Policy Guidelines for Motor Driven Units

Part 1: Analysis of standards and regulations for pumps, fans and compressors

October 2016

4E Electric Motor Systems EMSA

4E Energy Efficient End-use Equipment International Energy Agency

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Authors
Maarten van Werkhoven, EMSA Operating Agent
Rita Werle, EMSA Coordinator
Conrad U. Brunner, EMSA Task Leader International Standards

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4E Electric Motor Systems Annex (EMSA)

Electric motor systems in industrial plants, infrastructure applications and buildings that drive pumps, fans, compressors and other equipment, are responsible for 45 % of the world's total electricity consumption. New and existing technologies offer the potential to reduce the energy demand of motor systems across the global economy by 20 % to 30 %. The know-how to realise energy savings exists but is not widely applied.
The 4E Electric Motor Systems Annex (EMSA) promotes the opportunities for energy efficiency in motor systems by disseminating best practice information worldwide. It supports the development of internationally harmonised test standards and policies to improve the energy performance of new and existing motor systems.

Between 2008 and 2016, EMSA has:

- Contributed to the development of internationally harmonised and globally applicable technical standards for motor systems. EMSA participates in relevant International Electrotechnical Commission (IEC) standards committees and contributes independent research results.
- Established a global network of testing laboratories.
- Contributed to the SEAD Global Efficiency Medal Competition for Electric Motors.
- Helped to disseminate the messages of the IECEE (Worldwide System for Conformity Testing and Certification of Electrotechnical Equipment and Components) Global Motor Energy Efficiency Program.
- Expanded the Global Motor Systems Network to almost 5,000 contacts from more than 70 countries. Members include representatives of governmental bodies, international organisations, standards developers, researchers, motor systems efficiency experts, utilities, industrial end-users and manufacturers. Members receive the EMSA Newsletter in English, Chinese, Japanese, Russian or German, with updates on national and regional policy initiatives and EMSA's activities.
- Developed the Motor Systems Tool for engineers. The Motor Systems Tool helps to optimise the energy efficiency of a complete motor system.

The following reports related to motor systems have been published:

- EMSA Motor MEPS Guide (2009)
- EMSA Motor Policy Guide – Part 1 (2011)
- EMSA Policy Guidelines for Electric Motor Systems – Part 2 (2014)
- 4E Energy efficiency roadmap for electric motors and motor systems (2015)

Further information on EMSA is available at: www.motorsystems.org

4E Electric Motor Systems EMSA

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Summary

This Policy Guideline investigates policy options for harmonising standards and regulations for Motor Driven Units (MDUs) in two parts. This report (Part 1) describes existing standards and regulations. Part 2, to be published later, will provide recommendations for advancing standards and regulations and their harmonisation.

As shown in Figure 1 a Motor Driven Unit converts electrical power into rotational mechanical power and may consist of the following individual components: variable frequency drive, electric motor, mechanical equipment (e.g. gear, belt, clutch, brake, throttle) and a driven application (e.g. pump, fan, compressor, transport). Figure 2 shows two examples of MDUs.

Motor systems are responsible for 47 % of global electric energy consumption, or 9,370 TWh per year. Of this, energy use by pumps, fans and compressors account for 70 % [1]. This study therefore focuses pumps, fans and compressors.

An optimised MDU with energy efficient individual components matched together to meet the required task and load is able to yield energy savings of 20 % to 30 %, estimated be-

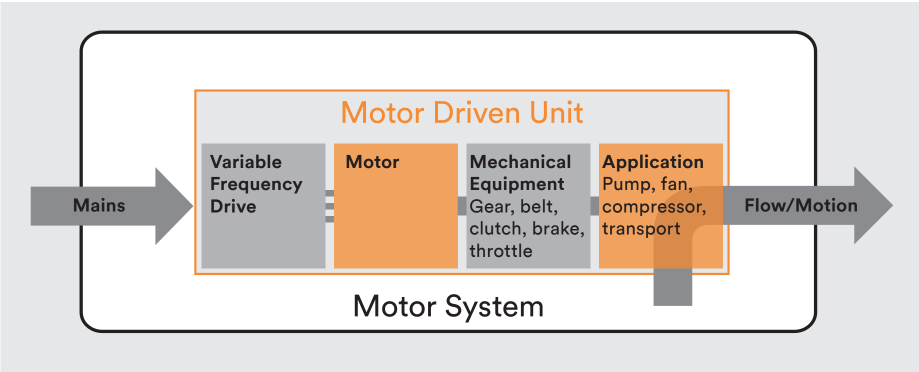

Figure 1: Motor Driven Unit definition. The orange boxes are components that are always part of a MDU

Fan-MDU: motor and fan
(Source: ebm papst, 2016)

Fan-MDU. Composition of one unit (from left to right): fan, mechanical equipment (belt), motor
(Source: Impact Energy, 2016)

Figure 2: Examples of Motor Driven Units

tween 1,900 and 2,800 TWh per year globally [1]. Standards underpin many energy efficiency regulations that apply to motors and other components within MDUs. Governments can stimulate the development and adoption of more energy efficient components and MDUs through setting mandatory Minimum Energy Performance Standards (MEPS) and increasing their stringency in subsequent years.

This study covers the following main global economies, accounting for 85 % of global electricity use of motor systems: Australia, Brazil, Canada, China, European Union (EU28 plus Switzerland, Norway and Turkey), India, Japan, Korea, Mexico, New Zealand, Russia, Saudi Arabia, South Africa and USA.

As of 2016 (see Table 1):

- 11 of the 14 countries studied have MEPS for motors. These countries account for 76 % of the global electricity use of motor systems.
- 4 countries have MEPS for pumps, covering 60 % of the global electricity use of motor systems.
- 3 countries have MEPS for fans, covering 43 % of the global electricity use of motor systems.
- 1 country has MEPS for compressors, covering 28 % of the global electricity use of motor systems.

Region (ranked by electricity use of motor systems)	**MEPS: yes / no *)**				**Electricity use **)**
	Motors	**Pumps**	**Fans**	**Compressors**	
China	y	y	y	y	28.3 %
USA	y	y	(y)	(y)	15.6 %
EU28 *)**	y	y	y	(y)	15.0 %
India	n	n	n	n	5.0 %
Japan	y	n	n	n	4.4 %
Russia	n	n	n	n	4.1 %
Korea	y	n	y+	n	2.7 %
Brazil	y	n	n	n	2.5 %
Canada	y	(y)	n	n	2.3 %
Mexico	y	y	n	n	1.4 %
South Africa	n	n	n	n	1.2 %
Saudi Arabia	y	n	n	n	1.0 %
Australia	y	(y*)	(y)	n	1.0 %
New Zealand	y	n	n	n	0.2 %
Electricity use (%) **)**	76 %	60 %	43 %	28 %	**85 %**

Notes

) (y) = under development; (y) = swimming pool pumps; y+ = domestic small fans;

**) % of global electricity use of motor systems, based on total electricity consumption (IEA 2014) of each country and its 5 major sectors;

***) Including Norway, Switzerland and Turkey

****) % of global electricity use of motor systems in countries with MEPS, April 2016

Table 1: Overview of existing policies for MDUs with MEPS in main economic regions (Source: CLASP's Global S&L Database, April 2016; World Bank 2014; IEA 2014; Appendix II of this report)

The current variety of regulated performance requirements across regions impairs the international trade of products. The current use of different terminology and definitions related to MDUs across regions makes it difficult to compare standards and regulations applied in different countries and can lead to confusion.
The analysis of the identified regulations for MDUs revealed a wide spectrum of **product definitions** per type of MDU (within the categories pumps, fans and compressors). Some of the diversity in the product definitions is explained by differences in climate and domestic markets (e.g. swimming pool pumps, fan systems, air conditioners), others by differences in the technology base used by local or regional manufacturers (e.g. fans together with motor and without).
The MEPS for each type of MDU (within the categories pumps, fans and compressors) show significant differences across countries regarding the:

- **Scope** – the components included in the MDU;
- **Metrics** – the determination of energy efficiency;
- **Methodology** – how the different components are included: default values, reference or test values, measured, calculated.

For pumps, which are most widely covered by MEPS, there are considerable differences in **scope**. In China, regulation for clean water pumps considers only one individual component, the impeller of a pump. The EU has two separate regulations for circulators and clean water pumps. For circulators the entire MDU of the integrated product is included; while for clean water pumps only the bare pump is included. In the USA the entire MDU is considered in the pump regulation, however, it applies to the MDU "as manufactured", i.e. this may include the bare pump, the motor and pump or the variable frequency drive, motor, pump.
In China, both the regulation for industrial fans and for centrifugal blowers consider only the fan as an individual component; while the EU considers all components within two different regulations: one for "fans driven by motors" and one for "ventilation units". In the USA, MEPS for industrial fans is under development.
Regulation for compressors is in place in China, and includes the compressor itself. In the EU and USA, regulations for air and natural gas compressors are under development.
The **metrics** and **methodologies** used to define efficiency within MEPS also differ between countries. China uses the input/output metrics in all types of MDU. In the EU and USA, the metrics used for clean water pumps show alignment regarding the metric efficiency (hydraulic pump efficiency), but differences in the used calculations and parameters, e.g. input/output of the pump itself in the EU vs. a relative index (pump energy index) using a reference pump, load profiles and duty points in the USA. These differences continue through the methodologies used: in the USA a calculation based and a testing based method is used, whereas the EU uses a testing based method. For the circulators the EU uses a relative efficiency index.
Many regulations for MDU-components (like motors, pumps) build on international IEC and ISO standards to define testing methods and performance classifications. In some cases countries adopt these standards without change into national standards, in other cases countries make alterations depending on specific national circumstances.
As countries/regions (EU, US) seek to establish minimum efficiency requirements for complete MDUs, they also consider appropriate testing, calculation methods and performance requirements. International standards for complete MDUs are not as advanced as for MDU-components and the need for further work in this area is evident, as illustrated by the development of ISO 12759 standard (Fans – Efficiency classification for fans, under revision) which originated from the EU regulations for circulators and fans.

Major findings

- **Products:** the differences in product definitions and/or categorisation of products within national MEPS regulations hinder analyses and international comparisons of coverage, metrics and efficiency levels.
- **Scope:** in all MEPS the efficiency of the target application (e.g. pump, fan) is within the scope and is required to be measured. The other components, if present and if included in the scope, are in most cases either accounted for by default values and/or calculated values. This does not lead automatically to encouragement of the most efficient MDUs.
- **Metrics and methodology:** efficiency may be defined by "input/output" or through "efficiency-indices" relative to a reference MDU. Calculation and test methods show some small and other larger differences, including aspects like specification of load and other parameters.
- International comparison of the product efficiency levels within national MEPS of MDUs per country is very difficult, due to the different product parameters used.

Currently the following regulations for MDUs are either under development or revision:

- Compressors (under development in the EU and USA)
- Fans (under revision in the EU, under development in the USA, in China efficiency levels under consideration)
- Pumps and motors (under revision in the EU)

Although regulators typically examine existing MEPS from other regions in the preparation of new or revised regulations, there appears no structured way of co-ordinating intelligence or closer alignment between regulators on aspects like product definitions and metrics.
For pumps, fans and compressors above 5 kW, many countries find it easier to define and implement individual component regulations. To develop and implement regulations for a Motor Driven Unit as a system consisting of several components is much more complex, and the enforcement of such regulations is also challenging.

In Part 2 of this study, further analysis will be undertaken to identify in more detail the actual differences of the specific **standards** and **policies** (under development, in effect or under revision). An action plan will be formulated for advancing and harmonising MDU standards and regulations, based on information and data on the differences on a component level and system level, with a focus on how to regulate components and MDUs and how to formulate policies for MDUs in new installations. The focus will be on those MDUs where on the short term most impact can be expected, and/or where regulators are aiming to develop and/or revise existing MEPS.

1 Introduction

1.1 Background

This Policy Guideline for Motor Driven Units (MDUs) investigates policy options for harmonising standards and regulations for Motor Driven Units. A Motor Driven Unit (MDU) converts electrical power into rotational mechanical power and consists of the following individual components: variable frequency drive (if available), electric motor, mechanical equipment (transmission, gear, belt, if necessary) and a driven application (pump, fan, compressor, transport, or other).

This Policy Guideline for MDUs was commissioned by the 4E Executive Committee in August 2015, following the 4E report "Energy efficiency roadmap for electric motors and motor systems" [6]. The current study was led by a working group of the 4E Electric Motor Systems Annex (EMSA). Outcomes of the work will be delivered in two parts:

1. **Existing standards and regulations:** Status quo of standards and regulations for MDUs in major global economies. Analysis of the countries covered regarding the scope, methodology and metrics of the requirements (this report).
2. **Recommendations for advancing and harmonising standards and regulations:** Coordination and steps for harmonising regulations for MDUs, their scope, metrics and methodology and to stimulate further countries to establish MDU regulations (upcoming report in the fall of 2017).

1.2 Short overview of the report

Section 1 gives an overview on the goal, covered regions and scope of this report. **Section 2** describes the scope of this report. It defines an MDU, explains energy use by MDUs and considers the potential benefits of improving the energy efficiency of the MDUs. **Section 3** describes the relevant IEC and ISO standards for MDUs. **Section 4** describes the methodology used to collect data and analyses data on standards and regulation for MDUs. **Section 5** contains the results detailed for motors, pumps, fans and compressors. **Section 6** describes the findings and the way forward.

1.3 Goal

The goal of these Policy Guidelines for MDUs (Part 1 and Part 2) is to recommend options for greater alignment between national policies, in particular Minimum Energy Performance Standards (MEPS) for MDUs. This Part 1 study focuses on comparing the following aspects of standards and regulations:

1. **Scope of standards and regulation**
   - What types, subcategories, combinations and sizes of products are included in regulations and standards?
   - What terminology is used to describe them?
2. **Efficiency metrics**

What different metrics are used:

- To determine the energy losses in the rated load condition at the test laboratory;
- To calculate the efficiency of the MDU (based on measured (mechanical) output over measured (electrical) input); or
- To alternatively define an efficiency index relative to an optimal reference machine.

3. **Methodology for establishing MEPS Requirements**
   - Which components of a MDU (VFD, motor, mechanical equipment, driven application) are included in the respective efficiency calculations?

- How are “missing” components (i.e. not manufactured by the same manufacturer and delivered to an industrial site as separate components) defined in the relevant national regulations and their underlying standards?
- Do these standards define components relative to a reference, default, or individually supplied component?

This analysis considers regulations that are already in force, in addition to those currently in draft stage (new and revised); and international standards, both published and currently in draft stage (see Table 3 and Table 4).

Benefits of alignment

Improved coordination and alignment of national regulations and international standards has the potential to provide important benefits for increasing energy efficiency in two ways. Firstly, it may initiate an intensive learning curve in industry through allowing consistent benchmarking of energy use between regions. Secondly, consistent regulation may ultimately facilitate the manufacturing and sales of globally accepted and tested more energy efficient components and systems. The global coordination of standards and MEPS is of benefit for manufacturers of MDUs, because it helps to avoid manufacturing and stocking of a large variety of MDUs to meet several efficiency levels. Also, it may reduce the repeated testing of the same products destined for different markets.

1.4 Covered regions

This report covers the main global economies, which account for 84 % of the global electricity use and 86 % of the global GDP (see Table 5). The economies have been grouped into 7 economic regions, and cover 44 countries:

1. USA, Canada, Mexico
2. European Union (EU28)[1], plus Switzerland, Norway and Turkey
3. China
4. Japan, Korea
5. Australia, New Zealand
6. Brazil
7. Russia, India, Saudi Arabia and South Africa

The first three regions are the three major economies in terms of GDP and electricity use: USA (incl. Canada and Mexico), European Union and China. They cover 65 % of the global GDP and 61 % of the global electricity use. The regions are shown in Table 2 on country level.
Some countries have already started establishing regulations for MDUs, reaping the next level of energy savings, with the European Union, the USA and China being the front runners. Therefore, the detailed analysis of this report focuses on these three main regions.

