

# EuP Lot 30: Electric Motors and Drives

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## *Task 1: Product Definition, Standards and Legislation*

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*Final*

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# 1 Definition

This section defines the product and the boundaries for the study. The product is categorised and its performance parameters are defined. This section also identifies and shortly describes relevant test standards and existing legislation.

The product group is defined in the invitation to Tender as *“Products in motor systems outside the scope of the Regulation 640/2009 on electric motors, such as special purpose inverter duty motors (asynchronous servo motors), permanent magnet motors, motors cooled by their load (fans), including motors and products under Article 1, Points 2(b), (c) and (d) and including drives, such as soft starters, torque or variable speed drives (VSD) from 200W- 1000kW. The study should also cover motors in the scope of the Regulation 640/2009 from 750kW 1000kW”*.

The short description for Lot 30 is quite broad, encompassing products in motor systems outside the scope of Regulation 640/2009 on electric motors. This includes, not only the motors that are specifically excluded in Article 1 of the Regulation, such as brake motors, but also other induction motors (single phase and 3-phase outside the 0.75-375 kW power range), motors specifically designed for inverter duty, and motors with different design such as permanent magnet motors. Furthermore, it also includes motor drives and controllers (e.g. **electro-mechanical starters**, soft starters, VSDs, etc.).

In Regulation 640/2009 [1] “electric motor” is defined as:

A single speed, three-phase 50 Hz or 50/60 Hz, squirrel cage induction motor that:

- has 2 to 6 poles,
- has a rated voltage of  $U_N$  up to 1 000 V,
- has a rated output  $P_N$  between 0,75 kW and 375 kW,
- is rated on the basis of continuous duty operation.

The study will focus on motors outside this scope, namely:

- Motors in power ranges outside the 0,75 kW – 375 kW power range covered by the previous Lot 11 study and the Regulation, with special attention given to small motors including and above 120 W and high power motors above 375 kW up to 1000 kW.
- Exceptions to the Regulation, described in its Article 1, point 2, such as brake motors and motors rated for different operating conditions.
- Special purpose inverter duty motors, used for wide speed range such in AC servomotor applications.
- Emerging state-of-the-art technologies such as: Permanent magnet motors (PM), Line-Start Permanent magnet motors, switched reluctance motors (SR), etc. On the EuP Lot 11 [2] study a brief analysis of other motor technologies, such as Brushless Permanent Magnet Motors, has already been conducted. However, at the time, these new very efficient technologies could not be considered “commodity” products. These were highly customised products without suitable standards (e.g. dimensions, mounting, power, torque specifications, etc.). Meanwhile, the market for these products has matured and standards have been developed, or are being developed, accordingly. It is intended to address these emerging technologies in more detail.

The importance of motor controllers has also been recognized to have a significant impact on the motor and motor systems efficiency and, therefore they shall also be included in the analysis, namely on the following aspects:

- The high potential savings of Variable Speed control, especially in centrifugal load applications, is also widely recognized and is to be the subject of further analysis including hardware, software and interaction with the motor, to evaluate its combined efficiency.
- Other motor controllers, which can be applied in loads with small variability, such as soft-starters.

The pertinence of the introduction of regulatory measures for the above mentioned products will be evaluated based on Article 15 of the Ecodesign Directive, specifically, products with large sales, high environmental impact and high potential reduction of that environmental impact.

In principle, all motors that are capable of continuous duty operation are to be analysed in this preparatory study. This includes those motors that are integrated into other equipment but that can be tested separately. Motors that are not capable of continuous operation at their rated power with a temperature rise within the specified insulation temperature class, are not considered since the low hours of use translate into small environmental impact, i.e., Furthermore, these motors sometimes have particular design features which are not compatible with ecodesign measures.

Motors for off-grid applications, such as battery powered tools, motors in mobile machinery and motors used in automobiles (e.g. powered windows, windscreen wipers) are not considered in this study.

## 1.1 Product Categorisation and Performance Assessment

The product categorisation will be primarily based on the Prodcom [3] categories.

**Prodcom** provides statistics on the production of manufactured goods. The term comes from the French "PRODUCTION COMMUNAUTAIRE". It is based on a product classification called the PRODCOM List which consists of about 4500 headings relating to manufactured products in which electric motors are included.

### 1.1.1 Motors

Table 1-1 presents the Prodcom classification for electric motors.

**Table 1-1 Prodcom categorisation for electric motors**

27.11.10.30	DC motors and generators of an output > 37.5 W but ≤ 750 W (excluding starter motors for internal combustion engines)
27.11.10.53	DC motors and generators of an output > 0.75 kW but ≤ 7.5 kW (excluding starter motors for internal combustion engines)
27.11.10.55	DC motors and generators of an output > 7.5 kW but ≤ 75 kW (excluding starter motors for internal combustion engines)
27.11.10.70	DC motors and generators of an output > 75 kW but ≤ 375 kW (excluding starter motors for internal combustion engines)
27.11.10.90	DC motors and generators of an output > 375 kW (excluding starter motors for

	internal combustion engines)
27.11.21.00	Universal AC/DC motors of an output > 37.5 W
27.11.22.30	Single-phase AC motors of an output ≤ 750 W
27.11.22.50	Single-phase AC motors of an output > 750 W
27.11.23.00	Multi-phase AC motors of an output ≤ 750 W
27.11.24.03	Multi-phase AC motors of an output > 0.75 kW but ≤ 7.5 kW
27.11.24.05	Multi-phase AC motors of an output > 7.5 kW but ≤ 37 kW
27.11.24.07	Multi-phase AC motors of an output > 37 kW but ≤ 75 kW
27.11.25.40	Multi-phase AC motors of an output > 75 kW but ≤ 375 kW (excluding traction motors)
27.11.25.60	Multi-phase AC motors of an output > 375 kW but ≤ 750 kW (excluding traction motors)
27.11.25.90	Multi-phase AC motors of an output > 750 kW (excluding traction motors)

For the purpose of this study, motors shall be divided into three major categories according to output power:

**Small motors** in the power range of 120 W<sup>1</sup> to 750 W. This group will namely include:

- General purpose single-phase induction motors
- General purpose single speed 3-phase induction motors
- Brushless Permanent Magnet Motors / EC Motors
- DC/Universal motors

Small motors constitute about 90% of the global stock, but only consume about 9% of the total electricity used by electric motors [4]. They are used in many applications such as appliances, small pumps, compressors and fans. These motors are often single-phase (induction, shaded-pole, or DC/Universal motor types), which are typically custom-made in large series to be integrated into specific machines or appliances.

**Medium motors** in the power range of 0.75 kW to 375 kW. This is the power range covered by the existing EC regulation, so special attention is to be given to exclusions and to the improvement potential.

This group will include:

- General purpose single speed 3-phase induction motors in the power range 0.75-375 kW, but which are excluded in the Regulation 640/2009, such as brake motors and motors for special applications and operating conditions
- Special purpose inverter duty motors
- Integrated Motors + VSD
- Permanent Magnet (PM) Motors, including Line-Start Permanent magnet (LSPM) motors
- Switched reluctance (SR) motors

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<sup>1</sup> Although the initial lower limit was 200 W it was decided to further lower this limit to 120 W to keep in line with the upcoming edition of IEC 60034-30-1 (see 1.2.6)

Medium motors, in this power range, are responsible for about 68% of the electricity consumed by electric motors globally. The market is largely dominated by three-phase AC induction motors (around 85% market share) but other technologies are used, such as conventional DC motors (declining market), PM motors and SR motors (increasing market).

General purpose single speed, single-phase induction motors in the power range above 0.75 kW, will not be considered because of their relatively lower performance compared with 3-phase motors and because of their declining market share.

**Large motors** in the power range above 375 kW, up to 1000 kW.

- General purpose single speed 3-phase induction motors (squirrel cage and wound rotor)
- Wound-rotor synchronous motors

According to CEMEP, motors in this power range are mostly rated for voltages over 1000 V and up to 6600 V. Therefore, the analysis in this study will also be extended to this voltage range.

Typically motors in this power range have customized design for very specific industrial applications and are often produced according to specific requirements of the purchaser. They account for only about 0.03% of the stock of all electric motors but consume about 23% of global motor electricity use [4]. Because of their large power and, in general, of their high number of operating hours, these motors tend to be specified to have a very high efficiency. Although motors in this power range are available to order, from catalogue, usually, these motors are individually designed according to the customer's specifications.

