Standards for efficient electric motor systems SEEEM building a worldwide community of practice

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Abstract

Over 300 million electric motors (apart from motors in household appliances) use 40 % of global electricity and have an energy efficiency potential between 20 % and 30 %. Barriers for the implementation of this potential in industrial electric motor systems are manifold. Besides higher initial investment (which will typically pay back in between one and three years) and typically oversized equipment running in less than nominal efficiencies there is an almost complete lack of transparency in the motor systems market: The various efficiency testing methods commonly used deliver different values and the absence of clear and unified marking schemes and labels makes it difficult for the end user to choose the most appropriate motor. Only 10 countries have so far enacted (plus 3 have planned) mandatory Minimum Energy Performance Standards for electric motors and very few have done so for entire motor systems like pumps, fans or compressors.

Motors are traded worldwide in large quantities. Product quality comparison standards therefore are crucial elements of free trade. This includes testing standards, energy efficiency classes, marking schemes, labels and minimum energy performance standards. Harmonization has to cooperate with stakeholders like manufacturers and their associations, distributors, Original Equipment Manufacturers (OEMs), end users, governments, academia and international standard associations. The economy of improved motor systems needs to be explained and users trained to invest accordingly.

We report about the ongoing process for harmonization of Standards for Energy Efficiency of Electric Motor Systems (SEEEM) since its launch in June 2006. We explain the strategy of technical and policy work to enable the international community to agree on advanced energy performance criteria for motors and eventually also for motor systems, coordinated levels and timelines. We report about the building of an international multi-stakeholder Community of Practice to speed and focus implementation processes in industrial (Japan, Europe, etc.) and also in developing countries (China, India, etc.). At a later stage we plan eventually to develop a package of concrete implementation steps for countries to consider in their energy & environmental policy development.

SEEEM Harmonization of Standards

Over 40 representatives of industry and business organizations, governments, utilities, academics, and energy agencies from 18 countries participated in the launch of the SEEEM (Standards for Energy Efficiency of Electric Motor Systems) initiative[1] on 20 June 2006 in London at a side event to EEDAL'06. The participants called for governments and other stakeholders to:

- Initiate a comprehensive market transformation strategy to promote efficient industrial electric motor systems worldwide;
- Harmonize energy efficiency testing procedures, efficiency classes and marking schemes for motors;
- Introduce a timeline for mandatory minimum energy performance requirements for motors and harmonize them at a high efficiency level;

- Support and engage in this community of practice to share experience, derive best practice and coordinate measures to promote efficient motor systems.

Industrial electric motors are employed throughout the global economy to drive a variety of applications including fans, pumps, compressors, materials processing, handling & transportation systems. These motor driven systems excluding motors in household appliances account for at least 40 % of total electricity demand worldwide. They are a key source of local pollution and greenhouse gas emissions from fossil-fired power plants. And they are responsible for a large share of the rapidly growing electricity demand in developing economies.

There is a global economic potential to improve the energy efficiency of industrial motor systems by roughly 20 % to 30 %, with payback times of typically less than 3 years. Uptake of high-efficiency motor systems in the EU alone could avoid over 100 million tonnes of CO_2 emissions annually – which corresponds to a quarter of the EU's target under the Kyoto Protocol – while also reducing energy bills of European business and environmental externalities by billions of Euros annually, and reducing the need for new power generation capacity and imports.

Global cooperative action is needed now to overcome barriers to the wider deployment of energy efficient motor systems, one of which is a lack of harmonization. SEEEM is an independent, multi-stakeholder effort to promote rapid market diffusion of high-efficiency motor component technologies and systems worldwide. The harmonization process will promote an international agreement on testing procedures, efficiency classes, marking schemes and labels that will make it possible to compare products globally. This, in turn, will allow for international benchmarking and steps to align performance requirements (e.g., minimum energy performance standards) and to design/implement cost-effective policies and incentives to promote the most efficient motor systems.

To achieve its overall objective, the community of practice has identified four areas for cooperative action:

- Efficiency testing procedures and tolerances;
- Efficiency classes, marking schemes and labels;
- Mandatory and voluntary performance requirements;
- Effective policies and incentives for energy efficient motor systems.

The work under the first three areas will focus on motors and other system components, whereas the policy work will encompass motor systems as a whole.

Energy used for electric motors globally

Although still no solid global data base for electric motors exist today we can - based on several sources - estimate (table 1) that electric motor systems (excluding household appliances) are responsible today for 40 % of total electricity production, i.e. they consume in 2006 some 7.4 PWh (10^{15} Wh) electricity. From a total global CO_2 emission of 26 billion tons, electric motors account for about 15 % or 4.3 billion tons of CO_2 (10^{15} g) every year. Energy efficiency is considered now to be the most cost-effective and low-risk strategy[2] to lower the increase of primary energy demand and to reduce greenhouse gas emissions.

Current estimates of electricity demand for motors are 70 % of industrial and 35 % of commercial & service sectors plus almost all of public infrastructure (e.g. water and sewage) and electric transport. These figures add up to the total of 40 % of global electricity for motors with a band of national variation depending on the degree of industrialization between below 30 % and above 50 %. These figures sound to many energy experts like a well-kept secret. A lot of discussion has been heard on efficiency measures in lighting, electronics, household appliances, et cetera. Industrial consumption for heat and mechanical energy has been hidden by a veil of industrial processes where a tonne of cement or steel, a million cans of beer or juice or thousand cars or TVs a day are the key production indicators. Time and money were the decisive scale on which industrial productivity was measured. A number of key energy intensive industries (cement, steel, paper, etc.) have worked over more than the last two decades to reduce their energy intensity and thus reduce emissions. Some of them have developed industry benchmarks to compare energy intensity of the same product. Only in the last decade the fact has been widely recognized[3]that every type of industry uses basically thermal and mechanical energy (very few use also electro-chemical and other types of energy). Thermal and mechanical processes can be well described and classified in energy efficiency scales. Energy losses can be searched for systematically and improvement plans with systematic short & mid range investment scenarios are profitable for all industries that tried even before the last price hike of oil. In many cases lower pollution, lower greenhouse gas emissions, less thermal and less electrical energy use go hand in hand.

Electric motors between less than 0.1 watt for the smallest and the biggest available piece of equipment with some 50 000 kW are used in a wide array of applications in buildings, industry, appliances and public infrastructure & transport where mechanical energy is provided by electricity: Motors drive

- Pumps for liquids (water, oil, refrigerants);
- Fans for gases (air, natural gas, steam);
- Compressors for refrigerants in cooling & heating and compressed air systems, and they also drive;
- Materials processing, handling & transportation systems (conveyors, calenders, escalators, trains, crushers, mixers, etc.).

In stationary applications electric motors have won the field for mechanical purposes over Diesel engines because of zero emissions at the point of use, longer lifetime, less maintenance and above all their efficiency is in the range of 80 % to 95 % while diesels in stationary use rarely go beyond 40 %.

