Accelerating the Global Adoption of

ENERGY-EFFICIENT ELECTRIC MOTORS AND MOTOR SYSTEMS

UN Environment – Global Environment Facility | United for Efficiency (U4E)

U4E POLICY GUIDE SERIES

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FOREWORD

Using more efficient motors, countries can save 300 TWh per annum of electricity in 2030, saving 200 Mt of CO_2 emissions (equivalent to the annual electricity generated by approximately 60 coal-fired power plants with a capacity of 1,000 MW).

Improving energy efficiency is the fastest, cheapest and cleanest way to get reliable power to more people. Well over half of the world's electricity is consumed by just four products: electric motor systems, lighting, room air conditioners, and residential refrigerators.

These products, and the transformers that help get power to them, often waste significant amounts of electricity due to poor designs and improper use. As a result, consumers and business face higher electricity bills, utilities struggle to meet excessive demand for power, governments are burdened with additional economic development challenges, and the planet suffers from worse pollution and greenhouse gas (GHG) emissions due to obsolete or poor design and improper use.

Most developed countries are well underway in the transition to energy-efficient motors. However, many developing and emerging economies are just starting to explore and implement such opportunities. A well-designed set of policies can help transform these markets by enabling them to leapfrog past out-dated technologies to superior, cost-effective alternatives.

United for Efficiency (U4E) is a global initiative launched in 2015 to accelerate such a transition and unlock lasting economic, health, environmental, and climate benefits. UN Environment leads U4E, with funding from the Global Environment Facility (GEF) and steadfast support from the UN Development Programme, CLASP, the International Copper Association, the Natural Resources Defense Council, and an array of global partners. Participating manufacturers include ABB, Arçelik, BSH Hausgeräte GmbH, Electrolux, MABE, MEGAMAN, Osram, Philips Lighting and Whirlpool Corporation.

This report guides policymakers on how to promote energy-efficient motors and motor systems in their national markets. It is based on U4E's Integrated Policy Approach, which has been applied around the world to bring about sustainable market transformations. The content was developed based on expert insights from over 20 organisations, ranging

from motor manufacturers and industry associations to environmental groups, academia, and governments. This balanced approach offers credible guidance to address common questions.

This report is part of a series of U4E guides, which cover lighting, room air conditioners, residential refrigerators and transformers. An additional overarching "Policy Fundamentals Guide" provides general guidance on the establishment of a national programme for energy-efficient products.

A wealth of additional resources and information on how to get involved in U4E is available at www.united4efficiency.org. U4E works under the umbrella of the Sustainable Energy for All initiative, leading its "Energy Efficiency Accelerators" of Lighting, Appliances and Equipment.

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U4E United for Efficiency

THIS REPORT FOCUSES ON **ENERGY-EFFICIENT ELECTRIC MOTORS AND MOTOR SYSTEMS**

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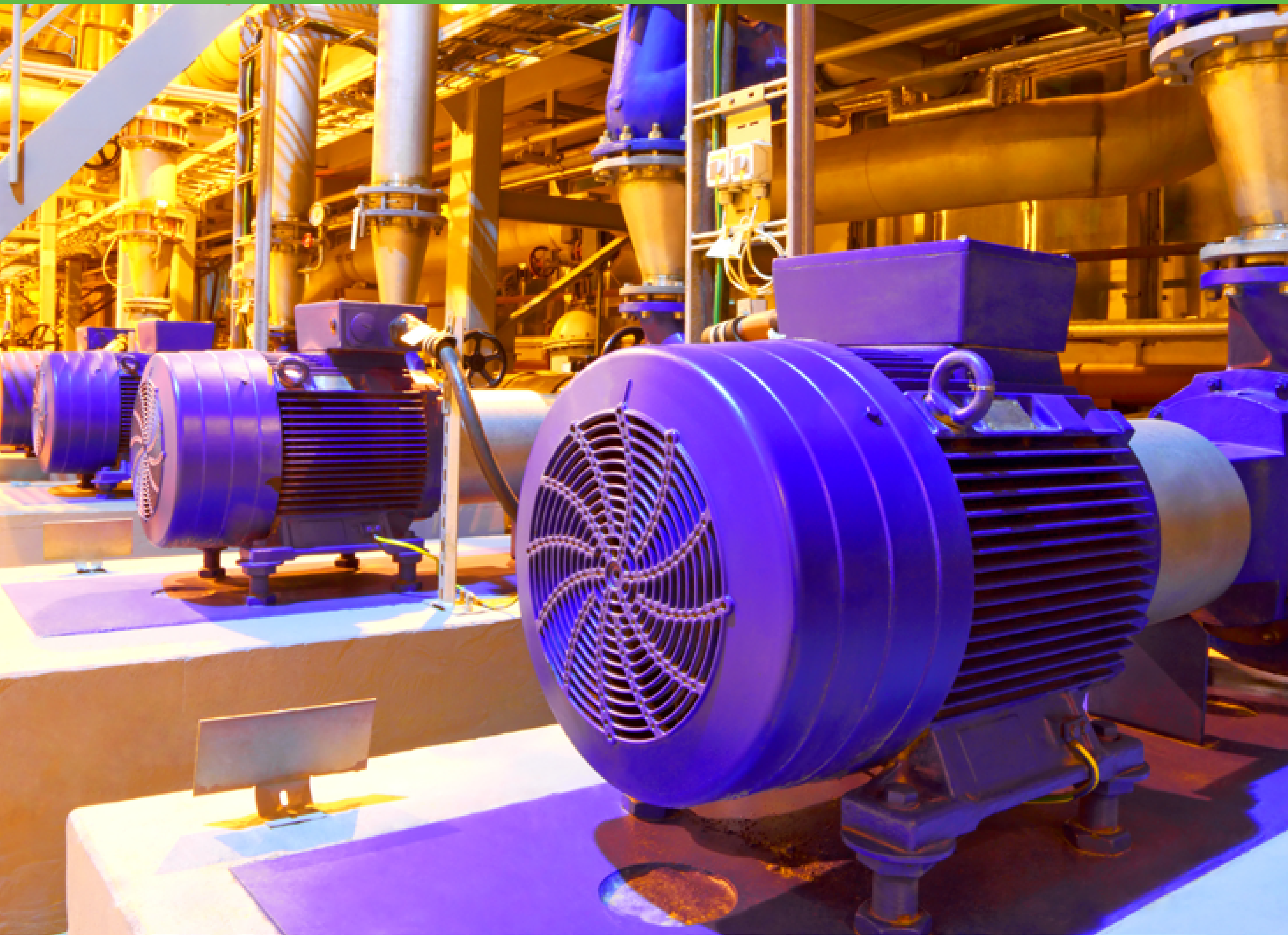


EXECUTIVE SUMMARY

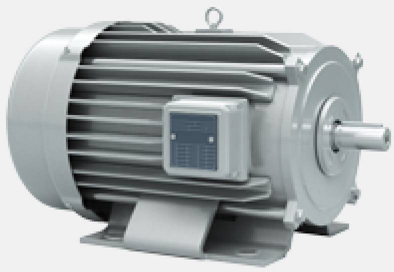
Motors convert electrical energy into motion. They are found everywhere, from micro motors in computer hard drives and small motors in domestic appliances to medium and large motors in commercial buildings and factories. A transition to energy-efficient motor systems can reduce their global electricity demand by 20 to 30 per cent in 2030.

The industrial and building sectors comprise 90 per cent of the electricity used by motors. The IEA has estimated that 53 per cent of all electrical energy, or 10,500 TWh per year, is used by electric motor systems globally, giving rise to around 6,800 Mt of carbon dioxide (CO_2) emissions (equivalent to the annual electricity generated by approximately 2,200 fossil fuel-fired power plants with a capacity of 1,000 MW).[1] This share is increasing as more of the transportation sector is electrified, fossil fuel-fired boilers in buildings are replaced with heat pumps, and the number of domestic appliances expands around the world.

General purpose, three-phase, medium-size induction motors and the systems that are driven by these motors are the target of policies recommended in this guide (see Figure 1). There is considerable international policy experience with this range of motors, and best practice examples are readily available for adaptation and replication by developing countries. These motors comprise 10 per cent of the global stock but account for 68 per cent of energy used by motors.[2] Once experience has been gained with regulating these motors, policies are typically expanded to cover additional motor sizes and types, other parts of the motor system (which is more complex but offers considerably larger energy savings potential), and the repair of existing motors that are already in use.

U4E has developed assessments for 150 developing and emerging economies on the respective financial, climate, and energy benefits of transforming their markets. The assessments show energy savings from motors in these countries could reach 300 TWh per annum in 2030, with a savings of 200 Mt of CO_2 emissions (equivalent to the annual electricity generated by approximately 60 coal-fired power plants with a capacity of 1,000 MW).[3]

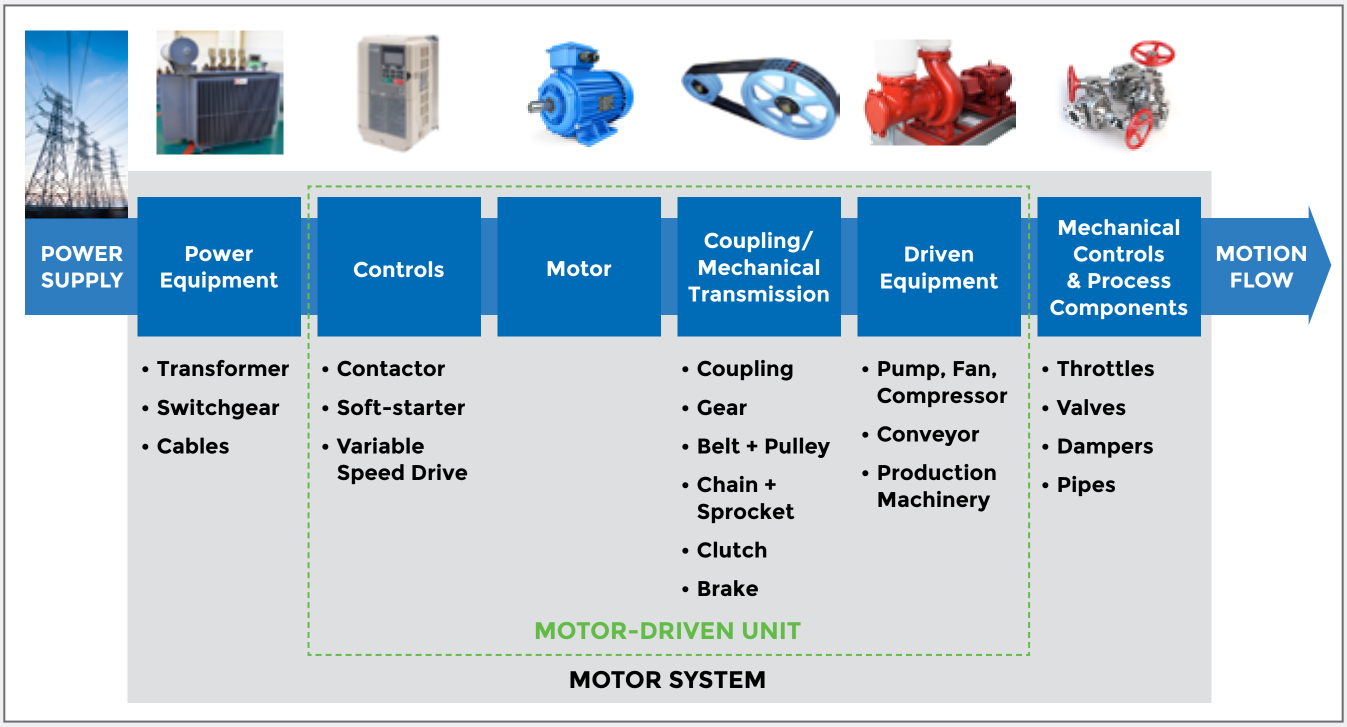
Figure 1: Examples of the motors targeted by this guide



The electric motor system (see Figure 2) includes equipment for supplying power, starting the motor and varying its speed, mechanically transmitting its motion to drive equipment (e.g. pumps, fans, compressors, production machines), and additional controls for subsequent parts of the process. Not all of the electrical energy that goes into a motor is converted to usable mechanical energy. Some of this energy is lost as heat during the conversion process. Such losses occur at each step in the electric motor system, which compound along the way and can result in significant overall inefficiencies.

A transition to energy-efficient motor systems would reduce the global electricity demand by motor systems by 20 to 30 per cent in 2030[4] depending on the actual development and implementation of energy efficiency and environmental policies globally.

Figure 2: Components of a motor system



There are many solutions to address energy losses. These solutions typically add to the initial price of the equipment, but they yield energy savings that lower utility bills. The end result for the purchaser is a lower overall lifetime cost of ownership of the motor system.

Well-designed and implemented policies are critical in eliminating poor performing models from the market and supporting high-efficiency alternatives.[5] Policies such as minimum energy performance standards (MEPS) are used to regulate the efficiency of the motor, and separately of the motor-driven unit (depicted in Figure 2). While policies to mandate motor efficiency are the principal focus of this guide, these should be accompanied by voluntary approaches that address the overall motor system, which is more complex but offers considerably larger energy savings potential.

A further area for policy intervention is motor repairs. A motor's performance may be diminished each time it is repaired in small, ill-equipped shops commonly found in developing countries. Motors are often repaired up to three times over their lifetime.

Over 40 countries representing 80 per cent of global electricity use in motor systems have successfully steered their markets toward higher efficiency using approaches described in this Policy Guide. The risks of inaction are immense, particularly for developing and emerging economies. An absence of robust and well-enforced policies – when most of the world has them – may cause them to become the destination for inferior motors that are not acceptable elsewhere.

Since motors have long lifetimes, sometimes 20 years or more, the electricity waste is locked-in for decades. Factories and businesses are less competitive as they spend more money than necessary to power their equipment while competing with energy conscious companies elsewhere in the world. Utilities that already struggle to meet electricity demand face unnecessary strains on the grid as additional inefficient motors enter the market. Appropriate and well-implemented policies have an immediate impact on the market, but it takes a number of years for the entire stock to be affected as new products replace old ones.

An Integrated Policy Approach to fully transform a market includes:

- **Standards and Regulations** that define which equipment is blocked from the market (those that do not meet minimum energy performance standards (MEPS), which equipment may be recognised for meeting performance and quality requirements, how to test the equipment, and other aspects. Standards and regulations are essential to the success of market transformation, and therefore are the cornerstone of the U4E Integrated Policy Approach.
- **Supporting Policies** that ensure the smooth implementation of standards and regulations and achieve broad public acceptance. Supporting policies include labels that endorse the performance of the equipment or allow for easy comparison of performance between competing products. Consumer awareness campaigns are also used to help purchasers make more informed decisions about the total cost of ownership of the equipment and to modify behaviour (e.g. encouraging the timely repair of equipment by certified technicians).
- **Finance and Financial Delivery Mechanisms** that address the barrier of higher upfront costs of efficient equipment through fiscal incentives such as grants, rebates and tax-relief, or by extending credit lines, partial risk guarantees, loans, bulk procurement opportunities, equipment leasing through financial intermediaries, and services through energy service companies.
- **Monitoring, Verification and Enforcement (MVE)** that track which equipment is sold in the market, test the equipment to ensure that claims of performance are accurate, and to prompt corrections by those that fail to comply. Otherwise, incentives intended for efficient products may reward sub-standard alternatives and non-compliant equipment will enter the market. This results in an uneven playing field, penalising manufacturers who comply with the requirements. Moreover, poor quality equipment that is advertised as energy-efficient will

disappoint consumers who may opt to avoid performance considerations in the future.

- **Environmental Sustainability and Health** considerations, given the hazardous wastes (e.g. lubricating grease) found in motors, the risks for workers during motor manufacturing and repair, the recycling opportunities for many components that can be diverted from landfills, and the need to get end-users engaged to facilitate waste collection and processing.

The guidance is meant to be flexible, rather than prescriptive. Each country should consider and make decisions based on its specific priorities and circumstances. This process should involve all relevant authorities and stakeholders in jointly determining priorities and the most appropriate pathways to achieve them.

KEY RECOMMENDATIONS FOR POLICYMAKERS:

- **Use this report, the "Fundamental Policy Guide", and other resources available at united4efficiency.org** to develop and implement a national efficient motors strategy.
- **Adopt mandatory MEPS** for general purpose, three-phase electric induction motors with two, four or six poles; rated output between 0.75 kW – 375 kW (i.e. 1 HP to 500 HP); rated voltage up to 1,000 Volts at 50 Hz or 60 Hz; and continuous duty operation.
  - **Level IE2** (defined by IEC 60034-30-1) is recommended as a starting point for countries that produce motors domestically.
  - **Level IE3** (defined by IEC 60034-30-1) is recommended as a starting point for countries that import all motors.
- **Collaborate with other countries** in the region to harmonise standards according to international best practices and to share resources and lessons learned.
- **Require that all motors feature IEC 60034-30-1 conformant nameplates.**
- **Conduct targeted outreach and training** to inform, educate, and gain the support of key stakeholders.
- **Aim to implement a MVE regime** within the national legal framework in time to coincide with the adoption of MEPS, and ensure accurate and reliable measurement of the energy efficiency of motors as prescribed by IEC Standard 60034-2-1.
- **Encourage adoption of best practices** (e.g. per ANSI/EASA AR100 or the specifications of the Consortium for Energy Efficiency) in repair shops to yield professional repairs so motors meet their original performance.
- **Assess existing sources of finance and conduct market analysis** to understand financial barriers so that applicable delivery mechanisms are in-place to support voluntary actions (e.g. encourage the purchase of motors with higher efficiency than MEPS, early-replacements of inefficient motors, upgrading motors systems).
- **Use voluntary supporting policies** to enhance the efficiency of motor driven units and the overall motor system.
- **Consider regulating motor driven units** after sufficient experience has been gained with the implementation of mandatory MEPS for motors.
- **Establish collection and recycling mechanisms** for motors that have reached the end of their useful life, as the cast iron, steel, aluminium, copper, stainless steel and brass parts that constitute more than 98 per cent of the material content are fully recyclable.

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ACRONYMS AND ABBREVIATIONS

AC .... Alternating Current

CO_2 .... Carbon Dioxide

DC .... Direct Current

DSM .... Demand Side Management

EASA .... Electrical Apparatus Service Association

EEM .... Energy-Efficient Motors

ESCO .... Energy Services Company

EU .... European Union

FAQ .... Frequently Asked Questions

GEF .... Global Environment Facility

GW .... Gigawatt (10^9 Watts)

HVAC .... Heating, Ventilation, Air-conditioning

IEC .... International Electrotechnical Commission

IM .... Induction Motor

kW .... Kilowatt (10^3 Watts)

LV .... Low Voltage

MEPS .... Minimum Energy Performance Standards

Mt .... Megaton (10^6 tonnes)

MV .... Medium Voltage

M&V .... Measurement and Verification (e.g. of energy savings)

MVE .... Monitoring, Verification and Enforcement

MW .... Megawatt (10^6 Watts)

NAMA .... Nationally Appropriate Mitigation Actions

NDC .... Nationally Determined Contributions

NGO .... Non-governmental Organisation

O&M .... Operation and Maintenance

OECD .... Organisation for Economic Co-operation and Development

PM .... Permanent Magnet

PPP .... Public Private Partnership

QR .... Quick Response (QR code)

RM .... Reluctance Motor

S&L .... Energy Efficiency Standards & Labelling Programme for Appliances and Equipment

SEAD .... Super-efficient Equipment and Appliance Deployment

SEC .... Specific Energy Consumption

SEforAll .... Sustainable Energy for All Initiative

SME .... Small and Medium Enterprises

SMPS .... Switch Mode Power Supply

TWh .... Terawatt-hour (10^{12} Watt-hours = 1 billion units of electricity)

U4E .... United for Efficiency

UNDP .... United Nations Development Programme

UNEP .... UN Environment

UNIDO .... United Nations Industrial Development Organization

US .... United States of America

$ .... United States Dollars

VFD .... Variable Frequency Drive

VSD .... Variable Speed Drive

1. INTRODUCTION

Electric motors convert electrical energy into motion and are found everywhere in homes, offices, buildings and factories. However, motors do not convert all the electrical energy to usable mechanical energy because some of it is lost as heat during the conversion process. At a motor system level, the energy losses are much greater due to additional inefficiencies in the mechanical and hydraulic components. Motor repairs, if carried out unprofessionally, are a source of further energy losses.

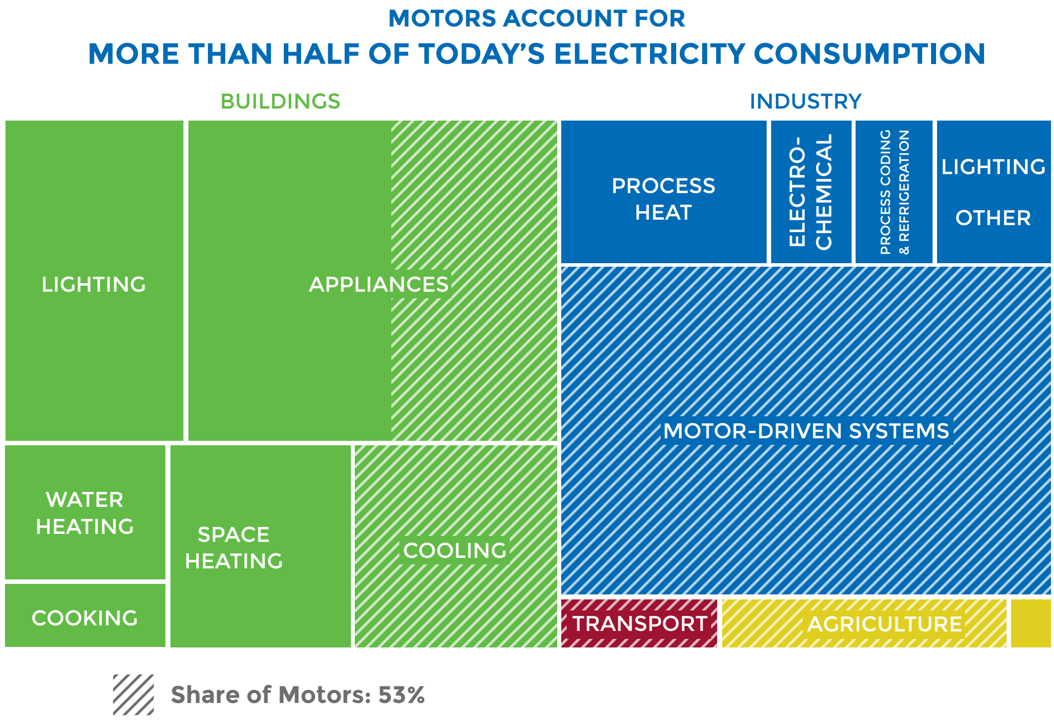
Establishing appropriate policy measures can drive markets to adopt robust performance standards, promote professional motor repair practices, and encourage efficiency improvements in the overall systems that are driven by motors. Policymakers around the world are exploring ways to stimulate action among key stakeholders to transform their respective markets.

This guide aims to support that policymaking process. It was designed with the participation of over 20 organisations, including intergovernmental organisations, environmental groups, international motor manufacturers, NGOs and academic institutions.

Induction motors and the systems that are driven by these motors are the target of policies recommended in this guide. More specifically, these motors are defined as general purpose, three-phase electric induction motors with two, four or six poles; rated output between 0.75 kW – 375 kW (i.e. 1 HP to 500 HP); rated voltage up to 1000 Volts at 50 Hz or 60 Hz; and continuous duty operation.

The IEA estimates that 53 per cent of global electricity, or 10,700 TWh per year, is consumed by electric motor systems, giving rise to 6,960 Mt of CO_2 emissions (see Figure 3).[6] Electric motors in the industry and buildings sectors account for around 57 per cent and 35 per cent of the global electricity consumption by electric motor systems respectively. Taken together, these two sectors account for over 92 per cent of the electricity consumed by motors, with the agriculture and transport sectors accounting for the remaining 8 per cent.

Figure 3: Global electricity consumption by end-use in 2014[7]



Each country is encouraged to analyse its own market, consider the guidance in this document, and to make policy decisions thereafter, that are based on its specific priorities and circumstances.

1.1 WHY LEAPFROG TO ENERGY-EFFICIENT ELECTRIC MOTORS AND MOTOR SYSTEMS?

Not all of the electrical energy that goes into a motor is converted to usable mechanical energy. Some of this energy is lost as waste heat during the conversion process. Such losses occur at each step in the electric motor system, which compound along the way and can result in significant overall waste. A transition to energy-efficient motor systems would reduce their electricity demand by 20 to 30 per cent in 2030[8] depending on the actual development and implementation of energy efficiency and environmental policies globally.

Many countries are taking action to address this opportunity. Australia, Brazil, Canada, China, the European Union (EU), India, Japan, Mexico, New Zealand, Norway, Republic of Korea, Saudi Arabia, Switzerland and Turkey – which together represent 81 per cent of the global electricity consumed by electric motor systems - have worked to transform their markets through regulations and supporting policies for electric motors.[9] Egypt and Indonesia are developing similar policies.

However, most developing and emerging economies are not taking such actions, often due to a combination of capacity challenges, financial barriers, and other opportunities that are more familiar than energy efficiency. An absence of energy efficiency policies can result in the entrenchment of inferior motors.

Since motors have long lifetimes, sometimes 20 years or more, the lack of policies locks-in electricity waste for decades. Factories and businesses are less competitive as they spend more money than necessary to power their equipment while competing with energy conscious companies elsewhere in the world. Utilities that already struggle to meet electricity demand face unnecessary strains on the grid as additional inefficient motors enter the market.

There is considerable international experience with regulating general-purpose induction motors, and best practices are available for adaptation by developing and emerging economies. Once experience has been gathered with regulating these motors, policies are typically expanded to cover additional motor sizes and types, other parts of the motor system (which is more complex but offers considerably larger energy savings potential), and the repair of existing motors that are already in use.

The U4E initiative conducted assessments of 150 developing and emerging economies on the financial, climate, and energy benefits of transforming their respective markets. The assessments show that across these economies in 2030, annual energy savings from general purpose, medium size, low-voltage, 3-phase electric induction motors could reach 300 TWh and annual savings in CO_2 emissions could reach 230 Mt.[10] The impact for motor systems would be an order of magnitude higher.

There are many other on-going programmes that try to help find mechanisms to mitigate climate change cost-effectively. These include, for example, climate change and sustainable energy efforts and commitments (country commitments through Nationally Determined Contributions or NDCs), the United Nations Framework Convention on Climate Change's Conference (UNFCCC) of the Parties XXI (COP 21) emission reduction targets, the Clean Energy Ministerial, the GEF programmes, the World Bank's programmes, the Super-efficient Equipment and Appliance Deployment (SEAD) Global Efficiency Award Medal for motors, and more.

The work promoting efficient motors and motor systems in any country should touch upon and draw from these programmes and initiatives. Most importantly, it should establish a more sustainable, energy-efficient and better quality national motors market for that country.

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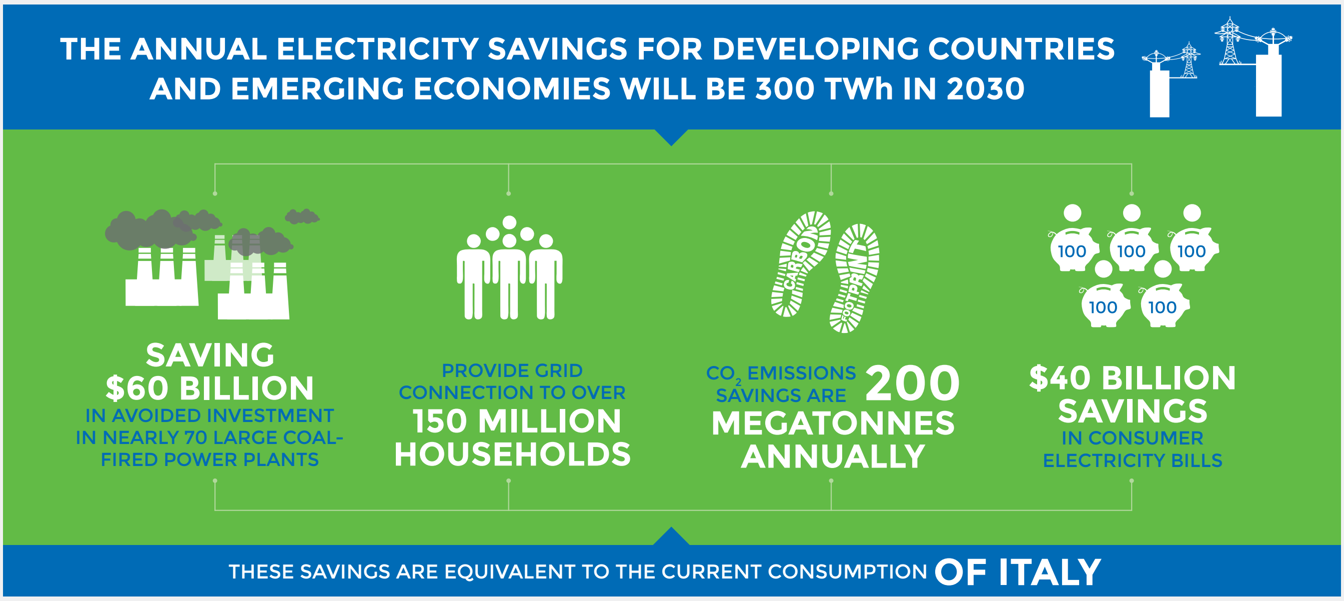


1.2 THE INTEGRATED POLICY APPROACH

A variety of barriers hamper the adoption of energy-efficient motors and motor systems, as noted in Table 1.

