EuP Lot 30:
Electric Motors and Drives

Task 7: Improvement Potential

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Contents

7 Task 7: Policy and Impact Analysis

7.1 Options

This subtask identifies and describes the individual design options for environmental improvement, based on the preceding technical analysis in Task 6.

The design options for each of the basecases are presented in Task 6, and are summarised in Table 1. This table presents each basecase and the related Best Available Technology options (efficiency and price) for each. It is these different design options that form the basis of the analysis in this section.

7.2 Basis of analysis for the different products

7.2.1 Induction Motors

The efficiencies in this category are taken from the IE classification scheme (IEC60034-30), for 4 pole 50Hz motors. The prices are best estimates from limited available information. An increase of 10% in stock has been assumed to account for the Brake and Explosion proof motors that were explicitly excluded from current regulation 640/2009. In all cases the frame size dimensions are kept the same, although a longer stack is allowed where needed.

NB. Strictly this category should be considered to be "Any line start and run single speed motor", but the existing nomenclature is used as it matches closely the existing regulation 640/2009.

For the **Small induction motors, 3 phase** <0.75kW that are not currently subject to regulation, the basecase is assumed to be IE1, with IE2 & IE3 shown as options using conventional technology. In addition, a LSPM motor is shown as BAT3, although any product that is line start and run could in theory be used as an alternative to an induction motor. It is acknowledged that there are technical differences which mean that they are not always a direct replacement, but this factor is not critical for this analysis. For **small induction motors, 1 phase** < 0.75kW, IE1 is also the assumed basecase. Two options are shown for improved performance: Addition of a second capacitor to create a Capacitor Start Capacitor Run motor (BAT1), and additional material (conventional technology) as BAT2.

For the **Medium induction motors**, IE2 is the assumed basecase, as this power range (0.75 to 375kW) is already regulated with IE2 as the MEPS. BAT options include achieving IE3 and IE4 with conventional technology, and also reaching IE4 with an LSPM.

Large induction motors >375kW are currently not regulated, but it is believed that they are typically at IE2 efficiency. BAT1 is therefore the IE3 level, assumed to be achieved with conventional induction motor technology. BAT2 and BAT3 represent higher efficiencies achieved through the use of already available technologies.

7.2.2 Variable Speed Drives

The Variable Speed Drives considered in the study are based on PWM inverters for induction motors, but are considered representative of controllers for all types of motor considered. This is reasonable on the basis that many VSDs are actually able to control many different types of motor. There is an advanced draft CENELEC Standard 50598-2 (to be finalized by the end of 2014) that proposes IE levels for VSD performance.,. In particular the baseline efficiency level for VSDs has been defined as the IE1 levels.

Little information is available on the standby power losses within VSDs, and so this is something that should be considered separately.

NB. "BAT1" is actually the industry norm, and so this is used as the basis of comparison of improved technologies. The Basecase data given represents the most energy intensive products sold, with the additional energy relating largely to additional functions included in the VSD package. It is the removal of the basecase that is one of the Policy Options considered.

7.2.3 Submersible Motors

These are analyzed here in order to provide data for their possible inclusion in an Extended Product Regulation under the LOT29 study on clean water pumps. The only option shown is for an improved conventional induction motor. Some are supplied with VSDs, but this will be accounted for within the Extended Product Model being developed as part of LOT29.

7.2.4 Motor + Controllers

In each case it is assumed that the improvement in efficiency is due to the use of a more efficient motor, both because this is easily quantifiable and the savings from improved VSDs are extremely modest. The total energy consumption takes account of the losses in the motor and VSD, and includes an increase in the motor losses due to the harmonic content of the waveform. BAT options are shown for a conventional IE4 motor, Permanent Magnet and Synchronous reluctance motor.

Analysis of the different technologies is relative to the use of an IE3 motor and basecase VSD. Later in this Task, separate analysis is shown that identifies the payback of new types of variable speed motors such as Permanent Magnet and Synchronous Reluctance.

Table 1 shows the key price and energy consumption inputs used in this analysis:

