ENGINEERING
TOMORROW

Danfoss

Ecodesign
We meet the **strictest requirements – yours**

EN 50598

Defines efficiency classes for frequency converters and motor-frequency converter systems

www.danfoss.com/vltecodesign

VLT®
THE REAL DRIVE

Definitions and scope of EN 50598

The EN 50598 standard defines efficiency classes for motor systems. The technical terms used for defining the classes are often unfamiliar to the general public.

Complete Drive Module

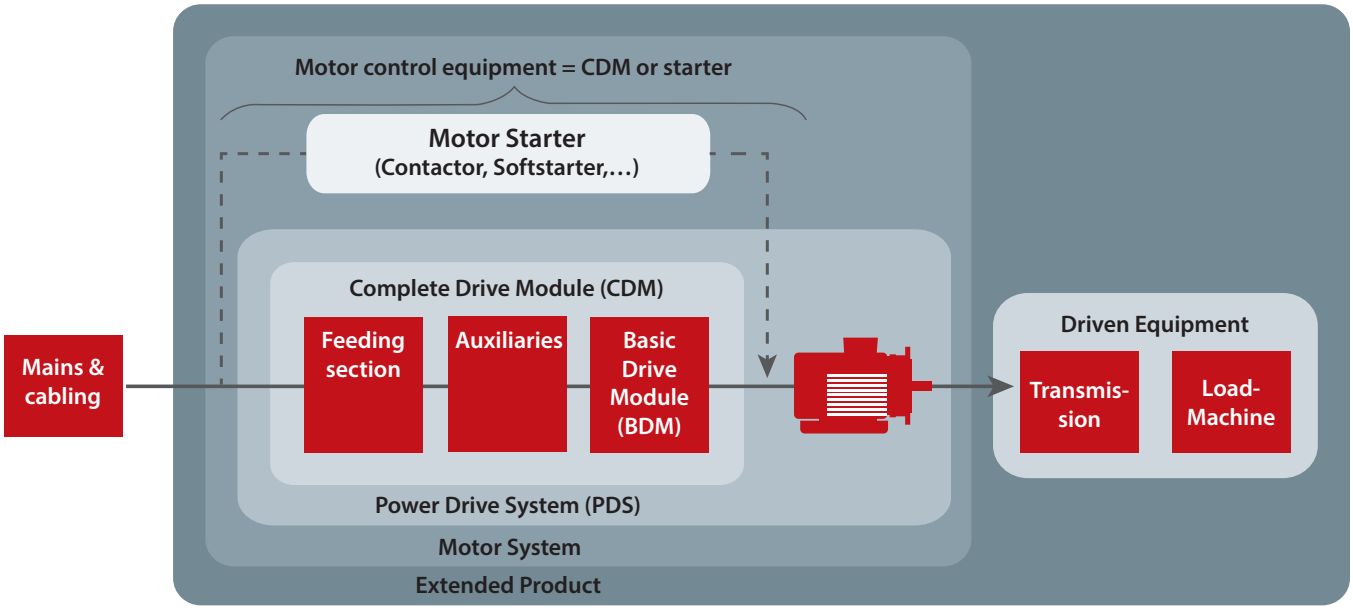
The complete drive module (CDM) consists of all components installed between the mains supply and the motor. It includes the power electronics components of the inverter and rectifier, auxiliaries such as protective devices, fans, auxiliary power supply transformers, cabling and filters. Components such as the RFI filter can also form part of the CDM.

Power Drive System

The Power Drive System (PDS) is the combination of motor and frequency converter. It consists of the CDM, the motor cable and the motor. The motor technology used is not specified – it can be any motor, for example an asynchronous, permanent magnet or synchronous reluctance motor.

Driven equipment

The driven equipment is the load machine, including mechanical transmission by means of belts or gears.



