Electric Motors and Variable Speed Drives

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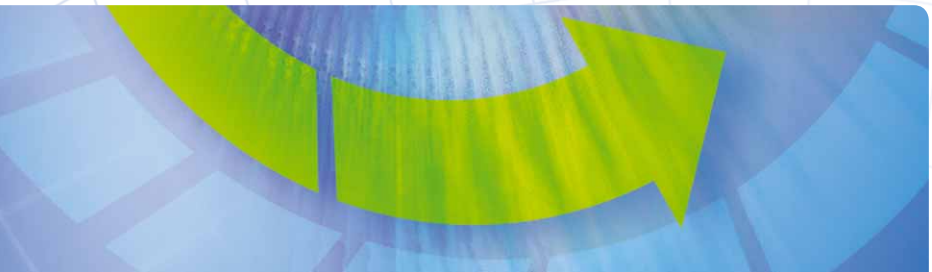


Introduction

The conservative and responsible use of energy to save resources, to reduce the amount of CO_2 emissions and to decrease energy costs is the order of the day. The electrical drive system plays a key role in this process. Electrical drives form the link between the electrical energy supply and the majority of mechanical processes, which require a large amount of energy. Machines driven by electrical motors consume 2/3 of all the electrical energy used in industry. If the old systems in German industry, commerce and public facilities, which have been running for decades, were all replaced by modern drive systems, this would result in annual energy savings of 38 billion kilowatt hours. Calculated for all of Europe, this figure would be 135 billion kilowatt hours. By using electronic speed control and energy-efficient motors, Europe's CO_2 emissions could be reduced by 69 million tonnes.

This brochure describes the new standardised international efficiency classes for standard three-phase motors, the new measuring methods and the requirements stipulated by the European Regulation 640/2009 of the European Commission for energy efficiency in motors and drive systems. This brochure also offers an overview of some of the world-wide existing national legislation and addresses subjects like material composition and life cycle cost.

The brochure is written for users, original equipment manufacturers (OEM), machine manufacturers and motor and drive system manufacturers.

1. Efficiency Classes of Motors and Measuring Methods

The „efficiency" describes how efficiently an electric motor transforms electrical energy into mechanical energy. Previously in Europe, low voltage three-phase motors have been graded and marketed in three efficiency classes – EFF3, EFF2 and EFF1 – based on a voluntary agreement between motor manufacturers and the European Commission. This classification system is well proven and has now been adapted in many countries around the world. Unfortunately, other countries have also developed their own national systems, which are very different from the European system. That was the reason for the German motor manufacturers in ZVEI, with the support of their European neighbours, to develop an energy efficiency standard for the International Electrotechnical Commission (IEC). The objective was to have a common international standard that replaces all the different national systems. This project was successful and the objective has been met.

The new international standard, IEC 60034-30:2008, defines efficiency classes IE1, IE2 and IE3 for three-phase motors. This ensures a common international basis for the design and classification of motors as well as for national legislative activities. At the same time, the IEC developed improved methods for determining the efficiency of these motors.

The international standards IEC 60034-30:2008 (classification) and IEC 60034-2-1:2007 (measuring methods) have been adopted as European standards without any changes as EN 60034-30:2009 and EN 60034-2-1:2007. For the sake of simplicity, the following sections will refer to the IEC standards only.

1.1 Previous efficiency classes of motors in Europe

In 1998, as part of the voluntary agreement between the European sector committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) and the European Commission, three efficiency classes were defined for the power range of 1.1 kW to 90 kW:

- EFF3 = Motors with a low efficiency level
- EFF2 = Motors with an improved efficiency level
- EFF1 = Motors with a high efficiency level

Note: In these guidelines, „motors" always refers to low-voltage three-phase motors.

1.2 New international standard for efficiency classes of motors (IE-code)

This voluntary agreement has since expired. However, the efficiency classes remain a registered European trademark. Use of the efficiency classes is based on a contractual licensing agreement between the participants in the voluntary agreement (motor manufacturers) and the license holder (CEMEP/Gimélec). This licensing agreement expires on 10 February 2010, but can be extended to 15 June 2011 upon request.

Standard IEC 60034-30:2008 defines the efficiency classes for low voltage three-phase motors with a power range from 0.75 kW to 375 kW. „IE" stands for „International Efficiency" and is combined with a number:

- IE1 = Standard efficiency
- IE2 = High efficiency
- IE3 = Premium efficiency

The measurement of the efficiency levels is carried out according to the procedure described in IEC 60034-2-1:2007 (see section 1.3).