Table 1 Assumed efficiency and price of different BAT/BNAT options

				Basecase		BAT1			BAT2			BAT3 - LSPM			BAT4 - PM			BAT5 - SR	
Basecase Ref	Description	Basecase Size (kW)	Running Hours pa	Energy (kWh)	Price (Euros)	Efficiency Grade	Energy (kWh)	Price (Euros)	Efficiency Grade	Energy (kWh)	Price (Euros)	Efficiency Grade	Energy (kWh)	Price (Euros)	Efficiency Grade	Energy (kWh)	Price (Euros)	Efficiency Grade	Energy (kWh)
1	Small induction motor - 1 phase IE1	0.37	400	136	60	IE2 (2nd cap)	117	69	IE2	113	78								
2	Small induction motor - 3 phase IE1	0.37	2,000	678	200	IE2	586	250	IE3	563	325	IE4 (LSPM)	539	500	IE4 (PM)	539	625		
3	Medium induction motor (S) - 3 phase IE2	1.1	2,250	1,923	150	IE3	1,861	188	IE4	1,795	244	IE4 (LSPM)	1,739	375	IE4 (PM)	1,739	469	IE4 (SR)	1,73
4	Medium induction motor (M) - 3 phase IE2	11	3,000	23,103	600	IE3	22,698	720	IE4	22,188	900	IE4 (LSPM)	21,747	1,440	IE4 (PM)	21,747	1,800	IE4 (SR)	21,74
5	Medium induction motor (L) - 3 phase IE2	110	6,000	437,820	6,000	IE3	433,690	6,900	IE4	429,637	8,280	IE4 (LSPM)	425,659	13,800	IE4 (PM)	425,659	17,250	IE4 (SR)	425,65
6	Large induction motor - LV IE2	550	6,000	2,170,800	25,000	IE3	2,152,804	28,750	IE4	2,146,132	34,500								
7	Large induction motor - MV IE2	550	6,000	2,137,061	35,000	IE3	2,119,344	40,250	IE4	2,112,776	48,300								
8	VSD - Very Small (IE1)	0.37	2,000	166	200	IE2 VSD	133	220	IE ?	116	770								
9	VSD - Small (IE1)	1.1	2,250	263	280	IE2 VSD	211	322	IE ?	184	1,159								
10	VSD - Medium (IE1)	11	3,000	1,472	1,130	IE2 VSD	1,178	1,300	IE ?	1,031	4,938								
11	VSD - Large (IE1)	110	6,000	20,024	5,320	IE2 VSD	16,019	6,384	IE ?	14,017	25,536								
12	VSD - Very Large (IE1)	550	6,000	98,240	41,790	IE2 VSD	78,592	50,148	IE ?	68,768	225,666								
16	Submersible borehole motor - Small	2.2	1,000	1,300	400	IE?	1,258	480											
17	Submersible borehole motor - Large	37	4,000	73,971	4,000	IE?	72,676	4,800											
18	Motor + VSD - Very Small (3 phs)	0.37	2,000	947	420	IE2 + VSD	836	470	IE3 + VSD	808	545				IE4 PM + VSD	672	758		
19	Motor + VSD - Small	1.1	2,250	2,518	472	IE3 + VSD	2,444	510	IE4 + VSD	2,365	566				IE4 PM + VSD	1,950	679	IE4 (SR) + VSD	1,95
20	Motor + VSD - Medium	11	3,000	28,901	1,900	IE3 + VSD	28,416	2,020	IE4 + VSD	27,804	2,200				IE4 PM + VSD	22,924	2,978	IE4 (SR) + VSD	22,92
21	Motor + VSD - Large	110	6,000	541,403	12,384	IE3 + VSD	536,447	13,284	IE4 + VSD	531,583	14,664				IE4 PM + VSD	441,677	33,269	IE4 (SR) + VSD	441,67
22	Motor + VSD - Very Large (LV)	550	6,000	2,683,552	75,148	IE3 + VSD	2,661,956	78,898	IE4 + VSD	2,653,950	84,648								

7.3 Impacts

7.3.1 Key assumptions underpinning environmental impacts

For the motors considered in this study, it was previously shown in Task 5 that it is the energy consumption that dominated environmental emissions, and so is the focus of the analysis in this section. In the absence of firm data on the non energy environmental impact of improved induction motors, the following assumptions have been made:

- Production phase. A nominal 20% increase of materials has been assumed for an increase of one IE level.
- Distribution. The distance and the packaged volume are assumed to be the same, as often the design will comprise a longer stack of active materials within the same casing.
- Maintenance. More efficient motors run cooler and so may have a longer time between maintenance, but this is a modest effect and so is not taken account of.
- Disposal. This is assumed to be the same.

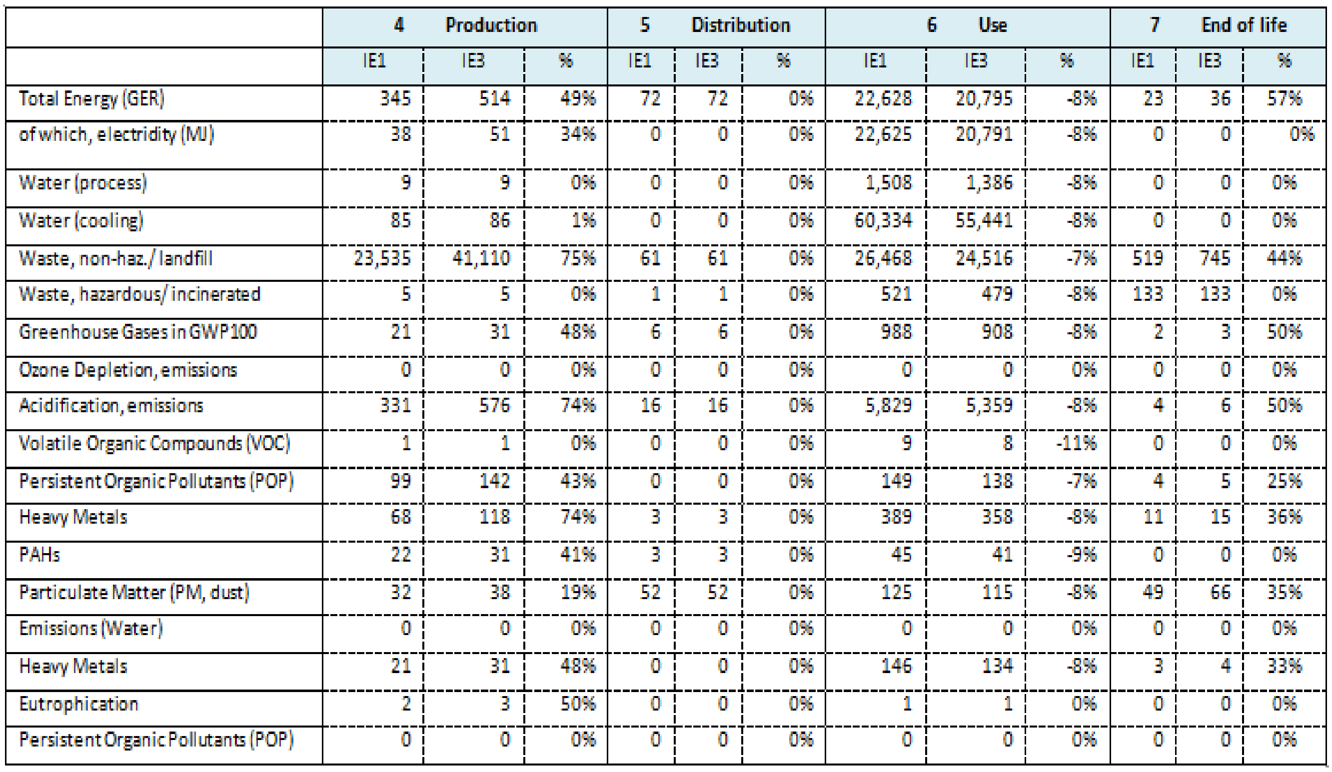
If any of these parameters are found at a later stage to be important, further analysis can be undertaken to refine this data, but from Task 5 analysis it is clear that over the lifetime, material content is much less significant than the energy consumption.

