Standard Format for IEC Standards -

Learning from motor standards for other electric equipment

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Abstract

IEC standards perform a very important role in enabling international trade of electric equipment. Ideally, they can be used to facilitate compliance with national energy efficiency regulations. Yet many IEC standards do not clearly include previsions for a well-defined scope or standard operating conditions. Neither do they include energy efficiency classifications that could also be used for mandatory requirements such as Energy Labels and Minimum Energy Performance Standards (MEPS).

The experience with updating the IEC 60034 standard series include efficiency classes as well as standard operating conditions for electric motors (IEC 60034-30-1) shows that an entire market has the opportunity to adopt the same efficiency measurement standard and classification scheme. The example also demonstrates that within five years such international standardization is possible. It has significant impact for the market transparency of quality products to be produced in one country and shipped across the globe for another country. It is essential for a successful market transformation towards higher energy efficient products.

It also shows that the user end of the supply chain of motors will ask for certification of the applicable products through existing schemes like IECEE[2], i.e. established requirements for the quality of the testing lab enabling the credible display of the measurement result on the rating plate.

The IEC Strategic Group (SG1) has agreed to support the implementation of the motor standardization experience to other mass produced electrical equipment like TVs, refrigerators, air conditioners, washing machines, lamps, etc. This is important because experience with CFL and LED lamps clearly shows that the difficulty in prescribing internationally coordinated efficiency levels has hindered harmonization and global market transformation.

However, it will be necessary to clarify (and maybe re-define) the role of international standard makers vis-à-vis national governments and their authority for energy efficiency requirements.

1. Why is a standard energy efficiency format needed for IEC standards?

Energy efficiency has changed the way we look at mass produced equipment and industry standards. It is no longer enough to just standardize safety issues or dimensional properties and other functional performance elements as the energy efficiency rating of a product has now moved to the foreground. The agreement between industry, governments and NGOs has grown strongly over the last decade that internationally compatible standards are necessary for all products that can easily be shipped and traded.

The standard - in the case of electrical equipment the IEC standard - has become the reference point for many governments to issue energy labels and minimum energy performance standards and to check their compliance. In order to facilitate the issue of labels and MEPS in national legislation a

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[1] 4E is the Implementing Agreement of the International Energy Agency IEA on "Efficient Electrical End-Use Equipment" www.iea-4e.org. EMSA is its "Electric Motor Systems Annex" www.motorsystems.org .

[2] IECEE: Worldwide System for Conformity Testing and Certification of Electrotechnical Equipment and Components, www.iecee.org

common understanding is necessary of what type of information should be available for all mass produced pieces of equipment.

Valuable experience has grown from the past decade of evolution in electric motor standards. The challenge that has emerged is:

- What are the key ingredients of a set of product standards to allow the goal of rapid adoption in national legislation?
- What kind of products lends themselves to such a standard format?

2. Who is IEC and what is its role?

The International Electrotechnical Commission IEC [1] today is the leading standard making organization in the field of all electrical, electronic and related technologies with some 10'000 technical experts contributing voluntarily world-wide. IEC gets its income form membership fees and the sale of standards. IEC works in parallel with the International Organization for Standardization (ISO [2]) that is responsible for almost 20'000 standards for manufacturing and technology, ranging from food safety to computers, and agriculture to healthcare. IEC and ISO cooperate together closely and coordinate their work in many general and organizational fields.

IECs goal are improved conditions for fair trade and transparent markets through global harmonization. To achieve this goal standards help to create a level playing field for industry and other stakeholders.

The IEC was founded as non-governmental and not-for-profit organization in 1906 in London, since 1948 it has its seat in Geneva Switzerland. Currently 82 countries are members and another 82 countries take part in an affiliate country program. An IEC member country (i.e. a National Committee, NC) signs a contract with IEC when becoming a member which obligates it to adopt International Standards "to the greatest extent possible" in its country. The scope of IEC work developed historically: it started with the most obvious coordination tasks: Terminology (TC1). Later individual products and other topics of general concern for industry followed: Rotating Machines (TC2) was the first group of equipment, then a group of standards to align engineering work procedures followed: Information structures, documentation and graphical symbols (TC3), Graphical symbols for use on equipment (TC4). Only thereafter a next group of equipment followed: turbines (TC4 and TC5), cables and grids, power electronics, batteries, lamps (TC34), appliances (TC59), and last photovoltaic (TC82).

