# EuP Lot 30:
# Electric Motors and Drives

## *Task 8:* *ENER/C3/413-2010*

**Final**

***July 2014***

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# Contents

## 8.1 Introduction

This task summarises the outcomes of all previous tasks and tries to identify a suitable selection of policy options that will lead to the reduction of environmental impacts with consideration to Life Cycle Cost and the best available technologies in the market. Scenario analysis projects the energy and economic savings for the period of 2013-2040 from each of these options.

Although Tasks 1-7 set the foundations for future work to be carried out by the European Commission, Task 8 presents a summary of policies that the authors of the report believe to be worthy of consideration in order to achieve the desired reduction of the environmental impacts of electric motors. A sensitivity analysis on some of the key parameters is carried out in order to examine the robustness of the results.

**Note that the preliminary policy options suggested for consideration do not reflect the views of the European Commission.**

**Notes on the Analysis in Task 8**

Since completion of Task 7, the following changes of assumptions and references have been made. Care should therefore be taken when comparing the analysis in Tasks 1-7 with the analysis in Task 8.

- The clarification from VSD suppliers that IE1 and not IE0 is the basecase has led to an IE2 VSD now being considered as BAT1, not BAT2 as previously considered.

- The additional assumption is made that 50% of all medium sized motors are embedded in machinery that is then exported out of the EU. Additionally, this reduction leads to the total expected motor electricity consumption in the EU. This accounts for the reduction in energy losses of these motors shown in Task 8. The environmental benefits of these motors that are exported are unquantifiable, as many will be sold into markets with MEPS that already demand IE2 or IE3 motors; but these additional savings will add to the overall global impact of any new policy measures adopted.

## 8.2 Policy analysis

The purpose of Task 8 is to suggest the most beneficial policy options on the products studied. In this section, policy options are identified considering the outcomes of all previous tasks. They are based on the definition of the product, according to Task 1 and modified/ confirmed by the other tasks. Specific recommendations to the motors and controls covered by the Lot 30 study are detailed in the following sub-sections.

**Note on underpinning energy calculations:**

Some of the options considered in this section require the conversion of electricity into primary energy. For that purpose, the conversion factor of 2.5 used is derived from Annex II of the Energy Service Directive (2006/32/EC), reflecting the estimated 40% average EU generation efficiency. This factor is also used in other parallel Ecodesign preparatory studies.

Please note that all other primary energy consumption values presented in this study (Task 5, Task 7 and in the other sections of Task 8) were calculated using the EcoReport tool, as required by the European Commission to undertake the cost and environmental impact analysis in Ecodesign preparatory studies.

## 8.3 Recommendations on Standardisation Mandates

There are no new requirements for standardization mandates to support the proposals for Induction Motor measures.

This is because there are already well proven and recently revised technical standards in place that adequately support the measures. These key standards are:

**IEC60034-2-1** Rotating electrical machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)

**IEC60034-30-1** Rotating electrical machines – Part 30-1: Efficiency classes of single-speed, three-phase, cage-induction motors (IE-code). For motors fed by electronic controllers, IEC 60034-30-2 is currently under development.

This standard currently only applies to LV motors, and so it is recommended that a mandate be issued to formally expand this to include MV motors.

For the measures that might apply to submersible pump motors, an industry standard procedure should be devised to formalize the procedure for changing to horizontal bearings, and for cooling the motor during testing.

## 8.4 Energy savings of Policy Options

### 8.4.1 Basis of projected savings for different measures

Table 1 summarises the energy savings that could in theory be achieved by the implementation of each different energy saving measure. These measures are further analysed and then selected measures combined to create the Policy Options discussed in section 3.4. Important Notes:

Table 1 Energy Savings from the introduction of different improved technology options, relative to **each basecase.**

| Ref. | Description | Basecase Size (kW) | BAT1 Technology | BAT1 Energy Saving (TWhpa) | BAT2 Technology | BAT2 Energy Saving (TWhpa) | BAT3 Technology | BAT3 Energy Saving (TWhpa) |
|---|---|---|---|---|---|---|---|---|
| 1 | Small induction motor - 1 phase IE1 | 0.37 | | | IE2 (CSIR) | 5.61 | | |
| 2 | Small induction motor - 3 phase IE1 | 0.37 | IE3 | 9.86 | IE4 | 12.15 | IE4 | 14.59 |
| 3 | Medium induction motor (S) - 3 phase IE2 | 1.1 | IE3 | 0.70 | IE4 | 4.73 | IE5 | 6.80 |
| 4 | Medium induction motor (M) - 3 phase IE2 | 11 | IE3 | 0.93 | IE4 | 6.84 | IE5 | 10.14 |
| 5 | Medium induction motor (L) - 3 phase IE2 | 110 | IE3 | 1.07 | IE4 | 6.96 | | |
| 6 | Large induction motor - LV IE2 | 550 | IE3 | 3.12 | IE4 | 4.19 | | |
| 7 | Large induction motor - MV IE2 | 550 | IE3 | 1.14 | IE4 | 1.53 | | |
| 8 | VSD - Very Small | 0.37 | IE1 | 0.75 | | | | |
| 9 | VSD - Small | 1.1 | IE1 | 0.62 | | | | |
| 10 | VSD - Medium | 11 | IE1 | 0.32 | | | | |
| 11 | VSD - Large | 110 | IE1 | 0.22 | | | | |
| 12 | VSD - Very Large | 550 | IE1 | 1.17 | | | | |
| 16 | Submersible borehole motor - Small | 2.2 | IE1 | 0.21 | | | | |
| 17 | Submersible borehole motor - Large | 37 | IE1 | 0.19 | | | | |

**Notes on the interpretation of Table 1:**

- Not all measures in Table 1 are necessarily economic, and so the most ambitious energy saving opportunities may not in practice be realizable.
- Energy savings are in addition to those claimed for existing regulations.
- As previously stated, the VSD BAT1 technology was previously designated as BAT2 in Tasks 1-7.
- Energy savings are all relative to the basecase technology, not the preceding technology type.
- The suggested Policy for each product is based on different BAT levels, and so it would not be meaningful to totalise for example “All BAT1” options, as it is unlikely that this approach would yield the most appropriate actions for each product.
- The energy savings for medium sized motors BAT1 (IE3) have been adjusted to take account of the assumed proportion (70%)of the medium sized induction motors sold each year that are already IE3 rather than the IE2 basecase assumed.
- Small induction motor 1-phase. BAT2 is based on the use of additional active material in a CSIR (Capacitor Start Induction Run) motor. (BAT1 was shown in earlier versions of this report as a Capacitor Start Capacitor Run motor, which is being used by many US manufacturers to achieve higher efficiencies. However, subsequent analysis has shown that the improvement in efficiency by the simple addition of a capacitor for the running mode, is not sufficient to achieve IE2 efficiency levels.
- In each case, the BAT3 column is for designs that are not yet or only just commercially available products.
- For such small motors, the additional weight and volume of using additional material would be a problem in some weight or size restricted equipment.
- Submersible borehole pump. The calculations are based on the IE0 to IE1 step, although the basecase is actually slightly below the IE0 level. The energy savings shown therefore represent a slight under-estimate. In addition the lack of an agreed procedure for testing these water cooled motors means that the values shown here are only approximate.
- For small motors, the jump in IE levels from IE1 to IE2 is much bigger than that from IE2 to IE3, and hence proportionately fewer savings would be gained by moving from IE2 to IE3.

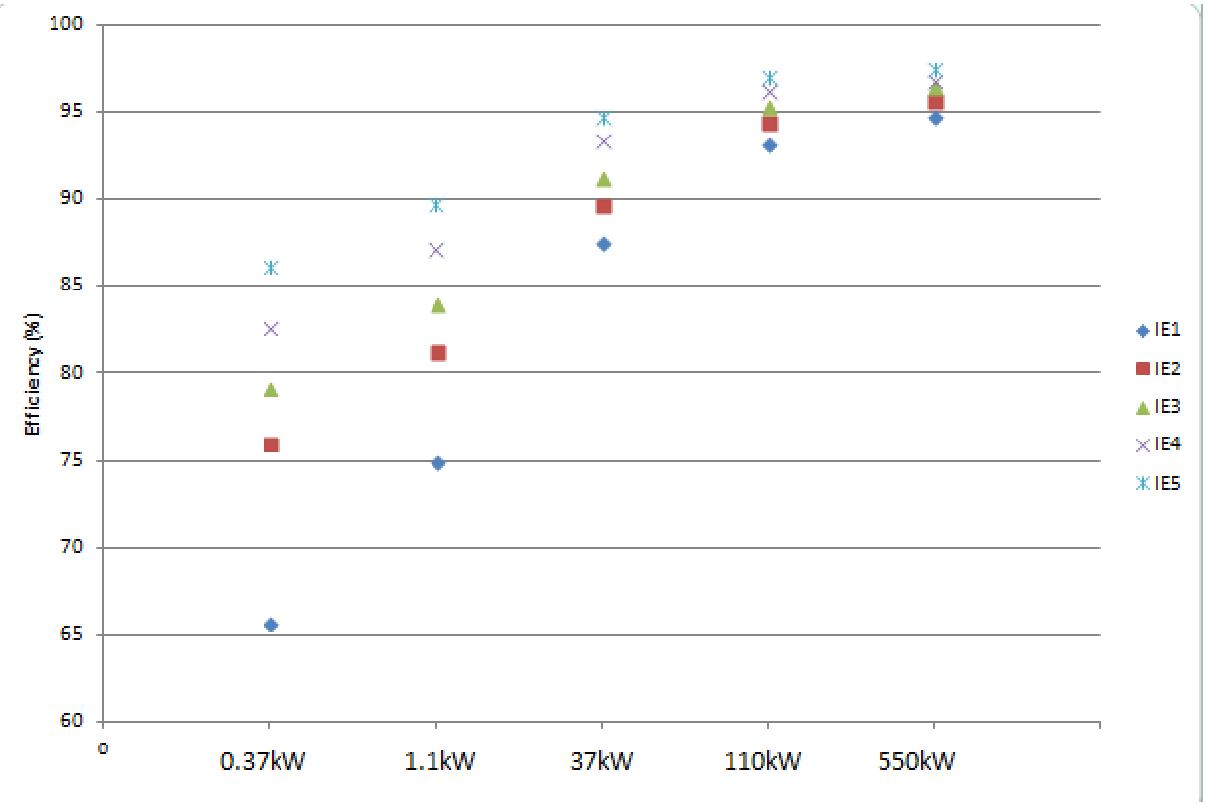



**Figure 1 Illustration of the much larger jump from IE1 to IE2 than for subsequent IE jumps, explaining the variation in energy savings from each BAT improvement for small motors in particular.**

### 8.4.2 Projected energy savings by measure

Tables 2a,b and Figure 2 summarise the projected energy savings from each of the energy saving measures subsequently considered for inclusion in the suggested Policy Options. The numbers in Table 2a are calculated by dividing the total energy saving for a measure by the lifetime of that product, with the assumption being that the whole stock is changed at a uniform rate over this time. Where more than one measure applies to a product, the savings for each additional IE level is the net additional saving from the most ambitious measure.

**Table 2 Energy savings of identified measures, by year.**

| Policy Measure | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MEPS at IE2 for Single Phase Motors | | | | 0.511 | 1.02 | 1.53 | 2.04 | 2.56 | 3.07 | 3.58 | 4.09 | 4.60 | 4.60 | 4.60 | 4.60 | 4.60 |
| MEPS at IE2 for Small Three Phase Motors | | | | 1.100 | 2.20 | 3.30 | 4.40 | 5.50 | 6.60 | 7.70 | 8.80 | 9.90 | 9.90 | 9.90 | 9.90 | 9.90 |
| Removal of IE2+VSD option for Medium Induction Motors | | | | 0.180 | 0.36 | 0.54 | 0.72 | 0.90 | 1.08 | 1.26 | 1.44 | 1.62 | 1.80 | 1.98 | 2.16 | 2.34 |
| MEPS at IE3 for Large Induction Motors | | | | 0.220 | 0.44 | 0.66 | 0.88 | 1.10 | 1.32 | 1.54 | 1.76 | 1.98 | 2.20 | 2.42 | 2.64 | 2.86 |
| MEPS at IE3 for Brake & Explosion Proof Medium Induction Motors | | | | 0.063 | 0.13 | 0.19 | 0.25 | 0.32 | 0.38 | 0.44 | 0.50 | 0.57 | 0.63 | 0.69 | 0.76 | 0.82 |
| MEPS at IE4 for Large Induction Motors | | | | | | 0.07 | 0.15 | 0.22 | 0.29 | 0.37 | 0.44 | 0.52 | 0.59 | 0.66 | 0.74 | 0.81 |
| MEPS at IE4 for Medium Induction Motors | | | | | | | | 0.527 | 1.05 | 1.58 | 2.11 | 2.63 | 3.16 | 3.69 | 4.21 | 4.74 |
| MEPS at IE4 for Brake & Explosion Proof Medium Induction Motors | | | | | | | | 0.127 | 0.25 | 0.38 | 0.51 | 0.63 | 0.76 | 0.89 | 1.01 | 1.14 |
| Totals | | | | 2.07 | 4.15 | 6.30 | 8.44 | 11.24 | 14.04 | 16.85 | 19.65 | 22.45 | 23.64 | 24.83 | 26.02 | 27.21 |