The use of Permanent Magnet rare earth technology is the most important difference in terms of material use, and so this is also considered as an option. However, it should also be noted that the business models for the use of these motors assume the reclamation of this material, and so in reality the environmental impact of these is spread in time over a large number of motors.

7.3.2 Environmental impact of improved technology

The impact of improved technology is shown in three representative examples of basecases, showing that for medium and large motors there is only a modest change in other environmental emissions when moving to the next BAT. For small motors, the difference is larger both because the efficiency jump is larger and because of the specific design constraints for this size of motor.

Table 2 Basecase 2 Small Motor - 0.37kW- Impact on moving from IE1 Motors to IE3



	4 Production			5 Distribution			6 Use			7 End of life		
	IE1	IE3	%	IE1	IE3	%	IE1	IE3	%	IE1	IE3	%
Total Energy (GER)	345	514	49%	72	72	0%	22,628	20,795	-8%	23	36	57%
of which, electricity (MJ)	38	51	34%	0	0	0%	22,625	20,791	-8%	0	0	0%
Water (process)	9	9	0%	0	0	0%	1,508	1,386	-8%	0	0	0%
Water (cooling)	85	86	1%	0	0	0%	60,334	55,441	-8%	0	0	0%
Waste, non-haz./ landfill	23,535	41,110	75%	61	61	0%	26,468	24,516	-7%	519	745	44%
Waste, hazardous/ incinerated	5	5	0%	1	1	0%	521	479	-8%	133	133	0%
Greenhouse Gases in GWP100	21	31	48%	6	6	0%	988	908	-8%	2	3	50%
Ozone Depletion, emissions	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Acidification, emissions	331	576	74%	16	16	0%	5,829	5,359	-8%	4	6	50%
Volatile Organic Compounds (VOC)	1	1	0%	0	0	0%	9	8	-11%	0	0	0%
Persistent Organic Pollutants (POP)	99	142	43%	0	0	0%	149	138	-7%	4	5	25%
Heavy Metals	68	118	74%	3	3	0%	389	358	-8%	11	15	36%
PAHs	22	31	41%	3	3	0%	45	41	-9%	0	0	0%
Particulate Matter (PM, dust)	32	38	19%	52	52	0%	125	115	-8%	49	66	35%
Emissions (Water)	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Heavy Metals	21	31	48%	0	0	0%	146	134	-8%	3	4	33%
Eutrophication	2	3	50%	0	0	0%	1	1	0%	0	0	0%
Persistent Organic Pollutants (POP)	0	0	0%	0	0	0%	0	0	0%	0	0	0%

Table 3 Basecase 4 Medium Induction Motor – 11kW- Impact of moving from IE2 to IE3

	Production			Distribution			Use			End of life		
	IE2	IE3	%	IE2	IE3	%	IE2	IE3	%	IE2	IE3	%
Total Energy (GER)	79,152	86,107	9%	255	255	0%	391,200	377,152	-4%	4,435	4871	10%
of which, electricity (in pri MJ)	5,271	5,760	9%	0	0	0%	390,281	376,168	-4%	0	0	0%
Water (process)	194	206	6%	-	0	0%	26,017	25,076	-4%	0	0	0%
Water (cooling)	2,963	3,169	7%	-	0	0%	1,040,638	1,002,992	-4%	2	-2	-200%
Waste, non-haz./ landfill	1,247,773	1,389,924	11%	149	149	0%	464,925	449,977	-3%	81,996	89771	9%
Waste, hazardous/ incinerated	42	44	5%	3	3	0%	8,992	8,667	-4%	990	990	0%
Greenhouse Gases in GWP100	5,011	5,455	9%	17	17	0%	17,093	16,482	-4%	331	364	10%
Ozone Depletion, emissions	-	0	0%	-	0	0%	-	0	0%	-	0	0%
Acidification, emissions	25,029	27,574	10%	49	49	0%	100,748	97,138	-4%	660	724	10%
Volatile Organic Compounds (VOC)	101	112	11%	3	3	0%	151	146	-3%	19	21	11%
Persistent Organic Pollutants (POP)	41,968	45,621	9%	1	1	0%	2,977	2,921	-2%	564	618	10%
Heavy Metals	1,926	2203	14%	8	8	0%	6,753	6,514	-4%	1,356	1483	9%
PAHs	21,645	23,448	8%	9	9	0%	1,024	1,014	-1%	0	0	0%
Particulate Matter (PM, dust)	5,580	6,101	9%	513	513	0%	2,864	2,791	-3%	6,037	6601	9%
Emissions (Water)	-	0	0%	-	0	0%	-	0	0%	-	0	0%
Heavy Metals	8,111	8,815	9%	0	0	0%	2,597	2,513	-3%	385	421	9%
Eutrophication	28	30	7%	0	0	0%	12	12	0%	22	24	9%
Persistent Organic Pollutants (POP)	-	0	0%	-	0	0%	-	0	0%	-	0	0%

