutoff levels.

Cut off (%)	ESCC S	ESCC L	ESOB S	ESOB L	MSS S	MSS L	MS S	MS L	ESCCi S	ESCCi L	Total Saving TWh pa
80	0.965	0.942	1.317	1.108	0.738	0.427	0.148	0.114	0.744	0.696	**7.199**
70	0.759	0.703	0.973	0.780	0.561	0.325	0.090	0.090	0.569	0.501	**5.349**
60	0.598	0.532	0.781	0.585	0.443	0.256	0.061	0.066	0.427	0.360	**4.109**
50	0.457	0.424	0.613	0.468	0.294	0.170	0.035	0.031	0.318	0.298	**3.108**
40	0.354	0.303	0.468	0.343	0.204	0.118	0.028	0.027	0.244	0.198	**2.286**
30	0.222	0.185	0.323	0.226	0.105	0.061	0.018	0.010	0.174	0.128	**1.450**
20	0.113	0.089	0.175	0.135	0.055	0.032	0.014	0.006	0.105	0.075	**0.800**
10	0.021	0.024	0.062	0.054	0.018	0.011	0.002	0.001	0.023	0.015	**0.232**

Table 7-4 Energy savings achieved by the introduction of cutoffs at 10% to 80% (Mechanical)

Cut off (%)	ESCC S	ESCC L	ESOB S	ESOB L	MSS S	MSS L	MS S	MS L	ESCCi S	ESCCi L	Total Saving TWh pa
80	1.146	1.047	1.564	1.316	0.894	0.491	0.195	0.140	0.884	0.773	**8.449**
70	0.901	0.781	1.155	0.926	0.679	0.373	0.118	0.111	0.676	0.556	**6.277**
60	0.711	0.591	0.927	0.695	0.536	0.294	0.080	0.081	0.507	0.400	**4.823**
50	0.542	0.471	0.728	0.556	0.356	0.196	0.046	0.038	0.377	0.331	**3.642**
40	0.421	0.337	0.555	0.407	0.247	0.136	0.037	0.034	0.290	0.220	**2.682**
30	0.263	0.205	0.383	0.268	0.127	0.070	0.024	0.012	0.207	0.142	**1.700**
20	0.134	0.099	0.208	0.161	0.067	0.037	0.019	0.008	0.124	0.083	**0.940**
10	0.025	0.027	0.074	0.064	0.022	0.012	0.003	0.001	0.028	0.016	**0.272**

Table 7-5 Energy savings achieved by the introduction of cutoffs at 10% to 80% (Electrical)

7.5.8 Estimation of energy savings – Manufacturer reaction Scenario 2: Moving worst pumps to mean efficiency level

Tables 7-6 and 7-7 summarise the energy savings calculated for each type of pump at different cutoff levels.

Cut off (%)	ESCC S	ESCC L	ESOB S	ESOB L	MSS S	MSS L	MS S	MS L	ESCCi S	ESCCi L	Total Saving TWh pa
80											
70											
60	0.912	0.881	1.234	1.027	0.694	0.401	0.134	0.107	0.698	0.646	**6.734**
50	0.778	0.733	1.028	0.833	0.579	0.335	0.100	0.089	0.585	0.528	**5.589**
40	0.647	0.594	0.837	0.659	0.465	0.269	0.071	0.071	0.476	0.419	**4.508**
30	0.518	0.465	0.680	0.518	0.358	0.207	0.052	0.052	0.375	0.321	**3.547**
20	0.373	0.326	0.502	0.373	0.246	0.142	0.036	0.033	0.273	0.224	**2.527**
10	0.199	0.176	0.286	0.216	0.125	0.072	0.019	0.015	0.152	0.124	**1.383**

Table 7-6 Energy savings achieved by the introduction of cutoffs at 10% to 80% (Mechanical)

Cut off (%)	ESCC S	ESCC L	ESOB S	ESOB L	MSS S	MSS L	MS S	MS L	ESCCi S	ESCCi L	Total Saving TWh pa
80											
70											
60	1.083	0.979	1.465	1.220	0.840	0.461	0.176	0.132	0.829	0.718	**7.903**
50	0.924	0.815	1.221	0.990	0.701	0.385	0.132	0.110	0.694	0.586	**6.558**
40	0.768	0.661	0.994	0.783	0.563	0.309	0.093	0.087	0.566	0.465	**5.289**
30	0.615	0.517	0.807	0.616	0.434	0.238	0.068	0.064	0.446	0.357	**4.162**
20	0.443	0.363	0.596	0.443	0.297	0.163	0.047	0.041	0.324	0.249	**2.965**
10	0.237	0.196	0.339	0.257	0.151	0.083	0.024	0.018	0.180	0.138	**1.623**

Table 7-7 Energy savings achieved by the introduction of cutoffs at 10% to 80% (Electrical)

7.5.9 Key results from LCC Analysis

For all pumps working under the standard running hours (except small vertical multistage pumps), there is a decreasing LCC with higher cutoffs. It should be noted that while the actual differences in LCC indicate that improving pump efficiency will save the consumer money, the differences are proportionately not that large. At reduced (50%) running hours, all submersibles also show an increasing LCC with higher cutoffs.

It should be noted that all the LCC analysis was using an assumed relationship between costs and efficiency. For some types of pumps, small differences in this relationship would impact the shape of the curves.

The non energy use costs of pumps are proportionately higher for the multistage pumps.

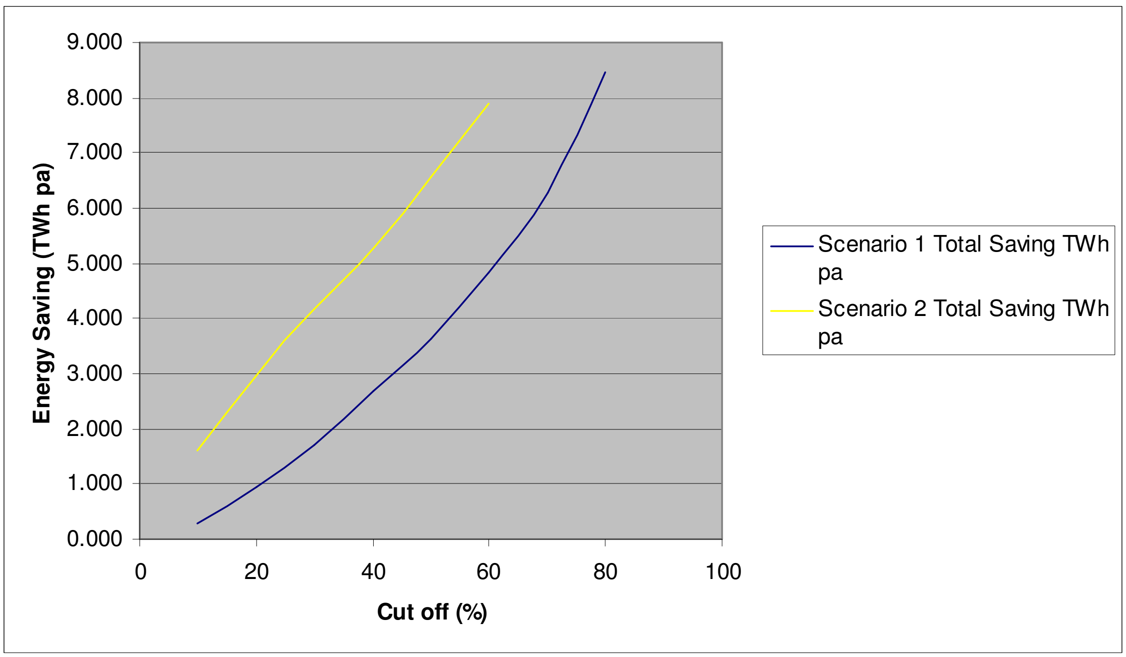


Figure 7-2 Energy savings (Electrical) from setting the cutoff at different levels, under scenarios 1 and 2.

The two scenarios analysed are only indicative of the manufacturer's reactions to any policy options. They are both if anything slightly pessimistic, as if manufacturers are re-designing any pumps, they are likely to replace them with a product that exceeds the current average efficiency.

Scenario 1 assumes manufacturers do the minimum possible. The cumulative savings at low cutoffs are only small, since only a few pumps are being impacted, and then the amount by which they are to be improved is only small. Scenario 2 is seen as being much more realistic, with 75% of the 40% cutoff savings achieved at the 20% cutoff under this scenario.

For a given cutoff, the split of energy savings for the different pumps are shown in figure 7-3 below.

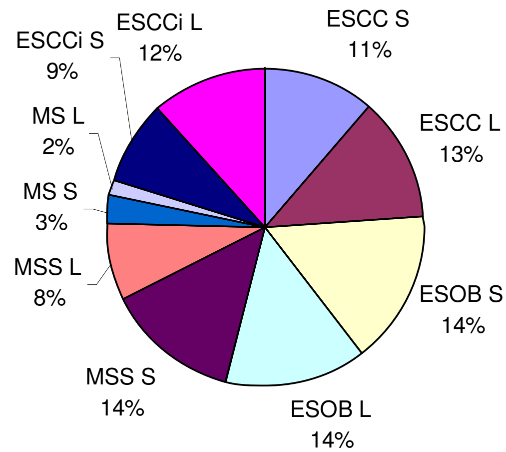


Figure 7-3 Split of energy savings, by type of pump, for equal cutoffs.

7.6 Long term targets (BNAT) and systems analysis.

While it is considered that there is little scope at present for pushing the efficiencies of the best pumps even higher, the use of power electronics to enable induction (or other) motors to be run at speeds other than the usual 1450 or 2900 rpm dictated by 50Hz induction motors will give further room for improvement in two ways:

- Freedom to design the hydraulics for the optimum motor speed, rather than being constrained to work at the nearest speed available.
- Potential to vary the speed of the motor to match actual demand.

This will give considerable additional energy savings, but this is outside the scope of this study.

Improving the approach to pump system design including 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 whole pumping system. The SAVE study[25] identified energy savings associated with these measures as follows:

- Selecting better sized pump: 4%
- Better installation / maintenance: 3%
- Better System Design: 10%
- Better System Control: 20%

[25] SAVE study on improving the efficiency of pumps, AEAT for European Commission, 2001.

7.7 Summary

This section has presented the analysis of the cost and energy savings from improving pump efficiency through removing the worst n% of pumps from the market. This is based on a statistically accurate analysis of the efficiencies of pumps sold on the market today, but the costs of different types of pumps and typical duty patterns are best estimates only.

Life Cycle Costing analysis has shown that (with the exception of some vertical multistage pump scenarios) removing the worst 80% of pumps from the market will still give the consumer a reduced life cycle cost through the reduced energy cost of improved pumps.

End suction types of pumps account for 73% of the estimated energy savings, (assuming that the same percentage of worst performing pumps is removed from each category).

This method is based on data provided by the detailed analysis of over 2,500 pumps by Technical University Darmstadt, (Annex 3).

For many products, legislation to remove the worst performing products will lead to a “bunching” of products just over the minimum threshold. This has been used as the first scenario. However, because many of the worst performing pumps are actually very old designs, if they were to be re-designed, they would probably achieve at least the basecase (mean) efficiency. The energy savings from this more optimistic scenario 2 have also been estimated.

Energy savings of 2.7 – 5.3TWh pa (electrical) can be achieved by removing the worst 40% of pumps from the market, and 8.4 TWh pa (electrical) can be achieved if all pumps below the 80% cutoff were raised to the 80% cutoff level. The exact value of energy saved by altering the cutoff depends on the industry reaction to any legislation, but it is expected that the savings would be towards the upper end of this range, c. 4.8 TWhpa.

8 Policy, Impact and Sensitivity Analysis

8.0 Overview

8.0.1 Summary

This chapter summarizes the outcomes of all previous tasks relevant for this chapter, it looks at suitable policy means to achieve the savings potential e.g. implementing LLCC as a minimum and BAT as a promotional target, using legislative or voluntary agreements, labelling and promotion. It draws up scenarios in the period 1990 – 2020 quantifying the improvements that can be achieved vs. a Business-as-Usual scenario. It makes an estimate of the impact on consumers as described in Appendix 2 of the Directive, explicitly. In a sensitivity analysis of key cost-effectiveness parameters, the robustness of different possible outcomes is analysed. Possible impacts on the pump manufacturing industry are also presented.

Two scenarios are modelled in this section, showing savings compared to the "business as usual" scenario (figure 8-1):

- Removal of the worst 20% of pumps in the timescale shown, leading to energy savings of 2.7TWh pa by 2020, and longer term energy savings of 3.1TWh pa (at 2020 usage levels) when all the old stock has been removed.
- Removal of the worst 40% of pumps in the timescale shown, leading to energy savings of 3.56TWhpa by 2020, and longer term energy savings of 5.8TWh pa (at 2020 usage levels) when all the old stock has been removed.

Under the business as usual scenario, energy consumption will increase to 166TWh pa by 2020.

Efficiency levels corresponding to each of the four policy scenarios shown can be derived from the "C" values shown in table 8.5. Because for each type of pump there are different minimum efficiency values for each flow:head combination, it is not possible to quote a single efficiency value for each of the different policy options. Instead, the "C" value is used to calculate the minimum efficiency level for any style of pump at any particular pump duty point.

Policy Option	Date
HEPs definition to allow labelling of top 20% of pumps in the market	2010
Removal of worst 10% of pumps from the market	2010
Removal of worst 20% of pumps from the market	2013
Removal of worst 30% of pumps from the market	2016
Removal of worst 40% of pumps from the market	2019

NB This is based on the current distribution of pumps

Figure 8-1 Summary of policy recommendations

Because there is little difference in price or technology in improving the efficiency of the types of pumps considered in this study, manufacturers are likely to replace non-compliant pumps with models beyond the new MEPS. The study therefore analysed the impact of various "cutoff" scenarios under two anticipated manufacturer reactions:

- Replacement with pumps on the new MEPS line (worst case)
- Replacement with pumps at the (current) 55th percentile point (reasonable to optimistic expectation).

The impact is estimated to be much closer to the latter of these two scenarios.

8.0.2 Pumps – overview

The study terms of reference set out the scope of the study to include water pumps in the following applications: Commercial Buildings, Drinking Water, Agriculture and the Food Industry**.**

These are regarded as mass produced commodity types of pump, where the user will not spend so much effort in specifying the optimum type, and so minimum pump efficiency standards of the type considered in this study are seen as being beneficial for reducing the environmental impact of pumps.

The types of (rotodynamic) pump considered in the study are:

- Single stage close-coupled (end suction close coupled) (ESCC)
- In –Line ESCC pumps (ESCCi)
- Single stage Water (end suction own bearing) (ESOB)
- Submersible multistage pumps; (4” & 6”) (mss)
- Vertical Multistage Water Pumps (ms)

This study estimates that there are a total of 17M installed pumps of these types in the EU 27, with sales of 1.5M pa, worth 1,500 Meuros pa. They consume a total of 137 TWhpa of energy, with an energy saving potential estimated at 5.8TWh pa by 2020, (in the hypothetical reference case that the 40% worst pumps were all removed from the market in 2010), equivalent to 3.5%. These pumps will be driven by an induction motor, with the parallel Lot 11 study on motors making separate recommendations on policy options for the motor. All of these pumps are centrifugal in style, and so operate on identical physical principles, but the two multistage designs have several stages in series in order to generate higher heads.

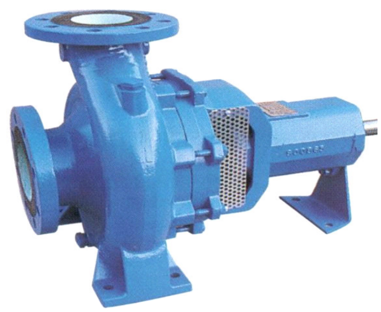


Figure 8-2 A typical End Suction Own bearing pump

For the types of pumps considered in this study, there are no fixed “standard” ratings as there for example with induction motors. Instead, manufacturers each offer a slightly different range of pumps with a variety of head and flow ratings. It is therefore not possible to have a simple table of minimum efficiencies against pump duty. This study is based on a new method of analysis that overcomes this problem.

The scope of this study is restricted to the pump only, but it is noted that there are much larger energy savings to be found by considering the whole system (including also the pipework, motor, controls and other components), However, system energy savings have proven so far to be difficult to achieve via regulatory action, as it is hard to define what is a fair energy performance level of an individual system. System energy savings are therefore best addressed by education-based actions, but it is recognised that this will only achieve a small portion of the total theoretical system energy savings. Hence the importance of implementing measures on the individual component, which should achieve a very high proportion of the energy savings potential of the types of pump identified in this report.

An important component that is closely related to the pump is the motor, which will often be supplied as a combined “pumpset.” Policy options for the motor are considered separately in the parallel Lot 11 EUP Motor study. It is not recommended that implementing measures on the combined pumpset should be considered, rather that the two products should be subject to individual implementing measures.

8.0.3 The pump system

A pump will be described in a catalogue in terms of head, flow and, usually, power. In order to include a power curve, a specific gravity of unity is used (i.e. a density of 1000 kg/m^3), in other words the catalogue shows the power absorbed when pumping clean cold water. The actual mechanical power consumption is calculated as P_{mech} = Q x H x density x g / pump efficiency. This means that it is not possible to give standard curves of power consumption against duty for all liquids, as generally the power consumption varies with fluid properties – although for this study because we are only considering clean water this is not a problem. In addition, the same pump can be used with different motor speeds and impeller sizes, which adds additional variation.

Because a pump will on average spend most of its life operating below its Best Efficiency Flow, part flow operation is usually more critical from an energy perspective. Furthermore, pumps can be designed to have different trade-offs between full and part flow efficiency. It is therefore important that performance at part flow is taken account of in the analysis.

There is no "standard" flow distribution pattern for the types of pumps that are being considered in this study, and so an assumed pattern has been used in the analysis of energy consumption.

8.0.4 Method of analysis

The MEEUP model states that this should be calculated based on actual and test standard conditions. However, there is currently no test standard condition, and so in order to derive the basecase model, an assumed flow profile was used, based on the experience of the study team, (table 8-1).

% of BEP flow	% of time at this flow
50	25
75	50
100	20
125*	5

*(Note that as shown in section 3.1, it is permissible to use many types of pumps "beyond" their rated flow point, providing that for example the NPSH is still adequate and that the motor has adequate power.)

Table 8-1 Proportion of time the pump is assumed to operate at each flow, (all types except End Suction Close Coupled in line).

End Suction Close Coupled In line pumps are used predominantly in heating applications, and so here the Blauer Engel distribution is used. This is shown in figure 8-3, and is described in more detail in the Lot 11 circulator report.

Flow (%)	Time (%)
100	6
75	15
50	35
25	44

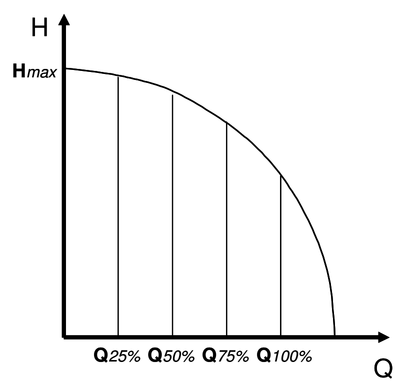


Figure 8-3 Assumed ESCCi load profile as described by the German *Blauer Engel* energy labelling scheme

8.1 Policy and scenario analysis

8.1.1 Precise definition of the types of pumps covered (Annex VII part 1)

The following types of pumps are in scope:

Pump types:
- Single stage end suction and in-line pumps, (incl. EN 733 or equivalent)
- Vertical multistage pumps with in-line design for the pipe connections
- Submersible multistage pumps for deep wells

Applications:
The scope **includes** the following applications:

- Pumps for water pumping applications:
- Municipal drinking water supply
- Building services for heating, air conditioning and for drinking water (residential, industrial, transport services and public buildings)

This includes clean water duty only, in any material (including cast iron, bronze, stamped stainless steel or plastic).

The scope **excludes** pumps used in other applications, such as chemical and petrochemical processes, high temperature heating systems with water or oil as heat transfer liquid, energy production etc. Small domestic shower, garden pond and rain water pumps are also excluded. Glandless heating circulators are excluded but are within the scope of the separate Lot 11 Circulator study.

1.) Single stage end suction Water (end suction own bearing ESOB), (end suction close coupled ESCC, includes In-line ESCCi as a sub-category)

- Operating temperature between -10 and +120°C
- Single suction, single impeller
- All efficiencies are based on the full (untrimmed) impeller.

For definition of specific speed (n_s) see paragraph 1.1.13.

Limits: QBEP min = 6 m^3/h, ns min = 6 rpm,
ns max = 80 rpm, P max = 150 kW
H max = 90 m at 1450 rpm,
H max = 140 m at 2900 rpm

2.) Vertical Multistage Water Pumps

- Operating temperature between -10 and +120°C.
- Vertical multistage pumps in in-line and ring section design.
- 2900 rpm pumps only.
- The efficiency is measured and judged on the basis of a 3 stage pump. At a higher number of stages the efficiency by nature increases.

Limits: QBEP ≤ 100 m^3/h, n = 2900 rpm

3.) Submersible multistage pumps; Nominal size 4" and 6"

Submersible multistage pumps are those that are used to pump water from boreholes in the ground. These boreholes are in standard sizes, with 4" and 6" being the most popular.

Only pumps with a nominal size of 4 or 6 inch are in scope.

8.1.2 Existing initiatives - Europump circulator voluntary labelling scheme

The most significant voluntary scheme to date for pumps generally is the **Europump circulator voluntary labelling scheme**. This is discussed in the parallel EuP Circulator report. It should be noted that this scheme is only possible because the product is used in defined systems with defined (or typical) duty patterns, and so it is not easily extendable to other classes of pump operating in systems with greatly varying characteristics. As an example, circulators will operate in a central heating system with fairly similar annual operating hours, and similar static/friction heads. The variability (eg different running hours according to climate or control method) can be dealt with in a quantitive way by defining different sub-groups of product application types. But general "water pumps" can have a duty that varies greatly from low hours (eg fire pumps) to high hours (constant water supply pressurisation), and from no head circulation systems to high head boost systems.

It is therefore not possible to identify different sub-sectors of the market in the same way, and hence impractical to simply extend this methodology to other pumps in the same way.

8.1.3 Existing initiatives – Europump/SAVE pump efficiency selection guide

Although not a regulatory measure, the **Europump/SAVE pump efficiency selection guide**[26] gives procurement advice on the efficiency that can be expected for End Suction close coupled and own bearing pumps. Of particular relevance to this study, it includes guidance on close coupled and end suction own bearing sub-categories of pump, which represents 50 % of the total energy use of pumps in the EC[27].

The purpose of the European Guide was to help purchasers choose pumps of good efficiency. It shows six plots of pump efficiency against flow, for End Suction Close Coupled, End Suction Own Bearings and Double entry Split Casing pumps, running at two and four pole speeds. To produce the plots, hundreds of pump efficiencies were obtained from maker's catalogues. From these, two lines were derived for each plot. The upper line represents the mean of the catalogue best efficiencies and is ideally the efficiency a user should aspire to for his pump main duty. However, since it is not always possible to source the ideal pump, another line was added, five to ten points below the upper line, to cover efficient pumps for which the required duty is away from the best efficiency point. Selection below the lower line was considered unacceptable unless there were exceptional circumstances.

It was felt that the concept of Specific Speed was too complicated to explain to the average pump buyer, so it was eliminated by using its effect in a novel way. A relationship was derived between pump Specific Speed and the efficiency drop from that at the optimum Specific Speed. This single relationship was felt to adequately satisfy the limited range of pump types being considered. It allowed correction curves for head to be applied to the plots of efficiency against flow. Thus a pump user can now enter the curves for the pump type he has chosen with his desired head, flow and speed and determine the efficiency levels against which he can judge the adequacy of the pump efficiency he is being offered by a supplier. It should be noted that this method involves a small approximation which makes it fine for pump selection, but probably inappropriate for legislation because of the size of these errors in some sizes.

26 The guide "European Guide to Pump efficiency for Single Stage Centrifugal Pumps" is shown in Appendix 3, and is also available as a free downloadable pdf document from www.europump.org, under "Europump Guides".
[27] Ref Europump data (as shown in appendix). This figure is still to be ratified, but shows the importance of these types.

The Guide also includes notes on minimising the loss of pump efficiency with time, other costs involved in the total operating system, and shows a comparison between a curve taken from the Guide and curves from four other sources.