The Agreement on Technical Barriers to Trade (World Trade Organization) tries to ensure that regulations, standards, efficiency measurement and certification procedures do not create unnecessary obstacles, while also providing members with the right to implement measures to achieve legitimate policy objectives, such as the protection of human health and safety, or the environment.

When an IEC standard is published no timing for implementation is generally given in IEC standards. In a small number of cases a voluntary "transition period" is suggested between the previous edition and this new edition of the International Standard itself.

3. How does IEC work?

IEC works from its Central Office (CO) in Geneva who supports technical committees in the development of standards. The operations of the CO and the setup of new TCs are guided by the Standardization Management Board (SMB) from elected members of NCs.

The members of the national committees are stakeholders from industry, academia, government and NGOs. The NCs operate generally from a national secretariat within their national standard organization. The NCs form the interested group of each TC by sending their experts to draft the technical content of standards; they vote in favor or against the proposed drafts and provide comments. Generally each NC has one vote. 75% of the votes are needed to approve a draft. The NCs setup national "mirror groups" for each IEC TC and rally their national experts to collaborate on a national level. The NC selects its representatives and sends them to attend meetings of the international TCs.

The TC consists of its experts delegated by the NCs. It elects the chairman who needs formal confirmation of the SMB. It develops its own business plan and tasks; it starts Working Groups (WG), selects their convenor and launches New Work Item Proposals. The WG and its convenor bear the largest share of the work to draft a new standard. The process of drafting a new IEC standard is laid out in the procedures for the technical work [3]. It includes the following main steps (see Table 1):

	Step	Minimum Delay
1	Launch of a New Work Item Proposal (NP) by a TC, circulation to NCs, decision by vote.	3 months
2	Setup of a Working Group (WG) in a specified TC or SC.	
3	Working Drafts (WD): internal drafts circulated within WG to reach consensus.	
4	Committee Draft (CD) circulated within NCs. Standardized format for comments. Discussion of comments at WG meetings.	3 months
5	Committee Draft for Voting (CDV) circulated within NCs. Standardized format for comments of NCs. Requires 75% acceptance by NCs to go forward. Discussion at WG meetings.	3 months
6	Final Draft International Standard (FDIS) circulated within NCs. Standardized format for comments of NCs. Requires 75% acceptance by NCs to go forward. Discussion at WG meetings.	2 months
7	Publication (after final editing and translation into French)	
8	Setup of maintenance team. Regular discussion at bi-annual TC meetings of need to renew, correct or withdraw of standard.	

Table 1 Steps and delays to draft and publish an IEC standard

The targeted delays for a standard are for the working draft (if not supplied with the proposal): 6 months; for the CD: 12 months; for the CDV: 24 months; for the FDIS: 33 months; and for the published standard: 36 months. If a new project is launched in a very decisive and clear way and consensus can be reached rapidly, the steps 1, 3, and 4 can be omitted. Theoretically the process for launching a new standard can then be shortened - if consensus can be achieved - to 6 months only.

The key goal of this international process is to achieve consensus among the NCs, the experts in the WGs and the stake holders involved. The success of this well established IEC procedure is due to its transparent and democratic decision-making process.

IEC provides each TC with a state of the art internet-based Collaboration Tool where each WG can access and store their documents and the meetings can be scheduled and messages sent to members. It also operates a public data base where all standards can be previewed and purchased via a web store.

4. IEC standards for motors

The International Electrotechnical Commission (IEC) is charged with international standards for electric rotating machines, i.e. motors and generators. Representatives from some 45 National IEC Committees (NCs), including 15 countries with observer status, work together on the development of motor standards in the Technical Committee 2 (TC2). The experts come from industry, government, universities, research and testing laboratories, and NGOs. All proposed new and amended standards go through a rigorous system of international scrutiny and are finally decided by voting by the NCs.