Extended product

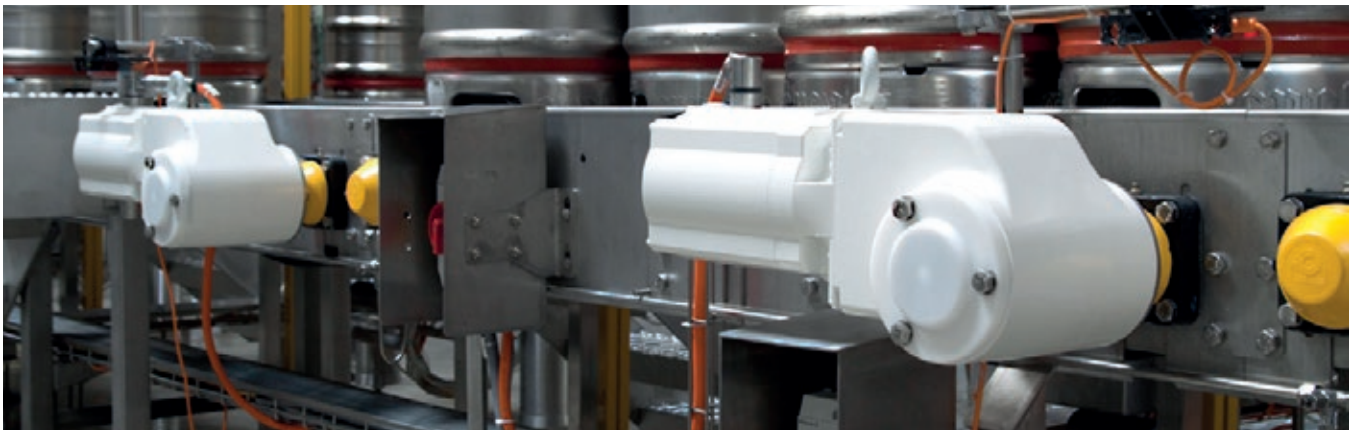
It is optimisation of the system, not the individual components, which ultimately saves energy in an application. This is why the extended product approach considers the effects of the combination of motor systems with load. The duty profile of the system is used to calculate the Energy Efficiency Index (EEI). The EEI is used to assess the energy efficiency of the system. The duty profiles and specific definition for EEI for different products are defined by the respective standardisation bodies.
The first standard to use this principle is a pump standard, due to be published in 2016.

Motor System

Control of the power supply to the motor is always required. The simplest solution is a switch. The PDS is a part of the Motor System.

VLT® fulfills the Ecodesign requirements

The Ecodesign Directive promotes energy efficiency improvements for a range of equipment including electric drives. In 2011 the EU introduced minimum requirements for the efficiency of AC motors. These requirements have been gradually intensified.



Similar to the IE classification of motors, EN50598-2 introduces IE classes for frequency converters and IES classes for frequency converter plus motor systems (known as power drive systems). The standard is published in early 2015.

The Danfoss VLT® frequency converter series already complies with the strictest requirements of this standard.

This means that VLT® frequency converters are classified as IE2 – the most efficient class. Of course, the efficiency measure includes the losses due to built-in RFI filters and DC chokes.

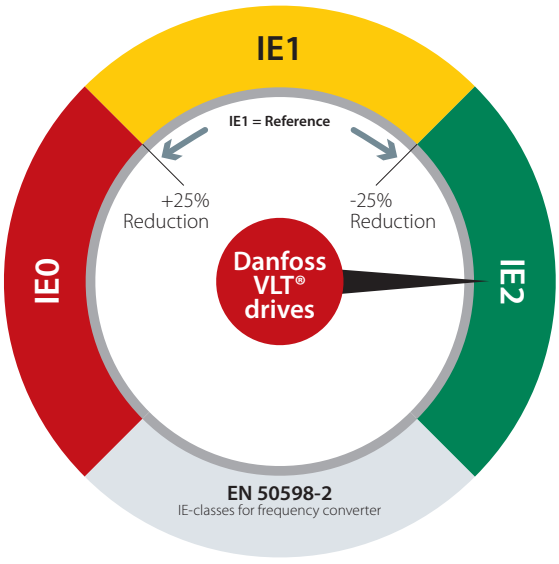
When the VLT® feeds a good IE2 motor or IE3/IE4 motor, then the system will achieve the highest IES class - IES2.

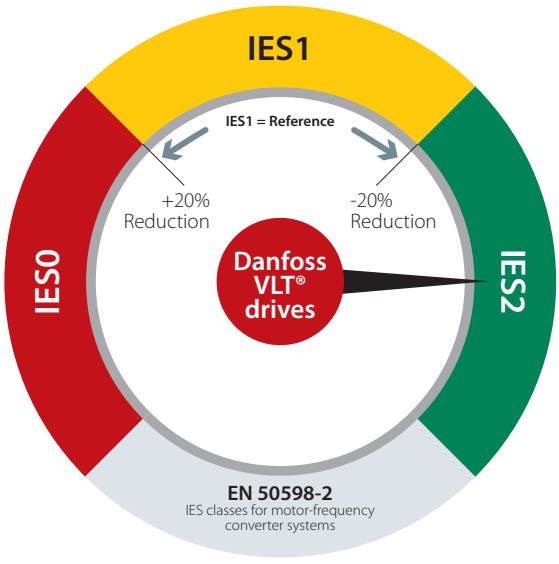
Danfoss publishes all information about IE/IES classes in manuals and online at: *www.danfoss.com/vltenergyefficiency.*

The part load losses for VLT® frequency converters according to EN50598-2 are also available at this site commencing early 2015.