Table 4 Basecase 6 Large Induction Motor – 550kW – Impact of moving from IE2 to IE3

	Production			Distribution			Use			End of life		
	IE2	IE3	%	IE2	IE3	%	IE2	IE3	%	IE2	IE3	%
Total Energy (GER)	97,702	108,709	11%	4,394	4,394	0%	31,014,656	30,757,665	-1%	9,832	10,788	10%
of which, electricity (in primary MJ)	12,253	13,299	9%	9	9	0%	31,013,320	30,756,230	-1%	-8	-8	0%
Water (process)	3,553	3,555	0%	-	-	0%	2,067,582	2,050,442	-1%	-5	-5	0%
Water (cooling)	15,161	15,230	0%	-	-	0%	82,702,011	82,016,411	-1%	-43	-43	0%
Waste, non-haz./ landfill	6,476,534	7,414,391	14%	2,145	2,145	0%	36,022,808	35,734,093	-1%	221,266	237,918	8%
Waste, hazardous/ incinerated	667	697	4%	43	43	0%	714,642	708,718	-1%	18,558	18,558	0%
Greenhouse Gases in GWP100	6,538	7,231	11%	261	261	0%	1,353,501	1,342,288	-1%	739	811	10%
Ozone Depletion, emissions	-	-	0%	-	-	0%	-	-	0%	-	-	0%
Acidification, emissions	83,503	96,248	15%	802	802	0%	7,986,771	7,920,695	-1%	1,647	1,785	8%
Volatile Organic Compounds (VOC)	371	398	7%	67	67	0%	11,692	11,595	-1%	49	53	8%
Persistent Organic Pollutants (POP)	34,722	38,487	11%	12	12	0%	203,626	201,978	-1%	1,523	1,638	8%
Heavy Metals	19,890	22,549	13%	109	109	0%	532,372	527,988	-1%	3,947	4,219	7%
PAHs	3,974	4,850	22%	144	144	0%	61,240	60,742	-1%	-1	-1	0%
Particulate Matter (PM, dust)	20,434	20,905	2%	10,941	10,941	0%	172,541	171,132	-1%	17,685	18,894	7%
Emissions (Water)	-	-	0%	-	-	0%	-	-	0%	-	-	0%
Heavy Metals	6,344	7,137	13%	3	3	0%	200,027	198,378	-1%	1,130	1,207	7%
Eutrophication	396	409	3%	0	0	0%	957	950	-1%	64	69	8%
Persistent Organic Pollutants (POP)	-	-	0%	-	-	0%	-	-	0%	-	-	0%

Data for BAT motor designs was sourced from the EUP LOT 11 Motors study, sections 4.1 and 7.1.

Unfortunately the MEEUP model has no data on permanent magnet material, and so it was not possible to model the change in material impact of their use to achieve high efficiencies.

7.4 Costs

For each design option, the additional cost has been estimated on the basis of incremental cost relative to the basecase price. See Table 1 for the assumed price of each option.

7.5 Analysis LLCC and BAT

7.5.1 Ranking of the Design options

Methodology for calculation of LLCC

For each design option (BAT), a whole Life Cycle Costing (LCC) is calculated, which sums the following factors;

Purchase price

+ Installation price

+ Maintenance price

+ Lifetime energy use

As expected for commercial motors, in each case the lifetime energy use was found to dominate the LCC.

The LCC for each BAT was compared in order to identify the Lease Life Cycle Cost (LLCC) option, which represents the best purchase option for the motor user (consumer). The breakdown of costs are summarized in Table 5 and 6. Table 6 and Figure 1 show the total Lifecycle costs of each, with the LLCC option shown in **bold**, (Figure 1).

Table 5 Lifetime cost data for different options, by product.

