

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

ENER Lot 28 – Pumps for Private and Public Wastewater and for Fluids with High Solids Content – Task 6: Technical Analysis BAT

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## Chapter 6: Technical analysis of best available technology (Task 6)

A Best Available Technology (BAT) for a product in this study is a technology or change in design that leads to less environmental impacts and is already available on the market, or whose technical feasibility has already been demonstrated (and expected to be introduced within 2-3 years). Best not yet Available Technology (BNAT) refers to a technology that has the potential to lead to further environmental performance improvements, but still is subject to research and development. BNAT is rather a future option or long-term trend.

The identification and analysis of BAT and BNAT provides input for the assessment of the improvement potential in Task 7. The intellectual property, technical feasibility and the availability on the market of BATs in a strict sense are not judged here, as the objective is to illustrate various technically available (or potentially available) options. However, Task 7 will consider these issues when suggesting possible improvement options applicable to wastewater pumps.

The results of this task are predominantly based upon available literature, which includes technical journals, magazines and research publications, as well as other sources such as interviews with technology experts, research institutes and the stakeholders of this study.

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 19<sup>th</sup> century that real improvements became possible. By the 1880's pump's hydraulic efficiencies of 80% were achieved. Today, hydraulic efficiencies well over 90% are achieved in larger clean water pumps. The hydraulic efficiency of wastewater pumps has to be considered in tandem with their ability to handle solids and become blocked or clogged by solids. As such, the maximum hydraulic efficiency of centrifugal wastewater pumps is around 89%, with the average hydraulic efficiency for radial centrifugal pumps with channel impellers being between 71% – 77%.

Innovation in wastewater pumps is driven by three key drivers:

- Energy consumption
- Reliability
- Ease of maintenance

Critically for wastewater pumps, hydraulic efficiency must not be bought at the price of reliability. This is a particular issue when regulating these pumps, as simple laboratory tests of a pump may not be representative of in –life service where complex geometries will quickly be worn down to a more representative “run-in” hydraulic efficiency.

Of the three drivers, the most important is the need for reliability, as the costs of call –out and damage if there is blockage are very high and a constant worry.

The BATs identified in this study only cover the energy consumption aspects of the pumps, this is because, as demonstrated in Task 5, the energy is responsible for the majority of the eco-impacts of the pumps in scope.

## 6.1 State-of-the-art for the products

Pumps, including wastewater pumps, are a very well established technology that has been refined for several hundred years, and therefore there is very little in terms of Best Not yet Available Technology (BNAT) appearing on the horizon. There will inevitably be small improvements in efficiency as computational fluid dynamics allows more experimentation and refinement to take place in the design process, and also as closer manufacturing tolerances become feasible.

Any significant improvements in the energy associated with wastewater pumping is likely to be achieved through the use of integrated controls for several pumps in a wastewater collection system at a network level. Controlling pumps together could potentially reduce the peaks in flowrate currently seen by holding some flow back to off-peak periods, thereby reducing the dynamic friction losses in the rising mains. As these types of control improvements are achieved at a network level, and not the product level, they are beyond the scope of this study.

This section presents an overview of the BATs currently available on the market both at the component and product level for the Base Cases selected in Task 5. BATs are design options, which allow a product to operate significantly better in terms of environmental performance than the average product on the market (represented by the Base Cases).

It is very important to note while reading the following section that the issues affecting the efficiency of pumps, such as hydraulics, surface friction and leakage are all interlinked to some extent and improvements made in one area may have a consequential effect on another. Also, the size and geometry of each pump will have play role in the extent to which these factors affect the pump's efficiency. All this makes it difficult to accurately attribute an efficiency improvement % to any one specific measure.

The overall % savings shown are as indicated by Europump.

### 6.1.1 BC-1: Centrifugal submersible radial sewage pumps 1-160 kW

The axial thrust from the pump is normally accommodated in the motor. Only roller bearings are used in these pumps. Seal losses for pumps above 5kW can be neglected. For smaller pumps seal losses can be a significant part of the total losses..

The remaining power losses are looked at theoretically for a specific pump in Appendix 1 of Task 4. These can be viewed as the hydraulic losses due to turbulence and surface friction, plus the leakage losses. These are considered in more detail 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, hydraulic efficiency, NPSHR against flow, solids handling and resistance to blocking.