Read more about the various energy efficiency classes in the following pages, including:

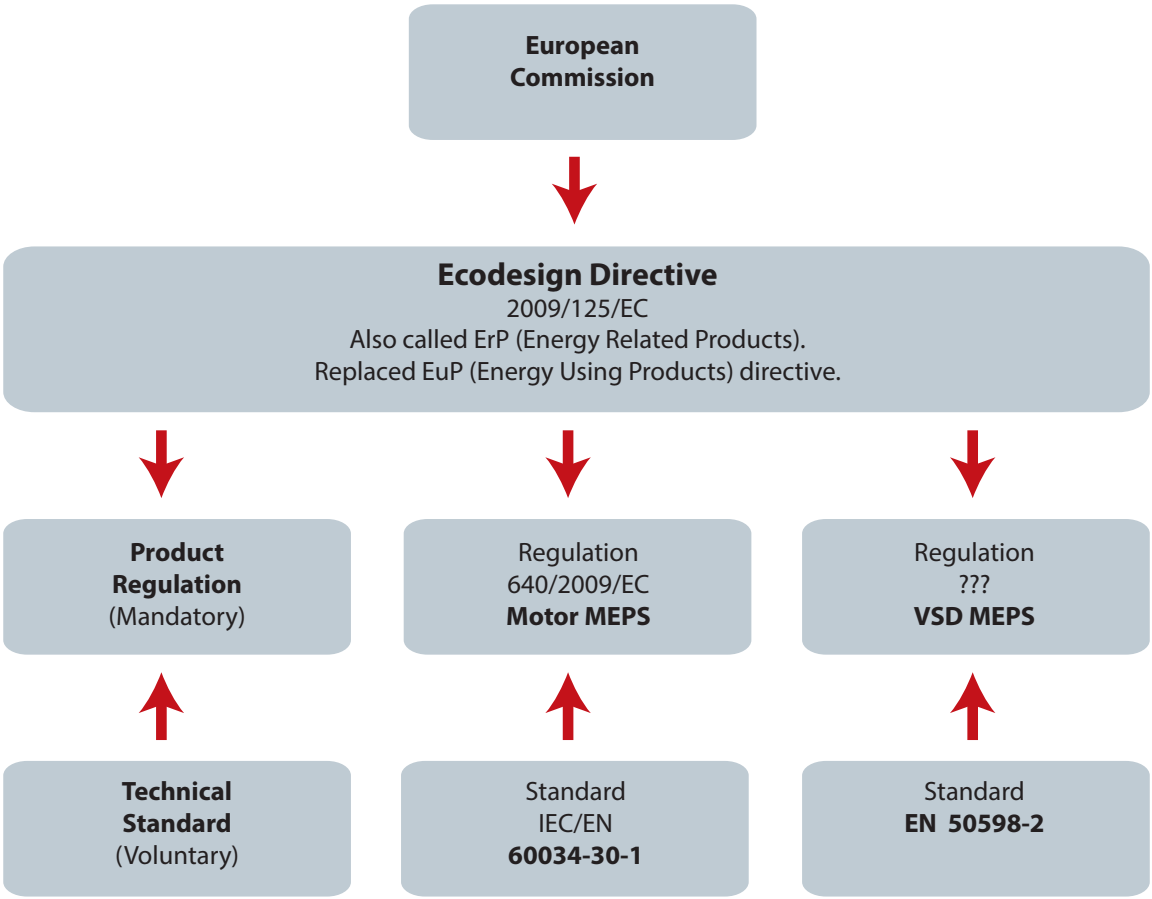
- Definitions
- Comparability of different products, systems and solutions
- Important design considerations
- Legal obligations





The Ecodesign Directive

The Ecodesign Directive aims to reduce the environmental impact of energy-related products during their entire lifetime. Therefore requirements are set for the design of the products.



Relationship between standards and regulation. Only parts of the standards are implemented in product regulation.