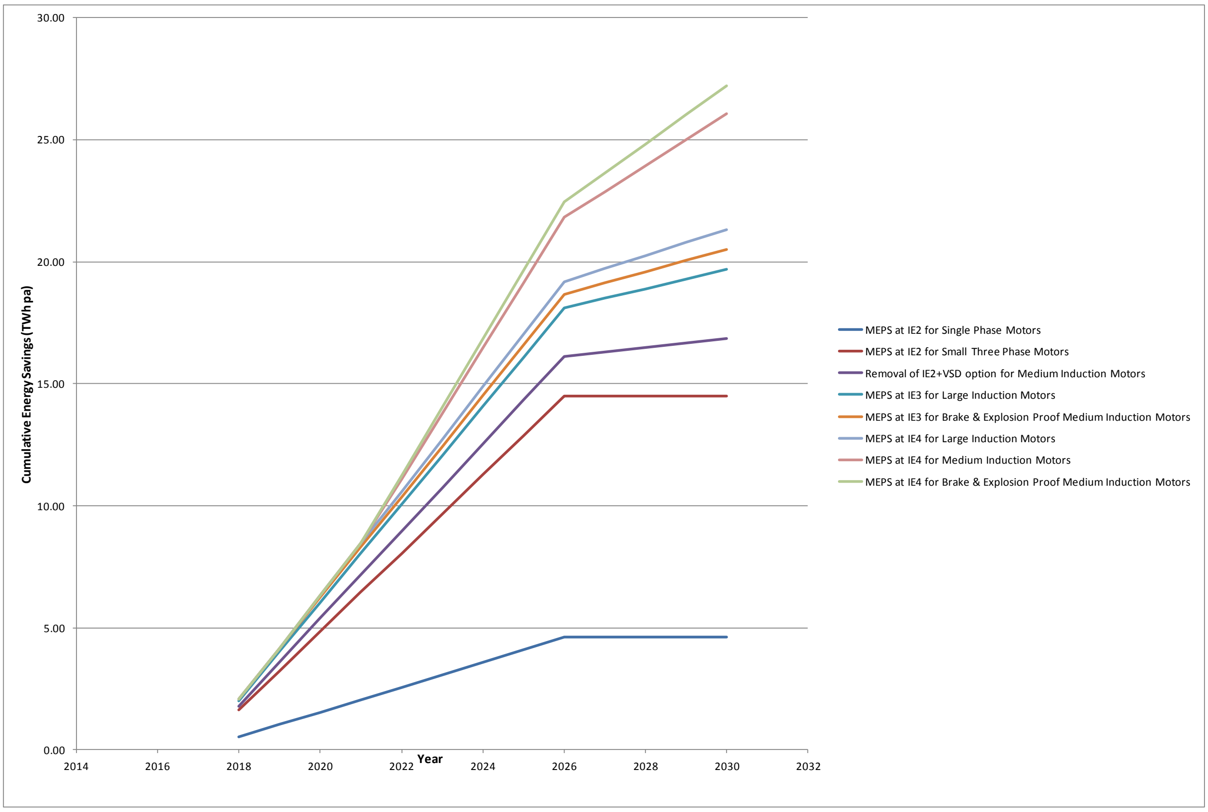



**Figure 2. Cumulative Energy Savings for all energy saving measures considered.**

### Notes on the interpretation of Table 2 and Figure 2

- Only in some cases is the 2030 time horizon sufficient for the total stock to be changed, and hence the 2030 total energy saving shown is less than the ultimate energy saving potential.
- The suggested start dates for each measure are taken from Table 4.
- The noticeable "kink" in 2026 is due to all small motors being changed, and hence the rate at which total energy savings accumulate after this date is much less.

### 8.4.3 Summary of Energy savings from suggested Policy Options

These energy saving measures are in some cases combined, giving the Total and 2030 projected energy savings for each of the suggested Policy Options shown in Table 3.

Table 2 Projected energy savings, by Policy Option.

| **Policy Option** | **Projected Total Energy Saving (TWhpa)** | **Projected Energy Saving (TWhpa in 2030)** |
|---|---|---|
| Policy Option 1a. Single Phase Motors to have a MEPS of IE2 | **4.6 TWhpa** | **4.6 TWhpa** |
| Policy Option 1b. Small (<0.75 kW) Three Phase Motors to have a MEPS of IE2 | **9.9 TWhpa** | **9.9 TWhpa** |
| Policy Option 1c. Large motors (375 – 1,000kW) LV and MV - Extension of existing regulation to introduce Mandatory MEPS at IE3.<br>Of this, 3.1TWhpa is from LV motors, and 1.1TWhpa from MV motors. | **4.2 TWhpa** | **2.9 TWhpa** |
| Policy Option 2. Removal of Option to use an IE2 motor where a VSD is used – all motors 0.75kW – 375kW to be IE3. | **2.7 TWhpa** | **2.7 TWhpa** |
| Policy Option 3. Expanding the types of motor included in existing regulation– Explosion proof and brake motors (Medium sized motors only) | **0.95 TWhpa** | **0.86 TWhpa** |
| Policy Option 4. Mandatory Information Requirements | **Not Applicable** | **Not Applicable** |
| Policy Option 5. Mandatory Measures for VSDs , to meet IE1 performance as MEPS | **Unknown** | **Unknown** |
| Policy Option 6. Raising of MEPS for medium and large induction motors from IE3 to IE4 | **9.4 TWhpa**<br>(7.9 TWhpa Medium, 1.4 TWhpa Large) | **5.6 TWhpa** |
| **Total Energy Savings** | **31.7 TWhpa** | **26 TWhpa** |

### 8.4.4 Timeline of specific ecodesign measures

The following table gives the suggested timelines for each of these Policy Options:

Table 3 Suggested Timelines for introduction of Policy Options

| Policy Option | Implementation Date | Rationale |
|---|---|---|
| Policy Option 1. Mandatory MEPS (Minimum Energy Performance Standards):<br>• IE3 for large motors (375kW – 1,000kW LV and MV)<br>• IE2 for all single phase motors >120W<br>• IE2 for all three phase motors 120W – 0.75kW. | 1 Jan 2018 | This gives sufficient time for all manufacturers to design and bring to market motors that meet these MEPS requirements. |
| Policy Option 2. Make IE3 the MEPS level for all medium sized motors (0.75kW – 375kW). | 1 Jan 2022 | Removal of the IE2 option when a motor is sold with a VSD ensures all motors are at IE3 level. These products already exist, but time is needed for manufacturers and the market to adapt to this change. |
| Policy Option 3. Expanding the types of motor included – MEPS at IE3 for Medium sized (0.75kW – 375kW) Explosion proof and Brake motors. | 1 Jan 2018 | This analyses the impacts of removing the exemption granted to explosion proof and brake motors under Regulation 640/2009 Leading manufacturers already have these designs available. A tight timeline is therefore suggested. |
| Policy Option 4. Mandatory Information Requirements. | 1 Jan 2018 | The date of initiation for this should coincide with the timescales for the motors impacted by Policy Options. |
| Policy Options 5. Removal of low efficiency VSDs from the market | 1 Jan 2018 (Date of first review) | VSDs must meet IE1 performance (as defined in CENELEC EN 50598 standard)<br>Other possible Measures should be considered at the time of first review, by which time further information should be available. |
| Policy Option 6<br>Raising of MEPS from IE3 to IE4 for all Medium and Large motors, from 0.75kW to 1,000kW | 1 Jan 2022 | This gives sufficient time for all manufacturers to design and bring to market motors that meet these MEPS requirements. The timing shown would make this an alternative to Policy Option 2, but the timing of policy Option 2 or 6 could be changed to stagger these in two steps. |

## 8.5 Scenario analysis

### 8.5.1 Type of scenarios considered

***Policy Option 1. Mandatory MEPS (Minimum Energy Performance Standards) for small and large motors set to IE3, (IE2 for single phase motors).***

**The energy saving for these measures is 23.1TWhpa (measures 1a-c in Table 3)**

The current global situation for medium sized induction motors (in the EU the 0.75 – 375kW or 1 – 500hp range), is that leading countries globally are introducing MEPS at IE2, and then IE3.

***Extract from regulation 640/2009, Article 3, Ecodesign requirements***

*1. from 16 June 2011, motors shall not be less efficient than the IE2 efficiency level, as defined in Annex I, point 1;*

*2. from 1 January 2015:*

*(i) motors with a rated output of 7,5-375 kW shall not be less efficient than the IE3 efficiency level, as defined in Annex I, point 1, or meet the IE2 efficiency level, as defined in Annex I, point 1, and be equipped with a variable speed drive.*

*3. from 1 January 2017:*

*(i) all motors with a rated output of 0,75-375 kW shall not be less efficient than the IE3 efficiency level, as defined in Annex I, point 1, or meet the IE2 efficiency level, as defined in Annex I, point 1, and be equipped with a variable speed drive.*

**Large Induction Motors**

The current situation is that for large induction motors, China alone has a MEPS. This indicates that regulating large motors should be seriously considered; if the EU does not follow suit then it might lead to a commercial imbalance for manufacturers trading in these two markets. However, the savings are small and most motors above 375 kW are specified based on total cost of ownership.

MV motors are defined as those operating from 1000 V and up to 6600 V. These are commonly designed for an individual site, with detailed design (and hence efficiency) subject to consideration of the impedance and short circuit capability of the local power supply. There are also technical reasons why it can be harder to achieve higher efficiencies than with comparable LV motors:

- higher amount of insulation material in the slot (compared to LV motors) leads to a lower cross sectional area of utilizable copper.
- higher motor cost requires high reliability of the insulation system (controlled partial discharges).
- increased insulation material will reduce the heat transfer parameter.
- thinner insulation would decrease the reliability of the motor.
- bigger winding overhangs are thermally and mechanically critical.
- motor size restrictions and application requirements lead to various cooling methods.

It should be noted that according to GB30254-2013 the China Grade 3 mandatory limit values are generally at a lower efficiency level than IE2.

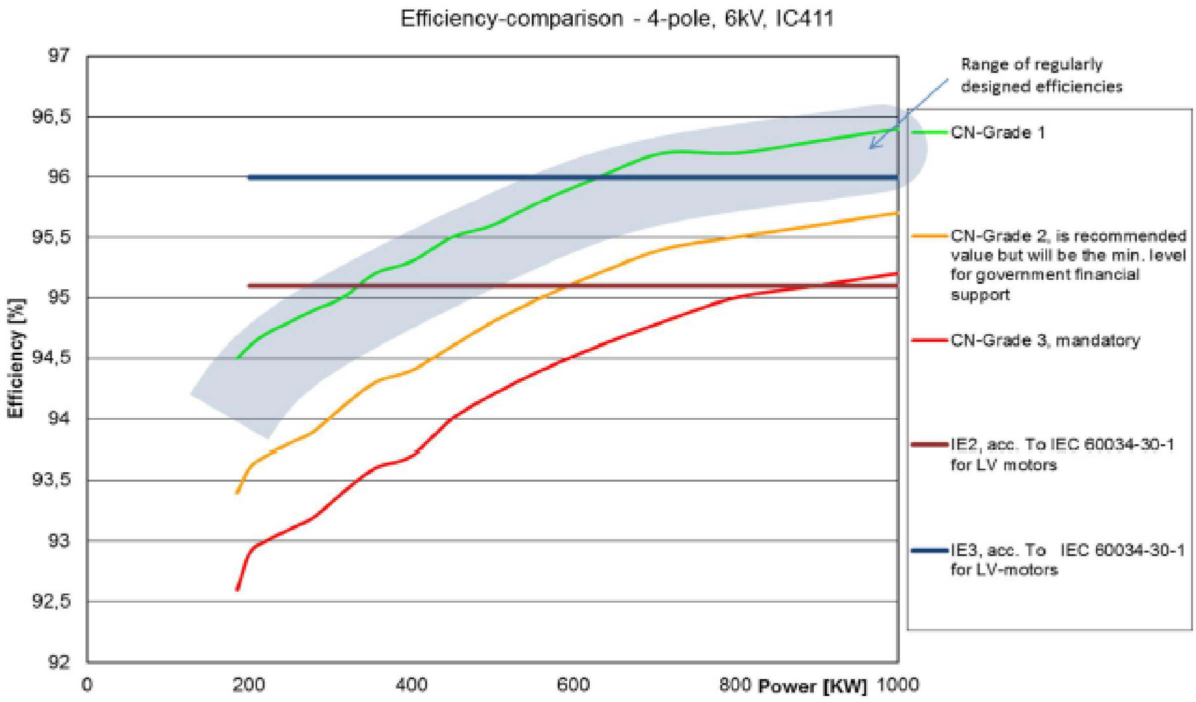



Figure 2 IEC efficiency levels in comparison with Chinese efficiency levels for MV motors (source: CEMEP)

As shown in the example below, considering the entire power supply and motor combination, it can be seen that the overall efficiency of a MV motor might be higher than that of a LV motor, even where the MV motor efficiency is apparently less.

