PEET Efficiency Trends Analysis

Status of Electric Motor Regulations

JULY 2022

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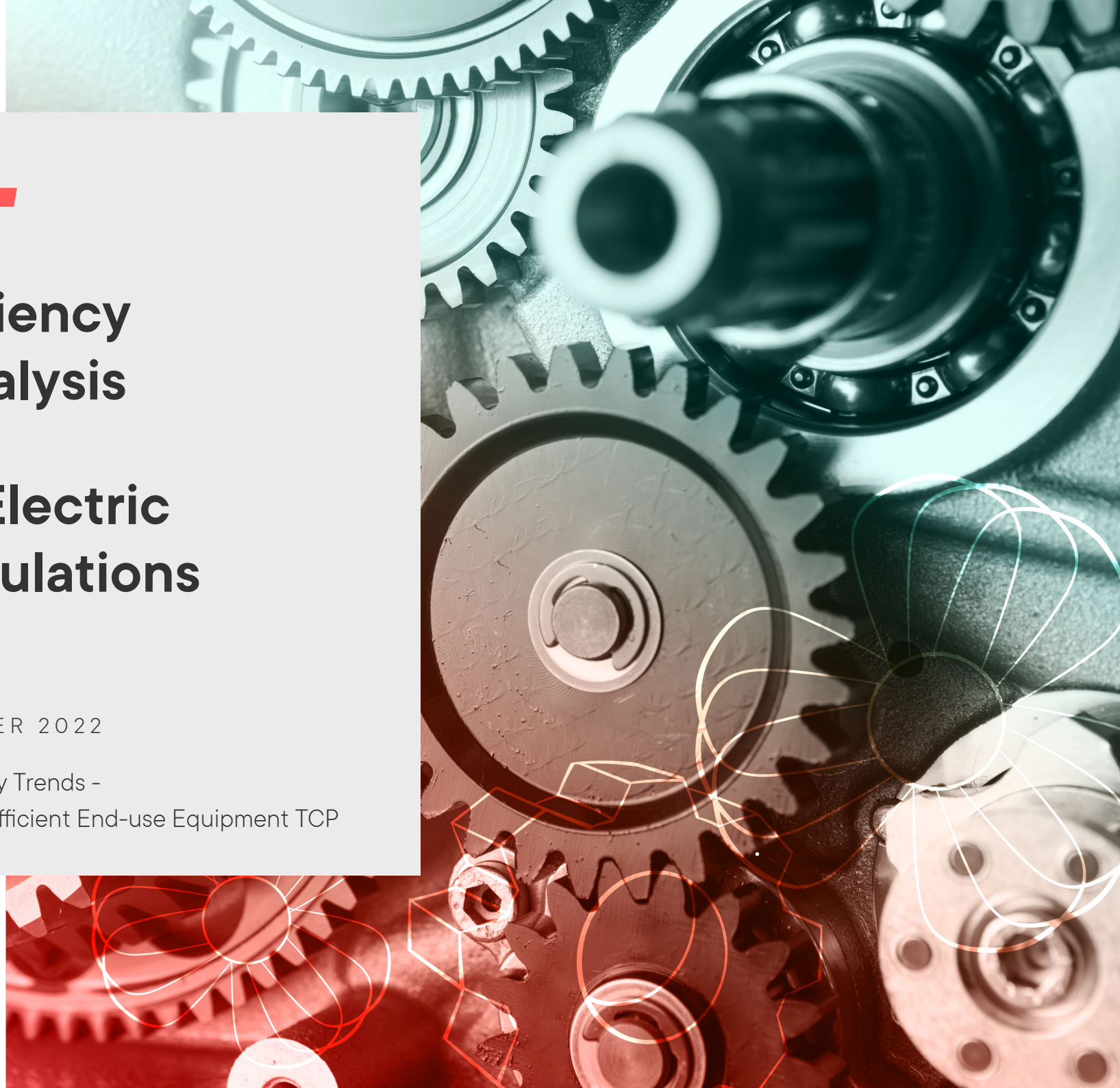
Product Energy Efficiency Trends -
A project of the Energy Efficient End-use Equipment TCP



About 4E

The Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E TCP), has been supporting governments to co-ordinate effective energy efficiency policies since 2008.

