From voluntary to mandatory: policy developments in electric motors between 2005 and 2009

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Abstract

The energy efficiency potential of improved electric motor systems is estimated as 10% of global electricity demand. Motor systems to run pumps, fans, compressors and material handling & processing are the dominant electricity user in industry. The large energy efficiency potential is only slowly being tapped by national and international activities. Experiences of electric motor systems market transformation programmes between 2005 and 2009 are reported in this paper. The conflicts of various industry groups and competing standards and their impact on slowing energy efficiency market development are explained. The build-up is described as a dedicated Community of Practice in the Standards for Energy Efficiency of Electric Motors Systems (SEEEM) with various stakeholders to promote the global harmonization of energy efficiency standards and to promote effective measures for their implementation. The importance of international standardization of testing procedures and efficiency classes at IEC for full market transparency is emphasized. The impact of the European Ecodesign programme for motors is reviewed.

Lessons learnt and useful conclusions for other mass produced electric equipments are summarized. Rapid market transformation happens because many key players - institutions and individuals - understand and accept a common goal and contribute jointly to the systematic development of voluntary and mandatory instruments.

Background

In 2005, there were (the following data are from Brunner/OECD 2008[1]) some 300 million electric motors of industrial size (i.e. larger than 0.75 kW output) running globally. They drive pumps, fans, compressors and material handling & processing equipment in industry, infrastructure and large buildings. Electric motors systems are responsible for some 40% of global electricity use. The energy efficiency potential of electric motor systems is considered to be on average between 20% and 30%. This amounts to a potential reduction of 10% of global electricity demand (and the associated CO_2 emissions reductions). With some 30 million new motors sold every year there is a large potential of cost efficient energy savings both in new and replacement systems.

A more energy efficient motor application is achieved through proper motor sizing according to the required loads, to the use of recent best available technology (BAT) with efficient motors (Premium Efficiency class IE3 according to IEC 60034-30) and adjustable speed drives, plus a wide periphery of efficient gears, couplings, brakes and transmissions that are selected and matched through advanced engineering skills. Thus, an efficient motor system is based on the systematic integration of optimal components for a given task. A global market transformation is needed to focus the various voluntary, mandatory and financial policy instruments to harvest the large energy efficiency potential in industry, infrastructure and building systems all over the world. In order to focus and speed up this market transformation an increasing number of various activities have taken place in the last decade.

The barriers to a rapid market transformation are lack of training and capacity of technical staff in factories, low awareness of favourable life cycle cost, split incentives between buy-

Table 1. Motor efficiency levels, test methods and Minimum Energy Performance Standards circa 2005. Source: John Mollet, ICA, EEMODS'05

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

er and user of motor systems and the absence of harmonized products available in global markets. Although motors and their driven equipment have been traded globally for many decades, discrepancies in many different national and regional standards for size, efficiency and verification of energy efficiency hamper and slow down a harmonized and transparent market development towards more energy efficiency. For example: until 2007 different electric motor testing methods and procedures produced different results and thus did not allow motor manufactures to compete in a transparent and credible fashion, especially in markets with mandatory energy performance standards.

THE FIRST STEPS TOWARDS A COMMUNITY OF PRACTICE

After a series of discussions at several international conferences (Summer studies arranged by the American Council for an Energy Efficient Economy ACEEE and the European Council for an Energy Efficient Economy eceee, Energy Efficiency in Motor Driven Systems EEMODS, Institute of Electrical and Electronics Engineers IEEE, etc.) a special workshop was convened by the European Joint Research Centre in September 2005 in Heidelberg Germany as a side event to EEMODS'05[2] to address this problem of harmonization. This gathering of international motor system experts became the crystallization point for a new global motor systems harmonization initiative. Table 1 shows the available information in 2005 on the global market share in four efficiency levels, mandatory and voluntary energy performance standards and different testing methods used.

In the following parts of the paper, both the market barriers (different testing standards, grid frequency and efficiency classification) are identified as well as the major change agents (US Industry and NGO cooperation, US and European MEPS introduction, the SEEEM harmonization initiative and the development of global IEC standards) are presented.

Identification of market barriers

INDUSTRIAL AND LARGE-SCALE USERS

Electric motors represent a typical product for industry use, but they are also found in many other sectors: first-cost conscious small & medium sized enterprises, large-scale manufacturing and process industry, commercial (and public) enterprises with large buildings and public entities running infrastructure systems. Most of these users are not oriented towards technical solutions and are not aware of the electric motor energy efficiency potential. A large majority of electric motors (50-80% according to various sources) are sold through wholesalers and Original Equipment Manufacturers (OEM) that have no direct contact with the end user. So, even with a least life cycle cost oriented end user, the market signal to the motor manufacturer would be very weak. Further, motors are used in the context of complex machinery where they are neglected as a minor cost fraction of the entire investment. Even cost conscious industrial users do not see the energy efficiency potential in this field and their advantage in lower total cost of ownership, even with typical pay back times as short as 1-3 years. Thus, the market is not very transparent and least life-cycle cost investment decisions are not the norm.

US AND EUROPE: DIFFERENT DEVELOPMENT SPEEDS AND CULTURES

In the US, motor system efficiency research, industry awareness building and training programmes have been on the agenda for decades. Programmes such as *MotorChallenge, Motor Decisions Matter* and *BestPractice* accompanied by an array of Motor Tip sheets and engineering tools (such as *MotorMaster+*) have been launched by both government agencies (DOE EERE), industry associations (NEMA, IEEE) and NGOs (ACEEE). The most successful schemes so far have been incentive programmes (based on free audits), public procurement programmes (Federal Energy Management Program, FEMP) and mandatory minimum energy performance standards (MEPS). MEPS were decided in 1992 when industry accepted that no rapid market transformation towards more efficient motors was possible otherwise.

Europe lags behind by more than a decade. Even with many similarities as to influential motor manufacturers, large industrial motor users and comparable material and energy prizing very little has been achieved in terms of market transformation: Industry wanted repeatedly to develop their markets without government influence, only voluntary labelling and market stimulation activities (MotorChallenge) have been accepted, but no MEPS.

The controversy of the accuracy, repeatability and reliability of USA and European motor efficiency tests has been growing since the late 90s[3,4,5]. Two key elements have been disputed:

- The impact of the different grid supply frequencies of 50 Hz in Asia and Europe versus 60 Hz in North and part of South America.
- The product variations from different motor efficiency testing methods.

DIFFERENT AC FREQUENCIES

60 Hz frequencies are used in grids representing some 38% of the global electricity use with USA, Canada, Mexico, part of Brazil and part of Japan. 50 Hz frequencies are used in networks representing some 62% of the global electricity use, primarily in Europe, Asia (minus part of Japan), Africa, South America (minus part of Brazil), and Australia.