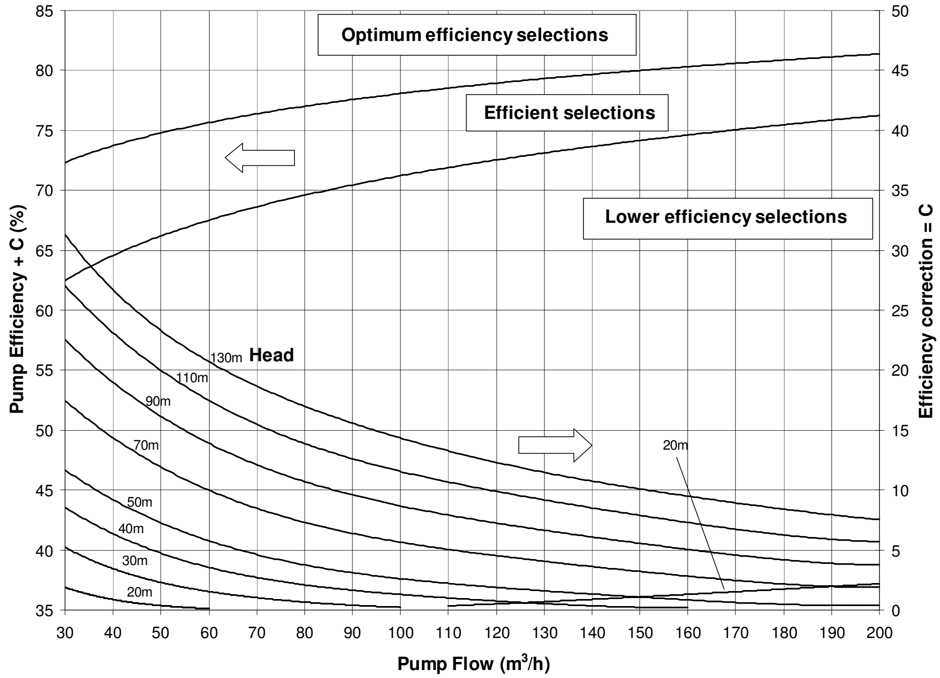


Figure 8-4 Typical plot from the European Guide (End Suction Own Bearings Pumps)

Worked example (ref figure 1.22):

Chosen pump type: End suction with own bearings.
Chosen duty for maximum efficiency: 80 m^3/h at 110 m.
Quoted pump performance: 60% efficiency at 2900 rev/min.
(Check materials, suction performance, etc, are satisfactory)

From graph: 'C' = 14.
Plot on graph: 'Pump Efficiency + C' = 60 + 14 = 74%.
The graph suggests that an additional 3 points of efficiency or more is possible.

8.1.4 Legislation at Member State Level

There is no relevant legislation at member state level. This reflects the difficulty in characterising pumps by efficiency – something which has been addressed and resolved as part of this study.

8.1.5 Impact of existing EU legislation

There is no existing EC legislation applicable to the pumps in the scope of this study.

8.1.6 Third Country Legislation

There are two pump efficiency schemes, one in Korea and the other in China. Given the importance of Far East markets for European and other manufacturers, these are of particular interest to the study. If any EC schemes were able to be devised on the same or similar basis to these existing national schemes, then it would make it easier for users to evaluate pumps from any supplier on the same basis. An important aspect of this study will be to determine the "best" method, with comparisons made with these existing schemes in section 8.

8.1.6.1 Korea

Official information on this scheme is not available, but the study group's understanding is summarised below.
The scheme is aimed at the voluntary certification of pump efficiency, with the objective of encouraging the development of new efficient pumps. It is devised by the Korea Energy Management Corporation (KEMCO).
The pumps targeted are centrifugal water supply pumps of the single stage and multistage types with discharge branches from 25 to 200mm bore, running at 2 pole and 4 pole speeds.
The requirements of the scheme are:

- The Flow at Best Efficiency must be within a 'specified range' for each discharge branch bore (different flow ranges for single stage and multistage).
- The Best Efficiency value must exceed a figure shown on a plot of efficiency against flow, designated the 'A' efficiency.
- The efficiency at all flows within the 'specified range' for a pump's discharge bore must exceed a figure shown on another plot of efficiency against flow, designated the 'B' efficiency (about 12 points of efficiency below the Best Efficiency value). This is intended to encourage 'broad' high efficiency curves.

Perceived problems inherent in this scheme include:

- There is, in effect, a tie-in between efficiency and discharge branch bore.
- The same target efficiencies are given for single stage and multistage pumps.
- The all-important effect of Specific Speed (and therefore pump generated head) appears to be ignored.
- A pump whose Best Efficiency flow is near the bottom end of the 'specified range' for its discharge branch bore has little hope of satisfying the 'B' efficiency at the top end of the 'specified range'.

8.1.6.2 China

GBT13007 –1991 is a standard of recommended efficiencies that was devised by the Chinese pump manufacturers. It is believed that it is currently only available in Chinese.

The scheme gives a graph of efficiency against specific flow for each of the types of pump included in the scheme:

- Single stage centrifugal pumpsfor freshwater pumping (5 – 10,000m3/h).
- Multiple stage pumps for clean water, (5 – 3,000m3/h).
- Petrochemical pumps (5 – 3,000m3/h).

There is also a correction factor (or efficiency allowance) that is added to the actual pump efficiency, which takes account of the actual head and flow – ie it takes account of the limitations of specific speed on pump efficiency.

There are two lines, for ns = (20 – 130) and (210 – 300).

For each pump, it must meet or exceed minimum efficiency criteria:

- The 'A' point, which is at rated (100%) flow.
- The 'B' points, which are at 50/60% (mans can chose) and 120% rated flow. The pump must exceed the B allowance at both of these points.

This therefore takes account of both peak and off-peak efficiency.

A mandatory National Standard of the People's Republic of China came into effect in December 2005. Although using a very similar methodology to that of GBT13007-1991, the levels are, as a result of lobbying by manufacturers, much lower. The pumps covered are for clear water and are of the types:

- Single Stage (single and double suction)

- Multistage
- Multistage Well

Mandatory minimum values of best efficiency are specified for the first time. The efficiency for each pump type is first derived from plots of best efficiency against flow and then corrected for Specific Speed, using the same correction curve for all pump types. This correction is very similar to that chosen for the EC SAVE study. This gives a 'Minimum Allowable' efficiency level which is quite low, and which is intended to eliminate the worst 15% of pumps from the market. Because of the details of the method, there is a "jump" in at ns = 300 – 600.

There is also an 'Evaluating' efficiency. Pumps achieving this level are allowed to be classed as 'Energy Conservation pumps'.

A new Standard is currently being proposed which includes a 'Target Minimum Allowable' efficiency level, which is expected to come into effect in 2010. This 'Target' is set at a level which would eliminate 90% of the 6000 pumps which have been analysed.

The comment is made by the author that the correction factor is actually more generous than the US ANSI/SP, and in practice Chinese pumps are considerably less efficient than US or European pumps.

Table 1.3 is a summary of the scope of each of the schemes;

Pump Type	SAVE / Europump	Kemco (Korea)	China	***Proposed EUP measures***
ESOB	X	X	X	***X***
ESCC	X	X	X	***X (inc ESCCi)***
Multistage Water	-	X	X	***X***
Multistage Well	-	-	X	***X***

Table 8-2 Scope of existing international schemes

8.1.7 Specific ecodesign requirements: minimum energy efficiency levels

The study looked at all relevant environmental impacts of the considered pumps. The most important environmental impact is by far the energy consumption at use, which dominate (see section 5.4.5) the total environmental impacts during the whole life-cycle. This is why ecodesign requirements are proposed only on energy consumption.

8.1.8 Calculation of the incremental energy savings from progressively removing the least efficient pumps from the market ("Manufacturers' reaction" to different cutoffs)

Table 8.5 gives the relative efficiencies at each decile of stock for each style of pump, from which the energy savings for removing different deciles of stock are calculated. Because the reaction from manufacturers is unknown, this was calculated on the basis that banned pumps would be replaced by pumps just on the threshold of those permitted, and also on an alternative scenario that pumps would be replaced by pumps of a higher level, (the 55th percentile). The actual ("manufacturers reaction" refered to in table 8-5) value used was calculated to be 80% between the two, weighted towards the higher level. This weighting is justified on the basis that there is little, if any, additional cost to the manufacturer of making improved pumps over the mid efficiency range.

The following table calculates the incremental energy savings in the following way:

Row 1 shows the scenario where manufacturers replace banned pumps with those that just exceed the cutoff
Row 2 shows the scenario where manufacturers replace banned pumps with those of much improved pumps.
Row 3 shows the estimated real life situation.
Row 4 shows the additional energy savings from the removal of each decile.
Row 5 shows the annual energy savings from the introduction of a policy to remove this decile. These numbers are used as the basis of the energy saving calculations in table 8-4.

Cutoff ***(percentage of worst performing pumps removed from the market)***	**10%**	**20%**	**30%**	**40%**	***40% adj* to 2020***	***70% adj to 2020***
Scenario 1 (manufacturer response) TWh pa	0.272	**0.940**	1.700	**2.682**	***3.256***	***4.800***
Scenario 2 (manufacturer response) TWh pa	1.623	**2.965**	4.162	**5.289**	***6.421***	***7.900***
Est. actual manufacturers response (80% of the way between scenario 1 and scenario 2) TWh pa	1.353	**2.560**	3.670	**4.768**	***5.788***	***7.280***
Additional total savings from each decile TWh pa	1.353	**1.207**	1.110	**1.098**		
Additional savings from each decile pa (based on the assumed 11 year life) TWh pa	0.123	**0.110**	0.101	**0.100**		

Table 8-5 Incremental energy savings from different cutoffs showing derivation of expected energy savings for different cutoffs. (Adj* means adjusted for expected sales growth of 1.5% pa).

The scenario analysis in table 8-5 shows that energy savings of 2.7 – 5.3TWh pa (electrical) can be achieved by removing the worst 40% (by efficiency) of pumps from the market, depending on the manufacturers reaction to any policy options. It is therefore expected that the energy savings from adopting the recommended 40% cutoff would be towards the upper end of this range, c. 4.8 TWhpa,

8.1.8 Eco-impact of different policy options for reference years (2 policy scenarios and business as usual scenario shown)

From 8.1.11, it is shown that the eco-impact of each policy option can be calculated in terms of the energy saving only[28]. Three policy scenarios are shown:

1.) **Business as Usual (BaU)**
It is assumed that the Business as Usual scenario would show no improvement in the energy performance of pumps. This is because there is no evidence to suggest any change in the efficiency of purchased products. The bau would lead to energy consumption of 166 TWh pa by 2020.

2.) **Removal of the worst 40% of performing pumps from the market**
For some other types of products manufacturers have been observed to re-design products to just meet the mandatory efficiency levels. But for the pumps considered in this study there is, over a limited range, little if any cost difference to the manufacturer for producing more efficient pumps. Manufacturers may therefore be expected to launch new pumps with efficiencies considerably higher than the proposed minimum efficiency level.

3.) **Removal of the worst 20% of performing pumps from the market**
This alternative scenario removes just the worst 20% of pumps from the market, phased as in scenario 2, ie the 20% cutoff being implemented in 2015.

[28] It should be noted that it is not possible to refer to particular values of minimum efficiency for each cutoff, as each cutoff relates to a whole “plane” of Q.H values and corresponding “C” values as described in section 8.1.12.1.

The phased withdrawal of the worst performing deciles means that much of the impact of these policy options will not be seen until after 2020. Therefore an additional ref 1 line is also plotted to indicate what the long term energy savings will be, which is based on the hypothetical immediate withdrawal of the worst 40% of pumps in 2010. *Note that that this is not a recommended policy option, rather it is for reference only.* In order to address the question "How much energy could possibly be saved in pumps?", an additional reference line is included that shows the energy savings if the 70% worst pumps were withdrawn from the market in 2010.

The estimated energy saving consumption for each reference year (2010, 2015, 2020) is calculated in table 8-4. The results are presented in figure 8-5, with the estimated 1990 reference energy consumption was 115TWh pa, but this is omitted for clarity. This shows 1.) bau, 2.) removal of worst 40% of pumps from the market, 3.) removal of worst 20% of pumps from the market, ref 1 removal of worst 70% of pumps from the market.

Year / Energy TWh pa)	1995	2007	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1.) Business as Usual (BAU) Scenario													
Total energy consumption pa	**114.6**	**137.0**	**143.3**	**145.6**	**147.5**	**149.7**	**152.1**	**154.3**	**156.6**	**159.1**	**161.4**	**163.9**	**166.3**
Data used in energy saving calculations													
Removal of lowest decile (0-10%)			0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123	**0.123**
Removal of 2nd lowest decile (10-20%)						0.110	0.110	0.110	0.110	0.110	0.110	0.110	**0.110**
Removal of 3rd lowest decile (20-30%)									0.101	0.101	0.101	0.101	**0.101**
Removal of 4th lowest decile (30-40%)												0.100	**0.100**
2.) Policy Scenario - Removing worst 40% of pumps from the market													
Total for year			0.123	0.123	0.123	0.233	0.233	0.233	0.334	0.334	0.334	0.433	**0.433**
Cumulative energy savings			0.123	0.246	0.369	0.602	0.834	1.067	1.401	1.734	2.068	2.501	**2.935**
Cumulative energy savings - adj for growth			0.129	0.261	0.397	0.658	0.926	1.202	1.601	2.014	2.436	2.992	**3.563**
Total energy consumption pa		**137.0**	**143.2**	**145.4**	**147.2**	**149.1**	**151.1**	**153.1**	**155.0**	**157.0**	**158.9**	**160.9**	**162.8**
2.) Policy Scenario - Removing worst 20% of pumps from the market													
Total for year			0.123	0.123	0.123	0.233	0.233	0.233	0.233	0.233	0.233	0.233	**0.233**
Cumulative energy savings			0.123	0.246	0.369	0.602	0.834	1.067	1.300	1.533	1.765	1.998	**2.231**
Cumulative energy savings - adj for growth			0.129	0.261	0.397	0.658	0.926	1.202	1.486	1.779	2.080	2.390	**2.708**
Total energy consumption pa		**137.0**	**143.2**	**145.4**	**147.2**	**149.1**	**151.1**	**153.1**	**155.1**	**157.3**	**159.3**	**161.5**	**163.6**
Ref 1 Energy savings from immediate removal of 40% worst pumps in 2010		0.000	0.453	0.921	1.400	1.895	2.405	2.928	3.468	4.026	4.595	5.184	**5.788**
Ref 1 Energy use from immediate removal of 40% worst pumps in 2010		**137.0**	**142.8**	**144.7**	**146.1**	**147.8**	**149.7**	**151.3**	**153.1**	**155.0**	**156.8**	**158.7**	**160.5**
Ref 2 Energy savings from immediate removal of 70% worst pumps in 2010		0.000	0.692	1.407	2.138	2.893	3.673	4.471	5.295	6.147	7.017	7.915	**8.838**
Ref 2 Energy use from immediate removal of 70% worst pumps in 2010		**137.0**	**142.6**	**144.2**	**145.4**	**146.8**	**148.4**	**149.8**	**151.3**	**152.9**	**154.4**	**155.9**	**157.5**

Table 8-4 Calculation of energy savings under different policy options and two reference scenarios.

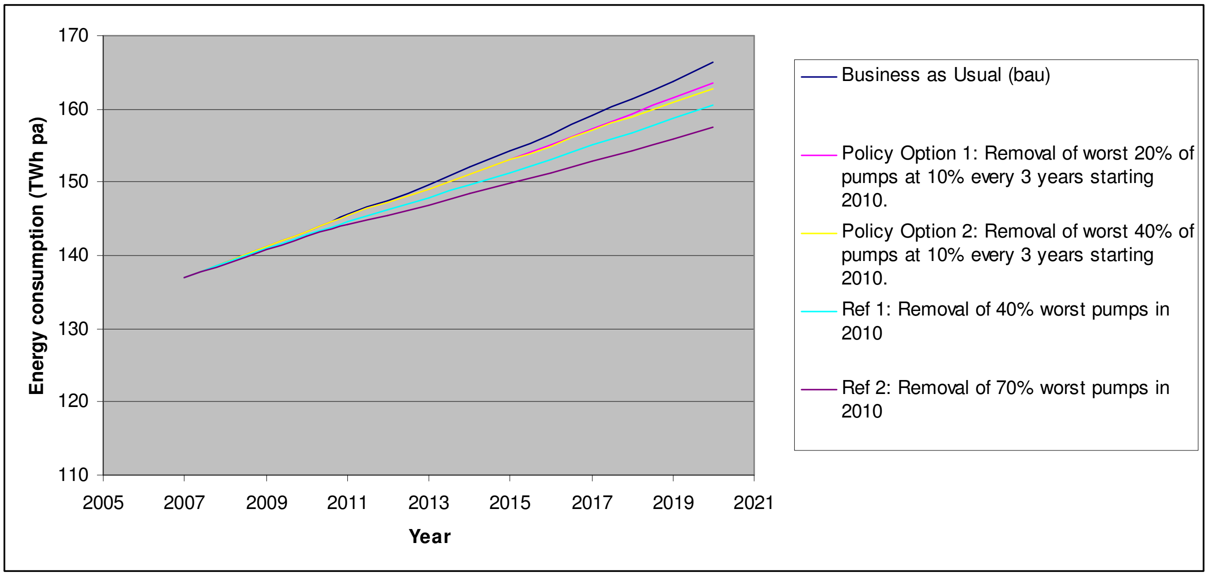


Figure 8-5 Projected pump energy consumption to 2020 under different scenarios.

8.1.9 Labelling

In addition to this minimum efficiency measure, the top 20% percentile of pumps should be defined as particularly efficient pumps. This would enable these top performing pumps to be formally recognised with a label, and in some countries financial or other incentives might even be offered to encourage the use of these pumps. However, it should be recognised that in general manufacturers will offer a family of pumps that has been developed over a long period of time, and so the efficiencies of individual pumps within a range are likely to be at a wide range of relative efficiency values. Therefore, without considerable additional development work, it is unlikely that any manufacturer would have an entire range of pumps that would meet the efficiency value. This is why it is suggested that the band should be set at 20% rather than a smaller proportion of products (eg 10-15%) of the market as seen with other products.

8.1.10 Option of premature replacement of pumps

For many of the pumps and scenarios assumed, the Life Cycle Cost analysis shows that while there is a reduction in cost to the consumer from moving to a more efficient pump, it is likely to be insufficient to tempt consumers to purchase a more efficient replacement pump before the existing one fails. There is also a considerable cost in fitting a new pump, and often a cost of process downtime during the replacement. **It is therefore thought that a scheme to promote the premature replacement of lower efficiency pumps would not be appropriate.**

8.1.11 LCC analysis of the different technology options

For the types of pumps considered in this study, there are no distinct technology differences between the worst and best performers, rather the differences are due to design detail and manufacturing precision. There is therefore no concept of Best Available Technology (BAT) or Best Not Available Technology (BNAT). However, for each type of pump, there will be an efficiency of pump that exhibits the least lifecycle cost (LLCC), and it is this concept that is used as one of the inputs when considering what implementing measures are appropriate.

8.1.12 Basis of legislation – the proposed pump efficiency classification Scheme

8.1.12.1 Basis of the scheme

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

Different types of pumps must have different efficiency criteria, with the common 2-pole and 4-pole speeds of each type being separately analysed within each category of pump.

Unfortunately this still means that there will be different efficiency criteria for the different (flow, head) duties within the range of pumps in each category. In practical terms it means that a simple chart or 2-D graph is not possible, instead a 3-D plane has to be used to present the data. Annex 3 explains how this is achieved, and also presents a single equation that describes this curve. Within acceptable limits of accuracy, it was considered that simply altering the constant C for different types of pump would describe well the mean efficiency at each duty point. So visually, the whole curve can be moved up or down an equal amount to define different cutoff values. As an alternative, graphs such as that in Annex 2 figure 9 can be used to allow quicker checking of efficiency criteria.

While this scheme is not currently a formally adopted European standard, it is considered sufficiently well developed (and in particular all stakeholders are content with it) that it could be used as the methodology for any policy options until such time as it does become formalised.

Since the efficiency bottom limit mainly depends on the specific speed and on the flow rate of a pump, it should be described by a three-dimensional plane. The shape of the plane was defined using data from a previous investigation carried out by the Technische Universität Darmstadt in 1998 [3] for an earlier SAVE project led by AEAT. A statistical evaluation of data collected from several questionnaires sent to European pump manufacturers was carried out and an envelope of the data of the efficiency values over n_s was created for 6 distinct flow rates under consideration of physical laws which determine dependence of pump internal losses on geometrical and operational pump data (as shown in figure 8.6.).

The six curves were extrapolated (quadratic polynomial) to the limits of the scope considered in this investigation and a plane fitting the curves (linear interpolation) was created (as it is shown in figure 8.7).

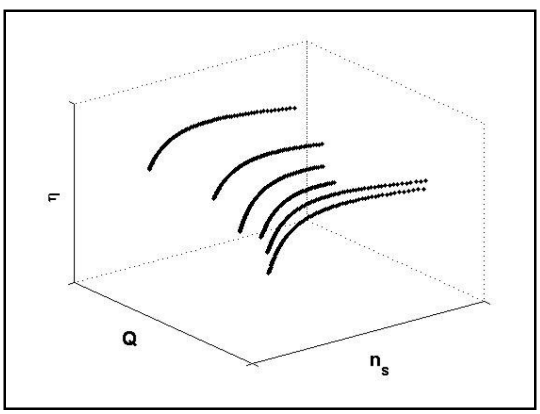


Figure 8.6: Curves from previous investigations

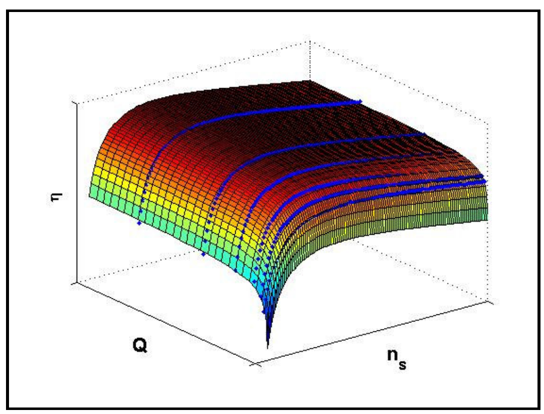


Figure 8.7: Extrapolated curves

The mathematical description of the plane was obtained by means of a 3-d quadratic polynomial approximation. The equation[29] defining the efficiency plane is:

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

with
$x = \ln(n_s)$ with n_s in [min^{-1}]
$y = \ln(Q)$ with Q in [m^3/h]

The final plane is shown in figure 8.8. The numbers of pumps (in percentage of the total data of one pump type) that do not fulfil the minimum efficiency requirements imposed by the plane are lying below the surface and are therefore "cut-off" by the plane.
With C used as a variable for each pump type, it is possible to identify the pumps with the lowest efficiencies for the size and specific speed considered. The plane is shifted downwards vertically according to the value of C, until the chosen quantity cut-off criterion is fulfilled. The shape of the plane is valid for all defined pump types.

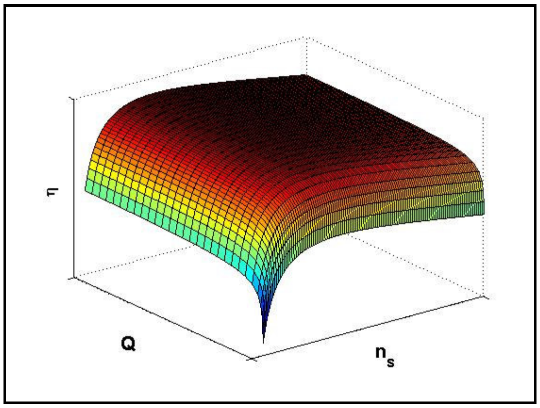


Figure 8.8: Final plane

Table 8.3 shows the values of C for the pump type considered and for different cut-off criteria.