A widespread program experience shows that increased energy efficiency for existing and new motor systems can average 20 % to 30 %, with individual systems having efficiency gains between 10 % and 80 %. Over a typical lifespan of 10 (for smaller) to 20 years (for larger motors) for an electric motor this would give a very important energy savings of some 8 % to 12 % of the total global electricity consumption. The potential energy savings within a decade can be 1.5 to 2.2 PWh per year

Table 1. Global electricity consumption for industrial electric motors

	Unit	Value
Electricity production global (2006)	PWh/a	18.6
Electricity production from fossil energy	PWh/a (%)	12.4 (67%)
Electricity for industrial motors (not included household appliances, consumer electronics, office equipment, vehicles)	PWh/a (%)	7.4 (40%)
Capacity for electric motors (peak)	TWe	1.6 to 2.3
Motor electricity, greenhouse gas emissions	G t CO2/a	4.3
Motor system energy efficiency improvement potential (average within life cycle 10..20 years)	min max	20% 30%
Electricity savings potential (industry and buildings)	PWh/a min max	 1.5 2.2
Greenhouse gas emission reductions potential	G t CO2/a min max	 0.9 1.4
Average electricity price (industrial end-users)	Euro/kWh	0.05
Electricity cost savings potential (industrial end-users)	Billion Euro/a min max	 75 110

Sources: IEA WEO 2006 and A+B International (2007)

and result in an emission reduction of 0.9 to 1.4 billion tons of CO_2 (IEA Energy Technology Perspectives estimates 1.5 Gt/a in 2050). The respective monetary equivalent of these electricity savings is to 75 to 110 billion Euro per year (10^9 €).

Their power rating, rotating speed and mode of operation primarily distinguish electric motors. In electronic equipment and household appliances the majority of electric motors are single phase and between 0.1 W and mostly below 1 kW mechanical load. Many (but not all) of these applications that exist in millions of pieces of equipment have relatively low efficiencies, but operate only a minor fraction of the year (between 100 and 1 000 hours per year). These motors are often custom tailored and used integrated inside specific pieces of equipment. Their performance can easily be monitored and improved in entire products like refrigerators, room air conditioners, washing machines, CD players, etc. Their overall energy consumption is considerably lower than the group of the larger size industrial type motors used both in the industrial and tertiary sector.

Our major concern is focused on mid size three phases asynchronous industrial electric motors between 0.75 kW and 200 kW, typically fed directly from the grid with alternate current (AC) that are used in industrial processes, larger buildings and infrastructure systems. There are over 300 million industrial size electric motors in use world wide. They are manufactured with standard sizes and defined product qualities in some 20 to 30 million new pieces every year (quotes are for periods between 2002 and 2005): Australia: 310 000 (Ryan 2005); China: 5.66 million (CNIS 2006); Europe EU-25: 10 million (De Almeida 2006); USA: 1.8 million (Bonnet 2006). These motors are traded as commodities worldwide and then built by OEMs into pumps, fans, compressors and mechanical drives, etc. They tend to have slightly higher nominal efficiency than smaller motors and run typically between 4 000 and 6 000 hours a year. Their total electricity consumption is over 80 % of the electricity consumption of motor systems, higher than lighting, household appliances, consumer electronics and office equipment together. In countries with a considerable share of industrial production like China their overall electricity consumption tends to be even higher.

Many motor systems run in parallel with workday hours in factories, offices and stores. They have an approximate installed peak electric load of 1.6 to 2.3 TWe (10^{12} W) and can thus reach over 50 % of global electric production capacity. They operate many kinds of systems with daytime and seasonal peak phenomena (e.g. summer cooling). Therefore motors are a very sensitive part of peak loads both for generating equipment and transmission capacity in the entire electric grid.

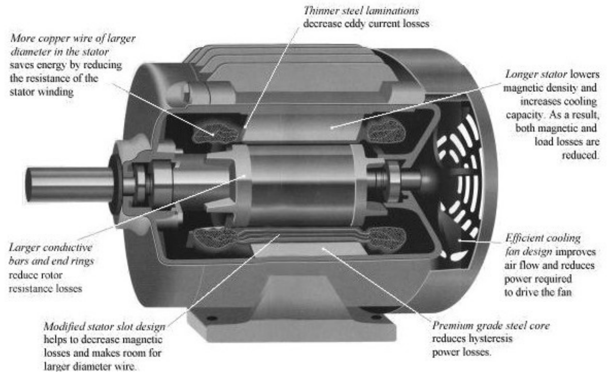
Need for Greater Alignment

Motors are manufactured in most parts of the world and are used in every part of the world. Between these two is a large commodity trading volume for standard motors. Data on production, sales, exports and imports exist in some key markets (Australia[4], Brazil[5], China[6], Europe[7], and USA[8]). Many old and famous European and American motor manufacturers have started their subsidiaries in Asian countries to be both closer to the emerging markets and to profit from cheap labor costs for exportable products. The German Electric Industry Association ZVEI is noting with considerable concern that 2005 the electric motor imports from China increased 40 % over the preceding year.

Motors are mainly traded between manufactures and OEMs and distributors, whereas large direct purchases from industrial end-users represent only a minority market share. In the low and medium power range OEMs buy between 80 % and 90 % of the motors. Obviously the end-user is directly interested in a cost effective product and system over its lifetime. He often selects a black box, i.e. a pump, fan, compressor or an entire heating, ventilation and air conditioning system with a number of unspecified electric motors hidden in it. The OEM (who sells a packaged product) and the wholesale distributor who sells to smaller end-users have not the same interest as end-users themselves. In both of the later cases the direct link between motor manufacturer and end-user is interrupted and valuable information is lost on its way.

Global motor trading means standardized products: Standard sizes, performance and quality. For this a large number of national and some international standards exist. There are numerous kinds of types & standardization categories for electric motors:

- **Size:** Frame dimension (volume, shaft, connecting and fixing elements), cooling type;
- **Performance:** Safety (electrical, temperature, pressure, fire, explosion), noise, vibration, rpm, kW, torque, starting behavior;
- **Operation and maintenance:** Standard testing and operation conditions, continuous (S1) and intermittent operation (S2 to S8);
- **Coefficient of performance**: Methods for testing of electric efficiency in partial and full load, power factor, tolerances;
- **Marking schemes and labels**: EPAct[9], NEMA Premium[10], CEMEP[11];
- **Energy efficiency classes**: EPAct, Premium, Eff 1/Eff 2/Eff 3, new IEC 60034-30;
- **Minimum performance standards:** EPAct/Eff1 or Eff 2.



Source: MotorUp Premium Efficiency Motor Initiative 2006

Figure 1. NEMA Premium motor design features

Current standards for electric motors are not well coordinated and not harmonized. They grew over the last ten decades in different parts of the world from national standards under different regional conditions (50 Hz and 60 Hz, horsepower and kilowatt, centimetre and inches, etc.). At present there is a wide spread agreement on the necessity of harmonizing the existing system of standards.

The development of more efficient electric motors is a long and gradual process of improvement with better understanding of loss distribution, more precise dimensioning and use of improved material properties.