Fourteen countries and one region have joined together under the 4E TCP platform to exchange technical and policy information focused on increasing the production and trade in efficient end-use equipment. However, the 4E TCP is more than a forum for sharing information: it pools resources and expertise on a wide a range of projects designed to meet the policy needs of participating governments. Members of 4E find this an efficient use of scarce funds, which results in outcomes that are far more comprehensive and authoritative than can be achieved by individual jurisdictions.

The 4E TCP is established under the auspices of the International Energy Agency (IEA) as a functionally and legally autonomous body.

Current Members of 4E TCP are: Australia, Austria, Canada, China, Denmark, European Commission, France, Japan, Korea, Netherlands, New Zealand, Switzerland, Sweden, UK and USA.

Further information on the 4E TCP is available from: www.iea-4e.org

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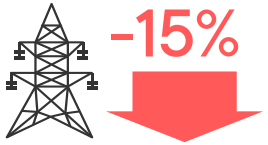
Context

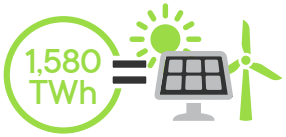
Since 2008, the Energy Efficient End-Use Equipment TCP (4E) has tracked the efficiency trends of major globally traded products and corresponding energy efficiency regulations. This enables 4E Members to identify whether their current policies are being effective, how these policies and the performance of products compares across different regions and opportunities for closer alignment.

This process forms a multi-lateral exchange between regulators within 4E Member countries that accelerates the development of product policies and increases the level of energy savings, while also reducing regulatory and cost burdens on industry and consumers.

Joint analysis by the IEA and 4E into the global impacts of energy efficiency regulations[1] has shown that:

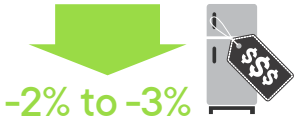


The longest running energy efficiency (EES&L) programmes are estimated to deliver annual reductions of around 15% of total current electricity consumption.



In the nine countries/regions for which data were available, these programmes reduced annual electricity consumption by a total of around 1,580 terawatt-hours in 2018 – similar to the total electricity generation of wind and solar energy in those countries.

On average, the energy efficiency of new major appliances in countries with EES&L programmes has increased two to three times the underlying rate of technology improvement.



The average purchase price of appliances covered by EES&L programmes declined at a rate of 2–3% per year.

Within 4E economies, energy efficiency regulations, taken to include minimum energy performance standards (MEPS), mandatory and voluntary energy labelling in this report, are a key driver for product efficiency. Core elements of these regulations include:

- The methods used to test and measure product performance
- The metrics used to define energy performance or efficiency
- The performance thresholds required by regulations

Since 2020, the 4E Product Energy Efficiency Trends (PEET) project has been monitoring the status of these elements across regulations for major appliance and equipment types across 4E Member countries.

1 IEA/4E TCP (2021), Achievements of Energy Efficiency Appliance and Equipment Standards and Labelling Programmes, IEA, Paris (2021). https://www.iea.org/reports/achievements-of-energy-efficiency-appliance-and-equipment-standards-and-labelling-programmes

Electric Motors

This latest PEET report summarises the status of energy efficiency regulations for **electric motors** within 4E economies.

Electric motors and motor systems[2] are core technologies within all economies, responsible for over 50% of the world's total electricity consumption. As a result, 4E has a dedicated group, EMSA[3], working on the advancement of international standardisation for electric motor systems that underpin national regulations. This report draws on the work of EMSA and ongoing discussions held between 4E Members.

This summary condenses many highly technical regulatory documents. However, to gain a thorough understanding, it should not replace consideration of these regulations.

This report explains the coverage of MEPS regulations by motor type within 4E economies, and then shows the corresponding MEPS thresholds based on the IE rating. It concludes with a brief summary of the major trends and opportunities for electric motor regulations.