An AC induction motor running at 60 Hz instead of 50 Hz turns with a 20% higher rotational speed and thus (with the same torque) with a 20% higher mechanical output. With this higher output the mechanical and electrical losses increase by less than 20%. An efficient 60 Hz motor is generally 0.5% to 2% (depending on size and speed) more efficient than a 50 Hz motor of the same construction and quality (see figure 1).

For a long time, the 50/60 Hz issue was not understood or accommodated for in standards, and the uncertainty has been exploited in marketing to claim superior products on both sides. Obviously this discrepancy is - especially with smaller motors and their geometrically defined lower efficiency - critical in market development towards higher efficiency classes.

TESTING STANDARDS

IEC Testing Standards

In a 2008 survey of all five large and global motor manufacturers, ***non-aligned standards were identified as the major market barrier*** to energy efficient motor products (see Table 2)[6].

The standard testing method for electric motors in Europe and Asia with 50 Hz frequency grid supply since 1972 was the International Electrotechnical Commission IEC 34-2 "*Rotating electrical machines – Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)"* (first edition 1972, last update 1997). This method provided only a default 0.5% value for the additional stray load losses, which is considered as far below the "real" value, especially in small motor sizes. This lead to the suspicion that motors tested according to this IEC standard were falsely classified from 1% to 3% points better than actual performance. This deviation can amount to a full efficiency class and thus having an unjustified market advantage.

IEEE Standards

In North America the Institute of Electrical and Electronics Engineers (IEEE) introduced the "*Standard Test Procedure for Polyphase Induction Motors and Generators*" IEEE 112 (first edition in 1984, last update 2004). It includes a motor efficiency test "Method B" which delivers a more complete and reliable measure to verify and compare standard, high efficient and premium efficient motors. The method includes an input-output test of an electric motor under laboratory conditions and provides a value for the five major motor losses (including the additional stray load losses) and their total. IEEE 112 B became the more accurate *State of the Art* testing method because it takes stray losses fully into account.

Market disturbance resulting from different test standards

Product quality is obviously a key feature in market transparency and a major prerequisite for market transformation. The unresolved conflict regarding the virtue of the North-American (60 Hz) test method vs. the primarily European (50 Hz) test method lead to growing market disturbances involving the CEMEP-led European motor manufacturers, who are influential as exporters in the entire 50 Hz world (Asia including part of Japan, Africa, Australia, part of South America) versus the NEMA-led USA manufactures who are dominant in the USA, Canada, Mexico and other 60 Hz parts of South America (Brazil) and Asia (Japan). The introduction of IE3 Premium Efficiency Motors in early 2000 accentuated the market disturbance.

Different countries were involved in this controversy in different degrees: Australia - mostly dependent on imports - was severely hurt by low quality imports where more self supporting economies like Japan and China with a large domestic production of motors were not. This obviously stimulated an early Australian MEPS introduction in 2001 (updated in 2006).

ENERGY PERFORMANCE STANDARDS AND LABELS

US Mandatory Standard Scheme

In the US, the awareness of the energy use of electric motors in industry grew after 1976 when a Department of Energy-commissioned report by Arthur D. Little showed the large energy efficiency potential[7]. The research in pilot studies and the training produced a wide spectrum of programmes, tools and campaigns. The US decision in 1992 to adopt mandatory minimum energy performance standards for electric motors came after a long controversy between industry (National Electrical Manufacturers Association NEMA) and non-government agencies (represented by ACEEE). Industry needed to be convinced that a mandatory scheme was to their advantage in selling more efficient (and slightly more expensive - but cost effective) motors to their industrial consumers. The Energy Policy Act EPAct established 1992 an accepted set of rules for regulation that were enforced by 1998 with the so called *EPAct-high-efficiency level* (equivalent to IE2). The introduction of mandatory MEPS proved to be successful and - in the absence of any other major market transformation instrument - let the market share of IE2 jump from below 20% to over 70% by 2005[8] within a relatively

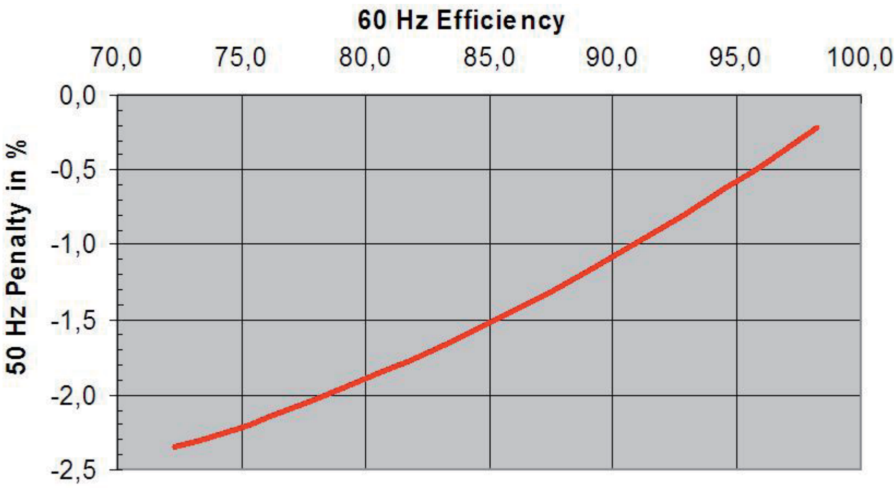

Figure 1. Efficiency difference for 50 Hz and 60 Hz motors. Source: Martin Doppelbauer 2007

Table 2. Barriers to trade: 15 options presented in a survey of five global manufacturers (A-E). Source: A+B International, OECD 2008

	Trade Barriers International	A	B	C	D	E	total
1	Pre-shipment inspection and customs procedures	(yes)	yes	yes	yes	yes	4
2	Quantitative import restrictions (Import licensing, Import quota or prohibitions)	no	yes	no	no	no	1
3	Import surcharges or border taxes	(yes)	no	yes	no	yes	2
4	State-trading monopoly or state monopoly control of imports	no	yes	no	no	no	1
5	Cargo handling and port procedures or requirements	no	yes	no	yes	yes	3
6	Technical product regulations, standards and approval procedures	yes	yes	yes	yes	yes	5
7	Restrictions on investment	no	yes	no	no	no	1
8	Restrictions on after-sales services	no	yes	no	no	yes	2
9	Price controls or administered pricing in destination market	no	yes	no	no	no	1
10	Regulations on payment; restrictive foreign exchange allocations to importers	no	no	yes	no	no	1
11	High or discriminatory taxes or charges in destination market	(yes)	yes	yes	yes	no	3
12	Subsidies or tax benefits given to competing domestic firms in destination country	no	yes	no	no	no	1
13	Violation of intellectual property protection	no	yes	yes	yes	no	3
14	Government procurement procedures in destination market	no	no	no	no	no	0
15	Informal "additional payments" required to effect import of your product	no	no	no	yes	no	1
	total	1	11	6	6	5	29

short period of time. The scheme still had a large list of exceptions for "non general purpose motors" that need not comply (like flange mounted motors and other definite or special purpose motors with variations in mechanical or electrical design), therefore the 70% practically meant a near 100% compliance of the motors that had to comply.

