Global effort for efficient motor systems: EMSA

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Abstract

Electric motor systems use 45% of electricity worldwide [1]. Savings potentials from motor systems are known, however, are largely not realized. The goal of the internationally coordinated program Electric Motor Systems Annex (EMSA) under the International Energy Agency's Implementing Agreement 4E (Efficient Electrical End-Use Equipment) is to spur a global market transformation towards efficient electric motor systems. The purpose of this paper is to show EMSA's efforts and results to date.

Facing the challenge of exploiting savings potentials in motor systems worldwide, EMSA identified four levels of action: 1) personal, 2) company, 3) national and 4) global level.

On the personal level, EMSA aims to raise awareness of industrial plant engineers, government and academia with its regular newsletter (2-3 issues per year). By means of a Motor Systems Tool calculating system efficiency, training materials with information and guidelines on motor systems efficiency, motor testing and Minimum Energy Performance Standards (MEPS) EMSA intends to stimulate action.

On the company level, EMSA will produce guidelines for the implementation of the international standard ISO 50001 for energy management, with a special focus on motor systems efficiency. A MEPS overview shall help motor manufacturers and users identify what minimum standards motors offered for sale on the market must comply with.

On the national level, EMSA aims to inform governments on savings potentials in motor systems and enhance information exchange. The EMSA Motor Policy Guide shows existing motor policies and gives recommendations on optimal policy design and implementation.

On the global level, EMSA advocates harmonized MEPS, motor testing and classification standards. EMSA encourages a dialogue between testing centres worldwide. It launched a software round robin to compare calculation algorithms and prepared a guide to test standard IEC 60034-2-1. EMSA also fosters a dialogue between stakeholders to create appropriate standards for new motor technologies (switched reluctance, permanent magnet).

Any country wishing to join forces with EMSA is welcome to do so.

Introduction

Electric motor systems are responsible for 45% (7 100 TWh per year) of global electricity consumption. 64% (4 500 TWh per year) of this is consumed by motor systems used in industry [1].

Savings potentials in motor systems exist, but are largely not realized. In order to facilitate the realisation of savings potentials, the international program Electric Motor Systems Annex (EMSA) was launched for a period of three years (2009 – 2011). EMSA was launched as part of the International Energy Agency's (IEA) Efficient Electrical End-Use Equipment (4E) Implementing Agreement, established in 2008. Five countries; Australia, Austria, Denmark, Netherlands and Switzerland are currently active in EMSA.

EMSA's goal is to push forward a global market transformation towards the use of more efficient electric motor systems by supporting governments in implementing relevant motor policies.

EMSA aims to motivate and support engineers, policy makers and their organisations and institutions to act on motor systems efficiency by targeted information (research, tools, training and events) and liaison between relevant stakeholders. This paper presents EMSA's efforts on this path.

The EMSA collaboration

The EMSA participants divide their work into Tasks, with one country taking the lead:

- Task A: Implementation support & outreach (Switzerland)
- Task B: Technical guide for motor systems (Denmark)
- Task C: Testing centres (Australia)
- Task D: Instruments for coherent motor policy (Austria)
- Task E: Training & capacity building (Denmark)
- Task F: Energy management in industry (Netherlands)
- Task G: New motor technologies (vacant)

Several countries are working together within one Task, sharing information and exchanging experience among each other. Country representatives meet twice a year to discuss progress and collaborate on issues of common interest. Meetings are often held back to back with international conferences (EEMODS, Motor Summit).

Savings potential

An estimate of the potential of global electricity savings in electric motor systems from 2010 to 2030 has been calculated and published in a Working Paper of the International Energy Agency [1]. According to the reference scenario, the electricity consumption of motor systems will almost double by 2030 due to growth especially in developing countries. The policy scenario shows a reduction potential of 20% which can go to 30% according to the least cost strategy.