The Ecodesign directive is the Directive 2009/125/EC of the European Parliament and of the Council. It is also known as the Energy-related Products (ErP) Directive, because all energy-related products with potential for energy savings fall within the scope of the directive.

Focus on ErP is the main difference from the previous edition of the directive (2004/32/EC) which focused on Energy-using Products (EuP) only.

Legal requirements are set by a European regulation based on the Ecodesign directive. The regulation sets requirements for minimum efficiency performance standards (MEPS).

Principle and validity

Various energy efficiency-related regulations around the world are often based on the same technical standards. The differences between different countries and regions are the timing and the efficiency levels (IE2, IE3, etc.).

The Ecodesign requirements which are set for Europe can be easily compared with similar initiatives in North America or Australia.

Ecodesign requirements for motors

Minimum efficiency requirements (MEPS) for motors are defined by law. EU Commission Regulation 640/2009 defines a minimum efficiency class for a well-defined group of motors. In early 2014 the scope was extended by the amendment 4/2014.

Efficiency classes

The IEC 60034-30-1 standard defines efficiency classes IE1 – IE4. In the EU regulation only classes IE1 – IE3 are used.

Application of legal requirements

The requirements for minimum efficiency performance apply to most motors fulfilling these criteria:

- Duty types S1 (continuous running) or S3 (intermittent periodic duty) with turn on > 80%
- 2 to 6 poles
- Power range 0.75 – 375 kW
- Nominal voltage up to 1000 V

Comparability: good

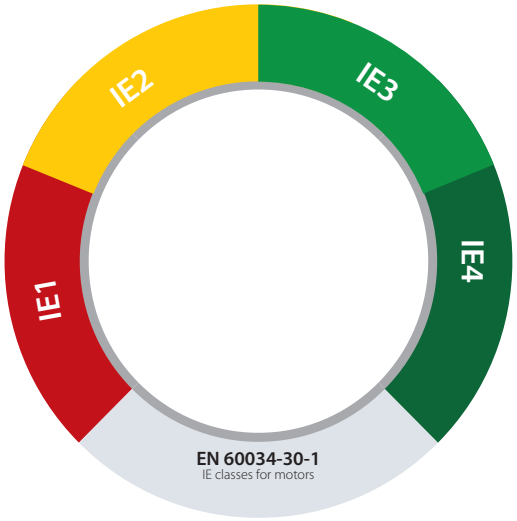
The minimum efficiency requirements (MEPS) provide a good comparability between motors. Remember that the classes have a certain "bandwidth".

Motors for use in the alternative to IE3 must be marked accordingly.

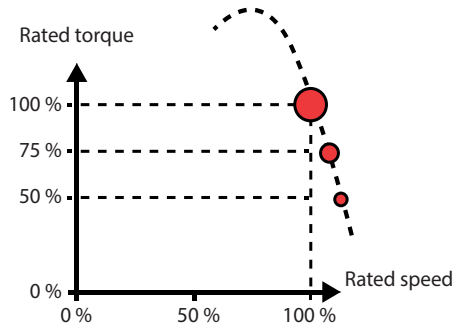
Step-wise intensification of requirements

Introduction date	Power range	MEPS	MEPS alternative
16.06.2011	0.75 – 375 kW	IE2	–
01.01.2015	0.75 – 7.5 kW	IE2	–
	7.5 – 375 kW	IE3	IE2 + frequency converter
01.01.2017	0.75 – 375 kW	IE3	IE2 + frequency converter

An additional intensification of the requirements is likely in 2018.



Motor IE classes according to IEC60034-30-1



= Nominal operation point, where IE class is defined
= Part load point according to standard

- IE classes are defined at the nominal motor load
- Efficiency levels for 50% and 75% rated torque at mains frequency need to be stated in the documentation
- The efficiency classes are defined for direct on line motors, independent of the motor technology
- Asynchronous motors with a higher efficiency typically run at a higher speed (RPM). Consider this in retrofit applications.
- Mechanical dimensions can vary depending on motor technology and IE class

Ecodesign requirements for frequency converters

Guidelines for assessing the efficiency of frequency converters are defined in the EN50598 standard. The standard is organised into several parts.

EN 50598-1:
Integration of the frequency converter and motor into an "extended product", for example, a pump.

EN 50598-2:
Definition of efficiency classes:

- Classes IE0 – IE2 for frequency converters.
- Classes IES0 – IES2 for power drive systems (frequency converter + motor).
- Also defines 8 points for partial load loss determination.