In the follow up - with no more potential for further market shares at the IE2 level - NEMA launched the Premium motor (IE3) in 2003 and managed to align a series of large US manufacturers to push the product with voluntary means and some local incentive programmes from utilities. By 2006 FEMP was ready to demand Premium motors for all public procurement. By the end of 2007 ACEEE launched together with NEMA a successful campaign to convince US Congress to adopt Premium as MEPS by 2011.

The success of the rapid US market transformation from below EPAct- to EPAct-level motors comes from the long-time and deep cooperation between NGO and industry coupled with a generous support from utilities. The combination of voluntary programmes with tools and training, financial benefits for the buyer and mandatory minimum standards to raise the level of performance has proven more successful than any only voluntary system. NGO (ACEEE) influence was imperative in bringing industry to accept ambitious efficiency goals. Motor industry associations (NEMA) brought government and power utilities to have incentive programmes in place years before

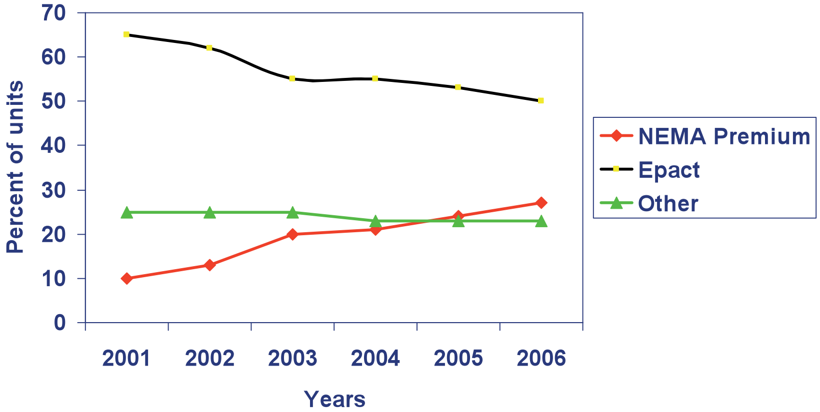

Figure 2. USA market transformation for motors Source: Rob Boteler, NEMA 2008

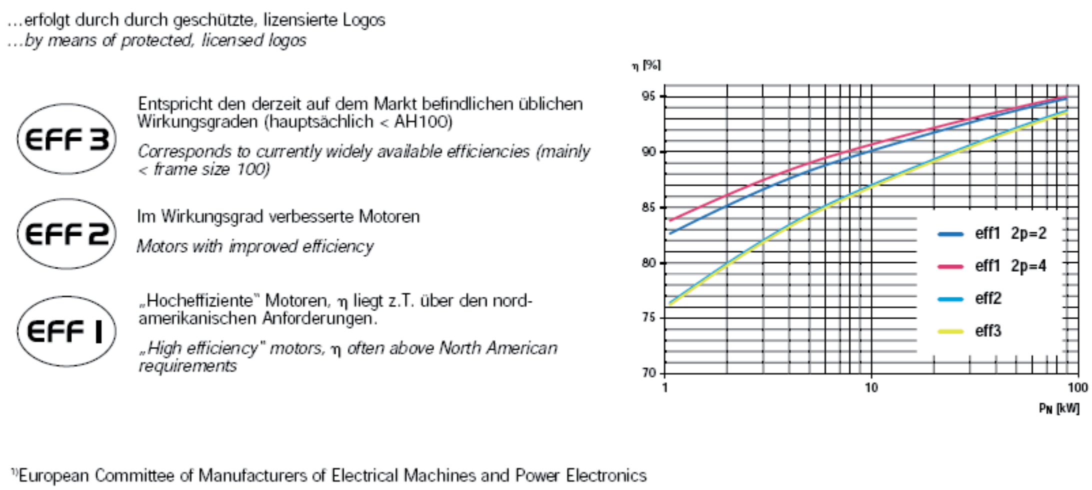

Figure 3. European CEMEP/EC voluntary agreement on motor efficiency classes and labels. Source: CEMEP 2007

mandatory standards were effective. US Congress adopted legislation in 1992 (and now again in 2007) for mandatory MEPS, which was a strong market intervention but nevertheless widely accepted by industry. Industry understood that more efficient (and more expensive motors) were favourable for their business prospects. This has sped up US market transformation and led to a smooth upgrading of the entire motor manufacturing industry.

European Voluntary Label Scheme

With growing awareness of manufacturers and consumers for energy efficient products and with the European efforts for a transparent market development, the mandatory EU Energy Label[9] scheme for household appliances was introduced in 1992. The motor manufacturers were asked to also contribute in this market transformation process. In 2005, the EU launched a Green Paper on energy efficiency entitled "*Doing More with Less*"[10] emphasizing a key strategy to both reduce cost and emissions plus produce sustainable employment. It was followed by an EU Action Plan for Energy efficiency[11].

The motor industry association of the European Committee of Manufacturers of Electrical Machines and Power Electronics CEMEP did not consider mandatory standards as practical and successful. After lengthy negotiations with the European Commission a first voluntary agreement was achieved in 1998 that 30 CEMEP members signed (manufacturers from 9 European countries including a US and a Brazil manufacturer). The label scheme with three efficiency classes Eff1, Eff2 and Eff3 was adopted in 1999 (see Figure 3). It was coupled with the industry commitment to cut Eff3 market shares in half within 5 years and to provide annual data of the progress made in market transformation.

The voluntary scheme to designate energy efficiency classes for low voltage AC motors of 1.1 kW to 90 kW is an important element of European efforts to improve energy efficiency. The classification scheme informs OEMs and motor users, in a simplified, visible manner about the importance of electric motor efficiency. The European motor manufacturers are aware of their responsibility for the environment and are going to continue their efforts to bring energy-saving motors to the market. The Voluntary Agreement of CEMEP as a self-commitment on the part of the motor manufacturers was renewed in 2006.

The scheme was slow in introducing the idea of different efficiency classes and their labels, which are still not mentioned in all manufacturers' catalogues and on every motor rating plate. It was quite successful in practically eliminating Eff3 motors from the market (see Figure 4), but it did not succeed in achieving a market share of more than 12% of efficient Eff1 motors in 8 years.