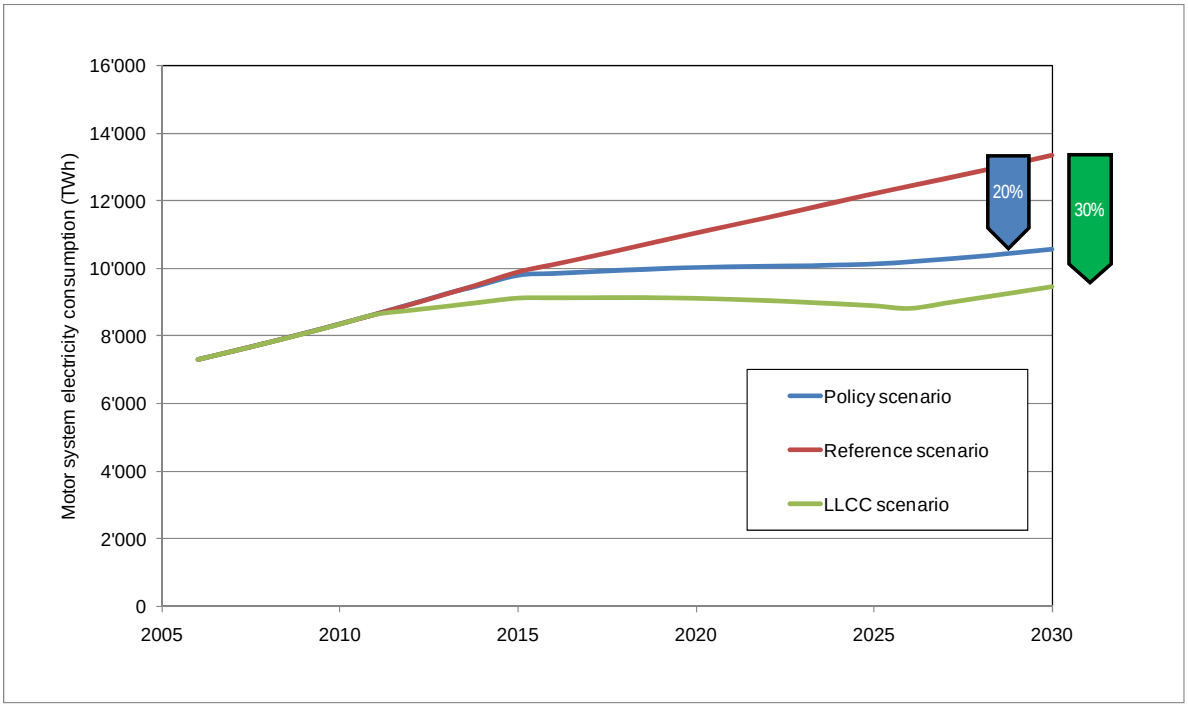

Figure 1 Scenarios for future development of global motor system electricity consumption
Source: [1], LLCC: Least Life Cycle Costing

The three key regions with the highest motor systems energy consumption are the USA, the EU-27 and China respectively. These three regions together consume about 56% of motor systems energy demand worldwide.[1]

Barriers

There are several barriers impeding the diffusion of efficient motor systems.

According to market theory, companies should choose to invest in efficient motor systems if the investment is profitable due to the savings from reduced energy costs. However, reality shows that despite the investments being profitable, this is often not the case. This may be explained by market deficiencies, such as:

- imperfect information: lack of information;
- adverse selection: if purchasers know less about (the energy performance) of products than suppliers, they may select on visible aspects (price);
- split incentives: priorities of company departments may conflict (e.g. product purchase requirements with short pay-back may impede efficiency investments with longer pay-back);
- hidden costs: e.g. for information collection and analysis, or a disruption in production;
- limited access to capital;
- risk aversion;
- etc.

Barriers to international trade include:

- different voltages and frequencies in different regions;
- differences in metric systems: SI (International System of Units) versus imperial;
- differences in standardisation (MEPS, efficiency classification and testing).

Motor manufacturers sell standard general purpose motors from catalogues and keep the most frequently used sizes in stock for rapid delivery. To keep production costs low (sustaining economies of scale) and being able to immediately remedy a failure and replace a damaged motor, motor manufacturers keep the number of motor types and models sold at a minimum. These generally do not include the most efficient motors.

Motor systems users fear production interruption, as it jeopardises core business: the manufacturing process. This leads to the practice of oversized motors, for presumably safe and continuous operation[2]. Motor users do not ask for life cycle costing but give more weight to the purchase price of the motor when they choose which model to buy. This is not a rational behaviour, as over 90% of the life cycle costs (purchase, operation, maintenance) of an average industrial motor are due to its electric energy consumption [3].

