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

ENER Lot 28– Pumps for private and public wastewater and for fluids with high solids content – Task 7: Improvement potential – Working document

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Chapter 7: Improvement Potential (Task 7)

Task 7 quantitatively analyses design improvement options, based on the Best Available Technologies (BATs) described in Task 6 for each of the product base-cases. The payback time indicates the duration of repayment required to offset the investments associated with the different options, it takes into account changes in purchase price, installation cost, repair and maintenance cost compared with unit-to-unit energy savings. The environmental impacts of each of these options are calculated by using the MEErP EcoReport tool. The economic impacts of each design option are assessed in terms of Life Cycle Cost (LCC). The assessment of LCC is relevant as it indicates the level of impact design options may have on the cost to users over the whole lifetime of the product. The assessment of both environmental and economic impacts allows the identification of the design improvement options with the Least Life Cycle Costs (LLCC) and the one that results in the most significant reductions in environmental impacts. The Best Not yet Available Technologies (BNAT) are also discussed, assessing long-term improvement potential of the wastewater pumps.

7.1 Identification of design options

This section presents the different improvement options applicable to each base-case. These design options are carefully selected keeping in mind that they:

- Do not result in significant variation in the functionality and the performance parameter of the pumps compared to the base-cases
- Have a significant potential for improvement in the environmental performance
- Not entail excessive costs on the manufacturer

The cost-effectiveness of an improvement option is expressed in terms of payback time in years, defined as a ratio between:

$$\frac{\Delta(\text{investment})}{\Delta(\text{annual running costs})}$$

Where "investment" includes the purchase and installation costs and "annual running costs" include the cost of the energy consumed and the costs of repair and maintenance. In the case of a payback time longer than the lifetime of the product, the return of the investment would not be possible.

7.1.1 Base-case 1: Centrifugal submersible: radial sewage pump 1-160 kW

Task 5 identified that reducing total energy consumption during use phase would be an effective way to also reduce the overall environmental impacts of a base-case 1 (BC1). Task 6 identified the improvement options that aim to reduce the total energy consumption. Each of the improvement options applicable to BC1 and its relative impact on the product price compared to the base-case are listed below. Table 7-1 presents the summary of the selected improvement options.

As can be seen from this table, option 1 provides electricity savings due to improved hydraulic performance by modifying the geometry of the impeller and the casing design. These modifications will increase the efficiency and result in electricity savings.

Of all non-combined improvement options, option 2 provides the biggest electricity savings compared to the base-case. This option comprises a number of improvements for different motor components. However, use of additional materials[1] to improve efficiency can be a problem, as it may be difficult to meet the standard frames sizes, especially in the low power range.

Apart from positive effects such as electricity savings and efficiency improvements, design options can have negative effects, which would have to be considered. For example, reducing the surface friction may result in high costs and time-consuming operations and reducing leakages will lead to an increase in costs and require tighter manufacturing tolerances.

Table 7-1: Identified energy savings potentials for BC1: centrifugal submersible pump: radial sewage pumps 1 to 160 kW

Improvement Options	Description	Annual energy consumption (kWh)	Product price (€)	Installation cost [€]	Repair & maintenance costs [€/year]	Payback time at product level (years)
Base-case 1	**Centrifugal submersible pump: radial sewage pumps 1 to 160**	7 972	3 373	1 434	782	
Option 1 (OP1)	Pump/hydraulics improvements	7 780	3 420	1 434	757	0.3

[1] The BoM of this option is assumed to same as that of the base-case due to unavailability of such data.

Improvement Options	Description	Annual energy consumption (kWh)	Product price (€)	Installation cost [€]	Repair & maintenance costs [€/year]	Payback time at product level (years)
Option 2 (OP2)	Motor improvements	7 438	3 542	1 434	757	0.8
Option 3 (OP3)	VSD[2]	7 262	4 047	1 506	819	No return of investment possible[3]
Option 4 (OP1+OP2+OP3)	Pump/hydraulic, motor and VSD improvements	6 537	4 263	1 506	770	4.1

7.1.2 Base-case 2: Centrifugal submersible: mixed flow and axial pumps

The selected improvement options for centrifugal submersible pumps with mixed flow and axial pumps do not differ much from those analysed for BC1. One of the main differences though, is that axial pumps have propellers rather than impellers. The implementation of high efficiency propellers will be done through the modification of the propellers' geometry.

Table 7-2: Identified energy savings potentials for BC2: Centrifugal submersible pump: Mixed flow and axial pumps

Improvement Options	Description	Annual energy consumption (kWh)	Product price (€)	Installation cost [€]	Repair & maintenance costs [€/year]	Payback time at product level (years)
Base-case 2	**Centrifugal submersible pump: Mixed flow & axial pumps**	175 000	15 000	3 750	950	
Option 1 (OP1)	Pump/hydraulics improvements	171 500	15 210	3 750	932	0.37

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[2] Energy savings used for the calculation of payback time is based on the unit to unit rate of 8.89% energy savings compared to Base-Case

[3] The increase in costs associated with the implementation of the option, compared to the base-case, outweighs the cost reductions generated by the energy savings of this option.

Improvement Options	Description	Annual energy consumption (kWh)	Product price (€)	Installation cost [€]	Repair & maintenance costs [€/year]	Payback time at product level (years)
Option 2 (OP2)	Motor improvements	168 000	15 750	3 750	931	0.78
Option 3 (OP3)	VSD[4]	133 000	16 200	3 937.5	978.5	0.32
Option 4 (OP1+OP2+OP3)	Pump/hydraulic, motor and VSD improvements	122 500	17 160	3 937.5	941.5	0.40

shows the potential electricity savings, price increase and payback periods for each of the design options selected.

7.1.3 Base-case 3: Centrifugal submersible pump – once a day operation

The summary of potential design improvements for centrifugal submersible pumps of once a day operation is presented in the Table 7-3.These improvements options for once a day operation pumps do not differ much from the ones analysed in the section on submersible radial sewage pumps. However, once a day operation pumps are smaller than radial sewage pumps, which leads to lower overall average efficiency. The implementation of motors improvements will result in lower losses of efficiency and improved efficiency of the pumps, and because of lower losses, operating temperature can be lower, which will lead to an improved reliability. These pumps are generally lower cost items and, therefore, less attention is given to their hydraulic design and manufacturing tolerances.

Table 7-3: Identified energy savings potentials for BC3: Centrifugal submersible pump – once a day operation

Improvement Options	Description	Annual energy consumption (kWh)	Product price (€)	Installation cost [€]	Repair & maintenance costs [€/year]	Payback time at product level (years)
Base-case 3	**Centrifugal submersible**	45	1 617	1 130	162	

[4] Energy savings used for the calculation of payback time is based on the unit to unit rate of 24%

Improvement Options	Description	Annual energy consumption (kWh)	Product price (€)	Installation cost [€]	Repair & maintenance costs [€/year]	Payback time at product level (years)
	pump – Once a day operation					
Option 1 (OP1)	Pump/hydraulics improvements	43	1 640	1 130	159	0.9
Option 2 (OP2)	Motor improvements	42	1 779	1 130	158.7	6.1
Option 3 (OP1+OP2)	Pump/hydraulic and motor improvements	40	1 801	1 130	155.7	3.6

7.1.4 Base-case 4: Centrifugal submersible domestic drainage pump<40mm passage

As can be drawn from the Table 7-4, which presents improvement potentials of the various options for centrifugal submersible domestic drainage pumps, similar performance enhancements could be achieved as those for centrifugal submersible pumps. These pumps are affected by the same modes of inefficiency that affect larger submersible centrifugal pumps in terms of hydraulic design, leakage and non-blocking performance. 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 for hydraulic efficiency. For both, the domestic drainage pumps and the submersible pumps, the combination of improvements will also entail the same constrains for each individual option.

Table 7-4: Identified energy savings potentials for BC4: Centrifugal submersible domestic drainage pump<40mm passage

Improvement Options	Description	Annual energy consumption (kWh)	Product price (€)	Installation cost [€]	Repair & maintenance costs [€/year]	Payback time at product level (years)
Base-case 4	**Centrifugal submersible domestic drainage pump<40mm passage**	7.00	300	150	0	

Improvement Options	Description	Annual energy consumption (kWh)	Product price (€)	Installation cost [€]	Repair & maintenance costs [€/year]	Payback time at product level (years)
Option 1 (OP1)	Pump/hydraulics improvements	6.30	304	150	0	No return of investment possible3
Option 2 (OP2)	Motor improvements	6.65	345	150	0	No return of investment possible3
Option 3 (OP1+OP2)	Pump/hydraulic and motor improvements	5.95	349	150	0	No return of investment possible3

7.1.5 Base-case 5: Submersible dewatering pumps

The summary of potential design improvements for submersible dewatering pumps can be seen in the Table 7-5. As dewatering pumps are essentially submersible radial sewage used to pump abrasive solids, similar performance enhancements could be achieve as those for submersible radial sewage pumps. Because of the conditions in which these pumps work, they are designed with highly wear resistant component to maintain good efficiency across their lifetime. An improvement of the hydraulics can increase the efficiency of a pump and reduce electricity requirements.

Table 7-5: Identified energy savings potentials for BC5: Submersible dewatering pumps

Improvement Options	Description	Annual energy consumption (kWh)	Product price (€)	Installation cost [€]	Repair & maintenance costs [€/year]	Payback time at product level (years)
Base-case 5	**Submersible dewatering pumps**	10 500	5 000	250	463	
Option 1 (OP1)	Pump/hydraulics improvements	9 975	5 070	250	442	0.5

Improvement Options	Description	Annual energy consumption (kWh)	Product price (€)	Installation cost [€]	Repair & maintenance costs [€/year]	Payback time at product level (years)
Option 2 (OP2)	Motor improvements[5]	9 975	5 250	250	441	1.7
Option 3 (OP1+OP2)	Pump/hydraulic and motor improvements	9 450	5320	250	420	1.1

7.1.6 Base-case 6: Centrifugal dry well pump

The summary of potential design improvements for centrifugal dry well pumps can be seen in the Table 7-6. Similar performance enhancements could be achieved for centrifugal dry well pumps as those for submersible pumps. Centrifugal dry well pumps are identical to submersible pumps in term of hydraulics, surface friction, leakage and non-blocking performance. Therefore, apart from one additional design improvement option (VSD), the same constrains and issues will arise for centrifugal dry well pumps as for submersible pumps.