	Quantity cut-off									
	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%
C (ESOB 1450)	134.38	132.58	131.70	130.68	129.35	128.07	126.97	126.10	124.85	122.94
C (ESOB 2900)	137.28	135.60	134.54	133.43	131.61	130.27	129.18	128.12	127.06	125.34
C (ESCC 1450)	134.39	132.74	132.07	131.20	129.77	128.46	127.38	126.57	125.46	124.07
C (ESCC 2900)	137.32	135.93	134.86	133.82	132.23	130.77	129.86	128.80	127.75	126.54
C (ESCCI 1450)	138.13	136.67	135.40	134.60	133.44	132.30	131.00	130.32	128.98	127.30
C (ESCCI 2900)	141.71	139.45	137.73	136.53	134.91	133.69	132.65	131.34	129.83	128.14
C (MS 1450)	134.83	134.45	133.89	132.97	132.40	130.38	130.04	127.22	125.48	123.93
C (MS 2900)	139.52	138.19	136.95	135.41	134.89	133.95	133.43	131.87	130.37	127.75
C (MSS 2900)	137.08	134.31	132.89	132.43	130.94	128.79	127.27	125.22	123.84	122.05

Table 8.5: Values of the variable C for different quantity cut-offs

The table 8-5 values read horizontally (cut-off 5% to cut-off 80%) result from the efficiency scatter of each pump type. The comparison of different pump types has to be done in consideration of the head and flow rate at b.e.p. using the mathematical equation presented above.[30]

[29] The equation is valid for quantity cut-offs from 5% to 80%.
The mathematical scope of the equation is $6 < n_s < 120$ [min^{-1}] and $2 < Q < 1000$ [m^3/h].
The plausibility has to be checked according to the cut-off criterion.
[30] At the time of writing there is further analysis being undertaken by TUD regarding detailed changes to the efficiency levels for Multiple Stage Submersible pumps. Results are expected Spring 2008.

An important advantage of using a three dimensional approach for the evaluation is that the scatter in efficiency values is properly showing the efficiency differences due to design and manufacturing of pumps of the same size and specific speed. If flow rate classes were used instead, the scatter would be broader due to the efficiency differences resulting from pumps of various sizes. Such an approach would not reflect the difference of the individual efficiency of each pump from the statistically mean value for the corresponding flow rate and therefore is not suitable to serve as an evaluation scheme. The data provided for the ESCC 1450 pump for example has an apparently too high efficiency scatter of 27.3 percentage points for a flow rate class of 70-100 m^3/h, the scatter is 21.3 percentage points for the smaller flow rate class of 80-100 m^3/h and 15.8 for 90-100 m^3/h. A correct efficiency scatter is only obtained by introducing a Q-dimension and thus using a three dimensional method.

8.1.12.2 Accounting for part load performance

As already discussed, because pumps spend much of their time working away from their rated duty, and efficiency can fall off rapidly below the 50% duty point, any scheme should take account of this real life performance. (A weighted efficiency scheme such as used in the circulator Blauer Engel scheme for heating systems is ideal, but this is not appropriate for pumps used in other applications. In the evaluation of pump performance and overall energy consumption in this study, a designated flow profile was therefore adopted that was designed to mimic "typical" pump duty, but because of its crudeness it was never anticipated that it used as the basis of a classification scheme.) However, manufacturers need a pump efficiency classification scheme that makes it impossible to design pumps with a steep fall off in efficiency either side of the BEP point in order to claim a higher efficiency than would be typical of real life operation.

The study group working in conjunction with stakeholders have therefore devised what is called a "house of efficiency" scheme that also requires pumps to pass efficiency thresholds at 75% and 110% of rated flow. The advantage of this is that pumps will be penalised for poor efficiency away from rated efficiency, hence it will take account of real life pump duties. This is detailed in p.4 of Annex 3. In fact, the results of the data collection indicate that <10% of pumps have performance with a particularly sharp peak at rated flow. It should be stated that while the scheme may appear complicated at first sight, in practice it has been easy for the manufacturers to apply the scheme to their pumps.

8.1.12.3 The 'House of Efficiency' scheme

The decision scheme 'House of Efficiency' [1] takes into account design and application purposes as well as the pump minimum efficiency dependence on flow. The minimum acceptable efficiency is therefore different for each pump type. The pass-or-fail scheme is based on two criteria A and B.

Criterion A is the pass-or-fail minimum efficiency requirement at the best efficiency point (b.e.p.) of the pump:

(A) $$\eta_{Pump}(n_s, Q_{BEP}) \geq \eta_{BOTTOM}$$

Criterion B is the pass-or-fail minimum efficiency requirement at part load (PL) and at overload (OL) of the pump:

(B) $$\eta_{BOTTOM-PL,OL} \geq x \cdot \eta_{BOTTOM}$$

That leads to bottom lines specific to each pump type at a certain flow (see fig. 8.9) which have to be defined, based on statistical data.

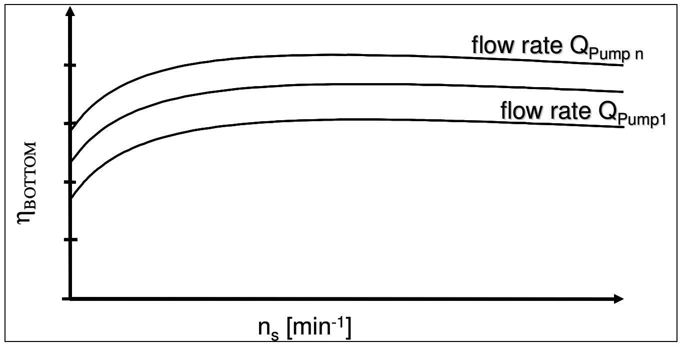


Figure 8.9: Bottom lines for different geometrical pump sizes (defined for nominal flow rate Qn > Q1) within one pump type (e.g. ESCC) [1]

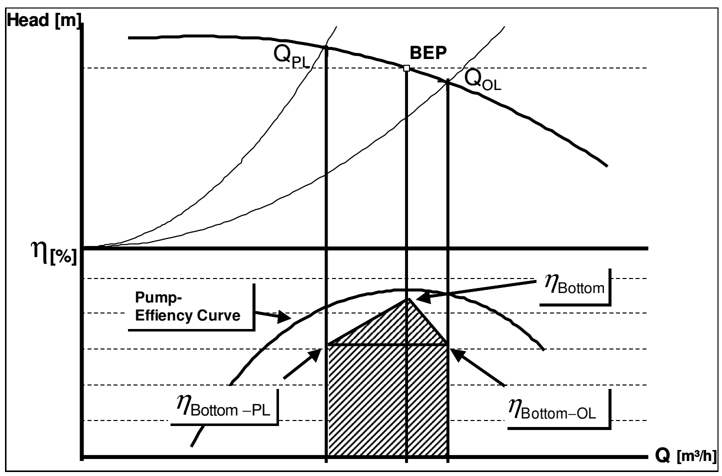


Figure 8.10: 'House of Efficiency' – explanatory representation of proposed scheme in a η(Q):flow-Plot [1]

In figure 8.10 the representation of the two criteria is shown in an η(Q):flow-plot. The pump efficiency curve with its maximum at the best efficiency point does not cross the 'roof of the efficiency house'. The part and over load minimum acceptable efficiencies at $0.75 \cdot Q_{BEP}$ and $1.10 \cdot Q_{BEP}$ build the roof-triangle with the minimum acceptable efficiency at best efficiency point. As a result, the pump efficiency curve has to be broad and high to fulfil the criteria. The shown example is for a pump passing the agreed efficiency criteria (not yet set) and would therefore pass the energy efficiency check. Subsequently it would be eligible for CE-marking in accordance with the applicable Directive. Pumps with robust trade-off criteria like NPSH, noise, application for dirty water or other aspects should separately be considered with their own minimum acceptable efficiency and specific factor 'X' to be defined.

The application of this scheme requires the definition of pump specific bottom lines for different flows as well as the factor *x* for part load and overload based on the statistical data provided by the manufacturers.

8.1.13 The ecodesign requirement for the pumps covered, implementing date(s), staged or transitional measures of periods. (Annex VII part 2)

The environmental impacts of pumps have been studied in detail in the following categories as detailed in Annex I sections 1.1 and 1.2 of the EUP Directive. The result of this work is that it is only the energy efficiency of the pump that should be the subject of regulatory action. This is shown in figure 8-11 that compares different environmental impacts by phase of life, showing how the in use phase dominates.

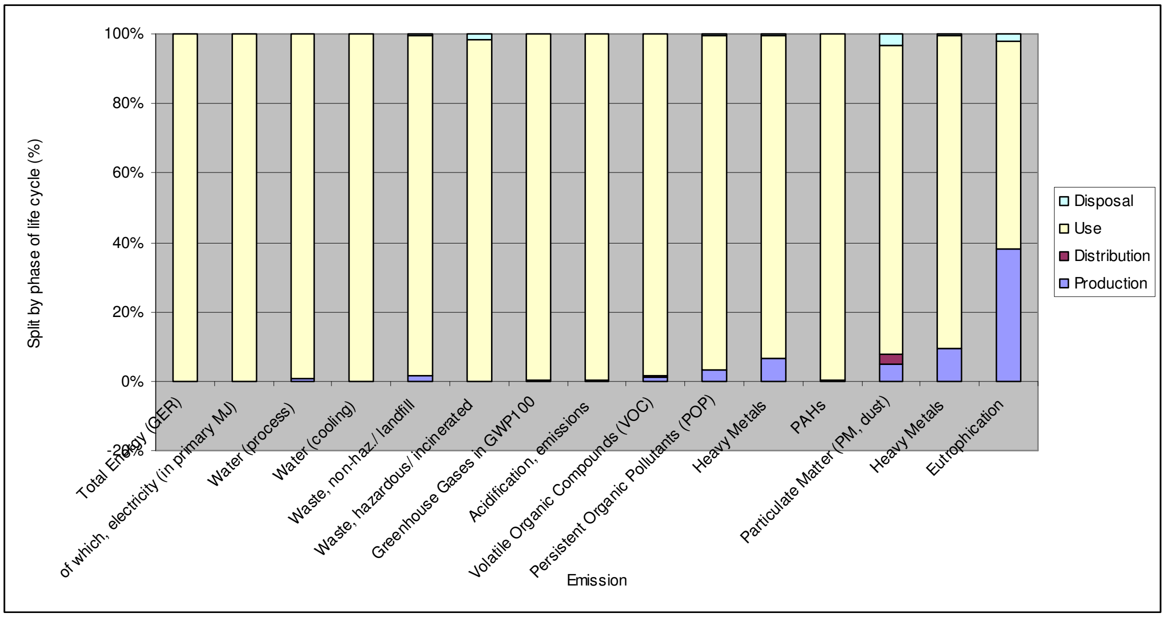


Figure 8-11 Environmental Impact by phase of lifecycle - End Suction own bearings pumps (small)

Given that there is little difference in materials between the best and worst pumps, in can be stated that there is no eco-penalty for implementing policy options that lead to an increase in sales of the most efficient types. The suggested phasing of implementing measures is as in table 8-6.

Efficiency levels corresponding to each of the four policy scenarios shown can be derived from the "C" values shown in table 8.5. Because for each type of pump there are different minimum efficiency values for each flow:head combination, it is not possible to quote a single efficiency value for each of the different policy options. Instead, the "C" value is used to calculate the minimum efficiency level for any style of pump at any particular pump duty point.

Policy Option	Date
HEPs definition to allow labelling of top 20% of pumps in the market	2010
Removal of worst 10% of pumps from the market	2010
Removal of worst 20% of pumps from the market	2013
Removal of worst 30% of pumps from the market	2016
Removal of worst 40% of pumps from the market	2019

NB This is based on the current distribution of pumps

Table 8-6 Phasing of implementing measures

8.1.14 The ecodesign parameters of pumps referred to in Annex I to which no ecodesign requirement is necessary (Annex VII part 3)

8.1.14.1 Generic ecodesign requirements

Generic ecodesign requirements aim at improving the environmental performance of EuPs, focusing on significant environmental aspects without setting limit values. Reducing the energy consumption of circulators will reduce the different emissions caused by the generation of electricity at power stations. Limiting values on energy efficiency will effectively set limits on some of the emissions listed below. **Therefore there is no need for defined limiting values on any other ecodesign parameters.**
Correct selection, installation and maintenance of pumps is critical both for least energy consumption and best reliability. While of huge importance, it is not though appropriate to ask manufacturers to provide information on this with their products, as it is not product specific.

8.1.14.2 WEEE and RoHS

All pumps analysed are outside of the scope of this Directive. In any case they contain no electrical or electronic components that would be impacted even if they were in scope.

8.1.14.3 Standby Power consumption

None of the products in this study have a standby power consumption, and so no measures are required.

8.1.15 Requirements on installation of the EUP (Annex VII part 4)

There are no additional installation requirements of pumps that have a direct relevance on the pumps' environmental performance.

Best practice in the installation of pumps and design of the entire pump system should though be followed for all pumping systems in order to minimise energy consumption and maximise product life.

8.1.16 Measurement standards to be used (Annex VII part 5)

Performance testing of pumps is to one of two ISO grades, Grade 1 (most accurate) or Grade 2 (least accurate) to EN ISO 9906-1999, (currently being revised). The tolerance on efficiency for Grade 2, which is the norm for mass produced pumps of the type with which this study is most closely concerned, is large.

For larger pumps, a user may request a test of the actual pump to Grade 1, but this costs additional money, and so will not be done unless specifically requested.

Smaller pumps produced in series (mass produced) tend to be sold (usually) without test and instead use the efficiencies shown on catalogue curves, with the efficiencies to the tolerances shown in Annex A of ISO EN 9906-1999.

With any efficiency ranking scheme, it is important that there is a level playing field, with no manufacturer seeking to exaggerate the efficiency of their products.

These factors mean that quoted efficiencies may not be sufficiently reliable indicators of actual performance, which makes selection of specific pump by the specifier on the basis of efficiency hard. Furthermore, the wide tolerances currently allowed on performance testing / efficiency quotation could make classification of pumps on the basis of efficiency difficult.

.It was not possible within the study to define precisely how tight it is practical to make the tolerances, but any proposals from CEN TC 197 SC2 (draft due end of January 2008) should be carefully reviewed to check that the new requirements will be adequately tight to underpin the recommended policy options.

8.1.17 Details for conformity assessment under Directive 93/465/EEC (Annex VII part 6)

The pumps in scope of this regulatory action shall be subject to conformity assessment under Directive 93/465/EEC module 1, (internal production control).

8.1.18 Requirements of the information to be provided by manufacturers (Annex VII part 7)

Manufacturers will need to make available the following documentation to any verifying body appointed by the European Commission or National Government . This is to facilitate the checking of the compliance of the product with the implementing measures

- Full results of performance tests to ISO 9906.
- Calibration certificates of measurement equipment.
- Details of the calculations of derived efficiency (in the case where performance is calculated from other models of a similar type).

8.1.19 Duration of the transitional period for placement of compliant EUP's on the market (Annex VII part 8)

It is suggested that 3 years is allowed for removal of each 10% of worse pumps, (based on existing spread). This will give manufacturers adequate time to re-design pumps to replace those that are non-compliant.

8.1.20 Date for the evaluation and possible revision of the implementing measures (Annex VII part 9)

Under both policy options the implementing measures should be reviewed 3 years before the date given for the removal of the final 10% of pumps, (ie 2013 and 2016). This will give manufacturers adequate time to prepare for any future changes, and other stakeholders time to see the impact of measures up to that time.

8.1.21 Distribution of products

The distribution of products was analysed in detail in the study, and is shown in summary in figure 8.12.

The spread of efficiency of each of the style of pumps analysed is shown below, with "S" and "L" denoting the small and large basecases respectively. Note that because of the method of statistical analysis, no accurate data on the efficiency of pumps at the extreme of the spread is shown, and so the figure below only shows the spread between the 10% and 80% percentile of pumps.

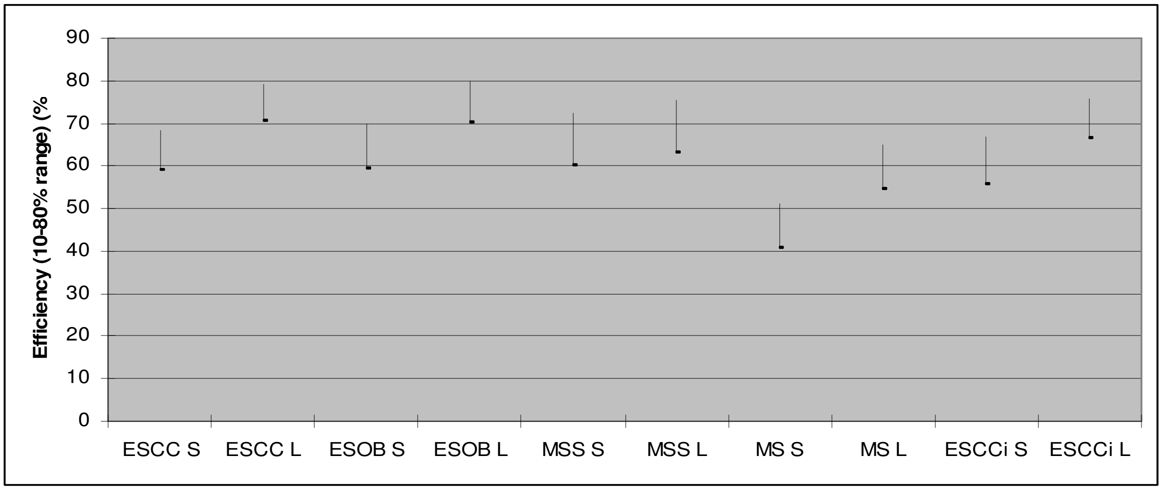


Figure 8-12 Spread of actual efficiencies (BEP) for each style of pump

Two scenarios were investigated relating to the distribution of replaced products:

- Non compliant pumps replaced by pumps just meeting the new MEPs.
- Non compliant pumps replaced by pumps at the highest level commensurate with little or no additional manufacturing cost – assumed to be at the 55th percentile.

The two scenarios analysed are only indicative of the manufacturer's reactions to any policy options. They are both if anything slightly pessimistic, as if manufacturers are re-designing any pumps, they are likely to replace them with a product that exceeds the current average efficiency.

Scenario 1 assumes manufacturers do the minimum possible. The cumulative savings at low cutoffs are only small, since only a few pumps are being impacted, and then the amount by which they are to be improved is only small. Scenario 2 is seen as being much more realistic, with 75% of the 40% cutoff savings achieved at the 20% cutoff under this scenario.

For a given cutoff, the split of energy savings for the different pumps are shown in figure 8.13.

It should be stressed that the scenarios in this sections relate to the ultimate energy savings achieved by cutoffs being at a range of different levels from 10-80% under two different assumed manufacturer reactions to these different MEPS. This is separate from the <u>*time-based*</u> *policy scenarios that relate to various different MEPS being introduced at different times..*

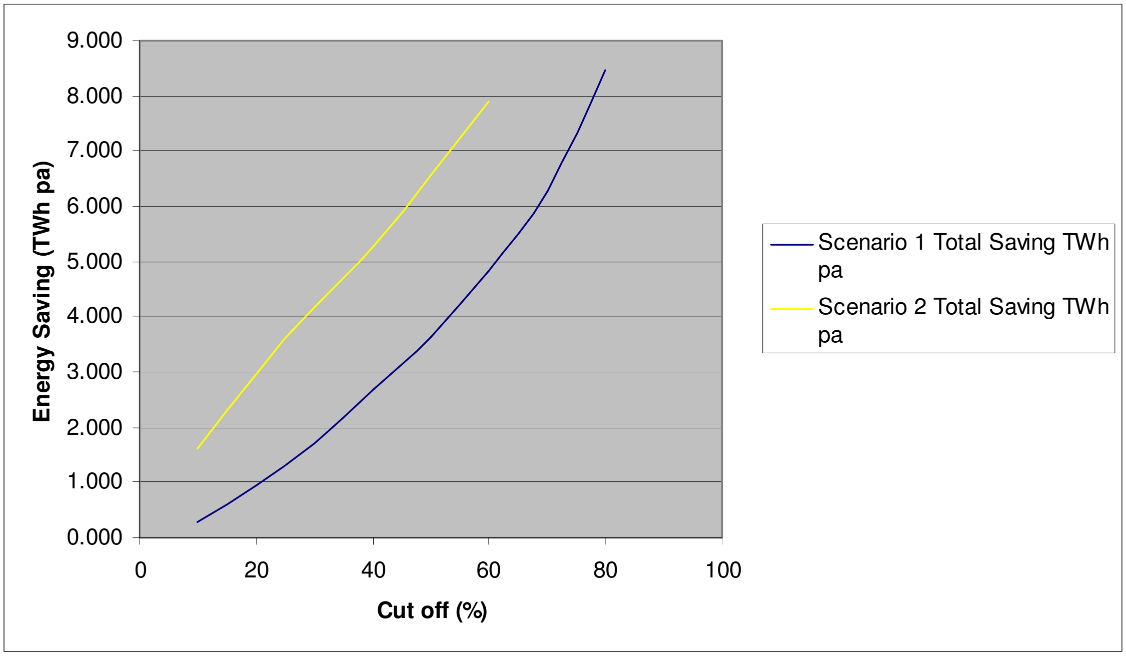


Figure 8-13 Energy savings (Electrical) from setting the cutoff at different levels, under manufacturer reaction scenarios 1 and 2.

The energy savings on which this is based are shown in figure 8.5 and 8.8.:

The mechanical or "shaft" energy is the mechanical (rotational) energy required by the pump. The electrical energy is that on the input to the driving motor, which is assumed to be a class Eff2 running at full load. *It is this electrical energy that is used elsewhere to calculate the environmental impact of the pump.*

8.1.22 Estimation of energy savings – Manufacturer reaction Scenario 1: Moving worst pumps to minimum allowable efficiency

Tables 8.7and 8.8 summarise the energy savings calculated for each type of pump at different cutoff levels. Actual efficiency levels corresponding to each cut off (%) can be derived from the "C" values shown in table 8.5. This "C" value is used to calculate the minimum efficiency level for any style of pump at any particular pump duty point.

Cut off (%)	ESCC S	ESCC L	ESOB S	ESOB L	MSS S	MSS L	MS S	MS L	ESCCi S	ESCCi L	Total Saving TWh pa
80	0.965	0.942	1.317	1.108	0.738	0.427	0.148	0.114	0.744	0.696	**7.199**
70	0.759	0.703	0.973	0.780	0.561	0.325	0.090	0.090	0.569	0.501	**5.349**
60	0.598	0.532	0.781	0.585	0.443	0.256	0.061	0.066	0.427	0.360	**4.109**
50	0.457	0.424	0.613	0.468	0.294	0.170	0.035	0.031	0.318	0.298	**3.108**
40	0.354	0.303	0.468	0.343	0.204	0.118	0.028	0.027	0.244	0.198	**2.286**
30	0.222	0.185	0.323	0.226	0.105	0.061	0.018	0.010	0.174	0.128	**1.450**
20	0.113	0.089	0.175	0.135	0.055	0.032	0.014	0.006	0.105	0.075	**0.800**
10	0.021	0.024	0.062	0.054	0.018	0.011	0.002	0.001	0.023	0.015	**0.232**

Table 8-7 Energy savings achieved by the introduction of cutoffs at 10% to 80% (Mechanical)

Cut off (%)	ESCC S	ESCC L	ESOB S	ESOB L	MSS S	MSS L	MS S	MS L	ESCCi S	ESCCi L	Total Saving TWh pa
80	1.146	1.047	1.564	1.316	0.894	0.491	0.195	0.140	0.884	0.773	**8.449**
70	0.901	0.781	1.155	0.926	0.679	0.373	0.118	0.111	0.676	0.556	**6.277**
60	0.711	0.591	0.927	0.695	0.536	0.294	0.080	0.081	0.507	0.400	**4.823**
50	0.542	0.471	0.728	0.556	0.356	0.196	0.046	0.038	0.377	0.331	**3.642**
40	0.421	0.337	0.555	0.407	0.247	0.136	0.037	0.034	0.290	0.220	**2.682**
30	0.263	0.205	0.383	0.268	0.127	0.070	0.024	0.012	0.207	0.142	**1.700**
20	0.134	0.099	0.208	0.161	0.067	0.037	0.019	0.008	0.124	0.083	**0.940**
10	0.025	0.027	0.074	0.064	0.022	0.012	0.003	0.001	0.028	0.016	**0.272**

Table 8-8 Energy savings achieved by the introduction of cutoffs at 10% to 80% (Electrical)

8.1.23 Estimation of energy savings – Manufacturer reaction Scenario 2: Moving worst pumps to mean efficiency level

Tables 8.9 and 8.10 summarise the energy savings calculated for each type of pump at different cutoff levels.