Basecase	Description	Basecase Size (kW)	Lifetime cost, by phase (Euros)														
					Basecase		BAT1		BAT2		BAT3		BAT4		BAT5	
			Installation	Maintenance	Purchase	Energy	Purchase	Energy	Purchase	Energy	Purchase	Energy	Purchase	Energy	Purchase	Energy
1	Small induction motor - 1 phase IE1	0.37	20	-	60	114	69	99	78	95	-	-				
2	Small induction motor - 3 phase IE1	0.37	20	-	200	571	250	493	325	473	500	454	625	454	-	-
3	Medium induction motor (S) - 3 phase IE2	1.1	40	-	150	1,978	188	1,914	244	1,846	375	1,789	469	1,789	375	1,789
4	Medium induction motor (M) - 3 phase IE2	11	80	700	600	23,761	720	23,345	900	22,821	1,440	22,366	1,800	22,366	1,440	22,366
5	Medium induction motor (L) - 3 phase IE2	110	250	6,000	6,000	695,915	6,900	689,350	8,280	682,907	13,800	676,584	17,250	676,584	13,800	676,584
6	Large induction motor - LV IE2	550	1,500	20,000	25,000	3,450,487	28,750	3,421,882	34,500	3,411,277	-	-				
7	Large induction motor - MV IE2	550	2,000	25,000	35,000	4,196,118	40,250	4,161,332	48,300	4,148,435	-	-				
8	VSD - Very Small	0.37	200	-	200	140	220	112	770	98	-	-				
9	VSD - Small	1.1	280	-	280	221	322	177	1,159	155	-	-				
10	VSD - Medium	11	1,130	200	1,130	1,514	1,300	1,212	4,938	1,060	-	-				
11	VSD - Large	110	5,320	1,200	5,320	20,594	6,384	16,475	25,536	14,416	-	-				
12	VSD - Very Large	550	41,790	1,200	41,790	156,152	50,148	124,922	225,666	109,307	-	-				
16	Submersible borehole motor - Small	2.2	20	250	400	1,215	480	1,176	-	-	-	-				
17	Submersible borehole motor - Large	37	40	8,000	4,000	103,744	4,800	101,928	-	-	-	-				
18	Motor + VSD - Very Small	0.37	220	-	420	-	470	-	545	-	-	-	758	-	-	-
19	Motor + VSD - Small	1.1	320	-	472	-	510	-	566	-	-	-	679	-	586	-
20	Motor + VSD - Medium	11	1,210	900	1,900	-	2,020	-	2,200	-	-	-	2,978	-	2,618	-
21	Motor + VSD - Large	110	5,570	7,200	12,384	-	13,284	-	14,664	-	-	-	33,269	-	29,819	-
22	Motor + VSD - Very Large	550	43,290	21,200	75,148	-	78,898	-	84,648	-	-	-				

Table 6 Life Cycle Costs of different Options

Basecase Ref	Description	Basecase Size (kW)	Total LCC (Euros)					
			Basecase	BAT1	BAT2	BAT3	BAT4	BAT5
1	Small induction m	0.37	194	**188**	193			
2	Small induction m	0.37	791	**763**	818	974		
3	Medium induction	1.1	2,168	2,142	**2,130**	2,204		
4	Medium induction	11	25,141	24,845	**24,501**	24,586		
5	Medium induction	110	708,165	702,500	697,437	**696,634**		
6	Large induction m	750	3,496,987	3,477,882	**3,467,277**			
7	Large induction m	750	4,258,118	4,236,632	**4,223,735**			
8	VSD - Very Small	0.37		**532**	1,068			
9	VSD - Small	1.1		**779**	1,594			
10	VSD - Medium	11		**3,841**	7,328			
11	VSD - Large	110		**29,379**	46,472			
12	VSD - Very Large	550		**218,060**	377,963			
16	Submersible bore	2.2	**1,885**	1,926				
17	Submersible bore	37	115,784	**114,768**				
18	Motor + VSD - Very	0.37	**640**	690	765		978	
19	Motor + VSD - Sma	1.1	**792**	830	886		999	906
20	Motor + VSD - Med	11	**4,010**	4,130	4,310		5,088	4,728
21	Motor + VSD - Larg	110	**25,154**	26,054	27,434		46,039	42,589
22	Motor + VSD - Very	550	**139,638**	143,388	149,138			