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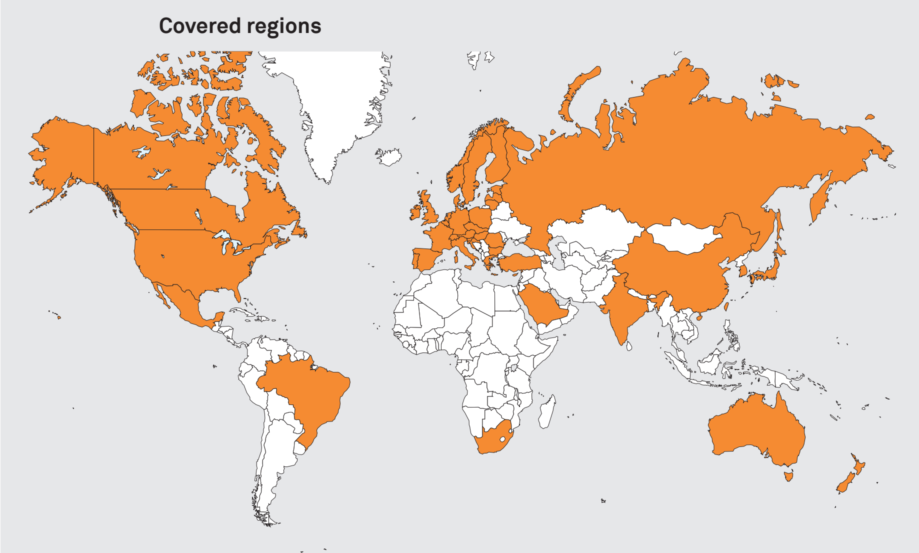
1 EU28 in this report refers to the 28 Member States of the European Union (EU) plus also Switzerland, Norway and Turkey. While Switzerland, Norway and Turkey are not part of the European Union, they are aligned with the Ecodesign regulation of the EU.



Ranking (on E-use)	Economy	Electricity use		GDP	
		(TWh/a)	% total	(bln US $)	% total
1	China	4716	23.8 %	10355	13 %
2	United States	3788	19.1 %	17419	23 %
3	European Union (28)*)	2872	14.5 %	19701	26 %
4	India	947	4.8 %	2049	3 %
5	Japan	951	4.8 %	4602	6 %
6	Russian Federation	738	3.7 %	1861	2 %
7	Brazil	501	2.5 %	2346	3 %
8	Canada	489	2.5 %	1785	2 %
9	Korea, South	487	2.5 %	1410	2 %
10	Saudi Arabia	272	1.4 %	746	1 %
11	Mexico	252	1.3 %	1295	2 %
12	Australia, New Zealand	247	1.0 %	1655	2 %
13	Turkey	205	1.0 %	798	1 %
14	South Africa	198	1.0 %	350	0 %
Total		16663	84 %	66372	86 %
World		**19836**	100 %	**77229**	100 %

*) including Switzerland and Norway

Table 2: Major economies by electricity use and Gross Domestic Product GDP (Sources: IEA 2014; World Bank 2014; CIA 2012, 2014)

2 Scope and focus on Motor Driven Unit

2.1 Scope

This report focuses on the Motor Driven Unit (see Figure 3), which consists of the following individual components:

1. Variable frequency drive, if available
2. Electric motor
3. Mechanical components (e.g. gears, belts, brakes and clutches), if necessary
4. Driven application

The MDUs covered in this study are specified according to their driven applications, i.e. pump-MDU, fan-MDU and compressor-MDU[2]. The electric motor itself is also covered because it is the main component of all MDUs[3] . Other driven applications apart from pumps, fans and compressors are not included in this report. Applications such as transport, industrial process and handling systems, are complex, individually designed and exist in a multitude of variations, making them difficult to regulate. Their share of electricity consumption and energy savings potential is also relatively small [5] (see Figure 5). The motors in these MDUs are in many cases covered by MEPS for motors.

Note: The Motor System has a wider border than the MDU. The MDU delivers a flow or a motion to an end-use equipment, for instance water for process cooling or cooling a machine. The Motor System can include all kinds of extra elements on the front end (other electric components e.g. transformers) and on the user end (e.g. ducts, pipes, throttles, heat exchangers). Figure 4 illustrates examples of different Motor Driven Units.

Variable frequency drive

While the variable frequency drive is one component of the Motor Driven Unit, this report does not specifically address VFDs because this topic has already been covered in the 4E Energy Efficiency Roadmap for Electric Motors and Motor Systems [6]. So far, no global energy performance standards or national MEPS exist for VFDs – although relevant standards are

2 In this report, the terms pump, fan and compressor refer to the actual Motor Driven Unit and are synonyms for pump-MDU, fan-MDU and compressor-MDU respectively.

3 EMSA uses the definition of MDU as a term that focuses on the driven equipment and includes the eventual mechanical equipment. "Extended Product Approach" (EPA) is a European definition which prioritises the driver (motor) over the driven equipment (pump) and does not include the mechanical equipment. See the definition of EPA under "Terminology and definitions".

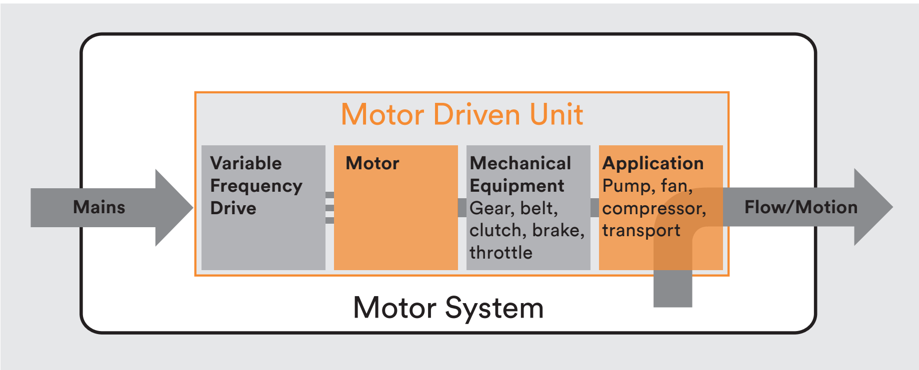


Figure 3: Motor Driven Unit definition. The orange boxes indicate the components that are always part of a Motor Driven Unit and that are of focus within this report.

under development within the IEC (see also Chapter 3).

The introduction of VFDs increases the savings due to better load control, but at the same time lowers the motor efficiency due to harmonics and additional losses from the converter. IEC standards for the combined use of motors plus VFDs are currently under development (IEC 61800-9-2[4]). So far, national regulations do not address this complex issue.

The use of variable frequency drives has the highest savings potential in applications with variable load (e.g. pump- and fan-MDUs[5]) compared to applications with constant load (e.g. conveyors).

2.2 Focus on Motor Driven Unit

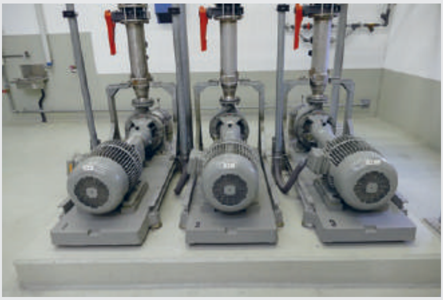
There are several reasons for focusing this report on the Motor Driven Unit and specifically on pump-, fan- and compressor-MDUs.

Electric motors have already been on the policy agenda for many years

Many economies around the world have recognised the high savings potential in electric mo-

4 Currently under development (FDIS 2016).

5 This is because closed loop pumps and fans use power exponentially with higher speeds.



Three pump-MDUs. Composition of one unit (from left to right): pump, mechanical equipment (clutch), motor (Source: Impact Energy, 2016)

Five circulators. One circulator is a complete Motor Driven Unit consisting of VFD, motor, pump (Source: Impact Energy, 2016)

Fan-MDU: motor and fan (Source: ebm papst, 2016)

Fan-MDU (from left to right): fan, mechanical equipment (belt), motor (Source: Impact Energy, 2016)

Figure 4: Examples of Motor Driven Units

tors and decided to set mandatory MEPS[6] for motors. Some economies have already tightened the stringency of their motor MEPS levels or extended the scope of covered products, as part of their efforts to regularly update regulations[7].
During the course of the last few years and in line with the policy agenda, EMSA has produced a number of publications proposing guidelines for policies concerning electric motors (see [6], [7], [8], [9]).
The attention of policy makers is now shifting from motors to systems, i.e. from an individual product to motors together with their driven applications.

High savings potential in systems

MDUs perform best if their individual components are energy efficient and matched together in an optimal way for the required task and load. A system optimisation will define the exact specification of the components to design an optimal energy efficient MDU. An optimised MDU is key to harvesting energy savings of 20 % to 30 % on average using the best available technology and suited to variations in demand and changing loads [1], [12].
The major driven applications used in motor systems are pumps, fans and compressors, responsible for approximately 70 % of the electricity demand by motor systems (see Figure 5).

6 Other policy types used in some countries are e.g. voluntary MEPS and label programs. See further policies for motors in [7] and [8].
7 See an overview of motor MEPS worldwide in [6].

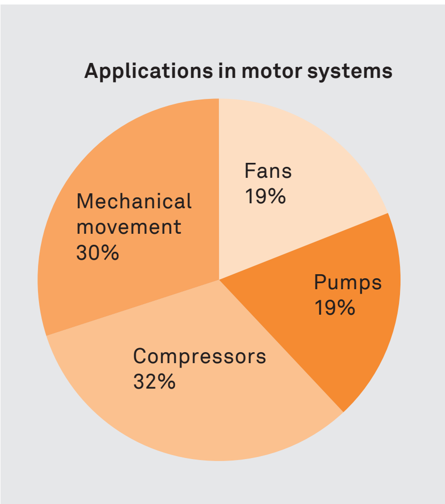


Figure 5: Estimated share of global motor electricity demand by application [1]

3 International standards

The global trade of electric motors has been greatly facilitated by a framework of international standards, defining testing procedures and a classification for energy efficiency. These standards, developed under the International Electrotechnical Commission (IEC), have been widely adopted and form the basis for the Minimum Energy Performance Standards (MEPS) that are now in force in most advanced economies and many developing countries. They allow the comparison of product performance and benchmarking across regions. The alignment of national regulations based on widely recognised international standards also reduces barriers to trade, enhancing international competition and higher efficiency of products.

The International Organization for Standardization (ISO) develops international standards for testing and performance classification of all kinds of machines and mechanical items e.g. industrial fans, fan wheels, pumps, pump impellers, compressors, compressor pistons, etc.

Internationally harmonised standards form a common base for national policies to increase the efficiency of MDUs. Basic regional conditions (variations in voltage, frequency, climate, etc.) are usually accounted for in these standards. This section gives an overview of the relevant international standards for motors and MDUs.

A number of IEC and ISO component standards are currently under revision and their scope is being expanded to cover issues relating to MDUs, such as:

- IEC TS 60034-2-3 (losses and efficiency classes of converter fed motors). Rotating electrical machines. Part 2-3: Specific test methods for determining losses and efficiency of converter-fed AC induction motors.
- IEC TS 60034-30-2 (efficiency classes for motors operated on variable speed). Rotating electrical machines. Part 30-2: Efficiency classes of variable speed AC motors (IE-code).

Also, new IEC and ISO standards are currently being published that cover the integration of the components within a MDU. Namely:

- IEC 61800-9-1 (losses and efficiency classes of MDU). Adjustable speed electrical power drive systems. Part 9-1: Energy efficiency of power drive systems, motor starters, power electronics and their driven applications – General requirements for setting energy efficiency standards for power driven equipment using the Extended Product Approach[8] (EPA) and semi analytic model (SAM).
- IEC 61800-9-2 (test methods and efficiency classes for converters and motors with converters). Adjustable speed electrical power drive systems. Part 9-2: Ecodesign for power drive systems, motor starters, power electronics & their driven applications – Energy efficiency indicators for power drive systems and motor starters.

IECEE Global Motor Energy Efficiency Programme

The IEC System of Conformity Assessment Schemes for Electrotechnical Equipment and Components (IECEE) launched the Global Motor Energy Efficiency Programme (GMEE) in 2015[9], based on the IECEE Certification Body Scheme. The goal of GMEE is to address trade barriers due to differing national regulations for motor efficiency, aiming to set up a globally harmonised and applicable programme. The Certification Body Scheme is based on IEC standards, with the main objective of realising the concept of "one product, one test, one certificate" through promoting the harmonisation of national standards with international standards [10]. Electric motors are the first product based on energy efficiency criteria to be included in the scheme.

8 See definition under "Terminology and definitions"
9 See IECEE Operational Document IECEE OD-2057 Edition 1.0

IEC-Standards		
Standard	Topic	Stage
IEC 60034-1:2010	Motor scope and tolerance	Published, revision pending 2017
IEC 60034-2-1:2014	Motor testing	Published
IEC TS 60034-2-3: 2013	Converter-fed motor testing	Published as Technical specification, revision pending
IEC 60034-30-1:2014	Efficiency classes for motors online (IE-code)	Published
IEC TS 60034-30-2	Efficiency classes for motors driven by converters	Draft Technical Specification (DTS)
IEC 61800-9-1	Efficiency classes and testing for converters and motors with converters and their driven applications	Final draft international standard (FDIS)
IEC 61800-9-2	Efficiency classes and testing for motors, converters and motor plus converters	Final draft international standard (FDIS)

Table 3: Relevant IEC standards (TS: Technical Specification)

ISO-Standards		
Standard	Topic	Stage
ISO 9906:2012	Rotodynamic pumps – Hydraulic performance acceptance tests – Grades 1, 2 and 3	Published
ISO 4409:2007	Pumps: Hydraulic fluid power – Positive-displacement pumps, motors and integral transmissions – Methods of testing and presenting basic steady state performance	Published
ISO 12759:2010	Fans – Efficiency classification for fans	Published, under revision
ISO 5801:2007	Industrial fans – Performance testing using standardized airways	Published
ISO 5802:2001	Industrial fans – Performance testing in situ	Published
ISO 16345:2014	Water-cooling towers – Testing and rating of thermal performance	Published
ISO 1217:2009	Displacement compressors – Acceptance tests	Published
ISO 5389:2005	Turbocompressors – Performance test code	Published
ISO 917:1989	Testing of refrigerant compressors	Published
ISO 11011:2013	Compressed air – Energy efficiency – Assessment	Published
ISO/ASME 14414: 2015	Pump system energy assessment	Published

Table 4: Relevant ISO standards

Testing capacity

MEPS depend on standards that define performance tests. In order to get accurate, reliable and repeatable energy performance values for components and MDUs for declaration and verification the measuring has to be performed in qualified testing facilities that have gone through an accreditation process (IEC ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories). It is important that also national reference laboratories exist that are independent of manufacturers" laboratories and can be used for check testing, round robins and training. Governments can support the development of capacity, training of staff and calibration of independent labs by using them regularly for product performance testing. If independent labs are not available in a country or region, laboratories in neighboring countries (e.g. in the framework of a bilateral or multilateral collaboration of countries) or accredited industry labs can be used.

4 Methodology

This section describes the methods used for collecting and analysing data on standards and regulations for MDUs in this report.

A survey was performed to collect and analyse the data on current standards and policies for motor driven units and specific components. In addition, data and information were collected on standards for testing and classification.

The research initially focused on the three major global economic regions: EU28, USA and China. The survey and analysis were performed in partnership with experts from these regions (Appendix III). Next, the focus was widened to include the other specified countries on their actual standards and regulations for MDUs (see section 1.4 Covered regions). This included input from a larger group of experts in the respective regions.

The results of this research are summarised in section 5 Results.

5 Results

5.1 Introduction

This section has a separate section per type of MDU: pumps, fans, compressors, as well as the motor itself:

1. Motors
2. Pumps
3. Fans
4. Compressors.

Motors are included since they have been the starting point for establishing MEPS and the motor is one of the two essential components of the MDU (see section 2 Scope). Each section has three tables with an overview per country/ region of:

a. Product group: overview of the product group and type within the relevant MEPS;
b. MEPS: details regarding the MEPS; what parts of the MDU are in the scope of the regulation, which metrics are used and what methodology is applied for setting the minimum requirements;
c. Test standards: details concerning the national and international test standards used within the specific countries.