Table 7-6: Identified energy savings potentials for BC6: Centrifugal dry well pump

Improvement Options	Description	Annual energy consumption (kWh)	Product price (€)	Installation cost [€]	Repair & maintenance costs [€/year]	Payback time at product level (years)
Base-case 6	**Centrifugal dry well pump**	12 505	3 433	1 563	807	
Option 1 (OP1)	Pump/hydraulics improvements	12 255	3 481	1 563	791.6	0.2
Option 2 (OP2)	Motor improvements[6]	12 230	3 604	1 563	782.3	0.6

[5] Motor improvements for submersible dewatering pumps needs a very sensitive approach, as any such motor improvements should not negative influence their portable (transportable /handheld) functionality.

[6] Please note that the motor saving values for this BC are only presented here for statistical evaluation purpose. The dry installed standard motors are at the majority already regulated by EC 640/2009, otherwise are currently considered in the scope of the Lot 30 preparatory study.

Option 3 (OP3)	VSD[7]	11 393	4 291	1 641.15	790.8	2.6
Option 4 (OP1+OP2+OP3)	Pump/hydraulic, motor and VSD improvements	10 993	4 511	1 641.15	750.7	1.3

7.1.7 Base-case 7A: Slurry pumps: Light duty

The summary of potential design improvements for slurry pumps with light duty can be seen in the Table 7-7. Slurry pumps work as dry well radial pumps designed to pump very abrasive solids. Because of that, most of the issues that affect the efficiency of dry well radial sewage pumps are the same as those that affect slurry pumps. Because slurry pumps are bigger, they are able to incorporate closed multi-vane impellers, what helps to maintain good hydraulics efficiencies, thereby reducing electricity consumption.

Table 7-7: Identified energy savings potentials for BC7A: Slurry pumps: Light duty

Improvement Options	Description	Annual energy consumption (kWh)	Product price (€)	Installation cost [€]	Repair & maintenance costs [€/year]	Payback time at product level (years)
Base-case 7A	**Slurry pumps: Light Duty**	130 000	20 000	5 000	1 275	
Option 1 (OP1)	Pump/hydraulics improvements	128 700	20 400	5 000	1 975	No return of investment possible3
Option 2 (OP2)	Motor improvements[6]	127 400	21 000	5 000	1 256	1.1
Option 3 (OP1+OP2)	Pump/hydraulic and motor improvements	126 100	21 400	5 000	1 956	1.9

7.1.8 Base-case 7B: Slurry pumps: Heavy duty

The selected improvement options for slurry pumps with heavy duty do not differ significantly from those analysed in the previous section. As explained above, slurry pumps work like dry well radial pumps. This type of slurry pumps has a much heavier duty than the one mentioned in the

[7] Energy savings used for the calculation of payback time is based on the unit to unit rate of 8.89%

section 7.1.8. Therefore, modifications on the hydraulics of the impellers will affect efficiency and energy consumption. In addition, the choice of materials and impellers of the pumps will be dictated by the type of solids being pumped.

Table 7-8 shows the potential electricity savings, price increase and payback periods for each of the design options selected.

Table 7-8: Identified energy savings potentials for BC7B: Slurry pumps: Heavy duty

Improvement Options	Description	Annual energy consumption (kWh)	Product price (€)	Installation cost [€]	Repair & maintenance costs [€/year]	Payback time at product level (years)
Base-case 7B	**Slurry pumps: Heavy Duty**	59 200	20 000	5 000	1 275	
Option 1 (OP1)	Pump/hydraulics improvements	58 608	20 400	5 000	2 275	No return of investment possible3
Option 2 (OP2)	Motor improvements[6]	58 016	21 000	5 000	1 256	1.3
Option 3 (OP1+OP2)	Pump/hydraulic and motor improvements	57 424	21 400	5 000	2 256	2.7

7.2 Analysis BAT and LLCC

The design options identified in the technical, environmental and economic analyses are ranked to identify the design improvement option with the least cycle environmental impacts and the Least Life Cycle Costs (LLCC). Building an energy-LCC curve (Y-axis= energy consumed and LCC, X-axis=options) allows the LLCC and BATs to be identified[8].

The performance of each improvement option will be compared using the base-case. The comparison is made in terms of primary energy consumption and LCC.

LCC is the sum of the product price, costs of energy and the costs of installation and maintenance as described in Task 4.

7.2.1 Base-case 1: Centrifugal submersible pump: Radial sewage pumps 1 to 160 kW

An environmental and economic assessment was carried out for each improvement option relevant for centrifugal submersible pump: Radial sewage pumps 1 to 160 kW using the EcoReport tool. Outcomes for the whole life cycle are provided in absolute values (in units) and in variations compared to the base-case.

[8] This is usually the last data point of the curve showing the product design with the lowest environmental impact, irrespective of the price.

Table 7-9: Environmental impacts of the BC1 and its improvement options[9]

Life-Cycle indicators per unit	Unit	Base-case 1	Option 1	Option 2	Option 3	Option 4
Total Energy (GER)	GJ	842.6	822.6	786.6	814.2	738.0
	% change with BC	0%	-2%	-7%	-3%	-12%
Of which, electricity	Primary GJ	837.6	817.5	781.5	809.1	732.9
	Final MWh	79.8	77.9	74.4	77.1	69.8
	% change with BC	0%	-2%	-7%	-3%	-12%
Water (process)	Kg SO2 eq.	56.1	54.7	52.3	54.2	49.1
	% change with BC	0%	-2%	-7%	-3%	-12%
Water (cooling)	Kg SO2 eq.	2232.6	2179.0	2083.0	2156.7	1953.6
	% change with BC	0%	-2%	-7%	-3%	-12%
Waste, non-haz./ landfill	Kg SO2 eq.	1188.1	1164.8	1123.0	1155.1	1066.8
	% change with BC	0%	-2%	-5%	-3%	-10%
Waste, hazardous/ incinerated	Kg SO2 eq.	20.5	20.1	19.2	19.9	18.1
	% change with BC	0%	-2%	-6%	-3%	-12%
Greenhouse Gases in GWP100	Kg SO2 eq.	36.9	36.0	34.4	35.7	32.3
	% change with BC	0%	-2%	-7%	-3%	-12%
Acidification, emissions	Kg SO2 eq.	218.5	213.3	204.0	211.2	191.5
	% change with BC	0%	-2%	-7%	-3%	-12%
Volatile Organic Compounds (VOC)	kg	0.3	0.3	0.3	0.3	0.3
	% change with BC	0%	-2%	-6%	-3%	-11%
Persistent Organic Pollutants	µg i-Teq	6.9	6.8	6.6	6.7	6.2

[9] The numbers in red show the option with the highest environmental impacts, and the green shows the option with the lowest environmental impacts

Life-Cycle indicators per unit	Unit	Base-case 1	Option 1	Option 2	Option 3	Option 4
(POP)	% change with BC	0%	-2%	-5%	-3%	-10%
Heavy Metals to air	g Ni eq.	15.3	14.9	14.3	14.8	13.5
	% change with BC	0%	-2%	-6%	-3%	-12%
PAHs	g Ni eq.	1.8	1.8	1.7	1.8	1.6
	% change with BC	0%	-2%	-6%	-3%	-11%
Particulate Matter (PM, dust)	kg	9.6	9.5	9.3	9.4	9.0
	% change with BC	0%	-1%	-3%	-2%	-6%
Heavy Metals to water	g Hg/20	5.7	5.6	5.3	5.5	5.0
	% change with BC	0%	-2%	-6%	-3%	-12%
Eutrophication	Kg PO4	0.0	0.0	0.0	0.0	0.0
	% change with BC	0%	-2%	-5%	-2%	-9%
Life-cycle cost	€	18,265.5	18,015.1	17,830.7	18,960.4	18,275.2
	% change with BC	0%	-1%	-2%	4%	0%

Design improvement options

Option 1 (OP1)	Option 2 (OP2)	Option 3 (OP3)	Option 4
Pump/hydraulic improvements	Motor improvements	VSD	OP1+OP2+OP3

Figure 7-1 shows that option 3 achieves the lowest environmental impacts of all the non-combined options. However, the combination of options 1+2+3 is the one achieving the lowest primary energy consumption in comparison with the base-case.

The ratio of LCC and the improvements options to the base-case is shown in the Figure 7-1. Electricity costs and maintenance and repair costs have the highest share of the LCC, while purchase price over the lifetime of the pump is the second biggest expenditure.

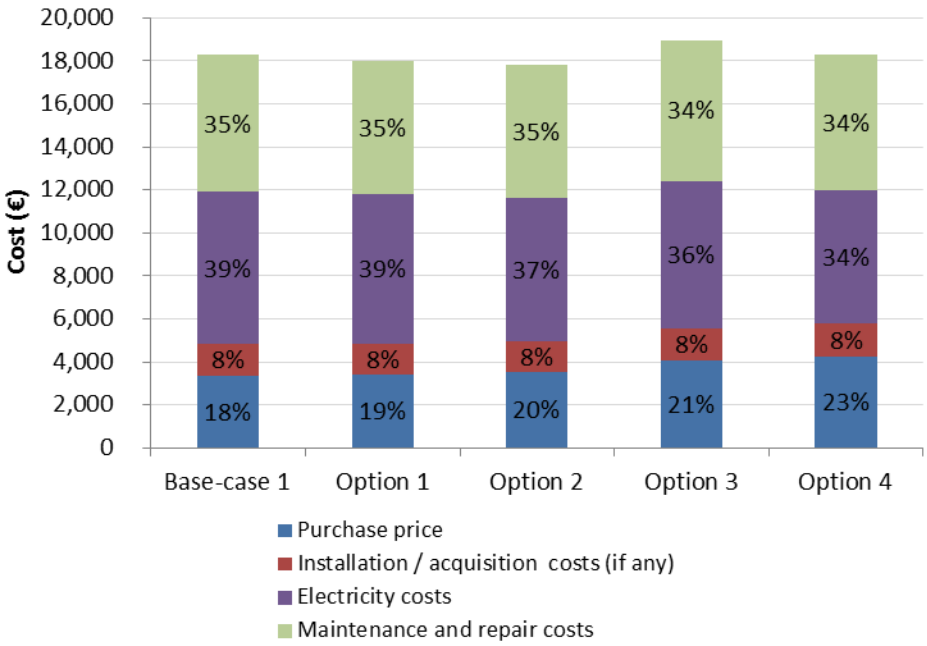

Figure 7-1: Life cycle costs of the improvement options for BC1

Option 1 (OP1)	Option 2 (OP2)	Option 3 (OP3)	Option 4
Pump/hydraulic improvements	Motor improvements	VSD	OP1+OP2+OP3

Figure 7-2 presents the comparison between primary energy consumption and life cycle costs of the base-case and its design options. The Least Life Cycle Cost option is option 2. The combination Option 4 is the BAT, however, the LLC of option 4 is similar to the LLC of the base-case.