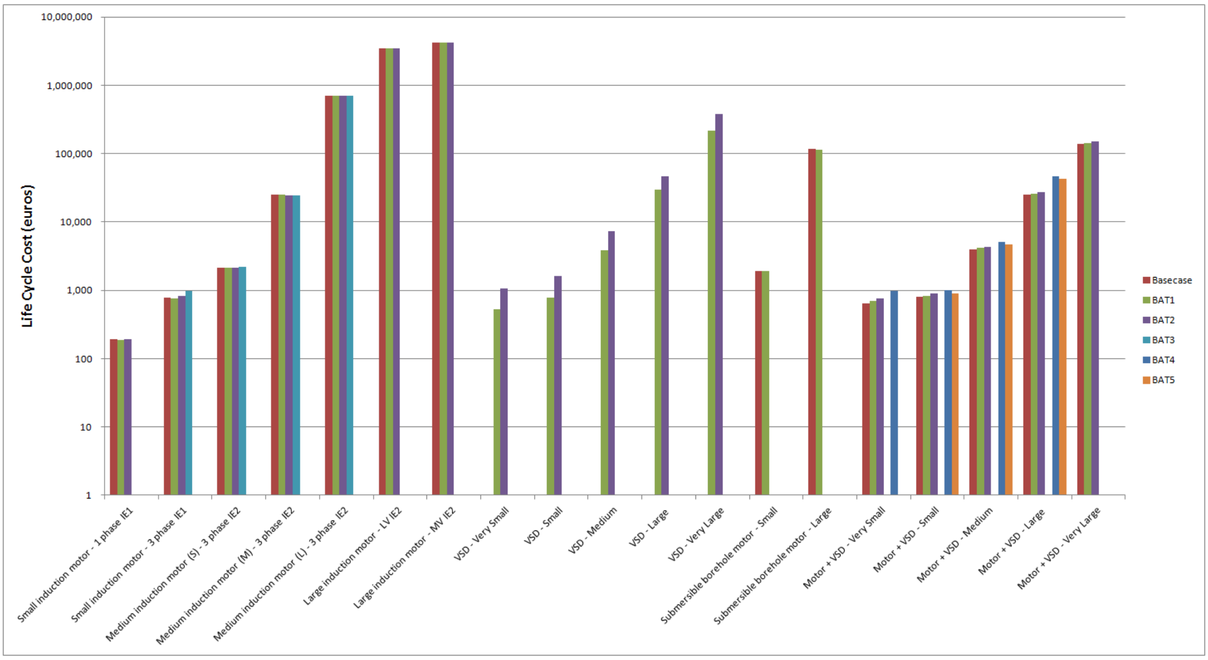


Figure 1 Total Life Cycle costs of different technological options for different product groups

Note that for clarity, all options are shown on the same graph, and so a log LLCC axis is used, with the important aspect being the identification of the smallest total LLCC. In summary, the technology options offering the LLCC for each basecase are:

Small Single Phase Induction Motor: Standard induction motor (IE1) with the addition of a second capacitor to increase efficiency to IE2.

All 3-Phase Motors: IE3 is the LLCC technology in all cases, except for the 110kW basecase where IE4 is the LLCC, and in general the LCC values for IE4 motors have values close to the values of IE3 motors.

VSDs: The only improvement option is too costly in all sizes, and so the assumed basecase remains the LLCC.

Motor + Controller: In all cases the SR technology offered the LLCC, followed by the PM technology.

Sensitivity analysis of paybacks of BATs to changes in running hours.

The calculations are based on assumed basecase average duties, but there are some groups of products such as portable cleaning machinery that will have a distinctly different duty profile. By undertaking sensitivity analysis of the running hours, the impact on these different groups of products can be identified through comparing paybacks with different assumed running hours, (see Task 8 for a detailed sensitivity analysis of these products).

Electricity prices are also predicted to increase, but without information on projected motor prices it is difficult to ascertain how paybacks might change into the future. The general assumption is that electricity prices will rise faster, and so looking forward the paybacks shown in this analysis will if anything be pessimistic.

7.5.2 Analysis of indirect impacts of the individual design option

An important issue is that more efficient induction motors inherently have lower slip, and so will run slightly faster. In uncontrolled systems where advantage of the additional work performed cannot be taken, then the energy saving will not be as large as hoped. To give an estimate of the magnitude of this effect, in the worst case (quadratic torque load such as centrifugal fan or pump with low or no static head), it may be considered that the power consumption will remain the same when a more efficient motor is used. This might impact 40% of motors installed as replacements. However, in the longer term this effect will reduce anyway because new motor driven equipment will be designed to take account of this change in speed. Therefore, the impact of this is not considered to be material when assessing the long term impact of more efficient motors.

A critical issue in the analysis of VSDs is that the system energy savings that they deliver are many times greater than the additional losses their use incurs in both the motor and VSD itself. Care must be taken that any MEPS applied to VSDs do not increase their price sufficiently that their use is reduced, as this will lose these much larger system savings. Estimates vary, but indicatively a reduction of 15% - 25% of all motor energy use can be achieved by the use of VSDs. This is concentrated in applications where there is a high friction flow component, such as pump and fan systems, and so the saving in those applications where it is technically and economically feasible is individually much larger than this figure.

The re-bound effect of more efficient motors is thought to be negligible. This is because the absolute saving in energy on any individual motor is only a few percentage points, and so insufficient for users to consider using them with less care about their duty cycle or load. The energy savings from the use of more efficient VSDs are similarly only very small, and so again there is no obvious rebound effect.

Extended Product Approach

The attribution of energy savings to the use of VSDs and other system controls is considered in detail in the Extended Product Approach (EPA) being developed within the LOT 28 and 29 Pump studies, and the Cenelec TC22x committee. It is not yet ready to be used to other systems, and so it is suggested that this is reviewed at an appropriate time with a view to use with a wider range of motor driven systems at the time of First Review of any regulations following from this study.

In summary it is expected that this will look at the losses of the motor, controller, transmission and driven load (fan, pump, compressor etc) under assumed operating conditions. It will therefore draw on the efficiency levels (MEI) of individual components as analysed in this Preparatory study, and then combine them to form an overall system energy efficiency index (EEI).

This means that all the motors and VSDs considered in this study will also be included in Extended Product Approach based regulations for any systems for which they are devised. Care must therefore be taken to avoid double counting of any energy savings identified. The protocol used in this study is that the internal losses of the motor and of the VSD are counted in this study, but the system savings are counted within studies such as LOT28, 29 and 31 pump and compressor studies. This means that this study looks only at the negative (internal energy loss) aspect of VSDs, with the system savings that their use enables being accounted for elsewhere.