Region (ranked by electricity use of motor systems)	**MEPS: yes / no *)**				**Electricity use **)**	**GDP ****)**
	Motors	**Pumps**	**Fans**	**Compres-sors**		
China	y	y	y	y	28.3 %	13 %
USA	y	y	(y)	(y)	15.6 %	23 %
EU28 ****)**	y	y	y	(y)	15.0 %	26 %
India	n	n	n	n	5.0 %	3 %
Japan	y	n	n	n	4.4 %	6 %
Russia	n	n	n	n	4.1 %	2 %
Korea	y	n	y+	n	2.7 %	2 %
Brazil	y	n	n	n	2.5 %	3 %
Canada	y	(y)	n	n	2.3 %	2 %
Mexico	y	y	n	n	1.4 %	2 %
South Africa	n	n	n	n	1.2 %	0 %
Saudi Arabia	y	n	n	n	1.0 %	1 %
Australia	y	(y*)	(y)	n	1.0 %	2 %
New Zealand	y	n	n	n	0.2 %	0 %
Electricity use (%) *)**	76 %	60 %	43 %	28 %	85 %	86 %
GDP (%) ***)**	79 %	64 %	42 %	13 %		

Notes
) (y) = under development; (y) = swimming pool pumps; y+ = domestic small fans;
**) % of global electricity use of motor systems, based on total electricity consumption (IEA 2014) of each country and its 5 major sectors;
***) % of global electricity use of motor systems in countries with MEPS, April 2016;
****) % of global GDP;
*****) % of global GDP of countries with listed MEPS, April 2016
******) Including Norway, Switzerland and Turkey.

Table 5: Overview of existing MEPS for MDUs in 14 countries, incl. EU28
(Data sources: World Bank 2014, [3], Appendix II)

Further details are shown in Appendix I regarding the scope of products within national MEPS regulations.
Further details are shown in extra tables for motors, pumps, fans and compressors in Appendix III.

5.2 Overview

The detailed analysis of the three major economies (EU28, USA and China) plus other countries, covering 85 % of the global electricity use and 86 % of the global Gross Domestic Product, shows the following picture of the status of MDU MEPS (see Table 5):

- Most countries have MEPS for electric motors (11 out of 14 countries);
- Four countries have MEPS for pumps;
- Three countries have MEPS for fans; and
- Only one country has MEPS for compressors.

Three out of the 14 countries do not have MEPS in place for any of the products under review, i.e. Russia, India and South Africa.
The first and positive result of the analysis is that 76 % of the global electricity consumption of motor systems (2014) and 79 % of the global Gross Domestic Product (GDP, 2014) is used in countries with MEPS for motors.
At the same time, the analysis also shows that 60 % of global electricity consumption of motor systems is used in countries with MEPS for MDUs with pumps, 43 % in countries with MEPS for MDUs with fans and 28 % in one country with MEPS for MDUs with compressors.

5.3 Motors

Product group and type

Amongst national MEPS for electric motors, asynchronous AC induction motors are the most frequently covered. The scope generally includes single and polyphase motors with an output power between 0.75 kW and 375 kW, with a voltage of 100 V to 1000 V (LV), operated with 2-, 4-, 6- and 8-poles at synchronous speeds between 750 to 3600 rpm in grids with a frequency of 50 Hz and/or 60 Hz. See Figure 6 for the electric motor typology according to voltage and output power.

In addition, the USA has MEPS in place for small motors (< 0.75 kW), as does China. Canada has regulations for small motors under development. China has MEPS in place for permanent magnet motors and for high voltage motors.
Table 6 gives an overview of MEPS on electric motors. Appendix I gives a more detailed description of the electric motors included in the different MEPS and Appendix III additional information on MEPS.

MEPS

The MEPS on motors consider the motor only, see Table 7. The motor efficiency is defined under the full load (one duty point) as input/output efficiency.
The IEC standards (60034-series for motors, and 61800-9-series for motors and converters, see section 3) define scope and tolerances, efficiency classifications and testing procedures. They form an internationally accepted technical platform and the basis for country or region specific MEPS.
The EU MEPS specifies two levels: IE3 and "IE2 motor + VFD", however the latter does not yet specify the efficiency of the VFD, or motor + VFD. In the EU, as part of the current revision of Regulation 640/2009 for electric motors, MEPS for VFDs are under consideration.
Some of the current MEPS on MDUs incorporate default values (losses or efficiencies). The IEC is currently working on a new publication[10] on the energy efficiency aspects of VFDs, which will include VFD loss measurement methods and efficiency classifications.
In the USA the MEPS have recently been revised with an extended scope towards a broader scope of motor types and power ranges, mostly at the level of IE3 (NEMA Premium) for specific motor types.
In China the MEPS are in place at IE2 level, but the planned increase toward the IE3 level for mid 2016 was recently (Q2 2016) postponed.

10 IEC 61800-9-2 is expected to be published by end of 2016/early 2017.

Test standards

A motor gains an efficiency rating through type testing, whereby a product is laboratory tested and its efficiency is stamped on its rating plate. After decades of discussions, today the IEC energy efficiency testing standard for electric motors IEC 60034-2-1[11] is recognised as the global reference method. It is technically equivalent to the Canadian CSA 390-10 and the US IEEE 112-2014, returning within a fraction of a percentage the same efficiency results. Many countries have older national standards based fully or partially on IEC 60034-2-1. The efficiency classification (IE-code) in IEC 60034-30-1 is based on the test method in IEC 60034-2-1.

Manufacturers have tried to lower their testing burden by devising methods for combined testing of some motor samples and calculating efficiencies of intermittent motors by interpolation. The DOE permits manufacturers in the US to use an alternative efficiency determination method (AEDM). The AEDM can be used to certify to DOE that other motors (which do not need to be physically tested) are compliant. IEC is studying this model and is in the process of defining a standard AEDM method and procedure.

The introduction of a VFD changes the motor efficiency due to harmonics and adds additional losses from the converter. The respective IEC standards are currently only under development. Also, the introduction of permanent magnet and switched and synchronous reluctance motors is not yet included in IEC standards and national MEPS (with exception of China which has MEPS for permanent magnet motors in place. Standards for high voltage (HV) motors are under consideration in IEC.

11 And its subsets in IEC 60034-2-2 for special motors, IEC 60034-2-3 for converter fed motors

Note to tables in Chapter 5:

Yes	= within scope (or text in header of the column)
Yes+	= indirectly
Yes*	= if present
No	= not in scope (or text in header of the column)

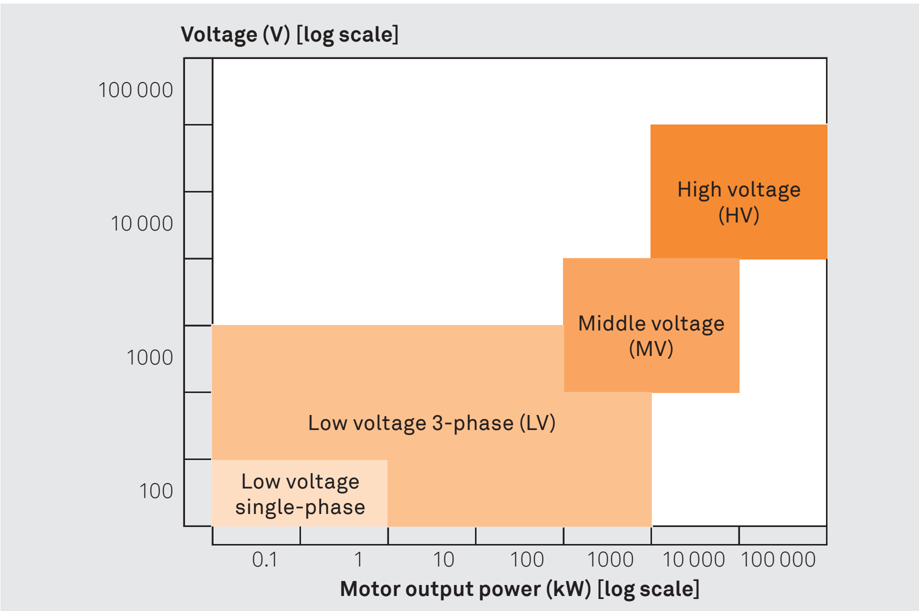


Figure 6: Electric motor typology according to voltage and output power

MOTORS – Product group						
Region	**Product type**	**Small** < 0.75 kW	**Medium** 0.75 – 375 kW	**Large** > 375 kW	**Sector**	**Regulation name**
China	Medium & small 3-phase general purpose		x		Industrial	GB 18613-2012
	Small power general purpose	x			Industrial	GB 25958-2010
	High-voltage 3-phase high voltage induction motor		x	x	Industrial	GB 30254-2013
	Permanent magnet synchronous motors		x		Industrial	GB 30253-2013 M
USA	Electric motor (3 phase)		x		Industrial	10 CFR Part 431
	Small electric motor (single phase)	x			Multi-sector	10 CFR Part 431
	Small electric motor (3 phase)	x			Multi-sector	10 CFR Part 431
EU	Three phase asynchronous general purpose motors		x		Multi-sector	CR No. 640/2009 amended by No. 004/2014
Australia	Small 3-phase General Purpose		x		Industrial	Greenhouse and Energy Minimum Standards (Three Phase Cage Induction Motors) Determination 2012
Japan	Small 3-phase General Purpose		x		n.a.	MEPS for 3 Phase Induction Motor
Korea	Small 3-phase General Purpose		x		n.a.	MEPS for 3 Phase Induction Motor
Brazil	Medium 3-Phase General Purpose		x		Multi-sector	Portaria Interministerial No 553/2005
Canada	Medium 3-Phase General Purpose		x		Multi-sector	Electric Motors (1 to 500 HP/0.746 to 375 kW
Mexico	Small 1-phase General Purpose	x	x		Industrial	NOM-014-ENER-2004
Mexico	Medium 3-Phase General Purpose		x		Industrial	NOM-016-ENER-2010
Saudi Arabia	Medium 3-Phase General Purpose		x		Multi-sector	SASO IEC60034-30

Table 6: Motors – Overview of product group and type in MEPS per region

MOTORS – Minimum Energy Performance Standards											
Region	**Product type**	**Scope**			**Metrics**			**Methodology for minimum requirement**			**Regulation name**
		Motor	VFD	Application	Efficiency[1]	Efficiency Index[2]	If EEI: losses[3]	Motor	VFD	Application	
China	Medium & small 3-phase general purpose	Yes	No	No	Yes, full load efficiency	No	–	Yes	No	No	GB 18613-2012
	Small power general purpose	Yes	No	No	Yes, full load efficiency	No	–	Yes	No	No	GB 25958-2010
	High-voltage 3-phase high voltage induction motor	Yes	No	No	Yes, full load efficiency	No	–	Yes	No	No	GB 30254-2013
	Permanent magnet synchronous motors	Yes	No	No	Yes, full load efficiency	No	–	Yes	No	No	GB 30253-2013 M
USA	Electric motor (3 phase)	Yes	No	No	Yes, full load efficiency	No	–	Yes	No	No	10 CFR Part 431
	Small electric motor (single phase)	Yes	No	No	Yes, full load efficiency	No	–	Yes	No	No	10 CFR Part 431
	Small electric motor (3 phase)	Yes	No	No	Yes, full load efficiency	No	–	Yes	No	No	10 CFR Part 431
EU	Three phase asynchronous general purpose motors	Yes	No	No	Yes, full load efficiency	No	–	Yes	No	No	CR No. 640/2009 amended by No. 004/2014

Notes: Yes* = if present.
- Scope: "Yes" means the respective component (Motor, VFD, Application) is in the scope of the regulation.
- Metrics: "Yes"means the respective metrics is applied.
- Methodology: "Yes" means the respective individual component is covered in the methodology for the metrics.
[1] output/input in %, [2] relative to ideal machine, [3] relative or absolute value

Table 7: Motors – scope, metrics, methodology in MEPS for motors

MOTORS – Test standards					
Region	**Product type**	**Test standards**		**Test procedure in regulation**	**MATCH Test standard & regulation**
		Global	Regional, National	Reg./Annex nr.	
China	Medium & small 3-phase general purpose	IEC 60034-2-1:2007	GB/T 1032:2012	GB 18613-2012 article 5	Match: "Not 100 % 1-to-1 in all cases; Normally, national standards do not directly include all international corresponding standards."
	Small power general purpose	IEC 60034-2-1:2007	GB/T 1032:2012	GB 25958-2010 article 5	see above
	High-voltage 3-phase high voltage induction motor	IEC 60034-2-1:2007	GB/T 1032:2012	GB 30254-2013 article 5	see above
	Permanent magnet synchronous motors	Refered: IEC 30034-2-1	GB/T 22669-2008 GB/T 22670-2008	GB 30253-2013 article 5	see above
USA	Electric motor (3 phase)	Testing is performed according to the DOE test procedure, which is based on IEEE 112-2004 or CSA C390-10. These test methods are similar to the IEC standards but not considered equivalent (i.e. testing is required to be performed according to the DOE test procedure).	Based on NEMA MG1-2009 which references: (1) CSA C390-10, (incorporated by reference, see §431.15), or (2) IEEE Std 112-2004 Test Method B, Input-Output With Loss Segregation, (incorporated by reference, see §431.15).	Appendix B to Subpart B of Part 431 – Uniform Test Method for Measuring Nominal Full Load Efficiency of Electric Motors. Efficiency and losses shall be determined in accordance with NEMA MG1-2009, paragraph 12.58.1, "Determination of Motor Efficiency and Losses", (incorporated by reference, see §431.15) and either: (1) CSA C390-10, (incorporated by reference, see §431.15), or (2) IEEE Std 112-2004 Test Method B, Input-Output With Loss Segregation, (incorporated by reference, see §431.15).	In the US manufacturers are required to test and certify their products based on the applicable DOE test procedure.
	Small electric motor (single phase)	Testing is performed according to the DOE test procedure, which is based on IEEE 112-2004 or CSA C390-10. These test methods are similar to the IEC standards but not considered equivalent (i.e. testing is required to be performed according to the DOE test procedure).	IEEE Std 114-2001, and CAN/CSA C747	10 CFR Part 431.444, associated Test Procedure: IEEE Std 114 CAN/CSA C747: 1) Single-phase small electric motors: Either IEEE Std 114-2001 or CSA C747 (incorporated by reference, see §431.443)	–
	Small electric motor (3 phase)	Testing is performed according to the DOE test procedure, which is based on IEEE 112-2004 or CSA C390-10. These test methods are similar to the IEC standards but not considered equivalent (i.e. testing is required to be performed according to the DOE test procedure).	IEEE Std 112-2004, and CAN/CSA C747	10 CFR Part 431.444, associated Test Procedure: IEEE Std 112-2004 Test Method A and B, and CAN/CSA C747: (2) Polyphase small electric motors less than or equal to 1 horsepower (0.75 kW: Either IEEE Std 112-2004 Test Method A or CSA C747 (incorporated by reference, see §431.443); or (3) Polyphase small electric motors greater than 1 horsepower (0.75 kW: Either IEEE Std 112-2004 Test Method B or CSA C390-10 (incorporated by reference, see §431.443).	–
EU	Three phase asynchronous general purpose motors	IEC 60034-1, IEC 60034-2-1, IEC 60034-30-1	EN 60034-1, EN 60034-2-1, EN 60034-30-1, All above is inherited IEC standards	No	90 % Requirement tables in regulation are an exact copy of the tables in IEC 60034-30-1; gray zone in terms of shaft seals that "may be removed"

Table 8: Motors – Test standards and test procedure in regulation

5.4 Pumps

Product group and type

MEPS for pumps include clean water pumps and circulator pumps for industrial and commercial use (Table 9). MEPS for pool water pumps are under development in the USA and Australia (currently in place as voluntary MEPS). In Canada regulations are under development for industrial clean water pumps.
National regulations use similar definitions for pumps, namely "equipment designed to move liquids by physical or mechanical action".
Differentiations start in the next level of defining the pump types or products, and characteristics: e.g. in the specification of the liquid itself (clean water, or liquids which may include entrained gases, free solids, and totally dissolved solids; and hydraulic specifications like viscosity etc.), in the in- or exclusion components of the MDU, in the pump characteristics like shaft power range, head and flow, and in the specification of the pump types itself:

- USA: regulation states: liquids which may include entrained gases, free solids, and totally dissolved solids; and includes a bare pump and, if included by the manufacturer at the time of sale, mechanical equipment, driver, and controls [11].
- EU: regulation states: "water pump" is the hydraulic part of a device that moves clean water by physical or mechanical action and is of one of the following five designs (ESOB, ESCC, ESCCI, MS-V, MSS, see Annex I)
  - Both USA and EU regulations use the same definition of clean water[12] and design temperature rage (–10 to 120 °C).
- China: the regulation refers directly to the "pump type, being "single-stage single-suction clean water centrifugal pump, single-stage double suction centrifugal pump water, multi-stage water pump" (GB 19762-2007).