Efficiency classes
The EN 50598-2 standard defines the efficiency classes IE0 – IE2 for frequency converters. If a frequency converter has 25% greater losses than the reference value of IE1 then it is classified as IE0.

If a frequency converter has 25% lower losses than the reference value of IE1 then it is classified as IE2.

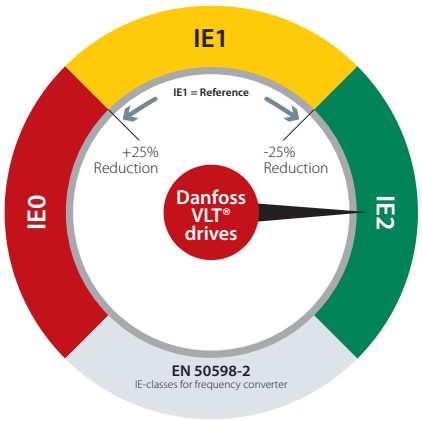
Applicability
The new standard covers frequency converters that meet the following criteria:

- Power rating range 0.12 kW – 1000 kW
- Voltage range 100 V – 1000 V
- Single axis AC/AC systems

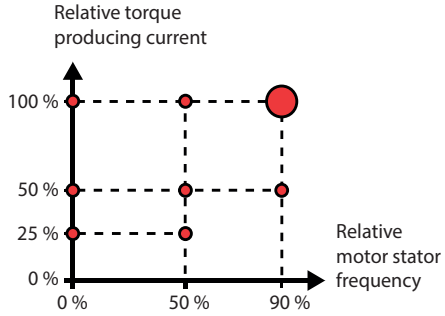
Frequency converters with active front end are out of scope for the classification, due to their typically higher losses.

Legal requirements
In Europe, minimum efficiency performance standards (MEPS) are expected at the IE1 level, in 2018.

Comparability: good
The IE classification is designated for a well-defined load, power factor and current. This enables an easy comparison of frequency converters based on efficiency classes.



IE classes for frequency converters according to EN 50598-2



= Nominal operation point, where IE class is defined
= Part load point according to standard

- The IE class is defined at an operating point of 90% frequency and 100% torque-producing current.
- Special test settings are not permitted.
- The classification for the frequency converter includes integrated options. Losses in options that are not built in (for example, EMC filters or chokes) are not included in the efficiency class but need to be documented if they
  - Comprise more than 0.1% of the rated frequency converter power, and
  - Are greater than 5 W.
- Losses at partial load can be documented by the manufacturer.

Ecodesign requirements for frequency converter – motor systems

IES efficiency classes for systems consisting of a frequency converter and a motor, are defined in the standard EN 50598-2.

The classification applies for:

- frequency converter and motor as separate components
- a "package" consisting of frequency converter and motor (PDS)
- products where the motor and frequency converter are integrated

Efficiency classes

The EN 50598-2 standard defines efficiency classes IES0 – IES2 for power drive systems (PDS). The width of the IES1 class is +/- 20%, unlike the +/- 25% of the IE class for frequency converters.

Applicability

Applicability is similar to IE classes for frequency converters:

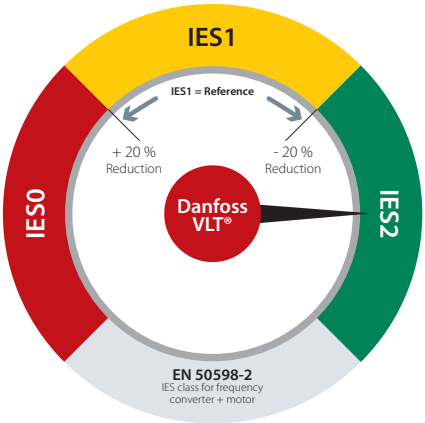
- Power range 0.12 kW – 1000 kW
- Nominal voltage 100 V – 1000 V
- Single axis AC/AC systems

Comparability: limited

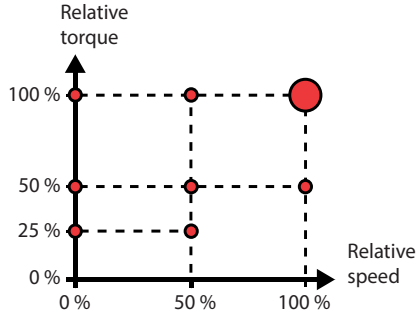
The EN 50598-2 standard defines the conditions for the determination of losses but it also permits deviations provided that they are documented. For example, different motor cable lengths, filter types, or motor types are permitted. These deviations make energy efficiency comparison of different power drive systems difficult.