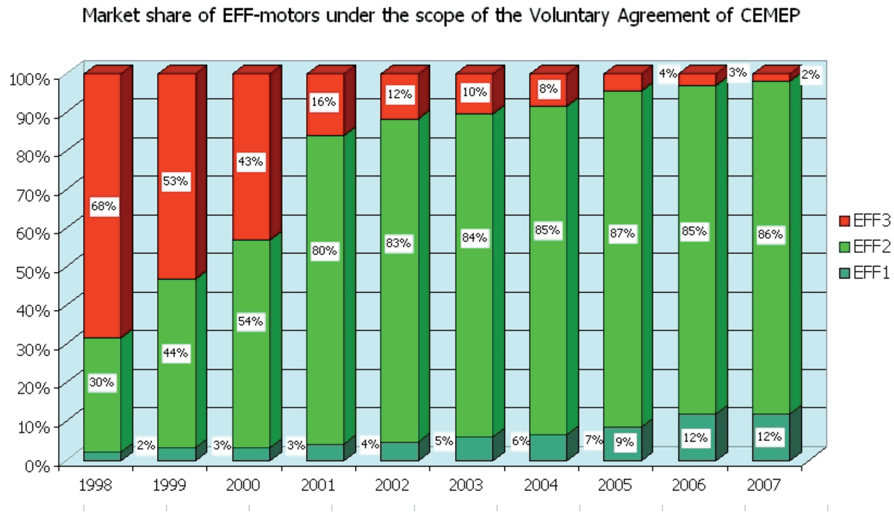

Figure 4. European motor market transformation. Source: CEMEP 2008

Table 3. Initial motor systems standards harmonization concept in 12 points. Source: A+B International, EEMODS'05

1. Motor Size 0,5 kW to 300 kW ■ 0,1 kW to 500 second phase	**7. Partial Load** ■ 75%, 50%, 25%
2. Testing Standard ■ IEEE 112 B or IEC 61972	**8. Motor Nameplate** ■ A to D
3. D (MEPS 2005) ■ Eff 1	**9. VSD Quality Standard** ■ losses
4. C (Best motor 2005) ■ US EPAct, Australian MEPS	**10. Integrated Pumps** ■ A to D
5. B (Best motor 2005) ■ Australian premium	**11. Shift Scale after 5 years** ■ 10% less than A
6. A (Best motor 2010) ■ 20% less losses than B	**12. Market share data** ■ publish annually

In comparison with the US, it is evident that the EU market transformation of electric motors sales with IE1 and below (Eff3) to IE2 efficiency level (Eff1 or EPAct) was 10 years behind and much less successful (12% instead of 70% market share). There is no evidence of different market conditions (that are not related to programmes and standards) such as manufacturing and material cost, energy price and market structure on the motor manufacturing and motor user side, that could explain the slow European market transformation other than the absence of programmes and MEPS. In particular, the early MEPS in the US appear to be crucial.

In March 2007 the European Committee of Domestic Equipment Manufacturers CECED publicly announced in an official statement that it would support mandatory minimum energy performance standards for household appliances because only voluntary measures together with mandatory labels could not successfully deliver the desired market transformation. In June 2007, the chairman of the LV Motor Working Group in CEMEP, Jürgen Sanders, announced at EEMODS'07 in Beijing that also CEMEP would support motor MEPS at Eff1 level[12]. This reversal of the previous position of the European industry came as a positive understanding that voluntary measures and labels only can achieve a limited market transformation. European motor and appliance manufacturers had suffered in the past decades from cheap imported products. The industry change of heart came less from altruism or ecological concerns but from well documented fears of further eroding market shares.

Stakeholder Community of Practice SEEEM

For the purpose of speeding up the process of market transformation and global harmonization, an informal international workshop was held during the Energy Efficiency in Motor Driven Systems Conference (EEMODS '05) in Heidelberg on 5 September 2005. An initial 12 point proposal (see Table 3) outlining the need for and the direction of the harmonization was discussed by participants from some 20 countries, including Australia, Brazil, China, India, European countries, New Zealand, and the USA (representing academia, motor manufacturers, standards organizations, national and international governmental agencies, etc.).

The proposal was considered interesting and received broad support. The participants agreed to intensify this process and to launch an international industrial motor system harmonization initiative. A second concept paper was sent to the participants of the Heidelberg meeting and other interested parties for comment in October 2005. Subsequently a series of bi- and multilateral talks were held before and during the Kyoto Protocol Conference of Parties COP 11 in December 2005 Montreal, with representatives from international institutions, governments and other institutions to secure their support for the initiative, structure the Work Plan and secure its funding. The International Energy Agency IEA held a workshop on Industrial Electric Motor Systems 15-16 May 2006 in Paris. In support of the G8 Plan a paper was issued[13] supporting the SEEEM harmonization drive.

The SEEEM Steering Committee with 11 members from 9 countries as well as a Technical Advisory Group (TAG) was appointed. The first meeting of the TAG (18 April 2006, New York) established the methodological foundation for the harmonization work. The public launch of SEEEM took place at the International Conference on Energy Efficiency on Domestic Appliances (EEDAL'06) in London on 20 June 2006. Over 40 representatives from 18 countries exchanged views on the proposed harmonization programme. A Launch Paper[14] was published together with a Media Statement: *The Community of Practice supports the harmonization process actively*. This was followed by several meetings: 9 April 2007 at the Motors Summit'07 in Zurich Switzerland, 13-14 June 2007 at EEMODS'07 in Beijing China, and 24 November 2008 at the Motor Summit'08 in Zurich Switzerland. In both Motor Summits important new findings were presented, among others from Canada[15,16], to clarify technical controversies:

- In 2007 on test results for comparing the proposed Eh star testing method for stray load losses with the IEEE 112B method
- In 2008 on tests results on efficiency of Variable Frequency Drives under varying load and speed.

SEEEM had now been established as a community of practice which was made possible by active collaboration with the following institutional Supporters:

- American Council for an Energy Efficient Economy (ACEEE)
- Australian Greenhouse Office (AGO)
- Austrian Energy Agency (EA)
- China National Institute of Standardization (CNIS)
- Collaborative Labelling and Appliance Standards Program (CLASP)
- International Copper Association (ICA)
- International Institute for Energy Conservation (IIEC)
- National Electrical Manufacturers Association (NEMA)
- Natural Resources Canada
- New Zealand Electricity Commission
- SenterNovem, The Netherlands
- Swiss Agency for Efficient Energy Use (S.A.F.E.)
- Swiss Federal Office of Energy (SFOE)
- Union of the Electricity Industry (Eurelectric)
- UK Market Transformation Programme (MTP)
- United Nations Development Programme (UNDP/GEF)

Participation from industry, academia and over 20 countries made the head start of the harmonization project. Subsequently work progressed also in two working groups:

WG 1 Technological Harmonization Issues (chaired by Anibal de Almeida)