[1] For more details on this global analysis and its results, see also the paper by Conrad U. Brunner “Harmonised Standards for Motors and Systems” written for the 7th International Conference on Energy Efficiency in Motor Driven Systems, Alexandria VA, 2011 - EEMODS’11.

[2] Motors are most often oversized to make them „strong enough” for the starting torque of the machine and – allegedly – ensure that machines are starting and running smoothly. However, once the machine is running, it requires less power which makes the motor operate at partial load and hence a lower efficiency.

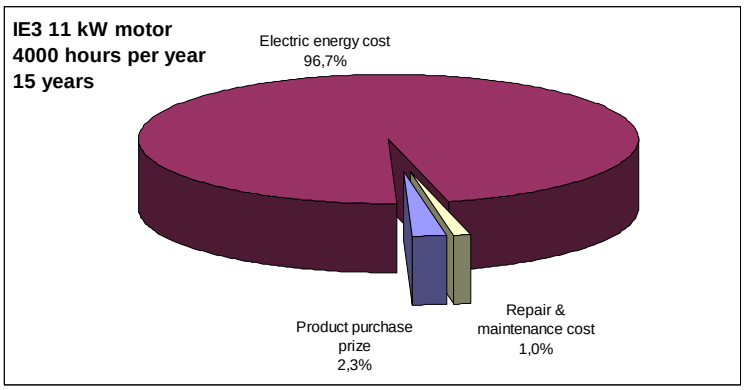

Figure 2 Life cycle cost of an 11 kW motor
Source: [3]

The fact that motor systems are very complex constitutes another barrier. In order to gain substantial savings, it is not enough to replace one system component, but the whole system needs to be assessed. In most cases, sufficient knowledge on energy efficient motor systems design and operation is lacking. Nevertheless, if there is an engineer willing to search for new technical solutions, this will require considerable time and effort, taking also into account convincing others (senior management) for an investment into energy efficiency.

How to exploit savings potentials?

In order to benefit from the available savings potential on a global scale, a systematic approach needs to be used.

Firstly, relevant actors need to be identified. Secondly, possible actions to motivate actors and steer the market towards energy efficient motor systems need to be designed.

64% of the energy consumption of motor systems is due to their use in industry. How does the industrial sector operate?

Qualified people are working in industrial plants worldwide to create value and satisfy their customers with their products. These plants are owned by companies which operate in countries where the applicable national laws and regulations are setting the context for the companies' rules of operation. The companies may deliver their products to other countries, where again the applicable national laws define what can be sold. All these national markets divided – or united (e.g. the European Union) – by laws and regulations add up to a global market. This structure led EMSA to the identification of four relevant groups of actors (see Figure 3), hence four levels of action:

1. Personal level: engineers responsible for the design, operation and maintenance of motor systems in industrial plants;
2. Company level: companies owning and operating these industrial plants;
3. National level: policy makers influencing the market by legally enforced Minimum Energy Performance Standards and other policy instruments;
4. Global level: all countries where motors are sold and motor systems used.

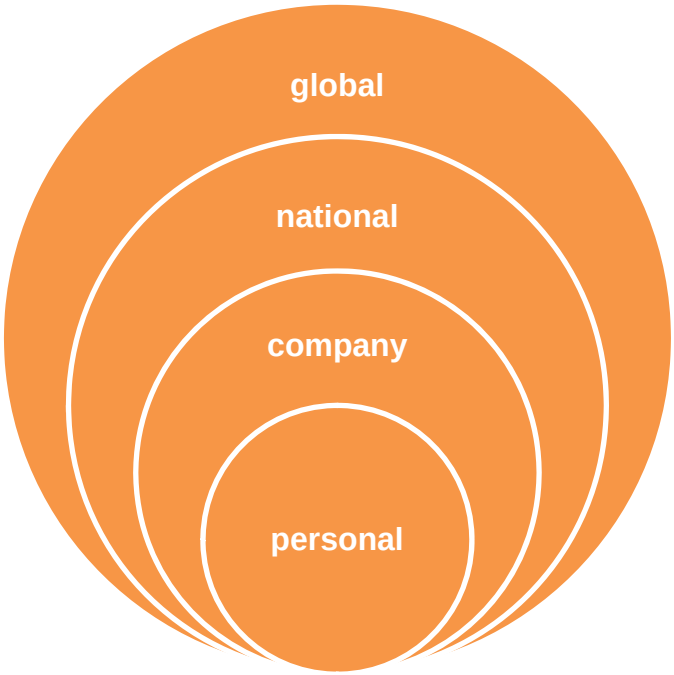

Figure 3 Relevant actors and levels of action
Source: A+B International, 2011

This approach needs to be complemented with attempting to understand the way of thinking of the relevant groups of actors:

1. How to motivate plant engineers for action?
2. How to motivate companies for action?
3. How to motivate and support policy makers in creating effective motor policy instruments?
4. How to motivate and support policy makers in harmonizing their efforts worldwide?