Table 4 Example showing the overall efficiency advantage of a MV motor system (source: CEMEP)

| | Motor Efficiency | Transformer losses | Cabling losses | Resulting efficiency |
|---|---|---|---|---|
| LV: 690 V | 96,9 % | 18,7 kW | 16 kW | 92,7% |
| HV: 6000 V | 96,5 % | 17 kW | 2 kW | 94,2% |

Motor: 750 kW, 4 pole with 690V (LV) compared to 6000V (HV) Connection to the 20 kV grid PCC, via transformer and motor cable length of 300m. Cabling gauges (LV: 2 x 240mm² or HV: 50 mm²)

**Small Motors**

The current situation is that for small motors, the US has already passed a MEPS regulation. Again, this is a positive indication that adopting MEPS for small motors should be considered. The US regulations (Figure 3) for single phase motors are between the IE2 and IE3 levels. For the important smaller sizes, they are close to the IE3 level. However, because of the differences in mains supplies to domestic and light commercial premises, single phase motors are much more common in light commercial applications in the US than they are in Europe.

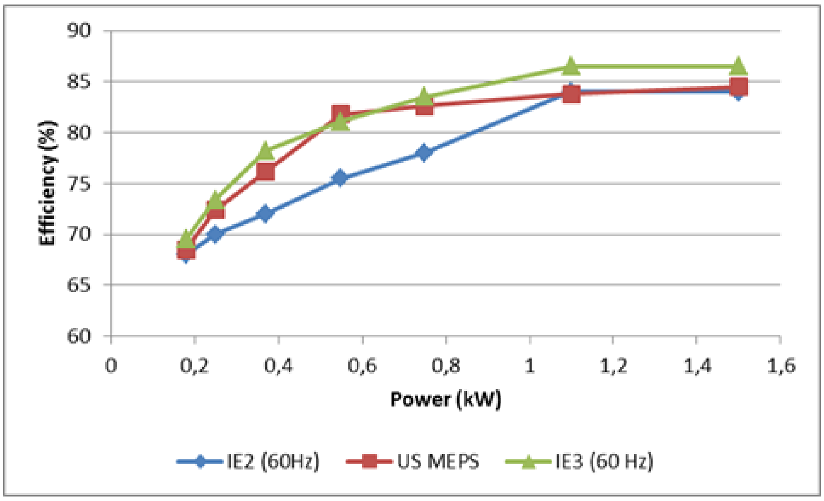



Figure 3 US MEPS for small 1-phase motors VS. IEC 60034-30 efficiency levels

Regulations are only proposed for induction (both single phase and three-phase) including shaded pole motors. Mechanically commutated motors, such as universal motors have too low running hours to justify regulation, (the brushgear used only has a limited life). This exclusion does not lead to a loophole, as this limited lifetime means that it would not be practical to use universal motors in applications that currently use induction motors.

Some of these motors are in domestic products that are already regulated, but in many cases these would anyway be excluded types (such as in hermetic pumps), and in any case this is not an automatic reason for not regulating a product. The regulations on circulators used in boilers is an example of where a product and a component within it are both regulated. It is estimated that 70% of these motors are sold within products that are themselves already regulated. Swimming pool pump motors are an example of an application that is not currently regulated, and so would be captured by this regulation. It is of note that these motors are used in a very wide range of domestic and commercial applications, and so the 400 hours pa average duty assumed in the calculations will include many products with much lower annual operating hours. Again, it should be noted that only motors rated on the basis of continuous duty would be included within the regulation.

**Proposed General Exclusion**

Motors to be used in portable apparatus where weight is an issue and/or there is a low duty should be specifically excluded. A possible basis of distinction is:

- Cordless or battery powered products.
- Products whose weight is supported by hand during operation, (e.g. hand held power tools).

Corded mobile products that move as part of their operation (e.g. mobile cleaning equipment) are included in scope.

Note that for single phase motors, the corresponding IE levels required will be one level below that of three phase motors. The higher material content, and hence price of single phase motors of the same size, means that this difference in MEPS will not cause any significant loophole through applications being changed to single phase to avoid the 3 phase regulation.

**→ Policy Option 1 is that the Ecodesign requirement in Article 3ª of the current regulation *640/2009* is extended to the following motors:**

**Small motors (including induction and shaded pole types), in the ranges;**

- **Single phase; Motors in the range 120 W and greater.**
- **Three phase; Motors in the range 120 W up to 0.75 kW.**

**Large motors (LV and MV) in the range > 375 kW – up to 1000 kW.**

Again, this only extends to continuous duty motors.

In summary, this would mean an amendment to the size range in the existing text within Article 3ª, which would now become

*(i) all* ***three phase*** *motors with a rated output of* ***120 W to 1000 kW*** *shall not be less efficient than the IE3 efficiency level, as defined in Annex I, point 1, or* ***(for motors with a rated output of 7.5kW to 375kW))*** *meet the IE2 efficiency level, as defined in Annex I, point 1, and be equipped with a variable speed drive. All* ***single phase*** *motors with a rated output of greater than or equal to* ***120W*** *shall not be less efficient than the IE2 efficiency level, as defined in Annex I, point 1.*

## *Policy Option 2. Make IE3 the MEPS level for all motors 0.75kW to 375kW*

**The Energy Saving for this measure is 2.7TWhpa.**

This option is to remove the" IE2+VSD" alternative to the mandatory purchase of an IE3 motor. The economics of these two options vary with size, but for an 11kW motor the price difference is shown in Table 5 below:

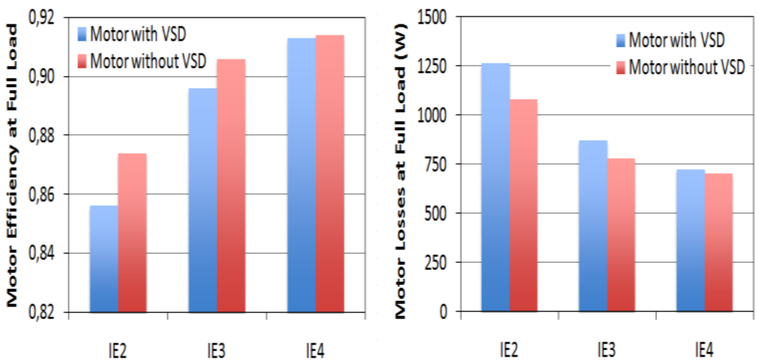
**Table 5. Net price of motor purchase options under regulation 640/2009**

| 11kW Motor options | Motor Price (Euros) | VSD Price (Euros) | Total Price (Euros) |
|---|---|---|---|
| **IE3 Motor** | 690 | | 690 |
| **IE2 Motor + VSD** | 600 | 1,130 | 1,730 |
| **Price Difference** | | | **1,040** |

This shows that on the basis of economics alone, this concession will not be sufficient to induce Users to specify a VSD where they would otherwise not have done so. The only exception is where the saving in motor cost will reduce the payback on investment below the required organisational threshold, but even here the increase in motor losses needs to be taken into account in order to get a true total cost of ownership. However, under the existing regulation 640/2009 applicable to Motors, substantial energy savings were claimed for the increased uptake of VSDs through the incentive of being able to use a lower cost motor. Because this IE2+VSD concession does not come into force until 2015, it is impossible at this stage to understand what impact the concession might have in reality on future sales

It should also be stated that IE3 are not only more efficient than IE2 motors when driven directly from the power line, but also they have reduced additional load losses when driven by a VSD,[1] as seen in the figure below.

As already stated, it is unclear what impact the concession is really having, but its removal so soon after implementation would send a negative message about VSDs to motor Users. The timing of removal of this IE2+VSD concession is therefore critical.




1- Motor efficiency and total losses at full load, with and without VSD, for several 7.5 kW motors (Source: ISR – University of Coimbra). Note that this only shows the full load performance, not that at part load, which will often be important on inverter driven motors where the duty profiles will mean that they spend proportionately more time operating at part load.

Longer term, it is hoped that the Extended Product Approach will be launched and focus attention on the design of the whole system, with a likely focus on the use of appropriate controls, such as VSDs. However, until this is launched, the IE2+VSD concession is regarded by the industry as being the best vehicle for promoting the energy saving benefits of VSDs.

| **Article 3. from 1 January 2017:** |
| --- |

*(i) all motors with a rated output of 0,75-375 kW shall not be less efficient than the IE3 efficiency level, as defined in Annex I, point 1, or meet the IE2 efficiency level, as defined in Annex I, point 1, and be equipped with a variable speed drive.* Currently Canada, Mexico, Switzerland, USA have IE3 as MEPS with no VSD concession.

The implications of changing a requirement that has not yet come into force would need to be carefully considered. In addition, enough time should be given for adaptation if IE2 medium size motors are to be taken out of the market. Hence a delayed implementation date of 2022 is suggested in order to give 7 years for the existing policy to be used for the promotion of VSDs. At this time, it is anticipated that the concession will anyway become redundant due to the introduction of the Extended Product Approach by this time.

**→ Policy Option 2 is for the removal of the alternative Ecodesign requirement in Article 3ª (i) of the current regulation 640/2009 that allows for the use of an IE2 motor where a VSD is used.**

### *Policy Option 3 Expanding the types of motor included – Explosion proof and brake motors (including medium sized motors)*

**This measure would save 0.95TWhpa.**

The current regulation specifically excludes several types of motor, with two types specified in Article 2 that it is proposed should be repealed.

**Article 2. This Regulation shall not apply to:**

……

*(c) motors specifically designed to operate:*

*(vi) in potentially explosive atmospheres as defined in Directive 94/9/EC of the European Parliament and of the Council ( 3 );*

*(d) brake motors;*

Regulation 640/2009 includes an exemption from its application for explosion proof and brake motors. It has been suggested that brake motors are used in applications with frequent starts-stops and so the inertia will lead to greater start up losses, but in practice they are usually standard duty motors with a brake added for additional speed of response. This is therefore considered not to be an adequate reason for exclusion, and in any case only continuous duty motors are in scope of the regulation. There is no technical or commercial reason why the exemption would need to be maintained for either of these types of motor.

- Motors with a brake attached. However, brake motors with a special rotor design and when the brake is an integral part of the inner motor construction and can neither be removed nor supplied by a separate power source during the testing of motor, should be excluded from any Regulation

- Motors for use in explosion proof atmospheres.

For clarity, ExE safety motors with larger clearances should now be specifically excluded.

**→Policy Option 3 is the removal of the current exclusion of explosion proof and brake motors.**

This would mean the removal of clauses (d) of article 2 of the existing regulation. In addition, clause (c) (vi) should be amended to :

*(c) motors specifically designed to operate:*

*(vi) Class ExE safety motors. However, those used in potentially explosive atmospheres as defined in Directive 94/9/EC of the European Parliament and of the Council ( 3 ) are explicitly in scope.*

## *Policy Option 4 Mandatory Information Requirements*

Information requirements under the existing regulation 640/2009 can reasonably be extended to all types of motor within the proposed extended scope of this regulation.

**Extract from Annex I of regulation 640/2009**

*2. PRODUCT INFORMATION REQUIREMENTS ON MOTORS*

*From 16 June 2011, the information on motors set out in points 1 to 12 shall be visibly displayed on:*

*(a) the technical documentation of motors;*

*(b) the technical documentation of products in which motors are incorporated;*

*(c) free access websites of manufacturers of motors;*

*(d) free access websites of manufacturers of products in which motors are incorporated.*

*As regards to the technical documentation, the information must be provided in the order as presented in points 1 to 12. The exact wording used in the list does not need to be repeated. It may be displayed using graphs, figures or symbols rather than text.*

*1. nominal efficiency (η) at the full, 75 % and 50 % rated load and voltage (U N );*

*2. efficiency level: 'IE2' or 'IE3';*

*3. the year of manufacture;*

*4. manufacturer's name or trade mark, commercial registration number and place of manufacturer;*

*5. product's model number;*

*6. number of poles of the motor;*

*7. the rated power output(s) or range of rated power output (kW);*

*8. the rated input frequency(s) of the motor (Hz);*

*9. the rated voltage(s) or range of rated voltage (V);*

*10. the rated speed(s) or range of rated speed (rpm);*

*11. information relevant for disassembly, recycling or disposal at end-of-life;*

*12. information on the range of operating conditions for which the motor is specifically designed:*

*(i) altitudes above sea-level;*

*(ii) ambient air temperatures, including for motors with air cooling;*

*(iii) water coolant temperature at the inlet to the product;*

*(iv) maximum operating temperature;*

*(v) potentially explosive atmospheres.*

*The information referred to in points 1, 2 and 3 shall be durably marked on or near the rating plate of the motor.*

*The information listed in points 1 to 12 does not need to be published on motor manufacturer's free access website for tailor-made motors with special mechanical and electrical design manufactured on the basis of client request. Information on the mandatory requirement to equip motors, which do not meet the IE3 efficiency level with a variable speed drive, shall be visibly displayed on the rating plate, technical documentation of the motor:*

*(a) from 1 January 2015 for motors with a rated output of 7,5-375 kW;*

*(b) from 1 January 2017 for motors with a rated output of 0,75-375 kW.*

*Manufacturers shall provide information in the technical documentation on any specific precautions that must be taken when motors are assembled, installed, maintained or used with variable speed drives, including information on how to minimise electrical and magnetic fields from variable speed drives.*

**→ Policy Option 4 is that the existing Product Information requirements within 640/2009 should be extended to include all motors under the extended power range of 0.12 kW to 1000 kW.**

This would mean a further addition to Annex I regarding the applicability of the information requirements:

*(c) from 1 January for motors with a rated output of 120W to 1,000kW.*

## Policy Option 5. Mandatory MEPS for VSDs at IE1

There is insufficient data to estimate the energy savings from this improvement, but it is thought that they would be small (indicatively <1.0TWhpa), and so no specific energy savings are attributed to this measure.

