Policies and Measures for Promoting Efficient Electric Motors in Industry

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Policies and Measures for Promoting Efficient Electric Motors in Industry

Lea Gynther
Sirpa Mustonen
Erja Saarivirta
Foreword

ADEME is coordinating a technical service for the World Energy Council (WEC) on Energy Efficiency Policies and Indicators for 2013-2016. As a part of the service, ADEME has initiated a set of policy reviews in different topics. This specific task focuses on review of policies and measures related to efficient electric motors in industry.

The report is based on a project called ‘Evaluation of Good Practices on Policy and Measures to Accelerate the Penetration of Efficient Electric Motors in Industry’. For practical reasons, a shorter name has been given to the report, namely ‘Policies and Measures for Promoting Efficient Electric Motors in Industry’.

The project has been implemented by Motiva Services Oy (Finland). The project team has been composed of: Lea Gynther (project manager, policy analyst), Sirpa Mustonen (communications expert, case studies) and Erja Saarivirta (technical expert).
Executive Summary

The proportion of electricity consumption by electric motors and electric motor-driven systems (EMDS) in industry is up to 46% of global electricity use. In industry, EMDS are estimated to account for approximately 70% of electricity consumption. Most common EMDS in industry are pumping, compressed air and material processing.

The cost-effective potential to improve energy efficiency of motor systems is roughly 20% to 30%, which would reduce total global electricity demand by about 10%. Technical measures for achieving the potential are using properly sized and energy-efficient motors, using variable speed drives when appropriate and optimization of the whole EMDS.

When saving measures are not implemented, this is a missed opportunity to gain cost savings as well as regarding reliability and flexibility, safety, increasing production volumes, improved operation conditions and easier maintenance. There are numerous reasons why the savings potential is not realized, even when pay-back times are very short. The most significant among them appear to be lack of reinforcement of legislation, missing lifecycle analysis (attention is paid only to procurement price) and inadequate skills leading to system oversizing (60% of systems are oversized). There may not be adequate attention to energy management in general, replacement culture is missing and inappropriate recoiling practices corrode efficiency.

While cost savings and threat of increasing energy prices can be driving forces behind change, image matters and corporate responsibility are arising among the positive driving forces for efficiency improvements. Among manufacturers of motors and EMDS, it is necessary to recognized business opportunities laying in customer needs. Those understanding them best can gain competitive edge.

Action needs to be stimulated among all key stakeholders within the motor systems market to achieve long-term market transformation. Therefore, a comprehensive range of policies are required to influence international/national standard makers, industry associations, industrial users and power utilities.

Policies and measures are needed in all phases of the motor lifecycle, ranging from product development and marketing to procurement and use. In 2014, 45.8 million low voltage motors were sold globally. The volume is estimated to grow to 51.6 million by 2019 representing a 2.5% annual growth rate. Many important policies and measures are in place to address the efficiency of new motors. The use phase is very important as well and special situations, like behaviour at breakage, all have efficiency implications. One important factor is the replacement of motors because many motors are used well beyond their planned service lives.

Minimum Energy Performance Standards (MEPS) are the key instrument steering the efficiency of new motors. MEPS are national regulation banning the sales of least efficient motors. In most cases, MEPS are harmonized with internationally standardized energy efficiency classification of motors. If properly enforced, MEPSs are a strong policy tool for new motors, but the amount of motors replaced or new investments are only a fraction of the total motor stock. The installed base is typically 7 to 11 times the annual domestic sales volume. In addition, MEPS
have no influence on, e.g., correct sizing, installation and running time. Lastly, as long as MEPS are not implemented everywhere or continue to be implemented at different levels of ambition, inefficient motors still continue to have global export markets.

In future, MEPS levels need to be elevated with view to cost-effectiveness, starting from the OECD markets. In non-OECD countries MEPS need to be introduced. Particularly in countries with developing industry, such as India, lack of MEPS is a missed opportunity for better energy efficiency and competitiveness.

In addition to MEPS, energy efficiency labels, procurement tools as well economic and information instruments all address the energy efficiency of new motors. Comparative or endorsement labels on mandatory or voluntary basis are in place both in OECE and non-OECD markets. These increase the visibility of energy efficient alternatives. Various calculation tools have been developed to enhance informed decisions. Tools enable life cycle analysis of different alternatives as well as appropriate system sizing. Subsidies, tax rebates or accelerated depreciation may be available for procurement of efficient motors and in development countries investments may be financed by international financing institutions. Financing can be enabled by soft loans with low interest rates and interest-free grace period particularly among small and medium sized enterprises while third party financing by energy service companies (ESCOs) may be an option for larger industries.

Use phase is typically addressed by energy management and energy services (e.g. energy audits), information measures and electricity taxation. Energy management systems (EMS) comprise a systematic and structured approach for reviewing the energy needs of a company and for implementing measures to reduce consumption, including putting in place monitoring and reporting systems. EMSs also cover organizational issues, like purchasing rules for buying and installing highly efficient equipment, maintenance procedures, training of personnel and tracking and evaluation of suggested and implemented energy saving opportunities. Therefore, EMS cannot be considered only as a measure for the use phase but it has improves investment behaviour as well.

Energy audits, implemented both on voluntary and mandatory basis, are an important tool for effective energy management. When full-scale EMS is too heavy for a smaller industry, it can still be useful to implement energy audits.

One of the key barriers has been identified to be lack of know-how. Skills may be lacking or outdated leading to e.g. system oversizing and poor repair. Capacity building can take many different forms from formal training to seminars and workshops and providing advice, planning tools and handbooks.

One major issue is rewinding the coils at motor breakage. This can be done 5-6 times during motor lifetime, particularly in developing countries. UNIDO has recommended that rewinding should only be used for motors with low annual running hours (below 2 000 hours per year). Without taking up a stand on the proposed threshold, widely communicating this kind of clear rules of thumb could change behaviour.
The existing motor stock is also surprisingly old in industrialised countries if the results of a Swiss survey\textsuperscript{1} can be generalised. This is a difficult issue to address but one effective policy is auditing of EDMS which gives information on the pay-back times.

# Table of Contents

- Foreword 3
- Executive Summary 4
- Table of Contents 7
- Abbreviations and Acronyms 9

1 Introduction 10
   - 1.1 Objectives 10
   - 1.2 General Approach 11
   - 1.3 Case Studies 11

2 Current Setting in the Electric Motor Market 13
   - 2.1 Motor Efficiency Categories 13
   - 2.2 Global Electric Motor Market 15
   - 2.3 Role of Electric Motors in Global Electricity Consumption 16

3 Benefits, Barriers and Driving Forces of Better Efficiency 18
   - 3.1 Savings Potential and Other Benefits 18
   - 3.2 Barriers 21
   - 3.3 Driving Forces 22

4 Policies and Measures 24
   - 4.1 Policy Overview 24
   - 4.2 Minimum Energy Performance Standards 26
   - 4.3 Energy Management 28
   - 4.4 Information Instruments 31
     - 4.4.1 Energy Labelling 31
     - 4.4.2 Capacity Building and Tools 33
     - 4.4.3 Awards and recognitions 35
   - 4.5 Economic Incentives 36
     - 4.5.1 Subsidies 36
     - 4.5.2 Fiscal Incentives 38
     - 4.5.3 Soft Loans 38
   - 4.6 Other Policies and Measures 38
     - 4.6.1 Voluntary Agreements 38
     - 4.6.2 Energy Saving Obligation Schemes 39
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.6.3</td>
<td>ESCO Financing</td>
<td>40</td>
</tr>
<tr>
<td>4.6.4</td>
<td>Technology procurement</td>
<td>41</td>
</tr>
<tr>
<td>5</td>
<td>Conclusions and Recommendations</td>
<td>42</td>
</tr>
<tr>
<td>6</td>
<td>Summary</td>
<td>44</td>
</tr>
<tr>
<td>6.1</td>
<td>Introduction</td>
<td>44</td>
</tr>
<tr>
<td>6.2</td>
<td>Driving Forces and Barriers</td>
<td>44</td>
</tr>
<tr>
<td>6.3</td>
<td>Starting Points for Policy Intervention</td>
<td>45</td>
</tr>
<tr>
<td>6.4</td>
<td>Policies and Measures</td>
<td>46</td>
</tr>
<tr>
<td>6.5</td>
<td>The Way Forward</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Annex 1 Case Studies</td>
<td>51</td>
</tr>
</tbody>
</table>
## Abbreviations and Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>ASD</td>
<td>Adjustable Speed Drives</td>
</tr>
<tr>
<td>CCEEMEP</td>
<td>European Committee of Manufacturers of Electrical Machines and Power Electronics</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>CO₂eq</td>
<td>Carbon dioxide equivalent</td>
</tr>
<tr>
<td>eemods</td>
<td>energy efficiency in motor driven systems [conference]</td>
</tr>
<tr>
<td>EASA</td>
<td>[US] Electromechanical Authority</td>
</tr>
<tr>
<td>EMDS</td>
<td>Electric Motor Driven Systems</td>
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<tr>
<td>EMS</td>
<td>Energy Management System</td>
</tr>
<tr>
<td>EMSA</td>
<td>Electric Motor Systems Annex</td>
</tr>
<tr>
<td>ESCO</td>
<td>Energy Service Company</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
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<td>GEF</td>
<td>Global Environmental Fund</td>
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<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
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<tr>
<td>IE</td>
<td>International Efficiency [motor classes]</td>
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<tr>
<td>IEA</td>
<td>International Energy Agency</td>
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<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
</tr>
<tr>
<td>INDC</td>
<td>Intended Nationally Determined Contributions</td>
</tr>
<tr>
<td>JRC</td>
<td>Joint Research Centre</td>
</tr>
<tr>
<td>MEPS</td>
<td>Minimum Energy Performance Standards</td>
</tr>
<tr>
<td>NEMA</td>
<td>National Electrical Manufacturers Association</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Cooperation and Development</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>SEAD</td>
<td>Super-efficient Equipment and Appliance Deployment Initiative</td>
</tr>
<tr>
<td>SME</td>
<td>Small and Medium-Sized Enterprise</td>
</tr>
<tr>
<td>UNIDO</td>
<td>United Nations Industrial Development Organization</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>VSD</td>
<td>Variable Speed Drive</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit</th>
<th>Equivalency</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg</td>
<td>kilo-gram</td>
</tr>
<tr>
<td>kW</td>
<td>kilo-Watt</td>
</tr>
<tr>
<td>kWh</td>
<td>kilo-Watt hour</td>
</tr>
<tr>
<td>Mt</td>
<td>Million tonnes</td>
</tr>
</tbody>
</table>
Introduction

1.1 Objectives

The objective of the project is to review policies and measures related to efficient electric motors in industry. Industry is the focus sector because the proportion of electricity consumption by electric motors and electric motor-driven systems (EMDS) in global electricity usage is particularly high in this sector, rising up to 46%.