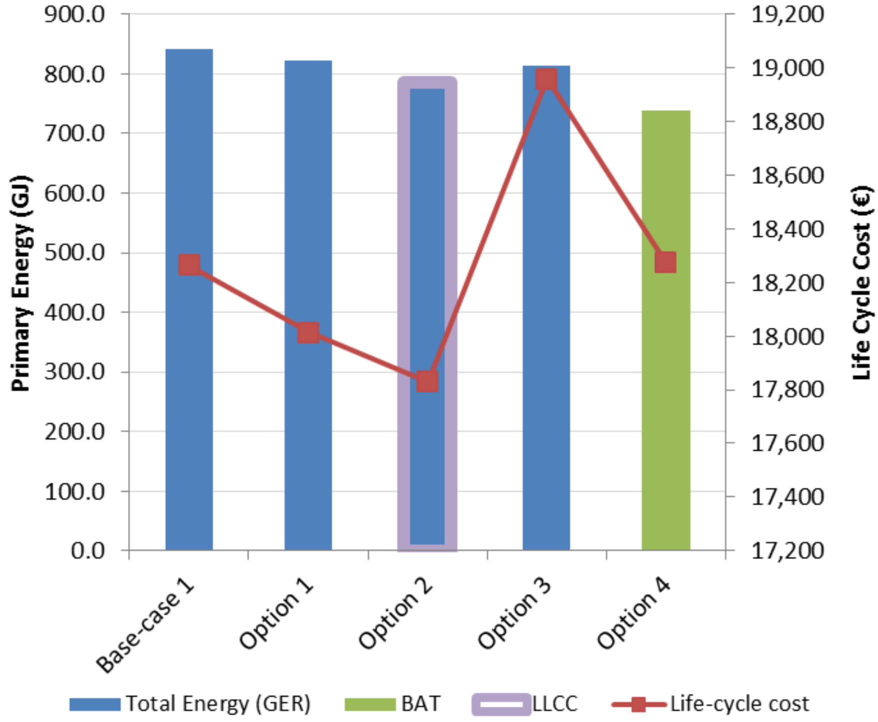

Figure 7-2: Identification of design improvement options with the least energy consumption and LLCC for BC1

Option 1 (OP1)	Option 2 (OP2)	Option 3 (OP3)	Option 4
Pump/hydraulic improvements	Motor improvements	VSD	OP1+OP2+OP3

7.2.2 Base-case 2: Centrifugal submersible pump: Mixed flow & axial pumps

Table 7-9 shows the environmental and economic impacts of the improvement options selected for BC2. Option 3 achieves the highest reduction in primary energy consumption, but the combination of all options (1+2+3) achieves the highest reduction in environmental impacts compared to the base-case. The lowest life cycle costs are also achieved through the combination of all options (1+2+3).

Table 7-10: Environmental impacts of the BC2 and its improvement options

Life-Cycle indicators per unit	Unit	Base-case 2	Option 1	Option 2	Option 3	Option 4
Total Energy (GER)	GJ	18396.4	18028.9	17661.4	17293.9	16191.4
	% change with BC	0%	-2%	-4%	-6%	-12%
Of which, electricity	Primary GJ	18377.1	18009.6	17642.1	17274.6	16172.1
	Final MWh	1750.2	1715.2	1680.2	1645.2	1540.2
	% change with BC	0%	-2%	-4%	-6%	-12%
Water (process)	Kg SO2 eq.	1226.2	1201.7	1177.2	1152.7	1079.2
	% change with BC	0%	-2%	-4%	-6%	-12%
Water (cooling)	Kg SO2 eq.	49001.7	48021.7	47041.7	46061.7	43121.7
	% change with BC	0%	-2%	-4%	-6%	-12%
Waste, non-haz./ landfill	Kg SO2 eq.	22249.4	21823.3	21397.2	20971.1	19692.9
	% change with BC	0%	-2%	-4%	-6%	-11%
Waste, hazardous/ incinerated	Kg SO2 eq.	427.1	418.6	410.1	401.7	376.3
	% change with BC	0%	-2%	-4%	-6%	-12%
Greenhouse Gases in GWP100	Kg SO2 eq.	803.2	787.2	771.1	755.1	707.0
	% change with BC	0%	-2%	-4%	-6%	-12%
Acidification, emissions	Kg SO2 eq.	4744.2	4649.6	4554.9	4460.3	4176.4
	% change with BC	0%	-2%	-4%	-6%	-12%
Volatile Organic Compounds (VOC)	kg	7.0	6.9	6.7	6.6	6.2
	% change with BC	0%	-2%	-4%	-6%	-12%
Persistent Organic Pollutants (POP)	µg i-Teq	126.0	123.6	121.2	118.8	111.6
	% change with BC	0%	-2%	-4%	-6%	-11%
Heavy Metals to	g Ni eq.	318.9	312.6	306.3	300.0	281.1

Life-Cycle indicators per unit	Unit	Base-case 2	Option 1	Option 2	Option 3	Option 4
air	% change with BC	0%	-2%	-4%	-6%	-12%
PAHs	g Ni eq.	37.0	36.3	35.6	34.8	32.7
	% change with BC	0%	-2%	-4%	-6%	-12%
Particulate Matter (PM, dust)	kg	115.8	113.8	111.7	109.7	103.7
	% change with BC	0%	-2%	-3%	-5%	-10%
Heavy Metals to water	g Hg/20	119.7	117.3	115.0	112.6	105.5
	% change with BC	0%	-2%	-4%	-6%	-12%
Eutrophication	Kg PO4	0.6	0.6	0.6	0.6	0.5
	% change with BC	0%	-2%	-4%	-6%	-11%
Life-cycle cost	€	182,590.1	179,531.0	176,940.6	174,390.7	165,682.1
	% change with BC	0%	-2%	-3%	-4%	-9%

Design improvement options

Option 1 (OP1)	Option 2 (OP2)	Option 3 (OP3)	Option 4
Pump/hydraulic improvements	Motor improvements	VSD	OP1+OP2+OP3

Figure 7-3 shows different shares of consumer expenses throughout the life cycle of BC2 and the design options. For all cases, electricity costs have the highest share (between 84% and 86% of the total).

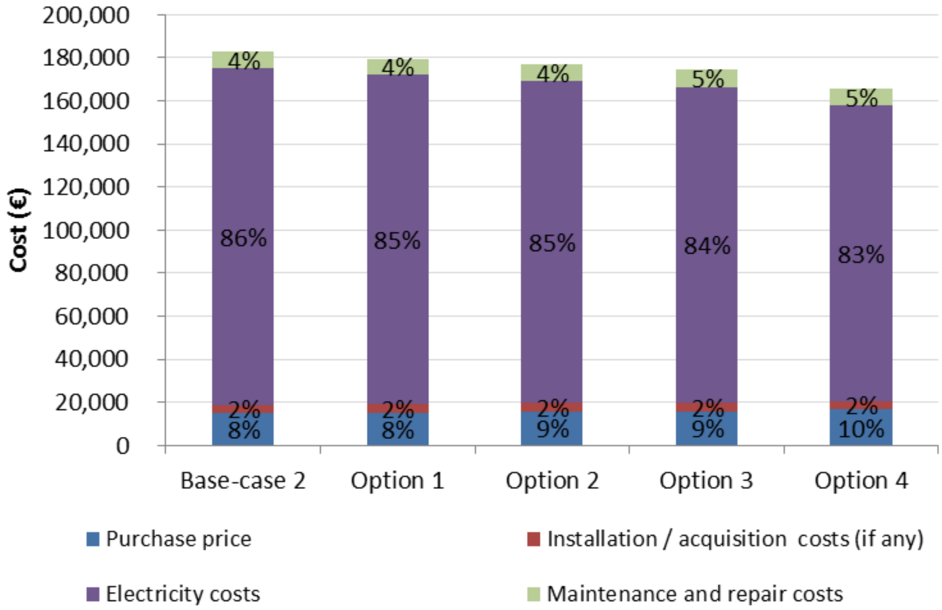

Figure 7-3: Life cycle costs of the improvement options for BC2

Option 1 (OP1)	Option 2 (OP2)	Option 3 (OP3)	Option 4
Pump/hydraulic improvements	Motor improvements	VSD	OP1+OP2+OP3

Figure 7-4 presents the comparison between LCC and primary energy consumption of BC2 and its design options. A combination option 4 is the option with the lowest environmental impacts and LLCC. This combination of options presents the LCC 9% lower that the base-case and the primary energy consumption 12% lower than the base-case.