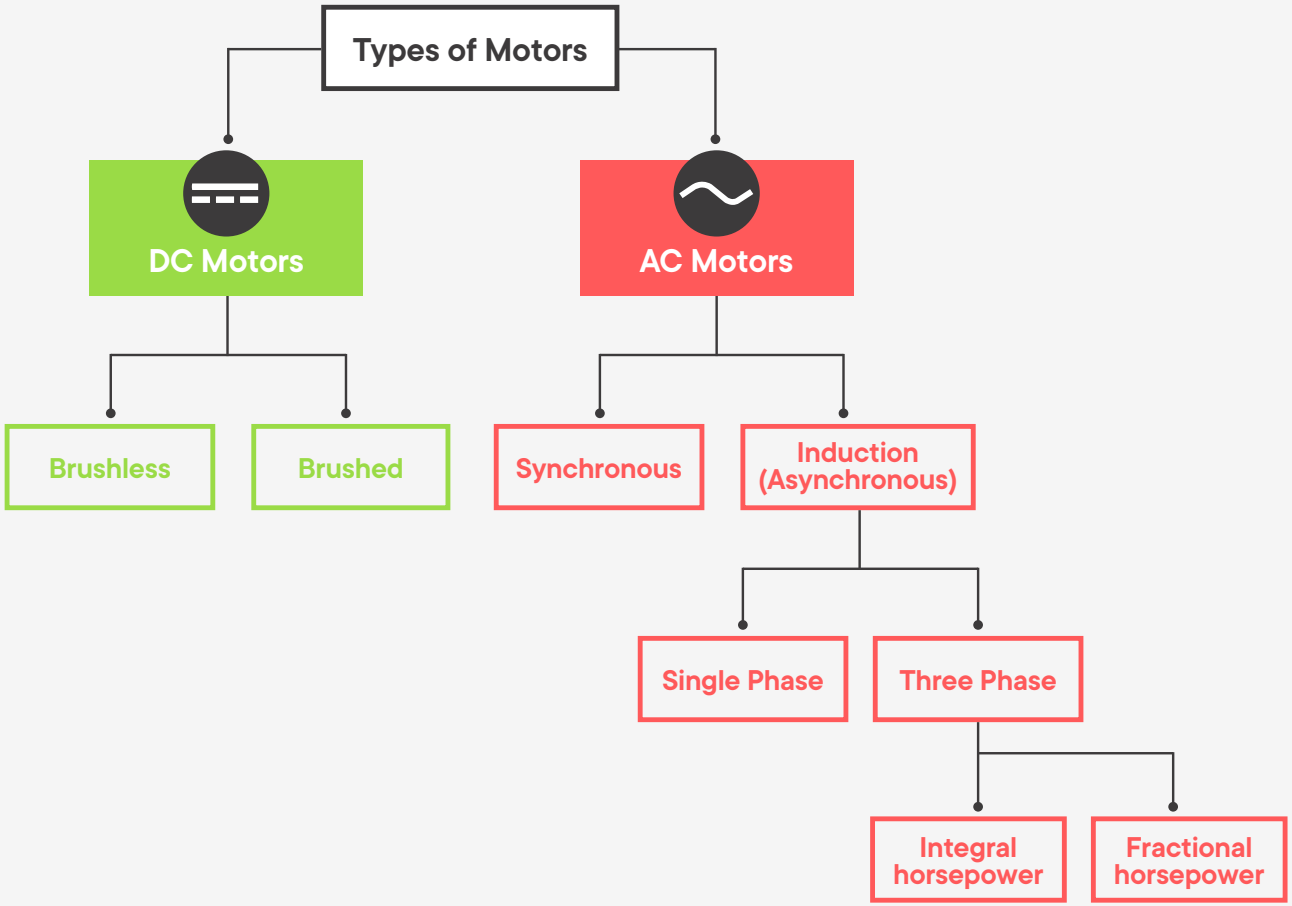
2 An electric motor system includes driven equipment like a pump, fan or compressor as well as other components such as a converter, a transmission, etc.
3 The 4E Electric Motor Systems Annex. See https://www.iea-4e.org/emsa

Motor Types

In this report, we focus on the following groups of motors since these are the most prevalent, consume the largest share of energy and are the focus of most energy efficiency regulations within 4E economies.