The principles of using smaller distance between impellers discs and smaller inlet diameters to improve hydraulic efficiency are not feasible in wastewater pumps as this will lead to an increase in friction and limitation of solids passing. Hydraulic design should not be adapted to increase efficiency to the point where it reduces the ability to handle solids effectively without blocking. This would result in increased life cycle costs and unreliable performance.

### ► Surface friction

#### ▷ Impeller

When considering channel impellers 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, but has never been justified on this type of pump. In practice it shows, that any fine surface treatment will be deteriorating after short operational time, due to the abrasive components in the wastewater.

Surface friction is not an issue when using vortex type impellers as they are designed to specifically minimise the contact between the impeller and the wastewater. Therefore, the smoothness of the impeller makes little difference to the overall hydraulic efficiency of the system.

#### ▷ Casing

The sidewalls should be fully machined to a hydraulically smooth finish. This is only partially done at present, as this is increasing cost and in many cases the entire sidewalls of the volutes are not accessible for a surface finish by machining.

### ► Leakage

Hydraulic efficiency could be improved by reducing the leakage at the wear rings, by reducing the clearance.

This would require a combination of tighter manufacturing tolerances, increased shaft diameter to minimise contact and wear at reduced or increased flow, and very hard but compatible wear ring materials (e.g. tungsten carbide). This approach does not often produce a sufficient cost increase compared to the efficiency gain.

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.

Another option is to periodically adjust the wear rings over time to minimise the clearances.

### ► Non-clogging performance

The ability of a wastewater pump to resist clogging, (also referred to as ragging or blocking) will affect its environmental performance. The hydraulic efficiency of centrifugal pumps is related to the number of impeller vanes and channel depth.<sup>1</sup> The issue with clogging pumps arises, as solids, especially fibrous materials, tend to attach themselves to the leading edge of impeller vanes. This in turn reduces the hydraulic performance in real world operation.

The BAT for these types of pump can achieve efficiencies of up to 88.7% if using a channel impeller and 63% when using a vortex impeller. However one must bear in mind that the attainable efficiencies are depending on the specific application and channel and vortex impellers have their specific advantages and disadvantages.

The benefits in clogging performance with vortex impellers are predominant in the small power range. For larger sizes especially designed channel impellers can reach equal clogging performance.

## 6.1.2 BC-2: Centrifugal submersible mixed flow and axial pumps

The axial thrust from the pump is normally accommodated in a ball type thrust bearing. There is little that can be done to reduce these small thrust bearing losses. The loss in the mechanical seal is negligible.

The remaining power losses are looked at theoretically for a specific pump in Appendix 1 of Task 4. These can be viewed as the hydraulic losses due to turbulence and surface friction. These are considered below.

### ► Hydraulic design

Axial pump have propellers rather than impellers, however there are similar issues surrounding the efficient hydraulic design. 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 propeller vane number, vane shape, inlet diameter, cross-sectional profile, and casing geometry. This should produce an effective compromise between the various curve shapes for head, power, hydraulic efficiency, NPSHR against flow, solids handling and resistance to blocking.

Axial flow pumps are fitted with fixed diffuser blades on the discharge, which are used to convert the rotational energy in the fluid that is produced by the action of the propeller, into additional pressure. The design of these diffuser blades can play an important role in the overall hydraulic efficiency of the pump, and each manufacturer will have their own method of choosing this geometry.

### ► Surface friction

#### ► Propeller

The propellers of low head axial pumps are mostly made from pressed steel, for larger pumps this is not possible regarding the high axial loads. The vast majority of propellers are machined and

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<sup>1</sup> Sustained Pump Efficiency – A True Measure of Hydraulic Efficiency (Xylem)



polished after casting. In most cases the casting method is precision casting which gives a good hydraulic performance.

#### ▷ Casing

The side walls should be fully machined to a hydraulically smooth finish. This is only partially done at present.

#### ▶ Non-blocking performance

Propeller pumps have normally to be operated with a screen in front, because of the high speed they are not designed to pump e.g. stones and because of the sharp leading edges they are only able to pump fibrous matter at limited extend.