Cut off (%)	ESCC S	ESCC L	ESOB S	ESOB L	MSS S	MSS L	MS S	MS L	ESCCi S	ESCCi L	Total Saving TWh pa
80											
70											
60	0.912	0.881	1.234	1.027	0.694	0.401	0.134	0.107	0.698	0.646	**6.734**
50	0.778	0.733	1.028	0.833	0.579	0.335	0.100	0.089	0.585	0.528	**5.589**
40	0.647	0.594	0.837	0.659	0.465	0.269	0.071	0.071	0.476	0.419	**4.508**
30	0.518	0.465	0.680	0.518	0.358	0.207	0.052	0.052	0.375	0.321	**3.547**
20	0.373	0.326	0.502	0.373	0.246	0.142	0.036	0.033	0.273	0.224	**2.527**
10	0.199	0.176	0.286	0.216	0.125	0.072	0.019	0.015	0.152	0.124	**1.383**

Table 8-9 Energy savings achieved by the introduction of cutoffs at 10% to 80% (Mechanical)

Cut off (%)	ESCC S	ESCC L	ESOB S	ESOB L	MSS S	MSS L	MS S	MS L	ESCCi S	ESCCi L	Total Saving TWh pa
80											
70											
60	1.083	0.979	1.465	1.220	0.840	0.461	0.176	0.132	0.829	0.718	**7.903**
50	0.924	0.815	1.221	0.990	0.701	0.385	0.132	0.110	0.694	0.586	**6.558**
40	0.768	0.661	0.994	0.783	0.563	0.309	0.093	0.087	0.566	0.465	**5.289**
30	0.615	0.517	0.807	0.616	0.434	0.238	0.068	0.064	0.446	0.357	**4.162**
20	0.443	0.363	0.596	0.443	0.297	0.163	0.047	0.041	0.324	0.249	**2.965**
10	0.237	0.196	0.339	0.257	0.151	0.083	0.024	0.018	0.180	0.138	**1.623**

Table 8-10 Energy savings achieved by the introduction of cutoffs at 10% to 80% (Electrical)

8.1.24 Growth rates and substitution effects

In the absence of any other information, an annual growth rate of 1.5% pa is assumed for all types of pump.

For these commodity types of pump, no form of substitute product can be identified.

8.1.25 Total environmental impact of the eco-design measures

The total environmental impact is calculated by adding the 2020 3.56TWhpa and 2.71 TWh pa energy saving for the 40% and 20% cutoffs respectively into the MEEUP model, giving the following results, (tables 8-11 – 8-12).

main life cycle indicators	value	unit
Total Energy (GER)	**2943675**	PJ
of which, electricity	280350.0	TWh
Water (process)*	**196245**	mln.m3
Waste, non-haz./ landfill*	**3413025**	kton
Waste, hazardous/ incinerated*	**67831**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**128460**	mt CO2eq.
Acidifying agents (AP)	**757996**	kt SO2eq.
Volatile Org. Compounds (VOC)	**1109**	kt
Persistent Org. Pollutants (POP)	**19295**	g i-Teq.
Heavy Metals (HM)	**50502**	ton Ni eq.
PAHs	**5799**	ton Ni eq.
Particulate Matter (PM, dust)	**16190**	kt
Emissions (Water)		
Heavy Metals (HM)	18980	ton Hg/20
Eutrophication (EP)	91	kt PO4

***=caution: low accuracy for production phase**

main life cycle indicators	value	unit
Total Energy (GER)	**2240832**	PJ
of which, electricity	213412.5	TWh
Water (process)*	**149389**	mln.m3
Waste, non-haz./ landfill*	**2598117**	kton
Waste, hazardous/ incinerated*	**51635**	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**97789**	mt CO2eq.
Acidifying agents (AP)	**577014**	kt SO2eq.
Volatile Org. Compounds (VOC)	**844**	kt
Persistent Org. Pollutants (POP)	**14688**	g i-Teq.
Heavy Metals (HM)	**38444**	ton Ni eq.
PAHs	**4414**	ton Ni eq.
Particulate Matter (PM, dust)	**12325**	kt
Emissions (Water)		
Heavy Metals (HM)	14448	ton Hg/20
Eutrophication (EP)	69	kt PO4

Tables 8-11and 8-12. Total 2020 environmental impact of the eco-design measures (removing the worst 40% and 20% respectively of pumps from the market.)

8.1.26 Harmonised standards – health and safety

ISO EN 809:1998 (Common safety requirements) is the most relevant document for general mechanical construction.

The American Petroleum Institute (API) imposes standards for pumps used in the oil industry. These are driven by safety requirements, which often result in reduced efficiency through demanding for instance larger clearances. *It is understood that these standards do not impact on the design of water pumps for the European market.*

The Pressure Equipment Directive: Pumps and pump units are not relevant to this directive.

8.2 Impact analysis industry and consumers

8.2.1 Timing of policy measures and impact on industry

The cost to manufacturers depends on the specifics of time scales and cut-off values selected, with table 8-13 being submitted by Europump as an indication of these costs. However, this is only approximate and it was not possible to independently verify this.

This is complicated because in addition to the engineering and tooling cost for new designs of pump, there will be implications on the range of pumps. For example, new pump volutes may be needed in order to avoid satisfying some pump duties with much reduced (trimmed) impellers, which will mean making more pump volute sizes than if lower pump efficiencies were allowable. Further, because many of the lower efficiency pumps will just be "odd" designs, it may not make sense to replace them with identical duties – because actually a whole range of pump duties should ideally be altered to minimise the cost of introducing a new range of compliant pumps that satisfy the spread of duties required.

Cut off (%)	Development costs of new pumps (Meuros)
10	43.2
20	120.9
50	550.8
80	1,382.4

Table 8-13 Estimated development costs of new pumps to meet different minimum cutoff values, (supplied by Europump)

Given the lack of technological barriers to improving pump efficiency, and the cost effectiveness of more efficient pumps to the consumer, the only limit to the level at which the minimum efficiency level should be set is the cost to industry. A long term goal of removing the current 40% worst performing pumps is therefore seen as being reasonable, with the question being the timescale over which this level should be reached. The limiting factor is the cost to manufacturers of designing and placing into production new ranges. It is suggested that interim targets of raising the cutoffs by 10% every 3 years, starting in 2011, should be agreed at an early date so that manufacturers can make long term plans for updating their ranges.[31] This pace would allow even smaller manufacturers time to replace products with products that comply. The disadvantage of this gradual increase in the MEPs level, rather than a single more abrupt change, is that it may cause some confusion to the market, and so thre would need to be adequate market surveillance.

However, there will be some companies that are unwilling or unable to invest in new pumps designs, and so these would lose business with consequent reduction in employment. It is expected that smaller companies would find it particularly hard to find the capital needed for this investment.

It is thought that the rate at which the MEPS will be raised will enable even the smaller manufacturers to comply, and so there should not be any loss of jobs. Because a MEPS level would be mandatory, competition from poorer products manufactured outside the EU will not be a problem. If set high enough, the MEPs levels will actually deter competition from outside the EU. The improved quality of manufacturing and design needed to reach the higher efficiencies will increase the skill level within manufacturers. Because of the very small increase in price to the user of the policies suggested, it is unlikely that it would lead to a decrease in the market through for example increased repair of older pumps.

[31] At the time of writing, manufacturers had not been consulted on the phasing of any specific legislation, and so it is a best estimate of the author, representing the timescales thought to be reasonable.

8.2.2 Cost to Consumer - affordability

Table 8-14 shows the annual purchase cost to the consumer of the cutoff being set to various thresholds from 10% to 80%. Although these total increases in cost may appear to be high, these figures should be compared to the estimated total value of the EU pumps market (for new pumps of this type) of 1,500Meuros pa. In addition the consumer will face installation costs of a similar value, and so the value of the increase in cost to the consumer for these increased pumps is proportionately not very significant for lower cut off values. For example, changing an ESOB (large) pump from the 10% cutoff level to the 40% cutoff level would reduce the LCC by 2,109 Euros under typical operating conditions.

The cost is calculated by looking at the difference in cost between the current situation and the costs of pumps at the efficiency that they are being moved to. This is then multiplied by the annual sales to get the total additional costs to the user each year.

Cut off (%)	ESCC S	ESCC L	ESOB S	ESOB L	MSS S	MSS L	MS S	MS L	ESCCi S	ESCCi L	Total cost pa (Euros)
80	12,420	11,385	6,072	3,450	35,162	9,660	13,800	3,450	4,968	4,554	**104,921,400**
70	6,120	5,610	2,992	1,700	17,326	4,760	6,800	1,700	2,448	2,244	**51,700,400**
60	2,880	2,640	1,408	800	8,154	2,240	3,200	800	1,152	1,056	**24,329,600**
50	1,080	990	528	300	3,058	840	1,200	300	432	396	**9,123,600**
40	1,080	990	528	300	3,058	840	1,200	300	432	396	**9,123,600**
30	1,080	990	528	300	3,058	840	1,200	300	432	396	**9,123,600**
20	720	660	352	200	2,038	560	800	200	288	264	**6,082,400**
10	0	0	0	0	0	0	0	0	0	0	**0**

Table 8-14 Cost to user (thousand euros pa) of making cutoffs from 10% to 80% the minimum standard

This increase in first cost at even the 50% cutoff level is <1% of the total current cost to the consumer, and so is not seen as being a barrier.

Tables 8-15 and 8-16 show the purchase cost and lifecycle cost of each type of pump at different efficiency values. They show the cost effectiveness to the user of purchasing a more efficient pump.

Purchase cost (euros)	End Suction Own Bearings (ESOB)		End Suction Close Coupled (ESCC)		End Suction Close Coupled Inline (ESCCi)		Submersible Multistage		Vertical Multistage	
Cut-off (%)	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large
80	484	1,100	990	3,630	990	3,630	1,001	1,100	1,100	1,100
70	462	1,050	945	3,465	945	3,465	956	1,050	1,050	1,050
60	449	1,020	918	3,366	918	3,366	928	1,020	1,020	1,020
50	440	1,000	900	3,300	900	3,300	910	1,000	1,000	1,000
40	440	1,000	900	3,300	900	3,300	910	1,000	1,000	1,000
30	440	1,000	900	3,300	900	3,300	910	1,000	1,000	1,000
20	436	990	891	3,267	891	3,267	901	990	990	990
10	418	950	855	3,135	855	3,135	865	950	950	950

Table 8-15 Purchase cost (euros) of different types of pump, by efficiency.

Lifecycle cost (euros)	End Suction Own Bearings (ESOB)		End Suction Close Coupled (ESCC)		End Suction Close Coupled Inline (ESCCi)		Submersible Multistage		Vertical Multistage	
Cut-off (%)	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large
80	9,749	32,733	8,951	36,154	12,052	53,629	15,486	16,465	13,457	16,465
70	9,928	33,446	9,026	36,509	12,262	54,525	15,508	16,498	13,445	16,498
60	10,043	33,938	9,107	36,839	12,473	55,309	15,533	16,531	13,436	16,531
50	10,168	34,291	9,201	37,095	12,672	55,704	15,592	16,606	13,439	16,606
40	10,309	34,777	9,300	37,535	12,851	56,610	15,649	16,676	13,446	16,676
30	10,489	35,361	9,466	38,086	13,068	57,434	15,731	16,775	13,460	16,775
20	10,743	35,981	9,646	38,679	13,362	58,268	15,778	16,833	13,457	16,833
10	11,054	36,886	9,877	39,251	13,917	59,761	15,812	16,880	13,457	16,880

Table 8-16 Lifecycle costs (euros) of different types of pump, by efficiency

8.3 Sensitivity Analysis of the main parameters

8.3.1 Life Cycle Costing & Sensitivity analysis

8.3.1.1 Life Cycle Costing analysis

For each pump style and size, the total lifecycle cost of ownership, assuming a 2% discount rate, is shown for three different running hours. The analysis is based on the typical EU 27 electricity prices of 0.075 euros/kWh . There are further permutations of electricity price and annual operating hours, but for clarity just the one graph is shown for the basecase "small" and "large" pump of each type. (These refer to the basecase model sizes used in the detailed analysis for the MEEUP report). However, if the average (middle) operating hours are assumed, a lower electricity price can be considered to have a similar impact on LCC as the reduced running hours shown.

The LCC analysis for each of the five pumps are shown in figures 8.14 – 8.23, for both the "small" and "large" basecases.

In all cases the Least Life Cycle Cost (LLCC) to the consumer is shown as the lowest point on the lines.

A major assumption is that all pumps fail at year 11, which is known from experience to be untrue. But in the absence of any other information this assumption is used in all the models. The impact of this is two-fold; the LCC for improvements in efficiency is improved as there is longer to reap the energy savings, but the total energy savings are less as it takes longer for stock to be replaced.

8.3.1.2 Summary of results

1.) For all pumps working under the standard running hours (except small vertical multistage pumps), (ie ESOB, ESCC, ESCCI and mss) there is a decreasing LCC with improving efficiency. This means that it is in the consumers interest to buy these pumps at up to the 80th percentile.

2.) Even at reduced (50%) running hours, all end suction types (ESOB, ESCC, ESCCi) still show a decreasing LCC with increasing efficiency. The LCC for submersible multistage pumps (mss) is fairly constant regardless of efficiency, and that for vertical multistage pumps is flat (large) or increases slightly (small).

3.) For higher running hours (or electricity prices), the LCC falls even more markedly for all types of pump.

4.) The non energy use costs of pumps are proportionately higher for the multistage pumps.

This analysis shows that from the consumers' perspective, it is in most cases financially advantageous to purchase more efficient pumps.

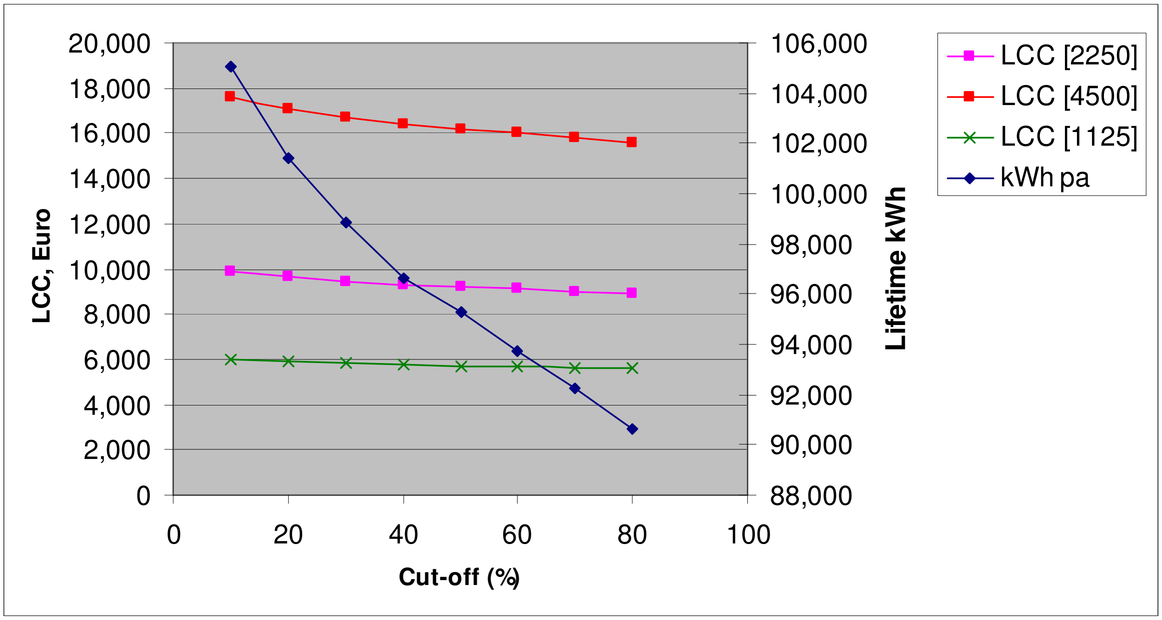


Figure 8-14 LCC Analysis ESCC Small pumps (25m^3/h at 32m, 2 pole)

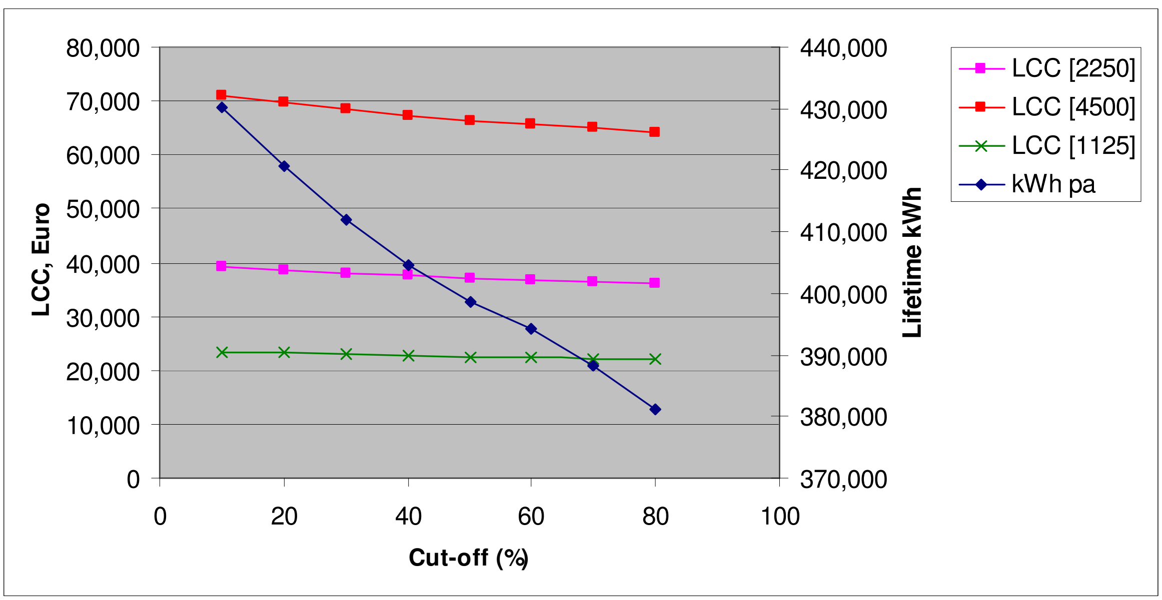


Figure 8-15 LCC Analysis ESCC Large Pumps (125m3/h at 32m, 2 pole)

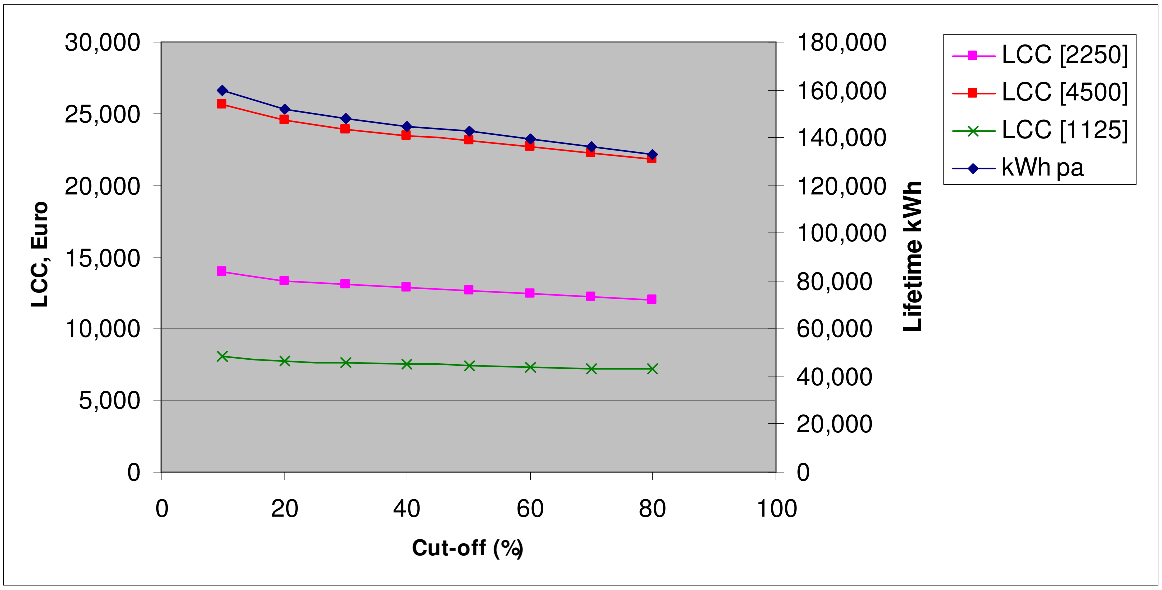


Figure 8-16 LCC Analysis ESCCi Small Pumps (25m3/h at 32m, 2 pole)

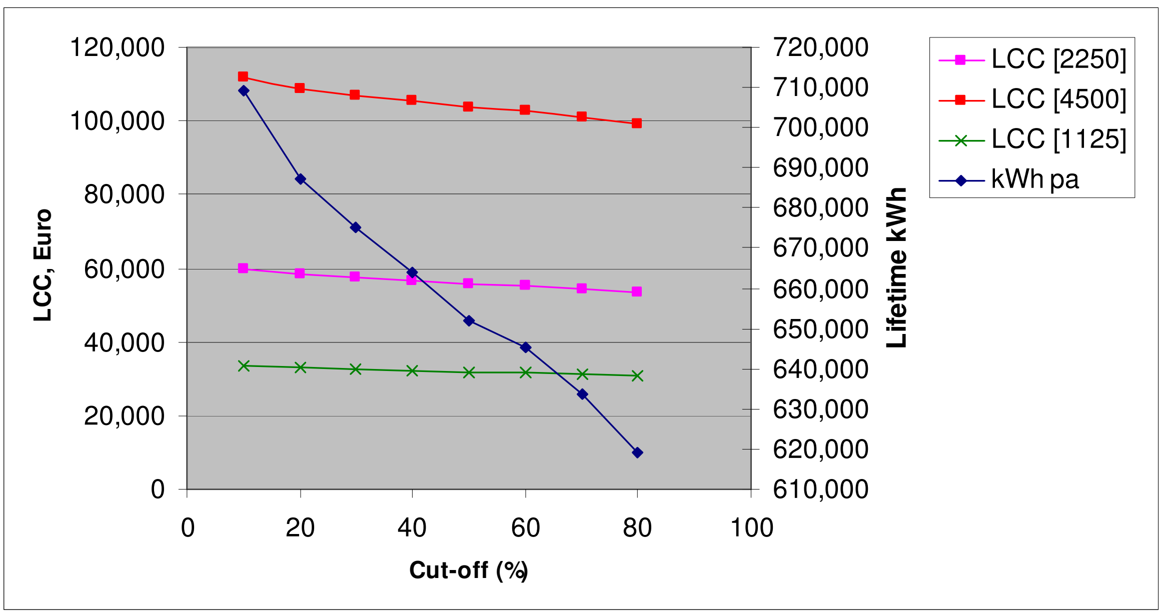


Figure 8-17 LCC Analysis ESCCi Large Pumps (125m^3/h at 32m, 4 pole)

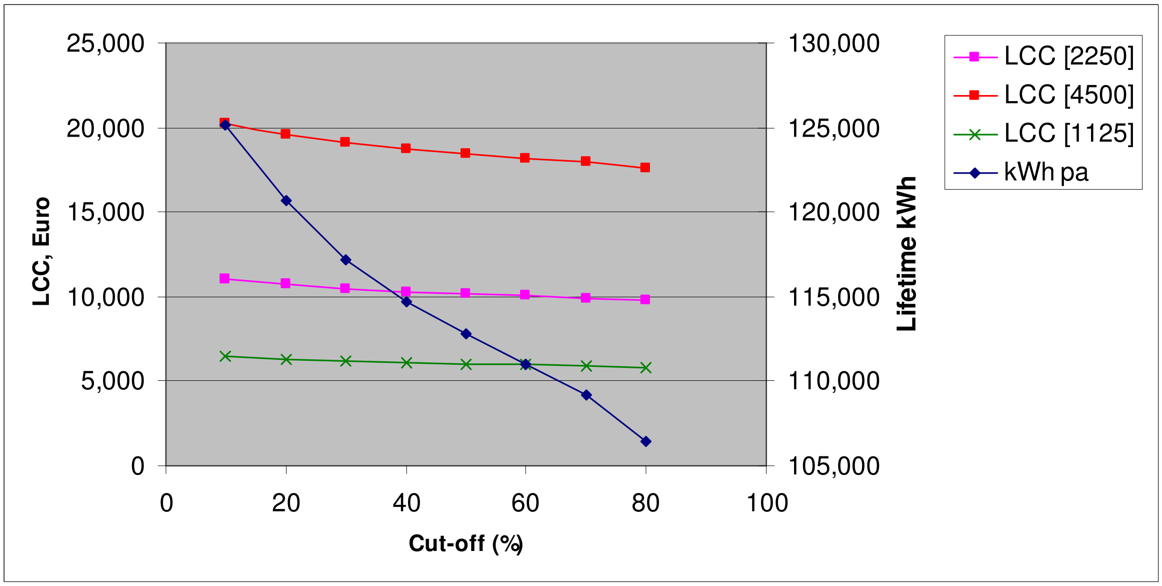


Figure 8-18 LCC Analysis ESOB Small Pumps (30m^3/h at 30m, 2 pole)