Important: The new efficiency class (IE-code) of a particular motor must be determined using the new measuring methods (section 1.3).

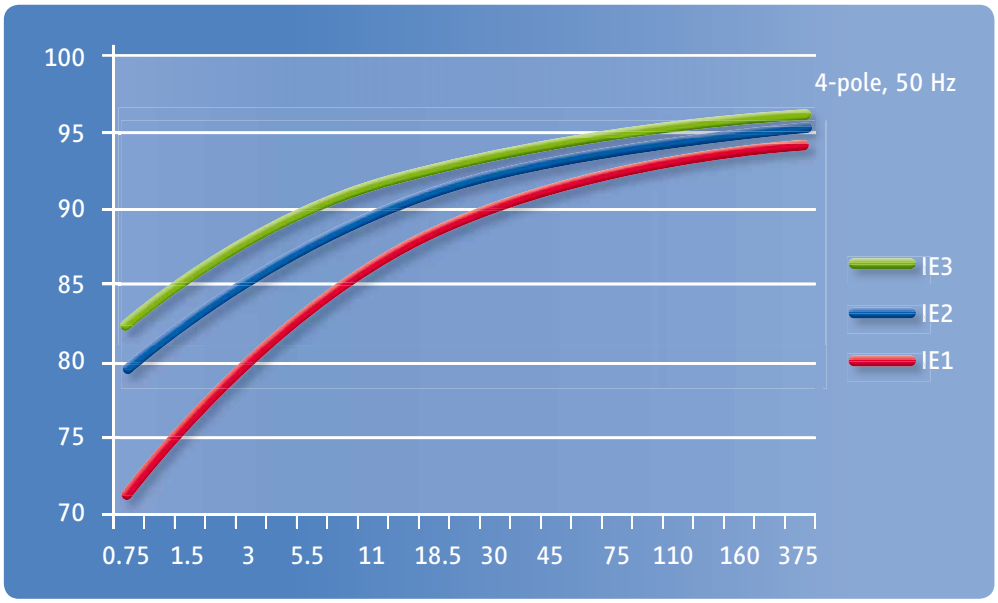


Image 1: International standard efficiency level curves (IE-code). Note: Excat values in section 1.6 efficiency classes

1.3 New IEC measuring methods

The new measuring methods in accordance with IEC 60034-2-1:2007 (standard methods for determining losses and efficiency from tests) apply for all motors described by IEC 60034-1. These methods help to generate more exact data regarding stray load loss. The new standard replaces the previous European standard EN 60034-2:1996, which expired on 1 November 2010. Motors that are marked according to the new efficiency class system (IE-code) are required to be measured using the new measurement methods.

1.4 Comparison of old and new efficiency classes

The new international efficiency class system (IE-code) has an open numbering system. Compared to the old EFF efficiency classes, it is now easier to add future developments. In addition, there is a new class – IE3 – which did not exist in the old European EFF classification system. The scope has also been extended significantly; the new IE-code applies to a larger power range as well as for the 60 Hz classes e.g. in the USA.

The main difference between the efficiency classes (EFF and IE) lies in the method used to determine them. In a direct comparison at the same motor, it is expected that the efficiency determined according to the new measuring method will be lower. For example, an 11 kW, 4-pole EFF1 motor with 91.0% efficiency is physically identical with a IE2 motor with 89.8% efficiency.