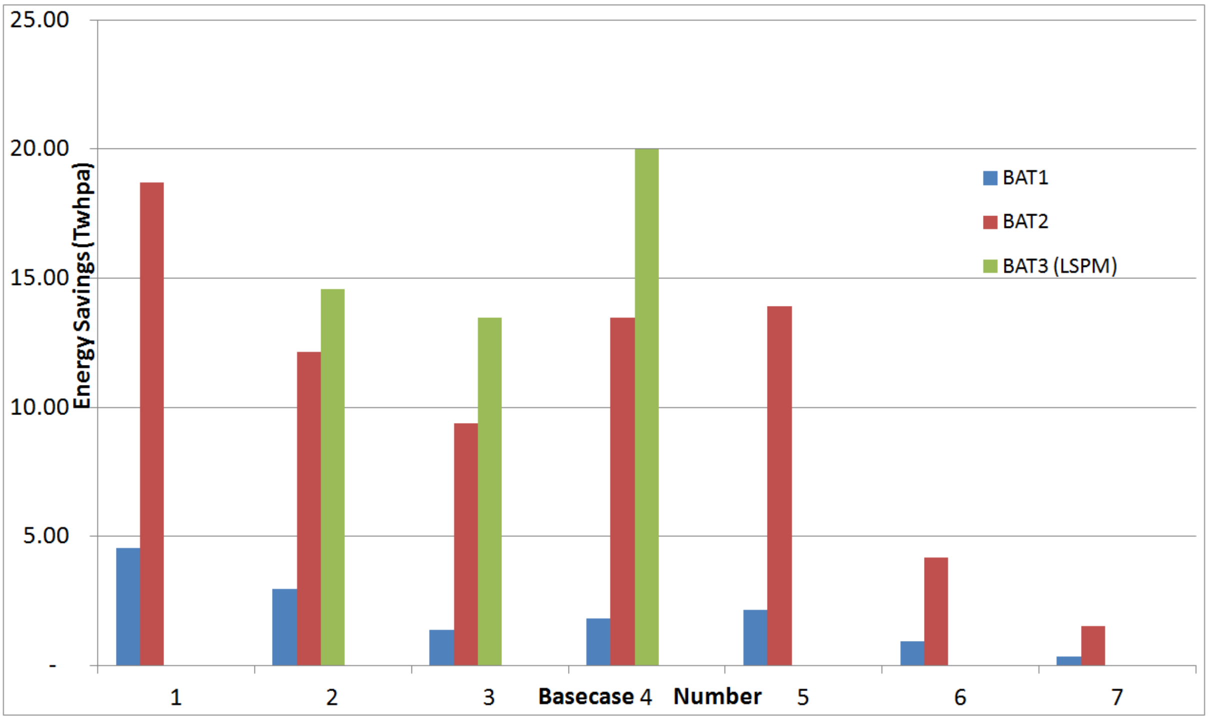
7.5.3 Impact of cumulative design options – comparison of Net energy savings for each option

Motors

For each motor technology option, the annual energy savings are shown in Figure 2 below. This shows several important features:

Small induction (or fixed speed) motors have the largest energy saving potential of products considered in this study.

Medium sized induction motors have a smaller energy saving potential, due largely to the existing regulations having captured much of the savings available. The savings shown relate only to the motors assumed to take advantage of the “IE2 + VSD” option under current regulation being changed to IE3.



Motor Size	BAT1	BAT2	BAT3
Small Motors (Basecase 1,2)	IE2	IE3	LSPM
Medium - Large Motors (Basecase 3-7)	IE3	IE4	LSPM

Figure 2 Annual energy savings for different options, by motor size range, (TWhpa)

Submersible Pump Motors. These only have a small energy saving potential, which will be captured within LOT29.

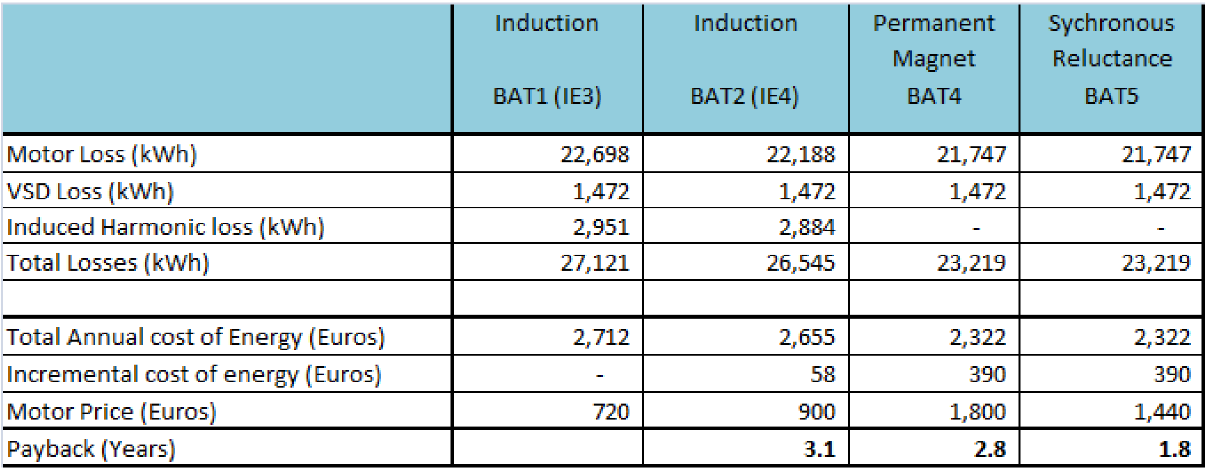
Variable Speed Drive

Based on the data received, the energy saving potential for VSDs is very small, and cost prohibitive. However, the use of motors that can only work when connected to a VSD means that the use of a VSD makes possible BAT4 and 5 motor technologies, as below.

