PEER-REVIEWED PAPER

How to achieve efficiency through the right mix of policies? Guidelines for electric motor policy implementation

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Abstract

Motor systems are responsible for more than 70 % of industrial electricity consumption. Policy can support industry in improving the energy efficiency of their electric motor systems and realize high savings. How should policies be designed and what mix of policy instruments should be applied? The Electric Motor Systems Annex (EMSA) of the International Energy Agency's 4E Implementing Agreement recommends the implementation of four major policy elements:

1. Mandatory measures. Minimum requirements for motors and applications shall be applied in every country, based on international standards. Whenever possible, product registration shall be mandatory. The build-up of qualified testing capacity is a must for compliance testing.
2. Voluntary measures. Voluntary agreements (including audit and energy management programs) move the market. Awareness raising and appropriate training enable industrial users to implement efficiency projects.
3. Financial incentives. Subsidies help to overcome barriers and motivate systematic efficiency improvements.
4. International exchange: Learning from successful examples in other countries reduces costs and risks of pitfalls in policy design and implementation.

The Policy Guidelines for Electric Motor Systems, to be published by EMSA in 2014, will present a choice of policy instruments for policy makers that transform the market and show successful examples from different countries deemed worthwhile to follow.

Examples include:

- Australian regime for rigorous registration, compliance and enforcement of motor regulations.
- Dutch Green Deal program Efficient Electric Motor Systems involving motor suppliers and service companies in retrofit projects.
- Austrian energy audit program for SMEs (energieeffiziente betriebe).
- Swiss Motor-Check method for a systematic motor systems audit and retrofit program.
- Motor Systems Tool helping industrial users assessing systems efficiency.

The paper will present the main findings of the publication [1].

Introduction

Electric motor systems are considered the largest group of end-use equipment: they are responsible for some 46 % of global electricity use [2]. They are used mainly in industry, in infrastructure systems, in transport of goods and people as well as in large building technologies. Electric motors between 1 Watt and 100 Megawatt drive pumps, fans, compressors and industrial handling and processing equipment. The analysis of 4,142 electric motors in Switzerland shows [3] that there is a

large fraction of very old, inefficient and oversized motor systems in use, without integration of components towards system performance, many without electronic means of controls that adapt to the necessary load, and no higher level factory automation and coordination. Numerous projects around the globe show that most motor driven systems can be energetically improved and as an average 10 % to 30 % of energy and running cost can be saved [4]. Typically the improvement of old motor systems and newly designed optimized motor systems pays the necessary additional investment for high efficient components back in less than 3 years.

A number of severe barriers between the manufacturer, the Original Equipment Manufacturer (OEM) and the end user hinder the optimal performance of electric motor driven systems. Many motors are built into larger production machines by OEMs that are keen to make their machines cheap and do not consider total cost of ownership or life cycle cost. Many factories lack qualified staff for energy matters and regularly available funds for efficiency investments.

The IEA Implementing Agreement "Efficient Electrical End-Use Equipment" (4E) is driving governments and industry to higher concerns for energy to be saved. Within 4E the "Electric Motor Systems Annex" (EMSA) steers the motor technology world towards the necessary knowledge and empowerment to reap the fruits of energy savings promised by new technology and better design and the economy of higher fuel and electricity prices.

An important insight into the best practices in energy efficiency policy around the globe is that there is no single instrument that is able to bring alone these energy savings swiftly. Also, the most cost-efficient solution will not automatically be adopted in the industrial context because other elements influence investment decision making like risks, costs and value attributed to energy efficiency [5]. The policy needs a mix of several ingredients, in four main areas:

1. Mandatory performance standards are necessary because international experience shows that the life cycle cost approach is not generally used and that industry still will buy the cheapest (least efficient) product for a certain task. Mandatory Minimum Energy Performance Standards (MEPS) on the other hand – based on national law – keep cheap, inefficient products from the market and let industrial buyers focus on premium products only.
2. Voluntary measures including labeling, voluntary agreements and awareness raising. Qualified and focused information is necessary for motor manufacturers and motor users, training for engineers who need also testing equipment for analyzing running stock and tools for the optimal design of new equipment.
3. Financial incentives help especially in industry to raise awareness for energy efficiency, to open the factory gates for expertise that will look at hidden improvement potentials and to convince management eventually to invest on regular efficiency improvements that keep the entire rolling stock up to date with modern efficiency technology.
4. International exchange is the most effective way for the design and implementation of successful policy instruments. Learning from the experience of other countries reduces the costs and risks of the envisaged policy instruments to the possible minimum.

EMSA has been engaged in motor policy since its outset in 2008. A first analysis was published in 2009 as "Motor MEPS Guide" [6] profiting mainly from the US experience in setting mandatory standards. In 2011 a second volume followed: "Motor Policy Guide, Part 1: Assessment of Existing Policies" [7] analyzing motor policy instruments in nine countries/regions. Now the "Policy Guidelines for Electric Motor Systems" is proposed that summarizes the experience in various countries with mandatory and voluntary schemes, with or without financial incentives and a multitude of information elements.

For the Policy Guidelines for Electric Motor Systems EMSA has been able to draw from the experience of a number of experts engaged with motor policy implementation within and out-side of EMSA who have contributed to the publication. With this publication EMSA wishes to help countries, governments, industry as well as standard makers to find a path towards a comprehensive energy efficiency development for electric motor systems.

Scope

The Policy Guidelines for Electric Motor Systems [1] chooses to cover the entire electric motor system from the electric input to the mechanical output that defines the efficiency and is best suited for maximum energy savings. EMSA describes the Motor System like this and uses this definition throughout the Policy Guidelines (Figure 1).