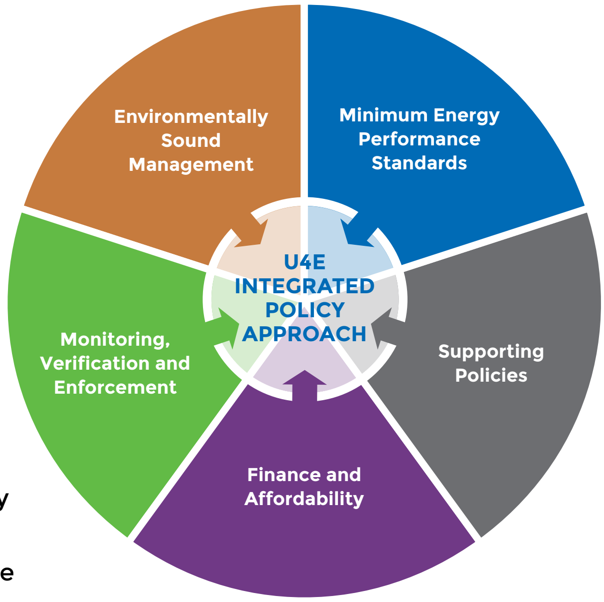
Table 1: Barriers to the adoption of energy-efficient motors and motor systems

BARRIER	DESCRIPTION	EXAMPLES
FINANCIAL	Higher first cost of more-efficient motors relative to less-efficient ones Cost of upgrading motor systems Cost of upgrading motor repair facilities	• Investments in energy efficiency are considered a lower priority to core business investments. • Emphasis on lowest upfront costs (generally less than 2 per cent of lifecycle costs) rather than on the recurring costs of lost energy (generally more than 98 per cent of lifecycle costs) at the procurement stage, although there is generally a strong business case based on lifecycle costing for the incremental investment in terms of quick payback. • Preference for repeated repairs of failed inefficient motors rather than replacement with efficient ones • Existence of a market for used motors • Small and complex transactions, inability to assess risks discouraging financiers. • Lack of confidence of financiers in future energy savings as an adequate security. • Local manufacturers may need to retool production for higher-efficiency motors.
MARKET	Market structures and constraints that prevent investments in energy-efficient motors and motor-systems	• Split incentive – most motors are procured as a part of larger systems through equipment manufacturers who incur the higher costs of more efficient motors, while end-users reap the benefits. End users demand low system prices, in turn pressuring equipment manufacturers to buy cheap motors, which are likely to be inefficient. • Split responsibilities for procurement and operations within companies, with independent budgets. • Operating plants are seldom disturbed for upgrading to higher-efficiency motors. The opportunity only arises when a motor fails. In such an event, the priority is often to get the plant up and running again as fast as possible by repairing the failed motor. • Distributors stock what sells in the local market, leading to limited availability and longer delivery times of high-efficiency motors until usage picks up, which in turn constrains the growth in usage. • Resistance from local motor manufacturers seeking protection by citing technology and financing constraints. • The presence of large inventories of unused but inefficient spare motors with users, which they consider wasteful to scrap (generally, no rule on motors in user stocks built before the effective date of regulations).

BARRIER	DESCRIPTION	EXAMPLES
INFORMATION AND CAPACITY	Lack of information and technical capacity for evaluating the potential savings from energy-efficient motors and systems	• Lack of awareness/conviction of the energy savings potential of energy-efficient motors and systems with users, partly due to missing technical capacity for evaluation and implementation of a motors efficiency programme. • Employees working with motor systems are inadequately trained on operating these optimally. • Equipment manufacturers and dealers are inadequately informed. • Motors systems are oversized and, therefore, inefficient due to layer upon layer of safety margins to cover unknowns and uncertainties, as well as due to equipment manufacturers' practices. • Lack of competent service providers for motor systems optimisation. • Motor repairers lack awareness of good practices.
REGULATORY AND INSTITUTIONAL	Structural characteristics of the political and legal system that make it difficult to promote efficient motors and systems	• Inadequately defined institutional roles and responsibilities for promoting energy efficiency. • Electricity subsidies distort the private business case for energy efficiency investments, causing a net public loss. • Nontariff barriers to imports of efficient equipment, like cumbersome registration processes or special requirements. Lack of harmonisation with trading partners. • Inadequate institutional capacities to deal with the large- scale imports of inefficient motors. • Inadequate monitoring, verification and enforcement capacities.
TECHNICAL	Inadequate technology	• Inadequate access to technology for designing and manufacturing high-efficiency motors with local industry. • Inadequate equipment and technical facilities with motor repair shops. • Lack of adequate/accredited testing capacities. • Limited resources to monitor, verify and enforce national regulations domestically and at customs.
ENVIRON-MENTAL RISK PERCEPTION	Environmental concerns over safe disposal of motors at end of life	• Absence of specific policies for disposal of motors at end of life, although individual policies may exist for its components–metals, plastics, rubber, hazardous wastes.

To address these issues and guarantee a sustainable transition to efficient motors and motor systems, UN Environment recommends a five step Integrated Policy Approach (see Figure 4).

Figure 4. Integrated Policy Approach to transform a market



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1.3 REPORT OVERVIEW

This report provides overall guidance and is a reference source for developing country and emerging economy policymakers to transition to energy-efficient electric motors and motor systems. It offers an overview of all the key elements for transforming a national motors market towards higher efficiency through the application of the Integrated Policy Approach. It makes note of the many existing best practice examples, resources and tools that are available for policymakers to use. This is a brief synopsis of each of the chapters in this report:

Chapter 2
Motor Technologies and Markets – gives an overview of motor and motor systems technology; enumerates the different components of motors systems; introduces energy efficiency classification; and describes some of the recent technological developments in the market.

Chapter 3
Standards and Regulations – introduces standards and regulations and specifically MEPS, the first part of UN Environment's Integrated Policy Approach, as a regulatory tool to transform motor markets towards higher energy efficiency. It provides an overview of the test standards and methods used to measure motor energy performance; outlines a systematic approach to developing MEPS; and spells out the benefits of harmonisation regionally, and with trading partners.

Chapter 4
Supporting Policies – introduces motor nameplate efficiency labelling as the principal mechanism for elimination of inefficient motors, and differentiating higher efficiency levels. Supporting policies include the promotion of voluntary approaches to improve motor systems efficiency and improve repair practices through regulatory incentives, and information and communication campaigns that enable end-users to assess energy-savings potential and benefit from least life cycle cost procurement practices.

Chapter 5
Financing – addresses the critical issue of overcoming first-cost barriers to market adoption, including topics such as financing sources, approaches and stakeholders. Areas covered include grants, tax rebates, energy service companies, lender finance, and equipment leasing schemes.

Chapter 6
Market Monitoring, Verification and Enforcement – discusses the importance of Market MVE from both a manufacturer and user's perspective. It discusses the critical role of government in establishing and maintaining a robust market compliance programme.

Chapter 7
Environmental Sustainability – provides a summary of the recycling of old low-voltage induction motors at the end of life, the processes of collection and recycling, and the financing mechanisms. It also provides an overview of the potential health risks associated with low-voltage motor production and usage, and mitigating measures.

Chapter 8
Implementation – provides a summary of the process governments may choose to follow to implement a policy-driven market transformation in their respective national markets.

Chapter 9
Resources – presents an overview of reports/resources and energy-efficient motors' programmes and initiatives from around the world, including a high-level summary, web-links and additional information.

Finally, the report offers a glossary (Annex A) of commonly used terms found in this report and an introduction to the basics of electric motors (Annex B).

2. MOTOR TECHNOLOGIES AND MARKETS

WHAT?	An introduction to electric motors and motor systems; an overview of the market end-use sectors, applications, and current technology trends; and explanations of energy losses, energy efficiency classes, energy efficiency testing standards and energy savings potential. This helps policymakers to have a basic understanding of the technology, and technical and market characteristics that will be referenced in subsequent chapters.
WHY?	Provides the foundation in terms of technology and markets for the subsequent discussions and policy decisions that will need to be made.
NEXT?	Some key questions to keep in mind: • What does the motors and motor systems market look like in my country? What proportion of demand does the domestic industry meet? How concentrated or fragmented is it? Which are the main application areas? • With which stakeholders in our national supply chain (e.g. power utilities, industrial firms, large building owners, civil society organisations, practitioners such as installers and repair shops) with a potential interest in a national initiative would I need to engage? • What are the market barriers to more efficient motors in my country, and how might these be overcome?

2.1 MOTOR TECHNOLOGIES

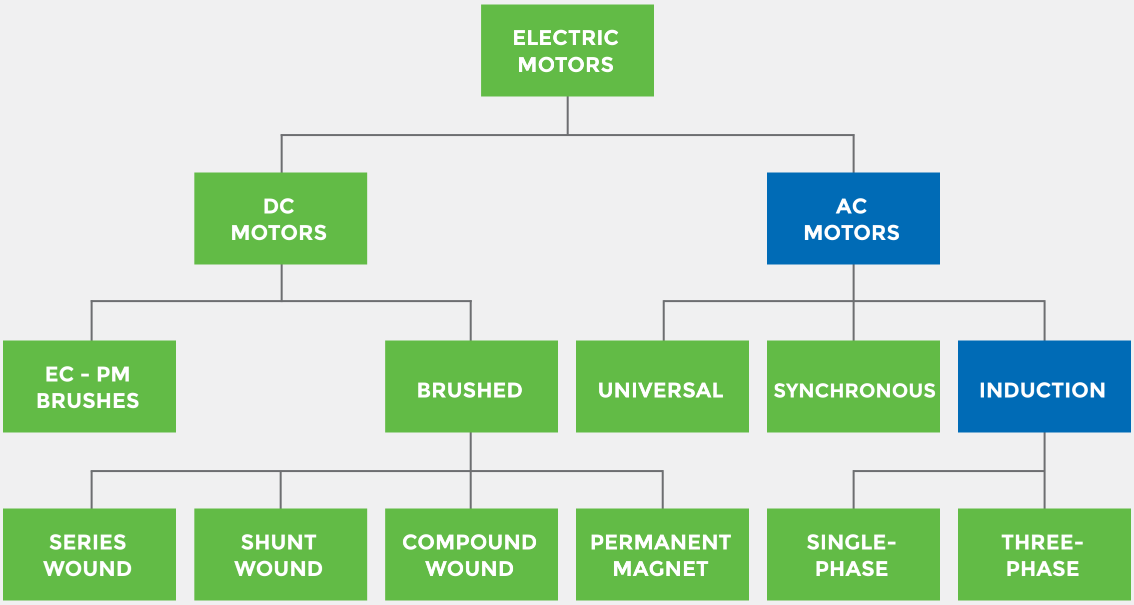


Figure 5: Types of motors[11]

There are several electric motor technologies[12], as shown in Figure 5 and Table 2. Of these, induction motors are the most common due to the simplicity of their construction, ruggedness and low-cost. This guide focuses on general purpose induction motors and the systems driven by these motors, as show in Figure 6. The target motors represent 10 per cent of motors in the global market, yet account for 68 per cent of the electricity used by motors.

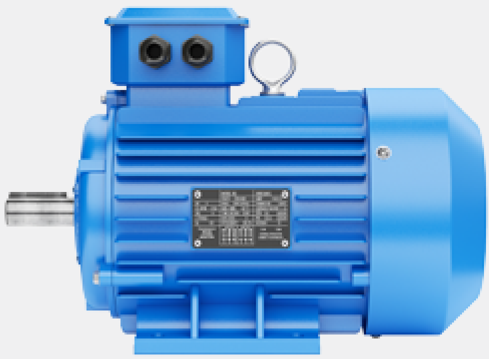


Figure 6: An induction motor

2.1.1 MOTOR APPLICATIONS

SIZE	RESIDENTIAL	AGRICULTURAL	TRANSPORTATION	COMMERCIAL	INDUSTRIAL	GAS, WATER UTILITIES
MICRO MOTORS < 0.12 kW	Disc drives, computer fans, toys, small domestic appliances (e.g. hairdryers)		Automotive auxiliaries (e.g. windshield wiper, power windows, fuel pump)	Office equipment (e.g. photocopier)		
SMALL 0.12 kW- 0.75 kW	Large domestic appliances (e.g. washing machines, refrigerators)	Water irrigation pumps for small fields	HVAC, Automotive auxiliaries (e.g. starter motor, alternator)	Office equipment (e.g. large shredder)	Power tools, machine tools, small fans and pumps	
MEDIUM 0.75 kW- 375 kW	Package HVAC systems, water pumps	Water pumps for large fields	Electric vehicle traction	HVAC (e.g. chillers), water pumps for large buildings	Fans, pumps, compressors, conveyors, process machines	
LARGE > 375 kW			Electric vehicle traction (e.g. drivetrain for automobiles, trains)		Fans, pumps, compressors, exhaust fans, process machines	Water pumps, sewage pumps, gas compressors

Table 2: Typical motor application examples

Shaded blue area highlights the motors addressed within this guide.

2.1.2 MOTOR SYSTEMS

A motor is a component of a larger system that is comprised of (see Figure 7):

- **Power Equipment:** The distribution transformer, which feeds the low-voltage bus, switchgear, meters, protection, command and control.

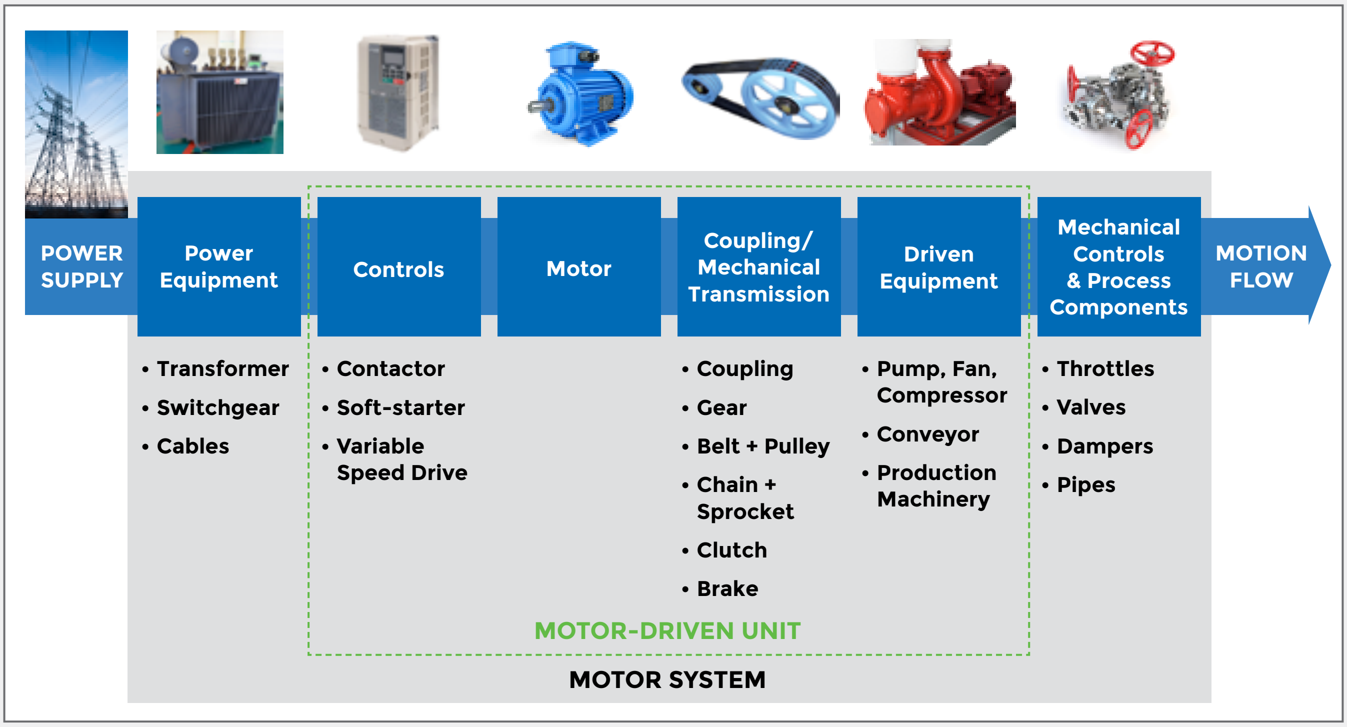
- **Optional Starter or Variable Speed Drive:** When the motor operates at a fixed-speed, power is drawn directly from the main power supply. If a lot of power is needed to start a fixed-speed motor, an additional soft-start may be incorporated in the system. When the speed of the motor needs to vary, an electronic speed controller (alternatively known as a variable speed drive, variable frequency drive, inverter or converter) is used.

- **Mechanical Transmission:** The motor shaft may be coupled directly to the driven equipment through a coupling, a gearbox, a belt and pulley, or a chain and sprocket arrangement. There could additionally be an electromagnetic clutch for decoupling and a drum or disc brake for stopping quickly.

- **Driven Equipment:** This could be a water or an air pump, a fan, a gas compressor, a conveyor to move materials, or some type of production machine.

- **Mechanical Controls and Process Components:** The remainder of the process can include pipes to carry liquids or gases, and valves, throttles and dampers to control the flow of liquids or gases.

Figure 7: Components of a motor system



2.1.3 ENERGY EFFICIENCY

2.1.3.1 ENERGY EFFICIENCY OF MOTORS

Energy Losses

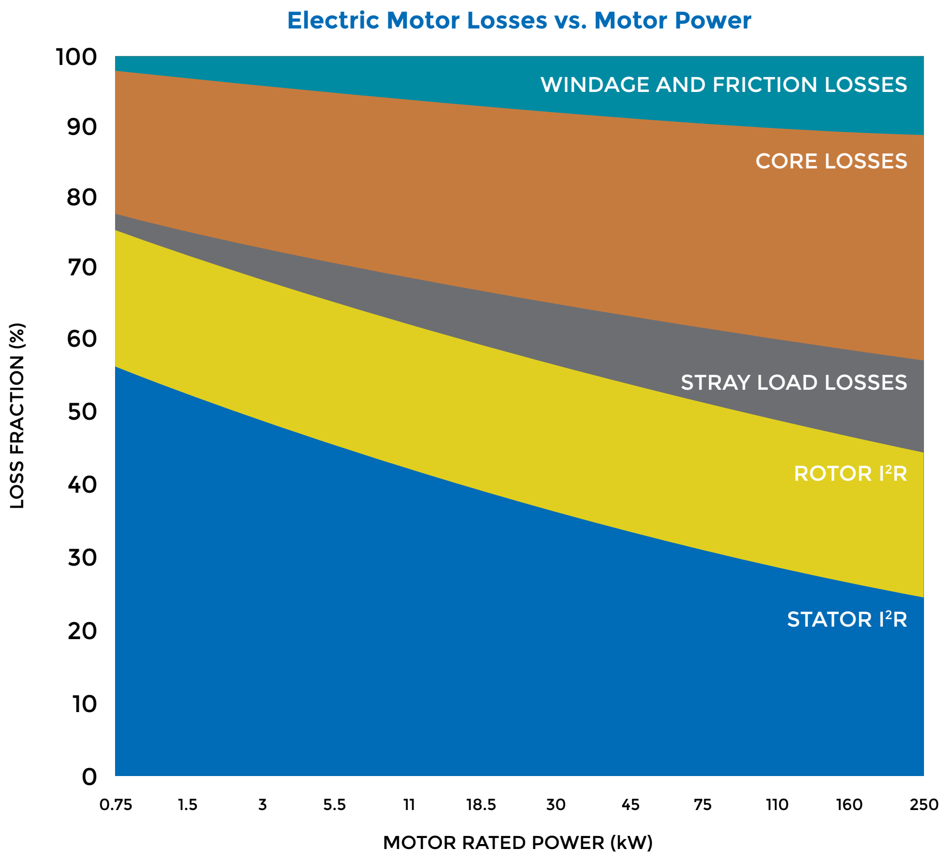
The process of converting electrical energy into mechanical energy delivered at the motor shaft[13] incurs losses, as it must:

- overcome resistance to the flow of current in the electrical coils of the stator and the rotor (called "stator I^2R" and "rotor I^2R" losses respectively)
- set up the stator and rotor magnetic fields, parts of which leak (called "core losses")
- compensate for electrical losses caused by the magnetic fields (part of core losses)
- overcome the friction in the mechanical bearings (part of "windage and friction losses")
- overcome the air resistance to the rotor and fan (part of "windage and friction losses")
- compensate for additional load losses[14] (called stray load losses).

This portion of the input electrical energy that is not converted into usable output mechanical energy is lost as heat.[15]

The relative proportion of the individual energy loss components and their variations with motor size is shown in Figure 8.

Figure 8: Typical fraction of losses in 50-Hz, four-pole squirrel cage induction motors[16]



Energy Efficiency

The percentage of the input electrical energy converted into usable mechanical energy is defined as the energy efficiency of a motor. The International Electrotechnical Commission (IEC) is an international standards organisation that prepares and publishes standards for electrical equipment. IEC Standard 60034-30-1 categorises electric motors based on their energy efficiency, either as IE1 (lowest efficiency), IE2, IE3, IE4, or IE5 (highest efficiency). Policymakers typically adopt one of these levels as the minimum performance requirement.

A large number of motors around the world do not even meet IE1. This is either because the country does not regulate and enforce motor standards or because it is an old motor. IE5 is not defined in detail yet, but it is envisaged for a future edition of the standard. It is the goal to reduce the losses of IE5 by some 20% relative to IE4. The level varies with the size of the motor, as can be seen in Figure 9.

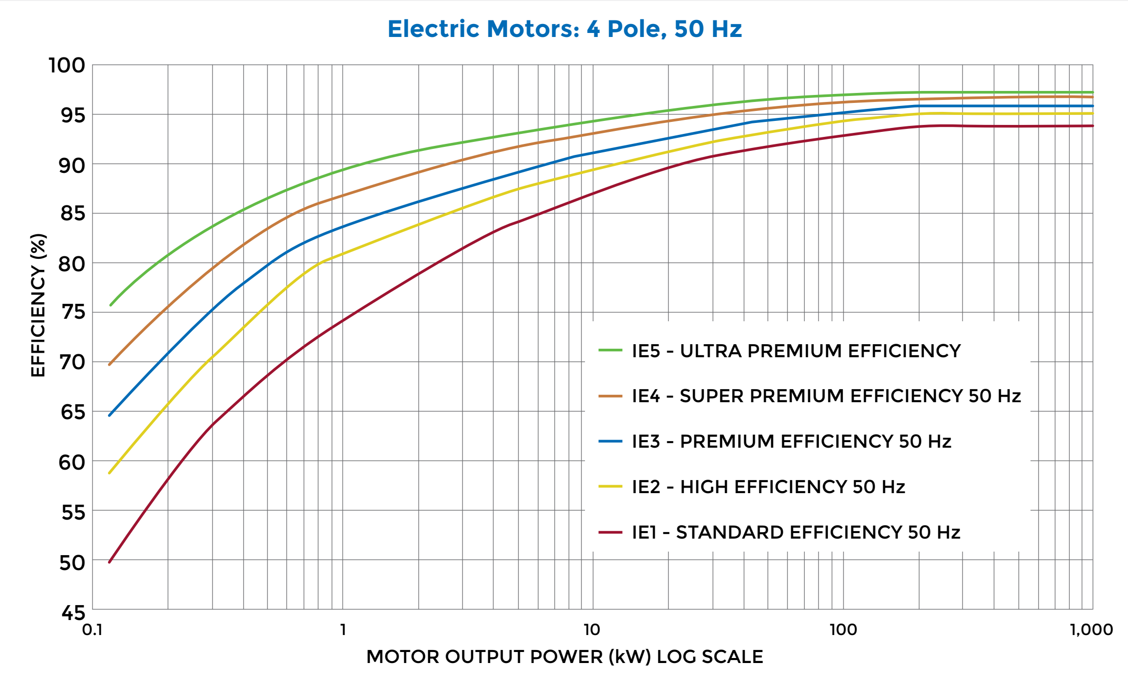
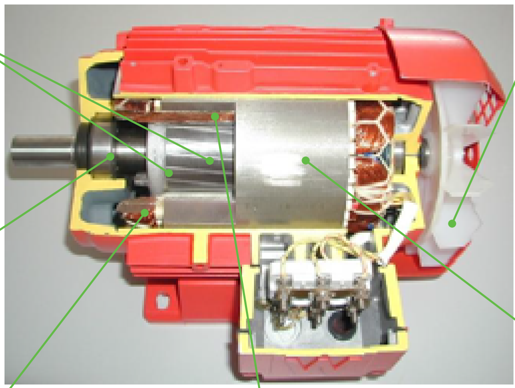


Figure 9: Example of IEC motor efficiency levels for a 4-pole motor operating at 50 H, similar curves exist for motors operating at 60 Hz[17]

Improving Induction Motor Energy Efficiency

The energy efficiency of induction motors can be improved by incorporating the design improvements shown in Figure 10, as well as through improved manufacturing practices. In practice, motor manufacturers typically take the lowest cost pathway to achieve the MEPS that has been adopted for a market. They use a combination of design improvements that depend on the prevailing costs of the materials.

Figure 10: Induction motor design improvements for higher efficiency[18]



A relatively small improvement in the energy efficiency percentage is equivalent to a substantial reduction of energy losses. By way of illustration, in the example of a 45 kW, 4 pole, 50 Hz motor, the difference in the efficiencies of IE4 and IE1 motors is only 3.7 per cent, but this is equivalent to a 47 per cent reduction in energy losses, as can be seen in Table 3.

Table 3: Comparison of efficiency classes for a 45 kW, 4-pole 50 Hz motor (2014)

EFFICIENCY CLASS	LOSSES (WATTS)	LOSS REDUCTION (%)	ENERGY EFFICIENCY (%)
IE1	4,073		91.7
IE2	3,335	-18	93.1
IE3	2,771	-32	94.2
IE4	2,170	-47	95.4

Improvements in induction motor design have ensured a steady reduction of losses and increases in energy efficiency over the years. Figure 11 shows the progressive reduction of losses in the best available design of a 45 kW, 4-pole induction motor since 1960. It shows that any motor built in 1990, if still in operation, would be less efficient than IE1, the lowest efficiency class today. This underscores the energy savings potential from the replacement of old motors and the risks of locking-in motor inefficiency given their long life.