The biggest proportion of motor electricity consumption is attributable to mid-size motors with output power of 0.75 kW to 375 kW. It should be noted, however, that electric motors are used in a wide number of other uses, e.g., in transport, infrastructures and in various appliances in the household and services sector. The last, although numerous, makes up only 9% of all electric motor power consumption. (IEA 2011)

Electric motors convert electrical power into mechanical power within a motor-driven system. The vast majority of the electricity used by an EMDS is consumed by the electric motor itself but considerable savings opportunities lay at the system level. Most common EMDSs in industry are pumping, compressed air and material processing.

Given the integration both at the system level and at the policy level, this report does not limit only to motors but discusses also policies and measures for industrial EMDSs. Largest savings potential can tapped by looking at total motor systems (Figure 1).

Figure 1 Energy savings/system level (Source: IEA 2011)
1.2 General Approach

The work was organized under the following tasks:

**Task 1. List of issues**
Issues relevant to policies for energy efficiency of motors were first defined and presented in a Power Point draft report to Ademe on 30 September 2015. This presentation initiated the analysis on the appropriate measures and packages of measures identifying different policy and measure types, best practices, benefits and success factors as well as barriers. A more detailed analysis was carried out in Task 3.

**Task 2. Collection of case studies**
Eleven case studies have been compiled in a standardized template. They are presented in Annex 1 of this report and included into the analysis of best practices in Chapter 4. A list of case studies and selection criteria are given in Chapter 1.3.

**Task 3. Analysis**
The analysis covered the identification of different policy and measure types and case examples of their utilization. Their working mechanisms, pros and cons, key success factors and difficulties occurred are analysed alongside their applicability in different circumstances and markets (developed or less developed countries). Also packaging of measures of different types is addressed. The role of different stakeholders and institutional aspects is described and analysed. Information will be given on cost and benefits (impacts on energy savings and/or CO₂ abatement) of the measures based on data available from literature and the case studies alongside with other benefits, so-called ‘multiple benefits’.

**Task 4. Reporting**
This task is the main reporting output of the project. In addition, major results have been summarized in a Power Point presentation.

**Task 5. Final workshop**
The results of this report are to be presented in a day workshop in London/Paris in spring 2016.

Recent information on policies and measures was collected also in the eemods’15 conference held in Helsinki, Finland in September 2015.

1.3 Case Studies

The following case studies have been identified and described in a standardized template in Annex 1 of this report.
Table 1  Case Studies

<table>
<thead>
<tr>
<th>Country</th>
<th>Programme</th>
<th>Policy instrument or operating mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Brazil</td>
<td>National Electricity Conservation Program (PROCEL) - Industry</td>
<td>Information/Audits, capacity building, labels</td>
</tr>
<tr>
<td>2  China</td>
<td>Minimum Energy Performance Standards/Energy label for motors</td>
<td>Legislation/MEPS and labels</td>
</tr>
<tr>
<td>3  European Union</td>
<td>Eco-design Directive</td>
<td>Legislation/MEPS</td>
</tr>
<tr>
<td>4  India</td>
<td>Voluntary standard and energy labels for industrial electric motors</td>
<td>Voluntary/Energy efficiency standards and labels</td>
</tr>
<tr>
<td>5  Indonesia</td>
<td>Promoting energy efficiency through system optimization and energy management standards</td>
<td>Energy management. Implemented on project basis.</td>
</tr>
<tr>
<td>6  Japan</td>
<td>The Top-Runner Programme</td>
<td>Legislation/MEPS</td>
</tr>
<tr>
<td>7  The Netherlands</td>
<td>Green Deal: Efficient electric motor systems</td>
<td>Information/Audits, information dissemination</td>
</tr>
<tr>
<td>8  South Africa</td>
<td>Energy Efficient Motors Programme</td>
<td>Financial/Subsidies</td>
</tr>
<tr>
<td>9  South Korea</td>
<td>Mandatory energy audits</td>
<td>Legislation/Audits</td>
</tr>
<tr>
<td>10 Switzerland</td>
<td>Competitive Tender Programme</td>
<td>Financial (financed through a green fee on electricity)/ Subsidies</td>
</tr>
<tr>
<td>11 United States</td>
<td>The MotorMaster+ tool</td>
<td>Information/Tool</td>
</tr>
</tbody>
</table>

The selection criteria used for the selection of case studies was the following:

- At least 5 cases from non-OECD
- Total objective 11 cases
- Selection of countries to reflect the relative distribution of electricity consumption by motors globally
- However, there should be a good geographical distribution
- Wide coverage of policy/measure types
- Monitoring and evaluation data needs to be available
- Policy/measure ongoing or closed recently (with the exception of the case study from South Africa, all the case studies are ongoing policies or programmes)
2.1 Motor Efficiency Categories

IEC 60034-30-1\textsuperscript{2} is an international standard of the International Electrotechnical Commission for rotating electrical machinery (IEC 2014). IEC 60034-30 specifies four classes: IE1 (standard), IE2 (high), IE3 (premium) and IE4 (super premium). A new class IE5 is not yet defined in detail but is envisaged for potential products in a future edition of the standard. For each class the efficiency is defined for a rated output range from 0.12 to 1000 kW. Earlier edition of the standard included three classes, IE1, IE2 and IE3 for an output range from 0.75 to 376 kW. All technical constructions of electric motors are covered as long as they are rated for on-line operation and not just three-phase, cage-induction motors as in the first edition of the standard.

Technical definition of IE classes

The efficiency of an electric motor is the ratio of mechanical output power to electrical input power. The following graph shows the nominal efficiencies (%) of different motor sizes in each efficiency class depending on motor size. A motor of a given size is labelled in an efficiency class based on its nominal efficiency.

Source: IEA 2011, fig. 3.

\textsuperscript{2} All IEC standards can be purchased at \url{www.iec.ch}. A preview of each standard on rotating electrical machines is available on the EMSA website at \url{https://www.motorsystems.org/iec-standards}. 
The IE-code and its efficiency levels create a basic vocabulary for governments to determine the efficiency level for their minimum energy performance standards (MEPS).

Motor testing is the basis for efficiency classification. The IEC has developed an internationally applicable testing Standard IEC 60034-2-1 for electric motors. However, many countries use their own national test standards while at the same time also make reference the IEC testing standard (IEC 2015). In some cases, national approaches are used to protect domestic motor production (IEA 2011).

Motor manufacturers are producing and selling electric motors across many countries. As test standards, efficiency levels and certification schemes vary from country to country, manufacturers initiated the Global Motor Labeling Programme under the IECEE (IEC System of Conformity Assessment Schemes for Electrotechnical Equipment and Components). The goal of the programme is to have one recognized test method (IEC 60034-2-1), one test report format, one certification process and one label for electric motors in all participating countries. Thus, each motor would have an "international passport": once certified for one particular level of energy efficiency in one country that would be recognized in another (participating) country as well. This would also make international cooperation among different countries on enforcement of regulations also possible. (IEC 2015)

Table 2 summarises both the existing IEC standards concerning electric motors as well as work in progress.

<table>
<thead>
<tr>
<th>Field</th>
<th>IEC reference</th>
<th>Year of publication</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standards in force</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Rating</td>
<td>IEC 60034-1, edition 12.0</td>
<td>2010</td>
<td>Rating and performance</td>
</tr>
<tr>
<td>Testing</td>
<td>IEC 60034-2-1, edition 2.0</td>
<td>2014</td>
<td>Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)</td>
</tr>
<tr>
<td>Testing</td>
<td>IEC 60034-2-1, edition 1.0</td>
<td>2010</td>
<td>Specific methods for determining separate losses of large machines from tests – Supplement to IEC 60034-2-1</td>
</tr>
<tr>
<td>Efficiency classes</td>
<td>IEC 60034-30-1, edition 1.0</td>
<td>2014</td>
<td>Efficiency classes of line operated AC motors (IE-code)</td>
</tr>
<tr>
<td>Guide</td>
<td>IEC 60034-31, edition 1.0</td>
<td>2010</td>
<td>Selection of energy-efficient motors including variable speed applications – Application guide</td>
</tr>
<tr>
<td><strong>Work in progress</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficiency classes</td>
<td>IEC 60034-30-2</td>
<td>Expected to</td>
<td>Efficiency classes of variable speed AC</td>
</tr>
<tr>
<td>Field</td>
<td>IEC reference</td>
<td>Year of publication</td>
<td>Title</td>
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<tr>
<td>----------------------------------------------------------------------</td>
<td>---------------</td>
<td>---------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Be published in 2016/17</td>
<td></td>
<td></td>
<td>motors</td>
</tr>
<tr>
<td>Converters: efficiency classes and test methods</td>
<td>IEC 61800-9-2</td>
<td>Expected to be published in 2016/17</td>
<td>Eco-design for power drive systems, motor starters, power electronics &amp; their applications – Energy efficiency indicators for power drive systems and motor starters</td>
</tr>
</tbody>
</table>