This means the Motor System includes all components within the boundary in Figure 1, which are relevant to the energy use during start and operation:

- The electrical input from a number of components inside the electric meter (i.e. mains cables, uninterrupted power supply, transformer, power factor correction, soft starter, switch gear, etc.),
- The electric motor including all its auxiliary elements for starting,
- The mechanical components (gears, transmission belts, brakes, clutches, throttles, etc.),
- The application based on the torque and speed profile and its eventual use (pump, fan, compressor, mechanical process, etc.),
- The net operational energy use of the application (output, i.e. flow of liquid in a pump or compressor or gaseous matter in a fan, including the energy needed to overcome the resistance and speed in ducts or pipes, heat exchangers, valves and its operating time, etc.); this includes the operational regime with periods of idling, stand-by and operation without use.

The more practical boundary condition for regulators is defined as the Motor Driven Unit[1]. It includes the three major technical components: variable frequency drive, electric mo-

1. In earlier texts this is also imprecisely referred to as "extended product".

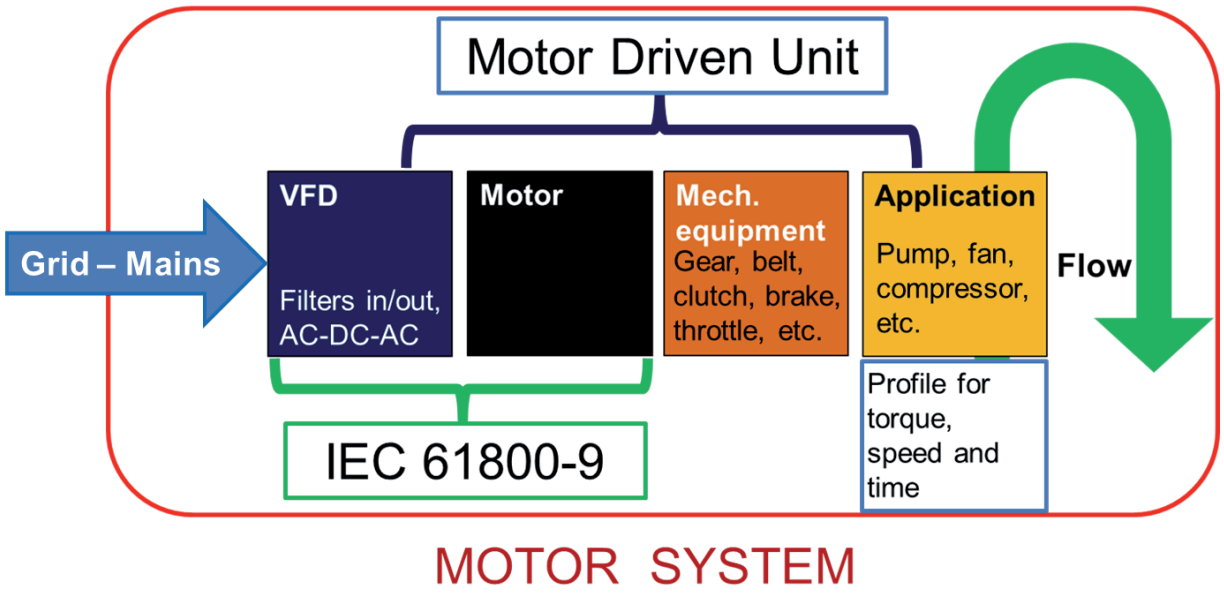

Figure 1. Motor System definition with red line as boundary. Source: EMSA 2013.

tor and application. It can also include the mechanical equipment (gear, belt, clutch, brake, throttle). It defines the typical boundary conditions both on the grid side and as well on the application side with a systematic profile for torque, speed and time. But it does not include the losses on both of these boundaries.

With the continuous improvement of all these components and their optimum interaction substantial energy savings can be made. Motor regulation therefore should focus on system performance, i.e. the best possible interaction of components to a meaningful and functional entity adapted to the necessary load or output (i.e. flow). Although this means an added complexity compared to regulating individual components, the approach of regulating systems is similar to the energy efficiency regulations used in building codes. For buildings, both minimum performance of individual components (i.e. a window) are in effect, while at the same time the overall energy demand (i.e. the specific final energy demand per m^2 of floor area per year) is set by law in several countries.

For the ongoing standardization work in IEC and ISO usually only a subset of components and their interaction is used: see indication for scope of IEC 61800-9 in Figure 1 that includes the interaction of motors with variable frequency drives only. The first wave of the next kind of MEPS are Ecodesign regulations for motors with integrated circulator pumps and variable frequency drives [2]. For legal requirement of the components and their interaction also a wider scope, like the Motor Driven Unit, can be chosen (in Figure 1) where all intermediary components are taken into account, while the electrical and mechanical boundary are defined by systematic bands of typical performance and losses. While it has to be acknowledged, that regulating entire systems is far more complex than regulating individual components, the work for determining efficiency and testing methods of smaller systems (e.g. motor plus VFD) has started at the international standard making bodies (IEC 61900-8) which paves the way for national implementation.

EMSA recommendations

GENERAL RECOMMENDATIONS

Based on the available evidence for successful mandatory and voluntary measures and financial incentives, a number of recommendations are presented here. It is understood that a mix of these three categories of policy measures are best suited to move the motor systems towards better energy efficiency. It is also understood that national policies – based on international experience – eventually have to be tailor made according to the existing national programs and laws, the potential legal influence the political system allows. Also, the national market situation with a number of domestic manufacturers for motors and components sets a different framework compared to countries where most products have to be imported.

The policy measures include activities on one side in the field of rapidly expanding economies in BRICS countries (Brazil, Russia, India, China, and South Africa) with a dominant share of new and larger factories that allow the investor to build highly energy efficient new motor systems with best available technology and low life cycle cost. The policy measures also include policies for highly industrialized and saturated economies in Europe and USA where the main load lies in upgrading existing systems.