### 6.1.3 BC-3: Centrifugal submersible once a day operation pump

The performance of a centrifugal submersible radial sewage pump 1 to 10kW once a day operation and a centrifugal submersible pump where the volute is part of the tank once a day operation is affected by all the same issues associated with standard submersible radial sewage pumps. However, they do tend to be physically smaller which in turn leads to them having lower overall average efficiencies. These pumps are generally lower cost items and as such they may not have the same attention given to them in terms of their hydraulic design and manufacturing tolerances. This goes some way to explain the wide spread of efficiencies from 26% to 78% for centrifugal submersible radial sewage pump 1 to 10kW once a day operation and 14% to 71% for pumps where the volute is part of the tank.

#### 6.1.3.1 Grinder pumps

Grinder pumps are nearly identical to radial submersible pumps; however, they incorporate a grinder attachment on the pump inlet. **The fact that the motor is used to operate two systems, the grinder and the pump impeller, make this type of pump unique in this lot insofar as the efficiency of both the grinder and pump are considered together.** An example of a grinder is shown in Figure 6-1. Grinder pumps are designed for the special purpose to disintegrate solids. Hence they can be pumped through pipes with small diameters. In principle these units have 3 elements: grinder – hydraulic – motor. For these applications there is no economical alternative, which can be used as substitute. Basically the increase of the discharge pipes in diameter are not possible as by the low wastewater production of single households otherwise the retention and septicity time of the sewage in the pipes would exceed any tolerance band.

The average efficiency of a grinder pump is 32%, however the BAT can operate at 42% if they have good hydraulics on the larger pumps.



Figure 6-1 Typical Grinder Element<sup>2</sup>

#### 6.1.4 BC-4: Centrifugal submersible domestic drainage pump < 40 mm passage

These pumps are affected by the same modes of inefficiency that affect larger submersible centrifugal pumps in terms of hydraulic design and non-blocking performance. They tend to be constructed from a high proportion of steel and plastic, therefore they will generally have low surface friction. The biggest limiting factor in their efficiency is their size, as they are small relative to the size of solids they handle. This means that their impellers tend to be optimised for non-clogging performance rather than hydraulic efficiency. The BAT in domestic drainage pumps <40 mm passage pumps can achieve efficiencies of around 60.8% although this efficiency is only attainable for larger pumps with relative small solids passage. This base case contains pumps for cellar drainage, which need only a solids passage of about 10mm as well as small vortex pumps with a solids passage of 25 to 40mm.

#### 6.1.5 BC-5: Submersible dewatering pumps

Dewatering pumps are essentially portable submersible radial sewage pumps, used for pumping abrasive solids. As such they are designed with highly wear resistant components to maintain good hydraulic efficiency across the lifetime of the pump. Dewatering pumps do have shrouds around the inlet to prevent larger solids from entering; therefore they are able to incorporate high efficiency, multi vane impellers. Therefore the efficiency of the pump can reach 72% on the BAT pumps with much of the variations in efficiency arising from the individual pump design. It is important that any improvements to the efficiency of the pumps do not remove the portable nature of the pumps.

The requirement on dewatering pumps is in general to have a steep performance curve. This makes the impeller channels small. In general, dewatering pumps has a strainer that prevents

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<sup>2</sup> "Flygt centrifugal grinder pumps – for heavy duty shredding applications" Xylem – Brochure  
<http://www.flygtus.com/3431809.pdf>

larger solids from entering into the hydraulic end. In some applications the amount of solids coming to the pump is so large so the strainer will get plugged quickly. In these applications the customer needs a pump that can handle larger solids but still have a steep curve. For these applications the only alternative available is what we call a sludge pump. These pumps have a vortex impeller. The total sales in Europe are estimated to be 5000 pumps per year and that the average shaft power is 2 kW. These sludge pumps cannot be in the same category as the other submersible dewatering pumps due to the difference in efficiency.



Figure 6-2 Dewatering pumps inlet shroud<sup>3</sup>

### 6.1.6 BC-6: Centrifugal dry well pumps

There are mechanical losses in the two anti-friction bearings and the mechanical seal in these pumps but they are not capable of significant reduction.