### 2.2 Global Electric Motor Market

In 2014, 45.8 million low voltage motors were sold globally. The volume is estimated to grow to 51.6 million by 2019 representing a 2.5% annual growth rate. In 2014 the shares of different efficiency classes in sales were: IE1 44% of unit sold, IE2 34%, IE3 14% and IE4 1%. Considerable transition towards more efficient motors is expected by 2019 partly driven by MEPS (see Figure 2). (Reine 2015)

In the case of low-voltage motors, the market was valued at $14.2 billion (€13.2 billion) in 2014. After accounting for 55% of the market’s revenues in 2013, IE1 motors made up an estimated 51% of the market in 2014 and are expected to comprise less than 25% of market revenues by 2019. These IE1 products are sold mainly in the emerging markets that have not yet adopted any type of efficiency regulations; however, many leading suppliers are still successfully selling these motors in developed countries such as the United States and Germany. IE2 motors represented an estimated 19.5% of market revenues in 2014, but are expected to account for more than 45% of total market revenues by 2019. IE3 motors accounted for only 2% of global revenues in 2010, but made up 15% of market revenues in 2014. The world market for industrial IE4 low-voltage motors is estimated to have been worth $159.2 million in 2014 with nearly 300,000 units shipped. (Reine 2015)

Variable speed drives are a commonly used technology to improve the efficiency of electric motors. The drives market is expected to continue to be one of the fastest-growing industrial automation equipment markets in the future (Reine 2015).
2.3 Role of Electric Motors in Global Electricity Consumption

Electric motor and motor-driven systems are very important users of electricity globally. They are estimated to be responsible for up to 46% of global electricity use. In industry, they are estimated to account for approximately 70% of electricity consumption. (EMSA 2014)

Amount of electricity used by electric motor systems in different countries and regions reflects the size. As shown by Figure 3, the largest user is China followed by USA and European Union. All other countries and regions make clearly smaller contributions.
ROW = Rest of the world

Figure 3  Electricity demand by electric motor systems by country or region (Source: Brunner and Werle, 2013)
Benefits, Barriers and Driving Forces of Better Efficiency

3.1 Savings Potential and Other Benefits

The cost-effective potential to improve the energy efficiency of motor systems is roughly 20% to 30%, which would reduce total global electricity demand by about 10%. Using the best available motors will typically save about 4% to 5% and linking these motors with electromechanical solutions that are cost-optimised for the end-user will typically save another 15% to 25% (IEA 2011). The higher investment cost is typically offset in three to five years (EMSA 2014).

Globally, tapping this potential would lead to huge electricity savings. If all countries adopted best practice MEPS (Minimum Energy Performance Standards) for industrial electric motors, approximately 322 TWh/year would be saved by 2030 with corresponding emission reductions of 206 Mt of CO₂ (IEA 2011). For example, the savings estimate by 2020 by the MEPS established through the Eco-Design Directive in Europe is 135 TWh/year by 2020, equivalent to the output of 22 nuclear reactors.

Comprehensive market data can be found also from, e.g. Switzerland and the US. In Switzerland, 4 142 motor systems were analysed in detail in 18 industrial and infrastructure facilities between 2010 and 2014 (see Chapter 4.1, Figure 6). 56% of motors are older than their operating life expectancy and 20% of the motors are equipped with a VSD³. Measurements on 104 motor systems on site showed that two thirds of the motors have an average load factor below 60% meaning that many motors are oversized. (TopMotors 2015)

In 2002, the United States Department of Energy (USDOE) published an energy efficiency assessment of US industrial sector motor systems titled United States Industrial Electric Motor Systems Market Opportunities Assessment. To capture the changing landscape, the USDOE has initiated a three-year Motor System Market Assessment (MSMA), led by Lawrence Berkeley National Laboratory (LBNL). The MSMA will assess the energy consumption, operational and maintenance characteristics, and efficiency improvement opportunity of U.S. industrial sector and commercial building motor systems. (Rao et al. 2015)

Technical options for achieving these savings can be grouped to three categories (IEA 2011):

- Use of properly sized and energy-efficient motors.
- Use of VSDs, where appropriate, to match motor speed and torque to the system mechanical load requirements. This makes it possible to replace inefficient throttling devices and, in some cases with “direct-drive”, to avoid wasteful mechanical transmissions and gears.

³ Adjustable speed drive (ASD) or variable speed drive (VSD) describes equipment used to control the speed of machinery. In this report, term variable speed drive (VSD) is used.
• Optimisation of the complete system, including correctly sized motor, pipes and ducts, efficient gears and transmissions, and efficient end-use equipment (fans, pumps, compressors, traction, and industrial handling and processing systems) to deliver the required energy service with minimal energy losses.

In industry, the requirements for pay-back times of energy efficiency projects are very stringent. The requirements are also different for pure energy efficiency investments (shorter) and process investments which also improve energy efficiency (longer). Today, pure energy efficiency investments are seldom implemented if the pay-back time exceeds one year which is lower than a bit earlier. This is a level which is not so easy to reach even in motor projects. Therefore, even a small financial support (e.g. a subsidy or tax rebate) can work as an important carrot in improving the attractiveness of an investment (see Chapter 4.5).

### Pay-back times of efficiency projects

Pay-back times of efficient motors are specific to a given time and place as prices of motors, variable speed drives (VSDs) and electricity vary by time and place. However, some observations on realized projects are given here.

UNIDO has collected some case materials from the factory level in different countries. For example, installation of 34 variable speed drives in a petrochemical company in China led to 28% electricity demand reduction per tonne of crude oil refined with pay-back time of 0.48 years. In another example, 102 VSDs were installed in one company in Mexico 20% reducing electricity demand of equipped motors; the pay-back time of the USD 400,000 investment was 1.5 years.

Within the scope of the China Motor Systems Energy Conservation Program (collaboration of UNIDO, the USDOE, the Energy Foundation and the Chinese government), energy audits were conducted in Chinese firms to improve the energy efficiency of their motor systems, namely compressed air, fan and pump systems. In total, 41 plants were evaluated and in most cases, investments in system optimization were made. The average estimated payback time was 1.4 years with variation from a few months to 5 years.

Alder Creek Lumber in the United States implemented a decision to purchase NEMA Premium motors. The first 200 horsepower motor replaced saves close to $8300 per year – a payback period of less than 12 months in energy costs alone. The factory had a large saving potential as the majority of the motor fleet of 175 (3-200 hp) had been in operation for over four decades. Motor management was enhanced by starting to use an inventory and database with software to aid in repair/replace decisions.

PCS Nitrogen’s fertilizer plant in the United States installed an adjustable-speed drive on the combustion fan serving a boiler to eliminate the generation of excess steam. The project had a simple pay-back time of two months saving 76,400 MMBtu (TJ) of energy and $420,000 of energy costs per year.

Source: UNIDO 2011, the US Motor Decisions Matter Campaign

Efficient use of resources does not mean simply using energy efficiently. Due attention needs to be paid to use of other resources, such as materials, and trade-offs between different resource categories need to be recognised. This holistic approach is called eco-design.

European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) has analysed the link of energy efficiency and use of materials in electric motors. According to a comparison presented by Sander (2015), the energy efficiency of a line-fed 11 kW IE4 motor is 5.7% better than that of IE4 while the former weights typically 100 kg and the latter 60 kg. This leads to 40 kg additional use of materials. In comparison, equipping IE1 motor with a variable speed drive of IES1 class improves energy efficiency by 55% but adds only 10 kg of materials.

The IEA (2015a) has analysed the contribution of some main equipment groups on greenhouse gas emission reductions in different regions (Figure 4). It analysed the additional savings which can be obtained by so-called Bridge Scenario in relation to the INDC scenario which represents the savings in Intended Nationally Determined Contributions for COP21. The Bridge Scenario builds on available technology and five proven policy measures including the introduction of new MEPS. In the additional savings in the Bridge Scenario the role of efficiency gains in industrial motors is particularly significant in China (about one third) but very important (about a quarter) in the expected emission reductions by 2030. It should be noted, that these emission reductions represent an additional potential to emission cuts announced in INDCs.

There are other benefits beyond energy savings and greenhouse gas emissions reductions associated with more efficient EMDSs. More efficient EMDSs lead to process and quality improvements, lower cooling demand and reduced noise levels. These benefits are due to the improved efficiency of the system components, better dimensioning, improved conditions of operation and easier maintenance, and particularly, due to better energy efficient control and adaptation to real demand. (EMSA 2014)

In addition, motors constructed with improved manufacturing technologies and materials usually have higher service factors, longer insulation and bearing lives as well as less vibration. All these factors increase reliability and lower failure rates which has prompted manufacturers to offer longer warranties for the most efficient models.

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4 There is a classification (IES) available for power system drives in the European Standard EN 50598-2. The IES class applies for systems consisting of frequency converter and motor, including necessary auxiliaries and it is defined at 100% speed and 100% torque. The three classes are IES0 (least efficient), IES1 and IES2 (most efficient).
3.2 Barriers

There is abundant literature on barriers for better efficiency in industrial motor systems, e.g. IEA 2011, Unido 2011 and EMSA 2014. In policy making it is important to recognise the barriers in each country to tailor the right package of measures to address these barriers.

In the following, brief categorisation of the barriers based on the abovementioned sources is presented.

Policy barriers:
- 69% of motor electricity is used in countries with MEPS for motors but most of these countries have not yet implemented the necessary compliance measures.
- Lack of public-private co-operation

Organisational:
- Energy efficiency (including motors) are not the focus of the management
- Responsible employees do not necessarily have adequate mandate for actions

Replacement practices:
- In large companies the department procuring a new motor is not the same as the department which monitors the motor's electricity bill
- (Small) companies emergency replacements are done at breakdown in which occasion only replacement time accounts (or emergency repairing causing losses)
- Companies may keep large stocks of backup motors of the same type to prepare for a breakdown
A systematic replacement culture is often lacking

Investment barriers:
- There is often no life-cycle view: There is too much weight on investment cost (efficient ones are typically 20-30% more expensive) instead of the running costs which are by far more important over the motor’s lifetime
- Stringent pay-back time requirements (2-3 years) can hinder ever very profitable investments (with internal rate of return even 20%) while motor system lifetimes are 10-20 years

Cultural barriers
- There may be habits for running motors even when there is not demand (weekends, overhaul shutdowns etc.)
- There can be an emphasis on hardware and software investments over knowledge improvements

Information barriers:
- Outdated engineering skills
  o Knowledge of employees on system optimization may be outdated (e.g. old rules of thumb are used) leading to use of excessively large motors. Better system-sizing know-how may be needed. At present, 60% of systems are oversized.
- Lack of monitoring/measurement data
  o Hinders savings calculations e.g. from VSDs
- The majority of electric motors are incorporated into motor systems and the end-user, who pays the electricity bill, often has no information on the motor incorporated (principal agent barrier).