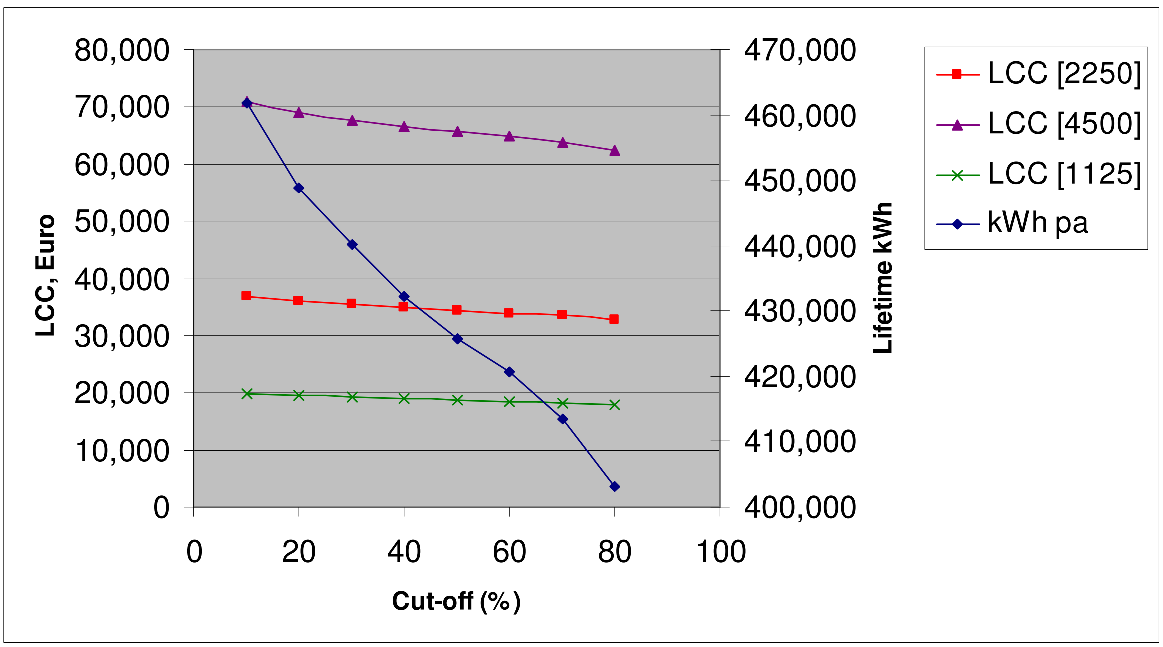


Figure 8-19 LCC Analysis ESOB Large Pumps (125m3/h at 32m, 4 pole)

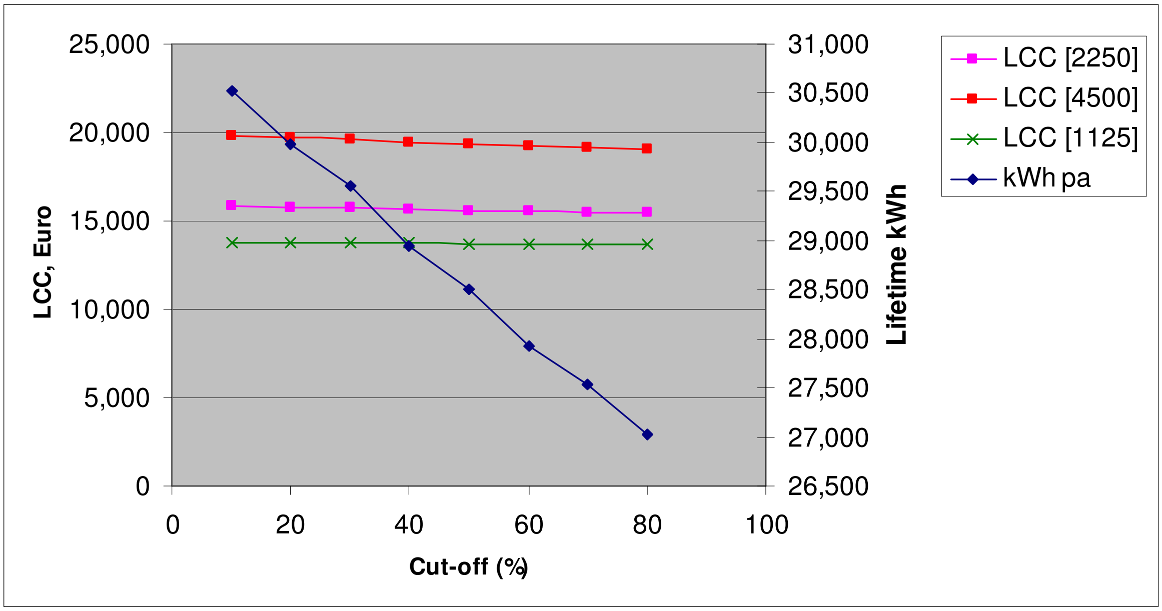


Figure 8-20 LCC Analysis Submersible Multistage Small Pumps (8.5m^3/hr at 59m, 2 pole)

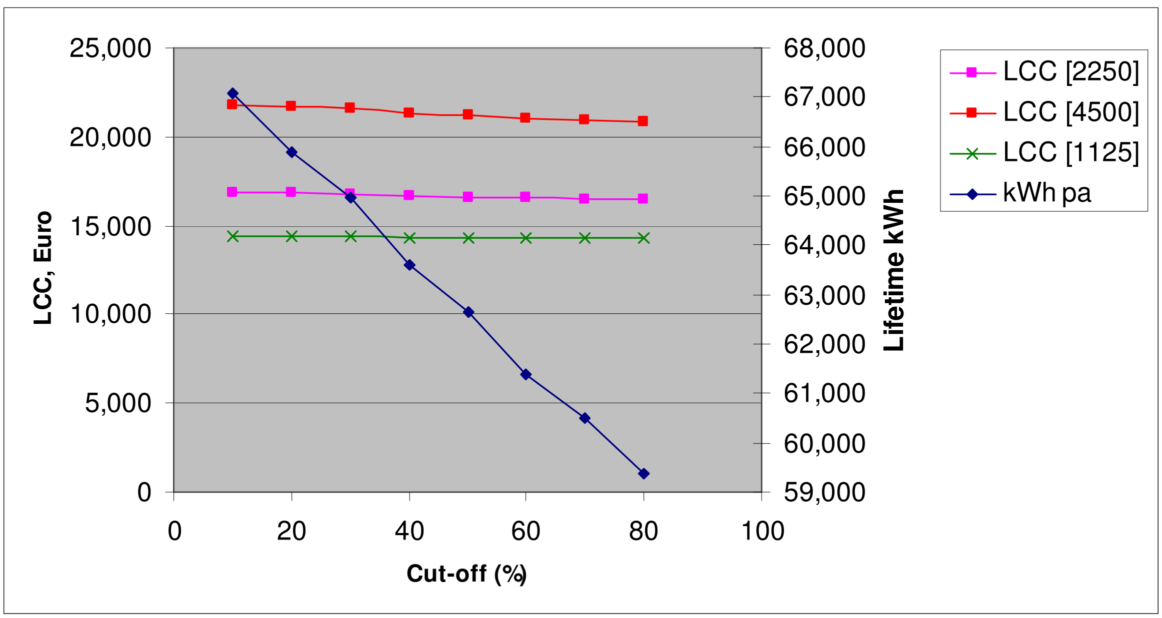


Figure 8-21 LCC Analysis Submersible Multistage Large Pumps (15m3/h at 88m, 2 pole)

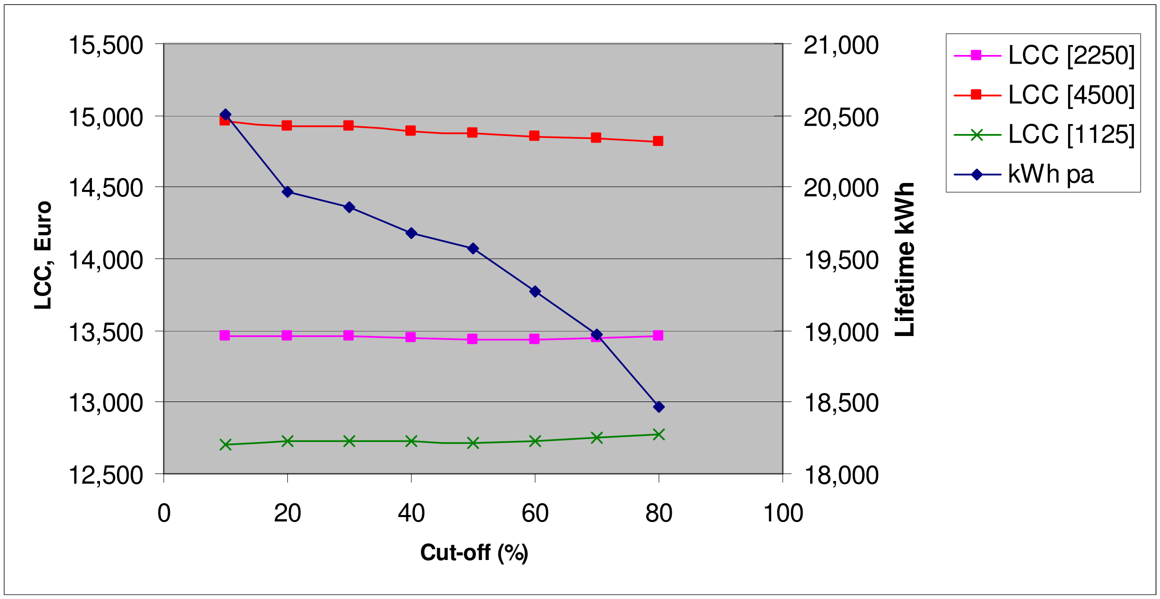


Figure 8-22 LCC Analysis Vertical Multistage Small Pumps (4m^3/h at 45m, 2 pole)

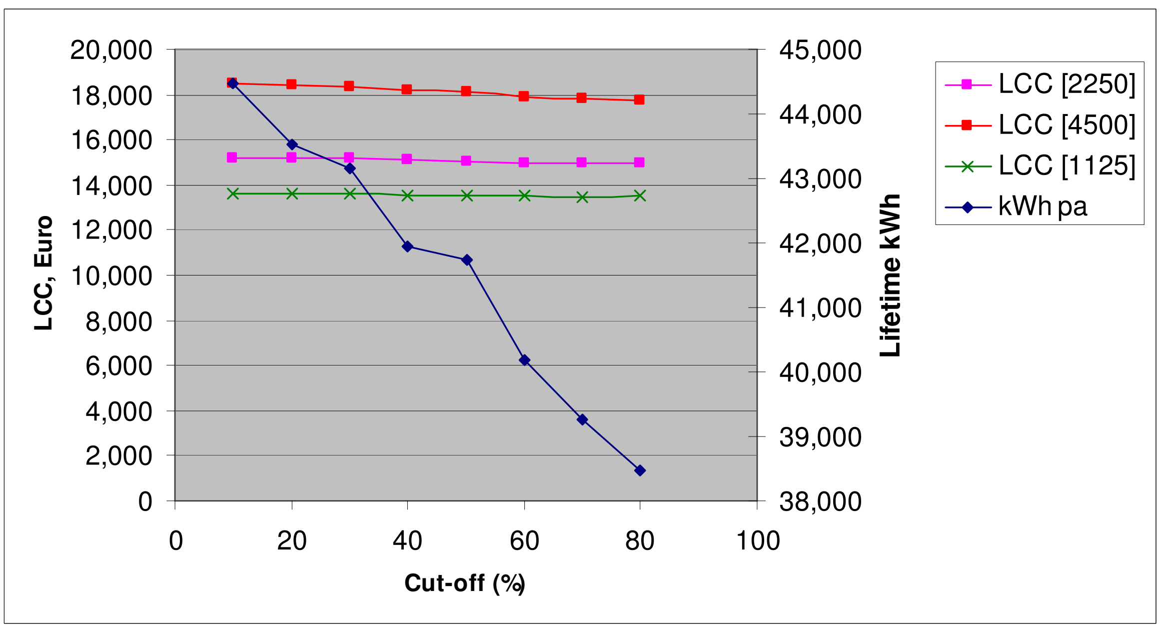


Figure 8-23 LCC Analysis Vertical Multistage Large Pumps (10m3/h at 42m, 2 pole)

8.4 Summary of recommendations

1.) Removing what are currently the worse 40% of pumps from the market is seen as being a reasonable medium term target, which would yield energy savings of c.3.6TWh pa by 2020 at little additional cost to the consumer. Once the full impact of such action is seen, then the energy savings from this measure will be 3.5% (or 5.8TWh pa at 2020 usage), representing a total of 16 TWh in the period 2012 to 2020. The limit to the speed at which this change can be implemented is therefore restricted just by the financial cost to manufacturers and also the number of personnel that they have available for designing and productionising new pump designs. It is suggested that interim targets of raising the cutoffs by 10% every 3 years, starting in 2010, would be reasonable. This relatively slow raising of minimum standards is suggested because of the high claimed cost to industry of 121Meuros for replacing the worst 20% of pumps from the market - any faster might put EU pump manufacturers at a competitive disadvantage.

2.) Life Cycle Costing analysis shows that, for most types of pumps, under typical operating conditions, it is cost effective to the User to select pumps that are within the current top 30% of pumps. If this could be achieved, it would lead to a reduction of 6.4% in pump energy consumption (8.8TWh pa at 2020 levels). There are no technical barriers to this, instead it is just the assumed cost to manufacturers of over 1,000 Meuros for re-designing pumps that is preventing this being proposed as a policy option within the 2020 timeframe of this study.

3.) In most real life applications, pumps will spend much of their time working some way from their design point, and so it is important to take account of this when classifying pump performance. The new “house of efficiency” scheme addresses this issue by setting efficiency criteria for not only 100% flow, but also sets slightly lower efficiency thresholds at 75% and 110% of rated flow that a pump must also exceed. This will avoid pumps passing the simple (rated flow) efficiency threshold, but actually performing very poorly when operated away from this point.

4.) A new methodology for setting the efficiency levels for different types of pumps has been devised, based on a 3-D plane. Although the derivation of this is technically complex, it is easy for manufacturers to use. This is thought to be the first time that a way has been found to compare pumps on a scientifically rigorous basis, and has been fully accepted by the manufacturers during the stakeholder process.

5.) While this methodology could be used as the basis of a “Top runner” or similar labelling scheme, it should be recognised that in general manufacturers will offer a family of pumps that has been developed over a long period of time, and so the efficiencies of individual pumps within a range are likely to be at a wide range of efficiency “cut off” values. Therefore, without considerable additional development work, it is unlikely that any manufacturer would have an entire range of pumps that would meet the efficiency value. This would make marketing the pumps difficult, and might even tempt some buyers to seek an “efficient” pump rather than purchase a correctly sized pump, hence leading to a net increase in energy consumption. However, denoting particularly efficient pumps does have several key advantages that it is felt outweighs these concerns:

- A defined high efficiency value will become a target efficiency value for manufacturers to achieve when designing new pumps. This will then lead to energy savings greater than those shown in points 1.) and 2.).
- It will define a higher efficiency performance standard (HEPS[32]) for programmes that wish to promote “high efficiency” pumps.
- A HEPs is useful in order to get users to think about issue of pump efficiency and pump system efficiency more generally.

It is therefore recommended that a High efficiency performance standard (HEPs) level is defined as those pumps in the current top 20% of products on the market.

[32] HEPS defines an actual performance standard, whereas the BAT is the Best Available Technology – the two will not necessarily be at the same level.

6.). The magnitude of allowed tolerances under the current ISO 9906 class 2 test standard compared to the observed spread of efficiencies for each type of pump mean that multi-level efficiency labelling schemes are inappropriate. Instead, just two efficiency lines (and hence three bands) are the most that is practical, corresponding to the mandatory CE/MEPs level and the voluntary label/HEPs level.

This test standard is being revised, and will have several new grades. It should be possible to chose a grade with tolerances tighter than the existing situation.

8.) The technical recommendations apply to the pump only, with separate recommendations for the motor driving it contained within the parallel Lot 11 Motor study.

9.) The detailed analysis showed it is only the energy performance of the product that is critical. With the exception of the requirement to supply test information, there are no other generic design requirements on manufacturers of pumps.

Relative Efficiency	Proposed levels
100%	*Most Efficient Pump*
90%	
80%	HEPS (Labelling scheme level)
70%	
60%	
50%	
40%	MEPS, Mandatory – CE mark
30%	
20%	
10%	
0%	*Least Efficient Pump*

Recommended MEPs and HEPs levels for pumps.

List of Abbreviations

BAT	Best available technology
BEP	Best efficiency point
BEQ	Best efficiency flow
BE	(Blauer Engel) A standardised circulator flow profile
BNAT	Best not available technology
BOM	Bill of materials
CO_2	Carbon Dioxide
DCF	Discounted Cash Flow
DIN	Deutsches Institut fur Normung eV
EEE	Electrical and electronic equipment
EEI	Energy Efficiency Index
Eff*n*	EU Efficiency class of motor efficiency
EIA	Environmental impact assessment
EN	European technical standard
ESCC	End Suction Close Coupled pump
ESCCi	End Suction Close Coupled In Line pump
ESOB	End Suction Own Bearings pump
EU	European Union
EUP	Energy using product
g	Gravitational constant
ISO	International standards organisation
H	Head
HEP	Higher Energy Performance
LCC	Life cycle cost
LLCC	Least life cycle cost
m	Meters
MEP	Minimum Energy Performance
ms	(Vertical) Multistage pump
mss	(Submersible) Multistage pump
m^3/h	Meters cubed per hour
MEEUP	Method for the Evaluation of Energy using Products
PM	Particulate Matter
Q	Flow
RoHS	Restriction of hazardous substances (directive)
RT	Room Temperature
n_S	Specific speed
SAVE	Specific action for vigorous energy saving (EC programme)
TOR	Terms of reference
VSD	Variable speed drive
WEEE	Waste electrical and electronic equipment directive

Appendix 1 Eurostats data on EU Pump usage (2006)

Year: 2005									
Product Code	29122413 - Submersible motor, single-stage rotodynamic drainage and sewage pumps	29122415 - Submersible motor, multi-stage rotodynamic pumps	29122417 - Glandless impeller pumps for heating systems and warm water supply	29122420 - Rotodynamic pumps <= 15mm discharge	29122430 - Centrifugal pumps with a discharge outlet diameter > 15 mm, channel impeller pumps, side channel pumps, peripheral pumps and regenerative pumps	29122451 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with a single entry impeller, close coupled	29122453 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single stage with a single entry impeller, long coupled	29122455 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with double entry impeller	29122460 - Centrifugal pumps with a discharge outlet diameter > 15 mm, multi-stage (including self-priming)
Country	**Production (Quantity)**								
Austria			0	0	0	0	0	0	0
Belgium	0		0	0	0			0	
Bulgaria	0	23	97		23	3394	2043	0	113
Cyprus	0	0	0	0	0	0	0	0	0
Czech Republic					0				
Denmark	2593	310439	4007097	0	72	2809	123169	11	286519
Estonia	0	0	0	0	0	0	0	0	0
Finland	500	800	0	0	75	0	4922	402	0
France	209507	319634	6410980		7512	120922	31760		
Germany	946633	228257	1324581	79044	94871	87237	532044	219	
Greece				0	0	0	0	0	0
Hungary		328		0			65873	0	
Ireland			0	0	0		0	0	0
Italy	1253956	882340	586080	348673	28503	660029	111823		107516
Latvia		0	0	0	0	0	0	0	0
Lituania	0	0	0	0	0	0	0	0	19
Luxemburg	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0
Netherlands			0						
Poland		0		0			606		
Portugal	4775	60865							87
Romania		1435				1149		0	0
Slovakia		0	0	0	0	0	0	0	0
Slovenia			0	0	0		0	0	0
Spain	57165	55736	5893		27181	35745	4786		12928
Sweden	268149	0		0	0		0		0
United Kingdom	130577		3577526			34618	86803	202	16948
EU15TOTALS									2,773,882
EU25TOTALS		1,877,108	16,420,228		381,223	1,017,918	980,573		2,774,069
EU27TOTALS		1,878,566				1,022,461			2,774,182

Table APP1.1 Eurostats data on EC pump production – by quantity, 2005.

Year: 2005									
Product Code	29122413 - Submersible motor, single-stage rotodynamic drainage and sewage pumps	29122415 - Submersible motor, multi-stage rotodynamic pumps	29122417 - Glandless impeller pumps for heating systems and warm water supply	29122420 - Rotodynamic pumps <= 15mm discharge	29122430 - Centrifugal pumps with a discharge outlet diameter > 15 mm, channel impeller pumps, side channel pumps, peripheral pumps and regenerative pumps	29122451 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with a single entry impeller, close coupled	29122453 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single stage with a single entry impeller, long coupled	29122455 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with double entry impeller	29122460 - Centrifugal pumps with a discharge outlet diameter > 15 mm, multi-stage (including self-priming)
Country	**Exports (Quantity)**								
Austria	31165	8986	4412	1043790	599	1061	3668	118	443
Belgium	126840	4463	10265	13314	20351	24475	586	5	376
Bulgaria	1567	20	1542	26	1	2255	310	0	220
Cyprus	6	91	0	0	0	0	1	0	0
Czech Republic	11787	1518	17695	4631082	259	1139	19035	1	82
Denmark	14793	280382	3852225	1703	2029	1761	344	13	400720
Estonia	318	23	406	30	4	136	13	0	31
Finland	9193	284	5360	73	51	873	561	2	508
France	368374	238649	7168996	28221	6968	54064	23543	27220	1182713
Germany	594598	78400	2832502	2249595	51977	197489	297767	1948	158288
Greece	28	938	12914	2	0	1623	9684	3	2518
Hungary	28396	4172	236989	21955	0	26999	37040	0	7432
Ireland	106882	131	246340	0	0	32	0	0	0
Italy	1503903	201627	634760	4085	21300	2143715	15886	51	50898
Latvia	2302	384	11053	84	0	1179	301	0	986
Lituania	562	2905	2170	1041	66	484	112	0	18
Luxemburg	140103262	0	1347	15660	2	1	1		0
Malta	0	25	0	0	0	0		0	0
Netherlands	215536	1318	16353	371	16257	8439	1423	0	1690
Poland	8257	7403	14723	3850	243	54223	13269	4	50
Portugal	8403	12405	129	0	0	0	14806	0	181
Romania	739	38	0	21290	0	5880	349	0	69
Slovakia	263	14	3283	3614	62	2392318	8249	1	0
Slovenia	5326	521	166177	923380	187	782	3299	7	1327
Spain	12436	5393	8789	708	1890	11369	12210	183	181
Sweden	343838	353	17122	2765	395	11853	949	14	81
United Kingdom	87413	5738	1307992	10572	1275	13899	96629	3295	142337
EU15TOTALS	140,992,391	477,063	3,273,441	937,525	47,887	167,565	262,467	28,237	353,815
EU25TOTALS	140,837,587	452,083	1,967,490	1,555,257	35,473	190,848	220,918	27,741	239,014
EU27TOTALS	140,817,884	445,709	1,825,194	1,554,085	34,914	176,903	216,435	27,721	230,747

Table APP1.2 Eurostats data on EC pump exports – by quantity, 2005.