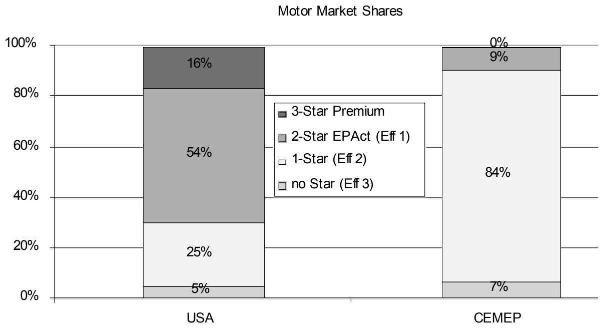


Figure 2. Motor Markets in USA and Europe: New motors sold with energy efficiency classes (2005)
Source: ICA 2005, CEMEP 2006

The Community of Practice

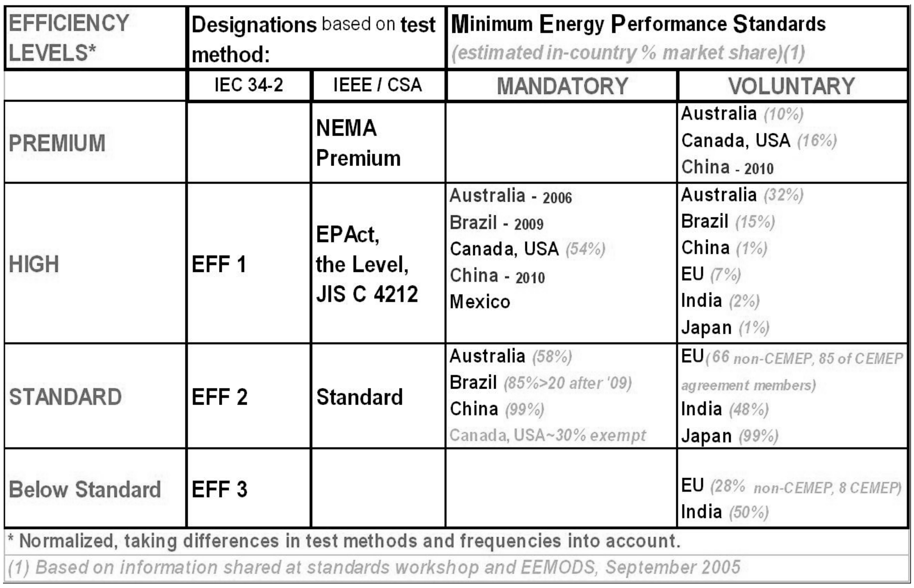
The ultimate goal of SEEEM[12] is to promote rapid market diffusion of high-efficiency motor component technologies and systems worldwide, in order to reduce industrial and building electricity demand and greenhouse gas emissions from electric power generation. To achieve this objective, the multi-stakeholder "Community of Practice" will facilitate:

- Greater alignment of international testing procedures, performance requirements and marking/labeling schemes;
- Collaboration on the design and enforcement of effective policies and incentives.

SEEEM is addressing the full suite of technical, economic and policy barriers. It has started its work by supporting technical harmonization projects on testing standards and energy efficiency classification (see paragraph on new Electric Motor Standards below). It will stay on this effort until harmonization and agreement on tolerances is achieved. We will then also focus on motor systems like pumps and fans to achieve the same level of harmonization. An intermediary report has been delivered at the Motor Summit in April 2007 in Zurich Switzerland.

SEEEM will then expand on policy strategies to support the efforts of governments to adopt effective market transformation initiatives, including voluntary agreements and mandatory Minimum Energy Performance Standards MEPS for electric motors and systems as for instance proposed by the ecodesign initiative in Europe for European Council decision in 2008. This will certainly be based on an international testing standard, the IEC marking scheme and would benefit from an internationally recognized label system. The level and timing of MEPS introduction will be at the discretion of individual countries and will necessarily take into account national circumstances and motor market situations. WTO member countries will have to ensure that national MEPS legislation is non-discriminatory and properly notified.

According to CLASP[13] only 10 countries today have MEPS for electric motors decided or enforced: Australia, Brazil, Canada, China, Costa Rica, Israel, Mexico, New Zealand, Taiwan, and USA; and MEPS are under preparation in Chile, Thailand and Vietnam. This means that a major challenge will be to both



EFFICIENCY LEVELS*	Designations based on test method:		Minimum Energy Performance Standards (estimated in-country % market share)(1)	
	IEC 34-2	IEEE / CSA	MANDATORY	VOLUNTARY
PREMIUM		NEMA Premium		Australia (10%) Canada, USA (16%) China - 2010
HIGH	EFF 1	EPAct, the Level, JIS C 4212	Australia - 2006 Brazil - 2009 Canada, USA (54%) China - 2010 Mexico	Australia (32%) Brazil (15%) China (1%) EU (7%) India (2%) Japan (1%)
STANDARD	EFF 2	Standard	Australia (58%) Brazil (85%>20 after '09) China (99%) Canada, USA~30% exempt	EU(66 non-CEMEP, 85 of CEMEP agreement members) India (48%) Japan (99%)
Below Standard	EFF 3			EU (28% non-CEMEP, 8 CEMEP) India (50%)

* Normalized, taking differences in test methods and frequencies into account.

(1) Based on information shared at standards workshop and EEMODS, September 2005

Source: John Mollet, ICA at EEMODS'05 Heidelberg, 2005

Figure 3. International motor markets

increase this number considerably and promote minimum efficiency levels to at least 2-Star by 2010 worldwide.

Going forward, we will work with supporters:

- to compile information and serve as a forum to exchange expertise on motor system efficiency compliance regimes;
- to promote the development of new high-efficiency (4-Star) motors which is particularly relevant in the low power range;
- to launch incentive programs (e.g., voluntary standards for state-of-the-art motors, harnessing carbon markets to promote motor system efficiency); and
- to initiate procurement programs;
- to promote and/or facilitate industry action to adopt high-efficiency motor systems.

This will enable us to continue to provide input into relevant policymaking processes.

Motor system boundary

Between the net mechanical energy delivered to the user's application and the actual electricity taken from the grid there are major sources of energy losses in four distinct parts:

- **Inefficient design**: Unnecessary high pressure in undersized pipes, ducts and auxiliary components (heat exchangers, louvers, etc.), and leaking systems, etc. because of high flow speeds and high pipe resistance;
- **Inefficient electric motors**: Motors not profiting from continuous technical advances in the last 20 years to reduce losses of AC induction motors;
- **Inefficient components**: Systems operating idle when not used and not well adjusted to the load, with throttles, oversized and thus under performing in partial load, inefficient transmission, etc.;
- **Poor power quality**: Motor efficiency can further be downgraded by voltage variations, harmonic distortions and voltage unbalance.