- Three-phase AC induction motors, including
  - Integral horsepower (>1 hp or ≥ 0.75 kW)
  - Fractional horsepower (<1 hp or < 0.75 kW)
- Single phase AC induction motors
- AC motors with a variable speed drive (VSD)
- DC motors.

A glossary is provided at the end of this report to explain the terminology used.



Coverage of Regulations

All 4E economies have minimum energy performance standards[4] (MEPS) in force for electric motors, however their scope varies. Their coverage across the types noted above is summarised in Table 1.

Although the total energy consumption by motors and its distribution across the various categories differs in each economy, the scope of regulations is a key factor influencing their impacts.

In the following tables, countries with aligned regulations are grouped by colour coding.

- Three-phase AC induction motors smaller than 0.75 kW are regulated in all but four 4E economies
- Single-phase AC induction motors are regulated in Canada/USA and China and will be regulated in European economies from July 2023
- Variable speed drives (VSD) have been regulated in European economies since July 2021
- Only China has MEPS for some DC motor types
- Only China currently applies energy labels to AC electric motors (however, other economies have rating plate requirements, using the IEC IE-class).

4 In this report, MEPS include the Japanese Top Runner programme.

Table 1: Coverage of MEPS regulations by motor type within 4E economies

	Three-phase AC induction motors						Variable Speed Drives	Single-phase AC	DC
Rated Power (kW)	<0.75	0.75-150	150-183	183-375[1]	375-1000	Explosion proof			
Australia		✔	✔			✔			
New Zealand		✔	✔			✔			
Canada	✔	✔	✔[2]	✔[2]	✔	✔		✔[3]	
USA	✔	✔	✔[2]	✔[2]	✔	✔		✔[3]	
China	✔	✔	✔	✔	✔	✔		✔[4]	✔[8]
EU	✔	✔	✔	✔	✔	✔[5]	✔[6]	✔[7]	
Switzerland	✔	✔	✔	✔	✔	✔[5]	✔[6]	✔[7]	
UK	✔	✔	✔	✔	✔	✔[5]	✔[6]	✔[7]	
Japan		✔	✔	✔					
Korea		✔	✔	✔		✔			

Notes

1 For simplicity, 375kW is shown as the upper and lower threshold boundary in these bands, however the actual value used in some economies is 373kW.

2 Canadian and US MEPS for three-phase AC induction motors in the capacity range 186–373kW. For NEMA Design A or B or IEC Design N motors they apply for 2 and 4 pole motors across the entire power range, for 6 pole motors up to 261 kW and for 8 pole motors up to 186 kW. For NEMA Design C and IEC Design H they apply up to 150 kW for 4, 6, or 8 pole configurations

3 Canadian and US MEPS for single-phase AC "open" motors cover capacitor-start, capacitor-run and capacitor start induction run motor types in the range of 0.18kW to 2.2kW

4 China's requirements for single-phase AC motors are distinguished into 3 types with applicable rated capacities of as low as (0.12kW to 3.7kW for capacitor-start asynchronous motors or for two-value capacitor asynchronous motors) or (0.12kW to2.2kW for capacitor-run asynchronous motors)

5 MEPS requirements come into force in 2023

6 MEPS requirements come into force in 2021 for VSDs rated above 0.12 kW and equal to or below 1000 kW, have a rated voltage between 100 V to 1,000 V and have only one AC voltage output

7 MEPS requirements come into force in 2023 for single-phase AC motors rated greater than 0.12kW regardless of sub-type

8 MEPS and efficiency grade (labelling) requirements cover permanent magnetic synchronous DC motors and brushless DC motors (10W~1100W) for air conditioner fans

Although all 4E economies cover three-phase AC induction motors larger than 0.75 kW within the scope of regulations, there are subtle differences in coverage, as shown in Table 2.