Variable Speed Motor + Controller Options

It is difficult to identify representative prices for products where there are few suppliers, and so the prices quoted for BAT4 and 5 are subject to a larger uncertainty than for the induction motor. In addition, as volumes increase, the prices for the improved technologies will fall. This is particularly true of the Synchronous Reluctance induction motor, where the technology inherently should cost less to manufacture than an induction motor equivalent.

It is considered that in all cases a universal VSD is used, which is capable of driving any of the types of motor shown here. On this basis the energy performance of each will be the same, and so these VSD losses are not included in this comparison. However, there should be negligible induced harmonic losses in the motors of these new technologies, and so the cost of these losses is accounted for.



	Induction BAT1 (IE3)	Induction BAT2 (IE4)	Permanent Magnet BAT4	Sychronous Reluctance BAT5
Motor Loss (kWh)	22,698	22,188	21,747	21,747
VSD Loss (kWh)	1,472	1,472	1,472	1,472
Induced Harmonic loss (kWh)	2,951	2,884	-	-
Total Losses (kWh)	27,121	26,545	23,219	23,219
Total Annual cost of Energy (Euros)	2,712	2,655	2,322	2,322
Incremental cost of energy (Euros)	-	58	390	390
Motor Price (Euros)	720	900	1,800	1,440
Payback (Years)		**3.1**	**2.8**	**1.8**

Figure 3 Payback (relative to IE3 induction motor) on BAT for variable speed driven motors

7.6 Long-term targets (BNAT) and systems analysis

7.6.1 Long term potential of new products

The induction motor is over a century old, and while changes in materials and design techniques have improved it hugely in terms of efficiency and size, the fundamental principles remain the same. The global focus on improving the efficiency of these products means that the limits of the technology are now understood, with IE4 seen as the limit beyond which further gains in efficiency are practically impossible or costly to achieve within the confines of the standard IEC frame sizes and

50Hz frequency that are the standard across Europe. Some manufacturers already have IE4 motors available at commercial or prototype level in some sizes.

The only major new design option is the use of copper for the rotor, which is a practical option already used by some manufacturers as a way to achieve higher efficiencies within the same volume. Indicatively this method can achieve at least a further half IE grade[1] for the same dimensions. Disadvantages are a higher cost in some sizes, and higher rotor inertia due to the additional rotor mass.

Beyond this, Line Start Permanent Magnet motors offer currently offer the only practical opportunity to achieve higher efficiency. However, this is limited in the maximum size in which it is available.

A VSD driven induction motor depresses the efficiency of the motor by an estimated 10-16%, equivalent to about half one IE grade. Further improvements to the high frequency performance of the motor are expected to help reduce this loss, which should be seen in the context of the large (often >50%) energy savings in the system that it is controlling.

The energy losses within the VSD itself are small, and should again be seen in the context of the bigger system savings that they enable.

New types of power semiconductor offer lower losses, both through lower switching losses and lower on state losses. These might reduce losses by about 25%. This will impact all types of motor controller by a similar amount, and is the likely basis of the BAT show.

New types of motors that require controllers are slowly being commercialized, which offer superior energy performance to variable speed induction motors. The offering of motors sold with dedicated controllers is changing the market towards considering the whole drive package as a “black box”. This makes it easier for new technologies to gain market share, but until they reach a critical market share they will always be at a disadvantage compared to the ready availability and inter-changeability of the induction motor. In the context of this study they represent very best BAT or BNAT, and so developments in this market should be closely followed to ensure that any policy options selected encourage their uptake. Currently the two options are: Permanent Magnet and Synchronous Reluctance.

7.6.2 Long term changes in application of motors

The application of Motor is so broad that no single change in end use will have much impact on the overall market. However, in countries with a declining industrial base there is a shift from industrial to commercial applications, with HVAC applications becoming more important. This phenomenon is behind the growth in the application of VSDs, which are well suited to the varying flows found in HVAC systems. This is also reflected in an increase in the relative share of smaller motors compared to larger motors.

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[1] Reference, International Copper Association

7.7 Conclusions

This section has identified the technical improvement options for each of the basecase considered. Provisional estimates of the energy saving potential of each have been made, with Least Life Cycle Cost analysis to identify those products that represent the best purchasing option to the consumer.

The analysis has identified the following technically and economically preferred options for each of the following technologies:

Single Phase and Small Three phase Induction motors: It is economic to increase the efficiency of these motors to IE2.

Large motors (>375kW to 1000kW): It is economic to increase the efficiency of these motors to IE3.

Excluded motors: Explosion proof and brake motors should be bought into scope, closing a current loophole.

The cost performance of IE4 motors looks attractive for some medium and large motors, but these products to dat3 have only limited availability.

VSDs: It is not economic to define a MEPS for VSDs, but it seems relevant to remove from the market low efficiency units (below IE1 as defined by EN 50598-2)..

Improved variable speed motor technology, in particular Permanent Magnet and Synchronous Reluctance motors, can offer good energy savings. However, it is unreasonable to set MEPS regulations at a level that effectively demands these, as they are only available from a small number of suppliers, and there are technical reasons why they cannot be used in every application.

It should be noted that the wider system energy savings from the use of variable speed controlled motors is not considered, which would represent considerable further energy savings. This point should be kept foremost when considering regulatory options.