While the Policy Guidelines are primarily meant to help policy makers, the recommendations are addressed to **five key actors** of policy implementation, namely national governments, international/national standard makers, industry associations, power utilities and industrial users. This is to acknowledge that while policy makers can trigger actions, there are several other groups of stakeholders they may wish to influence, as only their interplay can deliver a desirable result: as many kWh saved as the potential allows (see Figure 2).

Policy makers can influence the market by setting minimum requirements, thereby impacting industry: manufacturers not being able to sell products below a certain efficiency level and

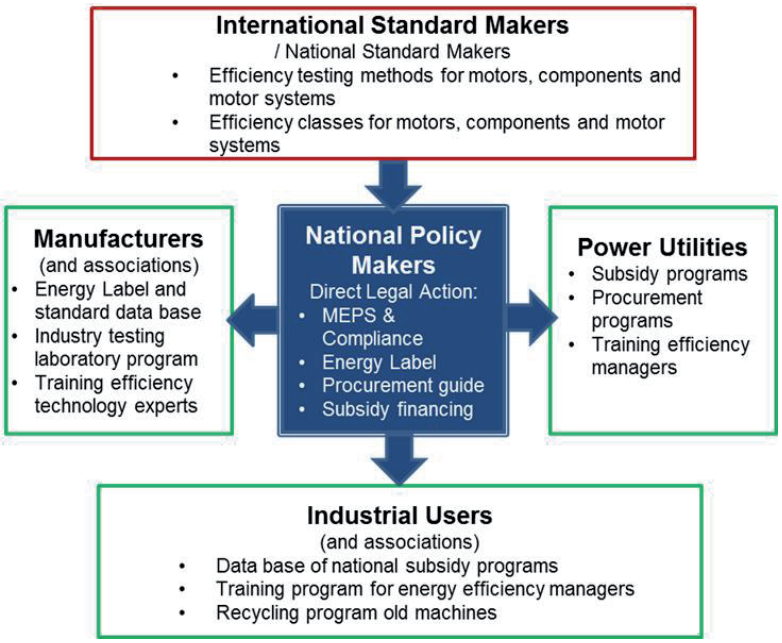

Figure 2. Influence of national policy makers. Source: A+B International, 2014.

industrial users not being able to purchase products below a certain efficiency level. Policy makers can oblige utilities to save energy (e.g. through yearly target setting) who can introduce subsidy and training programs to achieve actual savings. Policy makers can base the testing methods and efficiency classification on international standards, lifting trade barriers of globally traded products.

NATIONAL POLICY MAKERS

National governments need to work with legislators to secure their necessary legal instruments to work on mandatory standards and compliance. Policy means the definition of a mid- and long-term Energy Efficiency Policy for electric energy in industry including a target plan with annual monitoring and reporting. Provincial and local governments must be involved in the implementation and enforcement activities.

Based on the findings with old machines still in operation a 10-year **Old Age Retirement Program** for SMEs with the systematic replacement for motor systems 20 years and older should be implemented.

Recommendations: government

1. Mandatory energy performance standards (MEPS). First all energy relevant components of a motor system shall be covered by MEPS: motors, variable frequency drives, transmissions, gears, applications (pumps, fans, compressors). Second, smaller systems (e.g. motor plus VFD). Third the whole system shall be regulated, acknowledging that each step means exponential added complexity for the regulation. Fourth a compliance program for MEPS with regular **Check Tests** of randomly selected products in retail stores.
2. National MEPS shall be based on international standards which allow different levels of MEPS according to the individual context in each country. Abolishing conflicting regional and national standards makes the harmonization of standards possible on a global level and the trade of globally manufactured goods (motors, machines) much easier.
3. Product registration program: based on online industry motor energy performance database.
4. Setting energy efficiency targets for utilities and/or industrial end users.
5. Implementation of energy management and/or energy audit programs (in cooperation with national energy agencies).
6. Set up of awareness raising campaigns and benchmarking databases (in cooperation with manufacturer associations).
7. Set up of framework for financial incentives to support energy efficient motor driven systems (tax incentives, contracting).
8. Implementation of subsidy programs: in cooperation with power utility programs wherein the responsibility for financing and program operation can be shared.

INTERNATIONAL AND NATIONAL STANDARD MAKERS

Standard makers need to agree on internationally applicable testing standards and energy efficiency classification schemes. Also, standard makers are under constant pressure to up-date their standards according to the technical development and maintain harmonized cross-reference within their own standard body for very fragmented new considerations which are sometimes contradictory and need an appreciation of values and interests. National standard makers are invited to adopt and introduce international standards quickly into national standards.

Recommendations: standard makers

1. International standards: Put emphasis on developing international standards as base for national MEPS, rather than conflicting regional and national standards.

2. Motors: Precise definition of scope and tolerances of efficiency classes of motors: IEC 60034-1, ed. 13 (2014).
3. Motors: Testing and efficiency measurement standards, preferred method for motors and inter-acting components: IEC 60034-2-1, ed. 2, (2014), IEC TS 60034-2-3, ed. 1 (2013), IEC 61800-9, ed. 1 (2016).
4. Motors: Efficiency classes for motors and interacting components: IEC 60034-30-1, ed. 1, (2014), IEC 60034-30-2, ed. 1, (2015), IEC 61800-9 , ed. 1 (2016).
5. Motors: Guide for the application of IEC standards: IEC 60034-31, ed. 1, (2011).
6. Certification: IECEE[2] Global Motor Labeling Program.
7. Energy Management: ISO 50001, (2011).
8. Pumps, fans, compressors: ISO standards.
9. Energy Audits: ISO 50002 (draft).
10. Monitoring and Verification: ISO 50015 (draft), International Performance Measurement & Verification Protocol Volume 1, 2012 (IPMVP).