Table 2: Coverage of MEPS regulations for three-phase AC induction motor types larger than 0.75 kW as a function of motor characteristics within 4E economies

	Min power (kW)	Max power (kW)	Min poles	Max poles	Fixed speed	Duty types(s) [3]	Phases	Eligible voltage (V)	Eligible frequency (Hz)	Thresholds dependency on Open/closed?	Brake motors included? [4]	Explosion motors included? [5]	Frame type constraints [6]	TENV motors included? [7]	Other types included?	Other
Australia	0.73	<185	2	8	✔	S1 – S10 (excl S2)	3	≤1100	50 or 50/60	No	By default	By default	No	By default		
New Zealand	0.73	<185	2	8	✔	S1 – S10 (excl S2)	3	≤1100	50 or 50/60	No	By default	By default	No	By default		
Canada	0.746	375	2	8	✔	MG-1 or S1	Poly	≤600	60 or 50/60	Yes	Yes	Yes	Yes	Yes	Fire pump[9]	[8]
USA	0.75	373	2	8	✔	MG-1 or S1	Poly	≤600	60 or 50/60	Yes	Yes	Yes	Yes		Fire pump[9]	[8]
China	0.75	1000	2	8	✔	S1	3	<1000	50	No	By default	Yes	No	No		
EU	0.75	1000	2	8	✔	Continuous	3 or 1	>50-≤1000	50 or 50/60	No	No	From 2023	No	No		
Switzerland	0.75	1000	2	8	✔	Continuous	3 or 1	>50-≤1000	50 or 50/60	No	No	From 2023	No	No		
UK	0.75	1000	2	8	✔	Continuous	3 or 1	>50-≤1000	50 or 50/60	No	No	From 2023	No	No		
Japan	0.75	375	2	8	✔	S1 & S3	3	≤1000	50, 60 or 50/60	No	By default	No	No	By default		
Korea	0.75	375	2 or 4[1]	6 or 8[2]	✔	S1 & S3	3	≤600	60	Semi enclosed	Yes	Yes	Yes	No	Delta starting	

Notes

1 2≤200kW: 4>200kW

2 6>200kW: 8≤200kW

3 The rated duty cycles is shown as S1, S2, S3, etc (under the IEC system) or MG–1 for comparable cycles specified by NEMA

4 Brake motor is a motor equipped with an electromechanical brake unit operating directly on the motor shaft without couplings

5 In IEC standards 'Ex eb increased safety motor' means a motor intended for use in explosive atmospheres and certified 'Ex eb'. A similar definition & classification applies in NEMA standards.

6 According to IEC 60072–16 or equivalent NEMA frame sizes

7 Totally enclosed non-ventilated (TENV) motor' is a motor designed and specified to operate without a fan, and which dissipates heat predominantly through natural ventilation or radiation on the totally enclosed motor surface

8 NEMA A (2–8 poles), B (2–6 poles or 2–8), C (4–8 poles)

9 Fire pump motors are regulated in the range 0.75kW to 373(5) kW

Regulated Efficiency Requirements

Efficiency rating

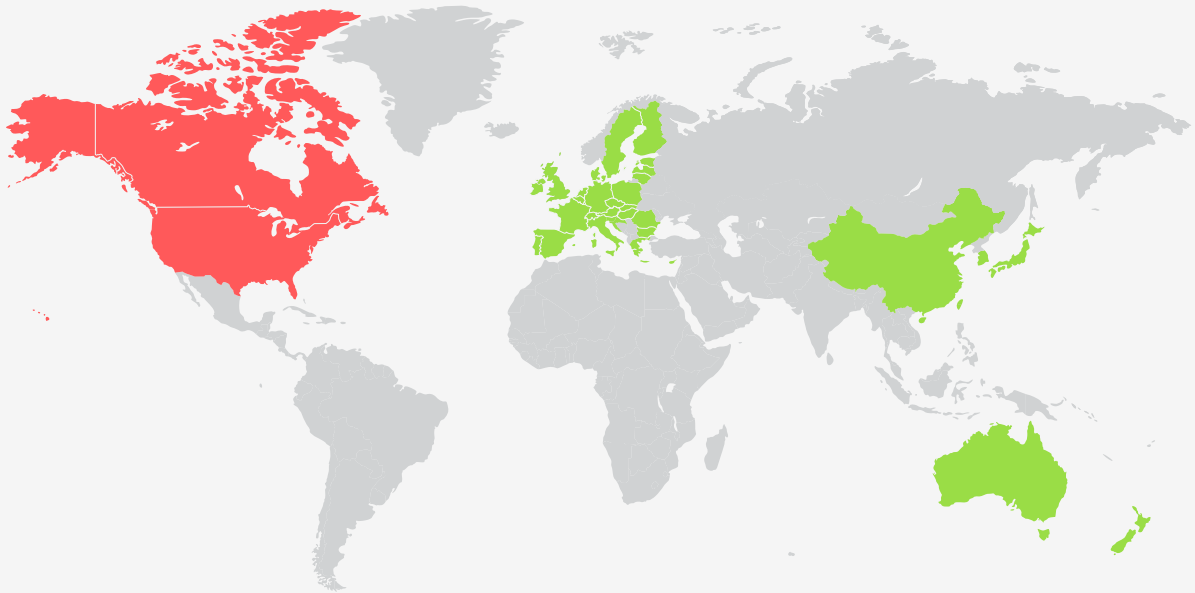
Standardised efficiency rating tiers for motor technologies are published by the International Electrotechnical Commission (IEC[5]) and the National Electrical Manufacturers Association (NEMA). The NEMA standard is used by North American economies, while all other 4E economies use the IE class system produced by the IEC to set performance requirements.