The products included cover a part of the total pump market. Within the EU for example a preparatory study is in progress. Appendix IV gives an overview of pump types under review (i.e. not yet covered in MEPS) and those already covered in EU-MEPS.

MEPS

Scope

The EU MEPS on circulators is the first example of a MEPS on MDU-level or Extended Product Approach[13] level. The regulation applies to the VFD, motor and pump and the performance requirements cannot be achieved without variable speed control.
For clean water pumps the scope of MEPS varies across regions. The USA MEPS applies to pumps[14] sold as bare pumps, pumps sold with electric motors and pumps sold with electric motors and continuous or non-continuous controls (VFD), whereas in the EU and China the regulation only applies to the (clean water) pump itself (see Figure 6 and Table 10).

Metrics, methodology

For circulators in the EU regulations a relative energy index is used: the smaller the index the more efficient the circulator. The EEI is evaluated based on a defined load profile. Hydraulic, mechanical and electrical losses are also taken into account.
For clean water pumps the metrics are based on the water pump's (unique) characteristics in terms of nominal speed, impeller size, mechanical shape, flow and hydraulic energy performance. The USA uses a load profile while the EU considers three duty points (Best Efficiency Point, Part Load and Overload – BEP, PL and OL).
In the USA an "efficiency index" is used: the "Pump Energy Index" (PEI) which is defined as

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12 Clean water is specifically defined by the Regulation as water with a maximum non-absorbent free solid content of 0.25 kg/m^3 and with a maximum dissolved solids content of 50 kg/m^3, provided that the total gas content of the water does not exceed the saturation volume. Additives that are needed to avoid water freezing down to –10 °C shall not be taken into account. This definition covers also drink water but it is not limited to it. Any water type that fulfils these specifications is clean water [12]

13 See definition under "Terminology and definitions"
14 The exact terminology and reference: Appendix A to Subpart Y of Part 431 – Uniform Test Method for the Measurement of Energy Consumption of Pumps.

the Pump Energy Rating (PER = "efficiency") for a given pump model divided by the pump energy rating of calculated minimal compliant pump model. The index is a relative value. In the regulation, the PER of a minimal compliant pump is calculated based on a C-value established by the standard combined with a calculation algorithm that incorporates default values. The current C-values in the regulation were designed to phase out the lowest 25th percentile of efficiency for specific pump types.

The C-values specified for the Radial Split Multi-Stage Vertical In-Line Casing Diffuser (in short RS-V) were targeted to harmonise with regulations recently enacted in the EU, because models in the RS-V equipment class are known to be global platforms with no differentiation between products sold in the USA, EU and China [2].

In the US, the applicable test procedure establishes two methods for the determination of a Pump Energy Index (PEI): a calculation based method and a testing based method; as well as a different approach to calculate the metric for pumps without controls (PEI_CL) and pumps with controls (PEI_VL).

In the EU, for clean water pumps an input/output metric is used: the "Minimum Efficiency Index" (MEI), which is defined as a dimensionless scale unit for hydraulic pump efficiency at Best Efficiency Point[15] at Part Load (PL: 75 %), full load and Over Load (OL: 110 %). The Hydraulic pump efficiency (η) is the ratio between the mechanical power transferred to the liquid during its flow through the water pump and the mechanical input power transmitted to the pump at its shaft.

Motor, pump (and VFD, if present) are typically tested as one unit; the motor has to be tested separately and the losses are to be sub-sequentially subtracted. From 1 January 2013 the required MEI was ≥ 0.1 and from 1 January 2015 the MEI is ≥ 0.4, which translates to excluding the 10 % (2013) and 40 % (2015) of the most inefficient pumps on the market.

In the current EU revision of the MEPS for clean water pumps, some of the considered options touch on the "MDU-concept" (i.e. taking the efficiency from a pump-component level towards the MDU-level), but seem still to be on the component level when it comes to efficiency specifications. As an example the handling of the combination of motor + VFD the following options can be considered: a) a VFD for variable flow applications, or, b) the best available motor technology in all cases. Available data show the potential for energy savings at MDU level being the highest on option b) (note: the best available technology for motors can be considered to be IE4 motors). Although motor technologies are recognized as very important for the energy efficiency of the Motor Driven Unit, most pump manufactures only choose motors according to the minimum requirements for motors (i.e. IE3, or IE2 + VFD). Only a few manufacturers are advancing to high efficient motors (i.e. IE4) for their pumps.

15 BEP: the operating point of the water pump at which it is at the maximum hydraulic pump efficiency measured with clean cold water

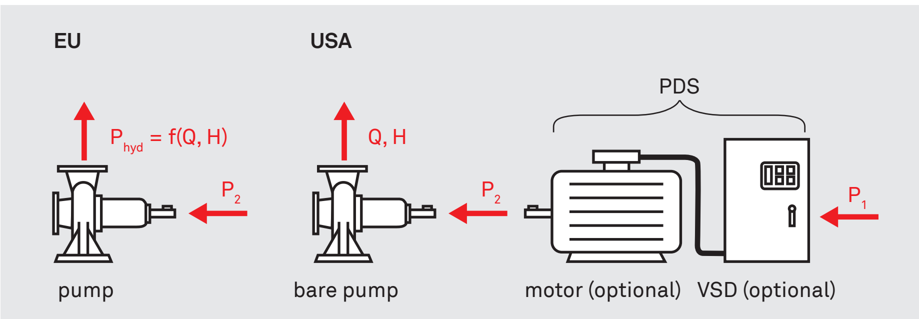

Figure 7: Pump (clean water) definition EU and USA

Differences in market trends and conditions in the various regions can lead to different levels of saving potential in those various regions. For example EU data for swimming pool pumps reveals only a minor share for variable flow applications (i.e. 2.9 %). This contrasts to the market trends in the USA and Australia where a growing share of these applications is observed [2].

Planned revisions or new MEPS

The EU MEPS are under revision and will not be completed before 2017. The USA established its MEPS for pumps in January 2016 and compliance is required on and after January 27, 2020. Canada and Australia are investigating the introduction of MEPS (mandatory) for swimming pool pumps. Australia has commenced a wide scoping study to explore the potential benefits of including MEPS for other types of pumps. In the USA the DOE is currently considering new MEPS and test procedures for circulator pumps and dedicated-purpose pool pumps (DPPP).

Test standards

The main global testing standard is the ISO 9906 "Rotodynamic pumps – Hydraulic performance acceptance tests – Grades 1, 2 and 3". This International Standard specifies hydraulic performance tests of rotodynamic pumps (centrifugal, mixed flow and axial pumps). Based on this ISO standard, regional/national standards have been developed for specific pump types, see Table 11.

PUMPS – Product group						
Region	Product type		Description	Sector	Regulation name	Most recent effective date
	Clean water	Other				
China	x		centrifugal pump for fresh water	Industrial	GB 19762-2007	1-March-2014
USA	x		Bare pumps, pumps sold with a driver, and pumps sold with a driver and controls	Multi-sector	10 CFR Parts 429 and 431	27-Jan-2020
EU		x	Glandless standalone circulators and glandless circulators integrated in products	Multi-sector	CR No. 641/2009 amended by No. 622/2012	1-Jan-2013
	x		Rotodynamic water pumps for pumping clean water. wich meet specific demands of technical specifications. Firefighting, displacement & self priming pumps are excluded.	Multi-sector	CR No. 547/2012 + communication of December 2012	1-Jan-2013, under revision
Australia		x	Swimming pool pump-units	Residential	AS 5102.2-2009 s (Voluntary Req.)	1-Jan-2010, under revision
Mexico	x		Vertical turbine pumps with external vertical electric motor for pumping clean water as specified in the standard.	Multi-sector	NOM-001-ENER-2000	1-Jan-2001
	x		Submersible deep well type clean water motor pumps operated by a submersible three-phase electric motor. The standard does not apply to sewage and mud pumps.	Multi-sector	NOM-010-ENER-2004	1-Jan-2005
	x		Clean water pumps and motor pumps with a power rating of 0.187 kW to 0.746 kW. The standard aims at residential water pumps used to fill rooftop water tanks due to the low water pressure in the water mains.	Residential	NOM-004-ENER-2008	1-Jan-2008
		x	Deep well water pumping systems, consisting of vertical centrifugal pump and electric motor (external or submersible), with power output from 5.5 to 261 kW (7.5 to 350 HP).	Multi-sector	NOM-006-ENER-1995	1-Jan-1995

Table 9: Pumps – Overview of product types in MEPS

PUMPS – Minimum Energy Performance Requirements

Region	Product type	Scope			Metrics			Methodology for minimum requirement			Regulation name	Regulation status
		Motor	VFD	Application	Efficiency[1]	Efficiency Index[2]	If EEI: losses[3]	Motor	VFD	Application		
China	Centrifugal pump for fresh water	No	No	Yes	Yes	No	–	No	No	Yes	GB 19762-2007	In effect
USA	Bare pumps, pumps sold with a driver, and pumps sold with a driver and controls	Yes*	Yes*	Yes	–	Yes	Relative	Yes*	Yes*	Yes	10 CFR Parts 429 and 431	Published
EU	Glandless standalone circulators and glandless circulators integrated in products	Yes	Yes	Yes	No	Yes	Relative[4]	Yes			CR No. 641/2009 amended by No. 622/2012	In effect
	Rotodynamic water pumps for pumping clean water.	No	No	Yes	Yes	No	–	–	–	Yes	CR No. 547/2012 + communication of December 2012	In effect; under revision

Notes: Yes* = if present.
- Scope: "Yes" means the respective component (Motor, VFD, Application) is in the scope of the regulation.
- Metrics: "Yes" means the respective metrics is applied.
- Methodology: "Yes" means the respective individual component is covered in the methodology for the metrics.
[1] output/input in %; [2] relative to ideal machine, [3] relative or absolute value, [4] The smaller EEI the more efficient circulator

Table 10: Pumps – MEPS: scope, metrics, methodology for minimum requirements

PUMPS – Test standards					
Region	**Product type**	**Test standards**		**Test procedure in regulation**	**MATCH Test standard & regulation**
		Global	Regional, National	Reg./Annex nr.	
China	Centrifugal pump for fresh water	ISO 9906:1999	GB/T 3216-2005	GB 19762-2007 article 4.3	GB 19762-2007 set MEPS for pumps. It refers GB/T 3216-2005 as testing procedure, which supports GB 19762-2007
USA	Bare pumps, pumps sold with a driver, and pumps sold with a driver and controls	Testing is performed according to the DOE test procedure, which is based on HI 40.6-2014 with modifications. Note: ISO 9906-2012 is equivalent to the predecessor of 40.6, HI 14.6.	Based on Hydraulic Institute (HI) Standard 40.6–2014 "Methods for Rotodynamic Pump Efficiency Testing", with modifications	10 CFR 431, Appendix A to Subpart Y of Part 431 – Uniform Test Method for the Measurement of Energy Consumption of Pumps provides the DOE test procedure for pumps. The DOE test procedure is based on the Hydraulic Institute (HI) Standard 40.6–2014 and establishes two methods for the determination of a Pump Energy Index (PEI): a calculation based method and a testing based method; as well as a different approach to calculate the metric for pumps without controls (PEI_CL) and pumps with controls (PEI_VL).	–
EU	Glandless standalone circulators and glandless circulators integrated in products	ISO 9906	EN 16297-1 EN 16297-2 EN 16297-3	641/2009; Annex II	100 %. The EN 16297 series has been developed to support EU regulation directly. They include cross-references to the regulation.
	Rotodynamic water pumps for pumping clean water.	ISO 9906	prEN 16480 (Expected published 2016)	547/2012; Annex III	100 %. The EN 16480 standard has been developed to support EU regulation directly. It includes cross-references to the regulation.

Table 11: Pumps – Test standards and test procedure in regulation

5.5 Fans

Product group and type

Regarding MEPS for fans, the main distinction is made between individual fans and ventilation units (for industrial and/or commercial use), and fans for residential use only. The definitions for the different types of fans and ventilation units in the EU and in the USA (in draft) are as follows:

- USA – fans: a device used in commercial or industrial systems to provide a continuous flow of a gas, typically air, by an impeller fit to a shaft and bearing(s). A fan may be manufactured with or without a housing component [13].
- EU – fans: "fan" means a rotary bladed machine that is used to maintain a continuous flow of gas, typically air, passing through it and whose work per unit mass does not exceed 25 kJ/kg, and which 1) is designed for use with or equipped with an electrical motor with an electric input power between 125 W and 500 kW (≥ 125 W and ≤ 500 kW to drive the impeller at its optimum energy efficiency point, 2) is an axial fan, centrifugal fan, cross flow fan or mixed flow fan, 3) may or may not be equipped with a motor when placed on the market or put into service [16].
- EU – ventilation units: a ventilation unit is an electric motor driven appliance equipped with at least one impeller, one motor and a casing. It is intended to replace utilised air by outdoor air in a building or part of a building [17].
- Ceiling fans are covered in separate MEPS but cover only the lighting (USA, Canada). In the USA the MEPS is under revision and targets the definition of airflow efficiencies and related energy efficiencies.

The terms "fan" and "blower" are used interchangeably in USA and China. Differences in the technology base of the regions exist, e.g. the majority of the fans sold in the USA are sold bare shaft, whilst in the EU a large number of fans are sold with an integrated motor [15].
Note: USA and Canada regulation on ceiling fans cover the lighting only, not the (efficiency of the) fan function.

MEPS

In China and the EU, MEPS on industrial fans are in effect. In the USA, an exploration of the proposed scope is in progress. In China an increase of efficiency levels is under consideration.
In the EU, the MEPS on ventilation units cover a series of different combinations of motor+impeller+casing+ducting. MEPS for residential (or domestic) fans are in place in the USA, China, the EU, Australia, Canada and Korea. In the USA and Canada, the regulation covers the lighting but not the fan function. The metrics for airflow (ceiling fans) are currently under development (see Table 12 and Table 13).
The USA DOE is considering MEPS for fans, which would include the electric motor and control (if present). The USA has no metric yet, but is considering an electrical input power metric evaluated at the declared operating point for all manufacturers.
In the EU the metrics include a default value for motor efficiency (based on No. 640/2009, IE2 or IE3, or a calculated value at IE2 level when the motor is not part of No. 640/2009), and a factor ("bonus") when a VSD is applied (to correct the losses of the VFD), but based on default efficiency values. The type of fans covered is described listed in Table 17 and in Appendix 1.
Ventilation units (residential and non-residential "RVU" & "NRVU") are covered in the EU. These are relatively complex components and the regulation is therefore correspondingly complex. The variety of products within this scope is equally wide, ranging from small residential to fairly large industrial units. They include motor, fan, VFD (if present), housing and other components such as heat recovery units and filters.

Test standards

The different regulations use global and regional testing standards such as ISO 5801, ISO 12759 and ANSI/ASHRAE Standard 103-2007, but in most cases modifications are added which can result in lack of clarity. For example:

- EU – ventilation units: it is not always clear whether the reference is static or total pressure; SEC (specific energy consumption) is not always well defined, and it is unclear how to handle additional components.
- EU – fans: fans are only evaluated in one duty point (BEP). The metric is effectively as defined in ISO12759. Current regulation requires a separate motor test to establish the compressibility factor in the calculation, however experience shows that this has negligible influence.