### 1.1.2 Motor Controllers

The high savings potential of Variable Speed control in certain applications is also widely recognized and is to be the subject of further analysis including hardware, software and interaction with the motor, to evaluate its combined efficiency.

The environmental advantages of other motor controllers, such as soft-starters and electro-mechanical starters, which can be applied in fixed speed applications, will also be evaluated. Soft-starters typically operate during a brief start-up period (typically less than 10 seconds). After this period, it is either bypassed to reduce the losses or for light loads it can enter in an energy-saving mode. The energy use of soft-starters seems, on a first approach, quite small.

Prodcom lists inverters in two different categories shown in Table 1-2.

**Table 1-2 PRODCOM categorisation for inverters**

27.11.50.53	Inverters having a power handling capacity $\leq 7.5$ kVA
27.11.50.55	Inverters having a power handling capacity $> 7.5$ kVA

Prodcom also considers Static Converters (excluding polycrystalline semiconductors, converters specially designed for welding, without welding equipment, accumulator chargers, rectifiers, inverters).

Because the ProdCom classification is not sufficiently categorized, the same power ranges used in the motors classification will be used for motor controllers.

### 1.1.3 Performance Parameters

The functional unit defines the quantification of the identified functions (performance characteristics) of the product<sup>2</sup>. That is to say, what the product does.

Electric motors are devices that convert electric energy into mechanical energy. Therefore, the primary performance parameter or “functional unit” is output power in kW. Also relevant is the speed at which the shaft rotates. Both these parameters are related to torque by the following equation.

$$Torque [N.m] = \frac{Power [W]}{speed [rad / s]}$$

## 1.2 Test standards

Almost all the major economies have some kind of voluntary or mandatory regulatory scheme regarding induction motor efficiency. Induction motors are by far the most used technology in industry and efforts to regulate motor efficiency have, therefore concentrated in this technology.

Most of major economies have mandatory minimum efficiency levels for motors sold in the respective countries and labeling schemes for the promotion of higher efficiency motors: *NEMA* and *EPAct* in the USA, *CSA* in Canada, *CEMEP –EU Agreement* and *Regulation 640/2009* in Europe, *COPANT* in South America, *AS/NZS* in Australia and New Zealand, *JIS* in Japan, *GB* in China and others.

To further increase confusion, these classifications schemes relied in the past on different efficiency test methods which can produce significantly different results. Therefore efficiency levels were not straightforwardly comparable. This was a source for potential confusion and an important market barrier.

The last few years have witnessed a substantial effort in harmonising the different test and classification standards, and subsequent labeling schemes in use. The International Electrotechnical Commission (IEC) has worked together with NEMA, CEMEP, IEEE and other international organizations and this work resulted in the publication of two major standards:

- *IEC 60034-2-1 (Ed. 1.0): Rotating electrical machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles), 2007* [5], which describes methods to determine motor efficiency from tests, and
- *IEC 60034-30 (Ed.1.0): Rotating electrical machines – Part 30: Efficiency classes of single-speed, three-phase cage-induction motors (IE-code), 2008* [6], which defines energy classes for induction motors

Efficiency in a motor is defined as the ratio of output (mechanical) power to input (electrical) power.

$$Efficiency = \frac{Output\ mechanical\ power}{Input\ electrical\ power}$$

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<sup>2</sup> ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework

The difference between input and output power is caused by the presence of losses in different parts of the motor. The **electrical losses** (also called Joule losses) are expressed by  $I^2R$ , and consequently increase rapidly with the motor load. Electrical losses appear as heat generated by electric resistance to current flowing in the stator windings and in the rotor conductor bars and end rings. **Magnetic losses** occur in the steel laminations of the stator and rotor. They are due to hysteresis and eddy currents, increasing approximately with the square of the flux-density. **Mechanical losses** are due to friction in the bearings, ventilation and windage losses. **Stray load losses** are due to leakage flux, harmonics of the air gap flux density, non-uniform and inter-bar currents distribution, mechanical imperfections in the air gap, and irregularities in the air gap flux density. In motors with brushes (e.g. wound rotor motors), **the brush contact losses** result from the voltage drop between the brushes and the commutator or the slip rings.

As an example, Figure 1-1 shows the distribution of the induction motor losses as a function of the motor power.

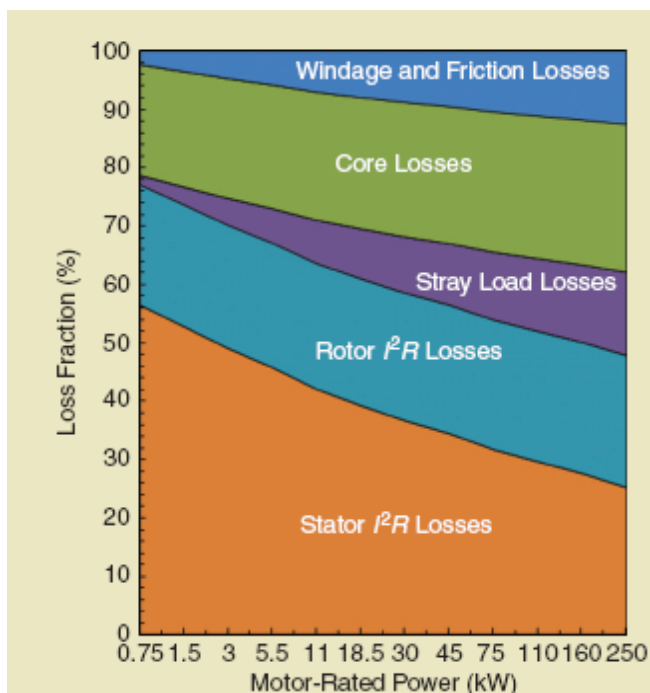


Figure 1-1 Typical fraction of losses in 50-Hz, in four-pole squirrel cage IMs [7]

Efficiency in an electric motor can be determined in two ways, directly and indirectly. Direct test methods rely on measuring the input power on the basis of the voltage and current supplied, and the output power based on the rotational speed and torque. Indirect methods involve measuring the input power and calculating the total losses by measuring and adding individual loss components.

### 1.2.1 IEC 60034-2-1 (Ed. 1.0), 2007

IEC 60034-2-1 (Ed. 1.0) [5], published in 2007, describes test methods to determine losses and efficiency of electric motors. It supersedes the old IEC 60034-2 (1996) and also the intermediate publication IEC 61972. In IEC 60034-2 [8] (commonly referred to as IEC 34-2) full load stray load losses in induction motors were arbitrarily assumed to be 0.5% of the full load input power. This method has a clear tendency to overestimate efficiency in the low-medium



power range. The error is not so important when testing low-efficiency motors, but leads to a significant influence when testing high-efficient motors.

IEC 60034-2-1 contains a test procedure (Indirect loss determination with PLL determined from residual loss) similar to IEEE 112B [9], which is the recognized test method in Canada, Mexico and the US, with some further improvements especially for smaller motors (1 kW and below).

IEC 60034-2-1 describes different test methods for both AC and DC machines with different levels of uncertainty associated. The choice of test to be made depends on the information required, the accuracy required, the type and size of the machine involved and the available field test equipment (supply, load or driving machine).

This test standard presents three tables with the preferred methods for the determination of efficiency and their associated levels of uncertainty.

As an example, the table regarding Induction motors is presented here.