In order to optimize system design we distinguish between three boundaries:

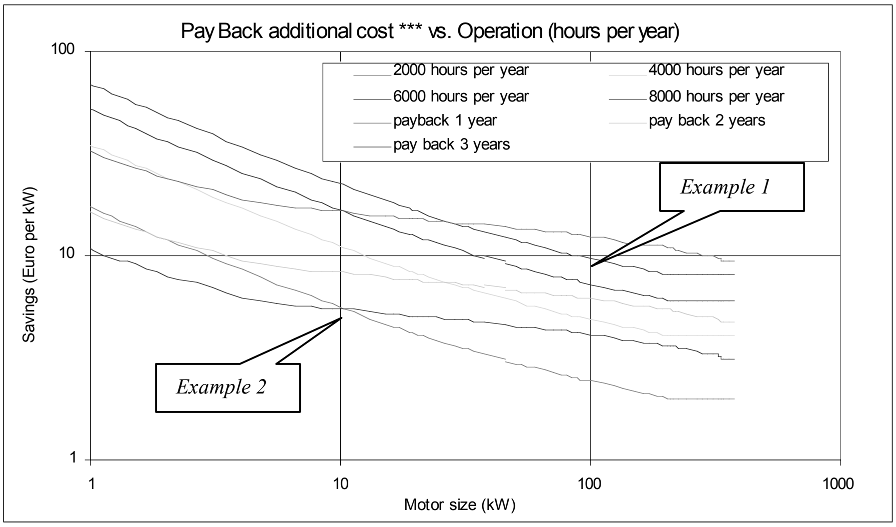
- The **electric motor** including its cooling system;
- The **core motor system**: motor including adjustable speed drive plus directly driven equipment like a pump, a fan, gear and, power control, etc.;
- The **total motor drive system**: Whole systems such as the building air conditioning system with ventilation and cooling equipment, the heating system with pumps and valves, the transport system with elevators, escalators, lifts and conveyor belts, etc.

Economy of efficiency

The basic concept of SEEEM and propagating more energy efficient motors is based on a more economical approach in industrial equipment involving the total motor system. The concept "life cycle cost" is traditionally not a common standard for equipment selection.

LCC: HIGHER INITIAL INVESTMENT – LOWER RUNNING COSTS

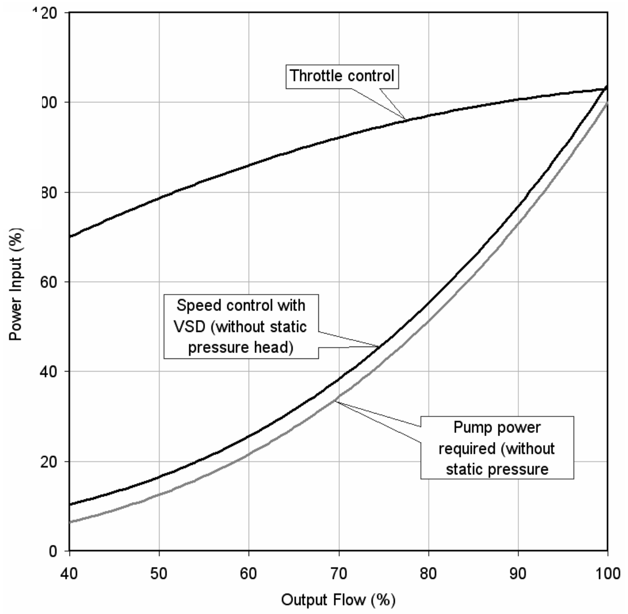
The tendency to move industrial production fast and design flexible according to market developments makes thinking in life cycle cost terms (LCC) more difficult. Still: Pay back times of one to three years are good news to investors when compared to other energy efficiency technologies and renewable energy investment[14]. Every feasible energy efficiency invest-



Example 1:
A new 100 kW 3-Star motor replacing a same size 1-Star motor running 6 000 hours per year has a pay back time through lower electricity costs (at 0.05 Euro per kWh) of 1.7 years;

Example 2:
A 10 kW motor running 2 000 hours per year has a pay back time of 3 years.

Figure 4. Pay back of 3-Star vs. 1-Star motors depending on annual operating time (0.05 Euro/kWh)



Source: Anibal T. De Almeida et al.

Figure 5. Input power for different flow control methods of a centrifugal pump[16]

ment not made is money lost on operating expenses for every year to come.

The optimum motor system is well adapted to its necessary load, has a power control for a 3-Star motor with an adjustable speed drive that responds to changes in load profile, has an efficient transmission system and has regular maintenance. The additional expense of 20 % to 30 % for high efficiency motors pays well within the first year of operation for new installations, within one to three years for existing systems.

The best pay back times are in motors with long operation hours (more than 4 000 hours per year) and a large efficiency improvement (this is possible in smaller motors between 1 to 10 kW). On the long run, looking at the entire technical life time, larger motors (100 kW) win out because they usually have longer annual operating hours and last for 20 plus years (smaller motors rather less than 10 years). This means you would want a one-year pay back on a new 1 kW motor but you can accept a longer pay back on a 100 kW motor.

NEW MOTOR SYSTEMS

In a new motor system with a high number of operating hours (over 3 000 per year) only the most efficient motor available on the market will be profitable for its owner and operator. The system will typically be without additional cost if the planning includes matching properly the application and it reduces unnecessary load: this will result in a smaller size motor running smoothly for a longer life cycle at lower total cost.

The case of new motor installations is especially crucial for rapidly expanding new economies: China with an annual GDP growth rate around 10 % has an annual growth of 15 % of electricity consumption. This is of course characteristic for rapid development with relatively low-grade equipment: Sad repetition of the old slogan “Buy now, pay later”.

REPLACEMENT OF EXISTING MOTOR SYSTEM

In industrialized countries the majority of industrial facilities and motors is already built and running. Maintaining and replacing existing systems is therefore the most frequent task. In existing industrial motor systems the situation is more complex than in new systems: Usually existing motors are oversized, low efficiency and with only inefficient mechanical devices for load variations like throttles and dampers. Many times a replacement for a broken motor is already stored in the factory and waits for its older brother to die. The industrial operator regularly has no time to interrupt production and to wait once a motor stalls. An immediate replacement is necessary not to interrupt production lines. Therefore the baseline is the replacement of a broken motor with exactly the same motor, same dimension, same size, same quality, same efficiency and same inefficient means of load adaptation like throttles. Replacing it with a more efficient motor of the same size will also pay within one to three years. Poor repair of failed motors can further degrade (up to 4 %) the already low efficiency of existing motors.

In mid and large size motor systems a thorough analysis of the operating motor stock has to be made well in advance to study an optimal replacement strategy. Downsizing and addition of load adjustment equipment with adjustable speed drives (ASD) is usually the profitable solution. This requires a preventive maintenance system[15] that has already prepared an optimal replacement strategy before the end of the motor life. Or an interruption will be tolerated in order to improve at least the core motor system.