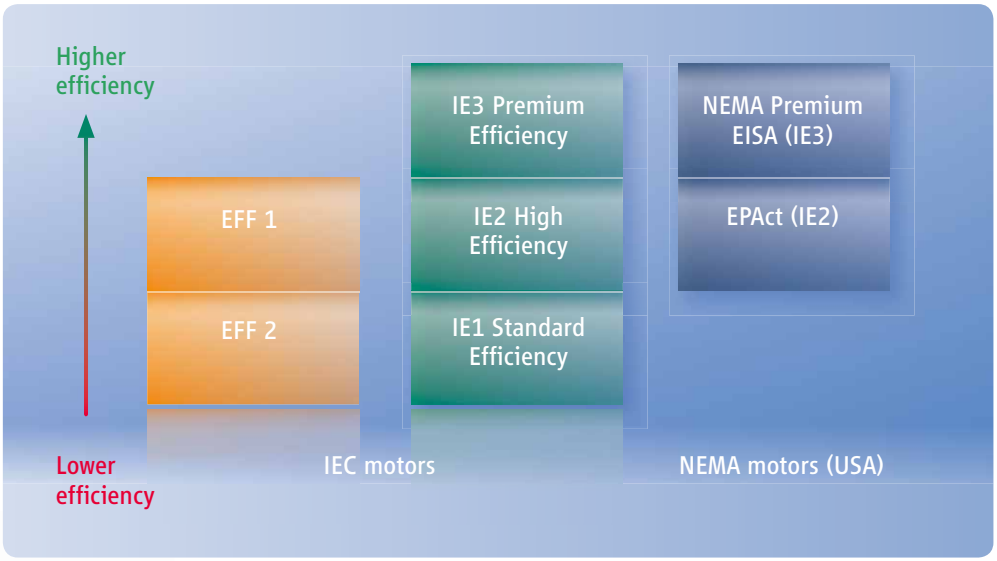


Image 2: Efficiency classes

1.5 Scope of new IEC efficiency class system (IE-code)

The efficiency class system specified under IEC 60034-30 is valid for low voltage three-phase cage-induction motors with the following specifications:

- Rated voltage up to 1,000 V
- Rated output between 0.75 kW and 375 kW
- Either 2, 4 or 6 poles
- Rated on the basis of continuous duty (S1) or intermittent periodic duty (S3) with cyclic duration factor of 80% or higher;
- Capable of operating direct on-line
- Rated for operating conditions in accordance with IEC 60034-1 (temperature, installation altitude, etc.)

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 are covered by this standard, although special shafts and flanges may be used in such motors.

Some motors covered by this standard may be equipped with auxiliary devices. However, as long as these auxiliary devices are not an integral part of the motor construction, the determination of efficiency in all possible combinations is not practical. Determinations for efficiency of such modified standard motors shall be performed on basic motors without auxiliary devices installed.

The following are exceptions to the classification system:

- Motors for short-time duty (S2) or switching operation (S3 < 80% to S10);
- Motors that were solely designed for converter operation (VSD) in accordance with IEC 60034-25 as well as
- Motors that have a highly specialised design customised for one particular application in such a way that it is not possible to measure the motor on its own (for example pump motors with wet rotors).

1.6 Efficiency classes IE1, IE2 and IE3

P_N in kW	IE1, 50 Hz			IE2, 50 Hz			IE3, 50 Hz		
	Number of Poles								
	2	4	6	2	4	6	2	4	6
0.75	72.1	72.1	70.0	77.4	79.6	75.9	80.7	82.5	78.9
1.1	75.0	75.0	72.9	79.6	81.4	78.1	82.7	84.1	81.0
1.5	77.2	77.2	75.2	81.3	82.8	79.8	84.2	85.3	82.5
2.2	79.7	79.7	77.7	83.2	84.3	81.8	85.9	86.7	84.3
3	81.5	81.5	79.7	84.6	85.5	83.3	87.1	87.7	85.6
4	83.1	83.1	81.4	85.8	86.6	84.6	88.1	88.6	86.8
5.5	84.7	84.7	83.1	87.0	87.7	86.0	89.2	89.6	88.0
7.5	86.0	86.0	84.7	88.1	88.7	87.2	90.1	90.4	89.1
11	87.6	87.6	86.4	89.4	89.8	88.7	91.2	91.4	90.3
15	88.7	88.7	87.7	90.3	90.6	89.7	91.9	92.1	91.2
18.5	89.3	89.3	88.6	90.9	91.2	90.4	92.4	92.6	91.7
22	89.9	89.9	89.2	91.3	91.6	90.9	92.7	93.0	92.2
30	90.7	90.7	90.2	92.0	92.3	91.7	93.3	93.6	92.9
37	91.2	91.2	90.8	92.5	92.7	92.2	93.7	93.9	93.3
45	91.7	91.7	91.4	92.9	93.1	92.7	94.0	94.2	93.7
55	92.1	92.1	91.9	93.2	93.5	93.1	94.3	94.6	94.1
75	92.7	92.7	92.6	93.8	94.0	93.7	94.7	95.0	94.6
90	93.0	93.0	92.9	94.1	94.2	94.0	95.0	95.2	94.9
110	93.3	93.3	93.3	94.3	94.5	94.3	95.2	95.4	95.1
132	93.5	93.5	93.5	94.6	94.7	94.6	95.4	95.6	95.4
160	93.8	93.8	93.8	94.8	94.9	94.8	95.6	95.8	95.6
200 – 375	94.0	94.0	94.0	95.0	95.1	95.0	95.8	96.0	95.8