Basic characteristics and performance of electric motors are standardized in the following IEC standards, the first versions of which were started many years before energy efficiency standards were required: geometry, mounting, protection, vibration and noise:

- Motor Dimensions
  IEC 60072-1, edition 6, 1991: Dimensions and output series for rotating electrical machines - Part 1: Frame numbers 56 to 400 and flange numbers 55 to 1080
- Motor Mounting
  IEC 60034-7, edition 2.1, 2001: Rotating electrical machines - Part 7: Classification of types of construction, mounting arrangements and terminal box position (IM Code)

- Enclosure protection
  IEC 60034-5, edition 4.1, 2006: Rotating electrical machines - Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) - Classification
- Motor Vibration
  IEC 60034-14 (grade N), edition 3.1, 2007: Rotating electrical machines - Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher - Measurement, evaluation and limits of vibration severity
- Motor Noise
  IEC 60034-9, edition 4, 2003: Rotating electrical machines - Part 9: Noise limits
- Explosive atmospheres
  IEC 60079-0 edition 6.0, 2011 (by TC/SC 31)

A general report on the standards development of IEC and CENELEC focusing on variable frequency drives has been presented by M. Patra at EEMODS 2011 [4].

5. IEC standards for the energy efficiency of motors

Here is a list of the current status of IEC standards prepared by IEC TC2 "Rotating Machinery" and its WGs that involve energy efficiency (see Table 2), plus the planned projects (see Table 3) also involving IEC TC22/SC22G:

IEC International Standard	Date of publication	Title	Status
IEC 60034-1	2010	Rating and performance	under revision, publication 2014
IEC 60034-2-1	2007	Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)	under revision, publication 2014
IEC 60034-2-2	2010	Specific methods for determining separate losses of large machines from tests - Supplement to IEC 60034-2-1	
IEC 60034-30	2008	Rotating electrical machines - Part 30: Efficiency classes of single-speed, three-phase, cage-induction motors (IE-code)	under revision, to be replaced by IEC 60034-30-1 and IEC 60034-30-2
IEC 60034-30-1	new, FDIS	Efficiency classes of line operated AC motors (IE-code)	publication 2014
IEC/TS* 60034-31	2010	Rotating electrical machines - Part 31: Selection of energy-efficient motors including variable speed applications - Application guide	
3) TS: Technical specification, to be reviewed after 3 years			

Table 2 List of current energy efficiency related motor standards and their revisions

In parallel to IEC TC2 also IEC TC22 SC22G "Adjustable speed electric drive systems incorporating semiconductor power converters" deals with variable frequency drives that have an impact on motor efficiency. So far no energy efficiency measurement standard or efficiency classification has been published. A new project has been launched:

IEC International Standard	Date of publication	Title	Status
IEC/TS 60034-2-3	new TS	Specific test methods for determining losses and efficiency of converter-fed AC induction motors	publication 2013
IEC 60034-30-2	new NP	Efficiency classes of variable speed AC motors (IE-code)	publication 2015
IEC 61800-9	new NP	Energy efficiency of adjustable speed electric power drive systems	publication 2016

Table 3 Planned energy efficiency standard for variable frequency drives and motors

A published IEC standard can be purchased in hardcopy and pdf from www.iec.ch. A preview including the title, foreword, introduction, table of contents and scope can be downloaded for free. A draft copy of a standard under work can be obtained from every national IEC committee.

6. How do IEC standards relate to national standards?

Technical regulations and product standards may vary from country to country. Having many different national regulations to obey and standards to follow makes life difficult for producers, exporters and national regulators. They push up costs for purchasers too. Repetitive product measurement and certification procedures are required by national authorities. If regulations are set arbitrarily, they could be used as an excuse for protectionism.

In many cases, national or regional standards precede international standards. So IEC work starts with a number of national and regional standards from a variety of professional organizations with the goal to unify them into an international standard. More recently, and with the increasing nature of global trade, many important issues are being developed first on the international level and subsequently adopted at the national level.

IEC cooperates with a number of regional and national standard bodies such as:

- African Electrotechnical Standardization Commission
- CANENA - Council for Harmonization of Electrotechnical Standardization of the Nations of the Americas
- CENELEC - European Committee for Electrotechnical Standardization
- COPANT - Pan American Standards Commission
- EASC - Euro-Asian Interstate Council for Standardization
- ETSI - European Telecommunications Standards Institute
- PASC - Pacific Area Standards Congress
- MERCOSUR - Mercado Común del Sur (Southern Common Market of South America)

It is not stated in IEC that a nation cannot start a new standard while an international standard on the same matter already exists. But all signatory countries to the World Trade Organization (WTO) under the "Technical Barriers to Trade" agreement (TBT) undertake not to do this. There is no enforcement method though; the TBT Agreement has various mechanisms, but the WTO approaches this problem only indirectly.