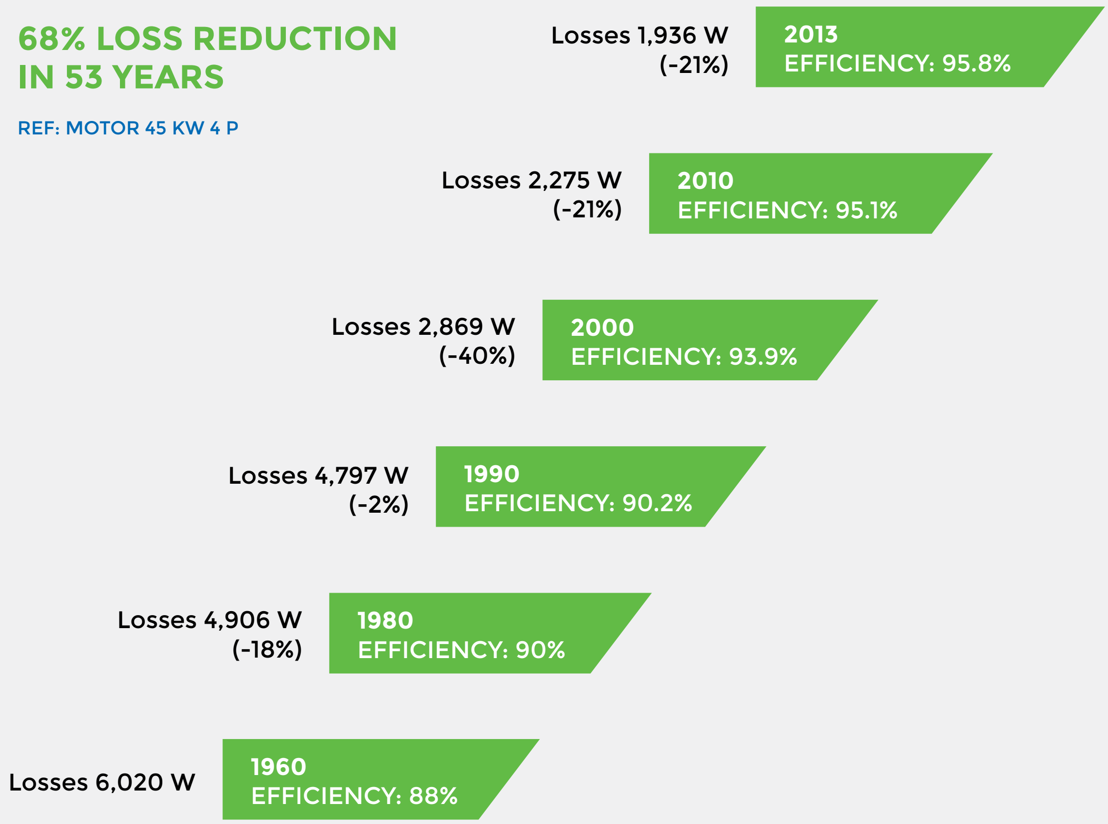


Figure 11: Induction motor energy efficiency improvements over the years– Example of 45 kW, 4-pole designs[19]

2.1.3.2 ENERGY EFFICIENCY REDUCTION AFTER MOTOR REPAIRS

Motors fail in service for various reasons. The most common cause is a failure of the bearings due to the mechanical vibrations or shocks from misalignment of shafts or improper assembly. Bearings also fail due to under- or over-lubrication or contamination of the lubricant.

The second most common cause is the failure of the coil insulation due to overheating caused by overloads, poor ventilation, contamination, or power quality issues such as unbalanced voltages and currents. This could also happen if the motor has previously been repaired poorly. There are other causes of motor failures as well such as mechanical damage, and a mismatch between the motor's characteristics and the starting torque requirements of the load.[20]

If a spare motor is readily available, the failed motor may be replaced and the driven equipment can go back into operation. The maintenance department must decide whether to repair or replace the motor depending on the extent of damage, the previous repair history of the motor, and the relative costs of repair versus replacement.

Professional maintenance strategies include a motor management programme to enable informed decisions.[21] If a spare motor is not available and a critical system is at a standstill, there is no option but to carry out prompt emergency repairs on the failed motor.

In practice, motors above a certain size (which depends on local labour and material costs) are typically more economical to repair than replace. In developing countries, lower labour and material costs mean that even small motors get repeatedly repaired, rather than replaced. Even if repairs are carried out very professionally, out-dated motors remain in operation for decades and opportunities to significantly improve performance are missed.

If, on the other hand, no exact spare motor is available and the driven system is at a standstill, or has been made operational through a temporary makeshift arrangement, there is no option but to carry out emergency repairs on the failed motor in order to take it back into operation at the earliest. In such an event, the pressure from the business owner who is confronted with a plant that is under-performing or at standstill is on the speed of repair, not its quality.

Professional shops that follow industry best practices, such as the Electrical Apparatus Service Association[22] specification ANSI/EASA AR100 or the repair specifications of the Consortium for Energy Efficiency[23], can make repairs that yield performance that is as energy-efficient as the original condition. Even with the best repairs, a technologically obsolete motor would never become as energy-efficient as current designs. Replacement rather than repair becomes more cost-effective at some point during a motor's lifetime due to the extra energy savings.

Anecdotal evidence suggests that in many countries motor repairs are often carried out in shops with inadequate equipment, processes, expertise, and quality. A survey of 45 service centres across China, Japan, New Zealand, US and Vietnam showed an increase in losses up to 6 per cent after motors were repaired.[24] See Table 4 for examples of a reduction in motor efficiency after repairs. Since a motor may be repaired several times during its life, these cumulative losses can become significant.

Table 4: Typical reasons for a reduction in motor efficiency after repairs

LOSS COMPONENT	CAUSE OF EFFICIENCY REDUCTION
STATOR COPPER	Reducing conductor cross-sectional area and/or increasing its length.
ROTOR COPPER	Damaged rotor cage, poor connections between bars and end rings and wrong or improperly installed bars.
CORE	Winding removal operation by: (1) applying improper burnout temperature, (2) overusing abrasive blasting with sand or a similar material; and (3) hammering the core.
FRICTION AND WINDAGE	Motor reassembly by damaging or improperly installing the bearings, applying excess greasing to the bearings and by using poor quality grease and the wrong size or type of fan.
STRAY	Use of poor repair techniques for motor dismantling, winding removal, core cleaning and motor rewinding.

2.1.3.3 ENERGY EFFICIENCY POTENTIAL OF MOTOR-DRIVEN SYSTEMS

A motor is just one of the components of a motor system. Improvements in the system can sometimes save as much as 10 times the energy as in the motor, alone.

Getting the motor size right is an easy way to maximise efficiency. Motors typically operate at peak efficiency when at 75 per cent load, but they are often oversized for the application as margins of safety in design, manufacturing and procurement cascade one on top of the other. Sometimes, these are oversized out of concern for the power quality (e.g. wide voltage fluctuations) or due to inaccurate assumptions about what is needed to drive the system.

Another simple measure is to install capacitors for compensating the reactive power drawn by motors, which is usually necessary to meet the power utility's requirements of a minimum power factor for the industrial plant. This reduces the current drawn from the main power supply, the energy losses in upstream equipment, and the size of the upstream power equipment.

In conventional pumps, compressors, fans and exhausters, the motor is run at a fixed-speed and the flow of liquid or gas is adjusted mechanically with a valve, throttle or damper in the fluid pipeline. In effect the power draw remains the same under all conditions (only the frictional losses are varied). This is an inefficient way of adjusting the fluid flow.

Considerable energy savings are possible if the speed of the motor (and therefore the power draw) is reduced with the help of a VFD when a lower flow rate is required, without increasing the friction in the pipeline. A further improvement could be achieved, by using a more efficient VFD instead of a less efficient one.[25] This energy saving is marginally offset by the additional losses in the motor caused by the non-sinusoidal waveforms of VFDs. The use of a VFD can also enable the elimination of mechanical gearboxes between the motor shaft and the driven equipment in applications requiring a constant torque over the speed range, thus leading to further energy savings.

In some motor-system applications, such as hoists or elevators, the mechanical energy gets stored temporarily during operation. This mechanical energy can be re-converted to electrical energy by using a VFD with a regenerative feature, thus saving on overall energy use.

In applications where gears are unavoidable, such as when high-torque is needed at low speeds, frictional losses in the gear teeth can be minimised by choosing a motor with a nominal speed as close as possible to the speed of the driven equipment. The choice of gear is also very important. Gear efficiency varies greatly depending on the design. Sometimes it is necessary to have a soft transmission (such as a belt and pulley between the motor and the driven equipment) to allow for vibrations. Traditional v-shaped belts can have losses as high as 7 per cent, which can be reduced to 1 – 2 per cent by using a chain and sprocket or a flat belt design.

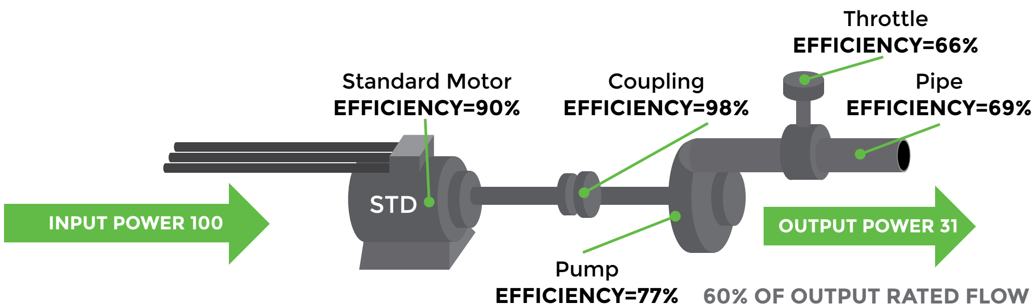
Finally, the energy efficiency of the driven equipment can be improved through proper selection for given process conditions and improvements in design. The piping design (bends, diameter) can also be improved.[26]

Considerable energy savings are possible if the speed of the motor (and therefore the power draw) is reduced with the help of a VFD when a lower flow rate is required, without increasing the friction in the pipeline.

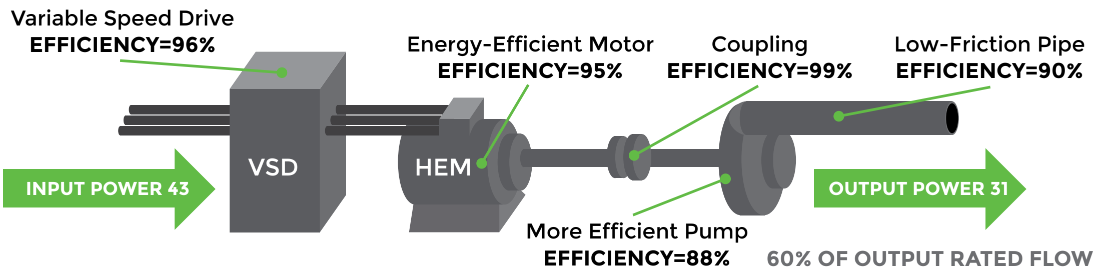
Figure 12 depicts an example of the redesign of a pumping system. The conventional design shown in the upper figure is operated to deliver 60 per cent of the rated fluid flow of the pumping system. The system efficiency is the product of the efficiencies of individual components, which in this example equals 31 per cent (e.g. 0.90 x 0.98 x 0.77 x 0.66 x 0.69 = 0.31). The lower figure shows a redesigned system for delivering the same fluid flow. A VSD, rather than a mechanical throttle, varies the flow. The motor, the pump, the coupling and the pipes have been replaced with higher efficiency ones. In the energy-efficient design, the input power required reduces from 100 to 43, thus giving a system efficiency of 72 per cent (31/43=0.72).

Figure 12: Energy savings potential of a typical motor system[27]

CONVENTIONAL PUMPING SYSTEM, SYSTEM EFFICIENCY = 31%



ENERGY-EFFICIENT PUMPING SYSTEM, SYSTEM EFFICIENCY = 72%



A comprehensive treatment of the subject can be found in the 2011 IEA publication “Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems”.

2.2 MARKET DEVELOPMENTS

2.2.1 TECHNOLOGY TRENDS

The induction motor has been the mainstay of fixed-speed applications ever since it was invented in the late 19th century due to its simplicity of connection and operation. Its ruggedness was enhanced with the development of die-cast aluminium rotors in the 1940s, which replaced fabricated copper rotors.

The development of mass production techniques for copper rotor die-casting during the last decade has enabled induction motors to become highly energy-efficient and meet even IE5 efficiency levels. Other alternative techniques for reaching high-efficiency levels in induction motors exist, as well. Developments in power electronics during the last three decades have made it possible to control motor speed in an easy and cost-effective way making these the preferred choice for variable-speed applications as well.

However, the market dominance of induction motors is being challenged by permanent magnet motors and reluctance motors, particularly in applications requiring the motor speed to be variable.[28] Table 5 provides a comparison of the technologies. One barrier for the rapid uptake of the newer motor technologies is the already high level of investment in induction motor technologies made by manufacturers around the world.

The cost of switching production is not appealing unless there is sufficient demand for these new motors. Induction motors are, therefore, expected to continue to dominate the market for both fixed-speed and variable-speed applications in the foreseeable future, with increasing inroads by permanent magnet motors (particularly in electric vehicles) and reluctance motors.

Table 5: Comparison of different commercially available motor technologies

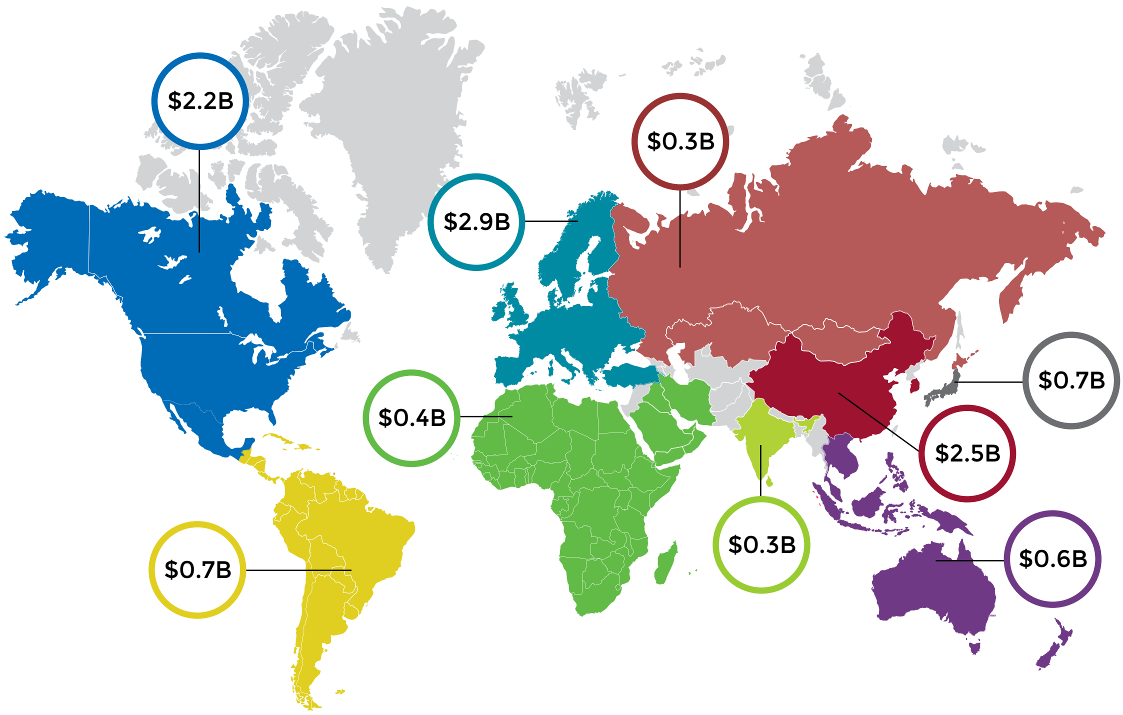
MOTOR TECHNOLOGY	INDUCTION MOTORS	PERMANENT MAGNET MOTORS	RELUCTANCE MOTORS
AGE OF TECHNOLOGY COMMERCIALISATION	Since late 19th century	21st century	21st century
SHARE OF INSTALLED STOCK (GLOBALLY)	> 80 %	Negligible	Negligible
BEST COMMERCIALLY AVAILABLE EFFICIENCY LEVELS (2016 CATALOGUE DATA)[29]	IE4	IE5	IE4
VARIABLE FREQUENCY DRIVE ESSENTIAL?	No	Yes	Yes
COST-EFFECTIVE FOR FIXED SPEED APPLICATIONS?	Yes	No	No
CONSTRUCTION OF ROTOR	Aluminum die-cast/ copper fabricated or die-cast	Rare earth (neodymium / dysprosium) or ferrite core permanent magnets	Magnetic steel
MECHANICAL STURDINESS	Intermediate	Least sturdy due to the potential for demagnetisation from shocks and vibration	Most sturdy due to simplicity of the rotor
COMPARISON OF TOTAL MOTOR WEIGHT FOR IE4 EFFICIENCIES	Heaviest	Lightest	Intermediate

2.2.2 MARKET STRUCTURE

The global low-voltage induction motors market is shared between three multinational companies with a combined market share of 30 per cent, and about 1,500 small- and medium-sized domestic manufacturing companies.[30] The multinational companies serve individual markets through regional and local manufacturing facilities.

The three largest markets for new motors are China, Europe and US. Brazil, China, Europe, Mexico and US are major induction motor manufacturing locations. In addition, there is a significant market for second-hand repaired and reconditioned motors in Brazil,[31] Turkey and other countries.

Figure 13: World market for low-voltage motors, 2016 in $ billions[32]



The global trend in sales of low-voltage motors has been toward ever-increasing average efficiency levels since 1995. This trend is expected to continue due to the adoption of market-transformation policies by governments (see Figure 13). It is expected that by 2019, more than 72 per cent of motors sold globally will have efficiency levels higher than IE2, including 29 per cent at IE3 and 2 per cent at IE4.[33] However, this is more reflective of the higher weightage of industrialised countries in the global statistics; the corresponding figures for developing countries are likely to be much lower, with a large proportion of IE1, and sub-IE1 efficiency motors.

In the absence of effective policy actions, as discussed in the following chapters, developing countries risk becoming dumping grounds for inefficient new and reconditioned motors. Given the typically long lifetimes of motors of up to two decades, there is a risk of this inefficiency being locked-in for decades.

3. STANDARDS AND REGULATIONS

WHAT?	A discussion on regulations and standards as policy tools for transforming markets; an overview of the test standards and methods used to measure motor energy performance; a summary of MEPS as a regulatory tool to transform motor markets towards higher energy efficiency; outline of a systematic approach to developing MEPS; the benefits of harmonisation regionally and with trading partners.
WHY?	Provides information on MEPS, the first part of UN Environment's Integrated Policy Approach, which is the cornerstone of market transformation.
NEXT?	Some key questions to keep in mind: • What is the status of test standards in my country and neighbouring countries? • Are we affiliated with IEC or the International Organization for Standardization (ISO)? • What data is available on the motors market in my country? • What is the proportion of demand met by domestic manufacturing? How concentrated or fragmented is the industry? Who are the key players? How current is their level of technology? • Do we have accredited testing facilities for motors or can we collaborate with testing facilities in other countries? • What level of ambition would be appropriate; should we adopt the technically achievable, economically justifiable efficiency level in one go or in multiple steps?

3.1 METRICS AND TESTING STANDARDS

A universal definition and classification nomenclature for motor energy efficiency requires a methodology for testing the motors. IEC 60034-2-1 (06/2014), *Standard Methods for Determining Losses and Efficiency from Tests*, covers Induction and other motors operated without a VSD, and indicates which instrumentation is needed to conduct the testing.[34] Existing standards are regularly enhanced and complemented with new standards.

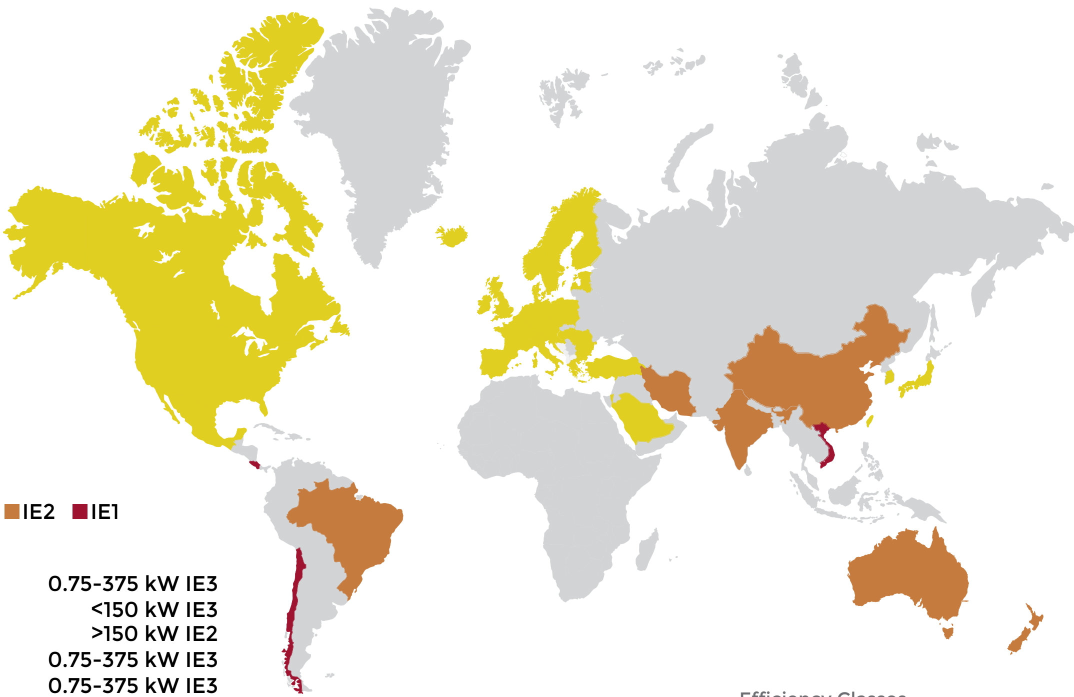
For induction motors, there are three preferred methods for type-tests that are more accurate for testing performance, and five alternate methods that can be used when a customer accepts a new motor at their facility or when the product is elsewhere in the field (rather than in a test laboratory). Test method 2-1-1B is recommended for the motors covered in this Guide. It is the most recently developed test method and assimilates elements of IEEE 112 method B, CSA IEEE 112 method B, and CSA C390-10, which may be more familiar in South America.

Complementing the above, the technical specification IEC/TS 60034-2-3, which is forecast for publication as a standard in early 2018, prescribes specific methods for determining losses and efficiencies of motors that are operated in conjunction with a VSD.

Regulatory Requirements

MEPS are regulations, which set a floor to the efficiency class of motors and motor-driven units that can be sold in a market, whether manufactured domestically or imported. In practice, the evolution of the market after the promulgation of MEPS is gradual rather than abrupt and depends on the compliance culture and enforcement. The experience of 41 countries shows that mandatory MEPS, as the cornerstone of an integrated policy approach, are the most effective instrument for transforming the market for motors to higher efficiencies.

Figure 14: Overview of MEPS Worldwide



Mexico, US	0.75-375 kW IE3
Canada	<150 kW IE3
	>150 kW IE2
Japan, Saudi Arabia	0.75-375 kW IE3
EU, Turkey	0.75-375 kW IE3
	or IE2+VFD
Taiwan	0.75-200 kW IE3
Republic of Korea	37-375 kW IE3
	0.75-30 kW IE2
Israel	7.5-375 kW IE3
	0.75-5.5 kW IE2
Australia, Brazil, New Zealand,	
Iran (Islamic Republic of)	<185 kW IE2
China	0.75-375 kW IE2
India	0.37-375 kW IE2
Costa Rica, Chile, Vietnam	IE1

Efficiency Classes:
IEC 60034-30-1, 2014
Output Power: 0.12 - 1000 kW
50 Hz and 60 Hz, line operated
2-, 4-, 6-, 8-poles
© Impact Energy Inc., TPA advisors by, (2017)

The benefits of well-implemented MEPS vary by stakeholder, but generally include:

- Efficiency levels are technically achievable and cost-effective for consumers in most applications
- Mandate (if coupled with robust monitoring, verification and enforcement) provides a high degree of certainty that energy savings will be achieved and sustained
- Minimal impact on governmental finances (unlike equipment incentives and subsidies that are intended to lower the burden of procurement costs on their constituents)
- Clearer signal to manufacturers and retailers of market demand for efficient products
- Opportunity for manufacturers and sellers of quality products to gain market share
- Research and product innovation are stimulated
- Average performance of products available for sale is improved
- Product quality is defined for sellers and buyers
- Manufacturers gain access to additional markets where equivalent MEPS are in place
- Can be easily adjusted iteratively as the market and motors technology evolve
- Maximises consumer benefits at minimum per unit transaction costs.

The challenges of developing and adopting MEPS generally include:

- Domestic motor manufacturers may need time, technical assistance, and financing to adapt their production
- Domestic motor manufacturers may not be able to source higher grades of magnetic steel at competitive prices due to domestic production constraints or high import tariffs
- Importers may need time to source efficient motors, and acquaint their staff and clients with these motors
- Policymakers may have a poor understanding of the market structure and lack technical detail on the products in the market
- Government officials, consumers, retailers, manufacturers and trade associations may not be sufficiently aware of the benefits of higher-efficiency motors
- The higher initial cost of higher-efficiency motors may lead to attempts to evade MEPS requirements, so a market monitoring, verification and enforcement regime needs to be in-place and sufficiently resourced by the time MEPS take effect.

Although desirable, it may not be practical to establish stringent MEPS until such issues are adequately addressed. Additional considerations are addressed in subsequent chapters of this Guide, and in the United for Efficiency "Policy Fundamentals Guide".

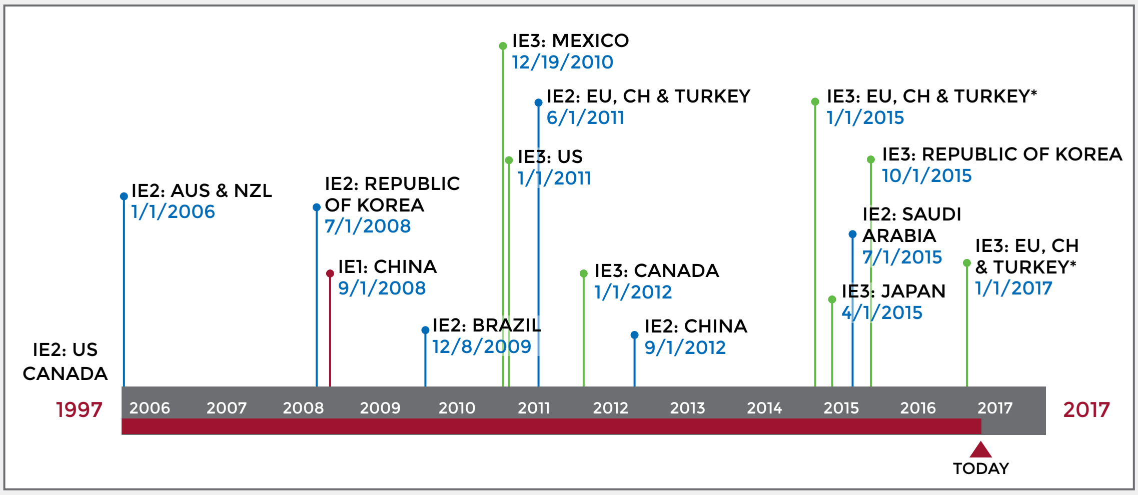
3.2 PROCESSES TO ESTABLISH REGULATORY REQUIREMENTS

To begin with, the scope of the MEPS needs to be defined. The medium-sized induction motors targeted by this guide are mostly found in industry and they present the greatest opportunity to reduce overall electricity consumption, as illustrated in Table 6. Also, there is considerable International policy experience with this range of motors and best practice policy examples are readily available, whereas the policy experience with motors outside this range is still being gathered (see Figure 14). MEPS, though desirable, are a lower priority as a policy tool for both small and large motors in comparison with medium-sized motors.

Large motors are a significant electricity user, but they are inherently more efficient, so the savings potential is usually lower. Being fewer in number and often custom-built for industrial applications, the acceptable minimum energy efficiency level is usually specified in purchase contracts. On the other hand, small motors are often operated intermittently and are used in domestic appliances such as refrigerators and washing machines, which are covered by separate energy efficiency regulations.

Table 6: Electricity use by motor size.[35]

MOTOR SIZE	PERCENTAGE OF STOCK (%)	PERCENTAGE OF ELECTRICITY USED (%)
SMALL (<0.75 kW)	90	9
MEDIUM (0.75 kW-375 kW)	10	68
LARGE (> 375 kW)	0.03	23



* 7, 5-375 kW – IE3 efficiency level or IE2 + VSD | ** 0,75-375kW – IE3 efficiency level or IE2 + VSD

Figure 15: Worldwide MEPS timeline as of March 2017[36]

USEFUL RESOURCES:

Guidelines from the European Comission on the Ecodesign and Energy Labelling regulations for Electric Motors.[37]

Information on Electric Motors Standards and Test Procedures in the US.[38]

It is recommended that developing and emerging economies start by setting MEPS for motors, which can deliver rapid and sustained energy savings. These should be accompanied by supporting policies (described in Chapter 4) to improve the efficiency of the motor system (see Figure 16). Over time, they can consider regulating motor driven units as well, after sufficient experience has been gained with MEPS for motors, as these are more complex.