MANUFACTURERS

Industry associations of manufacturers for motors and other important components of electric motor systems need to agree on labelling, testing, and training programs. In several cases, leading industries have been faster moving to the energy efficiency frontier than their association.

Recommendations: industry associations

1. Energy label program for motors and key components: based on IEC 60034-30-1/-2.
2. Industry testing laboratory: training and calibration program: in cooperation with government laboratory accreditation scheme.
3. Testing laboratory accreditation program. Regular update of accreditation, calibration through round robin testing campaigns.
4. Training program Energy Technology & Management in Industry: in collaboration with local universities.
5. Define a standard for motor energy performance data and set up an industry database in the web of member companies in accordance with national motor registration program.
6. Definition of purchasing recommendations for energy efficient equipment, Life-Cycle Cost calculation and criteria for offers.

2. Worldwide System for Conformity Testing and Certification of Electrotechnical Equipment and Components.

INDUSTRIAL USERS

The owners of enterprises and their industrial factories need to play a pro-active role in implementing government motor systems policy. This can also be seen as a service to industrial users provided by industry associations.

Recommendations: industrial users

1. Appointing one or more responsible persons within the factory who are dealing with energy efficiency.
2. Database of national, provincial and local subsidy programs: rapid access for individual and large consumers.
3. Participation in training programs.
4. Recycling program for old motors and components.

ELECTRIC POWER UTILITIES

Power utilities need to agree on their contribution towards electric energy efficiency in industry while understanding their economic benefit from demand reduction versus supply expansion. This means they can contribute to procurement and subsidy programs and stimulate training programs.

Recommendations: power utilities

1. Procurement programs for private and public institutions and large buyers.
2. Subsidy programs for end-users: Financed by voluntary (or mandatory) public benefit charge on kWh delivered to end consumers.
3. Using on-bill financing for implementing energy saving measures.
4. Training for demand side management of energy advisors in power utilities: In cooperation with industry training program for Energy Technology & Management in Industry, ISO 50001.

Good examples

There is already a variety of effective policy examples around the world to reach a market transformation of motor systems. Policy makers in every country can learn from the experience of other countries, which instrument should be used to reach specific targets, what pitfalls should be avoided, which stakeholders should be included and so on. However, what works in one country or region may not work in another one. Policy makers have to find out the best suitable instrument for boosting their energy efficiency markets.

The Policy Guidelines for Electric Motor Systems [1] bring policy makers examples of best working policies worldwide.

AUSTRALIA: REGISTRATION AND COMPLIANCE REGIME

Registration

Mandatory registration is the first stage in the monitoring, verification and enforcement of Australia's Equipment Energy Efficiency (E3) Program. Each model of electric motor that is regulated for energy efficiency in Australia must be registered

and meet a number of legal requirements before it can be supplied, offered for supply, or used for commercial purposes.

On 1 October 2012 national legislation, the Greenhouse and Energy Minimum Standards (GEMS) Act 2012, replaced a patchwork of state and territory legislation. The Australian GEMS Regulator is responsible for administering the legislation, which provides national consistency and a strong administrative and compliance framework for the regulation of products that use energy, or affect the energy used by another product.

The specific requirements for each regulated product are set in a legislative instrument called a GEMS determination. The determination for electric motors sets out specific requirements, including Minimum Energy Performance Standards (MEPS) and testing requirements, by referring to the applicable clauses in the relevant Australian/New Zealand standards.

Applications for the registration of electric motors are submitted to the Australian GEMS Regulator via an online registration system. Applications must be accompanied by a summary of a full laboratory test report which demonstrates that the electric motor meets the MEPS. No specific accreditation is required for laboratories undertaking the testing, and providing the test report, for registration purposes. Currently, the fee to register an electric motor is approximately EUR 430 (AUD 670).

Details of the products, once their application is approved, are placed on the GEMS Register, which the GEMS Regulator may publish. In addition to the Register, registrants may choose to make some of the product detail available publicly on a comparison tool available on the Energy Rating website at www.energyrating.gov.au. A range of information about each model, including energy efficiency and running costs, is available on the website to allow consumers to compare different models. There are currently over 6,000 approved motor registrations in the GEMS register.

To assist motors suppliers manage the cost of registering their range of products, the GEMS Regulator has provided a temporary fee concession option for electric motors. Registrants may include up to 10 electric motors in an application for a single fee provided they are of the same brand name and frame code. This fee concession will remain in place while consideration is given to allowing 'family of models' registrations for electric motors. In the future, a 'family of models' registration could mean that several electric motor models which have the same energy performance characteristics can be covered by a single registration. For compliance purposes, if one model in a family of models was found to be non-compliant, all models within the family would be considered to have failed. This could result in sanctions being applied in relation to all models in the family.

Sales and other data requirement

Approximately 277,000 three-phase motors were sold in Australia in 2010. The GEMS legislation includes the option for the Australian GEMS Regulator to require that registrants submit data relating to the manufacture, import, supply or export of a registered model, on a one-off or periodic basis. This data will facilitate the establishment of revised MEPS levels and labelling algorithms and will improve the evaluation of the E3 Program. Safeguards will be in place to ensure the confidentiality of this information.

Compliance: check-testing

The Australian check testing program enables the GEMS Regulator to verify through laboratory testing, whether the performance of an electric motor model meets the requirements of the legislative instruments, including the Greenhouse and Energy Minimum Standard (GEMS) Act 2012, and the claims of manufacturers and suppliers. Check testing encourages compliance with the GEMS Act and helps to uphold the integrity of the Equipment Energy Efficiency (E3) Program.