- Evaluate existing and new energy efficiency testing standards and levels of tolerance for efficiency determination, and recommend procedures for use by regulatory programmes that will promote international comparability
- Research and distribute results of comparative testing/calculation projects
- Recommend suitable energy efficiency classes and associated marking schemes (collaborate with IEC WG 31 on IEC 60034-30)
- Consider scope for harmonization of labelling scheme(s)
- Compile information on state-of-the-art motor technology and efficiency levels
- Ensure SEEEM input into relevant standard-making and regulatory processes

WG 2 Policy Issues (Co chaired by Paul Waide and Hans de Keulenaer)

- Recommend mandatory MEPS and timetables for compliance
- Recommend voluntary standards for state-of-the-art motors (coordination with WG 1)
- Compile information and serve as a forum to exchange expertise on motor efficiency compliance regimes, incentive programmes and procurement programmes
- Ensure SEEEM input into policymaking processes

The role of the SEEEM project[17] was that of a communication platform and a catalyst: Bringing information from reliable sources forward, having stakeholders discussed controversial issues in transparent formats and setting the pace for consequent standardization work in IEC. It profited from a few front runner countries and industries as well as parallel international work (Collaborative Labelling and Appliance Standards Program CLASP, International Task Force for Sustainable Products ITFSP, IEA and United Nations Development Programme UNDP). It eventually led to a more sustainable programme in the framework of an IEA Implementing Agreement on Efficient Electrical End-Use Equipment 4E the Electric Motor Systems Annex EMSA (www.motorsystems.org).

IEC standards for testing and efficiency classification

The International Electrotechnical Commission (IEC) founded 1906 in London and located in Geneva, Switzerland, is the leading global organization that prepares and publishes international standards for testing and efficiency classification with 68 national committees and 77 affiliated countries standards for all electrical, electronic and related technologies. These serve as a basis for national standardization and as references when drafting international tenders and contracts.

In IEC, the Technical Committee 2 (TC2) has been responsible for all international standards in rotating machinery (i.e. electric motors and generators) since 1949. A total of 28 nations are members (plus 7 observers) and participate actively in the work on new standards. The majority of the standards traditionally have to do with compatibility of sizes, safety features and the like. Energy efficiency was made a topic only in 2000.

In 1997 the IEC– on a previous mandate of the European Commission to CENELEC[18] – had started to work in TC2 in its Subcommittee 2G on a harmonized new motor testing method that would eventually improve on the 1972/96 version. After a four year long controversy, the introduction of a global standard IEC 61972: 2002 was decided but failed to be accepted by the European Committee for Electrotechnical Standardization CENELEC, the European arm of IEC. So in 2003, a newly formed WG 28 started to work on the IEC 60034-2-1 that was finalized and published 10 September 2007.

The new testing standard introduced several methods for verification of energy efficiency. It also included a rating of their "level of uncertainty", a measure to define qualitatively the accuracy and repeatability of the method. The best methods rated "uncertainty low" needed a full input-output test with both a speedometer and a torque meter. This equipment was considered complicated and costly in Europe, but has been standard practice for many years in the IEEE 112 method B testing in the USA and Canada. It will now slowly enter also other parts of the world in Europe and Asia. The new and general understanding is now that Premium Efficiency motors with efficiencies up to 96% need much better testing methods and testing equipment in both the industrial development and production quality control.

By the end of 2005 the European industry was aware that the existing controversy of testing and efficiency classes was not helpful for their global market development. The CEMEP initiated a new IEC project on efficiency classification led by Martin Doppelbauer, SEW-Eurodrive, Germany.

On 21 April 2006 a new work item proposal 2/1392/NP was launched to initiate a new IEC standard 60034-xy "Efficiency classes of single speed three-phase cage induction motors" in order to specify efficiency classes for energy efficient single-speed three-phase 50 Hz or 60 Hz cage induction motors in accordance with IEC 60034-1 that:

- have a rated voltage up to 1000 V;
- have a rated power between 1 kW and less than 200 kW;
- are rated on the basis of duty type S1 (continuous duty);
- are constructed to degree of protection IP4x or higher.
- The standard also applies to dual voltage motors provided that the flux saturation level is the same for both

As justification the following was stated: "Many different energy efficiency classes for cage induction motors are currently in use (i.e. NEMA, EPAct, CEMEP, Australia, Japan, Brazil etc.) and new classes are being developed (China, India, …). Therefore it becomes increasingly difficult for manufacturers to design motors for a global market. This new standard is intended to harmonize the different requirements so that one motor design per efficiency class can fit the global market for both 50 Hz and 60 Hz power supply. This will also reduce the growing confusion of international customers about different efficiency requirements in different countries." A first draft project was submitted to the IEC members together with the voting that contained three efficiency classes A, B and C in 50 Hz and 60 Hz for 2-, 4- and 6-pole machines from 0.75 kW to 200 kW.

The new project was voted favourably and the TC2 initiated a new Working Group WG 31 to continue the project with these members from 15 countries with Martin Doppelbauer as convenor.

Membership included representatives from large and small motor industry as well as energy consultants, university researchers, national testing laboratory and energy efficiency agencies from Australia, Brazil, China, Korea, Japan, South Africa, USA and Europe (Austria, Czech Republic, Finland, France, Germany, Italy, Poland, Serbia, Sweden, Switzerland and UK).

IEC WG 31 held only three meetings:

- 30 October 2006 in Frankfurt a.M., Germany
- 10/11 May 2007 in Washington DC USA
- 26/28 March 2008 in Johannesburg South Africa.

On the second meeting in Washington DC a formal encounter with a NEMA delegation took place. The goal was to present the IEC project and to negotiate a harmonized scheme for the existing 60 Hz and the new 50 Hz standards.

The final draft of the energy efficiency was accepted by both the voting CENELEC and IEC participants on 26 September 2008 and thus published on 21 October 2008. It now contains the following classification for 50 Hz and 60 Hz motors:

European Ecodesign regulation on motors, pumps and fans

More than 10 years after the USA Energy policy act, the European Commission published its proposal on Ecodesign of electrical equipment in August 2003 and the Ecodesign Requirements for Energy Using Products (EuP) Directive was decided by the European Parliament and Council in 2005[19] and came into force in member states in August 2007. It provides a framework for setting Ecodesign requirements for any large group of products (minimum 200 000 units sold per year) which use energy. It intends to change the long time European voluntary product standard policy and establishes a framework under which manufacturers of energy-using products will, at the design stage, be obliged to reduce the energy consumption and other negative environmental impacts occurring throughout the product life cycle. The Directive makes provision for the introduction of so-called implementing measures, which typically are minimum energy performance standards (MEPS) but other non-energy related requirements are not excluded. Ecodesign requirements for the first batch of 19 product groups (or "lots") have been adopted or are or in the process of being adopted by the Member States regulatory committee or are in the preparatory study phase. The first implementing measures