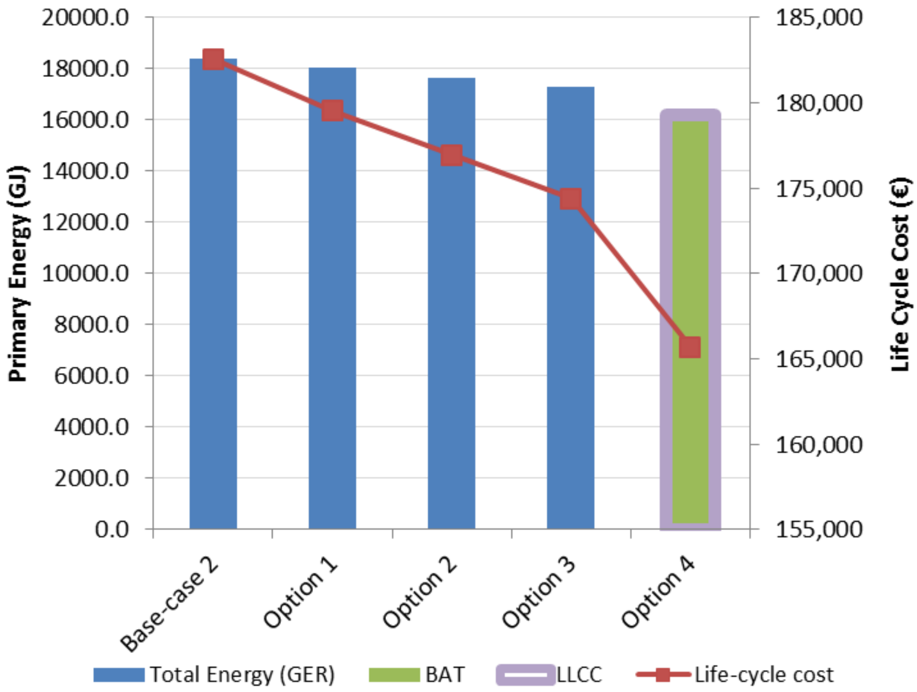

Figure 7-4: Identification of design improvement options with the least energy consumption and LLCC for BC2

Option 1 (OP1)	Option 2 (OP2)	Option 3 (OP3)	Option 4
Pump/hydraulic improvements	Motor improvements	VSD	OP1+OP2+OP3

7.2.3 Base-case 3: Centrifugal submersible pump – once day operation

The results of the environmental analysis of the different designs options for BC3 are presented in the Table 7-11. Option 2 results in the largest reductions of environmental impacts compared to Option 1 and the base-case, but it is the combination of options 1+2 that shows the most optimal results regarding environmental impacts.

Option 2 also shows higher life cycle costs than the base-case.

Table 7-11: Environmental impacts of the BC3 and its improvement options

Life-Cycle indicators per unit	Unit	Base-case 3	Option 1	Option 2	Option 3
Total Energy (GER)	GJ	6.9	6.7	6.6	6.5
	% change with BC	0%	-2%	-4%	-6%
Of which, electricity	Primary GJ	4.1	3.9	3.8	3.7
	Final MWh	0.4	0.4	0.4	0.3
	% change with BC	0%	-4%	-6%	-10%
Water (process)	Kg SO2 eq.	0.4	0.4	0.4	0.4
	% change with BC	0%	-2%	-4%	-6%
Water (cooling)	Kg SO2 eq.	10.3	9.9	9.6	9.2
	% change with BC	0%	-4%	-6%	-10%
Waste, non-haz./ landfill	Kg SO2 eq.	83.9	83.8	83.6	83.5
	% change with BC	0%	0%	0%	-1%
Waste, hazardous/ incinerated	Kg SO2 eq.	3.5	3.5	3.5	3.5
	% change with BC	0%	0%	0%	0%
Greenhouse Gases in GWP100	Kg SO2 eq.	0.3	0.3	0.3	0.3
	% change with BC	0%	-2%	-3%	-5%
Acidification, emissions	Kg SO2 eq.	2.2	2.1	2.1	2.1
	% change with BC	0%	-2%	-3%	-5%
Volatile Organic Compounds (VOC)	kg	0.0	0.0	0.0	0.0
	% change with BC	0%	0%	0%	-1%
Persistent Organic Pollutants (POP)	µg i-Teq	0.6	0.6	0.5	0.5
	% change with BC	0%	0%	0%	0%
Heavy Metals to air	g Ni eq.	0.5	0.5	0.5	0.5

Life-Cycle indicators per unit	Unit	Base-case 3	Option 1	Option 2	Option 3
	% change with BC	0%	-1%	-1%	-1%
PAHs	g Ni eq.	0.1	0.1	0.1	0.1
	% change with BC	0%	0%	-1%	-1%
Particulate Matter (PM, dust)	kg	3.6	3.6	3.6	3.6
	% change with BC	0%	0%	0%	0%
Heavy Metals to water	g Hg/20	0.2	0.2	0.2	0.2
	% change with BC	0%	-1%	-1%	-2%
Eutrophication	Kg PO4	0.0	0.0	0.0	0.0
	% change with BC	0%	0%	0%	0%
Life-cycle cost	€	3 876.9	3 877.4	4 014.5	4 015.1
	% change with BC	0%	0%	4%	4%

Design improvement options

Option 1 (OP1)	Option 2 (OP2)	Option 3
Pump/hydraulic improvements	Motor improvements	OP1+OP2

Figure 7-5 shows the share of different life cycle costs throughout the life cycle of BC3 and the design options. For all cases, the purchase price has the highest share (42%-45% of the total). The installation and acquisition costs represent the second largest share of the LCC. The electricity costs are very low (1%of total) compared to the purchasing and installation costs.

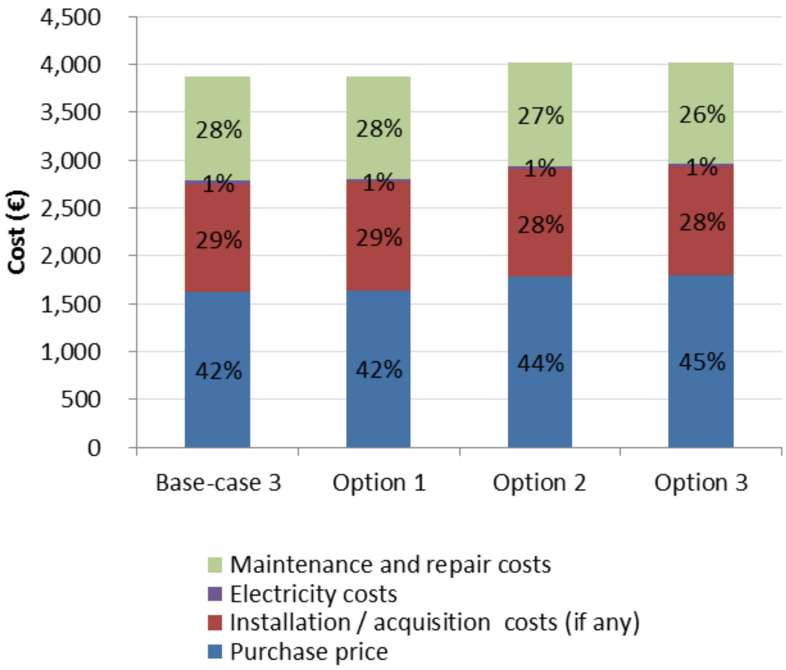

Figure 7-5: Life cycle costs of the improvement options for BC3

Option 1 (OP1)	Option 2 (OP2)	Option 3
Pump/hydraulic improvements	Motor improvements	OP1+OP2

Figure 7-6 presents the comparison between LCC and the primary energy consumption for BC3 and the design options. For this base-case, the combination of options 1+2 is the BAT, achieving 10.6% energy savings compared to the base-case. However, it has an increase of 4% in life cycle cost making the base-case the option with the LLCC.

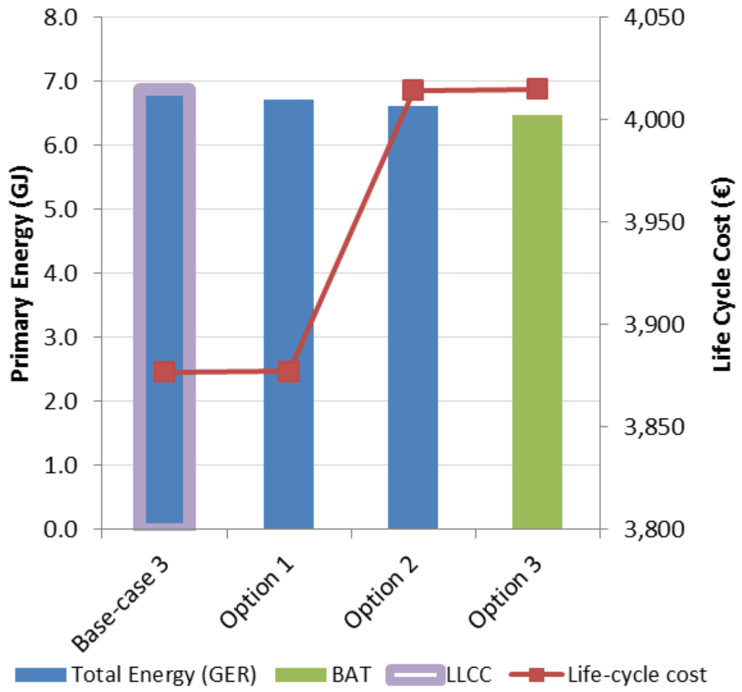

Figure 7-6: Identification of design improvement options with the least energy consumption and LLCC for BC3

Option 1 (OP1)	Option 2 (OP2)	Option 3
Pump/hydraulic improvements	Motor improvements	OP1+OP2

7.2.4 Base-case 4: Centrifugal submersible domestic drainage pump<40 mm passage

The results of the environmental analysis of the different designs options for BC4 are presented in the Table 7-12. Option 1 provides reductions in the environmental impacts compare to the base-case but it is the combination of options 1+2 that shows the most optimal results regarding environmental impacts.

As in the BC3, the combination of options 1+2 allows a reduction of electricity of 12% but there is an increase of the LCC equal to 11%.