The EMSA project group faced these questions when defining its work plan. The following section gives an overview of how EMSA aims to answer these questions and what results the collaboration of EMSA members has delivered.

1. Personal level

How to motivate plant engineers for action? According to EMSA, on the one hand by stimulating their sensitivity towards motor system efficiency issues. On the other hand with specific trainings, informing on system approach and life cycle costing.

Global Motor Systems Network

EMSA distributes its regular newsletter with information on latest technology, standards and policy developments across the globe as well as upcoming events concerning efficient motor systems. The newsletter has 2-3 issues per year and reaches over 2000 people in industry, government and academia. Editions are available in English, Chinese and German and are also available for download on www.motorsystems.org.

Figure 4 Snapshot of the EMSA Newsletter 4/2011: English version

Capacity building

It is not enough to raise awareness of engineers about motor systems efficiency but qualified professionals also need to be motivated and trained to act on it. For this, EMSA is preparing training materials which will be made available for download at www.motorsystems.org.

The training materials will address issues such as motor system design and optimization, motor system retrofits, life cycle costing, Minimum Energy Performance Standards (MEPS) for motors and core motor systems (e.g. fans), application of international IEC testing and classification standards, and so on.

Motor Systems Tool

Motor systems are complex interactions of different components and often oversized (see Barriers) [1]. Whether improving the efficiency of an old system or installing a new system, the optimization is not always self-evident. To help engineers in system optimization, EMSA prepared a Motor Systems Tool.

The Motor Systems Tool calculates the efficiency of complete motor systems. It provides technical support for choosing the optimal motor system.

The Motor Systems Tool takes into account all four main elements of a motor system: primary load, transmission, motor and control system. It calculates the load on each element and the efficiency of the complete system. The Motor Systems Tool dynamically calculates how changing system speed, load point or a system element influences total system efficiency.

The tool contains standard models for pumps, fans and compressors as well as transmissions with belts, gears, electric motors, variable frequency drives and combinations of these.[3]

[3] For more details on the Motor Systems Tool the paper of the developer Sandie B. Nielsen “The Motor Systems Tool - An outcome of Task B of the 4E EMSA project”, written for EEMODS’11 may be consulted.