Some special coordination rules exist between IEC and regional standardization bodies, such as the EU’s CENELEC. In CENELEC’s case, these rules are governed by the Dresden agreement [5]. And cover drafting and parallel voting. Additionally, IEC has a cooperation agreement with IEEE that allows for certain standards to display a dual logo [6].

7. Standards, Labels, MEPS, certificates

Different institutions active in developing motor policy are distinguished by their geographical territory (national, regional, global) and their enforcement powers (voluntary, mandatory). They meet under the common goal of market transparency and market transformation towards more energy efficient products. The clear evidence from earlier developments in the USA is that markets for industrial products are only moved with minimum energy performance standards that are applicable mandatorily to all new products put onto the market. All earlier voluntary schemes, labeling systems etc. did not move the sales figures fast enough into the right direction. The three key actors are presented in Table 4:

Key actor	Main tasks and duties
Global standard makers	Based on formal rules to reach international consensus of stakeholders the standard makers can publish international standards and technical specifications for product performance, efficiency measurement and classification. This can include also the thresholds for efficiency classes to be used in labels and tiers of MEPS.
National and regional governments	Based on national laws (proposed by government and accepted by parliament) the national government can set up an energy agency for energy efficiency advice to consumers and a regulator's office for market control; it can thus allocate the

	necessary resources and authority to execute these tasks. Governments can then issue regulations covering minimum energy performance standards and energy labels based on national or international standards. The labels (see Figure 1) can be voluntary or mandatory, a certification mark or true energy label, an endorsement or information, a comparative or absolute value, a continuous scale or categorical. They can also set-up a check-testing system to watch compliance of regulations. Government can also implement a compliance scheme involving check-testing and sanctions.
Certification bodies	Global or regional and national certification bodies can define the voluntary requirements for product performance including energy efficiency and issue a marking on the product rating plate to signal compliance. They can accredit testing laboratories, train their personal and issue orders for instrumentation calibration. Some also stipulate round robin tests to secure the accuracy of the measurement results.

Table 4 **Three basic actors in motor policy, label, MEPS and certification decisions**