No measures relating to Soft Starters are suggested, but measures are proposed for VSDs. The VSD market is dominated by models with IE1 performance (as defined in CENELEC EN 50598-2 standard) or above this level. The analysis in this study has made clear that there is currently no economic justification for setting a MEPS at a level higher than this. However it would be beneficial to remove from the market VSDs with performance below IE1, mostly being imported into the EU. Although this market segment is currently small, it would be opportune to put in place this regulation in order to avoid the risk of the segment growing in future.

Table 6. Reference CDM (VSD) losses for IE class 1 definition (values proposed in the draft of EN50598)

| $P_{rM}$ / kW | $S_{r,equ}$ / kVA | $I_{r,out}$ / A of the 400V RCDM | $p_{L,RCDM\ (90,100)}$ / % of $S_{r,equ}$ | $P_{L,RCDM\ (90,100)}$ / W |
|---|---|---|---|---|
| 0,12 | 0,278 | 0,401 | 35,87 | 100 |
| 0,18 | 0,381 | 0,550 | 27,31 | 104 |
| 0,25 | 0,500 | 0,722 | 21,82 | 109 |
| 0,37 | 0,697 | 1,01 | 16,86 | 118 |
| 0,55 | 0,977 | 1,41 | 13,22 | 129 |
| 0,75 | 1,29 | 1,86 | 11,03 | 142 |
| 1,1 | 1,71 | 2,47 | 9,53 | 163 |
| 1,5 | 2,29 | 3,31 | 8,23 | 188 |
| 2,2 | 3,30 | 4,77 | 7,21 | 238 |
| 3 | 4,44 | 6,41 | 6,74 | 299 |
| 4 | 5,85 | 8,44 | 6,41 | 375 |
| 5,5 | 7,94 | 11,5 | 6,03 | 479 |
| 7,5 | 9,95 | 14,4 | 5,86 | 583 |
| 11 | 14,4 | 20,8 | 5,45 | 784 |
| 15 | 19,5 | 28,1 | 5,20 | 1014 |
| 18,5 | 23,9 | 34,4 | 5,07 | 1212 |
| 22 | 28,3 | 40,8 | 4,99 | 1413 |
| 30 | 38,2 | 55,2 | 4,89 | 1866 |
| 37 | 47,0 | 67,8 | 4,81 | 2262 |
| 45 | 56,9 | 82,1 | 4,77 | 2712 |
| 55 | 68,4 | 98,7 | 4,76 | 3252 |
| 75 | 92,8 | 134 | 4,71 | 4370 |
| 90 | 111 | 160 | 4,68 | 5193 |
| 110 | 135 | 195 | 4,14 | 5582 |
| 132 | 162 | 234 | 4,12 | 6679 |
| 160 | 196 | 283 | 4,11 | 8058 |
| 200 | 245 | 353 | 4,09 | 10028 |
| 250 | 302 | 436 | 4,12 | 12445 |
| 315 | 381 | 550 | 4,11 | 15674 |
| 355 | 429 | 619 | 4,11 | 17628 |
| 400 | 483 | 698 | 4,11 | 19866 |
| 500 | 604 | 872 | 4,11 | 24794 |
| 560 | 677 | 977 | 4,10 | 27771 |
| 630 | 761 | 1099 | 4,10 | 31224 |
| 710 | 858 | 1239 | 4,10 | 35187 |
| 800 | 967 | 1396 | 4,10 | 39637 |
| 900 | 1088 | 1570 | 4,10 | 44564 |
| 1000 | 1209 | 1745 | 4,10 | 49521 |

**Key**

CDM – Complete Drive Module (VSD)

RCDM – Reference CDM

$P_{rM}$ – Reference Motor rated Power

$S_{r,equ}$ - Rated apparent output power of the CDM

$I_{r,out}$ - Rated CDM output current

$p_{L,RCDM}$ – Relative power losses of the RCDM, referred to its rated apparent power
$P_{L,RCDM}$ - Electrical power losses of the RCDM

The preceding analysis has shown that it is not cost effective to require the introduction of a MEPS for VSDs at a higher level than the current basecase models assumed. However, it would be useful to ensure that the worse performing VSDs are removed from the market, and hence a MEPS at IE1 is proposed for VSDs. No improved Soft Starter designs were identified, and so no MEPS are proposed.

There is the technical potential for further reduction in losses as technology improves, and as the understanding and characterisation of VSD losses improves. It is therefore suggested that Policy Options for relating to VSDs in particular are considered at the time of first revision.

The following aspects in particular of VSDs should be considered, with a view to introducing labelling requirements.

- The Extended Product Approach for motor systems would require the part load efficiency of VSDs to be stated, based on EN 50598, giving the information required. The technical specification[2] IEC 60034-2-3, regarding the efficiency of converter-fed motors has recently been approved.
- New technologies such as Permanent Magnet and synchronous reluctance motors offer efficiencies beyond those of VSD driven induction motors, namely in the low power range. While it would not be justifiable to mandate the use of VSD+motor combinations of these types, it might be useful to indicate to the user the existence of these improved products through a labeling requirement. The recently approved classification standard IEC 60034-30-1 already includes technologies other than induction motors.
- It is noted that no other regulations on motor controllers elsewhere in the world have been identified.

**→ Policy Option 5 is that VSDs must meet IE1 performance (as defined in CENELEC EN 50598-2 standard)**

### *Policy Option 6. MEPS raised to IE4 for all medium and Large sized Low Voltage three phase induction motors (0.75kW to 1,000kW).*

**This measure would save 9.4 TWhpa.**

Based on the flatness of the LCC curve, it can be justified to consider making IE4 the MEPS for all low voltage motors within scope of the current regulation in the power range 0.75kW to 1000 kW. However, the sensitivity analysis presented later in this report should be reviewed in order to understand the cost effectiveness of this measure under a range of operating conditions. It has not been possible to accurately predict the scope for price reduction through high volume production. However, there are two reasons to suppose that the scope for further price decrease below the premum used in the calculations is only modest:

[2] Technical Specifications are often published when the subject under question is still under development or when insufficient consensus for approval of an international standard is available (standardization is seen to be premature).

- The R&D effort to be recouped is comparatively modest, and if in line with normal product re-design cycles then the marginal cost of an IE4 design will be even less.
- The additional cost is mostly attributed to material costs, which will not be reduced through higher volume production of a new design.

In addition, the IE3 to IE4 premium is very similar to that of the IE2 to IE3 premium used, and so gives a good sense check on the validity of the assumed price premium for the IE4 motor. However, it is suggested that this price premium is monitored and the economics reconsidered at the time of first review.

IE4 induction motors are already available over a wide power range, although so far with limited manufacturer availability and very low sales. In addition there are practical considerations that will need taking into account, including the need to use non-standard frame sizes. So while it is true that it is technically challenging, especially in the small sizes, it is clearly possible to overcome these problems and produce commercial products. If the IE4 markets develops well in the next three years, a new clause may be added to Article 3 of the existing regulation 640/2009:

*4. from 1 January 2022:*
*(i) all motors with a rated output of 0,75-1000 kW shall not be less efficient than the IE4 efficiency level, as defined in Annex I, point 1.*

## 8.6 Sensitivity and Economic Analysis

### 8.6.1 Introduction

The previous payback 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. For each motor, the basecase running hours are shown in the caption.

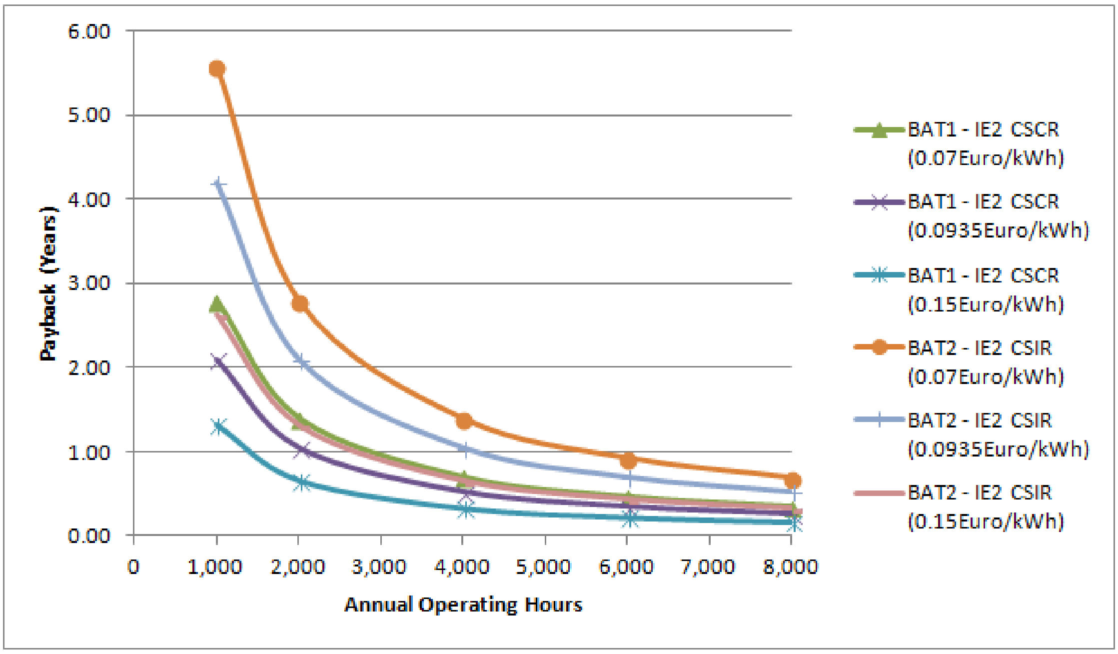
Electricity prices are also predicted to increase, but without information on projected motor prices it is difficult to ascertain how paybacks might change into the future. While it is expected that electricity prices will continue to rise, three electricity price scenarios are considered: 0.0935Euro/kWh (basecase), 0.7Euro/kWh (Optimistic) and 0.15Euro/kWh (Pessimistic).

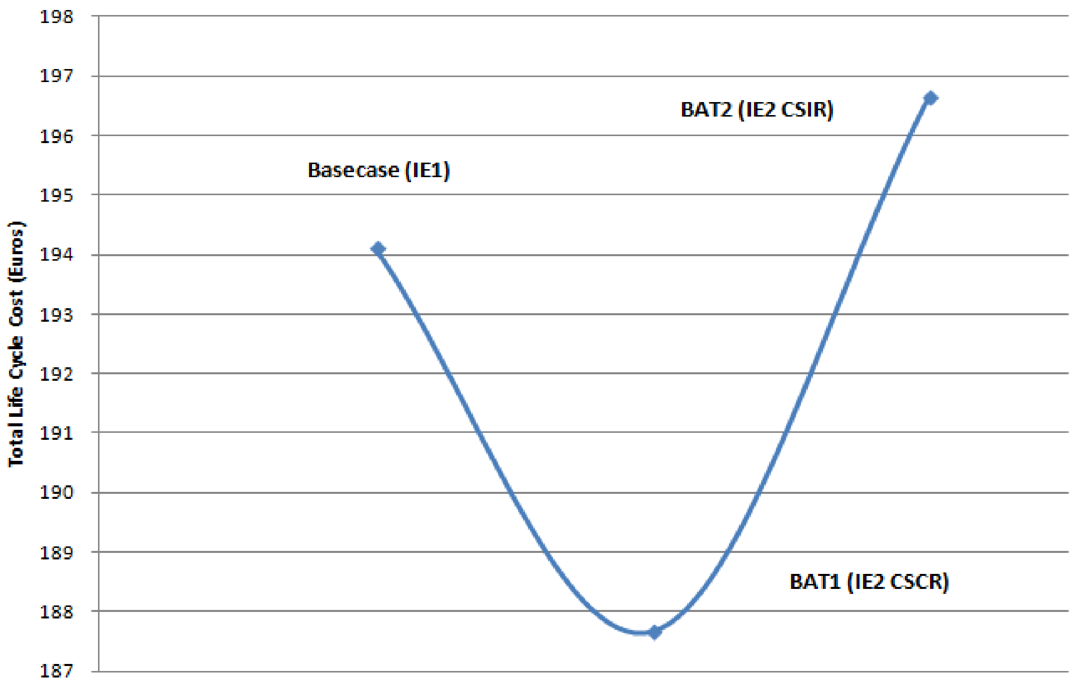
In this section, Life Cycle cost curves are also shown, as the best Payback may not always yield the Lowest Life Cycle (LCC) cost to the user. Careful comparison of the different methods is needed to identify the most appropriate Policy Option.

Note that the LCC curves are based on the assumed basecase running hours and cost of electricity, whereas the Payback curves take account of possible variation in these parameters.

It should be noted that in many cases the scaling of the LCC curves significantly exaggerates the actual variation in costs between different technologies.

### 8.6.2 Single phase Induction Motor (0.37kW)




Figures 2a & 2b. Payback and LCC analysis: Small induction motor - 1 phase IE1, 0.37kW (400 hours pa basecase).