Check testing of electric motors has been on-going since 2002. While it is currently the main compliance activity for electric motors, other activities in future may include education and awareness raising and registration surveys. Currently, approximately 30 electric motors undergo check testing each year to monitor compliance with the set MEPS level. The E3 Program spends approximately EUR 100,000 per year on the motors check-testing program. This amount includes the purchase and testing of motors.

Models are selected for check testing according to a range of risk-based criteria. Factors taken into account may include:

- Reports of possible non-compliance from competitors, consumer groups, individuals and overseas testing programs.
- Models with a high market share.
- Product types with the highest greenhouse gas emissions.
- Brands or models with a history of non-compliance or with no check test history.
- High efficiency claims.

Electric motors selected for check testing are, where possible, purchased anonymously from the market. After acquiring units of the selected models for testing, Stage One check tests are conducted according to the requirements set out in the relevant test standard. Wherever possible, check testing is only undertaken by those laboratories accredited with the National Association of Testing Authorities (NATA), Australia, or an accreditation body having mutual recognition with the NATA, Australia. A tolerance is applied to efficiency values which are obtained as a result of check testing. If the Stage One test indicates the model complies with GEMS requirements, the registrant is informed and no further action is taken.

If the Stage One test indicates the model fails to meet the performance or marking requirements, the Regulator will notify the registrant of the results of the failed check test. The registrant then has the option of cancelling the model's registration or proceeding to Stage Two testing which involves testing of an additional two or three units of the model. The registrant must supply the Regulator with a list of serial numbers of all units held in stock from which the Regulator chooses the required number of models. The registrant organises and pays for Stage Two testing.

Enforcement

If Stage Two testing indicates the model complies with relevant requirements, the registrant is informed of the pass result and no further action is taken. If the model fails the Stage Two check test, the Regulator may then undertake appropriate enforcement action as specified in the GEMS Act which could include cancellation of the model's registration and other penalties. For

more information, the E3 GEMS Check Testing policy is available from the Energy Rating website at www.energyrating.gov.au/programs/compliance/about.

NETHERLANDS: GREEN DEAL FOR EFFICIENT ELECTRIC MOTOR SYSTEMS

The Green Deal Efficient Electric Motor Systems (GDEMS) is part of the Dutch Green Deal program which has started in 2011. The Green Deal program is run by the Dutch Ministry of Economic Affairs. GDEMS is one of more than 100 other projects within the Green Deal program, all initiated on sustainable, green, innovative subjects. Green Deal projects are initiated by market actors, non-governmental organizations, whilst the Ministry of Economic Affairs delivers facilitating services and helps in removing existing barriers in regulation, market circumstances and such.

The GDEMS started at the end of 2012 and runs until mid-2015. It was initiated by a consortium of 28 private companies, i.e. manufacturers and service companies of efficient motor systems in industry.

The goal of GDEMS is to establish a standardized, systematic, step-by-step audit method for retrofitting motor systems applying best available technologies and life cycle costing principles which shall be proven through real-life application at 35 industrial users.

The audit and retrofit programs shall be implemented in five steps:

1. Identifying motor systems with efficiency potential.
2. Putting together a measure list.
3. Measuring motor systems, elaborating the savings options.
4. Putting together the business case (investments, savings).
5. Implementation according to a multi-annual plan.

Important elements of GDEMS are:

1. The involvement of motor suppliers and service companies, thus the supply side. The suppliers carry out the analyses at the industrial users which is a win-win situation: the suppliers learn to apply a new business model based on efficient systems and the industrial users save energy and get to know the benefits of efficient motor systems.
2. Best practices will be made available aiming at raising awareness and capacity building among suppliers, Original Equipment Manufacturers and industrial end-users. The knowledge transfer and exchange of experience will be facilitated through a network of participants.
3. Financing options (e.g. through ESCOs and other parties) shall be also investigated.

By the end of 2013 more than 10 industrial users have joined GDEMS from the dairy, metal, chemical industry and also infrastructure plants (water treatment).

AUSTRIA: ENERGY EFFICIENCY PROGRAM "KLIMA:AKTIV ENERGIEEFFIZIENTE BETRIEBE" FOR SMALL AND MEDIUM SIZED ENTERPRISES

Small and medium sized enterprises (SMEs) usually have limited resources and capacity for improving their energy efficiency. For that reason numerous European and national projects with the aim to support SMEs on their way to improved energy efficiency have already been carried out.

One of the best practices for improving energy efficiency in SMEs is to lead the SME step by step to the concrete implementation of energy efficiency measures. This starts with awareness raising activities, conducting energy audits in order to identify the main energy consumers and possible energy saving measures, supporting the implementation of measures and informing on existing subsidies for audits and investments. For these different supportive steps different players are relevant. SMEs can benefit the most from support programs the better all players are linked to each other and the better their activities are coordinated within a network.

The Austrian national energy efficiency program for enterprises "klima:aktiv energy efficient enterprises", administrated by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, supports SMEs in increasing

Figure 3. Participating motor suppliers and service companies of the GDEMS (October 2013). Source: TPA consultants, 2013.

Sector		1. Invent.	2. Selection	3. Options	4. Measure (0)	5. Business case	6. Implementation	7. Measure (1)
Metals industry	**Coolingwaterpumps, VSD + IE4**							
Water authority	**New pumpchaimber**							
Watertreatment	**Aeration processplant**							
Metals industry	**Process fan VSDs**							
Water company	**Pumps, VSDs + Motors**							
Papermill	**Coolingwaterpumps**							
Dairy industry	**Motorsystems analysis**							
Dairy industry	**Pump systems analysis**							
Farmaceuticals	**Ventilation Cleanrooms**							
Food industries	**Compressors VSD + motors**							
Watertreatment	**Cooling system: pumps and fans**							
Plastics production	**Motorsystems analysis**							

Figure 4. Advancement of the retrofit programs at the industrial users participating in GDEMS (October 2013). Source: TPA consultants, 2013.

their energy efficiency. The Austrian Energy Agency (AEA) is leading this program since 2005. Since the beginning the AEA is working on establishing an energy efficiency network for SMEs and developing supportive tools for SMEs to be distributed within the network.