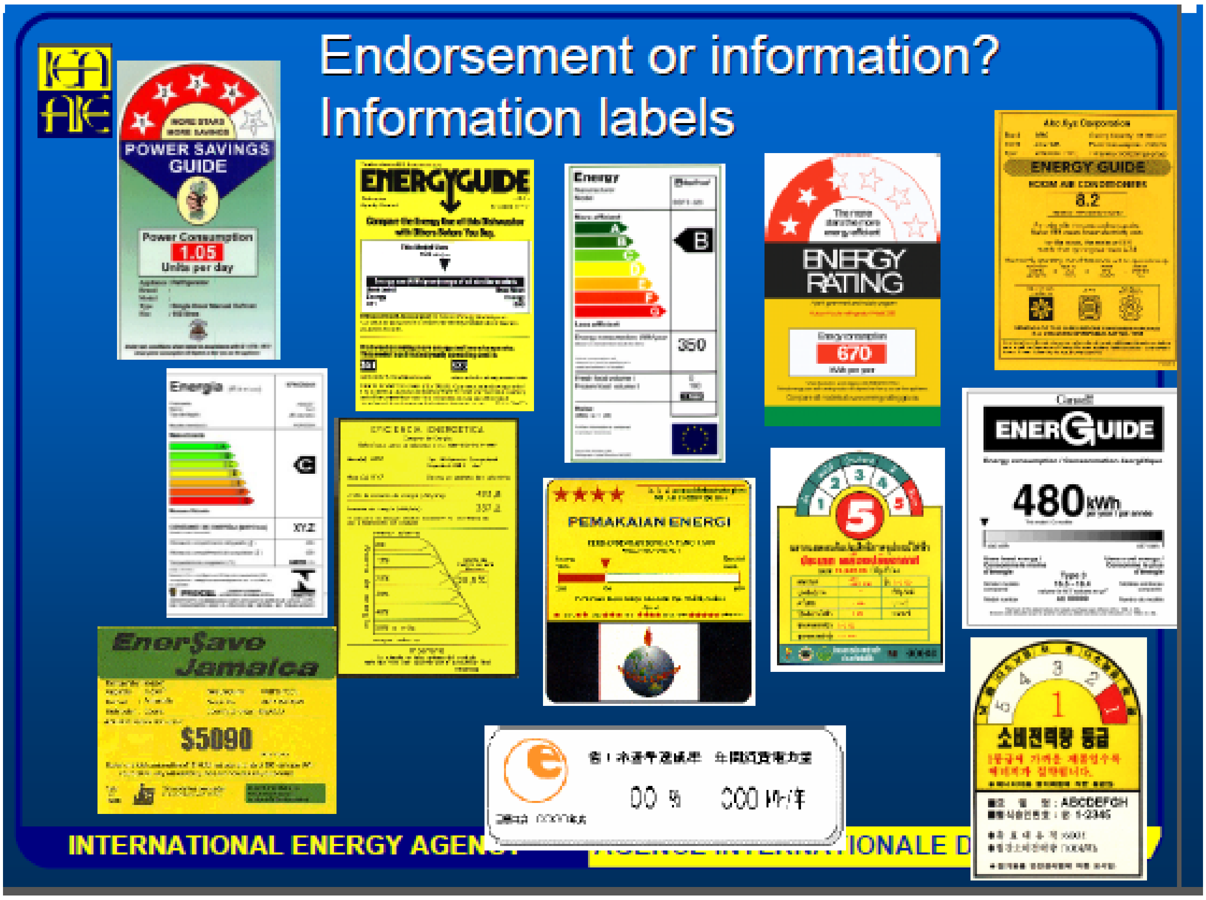

Figure 1 **Typology of national labels (Paul Waide IEA, 2004)**

8. The Motor standards and policy experience

The experience of the development of relevant standards for motors between 2007 and 2009 has been presented at eceee in 2009 [7]. A systematic approach to standardization for energy efficient electric motor systems between 2007 and 2013 has been presented to IEC SG1 in January 2013 [8]. It includes the introduction of the concept of uncertainty, the definition of a preferred measurement method of energy efficiency and the introduction of an energy efficiency classification system of motors.

The process of global harmonization started from the controversy in 2004 that the USA in its testing standard IEEE 112 had a method B [9] that included the measurement of the motor output with torque and speed and the calculation of additional stray load losses. The rest of the world was using the older IEC 60034-2 measurement standard with segregated losses that avoided the use of torque meters and included stray load losses only with an insufficient constant addition of 0.5%. This measurement method was in Europe considered sufficiently accurate and robust for a long period.

Meanwhile standard IE3 electric motors with output sizes over 100 kW achieve 96% efficiency. This is of course a challenge for every measurement and verification method. Small differences in methodology start to distort the results and become rapidly a nuisance to manufactures competing in the same market.

Ample scientific evidence [9] and [11] that the two key standards did not agree on the resulting efficiencies were published in a number of conference papers before the IEC TC2 was ready to reconsider. The USA motor industry complained about inappropriately higher efficiency ratings in European, Japanese and Chinese motors. The development of more reliable (but still costly) torque meters allowed for a bold step towards aligning the two basic measurement methods with IEC 60034-2-1 in 2007. This required of course many industry laboratories to upgrade their measurement instrumentation and to train their laboratory personnel accordingly.

In a historic encounter of an IEC TC2 WG31 delegation with an IEEE[3] and NEMA[4] delegation on 10/11 May 2007 in Washington DC the cooperation agreement on measurement was extended to also include the efficiency classification. This harmonization was complicated by the fact that in the countries supplied by their electrical power utilities with 60 Hz frequency (USA, Canada, Mexico, part of Brazil, and part of Japan) an electric motor rotates 20% faster than in the 50 Hz countries. The higher output power produces considerable lower losses. The IEC efficiency classification needed to bridge the 50 Hz IEC world with the 60 Hz NEMA world and account for this difference caused by laws of physics. At that time several large European industries (Siemens, ABB) were manufacturing motors in the USA according to US standards for the US market and in Europe with European standards for the European market. It was obvious that harmonization was needed.