Legal requirement

Regulatory legislation is not expected until at least 2023.



IES classes for power drive systems according to EN 50598-2:



= Nominal operating point, where IES class is defined
= Part load point according to standard

- The IES class applies for frequency converter – motor systems
- The IES class is defined at 100% speed and 100% torque
- The cable length between frequency converter and motor is defined. Deviations from the standard cable length or switching frequency are permitted, but must be documented
- Losses at partial load are documented by the manufacturer

Calculate PDS efficiency class based on frequency converter and motor data

For many applications the optimal solution is to combine frequency converters and motors which are sourced separately. The EN 50598-2 standard makes it possible to use such a combination. The efficiency class is calculated by addition of losses.
To determine the losses of the system, use the loss values for the individual components at the nominal operating point. Add together the losses of the frequency converter and the losses of the frequency converter-driven motor. The IES class is determined based on this sum, which represents the system losses. Use the same approach to determine system losses at a partial load operating point.

Reference loss values for motors and frequency converters

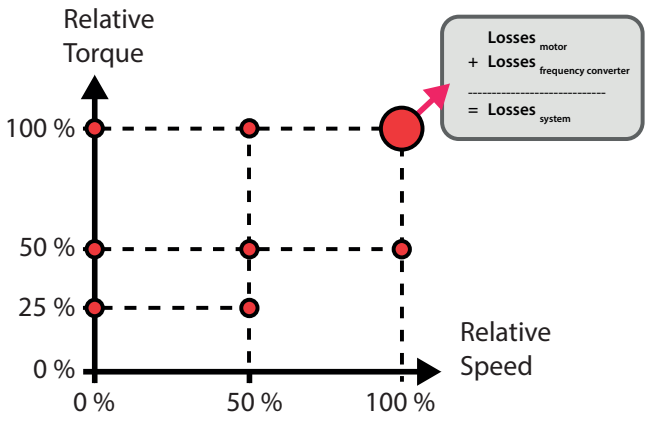
The standard defines loss values for so-called reference motors and reference frequency converters. These values are used to determine the IE or IES classes.

Calculation example

7.5 kW frequency converter (IE1) and motor (IE2)

Frequency converter losses:	675 W
Motor losses:	1032 W
System losses	1707 W

Determine the IES class from the table below, which is an extract from the standard EN 50598-2.



The system losses in the example are 1707 W, equating to efficiency class IES1.

Reference loss values for IES classification, EN 50598-2

Motor rating	IES0	IES1	IES2
3 kW	> 1138 W	758 W - 1138 W	< 758 W
4 kW	> 1397 W	931 W - 1397 W	< 931 W
5.5 kW	> 1754 W	1170 W - 1754 W	< 1170 W
7.5 kW	> 2161 W	1441 W - 2161 W	< 1441 W
11 kW	> 2851 W	1901 W - 2851 W	< 1901 W
15 kW	> 3596 W	2398 W - 3596 W	< 2398 W

What does Ecodesign mean for my drives applications?

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The Ecodesign standards and regulations have an important impact on energy savings and will in the future save energy in your application too.

Using efficiency classes increases the visibility of the efficiency of components. As a consequence, inefficient components will gradually disappear from the market. For example, IE1 motors.

The IE classes for motors and frequency converters enable comparison of components from an energy efficiency perspective. In the case of IES classes for frequency converter – motor systems the comparison is more difficult, as the exact conditions and components included in the system need to be known.

What do I need to comply with?

Users often experience situations where they need to know which technical requirements are legally mandatory and which are "on a voluntary basis", in order to fulfill technical standards.
The answer is not always easy and might even require advice from a legal counsel. The table at the bottom of this page summarises differences between legislation and standards. Of course, users and manufacturers can follow technical standards such as EN 50598-2 based on a mutual agreement.

Future developments

IE classes for motors are well known and have been around for some time. Users and manufacturers are experienced in using these classes and understand their advantages and disadvantages.

The new European standard EN 50598-2 defines efficiency classes for frequency converters and frequency converter – motor systems for the first time.