Year: 2005									
Product Code	29122413 - Submersible motor, single-stage rotodynamic drainage and sewage pumps	29122415 - Submersible motor, multi-stage rotodynamic pumps	29122417 - Glandless impeller pumps for heating systems and warm water supply	29122420 - Rotodynamic pumps <= 15mm discharge	29122430 - Centrifugal pumps with a discharge outlet diameter > 15 mm, channel impeller pumps, side channel pumps, peripheral pumps and regenerative pumps	29122451 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with a single entry impeller, close coupled	29122453 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single stage with a single entry impeller, long coupled	29122455 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with double entry impeller	29122460 - Centrifugal pumps with a discharge outlet diameter > 15 mm, multi-stage (including self-priming)
Country	Imports (Quantity)								
Austria	155636	21927	186184	1073227	3001	11435	16302	130	12406
Belgium	140823	8928	188494	26096	7062	25007	6161	67	44523
Bulgaria	8129	4392	58446	6999	114	3636	2634	18	3859
Cyprus	8605	4789	18311	2087	423	159	1300	13	346
Czech Republic	113526	42763	191762	8879	16405	39759	18958	4821	14340
Denmark	94584	3463	70940	4710	2682	2567	5397	8	108587
Estonia	4977	1050	13679	967	243	222	585	2	3452
Finland	67064	6840	25168	5148	825	2543	4438	65	2000
France	674643	74986	769614	343026	21880	98245	40990	1249	194921
Germany	1137137	125767	5164641	4531853	5180	2310689	72215	289	210317
Greece	20052	140107	233639	2780	16	8093	82798	474	20878
Hungary	83135	10482	335350	32918	363	6745	6706	76	10276
Ireland	55588	5430	118162	296	1948	2953	1646	47	4064
Italy	404577	27931	3035301	268634	4204	14855	484102	39	349951
Latvia	10996	2295	31477	576	26	1351	2493	8	4153
Lituania	4705	3133	43637	868	175	6923	709	1	2199
Luxemburg	392463	159	11557	541766	124	14438	807		177
Malta	3406	1853	466	321	759	239		243	14
Netherlands	899760	28629	521551	12476	75735	21852	23279	56	8497
Poland	106943	10155	756888	9437	1402	105494	12062	42	5209
Portugal	93594	35575	147817	5110	37	3380	1354	33	16145
Romania	90594	41875	0	9459	2266	1844	11929	752	2803
Slovakia	34366	2268	191108	4037	10355	777	37577	0	1363
Slovenia	34637	1120	60621	6045	1095	92103	3122	26	1157
Spain	118827	47381	247064	960373	111855	51337	29856	6393	43682
Sweden	182551	23288	347287	13089	487	108084	8574	3839	21104
United Kingdom	499879	59616	591870	81850	2122	7914	569581	309	335071
EU15TOTALS	1,769,511	107,715	425,721	5,440,269	48,776	904,365	389,503	1,149	40,925
EU25TOTALS	1,887,805	132,587	328,030	1,160,508	50,721	179,251	363,420	1,434	15,536
EU27TOTALS	1,921,242	162,368	324,662	1,173,257	52,884	178,361	368,243	1,434	15,678

Table APP1.3 Eurostats data on EC pump imports – by quantity, 2005.

Year: 2005									
Product Code	29122413 - Submersible motor, single-stage rotodynamic drainage and sewage pumps	29122415 - Submersible motor, multi-stage rotodynamic pumps	29122417 - Glandless impeller pumps for heating systems and warm water supply	29122420 - Rotodynamic pumps <= 15mm discharge	29122430 - Centrifugal pumps with a discharge outlet diameter > 15 mm, channel impeller pumps, side channel pumps, peripheral pumps and regenerative pumps	29122451 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with a single entry impeller, close coupled	29122453 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single stage with a single entry impeller, long coupled	29122455 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with double entry impeller	29122460 - Centrifugal pumps with a discharge outlet diameter > 15 mm, multi-stage (including self-priming)
Country	Production (Value)								
Austria			0	0	0	0	0	0	0
Belgium	0		0	0	0			0	
Bulgaria	0	41415	47551		14828	382452	1323244	0	262297
Cyprus	0	0	0	0	0	0	0	0	0
Czech Republic					0				
Denmark	8652406	77819185	142627687	0	153520	2751818	26549156	173784	85668966
Estonia	0	0	0	0	0	0	0	0	0
Finland	370846	400000	0	0	48720	0	29639620	701170	0
France	44268000	47868000	190113000		23087000	52867000	55576000		126270000
Germany	150816331	83984317	283344061	8465106	75207469	93521261	284383177		145138019
Greece				0	0	0	0	0	0
Hungary		456521		0			47567176	0	
Ireland			0	0	0		0	0	0
Italy	108844000	101126000	27116000	42979000	11028000	34817000	84641000		23156000
Latvia		0	0	0	0	0	0	0	0
Lituania	0	0	0	0	0	0	0	0	1158
Luxemburg	0	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0
Netherlands			0						
Poland				0			4399155		
Portugal	2075486	10018199							481454
Romania		1864214				747354		0	0
Slovakia		0	0	0	0	0	0	0	0
Slovenia			0	0	0		0	0	0
Spain	10524910	18420865	1856050		5952714	11949261	17794563		6833468
Sweden	265172804	0		0	0		0		0
United Kingdom	22405674	34831822	152089792		49350687	59593448	70596666	15874525	98680901
EU15TOTALS						274,027,700			
EU25TOTALS		382,631,359	813,493,928	57,454,038	191,736,835	277,910,956	671,659,886	70,799,792	
EU27TOTALS		384,536,988				279,040,762		70,799,792	

Table APP1.4 Eurostats data on EC pump production – by value (Euro), 2005.

Year: 2005									
Product Code	29122413 - Submersible motor, single-stage rotodynamic drainage and sewage pumps	29122415 - Submersible motor, multi-stage rotodynamic pumps	29122417 - Glandless impeller pumps for heating systems and warm water supply	29122420 - Rotodynamic pumps <= 15mm discharge	29122430 - Centrifugal pumps with a discharge outlet diameter > 15 mm, channel impeller pumps, side channel pumps, peripheral pumps and regenerative pumps	29122451 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with a single entry impeller, close coupled	29122453 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single stage with a single entry impeller, long coupled	29122455 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with double entry impeller	29122460 - Centrifugal pumps with a discharge outlet diameter > 15 mm, multi-stage (including self-priming)
Country	**Exports (Value)**								
Austria	6491110	1528370	1074770	2497760	1039740	1805330	1890540	73260	1296750
Belgium	7447250	1357780	1238310	506710	3739820	6717880	1723610	18780	457060
Bulgaria	295700	20370	58560	960	3450	206120	98350	0	645900
Cyprus	7710	257710	0	0	0	0	40	0	0
Czech Republic	2534660	221620	1256520	13274430	834870	1148750	507960	1860	858280
Denmark	6627810	76878510	137386870	140500	588500	1604640	5287190	31290	98811410
Estonia	232350	1490	164890	4050	2300	72580	16580	0	61710
Finland	20357720	97270	452640	17150	48720	232950	936410	2040	858780
France	75603510	21807440	196375730	818100	4781690	10967560	9650780	6599420	97368920
Germany	139838440	62527220	200829700	29154020	31328840	100102810	197714960	29133050	149784920
Greece	13130	282290	4016400	1700	0	4091280	444130	90	550690
Hungary	2135710	2498300	12742450	1018510	0	13538290	25864950	0	3228650
Ireland	35840340	58870	9781630	0	0	32770	0	0	0
Italy	50735480	35272040	28541860	222260	2516100	50804620	4676870	18330	6060980
Latvia	380620	84770	706350	1020	0	60740	140290	0	161450
Lituania	247420	211640	241580	91540	44870	68300	56640	0	6840
Luxemburg	36809100	0	43010	26610	800	880	9040		0
Malta	0	18410	0	0	0	0		0	0
Netherlands	7396600	1247480	1695920	17450	2317910	818140	3049080	0	308390
Poland	361700	386540	695090	150350	46740	2873890	293410	16620	56720
Portugal	527500	1295010	41590	0	0	0	1101450	0	807940
Romania	146320	18790	179170	1691980	1590	165570	1058460	0	46340
Slovakia	143290	32600	388560	139590	15710	607420	49690	0	0
Slovenia	869260	183400	6008810	3989270	79680	433720	573350	450	293860
Spain	6015040	1656560	702430	39730	875220	6696740	10652740	53300	1500280
Sweden	189363950	57800	3793780	172340	218300	1915990	378940	425650	516030
United Kingdom	12454860	1741060	36536940	882360	2578460	29483590	75091170	3188530	20962720
EU15TOTALS	259,005,120	104,761,810	166,653,290	9,905,690	27,212,380	90,523,500	187,107,470	35,207,020	158,506,020
EU25TOTALS	239,331,020	96,821,640	115,024,830	10,669,190	25,825,510	83,708,270	166,095,500	34,548,260	142,781,830
EU27TOTALS	234,397,730	94,573,390	106,508,890	10,651,440	25,224,580	81,587,610	162,305,010	33,175,460	138,416,520

Table APP1.5 Eurostats data on EC pump exports – by value (Euro), 2005.

Year: 2005									
Product Code	29122413 - Submersible motor, single-stage rotodynamic drainage and sewage pumps	29122415 - Submersible motor, multi-stage rotodynamic pumps	29122417 - Glandless impeller pumps for heating systems and warm water supply	29122420 - Rotodynamic pumps <= 15mm discharge	29122430 - Centrifugal pumps with a discharge outlet diameter > 15 mm, channel impeller pumps, side channel pumps, peripheral pumps and regenerative pumps	29122451 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with a single entry impeller, close coupled	29122453 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single stage with a single entry impeller, long coupled	29122455 - Centrifugal pumps with a discharge outlet diameter > 15 mm, single-stage with double entry impeller	29122460 - Centrifugal pumps with a discharge outlet diameter > 15 mm, multi-stage (including self-priming)
Country	**Imports (Value)**								
Austria	8975870	5886830	13054910	3076010	1205400	3776940	3103850	166490	3868520
Belgium	13139970	2847690	11979470	856180	1573020	4676840	7641000	132870	11218900
Bulgaria	1629110	698570	4006670	93240	259160	758370	930430	1130400	1504780
Cyprus	1017120	763630	1261370	126290	61310	11240	163060	1430	33980
Czech Republic	9265810	2968030	10780650	684840	669140	4348610	3286960	122950	4336550
Denmark	6408610	1754640	5982460	153180	625150	1657350	5607020	2300	20207400
Estonia	878470	204150	1745390	14260	32510	48090	981680	1310	693280
Finland	5602450	2582170	1435570	181690	753010	949020	4217450	14870	1876610
France	88006310	26229860	55881170	4446990	3921230	10796870	6514030	374640	47000730
Germany	81327440	36670930	163371520	19010960	2771340	52705340	30811080	1304920	68349960
Greece	2586440	3699230	14588060	196090	31730	1106470	165570	13710	2519900
Hungary	6615900	3510590	16141330	120490	387810	1453260	2483850	39140	4172290
Ireland	2885330	928060	6108670	82230	177490	573000	596940	20290	1282970
Italy	12223490	5860930	89160670	1672850	1552330	6752940	13256360	285830	24842930
Latvia	403820	409190	1813910	16080	22900	145200	475950	59250	983060
Lituania	1279460	979840	2099990	35490	89550	543280	974590	900	789560
Luxemburg	30298970	56780	3139660	97990	38110	89200	408160		111150
Malta	250220	212530	38140	32270	15400	20140		1040	11720
Netherlands	27185110	3161810	22022230	352050	4914520	4859700	6294780	53760	4990640
Poland	7493190	3039360	24048650	288400	729010	7669280	6330760	31930	3562260
Portugal	3815210	6448710	4427300	89450	311660	403580	716840	25450	5170570
Romania	7171030	4171030	9967640	367180	629440	2093420	2547470	86230	2565940
Slovakia	3480390	737400	6486950	232280	426500	726700	1529070	0	823260
Slovenia	1736940	513610	3997420	135220	549970	1646650	1309290	41430	933960
Spain	16157490	10278350	14507180	1619650	1245980	4061460	6551800	51660	14152020
Sweden	6601310	5052060	15152740	244410	741700	14424250	3445160	146230	7460280
United Kingdom	22048480	24818140	30300070	1102660	505860	4608780	9549940	579000	14937340
EU15TOTALS	35,038,010	14,923,780	13,961,420	17,908,180	1,614,140	17,419,900	31,038,220	1,659,080	15,291,330
EU25TOTALS	36,964,160	11,805,680	11,106,400	4,874,240	1,661,980	7,131,510	14,487,510	1,713,120	10,562,100
EU27TOTALS	37,576,400	13,527,400	11,481,230	5,182,840	1,902,240	6,995,080	14,778,600	1,713,120	8,780,720

Table APP1.6 Eurostats data on EC pump imports – by value (Euro), 2005.

Appendix 2 Design Factors Affecting Pump Efficiency[33]

Foreword

This Appendix is taken (without any modification) from Chapter 5. of the 'SAVE Study on Improving the Efficiency of Pumps', produced for the European Commission and issued in February 2001. It's intention was to give a purely theoretical indication of the effects of modifications to an idealised pump, not to be used to predict the performance of real pumps.

It was produced 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.

Due to this fact all theoretical examinations concerning the influences of design factors on pump efficiency were exemplarily demonstrated at a virtual, single stage end suction centrifugal pump operating at a speed of rotation of n = 1450 min-1 and a flow rate of Q = 180 m3/h. In connection with the value of specific speed ns this assumption is a measure for the size of the main hydraulic parts of a pump, which in the above mentioned case show dimensions greater than those of typical circulators or other small-sized 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.

In this regard it should be pointed out that the approaches and recommendations summarized in chapter 5 of the SAVE Study (Design Factors Affecting Pump Efficiency) shall only provide fundamental and descriptive information concerning secondary losses within centrifugal pumps and therefore are not intended to serve as strictly applicable instructions to improve the efficiency of any type and size of centrifugal pumps.

Therefore, while providing a useful technical understanding of the types of methods that can be used by manufacturers to improve pumps, these results should not necessarily be regarded as showing techniques for improvement of the types of pumps considered in this new EUP study.

[33] Extract from SAVE Study on improving the efficiency of pumps

Introduction

Due to the fact that the majority of the pump manufacturers within the EU have reached a level of know how which enables them to carry out hydraulically correct designed centrifugal pumps, the value of the practically attainable overall pump efficiency η of these machines is mainly influenced by factors such as surface roughness of parts which are in contact with the flow as well as the internal leakage flows through the sealing gaps. Especially the surface roughness of hydraulic parts strongly depends on the manufacturing techniques used. Further on the surface quality is a property which can get worse during life time of a pump and thereby causes energy losses during pump operation.

To quantify the effects of these above mentioned factors the following investigations on single-stage centrifugal pumps were carried out at the chair for Turbomachinery and Fluid Power at Darmstadt University of Technology:

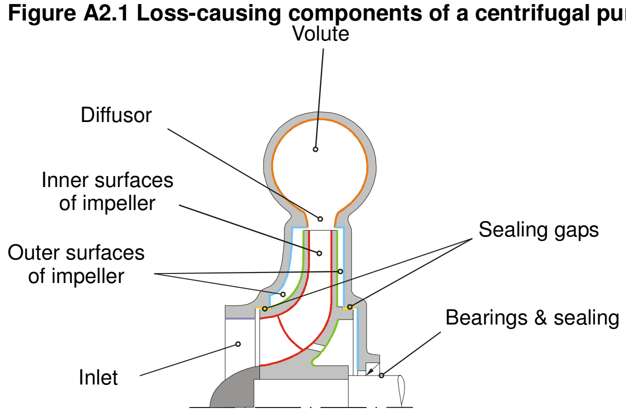
- The influence of different values of surface roughness
- The influence of smoothing several parts of pumps
- The influence of different gap clearances on the internal leakage flow rate

The specific speeds of the considered pumps covered the range from n_s = 10 min^{-1} up to n_s = 100 min^{-1} (corresponding to values from 520 min^{-1} up to 5200 min^{-1} in US-units) and represents the typical field of application of standard centrifugal pumps. By the aid of the similarity laws it is possible to transfer the results obtained for one pump size to another (respectively from one speed of rotation to another).

To carry out the investigations a special software tool was used, which was developed within the scope of a former research project named *"Attainable Efficiencies of Volute Casing Pumps"* sponsored by the Research Fund of the German Pump Manufacturer Association.

The main capability of this program is to estimate the maximum theoretically attainable efficiency $\eta_{max,th}$ of volute casing pumps. We explicitly want to point out that this software tool is no CFD code. To determine the friction losses for the parts shown in Figure A2.3 respectively the leakage flow rates through the sealing gaps the program uses differential equations as well as simplified mathematically loss approaches. All calculations are carried out on the base of a hydraulic design process considering common industrial design standards in respect to the geometrical settings.

Figure A2.1 Loss-causing components of a centrifugal pump



<u>Considered Losses</u>

- hydraulic losses:

friction losses
deceleration losses
wake losses
mixing losses (Volute)

- volumetric losses (gap flow)

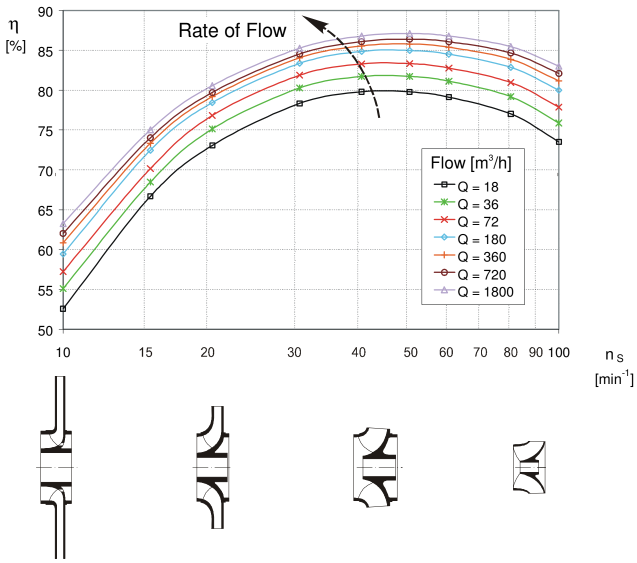
- mechanical losses

In order to evaluate the efficiency values estimated by the computer program additional experimental investigations were carried out at a centrifugal pump with a specific speed of n_s = 12 min^{-1}. This special test pump, designed according to usual industrial standards was equipped with very narrow sealing gaps (radial gap clearance equal to 0.1 mm) as well as hydraulic smooth surfaces. For this optimized pump the value of the inner efficiency η_i was measured at a special high precision test rig and compared to the theoretical value obtained by the computer program. The comparison of both values (for pump operation at the point of best efficiency) results in a very good agreement.

Results of the Theoretical Investigations

For the purpose within this SAVE study the above mentioned software tool was partly modified respectively extended in its capabilities. All the following figures which demonstrate the influence of the parameters surface roughness as well as gap clearance show efficiency values η respectively differences of efficiency values $\Delta\eta$ in per cent points that were plotted versus the value of specific speed n_s as defined in figure A2.2 (where n is the speed of rotation, Q the rate of flow and H the pump head).

Figure A2.2 The influence of rate of flow



Specific speed:

$$n_s = n \cdot \frac{Q^{1/2}}{H^{3/4}}$$

$n_s\,[\mathrm{min}^{-1}],\quad n\,[\mathrm{min}^{-1}],\quad Q\,[\frac{\mathrm{m}^3}{s}],\quad H\,[\mathrm{m}]$

$$n_{s,US-units} = 51.64 \cdot n_s$$

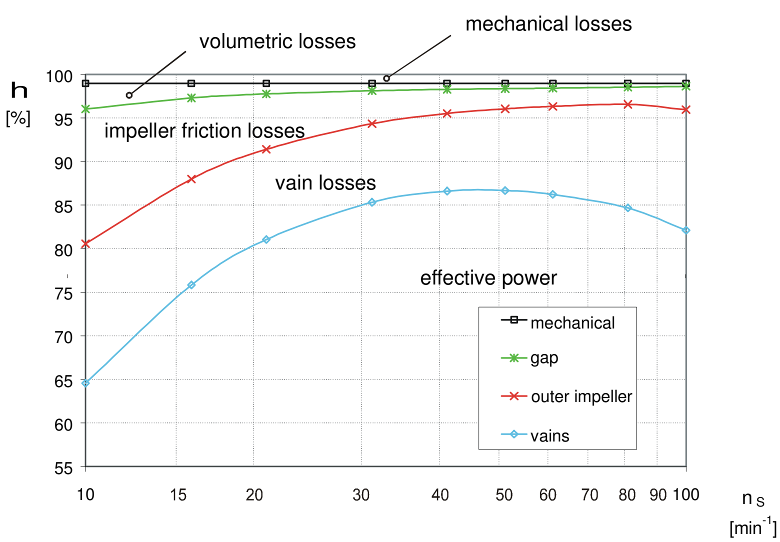
In the following:

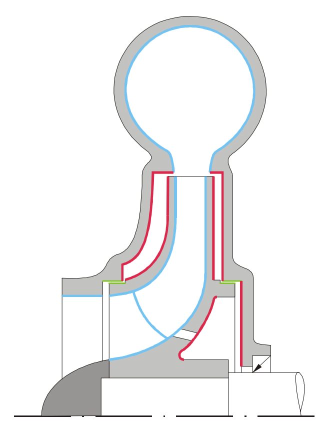
$n = 1450\,\mathrm{min}^{-1}$
$Q = 180\,m^3/h$

As shown in figure A2.2 every specific speed value corresponds to a typical impeller geometry, which means that low specific speeds characterize more radial extended impellers while higher specific speeds correspond to mixed flow respectively more axial types of impellers. Figure A2.2 exemplarily shows the dependence of the overall efficiency η on the rate of flow respectively pump size at constant speed of rotation ($n = 1450$ min^{-1}). It can be stated that an increase of the rate of flow leads to higher values of the overall pump efficiency, which is the effect of an increasing Reynolds number *Re*. The above figure also shows that the efficiency values for very low specific speeds are definitely smaller than for higher ones, which is due to the geometric as well as hydraulic attributes of such types of pumps.

In respect to a better comparability all results of the investigations shown in the following diagrams were generated for operating conditions characterized by a flow rate of 180 m^3/h and a speed of rotation $n = 1450$ min^{-1}.

Figure A2.3 Partial losses within a centrifugal pump





$n = 1450\,\mathrm{min}^{-1}$
$Q = 180\,m^3/h$

Depending on the value of specific speed which directly corresponds to the shape of the impeller different influences on the losses caused by several pump components can be mentioned. For pumps with lower specific speeds volumetric losses as well as losses due to disk friction at the back and front shroud of the impeller are very significant. This also applies to the losses within in the volute casing. For higher specific speeds the influence of blade friction losses within the impeller dominates and mainly determines the level of the overall efficiency η. According to former investigations based on statistically evaluated data it is known, that the largest potential regarding an improvement of efficiency does exist at low specific speeds.