Manufacturing barriers:
- Lack of internationally harmonized technical standards and testing procedures can result in trade barriers and cause obstacles for large production series
- Motors and appliances often manufactured by different companies
- Reluctance/slowness of manufacturers to conform to customer needs
- Lack of incentives to innovate

3.3 Driving Forces

Quite often in policy, analysis emphasis is put mainly on barriers to efficient practices. At the same time it is important to recognise the positive driving forces in the policy target groups. This can help in trying to find instruments which reinforce the impact of driving forces thus creating positive drive.

For electric motors systems, driving forces for improvements can be identified mainly at two levels, users of motor systems and manufacturers.
Among motor system users interest is in, but is not limited to, reduction of energy costs. This interest may be strengthened by threats of rising electricity prices - which inevitably happens over time. Energy efficiency improvements in motor systems quite often offer opportunities for cost savings with relatively short pay-back times. Alongside with cost, increasing number of companies also pay a lot of attention to image and social responsibility which is demonstrated in their annual environmental reporting.

There are a number of non-energy benefits to be acquired in the manufacturing process. Reliability and flexibility, safety, lower noise levels, increasing production volumes as well as improved operation conditions and easier maintenance are all important factors for industry and need to be emphasized in designing policy interventions.

The policy framework can be a very strong driver from the company point of view. Manufacturers simply have to conform to the legal requirements of the target markets. From user point of view, voluntary agreements can encourage implementation of measures on voluntary basis which is always more preferable to businesses, however, with the understanding that more stringent measures are like to be introduced if voluntary approach does not deliver adequate energy savings.

It is necessary for manufacturers to recognize business opportunities laying in customer needs. Those understanding this best can gain competitive edge. In addition to striving to develop new efficient models, various tools and services can be provided to customers including training, service contracts and analytical services for system optimization. At the same time manufacturers can take the opportunity of demonstrating corporate responsibility and building good image.

Visiting the websites of manufacturers show mixed results in terms of recognizing these opportunities for building competitive edge. While some sites portray energy efficiency as (almost) a front page matter leading the visitor immediately to further materials and positive case examples, others may just refer to energy efficiency or environmental protection almost as a little afterthought.

In response to the requirements from the different stakeholders (e.g. policy makers, customers) manufacturers can either simply choose just conforming with the requirements or take this as an opportunity to develop new business.

Summary of driving forces

- Cost reduction
- Preparation for rising energy prices
- Manufacturing benefits: reliability and flexibility, safety, lower noise, increasing production volumes, improved operation conditions
- Image and social responsibility
- Business opportunities
- Competitive edge
- Policy framework mandating or supporting energy efficiency gains
Policies and Measures

4.1 Policy Overview

Policies and measures are needed in all phases of the motor lifecycle, ranging from product development and marketing to procurement and use. Figure 5 shows the lifecycle steps and some applicable policy and measure types in each of them.

The majority of policies and measures in place are addressing the efficiency of new motors. Minimum Energy Performance Standards (MEPS), energy labels, procurement tools as well as subsidies and tax rebates all address their energy efficiency. If properly enforced, MEPSs are a strong policy tool for new motors, but the amount of motors replaced or new investments are only a fraction of the total motor stock. In addition, MEPSs have no influence on, e.g., correct sizing, installation and running time. Therefore, a balanced portfolio of supplementing policies and measures is needed.

OEM = Original Equipment Manufacturer

Figure 5 Policies by product cycle phase (Source: based on IEA 2011, modified by Motiva)

The use phase is very important as well and special situations, like behaviour at breakage, all have efficiency implications. This phase can be addressed by energy management and energy services (e.g. energy audits), information measures and electricity taxation. One noteworthy

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5 The basic definition of an OEM is a company that makes a part that is marketed by another company typically as a component of the second company’s product. In the case of motors, it means a manufacturer of equipment that uses a motor.
fact is that motors are quite often used beyond their planes service lives (Figure 6). The service life of motors has generally been estimated at between 10-20 years but Swiss surveys have found a large proportion of older motors still in use, with some units up to 60 years old. If this finding is applicable in other markets, it suggests that the turnover of the stock will be slower than has often been predicted (IEA 2015). Therefore, measures addressing only procurement do not suffice.

Figure 6    Actual age of motors compared to planned service life (Source: IEA 2015)

Initiative has been taken at the international level by the International Energy Agency (IEA) to prepare a best practice guide for policy instruments in the area of electric motor systems. Policy Guidelines for Electric Motor Systems were issued by the Electric Motor Systems Annex (EMSA) within the IEA 4E Project in 2014. The aim is to provide assistance to policy makers who wish to design and to implement a strategy to encourage the greater energy efficiency of electric motors and motor systems in industry. The guidelines comprise a description of a Motor Policy Toolkit consisting of eight policy measures: MEPS, labelling, voluntary agreements with industry, energy management programs, energy audit programs, company motor policy, financial incentives and awareness/information measures. (EMSA 2014, Kulterer et al. 2015).

Action needs to be stimulated among all key stakeholders within the motor systems market to achieve long-term market transformation. Therefore, a comprehensive range of policies are required to influence international/national standard makers, industry associations, industrial users and power utilities. Figure 7 shows the main stakeholders in market transformation for the electric motors and EMDss: (EMSA 2014, Kulterer et al. 2015)

- National policy makers: Governments can set MEPS but for them to be effective, compliance needs to be enforced. MEPS based on international standards can
reduce trade barriers. In addition to MEPS, governments have a wide array of other policy instruments which can be used.

- **International standard makers:** The role of standardization is to develop standards in all relevant areas.
- **Manufacturers:** Together with industrial associations, the industry can develop and/or support energy label programs, establish accredited testing laboratories, initiate and support training programmes and define procurement guidelines.
- **Industrial users:** The users of motors are encouraged to set energy saving targets, define responsibilities and train personnel for designing new and retrofitting old motor systems.
- **Power utilities:** Power industry can design and run procurement programs and subsidy programs for end-users and use innovative financing instruments to benefit from energy savings.

![Diagram of Influence of National Policy Makers](https://example.com/figure7)

*Figure 7  Influence of national policy makers (Source: EMSA 2014)*

### 4.2 Minimum Energy Performance Standards

Minimum Energy Performance Standards (MEPS) are a legislative instruments used by national governments and the EU to remove the most inefficient motors and EMDSs from the markets. Already about 70% of electricity consumed by electric motors occurs in countries with motor
MEPS. When properly enforced, they area a potentially very strong instrument. Change, however, takes some time because it typically takes 4-6 years for the transition to new MEPS to be complete (Reine 2015).

Globally, the regulations on electric motors were first introduced in all around North America. The United States implemented standards through the Energy Policy Act of 1992, but it was not until 2007 that the standards were applied. This so-called EPAct 92 standard was comparable to the IE2 class but the US has already initiated the IE3/NEMA Premium Motors shift in 2010. In Canada the first requirements came into force in 1997 and Mexico adopted the US EPAct standard in 1998. (IEA 2011, Unido 2011)

Brazil and China issued the first MEPS in 2002 but these concerned standard efficiency motors. MEPS for IE2 level took force in Brazil in 2009 and in China in 2011 (see Case Study 2) and Brazil is considering shift to the IE3 level in 2017. Australia and New Zealand have set the MEPS at the IE2 level since 2006. Other countries with MEPS at the level of at least IE2 include Chile (2011-), Israel (2008-), South Korea (2013/IE2 level, 2015/partly IE3 level), Switzerland (2011/IE2, 2015/same level as Eco-design in Europe), Taiwan (2015-) and Turkey (2015-, same level as Eco-design in Europe). In addition, a number of countries have implemented requirements at IE1 level. (Almeida et. al. 2008, Siemens 2015, Unido 2011)In India a voluntary motor standard was first adopted in 2004 and revised in 2011 covering IE2 and IE3 motors. MEPS at the level of IE2 are under preparation and expected to be adopted during 2016. At present, IE1 motors or those with lower efficiency are imported to India from countries which themselves have issued MEPS and manufacturers take the opportunity to export lower efficiency motors to India as these products cannot be sold in the domestic market anymore. Indian manufacturers of efficient IE3 and IE4 motors usually export their products instead of selling them in the domestic market. (Kumar 2016)

In the EU, the first MEPS were issued in 2009 and by the implementation of the Eco-design Directive. From June 2011, IE2 level was required and further requirements took effect in 2015 (see Case Study 6). The relatively late introduction of the MEPS in Europe followed a period of Voluntary Agreement with the industry, which had had a limited impact on the market. Existing regulation only covers part of the electric motors placed on the market and the European Commission has initiated preparatory studies to evaluate the possibility of extending the scope to motors outside the current power range and to technologies other than three-phase induction motors. (Almeida et. al. 2015)

In 2015, Japan included electric motors into its Top-runner Programme (see Case Study 3). It is quite different in structure from traditional MEPS. The Top Runner Programme triggers race to the top among manufacturers because the product on the market with the highest energy efficiency (the Top Runner) sets the standard (energy efficiency improvement target) for others. In each product group the standard is revised every 3-4 years.