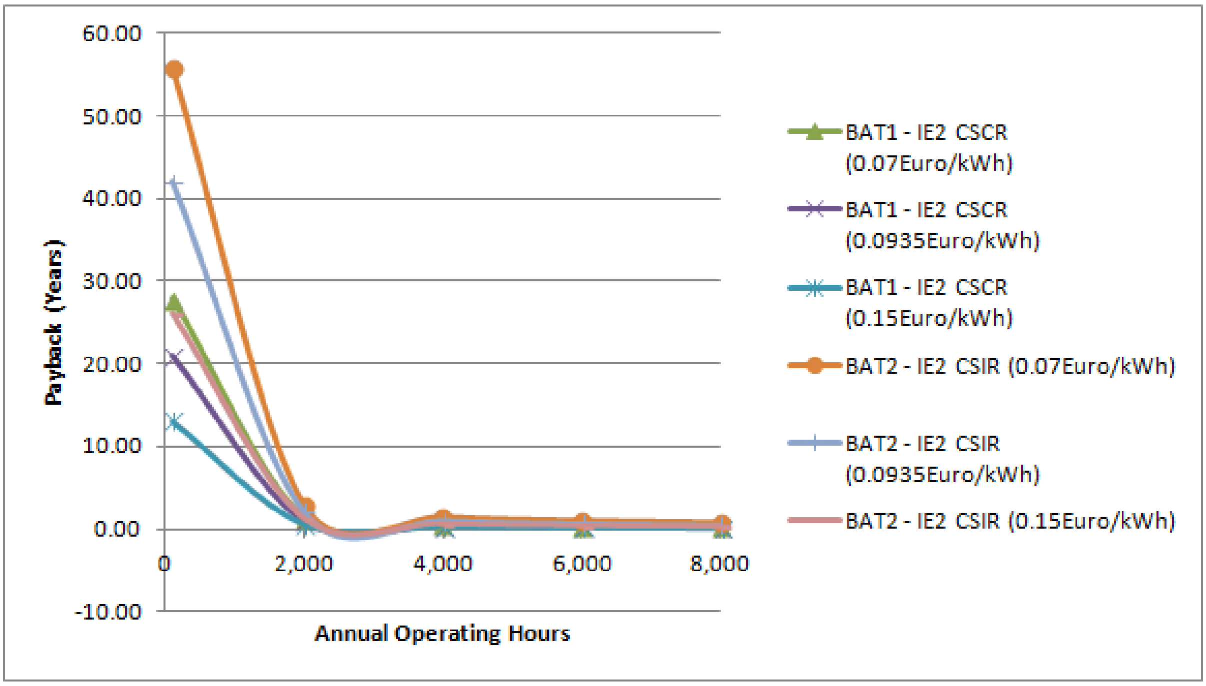
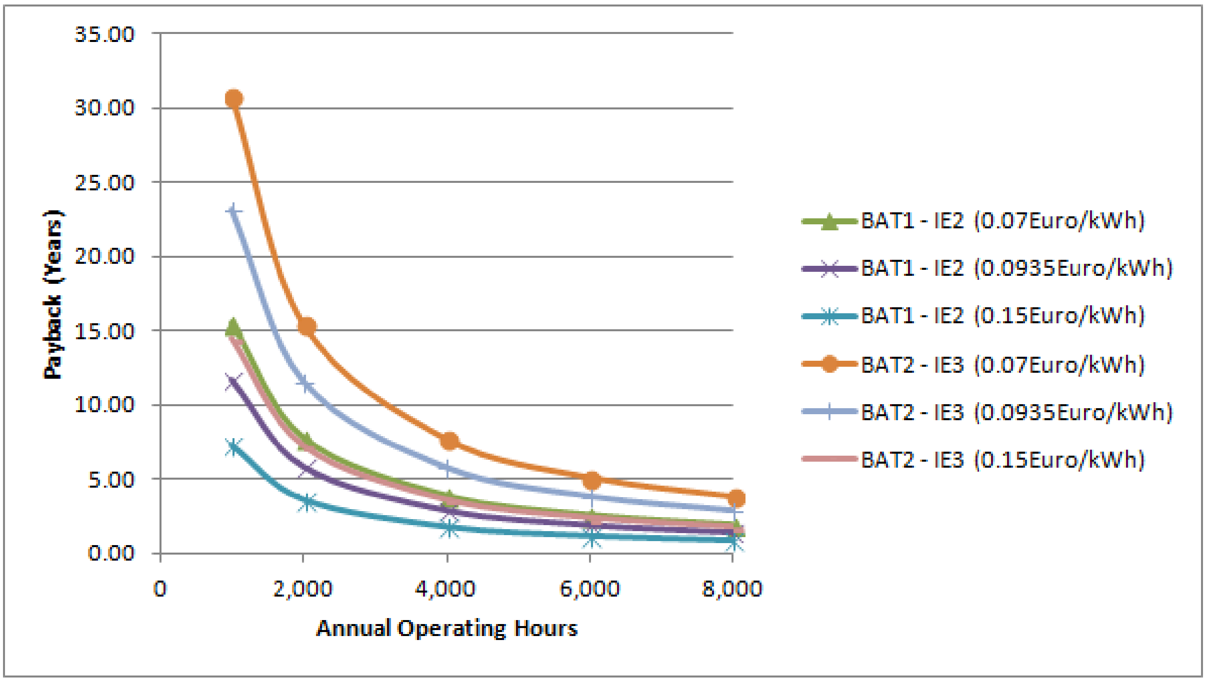
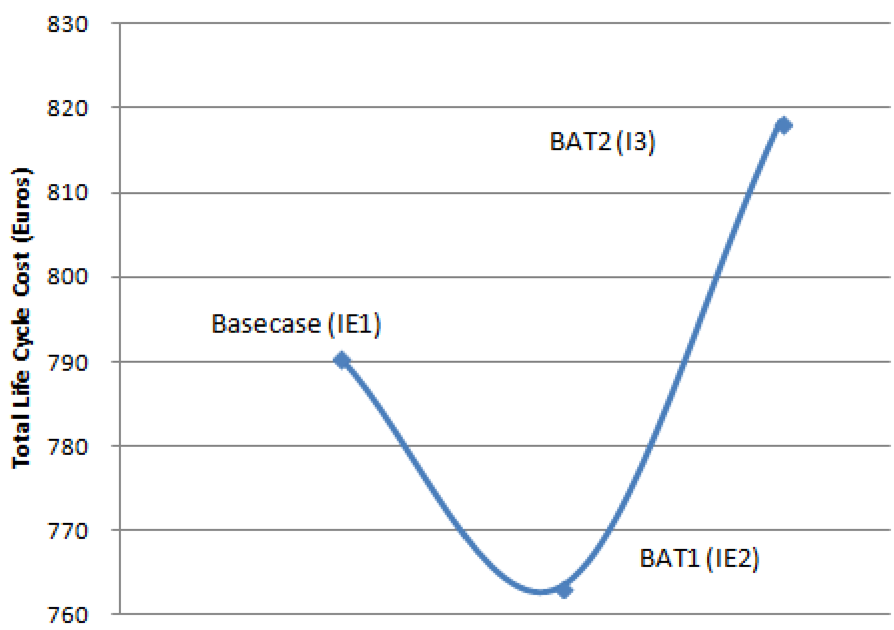



**Figure 4c Payback and LCC analysis: Small induction motor - 1 phase IE1, 0.37kW (400 hours pa basecase).**

For these small motors, some might have duties as low as 100 hours pa, and so the above diagram shows the payback seen in this more extreme case. Note that the apparent negative payback at 2,000-3,000 hours is just a function of the smoothing used in the graph plotting, it is not real.

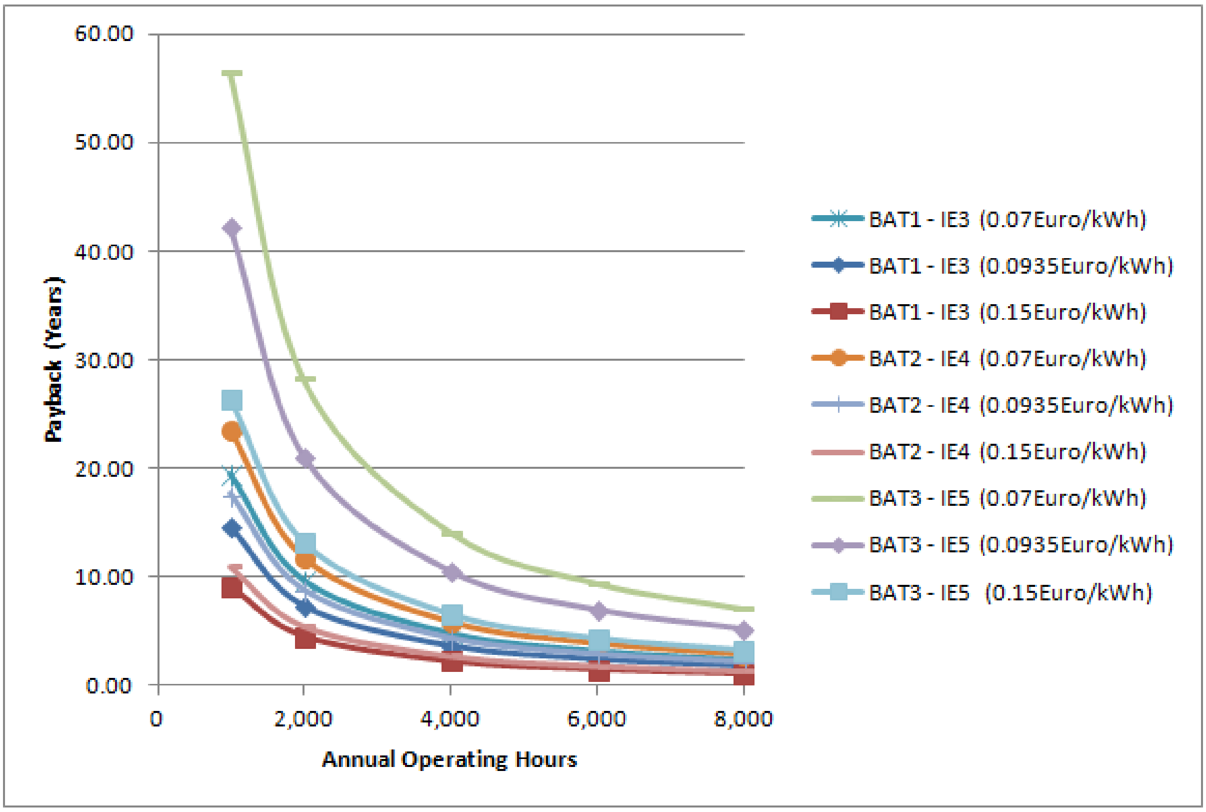
### 8.6.3 Small Three Phase induction motor (0.37kW)




Figures 3a and 3b. Payback and LCC analysis: Small induction motor - 3 phase IE1, 0.37kW (2,000 hours pa basecase)