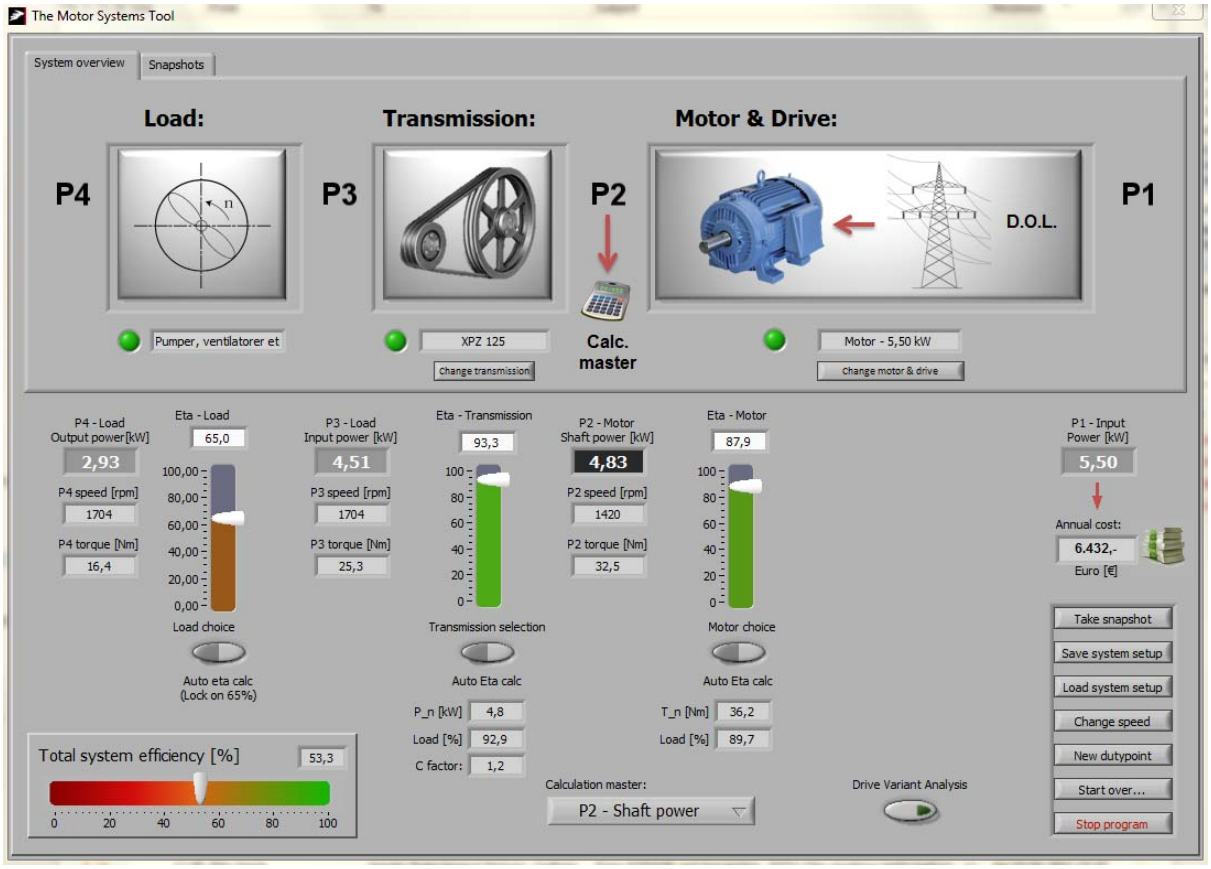

Figure 5 Motor Systems Tool screenshot

All these supporting materials and tools can be used to inform and train not only engineers working in industrial plants but also government officials responsible for creating policy instruments.

2. Company level

How to motivate companies for action? The question of how profit-oriented organizations make their investment decisions and which factors influence them has been researched in many disciplines [2]. EMSA tries to motivate twofold: by using a bottom-up and a top-down approach.

The bottom-up approach aims to motivate and train relevant people in the company to engage with motor system optimization, bringing in life cycle costing considerations to management as well (see Personal level), instead of the widely dispersed pay-back time criteria.

The top-down approach aims to integrate motor system efficiency as part of the energy management scheme.

Application of energy management standards

EMSA worked on including proper motor system management in the European standard for energy management EN 16001 and continued this effort for the international energy management standard ISO 50001 (published in June 2011).

The EMSA member Netherlands plans a pilot project with selected companies where the implementation of the international standard ISO 50001 is compared to the energy management system of the companies already in place. Audit results of the current systems show that the biggest drawback in implementation is low management responsibility. Certified international standards, like the upcoming ISO 50001 make a change possible.

EMSA will use results of the pilot project and results of the annual audits to produce fact sheets with guidelines aiding companies in the practical implementation of ISO 50001. Furthermore, EMSA will collect and demonstrate existing best practices highlighting energy management of motor systems.

Minimum Energy Performance Standards (MEPS)

National governments have the power to decide by setting Minimum Energy Performance Standards which products (motors, fans) can be offered for sale and purchased in their area of jurisdiction, that is, in their country. For motor manufacturers this means that they can only sell products which comply with MEPS in that country. For industrial users this means they can only purchase products which comply with MEPS. This is one very powerful tool for policy makers to regulate the market.

A detailed overview of MEPS in place worldwide will be available on www.motorsystems.org.

3. National level

How to motivate and guide policy makers for creating effective motor policy instruments? EMSA answered this question as follow. Firstly, by informing policy makers about existing potentials, secondly, by enhancing experience exchange, thirdly, by marking the path.

Potential

Experience from industrial efficiency programs shows an energy savings potential of 20% - 30% for motor systems [3] (see also Savings potential). Improved motor systems contain more efficient and correctly sized motors, variable frequency drives for variable loads, transmissions with synchronous belts and efficient gears or direct drives instead of V-belts and throttles. In order to renew and improve existing electric systems, policy instruments are needed not only for new installations but also to shift focus on and speed up the improvement of old industrial systems.