- ▶ **Hydraulic design**

Centrifugal dry well pumps are hydraulically identical to submersible pumps and therefore the same issues apply. Refer to section 6.1.1 for details.

- ▶ **Surface friction**

Centrifugal dry well pumps are identical to submersible pumps in terms of surface friction and therefore the same issues apply.

- ▶ **Leakage**

Centrifugal dry well pumps are identical to submersible pumps in terms of leakage and therefore the same issues apply.

- ▶ **Non-blocking performance**

The non-blocking performance is identical to centrifugal submersible pumps.

The BAT for these types of pump can achieve efficiencies of up to 88.7%

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<sup>3</sup> Warman Pumps – Product Information

[http://www.weirminerals.com/products\\_\\_services/centrifugal\\_dewatering\\_pumps/submersible\\_dewatering\\_pumps/sj\\_pump.aspx](http://www.weirminerals.com/products__services/centrifugal_dewatering_pumps/submersible_dewatering_pumps/sj_pump.aspx)

### 6.1.7 BC-7A&7B: Slurry pumps

Slurry pumps are dry well radial pumps, designed to pump very abrasive solids, with much higher solid to water ratios than dry well radial sewage pumps. As such most of the issues that affect the efficiency of dry well radial sewage pumps are the same as those that affect slurry pumps. The most significant difference is that slurry pumps tend to be larger and therefore are able to incorporate closed multi-vane impellers which helps to maintain good hydraulic efficiencies. They are designed to incorporate highly wear resistant materials such as erosion resistant cast alloys, or they may incorporate elastomer liners made from materials such as natural rubber or polyurethane. The choice of materials and impeller will ultimately be dictated by the type of solid being pumped.



Figure 6-3 Example of slurry pump<sup>4</sup>

### 6.1.8 Centrifugal Pumps with intelligent controls

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. For example, when using a VSD pumps can easily be controlled to rotate the impeller in the opposite direction when blocked. By this the blockage will be removed.

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.

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<sup>4</sup> Warman slurry pump – product description

[http://www.weirminerals.com/products\\_\\_services/centrifugal\\_slurry\\_pumps/horizontal\\_slurry\\_pumps/warman\\_wbh\\_pump.aspx](http://www.weirminerals.com/products__services/centrifugal_slurry_pumps/horizontal_slurry_pumps/warman_wbh_pump.aspx)

## 6.2 State-of-the-art at component level

### 6.2.1 Impellers

As described in Task 4, impellers have a key role in contributing towards the hydraulic efficiency and performance of wastewater pumps. The impellers used in wastewater pumps are different than those used in clean water pumps as they have to allow the free passage of solids through them and also have to be resistant to becoming clogged.

The state of the art in terms of sewage pump impellers is single channel and two channels, self-cleaning type ones. These impellers are designed to not only have a relatively high hydraulic efficiency when new, but also to maintain good levels of hydraulic efficiency through normal operation. This is because they are less susceptible to solids collecting on the leading edge due to the geometry of the impeller.

### 6.2.2 Motors

Motors for the pumps in this lot are regulated under Lot 11, or are being considered under ENER Lot 30. However it should be noted that in the case of submersible pumps, the pump and motor are integrated into one aggregate. However in almost all cases it will be possible for manufacturers to test the efficiency of pump and submersible motor separately. The chosen performance of the motor is linked to pump, the application and to other criteria, e.g. the acceptable weight for transportable drainage pumps.

Submersible pumps should therefore be managed as an Extended Product. For these products it is preferable to regulate with an Extended Product Approach since it enables much larger energy savings. Regulating on component level will not cover all losses such as losses from bearings, seals and cooling system. It also has the risk of hinder innovation and use of new technology. Regulation 641/2009 on Circulators is a great example on how far we reach in energy savings with an Extended Product Approach.

High efficiency motors are typically constructed with superior magnetic materials, larger magnetic circuits with thinner laminations, larger copper/aluminium cross-section in the stator and rotor windings, tighter tolerances, better quality control and optimized design. These motors, therefore, have lower losses and improved efficiency. Because of lower losses the operating temperature can be lower, leading to improved reliability.