Table 7-12: Environmental impacts of the BC4 and its improvement options

Life-Cycle indicators per unit	Unit	Base-case 4	Option 1	Option 2	Option 3
Total Energy (GER)	GJ	1.8	1.8	1.8	1.8
	% change with BC	0%	-3%	-1%	-4%
Of which, electricity	Primary GJ	0.6	0.6	0.6	0.6
	Final MWh	0.1	0.1	0.1	0.1
	% change with BC	0%	-8%	-4%	-12%
Water (process)	Kg SO2 eq.	0.0	0.0	0.0	0.0
	% change with BC	0%	-7%	-3%	-10%
Water (cooling)	Kg SO2 eq.	1.5	1.3	1.4	1.3
	% change with BC	0%	-9%	-5%	-14%
Waste, non-haz./ landfill	Kg SO2 eq.	32.6	32.5	32.5	32.5
	% change with BC	0%	0%	0%	0%
Waste, hazardous/ incinerated	Kg SO2 eq.	1.7	1.7	1.7	1.7
	% change with BC	0%	0%	0%	0%
Greenhouse Gases in GWP100	Kg SO2 eq.	0.1	0.1	0.1	0.1
	% change with BC	0%	-2%	-1%	-3%
Acidification, emissions	Kg SO2 eq.	0.7	0.7	0.7	0.7
	% change with BC	0%	-2%	-1%	-3%
Volatile Organic Compounds (VOC)	kg	0.0	0.0	0.0	0.0
	% change with BC	0%	0%	0%	0%
Persistent Organic Pollutants (POP)	µg i-Teq	0.2	0.2	0.2	0.2
	% change with BC	0%	0%	0%	0%
Heavy Metals to air	g Ni eq.	0.2	0.2	0.2	0.1
	% change with BC	0%	-1%	0%	-1%

Life-Cycle indicators per unit	Unit	Base-case 4	Option 1	Option 2	Option 3
PAHs	g Ni eq.	0.1	0.1	0.1	0.1
	% change with BC	0%	0%	0%	0%
Particulate Matter (PM, dust)	kg	1.9	1.9	1.9	1.9
	% change with BC	0%	0%	0%	0%
Heavy Metals to water	g Hg/20	0.0	0.0	0.0	0.0
	% change with BC	0%	-1%	0%	-1%
Eutrophication	Kg PO4	0.0	0.0	0.0	0.0
	% change with BC	0%	0%	0%	0%
Life-cycle cost	€	454.6	458.4	499.4	503.1
	% change with BC	0%	1%	10%	11%

Design improvement options

Option 1 (OP1)	**Option 2 (OP2)**	**Option 3**
Pump/hydraulic improvements	Motor improvements	OP1+OP2

In Figure 7-7 shows the share of different life cycle costs throughout the life cycle of BC4 and the design options. For all cases, the purchase price has the highest share (between 66% and 69% of the total). The electricity costs are very low (1%of total) compare to the purchasing and installation costs.

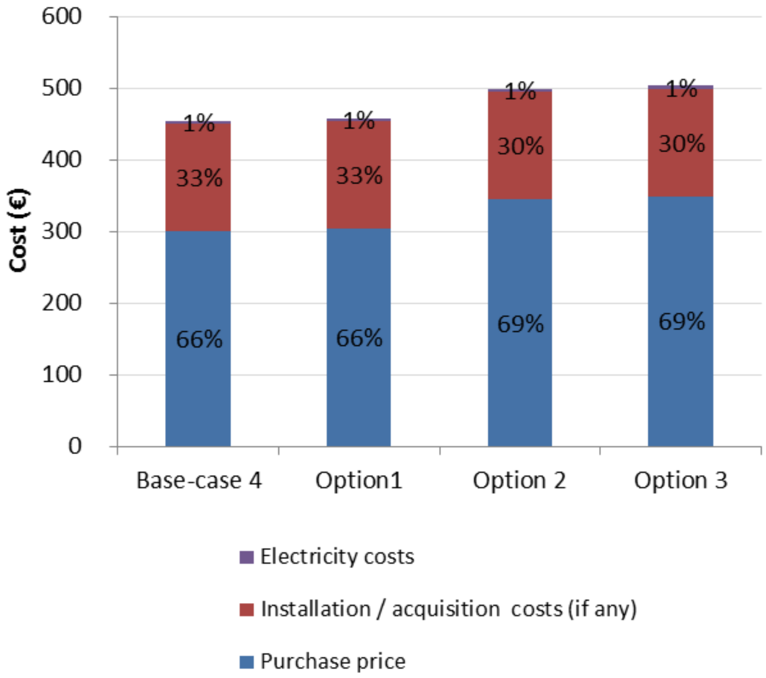

Figure 7-7: Life cycle costs of the improvement options for BC4

Option 1 (OP1)	Option 2 (OP2)	Option 3
Pump/hydraulic improvements	Motor improvements	OP1+OP2

Figure 7-8 shows the comparison between LCC and the primary energy consumption for BC4 and the design options. For this base-case, the combination of options 1+2 is the BAT, achieving 4% energy savings, but has an increase of 11% in life cycle costs. The LLCC is the base-case although the cost reduction compared to option 1 is only 1%.

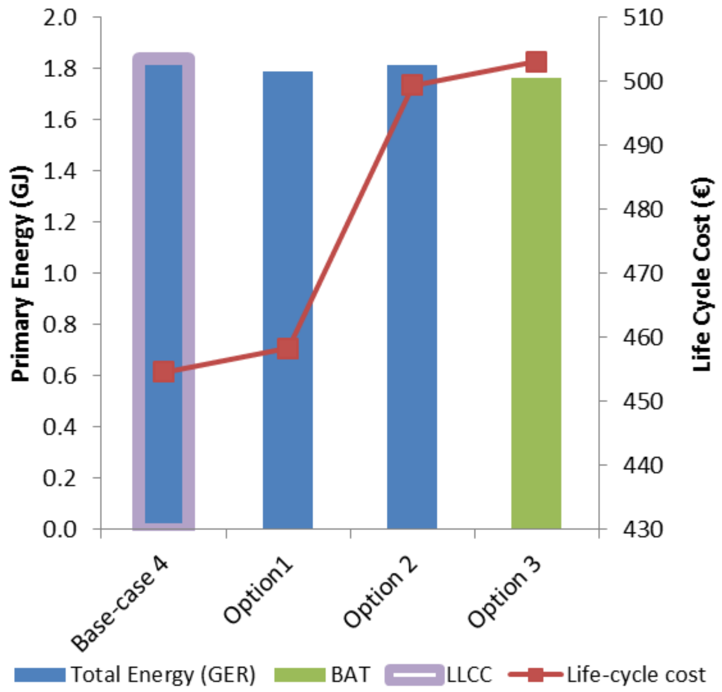

Figure 7-8: Identification of design improvement options with the least energy consumption and LLCC for BC4

Option 1 (OP1)	Option 2 (OP2)	Option 3
Pump/hydraulic improvements	Motor improvements	OP1+OP2

7.2.5 Base-case 5: Submersible dewatering pump

The results of the environmental analysis of the different designs options for BC5 are presented in the Table 7-13. Option 1 and option 2 respectively provide reductions in the environmental impacts compared to the base-case and total energy reductions equal to 5% but it is the combination of options 1+2 that allows the highest reduction of environmental impacts and consumer expenditure over the life cycle.

Table 7-13: Environmental impacts of the BC5 and its improvement options

Life-Cycle indicators per unit	Unit	Base-case 5	Option 1	Option 2	Option 3
Total Energy (GER)	GJ	1 107.1	1 051.9	1 051.9	996.8
	% change with BC	0%	-5%	-5%	-10%
Of which, electricity	Primary GJ	1 102.8	1 047.7	1 047.7	992.6
	Final MWh	105.0	99.8	99.8	94.5
	% change with BC	0%	-5%	-5%	-10%
Water (process)	Kg SO2 eq.	73.5	69.9	69.9	66.2
	% change with BC	0%	-5%	-5%	-10%
Water (cooling)	Kg SO2 eq.	2 940.1	2 793.1	2 793.1	2 646.1
	% change with BC	0%	-5%	-5%	-10%
Waste, non-haz./ landfill	Kg SO2 eq.	1 547.8	1 483.9	1 483.9	1 420.0
	% change with BC	0%	-4%	-4%	-8%
Waste, hazardous/ incinerated	Kg SO2 eq.	25.9	24.6	24.6	23.3
	% change with BC	0%	-5%	-5%	-10%
Greenhouse Gases in GWP100	Kg SO2 eq.	48.4	46.0	46.0	43.6
	% change with BC	0%	-5%	-5%	-10%
Acidification, emissions	Kg SO2 eq.	287.9	273.7	273.7	259.5
	% change with BC	0%	-5%	-5%	-10%
Volatile Organic Compounds (VOC)	kg	0.4	0.4	0.4	0.4
	% change with BC	0%	-5%	-5%	-9%
Persistent Organic Pollutants (POP)	µg i-Teq	8.2	7.8	7.8	7.5
	% change with BC	0%	-4%	-4%	-9%
Heavy Metals to air	g Ni eq.	19.8	18.8	18.8	17.9
	% change with BC	0%	-5%	-5%	-10%

Life-Cycle indicators per unit	Unit	Base-case 5	Option 1	Option 2	Option 3
PAHs	g Ni eq.	2.5	2.4	2.4	2.3
	% change with BC	0%	-4%	-4%	-9%
Particulate Matter (PM, dust)	kg	9.4	9.1	9.1	8.8
	% change with BC	0%	-3%	-3%	-6%
Heavy Metals to water	g Hg/20	7.3	7.0	7.0	6.6
	% change with BC	0%	-5%	-5%	-10%
Eutrophication	Kg PO4	0.0	0.0	0.0	0.0
	% change with BC	0%	-4%	-4%	-9%
Life-cycle cost	€	18 369.4	17 899.7	18 075.9	17 606.3
	% change with BC	0%	-3%	-2%	-4%

Design improvement options

Option 1 (OP1)	Option 2 (OP2)	Option 3
Pump/hydraulic improvements	Motor improvements	OP1+OP2

Figure 7-9 shows the share of different life cycle costs throughout the life cycle of BC5 and the design options. For all cases, the electricity costs have the highest share (between 51% and 48% of the total). The purchase prices and maintenance costs are the second largest contributors to the LCC. Installation costs have an impact of only 1% throughout the life cycle of BC5 and the design options.

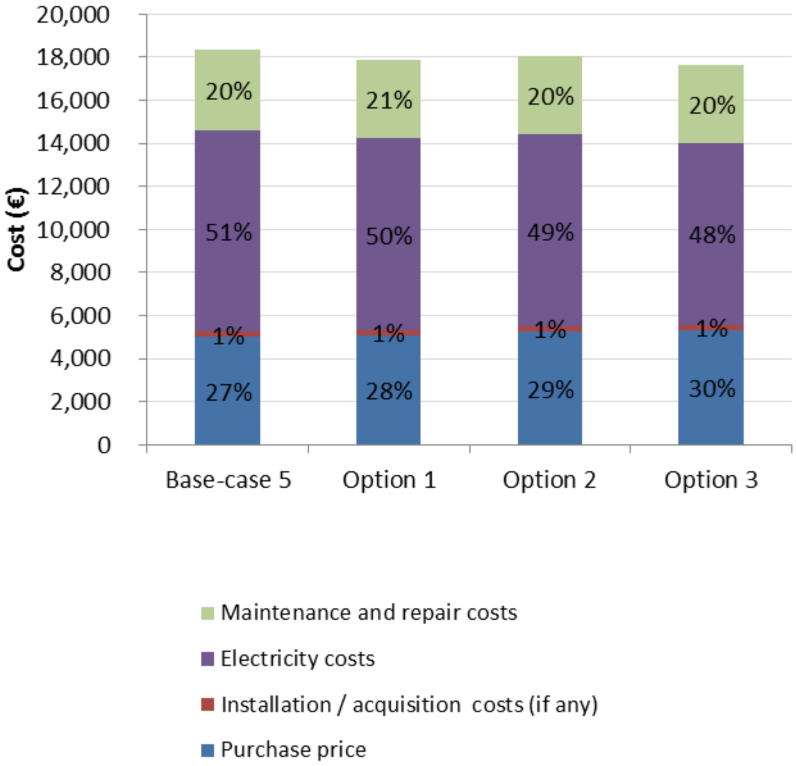

Figure 7-9: Life cycle costs of the improvement options for BC5

Option 1 (OP1)	Option 2 (OP2)	Option 3
Pump/hydraulic improvements	Motor improvements	OP1+OP2

Figure 7-10 shows the comparison between LCC and the primary energy consumption for BC5 and the design options. For this base-case, the combination of options 1+2 is the BAT as well as the LLCC, achieving 10% energy savings and a reduction of 4% in life cycle costs compared to the base-case.