	IEC 60034-30	CEMEP/EC	USA/NEMA
Premium Efficiency	IE3		NEMA Premium
High Efficiency	IE2	Eff1	EPAct
Standard Efficiency	IE1	Eff2	
Below Standard Efficiency		Eff3	

Figure 5. The energy efficiency classes from IEC compared with CEMEC/EC and NEMA/USA

IE3 94.6%

Figure 6. The new energy efficiency class and marking scheme for the rating plate in IEC 60034-30

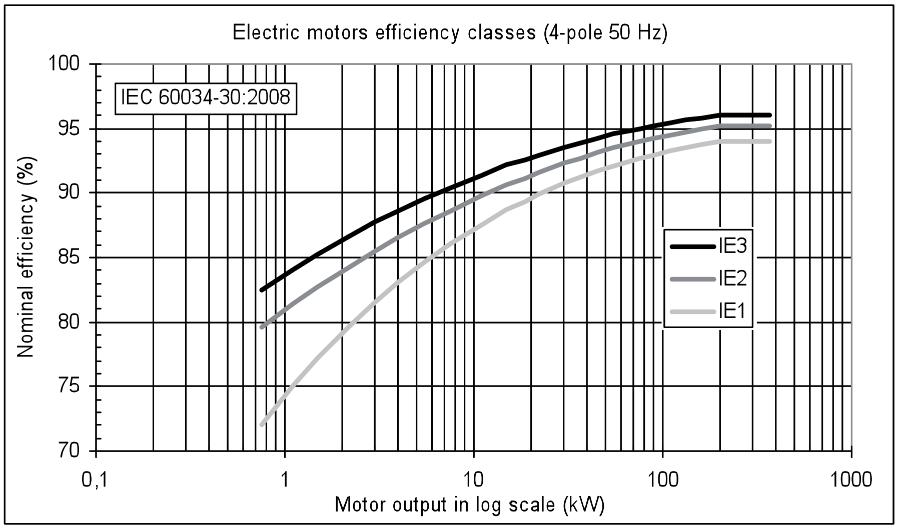

Figure 7. IEC 60034-30: Efficiency classes for 4-pole 50 Hz motors

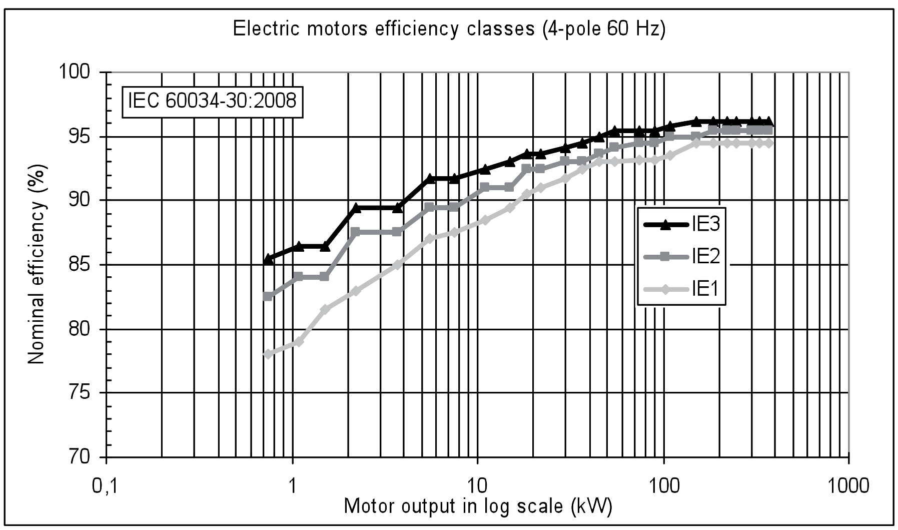

Figure 8. IEC 60034-30: Efficiency classes for 4-pole 60 Hz motors

were agreed upon the regulatory committee consisting of member states on 7 July 2008 (a horizontal measure for stand-by and off mode losses for all products) and the regulation finally took effect in January 2009 after having passed scrutiny by the European Parliament and WTO notification.

The first assessment of which product groups to be targeted for action after the initial 19 product groups have been processed, was established on 21 October 2008[20].

For each product category a sequence of steps where necessary to arrive at an eventual decision on MEPS by the EC[21]. The practical implementation of this policy is split product by product and based on several stages, involving not only the European Commission but also national governments and European Parliament.

THE PROCESS TO SET ECODESIGN REQUIREMENTS FOR A PRODUCT GROUP:

- The European Commission first launches a preparatory study to gather expertise on the product. The study takes 18 to 24 months and involves stakeholder meetings where industry and NGOs may comment.

Table 4. IEC 60034-30: Efficiency classes for 50 Hz motors with 2-, 4- and 6-poles

50 Hz									
	IE1 - Standard Efficiency			IE2 - High Efficiency			IE3 - Premium Efficiency		
kW	2-pole	4-pole	6-pole	2-pole	4-pole	6-pole	2-pole	4-pole	6-pole
0,75	72,1	72,1	70,0	77,4	79,6	75,9	80,7	82,5	78,9
1,1	75,0	75,0	72,9	79,6	81,4	78,1	82,7	84,1	81,0
1,5	77,2	77,2	75,2	81,3	82,8	79,8	84,2	85,3	82,5
2,2	79,7	79,7	77,7	83,2	84,3	81,8	85,9	86,7	84,3
3	81,5	81,5	79,7	84,6	85,5	83,3	87,1	87,7	85,6
4	83,1	83,1	81,4	85,8	86,6	84,6	88,1	88,6	86,8
5,5	84,7	84,7	83,1	87,0	87,7	86,0	89,2	89,6	88,0
7,5	86,0	86,0	84,7	88,1	88,7	87,2	90,1	90,4	89,1
11	87,6	87,6	86,4	89,4	89,8	88,7	91,2	91,4	90,3
15	88,7	88,7	87,7	90,3	90,6	89,7	91,9	92,1	91,2
18,5	89,3	89,3	88,6	90,9	91,2	90,4	92,4	92,6	91,7
22	89,9	89,9	89,2	91,3	91,6	90,9	92,7	93,0	92,2
30	90,7	90,7	90,2	92,0	92,3	91,7	93,3	93,6	92,9
37	91,2	91,2	90,8	92,5	92,7	92,2	93,7	93,9	93,3
45	91,7	91,7	91,4	92,9	93,1	92,7	94,0	94,2	93,7
55	92,1	92,1	91,9	93,2	93,5	93,1	94,3	94,6	94,1
75	92,7	92,7	92,6	93,8	94,0	93,7	94,7	95,0	94,6
90	93,0	93,0	92,9	94,1	94,2	94,0	95,0	95,2	94,9
110	93,3	93,3	93,3	94,3	94,5	94,3	95,2	95,4	95,1
132	93,5	93,5	93,5	94,6	94,7	94,6	95,4	95,6	95,4
160	93,8	93,8	93,8	94,8	94,9	94,8	95,6	95,8	95,6
200	94,0	94,0	94,0	95,0	95,1	95,0	95,8	96,0	95,8
220	94,0	94,0	94,0	95,0	95,1	95,0	95,8	96,0	95,8
260	94,0	94,0	94,0	95,0	95,1	95,0	95,8	96,0	95,8
315	94,0	94,0	94,0	95,0	95,1	95,0	95,8	96,0	95,8
330	94,0	94,0	94,0	95,0	95,1	95,0	95,8	96,0	95,8
375	94,0	94,0	94,0	95,0	95,1	95,0	95,8	96,0	95,8