Such a supportive network should consist of governmental organizations, energy agencies, energy consultants, training institutions for energy auditors and managers, manufacturers of energy efficient equipment and systems, energy measurement and monitoring experts, investment subsidy programs and audit programs.

The target group of the energy efficiency program is production companies (mainly SMEs) in the whole region of Austria. Its major target is to implement energy saving measures in the companies, in total up to 50 GWh/a and more. The instruments of the program reach from compiling target-oriented information materials, composing training materials for energy consultants, establishing 'train the trainer' concepts, carrying out trainings to establish energy benchmarking schemes and organizing an annual energy efficiency award.

Supportive tools within klima:aktiv:

- Energy audit tool on excel basis for analyzing the electricity and heat consumption of the SMEs (ProTool).
- Energy audit guidelines for special audits in technology areas like compressed air systems, pump system, ventilation systems, steam systems, cooling/chilling systems and lighting systems.
- Branch energy concepts for different branches like sawmill, flour mills, laundries, carpenters, bakeries, meat processing, garages and car traders, hairdressers.
- Online benchmarking system with actual Austrian benchmarks of the above mentioned branches.
- Awareness raising events like an annual energy efficiency award. With the last six awards the program got a collection of 170 case studies of successfully implemented energy efficiency measures in Austrian SMEs. Among them are many measures improving energy efficiency in motor systems which serve as best practice for SMEs and energy auditors.

All the above mentioned tools and documents are available at www.eebetriebe.klimaaktiv.at (only in German).

Standardised trainings for energy auditors:

- One day basic training on ISO 50001 and energy audit tool (ProTool).
- Seven days special trainings on:
  - compressed air systems,
  - pump systems,
  - ventilation systems,
  - steam systems,
  - cooling/chilling systems,

– lighting systems,

– IT systems and data center air conditioning.

Partner network:

- Network of technology partners (contact to companies, input to trainings, case studies, information in their newsletters and print media, etc.).
- Network of energy consultants (1,200 participants in trainings).
- Network of awarded companies (170 so far) with 170 case studies online.
- Network of support programs (financial subsidies for energy audits and investments in energy efficiency).
- Network of energy auditor training institutions and programs.

SWITZERLAND: MOTOR-CHECK FOR A SYSTEMATIC MOTOR SYSTEMS AUDIT

In Switzerland, the Swiss Agency for Efficient Energy Use (S.A.F.E.) developed the Motor-Check method which is used to identify and retrofit existing motor systems with the highest potential savings within an industrial plant. (S.A.F.E. is a non-governmental organization implementing motor market transformation programs on behalf of the Swiss government.)

The Motor-Check consists of four steps (see Figure 5). First, the efficiency potential of the whole plant is assessed. Second, a motor list with the oldest, longest running (operation hours per year) and largest (mechanical power) motors is compiled. Third, the most promising motors are selected and tested on-site. Typically, from a group of motors with very similar characteristics (e.g. motors of a conveyor belt) only one motor is tested and the results are applied to all motors within that group. After the testing, a list of possible measures, investment costs and savings is created. Fourth, the identified measures are implemented.

S.A.F.E. also developed Excel-based software tools and guides to help industrial users in carrying out the Motor-Check:

1. SOTEA (Software Tool für effiziente Antriebe – software tool for efficient drives) is used to assess the efficiency potential of motor systems in one plant. The goal is to give the industrial user a rough number of possible savings which largely depends on the age of the installed motor stock.
2. ILI+ (Intelligente Liste – intelligent list) is used to compile a list of motors, from which motors with the highest savings potential can be chosen for retrofit. The Decision Maker of the tool helps users identify a relatively small number of motors representing a relatively large share of total possible savings.
3. The standardized template for a motor testing protocol helps to summarize motor test results and proposed motor systems efficiency measures together with the expected costs and savings.

These tools are directly linked to and applied as part of the Motor-Check.

SWITZERLAND: EASY FINANCIAL INCENTIVE PROGRAM FOR MOTOR SYSTEMS RETROFITS

S.A.F.E. applies the Motor-Check methodology coupled with grants for each of the four steps in the Swiss financial incentive program EASY ("Effizienz für Antriebssysteme" – efficiency for motor systems). Up to date, 4,142 electric motors in 18 indus-

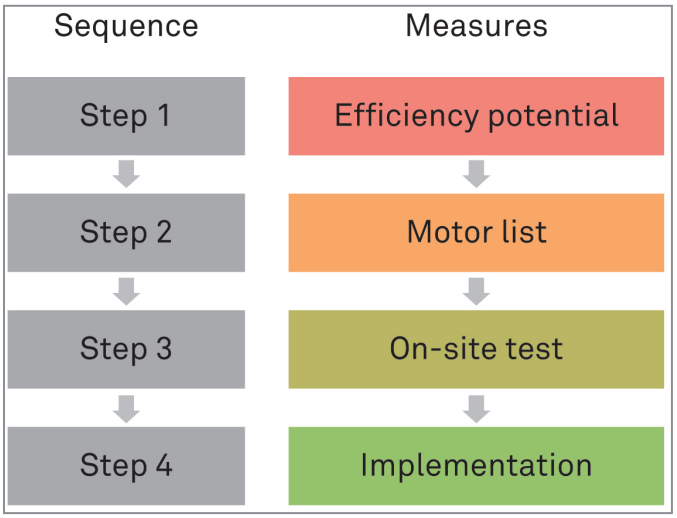

Figure 5. The four steps of the Motor-Check method. Source: S.A.F.E., 2014.