Figure 8 shows the annual realised and expected motor sales by efficiency class. It also relates the past and expected development to the introduction of progressive MEPS in some large market areas. Sales of IE1 motors are expected to somewhat decline by 2018 while the sales of IE2 and IE3 motors are expected to grow strongly. As the total volume of sales is growing, the proportion of more efficient motors in the totality is increasing.
In the above, only MEPS for electric motors are discussed. These are indeed widely applied globally. However, there are examples of MEPS also for EMDSs where a motor is a part of a wider system. This is particularly typical in consumer goods where the motor is completely integrated into product and there is a multitude of MEPSs for these product groups. In contrast, in industrial applications integrated systems (e.g. with pumps, fans and compressors) are excused from MEPS requirements. For example, Australia and New Zealand exclude motors that are constructed on the same shaft, e.g., compressors and air conditioning units. In the US, there are no efficiency standards for industrial pumps but the rulemaking process began in 2011 and according to the planned schedule, the standard is likely to be in place by the publication of this report. Further initiatives to regulate fans and compressors are underway in the US. Preparation of eco-design requirements for pumps and compressors is underway in the EU.

Establishing MEPS for EMDSs would require first segmenting the applications where motors are used. After this, requirements could be established for segments with largest saving potentials. Regulatory measures could go beyond devices and components that directly consume power also targeting the potential energy savings from improved energy performance of mechanical components, such as gears and drive belts. Certain common technologies are fundamentally inefficient and could potentially be regulated out of the market in favour of more efficient options. (IEA 2011)

4.3 Energy Management

Energy management systems (EMS) comprise a systematic and structured approach for reviewing the energy needs of a company and for implementing measures to reduce consumption, including putting in place monitoring and reporting systems. EMSs also cover
organizational issues, like purchasing rules for buying and installing highly efficient equipment, maintenance procedures, training of personnel and tracking and evaluation of suggested and implemented energy saving opportunities. (Kulterer et al. 2015)

Governments can play an important role in the implementation of energy management programs by establishing a framework to promote the uptake of EMSs, developing methodologies and tools and promoting the creation of new business opportunities in the area of energy services. (Kulterer et al. 2015)

A GEF-funded project implemented by Unido in Indonesia (Case Study 5) aims to promote pilot industries to have ISO 50001 certification during the project period from 2012 to 2017. The project is also building capacity through tools and training on energy management, including industrial systems optimization, to enable industries comply with ISO standards. Over 70 projects on system optimizations were identified during the pilot assessments, many of them involving motor driven systems with improvement potentials of 20% to 25%.

As industrial plants differ considerably from one another, so does the compressed air, pump or fan system and a system optimization is not possible without evaluating individual plants. Energy audits are an important energy management tool providing data on possible energy efficiency improvements and their cost-effectiveness. They can also pave the way for better commitment for implementing improvements. On the other hand, energy audits are often classified also as an information instrument. A certified energy management system necessitates the implementation of an audit. Otherwise, energy audits are carried out both on voluntary and mandatory bases. For example, European legislation requires periodical energy audits to be carried out in large enterprises.

The success of auditing schemes is closely linked with training of energy experts conducting audits. Therefore, particularly in developing countries, audit schemes should be accompanied by capacity development programmes. (Unido 2011)

Among other activities, energy audits (energy diagnoses) are part of the Brazilian National Electricity Conservation Programme (PROCEL) for industry (Case Study 1). Recently, PROCEL Industry has focused particularly on measures for optimising motor driven systems. In addition to energy diagnoses, the programme has had a strong focus on capacity development. Training in motor system optimization has been given to multipliers like university professors and consultants and motor system laboratories and education centres have been established in different universities. Next, multipliers trained industry staff in order for them to be able to conduct energy audits within their own companies. (Unido 2011)

In South Korea, energy audits are mandatory for energy-intensive companies whose annual energy consumption is over 2 000 toe (Case Study 9). Small businesses consuming less than 10 000 toe of energy annually are eligible for a 70% discount on the energy audit fees as charged by the government.

When considering the implementation of an energy management programme, there are a number of important considerations to be taken into account. They are given in the following box based on findings in EMSA (2014).
Implementation of an Energy Management Programme

- Clearly define the purpose of the programme
- Identify what materials and/or training are necessary to achieve the desired outcomes. E.g. guidance on how motor systems efficiency is to be considered within an energy management system, this would include:
  - The definition of purchasing criteria, motor inventory list, guideline for replacement, requirement for installation or acceptance tests, requirements for repair and maintenance.
  - The inclusion of purchasing recommendations (in cooperation with producers, suppliers and industry associations).
  - Design guidelines for the installation of new motor systems.
- To ensure active participation in the program, give careful consideration to how the program will be promoted and to any supporting mechanism for recognizing and communicating achievements. The program should consist of a balanced package of support, incentives and penalties for the target groups involved.
- Build mechanisms for monitoring the progress of participants and evaluating the success of the program into the program design. Decide what to measure and how and what level of reporting is required from participants to achieve this.

Source: EMSA 2014 and Kulterer et al. 2015

The following box describes an example of an innovative new approach developed in Sweden to help in energy management. The novelty of the MOVE Model is that it involves visualization, mutual learning, knowledge and experience sharing and can be implemented for identifying continuous improvement actions. The method was developed through a try-and-error approach, continuous improvement of the work methodology, testing in a pilot study and verifying in case studies. User-friendliness was considered the focus for paving the way for a future high implementation rate in organizations. The method involves a "train the trainer" concept which implies that corporate and process managers are trained by the project manager leading MOVE workshops. In this way, the knowledge stays within the company at the end of the project. (Svensson and Paramonova 2015)

The MOVE Model

The MOVE Model (Method for optimizing system efficiency in electric motor systems) was developed as an analytical methodology for identifying and addressing energy efficiency improvement opportunities in existing and new industrial electric motor systems. This participatory approach allows information acquired and knowledge gained by industrial personnel working with energy issues, maintenance, and production processes be immediately used for improvement suggestions.

MOVE is a four-step chronological model. An energy audit may be needed in order to define possible areas for improvement but it is not a requirement.
**Start:** An external ‘process leader’ coordinates the process. It gives a preparatory lecture with an overview on the methodology to the ‘process owner’ from the company. The process owner is a person employed by the manufacturing company and has formal major responsibilities in the manufacturing process analysed.

**Step 1:** The company organizes and sets up a ‘case study team’ (consisting of at least of 4 experts with right field of knowledge and expertise), collects critical data for the chosen manufacturing process and determines an internal strategy to carry out the activities in the following steps. The collected data are summarized and analysed by the external process leader. This is followed by a feedback procedure involving the process owner and experts.

**Step 2:** Process mapping (similar to value stream mapping) visualizes the process requirements affecting energy use, the product value flow and how it contributes to internal customer satisfaction. Here a requirement could be e.g. purity of a product and an internal customer e.g. the following manufacturing process which is outside the system boundary. The mapping process covers also “External efficiency”, i.e., “Why is energy used?” During process mapping, the most interesting requirements are identified and make up the overall criteria to fulfill in the identification of new energy efficiency measures. Process mapping is followed by brainstorming, which has two important functions: to involve all the participants and to make sure to capture efficiency measures which are outside the system boundary.

**Step 3:** Data is collected to describe the current system routines, automation controls and technical components and sort them out into seven motor system levels ranging from the motor (level 1) to full motor systems (level 3) and human factor (level 7). The existing system is described and the data are evaluated into three categories of energy efficiency. Step 3 concentrates on internal efficiency by choosing best technology and methodology to meet the requirements identified for external efficiency.

**Step 4:** In this step solutions are combined into a list of summarized energy efficiency measures. The measures are analysed, evaluated and placed on an evaluation matrix. Measures from different levels are combined to create new system solutions, meaning that improvements from multiple levels are merged into system efficiency measure. The matrix considers two important aspects of each measure, the impact and complexity of implementation. Finally, the measures are voted for and the highest-rated measures represent the area for the implementation process.

Source: Svensson and Paramonova 2015

### 4.4 Information Instruments

Information instruments are a mixed bunch of policies and measures consisting of both legislative initiatives (e.g. mandatory labelling) and information dissemination activities (e.g. capacity building, tools, advice, campaigns). Also energy audits discussed above (see Chapter 4.3) can be considered as information instruments.

#### 4.4.1 Energy Labelling

There are basically two types of energy labels in use, comparative energy efficiency labels and endorsement labels.
Energy labels are typically comparative with several categories (e.g. 1-5 stars or alphabetical rating). A product receives a label according to pre-set criteria and competition is created between models based on the rating. The system can be mandatory covering all products in a given product group or voluntary when not all products in the market must be labelled. Energy labels can be used in combination with MEPS whereby the lowest rating is the same as the MEPS minimum level.

In design of comparative labels, it is important that the scale is sufficiently broad to allow adequate differentiation between products and to avoid ‘bunching’ of products within one category at the top of the scale. In programme design of endorsement labels, the threshold for eligibility must be sufficiently high to accurately differentiate the best in the market place from the majority. The thresholds for all types of labels should be periodically reviewed and adjusted to reflect advances in technology. (Kulterer et al. 2015)

Endorsement labels given to products fulfilling pre-set criteria creates market advantage for producers whose products are labelled. An example is the Procel Seal in Brazil (Case Study 1) which is part of the Procel Programme. As of November 2015, 183 models had the label.

In China (Case Study 2), mandatory labels for small and medium motors were included in June 2008. The program applies to 0.75-375 kW, 2-6 poles, up to 1000 V/50 Hz, motors. To qualify for the label, small and medium motors must meet the requirements specified in the Chinese National Standard GB 18613-2012. The grades are in line with the classes in international standards IEC 60034-30 (IE2/IE3 motors) and IEC 60034-31 (IE4 motors). Motor efficiency must meet the specified level both at 100% and 75% loads. The labelling scheme complements a MEPS scheme whereby the minimum acceptable level is IE2. (Kulterer et al. 2015)

In India, motor labelling is voluntary (Case Study 4). The label consists of 1-5 stars depending on the efficiency. The labelling scheme complements a voluntary standard (and a forthcoming MEPS in 2016) whereby the minimum acceptable level is IE2.