### 8.6.4 Medium Induction Motor (S) (1.1kW)



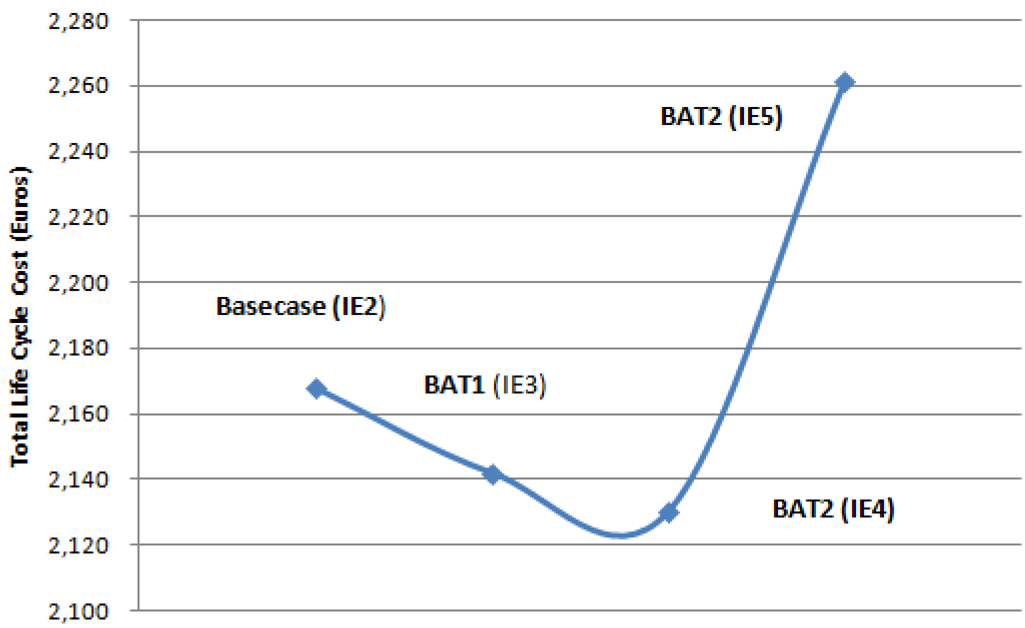
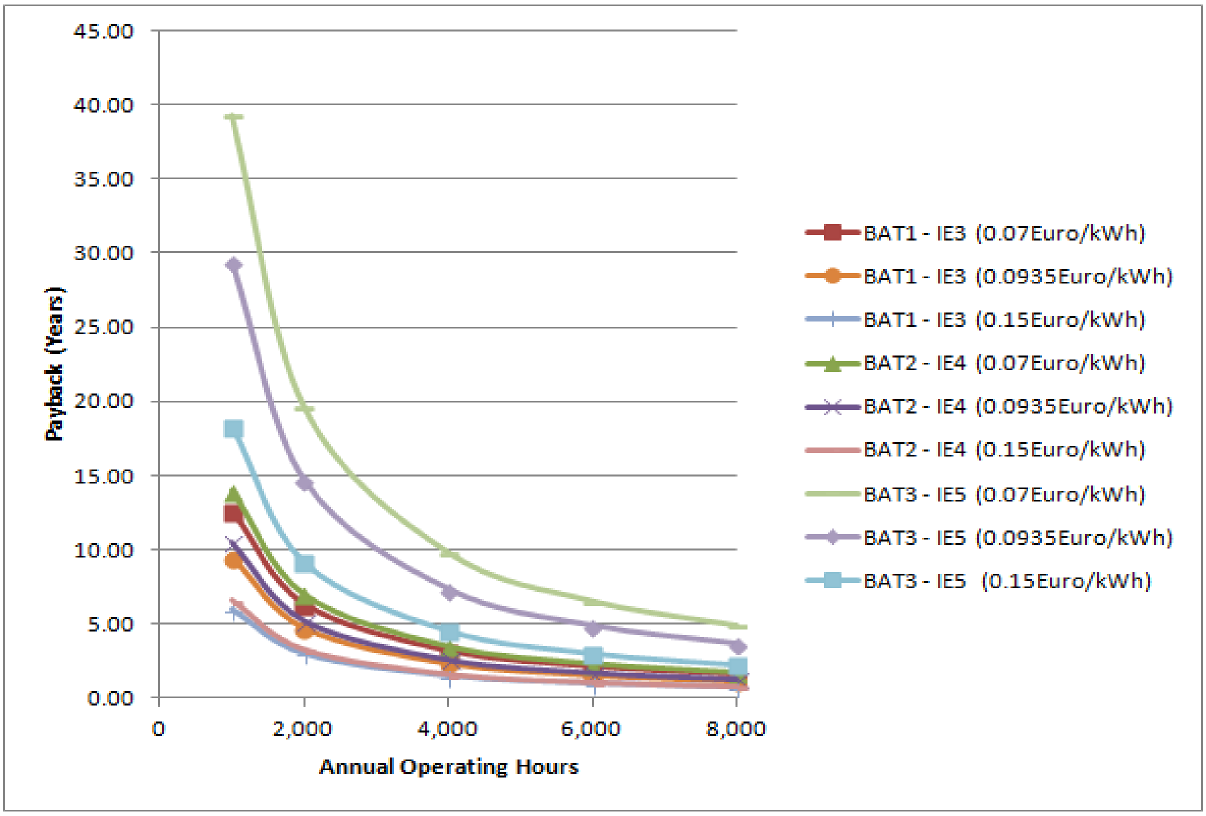




Figure 4a and 4b. Payback and LCC Analysis: Medium induction motor (S) - 3 phase IE2, 1.1kW (2,250 hours pa basecase)

### 8.6.5 Medium Induction Motor (M) (11kW)



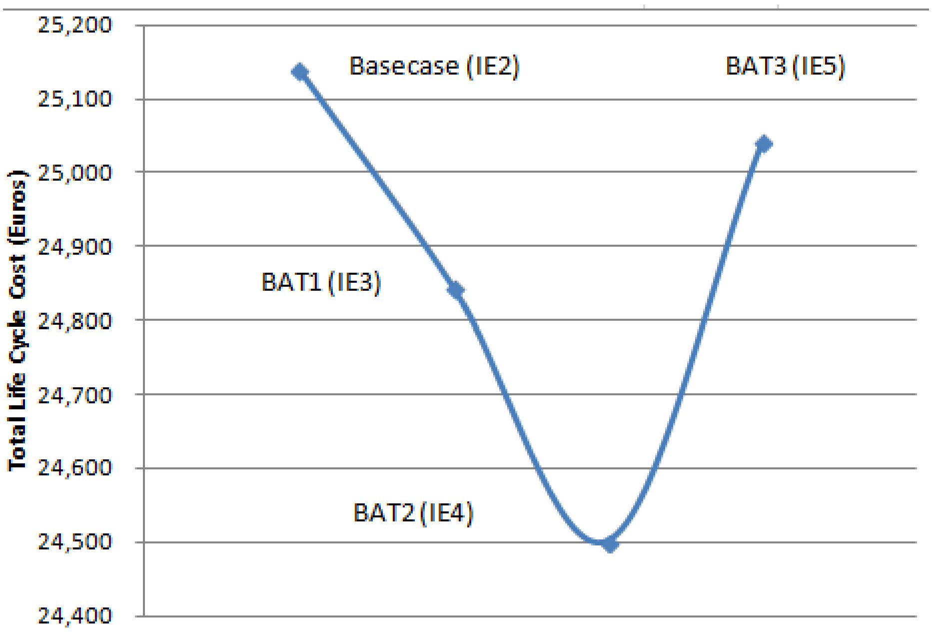
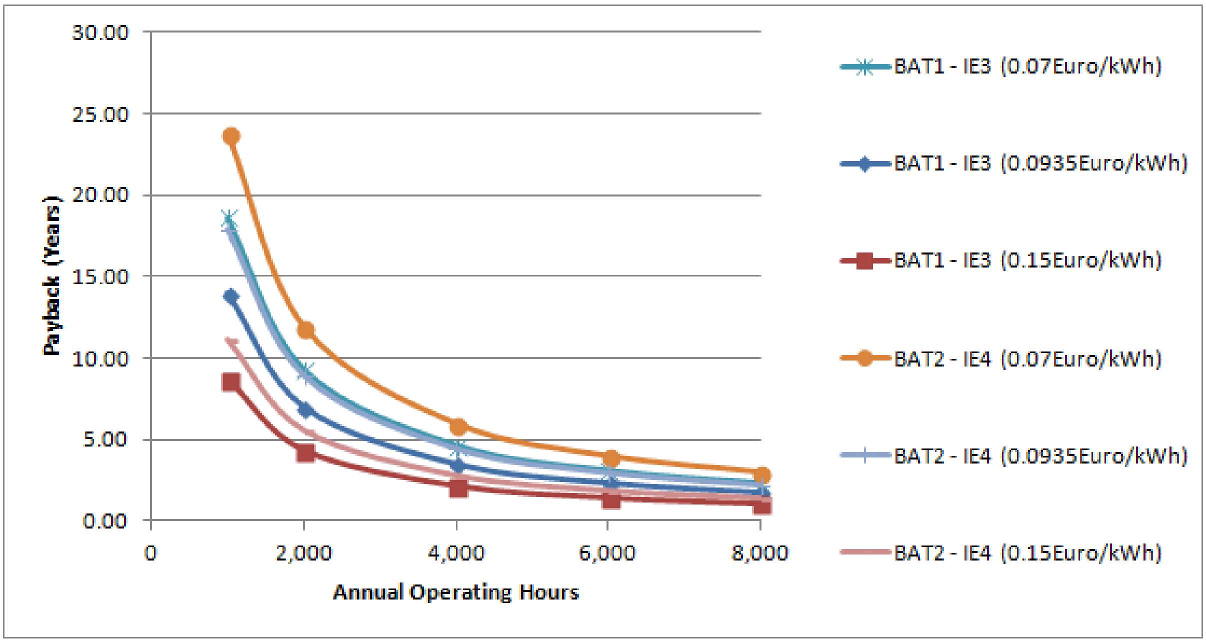




**Figure 5a and 5b. Payback and LCC Analysis: Medium induction motor (M), 11kW - 3 phase IE2, 11kW (3,000 hours pa basecase)**

### 8.6.6 Medium Induction Motor (L) (110kW)



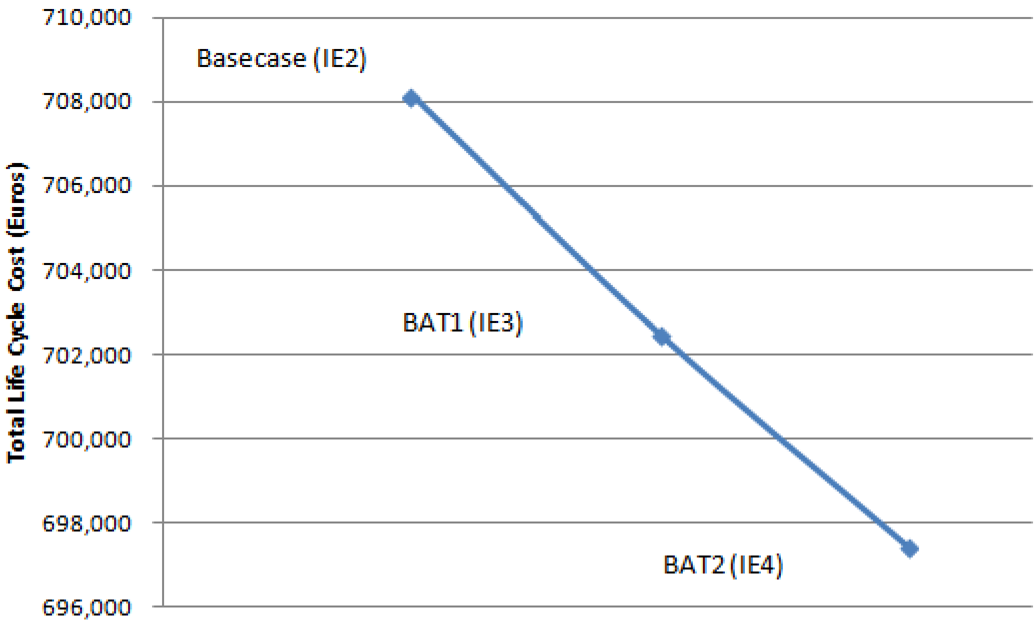
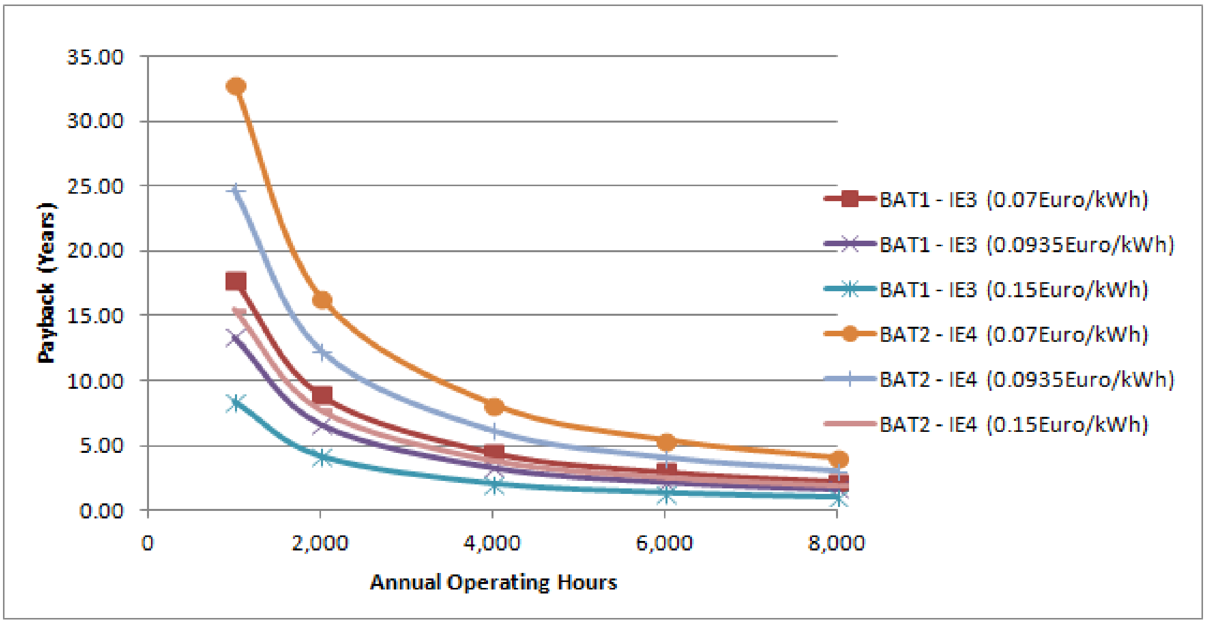




Figure 6a and 6b. Payback and LCC analysis: Medium induction motor (L) - 3 phase IE2, (6,000 hours pa basecase).