Table 1-3 Preferred methods for determining the efficiency of Induction Motors [5]

Method	Clause	Preferred method	Required facilities	Uncertainty
<b>Direct</b>				
Torque measurement	8.1.1	All single phase and polyphase $\leq 1$ kW	Torquemeter/dynamometer for full-load	Low
Calibrated machine test	Annex D		Calibrated machine	See Note 5
Dual-supply, back-to-back test	8.1.2		Machine set for full-load Two identical units	Low
<b>Total losses</b>				
Calorimetric method	Annex D		Special thermal enclosure	See Note 5
Single supply back-to-back test	8.2.1		Two identical units (wound rotor)	Low
<b>Summation of losses, with and without load test</b>				
$P_{LL}$ determined from residual loss	8.2.2.5.1	Three phase $> 1$ kW up to 150 kW	Torquemeter/dynamometer for $\geq 1,25 \times$ full-load	Low
$P_{LL}$ from assigned value	8.2.2.5.3			Medium to high
$P_{LL}$ from removed rotor and reverse rotation test	8.2.2.5.2		Auxiliary motor with rated power $\leq 5 \times$ total losses $P_T$	High
$P_{LL}$ from Eh-star test	8.2.2.5.4	(see Note 3)	Resistor for 150 % rated phase current	Medium
<b>Summation of losses, without load test</b>				
Currents, powers and slip from the equivalent circuit method $P_{LL}$ from assigned value	8.2.2.4.3		If test equipment for other tests is not available (no possibility of applying rated load, no duplicate machine)	Medium/high
<p><b>NOTE 1</b> Due to measurement inaccuracies, the determination of <math>P_{LL}</math> from residual losses is limited to correlation coefficients (see 8.2.2.5.1.2) greater than 0,95 and may have uncertainties of the determined efficiency exceeding <math>\pm 0,5</math> %.</p> <p><b>NOTE 2</b> In the "Uncertainty" column, "Low" indicates a procedure determining all loss-components from tests; "Medium" indicates a procedure which is based on a simplified physical model of the machine.</p> <p><b>NOTE 3</b> The method for <math>P_{LL}</math> from Eh-star test is suitable for motors between 1 kW and 150 kW; larger ratings are under consideration. The method requires that the winding can be connected in star.</p> <p><b>NOTE 4</b> In the "Uncertainty" column, "Low" indicates a procedure determining all loss-components from tests; "Medium" indicates a procedure which is based on a simplified physical model of the machine; and "High" indicates a procedure that does not determine all loss-components by tests.</p> <p><b>NOTE 5</b> Uncertainty to be determined.</p>				

The IEC 60034-2-1 standard is currently being revised to remove ambiguities and possible causes for confusion. Its text has also been edited to make it more readable and user friendly. It is expected to be published in 2014. The test methods are now grouped into preferred methods and methods for field or routine testing. Preferred methods have a low uncertainty and for a specific rating and type of machine only one preferred method is now defined. The requirements regarding instrumentation have been detailed and refined. The description of tests required for a specific method is now given in the same sequence as requested for the performance of the test. This will avoid misunderstandings and improve the accuracy of the procedures. In addition, for each method a flowchart shows the sequence of tests graphically. To maintain compatibility with existing national standards very few technical modifications are introduced.

### **1.2.2 IEC 60034-2-2 [10]**

Supplementary to IEC 60034-2-1 another standard was published, [10] which describes three additional test methods (Calibrated-machine test, Retardation test, Calorimetric method) to be applied mainly for large machines where the facility cost for other methods is not considered economical.

### **1.2.3 IEC/TS 60034-2-3:2013**

New general purpose induction motors can be used with inverters, since they are built with improved insulation materials able to withstand high  $dV/dt$  voltage waveforms. For low speeds (e.g. below 50%) the torque capabilities significantly drop if no additional cooling is used. When fed by an electronic variable speed drive the motor has additional harmonic losses, which depend upon many variables (switching frequency, PWM control algorithms, etc..). Harmonic losses are produced in the motor by the non-sinusoidal voltage and current waveforms generated by the converter and are in addition to the fundamental losses of iron, rotor-winding, stator-winding and additional-load.

IEC/TS 60034-2-3 *Rotating electrical machines - Part 2-3: Specific test methods for determining losses and efficiency of converter-fed AC motors*, was published in November 2013 as a technical specification. 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). This standard is aimed to evaluate the additional harmonic motor losses resulting from non-sinusoidal power supply and consequently the efficiency of the converter-fed motor, supplementing the methods intended for operation on sinusoidal supply.

### **1.2.4 IEC 60034-25**

Regarding special purpose inverter duty motors IEC Standard 60034-25, 2007, *Guidance for the design and performance of A.C. motors specifically designed for converter supply* [11], has been developed.

Variation of frequency over a wider range results in additional stress on the motor and the motors have to be specially designed to meet these conditions. Special designed motors for variable frequency drive can be used for frequency variations from a few Hz up to 200Hz or more. Typically these motors are designed for inherent low magnetic flux densities. The motors have at least class 'F' insulation and strengthened insulation by way of thicker insulation at certain points, improved overhand binding, and additional varnishing. Motors are generally in Totally Enclosed Force Cooled version having a separate motor / fan mounted on the primary motor, which cools the main motor. Rotors are balanced to higher degree. Depending on the range of RPM, special bearings are used and tolerances on the shaft and end covers are controlled to higher precision.

### **1.2.5 Efficiency test standards for controllers**

There are currently no efficiency test or classification standards for drives – Power Drive Systems (PDS) and Variable Speed Drives (VSDs) but effort is being put into its development, namely by:

- the Canadian Standards Association

*CSA 838 draft standard, regarding VSD testing*

- and CENELEC

Particularly relevant is the development of EN50598 by CENELEC TC22x, which will be divided into three parts:

- Part 1: Procedure for determining the energy efficiency indicators of motor driven applications by using the extended product approach and semi analytical models
- Part 2: Energy efficiency indicators for Power drive systems and Motor starters
- Part 3: Environmental aspects and product declaration for Power drive systems and Motor starters

The standard specifies a system-level methodology called the Extended Product Approach (EPA). The EPA allows determining the energy efficiency of motor systems, considering both the efficiency of the equipment and the requirements of the application and covers aspects of both mandates (M/470 and M/476).

Also, standards are being developed with regard to not only polyphase induction motors, but all other types of motors, such as single phase induction motors, permanent magnet synchronous and reluctance motors, at an international level.

#### **1.2.6 IEC 60034-30**

With the purpose of harmonising the different energy efficiency classification schemes for induction motors in use around the world, the International Electrotechnical Commission (IEC) introduced, in 2008, a classification standard – IEC60034-30 [6].

The standard covered single-speed three-phase 50 Hz or 60 Hz cage induction motors that:

- have a rated voltage  $U_N$  up to 1000 V;  
*NOTE - The standard also applies to motors rated for two or more voltages and/or frequencies*
- have a rated output  $P_N$  between 0,75 kW and 375 kW;
- have either 2, 4 or 6 poles
- are rated on the basis of duty type S1 (continuous duty) or S3 (intermittent periodic duty) with an operation time of 80% or more;
- are intended for direct on-line connection;
- are rated for operating conditions according to IEC 60034-1, clause 6.

Motors with flanges, feet and/or shafts with mechanical dimensions different from IEC 60072-1 are covered by this standard.

Geared motors and brake motors were covered by this standard although special shafts and flanges may be used in such motors.

Excluded were:

- Motors specifically made for converter operation according to IEC 60034-25 with increased insulation.
- Motors completely integrated into a machine (pump, fan, compressor, ...) which can not be separated from the machine.
- All other non-general-purpose motors (like smoke-extraction motors built for operation in high ambient temperature environments according to EN12101-3 etc).

The standard defined three levels of energy efficiency:

- IE3 – Premium efficiency (equivalent to NEMA Premium)
- IE2 – High efficiency (equivalent to EAct/EFF1)
- IE1 – Standard efficiency (equivalent to EFF2)

A fourth level, IE4 – Super Premium efficiency, was also introduced but not defined, since there was not sufficient market and technological information available to allow standardization. The nominal limits of Super-Premium Efficiency (IE4) were proposed in Annex A of IEC 60034-31 standard (Guide for the selection and application of energy efficient motors including variable-speed applications) [12]. This class is projected to have roughly 15-20% lower losses than IE3.

The efficiency levels of this Super Premium class at the time were believed to be too high to be achieved with standard induction motor technology, particularly for small motors. However, it was expected that advanced technologies (e.g. Permanent Magnet motors, Reluctance Synchronous motors) would enable manufacturers to design motors for this efficiency class with mechanical dimensions compatible to existing motors of lower efficiency classes, making this motors commodity products. Today, induction motors have reached the market with IE4 efficiency levels.