These two standards have become increasingly aligned due to extensive international cooperation over an extended period by organisations such as 4E EMSA.

The equivalence of the two sets of performance thresholds is shown here. Differences in the power supply mean that the two do not always match exactly, however for the purposes of this summary they are sufficiently close to be interchangeable.

NEMA	IEC
Standard Efficiency	IE1
High Efficiency	IE2
Premium Efficiency	IE3
Super Premium	IE4
No Standards	IE5

Each band of efficiency = 15% less motor loss



5 Standard IEC 60034-30-1 defines four efficiency classes (IE) for single speed electric motors with a rated capacity from 0.12kW to 1000 kW. IEC TS 60034-30-2 specifies efficiency classes for variable speed electric motors.

Summary of regulated efficiency requirements for electric motors in 4E countries, 2022–2023

Table 3 and Figure 1 contains a summary of the mandatory requirements for different categories of motors, in terms of the IE class.

It should be noted that where the requirements do not precisely match the capacity ranges two values may be shown. If requirements vary by the number of poles the value for a 4-pole motor is shown.

In the following tables, countries with aligned regulations are grouped by colour coding.

Table 3: Summary of regulated efficiency requirements for electric motors in 4E countries, 2023

Rated Power (kW)	Three-phase AC induction motors						Variable Speed Drives	Single-phase AC	DC
	<0.75	0.75-150	150-183	183-3751	375-1000	Explosion proof			
Australia		IE2[1]	IE2[1]						
New Zealand		IE2[1]	IE2[1]						
Canada	IE3[2]	IE3[2]	IE3 or IE2[2]	IE3 or IE2[2]		IE3 or IE2		IE3 or IE2	
USA	IE3[2]	IE3[2]	IE3 or IE2[2]	IE3 or IE2[2]		IE3 or IE2		IE3 or IE2	
China	IE3	IE3	IE3	IE3	IE3	IE3		IE0 or IE1[3]	IE1 or IE2
EU	IE3	IE4[4]	IE4[4]	IE4[4]	IE3	IE4[5]	IE2[6]	IE2[7]	
Switzerland	IE3	IE4[4]	IE4[4]	IE4[4]	IE3	IE4[5]	IE2[6]	IE2[7]	
UK	IE3	IE4[4]	IE4[4]	IE4[4]	IE3	IE4[5]	IE2[6]	IE2[7]	
Japan		IE3	IE3	IE3					
Korea		IE3	IE3	IE3		IE3			

Notes

1 Australian and New Zealand regulations cover three-phase AC motors in the range 0.73 to 185kW.

2 Canadian and US MEPS for polyphase AC squirrel cage induction motors in the 0.75 to 373(5) kW range distinguish between NEMA Design A & B (per IEC Design N) and NEMA Design C (per IEC Design H). For the NEMA A+B types the MEPS are mostly set at IE3 but some parts (depending on whether the motor is Open or Closed, the number of poles and the capacity) may be IE2 and some just above the IE3 threshold. Note the scope of requirements varies depending on the number of poles so 8 pole motors are only in scope up to 186 kW, 6 poles up to 261 kW and 4 or 2 poles the entire capacity range. NEMA Design C motors are only subject to MEPS in the 0.75kW to 150kW capacity range and for 4, 6 or 8 pole motors. These also have MEPS mostly at the IE3 level or just below (IE2) depending on the enclosure, number of poles & capacity. In addition, fire pump motors are regulated in the range 0.75kW to 373(5) kW.