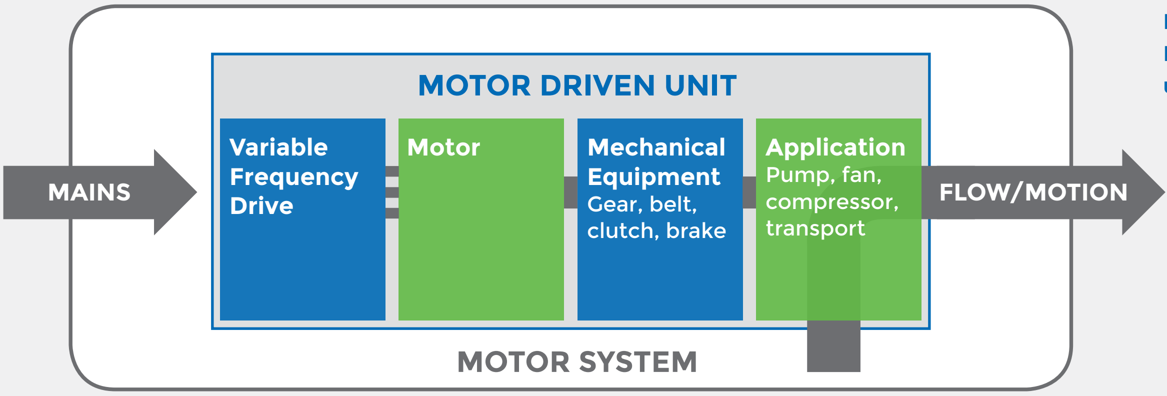


Figure 16: Motor-driven unit[39]

Developing MEPS

Motor MEPS need to be developed methodically and transparently with the support and participation of representatives from the supply chain, end users, power utilities, public institutions, civil society and the public. It is important that these key stakeholders are consulted and that their interests are addressed so that they understand and support the policy when it becomes effective.

This is usually a multi-year, iterative process, which is described in detail in the United for Efficiency “Policy Fundamentals Guide”. The selected MEPS and the pace of implementation must be fair to both manufacturers and users, not cause economic disruptions or distortions, and balance national objectives of energy and CO_2 savings with net economic benefits. A systematic approach[40] is outlined below:

1. **Establish a legal and institutional framework** for mandatory MEPS, which is a law.

2. **Survey the technical standards being followed by motor manufacturers and importers**, particularly for efficiency testing and classification. If national or regional standards are followed, are these harmonised with the international standards described in Section 3.1? If diverse standards are being followed, encourage alignment with international standards.

3. **Collate country-specific motor market baseline data** (e.g. on equipment sales, trends, prices, origin of the products, performance) with the help of industry associations and trade data, or through independent research organisations. For example:

   a. How many medium-sized motors by type and average price are sold annually?

   b. Which of these are manufactured in-country and which are imported?

   c. How many are imported as a part of motor systems?

   d. Who are the main manufacturers and import sources?

   e. How many are purchased by end users and equipment manufacturers respectively?

   f. What are the historical market trends?

   g. Can the average motor efficiency levels be estimated reliably? If not, IE1 efficiency levels could safely be assumed (in practise, a portion of the market may even be at sub-IE1 levels). Some data can be found at www.iea-4e.org. See the “Policy Fundamentals Guide” section 2.7 for additional insights on data collection.

4. With the help of leading motor manufacturers or industry associations, **determine the reasonable cost levels of motors of different efficiency levels by type and size range.**

5. **Collate information on the electricity tariff(s) and carbon emission factor(s), current, historical and projected.** Some sources for this information are the electricity regulator, power utilities, IEA (www.iea.org) and Enerdata (www.enerdata.com).

6. Once the baseline is established, **hypothetical scenarios should be developed for the energy, economic, and environmental impact** if MEPS are set at IE1, IE2, and IE3 levels, respectively. The scenarios should address questions such as:

   a. How much energy and CO_2 emissions would be saved at the national level?

b. What incremental upfront costs would users have to bear for higher efficiency?

c. How much would the users save in energy costs each year?

d. How many years would it take for the upfront investment to be paid back? This will provide the maximum economically justifiable level of MEPS.[41]

7. **Consult with motor manufacturers on the implications of MEPS** at each of these levels. Consider how to address (and advocate the elimination of) the market-distorting effects of energy subsidies or taxation on higher-efficiency equipment, if any. Be prepared for a variety of responses, as some will resist any regulation while others see an opportunity for brand building and gaining a competitive advantage. Inadequate access to technology and finance are legitimate constraints that may be cited as well. The regulation should not jeopardise the competitiveness of domestic industry, reduce employment potential, favour one manufacturer over another, or drive anyone out of business without having been given adequate time and support for adjustment. Through these consultations, it should be determined how much time and investment would be required by the domestic manufacturing industry to adjust to a MEPS level of IE1, IE2 and IE3 respectively.

8. **Gather perspectives from the other aforementioned key stakeholders.** Policymakers have the difficult but critical task of making well-informed determinations that account for competitiveness, employment, environmental, timeframe (e.g. keep in mind institutional and supply chain constraints), and other concerns.

9. **Set an appropriate MEPS level.** There is not a single MEPS level that will work for all developing and emerging economies because national circumstances vary

IE2, with a timetable for graduating to IE3, is recommended for countries that have domestic motor-manufacturing industries.

A graduation to IE3 helps to stay abreast with global best practices and improve manufacturers' access to international markets.

IE3 is recommended for countries without a domestic motor manufacturing industry.

Prescribing lower MEPS levels for motors that use a VFD is extremely difficult to monitor and enforce, and should be avoided.

10. **Build MVE capacity to ensure the success of MEPS.**

It may be better to delay MEPS rather than promulgate it without strong MVE.

Based on the above, it should be possible to conclude the technically feasible and economically justifiable MEPS level and the timeframe for adoption. The EU, US and nine other countries have adopted IE3. Figure 17 provides an overview of MEPS levels and testing standards in different countries, and Table 7 describes necessary components of electric motors MEPS.

Once established, MEPS programmes should be monitored, evaluated, updated, and revised every few years to ensure that they remain appropriate and relevant.

CASE STUDY: Cost Effective MEPS Levels, Indonesia

In 2016, the Energy Research Centre of the Netherlands developed a market-transformation programme for Indonesia after a two-year effort. One of the most significant findings is that in spite of electricity being partly subsidised, it is cost-effective for companies to replace existing IE1 motors with IE4 motors in most cases, with two-year payback periods. This payback period is faster when subsidies are reduced.

A tool to carry out this analysis can be accessed at the project website. Taken at the economy level, the potential energy savings from MEPS at IE3 are estimated at 4.4 per cent of the electricity used by the industrial and commercial sectors and 2.9 per cent with MEPS at IE2.

For more information click here.

Figure 17: MEPS and test standards by country

MINIMUM REQUIREMENTS ELECTRIC MOTORS WORLDWIDE				
EFFICIENCY LEVELS 3-phase induction motors (Low Voltage < 1,000 V)	EFFICIENCY CLASSES	TESTING STANDARD	PERFORMANCE STANDARD	
	IEC 60034-30-1, 2014	IEC 60034-2-1, 2014	Mandatory MEPS III	
	Global classes IE-Code I	Incl. stray load losses	National Policy Requirement	
SUPER PREMIUM EFFICIENCY	IE4	Preferred Method II SUMMATION OF LOSSES WITH LOAD TEST: Additional losses PLL determined from residual loss		
PREMIUM EFFICIENCY	IE3		Canada	(0.75 - 150 kW)
			Mexico	(0.75 - 375 kW)
			US	(0.75 - 375 kW)
			US	(0.18 - 2.2 kW)
			Republic of Korea***	(37 - 375 kW)
			EU 28*	(0.75 - 375 kW)
			Switzerland*	(0.75 - 375 kW)
			Turkey*	(7.5 - 375 kW)
			Japan Toprunner	(0.75 - 375 kW)
			Israel	(7.5 - 375 kW)
			Taiwan	(0.75 - 200 kW)
			Saudi Arabia	(0.75 - 375 kW)
HIGH EFFICIENCY	IE2		Australia	(< 185 kW)
			Brazil	(< 185 kW)
			Canada	(150 - 375 kW)
			China**	(0.75 - 375 kW)
			EU 28*	(IE2 + VFD)
			Republic of Korea***	(0.75 - 30 kW)
			New Zealand	(< 185 kW)
			Israel	(0.75 - 5.5 kW)
			Turkey	(0.75 - 5.5 kW)
			Iran (Islamic Republic of)	
			India *** *)	(0.37 - 375 kW)
STANDARD EFFICIENCY	IE1		Costa Rica	
			Chile	(< 7.5 kW)
			Vietnam	
BELOW STANDARD				

I) Output power: 0.12 kW - 1,000 kW, 50 and 60 Hz, line operated 2-, 4-, 6- and 8-poles | II) for 3-phase machines, rated output power < 1,000 kW | III) Minimum Energy Performance Standard | *) EU: IE3 or IE2 + VFD | **) China: IE3 under consideration | ***) Republic of Korea: >0.75 kW IE3 per 1-1-2018 | *** *) India: IE2 from 1-10-2017

Table 7: Components of a motors regulatory programme

COMPONENT	DESCRIPTION
SCOPE OF COVERAGE	The focus should be on general purpose electric induction motors, line operated, Totally Enclosed Fan Ventilated (TEFV) 2-, 4- and 6-pole motors rated between 0.75 kW and 375 kW under continuous operation, with a rated voltage up to 1,000 Volts, 3-phase, 50 Hz or 60 Hz. The policy framework should cover all motors sold in the country including those embedded in systems. It must clearly lay out the motor types and sizes that are covered within the scope of the regulation, with minimal specific exclusions.[42] Defining too many technical attributes, such as shaft extension dimensions, can create loopholes for the exemption of functionally identical motors with slightly different dimensions. The 2016 US regulation for integral horsepower motors 10 CFR 431 is a good example of effective scope definition.
TEST STANDARDS	The policy needs to state the test standard and method by which the motor energy performance will be assessed e.g. IEC 60034-2-1, method 1B Globally harmonised test standards and efficiency levels (IEC, NEMA) are advantageous for both customers and manufacturers by ensuring product availability and fair competition.
PERFORMANCE REQUIREMENTS	The regulation needs to specify the minimum performance levels that will be required. Manufacturers then develop products that meet or exceed these requirements. Note that the performance requirements could be one level at one point in time or could be multiple levels phased in over a longer period. The multiple levels approach offers more of a planning horizon to manufacturers; however, a greater degree of regulatory uncertainty when setting the standards as to what levels of ambition might be appropriate for different types or sizes of motors five to six years into the future.
CERTIFICATION AND COMPLIANCE	The regulation must inform manufacturers of the procedure they will follow when certifying products as compliant; this could include filing paperwork, entering information into a product registry database, keeping paperwork in-house for a period, and so on. The manufacturers and importers need clear instruction as to what is expected of them when they need to demonstrate compliance.
MARKET SURVEILLANCE	The regulation should inform suppliers as to the process that governments will use to conduct market surveillance. This could include, for example, the sample size tested, the escalation if a sample size is found to be in violation, the tolerances and statistics involved, or document checking. Because this could end up in a legal proceeding, it is important to set out the procedure clearly and fairly.
REVIEW/REVISE	Finally, it is important that the regulatory measures be reviewed and updated from time to time, as technology is continually improving. For example, a country may choose to require a review within one year of the final stage of a regulation taking effect.

3.3 HARMONISATION OF REGULATIONS AND STANDARDS

If MEPS are to be adopted in a country or regional market, stakeholders should consider whether to harmonise with existing motor MEPS regulations in their region or with those of a large trading partner. If one country in a trading region chooses to adopt MEPS that are not compatible with its neighbouring markets, this decision could be disruptive to the supply chain and may increase the cost of energy-efficient motors for all parties. This could occur due to the added costs to manufacturers of needing to perform different or additional tests, creating unique labels and catalogue numbers for each market, and tracking, keeping inventory and shipping country-specific motor products.

CASE STUDY: MEPS Development, Turkey

Turkey developed MEPS for low-voltage electric motors in alignment with the EU Eco-Design Directive for Electric Motors 640/2009/EC. The MEPS cover almost all 2-, 4- and 6-pole single speed, three-phase induction motors with a power range of 0.75 to 375 kW, rated up to 1000 V and on the basis of continuous duty operation.

The scheme has three stages to allow all manufacturers, in particular small and medium-sized producers, to adapt to the new requirements:

- Stage 1 – 18 June 2012 – Motors must meet IE2
- Stage 2 – 1 January 2015 – Fixed speed motors between 7.5 kW and 375 kW must meet IE3
- Stage 3 – 1 January 2017 – Fixed speed motors between 0.75 kW and 375 kW must meet IE3

For more information click here and here.

Harmonisation of MEPS offers many benefits that allow countries, private sector and consumers to avoid the costs of duplicating testing and non-comparable performance information and requirements. Stakeholders thus benefit from the removal of this administrative trade barrier and can leverage the better prices and choice of goods associated with the larger economies to which they are harmonised.

If countries have different requirements, it is difficult and time-consuming for a manufacturer to carry out the necessary tests for each specific country. Thus, harmonisation enables multiple national markets to be accessible for the cost of only one test.

Working within a region and with different organisations (e.g. government, private sector, civil society) can result in outcomes that are more effective. Regional cooperation can achieve positive results by sharing resources for energy-efficient motor policies and programmes. Many energy-efficient motor programmes are initiated each year at local, national and regional levels, which can inadvertently duplicate effort, conflict or cause confusion. A regional cooperation initiative helps to coordinate such programmes so that they do not conflict, and they achieve their results in a cost-effective manner.

For a successful regional cooperation initiative, consensus among the stakeholders is important. The following are some suggestions for promoting regional cooperation:

- Conduct roundtables and other consensus-building activities to reach agreement about particular issues, policies, guidelines, standards, and related subjects
- Identify liaisons in each country to be point of contact and lead on local activities
- Establish bilateral activities with another country in the region
- Conduct in-person and online events to share experiences and information
- Develop infrastructure for communication between stakeholders.

Regional cooperation can include:

- Developing a regional efficient motors roadmap to identify areas of cooperation and ways to share resources and build regional markets for efficient motors
- Establishing or harmonising motor specifications and standards that include energy performance
- Coordinating monitoring, verification and enforcement activities (e.g. verification of labels, mutual recognition of test results, sampling and checking MEPS compliance)
- Expanding motor test facilities to reduce costs and build a network of professionals, with some countries potentially specialising in certain aspects of testing
- Pooling resources and making use of the available structures and capacities within regions to improve the effectiveness, mutual reinforcement, and synergy between the various country programmes, making them more cost-effective and impactful.

Regional coordination and planning is also crucial for the success of large, complex projects that have cross-border and trade implications, or projects that are important for more than one government to address. Although specific requirements may vary from country to country (e.g. power range covered, specific exclusions), motor MEPS have gradually been harmonising mostly due to the global alignment of both test and classification standards.

Given the benefits of regional harmonisation, which can reduce the costs and complexity of developing and administering policies, such opportunities should be thoroughly investigated before developing country-specific standards and programmes.

CASE STUDY: Motor Energy Efficiency Regulations, Central America

Policymakers from six Central American countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama) are developing regionally harmonised regulations for the energy efficiency of low-voltage induction motors in the range of 0.746-373 kW.

The regulations, “Reglamento técnico centroamericano RTCA 97.47.04:14”, are being harmonised with the US Rule 10 CFR Part 431, as well as underscoring the advantages of a broader harmonisation effort both regionally and with important trading partners.

4. SUPPORTING POLICIES

WHAT?	A review of the applicability of product labelling policies to electric motors and the requirements for the nameplates of electric motors; how effective communication and education campaigns are designed, implemented, and monitored; policies for improved motor repair practices; other supporting policies for improving the energy efficiency of motor systems.
WHY?	Provides information on supporting policies, the second part of UN Environment's Integrated Policy Approach, which is critical for securing public support and accelerating the transformation of energy-efficient motors markets.
NEXT?	Some key questions to keep in mind: • What appliance-labelling scheme exists or has been tried in my country in the past? • Has our country convened an energy efficiency communications campaign in the past? If so, what worked and what did not work? Are there lessons to be learned from other communications campaigns (e.g. on safety) that could help? • Who would lead a national campaign in our country promoting energy-efficient motors? Which partners would be needed? What impact could it have? • What policies does our country have for improving the performance of the industry sector?

CASE STUDY: Estimated Impact of Supporting Policies for Motor Systems, Indonesia

In 2016, the Energy Research Centre of the Netherlands developed a market transformation programme for Indonesia after a two-year effort. The project has estimated that the upgrading of motor systems through supporting policies in addition to regulating motor MEPS at IE3 levels could potentially save 19 per cent of the electricity used in industry and commerce.

Industry would save $1.5 billion in energy costs and the government, $1 billion in subsidies annually. Indonesia could scrap half the coal-fired power plants it is planning, saving $11 billion.

These cost savings are much more than the investments required in the programme. There are other economic benefits, too: a 15-fold increase in job creation and a 10-fold increase of cost-effective investments in motor-system technologies.

For more information click here.

4.1 LABELLING

Labels display information about products' energy efficiency so that purchasers can better distinguish between models, which helps pull more efficient products into the market.

Labelling works differently for consumer products and motors. Consumer products are mainly purchased by lay people in physical or online stores. Simple, appealing and visually communicative labels can influence their choices. However, motors are typically purchased by technically adept businesses using procurement specifications via impersonal channels and often in bulk quantities. The emotional and visual elements of the labels are less important than the technical information.

IEC Standard 60034-30-1 categorises electric motors into efficiency levels IE1 to IE5 per their respective energy efficiencies. This categorisation is backed by clearly defined efficiency tables and based on clearly defined test protocols.

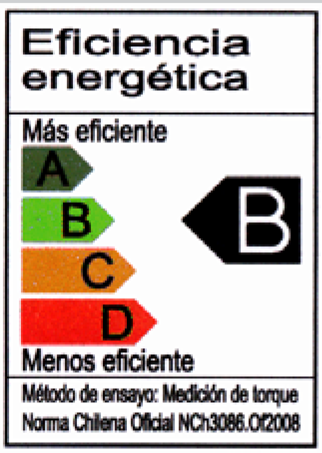
The IE levels are recognised and used internationally.[44] These levels facilitate comparison and help create a demand-pull for efficiencies above MEPS. They can serve as the basis for other policies such as financial incentives without imposing any additional burden on manufacturers and importers.

A requirement of this standard is that the rated efficiency (e.g. 96.2 per cent) and the efficiency class (e.g. IE3) shall be durably marked on the nameplate. A typical nameplate conforming to this requirement gives considerable information on the motor, showing not only information on efficiency, but also how the same motor can be used at different voltages and frequencies in different countries.

It is recommended that countries require IEC 60034-30-1 conformant motor nameplates (see Figure 18 for an example). Countries should not create a unique nameplate or extend the labelling requirements from consumer appliances to motors.

Figure 18: A typical motor nameplate incorporating key efficiency data (efficiency at different loads, voltages and frequency) as required by IEC 60034-30-1

~3 3,15S/M-04 IP55 INS CL F ΔT 80 K S1							SF 1,00		AMB 40˚C
V	Hz	kW	RPM	A	PF	Eff	100%	75%	50%
380 Δ / 660 Y	50	185	1,485	332/191	0.88	IE3	96.3	96.3	95.9
400 Δ / 690 Y			1,490	318/184	0.87		96.5	96.3	95.8
415 Δ / –			1,490	310/–	0.86				
460 Δ / –	60		1,790	284/–	0.85		96.2	95.8	95.0
– 6,319-C3(45g) – 6,316-C3(34g) MOBIL POLYREX EM 11,000 h	W2 U2 V2 U1 V1 W1 ΔL1 L2 L3		W2 U2 V2 U1 V1 W1 ΔL1 L2 L3		NEMA Eff 96.2% 250HP 460 V 60Hz 1,790 RPM 284 A PFO.85 Des A Code H SF1.15 CC029A Alt 1,000 m.a.s.l. 1,259 kg				



CASE STUDY: Mandatory Energy Labelling for Motors, Chile

In 2008, Chile included electric motors among the products mandatorily required to carry energy labels A to D (see alongside) according to the country's labelling programme, which principally covers consumer appliances. Since Chile has no domestic motor manufacturers and no domestic motor testing laboratories, it meant that foreign suppliers had to go through a cumbersome testing and certification process and provide labels specific to the small Chilean market, which was not cost-effective and proved to be a market barrier for importing energy efficient motors.

Labels can also be associated with competitions for 'best in market'. In this scheme, a programme specification is established, and suppliers enter the competition to earn the accolades from participation and potentially from winning the competition. The Clean Energy Ministerial established the Super-Efficient Equipment and Appliance Deployment (SEAD) Global Efficiency Medal in 2012, and has conducted global competitions on electric motors, televisions, and lighting products so far.[45]

4.2 COMMUNICATION AND EDUCATION

4.2.1 DESIGNING A COMMUNICATIONS CAMPAIGN

An effective communication and education campaign informs, educates, and gains the active support of key stakeholders. There are seven steps involved in designing such a campaign, as shown in Figure 19.[46]

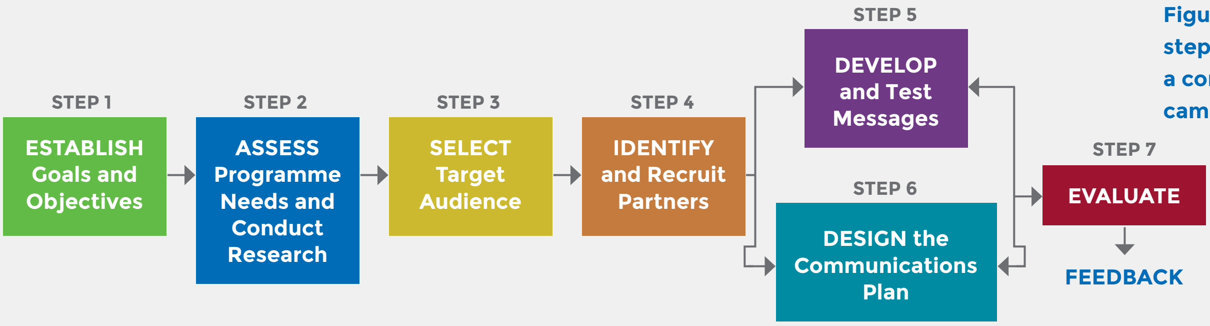


Figure 19: Major steps in creating a communications campaign[47]

Table 8: Motors communication campaign stakeholders and areas of interest/ involvement

4.2.2 IDENTIFYING AND ENGAGING STAKEHOLDERS

Table 8 depicts the target audiences of an energy-efficient motors communication and education campaign, examples of the stakeholders in these groups, and their primary interests and potential areas for involvement.

TARGET AUDIENCE	PRIMARY INTERESTS	AREAS OF INVOLVEMENT
PUBLIC INSTITUTIONS • Political executive and legislature • Regulatory bodies particularly electricity regulators • Standards bodies • Accreditation bodies • Enforcement officials • Customs authorities.	• Reduce need for new power plants, reduce GHG emissions, while improving the national economy • Protect domestic industry and jobs while respecting trade obligations and without limiting trade opportunities. • Ensure market transformation to energy-efficient products.	• Policy formulation, legislation, funding and human resource support for energy efficiency market transformation programme • Support to regulatory initiatives and policy implementation • Evaluation and monitoring of programme against established targets • Public procurement policy • Standards and Regulations • Incentives and subsidies • Testing lab accreditation • Product registration • Compliance • Communication campaign.
POWER UTILITIES	• Reduce peak demand • Increase energy access.	• Demand-side management programmes • Incentive and subsidy programmes for efficient motors.
SUPPLY CHAIN • Motor manufacturers • Motor repair shops • Motor industry associations • Dealers • Equipment manufacturers • System integrators.	• Seek competitive advantage, improved market share • Protect against business disruptions • Minimise costs, seek return on new investments • Be seen as an environmentally sensitive, responsible corporate citizen • Gain public recognition.	• Assist regulators in determining level of ambition and timeline • Upgrade capacities for design, manufacture, testing and marketing of energy-efficient motors • Ensure accurate energy labelling • Act as change agents • Facilitate direct and indirect end-user communication.
END USERS • Company management • Energy managers • Maintenance managers • Purchase managers • Facility managers • Energy auditors • ESCOs • Energy consultants.	• Create sustainable corporate performance–financial, environmental • Save costs, improve productivity • Maintain plant uptime.	• Develop company energy policy, motor-management policy, procurement policy • Acquire information and develop capacity to make informed decisions about the savings associated with a switch to efficient motors • Conduct energy audits • Provide data on procurement practices.
OTHERS • Civil society • Environmental organisations • Educational institutions • Research and training institutes • Media and general population.	• Sustainable development, environmental protection • Education and training.	• Assist public institutions with the development and implementation of sustainable appliance policies • Identify best practices and policies • Publish formal and informal education and training materials • Increase awareness and develop knowledge about energy-efficient motors among professionals and users • Support for sustainable appliance policies among general population.

Education and training programmes should be carried out for motor manufacturers, repairers and end users. Many end users lack the tools and knowhow to reliably assess the energy-savings potential of individual motor applications within their plants, or how to optimise motor systems and create a bankable business case for investment.

Many professional energy auditors are better equipped to assess the savings potential from improvements in other plant areas such as process energy, thermal leakages, air and water leakages, rather than from motors and motor systems. Therefore, training content in the form of practical tools, guides, reports and manuals should be leveraged to bridge these gaps of knowledge and ability. As a rule, these should be held at neutral venues, but some could be conducted onsite for large companies.

Please see the IEA 4E "Policy Guidelines for Electric-Motor Systems, Part 2", 2014, sections 6.8.4 to 6.8.9 for best practice examples of motor communication campaigns, awards, guides, training programmes, energy-savings tools and lifecycle costing calculations.[48]

4.3 OTHER SUPPORTING POLICIES

The following sections describe policies to address the potential loss of energy efficiency during motor repairs, as well as for realising the energy savings potential of motor systems.

4.3.1 IMPROVING MOTOR REPAIR PRACTICES

Considerable energy can be saved through upgrading of repair practices. Electric motor losses can increase after repairs if carried out unprofessionally, which can happen up to three times over a motor's lifetime. When carried out in accordance with industry best practices, the repaired motor should perform at least as well as the original one.[49]

Typical poor repair practices relate to inadequate equipment, processes and knowhow and missing quality standards, more so in developing countries. Policy interventions could cover the following:

- Awareness campaigns
- Training materials and facilities
- Financing schemes for equipment upgrading in repair shops
- Developing repair quality standards and certification/accreditation programmes[50]
- Repair quality labels.

These recommendations are elaborated in a study commissioned by the Clean Energy Ministerial SEAD programme.[51]

Electric motor losses can increase after repairs if carried out unprofessionally, which can happen up to three times over a motor's lifetime. When carried out in accordance with industry best practices, the repaired motor should perform at least as well as the original one.

4.3.2 INDUSTRY ENERGY PERFORMANCE TARGETS

Countries with energy-intensive industries like mining, cement, or textiles can consider special policies focused on reducing the specific energy consumption (SEC = units of energy required per unit of production) of individual companies in these sectors and the sector as a whole.[52] These companies will also usually be among the top 10 per cent in size and consume 70 to 80 per cent of the electricity used by industry.

Policymakers can benchmark[53] the SEC of domestic industry internationally or compare individual companies with the least energy intensive domestic producer, or even of a company vis-à-vis its own past performance, to arrive at the energy-savings potential. These benchmarks can then be used to set improvement targets, that could be supported (e.g. by enabling access to superior technology, knowhow), incentivised (e.g. through public recognition, trade-able certificates, subsidies, tax rebates) and mandated (e.g. under threat of penalties).

SEC can be reduced is many ways, including by eliminating leakages of water/steam, improving technology, restructuring industrial processes. To ensure that the upgrading of motor systems is prioritised, there should be specific motor efficiency elements or a sub-target for reduced electricity consumption within the overall target for an energy mix, which usually includes oil, gas and coal.