The Extended Motor Product Label Initiative (EMPLI) is a US based collaborative effort to develop voluntary labels for motor-driven systems (e.g., a fan, pump, or compressor and the motor and associated controls) based on test standards, metrics and MEPS concurrently being developed by the US DOE. EMPLI involves over two dozen representatives from the motor-drive equipment manufacturing sector, trade organizations, utilities, energy efficiency program administrators, and energy efficiency nongovernmental organizations. The American Council for an Energy-Efficient Economy (ACEEE) has functioned as the convening organization. The performance metric has not been decided yet and it could be numerical (e.g., 40, 50, 60, and so on) or strictly comparative (e.g., “good,” “better,” “best”). It is anticipated that companies could require the forthcoming label as a purchasing specification as is the case with the NEMA Premium level for motors. The new labels can also be combined with energy efficiency programmes by utilities as they will simplify the measurement and verification (M&V) for incentive programs by establishing straightforward eligibility requirements and the associated deemed energy savings. (Rogers et al. 2015)
4.4.2 Capacity Building and Tools

One of the key barriers has been identified to be lack of know-how. Skills may be lacking or outdated leading to e.g. system oversizing and poor repair. Capacity building can take many different forms from formal training to seminars and workshops and providing advice, planning tools and handbooks.

Training courses organised by various bodies (e.g. the educational system, adult training organisations and motor manufacturers) are typically quite well available for acquiring or updating skills. However, the barrier is their cost including both work time and tuition. To lower costs, on-line training modules have been developed. In addition, e.g. many energy efficiency agencies publish handbooks and brochures for information dissemination. Also motor manufacturers publish technical information and tools e.g. to help in correct specifications.

Various calculation tools have been developed to enhance energy management and informed decisions. One example is the long-running tool MotorMaster+ in the United States and its spin-off MotorMaster International (Case Study 11 and Case Woodgrain Millworks). MotorMaster+ enables the companies to evaluate the energy efficiency opportunities of their motor-driven systems using an unbiased approach. This software tool handles everything from calculating the simple payback on a single motor purchase to comprehensive, integrated motor management. The software quickly identifies inefficient or oversized facility motors and computes the savings that can be achieved by replacing older, standard efficiency motors with premium efficiency models.

Case Woodgrain Millworks, United States
Woodgrain Millwork in Fruitland, Idaho, makes wood molding for door and window parts for manufactured housing. Electricity bills from running motors were $52,000 annually. MotorMaster+ software was used to compare an existing motor to comparable new energy efficient models. The software identified a new motor with 1.3 percent greater efficiency which would save $600 annually. The new motor was also priced comparably to the cost of the rewind and mechanical repairs, which were expensive. The motor was replaced for a more efficient one saving 20,700 kWh per year. Woodgrain has over 500 more motors in the plant multiplying the savings opportunities.


Another more recent example is the Motor Systems Tool developed under Electric Motor Systems Annex (EMSA) program in 2011. The tool is intended to assist engineers, machine builders, machine component suppliers, energy consultants and others working on optimizing machine systems to benefit from reduced electricity consumption. (EMSA 2015b)

Key objectives of the Green Deal Programme in the Netherlands (Case Study 7) are to encourage a wider application of efficient electric motor systems in industry by exploring and communicating the potential of motor systems in example projects, and strengthening the competitiveness of the partners by developing innovative products and services for motor systems. One of the three key elements of the Programme is knowledge transfer and communication to end users. Another one is developing a standard approach or working method for analysing and optimizing a specific motor system. Data from practical case examples
has been collected through piloting the approach. Savings range from 4-10% in cases where only older motors were replaced by premium motors up to 40% as a result of improving a total motor system. (van Werkhoven et al. 2015)

In Australia the Federal Energy Efficiency Information Grants are provided to industry associations and non-profit organisations that work with SMEs and community organisations to provide information on the smartest ways to use energy. Grants vary between $100 000 and $1 million for eligible projects.
Rewinding the coils

Information measures are usually the key to addressing potential efficiency losses caused by repair, particularly rewinding the coils in the case of breakages. The decision needs to be made between two options. One is spending certain amount on having the motor rewound and keeping the operating cost the same or even potentially higher due to efficiency losses. The other is spending more for a new efficient motor but reducing the operating cost.

The main steps in motor rewinding are the dismantling of the motor and checking for damages, removal of the old windings as well as insulation and cleaning of the stator core and, finally, rewinding with new wire and efficiency testing. Good rewinding needs reliable repair shops that use low temperature bake out ovens, high quality materials and a quality assurance programme to ensure that motor efficiency is tested after rewinding and that the motor was not damaged during the process. Rewinding is even more common in developing countries due to the relatively low labour costs and the high price of new motors. Some motors are rewound 5-6 times before they are finally scrapped. Due to risks of efficiency losses, Unido has recommended that rewinding should only be used for motors with low annual running hours (below 2 000 hours per year) and know-how in repair should be improved.

Effort has been made to standardize motor repair practices, including testing, e.g. by ANSI/EASA which issued the latest revision of ‘Recommended Practice for the Repair of Rotating Electrical Apparatus Standard’ (AR100-2015) in 2015.

Source: Unido 2011, EASA website

4.4.3 Awards and recognitions

Awards and recognitions are in place for motor manufacturers, motor repair and motor users. An example of each type is given here (Figure 9).

The Super-efficient Equipment and Appliance Deployment (SEAD) Initiative is a voluntary collaboration established in 2009 among governments working to promote the manufacture, purchase, and use of energy-efficient appliances, lighting, and equipment worldwide. The SEAD Motor Award is an international competition which identifies motors that demonstrated the greatest energy efficiency both internationally and in three regions – Australia, India, and North America. By recognizing and promoting super-efficient electric motors, the SEAD competition helps buyers make informed purchasing decisions that can lower energy bills and spur greater innovation among manufacturers. (SEAD 2015)

The Electro-mechanical Authority (EASA) in the US has developed an international accreditation programme that accredits motor repair companies which have successfully demonstrated that they follow the prescribed good practices to consistently deliver quality electromechanical repairs that maintain or improve electric motor efficiency and reliability. Independent third-party auditors are used in the evaluation. The programme includes mechanical repairs as well as electrical rewinding of three-phase, squirrel-cage motors that are repaired in accredited service centres. The programme is open both to EASA members and non-members. (EASA 2015)
Since the launch of the EU Motor Challenge Programme (see Chapter 4.6.1) in 1993, the Programme has been recognising the endeavours of participating industries by rewarding them with an award for demonstrating the most efficient and innovative ways of transforming electrical into mechanical power, recognising the importance of electrical motors as central devices in modern industrial production.

![Motor Challenge Programme](image)

Figure 9  Examples of motor award programmes

4.5 Economic Incentives

Despite typically very short pay-back times of VSD installations and relatively short pay-back times of efficient motors in comparison to their lifetimes, financial incentives still have an important role in the implementation of improvements. Even a moderate economic incentive can be the final trigger for an energy efficiency investment being implemented as they tend to be of secondary importance in decision making in industry compared to investments in production - regardless of their cost-effectiveness.

4.5.1 Subsidies

It is quite usual that subsidies are given to promote energy efficiency. Energy efficient motors and VSDs are among the commonly supported technologies. Subsidized energy audits promote a bit more indirectly the shift to better efficiency. In development countries investments may be financed by international financing institutions instead of government policies and programmes.

Eskom in South Africa (Case Study 8) launched an Energy Efficient Motors Programme in mid-2007. The programme promotes the replacement of old, inefficient motors with new, highly-efficient motors, through subsidising the purchase cost. Efficient motor suppliers registered with Eskom are directly paid the subsidy, resulting in an immediate discount off the purchase price for the consumer. For motors to be subsidised, the suppliers must be accredited.
by Eskom, for the company’s financial status and the motors technical specifications to be verified and approved. The purchaser must trade in their old motor, along with all components, for scrapping. Subsidies ranging from ZAR 400 to ZAR 3 500 (27-233 euros) are offered for premium efficiency motors. Eskom regularly performs random process compliance audits, while an independent measurement and verification body will verify the megawatt savings achieved by the programme. (IEA Energy Efficiency Policies and Measures Database)

In Turkey, businesses having less than 250 employees and an annual energy consumption over 200 tep\(^6\) can benefit of grants from the KOSGEB (Small and Medium Enterprises Development Organization). The level is up to 60% of the project cost with cap of 30 000 TL (about 9500 euros). YEGM Productivity Enhancement Project (EIP) runs another programme, where energy-saving measures identified through energy audits can benefit from grants up to 30% of the cost of the investment required, with an upper limit of 300 000 TL (about 52 200 euros). The payback period should be 5 years or less.

In Switzerland, the Competitive Tender Programme supports financially the implementation of the federal Energy Strategy 2050 (Case Study 10). Funding is granted on the basis of an auction process for projects with the lowest cost efficiency per saved kWh i.e. project which would not have been implemented without the subsidy. Subsidies vary from 20% (payback time at least 2 years) to 40% (payback time at least 6 years) of eligible costs. The tenders are funded by a surcharge on transmission cost in the high voltage electricity grid. In New Zealand, subsidies are given for businesses that invest in energy-saving technology, in the case of motor replacement up to NZ$ 2 000 (about 1200 euros).

The Chinese “Ten Key Projects” Programme was launched in 2004 and it has been included both in the 11th and 12th 5-year plans (FYP). Motor system energy conservation is among the Ten Key Projects and the objective was to improve energy efficiency by 2-3% by 2015. Financial rewards were given for realised energy-savings. During the 12th FYP the rate of rewards was 250 RMB (about 36 euros) per tce saved in East China and 300 RMB per tce\(^7\) saved in Central and West China. The threshold of minimum energy savings to qualify for the rewards was 5 000 tce.