3 China's requirements for single-phase AC motors are distinguished into 3 types with applicable rated capacities of as low as 0.12kW to 3.7kW for capacitor-start asynchronous motors or for two-value capacitor asynchronous motors or 0.12kW to 2.2kW for capacitor-run asynchronous motors.

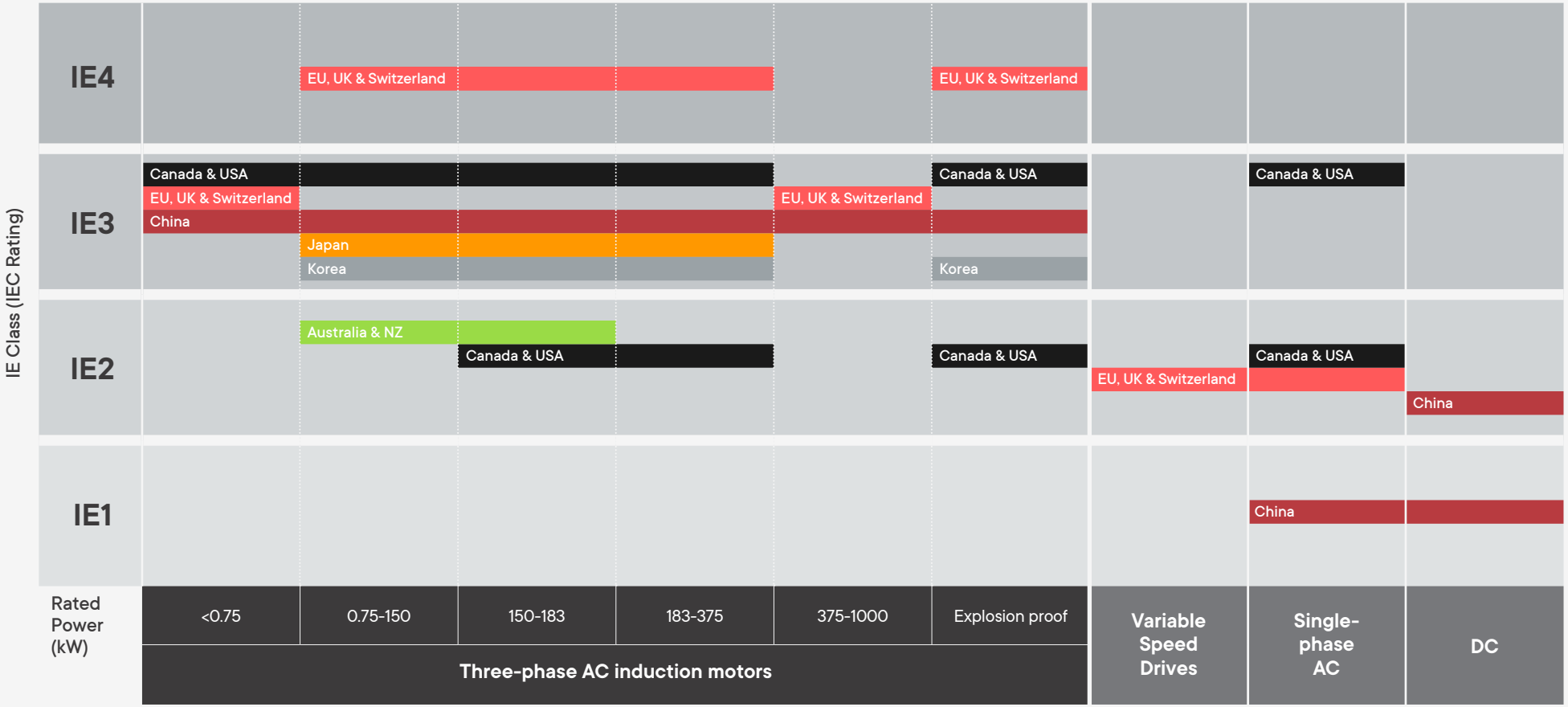
4 New European requirements come into force in 2023: IE4 requirements for polyphase AC squirrel cage induction motors are for motors rated above 75 kW and equal to or below 200 kW only.