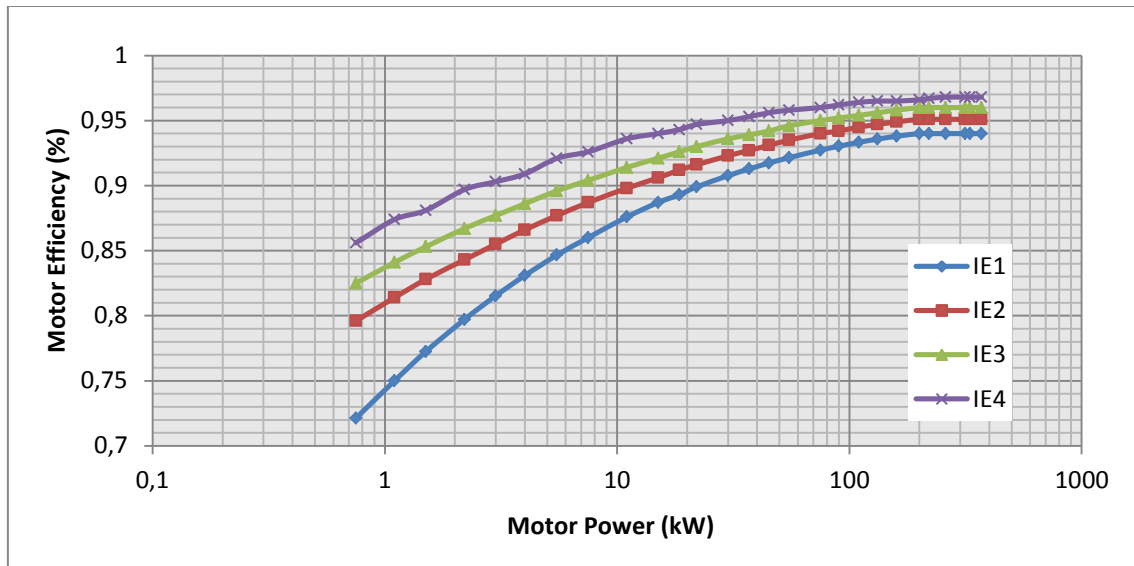


Figure 1-2. IE1, IE2 and IE3 efficiency levels in the IEC 60034-30 standard for 4 poled motors [6] and the new IE4 proposed in the IEC 60034-31 standard [12].

Efficiency and losses shall be tested in accordance with IEC 60034-2-1 [5]. The selected test method shall be associated with low uncertainty and shall be stated in the documentation of the motor.

Both standards will hopefully end the difficulties manufacturers encounter when producing motors for a global market and will help make the market more transparent.

IEC 60034-30 has recently been revised (March 2014). It is now divided into two parts:

- Part 1 - Efficiency classes of line operated AC motors (IE code)
- Part 2 - Efficiency classes of variable speed AC motors (IE code)

Part 2 is still under development.

IEC 60034-30-1 significantly broadens the scope of products covered. The power range has been expanded to cover motors from 120 W to 1000 kW. All technical constructions of electric motors are covered as long as they are rated for direct on-line operation. These include single-phase motors, not just three-phase motors as in the previous edition, and line-start permanent magnet motors.

The standard covers single-speed electric motors that are rated according to IEC 60034-1 or IEC 60079-0 (explosive atmospheres), are rated for operation on a **sinusoidal voltage** supply and:

- have a rated power  $P_N$  from 0,12 kW to 1000 kW
- have a rated voltage  $U_N$  above 50 V up to 1 kV
- have 2, 4, 6 or 8 poles
- are capable of continuous operation at their rated power with a temperature rise within the specified insulation temperature class;

*NOTE – Most motors covered by this standard are rated for duty type S1 (continuous duty). However, some motors that are rated for other duty cycles are still capable of continuous operation at their rated power and these motors are also covered.*

- are marked with any ambient temperature within the range of – 20 °C to + 60 °C

*NOTE – The rated efficiency and efficiency classes are based on 25 °C ambient temperature according to IEC 60034-2-1.*

*NOTE – Motors rated for temperatures outside the range – 20 °C and + 60 °C are considered to be of special construction and are consequently excluded from this standard.*

*NOTE – Smoke extraction motors with a temperature class of up to and including 400 °C are covered by this standard.*

- are marked with an altitude up to 4 000 m above sea level.

*NOTE – The rated efficiency and efficiency class are based on a rating for altitudes up to 1000 m above sea level.*

Excluded are:

- Single-speed motors with 10 or more poles or multi-speed motors
- Motors with mechanical commutators (such as DC-motors)
- Motors completely integrated into a machine (for example pump, fan and compressor) that cannot be practically tested separately from the machine even with provision of a temporary end-shield and drive-end bearing;

*NOTE – This means the motor must: a) share common components (apart from connectors such as bolts) with the driven unit (for example, a shaft or housing) and; b) not be designed in such a way as to enable the motor to be separated from the driven unit as an entire motor that can operate independently of the driven unit. That is, for a motor to be excluded from this standard, the process of separation must render the motor inoperative.*

*NOTE – (TEAO, IC417) Totally enclosed air-over machines, i.e. totally enclosed frame-surface cooled machines intended for exterior cooling by a ventilating means external to the machine, are covered by this standard. Efficiency testing of such motors may be performed with the fan removed and the cooling provided by an external blower with a similar airflow rate as the original fan.*

- Motors with integrated frequency-converters (compact drives) when the motor cannot be tested separately from the converter;

*NOTE – Energy-efficiency classification of compact drives must be based on the complete product (PDS = Power-Drive System) and will be defined in a separate standard. A motor is not excluded when the motor and frequency-converter can be separated and the motor can be tested independently of the converter.*

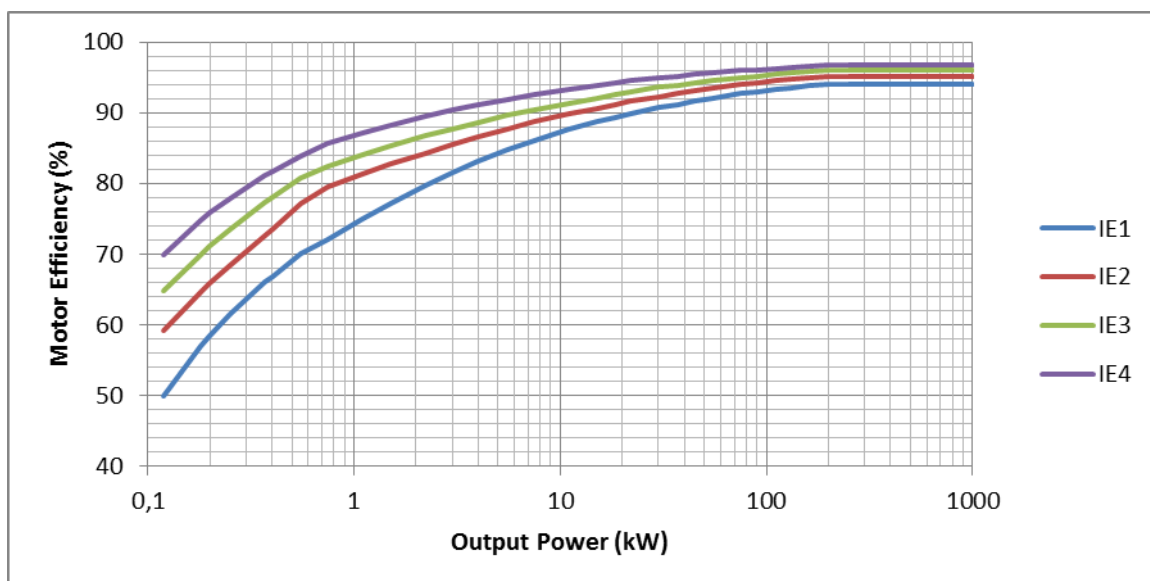
- Brake motors when the brake is an integral part of the inner motor construction and can neither be removed nor supplied by a separate power source during the testing of motor efficiency

*NOTE - Brake motors with a brake coil that is integrated into the flange of the motor are covered as long as it is possible to test motor efficiency without the losses of the brake (for example by dismantling the brake or by energizing the brake coil from a separate power source).*

*NOTE - When the manufacturer offers a motor of the same design with and without a brake the test of motor efficiency may be done on a motor without the brake. The determined efficiency may then be used as the rating of both motor and brake motor.*

- Submersible motors specifically designed to operate wholly immersed in a liquid
- Smoke extraction motors with a temperature class above 400 °C

The standard defines 4 efficiency classes IE1, IE2, IE3 and IE4. The IE4 efficiency level is now included in the standard while an IE5 level is envisaged for a future revision, with the goal of reducing the losses of IE5 by some 20% relative to IE4.