MAJOR IMPROVEMENT MEASURES

Major measures to improve the core motor system efficiency besides choosing high efficient motors include:

- **Grid**: Provide for small variations around the nominal voltage, low harmonic distortion and well balanced phases;
- Reduce unnecessary **operating load**: Fix leaks, reduce resistance in pipes, ducts and auxiliary equipment, slow flow speed to match process requirements;
- Proper choice of **driven elements**: e.g. pump turbine, fan propeller and compressor type adjusted to task and load;
- Reduce **operating time**: Automatic (or manual) stop when idle, install operating meters;
- Motor and system **sizing**: Size adjusted to load and necessary starting torque (no over-sizing;
- **Load variations**: No mechanical throttles and valves, but adjustable speed drives (ASD) with electronic frequency inverters to continuously follow changing load patterns. In Germany more than a third of new motors now use ASD.
- **Transmission**: Direct drive wherever possible or effective belts and efficient gear systems;
- **Maintenance:** Mechanical bearings need maintenance or replacement after 10 000 to 100 000 hours depending on operation conditions, electric windings with new insulation materials after 100 000 hours. Regular check are necessary on cooling system for overheating that not only increases losses but can also accelerate wear of electrical or mechanical parts.

Many of the above items can also reduce initial investment and all of them will considerably reduce operating and energy costs. Usually a well-balanced system runs cooler, with less vibration and therefore generates a longer life cycle with less maintenance. ASDs can also decrease mechanical wear and tear. Still additional initial costs remain for the high efficiency motor itself because of added material in the motor and extra cost of the ASD. This higher initial cost forms a considerable barrier especially in expanding economies in the developing part of the world. Life Cycle Cost analysis is still not standard practice in industry also in the developed part of the world. Financial incentives (loans, tax breaks, CDM, etc.) can help to remove these investment barriers.

ADJUSTABLE SPEED DRIVES (ASD)

Motor efficiency in partial load is in many applications more important than under nominal 100 % load. The choice and optimal use of electronic inverters to adjust the speed to the necessary load (ASD) leaves many open questions: There are no standard load profiles available to decide easily on the cost/benefit for the introduction of an ASD. Early testing results show that the ASD also has an efficiency price in full load: It can diminish nominal efficiency by 2 to 3 % at full load[17].

Therefore the additional cost of an ASD has to be evaluated against the average annual efficiency. The relative cost of an ASD (Euro per kW) is considerably higher in small size motors (0.5 to 10 kW) and easily arrives at more than the motor itself. Although the prices of electronic equipment in general, ASD in particular, are on a downward trend, only a clear look at cost/benefit can determine the feasibility. Hopes for better prices in the near future lay with integrated systems like pumps & fans, where the motor, the pump & fan form one compact unit together with the ASD.

GREY ENERGY

Some times the economic view and the financial expenditures are not equal to the ecological evaluation of product life cycles. Here the gray energy incorporated in the manufacturing, transportation, maintenance cycles and the final dismantling of the motor system have to be evaluated. Only when the total efforts in material and its associated waste, pollution, hazards are positive an exchange or a new motor with a higher efficiency is ecologically sound.

Judging from some major experiences in motor design and use the impact of additional material (like steel, aluminum and copper) in energy efficient motors does not diminish its ecological pay back time: Usually some 96 % of the life cycle cost of an electric motor is the cost of its operating electricity. The rest of 4 % is split between its original sales price and installation 2.5 %, and 1.5 % maintenance cost.

Example: 11 kW 4-pole Eff 1 motor, running 4 000 hours per year for 12 years with a nominal efficiency of 90 %.

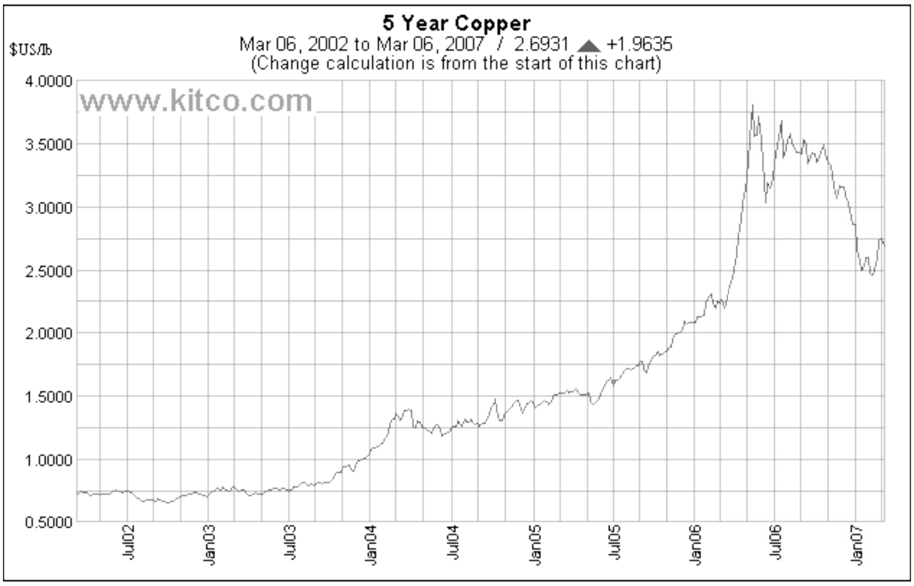
• Initial cost:	750 Euro	(2.5 %)
• Electricity used:	586 MWh	(at 0.05 Euro per kWh)
• Electricity cost:	29 300 Euro	(97.5 %)

Early results from the ecodesign studies (EuP Lot 11, Motors[18]) tend to confirm these results also from ecological judgment based on detailed material analysis. The additional use of copper for increased efficiency tends to pay 1 000 times in CO_2 terms[19].

MATERIAL COST & ENERGY PRICE

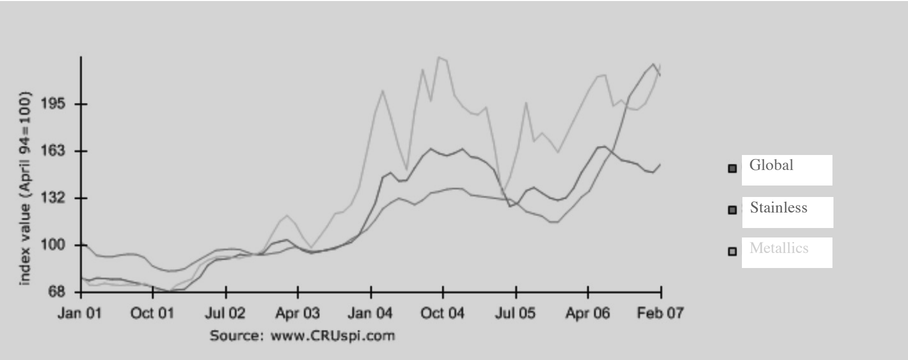
Motor costs are largely dependent on material cost with labor being less than 20 % of factory production costs[20]: With high price volatility of necessary electrical grade steel (cold-rolled coil), aluminum and copper becoming increasingly necessary also for rotors, the price development is crucial for optimal design. CEMEP and ZVEI[21] develop a continuous watch on the development of material price to help manufactures to justify their pricing.