Table 1: Efficiency classes for 50 Hz in accordance with IEC 60034-30:2008

P_N in kW	IE1, 60 Hz			IE2, 60 Hz			IE3, 60 Hz		
	Number of Poles								
	2	4	6	2	4	6	2	4	6
0.75	77.0	78.0	73.0	75.5	82.5	80.0	77.0	85.5	82.5
1.1	78.5	79.0	75.0	82.5	84.0	85.5	84.0	86.5	87.5
1.5	81.0	81.5	77.0	84.0	84.0	86.5	85.5	86.5	88.5
2.2	81.5	83.0	78.5	85.5	87.5	87.5	86.5	89.5	89.5
3.7	84.5	85.0	83.5	87.5	87.5	87.5	88.5	89.5	89.5
5.5	86.0	87.0	85.0	88.5	89.5	89.5	89.5	91.7	91.0
7.5	87.5	87.5	86.0	89.5	89.5	89.5	90.2	91.7	91.0
11	87.5	88.5	89.0	90.2	91.0	90.2	91.0	92.4	91.7
15	88.5	89.5	89.5	90.2	91.0	90.2	91.0	93.0	91.7
18.5	89.5	90.5	90.2	91.0	92.4	91.7	91.7	93.6	93.0
22	89.5	91.0	91.0	91.0	92.4	91.7	91.7	93.6	93.0
30	90.2	91.7	91.7	91.7	93.0	93.0	92.4	94.1	94.1
37	91.5	92.4	91.7	92.4	93.0	93.0	93.0	94.5	94.1
45	91.7	93.0	91.7	93.0	93.6	93.6	93.6	95.0	94.5
55	92.4	93.0	92.1	93.0	94.1	93.6	93.6	95.4	94.5
75	93.0	93.2	93.0	93.6	94.5	94.1	94.1	95.4	95.0
90	93.0	93.2	93.0	94.5	94.5	94.1	95.0	95.4	95.0
110	93.0	93.5	94.1	94.5	95.0	95.0	95.0	95.8	95.8
150	94.1	94.5	94.1	95.0	95.0	95.0	95.4	96.2	95.8
185 – 375	94.1	94.5	94.1	95.4	95.4	95.0	95.8	96.2	95.8

Table 2: Efficiency classes for 60 Hz in accordance with IEC 60034-30:2008

2. EuP Directive and EU Motor Regulation

The European Union set the environmental goal of reducing greenhouse gas emissions by 20% by the year 2020. Early measures taken to reach this goal were the ban on incandescent light bulbs and the specifications for the reduction of standby losses. The legal basis for these measures is the EuP Directive (2005/32/EC), adopted on 6 July 2005, which defines the requirements for the ecodesign of energy-using products. The EuP Directive forms the basis for numerous product-related directives. On 21 October 2009, a new version of this directive went into effect (2009/125/EC). This new directive expanded the requirements to include the ecodesign of energy-related products (ErP – Energy-Related Products). Germany's national version of this directive is the Energy-Using Products Act (Energiebetriebene-Produkte-Gesetz – „EBPG"), which is often referred to as the „ecodesign directive".

2.1 Commission Regulation (EC) 640/2009

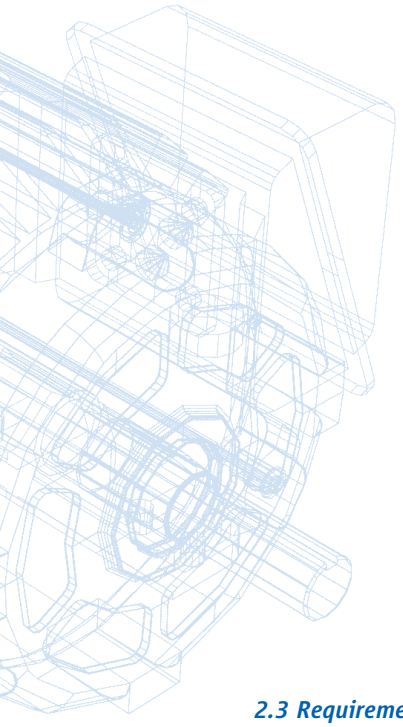
Commission Regulation 640/2009, adopted on 22 July 2009, specifies the requirements regarding the ecodesign of electric motors and the use of electronic speed control (VSD). These requirements also apply when these devices are integrated in other products (e.g. machines).

2.2 Scope and exceptions

The scope of the EuP Motor Regulation is more limited than that of IEC 60034-30. Both include low voltage three-phase cage-induction motors for 50 Hz or 50/60 Hz with the following properties:

- Rated voltage up to 1,000 V
- Rated output between 0.75 kW and 375 kW
- Either 2, 4 or 6 poles
- Rated for continuous duty

The differences between the EuP Motor regulation and IEC standard lie in the exceptions and in the additional operating mode, S3 (cyclic duration factor ≥ 80%).