CASE STUDY: Perform Achieve and Trade, India

Perform, Achieve and Trade is a mandatory programme introduced by the Indian government in 2013 covering eight energy-intensive industry sectors. An annual SEC improvement target is set for each individual industrial unit based on its past SEC, benchmarked on the industrial unit with the lowest SEC. Thus, less-efficient units have higher SEC improvement targets than units that are already efficient.

If an industrial unit is able to exceed its SEC reduction target, it earns a certificate from the government in units of one tonne of oil-equivalent. These certificates are tradable on an exchange. On the other hand, if an industrial unit is unable to meet its SEC reduction target, it has to make up the shortfall by buying certificates from the market. The merits of this programme are that there is a transparent incentive-penalty mechanism built-in at a very low-cost to the government, essentially for ensuring compliance.

As a prelude to this programme, the Indian government had separately mandated that all industrial units within these eight sectors above a certain energy use level must employ a certified energy manager, conduct energy audits and conduct energy saving programmes.

For more information click here.

4.3.3 ENERGY MANAGEMENT PROGRAMMES

Energy Management Programmes are government-led initiatives encouraging individual companies to adopt management systems for improving their energy performance in a systematic way. These complement the top-down approaches of the previous section by equipping companies with a framework and tools to identify energy-savings opportunities, implement savings measures, and evaluate outcomes. The IEA has developed a guide[54] to assist policymakers in developing such programmes.

By participating in such a programme, apart from contributing to the national savings in energy and carbon emissions, companies benefit directly through lower costs, reduced exposure to energy price fluctuations, and improved competitiveness.

The international standard ISO 50001:2011, Energy Management Systems (EnMS) – Requirements with guidance for use, requires companies to develop such systems for continuous improvement in energy performance through a Plan-Do-Check-Act (PDCA) cycle. This is the same PDCA cycle of other well-known standards like ISO 9001, Quality Management Systems and ISO 14001, Environmental Management Systems; it is easier for companies to adopt and implement ISO 50001-EnMS if they are familiar with these standards.

The adoption of an Energy Management System usually moves companies to create policies and practices for regular energy performance assessments, including on energy-efficient motors and motor systems, although these could be standalone policies as well.[55] The United Nations Industrial Development Organization (UNIDO) Industrial Energy Efficiency Programme[56] focuses on promoting and supporting industrial Energy Systems Optimisation (ESO) as a complementary approach to EnMS implementation.

The emphasis of ESO is on systems design as well as on operation and maintenance practices. UNIDO assists developing country governments with policymaking technical assistance, institutional capacity building and market transformation support for adoption, implementation and dissemination of EnMS and ESO, including motor systems.

UNIDO international trainers work with national partners to create awareness and provide user and expert training over a period of six to nine months. Working with governments, companies and local energy efficiency service providers, the UNIDO programme creates a ‘push-pull’ market dynamic for EnMS and ESO services and projects.

CASE STUDY: Motor System Energy Conservation Programme, China

Through a combination of in-depth technical classroom training and on-the-job practices and measurement experience, UNIDO trained 22 Chinese engineers and energy efficiency consultants from the Jiangsu and Shanghai provinces in motor-system energy optimisation techniques. Within two years after completing training, these Chinese experts conducted 38 industrial plant assessments and identified nearly 40 million kWh in energy savings.

For more information click here.

4.3.4 ENERGY AUDIT PROGRAMMES

An energy audit is a systematic identification of opportunities for cost-effective energy savings in a company, including in motor systems, by an internal or external certified energy auditor. An energy audit is usually followed by an implementation plan for the most cost-effective energy-savings measures.

An energy audit programme is a government-led initiative encouraging and supporting companies to conduct periodic energy audits, sometimes mandatorily, and provides methodologies, tools, training and certification for energy auditors. This is usually a component of a broader policy such as an industry sector energy policy, an energy management programme, or a financial assistance programme, although it could be a standalone policy as well. From the perspective of motors, energy audit programmes should support energy auditors with motors specific methodologies, tools and training.[57]

CASE STUDY: Motor-Check Motor Systems Energy Audit Methodology, Switzerland

The Swiss Agency for Efficient Energy Use has developed a methodology for identifying opportunities for motor system retrofits with the highest energy savings potential and implementing improvement measures. This methodology is applied in conjunction with a financial assistance programme called “EASY”.

For more information click here.

CASE STUDY: Certification of Energy Auditors, India

The Energy Conservation legislation mandates that all industrial units above a certain energy use level must employ a certified energy manager, conduct energy audits and conduct energy saving programmes. In accompaniment, the Bureau of Energy Efficiency trains and certifies energy managers and energy auditors and maintains a list of such auditors on its website.

For more information click here.

4.3.5 COMPANY MOTOR MANAGEMENT PROGRAMME

A company motor (energy efficiency) policy[58] enables a company to systematically transition to higher-efficiency motors and systems over time. It is usually a component of a broader government policy such as an Industry Sector Energy Policy or an Energy Management Programme, although it could be a standalone policy as well. Such a policy typically lays down

- A consideration of energy efficiency and lifetime costs, while procuring motors and drive systems
- Rules for repair/replace decisions when motors fail, incorporating energy savings considerations
- Requirements to prevent loss of efficiency due to improper installation
- Guidelines for ensuring professional motor repairs with no loss of efficiency.

A broader company motor management[59] programme would additionally include elements such as:

- Motor data management and analysis
- Motor surveys and tagging
- Motor inventory analysis
- A spares stocking policy
- Preventive and predictive maintenance.

CASE STUDY: Green Deal on Efficient Electric Motor Systems (2012 – 2015), Netherlands

The Green Deal aimed to grow the use of efficient motor systems in industry. It was a partnership between motor suppliers, service and maintenance companies, their trade associations and the Dutch Ministry of Economic Affairs.

The main elements of the programme were to:

1. Define an audit format for efficiency improvements in motor systems
2. Execute audits and develop and implement sound business cases on efficient motor systems, delivering concrete energy savings
3. Transfer the knowledge gained and communicate the results to end users and the supply chain to advance working methods, capacities and energy savings.

The government supported the programme by offering project management and communicating with industry sectors and representatives. The energy investment scheme included rebates on investments in super-efficient motors and systems. The average savings at a company level ranged from 6 to 40 per cent, with an average of 12 per cent. Total savings of 2.6 GWh year were achieved by 15 completed projects. If all the projects initiated during the programme are completed the average saving rate will rise to 15 per cent, with a total savings of 15-20 GWh/year.[60]

CASE STUDY: Voluntary Agreements on Energy Efficiency, Netherlands

Since 1992, the Dutch government has entered into voluntary (though binding upon signature), agreements on energy efficiency improvement targets with industry partners and institutions. The objective is to reduce the energy used per unit of product or service delivered through a 2 per cent per annum improvement in energy efficiency.

The participating companies have to implement a three-fold set of activities:

1. Making an Energy Efficiency Plan every four year
2. Yearly monitoring of production levels and energy use
3. Maintaining an energy management system.

The Energy Efficiency Plan quantifies the energy-saving measures that are to be implemented over a period of three years. In the past few years, specific attention has been paid to motor-system efficiency within the Voluntary Agreements approach. All known measures from the Motor Challenge Programme are listed for use in formulating the Energy Efficiency Plans. The Motor System Action plan and IE3-motors from 7.5 kW up to 375 kW has been put on the Energy List of the Energy Investment Allowance, which is a tax relief programme for companies that invest in energy-saving equipment and sustainable energy.

The instrument of Voluntary Agreements engages the companies with energy efficiency-related activities like thematic workshops, pilot projects, energy audits and technology roadmaps. Participating companies operate a required energy-management system, based on (elements of) ISO 14001, which is being transformed toward standards such as ISO 50001 and new methods such as the CO_2 performance indicator. Electric motor systems are addressed within this framework and clear links toward organisation, procurement and sustainability issues are being developed.[61]

5. FINANCE AND DELIVERY MECHANISMS

WHAT?	This chapter addresses how to finance energy-efficient motors and systems, including both sources of finance and delivery mechanisms.
WHY?	Finance is a significant barrier to the transformation of the market to energy-efficient motors and motor systems. This chapter addresses how public finance, multilateral development finance, and climate finance can help address this barrier through diverse delivery mechanisms.
NEXT?	Some key questions to keep in mind: • What are the financial barriers to transformation of the market to energy-efficient motors and motor systems? • Which economic policies or financial incentive programmes could be effective in reducing or removing these financial barriers and facilitating market transformation in our country? • Which stakeholders should we engage to learn about financial barriers and work with to encourage the creation of new market-delivery mechanisms? • What new market-delivery mechanisms, such as energy service companies, leasing schemes or other approaches, could be effective in our country? • Are there bilateral or multilateral sources of technical assistance, grants or finance that would stimulate and accelerate the efficient motors market?

Implementing a market transformation programme requires funding to overcome market barriers, develop capacity, drive local investor confidence, raise awareness, and establish the infrastructure and stakeholder alignment necessary for successful implementation and programme sustainability. Financing is required for the market transformer (i.e. government) to ensure appropriate policy development and implementation, and the market is transformed (i.e. market actors) to develop or buy energy-efficient products.

While financial barriers exist across the entire supply chain (see Table 9 for examples), the experiences of many countries show that policymakers most often target two barriers:

1. **Reduce the cost of energy-efficient products for customers**
   a. policies providing financial incentives to mitigate the initial purchase premium associated with energy-efficient equipment
   b. policies encouraging customers to consider the lifecycle costs of using equipment rather than simply the initial capital purchase cost.
2. **Encourage investment in the supply of energy-efficient products**
   a. Policies encouraging investments in equipment and tools needed to manufacture or service energy-efficient equipment
   b. Policies encouraging investment in the development of new innovative products.

This chapter is divided into two main parts. The first part is a high-level summary of the sources of finance available to countries for energy efficiency programmes. More detail on these sources can be found in the United for Efficiency "Policy Fundamentals Guide", which sits as a companion guide to this report and provides information on topics that cut across all the products covered under U4E. The second part of this chapter concentrates on the development and promotion of financial delivery mechanisms.

Table 9: Some examples of financial barriers for the actors in the market under transformation

ACTOR	FINANCIAL BARRIER	CONTEXT
CUSTOMER	Higher upfront cost of an energy-efficient motor relative to purchase of an inefficient motor	Customer uses capital equipment price to make purchase decision rather than evaluate total cost of ownership
	Higher upfront cost of energy-efficient motor relative to repair of existing inefficient motor	Customer uses capital equipment price to make purchase decision rather than evaluate total cost of ownership
	Lack of adequate own funds to buy new equipment	Desire to purchase equipment exists but inadequate own funds available to make purchase
	Lack of access to bank loans to buy new equipment	Desire to purchase equipment exists but unable to borrow to make purchase
	Internal Rates of Return (IRRs, a commonly used measure of returns on investments) are low and not at all attractive versus investments in their core business	Hurdle rates for investing internal capital in industrial facilities are a payback in one – two years
	View motors as infrastructure assets and not interested to replace unless broken	Not willing to use their credit or internal budget capacity for noncore business use
	Lack of awareness and/or no confidence that estimated savings will be realised and can be measured and verified	Must have confidence that estimated savings will be realised.

ACTOR	FINANCIAL BARRIER	CONTEXT
LENDER	Unable to assess project technical risks or commercial returns from an energy efficiency project	Project does not meet required lending criteria e.g. adequate security of repayment, rate of return; funding is not provided.
	Transaction size too small	
	Current corporate lending practices require collateral which motors do not have sufficient value to provide	
SUPPLIER	Cannot afford to hold additional, rarely requested, inventory	At the start of market transformation suppliers are reluctant tie up capital in efficient products they cannot sell quickly
	The cost of energy-efficient equipment can be higher	Due to customer barriers (presented above) sales take longer or fall through; finding rare customers who wish to buy energy-efficient equipment is expensive
	Suppliers lack the capital to buy materials to build products that have been ordered (i.e. provisional sales)	Provisional customer sales have occurred, but suppliers lack capital to provide solution
	Suppliers lack the capital to upgrade service facilities	New products can require new servicing approaches, but suppliers lack investment.
MANUFACTURER	Manufacturers lack funding for research and development into new MEPS compliant products	Market transformation seeks to stimulate above the norm levels of product performance that may require above the norm levels of R&D investment; without R&D, funding local manufacturers' market share may be squeezed
	Manufactures need to retool to build new innovative products	Upfront investment in retooling.

5.1 SOURCES OF FINANCE

There are numerous finance sources to help support energy efficiency programmes, particularly for resource-constrained countries. This section briefly identifies some of the sources, and interested parties are directed to the United for Efficiency "Policy Fundamentals Guide", which provides an overview along with case studies and hyperlinks to various sources of finance for energy efficiency projects and programmes.

- **Public Finance**–the most direct way for governments to pay for motor energy efficiency programmes is to allocate public funds from the domestic budget. Another option is to involve electric utilities through the traditional utility demand-side management approach.
- **Commercial Finance**–commercial financial institutions are starting to understand the compelling aspects of energy efficiency and are developing suitable financing mechanisms. Examples of commercial finance include bank loans, leasing, third party financing, performance contracting, and ethical/green investment funds. The climate friendly bond market was worth around $70 billion in 2016. Commercial lending is more suited to the purchase of equipment rather than for financing the development and execution of government programmes.
- **Sources of Development Finance**–developing countries may seek nondomestic sources of finance – e.g. African Development Bank, Asian Development Bank, European Bank for Reconstruction and Development, European Investment Bank, Inter-American Development Bank, and World Bank. Non-domestic sources of finance can provide concessional rate loans to governments. In 2015, these sources lent $25 billion on climate friendly projects, and this lending leveraged a further $66 billion in private finance.
- **Sources of Climate Finance** - financing mechanisms designed to reduce CO_2 emissions and other environmental impacts. These mechanisms often provide grants and low-cost loans and can blend with other sources of finance to help scale up the implementation of energy efficiency programmes. Examples of climate financing include Clean Development Mechanism (CDM), Climate Investment Funds, GEF, Green Climate Fund (GCF), Nationally Appropriate Mitigation Actions (NAMAs), and a variety of foreign assistance programmes offered by national governments (see Figure 20). These financing mechanisms require measurement and verification of CO_2 emissions reduction in addition to energy savings.

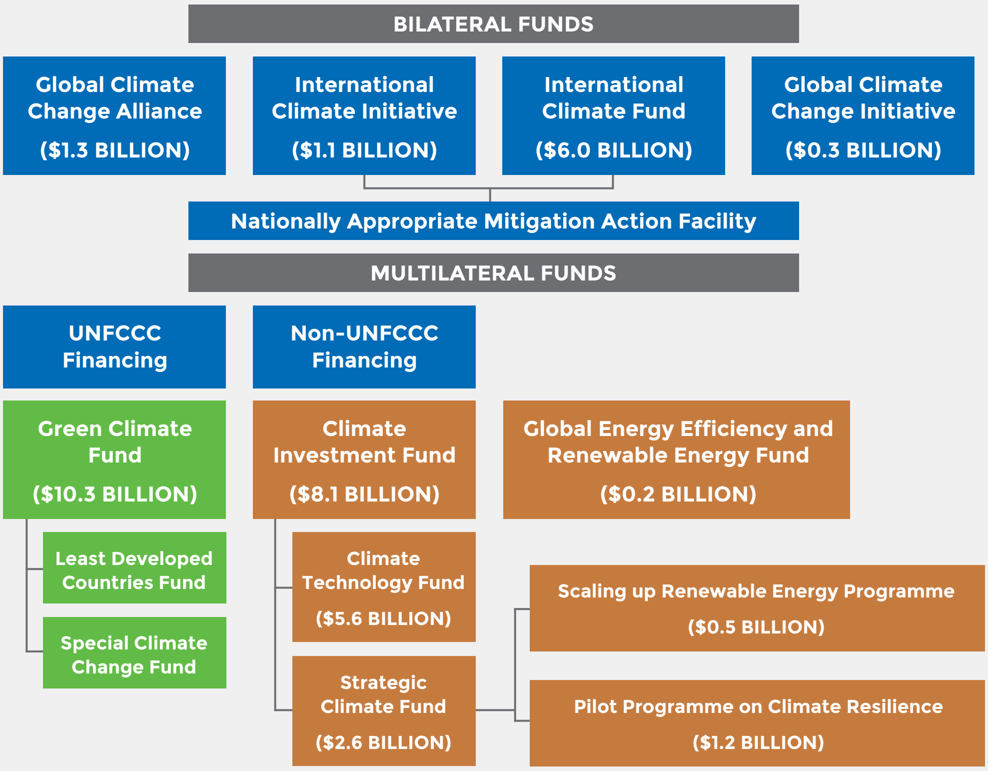


Figure 20: Climate Funds accessible by developing countries[62]

5.2 FINANCIAL DELIVERY MECHANISMS

Numerous delivery mechanisms exist to enable policymakers to use the financial sources to support the market transformation to energy-efficient motors and motor systems (see Table 10 for examples). Each delivery mechanism will be more or less effective at mitigating a particular financial barrier.

Market analysis should be undertaken to clearly understand and verify the targeted financial barriers in sufficient detail to enable selection of an applicable delivery mechanism along an appropriate configuration (e.g. financial benefit is sufficient to mitigate the financial barrier for the identified market actors impacted by the financial barrier). The delivery mechanisms described below are not meant to cover the expenses of the development of government policies and programmes.

Table 10: Common financing mechanisms for energy-efficient motors and motor systems

PROGRAMME TYPE	DEFINITION/PURPOSE	ADVANTAGES	DISADVANTAGES
GRANTS	Reduce the up-front costs associated with investing in energy-efficient motors and systems.	Easy implementation. Can accelerate market transformation. In some cases, can be offset through reduced energy subsidies.	Burden on government finances. Can distort normal market pricing. Money can only be given out once.
TAX RELIEF OR REBATE OR ACCELERATED DEPRECIATION	Reduce the up-front costs associated with investing in energy-efficient motors and systems.	Uses existing tax system. Proven ability to support large volume, productised equipment. Often used in conjunction with product performance standards to reduce information asymmetry.	Minor burden on government finances. Existing tax system not designed to support efficient technology. This may hamper innovation and support for customised equipment.

PROGRAMME TYPE	DEFINITION/PURPOSE	ADVANTAGES	DISADVANTAGES
CREDIT LINES	Development banks provide commercial banks with access to funds at low interest rates with clear conditions for onwards lending to third parties.	Commercial banks lend at more favourable rates for energy efficiency investments.	Provides liquidity but may not overcome the full risk-return profile of energy efficiency projects.
GUARANTEES	Development banks agree (i.e. guarantee) to take on a level of potential financial losses (e.g. as a percentage of total loss, capped financial amount).	Encourages lenders to enter the energy efficiency market by reducing their risk barriers to entry.	Maybe useful in some sectors (energy-intensive industries) but not others (SMEs).
INSURANCE	Mitigation of performance risks of the technology not performing as expected.	Could de-risk energy efficiency projects for multiple actors. Similar to existing products.	Relatively new to market. Limited real world experience.
SAVINGS BASED LENDING	Lending against future savings from energy efficiency projects.	Enables companies and developers to access finance for energy efficiency Projects. Can be closely targeted on demand and supply-side actors.	Risk of default, but experience shows this can be lower than typical bank default levels.
ENERGY SERVICE COMPANIES (ESCOS)	ESCOs are businesses that secure funding, develop, implement and assume the technical and commercial risks for energy efficiency improvements. Compensation is normally tied to long-term energy savings being achieved.	Reduces the risk and up-front costs through energy performance contracts. Installation and management costs of assets for efficiency upgrades are included in the Contract.	Can be challenging to measure and verify savings. Profit focus favours investment in products with a short payback. Need strong regulatory and financial institutions. Need case studies that verify estimated energy efficiency savings with proven performance measurement and verification.[63]
VENDOR FINANCING AND LEASING	Reduced upfront capital requirements–consumer rents the asset instead of purchasing it. There is usually an option for the consumer to purchase the asset at a depreciated value eventually.	No impact on Lessee's Profit & Loss statement as lease rental is paid through energy savings. No capital investment required.	Best applied where a mature asset leasing market already exists and when the assets have a current market value that exceeds financed amount.
UTILITY DEMAND SIDE MANAGEMENT	Utility supports energy efficiency investments by electricity users to flatten the load curve. Provides a medium for subsidy/ loan disbursement and repayment.	Reduced upfront costs through demand aggregation and bulk procurement. Ease of repayment through electricity bills in instalments.	More suited for standard energy-efficient motors sold in high volumes than for motor system upgrades that can be very user specific.

5.2.1 GRANTS, REBATES, TAX-RELIEF

Grants, rebates or tax-relief can reduce the up-front cost of investment in motors of a higher efficiency class than the MEPS compliance level or in projects for upgrading the energy efficiency of motor systems. When taken together with the energy cost savings, the expected rate of return of the investment is improved, thereby strengthening the overall business case for investment.

CASE STUDY: Additional Depreciation–Energy Investment Scheme, 2017, Netherlands

The Netherlands allows companies investing in IE4 motors an additional tax depreciation of 41.5 per cent over and above the normally allowed depreciation rate. On an average, companies save about 10 per cent of the investment by way of lower taxes, on top of the savings in energy costs.

Investments in other energy efficiency measures listed in the scheme, updated annually, qualify as well, provided these can demonstrate an energy savings of between 0.6 – 1.5 Nm3 of natural gas equivalent per annum per € of investment. The government has an annual budget for the Scheme and may limit or suspend it if this is exceeded.

Each of these financial incentives can be used to, for example, influence customer purchase decisions. The size of the financial incentive can be set to encourage the adoption of new technologies (i.e. create additional market demand), or more subtly, alter purchase behaviour when the need to buy has been proven (e.g. tax relief can provide a financial “rudder effect” encouraging a customer to switch from buying an inefficient product to an efficient one).

A grant improves cash flow at the point of purchase, a rebate improves cash flow after the point of confirmed purchase (i.e. a reimbursement), and tax relief improves cash flow either at the time of purchase (e.g. purchase tax or VAT reduction) or at the end of the financial year (e.g. credit, capital allowance). Each requires the purchasers to be able to access different levels of interim capital. Each improves the business case for investment and the rate of return to varying degrees.

CASE STUDY: EASY & SPEED Programmes for Motor System Retrofits, Switzerland

The Swiss EASY programme ran from 2011 to 2014 and gave grants to eight companies for improving the energy efficiency of motor systems. The grant covered 100 per cent of the cost of the initial study to estimate the savings potential, 75 per cent of the next step of creating a detailed list of motors in the plant with nameplate and application data, 50 per cent of on-site testing and 10 per cent of implementation.

The programme achieved lifetime savings of 74 GWh in electrical energy and cost the government 1 million CHF (approximately $1 million). The structurally similar SPEED programme for fans, pumps and compressors, running from 2015-2017, has succeeded this.

For more information click here and here.

5.2.2 CREDIT LINES AND PARTIAL RISK GUARANTEES

Lending to energy efficiency projects often lags because local banks' traditional corporate, asset-based lending practices do not allow them to offer attractive project-based financing terms to facility owners or project developers. They also lack the capacity to evaluate and manage the risks of energy efficiency projects and are unwilling to invest time to acquire such skills due to the small transaction sizes and the resulting perception of a small-sized market opportunity. Larger governmental and/or international financial institutions driven by green objectives can step in to provide dedicated credit lines (low-interest funds dedicated for lending to energy efficiency projects), technical support and share the lending risks with the local banks.[64]

Credit lines are one of the most common instruments used in energy efficiency finance interventions and are often provided at rates that are more favourable than those found in the local market. International experience has shown that credit lines can also provide a stable source of additional funding that can be lent by local banks to suppliers and users to stimulate the supply and demand for energy-efficient equipment. Caution must be exercised where credit lines are used to expand the funding of existing financial products as this can lead to further investment in existing markets reducing transformative change to energy-efficient markets.

Partial risk guarantees, which are usually publicly funded, encourage financiers to expand into markets that are perceived as too risky under normal conditions. The guarantor accepts a fixed percentage of losses incurred by the financier for either performance or credit failure. Partial risk guarantees may be better suited to large projects (e.g. energy efficiency projects at a large energy intensive company) with greater risk-return profiles.

CASE STUDY: Kayseri and Bursa OIZ loan Support Programmes, Turkey

In a pilot project, the Turkish government offered a credit line of up to $100,000 per company to banks for onwards lending for projects to replace IE1 motors with IE3 in the Kayseri OIZ industrial complex. The pre-condition was that old motors would have to be surrendered and scrapped.

Out of a 130 large (above 50 TOE with an average of 100 motors with an average capacity of 45 kW each) energy-consuming firms, only one firm applied for a loan. A survey determined the following reasons for the unwillingness of the other firms to apply for a loan:

- Firms do not want to surrender replaced motors as it made more economic sense to resell them to the refurbished motors market (60 per cent)
- Energy efficient motors are not in their short-term investment plan (52 per cent)
- Electricity consumption share of motors is low (40 per cent)
- Do not want a new credit line (37 per cent)
- Do not want to pay for energy audits (35 per cent)
- Using energy-efficient motors already (26 per cent)
- Do not believe the benefits (or profits) from replacement (20 per cent)
- Do not want to allocate time/stop the production (16 per cent)
- Thinks that procedures are complicated/bureaucracy is high (12 per cent)
- Unaware of the support programme (three per cent).

Based on the experience gained, a modified programme shall be run in the Bursa OIZ comprising 250 firms beginning in 2017. This shall cover both SMEs and large firms.

CASE STUDY: Insurance/Risk Mitigation for Energy Savings– Inter-American Development Bank Pilot, Mexico and Regional

The Inter-American Development Bank has been conducting a pilot project in Mexico of providing commercial banks with insurance for the risks associated with financing energy-efficiency projects since December 2014. This is of potential relevance to other developing countries.

A business model has been developed in which an insurance component underwrites projected savings for specifically defined and verifiable energy efficiency measures, thereby assuring banks and hosts of dependable project financial flows and energy savings.

The initiative is established as a partnership between public and private stakeholders–local financial institutions, insurance companies, energy service providers, national development banks and multi-lateral development banks.

For more information click here and here.

5.2.3 INSURANCE

Insurance can mitigate the risk of an energy-efficient technology not performing as expected, covering the losses for the customer, supplier and financier, or a select combination of them. As part of due diligence the insurer evaluates the technical and economic viability of the energy efficiency project, and then offers and insurance product with a risk-weighted premium. Such insurance gives investors' confidence that the energy efficiency project can deliver the projected commercial returns using the proposed technology. Improved confidence reduces the financing cost of capital, and this reduced cost of capital may more than offset the insurance premium.

5.2.4 SAVINGS-BASED LENDING

Access to capital is one of the most significant financial barriers to investments in energy efficiency. Conventionally, loans are secured through the physical or financial assets of the borrower. However, company owners and developers can find this securitisation challenging to overcome. In particular, SMEs often lack existing financial assets and have limited physical assets (i.e. below the level required for securitisation). Equally, lenders consider SMEs as risky investments and ask for prohibitively high rates of return, i.e. interest payment.

Providing savings-based lending can overcome this barrier to capital.

International experience has shown that fiscal incentives focused on stimulating savings-based lending can significantly stimulate the supply and demand for energy-efficient equipment. Such incentives also deliver cost-effective environmental and wide-ranging economic benefits (e.g. cost savings, new jobs, and new markets).

Central to successful savings-based lending programmes has been lender-driven technical verifications of the identified revenue streams that occur due to the use of energy-efficient technology. Such technology reduces energy costs, and these savings can then be used to repay the loans.

CASE STUDY: Carbon Trust 0 per cent Loan Scheme for Energy Efficiency Projects by SMEs, UK

With a Credit line provided by the UK government, the Carbon Trust provides SMEs with 0 per cent unsecured loans for specific energy-efficiency projects. Loans are awarded based on an independent expert estimation and verification of the energy savings potential of a project. Since 2003 over $300 million has been loaned to 7,000 enterprises, and this should deliver 2.2 $MtCO_2$ in carbon emissions reductions and reduce energy bills by $560 million. Over 2,000 suppliers have actively participated and used the scheme to sell their energy-efficient products.

For more information click here.

5.2.5 ENERGY SAVINGS PERFORMANCE CONTRACTING THROUGH ESCOS

An energy service company (ESCO) is a commercial business providing a broad range of turnkey energy solutions including energy audits, system designs, financing and implementation of energy efficiency projects. ESCOs represent a mechanism for delivering energy efficiency finance effectively, as funds are provided to the ESCO rather than to the energy user through one or more of the instruments described earlier such as credit lines. There is no capital cost to the energy user.