In Australia, the Clean Technology Innovation Program offer grants of AUD 50 000 to 5 million (33 300 to 3.3 million euros) on a dollar-for-dollar basis to companies investing in research and development in the energy efficiency field. In addition, merit-based grant mechanisms are in place for investments in energy efficient capital equipment and low emissions technologies, processes and products.

In Europe financing is available also from the EU through structural and investment funds, particularly the European Regional Development Fund which supports e.g. energy efficiency in SMEs and the Cohesion Fund which supports new EU Member Countries. (EU 2015)

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\(^6\) 1 tep = 41.868 GJ = 11.63 MWh

\(^7\) 1 tce = 29.306 GJ = 8.14 MWh
4.5.2 Fiscal Incentives

Fiscal incentives are most commonly tax deductions on energy or environmental taxes, or accelerated depreciation allowance for capital cost.

In Sweden, a possibility for a tax rebate on electricity tax has been used as a ‘carrot’ in the voluntary energy efficiency agreements provided that energy management system is implemented and savings are achieved (see Chapter 4.6.1).

Singapore allows one-year depreciation instead of normal three years for replace old, energy-consuming equipment in its scheme ‘One-Year Accelerated Depreciation Allowance for Energy Efficient Equipment and Technology’ (ADAS). List of eligible equipment covers high efficiency electric motors and VDSs.

Similarly in the United Kingdom, the Enhanced Capital Allowance (ECA) scheme provides businesses with a first year 100% tax allowance on designated energy efficient equipment investments, including energy efficient motors and VDSs. The list of eligible products (the Energy Technology Product List, ETPL) is updated monthly.

In the Netherlands, an asset is eligible for 41.5% deduction from the taxable profit when it is more energy efficient than standard equipment used; this means a net discount of approximately 10% of the investment costs given the 25% taxation level for Dutch businesses.

4.5.3 Soft Loans

A soft loan is a loan given with lower interest rate than typically available in the market. In addition, it can include an interest-free grace period and other provisions such as sifting the requirements for guarantees. Typically, soft loan programmes target small and medium sized enterprises (SMEs). According to the WEC database on Energy Efficiency Policies and Measures, these programmes are as common both in OECD and non-OECD countries. In non-OECD countries loans are often provided by international development organisations.

In Taiwan low-interest loans are provided for SMEs for the purchase of e.g. energy conservation machinery and equipment, including high-efficiency motors and compressed air systems. The low-interest loans can cover up to 80% of the investment cost. Up to 90% of interests are supported by the Small and Medium Businesses Foundation. The loan period is seven years including a 3-year grace period.

In France the Eco-Energy Loan Programme, running since March 2012, is designed for SMEs to finance certain particularly energy-intensive technologies including electric motors. Loans have a 2% interest rate and range from 10 000 to 50 000 euros for a period of five years, including one year grace period. No additional guarantees may be required.

4.6 Other Policies and Measures

4.6.1 Voluntary Agreements

Two types of voluntary agreements have impact on motor efficiencies. One type is voluntary agreements with motor manufacturers on moving towards higher efficiencies. The European Union had a voluntary agreement with European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) from 1999 until the introduction of MEPS.
Another type of voluntary agreements are those signed between national governments and industry. Typically the agreements cover all types of energy and systems in industrial facilities, not concentrating particularly on motors, but motor or EMDS improvements are implemented among other measures. The voluntary agreements can be introduced as stand-alone measures or as a part of policy package consisting of e.g. subsidised energy audits, financial incentives (investment subsidies or tax rebates). Obligations for energy management systems can be incited on companies joining the agreements.

In Finland, industries joining the voluntary energy efficiency agreements have often carried out subsidised energy audits but due to the implementation of the Energy Efficiency Directive, subsidies are available only for industries not subject to mandatory audits stipulated by the Directive. Energy intensive industries joining the agreements must implement an energy management system (EMS).

In a voluntary agreement scheme in Sweden, energy intensive industries implement a standardised EMS and carry out an energy audit. Subject to implementation of measures, the companies can avoid paying the electricity tax. New entrants to the programme were accepted from 2005 to 2012 and the programme will seize in 2017 because the tax rebate cannot be continued for EU rules.

The Motor Challenge Programme is a European Commission voluntary programme (launched in February 2003) through which industrial companies are aided in improving the energy efficiency of their Motor Driven Systems (JRC website). The core of the Programme is an Action Plan by which a Challenge Partner commits to undertaking specific measures to reduce energy consumption. The Partners will receive advice and technical assistance in defining and carrying out the Action Plan and public recognition for their contribution to achieving the objectives of the European Union’s energy and environmental policies. An evaluation report from 2010 showed moderate savings of 185 GWh/a due to the limited number of participants. Motor Challenge Programme has been launched also, e.g., in the US.

4.6.2 Energy Saving Obligation Schemes

Under an energy saving obligation scheme energy suppliers or distributors are obliged to achieve certain energy savings among their customer. White certificates are documents certifying that this saving has been achieved. The certificates can be tradable.

The Italian white certificates scheme, which has been in operation since 2005, imposes obligations on electricity and natural gas distributors with more than 50 000 customers. One of the eligible measures is improving the efficiency of electric motors in industry. Each of the eligible projects is expected to issue tradable white certificates for a period of five years (Di Santo et al. 2014)

In Poland, the Energy Efficiency Act of 2011 introduced a white certificate scheme and it started at the end of December 2013. An obligation is placed on suppliers of electricity, heat and gas fuels to end-users. Investors prepare investments and take part in a tender procedure organised by the Energy Regulatory Office. The right of issuing tradable white certificates based on projects savings is liked to success in the tendering procedure. For example, replacement of electric motors and installation of variable speed drives to industrial motors is listed among the eligible project types.
4.6.3 **ESCO Financing**

An Energy Service Company (ESCO) is a company delivering energy efficiency services and being wholly or partially paid based on the achievement of energy savings and/or on the meeting of other performance criteria. ESCO services can consist of energy audits, feasibility studies, engineering design, equipment procurement, subcontractor management, construction, measurement and verification, operation and maintenance and organising the project financing. Replacement of electric motors, installation of variable speed drives (VSD) and compressed air systems can be among the technologies covered by ESCOs. (Serrenho 2013)

The Joint Research Centre (JRC) has studied the both the general barriers for ESCOs as well as specific barriers for ESCOs in motor systems (Serrenho 2013). General barriers include e.g. low awareness, lacking motivation and small project size particularly in SMEs. In addition, the following barriers specific to motor systems were identified:

- Difficulty to predict energy consumption and assess the project risk
- High transaction costs
- High technical risk perceived and concerns over the safety and reliability of equipment
- Fear of job losses
- Energy savings are “not tangible”
- Lack of trust in ESCOs

The JRC (Serrenho 2013) proposes to alleviate the problem particularly in the SME segment of industry by creating “mini-ESCOs” of the mechanical/electrical service contractors who already work with SMEs. Most SMEs already have trusted service contractors who know their facilities well and there is an on-going working relationship. The contractors provide preventive maintenance, breakdown repairs and sometimes small capital upgrades. Small contractors are particularly sensitive to maintaining good customer relations meaning that complex contracts are not necessarily needed to cover contingencies of savings being less than a guaranteed level. The overhead of building a new relationship with a new ESCO can be avoided.

More recently there has been increasing interest by VSD manufacturers to install VSDs in industrial facilities using the ESCO model. In some cases the VSD manufacturers have teamed up with an existing ESCO serving industry. The ESCO has provided an energy audit, arranged financing, provided technical guarantees and monitored the savings. (Serrenho 2013)

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**Case Kemira, Finland**

In Finland, VSDs were installed in five industrial fans (1 290 kW) in a fertilizer factory. Power demand was cut down to 480-580 kW and annual energy savings totaled 4 000 MWh/a. The savings opportunity was identified in an energy audit and implemented through the ESCO model. An investment subsidy of 25% was given to the investment. The contract period with the ESCO company was three years during which the ESCO received 80% of the avoided costs of electricity.
4.6.4 **Technology procurement**

Technology procurement is a method to trigger producers to develop more energy efficient and thereby more environmentally friendly products and systems by making an effort to aggregate demand. These competitions do not aim to support individual manufacturers, but to influence the entire market. Elements of a procurement competition for new technology are:

1. A consortium is formed
2. Each purchaser pledges to buy a specific amount of the winning product
3. The purchasers identify their needs and express their requirements in a detailed list (the enquiry specification)
4. Companies issue detailed technical description of their proposed or actual products
5. Product prototypes complying with the specifications are ordered and tested
6. Limited numbers of the best product or products are ordered and tested
7. One or more winners are selected. Apart from getting the honour, these are awarded either financial means or an order of a number of products from the purchasing group.

The Swedish Energy Agency has initiated and partly financed nearly 60 technology procurements since the beginning of the 1990s. The Agency can also give an investment support to the first series produced. Motors have been part of the technology procurement scheme (MURE 2015). The IEA has sponsored a number of technology procurement projects for electric motors.
Conclusions and Recommendations

Given the relative significance in global energy consumption, electric motors and electric motor driven systems (EMDS) need to have a particular focus in policy making. However, they are quite often addressed in the broader context of industrial energy efficiency; this can be seen e.g. in various international databases on energy policies and measures. It would be useful to check whether the existing national measures adequately address EMDS or whether more focused policies and programmes are needed. For example, should there be specific audit models for these systems for cases when the industry may consider a full audit too heavy.

Tapping the large potential associated with motors, requires a system approach for the whole EMDS. Focus is quite often only in motors as demonstrated by the lack of Minimum Energy Performance Standards (MEPS) for EMDS. Some initiatives have been taken in this respect but more decisive action is needed. A particular concern is the system oversizing which requires information dissemination but could also be addressed by creating co-operation between users and manufacturers of motors and the other components of EMDS.

International standards are an important basis for establishing national MEPS which have been widely introduced and proven a successful policy tool. However, any inconsistencies in national MEPS with respect to international standards should be eliminated to avoid trade barriers. It also takes a considerable time for the MEPS to transform the market and they only affect sales of new motors. MEPS need to be made more stringent over time, however, with a view to the changes in cost-effectiveness, and possibly extended to a larger power range. The IEA (2015b) proposes in its roadmap for motors that North America, Europe and Japan could aim at adopting MEPS level of IE4 by 2020 or soon after.