Potential of reduction according to criteria

Criteria		Default values	My values	Number of motors		Potential of reduction of energy		Potential of reduction of costs	
				absolute	in %	[kWh/a]	[kWh/LC]	[CHF/a]	[CHF/LC]
(1) Rate of realisation of the maximal saving potential in %		50	70	145	22%	480'838	7'341'977	60'105	917'747
(2) Age, older than x years		15	13	396	61%	599'043	8'450'073	74'880	1'056'259
(3) Operating hours per year > x Stunden		3000	5000	334	51%	468'685	5'726'851	58'586	715'856
(4) Dimension of motors > x kW		10	8	151	23%	443'558	6'980'616	55'445	872'577
(5) Motors without FC (frequency converter)		yes	yes	606	93%	701'838	9'273'035	87'730	1'159'129
(6) Application	Pump	yes	yes	0	0%	0	0	0	0
	Ventilator	yes	yes	144	22%	135'617	1'545'474	16'952	193'184
	Compressor air compr.	yes	yes	0	0%	0	0	0	0
	Compressor cold	yes	yes	0	0%	0	0	0	0
	Mechanical conveyor	yes	yes	0	0%	0	0	0	0
	Others	yes	yes	508	78%	645'643	8'924'267	80'705	1'115'533

Figure 6. ILI+ Decision Maker, www.topmotors.ch. Source: S.A.F.E., 2014.

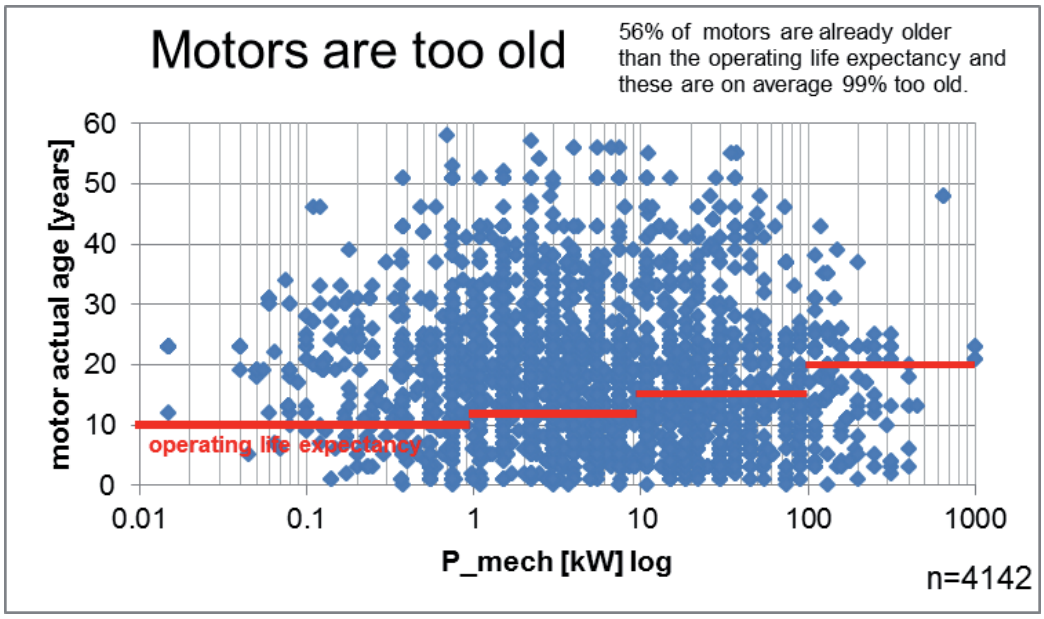

Figure 7. Motor age and expected lifetime. The line shows the expected lifetime of motors according to [8]. Source: S.A.F.E., 2014.

Table 1. Motor systems components and Motor Systems Tool features.

Motor systems components	Available features of the Motor Systems Tool
Load	four torque profiles (speed/torque relations)
Transmission	many different belt types
Motor	helical/worm/bevel gear models
Control system	IE1/IE2/IE3

trial and infrastructure plants have been assessed within the program. The results show that 56 % of motors in operation are too old (see Figure 7). These motors are on average 99 % too old which means that most motors have been running almost twice as long as their expected lifetime. The oldest motor found has been running since 64 years.

More information on the EASY program and its results can be found at www.topmotors.ch/easy.

MOTOR SYSTEMS TOOL FOR ASSESSING SYSTEM EFFICIENCY

Optimizing motor systems is about choosing the right components and getting them to work well together, thereby achieving the maximum possible efficiency of the entire system. In order to facilitate and support the optimization of an entire motor system, EMSA has developed the Motor Systems Tool. The Motor Systems Tool calculates the efficiency of a complete motor system, composed of:

- Load, thus the characteristics of the driven machine (pump, fan, compressor, conveyor belt, etc.).
- Transmission (belt and gear), if any.
- Motor.
- Variable frequency drive, if any.

The Motor Systems Tool is impartial and independent of manufacturers' specifications. It is built up of standardized models for all implemented components (motor, variable frequency drive, transmission, gear), thereby ensuring that no specific products or manufactures are being favoured over others.

Most of the models used are based on measurements during the last decade carried out at the accredited laboratories of the Danish Technological Institute, combined with the known theory of certain components, anonymous data from manufacturers, legislation rules, results of actual compliance testing, etc.