Motor Policy Guide

How to exploit best available potentials? EMSA tried to answer this question by collecting and analyzing policy instruments for motor system efficiency in place in different countries in a Motor Policy Guide. Part 1 of the guide presents a collection of policy instruments in Australia, China, the European Union, the USA and some European countries (Austria, Netherlands, Sweden, Switzerland, United Kingdom). Instruments assessed include:

- Minimum Energy Performance Standards (legally binding and voluntary for higher efficiency)
- Labels
- Energy management schemes and audit programs
- Training and education programs
- Awareness raising programs
- Information platforms
- Financial incentives: rebate programs, tax allowances, co-funding schemes

Based on the assessment, the “recipe” of a successful policy instrument for motor systems efficiency was identified as:

1. *Minimum Energy Performance Standards*. MEPS are essential for pushing the market, removing the least efficient technologies.
2. *Information and education*. Awareness raising, audit guidelines, assessment tools and trainings are important accompanying measures to make engineers aware of existing savings potentials and help in exploiting these potentials with education and guidance.
3. *Financial incentive programs*. Incentives can give the first push to stimulate action and convince users to invest time and money into efficiency.

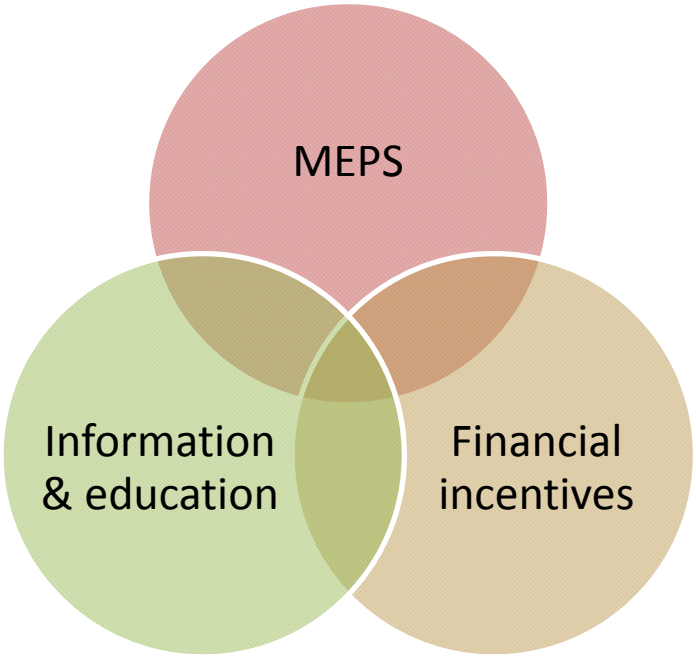

Figure 6 Elements of a successful policy instrument for market transformation
Source: A+B International, 2011

Recommendations for national motor efficiency program design and management are:

- Set clear and quantifiable program goal;
- Secure independent financing;
- Ensure neutral program management – to be in place for the whole program duration;
- Integrate all relevant stakeholders (manufacturers, OEMs, trade associations, motor systems users, service companies, energy utilities, energy consultants, local and national government authorities and officials);
- Define criteria upon which to measure success of program participants and of the whole program;
- Define a standardized reporting structure to monitor results;
- Set up any instruments or institutions to ensure compliance;
- Publish program results.[4]

EMSA will continue to investigate how national policies can be harmonized on a global level and aims to define in Part 2 of the Motor Policy Guide a detailed roadmap for global market transformation.

4. Global level

How to motivate and support policy makers in harmonizing their efforts worldwide? If policy makers are made aware of motor systems savings potential, they are more likely to start introducing policy instruments to exploit these potentials. This is a good start. However, such activities cannot stop at the border of a country but need to be harmonized on a global level to reduce trade barriers.

MEPS

Once policy makers are determined to implement measures for transforming the market, introducing MEPS will be the first step. However, if different countries have different minimum standards – or worse: none – this leads to a split global market, where motor manufacturers may sell and motor

[4] For more details on the Motor Policy Guide, see the paper EMSA-Analysis of Motor Policies around the World by Konstantin Kulterer written for EEMODS'11.

users may buy highly efficient products in one country and cheap material with low efficiency in another. If MEPS are harmonized, no such parallel markets exist.