At the moment it is a concern that MEPS are not in place even in all large markets such as Indian and Russia but also many smaller non-OECD countries lack MEPS. In total, about 30% of electricity used by motors is consumed in markets without MEPS. This is a missed opportunity, particularly in countries with growing industry because energy efficiency and better competitiveness in the longer term could be pursued from the beginning. Globally operating motor manufacturers are making an advantage of the situation by selling poorer efficiency motors to these markets while MEPS are in place in their home markets.

The use phase is very important as well and special situations, like behaviour at breakage, all have efficiency implications. This phase can be addressed by energy management and energy services (e.g. energy audits), information measures and electricity taxation.

Introduction of Energy management systems (EMS) need to be encouraged. EMS comprise a systematic and structured approach for reviewing the energy needs of a company and for implementing measures to reduce consumption, including putting in place monitoring and reporting systems. EMSs also cover organizational issues, like purchasing rules for buying and installing highly efficient equipment, maintenance procedures, training of personnel and tracking and evaluation of suggested and implemented energy saving opportunities. Therefore, EMS has an impact both on the use phase and investment behaviour.
Energy audits are an important tool for effective energy management. Savings opportunities can be recognised both for motors and EMDS, such as compressed air systems. While full scale EMS may be a too heavy to implement particularly in smaller industries, tools like energy audits could still be applicable. Undertaking an energy audit may also warrant use of financial support.

There are clear information barriers which hamper energy efficiency. Further effort is needed in building up skills. One major issue is rewinding the coils at motor breakage. This can be done 5-6 times during motor lifetime, particularly in developing countries. UNIDO has recommended that rewinding should only be used for motors with low annual running hours (below 2 000 hours per year). Without taking up a stand on the proposed threshold, widely communicating this kind of clear rules of thumb could change behaviour.

The existing motor stock is also surprisingly old in industrialised countries if the results of a Swiss survey can be generalised. One effective policy is auditing of EDMS which gives information on the pay-back times. Information on good examples, results of real saving projects, can also be disseminated.

The requirements for pay-back times in industry are stringent and even more so in the times of sluggish economy. Industry seldom implements pure energy efficiency investments with pay-back times beyond one year. Even in industrialised countries, financial/fiscal incentives are needed to make energy efficiency investments attractive in comparison to other investments. Even a relatively small support can give important psychological leverage.

Advantage needs to be taken of benefits beyond direct monetary gains from lower energy bills. Better reliability and flexibility, safety, increasing production volumes as well as improved operation conditions and easier maintenance are all important factors for industry. These benefits can be achieved by using more efficient modern motors which needs to be emphasised in communication with the industry.
Summary

6.1 Introduction

Electric motors convert electrical power into mechanical power within a motor-driven system (EDMS). Most common EMDSs in industry are pumping, compressed air and material processing. The vast majority of the electricity used by an EMDS is consumed by the electric motor itself but considerable savings opportunities lay at the system level. The biggest proportion of motor electricity consumption is attributable to mid-size motors with output power of 0.75 kW to 375 kW.

The proportion of electricity consumption by EDMS in industry is up to 46% of global electricity use. In industry, EMDS are estimated to account for approximately 70% of electricity consumption.

The cost-effective potential to improve energy efficiency of motor systems is roughly 20% to 30%, which would reduce total global electricity demand by about 10%. Technical measures for achieving the potential are using properly sized and energy-efficient motors, using variable speed drives when appropriate and optimization of the whole EMDS.

6.2 Driving Forces and Barriers

In addition to energy savings, and consequent cost savings, better technology entails other benefits. Reliability and flexibility, safety, increasing production volumes as well as improved operation conditions and easier maintenance are all important factors for industry and need to be emphasized in designing policy interventions.

The policy framework can be a very strong driver from the company point of view. Manufacturers simply have to conform to the legal requirements of the target markets. Users can either be forced to implement measures by legislation or they can be encouraged by providing supporting policy infrastructure (e.g. voluntary agreements), energy management tools (energy audits) and economic incentives.

It is necessary for manufacturers to recognize business opportunities laying in customer needs. Those understanding these best can gain competitive edge. In addition to striving to develop new efficient models, various tools and services can be provided to customers including training, service contracts and analytical services for system optimization. At the same time manufacturers can take the opportunity of demonstrating corporate responsibility and building good image.

There are numerous reasons why the savings potential is not realized even when payback times are short. The most significant among them appear to be lack of legislation. Quite often attention is paid only to procurement price and lifecycle analysis is missing. Inadequate and outdated skills lead to system oversizing (60% of systems are oversized). There may not be
adequate attention to energy management in general, replacement culture is missing and inappropriate recoiling practices corrode energy efficiency. The issue of recoiling is particularly serious in developing countries but happens also in industrialised countries.

6.3 Starting Points for Policy Intervention

Action needs to be stimulated among all key stakeholders within the motor systems market to achieve long-term market transformation. Therefore, a comprehensive range of policies are required to influence international/national standard makers, industry associations, industrial users and power utilities.

As shown by the following figure, policies and measures are needed in all phases of the motor lifecycle, ranging from product development and marketing to procurement and use. In 2014, 45.8 million low voltage motors were sold globally. The volume is estimated to grow to 51.6 million by 2019 representing a 2.5% annual growth rate. Many important policies and measures are in place to address the efficiency of new motors.

The use phase is very important as well and special situations, like behaviour at breakage, all have efficiency implications. One important goal is to activate replacement of old motors because many motors are used well beyond their planned service lives. The service life of motors has generally been estimated at between 10-20 years but Swiss surveys (IEA 2015) have found a large proportion of older motors still in use, with some units up to 60 years old.

Figure Policies by product cycle phase (Source: based on IEA 2011, modified by Motiva)
Initiative has been taken at the international level to prepare a best practice guide for policy instruments in the area of EMDS. Policy Guidelines for Electric Motor Systems were issued by the Electric Motor Systems Annex (EMSA) within the International Energy Agency’s 4E Project in 2014. The aim was to provide assistance to policy makers who wish to design and to implement a strategy to encourage the greater energy efficiency of electric motors and motor systems in industry. The guidelines comprise a description of a Motor Policy Toolkit consisting of eight policy measures: MEPS, labelling, voluntary agreements with industry, energy management programs, energy audit programs, company motor policy, financial incentives and awareness/information measures.

6.4 Policies and Measures

Minimum Energy Performance Standards (MEPS), energy labels, procurement tools as well as subsidies and tax rebates all address the energy efficiency of new motors.

MEPS are a legislation tool banning the sales of least efficient motors; already about 70% of electricity consumed by electric motors occurs in countries with motor MEPS. In most cases, national MEPS are harmonized with internationally standardized energy efficiency classification of motors. At present, the international standard IEC 60034-30 specifies four classes: IE1 (standard efficiency), IE2 (high), IE3 (premium) and IE4 (super premium).

If properly enforced, MEPS are a strong policy tool for new motors, but the amount of motors replaced or new investments are only a fraction of the total motor stock. The installed base is typically 7 to 11 times the annual domestic sales volume. In addition, MEPS have no influence on, e.g., correct sizing, installation and running times. Lastly, as long as MEPS are not implemented everywhere or continue to be implemented at different levels of ambition, inefficient motors still continue to have global export markets.

Comparative or endorsement labels on mandatory or voluntary basis are in place in numerous markets. These increase the visibility of energy efficient alternatives. International awards on efficient motors have the same effect, however, they are not as well known by those making procurement decisions.

Various calculation tools have been developed to enhance informed decisions. Tools are available for life cycle analysis of different alternatives as well as for system sizing.

Subsidies, tax rebates or accelerated depreciation may be available for procurement of efficient motors. Energy efficient motors and variable speed drives are among the commonly supported technologies in industry. In development countries investments may be financed by international financing institutions instead of government policies and programmes.

Also financing is an important in the implementation of investments. A soft loan is a loan given with lower interest rate than typically available in the market. In addition, it can include an interest-free grace period and other provisions such as sifting the requirements for guarantees. Typically, soft loan programmes target small and medium sized enterprises. For larger industries also third party financing by energy service companies (ESCOs) may be an option.
The use phase is very important as well and special situations, like behaviour at breakage, all have efficiency implications. This phase can be addressed by energy management and energy services (e.g. energy audits), information measures and electricity taxation.

Energy management systems (EMS) comprise a systematic and structured approach for reviewing the energy needs of a company and for implementing measures to reduce consumption, including putting in place monitoring and reporting systems. EMSs also cover organizational issues, like purchasing rules for buying and installing highly efficient equipment, maintenance procedures, training of personnel and tracking and evaluation of suggested and implemented energy saving opportunities. Therefore, EMS cannot be considered only as a measure for the use phase but it has improves investment behaviour as well.

Energy audits are an important tool for effective energy management. Savings opportunities can be recognised both for motors and EMDS, such as compressed air systems. Energy audits are implemented both on voluntary and mandatory basis in different countries or markets.

One of the key barriers has been identified to be lack of know-how. Skills may be lacking or outdated leading to e.g. system oversizing and poor repair. Capacity building can take many different forms from formal training to seminars and workshops and providing advice, planning tools and handbooks.

From user point of view, voluntary agreements can encourage implementation of measures on voluntary basis which is always more preferable to businesses, however, with the understanding that more stringent measures are like to be introduced if voluntary approach does not deliver adequate energy savings. One possibility based on normative steering are the energy saving obligations schemes (white certificate schemes), whereby energy suppliers or distributors are obliged to achieve certain energy savings among their customer.

6.5 The Way Forward

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References


Internet sources:

- Databases on energy efficiency policies and measures:
  - WEC: [https://www.worldenergy.org/data/energy-efficiency-policies-and-measures/](https://www.worldenergy.org/data/energy-efficiency-policies-and-measures/)