FANS – Product group					
Region	**Product type**	**Description**	**Sector**	**Regulation name**	**Most recent effective date**
China	Cooktop/Cooker Hood	–	Residential	GB 29539-2013	10-January-2013
	Ceiling Fan	–	Residential	GB 12021.9-2008	1-January-2009
	Industrial blower	Applies to the following types of fan: -centrifugal and axial-flow type for general use; centrifugal ID-fan for industial steam boiler; centrifugal IF-fan and ID-fan for boiler of power station; axial type fan used at power station; centrifugal fan for AC. Does NOT apply to specialized-structured and used fans like jet type fan, cross-flow fan, and roof fan.	Industrial	GB 19761-2009	1-September-2010
	Centrifugal blower	Applies to centrifugal blower	Industrial	GB 28381-2012	1-September-2012
USA	Industrial fans	Scope development in progress	Industrial	Not Yet Final	n.a.
	Ceiling fan	Ceiling fan means a nonportable device that is suspended from a ceiling for circulating air via the rotation of fan blades, as defined by 42 U.S.C. 6291 (16).	Residential	10 CFR 430.32(s)(1)	1-January-2007
	Furnace/duct fan	An electrically-powered device used in a consumer product for the purpose of circulating air through ductwork as defined by 10 CFR 430.2 Applies to the furnace fans listed in Table 1 of 10 CFR 430.32(y): furnace fans used in weatherized and non-weatherized gas furnaces, oil furnaces, electric furnaces, and modular blowers. Not included: furnace fans incorporated into hydronic air handlers, SDHV modular blowers, SDHV electric furnaces, and CAC/HP indoor units.	Residential	10 CFR Parts 429 and 430	3-July-2019
EU	Ventilation units	RVU – Residential Ventilation Unit; NRVU – Non Residential Ventilation Unit; with: UVU – Unidirectional Ventilation Unit; BVU – Bidirectional Ventilation Unit All defined by technical specs of flow, power consumption etc.	Multi-sector	CR No. 1253/2014 + CR No. 1254/2014 – Energy labeling	1-January-2016
	Fans drivens by motors	Fans driven by motors with an electric input power between 0.125 kW and 500 kW, including those integrated in other energy-related product.	Multi-sector	CR No. 327/2011	1-January-2013
Australia	New fan-units	Under development – considering IEC standard (fan unit driven by an electric motor with power input of 125 W to 500 kW or variant thereof.	Non Domestic	n.a.	n.a.
Korea	Portable Fan	By KS C 9301 household electric fan (desktop or stand) which has the diameter of wing of 20~41 cm and the axial single wing run by induction motor to be used in general (table, stand, etc).	Domestic	MEPS for Electric Fan	1-January-2009
Canada	Ceiling Fan	Household ceiling fan	Residential	Ceiling fans and ceiling fan light kits	1-January-2010

Table 12: Fans – Overview of product group and type in MEPS per region

FANS – Minimum Energy Performance Requirements										
Region	**Product type**	**Scope**			**Metrics**			**Methodology for minimum requirement**		
		Motor	VFD	Appli-cation	Efficiency[1]	Efficiency Index[2]	If EEI: losses[3]	Motor	VFD	Application
China	Cooktop/Cooker Hood									
	Ceiling Fan									
	Industrial blower	No	No	Yes	Yes	No	–	No	No	Yes
	Centrifugal blower	No	No	Yes	Yes	No	–	No	No	Yes
USA	Industrial fans	Yes	Yes*	Yes	x	Yes, possibly "fan energy index" included: the maximum allowable electrical input power divided by the actual fan electrical input power at a given operating point	x	x	x	x
	Ceiling fan	Yes	Yes	Yes	Yes, current: design requirements, Next: Airflow Efficiency (CFM/Watt)	No	–	Yes	Yes	Yes
	Furnace/duct fan	Yes	Yes	Yes	Yes, FER (Watts/CFM)	No	–	Yes	Yes	Yes
EU	Ventilation units	Yes_i	Yes*	Yes	No	Yes	Absolute	Yes, indirectly, must comply to EU No. 640/2009 if separable	Yes*	Yes
	Fans drivens by motors	Yes_i	Yes*	Yes	Yes, efficiency is calculated as the product of all parts of the drive train. An efficiency "bonus" is included in the calculation where a VSD is used.	No	–	Yes, indirectly, must comply to EU No. 640/2009 if separable	Yes, the "bonus" includes an allowance for VSD losses	Yes

Notes: Yes* = if present; Yes_i = indirectly; x = in development; – = not applicable
- Scope: "Yes" means the respective component (Motor, VFD, Application) is in the scope of the regulation.
- Metrics: "Yes" means the respective metrics is applied.
- Methodology: "Yes" means the respective individual component is covered in the methodology for the metrics.

[1] output/input in %; [2] relative to ideal machine; [3] relative or absolute value

Table 13: Fans – scope, metrics, methodology for MEPS

FANS – Test standards					
Region	**Product type**	**Test standards**		**Test procedure in regulation**	**MATCH Test standard & regulation**
		Global	Regional, National	Reg./Annex nr.	
China	Cooktop/ Cooker Hood	/	/	GB/T 17713-2011	/
	Ceiling Fan	/	/	GB 12021.9-2008, GB 13380	/
	Industrial blower	ISO 5804:1997	GB/T 1236 GB/T 10178	GB 19761-2009 Article 5	Not 100 % 1-to-1 in all cases; normally, national standards do not directly include all international corresponding standards.
	Centrifugal blower	Not specified clearly in JB/T 3165	JB/T 3165	GB 28381-2012 Article 6	see above
USA	Industrial fans	x	x	The term sheet recommends that DOE bases its test procedure on the latest version of AMCA 210 Laboratory Methods of Testing Fans for Certified Aerodynamic Performance	–
	Ceiling fan	The Energy star method is not accociated to any international ones.	DOE latest test procedure is based on ENERGY STAR Testing Facility Guidance Manual: Building a Testing Facility and Performing the Solid State Test Method for ENERGY STAR Qualified Ceiling Fans, Version 1.1 with modifications.	The DOE test procedure is described at 10 CFR Part 430 Appendix U to Subpart B,10 CFR 430.23(w). It is based on ENERGY STAR Testing Facility Guidance Manual: Building a Testing Facility and Performing the Solid State Test Method for ENERGY STAR Qualified Ceiling Fans, Version 1.1	–
	Furnace/duct fan	–	DOE's test procedure is based on ANSI/ASHRAE Standard 103-2007, with modifications	Final Rule: Test Procedure, Federal Register, 79 FR 499 (January 3, 2014) based on ANSI/ASHRAE Standard 103-2007, with modifications	–
EU	Ventilation units	ISO 5801	EN 308; EN 1341-X series; EN 13053 + additional standards for sound level testing	1253/2014; Annex VIII & IX includes calculation examples, not test procedures	75 % – Many gray zones Not always clear wether reference is static or total pressure, SFP is not always well defined, how to handle additional components
	Fans drivens by motors	ISO 5801 ISO 12759	–	327/2011; Annex II includes calculation examples, not test procedures	90 % – Grey zone defining the term “free inlet”.

Table 14: Fans – Test standards and test procedure in regulation

5.6 Compressors

Product group and type

MEPS for compressors are in place in China and are under development in the USA and the EU, covering the product type "air compressors". Compressor applications for specific types of cooling and air-conditioning units are not included in this report.

MEPS

The status of MEPS for air and natural gas compressors is shown in Table 15 and Table 16. A MEPS for air compressors is in place in China; while policies are in development for air and natural gas compressors in the USA and the EU.

China: the MEPS entered into force from 1 December 2009. After a period of four years the MEPS will be increased to a higher level, including a revision of the (classification) standards.

USA: the scope focuses on air and natural gas compressors. Most recent publications are from 2014: a Framework Document regarding a MEPS for commercial and industrial air compressors (79 FR 6839 – 5 February 2014). Further analyses by DOE are in progress.

EU: the rulemaking for compressors is in progress. A preparatory study from 2014 covers compressors for standard air applications: rotary standard air compressors and piston standard air compressors when driven by a three-phase electric motor. No regulation has been defined yet. A second preparatory study has been launched (summer 2015) to cover low pressure and oil free application ranges in particular, with an expected final report in April 2017.

COMPRESSORS – Product group					
Region	**Product type**	**Description**	**Sector**	**Regulation name**	**Most recent effective date**
China	Air compressor	The following types of air compressors are covered: Direct drive portable reciprocating piston air compressors, Reciprocating piston micro air compressors, Oil-free reciprocating piston air compressors, Stationary reciprocating piston air compressors for general use, Oil injected screw air compressors for general use, Oil injected single screw air compressors for general use, and Oil flooded sliding vane air compressor for general use.	Industrial	GB 19153-2009	1-December-2009
USA	Air compressor	Scope determination in progress. Some preliminary discussions are provided in the Framework document 79 FR 6839 (February 5, 2014).	Multi-sector	unknown	/
EU	Air compressors	Compressors for standard air applications. Rotary standard air compressors with a volume flow rate between 5 to 1280 l/s and piston standard air compressors with a volume flow rate between 2 to 64 l/s, when driven by a three-phase electric motor. A new scope will be defined in the current 2nd EU Prep-study.	Industrial	WD 2014	/

Table 15: Compressors – Overview of product group and type in MEPS per region

COMPRESSORS – Minimum Energy Performance Requirements												
Region	**Product type**	**Scope**			**Metrics**			**Methodology for minimum requirement**				**Regu-lation name**
		Motor	VFD	Appli-cation	Efficien-cy[1]	Effi-ciency Index[2]	If EEI: losses[3]	Motor	VFD	Appli-cation	Additional informa-tion	
China	Air com-pressor	No	No	Yes	Yes	No	–	No	No	Yes	For industrial products, MEPS and energy efficiency classification are shown in a lot of tables for different technologies, sizes and capacities.	GB 19153-2009
USA	Air com-pressor	/	/	/	Analysis in prog-ress	Analysis in prog-ress	Analysis in prog-ress	/	/	/	Current design re-quirements explained	un-known
EU	Air com-pressors	/	/	/	Yes (isoen-tropic ef-ficiency)	No	–	/	/	/	/	WD 2014
	Low pres-sure and oil free application ranges	/	/	/	/	/	/	/	/	/	/	

Notes: ¨/ = not available; – = not applicable
- Scope: "Yes" means the respective component (Motor, VFD, Application) is in the scope of the regulation.
- Metrics: "Yes" means the respective metrics is applied.
- Methodology: "Yes" means the respective individual component is covered in the methodology for the metrics.
[1] output/input in %; [2] relative to ideal machine, [3] relative or absolute value

Table 16: Compressors – MEPS: scope, metrics, methodology for minimum requirements

COMPRESSORS – Test standards					
Region	**Product type**	**Test standards**		**Test procedure in regulation**	**MATCH Test standard & regulation**
		Global	Regional, National	Reg./Annex nr.	
China	Air compressor	ISO 1217:1996	GB/T 3853	GB 19513-2009 article 5.1.2, 5.2 and 5.3	GB 19513-2009 set MEPS and energy efficiency classification for displacement air compressors. It refers GB/T 3853 and other technical standards as testing method, which supports GB 19513-2009
USA	Air compressor	Analysis in progress	Analysis in progress	In the Framework document, DOE requested comments on the use of the ISO 1217 and ISO 5389 test procedures, as well as any other test procedures as the basic for the development of a DOE test procedure	–
EU	Air compressors	ISO 1217 & ISO 5389	–	–	–

Table 17: Compressors – Test standards and test procedure in regulation

6 Findings and observations

6.1 Findings – overview

National regulations within each country cover a wide spectrum of product types (or subcategories) of motors, pumps, fans and compressors, with some alignment in terms and definitions but also considerable variations between countries.

There is alignment with respect to the terms used at the product type level, e.g. with motors and pumps. Ambiguities occur through the use of non-identical wordings and through differences in products and markets leading to different product categories and/or types.

On a more detailed level at least 50 different product categories are identified (see Appendix I), for motors, pumps, fans and compressors. Differences occur in the:

- Typology (or categorisation) of products, e.g. "End suction own bearing" and "End suction frame mounted/own bearings".
- Defined product groups, e.g. clean water pumps, industrial fans, fan units; exclusion of products.
- Technical specifications, e.g. definition of water type (clean, waste, high solids), definition of product (component included or excluded) and all kind of functional parameters (e.g. power ranges), etc.

Motors

Motors are the first component (of the MDU), which have become covered by MEPS on a global scale. The majority of the countries (11 out of 14) covered in this research have MEPS for motors in place. Together they cover 76 % of the global electricity use of motor systems.

MEPS regulations for electric motors are highly comparable across regions. A prerequisite for making a global alignment of MEPS levels possible has been the availability of globally accepted, harmonised standards for electric motors. These standards define scope, efficiency metrics and one preferred testing methodology and are part of the IEC 60034 series.

The scope of each regulation differs on a more detailed level, in terms of motor size range, as well as inclusions and exclusions. Currently 3 out of 14 countries (the USA, Canada and EU) have established MEPS at the premium efficiency level IE3 .

Recently China postponed the shift towards IE3; the USA extended the scope of their MEPS for motors towards other types and ranges of motors, keeping the highest efficiency level at IE3[16].

Pumps

MEPS for pumps are in place in 4 (of the 14) countries. These 4 countries cover 60 % of the global electricity use of motor systems.

Two main pump-MDU types are currently covered by MEPS: clean water pumps and circulators.

There is some international alignment of the used product categories, but the definitions in the different regulations are not fully aligned. For one specific pump type (Radial Split Multi-Stage Vertical In-Line Casing Diffuser – in short RS-V), the USA MEPS values are targeted to be aligned with the EU MEPS with minor deviations. The reason for this alignment is that RS-V pumps are globally traded with no differentiation between products sold in the USA, EU and China.

Scope

EU MEPS on circulators is the first example of MDU-level regulation.

For clean water pumps, the MDU scope across regions differ greatly. In the EU and China, the regulation applies only to the pump itself – and does not cover the whole MDU, whereas in the USA the regulation applies to the pump; motor and pump; or VFD and motor and pump.

This also suggests that the EU and China MEPS do not encourage the use of high efficient motor and VFD, since these are not included in the scope.

16 The EU MEPS specifies two levels: IE3 and "IE2 motor + VFD"

Metrics, methodology

The EU MEPS on circulator pumps defines the metrics – an efficiency index – for the whole unit, i.e. VFD-motor-pump. The current level of MEPS on circulators cannot be achieved without variable speed control.

The metrics used for clean water pumps in the EU and USA show alignment regarding the metric efficiency (hydraulic pump efficiency), but differences in the used methodologies, regarding calculations, parameters and testing. The EU MEPS for clean water pumps does not take into account values for motor and VFD (if applicable), but the input/output of the pump itself; the MDU is tested as one unit, and thereafter motors are tested separately and its losses are subtracted. The USA MEPS for clean water pumps applies a relative index (pump energy index) using a reference pump, load profiles (constant and variable load) and duty points. In the US a calculation based as well as a testing based method are in place, whereas the EU uses a testing based method.

Testing standards used in the regulations are based on an international ISO standard. However, in all cases they are applied through national testing standards. These may in many cases contain small additions/alterations and are adjusted to the regional regulations.

Fans

MEPS for fans are in place in 3 (of the 14) countries. These 3 countries cover 43 % of the global electricity use of motor systems.

Different product groups are defined for fans, for industrial use (China) and general use (EU), and fan-units for general use (EU). Further differentiation is made regarding type, size, ducts. In the USA, a regulation for industrial fans is under development.

Scope, metrics, methodology

The EU regulations for fans and ventilation-units includes all components of the MDU, including the VFD if present.

The metrics for the fans is efficiency (overall input/output), including all part-efficiencies of the MDU components. The motor must comply to EU 640/2009 if separable, and an allowance included for VFD losses where a VFD is present. However, if the motor is not separable, a "standard" loss is calculated, based on an IE2 class motor.

The Chinese MEPS include only the fan itself. The metric is input/output efficiency.

The testing methodologies used for the regulations are based on ISO standards but defined through national standards which do not always have a 100 % match with the ISO standard. This can lead to ambiguities in the regulation, e.g. EU ventilation-units: definition of pressures, and handling of additional components.

Compressors

MEPS for compressors are in place in 1 (of the 14) countries. This country covers 28 % of the global electricity use of motor systems.

Regulation for compressors is in place in China, and includes the compressor itself. In the EU and USA, regulations for air and natural gas compressors are under development.

6.2 Observations

The scope of national regulations within each country shows a wide spectrum of product types (or subcategories) of motors, pumps and fans, which vary considerably between countries. This can be explained, by:

- Variations in climate and domestic demand (e.g. hot climates with swimming pool pumps, AC because of higher cooling demand).
- Other subcategories are missing because the process of covering products takes time and proceeds, step by step, usually starting with the most common and widely used products.
- Differences in the technology base of the region, e.g. the majority of larger fans (above 5 kW sold in the USA are sold bare shaft, whilst in the EU a large number of fans are sold with an integrated motor. This can leads to differences in the scope (definition of MDU with a combination of motor-transmission-fan) and metrics of the regulations.