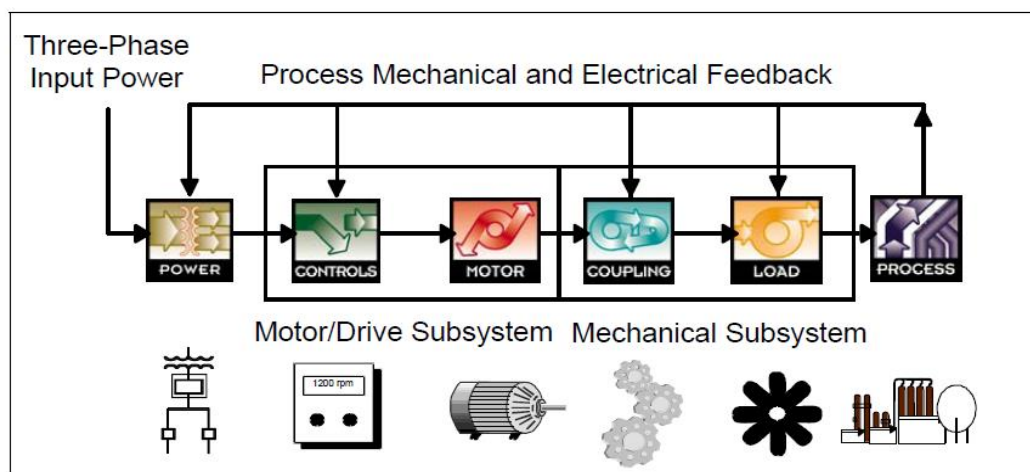
**Figure 1-3. Efficiency levels in the draft IEC 60034-30-1 standard for 4 poled motors, 50 Hz**

The efficiency levels in the power range 0,75 to 375 kW, already covered by the previous edition of the standard suffered no changes. Between 0,12 and 0,75 kW the limit values of efficiency were extrapolated, and between 375 and 1000 kW the fixed values were expanded.

The standard sets limit values of efficiency for each class regardless of technology used, to allow for the straightforward comparison between different technologies. It should be noted that not all of the motor technologies covered by this standard will be capable of reaching all efficiency levels.

### 1.2.7 IEC 60034-31

The recognition that in a motor driven application inefficiencies are present throughout the entire system (power supply, electric motor, speed controls, mechanical transmission, end-use device, etc.), as shown in Figure 14, and are influenced by diverse factors, such as maintenance practices, load management, intensity of use, etc. led to a recent standard (2010) dealing with the application of energy-efficient induction motors published by IEC:



**Figure 1-4. Typical components in a motor system.**

- IEC 60034-31 (Ed.1.0): Rotating electrical machines - Part 31: Selection of energy-efficient motors including variable speed applications - Application guide, 2010 [12]

The standard is intended to help manufactures, end-users, regulators, and other interested parties, with application issues regarding the use of energy-efficient motors and motor systems.

## 1.3 Existing relevant environmental legislation inside and outside the EU and existing self regulation.

Motor efficiency regulations around the world are limited to AC induction motors. An overview of the AC three-phase induction motor efficiency voluntary agreements and regulation around the world is presented in Table 1-4.



**Table 1-4 Overview of Minimum Energy Performance Standards (MEPS) Worldwide**

Efficiency Levels	Efficiency Classes	Testing Standard	Performance Standard
	IEC 60034-30	IEC 60034-2-1	MEPS
Premium Efficiency	IE3	Low Uncertainty	USA Europe 2015* (>7,5kW), 2017 Canada Korea 2015
High Efficiency	IE2		USA Mexico Canada Australia New Zealand Brazil Korea China Europe Switzerland
Standard Efficiency	IE1	Medium Uncertainty	China Brazil Costa Rica Israel Taiwan Switzerland

\* IE3 or IE2 + VSD

These minimum energy performance standards and test methods rely on similar classification schemes, although the nomenclature is sometimes different which is a source of market confusion.

**Table 1-5 Different classifications used worldwide**

USA	EPAct/NEMA Premium
Australia	Minimum Efficiency/High Efficiency
China	Grade 1, 2 and 3
EU	IE1, IE2, IE3

### European Union

In 1998 a voluntary agreement supported by the European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) and the European Commission was established and signed by 36 motor manufacturers, representing 80% of the European production of standard motors. In this agreement three motor efficiency levels were defined as:

1. EFF1 (similar to IE2)
2. EFF2 (similar to IE1)
3. EFF3 (below standard)

Based on this classification scheme there was a voluntary undertaking by motor manufacturers to reduce the sale of motors with EFF3 efficiency levels (standard efficiency).

The CEMEP/EU agreement was a very important first step to promote motor efficiency classification and labeling, achieving a significant market transformation. Low efficiency motors were essentially removed from the EU motor market which, at the time, was a positive development. However, the penetration of high and premium efficiency motors in 2009 was still very modest.

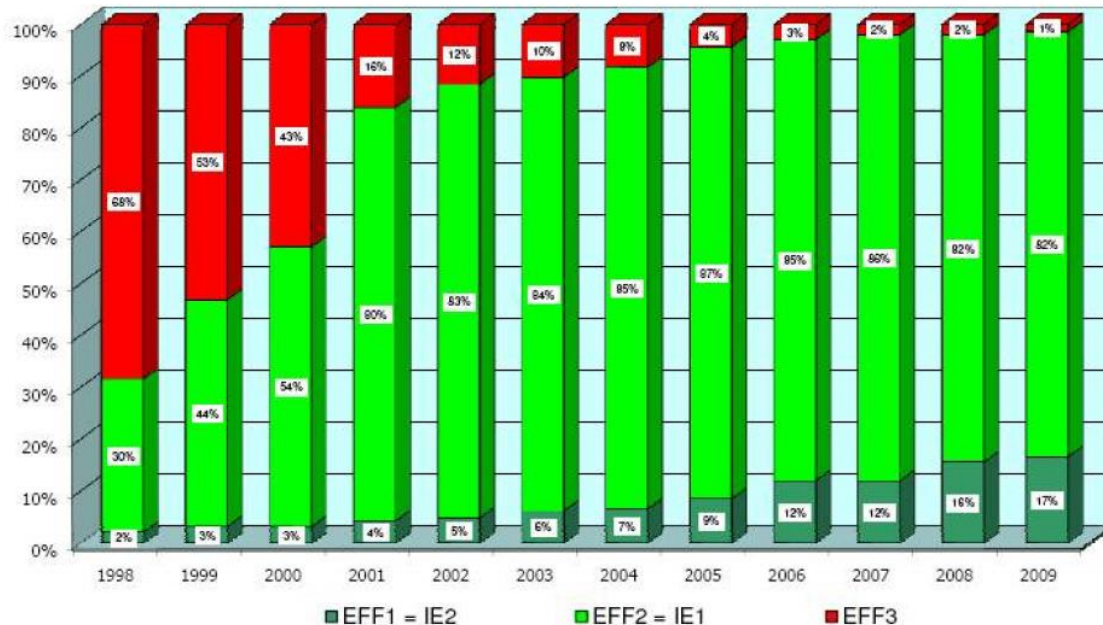


Figure 1-5 Total motor-sales in the scope of the CEMEP/EU Voluntary Agreement in the period 1998-2009 [2]

With the aim of improving the penetration of high-efficiency electric motors in the European market, the European Commission decided that it was time to set mandatory efficiency levels for motors sold within the European Union. Efficiency levels were based on the IEC60034-30 classification standard.

Minimum efficiency requirements were set in the Commission Regulation (EC) No 640/2009 [1], as follows:

1. from 16 June 2011, motors shall not be less efficient than the IE2 efficiency level
2. from 1 January 2015: motors with a rated output of 7,5-375 kW shall not be less efficient than the IE3 efficiency level, or meet the IE2 efficiency level and be equipped with a variable speed drive.
3. from 1 January 2017: all motors with a rated output of 0,75-375 kW shall not be less efficient than the IE3 efficiency level, or meet the IE2 efficiency level and be equipped with a variable speed drive.