Stator losses can be reduced by increasing the cross-section of stator windings which lowers their electrical resistance reducing I<sup>2</sup>R losses. This modification is where the largest gains in efficiency are achieved. High efficiency motors typically contain about 20% more copper than standard efficiency models of equivalent size and rating.

Increasing the cross-section of the rotor conductors (conductor bars and end-plates) and/or increasing their conductivity (e.g. using copper instead of aluminium), and to a lesser extent by increasing the total flux across the air gap between rotor and stator reduces the rotor losses.

Magnetic core losses occur in the steel laminations of the stator and rotor and are mainly due to hysteresis effects and to induced eddy currents. Both types of losses approximately increase with the square of the magnetic flux density. Lengthening the lamination stack, which reduces the flux density within the stack, therefore reduces core losses. These losses can be further reduced through the use of magnetic steel with better magnetic properties (e.g. higher permeability and higher reluctance) in the laminations. Another means to reduce the eddy currents magnetic core losses is to reduce the laminations' thickness. Eddy current losses can also be reduced by ensuring adequate insulation between laminations, thus minimising the flow of current (and  $I^2R$  losses) through the stack.

The additional materials used in order to improve efficiency can present themselves as a problem, as it may be difficult to meet the standard frame sizes especially in the low power range. Of course, this is not always the case since in many cases only the stator and rotor laminations are a little longer.

Brushless Permanent Magnet (BPM) Motors are rapidly becoming one of the most popular motor types and are beginning to be used in smaller wastewater pumping applications, typically below 15 kW. They differ from Brushed Permanent magnet motors in that the magnets are in the rotor instead of the stator, and in the commutation method, which is controlled electronically. BPM Motors, therefore, avoid use of a commutator and brushes.

Main characteristics:

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

These motors are still highly customized without suitable standards (e.g. dimensions, mounting, power, torque specifications, etc.) that would allow a commodity market to develop. Because of high volumes production for individual specialized applications, their cost has been decreasing and may become a key player particularly in the low power range.

### 6.2.3 Variable speed drives

Variable speed drives can be used with a small subsection of wastewater pumps to improve energy efficiency. In situations where there is a need to vary the flow of the pumps, such as in

activated sludge plants in sewage treatment works, variable speed drives can be used to match pump outputs to the demand and save energy in the process.

Most wastewater pumping operations are fixed speed and therefore there would be an energy penalty associated with installing a variable speed drive to them, as they have higher losses than direct on line starters.

## 6.2.4 Summary of BAT options

In this section, the best available technology options are summarised for each of the seven BaseCases<sup>5</sup>. The data used in the tables presented in this section is partly based on the inputs from the industry, literature review and own estimates of the study authors. The change in annual energy consumption data was provided by Europump, the impact on cost of motors and VSDs is based on literature review (mainly data available in ENER Lot 11 and ENER Lot 30 preparatory studies) and the remaining data on cost impact is based on the own estimates of the study authors.

Table 6-1: Summary of BAT options for BC 1: centrifugal submersible pump - radial sewage pumps 1 to 160 kW

BAT	Annual energy consumption change [%]	Annual energy consumption change [kWh]	Impact on purchase cost	Consumer purchase cost change [€]	Unit to unit purchase cost change [€]	Impact on installation cost	Consumer installation cost change [€]	Impact on repair & maintenance costs	Consumer Repair and maintenance price change [€]
Pump/hydraulic improvements <sup>6</sup>	2.4%	-192	1.4%	46.7	46.7	0.0%	0	-1.9%	-24.7
Motor improvements	6.7%	-534.1	5.0%	166.9	166.9	0.0%	0	-2.0%	-24.7
VSD <sup>7</sup>	3.4%	-271	20.0%	161	805	5.0%	71.7	3.0%	37

It is important to note that **85%** of the pumps in this base case are in the **1 – 10kW** range. This accounts for the relatively large savings associated with the motors. It is not anticipated that savings of this level are achievable in the larger pump sizes.