An important observation of this study is that terms and definitions related to the Motor Driven Unit (as a whole and its individual components) vary across regions. This makes a comparison of standards and regulations applied in different countries difficult and can lead to confusion, impairing the international trade of products. Using a clear and eventually uniform terminology is a prerequisite for making international alignment possible, stimulating competition on a global level for energy efficient products and leading eventually to more energy savings and larger CO_2 emission reductions.

Many regulations for MDU-components (like motors, pumps) build on international IEC and ISO standards to define testing methods and performance classifications. In some cases countries adopt these standards without change into national standards, in other cases countries make alterations depending on specific national circumstances.

As countries/regions (EU, US) seek to establish minimum efficiency requirements for complete MDUs, they also consider appropriate testing, calculation methods and performance requirements. International standards for complete MDUs are not as advanced as for MDU-components and the need for further work in this area is evident, as illustrated by the development of ISO 12759 standard (Fans – Efficiency classification for fans, under revision) which originated from the EU regulations for circulators and fans.

Regulating components versus systems

In the multitude and variety of larger applications (above 5 kW), many countries still prefer component standards and regulations for pumps, fans, and compressors because it is much easier to define and implement them.

To develop and implement standards and regulations for a Motor Driven Unit as a system consisting of several components, rather than for a single product only like a motor, is much more complex.

A MDU regulation usually requires a default motor and its respective efficiency has to be defined. This can result in a mismatch between the effective MEPS for the motor and the default efficiency of the motor, as defined in the MDU regulation. For example, in the European MEPS for fans, when the motor is not supplied or excluded in the motor MEPS, IE2 is the default efficiency – while the actual minimum requirement for motors in the European Union is already IE3 (or IE2+VFD), and when a VFD is applied a compensation factor is applied.

From a technical point of view, it is not important whether the components of a MDU are manufactured and sold as single components and assembled into a MDU at the user's factory, or manufactured by one company and sold as one integrated unit. In the case of selling an integrated product manufactured by one company, no reference products for any missing components of the MDU need to be defined. Integral performance values for the MDU can be measured and stipulated. The EU MEPS on circulator pumps (EC No 641/2009) defines the scope and metrics for the complete unit and was relatively easily agreed with the manufacturers and their association, because the technology of integrated glandless circulating pumps[17] for heating and cooling systems has been on the market for many decades. From a manufacturer's point of view, it is easier for this kind of MDU to deliver only one integral MDU test report and logical to comply with only one (integral) MDU performance requirement[18].

The enforcement of such regulations, i.e. to integral efficiency testing and efficiency classification levels, is a new challenge for standards and MEPS, because of a lack of data and experience.

It should also be mentioned that MEPS can cover both an entire appliance and individual MDUs. For example, a household appliance like a washing machine includes a number of MDUs with pumps, fans and compressors. A "dual regulation", i.e. setting for the entire appliance (washing machine) and the individual MDUs as well prevents low efficiency MDUs

17 Using the transported fluid as cooling system

18 For motors, the IECEE Global Motor Energy Efficiency Programme aims to realise the concept of one recognised test method, one test report format, one certification process, on an internationally harmonised scale (see section 3 Standards).

from being built into appliances which as a stand-alone MDU would not meet their MEPS. For example, the EU regulation No 327/2012 for fans explicitly mentions that fans built into appliances are also included in the scope of the fan regulation and have to comply with the respective MEPS.

6.3 Part 2

In Part 2 of this study, further research and analysis will be undertaken to identify in more detail the actual differences of the specific standards and policies (under development, in effect or under revision):

- In national testing standards and alignment towards globally used IEC and ISO standards.
- Specification and alignment of terminology used in national MEPS and international standards.

The focus will be on those MDUs where on the short term most impact can be expected and/or where regulators are aiming to develop and/or revise existing MEPS. On the level of pumps, fans and compressors, this is:

- MEPS for compressors that are currently under development in the USA and EU.
- MEPS for fans that are under development in the USA, and under revision in the EU. In China an increase of efficiency levels is under consideration.
- MEPS for pumps that are under revision in the EU.

An action plan will be developed giving information and data (as available) on the differences on a component level and system level, with a focus on how to regulate components and MDUs and how to support policies for MDUs in new installations. Opportunities on the short-term will be explained based on this schedule of development of MEPS in these regions.

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[16] Commission Regulation EU 327/2011 of 30 March 2011; implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for fans driven by motors with an electric input power between 125 W and 500 kW.

[17] Commission Regulation EU 1253/2014 of 7 July 2014 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for ventilation units.

8 Glossary

Asynchronous motor: An alternating current (AC) motor which does not run at synchronous speed. The ordinary induction motor is an asynchronous motor – single or polyphase.

Ecodesign: The Ecodesign Directive provides a procedure for setting mandatory requirements on relevant environmental characteristics, e.g. energy efficiency, of products placed on the market of the European Union.

Efficiency: The efficiency of a motor (or a motor driven unit) is the ratio of mechanical output to electrical input. It represents the effectiveness with which the motor converts electrical power into mechanical power at the output shaft under specified operating conditions.

Energy performance: The characteristics of a product in respect to the energy or power it consumes under certain conditions.

Frame: Motor mounting and shaft dimensions as standardised by IEC or NEMA, which facilitates interchangeability.

Harmonisation: The adoption of the same test procedure or performance standard level or energy labelling criteria or design as that of an international organisation or trading partner or the mutual recognition of test results for a particular appliance through multilateral forum or compact.

IE-code: Efficiency classification based on IEC 60034-30-1, 2014, e.g. IE1, IE2, IE3, IE4

Induction motor: An alternating current motor in which the primary winding on one member (usually the stator) is connected to the power source. A secondary winding on the other member (usually the rotor) carries the induced current. There is no physical electrical connection to the secondary winding; its current is induced.

Load: The power required of a motor to drive attached equipment. This is expressed as power (kW) or torque (Newton meter, Nm) at a certain motor speed (rotations per minute, rpm).

Electric motor: A machine that converts electrical power into rotational mechanical power.

LV: Low voltage motor, operates below 1000 Volt and also typically has an output power of below 1000 kW.

Motor Driven Unit: A Motor Driven Unit (MDU) converts electrical power into rotational mechanical power and consists of the following individual components: variable frequency drive (if available), electric motor, mechanical equipment (transmission, gear, belt, if necessary) and a driven application (pump, fan, compressor, transport, or other).

Performance standard: Prescription of minimal efficiencies (or maximum energy consumption, or maximum losses) that manufacturers must achieve in order to be able to sell a product. The standard specifies energy performance but not the technology or design specifications for a product.

Permanent magnet motor: Type of direct current (DC) motor where the field poles and the armature poles are electromagnets. The only current used by the motor is that of the armature. It has high starting torque, good speed regulation and a definite maximum speed. It is highly efficient and valuable for constant and variable speed applications. It has to be started with a VFD or special hybrid features of the motor.

Power: Power is the rate of doing work. It is the amount of energy consumed per unit time. In the SI system, the unit of power is the joule per second (J/s), known as the Watt.

Synchronous reluctance and switched reluctance motor: Type of electric motor that induces non-permanent magnetic poles on the ferromagnetic rotor. Torque is generated through the phenomenon of magnetic reluctance. It is simple, very efficient and highly valuable for applications with variable speed. It has to be started with a VFD.

Test: A laboratory procedure to determine one or more characteristics of a given product, according to a specified methodology.

Variable frequency drive (VFD): Electronic controller to adapt the line frequency (50 or 60 Hz) to the required rotational speed of the motor for the necessary load of the application. Also called variable speed drive or frequency converter.

Based on [4] and other sources

9 Acronyms

4E	Implementing Agreement Energy Efficient End-use Equipment
AC	Alternating current
AC	Air conditioning
BEP	Best Efficiency Point
BRICS	Brazil, Russia, India, China, South Africa
CSCR	capacitor-start capacitor-run motor (single phase motor)
CSIR	capacitor-start induction-run (single phase motor)
DC	Direct current
DOE	Department of Energy (USA)
DPPP	Dedicated-purpose pool pumps
EI	Efficiency Index
EEI	Energy Efficiency Index
EMSA	Electric Motor Systems Annex of the IEA 4E
EPA	Extended Product Approach
FDIS	Final Draft International Standard
GMEE	Global Motor Energy Efficiency Programme
EU	European Union (with 28 Member States as of 2015)
FR	Federal Register (USA)
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IECEE	IEC System of Conformity Assessment Schemes for Electrotechnical Equipment and Components
ISO	International Organization for Standardization
MEI	Minimum Efficiency Index
MEPS	Minimum Energy Performance Standard (mandatory). In many countries the term Minimum Energy Performance Standard (MEPS) is also used
MDU	Motor Driven Unit
NEMA	National Electrical Manufacturers Association
NRVU	Non Residential Ventilation Unit
OL	Over Load
PEI	Pump Energy Index
PL	Part Load
RVU	Residential Ventilation Unit
SEC	Specific Energy Consumption
TS	Technical Specification in IEC
USA	United States of America
VFD	Variable frequency drive
VSD	Variable speed drive

10 Terminology and definitions

During the course of the analysis, the need to clarify key terms arose, because it was observed that there are differences in terminology across regions. This section defines key terms used in this report.

10.1 Technical terminology

1. Motor

- Electric motor: a machine that converts electrical power into rotational mechanical power.
- Rotating machine: generic term in IEC for motors and generators.
- Driver: generic term for a motor in the USA.

2. Variable frequency drive

The terms variable frequency drive (VFD) and converter are used as synonyms. There are several other terms used as synonyms for a variable frequency drive, including:

- Control system: generic terms for electronic components capable of varying speed.
- Control: in the USA the definition of controls is broader than just "VFD"; control means any device that can be used to operate the driver. Examples include, but are not limited to, continuous or non-continuous controls, schedule-based controls, on/off switches, and float switches.
- Converter: generic term for VFD.
- Variable speed drive (VSD), term used in EU regulations.
- Adjustable speed drive (ASD), term used in the USA .
- Drive: short for variable frequency drive.

3. Motor Driven Unit

EMSA uses the term "Motor Driven Unit" since 2013 and proposes the following definition:
"A Motor Driven Unit (MDU) converts electrical power into rotational mechanical power and consists of the following individual components: variable frequency drive (if available), electric motor, mechanical equipment (gear, belt, clutch, brake, throttle if necessary) and a driven application (pump, fan, compressor, transport, or other)."
See section 2 Scope for further details.

4. Extended Product Approach

In the EU, the term "Extended Product" was introduced in 2012, during the revision of the European Ecodesign regulation for water pumps No 547/2012. As the Ecodesign framework regulation allows only MEPS for single products, Europump (the European association of pump manufacturers) proposed the term "Extended Product" in order to recognise that pumps are composed of at least two components (e.g. motor and pump). The idea for this proposal is that this combination (motor and pump) can have one testing method and one efficiency requirement.
In a more recent European CENELEC standard (EN 50598-2: 2013 and EN 50598-1: 2014), MDUs have subsequently been referred to as "Extended Products" and an "Extended Product Approach" was defined. The "Extended Product Approach" adds individual losses of different components to calculate the total loss of the system and thereby define the system efficiency. The European definition of the "Extended Product" prioritises the driver (motor) over the driven equipment (pump) and does not include the mechanical equipment. EMSA preferred using a term that focuses on the driven equipment and includes the eventual mechanical equipment which resulted in defining "Motor Driven Unit".

5. Pump, fan, compressor

The terms pump, fan and compressor refer to the actual Motor Driven Unit and are synonyms for pump-MDU, fan-MDU and compressor-MDU respectively.

10.2 Policy terminology

1. "Standard" means a globally recognised (e.g. IEC or ISO) measurement method or efficiency classification scheme.
2. "Regulation" is a legal measure for requirements of performance and/or declaration for products in one country. (In the USA, a regulation is also called a rule and the process of establishing a regulation rulemaking.)
3. "Minimum Energy Performance Standard" (MEPS[19]) means a mandatory minimum efficiency requirement for a product within one country as stipulated in the relevant national regulation. In the USA the term energy conservation standards is also used.
4. "Policy" is a set of national instruments and measures introduced by public authorities in a coherent way to achieve energy savings within a country.

19: In this report, the abbreviation MEPS is used for both the singular and plural form (Minimum Energy Performance Standard/s).

Appendix

I Contacted institutions and persons

Australia	Peter McLoughlin, Department of Industry, Innovation and Science Simon Newman, Department of Industry, Innovation and Science
Austria	Konstantin Kulterer, Austrian Energy Agency
Canada	Katherine Delves, Natural Resources Canada
China	Hu Bo, Top10 China
EU	Sandie B. Nielsen, Danish Technological Institute Hugh Falkner, Atkins Ltd
Japan	Norihiko Ozaki, Institute of Applied Energy
Korea	Ju KyungHoon, Korean Energy Agency
Sweden	Thomas Björkman and Stefan Nording Swedish Energy Agency
USA	Sanaee Iyama, Lawrence Berkeley National Laboratory John Cymbalsky, Department of Energy

II Overview of "MEPS Scope" with detailed technologies for motors, pumps, fans, compressors

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III Sets of tables with additional information for motors, pumps, fans and compressors

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IV Overview of pump types in EU legislation and preparatory studies Lot 28 and 29

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MOTORS			
Region	**Product type**	**Detailed description**	
China	Medium & Small 3-phase General Purpose	Medium & Small 3-phase General Purpose (GB 18613-2012): general purpose electric motors or general purpose anti explosion electric motors with the following characteristics:	- three-phase AC, with voltage lower than 1000 V and frequency of 50 Hz; - rated power between 0.75 kW – 375 kW; - number of poles of 2, 4, and 6; - single-speed closed self-fan cooling; - N design
	Small power General Purpose	Small power General Purpose (GB 25958-2010): motors for general service, including:	1) three-phase asynchronous small-power (10 W – 2200 W) motors powered by AC power and work under 50Hz and with rated voltage under 690 V; 2) capacitor run asynchronous motors (10 W – 2200 W); 3) capacitor start asynchronous motors (120 W – 3700 W); 4) two value capacitor asynchronous motors (250 W – 3000 W); 5) motors for fan used in room air conditioner (6 W – 550 W).
	Permanent magnet synchronous motors (GB 30253-2013).	The power range of permanent magnet motor is between 0.55 and 375 kW.	For elevator permanent magnet motors, the range is between 0.55 and 110 kW. For motor and VFD integrated product, the power range is between 0.55 and 90 kW.
	High-voltage 3-phase high voltage induction motor	**Categories:** GB 30254-2013) to cover three phase medium and high voltage induction motors (6 kV up to 25 MV), with output power from 220 kW to 24 000 kW, with 2, 4, 6, 8, 10 and 12 poles.	This standard includes three efficiency tiers, from the lowest tier 3, to the most stringent tier 1.
US	Electric Motors (3 phase) (10 CFR Part 431). This regulation sets requirements for General purpose electric motors Subtype I and Subtype II – including Fire Pump motors.	- Subtype I stands for standard ratings with either "usual" or "unusual" service conditions (resp. NEMA MG1–1993, paragraph 14.02; or paragraph 14.03). - Subtype II means any motor incorporating the design elements of a general purpose electric motor (subtype I) that are configured as one of the following: an U-frame motor; a NEMA Design C motor; a close-coupled pump motor; a footless motor; a vertical solid shaft normal thrust motor (as tested in a horizontal configuration); an 8-pole motor (900 rpm); or a poly-phase motor with voltage of not more than 600 volts (other than 230 or 460 volts). Recently the regulation has been expanded, with a compliance date of June 1, 2016, towards general purpose, definite purpose, and special purpose motors with a few exceptions.	The statutory definition of "electric motor", used to describe the scope of the updated regulation, means a machine which converts electrical power into rotational mechanical power and which: (1) Is a general purpose motor, including motors with explosion-proof construction; (2) is a single speed, induction motor; (3) is rated for continuous duty operation, or is rated duty type S–1 (IEC)3 ; (4) contains a squirrel-cage or cage (IEC) rotor; (5) has foot-mounting, including foot-mounting with flanges or detachable feet; (6) is built in accordance with NEMA T-frame dimensions, or IEC metric equivalents (IEC); (7) has performance in accordance with NEMA Design A or B characteristics, or equivalent designs such as IEC Design N (IEC); and (8) operates on polyphase alternating current 60-Hertz sinusoidal power, and is (i) rated 230 volts or 460 volts, or both, including any motor that is rated at multi-voltages that include 230 volts or 460 volts, or (ii) can be operated on 230 volts or 460 volts, or both. The amended standards do not apply to the following electric motors: (1) Air-over electric motors; (3) Liquid-cooled electric motors; (4) Submersible electric motors; and (5) Inverter-only electric motors.
	Small open motors rated from 1/4 to 3 horsepower (0.18 kW up to 2.2 kW and 60 Hz with 2, 4 and 6 poles	These US regulations cover a variety of different technologies (as defined in 10 CFR 431.442 and included in 10 CFR 413.446):	- single phase: - capacitor-start capacitor-run (CSCR); - capacitor-start induction-run (CSIR). - poly-phase motors.
EU	Three phase asynchronous general purpose motors with a shaft power range from 0.75 to 375 kW (1 – 500 hp). CR 640/2009 amended by CR 004/2014	Several technical specifications define the motor including: - single speed, - 50 or 60 Hz, - 2 – 6 poles, - max. 1000 V and - motor ratings based on continuous duty.	**Currently under revision:** Consideration is being given to upgrade the requirements for motors, to include a broader scope from 0.12 kW to 1000 kW and to include 8 pole machines. It is also expected that the next regulation will include MEPS on frequency converters. This may come into force after 2016.