The following are exempted from the EuP Motor Regulation:

a) Motors designed to operate wholly immersed in a liquid
b) Motors completely integrated into a product for which the energy efficiency cannot be measured independently of the product
c) Motors that are specially designed for operation under the following conditions:
   i) At altitudes exceeding 1,000 meters above sea level
   ii) Where ambient air temperatures exceed 40°C
   iii) At maximum operating temperatures above 400°C
   iv) Where ambient air temperatures are less than -15°C for any motor or less than 0°C for a motor with air cooling;*
   v) Where the water coolant temperature at the inlet to a product is less than 5°C or exceeding 25°C
   vi) In potentially explosive atmospheres as defined in Directive 94/9/EC of the European Parliament and the European Council (3)
d) Brake motors

2.3 Requirements and schedule

The individual requirements will come into effect in accordance with the following schedule:

- From 16 June 2011, motors placed for the first-time on the market shall have a minimum efficiency class of IE2.
- From 1 January 2015: motors with a rated output between 7.5 - 375 kW shall have a minimum efficiency class of IE3, or minimum IE2 if they are operated/equipped with electronic speed control (VSD).
- From 1 January 2017: motors with a rated output between 0.75 - 375 kW shall have a minimum efficiency class of IE3, or minimum IE2 if they are operated/equipped with electronic speed control (VSD).

Electronic speed control is carried out using a frequency converter (VSD) that adjusts the speed of the motor – and therefore the power produced – based on the energy needed. See section 3 for the detailed implementation strategy for this schedule.

* Note: The European Commission has confirmed that the word „air cooling" is a typing mistake and should be corrected into „water cooling". The current text of the directive is valid until further notice.

2.4 Scope of standard and directive

Standards function as recommendations that can be observed voluntarily by anyone. Standards are not legally binding, however they may become so as a result of legal regulations imposed by lawmakers or through contracts in which compliance is mandatory. They often serve to clarify undefined legal terms – for example the term „state of the art" – thereby gaining legal significance.

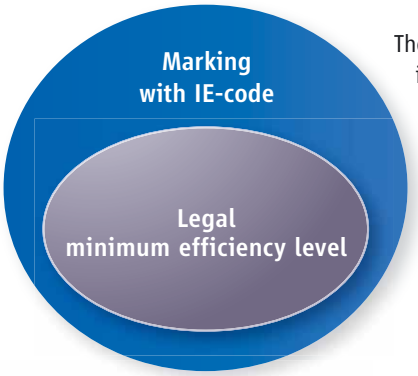


Image 3: Scope of standard and directive

The standard IEC 60034-30:2008 defines efficiency classes for motors, thereby creating a common international guideline. However, the standard itself does not specify whether motors are required to comply with a particular minimum efficiency class. This is specified by the applicable national laws and directives. In Europe, Commission Regulation 640/2009 specifies the minimum requirements.

Please note that the scope of the EU Motor Directive (section 2.2) is more limited than that of IEC 60034-30.

	Which motor falls under which scope?	Standard IEC 60034-30: 2008 Class markings for IE1, IE2, IE3	EuP directive/ Regulation 640/2009 Legal minimum requirement
1.	Standard three-phase induction motor 0.75 – 375 kW 2, 4, 6 pole, continuous duty, 50 Hz or 50/60 Hz *(Note: Also applies if the motor is integrated in a machine.)*	Yes *Note: Also S3 operating mode (cyclic duration factor ≥80%)*	Yes
2.	Standard three-phase induction motor with auxiliary devices (shaft seals, back-stops, speed sensors etc.) 0.75 – 375 kW, 2, 4, 6 pole, continuous duty, 50 Hz or 50/60 Hz *(Note: Measurement of efficiency without auxiliary devices)*	Yes *Note: Also S3 operating mode (cyclic duration factor ≥80%)*	Yes
3.	Geared motors	Yes	Yes
4.	Explosion-protected motors	Yes	No
5.	Brake motor: A motor equipped with an electro-mechanical brake unit operating directly on the motor shaft without couplings.	Yes	No
6.	Motors completely integrated into a machine (for example pump, ventilators, gear or compressor) of which the efficiency cannot be tested independently from the machine.	No	No
7.	Other types of motors (e.g. permanent magnet motors, pole-changing motors, motors for switching operation e.g. servomotors)	No	No

Table 3: Comparison of scope of IEC/EU Motor Regulation

2.5 Efficiency marking on motor

Each motor must be equipped with a rating plate. The data on the rating plate is specified in standard IEC 60034-1. This includes the efficiency level of the motor η at 100% rated load only. The Motor Regulation also requires the indication of the efficiency level at 75% and 50% rated load.