### 8.6.7 Very Large Induction Motor, 550kW Low Voltage



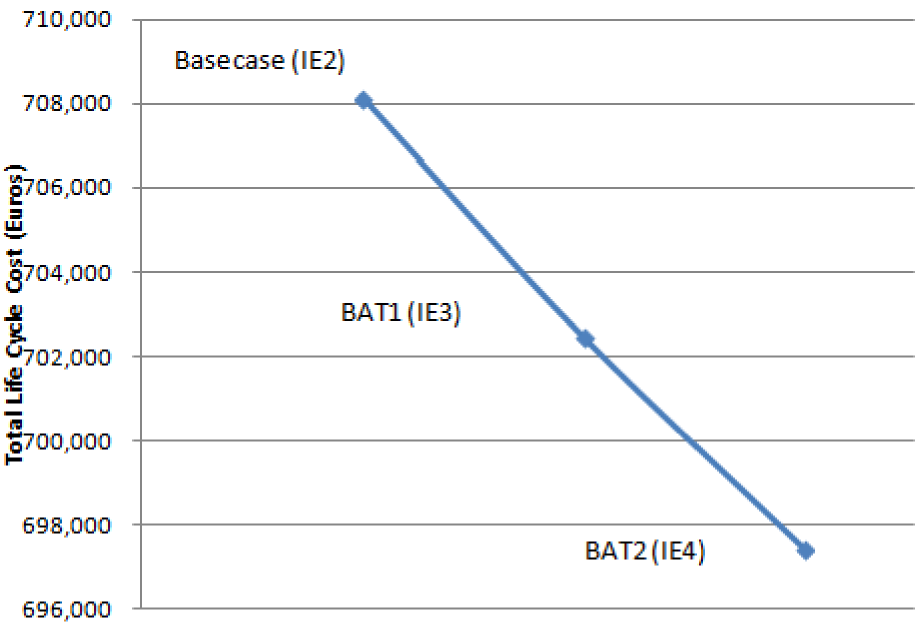
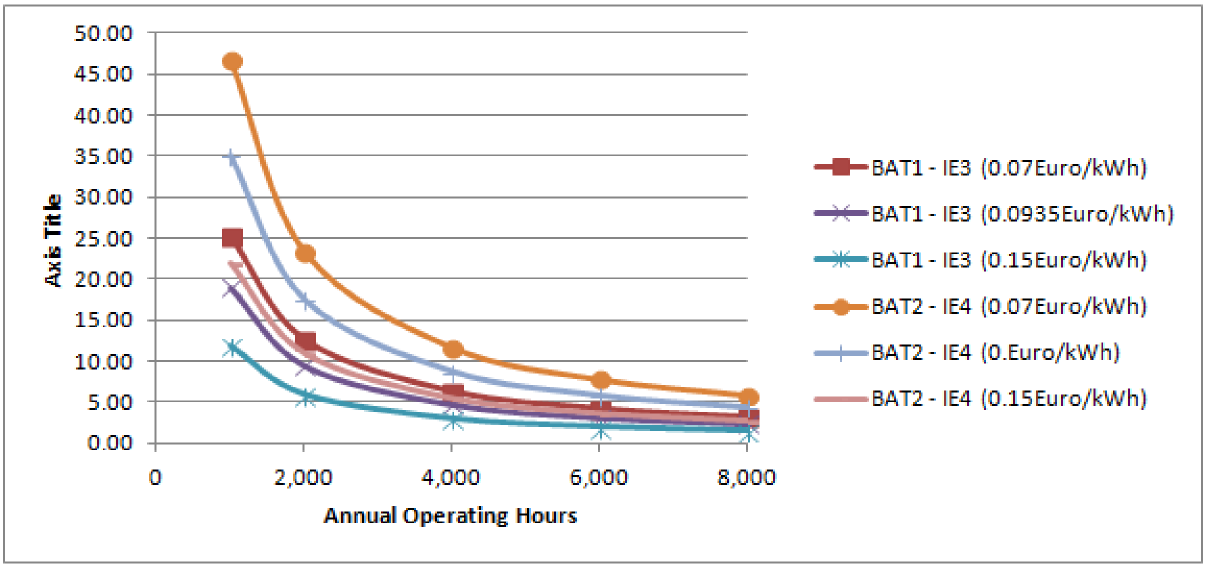




Figure 7a and 7b. Payback and LCC analysis: Large induction motor - LV IE2, (6,000 hours pa basecase).

### 8.6.8 Very Large Induction Motor, 550kW Medium Voltage



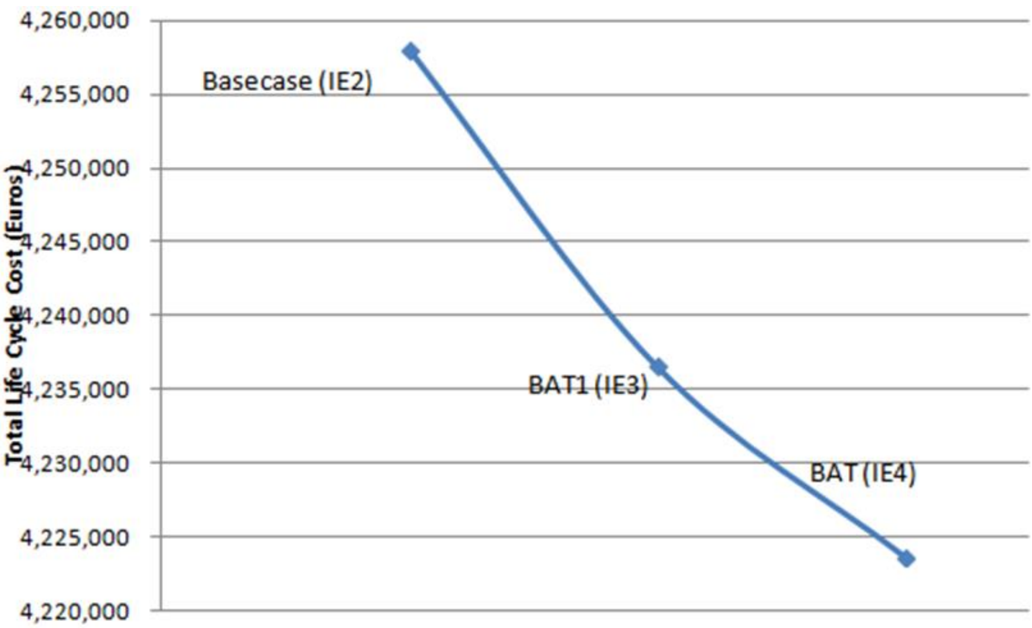
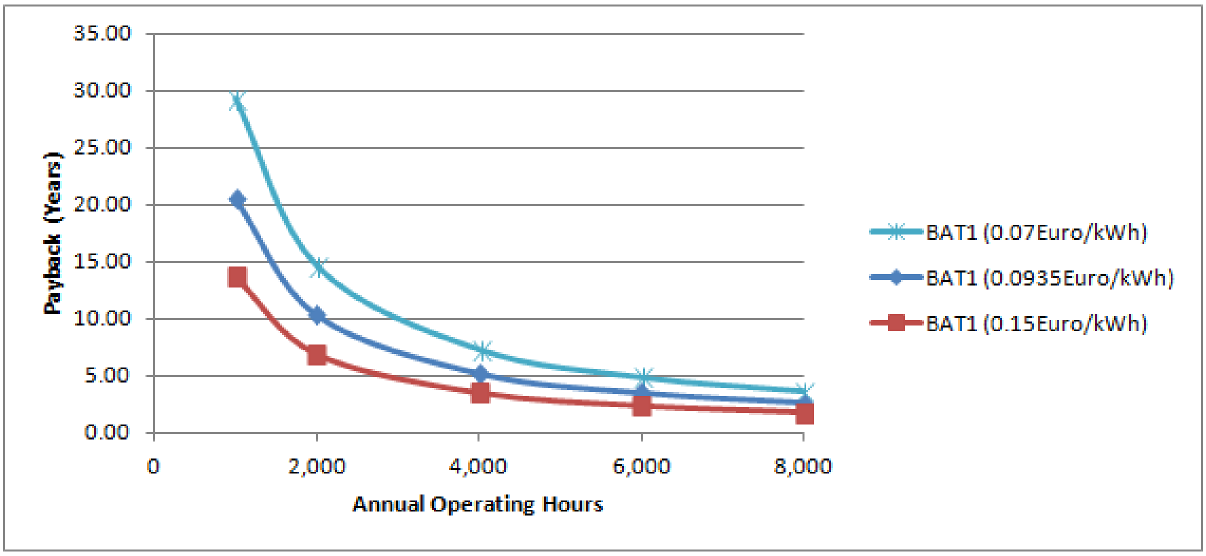




Figure 8a and 8b. Payback and LCC analysis: Large induction motor - MV IE2, (6,000 hours pa basecase).

### 8.6.9 Small Submersible Pump Motor (2.2kW)



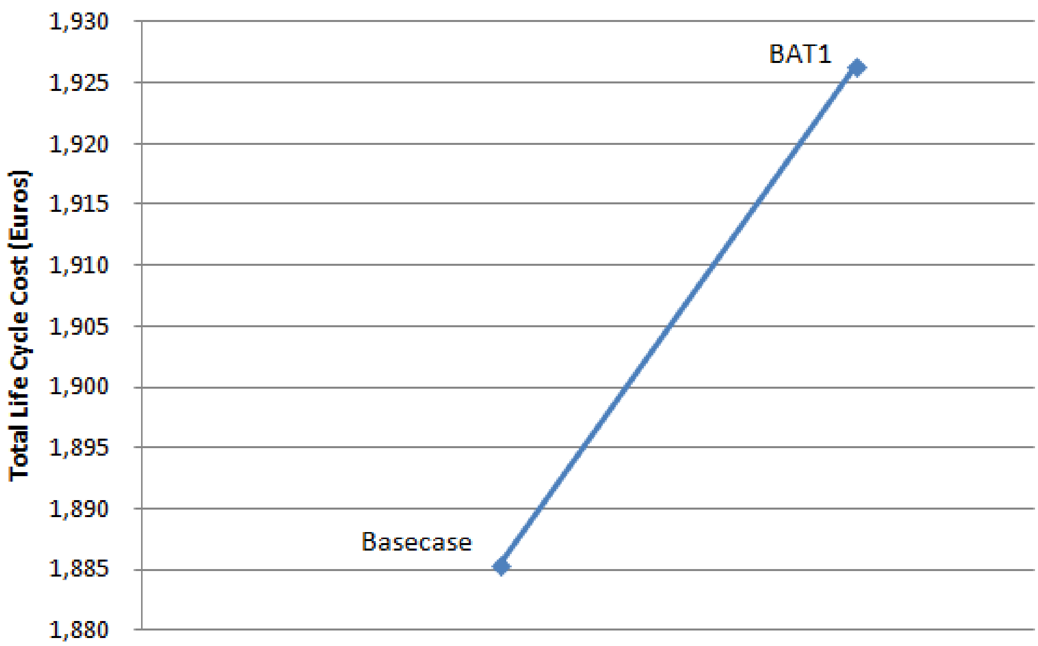
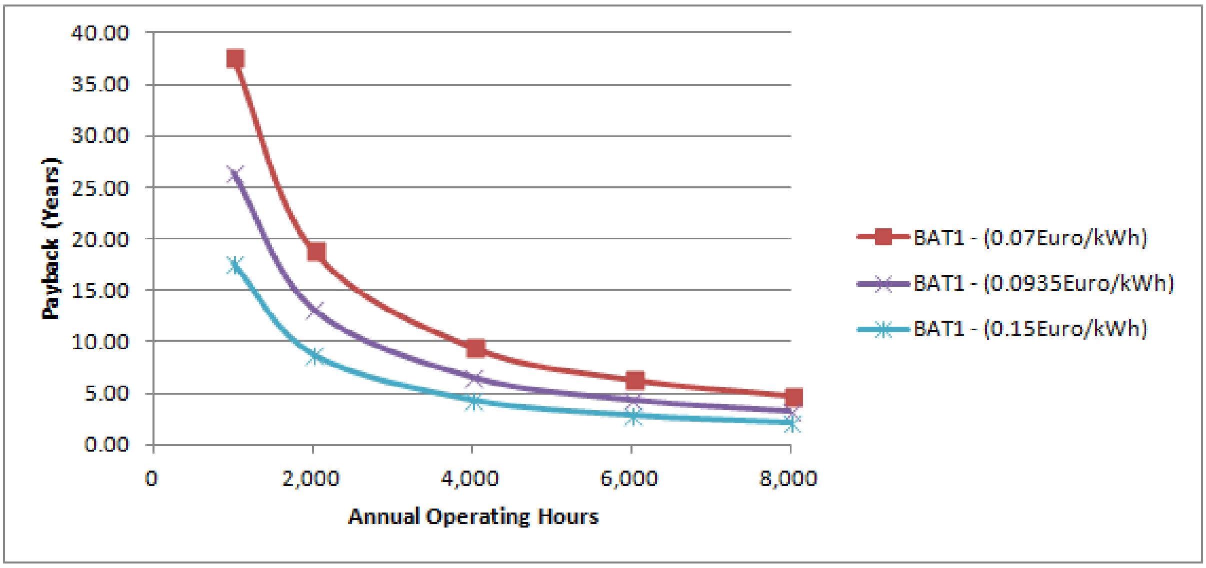




Figure 9a and 9b. Payback and LCC Analysis: Small Submersible Pump motor, (1,000 hours pa basecase)