These requirements apply to 2-, 4- and 6-pole, single speed, Three-Phase, induction Motors in the above mentioned power ranges, rated up to 1000 V and on the basis of continuous duty operation.

The following types of motor are excluded:

- motors designed to operate wholly immersed in a liquid;
- motors completely integrated into a product (e.g. pump or fan) where the motor's energy performance cannot be tested independently from the product;

- motors specifically designed to operate:
  - at altitudes exceeding 1000 meters
  - where ambient air temperatures exceed 40°C;
  - in maximum operating temperatures above 400°C;
  - where ambient air temperatures are less than –15°C (any motor) or less than 0°C (air-cooled motors);
  - where the water coolant temperature at the inlet to a product is less than 5°C or exceeds 25°C;
  - in potentially explosive atmospheres as defined in Directive 94/9/EC;
- brake motors.

The regulation has since been amended by Regulation (EC) No 4/2014 and will reinforce the existing Regulation by closing most of the loopholes that have become apparent by redefining the limit values applied to altitude, maximum and minimum ambient air temperatures and water coolant temperatures.

This amendment revises the scope of exceptions to motors specifically designed to operate:

- at altitudes exceeding 4 000 metres above sea-level;
- where ambient air temperatures exceed 60 °C;
- where ambient air temperatures are less than –30 °C for any motor or less than 0 °C for a motor with water cooling;
- where the water coolant temperature at the inlet to a product is less than 0 °C or exceeding 32 °C;

Additionally, manufacturers were previously obliged to mark efficiency at 100%, 75% and 50% of rated load. Following the amendment only the figure for 100% rated load needs to be shown in the case of small motors (“where the size of the rating plate makes it impossible to mark all the information...”).

For the evaluation of the best available option (IE2 motor + VSD; IE3 motor fixed speed or IE3 motor + VSD) the following guidelines can be used in order to provide the users the most efficient solution [13]:

*“Applications with fully loaded motors running at the network frequency and controlled by fixed speed motor starters, would consume less energy than if they were controlled by a Variable Speed Drive (VSD). Other applications, particularly variable torque loads, would reduce their energy consumption by using a VSD to match the motor speeds to the variations of the process demands. Both of the above statements apply to either an IE2 motor or an IE3 motor.*

*Referring to the Regulation (EC) 640/2009, Article 3, sub clauses 2 and 3, the end user has the decision whether to use an IE3 motor (fixed or variable speed), or an IE2 motor controlled by a variable speed drive. The end user should base their decision on which solution offers the lowest energy consumption for the dedicated application.*

*The determination of the lowest energy consumption for each specific application shall be performed in accordance with the standard (project number 23551) being developed by CENELEC CLC/TC 22X/WG 06. This standard is in response to European Commission mandate M/476 and M/470.”*

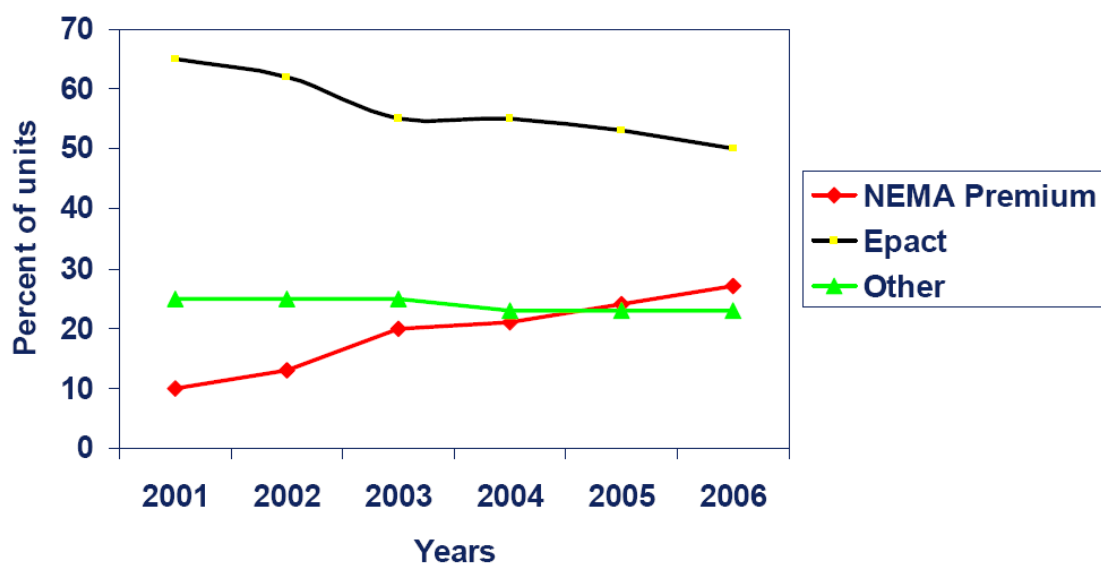
## United States of America

In 1992, the US Congress approved the Energy Policy Act (EPAct), which set minimum efficiency requirements (similar to IE2) for motors manufactured or imported for sale in the USA. These mandatory standards became effective in October 1997. From that time until 2008 the market sales for that efficiency level grew from 15% to 54%. The remaining market is evenly split between Premium motors and low efficiency motors outside the scope of the standard.

**Table 1-6 Characteristics of the motors included on EPAct [14]**

<b>Motors included in EPACT scheme:</b>
Polyphase squirrel-cage induction motors, NEMA Design A and B
Rated power 1-200 hp
Single-speed
230/400 Volts
60 Hz
Continuous rated
Tested in accordance with IEEE 112- Method B
2, 4 and 6 poles
Type of Enclosure: Totally Enclosed Fan-Cooled (TEFC) and Open Drip-Proof (ODP)

Meanwhile, many utilities and industry associations were promoting motors with a higher efficiency than EPAct mandatory levels (similar to IE2). Therefore the National Electrical Manufacturers Association (NEMA) felt a need to define a classification scheme for premium higher efficiency motors (similar to IE3). In June 2001, NEMA granted such "better-than-EPAct" motors special recognition by creating a label designated NEMA Premium. In 2001-2002 the total net units shipped went up approximately 30%. In 2002-2003 there was a 14% increase over the previous years. In 2006 NEMA Premium motors constituted 20-25% of the market share in the USA.



**Figure 1-6. Market Penetration of NEMA Premium (voluntary) and EPAct (mandatory) motors (2001-2006) [15]**

In order to further improve the market penetration of Premium Efficiency motors, the US Congress approved Energy Independence and Security Act of 2007 (EISA), which was enforced in December 2010. It not only sets higher minimum efficiency mandatory levels but also broadens the scope of existing standards, as follows:

- Current minimum efficiency standards of general purpose induction motors as defined in the 1992 EAct and covered by federal legislation should be raised to NEMA Premium levels (IE3).
- Seven types of low voltage poly-phase, integral-horsepower induction motors not currently covered under federal law should be subjected to minimum efficiency standards at the levels defined in 1992's EAct (IE2) for general purpose induction motors.
  - U-Frame Motors
  - Design C Motors
  - Close-coupled pump motors
  - Footless motors
  - Vertical solid shaft normal thrust (tested in a horizontal configuration)
  - 8-pole motors (900 rpm)
  - All poly-phase motors with voltages up to 600 volts other than 230/460 volts
- General purpose induction motors with power ratings between 200 and 500 horsepower should also meet minimum efficiency levels as specified in 1992's EAct (IE2).

EISA does not apply to:

- Motors with a special customer flange;
- Vertical Motors;
- Hollow shaft
- P-Base solid shaft (hp, LP...) different from "Normal thrust"
- Special shaft motors (Typically TZ, TCZ, TDZ, TY, LPZ...);
- 201 Hp – 500Hp design A or Medium Voltage;
- Brake motors with an integral brake design that is factory built within the motor;

With the adoption of these new requirements, the sales of premium efficiency motors are expected to exceed 70% by 2013.