This development of the material cost will of course also stimulate new optimization in existing technology with use



Source Kitco Base Metals, 7 March 2007

Figure 6. Copper prices 2002-2007 ($ per pound)



Source: CRU Steel price Index, 7 March 2007

Figure 7. Steel prices 2001-2006 (Index April 1994 = 100)

of electronic components (ASD) and with permanent magnet motors for smaller size motors - increasing in size lately up to 20 kW. On the long run new and different motor technologies are possible: Still supra conducting has not been commercially successful for regular electric motor applications. Miniaturization and integrating of both electronic components and driven equipment (turbines, propellers, compressors, tractors and gears) still leave a large field open for energy efficiency, material and cost improvement.

While material prices for copper, aluminum and steel went up, also energy prices went up: Oil, gas and subsequently electricity prices show also a clear long term tendency to rise. Rising fuel prices coincide with increasing installation costs in new power plants and transmission lines. Energy taxing and surcharges on carbon emissions already have an impact. The subsequent optimalization has therefore to consider the integral of the development in material and labor cost plus energy prices.

New electric motor standards

SEEEM has recognized that diverging or lack of motors standards are a major barrier to rapid market transformation. On of our first projects therefore was to support, stimulate and speed up the harmonization of motor efficiency testing standards and energy efficiency classification.

Great achievements had been made to harmonize international testing methods. In the USA and Canada they are based on their IEEE 112 Method B[22] that relies on the integral testing method using a torque meter. The European and Asian countries were relying on the existing IEC 60034-2 (edition 2)[23] where the additional stray load losses are assumed to be 0.5 % of full load input power (constant over the whole range of sizes). This led the CEMEP motor classification scheme with Eff1/Eff2/Eff3 to make for a higher level than the actual motor efficiency. The difference in efficiency percentage points is relevant and is typically between 1.1 % for small 1.1 kW motors down to 0.7 % to 0.9 % for larger 90 kW motors.

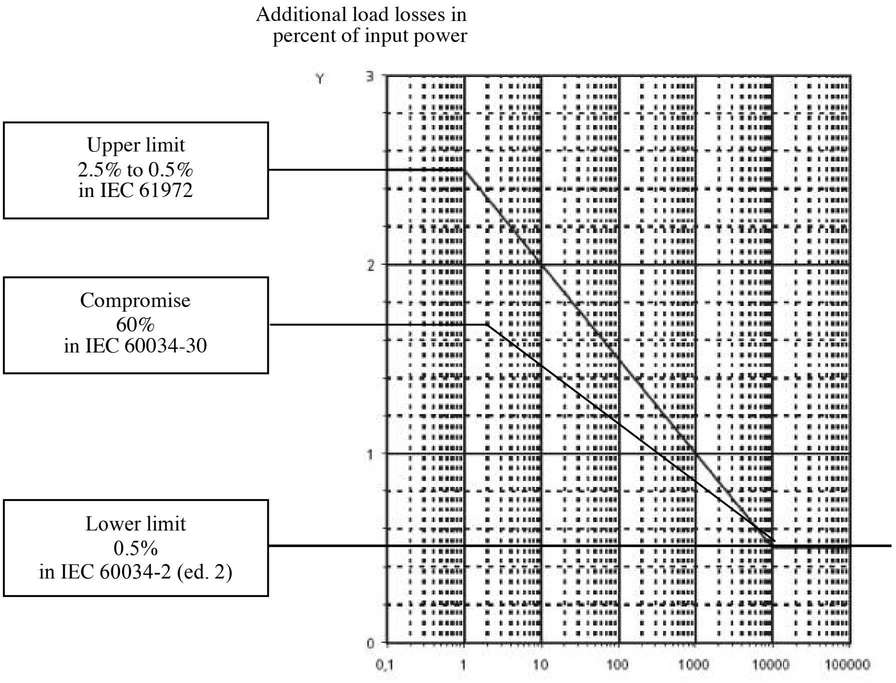


Figure 8. Default values for additional stray load losses in IEC 61972[24]

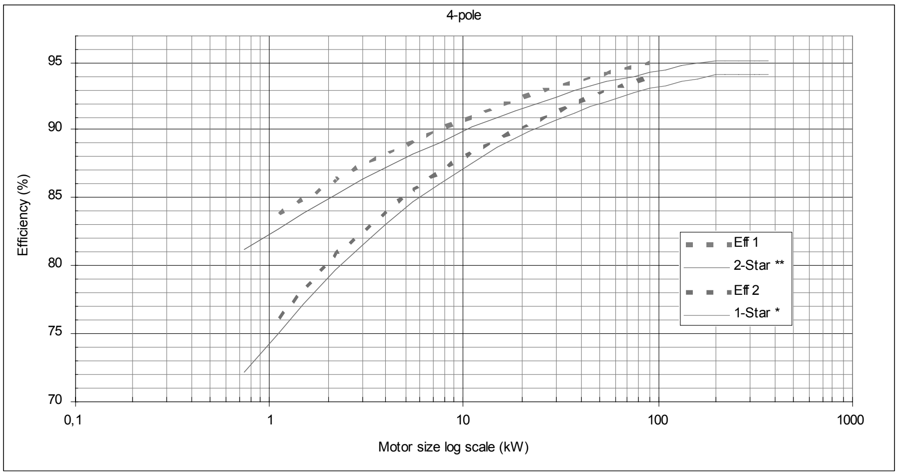


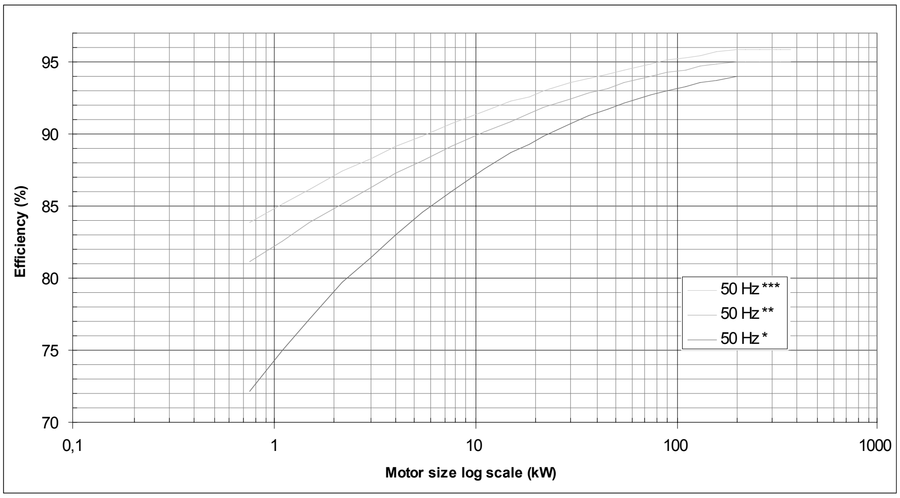
Figure 9. Adaptation of Eff 1 and Eff 2 levels to new testing method in IEC 61972

In 2002 IEC adopted an advanced testing method IEC 61972 that was based on an integral testing compatible with the USA and Canada. It also included default values for stray load losses that were considered to be on the upper limit of possible values. European CENELEC refused to adopt this testing standard in Europe out of fear for additional cost for testing equipment and labor cost (it was claimed to take 10 % to 15 % more testing time), especially for mid and large size motors and for small and mid size manufacturers that could not afford it.