### 8.6.10 Large Submersible Pump Motor (37kW)



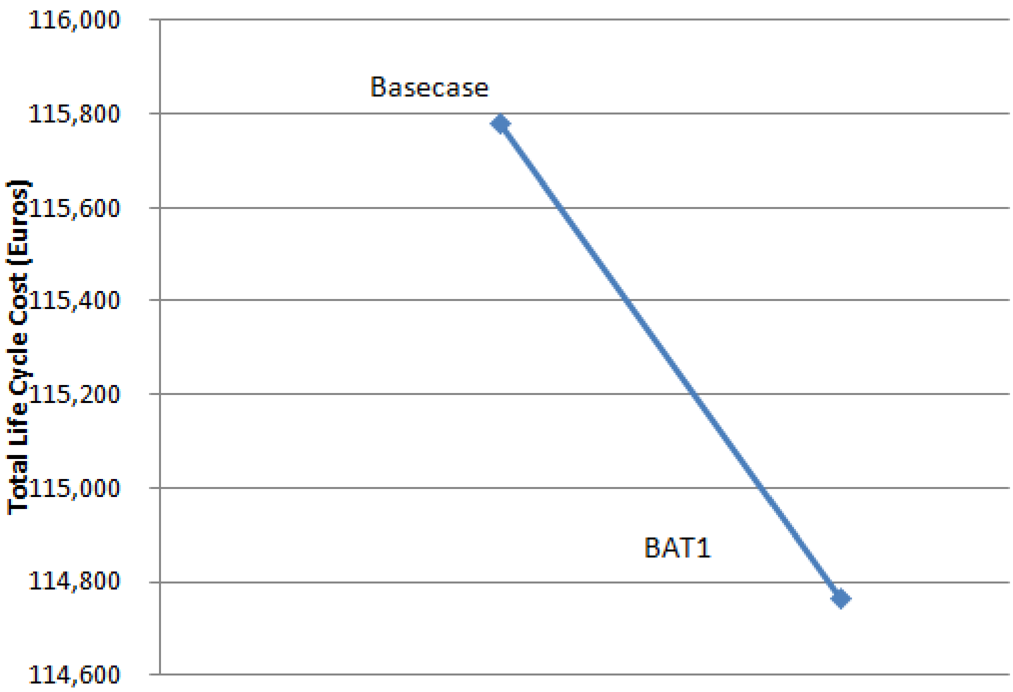




Figure 10a and 10b. Payback and LCC analysis: Large Submersible Pump motor, (4,000 hours pa basecase)

### 8.6.11 LCC Analysis of Variable Speed Drives

For VSDs, the market is larger based at the IE1 level, only a small proportion of VSDs are sold at the IE0 level, and hence IE1 is considered as the basecase. The extremely high relative costs of IE2 VSDs means that the paybacks are extremely long, and so only a LCC analysis is shown here.

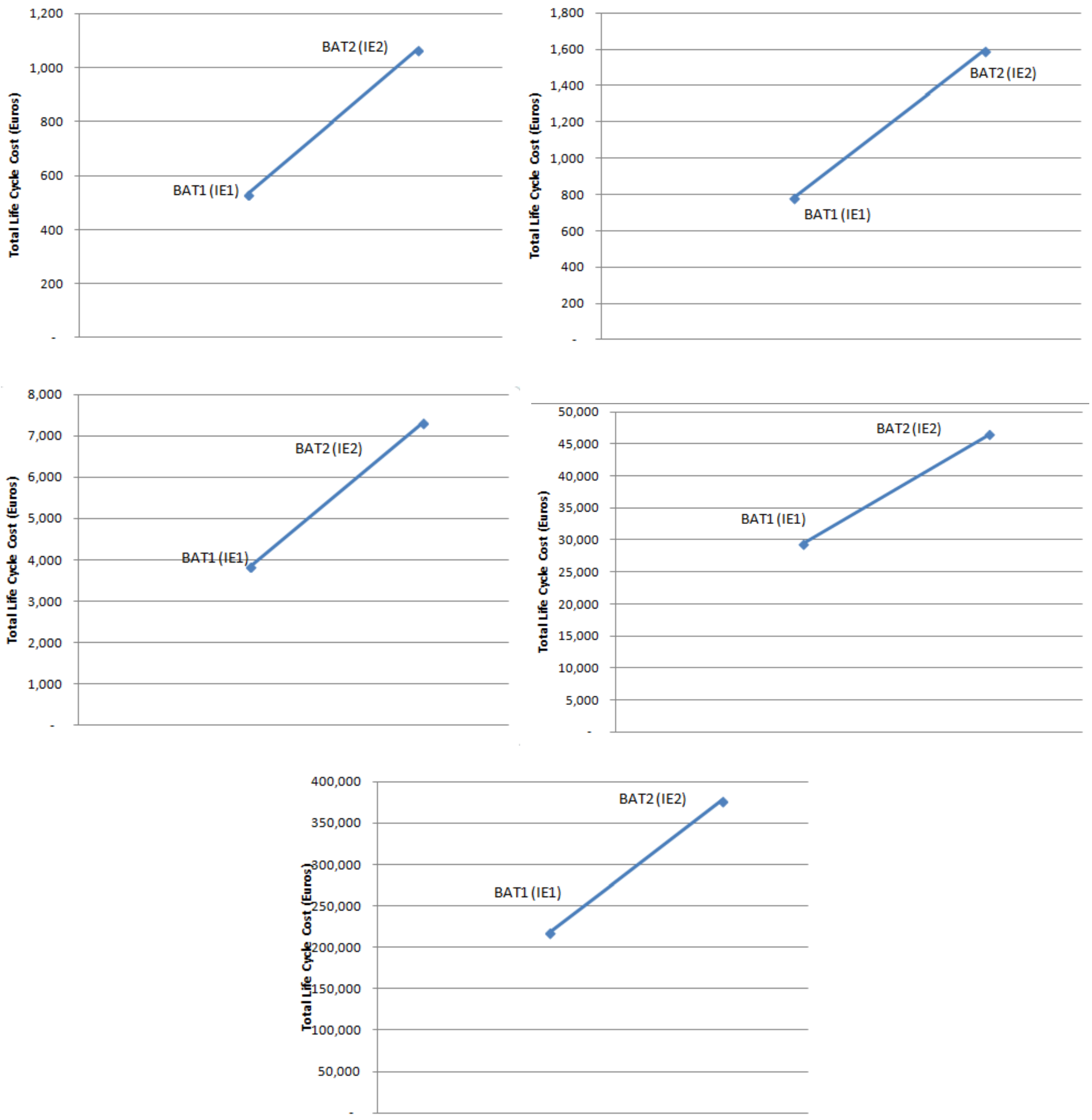



Figure 5 a-e. LCC analysis of VSD options (0.37kW, 1.1kW, 11kW, 110kW, 550kW)

## 8.7 Impact analysis

### 8.7.1 Scope of Impact Analysis

The Ecodesign requirements should not entail excessive costs nor undermine the competitiveness of European enterprises and should not have a significant negative impact on consumers or others users. In this section, the following impacts are assessed:

- Impacts on manufacturers and competition;
- Impacts on consumers;
- Impacts on innovation and development; and
- Social impacts.

### 8.7.2 Impacts on manufacturers and competition

The timeline to implement the MEPS should take into account the development of efficiency test standards, product redesign cycle and adaptation of production lines. All the technologies described in this study and considered as improvement options in the scenarios are already available on the market. As a result, the implementation of MEPS is technically achievable, although it may require additional expenditure by the manufacturers.

While some manufacturers already have available improved motors available in the EU, not all the manufacturers include them in their designs, and the launching of these new products will require some redesign work. Therefore the possible implementation of MEPS could require some investment in technology and product development, or in adapting their production lines to offer the more efficient products. For the typical SME manufacturer, the cost of re-designing motors in the IEC80 to IEC180 frame size range is estimated at 5 MEuro per manufacturer (CEMEP estimate).

The actual additional cost to manufacturers will depend on when new designs were anyway planned. Hence giving longer time to implementation will reduce the financial impact on them. There are claims that the efficiency levels demanded for single phase motors will mean that new specific laminations will need to be designed, as the shared used of three phase laminations will no longer be possible.

As the considered design improvement options are already understood, the critical issue is the availability of resources (technical experts and finance) to develop the products. Therefore, a notice period of at least 24 months from date of agreement on possible measures should be sufficient for all the manufacturers to redesign their products, adapt the production lines and develop test methods to verify the compliance with the legal requirements. All suggested measures have this as a minimum time, with other factors such as the need to make changes to different product ranges accounting for the longer times suggested for some measures.

The motor market is international, and so manufacturers outside of Europe will also be impacted. However, there is a move internationally to adopt high levels of efficiency as MEPS, and so raising EU MEPS in line with these will in many cases not need lead to any additional costs. The EU with first class manufacturers at World level also benefits from taking a leading role in the promotion of cost-effective energy-efficient technologies. This is already happening at the standardization level, namely addressing power drive systems. Low volume manufacturers can reduce the investment cost by purchasing components (for example cases) or sub-assemblies (for example rotors) from third parties.

Technical standards are in place to support the regulation of low voltage motors in the 120W to 1000kW range.

But work is required to define industry standard testing for submersible pump motors, where agreement on changing of bearings and motor cooling during test is required.

### 8.7.3 Impacts on customers

For the improvement options presented in Task 6, the functional unit and the quality of service given by the improved product will not always remain the same. Key issues include:

- Higher efficiency models create less heat and usually have a lower surface temperature, potentially leading to longer lifetimes. However, the use of Class H insulation in place of Class F previously used allows higher running temperatures, and so any advantage is less significant.
- LSPM motors have problematic starting behavior.
- More efficient induction motors will be longer, that might present mounting problems and higher transport costs. This will in some cases incur additional re-design costs for the products they are used on.
- More efficient induction motors will be heavier, creating additional cost for transport and maybe mounting. This additional weight represents a particular problem in portable equipment.
- Synchronous reluctance and converter driven PM motors always require a converter to drive them, whereas induction motors can run without a controller.

In the case of any additional costs to manufacturers, these could be reflected in a higher purchase price for customers. However, the lower energy consumption during the use phase would compensate for the higher purchase price of the motor – the payback times are shown in section 3.5. This would also mean that more capital to purchase the more efficient products would be required. The scenario analysis already shows some of the expected monetary impacts for users.

### 8.7.4 Impacts on innovation and development

The proposed policy options will remove inefficient motors and VSDs from the market but it is unlikely to lead to big technological changes. This happens mainly because the products with the improvement options identified in this study already exist in the market.

The proposed MEPS can be seen as an opportunity for manufacturers to search for innovative and efficient technological solutions. As mentioned, it seems that with the current trend of research and development activities in EU manufacturing companies, it should be feasible that most manufacturers can meet the proposed requirements.

However, in general the technology required to achieve these levels is well understood; the focus will be on trying to achieve it at minimum additional cost.

### 8.7.5 Social impacts

Most of the manufacturers of motors have production plants within the EU. Upgrading or changing production lines in the EU is often viewed as an opportunity to decide whether to relocate the production plant to another country – within or outside the EU – or not. If performance standards were set, they are not thought to have a detrimental impact on the number of jobs or the well-being of the EU manufacturers' employees.

In addition, the technologies to fulfill the proposed Ecodesign requirements presented do not require any specific material that might be difficult to obtain within the EU.

## 8.8 Conclusions

This Task report brings together the findings of the previous tasks of the preparatory study for Ecodesign requirements of motors and motor controls. It has presented possible Ecodesign requirements for motors and controls to achieve environmental and economic improvements at EU level with a potential cost-effective savings of up to **31.2 TWhpa**, of which **26 TWhpa** is achievable by 2030.

*MEPS for Motor and VSDs*

Several of these Policy Options are in line with the already expressed sentiments of many of the stakeholders following this study:

- PO 1: Expansion of scope of existing regulation to include MEPS at IE3 for small and large three phase induction motors, and at IE2 for single phase motors. Saving 18.7 TWhpa.
- PO 3: Removal of the exemption given to explosion proof and brake motors under Regulation 640/2009. Saving 0.95 TWhpa.
- PO 5: Set a MEPS at IE1 for VSDs so as to remove the poorest efficiency models from the market. Energy savings very small, none attributed to this measure.

In addition, the analysis has identified two further additional options that yield appreciable energy savings:

- PO 2: Removal of the current option to use an IE2 motor instead of an IE3 motor, providing that a VSD is used. Saving 2.7 TWhpa.
- PO 6: Raising of MEPS for medium and large motors to IE4. Saving 9.4 TWhpa.

In addition, PO4 regarding information requirements has no directly attributable energy savings, but is necessary to increase the scope of the information requirements to support the expanded scope of proposed motor regulation.

Global harmonization of motor and drive regulations is an advantage to both producers and users of motors, with the important USA market for example having regulations that can be considered equivalent to PO1 (small motors only), PO2 and PO3.

IE4 motors are at an early stage of development, and currently most appropriate for applications with long running hours. However, the economics might change in future, and so it is suggested that if PO6 is not adopted now, it is reconsidered at the time of first review.

### *Submersible Borehole Pumps*

Small energy savings from the introduction of MEPS or submersible borehole pumps have also been identified. These are usually sold as part of integrated pumps, and so the decision on any measures related to these products will be made through the stakeholders of LOT29. However, it is anticipated that any measures would be part of this motor regulation.

### *Variable Speed Motors*

The use of VSDs for saving energy is very important, and although their losses are relatively small, it seems relevant to remove from the market the lower efficiency units (below IE1).

Task 7 showed how for variable speed applications there are motors that offer lower losses than conventional induction motors: Permanent Magnet motors offer excellent performance, but are prohibitively expensive to be used as the basis for MEPS. Synchronous Reluctance motors offer similar performance but at lower cost, however they are only available from one major supplier. Both these alternatives to induction motors also lack the essential ability that induction motors possess of being capable of direct line operation. It was therefore not obvious how MEPS could be introduced that might effectively remove the induction motor from this market. If any applicable MEPS was too demanding, users may decide not to use variable speed control at all.