ZVEI is of the opinion that it is sufficient to indicate the efficiency level at 100% rated load on the rating plate only, as described in IEC 60034-1. It is considered to be sufficient to list the efficiency level at 75% and 50% rated load in the documentation of the product only. ZVEI has requested clarification from the European Commission. Note that the current text of the regulation remains valid until further notice.

3. Implementing the Requirements of the EU Motor Regulation

Image 4: CE marking

The manufacturer or an authorised representative must ensure that the motors conform with the requirements of Commission Regulation 640/2009. Just as for other European product requirements („CE Directives") the date of the „first-time placing on the market," and in certain cases, the „putting into service" of products determine the effectiveness of these requirements.

The following sub-clauses 3.1 to 3.6 are ZVEI positions that have been prepared based on legal requirements and European Commission publications regarding CE Directives.

3.1 Date of first-time placing on the market

Motors that were placed on the market before the deadline of 16 June 2011 may continue to be sold after the deadline. They may also be put into service and operated in accordance with the regulations in effect before that deadline.

Practical example
Manufacturer A, identified by name on or near the product, may place motors with an efficiency level lower than efficiency class IE2 in accordance with the scope of Directive 640/2009 on the market until 15 June 2011. These motors are considered to have been placed on the market legally if they have been transferred to another legal person (e.g. distributors, LTD sales company of the manufacturer) before this date. They may then be resold, put into service and used after the deadline of 16 June 2011.

3.2 Motors integrated into other products

Motors that were placed for the first-time on the market before the deadline of 16 June 2011 may also be integrated into other products after the deadline.

Practical example
A machine (e.g. compressor, pump) contains an integrated motor of efficiency class IE1 in accordance with Directive 640/2009. The manufacturer of this motor is identified by name on or near the integrated motor. The motor was first-time placed on the market before 16 June 2011 in accordance with the law. The machine with the integrated motor of efficiency class IE1 may be placed on the market and used even after the deadline of 16 June 2011.

By including motors that are integrated into other products, and which therefore are not first-time placed on the market as motors, the regulation prevents circumvention of the law by the purchase of imported products (e.g. machines).

Practical example
A pump, in this case a finished product that contains a motor in accordance with the scope of Directive 640/2009, is imported into the European community. The integrated motor must comply with the requirements of Directive 640/2009. In this case, this is the first time the motor is being placed on the European market as an integrated motor.

3.3. Spare motors

The regulation does not allow any exception for spare motors. Please note the requirements listed in sub-clause 3.1 „Date of first-time placing on the market".

Practical example
A motor of efficiency class IE1 may not even be placed on the market (for the first time) as a spare part after the deadline of 16 June 2011 in accordance with the scope of Directive 640/2009.

3.4 Consignment stock

There are different contracts for consignment stock. In practice, consignment stock refers to products held in the stock of a supplier or a service provider that belongs to the company of the customer (buyer). The products remains the property of the supplier until the customer removes it from the stock. The delivery date is considered to be the date upon which the product is removed from the stock. The invoice will be based on this date. However, in the act of placing the energy-using product in consignment stock (subject to or free of charge), the supplier is performing a first-time placing on the market of the product in question.

Practical example
Motors covered by the scope of Directive 640/2009 with an efficiency level lower than efficiency class IE2 that have been placed in consignment stock before the deadline of 16 June 2011, allowing the customer unlimited power of disposal, may be removed from the stock and used by the customer after the appointed date.

3.5 Putting motors with variable speed drive into service

Motors of efficiency class IE2 may also be placed on the market after the deadline of 1 January 2015, provided that they comply with certain conditions. These conditions stipulate that the manufacturer or an authorised representative must display a notice on the motor itself and in the product information that indicates that the motor in question may only be operated using electronic speed control, in accordance with the EuP Motor regulation. For motors of class IE2 that have been placed on the market before 1 January 2015 (2017), see sub-clause 3.1 „Date of first-time placing on the market".

3.6 Exports outside the European economic area

The following are not cases of placing products on the market in the sense of the ErP Directive 2009/125/EG[1] and its implementing regulations:

- if the product is exported from a manufacturer in a member state to a third country outside the European economic area (EEA).
- if a manufacturer's product is transferred to an exporter (traders or machine manufacturers) that then exports it outside the EEA independently or as an integrated component

Practical examples

- A manufacturer based in the European economic area (EEA) can produce and distribute motors of class IE1 within the scope of regulation 640/2009 even after 16 June 2011 insofar as these motors are exclusively intended for export outside the EEA. These motors cannot be labelled with the CE marking.
- A manufacturer in the European economic area (EEA) of machines integrates electric motors into its machines and exports these exclusively to countries outside the EEA. The integrated motors do not need to comply with regulation 640/2009 and other CE Directives and must not be labelled with the CE mark.