A new motor efficiency classification scheme was necessary also because the earlier European motor efficiency scheme developed by the Joint Research Center of the European Commission together with the manufacturers association CEMEP (eff1, eff2 and eff3) was still based on the old incomplete testing standard and could therefore no longer be upheld. The IEC and the European industrial community were hesitant at the time to adopt the IE-code which eventually prepared the way in 2009 for MEPS for motors in the Ecodesign Regulation no 640 [12]. The main reason was that the smaller motor output sizes in the USA have a slightly larger frame in NEMA standards than in IEC. The necessary additional copper wire to reach IE3 can be easily accommodated within the diameter and length of an USA frame, but it was tight and more difficult to do so in IEC frames.

The European motor industry association CEMEP finally agreed with its members in 2008 on mandatory requirements. The key element for the change of policy was the understanding that only MEPS at IE2 level could successfully eliminate low cost, low efficiency imported products. The final adoption of the EU’s Ecodesign Regulation led to a compromise which industry favored: the user shall have a choice in 2015 between selecting an IE3 motor or an IE2 motor together with a variable frequency drive (VFD).

9. The standard format

The necessary standards include an array of documents in five groups that cover the most important issues at stake (see Figure 2):

[3] IEEE: Institute of Electrical and Electronics Engineers
[4] NEMA: National Electrical Manufacturers Association

1	2	3	4	5
SCOPE	**TESTING**	**EFFICIENCY CLASSES**	**GUIDE**	**CERTIFICATION**
IEC 60034-1	**IEC 60034-2-1**	**IEC 60034-30**	**IEC/TS 60034-31**	**IECEE e3**
standard use conditions, only selected technologies in the scope	one preferred testing method, procedure prescribed in detail (accuracy, repeatability); check-testing!	3 major efficiency classes: IE1 > IE2 > IE3, open to advanced technology (IE4)	background, application, context, system integration, tools?	conformity assessement, lab accreditation, expert training, round robin, global label

IECEE: System of Conformity Assessment Schemes for Electrotechnical Equipment and Components

Figure 2 The necessary five elements of a standard format for standards in sequence

a) A well-defined product and clear operation scope: IEC 60034-1 includes the definition of the types of products involved (motors and generators, DC, AC synchronous and asynchronous), operating environment (temperatures, height above sea levels, etc.), the operation modes (continuous S1 or intermittent), the measurement instrumentation (ambient and motor temperatures, voltage, current, frequency, rotational speed, torque, etc.) and their allowable tolerances, the display of the rated performance data on the rating plate and in the product documentation. With motor efficiency reaching 96% the tolerance definition and band widths need to be reconsidered. The losses (1 minus efficiency) are the base for the tolerance definition. Currently for electric motors up to 150 kW a 15% tolerance for the losses is allowed (above 150 kW: only 10%). This makes a motor below 150 kW with 96% efficiency tolerate also 95.4% and a bigger motor also 95.6%. The tolerance is of course masked by both the variation in performance from product to product plus the measuring tolerance in the laboratory stemming from the instrument precision, the training of the personnel and the clarity of the measurement standard.

b) The progressively amended IEC standards for determining losses and efficiency measurement: The efficiency measurement standard IEC 60034-2-1, edition 1 from 2007 was continuously improved based on systematic research in a number of both independent and manufacturer's testing laboratories. Efficiency (η) is defined as output (mechanical power) over input (electrical power). The measurement of the mechanical output at the motor shaft involves torque and rotational speed; these measurements require sophisticated instruments and have higher tolerances as electrical properties on the input side. This is the reason why a method of measuring segregated losses delivers more accurate results as a pure output and input measurement. The standard aims for better accuracy and good repeatability when the same motor is measured again at the same lab or shipped to another lab and measured there. It includes the concept of uncertainty: the available efficiency measurement methods are classified as high/medium/low according to their uncertainty; but a quantitative description of the uncertainty was not yet established. In 2007 IEC TC2 launched an international Round Robin testing campaign to compare the accuracy of key available measurement methods. The findings published in 2011 [13] are based on results from 17 laboratories from 11 countries that had submitted a total of 194 individual measurement sets of 75 different motors. In its revised edition IEC 60034-2-1, edition 2, it includes the concept of a "preferred method", i.e. all motors of the same type are measured with one single method to determine their efficiency rating. It also sets much stricter standards for procedures as to the sequence and delays of measurements and the necessary temperature equilibrium (see Figure 3). The current revision is ready to be published in 2014. The revised standard promises to be a good tool for regulators and compliance institutes that have the difficult task of check-testing products put onto the market.