Table 5. IEC 60034-30: Efficiency classes for 60 Hz motors with 2-, 4- and 6-poles

60 Hz										
		IE1 - Standard Efficiency			IE2 - High Efficiency			IE3 - Premium Efficiency		
hp	kW	2-pole	4-pole	6-pole	2-pole	4-pole	6-pole	2-pole	4-pole	6-pole
1	0,75	77,0	78,0	73,0	75,5	82,5	80,0	77,0	85,5	82,5
1,5	1,1	78,5	79,0	75,0	82,5	84,0	85,5	84,0	86,5	87,5
2	1,5	81,0	81,5	77,0	84,0	84,0	86,5	85,5	86,5	88,5
3	2,2	81,5	83,0	78,5	85,5	87,5	87,5	86,5	89,5	89,5
5	3,7	84,5	85,0	83,5	87,5	87,5	87,5	88,5	89,5	89,5
7,5	5,5	86,0	87,0	85,0	88,5	89,5	89,5	89,5	91,7	91,0
10	7,5	87,5	87,5	86,0	89,5	89,5	89,5	90,2	91,7	91,0
15	11	87,5	88,5	89,0	90,2	91,0	90,2	91,0	92,4	91,7
20	15	88,5	89,5	89,5	90,2	91,0	90,2	91,0	93,0	91,7
25	18,5	89,5	90,5	90,2	91,0	92,4	91,7	91,7	93,6	93,0
30	22	89,5	91,0	91,0	91,0	92,4	91,7	91,7	93,6	93,0
40	30	90,2	91,7	91,7	91,7	93,0	93,0	92,4	94,1	94,1
50	37	91,5	92,4	91,7	92,4	93,0	93,0	93,0	94,5	94,1
60	45	91,7	93,0	91,7	93,0	93,6	93,6	93,6	95,0	94,5
75	55	92,4	93,0	92,1	93,0	94,1	93,6	93,6	95,4	94,5
100	75	93,0	93,2	93,0	93,6	94,5	94,1	94,1	95,4	95,0
125	90	93,0	93,2	93,0	94,5	94,5	94,1	95,0	95,4	95,0
150	110	93,0	93,5	94,1	94,5	95,0	95,0	95,0	95,8	95,8
200	150	94,1	94,5	94,1	95,0	95,0	95,0	95,4	96,2	95,8
250	185	94,1	94,5	94,1	95,4	95,4	95,0	95,8	96,2	95,8
300	220	94,1	94,5	94,1	95,4	95,4	95,0	95,8	96,2	95,8
350	250	94,1	94,5	94,1	95,4	95,4	95,0	95,8	96,2	95,8
400	300	94,1	94,5	94,1	95,4	95,4	95,0	95,8	96,2	95,8
450	330	94,1	94,5	94,1	95,4	95,4	95,0	95,8	96,2	95,8
500	375	94,1	94,5	94,1	95,4	95,4	95,0	95,8	96,2	95,8

- The Commission uses the outcomes of the study to issue a Working Document suggesting policy options. Approximately one month later, the document is discussed in the 'Ecodesign Consultation Forum' composed of stakeholders (Member States, 14 industry groups, 4 seats for green NGOs and 2 for consumer NGOs).
- The Commission then launches an additional social and economic impact assessment, which can be used to undermine the environmental ambition of the measure.
- A finalised draft measure is submitted for vote to the Regulatory Committee composed of Member States officials.

Amendments can be discussed and a qualified majority has to be reached for the vote.

- The resulting text is then transmitted to the European Parliament, which can exert a 'reinforced scrutiny role'. In case of major disagreement with Member States, a conciliation procedure is followed.
- The very last draft is notified to WTO. The measure is published in the EU Official Journal and shall be implemented in all Member States.

The product group electric motors, pumps, circulators and fans was defined as Lot 11 and was after a tender given for the technical study to a project group consisting of the following persons and institutions.

- Lot 11 Coordination AEA Technology, UK
- Motors: University of Coimbra, Professor Anibal T. de Almeida, Portugal[22]
- Fans: Dr. Peter Radgen, ISI-Fraunhofer Institut, Germany
- Pumps: AEA Technology, Hugh Falkner, UK
- Circulators: AEA Technology, Hugh Falkner & Charles Gaisford, UK

The technical studies were based on a previously established common methodology (R. Kemna et al., VHK[23]). They include the following steps:

1. Product Definition, Standards & Legislation;
2. Economics & Market;
3. Consumer Analysis & Local Infrastructure;
4. Technical Analysis Existing Products;
5. Definition of Base Case(s);
6. Technical Analysis of Best Available Technology;
7. Improvement Potential;
8. Policy, Impact and Sensitivity Analyses.

Therefore for all products an environmental impact assessement study based on a detailed bill of materials of standard products (Base Line) and more efficient products (Best Available Technology) had to be made. A life cycle cost study was made by comparing BAT and Baseline products. Several scenarios for introduction of MEPS and their eventual energy savings in Europe were provided.

The technical study were guided by the EC representatives (Ismo Grönroos-Saikkala) and closely followed by a large stakeholder group (40 plus European and international representatives from industry, academia, associations, and national institutes). The entire process with drafts, comments, stakeholder meetings and minutes was transparent and always available in the internet (www.ecomotors.org). The key data for specific cost of motors depending on their efficiency were provided by CEMEP. The findings of the technical studies were published in April 2008.

The EU Lot 11 motor studies were basing their findings on parallel development of IEC standards on motor testing and efficiency classification.

The key findings of the Lot 11 motor study are clear:

- Over 90% of the cost and the environmental impact stems from the use phase of a motor.
- The highest efficiency class motors with added material have no negative environmental impact.
- Motors running more than 2000 hours per year are with today's industrial electricity prices (0.075 Euro per kWh average industry electricity price in EU-25 in 2007) cost effective in the highest available efficiency class IE3.

The commission proposal presented and discussed at the Consultation Forum on 27 May 2008 in Brussels consisted of two tiers of MEPS for electric motors:

- IE2 in 2011
- IE3 in 2015

The NGO group[24] insisted on a more rapid implementation in the full scope of 0.75 kW to 375 kW motors. The industry representation who is mainly concerned with reducing market influence of Asian and US imports is not ready to accept MEPS for IE3.