Note:
It it to be taken care that these motors are sold for use outside of the European economic area only.

3.7 Market surveillance

Market surveillance is the responsibility of the EU member states. The member states shall designate the authorities responsible for market surveillance and specify the necessary tasks, powers and organisational arrangements. In Germany, market surveillance is the responsibility of the federal state authorities. The German Federal Institute for Materials Research and Testing (Bundesanstalt für Materialforschung und -prüfung –„BAM") is responsible for coordinating the exchange of information between the federal state authorities in charge of market surveillance and the other EU member states. BAM supports the federal state authorities in the development of their surveillance concept and in the inspection of the effectiveness of their market surveillance methods.

[1] Replacement for the preceding EuP Directive 2005/32/EC

4. International Regulations for Energy-Efficient Motors

World-wide there are various national regulations for the use of energy-efficient motors. Some of these are currently in effect and some are still in progress. Table 4 provides an overview of the regulations in important industrial countries. We cannot guarantee that this table is complete, as this topic is currently being developed rapidly.

Country	Information:
Australia	http://www.energyrating.gov.au/man1.html
Brazil	http://www.inmetro.gov.br
Chile	http://www.sec.cl http://www.clasponline.org/clasp.online.worldwide.php?teststandard=1086
China	http://www.cnis.gov.cn http://www.energylabel.gov.cn
Canada	http://www.oee.nrcan.gc.ca/regulations/home_page.cfm
Korea	http://www.mke.go.kr/ http://www.co2.kemco.or.kr/
Mexico	http://www.sener.gob.mx/webSener/portal/ndex.jsp?id=19
Switzerland	http://www.bfe.admin.ch/themen/00507/04257/index.html?lang=de
South Africa	http://www.sabs.co.za http://www.sabs.co.za/index.php?page=electrorotating
U.S.A.	http://www.nema.org/gov/energy/efficiency/premium/

Table 4: Overview/selection of national energy efficiency regulations for motors

5. Material Composition of Motors

The ecodesign directive also affects the material composition of the relevant products. A study sponsored by the European Commission determined that it is the use phase rather than the manufacturing phase that determines the environmental characteristics of a particular motor. The European sector committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) determined average values for the material composition. Tables 5 through 7 show the most important materials used to manufacture motors in power ranges 1.1 kW, 11 kW and 110 kW in efficiency classes IE1 and IE2.

	1.1 kW motor, IE1		1.1 kW motor, IE2	
	Average kg/per kW	Tolerance	Average kg/per kW	Tolerance
Electrical steel	5.40	-	8.00	-
Other steel	1.50	-	1.60	-
Cast iron*	2.50	0.0 – 5.0	2.50	0.0 – 5.0
Aluminium*	1.70	0.5 – 2.5	2.00	0.5 – 4.0
Copper	1.24	-	1.90	-
Insulation material	0.05	-	0.05	-
Packaging material	1.00	-	1.00	-
Impregnating resin	0.30	-	0.30	-
Paint/Colour	0.10	-	0.10	-

Table 5: Typical material composition of a 1.1 kW motor in class IE1 or IE2

	11 kW motor, IE1		11 kW motor, IE2	
	Average kg/per kW	Tolerance	Average kg/per kW	Tolerance
Electrical steel	3.60	-	4.80	-
Other steel	0.95	-	1.00	-
Cast iron*	1.30	0.0 – 2.0	1.30	0.0 – 2.0
Aluminium*	0.90	0.2 – 1.5	1.00	0.25 – 1.8
Copper	0.64	-	0.90	-
Insulation material	0.02	-	0.02	-
Packaging material	0.90	-	0.90	-
Impregnating resin	0.10	-	0.10	-
Paint/Colour	0.05	-	0.05	-

Table 6: Typical material composition of a 11 kW motor in class IE1 or IE2

	110 kW motor, IE1		110 kW motor, IE2	
	Average kg/per kW	Tolerance	Average kg/per kW	Tolerance
Electrical steel	3.10	-	3.60	-
Other steel	0.67	-	0.70	-
Cast iron	3.00	-	3.00	-
Aluminium	0.18	-	0.20	-
Copper	0.54	-	0.60	-
Insulation material	0.01	-	0.01	-
Packaging material	0.50	-	0.50	-
Impregnating resin	0.05	-	0.05	-
Paint/Colour	0.01	-	0.01	-