<sup>5</sup> Please note: all statements on improvement potentials for the different pumps (BC 1 to BC 7) and their BATs are based on estimations and have to be evaluated in combination with assumptions on user behaviour

<sup>6</sup> This includes Improved case geometry, Surface friction reduction, Leakage reduction and Improved impeller efficiency for all base cases;

<sup>7</sup> VSD is applicable only when static head vs. total head is below a certain percentage, otherwise it may even lead to higher energy consumption



The savings associated with the VSDs are the total savings averaged across all the pumps in the base case. It is estimated that VSDs are only applicable to approximately 26% of these pumps, of which 6 % are already operated with them. Therefore only 20% of the savings associated with the implementation of VSDs can be considered when assessing the base case as a whole.

The figure shown in the "Consumer purchase price change" column reflects the stock weighted average price change associated with implementing VSDs across all the pumps in the base case. The "Unit to unit price change" column reflects the increase in purchase price as a result of changing from a standard starter to a VSD on a unit to unit basis.

Table 6-2: Summary of BAT options for BC 2: centrifugal submersible pump - mixed flow and axial pumps

BAT	Annual energy consumption change [%]	Annual energy consumption change [kWh]	Impact on Purchase Cost	Consumer purchase price change [€]	Unit to unit price change [€]	Impact on Installation Cost	Consumer installation price change [€]	Impact on repair & maintenance costs	Consumer Repair and maintenance price change [€]
Pump/hydraulic improvements	2.0%	-3 502	1.4%	210	210	0.0%	0	-1.9%	-18
Motor improvements	4.0%	-7 004	5.0%	750	750	0.0%	0	-2.0%	-19
VSD7	6.0%	-10 506	5.0%	240	1 500	5.0%	187.5	3.0%	28.5

The savings associated with the VSDs are the total savings averaged across all the pumps in the base case. VSDs are in the BC-2 only applicable to the pumps, which are used as recirculation pumps. These are 40% of base, of which 24 % are already operated with them. Therefore only 16% of the savings associated with the implementation of VSDs can be considered when assessing the base case as a whole. The figure shown in the "Consumer purchase price change" column reflects the stock.

Table 6-3: Summary of BAT options for BC 3: centrifugal submersible pump – once a day operation

BAT	Annual energy consumption change [%]	Annual energy consumption change [kWh]	Impact on Purchase Cost	Consumer purchase price change [€]	Unit to unit price change [€]	Impact on Installation Cost	Consumer installation price change [€]	Impact on repair & maintenance costs	Consumer Repair and maintenance price change [€]
Pump/hydraulic improvements	4.0%	-2.0	1.4%	22.5	22.5	0.0%	0	-1.9%	-3.0
Motor improvements	6.6%	-2.9	10%	160.7	160.7	0.0%	0	-2.0%	-3.3

The annual consumption change and consumer price change figures in the above table are based on a stock weighted average for grinding pumps, radial sewage pumps 1 – 10kW, and pumps where the volute is part of the tank.

Table 6-4: Summary of BAT options for BC 4: centrifugal submersible domestic drainage pump < 40 mm passage

BAT	Annual energy consumption change [%]	Annual energy consumption change [kWh]	Impact on Purchase Cost	Consumer purchase price change [€]	Unit to unit price change [€]	Impact on Installation Cost	Consumer installation price change [€]	Impact on repair & maintenance costs	Consumer Repair and maintenance price change [€]
Pump/hydraulic improvements	10%	-1	1.4%	4.2	4.2	0.0%	0	-1.9%	0
Motor improvements	5.0%	-0.35	15%	45	45	0.0%	0	-2.0%	0

Table 6-5: Summary of BAT options for BC 5: submersible dewatering pumps

BAT	Annual energy consumption change [%]	Annual energy consumption change [kWh]	Impact on Purchase Cost	Consumer purchase price change [€]	Unit to unit price change [€]	Impact on Installation Cost	Consumer installation price change [€]	Impact on repair & maintenance costs	Consumer Repair and maintenance price change [€]
Pump/hydraulic improvements	5.0%	-525	1.4%	70	70	0.0%	0	-1.9%	-21
Motor improvements <sup>8</sup>	5.0%	-525	5.0%	250	250	0.0%	0	-2.0%	-22

Table 6-6: Summary of BAT options for BC 6: centrifugal dry well pumps - radial sewage pumps 1 to 160 kW