Influence of different values of surface roughness

Figure A2.4 The influence of surface roughness

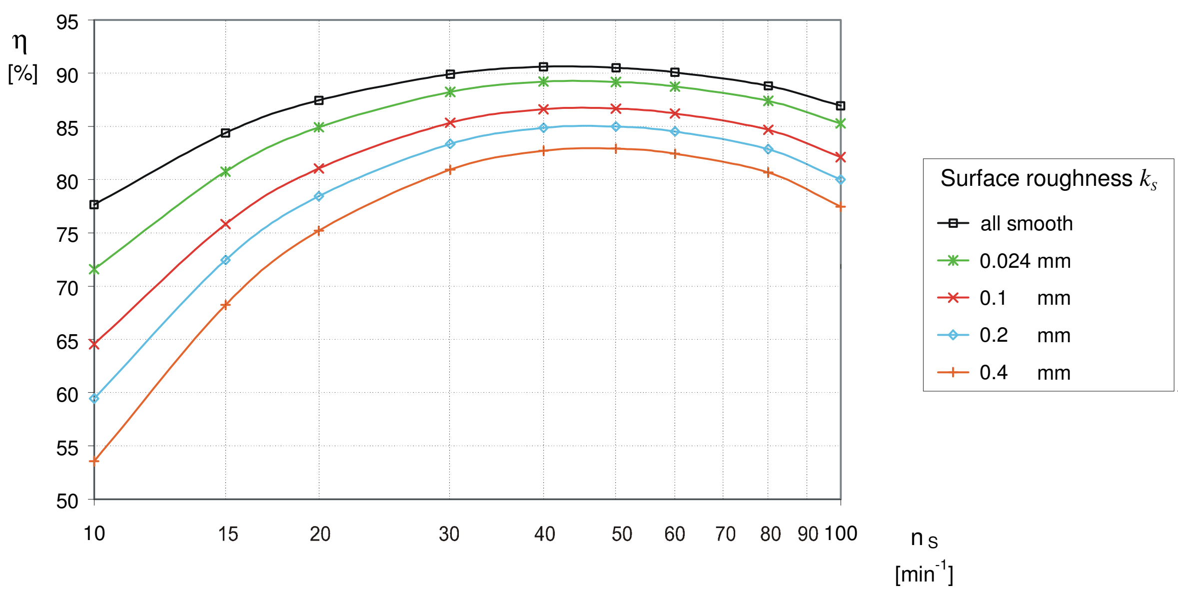


Figure A2.4 demonstrates the general influence of different values of surface roughness whereas all inner surfaces of the pump show identical conditions.
It is remarkable that the gain of efficiency due to smoothing the inner surfaces of a centrifugal pump is estimated more than 5 per cent points compared to pumps showing top quality sand-cast-rough surfaces (surface roughness $k_s \approx 0.024$ mm). Compared to pumps showing a very low surface quality (e.g. due to low quality of manufacturing, corrosion or incrustation which can result in a value for the surface roughness up to $k_s = 0.4$ mm) a theoretical efficiency improvement of even more than 20 per cent points could be estimated for pumps of very low specific speed ($n_s = 10$ min^{-1}).

The Influence of smoothing several parts of pumps

Since smoothing a whole pump is a very cost intensive manufacturing process (especially for small and medium sized pumps produced by a normal sand cast method) the influence of smoothing only several parts of the pump (i.e. volute, casing, outer surface of impeller, inner surface of impeller) was investigated theoretically by the aid of the described software.

The result of this parameter study shows, that also in case of partial smoothing the maximum efficiency improvement is to be expected for pumps with low specific speeds and can reach values of roughly 6.5 per cent points (e.q. in case of smoothing the outer surfaces of a radial impeller showing a origin surface roughness $k_s = 0.2$ mm). With respect to an overall surface treatment of the impeller the investigations showed also, that a smoothing of the inner surfaces is primarily favourable for pumps with higher specific speeds ($n_s > 30$ min^{-1}), where the hydraulic losses were mainly quantified by the flow velocity within the impeller.

The Influence of Only Partly Smoothing the Outer Surface of the Impeller

Due to the fact that especially for radial pump impellers ($n_s < 30$ min^{-1}) smoothing the outer surfaces of the impeller front and back shroud (by turning) is a very efficient and less costly procedure to reduce the losses, i.e. improvement of pump efficiency, the effect of smoothing the impeller front and back shroud only partly was also investigated by an appropriate theoretical parameter study.

As a result of this study it could be estimated, that smoothing only 40 % of the outer surface of the back and front shroud (starting the turning process at the impeller outlet diameter D_2) an efficiency improvement of roughly 5.5 per cent points still can be estimated. This value decreases to 3.5 per cent points in the case of smoothing only 20 % of the outer surface of the back and front shroud. Du to this fact there is no need to smooth the impeller at smaller diameters where turning gets more difficult because of the more complicated impeller contour.

As a validation of the above mentioned effect for the test pump ($n_s = 12$ min^{-1}) available at the chair of Turbomachinery and Fluid Power at Darmstadt University of Technology an improvement of efficiency of about 2 per cent points could be measured by smoothing 50 per cent of the outer surface of the impeller back and front shroud (whereas the original surface roughness k_s before smoothing showed a very low (good) value of roughly 0.03 mm).

Figure A2.5 summarises the theoretical estimation results obtained by the several parameter studies. The labelled efficiency values roughly quantify the maximum gain of efficiency (in per cent points) that can be expected by smoothing the wetted surfaces of a centrifugal pump showing a surfaces roughness equal to a k_s value of 0.2 mm. Depending on the specific speed of a pump the efficiency values can be significantly less.

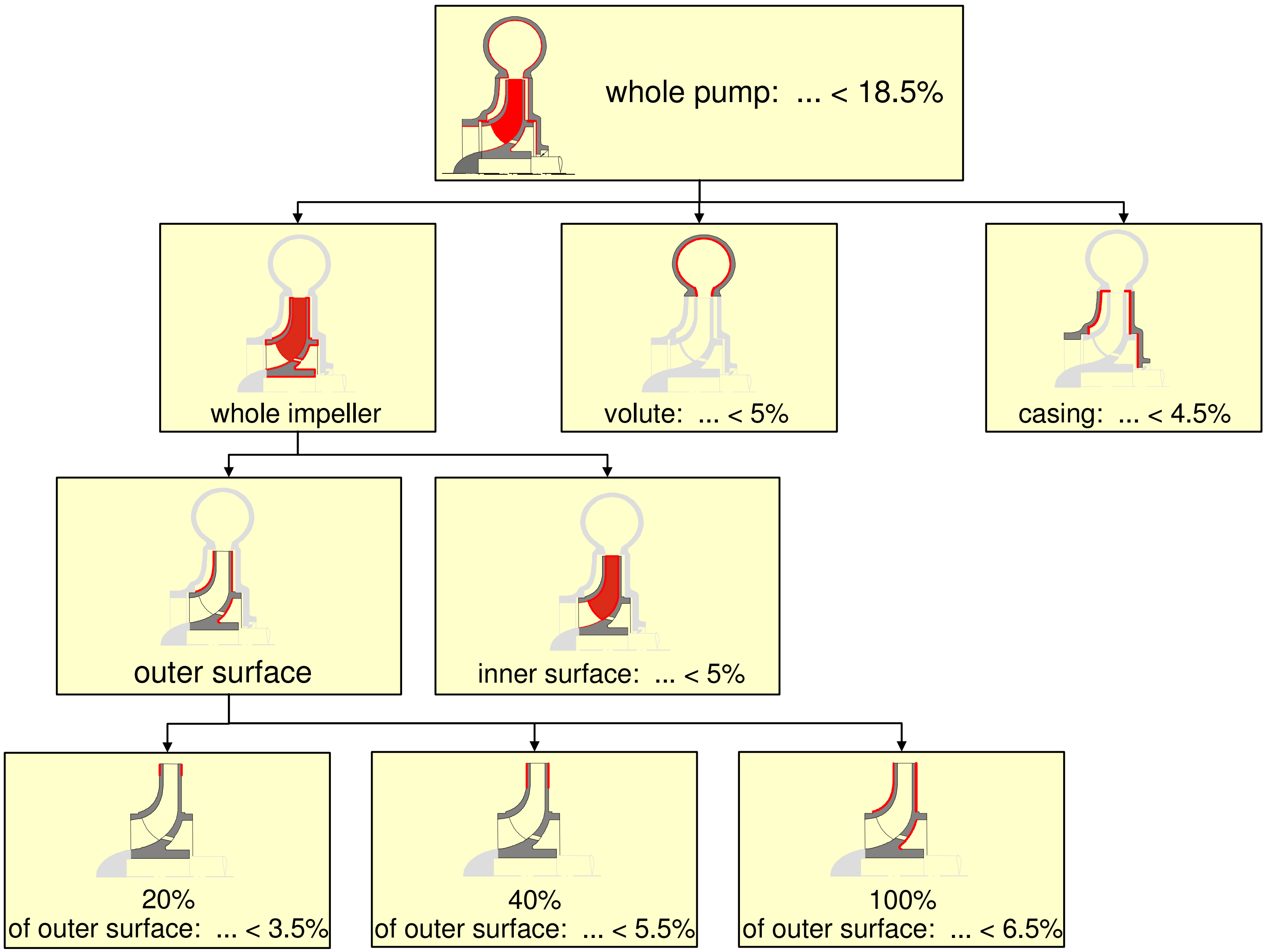
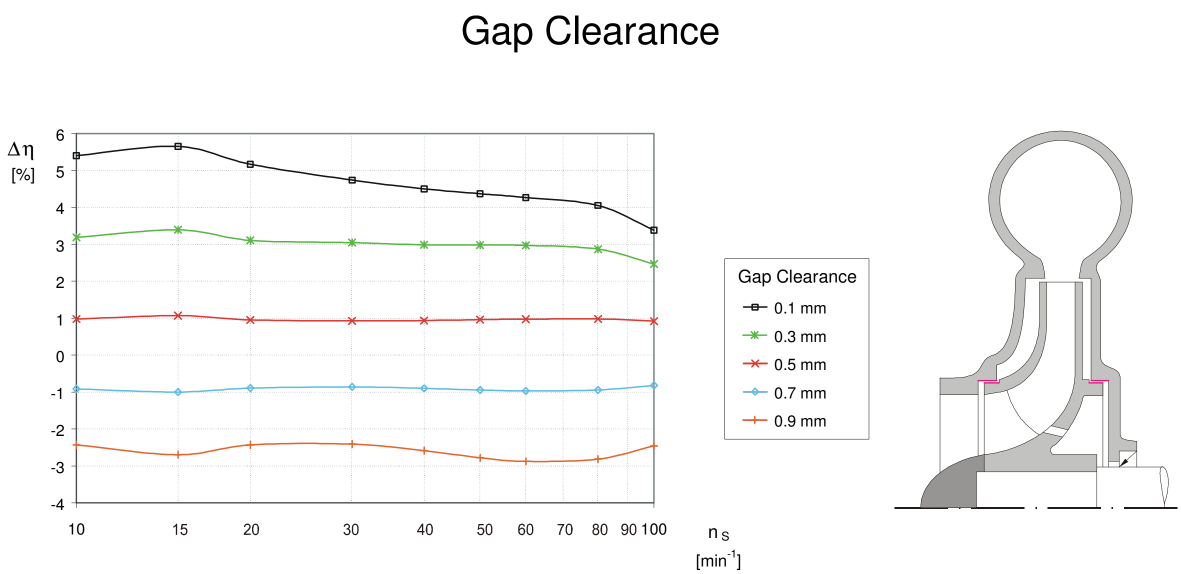


Figure A2.5 Maximum improvement of efficiency for several smoothing steps (estimated by theoretical calculations for medium size pump of 180 m^3/h))

Influence of Different Gap Clearances on the Internal Leakage Flow Rate

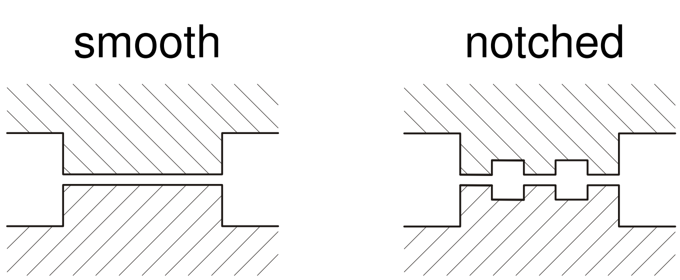
Volumetric losses are mainly caused by the existence of a suction-sided sealing gap which serves as a throttle in order to reduce the secondary flow from the impeller out- to inlet as well as a an additional pressure-sided sealing gap which usually belongs to the axial thrust balancing system of a single-stage centrifugal pump. This internal leakage flows strongly depend on the clearance of the sealing gaps. Figure A2.6 shows the change in efficiency due to a variation of the gap clearance (the change in efficiency refers to a smooth gap with a radial gap clearance of 0.6 mm).

Figure A2-6 The influence of secondary flow through the sealing gaps



The above diagrammed estimation results demonstrate that a reduction of gap clearance for instance from 0.6 mm to 0.3 mm can improve the pump efficiency about 3 per cent points. A possible additional treatment to reduce the internal leakage flows is to furnish one or both gap surfaces with circumferential notches (Fig. A2.7).

Figure A2.7 Different types of sealing gaps



The theoretically carried out parameter study showed, that notching gaps of the type usually used in standard centrifugal pumps (cylindrical gaps with a relatively short gap length), only leads to a slight improvement of the pump efficiency.

Conclusions

The presented results show, that for single-stage standard centrifugal pumps within a range of specific speed n_s = 10 min^{-1} up to n_s = 100 min^{-1} (corresponding to values from 520 min^{-1} up to 5200 min^{-1} in US-Units), the highest potential for an efficiency improvement can generally be found in the region of low specific speeds. All efforts aimed at an improvement of the surface quality of several parts of the pump which are in contact with the flow cause a gain of efficiency. With regard to the manufacturing costs which result from such additional surface treatments the smoothing of the outer front and back shroud of the impeller can be proposed as a cost-efficient procedure to improve the efficiency. Furthermore it could be shown that it is recommendable to reduce the clearance of the sealing gaps to the smallest possible value in order to increase the volumetric efficiency.

It should also to be mentioned, that the conditions of the surfaces as well as the sealing gaps within a centrifugal pump normally depend on the time of operation, which means that there is a strong necessity to check these parameters at reasonable intervals during the life time of a pump.

Appendix 3 A method to define a minimum level of pump efficiencies based on statistical evaluations

(Technical University Darmstadt)

Chair of Fluid Systems Technology

Prof. Dr.-Ing. Peter Pelz
Prof. Dr.-Ing. Bernd Stoffel

Final report

of
EUROPUMP JWG on EuP

concerning activities on

"A method to define a minimum level for pump efficiencies based on statistical evaluations"

Darmstadt, 17.09.2007

Execution of evaluation:

Dr.-Ing. Miriam Roth
Dr.-Ing. Gerhard Ludwig
Dipl.-Ing. Valérie Bischof

Chairman of the institute:

Prof. Dr.-Ing. Peter Pelz

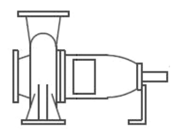
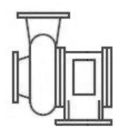
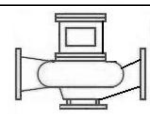
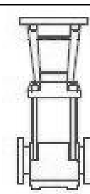
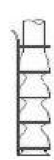
Objectives

The following report is the result of the EuP Joint Working Group (JWG) of EUROPUMP, the European Association of Pump Manufacturers. It takes into account aims of the study group for LOT11 (AEA – Future Energy Solutions) and concerns of the manufacturers participating in the JWG.

The purpose of this work was to propose a concept of a go/no-go scheme for pump efficiency evaluation. The pumps considered are water pumps in commercial buildings, for drinking water pumping, food industry and agriculture. A minimum level limit (bottom curve) for the efficiency values of several pump types was to be determined. Each pump is characterized by its type, its specific speed n_s and its size.

In order to obtain data which is representative for a customary pump selection, 16 manufacturers of 7 EU countries have given pump values of flow rate, head and efficiency at the best efficiency point (b.e.p.) as well as at part load ($0.75 \cdot Q_{b.e.p.}$) and overload ($1.10 \cdot Q_{b.e.p}$). 5 different pump types with 2-pole as well as 4-pole electric motors have been considered (see Table 1); the total amount of pump data processed was 2390.

Table 0-1: Water pumps considered in the investigation

Pump Type		**Number of Pumps**	
		4-pole motor	**2-pole motor**
ESOB End Suction Own Bearings pump		532	412
ESCC End Suction Close Coupled pump		435	364
ESCCI Inline End Suction Close Coupled pump		187	165
MS Multistage pump		55	85
MSS Submersible Multistage pump		-	155
		∑ 2390	

Section 1: Efficiency considerations

Data processing

The specific speed n_s of each pump of the data was calculated

$$n_s = n \cdot \frac{Q^{\frac{1}{2}}}{\left(\frac{H}{i}\right)^{\frac{3}{4}}}$$

Specific speed n_s [min^{-1}]
Rotational speed n [min^{-1}]
Flow rate Q [m^3/s]
Pump head H [m]
Number of stages i [-]

The range of specific speed of all pumps is from n_s 6 to 110.5 min^{-1} (approximately 312 to 5746 rpm in US-units), and the range of flow rate is from 1.8 to 1200 m^3/h (approximately 8 to 5280 gpm). Figure 1 and figure 2 show the range of specific speed and of the flow rate for each pump type.

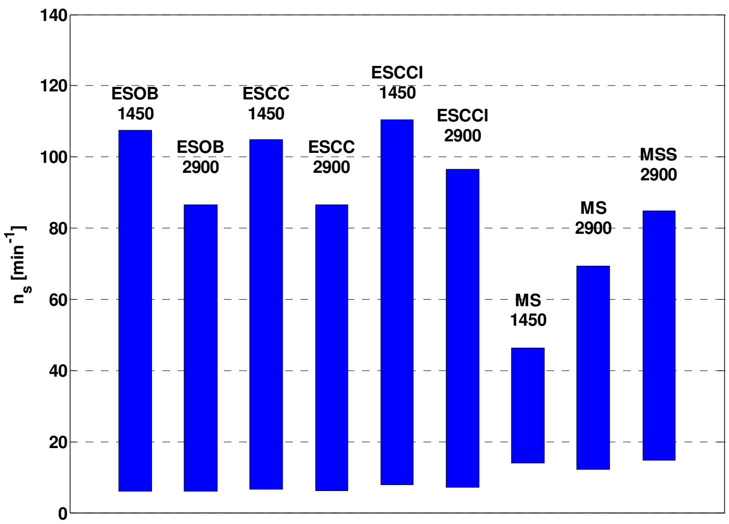


Figure 0-1: Range of specific speed of the data

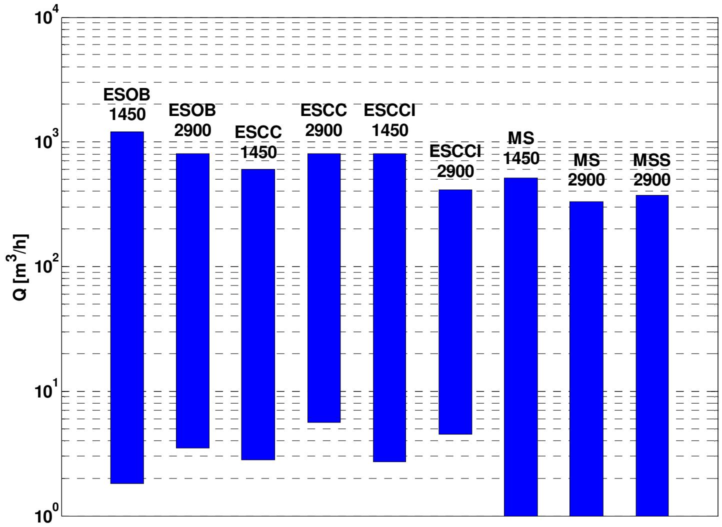


Figure 0-2: Range of flow rate of the data

Scope

It was agreed by the EuP-JWG that the scope of water pumps having to fulfil the minimum efficiency requirement is defined as follows (see Table 2 and Appendix 1):

Table 0-2: Hydraulic scope according to the pump type

Pump type	Defined scope				
ESOB	$n = 1450\ min^{-1}$	$Q_{b.e.p.} \geq 6\ m^3/h$	$H_{b.e.p.} \leq 90\ m$	$6\ min^{-1} \leq n_s \leq 80\ min^{-1}$	$P_2 \leq 150\ kW$
ESCC					
ESCCI					
ESOB	$n = 2900\ min^{-1}$	$Q_{b.e.p.} \geq 6\ m^3/h$	$H_{b.e.p.} \leq 140\ m$	$6\ min^{-1} \leq n_s \leq 80\ min^{-1}$	$P_2 \leq 150\ kW$
ESCC					
ESCCI					
MS	$n = 2900\ min^{-1}$			$Q_{b.e.p.} \leq 100\ m^3/h$	
MSS	3“ ≤ nominal size ≤ 6“				

Scheme: ‘House of Efficiency’

The decision scheme ‘House of Efficiency’ [1] takes into account design and application purposes as well as the pump minimum efficiency dependence on flow. The minimum acceptable efficiency is therefore different for each pump type. The pass-or-fail scheme is based on two criteria A and B.

Criterion A is the pass-or-fail minimum efficiency requirement at the best efficiency point (b.e.p.) of the pump:

Ⓐ $$\eta_{Pump}(n_s, Q_{BEP}) \geq \eta_{BOTTOM}$$

Criterion B is the pass-or-fail minimum efficiency requirement at part load (PL) and at overload (OL) of the pump:

Ⓑ $$\eta_{BOTTOM-PL,OL} \geq x \cdot \eta_{BOTTOM}$$

That leads to bottom lines specific to each pump type at a certain flow (see fig. 3) which have to be defined, based on statistical data.

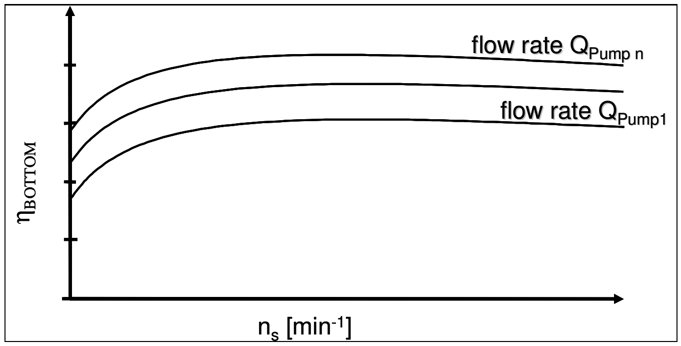


Figure 3: Bottom lines for different geometrical pump sizes (defined for nominal flow rate Qn > Q1) within one pump type (e.g. ESCC) [1]

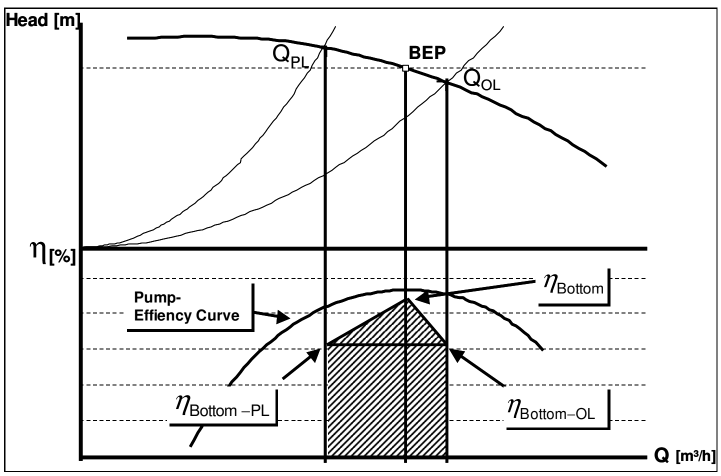


Figure 4: 'House of Efficiency' – explanatory representation of proposed scheme in a η(Q):flow-Plot [1]

In figure 4 the representation of the two criteria is shown in an η(Q):flow-plot. The pump efficiency curve with its maximum at the best efficiency point does not cross the 'roof of the efficiency house'. The part and over load minimum acceptable efficiencies at $0.75 \cdot Q_{BEP}$ and $1.10 \cdot Q_{BEP}$ build the roof-triangle with the minimum acceptable efficiency at best efficiency point. As a result, the pump efficiency curve has to be broad and high to fulfil the criteria. The shown example is for a pump passing the agreed efficiency criteria (not yet set) and would therefore pass the energy efficiency check. Subsequently it would be eligible for CE-marking in accordance with the applicable Directive. Pumps with robust trade-off criteria like NPSH, noise, application for dirty water or other aspects should separately be considered with their own minimum acceptable efficiency and specific factor 'X' to be defined.

The application of this scheme requires the definition of pump specific bottom lines for different flows (see figure 3) as well as the factor *x* for part load and overload based on the statistical data provided by the manufacturers.

Minimum efficiency requirement and cut-off values

Since the efficiency bottom limit mainly depends on the specific speed and on the flow rate of a pump, it should be described by a three-dimensional plane. The shape of the plane was defined using data from a previous investigation carried out by the Technische Universität Darmstadt in 1998 [3]. A statistical evaluation of data collected from several questionnaires sent to European pump manufacturers was carried out and an envelope of the data of the efficiency values over n_s was created for 6 distinct flow rates under consideration of physical laws which determine dependence of pump internal losses on geometrical and operational pump data (as shown in figure 5).

The six curves were extrapolated (quadratic polynomial) to the limits of the scope considered in this investigation and a plane fitting the curves (linear interpolation) was created (as it is shown in figure 6).