**The tolerances for cast iron and aluminium are given because both materials are suitable for use in certain parts of the motors (e.g. the housing).*

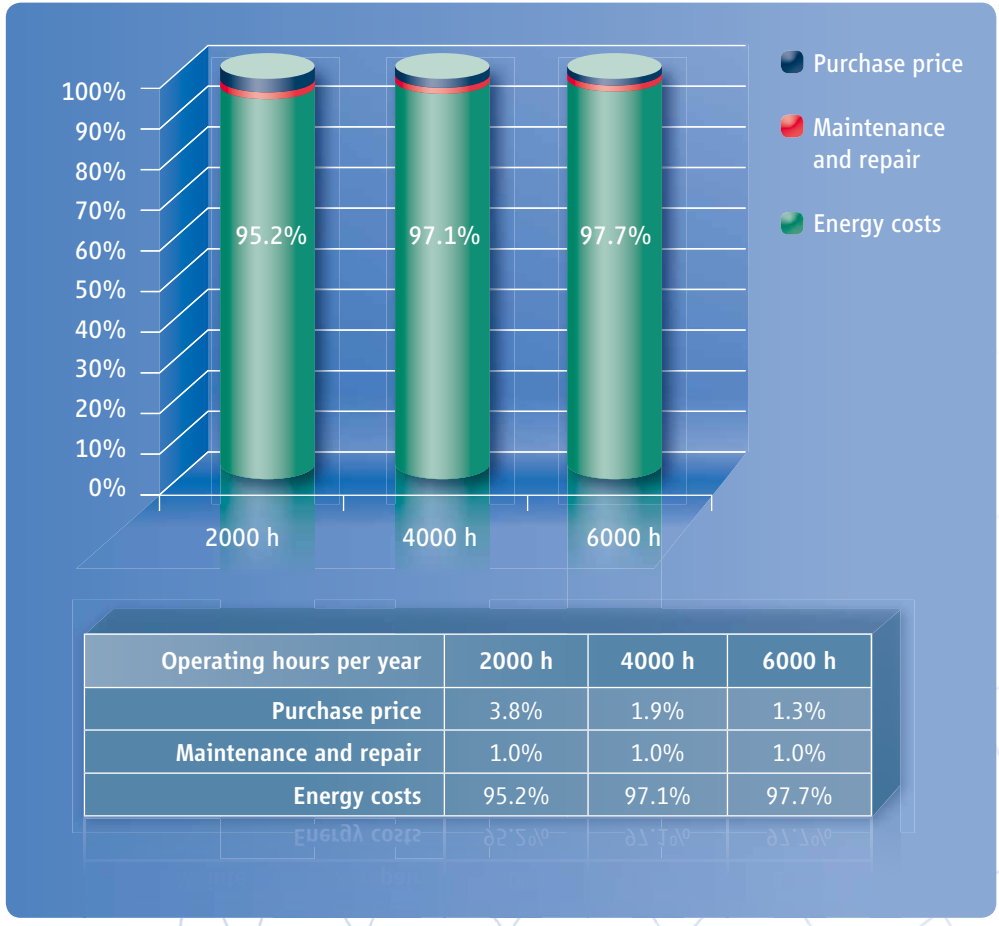
Table 7: Typical material composition of a 110 kW motor in class IE1 or IE2

The amount of material used increases with higher efficiency classes. Motors of efficiency class IE3 require a much greater use of materials than motors of efficiency class IE2. The purchasing price also increases for higher efficiency classes. In terms of the cost of the entire life cycle of the unit, in spite of the higher purchasing price, these motors pay for themselves within a relatively short time (see section 6).

6. Life Cycle Cost Analysis

The increased purchasing price for energy-efficient drive systems is often quickly recovered due to the total savings in energy costs. For this reason, it is important to conduct a life cycle cost analysis (LCC analysis) before making investment decisions in order to evaluate the total economic benefits of a particular drive system.

A very simple LCC analysis can be carried out for the motor as a component. The energy costs during the use phase are significant, leading to relatively short pay-back periods.



Operating hours per year	2000 h	4000 h	6000 h
Purchase price	3.8%	1.9%	1.3%
Maintenance and repair	1.0%	1.0%	1.0%
Energy costs	95.2%	97.1%	97.7%

Image 5: LCC analysis, 11 kW motors, life cycle 15 years, IE2
(Source: Preparatory Studies, EUP- Lot 11 Motors)

7. References

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- Directive 2005/32/EC establishing a framework for the setting of ecodesign requirements for energy-using products
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