The biggest motor electricity consuming regions, USA, EU-27 and China, have implemented or are currently implementing MEPS for motors. However, there are also countries with high motor electricity consumption and no MEPS, e.g. Russia and India who together represent 8% of global motor electricity consumption [1]. Based on already decided legislation, countries with MEPS for motors will cover 70% of global motor electricity demand by 2015 (see Figure 7). It is essential to convince more countries to introduce MEPS, starting with the biggest consumers not applying MEPS yet.

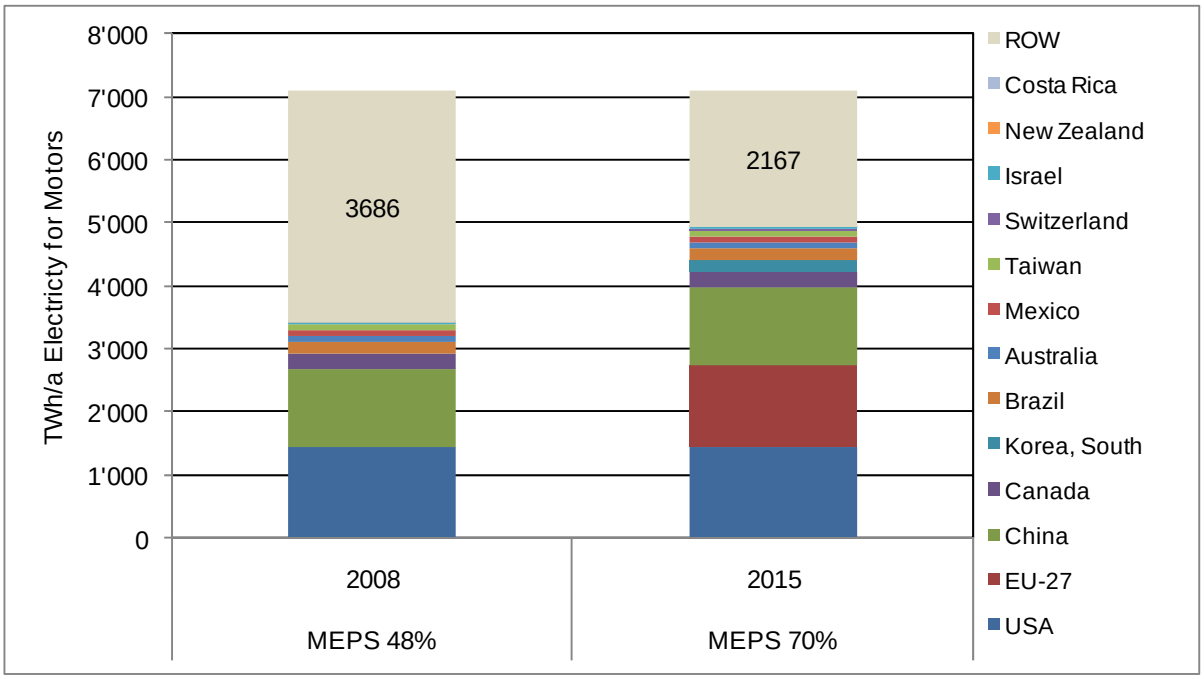

Figure 7 Countries with MEPS
Source: A+B International 2011, ROW: rest of the world

Globally harmonized MEPS can only be achieved if there are clear global standards on how to test motors and determine their efficiency.

Input to testing standard IEC 60034-2-1

The international IEC 60034 standard Rotating Electrical Machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles) was published in 2007. It is currently being revised by the International Electrotechnical Commission (IEC) to improve efficiency testing accuracy and repeatability.

In order to facilitate this work, an international Round Robin was launched in 2007. A series of tests were made in the same laboratory on a single motor, in the same laboratory on motors of the same design with the same test method and by different laboratories on the same motor [4].[5]

This effort shows that test procedures can be interpreted in different ways. This fact was also recognised by EMSA. To contribute to the correct interpretation of the test standard, EMSA produced an explanatory guide to the standard (available at www.motorsystems.org).[6]

[5] More details on the results of the Round Robin can be found in the respective paper of Axel Möhle, written for EEMODS'11.