BAT	Annual energy consumption change [%]	Annual energy consumption change [kWh]	Impact on Purchase Cost	Consumer purchase price change [€]	Unit to unit price change [€]	Impact on Installation Cost	Consumer installation price change [€]	Impact on repair & maintenance costs	Consumer Repair and maintenance price change [€]
Pump/hydraulic improvements	2.0%	-250	1.4%	53	53	0.0%	0	-1.9%	-15.4
Motor improvements <sup>9</sup>	2.2%	-279.4	5.0%	166.9	166.9	0.0%	0	-2.0%	-24.7

<sup>8</sup> Dewatering pumps are hand held devices that are typically moved on a day to day basis. As such, motor improvements that increase the weight of the pump over the safe handling weight cannot be applied to these pumps.

<sup>9</sup> numbers provided here are taken from The Lot 30 study

VSD7	4.0%	-500.2	25.0%	192	952	5.0%	78.15	-2.0%	-16.2
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It is important to note that **74%** of the pumps in this base case are in the **1 – 10kW** range. This accounts for the relatively large savings associated with the motors. It is not anticipated that savings of this level are achievable in the larger pump sizes.

The savings associated with the VSDs are the total savings averaged across all the pumps in the base case. It is estimated that VSDs are only applicable to approximately 26% of these pumps, of which 6 % are already operated with them. Therefore only **20%** of the savings associated with the implementation of VSDs can be considered when assessing the base case as a whole.

The figure shown in the "Consumer purchase price change" column reflects the stock weighted average price change associated with implementing VSDs across all the pumps in the base case. The "Unit to unit price change" column reflects the increase in purchase price as a result of changing from a standard starter to a VSD on a unit to unit basis.

Table 6-7: Summary of BAT options for BC 7A: light duty slurry pumps

BAT	Annual energy consumption change [%]	Annual energy consumption change [kWh]	Impact on Purchase Cost	Consumer purchase price change [€]	Unit to unit price change [€]	Impact on Installation Cost	Consumer installation price change [€]	Impact on repair & maintenance costs	Consumer Repair and maintenance price change [€]
Pump/hydraulic improvements	1.0%	-1 300	2%	750	750	0.0%	0	1.0%	700
Motor improvements <sup>9</sup>	2.0%	-2 600	5.0%	1 875	1 875	0.0%	0	-2.0%	-19

Table 6 8: Summary of BAT options for BC 7B: heavy duty slurry pumps

BAT	Annual energy consumption change [%]	Annual energy consumption change [kWh]	Impact on Purchase Cost	Consumer purchase price change [€]	Unit to unit price change [€]	Impact on Installation Cost	Consumer installation price change [€]	Impact on repair & maintenance costs	Consumer Repair and maintenance price change [€]
Pump/hydraulic improvements	1%	-592	2%	1 600	1 600	0.0%	0	1.0%	1000
Motor improvements <sup>9</sup>	2%	-1 184	5.0%	4 000	4 000	0.0%	0	-2.0%	-19

The annual consumption change and consumer price change figures in the above table are based on a stock weighted average for both light and heavy duty slurry pumps.

## 6.3 State-of-the-art of best existing product technology outside the EU

Wastewater pump products – both, residential and non-residential - available in the EU are essentially of similar design to appliances sold outside the EU. Therefore, no different more efficient technologies have been identified outside the EU.

## 6.4 Conclusion

As pumps are a very well established technology there is very little in terms of BNAT at the product level that is likely to be released into the market in the next 2 – 3 years. Therefore, the majority of this chapter has focused on the BATs of the wastewater pumps in the study. The energy costs for a wastewater pump represent a significant proportion of the whole life costs and therefore it is important to consider the efficiency of the pumps across its whole lifespan. It is clear that wastewater pumping is a mature technology and there are not many significant gains to be made through improvements in hydraulic efficiency. A significant area for improvement for submersible pumps is the motors, as these have not yet been subject to other minimum motor efficiency regulations. VSDs could also lead to significant energy savings for some of the Lot 28 pumps (BC 1, BC2 and BC6). The big efficiency improvements are likely to be found in terms of control improvements at the network level, where several pumps are controlled together. As these types of control improvements are achieved at a network level, and not the product level, they are beyond the scope of this study.

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