Work has begun within the International Electrotechnical Commission (IEC) to develop an international standard equivalent to EN 50598. The designation for the new IEC standard will be IEC 61800-9.
The general principles of the IEC standard will most probably correspond to those of the European standard. Some adaptations are required, for example for the use of 60 Hz frequency. The publication of the IEC standard will benefit international trade by enabling comparison between frequency converters and frequency converter – motor systems.

Differences between standards and legislation

Legislation is political documentation free of specific technical details.
The technical details are defined in standards. Compliance with legislation is mandatory – it is law, issued by the legislative branch of a national or supranational government. Standards are written by experts in relevant standardization bodies, for example:

- International Electrotechnical Comission IEC
- European Committee for Electrotechnical Standardization CENELEC.

Standards reflect the technical state of the art. Their role is to establish a technical common ground for cooperation between market actors.

Comparison of legislation and standards:

Criteria	Legislation	Standard
Objective	Regulation and market surveillance	Represents the state of the art
Authors	Written by legislators	Written by technical experts
Use	Legally mandatory	Use is not mandatory
Availability	Available free of charge	Standards are sold by IEC, CENELEC and the fee covers the authoring and maintenance costs
Fundament	Technical statements and requirements are generally based on technical standards	The content is based on results from the scientific and industrial community
Examples	EU Commission regulation 640/2009 sets MEPS for 50 Hz motors. Mandatory classes IE1 – IE3.	Standard IEC60034-30-1 defines efficiency classes for 50/60Hz motors: IE1 – IE4. Standard EN50598 defines efficiency classes for frequency converters: IE0-IE2.

What does Ecodesign mean for my drives applications?

Important criteria for selection of motor or frequency converter-motor system

Motor manufacturers employ a variety of concepts to achieve high efficiency in electric motors. In addition to the tried and tested three-phase asynchronous motors, permanent magnet (PM) motors and synchronous reluctance motors (SynRM) are now making their mark with the highest energy efficiency classes of all, for industrial and commercial use. All motor technologies in the same efficiency class provide comparable efficiency at the nominal operating point, but they differ in many aspects of performance, such as starting behavior or partial-load characteristics.

The following overview will present aspects that you should consider when selecting the right solution. Besides technical issues, also economy and logistics are considered.

Technology, dimensions and availability

First and foremost, the application naturally determines the motor characteristics. Which torque, at what speed, is required of the motor? What are the operating characteristics and are special motors required, for example submersible motors?

Perhaps the most critical requirement is compliance with permitted installation dimensions. For example, during service or retrofit, if the only motors available are too large for the existing installation dimensions, then significant challenges arise. Extensive reconstruction or extension work is inevitable.

The selected motor must also be suitable for frequency converter operation. This means that the motor insulation must be suitable for the pulsed output voltage of the frequency converter. This is not always the case, particularly for older motors. To be able to operate the motor also directly on-line, its operating characteristics must be suitable for the application. Without a frequency converter, unsuitable motors can cause problems. For example, a three-phase asynchronous motor with an aluminum rotor has a lower starting torque than the same motor with a copper rotor.

For more information about the differences between the various motor types, refer to the Danfoss brochure Motor technologies for higher efficiency in applications.

Logistics and commercial factors

The greater the diversity of motor technologies used in an installation, the higher the cost of storage. The motor frame size also plays a role in determining the extent to which alternative motor technologies or replacement motors can be used.

Due to limited ordering volumes, the purchase price for motors based on new technologies is often significantly higher than for the well-established motor types, which have been produced in large numbers over many years. There are hidden costs in the delivery capability. The fewer the number of manufacturers offering a particular technology, the more vulnerable the customer becomes to price increases, or regional or global delivery bottlenecks.
Three-phase asynchronous motors are available worldwide in standardised frame dimensions. However, this does not apply to all motor technologies or for high-efficiency three-phase asynchronous motors. In a service situation, if no suitable motor is available locally, and delivery is only possible using long and expensive shipping methods, then this limitation can be very expensive. Alternatively, the operator must establish and maintain local stock.

One frequency converter for all motor types

In principle, nearly all motors can be monitored with predefined voltage values at defined frequencies, the so-called U/f characteristic. However, the theoretical efficiency of each motor technology can only be achieved in practice with control algorithms specifically adapted to the individual technology.