The Motor Systems Tool is intended for a broad global audience: engineers working in industrial plants, energy consultants, original equipment manufacturers, trainers and teachers at schools and universities as well as government officials responsible for creating policy instruments.

The Motor Systems Tool can be downloaded for free from www.motorsystems.org (registration required). For more information on the Motor Systems Tool including the development history see www.motorsystems.org/motor-systems-tool.

Conclusions and Recommendations

In the last years the topic of energy efficient motor systems got a lot of attention and was supported on international level from the International Energy Agency, the United Nations Industrial Development Organization (UNIDO), the Super-efficient Equipment and Appliance Deployment Initiative (SEAD) and on regional level with Minimum Energy Performance Standards (MEPS) in major nations and economic regions (e.g. USA, EU).

Here the need is to consolidate those efforts by closing loopholes in the standards concerning the motors within the scope,

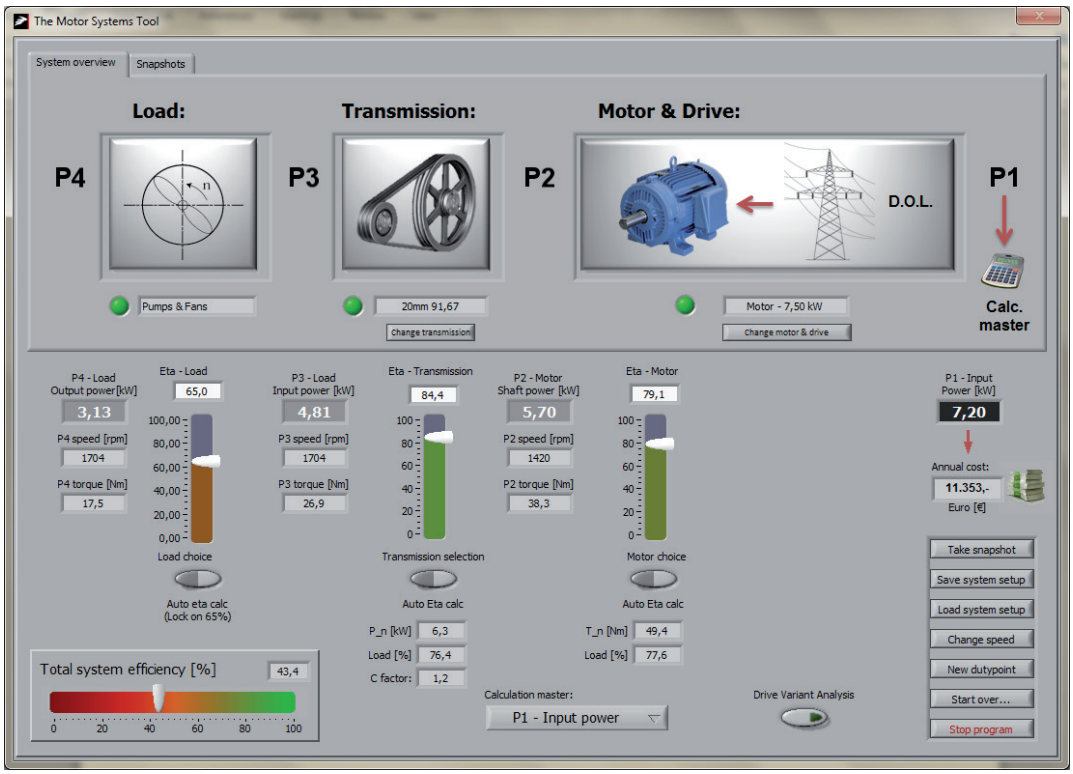

Figure 8. Motor Systems Tool main screen. Source: www.motorsystems.org.

improve and develop testing standards for the different motor system components by specification of testing methods, improve market surveillance activities and increase the minimum efficiency levels. In addition, regions without MEPS, especially those countries with rapidly expanding economies, should be convinced to introduce those standards and learn from the pitfalls of the implementation in other countries.

The real effort must now be on the next level: To increase the efficiency of the entire motor system from the electric input to the mechanical output and consider efficiency of motors already in use. New standardized approaches for energy management (ISO 50001) and energy audits (ISO 50002) can and should be used as tools to deal with industrial motor efficiency in "real life". People in the companies (energy managers), motor system planners and energy auditors have to get support for their activities and specific work with guidelines, tools, measuring processes and equipment. Those efforts have to be supported by legal and financial incentives.

This way substantial energy savings can be made. For this more difficult task different policy approaches and more complex cooperation of stakeholders are necessary.

The policy needs a mix of several ingredients, in four main areas:

- Mandatory performance standards.
- Voluntary measures (labelling, voluntary agreements, awareness raising and training of experts and energy managers).
- Financial incentives (e.g. tax incentives, subsidies).
- International exchange.

At least five different stakeholders have to be involved to take the road to high efficient motor systems:

- **Government** has to decide on mandatory energy performance standards (MEPS) for all relevant motor systems components and there combinations based on international standards and set activities for enforcement, like product registration. Furthermore governments are responsible for setting energy efficiency targets, implementing energy management and energy audit programmes. All those programmes need to be supported by awareness raising campaigns and financial incentives.
- **National standard makers** should put emphasis on developing international standards in all relevant areas from motor system components to certification and labelling programmes, energy management and energy audits, measurement, verification and benchmarking.
- **Manufacturers and industrial associations** should develop and/or support energy label programs, set up of testing laboratories, initiate and support training programs and define purchasing recommendations.
- **Industrial users** must set energy saving targets, define responsibilities and implement processes for training of the key personnel, for replacement, and improvement of running motor systems. They also should define requirements for installation.
- **Electric power utilities** should develop procurement programs and subsidy programs for end-users and use innovative financing instruments to profit from energy savings recommended to their customers.

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Endnotes

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