Work has been started on a compromise testing standard IEC 60034-2 (edition 4)[25] in 2005. It was adopted by a large majority in 2006 and will be up for final vote in 2007. It includes both methods of IEC 61972 but adds a revised calculation method named "eh star" that should reduce the testing effort especially in larger machines. Eh star was initially proposed already in 1967 by Heinz Jordan et al. from the University of Hannover Germany to account for the so far underestimated additional stray load losses[26]. The term eh star was derived from "einphasig mit Hilfswiderstand" in star arrangement. Initial tests performed and published by Jordan in 1967 showed the eh star method giving slightly lower additional load values than results from the reverse rotation test of IEEE 112B. The 2005 available testing results from Universities of Nottingham (Keith Bradley) and University of Amsterdam (Andreas Binder, et al.)[27] show a fairly good correlation with other methods and no bias. Natural Resources Canada and other testing institutes will carry out further independent testing to check whether eh star will eventually be an acceptable testing method worldwide.

In 2006 CEMEP also initiated a New Work Item for Energy Efficiency Classes IEC 60034-30[28] that will be presented by WG 31 chairman Martin Doppelbauer (see *Figure 10*).

The advantage of the new 3-Star classification for AC motors between 0.75 and 370 kW clearly is its contribution for unification and harmonization of the global marking schemes and



Source: Martin Doppelbauer, draft February 2007

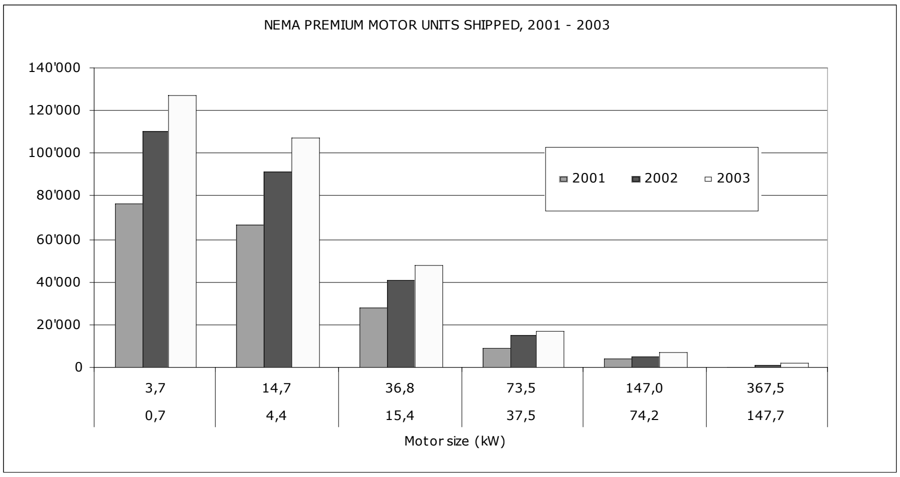
Figure 10. Proposed new IEC 60034-30 Energy Efficiency Classes 0.75 kW – 370 kW (4-poles, 50Hz)

labels. With the introduction of a Premium 3-Star level it both shows the "reach standard" for today and leaves open the later technological development for an eventual 4-star Super Premium motor. A 3-Star system increases efficiency compared with a wide spread 1-Star today by 10 percentage points (for small sizes) to 2 points (for large motors) and thus reduces losses still by 30 % to 40 %. It also gives coordinated classifications for 60 Hz and 50 Hz motors and shows the physical elements that distinguish the losses in these two conditions. The old CEMEP values for Eff1 and Eff2 have been downgraded by a compromise value (see figure 8) of 60 % of the difference between IEC 60034-2 (ed. 29) and IEC 61972. All efficiency curves are given in mathematical formula in smooth form to allow for various regional and national distinctions for frame dimensions and motor sizes.

The complete set of action

Many economies have already shown a progressive effort in the field of energy efficient electric motors and systems. We can learn from their experience of moving the market in a decade. And we can expand of the guidance CLASP gives from introducing Standard & Label programs for household appliances and industrial motors worldwide[29]. SEEEM wants to focus and propagate the major ingredients of successful national motor policy – embedded in an international drive for awareness like IEA's 2006 "Towards a Plan of Action"[30] and the EC's "Action Plan for Energy Efficiency" also in 2006[31]:

- **Motor market transparency**: Market research is necessary to show major production volume, import/export and user volumes, motor categories and types of stakeholders. The data should be compared with international benchmarks to understand specific national characteristics. It needs also to deliver annual progress data for policy steering and public information use.
- **Independent motor testing** needs to be based on agreed verification methods. Round robin tests with international testing laboratories and national industrial testing facilities to check compliance and tolerance levels.
- **Consistent marking scheme and labeling:** International standard energy efficiency classes (3-, 2- and 1-Stars) on each motor nameplate including value for tested efficiency will be available after 2008. This will also enhance market transparency and allows end-users and OEM to better decide on product purchases based on real product quality information.
- **MEPS:** National legislation for timely introduction (needs 2 to 4 years ahead of enforcement) of mandatory market thresholds for all electric motors sold. Market monitoring and compliance checks are necessary. The MEPS also has to be reviewed regularly like the DOE now does for EPAct (small electric motors: determination analysis until 6/2006; electric motors 1-200 hp: standards until 6/2011)[32]. MEPS can be distinguished in industrialized economies who can have 2-Star in place by 2008 and may move up to 3-Star by 2010-2012. Developing countries would delay this timeline by 2 to 5 years according to their ability to adapt their markets.
- **Advanced products "Reach Standard":** Advanced innovative product specification for trendsetting manufacturers and on front running users. Advance notice of eventual shift of reach standards to become the new MEPS. This is important both to stimulate manufacturers in planning their production capabilities ahead and to give users a framework to optimize their mid term investment policy plan.
- **Quality repair:** Motors rewound after failure tend to increase losses by 8 % to 10 % and thus have lower efficiencies of several percentage points. With more expensive efficient new motors a common loophole especially in mid to large size motors is switching to cheaper low quality repair. Standards on good repair practice[33] are necessary and have to be enforced to avoid backlash in MEPS programs.
- **Building codes**: Heating, ventilation and air conditioning systems contain electric motors in various forms and types. They can be regulated via building codes, component and/or building energy performance standards.