Motor technologies for higher efficiency in applications

Being an independent manufacturer of drives, Danfoss supports all typical motor types and continues development to supoprt new technologies. Danfoss frequency converters feature optimal motor control algorithms for high-efficiency operation of:

- Asynchronous motors
- Permanent magnet (PM) motors
- Synchronous reluctance (SynRM) motors

Read more about these topics in the brochure „Motor technologies for higher efficiency in applications". It is available from your local Danfoss representative, or by download from ***www.vlt-drives.danfoss.com.***

Otherwise it is not possible to optimise operation for every operating point of the motor with variable load.
Nearly all common motor technologies require use of a frequency converter, or can be driven by a frequency converter. However, this raises an issue: can all of the motors on one site be operated with just one type of frequency converter?

If this is not the case, the site staff runs the risk of being compelled to work in a very heterogeneous system landscape. In practice, this means higher training costs for designers, operators and maintenance personnel, and higher costs for stocking parts for multiple equipment types. It is therefore a great advantage to operate all motor types with just one type of frequency converter. For example, as an independent manufacturer of frequency converters, Danfoss supplies a single solution able to drive all standard motors commonly used in industrial and building automation applications. This allows plant operators to use the same operator interface, the same system interfaces, the same extensions and proven, reliable technology over the entire power range - and throughout the plant. Spare parts management and maintenance are both simplified, and training costs drop.

Danfoss frequency converters have traditionally offered optimised control algorithms for high efficiency operation of standard asynchronous and PM motors. Now new control algorithms are available, optimised for SynRM motors. Danfoss also simplifies commissioning and service with helpful functions.

A good example is the automatic motor adaptation (AMA) functionality, which measures the motor characteristics and optimises the motor parameters accordingly. In this way, the motor always works in a highly efficient manner. The operator saves energy and reduces costs.

Consider this!

Pre-defined frequency converter-motor bundles offer only limited differentiation possibilities in regional or global markets – both technically and commercially.

By contrast, Danfoss will support you in selecting the optimal motor technology and the dedicated frequency converter for your application!

Factors to consider when selecting motors and frequency converter-motor systems

Technical requirements	Logistical considerations	Commercial considerations	Service and maintenance
■ Compliance with specified efficiency class ■ Available space and motor size ■ Operating conditions (start, direct on line operation, etc.) ■ Customer specifications	■ Motor and frequency converter stock ■ Motor size (not compatible with IE1) ■ Regional availability ■ Delivery time	■ Lifetime cost, total cost of ownership ■ Motor price ■ Raw material additional cost ■ Transportation cost ■ Savings through higher energy efficiency	■ Regional/global availability ■ Number of motor and frequency converter variants on site ■ Knowledge about maintenance and commissioning ■ Training availability

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The vision behind VLT®

Danfoss is a market leader in the development and manufacture of frequency converters – serving new customers daily.

Environmental responsibility

Danfoss VLT® products – considering people and the environment
All production sites for VLT® frequency converters certified to ISO 14001 and ISO 9001.
Danfoss' activities take employees, jobs and the environment into consideration. Production processes produce minimum noise, emissions and other environmental impacts. In addition, Danfoss seeks to protect the environment when disposing of waste and end-of-life products.

UN Global Compact
Danfoss has confirmed its commitment to social responsibility by signing the UN Global Compact. Our subsidiaries are aware of their responsibility with respect to local conditions and practices.

Energy savings through VLT®
The energy saved in the annual production of VLT® frequency converters is as much as that generated by a large power station each year. Improved process control optimises product quality and reduces waste and wear on the production lines.

Dedicated to drives

Danfoss VLT Drives is a global leader in the area of drive engineering and manufacture. In 1968 Danfoss introduced the world's first mass-produced frequency converters for three-phase motors, and since then has specialised in drive solutions. Today, VLT® stands for reliable technology, innovation and expertise for drive solutions within many different branches of industry.

Innovative and intelligent frequency converters

Danfoss VLT Drives, headquartered in Graasten, Denmark, employs 2500 staff for the development, production, consulting, sales and maintenance of Danfoss drive solutions in over 100 countries.

The modular frequency converters are manufactured according to customer requirements and supplied fully assembled. This ensures that every VLT® is a state-of-the art device when delivered.

Trust the world experts

To ensure the consistent high standard of quality of our products, Danfoss VLT Drives controls and monitors every important product element. The group has its own research and software development department as well as modern production facilities for hardware, power modules, printed circuit boards and accessories.

VLT® frequency converters are used in diverse applications worldwide. The experts of Danfoss VLT Drives support customers with extensive specialised knowledge relating to specific applications. Comprehensive advice and a fast service ensure an optimal solution with high reliability and availability.

A project is only complete when our customers are fully satisfied with the drive solution.