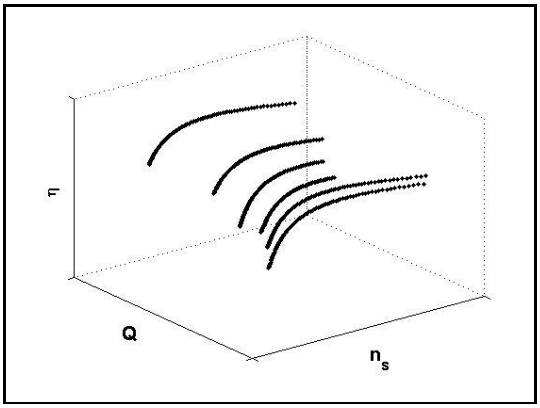


Figure 5: Curves from previous investigations

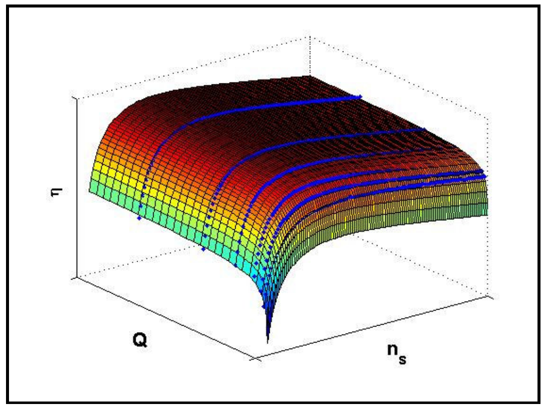


Figure 6: Extrapolated curves

The mathematical description of the plane was obtained by means of a 3-d quadratic polynomial approximation. The equation[34] defining the efficiency plane is:

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

with
$x = \ln(n_s)$ with n_s in [min^{-1}]
$y = \ln(Q)$ with Q in [m^3/h]

The final plane is shown in figure 7. The numbers of pumps (in percentage of the total data of one pump type) that do not fulfil the minimum efficiency requirements imposed by the plane are lying below the surface and are therefore "cut-off" by the plane.
With C used as a variable for each pump type, it is possible to identify the pumps with the lowest efficiencies for the size and specific speed considered. The plane is shifted downwards vertically according to the value of C, until the chosen quantity cut-off criterion is fulfilled. The shape of the plane is valid for all defined pump types.

[34] The equation is valid for quantity cut-offs from 5% to 80%.
The mathematical scope of the equation is $6 < n_s < 120$ [min^{-1}] and $2 < Q < 1000$ [m^3/h].
The plausibility has to be checked according to the cut-off criterion.

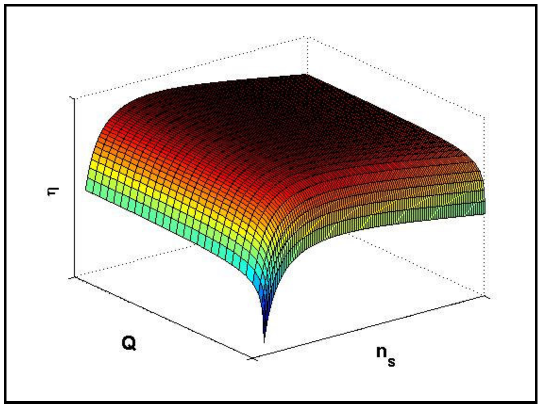


Figure 7: Final plane

Table 3 shows the values of C for the pump type considered and for different cut-off criteria.

Table 3: Values of the variable C for different quantity cut-offs

	Quantity cut-off									
	5%	10%	15%	20%	30%	40%	50%	60%	70%	80%
C (ESOB 1450)	134.38	132.58	131.70	130.68	129.35	128.07	126.97	126.10	124.85	122.94
C (ESOB 2900)	137.28	135.60	134.54	133.43	131.61	130.27	129.18	128.12	127.06	125.34
C (ESCC 1450)	134.39	132.74	132.07	131.20	129.77	128.46	127.38	126.57	125.46	124.07
C (ESCC 2900)	137.32	135.93	134.86	133.82	132.23	130.77	129.86	128.80	127.75	126.54
C (ESCCI 1450)	138.13	136.67	135.40	134.60	133.44	132.30	131.00	130.32	128.98	127.30
C (ESCCI 2900)	141.71	139.45	137.73	136.53	134.91	133.69	132.65	131.34	129.83	128.14
C (MS 1450)	134.83	134.45	133.89	132.97	132.40	130.38	130.04	127.22	125.48	123.93
C (MS 2900)	139.52	138.19	136.95	135.41	134.89	133.95	133.43	131.87	130.37	127.75
C (MSS 2900)	137.08	134.31	132.89	132.43	130.94	128.79	127.27	125.22	123.84	122.05

The table values read horizontally (cut-off 5% to cut-off 80%) result from the efficiency scatter of each pump type. The comparison of different pump types has to be done in consideration of the head and flow rate at b.e.p. using the mathematical equation presented above.

An important advantage of using a three dimensional approach for the evaluation is that the scatter in efficiency values is properly showing the efficiency differences due to design and manufacturing of pumps of the same size and specific speed. If flow rate classes were used instead, the scatter would be broader due to the efficiency differences resulting from pumps of various sizes. Such an approach would not reflect the difference of the individual efficiency of each pump from the statistically mean value for the corresponding flow rate and therefore is not suitable to serve as an evaluation scheme. The data provided for the ESCC 1450 pump for example has an apparently too high efficiency scatter of 27.3 percentage points for a flow rate class of 70-100 m^3/h, the scatter is 21.3 percentage points for the smaller flow rate class of 80-100 m^3/h and 15.8 for 90-100 m^3/h. A correct efficiency scatter is only obtained by introducing a Q-dimension and thus using a three dimensional method.

Part load and overload

The pump data given by the manufacturers was evaluated at part load ($0.75 \cdot Q_{b.e.p.}$) and overload ($1.10 \cdot Q_{b.e.p}$).

A part load coefficient x was calculated with

$$x = \frac{\eta_{partial\,load}}{\eta_{b.e.p.}}$$

for each pump type and the standard deviation was determined. Figure 8 (left figure) shows the part load coefficient x and the double standard deviation, which includes 95.5% of all pumps of a type. The mean value of the part load coefficient for all pump types was calculated for part load to $x_m = 0.947$.

Using the same efficiency plane described in the previous sections, one can determine the minimum efficiency requirement for part load with

$\eta_{BOT,PL} = 0.947 \cdot \eta_{BOT,b.e.p.}$

A mean overload coefficient of $x_m = 0.985$ was determined using the same method (figure 8 right figure). One can determine the minimum efficiency requirement for overload with

$\eta_{BOT,OL} = 0.985 \cdot \eta_{BOT,b.e.p.}$

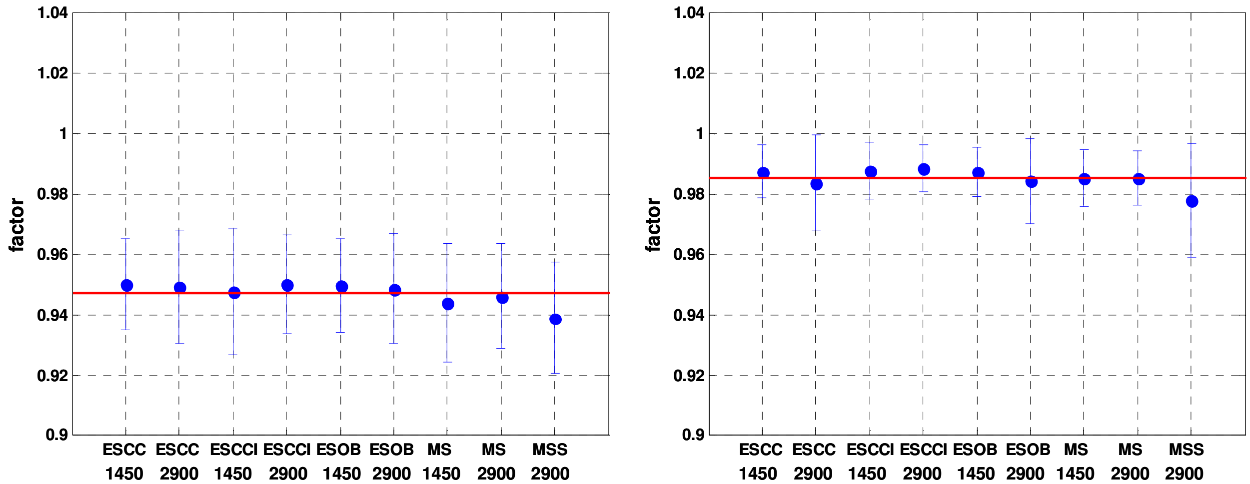


Figure 8: Coefficients for part load (left figure) and overload (right figure)

Example of application of the methodology (cut off 10%)

A pump with the following characteristics is to be evaluated:

Pump type:	ESOB
Rotational speed:	1450 min^{-1}
Flow at b.e.p.:	400 m^3/h
Head at b.e.p.:	10 m
Efficiency at b.e.p.:	85.7 %
Efficiency at part load $Q_{PL} = 0.75 . Q_{b.e.p.} = 300\ m^3/h$:	80.5 %

1. **Exact method (mathematical evaluation)**

Step 1:
The specific speed is calculated to $n_s = 85.95\ min^{-1}$

Step 2:
The value of C is looked up in table 3 for the pump type and the cut-off criterion (ESOB, 4 pole motor, cut-off 10%):

C = 132.58

Step 3:
The minimum efficiency requirement for b.e.p. is calculated with the formula

$\eta_{BOT,b.e.p.} = - 11.48\ x^2 - 0.85\ y^2 - 0.38\ xy + 88.59\ x + 13.46\ y - C$

$\eta_{BOT,b.e.p.} = 74.2535\ \%$

Step 4:
The obtained value is compared to the efficiency of the pump at b.e.p.

$\eta_{pump,b.e.p.} > \eta_{BOT,b.e.p.}$

Step 5:
The minimum efficiency requirement for part load is calculated with the formula

$\eta_{BOT,PL} = 0.947\ \eta_{BOT,b.e.p.}$

$\eta_{BOT,PL} = 70.32\ \%$

Step 6:
The obtained value is compared to the efficiency of the pump at part load.

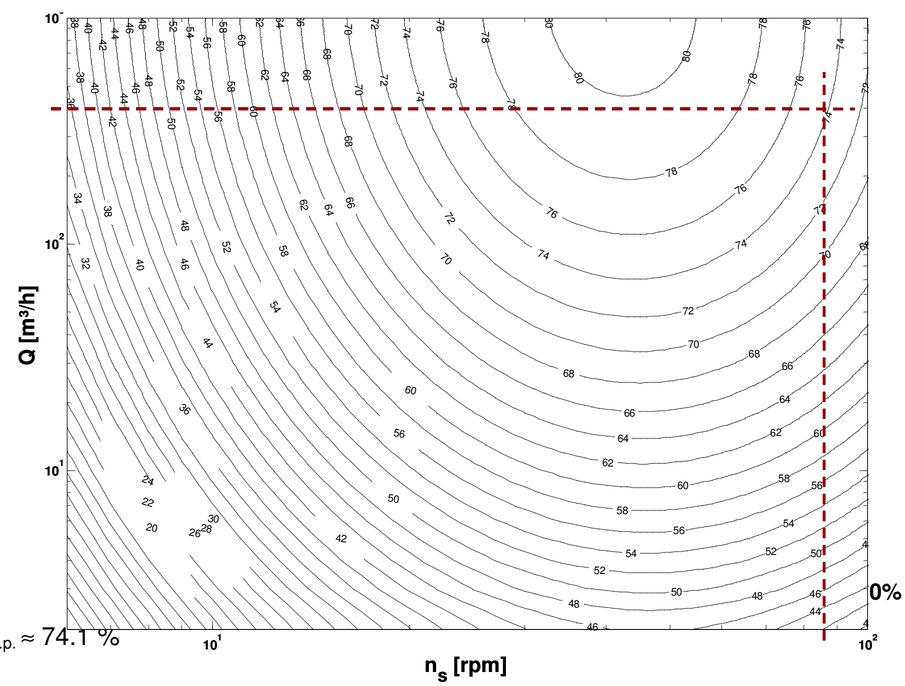
$\eta_{pump,PL} > \eta_{BOT,PL}$

2. Graphical method

Step 1:
The specific speed is calculated to $n_s = 85.95\ min^{-1}$

Step 2:
The 2D graph for the pump type (ESOB, 4 pole motor, cut off 10%) is looked up

Step 3:
The minimum efficiency requirement value is determined graphically.



$\eta_{BOT,b.e.p.} \approx 74.1\ \%$

Step 4:
The obtained value is compared to the efficiency of the pump at b.e.p.

$\eta_{pump,b.e.p.} > \eta_{BOT,b.e.p.}$

<u>Step 5:</u>
The minimum efficiency requirement for part load is calculated with the formula

$\eta_{BOT,PL} = 0.947\ \eta_{BOT,b.e.p.}$

$\eta_{BOT,PL} \approx 70.17\ \%$

<u>Step 6:</u>
The obtained value is compared to the efficiency of the pump at part load.

$\eta_{pump,PL} > \eta_{BOT,PL}$

Section 2: Energy savings

Scenario considerations

An estimation of the energy savings according to the selected cut-off criterion and pump type was carried out. The power consumption considered is the shaft power P2, excluding motor losses. The amount of energy savings depends strongly on what will be done with the pumps not fulfilling the minimum efficiency requirements. Different scenarios could be thought of; it is very likely that a combination of them will occur in reality.

One possible scenario is that the pumps not fulfilling the minimum acceptable efficiency limit are improved by design and manufacturing measures just to an extent to meet the requirements of efficiency imposed by the defined bottom efficiency plane. Another possible scenario would be that the pumps are improved to a level which is the average plane (old C mean) of the pump data. The last scenario and the one considered in this work is that the pumps failing the minimum acceptable efficiency are removed from the market and replaced by pumps of the same size and specific speed with an efficiency lying on the new average plane (new C mean) calculated from the data field excluding the removed pumps. Figure 10 illustrates this approach.

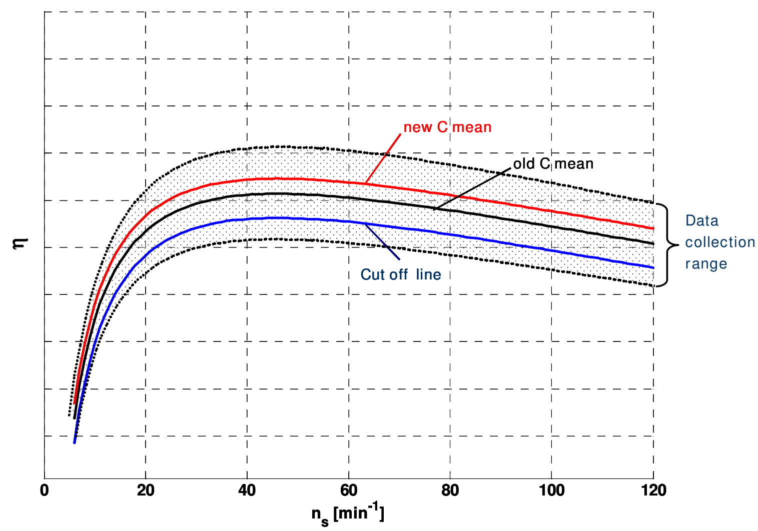


Figure 10: Cut-off and C-mean planes
(for better visualisation the efficiency lines are shown for one flow rate only)

Estimation of the power savings

The annual energy consumption (AEC) of each pump type is the sum of the product of the numbers of pumps of one pump type (z), the running hours per year (t) and the average power consumption of this pump type per year (P_{avrg}). The power considered is P2, which is the shaft power input that does not include the motor losses.

Annual energy consumption [TWh]

$$AEC = \sum z \cdot t \cdot P_{avrg}$$

The energy consumption of the installed stock (STC) is the product of the pump's lifetime (n=10) and the annual energy consumption (AEC).

Stock energy consumption [TWh]

$$STC = n \cdot AEC$$

After removing the pumps with low efficiencies from the market and replacing them by better ones, the reduced energy consumption in ten years from now (REC) may be calculated by subtracting the power savings from the energy consumption of the installed stock.

$$\text{Reduced energy consumption in 10 years from now [TWh]}$$
$$REC = STC\,(1 - S)$$

S is the percentage of mean power reduction of all pumps of a pump type. It is calculated by summarizing the relative power improvement of each pump failing the minimum efficiency requirements and dividing the result by the total number of pumps of a pump type (N_{pumps}). The result is the mean relative power improvement in percent achieved by replacing the pumps failing the cut-off demands by better ones (see the scenario described above).

$$\text{Power Savings [\%]}$$
$$S = \frac{\sum_{i}^{Nimpr} k_i \cdot \frac{(P_{b.e.p.,i} - P_{BOT,i})}{P_{b.e.p.,i}}}{N_{pumps}} \cdot 100$$

for each pump (index i) needing improvement:

$$(P_{b.e.p.} - P_{BOT}) = \frac{\rho\, g\, Q_{b.e.p.}\, H_{b.e.p.}}{\eta_{b.e.p.}} - \frac{\rho\, g\, Q_{b.e.p.}\, H_{b.e.p.}}{\eta_{BOT}} = \rho\, g\, Q_{b.e.p.}\, H_{b.e.p.}\, \frac{(\eta_{BOT} - \eta_{b.e.p.})}{\eta_{b.e.p.} \cdot \eta_{BOT}}$$

η_{BOT}:	efficiency value imposed by the bottom efficiency plane [-]
P_{BOT}:	reduced power consumption value on the bottom efficiency plane [W]
$\eta_{b.e.p.}$, $Q_{b.e.p.}$, $H_{b.e.p}$, $P_{bep.}$:	efficiency [-], flow rate [m^3/s], head [m], power consumption [W] of the pump at b.e.p.
ρ:	water density [kg/m^3]
g:	gravity constant [m/s^2]
k:	weighting coefficient of the pump [-]
N_{pumps}:	total number of pumps [-]
N_{impr}:	number of pumps failing the efficiency requirements [-]

It should be pointed out that the percentage of power savings S applies to the scope of data given by the manufacturers (k =1); the running hours of each pump would be necessary in order to realize a weighting k_i and make an accurate estimation of the energy savings on the market.

Table 3 shows the results for the reduced energy consumption of each pump type for different cut-off criteria, as well as the total savings of energy in percentage and Terrawatthours in 10 years from now.

Table 3: Reduced energy consumption and energy savings for different quantity cut-offs

Pump type	Stock consumption	Reduced energy consumption in [TWh] by cut-off [%]								
	[TWh]	5%	10%	15%	20%	30%	40%	50%	60%	80% (2)
ESOB 1450	27.00	26.79	26.66	26.55	26.44	26.23	26.03	25.80	25.49	25.35
ESOB 2900	27.00	26.82	26.66	26.52	26.40	26.18	25.99	25.76	25.46	25.33
ESCC 1450	20.25	20.09	19.99	19.90	19.82	19.68	19.53	19.38	19.21	19.13
ESCC 2900	20.25	20.12	20.00	19.90	19.82	19.66	19.51	19.36	19.21	19.13
ESCCI 1450	12.00	11.91	11.85	11.80	11.75	11.65	11.55	11.45	11.32	11.27
ESCCI 2900	12.00	11.90	11.82	11.76	11.69	11.56	11.46	11.34	11.21	11.14
MS 1450	4.50	4.48	4.46	4.44	4.41	4.36	4.30	4.26	4.20	4.17
MS 2900	4.50	4.46	4.44	4.42	4.40	4.36	4.32	4.28	4.19	4.15
MSS 2900	16.80	16.65	16.53	16.42	16.32	16.15	15.93	15.79	15.53	15.43
Total stock consumption [TWh]	144.30	143.22	142.40	141.71	141.05	139.85	138.63	137.41	135.82	135.12
energy savings in 10 years from now [%]		0.75%	1.31%	1.79%	2.25%	3.08%	3.93%	4.77%	5.87%	6.36%
energy savings P1 in 10 years from now [TWh]		**1.08**	**1.90**	**2.59**	**3.25**	**4.45**	**5.67**	**6.89**	**8.48**	**9.18**

A graphical representation of the results for all pumps is shown in figure 11. Figure 12 shows the energy savings in ten years from now for each pump type for different cut-off criteria.

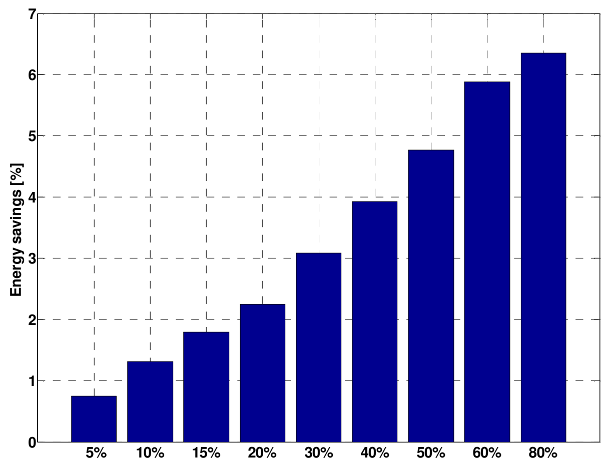


Figure 11: Total annual energy savings for different quantity cut-offs [%]

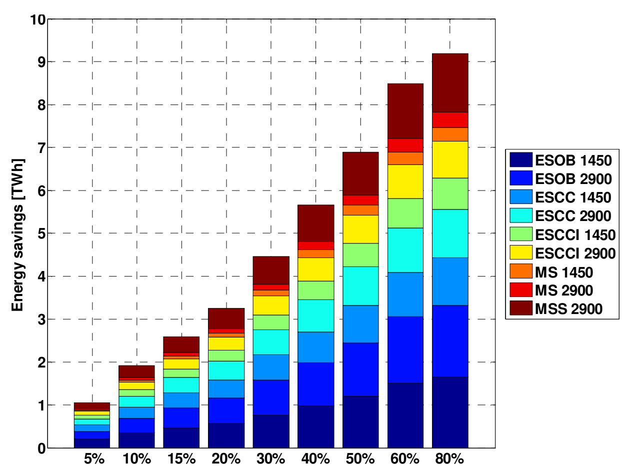


Figure 12: Energy savings of each pump type for different cut-offs [TWh]

References

[2] Since the efficiency maximum is determined by the 80% cut-off plane, all pumps lying under the 80% quantity cut-off plane are improved to meet the efficiency requirements imposed by this upper limit (in difference to figure 10)

1. Bartoschek, M., Bidstrup, N. and Teepe, M., '*Energy Efficiency Evaluation of Pumps in Europe - Europumps proactive approach to the Energy Using Products Directive',* EEMODS - Energy Efficiency in Motor Driven Systems Conference, Beijing China, 2007.

2. Stoffel, B. and Lauer, J., *'Theoretically attainable efficiency of centrifugal pumps',* Summary of the final report on the research project for VDMA, Technical University of Darmstadt, 1994.

3. Stoffel, B. and Lauer, J., *'Attainable efficiencies of volute casing pumps',* Summary of the final report on the research project for Europump, Technical University of Darmstadt, 1998.

4. Stoffel, B., Ludwig, G., and Meschkat, S., *'Evaluation of efficiency values considering the effect of pump size modularity'*, Technical University of Darmstadt, 2002.

Appendices

1. Knapp, P., *'EuP-JWG Agreement on Proposal for scope of water pumps which have to fulfil minimum efficiency requirement',* 2007.

2. List of the pump manufacturers who provided data for the evaluation.

Appendix 2:
List of the pump manufacturers who provided data for the evaluation

Allweiler, Radolfzell, Germany

Calpeda S.p.A., Montorso Vicentino, Italy

Caprari S.p.A., Modena, Italy

Cpma, Czech Pump Manufacturers Association, Lutin, Czech republic

Flowserve Pump Ltd., Newark, Great Britiain

Grundfos, Bjerringbro, Denmark

Johnson Pump, Örebro, Sweden

KSB AG, Frankenthal, Germany

LOWARA srl, Montecchio Maggiore Vicenza, Italy

Oddesse, Oschersleben, Germany

Osna Pumpen, Osnabrück, Germany

Peme Gourdin, Biot, France

Ritz, Schwäbisch Gmünd, Germany

SAER Elletropompe S.p.A., Guastalla, Italy

Sterling SIHI, Itzehoe, Germany

WILO, Dortmund, Germany

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