Source: NEMA 2004

Figure 11. NEMA Premium motor sales

- **Procurement programs**: Public or private agencies can speed up the introduction of advanced efficiency systems (reach) by demanding these products/systems in procurement for use in small and full scale projects or whole public infrastructure systems. A recent US example is FEMP[34] with NEMA Premium motors in 2006. Procurement also stimulates market development because early movers give manufacturers confidence for production shifts.
- **Incentive programs**: Governments at various levels, as well as authorized entities such as utilities or ESCOs, can offer a range of incentives to encourage the uptake of efficient equipment and practices. These range from subsidized audit programs to uncover cost-effective energy-saving potential to tax credits or other fiscal incentives and can target manufacturers, distributors or equipment end-users.
- **Voluntary programs**: Manufacturers and end-users have a wide range of cost-effective options to increase the adoption of high-efficiency equipment, systems and practices. Motor end-users might take advantage of free audit programs to identify retrofit opportunities; they can implement energy management systems or specify the use of high-efficiency equipment in motor replacement plans or industry-wide codes of conduct. Motor manufacturers can offer pay-as-you-go schemes for ASDs and efficient motor systems, which could leverage carbon markets, or offer climate friendly equipment for which the lifecycle energy use and greenhouse gas emissions have been offset by mitigation projects. Multinational corporations can facilitate the uptake of efficient motors by companies in their global supply chains.
- **Training & tools**: Motor databases (EuroDEEM[35]), motor and system sizing tools (Motor Master+[36], Promot[37]), standard testing equipment and procedures for Audits. Specific education and training programs for motor manufacturers, engineers, users, administration agencies, ESCO's, Motor Challenge[38], etc.

Some European industry representatives have voiced concerns about the added cost to manufacturers that might arise from adoption of new testing standards (in particular, costs that would arise, if motors had to be requalified according to new standards), as well as about the willingness of their clients to pay the extra cost for Eff 1 motors. CEMEP therefore takes the position that overall motor system efficiency improvement and the appropriate use of ASDs should be emphasized, rather than a focus on mandatory standards for motor efficiency[39], following their successful implementation of a 1999 Voluntary Agreement (VA) with the EC, which resulted in the rapid elimination of Eff 3 motors.

Obviously NEMA and the US motor manufacturers had the same hesitance at the outset - over a decade ago – but eventually invited federal government regulation under EPAct in 1992 to avoid an unworkable patchwork of State regulation and to insure industry input (enforced after 5 years transition time in 1997). Now market figures and high industry profits in the USA and Canada show the results of the rapid market development clearly. International markets can only be - without environmental legislation to begin with - legally closed for competitors from imports against WTO rules and technological development cannot be stalled without loss of market shares and brand leadership.

In many countries and with a number of categories of energy using equipment different policies have been tried in the last two decades:

- Codes of Conduct (CC) that bind an industry (or their associations) to its promise,
- Voluntary Agreements (VA) between industries (or their associations) with states,
- Mandatory Minimum Energy Performance Standards (MEPS).

Obviously all of them have a chance to deliver results. They depend on the difference of the project path compared to the base line, the continuous monitoring and the sanctions for non-compliance.

Next steps for SEEEM

SEEEM has only started by mid 2006: According to its work plan electric motors come first, work on motor systems (or more precisely: core motor systems) is next. The work is organized in three working groups:

- WG 1: Harmonization Issues
- WG 2: Policy Issues
- WG 3: Stakeholder Support

WORKING GROUP 1: HARMONIZATION ISSUES

Prof. Anibal de Almeida (University of Coimbra, Portugal) was appointed to chair WG 1. The WG 1 has been engaged in launching the New Work Item IEC 60034-30 "Energy Efficiency Classes" (i.e., ensuring participation, submission of proposals consistent with the SEEEM report "Market Transformation to Promote Efficient Motor Systems"); obtaining test results on the Eh-Star methodology included in the new IEC 60034-2 (edition 4) testing standard from the Nottingham (UK) and Darmstadt (Germany) universities for consideration by WG 1; and liaising with groups involved in the development of ecodesign standards under the EU Energy-using Product Directive. Work will now focus on advanced motor technologies, ASD integration and systems evaluation aspects, system considerations, definition of super premium motors, etc.

WORKING GROUP 2: POLICY ISSUES

Paul Waide (IEA, Paris) is chairing WG 2. In the meantime, we at A+B International have been working to bring SEEEM to the attention of stakeholders and relevant policy processes, such as the UN Framework Convention on Climate Change and Kyoto Protocol, the G8 "Gleneagles Plan of Action", "Marrakech Process International Task Force for Sustainable Products[40]" which intends to build upon SEEEM in its future work, and the Asian Pacific Partnership on Clean Development & Climate. This effort has been closely linked with our fundraising activities. Building a network of stake holders in international agencies and national governments, developing of a set of clear steps for introduction of MEPS.

WORKING GROUP 3: STAKEHOLDER SUPPORT

Hans de Keulenaer (European Copper Institute, Brussels) has been appointed to chair WG 3, and he has already made European Copper Institute tools available for use by SEEEM. These include tools for knowledge management and knowledge sharing. With these electronic means for learning and marketing, we can facilitate WG 3 (and all other WG's) participation from all over the world without engaging in unnecessary costly, time consuming and polluting travel.

In addition, we are working intensively with UNEP and UNDP in order to prepare a proposal for a Global Environment Facility GEF SEEEM project, which would facilitate the full integration of developing countries in activities to move towards efficient motors.

Finally, we are beginning to develop strategic alliances with many more global partners to facilitate outreach and to leverage synergy potential with other efforts. In a global program with a strong focus on developing countries new means of communication that need much less international travel have to be put into play: Expanding electronic communication tools and data base for best practice can be used to save time, cost and greenhouse gas emissions.

The first technical phase 2006/07 with harmonized standards for testing, tolerances, marking schemes etc. will be followed 2007/08 by the more intricate networking in the policy field to inspire countries for MEPS and other facilitative policies and programs and set up a global system of monitoring and compliance checks. We will need international institutions to support the work (CLASP, IEA, and WBCSD) and also we will need the support of international agencies like UNDP and UNEP to reach the less developed economies but due to rapid expansion more crucial part of the world at the same time in history. And we want to gain the confidence and the support of the existing standard organizations IEC and IEEE and the manufacturing associations like NEMA, JEMA, CEMEP, etc. We are co hosting the Motor Summit 200710/11 April 2007 in Zurich Switzerland together with S.A.F.E. and SFOE, SEEEM hosts a side event for stakeholders.

We at SEEEM will be working with other partners in 2007 to address issues of mutual interest. We have participated in launching the new IEA implementing agreement of energy efficient equipment on 9 March 2007 in Paris; we will chair (and SEEEM members will participate in) a panel on CDM methodologies for motor-driven systems at the UNIDO/Climate Technology Initiative/UK Trade and Investment Seminar on Industrial Energy Efficiency under CDM/JI (19-20 March 2007, Vienna), as well as facilitate a discussion session on linking the energy efficiency and climate communities. At the CDM Joint Coordination Workshop (24-25 March 2007, Bonn), we will present our views on energy efficiency promotion under the Clean Development Mechanism, using motor systems as an example. And we intend to work with EU-JRC and other partners to conduct a workshop "Defining a Clean Development Mechanism Pilot Program to Promote High-Efficiency Electric Motor Systems" immediately following the EEMODS and SEEEM Side Event (June 2007).

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