In spring 2009 the impact assessment has been completed and the MEPS proposal for motors finalized. The respective proposals for circulators are also underway, the fans and pumps are delayed.

The compromise reached at the meeting of the Regulatory Committee decision on 11 March 2009 looks like this:

- IE2 will be mandatory in 2011
- IE3 or IE2 with integrated variable speed drive will be mandatory in 2015 (for motors ≥ 7.5 kW)
- IE3 or IE2 with integrated variable speed drive will be mandatory in 2017 (also including motors < 7.5 kW).

After lengthy deliberations explosion proof motors and brake motors were exempted from the scope.

After the positive vote of the EC Regulatory Committee on the motor proposal the goal is now to be ready for adoption in June 2009.

The entire EuP Ecodesign procedure for motor products in Lot 11 was relatively transparent and quite successful. Neither slowing industry influence nor more ambitious NGO demands could of course be fully satisfied. The compromise reached is by all means a stark departure from the decade-old voluntary scheme approach typical for European industry. The fact that there were many different products evaluated with a common methodology and then decided in parallel certainly was helpful for the European Council and Parliament to better understand the drive of this entire legislative process.

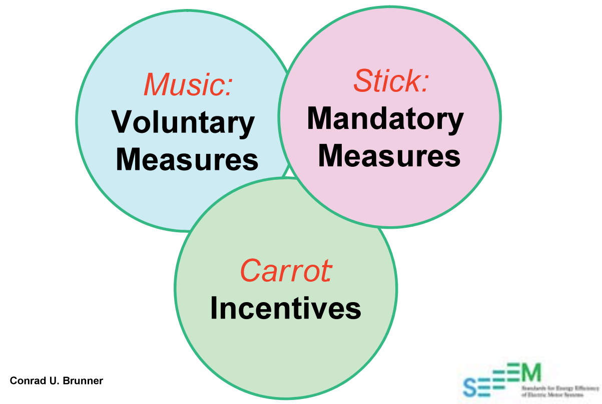

Figure 9. Market transformation needs three basic instruments Source: A+B International, EEMODS'07

Lessons learnt for other mass produced products

PARALLEL DEVELOPMENTS WITH OTHER MASS PRODUCED PRODUCTS – THE CASE OF CFLS

Compact Fluorescent Lamps (CFLs) offer a good case for a comparative process to study. At the RightLight 6 conference held in Shanghai in May 2005, the first meeting of the so-called CFL harmonization initiative was held. At that time, it was recognized that there were almost 50 different specifications for integrated CFLs available in the world. If these specifications could be reduced to a limited number, any organization interested in large-scale procurement would not have to spend time on defining what products they would need. By adopting an existing, reliable "drop-in" specification, much would have been won in terms of speed, resources and cost.

An international group consisting of energy agency representatives, lighting manufacturers, large users and standardization bodies was involved in the process. A number of stakeholder meetings were held between 2005 and 2007, and the meetings dealt with issues such as performance specifications, test protocols, verification testing and compliance. It should be noted that CFLs represent a true consumer product and price is extremely important for buyers.

Having used the multitude of specifications, a proposed IEC standard was presented for voting in 2007. Just as with motors, the IEC standard itself contained both for efficiency and a number of quality related issues, such as start-up time and warm-up time. Unfortunately, the IEC standard was not approved, but the work to harmonize specifications appears to have been useful for specifiers of CFLs.

CONCLUSIONS AND RECOMMENDATIONS ON ELECTRIC MOTORS AND FURTHER MASS PRODUCED EQUIPMENT

The electric motor market is typical for mass produced equipment, and experiences in this field are in many ways applicable to other electric appliances. However, the transfer of energy efficiency policy experience in electric motors to household appliances, consumer goods, office equipment and lighting must be carefully distinguished because it is mainly oriented towards industrial and commercial consumers and not the general consumer and households. Whereas electric motors are sold in a very cost conscious industrial environment in larger quantities, lamps, household appliances and electronic equipment cater to a much more life-style and design-conscious type of buyer of single products. Another important difference is the fact that motors to a larger extent are delivered to the end-use costumer through OEM manufacturers than most consumer appliances.

Although the process of global market transformation in electric motor systems is by no means completed, some experiences can be discussed here. Market transformation towards energy efficiency is only successful with a combination of voluntary and mandatory measures and financial incentives. The 10 lessons learnt are impressions by the authors who have been involved actively in the transformation process. The extent to which they can be generalised has to be studied in more detailed analyses.

The authors of this paper have made an attempt at summing up the lessons learnt in the motor experience as ten steps for market transformation. These are presented in the Figure 9 and Table 6[25].

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Table 6. Lessons learnt: Ten steps for market transformation

1	Harmonized international standards for testing, efficiency classifications and labels are necessary. Why not start with IEC and ISO respectively right away, not to waste time at the regional or national levels (CENELEC, ANSI, etc.).
2	The selection of active and competent IEC WG members is important for broad country representation. A fast chairman helps to conclude the work with in 2 to 3 years. Often IEC members are only representatives from manufacturing industry with narrow scope. Stakeholders from producing and user industry need to be included from the outset. The mix with researchers, testing labs and energy efficiency agencies and consultants is helpful.
3	Neither traditional Euro-centricity nor American hegemony attempts can reach international harmonization. The inclusion of large Asian players (China, India) and other parts of the world (South America, Australia, South Africa, etc.) is imperative to reach global agreement because only in this way the conflicting interests and market influence can be balanced.
4	Government representatives are key players to make pressure for energy efficiency (not just industry sales).
5	Senior academia members as independent council can bring factual explanation instead of controversy and play a moderating impact as bridge builders between direct industry issues.
6	Select a product and not a system to start with. The more precise scope you work with, the more rapid standardization is possible. Go step by step from single well determined product to periphery components (core system) and continue eventually to more complex total system.
7	An international testing campaign - Round Robin - gathers new evidence to change barriers of preconceived notions and experiences.
8	Harmonization goes in four distinct steps in this sequence: 1) testing standards, 2) efficiency classes, 3) marking scheme and labels and 4) MEPS. Do not confuse the proceeding *international* S&L harmonization procedure with subsequent *national* legislative action on MEPS.
9	MEPS involve regulations on national levels. Many countries first have to prepare their legal system in order to be able to eventually regulate mandatory MEPS and to follow up with an implementation and enforcement system. See "Motor MEPS Guide" for advice.
10	Decide on *definitive efficiency goal* with early announcement in order to give industry ample time to adapt production. Go there in steps and compromise only on the delays not on the eventual efficiency goals. Use financial incentives together with energy-related advisory services, information and knowledge transfer, campaigns to speed up the voluntary phase in order to improve industry transition.

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