Table 18: The scope of motors covered under the respective national regulation shows significant differences

PUMPS			
Region	**Product type**	**Detailed description**	**Under revision**
Clean water pumps			
China	Centrifugal pumps	- single stage single suction clear water centrifugal pump, - single stage double suction clear water centrifugal pump, - multiple stage clear water centrifugal pump	no
US	Three different pump configurations: - bare pumps, - pumps sold with a motor, - pumps sold with a motor and control.	- end suction close-coupled (ESOB), - end suction frame mounted/own bearings, - in-line, - radially split, - multi-stage, - vertical, - in-line diffuser casing, - submersible turbine.	no
EU	Clean water pumps: rotodynamic water pumps for pumping clean water (Several technical specifications define each type within scope. These include: specific speed, motor speed, minimum and maximum flow, maximum pressure, pump diameter and temperature of the pumped media)	- end suction own bearing (ESOB), - end suction close coupled (ESCC), - end suction close coupled inline (ESCCi), - vertical multistage (MS-V), - submersible multistage (MSS). Excluded: Firefighting, displacement & self priming pumps.	Under consideration: increased MEPS requirements and new types: - horizontal multi-stage; - self-priming; - booster-set; - swimming pool pumps; - centrifugal pumps for wastewater (submersible and dry well, different types), for sludge and for storm and effluent water, and dewatering; and Slurry pumps.
Mexico	Clean water pumps	**Categories** - vertical turbine pumps with external vertical electric motor for pumping clean water. - submersible deep well type clean water motor pumps. - deep well water pumping systems, consisting of vertical centrifugal pump and electric motor (external or submersible), with power output from 5.5 to 261 kW (7.5 to 350 HP). - clean-water pumps and motor pumps with a power rating of 0.187 kW to 0.746 kW. Aiming at residential water pumps used to fill rooftop water tanks due to the low water pressure in the water mains.	
Circulators			
EU	- glandless standalone circulators, - glandless circulators integrated in products.		
Pool pumps			
US and Canada	Swimming pool pumps (Voluntary program, under the Energy Star program by EPA /US and NRC/Canada)		Yes
Australia	Swimming pool pumps	- all single phase pump-units for residential swimming pools and spa pools, and which are capable of a flow rate equal to or greater than 120 L/min. - single-speed, dual-speed, multi-speed and variable speed pump-units with an input power of less than or equal to 2500 W for any of the available speeds. - pump-units for the circulation of water through filters, sanitisation devices, cleaning devices, water heaters (including solar), spa or jet outlets or other features forming part of the pool. - pump-units that form part of a complete new pool installation as well as pump-units intended for sale as replacements for existing pools. - all water-retaining structures designed for human use, (i) that are capable of holding more than 680 litres of water; and (ii) that incorporate, or are connected to, equipment that is capable of filtering and heating any water contained in it and injecting air bubbles or water into it under pressure so as to cause water turbulence.	Yes

Table 19: The scope of pumps covered under the respective national regulations

FANS				
Region	**Product type**	**Detailed description**		**Under revision**
Ventilation, fans & blowers				
EU	Ventilation Units	- RVU – Residential Ventilation Unit - NRVU – None Residential Ventilation Unit; - UVU – Unidirectional Ventilation Unit - BVU – Bidirectional Ventilation Unit	All defined by technical specs of flow, power consumption etc.	
Fans				
US	Fans	Ceiling fans: Ceiling fan means a nonportable device that is suspended from a ceiling for circulating air via the rotation of fan blades, as defined by 42 U.S.C. 6291 (16).		Under revision
Canada	Fans	Household Ceiling fans		no
Korea	Portable fans	Household electric fan (desktop or stand) which has the diameter of wing of 20~41 cm and the axial single wing run by induction motor to be used in general (table, stand, etc).		
Fans and blowers				
China	Industrial Blower	Applies to for the following types of fan: centrifugal and axial-flow type for general use, centrifugal ID-fan for industial steam boiler, centrifugal IF-fan and ID-fan for boiler of power station, axial type fan used at power station, centrifugal fan for AC.	Does NOT apply to specialized-structured and used fans like jet type fan, cross-flow fan, and roof fan.	
	Centrifugal blower	Applies to centrifugal blower		
US	Commerical and industrial fans and blowers	Under development, not yet final		Under development
EU	Fans drivens by motors	Fans driven by motors with an electric input power between 0.125 kW and 500 kW, including those integrated in other energy-related product.		Under revision
Furnace/duct fans (residential)				
US	Furnace/Duct fans: an electrically-powered device used in a consumer product for the purpose of circulating air through ductwork.	Products addressed in current rulemaking: Furnace fans used in weatherized and non-weatherized gas furnaces, oil furnaces, electric furnaces, and modular blowers.	Not subject to the standards: Furnace fans incorporated into hydronic air handlers, SDHV modular blowers, SDHV electric furnaces, and CAC/HP indoor units.	Pending implementation

Table 20: The scope of fans covered under the respective national regulations

COMPRESSORS			
Region	**Product type**	**Detailed description**	**Under revision**
China	Air compressors	The following types of air compressors are covered: - Direct drive portable reciprocating piston air compressors, - Reciprocating piston micro air compressors, - Oil-free reciprocating piston air compressors, - Stationary reciprocating piston air compressors for general use, - Oil injected screw air compressors for general use, - Oil injected single screw air compressors for general use, and - Oil flooded sliding vane air compressor for general use.	
US	Air and natural gas compressors	Compression of a gas, such as air or natural gas, is a thermodynamic process whereby the gas enters a compressor machine or apparatus at one condition of pressure, volume, and temperature and exits at a condition of increased pressure and temperature with corresponding decreased volume. Compressed air can be converted into useful work to power a wide variety of commercial and industrial equipment that use large volumes of air, such as pneumatic manufacturing tools in automated factories used for assembling car parts and bulk packaging of consumer products. Natural gas compressors can be used in the gathering, transmission, and distribution of natural gas.	In preparation
EU	Air compressors	Compressors for standard air applications. - Rotary standard air compressors with a volume flow rate between 5 to 1280 l/s and - piston standard air compressors with a volume flow rate between 2 to 64 l/s, when driven by a three-phase electric motor. A new scope will be defined in the current 2nd EU Prep-study.	No regulation defined: main conclusion of the first study is, that low-pressure and oil-free compressors were missing from the study. Regulating the others only would “twist” the market unfair. A new study has been launched last summer 2015, (1st stakeholder meeting February 16) with an expected final report in April 2017.

Table 21: The scope of compressors covered under the respective national regulations

III Sets of tables with additional information for motors, pumps, fans and compressors

MOTORS – Product group							
Region	**Product type**	**Small** < 0.75 kW	**Medium** 0.75 – 375 kW	**Large** > 375 kW	**Description**	**Sector**	**Regulation name**
China	Medium & small 3-phase general purpose		x		Applies to general purpose electric motors or general purpose anti explosion electric motors with the following characteristics: three-phase AC, with voltage lower than 1000V and frequency of 50Hz; rated power between 0.75 kW-375 kW; number of poles of 2, 4, and 6; single-speed closed self-fan cooling; N design.	Industrial	GB 18613-2012
	Small power general purpose	x			Applies to motors for general service, including: 1. three-phase asynchronous small-power (10W-2200W) motors powered by AC power and work under 50Hz and with rated voltage under 690V; 2. capacitor run asynchronous motors (10W-2200W); 3. capacitor start asynchronous motors (120W-3700W); 4. two value capacitor asynchronous motors (250W-3000W); 5. motors for fan used in room air conditioner (6W-550W).	Industrial	GB 25958-2010
	High-voltage 3-phase high voltage induction motor		x	x	Applies to large & medium cage three-phase high voltage induction motor	Industrial	GB 30254-2013
	Permanent magnet synchronous motors		x		Applies to permanent magnet synchronous motors For elevator permanent magnet motors, the range is between 0.55 and 110 kW. For motor and VFD integrated product, the power range is between 0.55 and 90 kW.	Industrial	GB 30253-2013 M
USA	Electric motor (3 phase)		x		General purpose electric motor (subtype I and II), as defined in 10 CFR 431.12	Industrial	10 CFR Part 431
	Small electric motor (single phase)	x			only CSIR, CSCR motors; small electric motors as defined in 10 CFR 431.442 and included in 10 CFR 413.446	Multi-sector	10 CFR Part 431
	Small electric motor (3 phase)	x			only polyphase motors; small electric motors as defined in 10 CFR 431.442 and included in 10 CFR 413.446	Multi-sector	10 CFR Part 431
EU	Three phase asynchronous general purpose motors		x		Three phase motors of shaft power range 0,75 to 375 kW (1 - 500 hp). Several technical specifications define the motor. These include: single speed, 50 or 60 Hz, 2-6 poles, max 1000V and motor ratings based on continuous duty.	Multi-sector	CR No. 640/2009 amended by No. 004/2014
Australia	Small 3-phase General Purpose		x		This Standard applies to three-phase cage induction motors with ratings from 0.73 kW and up to but not including 185 kW. The scope covers motors of rated voltages up to 1100 V a.c. NOTE: This range includes motors with ratings of 1 hp and 1 CV/PS (French/German or metric horsepower). MEPS does not apply to submersible motors, integral motor-gear systems, variable or multi-speed speed motors or those rated only for short duty cycles (IEC60034-2 duty rating S2).	Industrial	Greenhouse and Energy Minimum Standards (Three Phase Cage Induction Motors) Determination 2012
Japan	Small 3-phase General Purpose		x		The regulated efficiency of each category is defined on IE3 4 pole motor efficiency. 0.75 kW~375 kW. The time average of the efficiency defined multiplier used for 2 pole and 6 pole motors.	n.a.	MEPS for 3 Phase Induction Motor
Korea	Small 3-phase General Purpose		x		By Annex 1 3 Phase Induction motor shall be the rated output of 0.75 kW ~ 375 kW.	n.a.	MEPS for 3 Phase Induction Motor
Brazil	Medium 3-Phase General Purpose		x		Three-phase electric motors	Multi-sector	Portaria Interministerial No 553/2005
Canada	Medium 3-Phase General Purpose		x		Electric motors (1 to 500 HP/ 0.746 to 375 kW.	Multi-sector	Electric Motors (1 to 500 HP/0.746 to 375 kW
Mexico	Small 1-phase General Purpose	x	x		Standards NOM-014-ENER-2004 applies to single-phase squirrel cage air-cooled induction AC motors with a rated output of 0.180 kW to 1.500 kW, with single rotation frequency, 2, 4 or 6 poles, split phase or capacitor start, open or closed.	Industrial	NOM-014-ENER-2004
Mexico	Medium 3-Phase General Purpose		x		Standard NOM-016-ENER-2010 applies to three-phase squirrel cage induction AC motors with a rated output of 0.746 kW to 373 kW, open or closed, with a rated voltage up to 600 V, with single rotation frequency, in horizontal or vertical position.	Industrial	NOM-016-ENER-2010
Saudi Arabia	Medium 3-Phase General Purpose		x		General purpose low-voltage mid-size motors (between 0.75 kW and 375 kW)	Multi-sector	SASO IEC60034-30

Table 22: Motors – Overview of product group and type of MEPS for motors, with detailed description

MOTORS – Minimum Energy Performance Standards

Region	Product type	Scope			Metrics			Methodology for minimum requirement				Sector	Regulation name	Regulation status	Most recent effective date
		Motor	VFD	Application	Efficiency[1]	Efficiency Index[2]	If EEI: losses[3]	Motor	VFD	Application	Additional information				
China	Medium & small 3-phase general purpose	Yes	No	No	Yes, full load efficiency	No	-	Yes	No	No	For industrial products, MEPS and energy efficiency classification are shown in a lot of tables for different technologies, sizes and capacities.	Industrial	GB 18613-2012	In effect	1-September-2012
	Small power general purpose	Yes	No	No	Yes, full load efficiency	No	-	Yes	No	No	See above	Industrial	GB 25958-2010	In effect	1-July-2011
	High-voltage 3-phase high voltage induction motor	Yes	No	No	Yes, full load efficiency	No	-	Yes	No	No	See above	Industrial	GB 30254-2013	In effect	1-September-2014
	Permanent magnet synchronous motors	Yes	No	No	Yes, full load efficiency	No	-	Yes	No	No	See above	Industrial	GB 30253-2013 M	In effect	1-September-2014
USA	Electric motor (3 phase)	Yes	No	No	Yes, full load efficiency	No	-	Yes	No	No	Standard: broadly equivalent to IE3 (Premium) or IE2 depending on motor category and horsepower. Amended Standard: Equivalent to IE3 levels (Premium) except for fire pump electric motors (IE2) (starting June 2016)	Industrial	10 CFR Part 431	In effect	1-June-2016
	Small electric motor (single phase)	Yes	No	No	Yes, full load efficiency	No	-	Yes	No	No	Average full load efficiency as specified in the Code of Federal Regulations, 10 CFR 431.446	Multi-sector	10 CFR Part 431	In effect	3-September-2015
	Small electric motor (3 phase)	Yes	No	No	Yes, full load efficiency	No	-	Yes	No	No	Average full load efficiency as specified in the Code of Federal Regulations, 10 CFR 431.446	Multi-sector	10 CFR Part 431	In effect	3-September-2015
EU	Three phase asynchronous general purpose motors	Yes	No	No	Yes, full load efficiency	No	-	Yes	No	No	Motor efficiency (%) is established and compared to a reference efficiency from tables in the regulation. A motor is only evaluated in one duty point (100%;100%) 16-06-2011: For entire scope; min. IE2 01-01-2015: For motors >= 7.5 kW; min. IE3 or IE2 + VSD 01-01-2017: For entire scope; min. IE3 or IE2 + VSD.	Multi-sector	CR No. 640/2009 amended by No. 004/2014	In effect; under revision	16-June-2011

Notes: Yes* = if present.
- Scope: "Yes" means the respective component (Motor, VFD, Application) is in the scope of the regulation.
- Metrics: "Yes"means the respective metrics is applied.
- Methodology:"Yes" means the respective individual component is covered in the methodology for the metrics.