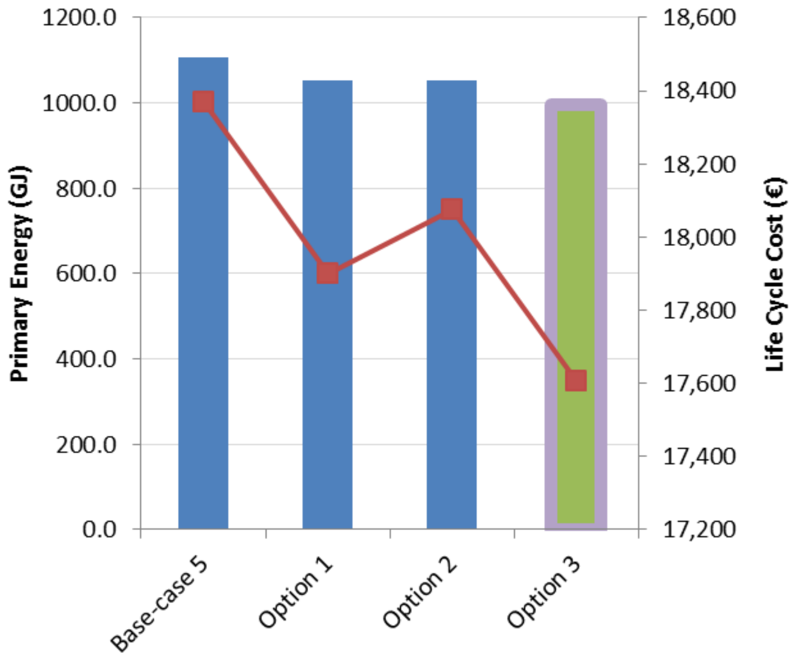

Figure 7-10: Identification of design improvement options with the least energy consumption and LLCC for BC5

Option 1 (OP1)	Option 2 (OP2)	Option 3
Pump/hydraulic improvements	Motor improvements	OP1+OP2

7.2.6 Base-case 6: Centrifugal well pump

The results of the environmental analysis of the different designs options for BC6 are presented in Table 7-14. Option 3 provides reductions in the environmental impacts compared to the base-case and primary energy reduction of 4% but it is the combination of options 1+2+3that allows the highest reduction of environmental impacts and consumer expenditures over the life cycle.

Table 7-14: Environmental impacts of the BC6 and its improvement options

Life-Cycle indicators per unit	Unit	Base-case 6	Option 1	Option 2	Option 3	Option 4
Total Energy (GER)	GJ	1973.3	1933.9	1929.9	1894.5	1811.8
	% change with BC	0%	-2%	-2%	-4%	-8%
Of which, electricity	Primary GJ	1969.9	1930.5	1926.5	1891.1	1808.4
	Final MWh	187.6	183.9	183.5	180.1	172.2
	% change with BC	0%	-2%	-2%	-4%	-8%
Water (process)	Kg SO2 eq.	131.6	129.0	128.7	126.4	120.9
	% change with BC	0%	-2%	-2%	-4%	-8%
Water (cooling)	Kg SO2 eq.	5252.5	5147.5	5137.0	5042.5	4821.9
	% change with BC	0%	-2%	-2%	-4%	-8%
Waste, non-haz./ landfill	Kg SO2 eq.	2339.0	2293.3	2288.7	2247.6	2151.7
	% change with BC	0%	-2%	-2%	-4%	-8%
Waste, hazardous/ incinerated	Kg SO2 eq.	46.5	45.6	45.5	44.7	42.8
	% change with BC	0%	-2%	-2%	-4%	-8%
Greenhouse Gases in GWP100	Kg SO2 eq.	86.2	84.5	84.3	82.8	79.2
	% change with BC	0%	-2%	-2%	-4%	-8%
Acidification, emissions	Kg SO2 eq.	507.9	497.8	496.7	487.6	466.3
	% change with BC	0%	-2%	-2%	-4%	-8%
Volatile Organic Compounds (VOC)	kg	0.8	0.8	0.8	0.7	0.7
	% change with BC	0%	-2%	-2%	-4%	-8%
Persistent Organic Pollutants (POP)	µg i-Teq	13.7	13.5	13.4	13.2	12.7
	% change with BC	0%	-2%	-2%	-4%	-8%
Heavy Metals to air	g Ni eq.	34.3	33.6	33.5	32.9	31.5

Life-Cycle indicators per unit	Unit	Base-case 6	Option 1	Option 2	Option 3	Option 4
	% change with BC	0%	-2%	-2%	-4%	-8%
PAHs	g Ni eq.	3.9	3.8	3.8	3.8	3.6
	% change with BC	0%	-2%	-2%	-4%	-8%
Particulate Matter (PM, dust)	kg	16.3	16.1	16.1	15.9	15.4
	% change with BC	0%	-1%	-1%	-3%	-5%
Heavy Metals to water	g Hg/20	12.9	12.6	12.6	12.4	11.8
	% change with BC	0%	-2%	-2%	-4%	-8%
Eutrophication	Kg PO4	0.1	0.1	0.1	0.1	0.1
	% change with BC	0%	-2%	-2%	-3%	-7%
Life-cycle cost	€	29,258.5	28,830.2	28,914.3	29,403.6	28,631.2
	% change with BC	0%	-1%	-1%	0%	-2%

Design improvement options

Option 1 (OP1)	Option 2 (OP2)	Option 3 (OP3)	Option 4
Pump/hydraulic improvements	Motor improvements	VSD	OP1+OP2+OP3

Figure 7-11 shows he share of different life cycle costs throughout the life cycle of BC6 and the design options. For all cases, the electricity costs have the highest share (between 49% and 52% of the total). The maintenance and repair costs are the second largest contributor to the LCC with a share of 29%- 31% respectively. Installations costs and have comparatively little impacts throughout the life cycle of BC6 and the design options.

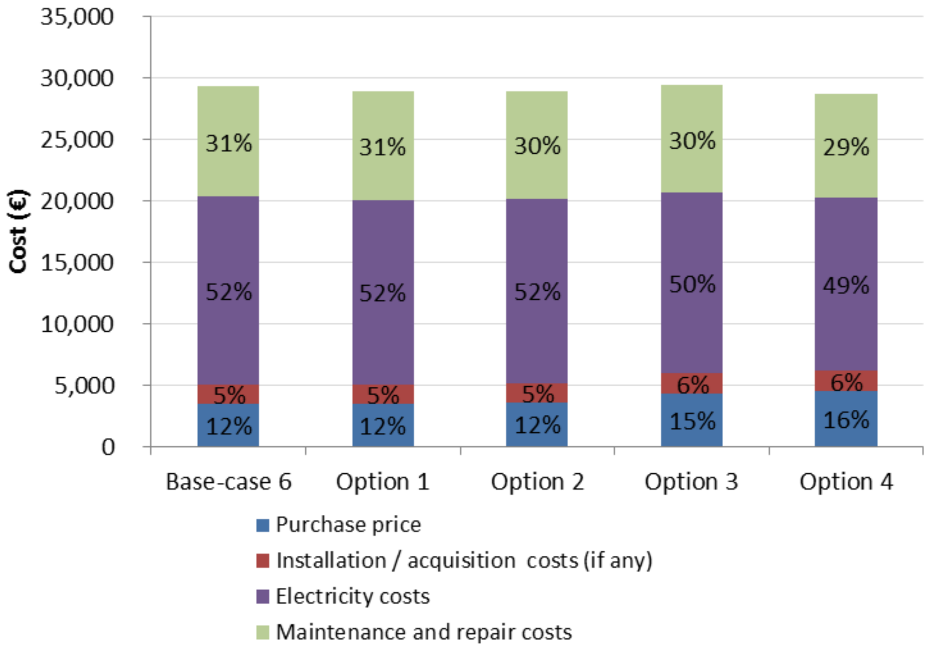

Figure 7-11: Life cycle costs of the improvement options for BC6

Option 1 (OP1)	Option 2 (OP2)	Option 3 (OP3)	Option 4
Pump/hydraulic improvements	Motor improvements	VSD	OP1+OP2+OP3

Figure 7-12 presents the comparison between LCC and the primary energy consumption for BC6 and the design options. The combination option 4 is the BAT as well as the LLCC, achieving 8% energy savings and a reduction of 2% in life cycle costs compared to the base-case.