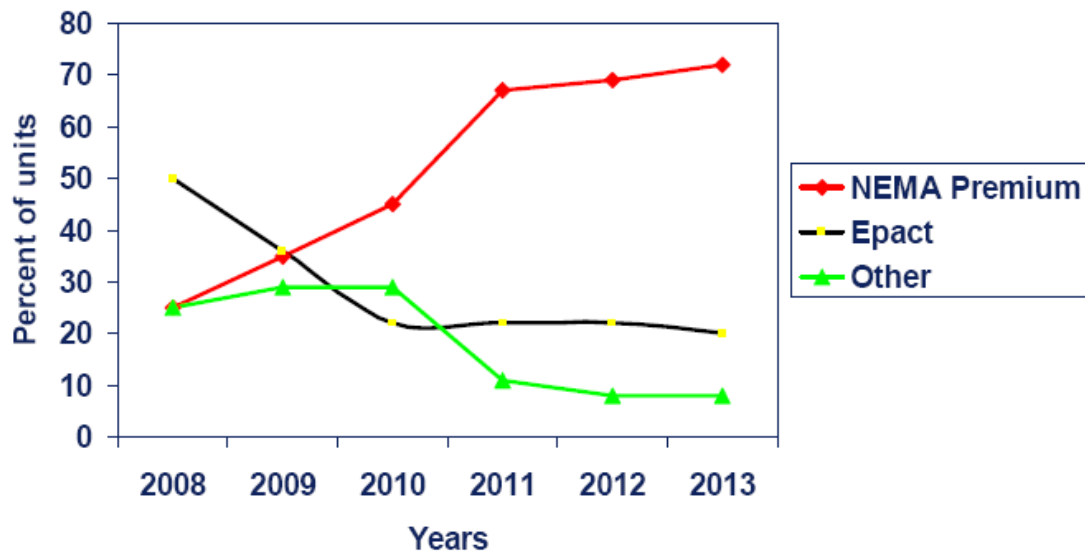


Figure 1-7. Expected impact of NEMA Premium® as a regulated product [15]

The USA has recently issued a regulation, Energy Conservation Standards for Small Electric Motors, regarding the efficiency of “small induction motors”, either single-phase or polyphase, ranging from 1/4 to 3 horsepower (0,18 to 2,2 kW), to be enforced in 2015. The Energy Policy and Conservation Act (EPCA) defines small electric motors as a NEMA (National Electrical Manufacturers Association) general purpose alternating current single-speed induction motor, built in a two-digit frame number series in accordance with NEMA Standards Publication MG1–1987.

The standards apply to three types of electric motors:

- Polyphase Small Electric Motor
- Single-phase Capacitor-Start Induction-Run
- Single-phase Capacitor-Start Capacitor-Run

Next tables present the efficiency levels for polyphase; capacitor-start, induction run, and capacitor-start, capacitor-run motors.

Table 1-7 Standard levels for polyphase small electric motor

Motor output power	Six poles	Four poles	Two poles
0.25 Hp/0.18 kW	67.5	69.5	65.6
0.33 Hp/0.25 kW	71.4	73.4	69.5
0.5 Hp/0.37 kW	75.3	78.2	73.4
0.75 Hp/0.55 kW	81.7	81.1	76.8
1 Hp/0.75 kW	82.5	83.5	77.0
1.5 Hp/1.1 kW	83.8	86.5	84.0
2 Hp/1.5 kW	N/A	86.5	85.5
3 Hp/2.2 kW	N/A	86.9	85.5

Table 1-8 Standard levels for capacitor-start induction-run and capacitor-start capacitor-run small electric motors

<b>Motor output power</b>	<b>Six poles</b>	<b>Four poles</b>	<b>Two poles</b>
0.25 Hp/0.18 kW	62.2	68.5	66.6
0.33 Hp/0.25 kW	66.6	72.4	70.5
0.5 Hp/0.37 kW	76.2	76.2	72.4
0.75 Hp/0.55 kW	80.2	81.8	76.2
1 Hp/0.75 kW	81.1	82.6	80.4
1.5 Hp/1.1 kW	N/A	83.8	81.5
2 Hp/1.5 kW	N/A	84.5	82.9
3 Hp/2.2 kW	N/A	N/A	84.1

Single-phase small electric motors are commonly found in products and appliances including pumps, fans, and power tools. Polyphase small motors are used to drive such equipment as pumps, fans, and compressors.

Minimum energy performance standards in Mexico are similar to the USA.

#### **Canada [16]**

Canada has had minimum energy performance standards in place since 1995. This standards were amended in 1997 to include explosion-proof motors and integral gear assembly motors.

The regulation regarding electric motors was again revised and, as of January 2010, has a more stringent scope and minimum efficiency levels. The revised regulation applies to electric motors, including motors incorporated into another product, that:

- is rated for continuous duty operation
- is a design type that is :
  - an electric three-phase induction design,
  - a cage or squirrel-cage design, and
  - a NEMA design A, B or C with NEMA T or U frame dimensions, or IEC design N or H;
- is designed to operate at a single speed
- has a nominal output power of not less than 0.746 kW (1 hp) and not more than 375 kW (500 hp),
- has a nominal voltage of not more than 600 V AC
- has a nominal frequency of 50/60 Hz or 60 Hz
- has a two, four, six or eight pole construction
- has an IP code from 00 to 66
- is of open or enclosed construction
- is of foot-mounted construction or flange-mounted construction, and
- has a standard shaft, R-shaft or S-shaft, or is a close-coupled pump motor or a vertically-mounted solid shaft normal thrust motor;

The regulation excludes:

- a NEMA design A or C motor of more than 150 kW (200 hp) and not more than 375 kW (500 hp) or
- an IEC design H motor of more than 150 kW (200 hp) and not more than 375 kW (500 hp).

Motors that match the above description and that:

- have an output power of not less than 0.746 kW (1 hp) and not more than 150 kW (200 hp),
- have two, four or six poles
- are NEMA T frame or IEC frame number of 90 or above
- are NEMA design A or B or IEC design N
- have a standard shaft, R-shaft or S-shaft and IEC equivalent
- have foot-mounting or C-face mounting with feet or detachable feet or D-flange mounting with feet or detachable feet

Must meet or exceed Premium (IE3) efficiency levels.

Motors that are in the scope of the regulation and that meet any one of the following definitions below:

- eight pole construction
- NEMA U frame
- NEMA design C or IEC design H
- close-coupled pump motor
- vertically-mounted solid shaft normal thrust motor
- fire pump duty motor
- motor that it is not a foot-mounting, including a non foot-mounting type C face-mounting or a non-foot mounting type D flange-mounting motors
- integral gear assembly motor
- it is a two, four, six or eight pole, NEMA design B or IEC design N motor with an output power greater than 150 kW (200 hp) and not more than 375 kW (500 hp)

Must meet or exceed Energy Efficient (IE2) efficiency levels.

## **Brazil**

Brazil started a voluntary labelling program for induction motors in 1993. It was a coordinated effort between motor manufacturers, CEPEL (Centro de Pesquisas de Energia Elétrica da Eletrobras) and INMETRO (Instituto Nacional de Metrologia, Normalização e Qualidade Industrial). The program defined periodically revised efficiency levels, for standard- and high-efficiency motors.

In 2002, MEPS were introduced by Decree 4.508/2002, applying to:

- Motors with electric single speed, three-phase 60 Hz, squirrel cage induction
- 2 to 8 poles
- Rated voltage of  $U_n$  up to 600 V
- Rated output  $P_n$  between 1 up to 250 hp (0,75 up to 185 kW) for 2 and 4 poles, 1 up to 200 hp (0,75 up to 150 kW) for 6 poles and 1 up to 150 hp (0,75 kW up to 110 kW) for 8 poles
- Rated on the basis of continuous duty operation
- Cat N, H (ABNT - IEC) or design A, B or C (NEMA);



- Motors with intermediate power;
- Motors with special bearings;
- Close coupled pump (JM and JP);
- Totally Enclosed Fan Cooled motors;

Motors below the standard efficiency levels (similar to IE1) were not allowed for sale in the country.

In 2010 MEPS were raised to high efficiency levels (IE2).