ESCOs often act as project developers for a comprehensive range of energy efficiency measures, assuming the technical and commercial risk. The difference between ESCOs and other energy efficiency companies is that ESCOs use performance-based contracting, and their compensation is therefore directly linked to the actual energy savings on the client site. The energy user pays an agreed regular fee to the ESCO, which is usually lower than the energy cost savings using the ESCO's technology, leaving behind a surplus. An ESCO programme requires strong financing partners and an enabling legal and regulatory framework for success.

CASE STUDY: National Energy-Efficient Agriculture Pumps Programme, India

Many governments in emerging economies subsidise energy tariffs to improve affordability or to improve political standing. Subsidies hide the true cost of energy and discourage up-front spending and the development of financing mechanisms for energy efficient technologies. Reducing energy subsidies is not always feasible or desirable because this can be in conflict with the goal to expand energy access. However, it is possible to reduce energy subsidies by subsidising energy-efficient equipment through grants.

In India, electricity is heavily subsidised and is sometimes free for farmers due to political reasons. With almost no disincentive of energy costs, farmers use inefficient agricultural pumps, as these are cheaper than efficient ones.

The publicly owned ESCO, Energy Efficiency Services Limited (EESL) launched a pilot programme in 2016 to replace 200,000 inefficient pump-sets with labelled ones, free of cost to the farmer. These superior pump-sets have a smart control panel built-in, with a smart meter and a SIM card. The SIM card enables the farmer to switch the pumps on and off from his mobile phone and the smart meter enables him to monitor consumption in real time.

Through public tendering and bulk procurement, the costs of the labelled pump-sets have been kept down. EESL bears the costs of the pump-sets and recovers these through the savings in energy subsidies from the state owned distribution utilities.

The programme is expected to result in 30 per cent energy savings and a reduction in annual subsidies by approximately $3 billion.

For more information click here.

CASE STUDY: ESCO: Energy Drive Systems, South Africa

Energy-intensive industries such as mining require custom tailored, technically complex solutions. However, these firms either lack the capital or perceive a high risk of returns due to the technical complexity and process downtime.

Energy Drive Systems undertakes a technical audit and confirms the level of saving their technology can deliver. On customer acceptance of commercial terms, they design, deliver, install and manage a bespoke VSD solution for the period of the ESCO agreement. Systems are paid by taking a proportion of the costs savings delivered through reduced energy use.

Nearly 200 solutions have been provided by Energy Drive Systems across 27 client premises in South Africa and the UK.

A breakdown of the savings:

- > 75 per cent Energy Savings are achieved for 9 per cent of clients
- 55 – 75 per cent Energy Savings are achieved for 45 per cent of clients
- up to 55 per cent Energy Savings are achieved for 46 per cent of clients.

For more information click here.

5.2.6 VENDOR FINANCING AND LEASING

Leasing agreements establish a fixed-payment contract where the consumer rents the asset instead of purchasing it. The finance for the leasing contract may be derived from a financial institution, the equipment vendor, or some other source. A country's tax and incorporation laws will have some impact on how the lease operates.

Leasing balances the lease rental with energy savings and, therefore, is neutral to the profit and loss account of the lessee during the payback period. The lease payments to be made by the lessee are fixed and not linked to the achievement of project savings. However, in an industrial context, the asset is usually a bespoke equipment or system and, therefore, is required to be reflected in the user's balance sheet. This is unlike photocopiers and automobiles, for example, which may stay on the lessor's books.

Several different financing structures can be applied, including an "operating lease" whereby the manufacturer offers the lessee a fixed short-term lease and transfers only the right to use the equipment for a fixed monthly rent, after which it remains the property of the owner. Another financing structure is a "hire purchase agreement" allowing for gradual payment for the equipment over the defined operating period, and at the end of the contract the assets, now fully paid off, automatically become the property of the lessee or customer.

5.2.7 UTILITY DEMAND-SIDE MANAGEMENT

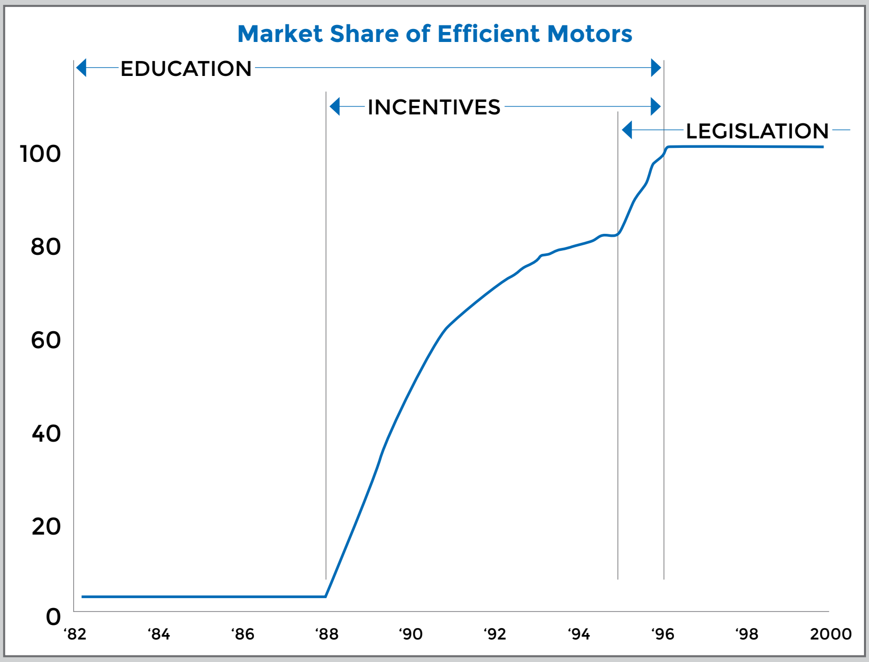
Demand-Side Management (DSM) refers to all market interventions by electricity distribution utilities to flatten the load curve by reducing the ratio of peak to average demand. The economic rationale for doing this is that while investments in power infrastructure are driven by peak demand, the returns on those investments are proportional to the average energy sold. Promoting end-use energy efficiency solutions is one such market intervention.

DSM programmes can aggregate demand, enable bulk procurement and be used to channel subsidies and loans on favourable terms for investments in energy-efficient motors. The loans are repaid by energy users through energy savings in monthly electricity bills over a certain agreed period. The utility bears the programme costs, which includes consumer awareness and information campaigns.

A regulatory driver or enabler is usually needed for DSM programmes.

CASE STUDY: Motor DSM Programme - British Columbia Hydro, Canada

British Columbia Hydro's DSM programme increased the market share of efficient motors from 3 to 60 per cent in a period of three years. The utility provided a financial incentive to the purchasers of energy-efficient motors equal to the price difference of those motors in relation to standard motors. The motor vendors and distributors also received a financial incentive to ensure that the market supply was adjusted to the new demand for efficient motors. The utility supported legislated efficiency standards to sustain the market, and ramped down the programme as market forces and standards took effect at the end of 1995.



For more information click here, and here.

6. MARKET MONITORING, VERIFICATION AND ENFORCEMENT

WHAT?	Describes the processes for establishing and maintaining a robust Monitoring, Verification and Enforcement (MVE) regime, which is critical to the success of energy efficiency standards and labelling.
WHY?	A robust MVE regime safeguards the credibility of the programme, raises user confidence, and provides a level playing field for the supply chain. Suppliers get discouraged from noncompliance by the certainty of exposure and adverse consequences, and get encouraged to bring products that are more efficient to the market. Users have the confidence that product efficiency is indeed as it is claimed to be. Policymakers get the reassurance that the intended benefits from the programme to the economy and the environment are secure.
NEXT?	Some key questions to keep in mind: • Do we have the legal framework around which to structure a complete MVE scheme? • Which government bodies oversee product safety? Could their function be expanded to include energy efficiency as well? • What public resources are available to staff and finance a MVE regime?

MVE revolves around monitoring markets, verifying compliance and enforcing the regulation on companies that fail to meet them. Figure 21 highlights the fundamental aspects of MVE.

MONITORING

Collecting information about compliance with the programme requirements through market surveillance activities to seek out potential cases of noncompliance for further verification testing.

VERIFICATION

Verification testing or processes to determine whether a product performs according to its claimed energy performance value: often a third-party test.

ENFORCEMENT

Acting in response to noncompliance offences with a suite of timely and appropriate actions: build on rigorous testing and yielding a high return in terms of market and consumer protection.

Figure 21: The market monitoring, verification and enforcement process

The goal of MVE is to ensure the integrity of market-transformation programmes by minimising if not eliminating the sale of noncompliant products after the effective date of a regulation.

A robust MVE regime benefits all the three main stakeholders involved: the supply chain, purchasers, and policymakers, as depicted in Figure 22.

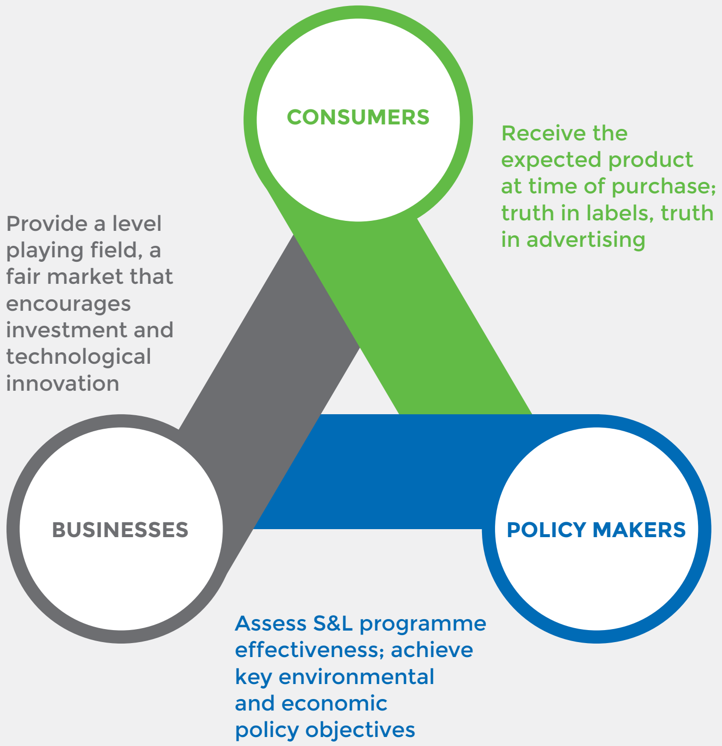
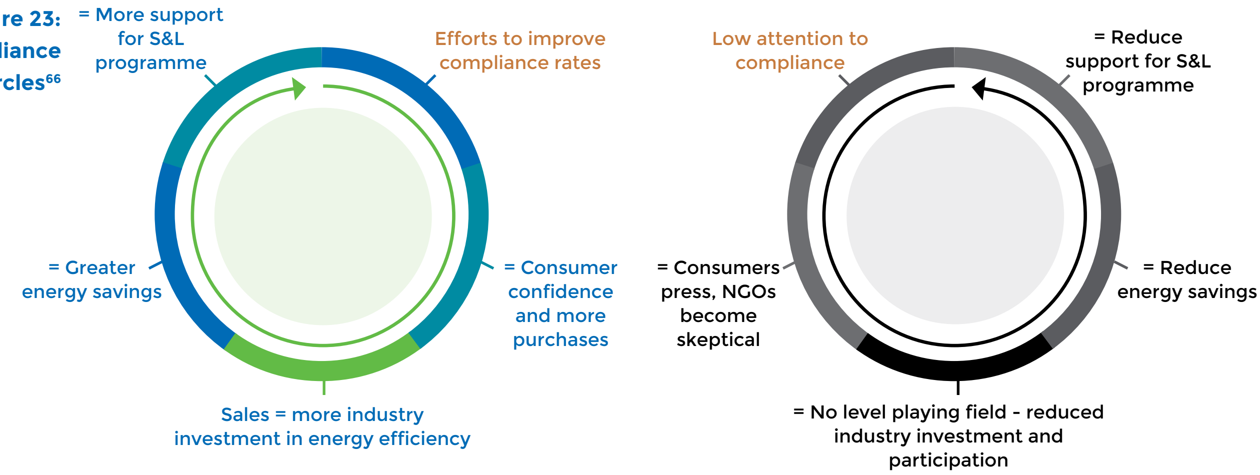


Figure 22: MVE benefits to key stakeholders[65]

On the other hand, a weak MVE regime leads to the eventual failure of the policy. The two "compliance circles" in Figure 23 illustrate the self-reinforcing nature of robust and weak MVE regimes, which lead to high and low compliance rates respectively:

Figure 23: The Compliance circles[66]



6.1 LEGAL AND ADMINISTRATIVE FRAMEWORK

A strong foundation within the national legal framework is crucial for an MVE scheme. This foundation should encompass legal authority, enforcement powers and penalties. The legal framework for an energy efficiency enforcement regime will depend on the national governance structure, on existing legislation, and on the infrastructure and design of the MVE process.

Legal frameworks must clearly delineate responsibilities between the different government agencies implementing MVE nationally, including the agency responsible for coordinating the MVE scheme, and other agencies such as customs, standards and metrology that will have central roles. The framework could bestow the authority for an agency to issue fines and block the sale of noncompliant products from entering the market.

The operational framework within which the enforcement authority operates should be transparent. This improves compliance rates through clear communication and understanding of the MVE scheme.

A strong foundation within the national legal framework is crucial for an MVE scheme. This foundation should encompass legal authority, enforcement powers and penalties.

CASE STUDY: Building on Existing Product Safety Legislation, Cambodia

Cambodia currently has no legal framework in place for authorising the enforcement of non-compliance for energy efficiency. However, a regulatory framework exists for the Safety Label for Electrical and Electronic Household Products.

This piece of legislation covers provisions for:

- Commercial fraud repression
- Actions against products or services which are likely to induce grave or imminent dangers
- Inspection procedures for quality and safety of products, goods and services; and
- Offences.

Although these provisions focus on product safety, these can be modified and adapted to address energy efficiency violations. The same agencies responsible for enforcement of product safety, the Ministry of Industry and Handicraft and the Ministry of Mines and Energy, can equally adapt their experience to enforce energy efficiency legislation.

6.2 FINANCING MONITORING, VERIFICATION AND ENFORCEMENT SCHEMES

The costs of a national MVE scheme will vary with the scope of the programme as well as local or regional factors, such as labour and services costs. When planning how to allocate funding for an MVE scheme, the managing agency typically considers the relative scale of the harm caused (i.e. cost of wasted energy, loss of consumer confidence, and frequency of noncompliance).

In general, more resources are allocated toward addressing cases of non-compliance that have the greatest impact and occur frequently. Budget allocation should be an evidence-driven, risk-based process that is transparent and defensible.

The areas of an MVE scheme, which incur costs, are listed below:

- **Establishment Costs**–setting up a main office and possibly field offices with new equipment
- **Staff Costs**–hiring and training/capacity building the staff, covering the key areas of administration, investigation and management, and in specialist areas such as customs officials and test labs
- **Communications**–informing the market about the regulations, the MVE scheme and enforcement proceedings, as deterrence is highly cost-effective; and
- **Legal and Enforcement Action**–the MVE agency needs to have (and be seen to have) sufficient funding to use its full range of legal powers.

The success of an MVE scheme will depend on identifying a secure and sustainable source of funding that will be maintained for a given market. Governments must assess what is equitable and feasible, and construct a solution that will fit within their framework. Robust MVE schemes require good market awareness, sampling and testing.

The success of an MVE scheme will depend on identifying a secure and sustainable source of funding that will be maintained for a given market.

The most common source of funding is the government's own general operating budget; however, this does not need to be the only source of funding. Cost recovery from suppliers can also be another source of funding, with many programmes around the world introducing cost-recovery elements to their schemes. Cost recovery can be partial or complete and can be achieved through registration fees, verification testing fees, enforcement fines, etc.

Many programmes collect funds from suppliers during registration. This may take the form of an annual payment, a one-off payment for a specified period, or a higher initial fee followed by a smaller annual payment. Registration fees are generally levied on product groups rather than brands or suppliers, as this best reflects the costs involved.

An increasing number of programmes require that products have third-party certification from an independent body as a condition of entry to the programme. While this is not cost recovery per se, it can reduce the costs of the programme because the system administrator is in effect delegating some of the responsibility for ensuring products meet the necessary requirements to third parties paid by the product suppliers.

Finally, support for MVE schemes can also be derived from stakeholders in the market. Collaboration and cooperation with industry or civil society may provide additional resources. For example, by providing expertise, supporting data collection and sharing, or even providing testing facilities.

Prior to engaging in this form of collaboration, the goals of cooperating need to be established, as some contributions may not be admissible as a foundation for legal action (e.g. there may be a conflict of interest in using industry funding to legally prove noncompliance of competitors in the market).

All compliance regime designs that deliver similar rates of compliance are likely to have similar overall costs. However, the costs may be distributed differently among governments, industry and consumers.

Table 11 lists the three most common processes for the provision of information on product performance, which plays a substantial role in monitoring and enforcing the programme. In the first model, the supplier's self-certification of energy performance is an acceptable entry condition. In the second model, the supplier's declaration of energy performance is based on a test report from an independent laboratory, which need not be accredited. In the third model, a verification authority administers the testing and certification (see 6.4 below) of motors by an accredited laboratory prior to market entry. The verification authority may be a private, public or industry organisation.

Table 11: Most common models of cost distribution among stakeholders

ENTRY CONDITION	DISTRIBUTION OF COSTS		
	GOVERNMENT/ PROGRAMME	MANUFACTURERS/ SUPPLY CHAIN	USERS
In-house testing, calculation or self-declaration allowed	High cost in market surveillance and verification testing	Low compliance costs	None
Independent tests required	Medium cost in market surveillance and verification testing	Medium initial compliance costs	May fund compliance costs in price of equipment
Third-party verification and/or certification required	Low-cost in market surveillance and verification testing	High initial compliance costs	May fund compliance costs in price of equipment

Since each of these models allocates costs to stakeholders differently, a key factor in the choice of system is the consideration of which is most equitable and feasible. Assess the pros and cons of each entry condition within context, since there is no one-size-fits-all solution.[67]

6.3 EFFICIENT MOTORS MARKET BASELINES AND ASSESSMENTS

A market baseline provides a snapshot of the products available in a market at a given point in time. It provides a sound technical foundation for the development of new, or revised, policies for efficient motors. Market baselines enable policymakers to gain a thorough understanding of product availability, performance, pricing, and other important factors influencing policy development.

Market baselines are refreshed over time so policymakers can understand market trends and responses to policies and programmes. This information facilitates the development of more effective regulations.

6.4 PRODUCT REGISTRY SYSTEMS

Product registration systems offer an initial compliance gateway whereby suppliers register compliant products with the regulatory authority. They provide a simple, practical tool for verification by persons who are not subject matter experts, such as customs officers. The registration process usually requires manufacturers to submit those test results on the products, and certify that the product performance meets the MEPS, and/or any labelling requirements, before the product can be placed on the market.

The data fields typically recorded in these databases for motors include manufacturer, brand name, rated kW and speed, nominal supply voltage and frequency, frame size and type of enclosure, standards followed, declared full load efficiency and power factor, and efficiency level as per IEC 60034-30-1. The data requirements should be kept simple, focusing on information relevant from a regulatory perspective. Thermally equivalent motors should not appear more than once, even if these have different electrical designs or starting performance.

The current US DOE template (available here.) ***can be used as an example.*** Registration fees should be kept at a reasonable level.

When governments set up product registration systems, they must do so via legislative and/or regulatory authority. Mandatory registration systems are in place for products with MEPS or energy labelling in Australia, Canada, China, India, New Zealand, Singapore and the US, among others. Information included in these registration systems can include energy performance data, technical product specifications, sales figures, and product prices. The registration systems are generally designed to meet the needs of many different stakeholder groups, as shown in Table 12.

In the US, each manufacturer must request a Compliance Certification number from the DOE and motors should be pre-validated before they can be introduced into the market. The manufacturers must either have the motors tested at a certified independent laboratory or calculate the motor's efficiency using a tool that has been qualified as an Alternative Efficiency Determination Method or AEDM.[68]

By contrast, in Europe, manufacturers place their motors on the market through a self-declaration process. In this system the manufacturer declares that the product is compliant to European Union directives by placing the CE mark on the motor. There is no requirement for advance registration or a qualification process.[69]

Although motor registration into a database is a valuable tool, the process should be simple. A cumbersome process can discourage some manufacturers and become a burden on market surveillance authorities as well.

Table 12: Product registry system users and their potential needs

STAKEHOLDER	POTENTIAL USER NEEDS
POLICYMAKERS	Provides a record of baseline data to support policymaking; expands the evidence database for market surveillance; serves as a storehouse of ancillary information and data about products on the market
MANUFACTURERS AND SUPPLIERS	Facilitates declaration of conformity with regulatory/voluntary requirements; provides information about innovation in product design (fostering competition and innovation); strengthens brand credibility; helps to ensure a level playing field
CONSUMERS	A database of product-specific information in the public domain; opportunity for advanced features through apps or other tools, doing product searches; enhances transparency of communication about product performance
DISTRIBUTORS	Retailers can verify products being supplied are registered and compliant with local laws
OTHER PLAYERS	Registry information can be used to determine product performance for market pull programmes incorporating financial incentives, subsidies and prizes.

For more information on product registry databases, ***see the recent UN Environment publication***.[70] In addition, the following are examples of mandatory product registry databases in Australia and the US:

- Australia–Equipment Energy Efficiency Appliance and Equipment Database, (click here for link to the databases)
- US DOE Compliance Certification Database, (click here for link to databases).

6.4.1 CERTIFICATION AND COMPLIANCE TESTING

Certification is the process of ensuring that a motor meets the claimed energy performance before it is placed in the market and can be done in one of three ways:

- **Self-declaration:** By testing in the manufacturer's own accredited test laboratory
- **Third-party certification:** By testing in an independent test laboratory
- **Calculation by an Alternative Energy Determination Method (AEDM) tool.**

The processes for certification of motors vary widely across the world as can be seen in Table 13. ***Given the widespread cross-border trade in motors either by themselves or as part of systems, the differences in requirements beyond efficiency (e.g. marking, certification, registration) and the high associated costs in small individual national markets, it makes great sense to share test results with trading partners or in a region.*** Examples of such co-operation agreements exist around the world with varying levels of formality.[71]

Table 13: MEPS Certification processes in different countries[72]

MEPS	PROCESS TO OBTAIN APPROVAL TO START SALES	TESTING	QUALITY ASSURANCE
AUSTRALIA	Registration with type test report to government web pages	Manufacturer lab	Manufacturer's quality system
BRAZIL	Manufacturer test lab approval, registration including technical documentation	Manufacturer lab once approved by INMETRO	Yearly follow up testing of manufacturer products
CANADA	Third party approval for test laboratory	Certified lab (manufacturer or a third party)	Quarterly audits of production units by a third party, yearly audit of manufacturer test lab
CHINA	Registration including test reports and technical documentation	Manufacturer lab	Audit by authorities every five years
EU	Self-certification, CE mark	Manufacturer lab	Manufacturer's quality system
JAPAN	Self-certification	Manufacturer lab	Annual reporting, Manufacturer's quality system
REPUBLIC OF KOREA	Registration incl. Type test reports	Korea Testing lab	Annual reporting, manufacturer's quality system
SAUDI ARABIA	Registration to Saudi Standards, Quality and Metrology Organization (SASO) web pages and third party certification of conformity	Manufacturer lab approved by SASO	Validity of registration up to 12 months
US	Third party approval for test laboratory, AEDM	Certified lab (manufacturer or a third party)	Manufacturer's quality system

The IE CEE Global Motor Energy Efficiency Programme (GMEE)[73] is a new initiative, which aims to create a regime under which a single test in an accredited test laboratory anywhere in the world will be recognised in any member country. GMEE will also harmonise the performance certification process across countries and regions.

The GMEE Operational Document (OD-2057) was approved by the management committee of IECEE in June 2015. It is expected that the GMEE programme will increasingly be adopted in the months and years ahead, thereby resulting in considerable simplification of the certification process for both developed and developing countries, cost reductions and elimination of a potential technical barrier to trade (see Figure 24).

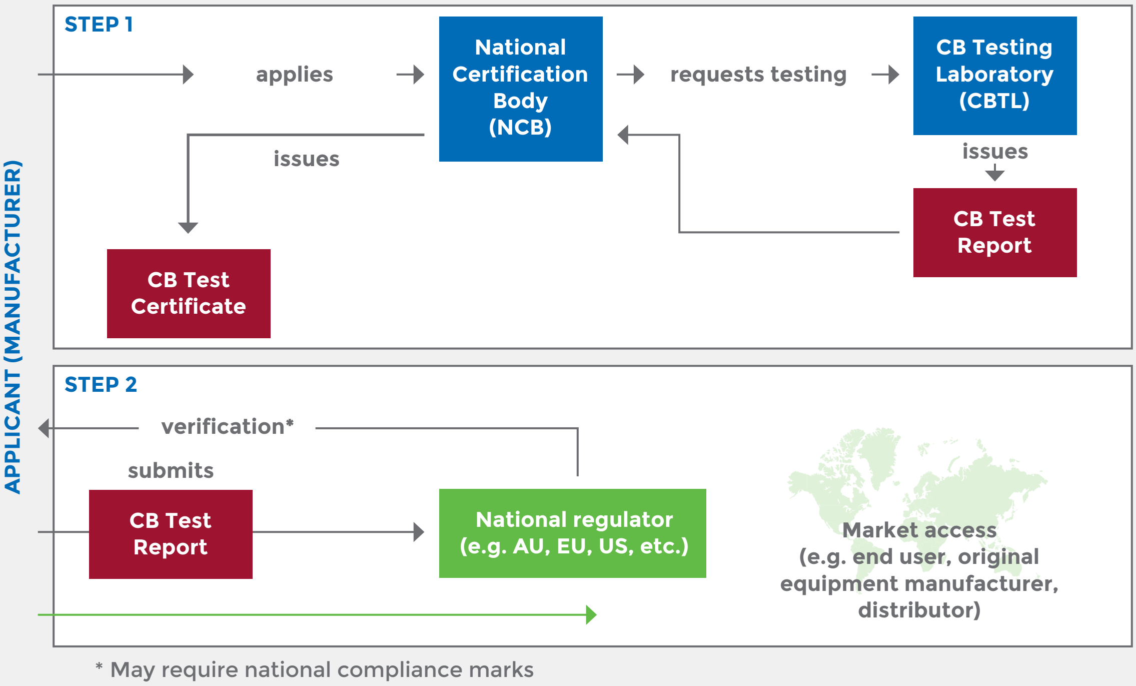


Figure 24: Process for obtaining national certification for a GMEE product[74]

Compliance testing is the process of making checks on motors that are already in the market against their claimed energy performance. Such testing can be carried out as a random check on representative samples (check testing), or in response to market intelligence on possible noncompliance, usually from competing manufacturers (challenge testing).

The compliance testing of motors faces a few challenges:

- The choice of motors for check-testing needs to be exercised carefully, as testing is expensive and the budget is limited. Different criteria are used: Is there market intelligence about likely compliance issues? Has there been a past record of failures? Do the motors have a high market share? Is the manufacturer a new entrant? Is the overall impact on energy consumption high (smaller motors are sold in higher volumes than larger motors)? Would the deterrence impact be higher for a given testing effort? Care must be taken that manufacturers are treated equitably.
- Determining whether a motor is covered by the regulation is not always easy. Where motors are required to be pre-registered, the number of variations should be kept low as each additional variation incurs testing costs, which are ultimately borne by the market, but not so low that there is inadequate differentiation. A regulation is usually worded rather tightly to be specific, but if the wording is too narrow, a minor tweak to the motor specifications can take it beyond regulatory scope. For

example, the regulation might specify a temperature range of -10 to +400C; however, to escape coverage, a motor nameplate could say -11 to +400C, although there may be no difference in design or construction between the two. The guiding principle is that thermally equivalent motors should be clubbed together, although there may be minor constructional differences. Another consideration is that this grouping needs to be aligned with customs codes for ease of application of the regulations to imports as well.