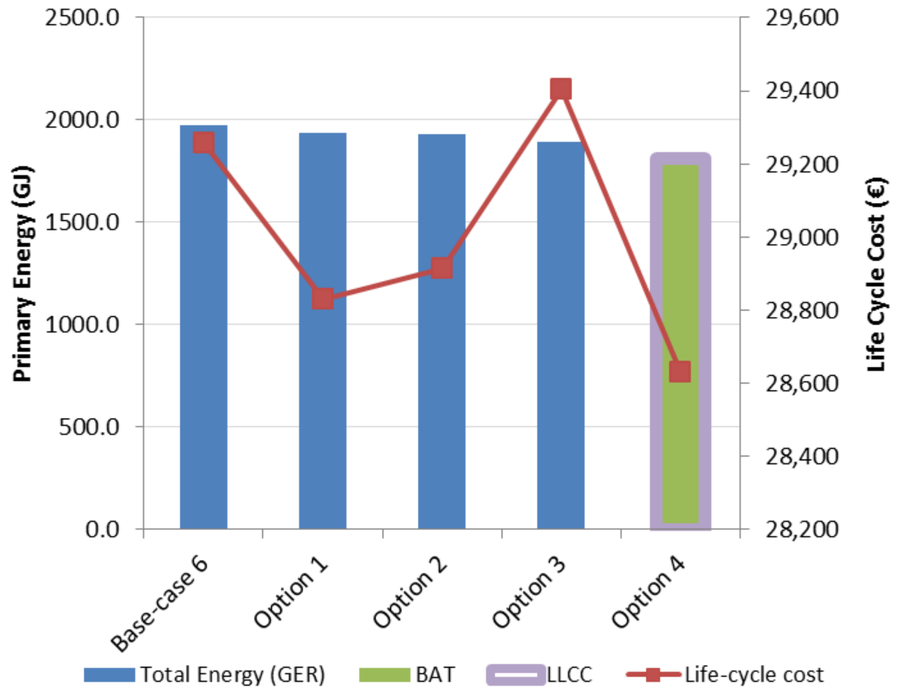

Figure 7-12: Identification of design improvement options with the least energy consumption and LLCC for BC6

Option 1 (OP1)	Option 2 (OP2)	Option 3 (OP3)	Option 4
Pump/hydraulic improvements	Motor improvements	VSD	OP1+OP2+OP3

7.2.7 Base-case 7A: Slurry pumps: Light duty

The results of the environmental analysis of the different designs options for BC7A are presented in Table 7-15. The combination of options 1+2, option 3 provides highest reductions in environmental impacts compared to the base-case and a total energy reduction of 3%. Option 3 also displays the LLCC with a 2% reduction compared to the LCC of the base-case.

Table 7-15: Environmental impacts of the BC7A and its improvement options

Life-Cycle indicators per unit	Unit	Base-case 7A	Option 1	Option 2	Option 3
Total Energy (GER)	GJ	34 161.7	33 820.5	33 479.2	33 138.0
	% change with BC	0%	-1%	-2%	-3%
Of which, electricity	Primary GJ	34 134.3	33 793.1	33 451.8	33 110.6
	Final MWh	3 250.9	3 218.4	3 185.9	3 153.4
	% change with BC	0%	-1%	-2%	-3%
Water (process)	Kg SO2 eq.	2 280.9	2 258.2	2 235.4	2 212.7
	% change with BC	0%	-1%	-2%	-3%
Water (cooling)	Kg SO2 eq.	91 003.3	90 093.3	89 183.3	88 273.3
	% change with BC	0%	-1%	-2%	-3%
Waste, non-haz./ landfill	Kg SO2 eq.	40 180.8	39 785.1	39 389.5	38 993.8
	% change with BC	0%	-1%	-2%	-3%
Waste, hazardous/ incinerated	Kg SO2 eq.	786.5	778.7	770.8	762.9
	% change with BC	0%	-1%	-2%	-3%
Greenhouse Gases in GWP100	Kg SO2 eq.	1 491.7	1 476.8	1 461.9	1 447.0
	% change with BC	0%	-1%	-2%	-3%
Acidification, emissions	Kg SO2 eq.	8 794.6	8 706.7	8 618.8	8 531.0
	% change with BC	0%	-1%	-2%	-3%
Volatile Organic Compounds (VOC)	kg	13.1	12.9	12.8	12.7
	% change with BC	0%	-1%	-2%	-3%
Persistent Organic Pollutants (POP)	µg i-Teq	232.3	230.1	227.9	225.6
	% change with BC	0%	-1%	-2%	-3%
Heavy Metals to air	g Ni eq.	589.8	583.9	578.1	572.2
	% change with BC	0%	-1%	-2%	-3%

Life-Cycle indicators per unit	Unit	Base-case 7A	Option 1	Option 2	Option 3
PAHs	g Ni eq.	67.4	66.8	66.1	65.4
	% change with BC	0%	-1%	-2%	-3%
Particulate Matter (PM, dust)	kg	220.4	218.5	216.6	214.7
	% change with BC	0%	-1%	-2%	-3%
Heavy Metals to water	g Hg/20	221.8	219.6	217.4	215.2
	% change with BC	0%	-1%	-2%	-3%
Eutrophication	Kg PO4	1.1	1.1	1.1	1.1
	% change with BC	0%	-1%	-2%	-3%
Life-cycle cost	€	268 313.9	266 679.1	264 447.6	262 812.8
	% change with BC	0%	-1%	-1%	-2%

Design improvement options

Option 1 (OP1)	Option 2 (OP2)	Option 3
Pump/hydraulic improvements	Motor improvements	OP1+OP2

Figure 7-13 shows the share of different life cycle costs throughout the life cycle of BC7A and the design options. For all cases, the electricity costs have the highest share (82% -83% of the total). The purchase prices and maintenance costs are the second largest contributors to the LCC with between 7% - 8% of the share. Both installations costs have very little impact throughout the life cycle of BC7A and the design options.

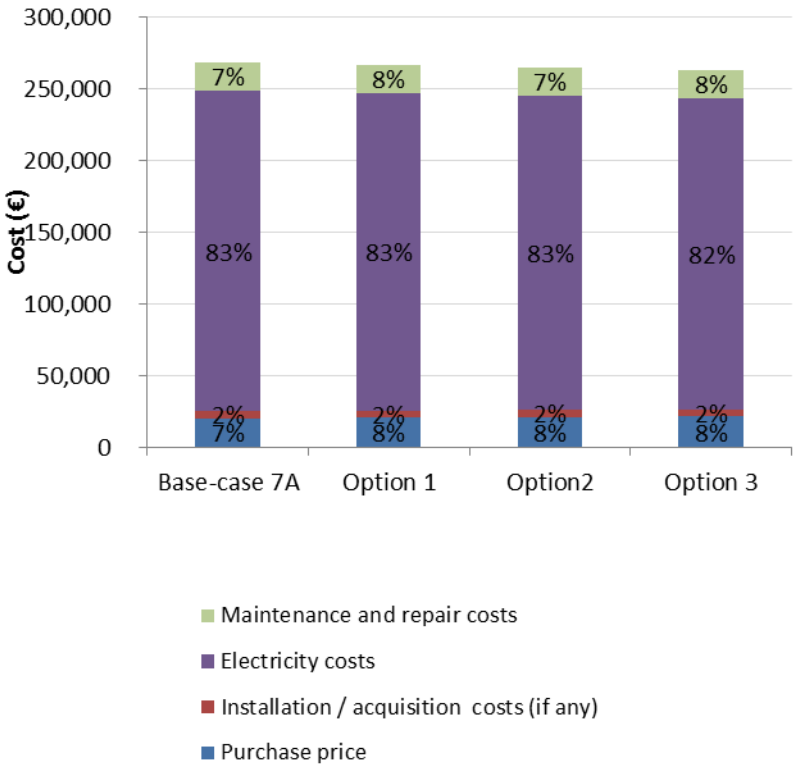

Figure 7-13: Life cycle costs of the improvement options for BC7A

Option 1 (OP1)	Option 2 (OP2)	Option 3
Pump/hydraulic improvements	Motor improvements	OP1+OP2

Figure 7-14 presents the comparison between LCC and the primary energy consumption for BC7A and the design options. The combination option 3 appears as the BAT and the LLCC, with energy savings of 3% and reduction of the LLC of 2% compared to the base-case.

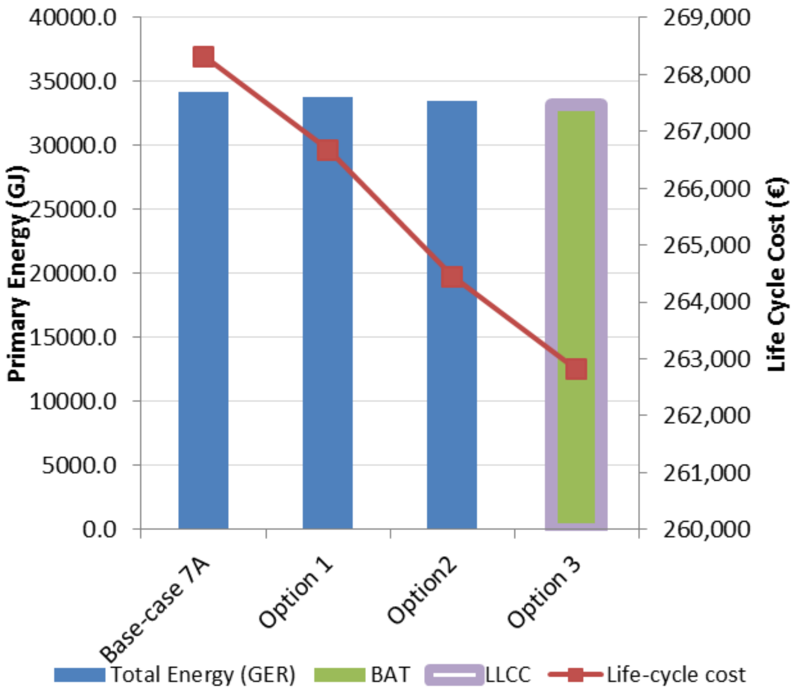

Figure 7-14: Identification of design improvement options with the least energy consumption and LLCC for BC7A

Option 1 (OP1)	Option 2 (OP2)	Option 3
Pump/hydraulic improvements	Motor improvements	OP1+OP2

7.2.8 Base-case 7B: Slurry pumps: Heavy duty

The results of the environmental analysis of the different design options for BC7B are presented in the Table 7-16. As demonstrated for BC7A, the combination option 3, provides the highest reductions in the environmental impacts compared to the base-case and a reduction in the total energy share of 3%. But also both option 1 and option 2 show environmental improvements respectively compared to the base-case.