[1] output/input in %, [2] relative to ideal machine, [3] relative or absolute value

Table 23: Motors – scope, metrics, methodology in MEPS for motors, with additional information on methodology

Region	Product type	Test standards		Test procedure in regulation	MATCH Test standard & regulation	Additional information to regulation
		Global	Regional, National	Reg./Annex nr.		
China	Medium & small 3-phase general purpose	IEC 60034-2-1:2007	GB/T 1032:2012	GB 18613-2012 article 5	Match: "Not 100 % 1-to-1 in all cases; Normally, national standards do not directly include all international corresponding standards."	
	Small power general purpose	IEC 60034-2-1:2007	GB/T 1032:2012	GB 25958-2010 article 5	see above	
	High-voltage 3-phase high voltage induction motor	IEC 60034-2-1:2007	GB/T 1032:2012	GB 30254-2013 article 5	see above	
	Permanent magnet synchronous motors	Refered: IEC 30034-2-1	GB/T 22669-2008 GB/T 22670-2008	GB 30253-2013 article 5	see above	
USA	Electric motor (3 phase)	Testing is performed according to the DOE test procedure, which is based on IEEE 112-2004 or CSA C390-10. These test methods are similar to the IEC standards but not considered equivalent (i.e. testing is required to be performed according to the DOE test procedure).	Based on NEMA MG1-2009 which references: (1) CSA C390-10, (incorporated by reference, see §431.15), or (2) IEEE Std 112-2004 Test Method B, Input-Output With Loss Segregation, (incorporated by reference, see §431.15).	Appendix B to Subpart B of Part 431 – Uniform Test Method for Measuring Nominal Full Load Efficiency of Electric Motors. Efficiency and losses shall be determined in accordance with NEMA MG1-2009, paragraph 12.58.1, "Determination of Motor Efficiency and Losses", (incorporated by reference, see §431.15) and either: (1) CSA C390-10, (incorporated by reference, see §431.15), or (2) IEEE Std 112-2004 Test Method B, Input-Output With Loss Segregation, (incorporated by reference, see §431.15).	– In the US manufacturers are required to test and certify their products based on the applicable DOE test procedure.	Final rule published 29-May-2014
	Small electric motor (single phase)	Testing is performed according to the DOE test procedure, which is based on IEEE 112-2004 or CSA C390-10. These test methods are similar to the IEC standards but not considered equivalent (i.e. testing is required to be performed according to the DOE test procedure).	IEEE Std 114-2001, and CAN/CSA C747	10 CFR Part 431.444, associated Test Procedure: IEEE Std 114 CAN/CSA C747: 1) Single-phase small electric motors: Either IEEE Std 114-2001 or CSA C747 (incorporated by reference, see §431.443)	–	-
	Small electric motor (3 phase)	Testing is performed according to the DOE test procedure, which is based on IEEE 112-2004 or CSA C390-10. These test methods are similar to the IEC standards but not considered equivalent (i.e. testing is required to be performed according to the DOE test procedure).	IEEE Std 112-2004, and CAN/CSA C747	10 CFR Part 431.444, associated Test Procedure: IEEE Std 112-2004 Test Method A and B, and CAN/CSA C747: (2) Polyphase small electric motors less than or equal to 1 horsepower (0.75 kW: Either IEEE Std 112-2004 Test Method A or CSA C747 (incorporated by reference, see §431.443); or (3) Polyphase small electric motors greater than 1 horsepower (0.75 kW: Either IEEE Std 112-2004 Test Method B or CSA C390-10 (incorporated by reference, see §431.443).	–	-
EU	Three phase asynchronous general purpose motors	IEC 60034-1, IEC 60034-2-1, IEC 60034-30-1	EN 60034-1, EN 60034-2-1, EN 60034-30-1, All above is inherited IEC standards	No	90 % Requirement tables in regulation are an exact copy of the tables in IEC 60034-30-1; gray zone in terms of shaft seals that "may be removed"	The coming revision of the motor regulation is expected to expand the scope to 0.12 kW → 1.000 kW and also include 8 pole machines. It is also expected the next regulation will include MEPS on frequency converters

Table 24: Motors – Test standards and test procedure in regulation with additional information to regulation

PUMPS – Test standards

Region	Product type	Test standards		Test procedure in regulation	MATCH Test standard & regulation	Additional information		Additional information to regulation
		Global	Regional, National	Reg./Annex nr.		Motor	MDU (Motor Driven Unit)	
China	centrifugal pump for fresh water	ISO 9906:1999	GB/T 3216-2005	GB 19762-2007 article 4.3	GB 19762-2007 set MEPS for pumps. It refers GB/T 3216-2005 as testing procedure, which supports GB 19762-2007			
USA	Bare pumps, pumps sold with a driver, and pumps sold with a driver and controls	Testing is performed according to the DOE test procedure, which is based on HI 40.6-2014 with modifications. Note: ISO 9906-2012 is equivalent to the predecessor of 40.6, HI 14.6.	Based on Hydraulic Institute (HI) Standard 40.6–2014 "Methods for Rotodynamic Pump Efficiency Testing", with modifications	10 CFR 431, Appendix A to Subpart Y of Part 431 – Uniform Test Method for the Measurement of Energy Consumption of Pumps provides the DOE test procedure for pumps. The DOE test procedure is based on the Hydraulic Institute (HI) Standard 40.6–2014 and establishes two methods for the determination of a Pump Energy Index (PEI): a calculation based method and a testing based method; as well as a different approach to calculate the metric for pumps without controls (PEI_CL) and pumps with controls (PEI_VL).	–	–	Yes	As per 2016-01-26 a Final Rule has been published. The effective date of this rule is March 28, 2016. Compliance with the new standards established for pumps in this final rule is required on and after January 27, 2020. On August 25, 2015 DOE has initiated a separate rulemaking for dedicated purpose pool pumps.
EU	Glandless standalone circulators and glandless circulators integrated in products	ISO 9906	EN 16297-1 EN 16297-2 EN 16297-3	641/2009; Annex II	100 % The EN 16297 series has been developed to support EU regulation directly. They include cross-references to the regulation.	Cannot be separated from circulators	0	Circulators are the first applicable example on extended product approach. The EEI is evaluated based on a defined load profile and both hydraulic, mechanical and electrical losses are taken into account. Note: MEPS on circulators cannot be achieved without variable speed control!
	Rotodynamic water pumps for pumping clean water.	ISO 9906	prEN 16480 (Expected published 2016)	547/2012; Annex III	100 % The EN 16480 standard has been developed to support EU regulation directly. It includes cross-references to the regulation.	The motor typically has to be separated and shaft power established in the corresponding duty points.	Yes, Motor, pump (& VSD) are typically tested as one unit; motor losses are subsequentially subtracted.	The three duty points are at 100 % flow (BEP), 110% flow (OL) & 75 % flow (PL) All three must meet the calculated effiency requirement for MEI = 0.1 and MEI = 0.4 respectively. The tolerance is 5 % (absolute value) for compliancy. It is expected that the revision includes additional pumps and increases the MEPS requirements for water pumps in general.

Table 25: Pumps – Test standards and test procedure in regulation with additional information to regulation

FANS – Test standards						
Region	**Product type**	**Test standards**		**Test procedure in regulation**	**MATCH Test standard & regulation**	**Additional information to regulation**
		Global	Regional, National	Reg./Annex nr.		
China	Cooktop/ Cooker Hood	/	/	GB/T 17713-2011	/	
	Ceiling Fan	/	/	GB 12021.9-2008, GB 13380	/	
	Industrial blower	ISO 5804:1997	GB/T 1236 GB/T 10178	GB 19761-2009 Article 5	Match: "Not 100 % 1-to-1 in all cases; Normally, national standards do not directly include all international corresponding standards."	
	Centrifugal blower	Not specified clearly in JB/T 3165	JB/T 3165	GB 28381-2012 Article 6	see above	
USA	Industrial fans	x	x	The term sheet recommends that DOE bases its test procedure on the latest version of AMCA 210 Laboratory Methods of Testing Fans for Certified Aerodynamic Performance	–	DOE published a notice of public meeting and availability of the framework document regarding energy conservation standards for commercial and industrial fans and blowers. 78 FR 7306 February 1, 2013. Since May 2015, DOE has participated in a negotiated rulemaking for these products. To support these discussions, DOE published two notice of data availability (December 2014, May 2015) which presented an analysis of the potential impacts of setting standards. The term sheet negotiated includes scope of coverage but not standards levels.
	Ceiling fan	The Energy star method is not accociated to any international ones.	DOE latest test procedure is based on ENERGY STAR Testing Facility Guidance Manual: Building a Testing Facility and Performing the Solid State Test Method for ENERGY STAR Qualified Ceiling Fans, Version 1.1 with modifications.	The DOE test procedure is described at 10 CFR Part 430 Appendix U to Subpart B,10 CFR 430.23(w). It is based on ENERGY STAR Testing Facility Guidance Manual: Building a Testing Facility and Performing the Solid State Test Method for ENERGY STAR Qualified Ceiling Fans, Version 1.1	–	Ceiling fans manufactured and distributed in commerce, as defined by 42 U.S.C. 6291 (16), on or after January 1, 2007, must meet the standards specified in the Code of Federal Regulations, 10 CFR 430.32(s)(1). All ceiling fans manufactured on or after January 1, 2007, shall have the following features: Fan speed controls separate from any lighting controls; Adjustable speed controls (either more than 1 speed or variable speed); The capability of reversible fan action, except for: Fans sold for industrial applications; Fans sold for outdoor applications; and Cases in which safety standards would be violated by the use of the reversible mode.
	Furnace/ duct fan	–	DOE's test procedure is based on ANSI/ASHRAE Standard 103-2007, with modifications	Final Rule: Test Procedure, Federal Register, 79 FR 499 (January 3, 2014) based on ANSI/ASHRAE Standard 103-2007, with modifications	–	Furnace fans incorporated into hydronic air handlers, SDHV modular blowers, SDHV electric furnaces, and CAC/HP indoor units are not subject to the furnace fan standards
EU	Ventilation units	ISO 5801	EN 308; EN 1341-X series; EN 13053 + additional standards for sound level testing	1253/2014; Annex VIII & IX includes calculation examples, not test procedures	75 % – Many gray zones Not always clear wether reference is static or total pressure, SFP is not always well defined, how to handle additional components	RVU & NRVU are relatively complex components and the regulation is therefore correspondingly complex (19 pages). The variety of products within this scope are equally wide, going from small residential to fairly large industrial units. A part of eco-design regulation on ventilation units is energy labelling for residential units (RVU) covered by 1254/2014
	Fans drivens by motors	ISO 5801 ISO 12759	–	327/2011; Annex II includes calculation examples, not test procedures	90 %. Grey zone defining the term "free inlet".	Fans are only evaluated in one duty point (BEP). The ecodesign requirements for fans are set out in Annex I of the Regulation. The metric is effectively ISO12759. Procedures for calculations for the purposes of compliance and verification of compliance are defined in appendices II and III to the Regulation. Current regulation requires separate motor test to establish the compresabilityfactor in the calculation. Experience shows though that influence from this is neglitable.

Table 26: Fans – Test standards and test procedure in regulation with additional information to regulation

COMPRESSORS – Test standards						
Region	**Product type**	**Test standards**		**Test procedure in regulation**	**MATCH Test standard & regulation**	**Additional information to regulation**
		Global	Regional, National	Reg./Annex nr.		
China	Air compressor	ISO 1217:1996	GB/T 3853	GB 19513-2009 article 5.1.2, 5.2 and 5.3	GB 19513-2009 set MEPS and energy efficiency classification for displacement air compressors. It refers GB/T 3853 and other technical standards as testing method, which supports GB 19513-2009	
USA	Air compressor	Analysis in progress	Analysis in progress	In the Framework document, DOE requested comments on the use of the ISO 1217 and ISO 5389 test procedures, as well as any other test procedures as the basic for the development of a DOE test procedure	–	DOE published a Federal Register notice of public meeting for natural gas compressors. 79 FR 70797 (November 28, 2014). A public meeting was held on December 17, 2014 in Washington, DC
EU	Air compressors	ISO 1217 & ISO 5389	–	–	–	NB Note that this considers waste heat to be a benefit, and so is only useful for MEPS purposes. It does not represent the air: wire power. No regulation defined: main conclusion of the first study is, that low-pressure and oil-free compressors were missing from the study. Regulating the others only would "twist" the market unfair. A new study has been launched last summer 2015, (1st stakeholder meeting February 16) with an expected final report in April 2017.

Table 27: Compressors – Test standards and test procedure in regulation with additional information to regulation

IV Overview of pump types in EU legislation and preparatory studies Lot 28 and 29

Pump type	547/2012	Lot 28	Lot 29
End suction own bearing pumps (ESOB, ≤150 kW	x		
End suction close coupled pumps (ESCC, ≤150 kW	x		
End suction coupled inline pumps (ESCCi, ≤150 kW	x		
Vertical multistage pumps (MS-V, <-25 bar)	x		
Borehole submersible multistage water pump (MSS, 4" or 6")	x		
Centrifugal submersible pumps (radial sewage pumps up to 160 kW		x	
Centrifugal submersible pumps (mixed flow & axial pumps)		x	
Centrifugal submersible pumps (once a day operation, up to 10 kW)		x	
Centrifugal submersible domestic drainage pumps (<40 mm passage)		x	
Submersible dewatering pumps		x	
Centrifugal dry well pumps		x	
Slurry pumps (light duty)		x	
Slurry pumps (heavy duty)		x	
Swimming pool integrated motor & pumps with build-in strainer (up to 2.2 kW			x
Swimming pool integrated motor & pumps with build-in strainer (over 2.2 kW			x
Fountain and pond pumps (up to 1 kW			x
Small aquarium pumps for domestic/small/ non-commercial applications			x
Aquarium power head pumps (up to 120 kW			x
Spa pumps for domestic and commercial use			x
Counter current pumps			x
End suction close coupled pumps (ESCC, 150 kW – 1 MW)			x
End suction coupled inline pumps (ESCCi, 150 kW – 1 MW)			x
End suction own bearing pumps (ESOB, 150 kW – 1 MW)			x
Submersible multistage borehole pumps (MSS, 8", 10", 12", 12"+)			x
Vertical multistage pumps (MS-V, >25 bar)			x

Figure 8: Overview of pump types in EU legislation and preparatory studies Lot 28 and 29 [2]

The IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E)

4E is an International Energy Agency (IEA) Technology Collaboration Programme established in 2008 to support governments to formulate effective policies that increase production and trade in energy efficient end-use equipment. As the international trade in appliances grows, many of the reputable multilateral organisations have highlighted the role of international cooperation and the exchange of information on energy efficiency as crucial in providing cost-effective solutions to climate change. Twelve countries from the Asia-Pacific, Europe and North America have joined together under the forum of 4E to share information and transfer experience in order to support good policy development in the field of energy efficient appliances and equipment. They recognise the huge benefits for energy security, economic development and greenhouse gas abatement from maximising the use of energy efficiency to meet future energy demand. 4E focuses on appliances and equipment since this is one of the largest and most rapidly expanding areas of energy consumption. With the growth in global trade in these products, 4E members find that pooling expertise is not only an efficient use of available funds, but results in outcomes that are far more comprehensive and authoritative. However, 4E does more than sharing information – it also initiates projects designed to meet the policy needs of participants, enabling better informed policy making. The main collaborative research and development activities under 4E include:

- Electric Motor Systems (EMSA)
- Solid State Lighting
- Electronic Devices and Networks
- Mapping and Benchmarking

Current members of 4E are:

Australia, Austria, Canada, Denmark, France, Japan, Korea, Netherlands, Switzerland, Sweden, UK and USA.

Key achievements by 4E members include:

- The platform provided by 4E has given member governments a deeper understanding of the current and future priorities for energy efficiency policies within each country, which they use as a basis for making informed choices about national policy options.
- The 4E platform promotes knowledge sharing, and equally importantly, develops contact amongst peers which engenders on-going communication beyond the 4E environment.
- 4E's reports have enabled 4E countries to compare the performance of locally available products against those in the rest of the world and to identify global trends in different technology areas. These have assisted governments to set national policy priorities.
- 4E has developed best practice methodologies for building national scenarios, as well as the collection and analysis of data. These have helped governments to improve their evaluation of national program impacts.
- 4E provides a forum for governments to explore opportunities for research or policy development collaboration on specific products through multi-lateral or bi-lateral arrangements.
- 4E projects have supported national capacity building in high quality accredited testing laboratories for appliances and equipment.
- 4E has provided governments with representation at international appliance standards forums, making these more relevant to the needs of policy makers.
- The outputs of 4E have provided tangible evidence of the benefits of energy efficiency and assisted members to reinforce the rationale for their own program renewal and boost the allocation of resources.
- Between 2008 and the end of 2015, there have been a total of 660 publications, workshops, presentations and other outreach activities undertaken by 4E aimed at government officials and industry.

Energy Efficient End-use Equipment
International Energy Agency

Further information on 4E is available at:
www.iea-4e.org

Policy Guidelines for Motor Driven Units – Part 1: Analysis of standards and regulations for pumps, fans and compressors, 2016