- Unlike consumer products, motors cannot be purchased anonymously from the retail market. While small commonly used motors can be procured through dealers and stockists, the larger and less common ones need to be procured directly from the manufacturer or importer with a delivery lead-time in weeks. Invariably the purpose of procurement can be inferred, and this gives rise to the possibility that the motor offered for testing may be a specially designed one.
- The decision on whether to test at an independent test laboratory or at the manufacturer's accredited test laboratory is an important one as the two-way transportation can be a major component of testing costs.
- Ensuring the compliance of motors imported as a part of systems is a serious but important challenge to address, given that 70 per cent of motors are purchased as a part of a system Firstly, the entire system would have to be purchased and the motor removed from it for testing – involving higher costs as well as logistics. Secondly, the motor may be fitted to the system and be difficult to separate. The motor may require special cooling to achieve the claimed performance. The motor may also carry the system manufacturer's nameplate, and not that of the motor manufacturer, making it difficult to correlate with test documents. Finally, it may be sourced from a country with less stringent standards.
- Testing based on information provided by competitors requires sensitive handling. On the one hand, such market intelligence is needed, but on the other hand, the compliance regime should not be allowed to be misused by manufacturers to hurt a competitor unfairly.

6.4.2 TEST LABORATORIES

The accurate and reliable measurement of the energy efficiency of motors as prescribed by IEC Standard 60034-2-1-1B described in section 3.6.2 above provides the foundation for a robust MVE system and the effective implementation of MEPS and labels. These measurements need to be carried out in laboratories that can be relied upon to deliver very high accuracy results consistently.

The certification of test laboratories is carried out by an accreditation body. As an example, the leading accreditation body for motor test laboratories in the US is the National Institute of Standards and Technology, and it operates the National Voluntary Laboratory Accreditation Programme (NVLAP). The programme has published a handbook[75] on the procedures, requirements and guidance for the accreditation of testing and calibration laboratories. In summary, it includes the following:

1. **Management Requirements**
   These cover quality systems including the organisation, document control, subcontracting and purchasing, customer servicing, complaint handling, dealing with non-conformances by way of corrective and preventive actions,

maintenance of records, internal audits and management reviews.

2. **Technical Requirements**
   These cover:
   - Personnel: their qualifications, experience, competencies
   - Periodic testing performance competency reviews
   - Training programme: on the job, formal classroom study, attendance at conferences, others
   - Testing area layout and environmental conditions
   - Laboratory test and calibration methods documentation and method validation
   - Estimation of measurement uncertainty
   - Testing equipment: documented periodic calibration and quality assurance
   - Test reports: how to be generated, data analysis, and storage.

As can be seen, the requirements are quite stringent and only a limited number of motor test laboratories can fulfill these on an on-going basis.

Although having a national laboratory can be a prestigious asset, these are expensive facilities to establish, commission, earn accreditation for, and maintain. There needs to be a certain minimum level of paid tests each year for a laboratory to be financially viable to retain experienced, qualified staff and maintain quality standards.

Unless manufacturers and testing agencies can utilise the laboratory capacity optimally, the facilities will fall into disuse. Thus, ***for countries with smaller motor markets, it may make sense to look at outsourcing their laboratory test needs to neighbouring countries or other entities until their market grows, and they are able to justify direct investment in a domestic facility.*** For example, the 28 member states of the EU are individually responsible for MVE, but the compliance testing is done in only a handful of laboratories and shared. Such shared testing can form part of a harmonised MEPS for motors within geographic regions, which reduces the cost of MEPS implementation, verification and enforcement.

6.5 PROACTIVE COMMUNICATIONS

Communication is a critical element of any successful MVE scheme. Manufacturers are kept aware of their legal obligations, and the consequences of noncompliance, thus gaining their respect and improving compliance rates. Consumers are given confidence that motor efficiencies are indeed as these are claimed to be by manufacturers. Highlighting specific examples of enforcement actions in response to noncompliance can also be a powerful deterrent to others.

Governments should develop a dedicated module for MVE within the broader communications plan that is fine-tuned for all main stakeholders in the supply chain. It should address compliance requirements, the risk of detection and sanctions, any corrective action taken, and so on. Governments may choose to list the number and frequency of surveys and tests, identify plans for future compliance work and publish information about their work. Governments may also consider publicising ("naming and shaming") products and brands that are non-compliant.

Training and guidance can also help improve compliance. For example, governments can offer courses that explain the regulatory requirements, maintain a regulatory hotline or email service to answer questions, and post frequently asked questions and guidance on reporting and documentation requirements on a website. These approaches help to minimise the costs of compliance and thereby help with overall success.

CASE STUDY: Communications Outreach to Inform Suppliers, Sweden

The Swedish Energy Agency has recognised that one of the best ways to strengthen their MVE programme is through proactive communication with manufacturers and importers in Sweden. The Agency organises information sessions and webinars, prepares leaflets and postal campaigns, advertises in trade magazines, provides software tools, and operates a hotline to ensure that it is complete and transparent in providing information about any new regulations.

By conducting proactive communications, Sweden helps to ensure all the stakeholders are informed about the requirements and the programme they operate around MVE, thus serving as a deterrent to any companies who may be considering not being compliant.

For more information click here.

6.6 MARKET MONITORING

One of the most critical functions of a government market surveillance authority is to conduct regular, on-going monitoring of the market to ensure that the motors being supplied are compliant with regulations. The aim is to identify potential cases of noncompliance for verification testing and use the monitoring results as a first step for engagement with industry to reach compliance.

Market monitoring can be carried out in different ways:

- By checking documentation furnished to registry systems
- By customs authorities confirming all required documentation is provided
- By checking in dealerships whether motor nameplates meet the IEC norms
- By scanning manufacturers' websites for energy efficiency information
- By providing a hotline for user and competitor complaints
- By monitoring results shared by other economies.

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6.7 REGULATORY ENFORCEMENT

Enforcement should be visible, and sanctions should be certain to deter non-compliance.

When addressing cases of non-compliance, it is recommended that enforcement authorities carefully consider the degree of non-compliance to respond with a proportionate enforcement action. The available enforcement actions should be flexible. The penalties and powers of the enforcement authority should be set out in law. The powers and actions should be further outlined in administrative procedures or operational guidelines.

Many enforcement authorities develop an "Enforcement Pyramid" to inform and manage their enforcement response strategies (see Figure 25). A pyramid of sanctions ensures speed and proportionality, and keeps costs low. The pyramid can be populated to be most effective for the national enforcement strategy, in accordance with the legal requirements and resources available to the enforcement authority, and the characteristics of the programme and its participants and stakeholders.

The bottom of the pyramid typically features more informal actions, while the top of the pyramid should reflect the most severe enforcement response to non-compliance e.g. notices, fines, delisting, and naming and shaming. Legal enforcement can be expensive and should be a last resort. The guiding criterion should be that the cost of sanctions should outweigh the potential benefits of non-compliance to the manufacturer.

In practise, motor manufacturers prefer a quiet, speedy resolution. They respond constructively as they fear the loss of reputation the most, followed by the loss of market share that would follow the withdrawal of a group of motors from the market. A proactive communication strategy is critical to the success of an enforcement regime.

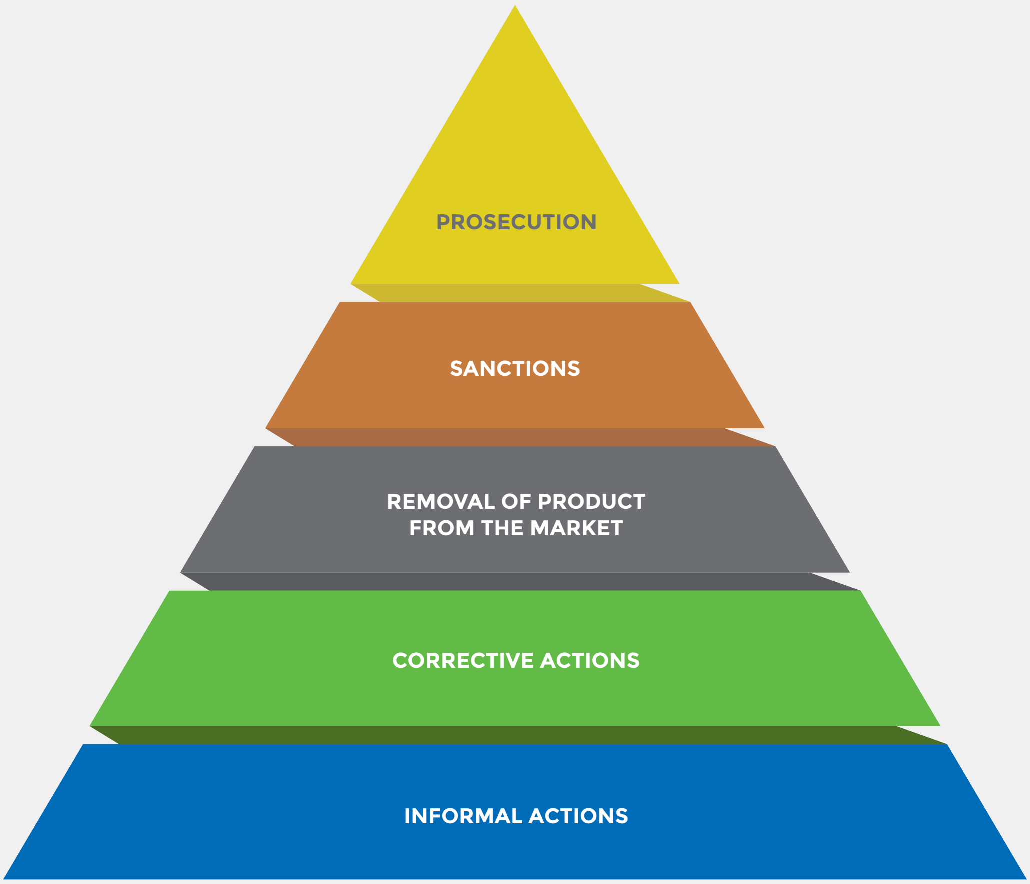

Figure 25: Pyramid of escalating enforcement[74]

Wide variations are possible in the efficiency levels of identical motors due to small variations in the manufacturing process, materials, and testing uncertainties. Therefore, IEC 60034-1 allows a 15 per cent tolerance on the measured efficiency (10 per cent above 150 kW), and the US Rule allows 20 per cent.

Wide variations are possible in the efficiency levels of identical motors due to small variations in the manufacturing process, materials, and testing uncertainties. Therefore, IEC 60034-1 allows a 15 per cent tolerance on the measured efficiency (10 per cent above 150 kW), and the US Rule allows 20 per cent. In practise, it is statistically possible for a single motor to exceed this tolerance even if the manufactured lot is within the range. As a result, retesting of motors on a sample of three to five motors is allowed in different enforcement regimes, with the manufacturer asked to bear the cost.

For more information on effective enforcement schemes, please see a recent UN Environment report[76] that serves as a practical resource to policymakers on the steps to follow when implementing a national enforcement programme. This report covers (a) legal and administrative foundation for enforcement; (b) enforcement budget and activity planning; (c) identifying types of noncompliance; and (d) communicating to stakeholders.

CASE STUDY: Market Surveillance and Enforcement, Turkey

During the first phase (2015), samples of 12 motor types from 7 different manufacturers (domestic and foreign) were tested independently. The products of three manufacturers failed to meet the MEPS. Warnings were issued but there was no penalty.

In the second phase (2016), samples of 15 motor types from 10 manufacturers were tested and 53 motors failed. The sales of 389 motor types from the 3 manufacturers involved have been prohibited as a consequence.

For more information click here.[77]

7. ENVIRONMENTALLY SOUND MANAGEMENT

WHAT?	This chapter provides a summary of the recycling of old low-voltage induction motors at the end of life, the processes of collection and recycling, and the financing mechanisms. It also provides an overview of the potential health risks associated with low-voltage motor production and usage.
WHY?	Low-voltage induction motors largely contain metals, rubber and plastics that can be recycled/recovered/reused, as well as small quantities of materials that could be hazardous if simply dumped in a landfill. By ensuring necessary norms and regulations, a “circular economy” objective can be achieved.
NEXT?	Some key questions to keep in mind: • How effectively does the collection of old motors take place in our country? • Are regulations for the recycling of metals in place? • Are regulations for the safe handling of hazardous materials in place? • Are norms for safeguarding health and safety in industry in place?

Environmentally sound management incorporates the concept of a product’s full life cycle, from raw materials used in manufacturing through to end-of-life recovery and recycling. This approach gives regulators a suitable framework to analyse and manage the performance of goods and services in terms of their impact on the environment.

When life cycle management principles are applied to electric motors, the assessment usually concentrates on the following three stages of a product's lifecycle:

- **Production:** focuses on the raw materials and production techniques involved in manufacturing the product, including hazardous substances and the risks these may pose to the health and safety of workers. This covers the techniques used for repairs that may be carried out during a motors' lifetime as well.
- **Usage:** focuses on the environmental impact of electric motors during the use phase (i.e. from indirect power plant related emissions).
- **End-of-Life:** focuses on the end-of-life management of electric motors, highlighting examples of best practices in establishing, managing and financing end-of-life collection, recycling and environmentally sound management, and final disposal.

Optimisation across these stages requires minimising the environmental impacts occurring during each stage. The phase-out of inefficient motors is an effective intervention from a "use" point of view. It can offer a significant reduction in energy consumption and, therefore, prevention of climate change through avoided CO_2 emissions from fossil-fuel power stations. Among all aspects of a motor's lifecycle, reducing energy consumption during its operation is by far the most significant and positive change to be made.

The implementation of environmentally sound management requires the following elements be considered:

1. policy and legal framework
2. collection schemes and related awareness raising activities
3. transportation, storage and recycling programmes; and
4. financial mechanisms to cover the running costs.

The average material content used in the manufacturing of induction motors[78] is depicted in Table 14.

Table 14: Average material content used in the manufacturing of induction motors[79]

	CAST IRON FRAME MOTORS (%)	STEEL FRAME MOTORS (%)
CAST IRON	35-45	5-15
STEEL	46-55	70-80
ALUMINUM	1-3	1-3
COPPER	7-11	7-11
PLASTIC, RUBBER, INSULATION MATERIALS, ETC.	Less than 1	Less than 1
STAINLESS STEEL	Less than 1	Less than 1
BRASS	Less than 1	Less than 1
OTHER	Less than 1	Less than 1

At the end of life of an induction motor, the cast iron, steel, aluminium, copper, stainless steel and brass parts, which constitute more than 98 per cent of the material content, are fully recyclable.

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The recycling of metals not only conserves valuable natural resources, but also requires less energy than extracting the respective metal from its ore.

Apart from metals, an electric motor uses a small quantity of rubber and plastic for the fan and terminal board, which are recyclable as well. The electronic printed circuit boards, electrolytic capacitors and semiconductor devices used in variable speed drives should be handled in accordance with regulations covering e-waste.[80]

7.1 POLICY AND LEGAL FRAMEWORK

In most countries, overarching national environmental regulations define the legal framework applicable to the motors industry. The ISO 14001 international environmental management standard provides the basis for the creation of environmental management systems by producers and recyclers of motors. The cornerstone of this standard is a commitment to the systematic and continual improvement of environmental performance through:

- Reduced use of energy and materials
- Safe management of chemicals, reduced use of solvents, phasing out of hazardous substances
- Minimisation of waste on the principles of 'reduce, reuse and recycle'.

Any local regulations covering metals' recycling would apply to the metals collected from motors as well. Similarly, the lubricating grease from the bearings is a hazardous waste and should be handled according to local regulations for the safe disposal of petroleum products.

7.2 COLLECTION SCHEMES

The purchase of old motors and their onward sale by scrap dealers take place at prices linked to the current prices on the London Metal Exchange. The margins earned in this process are adequate to cover the effort of collecting the smallest motors, thus ensuring a high degree of collection.[81]

7.3 RECYCLING PROGRAMMES

The old motors collected by scrap dealers are resold to scrap-processing units, where these are disassembled. The respective metals are segregated and pre-processed by a combination of manual, mechanical, chemical and pyro- and hydro-metallurgical processes. Afterward, the metal scrap is delivered as raw material to metal producers.

Lubricating grease from the bearings is a hazardous waste and is handled according to local regulations for the safe disposal of petroleum products.

Insulation material can be disposed of in normal landfills.

CASE STUDY: Shar Metal, a Typical Global Scrap and Metal Recycling Company

Shar Metal is a typical scrap and metal recycling company operating across several countries. It receives a wide variety of metal and plastic bearing scrap products, including motors and motor system components from all over the world, and disassembles and dismantles these in large collection and processing warehouses according to the content–copper, brass and copper alloys, aluminium, lead, zinc, stainless steel, iron and plastics. After processing, the scrap metals and plastics are supplied to the respective producers as input raw material.

For more information click here.

7.4 FINANCING ENVIRONMENTALLY SUSTAINABLE MANAGEMENT

Recycled materials supply more than 40 per cent of the global raw material needs.[82] Recycling is a $200 billion global industry, with more than 800 companies employing more than 1.6 million people in over 70 countries.

The industry's focus is on all sources of ferrous and nonferrous metals, plastics, rubber, paper and e-waste among others and is therefore much larger in scope than motors alone. The individual businesses in the recycling industry are operated and financed as self-sustaining commercial entities, without reliance on any form of public finance.

The intrinsic value of the metals used in induction motors, particularly copper as well as that of other trace elements carried by it and recoverable during copper recycling (such as platinum, palladium, gold, silver, arsenic, selenium, tellurium, nickel, cobalt, tin, zinc), ensures that these are invariably sold at the end of life to a recycler, and are not disposed of in a landfill. The recycler recovers the cost of collection, transportation and processing through the sale of the reprocessed metals and other materials as raw materials to the respective production chain at a profit.

The environmentally sustainable management of motors at end of life is driven by the profit motive of the recycling industry and is thus self-financing.

7.5 HEALTH

This section presents an overview of the potential health risks associated with low-voltage motor production and usage. Most of these risks are not unique to motors but are common with general manufacturing and the operation of heavy machinery.

The handling of objects in production with, for example, trucks and lifting equipment requires appropriate safe distances, handling, and lifting instructions to avoid safety hazards.

During the production of electric motors, potentially hazardous chemicals are used in the rotor assembly, stator impregnation, rotor die-casting and surface treatment of parts and assembled motors. Workers are exposed to the risk of touching chemicals, inhaling vapours or dust, and the risk of high heat from melted aluminium. Induction heaters used in the production for local heating of objects may impose a risk through electromagnetic radiation. Testing of motors involves potentially dangerous levels of voltage and current.

Documented risk assessments are recommended to ensure workplace health and safety of critical work phases– the scope and depth depends very much on the requirements of local health and safety authorities and applicable health and safety legislation.

In general, the intent is to classify and rank risks by probability of occurrence and degree of hazard (e.g. using a scale from 1 to 3). The multiplication of probability and degree of hazard results in the risk severity from minimal to unbearable and helps to define the necessary mitigating actions, for example:

- Using protective clothing or eyewear
- Hearing protection
- Local removal of potentially hazardous vapours, gases or dust, required ventilation to do so
- Specific work instructions for safe operation and ergonomic work methods
- Regular health inspections to track and identify symptoms and levels of exposure that might be related to identified risks.

The repair of motors includes some of the same work as new production, so similar precautions are needed.

In the use of motors, the risks are similar to any operation of heavy machinery.

8. PROGRAMME PREPARATION, DESIGN AND IMPLEMENTATION

To support governments in promoting energy efficiency and removing obsolete products, and transforming markets to energy-efficient motors, U4E has developed a step-by-step guide called "Policy Fundamentals Guide". This guide offers an overview of the key elements required to transform a national appliance and equipment market towards more energy-efficient products through the application of the U4E Integrated Policy Approach.

The Guide is crosscutting for all U4E priority products, including lighting, residential refrigerators, air conditioners, transformers and electric motors. The approach can also be expanded to other energy-consuming products.

By following the approach outlined in the Guide, national governments and regional institutions can develop a clear vision and policy goals, identify specific objectives, and determine the required processes (such as identifying resource requirements and responsibilities and tracking performance to ensure transparency). By establishing a systematic plan, regions and countries ensure that the approach adopted is coherent and will save time, effort and resources.

The actual components in the strategy may vary per each country's situation and needs. The guidance should be adapted to meet the local context and needs.

The process should be led by governments or regional institutions with methodological support, guidance and technical advice from U4E (and/or other) experts. It should involve all relevant stakeholders to determine priorities jointly, and the most appropriate pathways to achieve them.

The following is a brief overview of the "Policy Fundamentals Guide":

Chapter 1
Introduction – provides an overview of the benefits of energy-efficient products and the U4E Integrated Policy Approach.

Chapter 2
How to Prepare for Programme Implementation – introduces the organising bodies and overarching legislative and legal frameworks that need to be in place to operate an effective programme. It provides guidance on the resources required for implementing a programme and strategies for securing those resources. It also provides information on collecting data and prioritising products for inclusion in a programme.

Chapter 3
How to Design and Implement Market Transformation Programmes – provides the basic steps to follow when designing and implementing market transformation policies—including market assessment, barrier analysis, regulations, standards, labels, awareness campaigns, and awards and recognition programmes. It provides case studies of effective implementation in countries across the world and recommendations for developing regional initiatives.

Chapter 4
How to Make Efficient Products Affordable – addresses the critical issue of overcoming first-cost barriers to market adoption, including topics such as financing sources, approaches and stakeholders. Topics covered include energy service companies, financing programmes, bulk procurement schemes, and electric utility programmes. This section also describes how countries with subsidised electricity tariffs can use innovative schemes to drive efficiency.

Chapter 5
How to Establish and Improve Compliance Programmes – discusses the importance of monitoring, verification, and enforcement (MVE) schemes from both a manufacturer's and a consumer's perspective. It also discusses the critical role of government in establishing and maintaining a robust market surveillance programme.

Chapter 6
Environmentally Sound Management – provides a summary of the importance of safe and sustainable recycling and disposal programmes. It also touches on the development of health and safety standards for products, particularly those with toxic or harmful components.

Chapter 7
How to Measure Success and Improve Programmes – describes the key components of an evaluation framework to measure the results from market transformation programmes and then use those results to improve programmes.

Chapter 8
Resources – presents reports and resources from energy-efficient appliance, equipment, and lighting programmes and experts around the world.

Prepare for Market Transformation Programme
U4E Fundamental Policy Guide - Chapter 2
- Consider regional cooperation
- Organise government bodies and key stakeholders
- Put overarching legislative and legal frameworks in place
- Identify and secure resources needed for implementation
- Collect data and prioritize products
- Agreement to the national efficient product strategy

Design and Implement U4E Integrated Policy Approach
- Select or develop test standards regulations (U4E Fundamental Policy Guide - Chapter 3)
- Develop Minimum Energy Performance Standards (Chapter 3)
- Develop supporting policies including labels, communications and public awareness campaigns (Chapter 3)
- Develop financing programmes to address first-cost barriers (Chapter 4)
- Develop or enhance monitoring, verification and enforcement capacities (Chapter 5)
- Consider a product's impact at each stage of its life-cycle when designing policies (Chapter 6)

Measure Success and Improve Programmes
U4E Fundamental Policy Guide - Chapter 7
- Plan the evaluation and set objectives
- Identify resources needs and collect data
- Apply evaluation findings to improve policies and processes

9. RESOURCES

The following resources are available to support countries and regions in the development of energy-efficient motors and motor systems activities and strategies:

- **American Council for an Energy-Efficient Economy (ACEEE)** –a nonprofit, 501(c)(3) organisation, acts as a catalyst to advance energy efficiency policies, programmes, technologies, investments, and behaviours. Focusing on the US, ACEEE seeks to harness the full potential of energy efficiency to achieve greater economic prosperity, energy security, and environmental protection. ACEEE carries out its mission by: (1) conducting in-depth technical and policy analyses; (2) advising policymakers and programme managers; (3) working collaboratively with businesses, government officials, public interest groups, and other organisations; (4) convening conferences and workshops, primarily for energy efficiency professionals; (5) assisting and encouraging traditional and new media to cover energy efficiency policy and technology issues; and (6) educating consumers and businesses through our reports, books, conference proceedings, press activities, and websites. ACEEE was founded in 1980 by leading researchers in the energy field. Since then it has grown to a staff of about 50. ACEEE focuses on energy policy (federal, state, and local), research (including programmes on buildings and equipment, utilities, industry, agriculture, transportation, behaviour, economic analysis, and international initiatives.

- **European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP)** – the members of CEMEP are the National Associations in Europe, representing manufacturers of electric motors, variable speed drives and uninterruptible power supplies. The organisation allows industry to co-ordinate actions at the European level. Its Industry Group Low-Voltage A.C. Motors aims to support fair competition in the field of LV Motors in Europe through innovation and advanced technology in conjunction with technical expertise and practical policymaking assistance to relevant EU authorities. CEMEP publishes leaflets and position papers on energy efficiency in motor systems.

- **CLASP** – a nonprofit international organisation promoting for energy efficiency standards and labels (S&L) for appliances, lighting, and equipment. CLASP improves the environmental and energy performance of the appliances and related systems, lessening their impacts on people and the world around us.

CLASP develops and shares practical and transformative policy and market solutions in collaboration with global experts and local stakeholders. Since 1999, CLASP has worked in over 50 countries on six continents pursuing every aspect of appliance energy efficiency, from helping structure new policies to evaluating existing programmes.

- **The Climate Group** – an award-winning, international nonprofit with offices in Greater China, North America, India and Europe. Its goal is to help leaders transition to a prosperous low-carbon economy, driven by the rapid scale-up of clean and renewable energy. It works in partnership with the world's most influential business, state, regional, finance and civil society leaders. For over a decade it has worked to demonstrate the economic and business case for the low-carbon economy and create the political conditions necessary for a strong global framework that addresses climate risks and maximizes climate opportunities. The global climate deal that has been struck at the Paris COP represents a new beginning: the chance to accelerate our low-carbon future. The Climate Group works with governments, businesses and investors to implement the Paris Agreement, holding them to account where appropriate through reporting mechanisms, and ensuring to bend the emissions curve downward to secure a thriving, clean economy for all.

- **EASA** – an international trade organisation of nearly 1,800 electromechanical sales and service firms in 63 countries. Through its many engineering and educational programmes, EASA provides members with a means of keeping up to date on materials, equipment, and state-of-the art technology. EASA also provides engineering consulting services to members and works with manufacturers, industry organisations and government agencies to promote better repair standards. It also sponsors numerous training and educational programmes. EASA has developed an international accreditation programme for service centres based on the standard ANSI/EASA AR 100: Recommended Practice for the Repair of Rotating Electrical Apparatus.

- **European Commission Joint Research Centre (EC JRC)** –the European Commission's science and knowledge service employs scientists to conduct research and provide independent advice and support to EU policy. It conducts a biennial international conference on energy efficiency in motor system Energy Efficiency in Motor-Driven Systems (EEMODS) in odd years, bringing together policymakers and energy efficiency experts from industry, research labs, universities and standardisation organisations to discuss the progress of electric motor systems energy efficiency policies and technologies.

- **European Council for an Energy-Efficient Economy (ECEE)** – a membership-based nonprofit association. As Europe's largest and oldest NGO dedicated to energy efficiency, they generate and provide evidence-based knowledge and analysis of policies, and they facilitate co-operation and networking. ECEEE members are found among private and public organisations, as well as among all those professionals from all sectors who share ECEEE's goals. ECEEE offers governments, industry, research institutes and citizen organisations a unique resource of evidence based knowledge and reliable information. ECEEE promotes the understanding and application of energy efficiency in society and assists its target groups–from policymakers to programme designers to practitioners–with making energy efficiency happen. ECEEE is registered as a Swedish organisation and has its secretariat in Stockholm. ECEEE participates actively in the European policymaking process, the organisation participates in a number of EU policymaking and advisory fora, and frequently comments on European energy policy through position papers and responses to public consultations. ECEEE has also held expert workshops and briefings for policymakers.

  It has co-operated with the European Commission, the Parliament and the EU presidency, to hold expert seminars. These institutions appreciate the competence and integrity offered by ECEEE's network of members.