[6] More details on the explanatory guide can be found in the paper of Sarah Hatch, Hugh Falkner, Melanie Slade and Lelde Vitols: "Testing Centres Network: Explanatory guide for motor testing – Task C under IEA 4E Electric Motor Systems Annex" written for EEMODS'11.

Global network of testing centres

In addition, EMSA established an International Testing Centers Network to improve the exchange on motor testing between testing laboratories worldwide, in particular on the use of the IEC 60034-2-1 procedures. Network members are industry, government, university and independent laboratories located in Europe, the Asia-Pacific, North- and South America and Africa. Two workshops were held at EEMODS'09 in Nantes France and at the Motor Summit 2010 in Zurich Switzerland, with increasing interest. An online web forum (http://www.leonardo-energy.org/international-motor-efficiency-forum-testing-centres-network) with articles regularly published is available for network members.

One network member, CalTest (Australia), developed a set of sample test data to check accuracy and consistency of laboratory algorithms and circulated this to ten members at the second workshop at the Motor Summit 2010. The results of this software round robin will be presented at EEMODS '11 by Andrew Baghurst.[7]

Standards for new motor technologies

Developing appropriate standards for testing and classification of motors is essential. In addition, standards for other system components (e.g. variable speed drives on which work in IEC is ongoing) are also necessary.

In order to keep up with technological developments, standards need to be created for new motor technologies (e.g. switched reluctance motor, permanent magnet motors) as well. EMSA aims to contribute to this by facilitating dialogue between standards developers, motor manufacturers and users and policy makers. A first workshop on this matter was held at the Motor Summit 2010 in Zurich Switzerland.

Roadmap for policy action

Harmonized Minimum Energy Performance Standards, harmonized standards, global stakeholder co-operation – this is the vision of EMSA. How to achieve this? EMSA plans to draw a roadmap for global action on pushing the market (motor manufacturers and users) towards more efficient motor systems. To investigate this issue, EMSA will draw from the International Energy Agency's information papers "Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems" by Paul Waide and Conrad U. Brunner et al. and "Walking the Torque – Proposed work plan for energy-efficiency policy opportunities for electric motor-driven systems" by Shane Holt and Hugh Falkner.

EMSA outlook

EMSA was launched in 2009 with a three-year project plan. Being in the third project year, discussions are ongoing on the continuation of the project for three more years, which is formally not yet decided. EMSA members expect to face the following developments in the upcoming project years:

1. Complex "motor systems" including a wider scope of efficiency technologies and instruments will require adequate tools for optimization.
2. More advanced standards including variable frequency drives and new motor technologies (permanent magnet, switched reluctance, etc.) will require both research for the design and push for rapid diffusion.
3. The growing number of countries with mandatory Minimum Energy Performance Standards will lead to setting higher MEPS-levels, thus a shift from IE2 to IE3 and the inclusion of integrated systems such as pumps, fans and compressors.

EMSA is determined to stimulate and promote these processes with adequate tools, bringing together necessary information and liaising between relevant stakeholders. Any country wishing to participate in the work of EMSA is welcome to bring its national resources and competencies into the project.

[7] See also the paper "Developing a standard algorithm for the calculation of induction motor efficiency based on International Standard IEC 60034-2-1" by Andrew Baghurst, Pierre Angers and Martin Doppelbauer, written for EEMODS'11.

Conclusions

Electric motor systems are responsible for 45% of global electricity demand, 64% of this in industry. There are considerable savings potentials of 20 – 30% which could be used to reduce energy demand. In order to realize this potential, EMSA uses a systematic approach to motivate and support relevant people and institutions.

The four levels of action are:

1. Personal level: engineers working in industrial plants shall be made aware of potential savings and ways to exploit them. EMSA informs with a regular newsletter on motor efficiency issues and offers a technical guide for motor systems, the Motor Systems Tool and training materials for use.
2. Company level: Motor manufacturers need to know which requirements their product need to comply with on which market. Motor systems users may apply an energy management scheme and rely on their well-trained professionals.
3. National level: policy makers need to be informed on savings potential and on how to design effective policy instruments. EMSA encourages the introduction of MEPS and offers a Motor Policy Guide to show the way.
4. Global level: EMSA advocates the harmonization of MEPS, testing and efficiency standards for motors, core motor systems and motor system components.

EMSA plans to continue its work until 2014 and welcomes any new countries to actively participate as members.

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