5 IE2 levels is for "Ex eb increased safety motors", otherwise as per normal motor types.

6 IE2 requirements are for Variable Speed Drives rated above 0.12 kW and equal to or below 1000 kW. Note the IE levels for VSDs not the same as the IE levels for motors only.

7 New European requirements come into force in 2023: IE2 requirements apply to single-phase AC motors above 0.12 kW.

Figure 1: Summary of MEPS requirements for electric motors in 4E countries, 2023



Notes

The footnotes for Table 3 also apply to this Figure.

Trends

4E economies continue to grow the quantity of energy saved from electric motors by increasing the stringency of energy efficiency regulations and expanding their scope to cover more motor types.

Notable examples of recent upgrades to both raise the level of ambition and expand the scope include:

New regulations in China came into effect on 1st June 2021

The EU/UK/Switzerland have adopted a range of requirements that came into force from 1 July 2021, and additional measures from 1 July 2023

Work is currently underway in the US and New Zealand to investigate further opportunities for electric motors.

As shown in the preceding tables, there is considerable variety in the range of exclusions in current regulations. The fact that these are not universal suggests that some may not be warranted. Their removal may provide opportunities to increase energy savings, simplify regulations and eradicate loopholes.

The expansion of international standards applicable to small motors over recent years has resulted in the inclusion of these products within the scope of regulations in several economies. Similarly, the advent of IEC standards for variable speed drives will enable this product group to be regulated by more countries, as in the EU.

Further opportunities exist with motor types that are currently not regulated anywhere, including three-phase induction motors with wound-rotors ('slip motors') and three-phase synchronous motors.

A significant number of motors are sold as components within other equipment. This poses very significant challenges for regulations and verification procedures for embedded motors and equipment with embedded motors affecting both industry and regulators. Since the regulatory treatment of these varies across different jurisdictions there are opportunities for international collaboration to better understand the different approaches and their impacts.

Glossary

The following terminology is used in this report.

AC	Alternating current (AC) describes the flow of electric charge that periodically reverses, as in most mains electricity from the grid
DC	Direct current (DC) refers to the unidirectional flow of electrons and is typically used in low-voltage applications
Duty	The statement of the load(s) to which a motor is subjected, including, if applicable, starting, electric braking, no-load and rest and de-energised periods, and including their durations and sequence in time
Duty type	A continuous, short time or periodic duty, comprising one or more loads remaining constant for the duration specified, or a non-periodic duty in which load, and speed vary within the permissible operating range
Fractional hp motors	Motors rated at < 1 horsepower (i.e. < 0.75 kW)
Full load	The load that causes a motor to operate at its maximum rating
IEA	International Energy Agency
IE class	The 'International Efficiency' classification of motors and VSDs defined by the respective IEC Standards
IEC	International Electrotechnical Commission
Integral hp motors	Motors rated at 1 horsepower or greater (i.e. ≥ 0.75 kW)
ISO	International Organization for Standardization
Load	All the values of the electrical and mechanical quantities that signify the demand made on a rotating machine by an electrical circuit or a mechanism at a given instant
MEPS	Minimum energy performance standard
NA	Not available (or applicable)
NEMA	National Electrical Manufacturers Association
PEET	Product Energy Efficiency Trends project under the 4E TCP
Rating	The set of rated values and operating conditions
Rated value	A quantity value assigned, generally by a manufacturer, for a specified operating condition
Rated output	The value of the output included in the rating. For a motor it means the mechanical power available at the motor shaft under rated operating conditions. It is expressed in kilowatts (kW) in countries following the metric system, and in horsepower (hp) in other countries.
Single-speed motor	A motor rated for 50 Hz and/or 60 Hz on-line operation
TR	Top Runner Programme in Japan
VSD	Variable speed drive