- **IEA** –an autonomous organisation that works to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA's four main areas of focus are: energy security, economic development, environmental awareness, and engagement worldwide. Founded in response to the 1973/4 oil crisis, the IEA's initial role was to help countries coordinate a collective response to major disruptions in oil supply through the release of emergency oil stocks. The IEA has a staff of 260 enthusiastic professionals (energy analysts, modellers, data managers/ statisticians, technicians, secretaries and support staff) working together on global energy challenges.
- **IEC** –an intergovernmental standards organisation of 82 member countries and 82 affiliate countries based in Geneva. IEC creates and publishes international standards related to electrical equipment. IEC standards provide the foundation for international harmonisation of electric motor energy efficiency classification and testing standards. IEC Standards have been referenced extensively throughout this Policy Guide.
- **4E EMSA**– an IEA Technology Co-operation programme supported by six IEA member countries. 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. EMSA has published several reports related to motor systems since 2009. EMSA conducts a biennial conference on energy efficiency in motor systems, the 'Motor Summit', in even years.
- **IEC Conformity Assessment Association (IECEE)** – the Association uses IEC Standards and members reciprocally to recognise conformity certificates. IECEE comprises 57 member countries, nearly 80 participating National Certification Bodies and close to 500 Testing Laboratories. The IECEE Certification Body scheme aims for "one product, one test, one certificate." The IECEE Global Motor Energy Efficiency Programme initiative aims to create a regime under which a single test in an accredited test laboratory anywhere in the world will be recognised in any member country.
- **IIP** – a not-for-profit organisation funded by the Climate-Works Foundation to promote the efficient use of energy in industry. IIP maintains global databases on Industrial Efficiency Policies, Programmes, Financing and Technology. IIP has a country focus on China, India and the US.
- **ICA** – a not-for-profit organisation of the global copper industry, with the mandate to promote the sustainable use of copper. ICA has conducted regional and national programmes for the promotion of electric motor energy efficiency through policies, standards and regulations in developed and developing countries since 1994. It has been a leading participant in international efforts and actions for the advancement of the cause of energy efficiency and climate change mitigation. Among its various initiatives, ICA sponsors and administers Leonardo Energy, a dedicated portal for sustainable energy professionals. Leonardo Academy hosts several free on-line training programmes including on energy-efficient motors and motor systems suitable for self-learning at the trainee's own pace and convenience. The training material comprises a video recording, presentation slides and a short learning test.

- **IEE** – the UNIDO IEE programme builds on more than three decades of experience and unique expertise in the field of sustainable industrial development. Combining the provision of policy development assistance and training for all market players, UNIDO IEE aims at removing the key barriers to continuous improvement of energy efficiency in industries. The programme hinges on two core concepts: energy system optimisation and energy management standards.

- **LBNL** – a member of the US laboratory system supported by the US DOE. It is managed by the University of California and conducts research across a wide range of scientific disciplines. The Energy Analysis and Environmental Impacts Division, International Energy Studies Group at LBNL performs economic, engineering, and environmental analyses in support of efficiency standards and regulations development internationally, including for electric motors.

- **National Electrical Manufacturers Association (NEMA)** – the Association has, in addition to its other activities, been at the forefront of efforts to transform motors markets in the US as well as internationally to the highest efficiency levels. NEMA publishes over 600 standards, application guides, white papers and technical papers.

- **National Institute of Standards and Technology (NIST)** – a physical US-based science laboratory supported by the US Department of Commerce with a focus on measurement infrastructure. The National Voluntary Laboratory Accreditation Programme (NVLAP) provides third-party accreditation to testing and calibration laboratories based on ISO/IEC 17025:2005, including for the energy efficiency testing of motors. Outside of the US, NVLAP has accredited test laboratories in China, Mexico, Taiwan and Vietnam.

- **SEAD Initiative** – an initiative of the Clean Energy Ministerial, SEAD seeks to engage governments and the private sector to transform the global market for energy efficient equipment and appliances. SEAD initiated an international collaboration of technical and policy experts in solid-state lighting, which worked to promote alignment and improvements in the scope and stringency of international standards and labeling programmes. Current SEAD member governments include Australia, Brazil, Canada, the European Commission, Germany, India, Indonesia, Mexico, Russia, Saudi Arabia, South Africa, Sweden, Republic of Korea, United Arab Emirates, UK; and China and the US maintain an observer status.

ANNEX A. GLOSSARY

Compliance: conforming to a rule, such as a law, policy, specification or standard. Also, fulfilment by countries/businesses/ individuals of emission reduction and reporting commitments under the UNFCCC and the Kyoto Protocol. (UNFCCC)

Conformité Européenne Marking (CE Marking): states that a product is assessed before being placed on the market and meets EU safety, health and environmental protection requirements. Used in the European Economic Area (EEA), consisting of the 28 EU Member States, and the European Free Trade Association (EFTA) countries i.e. Iceland, Liechtenstein and Norway. Per decision No 768/2008/ EC of the European Parliament and of the Council of 9 July 2008 on a common framework for the marketing of products, and repealing Council Decision 93/465/EEC.

Cooling: a procedure by means of which heat resulting from losses occurring in a motor is given up to a primary coolant, which may be continuously replaced or may itself be cooled by a secondary coolant in a heat exchanger.

Direct Efficiency Determination: method by which the determination of efficiency is made by measuring directly the input power and the output power.

Duty: the statement of the load(s) to which the 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 generally load and speed vary within the permissible operating range. Duty type S1 – Continuous-running duty: Operation at a constant load maintained for sufficient time to allow the motor to reach thermal equilibrium.

Full Load: the load that causes a motor to operate at its rating.

Full Load Value: a quantity value for a motor operating at full power, torque, current or speed.

Greenhouse Gases (GHGs): The atmospheric gases responsible for causing global warming and climate change. The major GHGs are carbon dioxide (CO_2), methane (CH4) and nitrous oxide (N20). Less prevalent but very powerful GHGs are: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6). (UNFCCC)

Indirect Efficiency Determination: method by which the determination of efficiency is made by measuring the input power or the output power and determining the total losses. Those losses are added to the output power, thus giving the input power, or subtracted from the input power, thus giving the output power.

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.

Minimum Energy Performance Standard (MEPS): a mandatory minimum performance level that applies to all products sold in a market, whether imported or manufactured domestically.

Motor Driven Unit (or motor-driven unit, p.9) consists of the core components: motor, controls, transmission and application (like a pump, fan or compressor).

Motor System: the electric motor system (see Figure 2) includes equipment for supplying power, starting the motor and varying its speed, mechanically transmitting its motion to drive equipment (e.g. pumps, fans, compressors, production machines), and additional controls and subsequent equipment or process components like ducting etc.

Power Factor: the ratio of ‘active’ or ‘real’ power (i.e. useful power) to ‘apparent’ power drawn by a motor from the mains.

Rated Output: the value of the output included in the rating.

Rated Value: a quantity value assigned, generally by a manufacturer, for a specified operating condition of a motor. NOTE The rated voltage or voltage range is the rated voltage or voltage range between lines at the terminals.

Rating: the set of rated values and operating conditions.

Registration Verification: process of confirming that registered products meet the requirements of a programme’s entry conditions.

Routine Test: a test to which each individual motor is subjected during or after manufacture to ascertain whether it complies with certain criteria.

Self-certification: practice of submitting information about one’s product in a formal statement rather than being obliged to ask a third party to do so.

Single-speed Motor: motor rated for 50 Hz and/or 60 Hz on-line operation.

SI Unit: any of the units adopted for international use under the Système International d’Unités.

Tolerance: the permitted deviation between the declared value of a quantity and the measured value.

Type Test: a test of one or more motors made to a certain design to show that the design meets certain specifications.

ANNEX B. ELECTRIC MOTOR BASICS

Motion from Electricity

An electric motor is a device for converting electrical energy into mechanical energy, i.e. motion.

The two main components of a motor are a stationery assembly of electromagnetic coils arranged around a cylindrical axis, called the stator winding, and a moving mechanical shaft called the rotor, which is free to rotate concentrically within the stator. The rotor is mounted on bearings at both ends of a sturdy cast-iron or steel housing, which is firmly attached to a terrestrial surface. In the case of an induction motor, the rotor is equipped with a second assembly of electromagnetic coils, fabricated copper bars, or more commonly, aluminum bars in the form of a squirrel cage.

A set of electric currents is passed through the stator electromagnetic coils to set up a primary magnetic field, which rotates in space around its axis although the coils themselves do not move. The speed of rotation is proportional to the frequency of the electric supply. The relative movement of this primary magnetic field across the rotor coils or cage causes a current to flow in these by the principle of electromagnetic induction, giving this type of motor its name. This rotor current in turn sets up a secondary magnetic field around the rotor. The primary magnetic field pulls the secondary magnetic field, and thus the rotor assembly along with it, as it rotates in space around its axis. In turn, the rotor drives the equipment attached to its shaft thus completing the conversion from electricity to motion.

Attributes of Motors

Motors have the following attributes:

Power Supply

- The electric supply can be either direct current (DC) or alternating current (AC).
- The AC supply can be either single-phase (1-ph) or three-phase (3-ph).
- The frequency of the AC supply can either be 50 Hz or 60 Hz.
- The voltage level could be low, below 1,000 volts (LV), medium (MV), or high, above 6,600 volts (HV).

All the motors covered by this policy guide are fed by a 3-phase AC LV supply, 50 Hz or 60 Hz.

Power

Power is measured in watts (W), kilowatts (kW), or mega-watts (MW). Motors are classified according to the mechanical power these deliver at the motor shaft at rated speed into Micro (<0.12 kW), Small (0.12-0.75 kW), Medium (0.75-375 kW) and Large (>375 kW).

Speed

The synchronous speed of a motor in revolutions per minute (RPM) is proportional to the supply frequency and inversely proportional to the number of magnetic poles[83] of the motor according to this formula:

Table 15: Typical synchronous speeds of motors

SYNCHRONOUS SPEED (RPM) = 120*SUPPLY FREQUENCY				
NUMBER OF POLES	2	4	6	8
SYNCHRONOUS SPEED IN RPM AT 50 HZ SUPPLY	3,000	1,500	1,000	750
SYNCHRONOUS SPEED IN RPM AT 60 HZ SUPPLY	3,600	1,800	1,200	900

The most commonly used pole configuration is 4-poles.

For induction motors, the rated speeds are slightly lower than the synchronous speeds. These are also alternatively known as **asynchronous motors**.

Torque

The rated power (kW) and rated speed (RPM) of a motor together determine the rated torque (in Newton-meters or N-m) that the motor delivers at its shaft by the relationship

$$\text{Rated Torque (N-m)} = 9{,}550 \times \frac{\text{Rated Power (kW)}}{\text{Rated speed (RPM)}}$$

Physical Size

In order to ensure mechanical interchangeability, the mounting dimensions and shaft height of a standard motor from its base measured in mm must conform to a standard set by IEC for both 50 Hz and 60 Hz motors (called IEC frame sizes) or by NEMA for 60 Hz motors (called NEMA frame sizes). A typical IEC frame size series is 100,112,132,160 and so on. This constraint on diameter indirectly determines the length of the motor for a given type/design/kW/pole combination as well. This is reflected in the standardised designation by the letters S (short), M (Medium), L (Large) following the frame size number (e.g. 100L, 112S, 132M).

Induction Motors

Figure 26 is a sketch showing the different components of a motor. In addition to the stator and rotor as described above, it shows different parts of the enclosure, bearings and an axial fan mounted on the rotor shaft to evacuate heat produced during the motor operation through forced convection. Figure 27 shows the same details as seen physically.

Figure 26: Assembly diagramme of an induction motor[84]

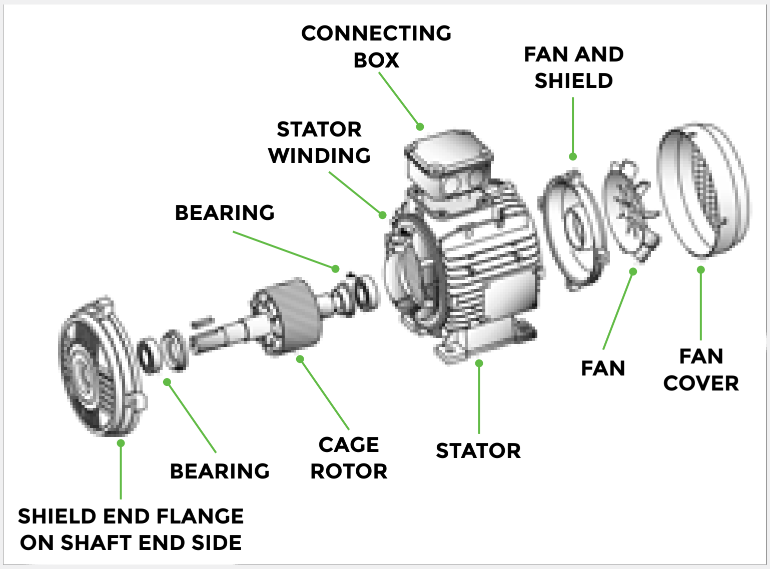
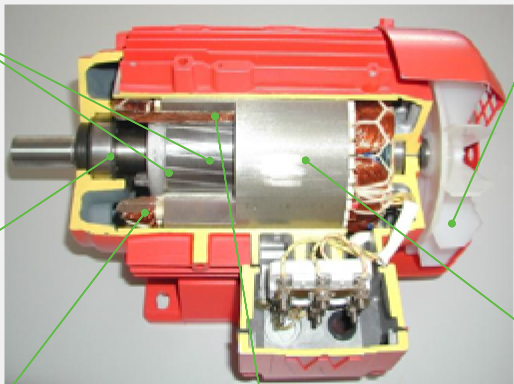


Figure 27: Cutaway picture of an induction motor[85]



Other Motor Types

A **synchronous motor** is so named because its speed is exactly proportional to the frequency of the 3-Ph AC supply. Unlike in the induction motor, the secondary magnetic field is independent of the primary magnetic field and is produced either from a separate DC supply or by a **permanent magnet**. The latter is also known as a permanent magnet synchronous motor. Unlike induction motors, synchronous motors cannot start directly when connected to a supply. These require either an electronic controller or an additional winding like an induction motor rotor for starting (the latter is called a line start permanent magnet).

A **switched reluctance motor** has only one magnetic field, created by the stator winding. The rotor is constructed of a ferromagnetic material and is shaped in such a way that its position within the stator magnetic field is always unstable except in one position (the point of least reluctance). When the stator magnetic field rotates, the rotor moves along with it. A constructional variation is a synchronous reluctance motor. By virtue of a cylindrical design, the synchronous reluctance motor has an equal number of stator and rotor poles and thus overcomes the torque pulsations of the switched reluctance motor, which must have unequal poles to rotate. Unlike induction motors, **reluctance motors** require an electronic controller with or without rotor position feedback for their operation.

The **DC motor** operates on a DC supply as the name suggests. Unlike in the induction motor, the secondary magnetic field is independent of the primary magnetic field and is produced either from a separate DC supply or by a permanent magnet. The use of DC motors is now limited to applications where the source of power is necessarily DC, such as a storage battery or switched-mode power supply. Examples include computer hard drives, CD/DVD players, cordless power tools, small battery operated vehicles, automotive auxiliaries and toys. DC motors are also used in some special large drive applications such as steel mill main drives.

The **universal motor** derives its name from the fact that it can operate on both DC and single phase AC. Its construction similar to that of a DC motor. Its use is limited to low duty cycle, high-speed applications, such as drilling machines, portable tools and food processors.

FOOTNOTES

1 IEA, 2016. World Energy Outlook 2016

2 IEA, 2011. Energy Efficiency Policy Opportunities for Electric Motor-Driven Systems

3 Weighted carbon emissions factor for electricity used by motors in these 150 countries is 750 g/kWh as assessed by U4E.

4 IEA 4E EMSA (2016) Policy guidelines for motor-driven units – part 1

5 IEA World Energy Outlook 2016 estimates the savings to reach 3,050 TWh by 2040 in the 450 scenario

6 IEA (2011) Energy efficiency policy opportunities for electric motor-driven systems; with updated global energy consumption data based on IEA 2014 statistics

7 IEA (2016) World Energy Outlook 2016

8 IEA 4E EMSA (2016) Policy guidelines for motor-driven units – part 1

9 IEA 4E EMSA (2016) Policy guidelines for motor-driven units – part 1

10 Weighted carbon emissions factor for electricity used by motors in these 150 countries is 750 g/kWh as assessed by U4E.

11 de Almeida, Anibal T. and others (2008) Energy Using Product Directive Lot 11 Motors

12 More detailed coverage of motor technologies is provided in Annex B: Electric motor basics

13 Induction motor operation is described in greater detail in Annex B: Electric motor basics

14 In addition, motors operated through variable frequency drives have heat losses due to their non-sinusoidal waveforms

15 A more detailed treatment of energy loss components of induction motors is available in IEC 60034-31

16 de Almeida, Anibal T. and others (2014) EuP Lot 30: Electric Motors and Drives. ISR University of Coimbra and Atkins.

17 Curves derived from the efficiency tables in (IEC 60034-30-1, 2014). Source: IEA 4E EMSA

The new class IE5 is not yet defined in detail but is envisaged for potential products in a future edition of the standard IEC 60034-30-1. It is the goal to reduce the losses of IE5 by some 20 % relative to IE4.

18 Source: Institute of Systems and Robotics, University of Coimbra, Portugal

19 From M. Brinks, WEG Netherlands, 1 Oct 2014

20 ECONOLER (2014) Motor Repairs: Potential for Energy Efficiency Improvement, Study for Super-Efficient Appliances Deployment/Clean Energy Ministerial

21 Guidelines for an effective motor management programme are available at https://www.copper.org/environment/sustainable-energy/electric-motors/case-studies/a6141.html#a5

22 The Electrical Apparatus Service Association (EASA) is an international trade organisation of nearly 1,800 electromechanical sales and service firms in 63 countries. Available at www.easa.com/accreditation

23 Available online at www.cee1.org

24 ECONOLER (2014) Motor Repairs: Potential for Energy Efficiency Improvement, Study for Super-Efficient Appliances Deployment / Clean Energy Ministerial

25 The improvement is small when compared with the savings resulting from speed variation. However, there are large differences in the energy efficiency of VSDs that can result in significant savings. At partial load, the difference may be in the 2-4 per cent range. The new standards EN-50598-2 and IEC 61800-9 provide the efficiency classification of VSDs.

26 Detailed guidelines and tools for targeting and implementing efficiency improvements in electric motor systems are available at http://www.leonardo-academy.org/course/view.php?id=363

27 de Almeida, Anibal T. and others (2001) VSD's for Electric Motor Systems, SAVE.

28 The technical aspects of different motor technologies are covered in Annex B: Electric Motor Basics

29 Institute of Systems and Robotics, University of Coimbra, Portugal, 2016. Presentation to the Motor Summit 2016.

30 IHS World market for LV motors (2016)

31 A study carried out by the Catholic University of Rio De Janeiro on behalf of ABINEE and Procobre in 2012-13 showed that 1.8 million industrial motors are repaired and commercialised annually, with an estimated energy loss of 7.1 TWh or 1.5 per cent of the total electricity consumption in Brazil.

32 IHS

33 Chausovsky, A. (2014) Motor market update presentation to the Motor Summit 2014.

34 Other relevant IEC Standards were introduced in Chapter 2; IEC 60034-1: 2010 Rating and performance, IEC 60034-30-1, edition 1.0, 2014: Efficiency classes of line operated AC motors.

35 IEA (2011) Energy efficiency policy opportunities for electric motor-driven systems; with updated global energy consumption data based on IEA 2014 statistics

36 Institute of Systems and Robotics, University of Coimbra, Portugal

37 EU Regulation No 640/2009 amended by No. 004/2014 https://ec.europa.eu/energy/sites/ener/files/documents/20141211_GuidelinesElectricMotors%20cover.pdf

38 Electric Motors Standards and Test Procedures, available at https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=6&action=viewlive#current_standards

39 IEA 4E EMSA

40 General guidelines for developing an effective standards and labelling programme are available at www.clasp.ngo/en/Resources/Resources/PublicationLibrary/2005/SL-Guidebook-English

41 For more information see: www.clasp.ngo/en/Resources/Resources/PublicationLibrary/2005/SL-Guidebook-English

42 The list of excluded motors is a very important step when defining the scope of MEPS. Specific exclusions, such as brake motors, explosion proof, liquid immersed, intermittent duty motors, and motors integrated into other products are a much-debated issue with repercussions in both the achievable savings and market surveillance activities.

43 Regional harmonisation would mean that the policy documents are harmonised and preferably have the same MEPS levels. However, if needed, the time required to reach the common level could be different, as national circumstances in a trading block vary considerably e.g. Philippines and Singapore in ASEAN.

44 A move to create truly international labels for motors is the IECEE GMEE. The aim is to create a regime under which a single test in an accredited test laboratory anywhere in the world will be recognized in any member country. GMEE will also harmonise the performance certification process across countries and regions. The GMEE Operational Document (OD-2057) was approved by the management committee of IECEE in June 2015. It is expected that the GMEE programme will increasingly be adopted in the months and years ahead, thereby resulting in considerable simplification of the certification process for both developed and developing countries, cost reductions and elimination of a potential technical barrier to trade.

*[*IECEE=IEC Conformity Assessment Association comprises 57 member countries, nearly 80 participating National Certification Bodies and close to 500 Testing Laboratories. It uses IEC Standards and members reciprocally recognize conformity certificates. The IECEE Certification Body (CB) scheme aims for " one product, one test, one certificate".] https://www.ieceee.org/*

45 For more information see: http://superefficient.org/Global-Efficiency-Medal.aspx

46 A detailed coverage of how communication campaigns for Appliance Energy Efficiency Standards and Labelling Programmes are designed is provided in Chapter 7 of www.clasp.ngo/en/Resources/Resources/PublicationLibrary/2005/SL-Guidebook-English

47 CLASP (2005) Standards and Labelling Guidebook

48 For more information see: www.motorsystems.org

49 ANSI/EASA AR 100-2015 (2015) Recommended Practice for the Repair of Rotating Electrical Apparatus. Available at www.easa.com

50 EASA carries out accreditation of service centres to assure that these use prescribed good practices to maintain motor efficiency and reliability during repairs. Outside of Europe and the North America, service centres have been accredited by EASA in Thailand and Azerbaijan. Available at www.easa.com

51 ECONOLER (2014) Motor Repairs: Potential for Energy Efficiency Improvement. SEAD programme and Asia-Pacific Economic Cooperation/Collaborative Assessment of Standards and Testing. Available at www.SuperEfficient.org.

52 IIP has developed a database and research report to support countries developing policy packages for industrial efficiency improvement http://iepd.iipnetwork.org/content/policy-pyramid

53 For a more detailed coverage of benchmarking, policy references and further case studies, see IEA 4E "Policy Guidelines for Motor Systems, Part 2", 2014, sections 6.8.10 and 6.3 respectively. Available at www.motorsystems.org

54 IEA, Institute for Industrial Productivity (2012) Policy Pathway Series: Energy Management Programmes for industry . Available at www.iea.org/publications/freepublications/publication/policypathwaysindustry.pdf

55 For case studies around the implementation of Energy Management Systems by companies, see http://www.cleanenergyministerial.org/Portals/2/pdfs/Sidpec_Egypt.pdf#_blank | http://www.cleanenergyministerial.org/Portals/2/pdfs/Shree%20Cement_India.pdf#_blank

56 For more information see: http://www.unido.org/what-we-do/environment/o591190/industrial-energy-efficiency/focus-areas/energy-management-standards.html

[57] For more information see: IEA 4E "Policy Guidelines for Motor Systems, Part 2", 2014, section 6.5. Available at www.motorsystems.org

[58] For more information see: IEA 4E "Policy Guidelines for Motor Systems, Part 2", 2014, section 6.6. Available at https://www.motorsystems.org/. Further company case studies are available at https://www.unido.org/fileadmin/user_media/Services/Research_and_Statistics/WP112011_Ebook.pdf

[59] Applied Industrial Technologies https://www.applied.com/base.cfm?page_id=3826

[60] Van Werkhoven, M. et al, 2015. Green Deal – Results and lessons learned in two years of cooperation of industry and government in the Dutch Green Deal programme on motor systems, EEMODS 2015.

[61] Van Werkhoven, M. et al, 2014. Engaging Dutch industry in implementing efficient motor systems with the Green Deal Programme. ECEEE industrial summer study.

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[63] M&V of Energy Savings
End users, intermediaries like ESCOs, and financiers all need to be convinced that the estimated savings in energy efficiency projects will indeed be achieved. Calculating energy savings in energy efficiency projects is unique in that it comes from the absence of energy use and thus cannot be measured like kilowatt hours generated from traditional power or renewable energy supply side projects. Savings are determined by analysing measured energy use after implementation of an energy efficiency project versus the 'Energy Baseline' prior to its implementation.

M&V guidelines have been developed in the globally-recognised International Performance Measurement and Verification Protocol (IPMVP), which is a document containing the generally accepted principles for the measurement, verification and calculation of the energy savings of energy efficiency projects. These principles are contained in the "IPMVP Core Concepts" document owned and managed by the non-profit, Efficiency Valuation Organization (EVO), and can be downloaded at no cost from EVO's website at: evo-world.org/

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[65] Mark Ellis & Associates and CLASP (2010) A Survey of Monitoring, Verification and Enforcement Regimes and Activities in selected countries, Final Report.

[66] Ibid.

[67] Ellis & Associates, 2010. Compliance Counts: A Practitioner's Guidebook on Best Practice Monitoring, Verification and Enforcement for Appliance Standards & Labelling, www.clasp.ngo

[68] An AEDM is an analytical calculation tool for determining energy efficiency and, therefore, it is cheaper and less time-consuming than physical testing of the motor in a laboratory. AEDMs are developed by individual manufacturers (as manufacturing processes vary) and are rigorously vetted through a series of laboratory tests, before these are allowed by the US DOE. For more information see http://energy.gov/eere/buildings/appliance-and-equipment-standards-programme

[69] SEAD Super-Efficient Appliances Deployment Initiative, 09/2015

[70] UN Environment (2016) Developing Lighting Product Registration Systems. Available at http://www.enlighten-initiative.org/portals/0/documents/Resources/publications/Developing_lighting_product registration_systems_February 2016.pdf

[71] Denmark, Sweden and UK formally share costs of testing through the pilot Ecopliant initiative.

- The European Commission has created a platform for the sharing of information between European Member State Market Surveillance authorities – the ICSM (Information and Communication System on Market Surveillance) database.
- Australia formally shares results with New Zealand, and sometimes informally with other IEC members.

[72] Malinowski, J. and Korkeakoski, J. (2016) CEMEP/NEMA presentation to the Motor Summit 2016.

[73] IECEE IEC Conformity Assessment Association comprises 57 member countries, nearly 80 participating National Certification Bodies and close to 500 Testing Laboratories. It uses IEC Standards and members reciprocally recognise conformity certificates. The IECEE Certification Body scheme aims for "one product, one test, one certificate". https://www.iecee.org/

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[76] UN Environment (2016) Enforcing Efficient Lighting Regulations, Guidance Note. Available at http://www.enlighten-initiative.org/portals/0/documents/Resources/publications/Enforcing%20Efficient%20Lighting%20Regulations_February%202016.pdf

77 UN Environment (2016)

78 The ferrite magnets used in ferrite-based permanent magnet motors comprise a compound of iron with other metals and are therefore more challenging to recycle than pure metals. Although the same process is followed for collection, the recycling industry is still gathering experience with these new products. The handling of the rare earth metals Nd, Dy, Tb and Pr used in rare-Earth based permanent motors at end of life presents entirely different challenges from the common metals used in induction motors. These topics are less relevant for developing countries and are not covered in this policy guide. A research project on these topics MORE is currently being conducted by a German consortium. See http://www.isi.fraunhofer.de/isi-en/n/projekte/MORE_en.php

79 ABB. Brochure on Recycling Instructions number ABB/LV Motors/3GZF500930-5 B

80 For an example of e-waste regulations in a developing country see http://www.moef.gov.in/sites/default/files/EWM%20Rules%20 2016%20english%2023.03.2016.pdf

81 ABB. A brochure that provides detailed instructions for the disassembly of low-voltage induction motors at the end of life is ABB/LV Motors/3GZF500930-5 B

82 Bureau of International Recycling. For more information see: http://www.bir.org/industry/

83 A physical magnet is conventionally described as having a north pole and a south pole, analogous to the earth's magnetic axis. The terminology is carried over to electromagnetism, where each magnet comprises a north-south pole pair. Thus a 6-pole motor comprises three electromagnets arranged symmetrically around a cylindrical axis, each with a north and a south pole.

84 Institute of Systems and Robotics, University of Coimbra, Portugal

85 Ibid.

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