Table 7-16: Environmental impacts of the BC7B and its improvement options

Life-Cycle indicators per unit	Unit	Base-case 7B	Option 1	Option 2	Option 3
Total Energy (GER)	GJ	15 655.4	15 500.0	15 344.6	15 189.2
	% change with BC	0%	-1%	-2%	-3%
Of which, electricity	Primary GJ	15 550.2	15 394.8	15 239.4	15 084.0
	Final MWh	1 481.0	1 466.2	1 451.4	1 436.6
	% change with BC	0%	-1%	-2%	-3%
Water (process)	Kg SO2 eq.	1 044.4	1 034.1	1 023.7	1 013.4
	% change with BC	0%	-1%	-2%	-3%
Water (cooling)	Kg SO2 eq.	41 465.1	41 050.7	40 636.3	40 221.9
	% change with BC	0%	-1%	-2%	-3%
Waste, non-haz./ landfill	Kg SO2 eq.	20 692.7	20 512.5	20 332.3	20 152.2
	% change with BC	0%	-1%	-2%	-3%
Waste, hazardous/ incinerated	Kg SO2 eq.	358.1	354.5	351.0	347.4
	% change with BC	0%	-1%	-2%	-3%
Greenhouse Gases in GWP100	Kg SO2 eq.	688.1	681.3	674.5	667.7
	% change with BC	0%	-1%	-2%	-3%
Acidification, emissions	Kg SO2 eq.	4 030.1	3 990.1	3 950.1	3 910.1
	% change with BC	0%	-1%	-2%	-3%
Volatile Organic Compounds (VOC)	kg	6.8	6.7	6.6	6.6
	% change with BC	0%	-1%	-2%	-3%
Persistent Organic Pollutants (POP)	µg i-Teq	143.8	142.8	141.8	140.8
	% change with BC	0%	-1%	-1%	-2%
Heavy Metals to air	g Ni eq.	288.2	285.5	282.9	280.2
	% change with BC	0%	-1%	-2%	-3%

Life-Cycle indicators per unit	Unit	Base-case 7B	Option 1	Option 2	Option 3
PAHs	g Ni eq.	30.9	30.6	30.3	30.0
	% change with BC	0%	-1%	-2%	-3%
Particulate Matter (PM, dust)	kg	222.5	221.6	220.7	219.9
	% change with BC	0%	0%	-1%	-1%
Heavy Metals to water	g Hg/20	108.6	107.6	106.6	105.6
	% change with BC	0%	-1%	-2%	-3%
Eutrophication	Kg PO4	0.8	0.8	0.8	0.8
	% change with BC	0%	-1%	-1%	-2%
Life-cycle cost	€	146 649.1	146 231.0	145 216.2	144 798.0
	% change with BC	0%	0%	-1%	-1%

Design improvement options

Option 1 (OP1)	**Option 2 (OP2)**	**Option 3**
Pump/hydraulic improvements	Motor improvements	OP1+OP2

Figure 7-15 shows the share of different life cycle costs throughout the life cycle of BC7B and the design options. For all cases, the electricity costs have the highest share (68% - 69% of the total). The purchase price and maintenance costs are the second largest contributor to the LCC with a share of around 14%.

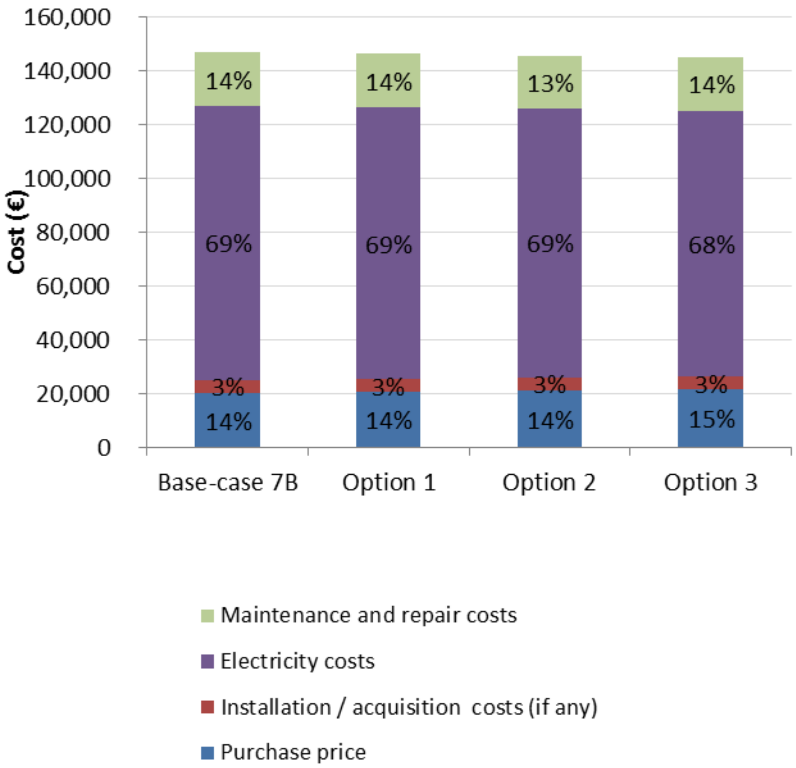

Figure 7-15: Life cycle costs of the improvement options for BC7B

Option 1 (OP1)	Option 2 (OP2)	Option 3
Pump/hydraulic improvements	Motor improvements	OP1+OP2

Figure 7-16 presents the comparison between LCC and the primary energy consumption for BC7B and the design options. The option 3 appears to be the BAT and the LLCC with a reduction of 1% of the life cycle cost.

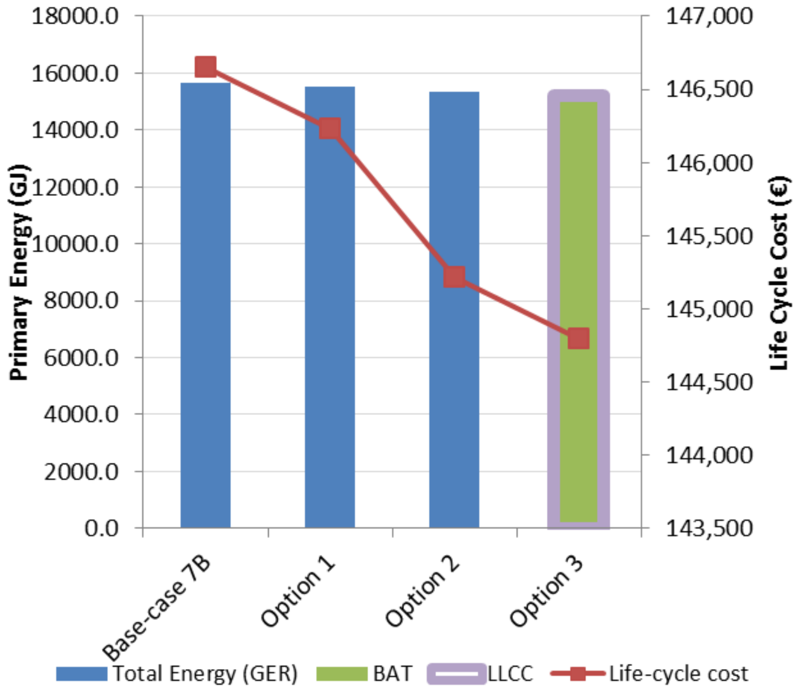

Figure 7-16: Identification of design improvement options with the least energy consumption and LLCC for BC7B

Option 1 (OP1)	Option 2 (OP2)	Option 3
Pump/hydraulic improvements	Motor improvements	OP1+OP2

7.3 BNAT and long-term systems analysis

Pumps, including wastewater pumps, are a very well established product that has been refined for several hundred years, and, therefore, there are just minor things that can be considered for the Best Not yet Available Technology (BNAT). 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 because closer manufacturing tolerances become feasible.

Any significant improvements in the energy associated with wastewater pumping are likely to be achieved through the use of integrated controls for several pumps in a wastewater collection system at a network level. Controlling several pumps together could potentially reduce the peaks in flow rate that are currently observed 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 at a product level, they are beyond the scope of this study.

7.4 Conclusions

Several improvement options are available for each base-case, with different payback periods and a small number of constraints. Combinations of these improvement options (which forms the basis of extended product approach) provide potential for significant energy savings, leading to the minimisation of negative environmental impacts.

In terms of potential energy savings, all three improvement options offer different prospects depending on the respective base-cases. Whereas motor improvements and some pump/hydraulic improvements, which include: improved case geometry, surface friction reduction, leakage reduction and improved impeller efficiency, are applicable to all base-cases, VSD[10] is only feasible for BC1, BC2 and BC6.

Motor improvements alone, seem to offer the biggest potential energy consumption savings that range from 4% to 6.7%. The savings achieved by VSD range from 3.4% to 6% for the pumps which these improvements can be implemented on[10]. However, a combination of pump/hydraulic improvements yields 10% energy savings for BC4 and savings range between 1-5% for all other base-cases.

In terms of investments payback period, the following base-cases offer the shortest payback periods (around 2 years) for all of their design improvement options

- Base-case 2: Centrifugal submersible pump - mixed flow & axial pumps
- Base-case 5: Submersible dewatering pumps
- Base-case 6: Centrifugal dry well pump

Unlike all other improvement options, hydraulic improvement requires no significant additional investments and is applicable to all base-cases. However, the payback time of hydraulic improvements varies widely between the different base-cases, from less than 1 year (BC 1, BC2, BC3, BC5 and BC6) to not ever generating returns on investments (BC4, BC7A and BC7B). Although motor improvement is the options that offer biggest energy savings for all base – cases except for BC4, payback time is longer. For VSD, which is applicable for three base-cases (BC1, BC2 and BC6), the payback time is low for BC2 and BC6 (0.32 and 2,6 years, respectively) but too high to justify investments for BC1. .

The results show that throughout all the base-cases, the BAT is always a combination of several improvement options. A combination of all options considered is the BAT for all the base-cases.

The following results were obtained for LLCC. In three base-cases (BC1, BC3 and BC4), the option with LLCC is not the combination of all improvement options. For BC1 motor improvements is the LLCC option. For both BC3 and BC4 on the other hand, the LLCC is associated with no improvement option at all, but with the base case itself.

[10] Please note that the VSD technology only provides a benefit in applications where variable speed is needed. Some pump applications would not benefit from this option if they only operate at full speed.

For the remaining five base-cases, the LLCC is a combination of all the independent improvement options. For these five base-cases the LLCC is therefore the same as the BAT.

Currently, not available improvement options have a potential to become more affordable over the coming years. This is the case for the use of integrated controls for several pumps in wastewater collection system at a network level.

Hence, steadily increasing levels of energy efficiency can be achieved without significant additional economic impacts. These results will be discussed in context of potential policy measures in Task 8.

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