### **Australia / New Zealand**

Australia has implemented its Minimum Energy Performance (MEPS) requirements in October 2001 for three phase electric motors from 0.73kW to <185kW which were set out in AS/NZS 1359.5-2000. MEPS does not apply to submersible motors, integral motor-gear systems, variable or multi-speed motors or those rated only for short duty cycles

These MEPS were updated in April 2006 which are set out in detail in AS/NZS 1359.5-2004, published in September 2004. Minimum Efficiency levels were raised to IE2 equivalents and High Efficiency to IE3 equivalents.

Two methods of efficiency measurement, described in AS 1359.102, are allowed:

- Method A, identical to method 1 of IEC 61972 and technically equivalent to method B specified in IEEE 112;
- Method B, based on IEC 60034-2 “summation of losses” test procedure.

Therefore, there are two tables for each efficiency level, depending on the method used to determine efficiency.

### **China [17]**

China first introduced Minimum Energy Performance standards in 2002 (GB18613: 2002). The standard has since been revised and substituted by GB18613: 2006 – “The minimum allowable values of energy efficiency and the energy efficiency grades for small and medium three-phase asynchronous motors”. The revised standard, based on the CEMEP-EU Agreement, established energy efficiency Grades (Grade 1, 2 and 3), grade 1 being the highest efficiency level.

The standard was enforced in 2007 and prevented motors with efficiency below the Grade 3 level (equivalent to IE1) from being manufactured or sold in the country. The minimum efficiency requirements were raised to IE2 levels in 2011 and further to IE3 until 2015. A label for IE4 efficiency motors is also expected to be introduced as a voluntary scheme.

It applies to general purpose motors (including explosion-proof) with 690V and lower voltage, 50Hz three-phase alternating current power supply, the scope of rating power between 0.55kW to 315kW for grade 2 (IE2) and grade 3 (IE1), and 3KW to 315KW for grade 1 (IE3), the numbers of poles are 2, 4 and 6, single-speed close fan-cooled and N design.

Motor efficiency should be tested according to the method of Loss Analysis prescribed in GB/T 1032. In where, the stray loss of motors is calculated as 0.5% of rated input power. This test method is described in IEC 60034-2-1 as being a medium uncertainty test method and is

therefore, not accepted as a valid test method in the IEC60034-30 classification standard. Provisions are being taken to revise GB/T 1032 in order to coordinate it with IEC standards.

MEPS for small motors were recently enforced in China (GB 25958-2011 - Minimum allowable values of energy efficiency and efficiency grade for small-power motors)

This standard applies to small three-phase asynchronous motors (10W - 2.2kW), capacitor-run asynchronous motors (10W - 2.2kW), capacitor-start induction motors (120W - 3.7kW), double-value capacitor induction motors (250W - 3kW) for general purpose with the voltage  $\leq$  690V, 50Hz AC power, and also to fan motors for room air conditioner (6W - 550W).

A labelling and financial incentive scheme for Medium Voltage (6000V) and High Voltage (10000) three-phase asynchronous motors is also being introduced. It covers motors in the 355 kW to 25000 kW power range.

In 2009, an energy labelling scheme for VSDs was introduced, covering variable frequency speed regulation devices using three-phase AC power supply, which voltage is no higher than 660V, frequency of 50Hz, and power no bigger than 315kW.

### **Rest of the World**

Other countries are recognizing the importance of energy efficiency in electric motors and its potential economic and environmental impact and are working on developing mandatory minimum energy performance standards to be implemented in the near future. These standards are expected to follow the IEC 60034-30 classification.

Some examples of foreseen regulation include:

Japan: IE2 expected for 2012

- 220/220/400/440 V, 50/60 Hz, 0.2 – 160 kW, 2 – 6;

India: IE2 expected for 2013

- 415/690 V, 50 Hz, 0.37 – 315 kW, 2 – 8 poles;

Israel: IE3 expected for 2015

- 400 V, 50 Hz, 0.75 – 185 kW, 2 – 8 poles;

United Arab Emirates: IE2 expected for 06/2011 (based on EC Nr. 640/2009 European Union) with recommendations;

- 400 V, 50 Hz, 0.75 – 375 kW, 2 – 6 poles;

#### **1.3.1 WEEE Directive (Directive 2002/96/EC)**

With the purpose of preventing waste of electrical and electronic equipment (WEEE), the EU adopted Directive 2002/96/EC imposing responsibility on producers for the environmental impact of the disposal of such waste.

Furthermore, it states that Member States should encourage the design and production of electrical and electronic equipment that facilitates reuse, recycling and other forms of

recovery of such wastes in order to reduce them. Producers should not prevent, through specific design features or manufacturing processes, WEEE from being reused, unless such specific design features or manufacturing processes present overriding advantages, for example with regards to the protection of the environment and/or safety requirements.

In the WEEE Directive “electrical and electronic equipment” (EEE) is defined as:

- Equipment which is dependent on electric currents or electromagnetic fields in order to work properly
- Equipment designed for use with a voltage rating not exceeding 1000 Volt for alternating current and 1500 Volt for direct current;
- Equipment for the generation, transfer and measurement of such currents and fields

And cover EEE falling under the following categories (Annex IA of the WEEE Directive):

- Large household appliances
- Small household appliances
- IT and telecommunications equipment
- Consumer equipment
- Lighting equipment
- Electrical and electronic tools (with the exception of large-scale stationary industrial tools)
- Toys, leisure and sports equipment
- Medical devices (with the exception of all implanted and infected products)
- Monitoring and control instruments
- Automatic dispensers

Some electric motors, particularly in the small power range (120W to 750W) can be a part of some of the products included in the above categories and so responsibilities are believed to fall on the producers of the complete equipment. Separately sold electric motors do not fall in the scope of the WEEE Directive.

Furthermore, any equipment that is a part, component or subassembly of a fixed installation is also outside the scope of the WEEE Directive.

As a consequence, components (such as electric motors, variable speed motor drives, switchgear & controlgear products, etc.) of fixed industrial installations do not fall within the scope of the WEEE Directive, since they are not finished products, but part of equipment that does not fall under the scope of the WEEE.

### **1.3.2 RoHS Directive (Directive 2002/95/EC)**

The Restriction on the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Directive - RoHS) Directive 2002/95/EC – which took effect July 1, 2006 – restricts the use of certain hazardous substances in electrical and electronic equipment.

Member states should ensure that from that date forward, new products do not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE).

This directive covers electrical and electronic equipment as defined in the WEEE Directive and equipment falling under the categories defined in its Annex IA.

As mentioned earlier, some electric motors can be a part of some of the equipments covered by the directive. Therefore, producers of such equipment should ensure that none of the motors to be included in their equipment contain any of the hazardous substances mentioned in the directive.

## 1.4 Summary

This study will address electric motors that are not covered by the current European energy efficiency regulation (EC Regulation 640/2009) with special attention given to motors:

- outside the power range 0,75 kW to 375 kW
- in the 0,75 kW to 375 kW power range, but which are currently excluded from the Regulation, such as:
  - brake motors, other operation ratings
  - other technologies (single-phase motors, PM motor, SR motors, Special purpose inverter duty motors)

The recognised potential impact of motor controllers, such as VSDs and Soft-starters, on the efficiency of motor systems as been acknowledged and these products will also be evaluated in detail.

Motors will be divided into three categories based on output mechanical power:

- Small motors – 0,120 kW to 0,750 kW
- Medium motors – 0,750 kW to 375 kW
- Large motors – 375 kW to 1000 kW

Electronics controllers will be divided into two categories, based on apparent power handling capability:

- having a power handling capacity  $\leq 7.5$  kVA
- having a power handling capacity  $> 7.5$  kVA

Recently developed standards on motor efficiency testing and classification (IEC 60034-2-1 and IEC 60034-30), which harmonise different efficiency test methods and efficiency classification schemes in use around the world, allowed to overcome the difficulties manufacturers encounter when producing motors for a global market and helped to make a more transparent market.

Other standards in development regarding test methods for converter-fed motors (IEC 60034-2-3), and test methods and classification of Power Drive Systems and motor controllers (CLC 52800-x), will hopefully become the basis for efficiency standardization of these products with high potential for environmental impact reduction.

Almost all the major economies have some kind of voluntary or mandatory regulatory scheme regarding induction motor efficiency. An overview of different motor efficiency regulation in use around the world is given, showing an increasing stringency on the adopted efficiency levels.



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