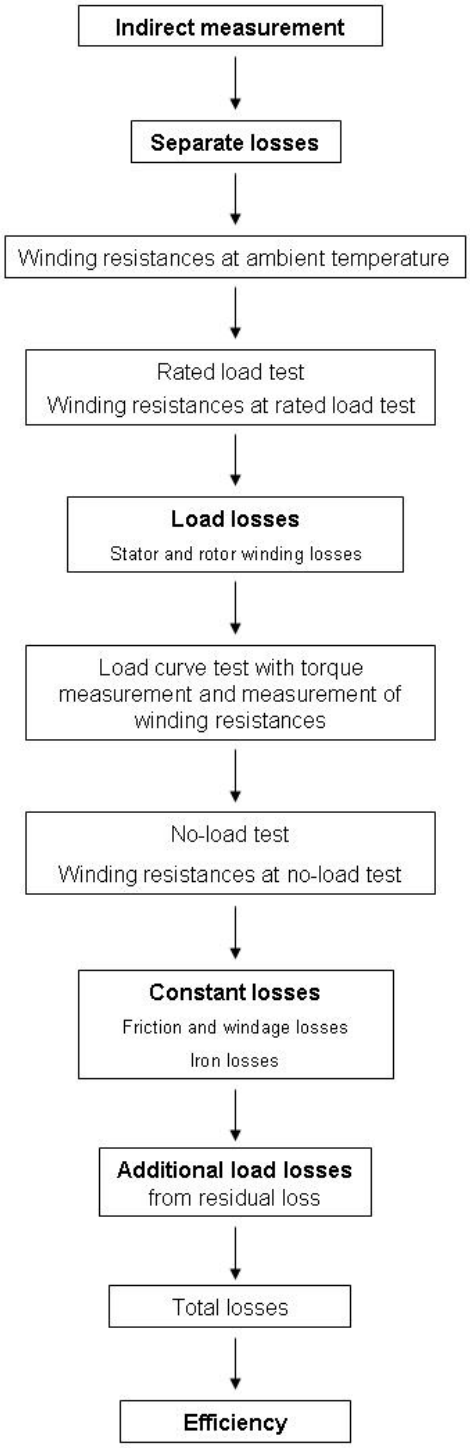

Figure 3 Preferred measurement method: Motor efficiency measurement sequence (IEC 60034-2-1, FDIS 2013)

c) The IEC energy efficiency classification: IEC 60034-30 in 2008 was based on the advanced efficiency measurement standard in IEC 60034-2-1 and defined the new IE-code with three levels of motor efficiency classification: IE1 Standard Efficiency, IE2 High Efficiency and IE3 Premium Efficiency. It is applicable for electric motors operated on a grid frequency of 50 Hz or 60 Hz, with an output power ranging from 0.75 kW up to 375 kW, and with 2-, 4- and 6-poles. In its revised edition IEC 60034-30-1, it enlarges the scope to smaller motors with 0.12 kW up to larger motors with 1000 kW; it also includes 8-pole motors and defines now also the IE4 Super Premium Efficiency level (see Figure 4). It allows all motor technologies to be classified: motors to be capable of running online in IEC 60034-30-1, motors only capable to be operated with a VFD: IEC 60034-30-2. And it closes loopholes of the scope of motors to be included. The current revision is ready to be published in 2014.

Today the following 40 countries (including EU 27) have adopted mandatory MEPS, individually set at IE1, IE2 or eventually at IE3 levels with a dedicated time plan for the upgrade (see Table 5).

All of these countries use the IE-Code in IEC 60034-30 as a reference and the respective procedure to establish efficiency classes for electric motors.

Australia
Brazil
Canada
China
Costa Rica
European Union (27)
Israel
Korea South
Mexico
New Zealand
Switzerland
Taiwan
Turkey
USA

Table 5 Motor MEPS countries (2013)

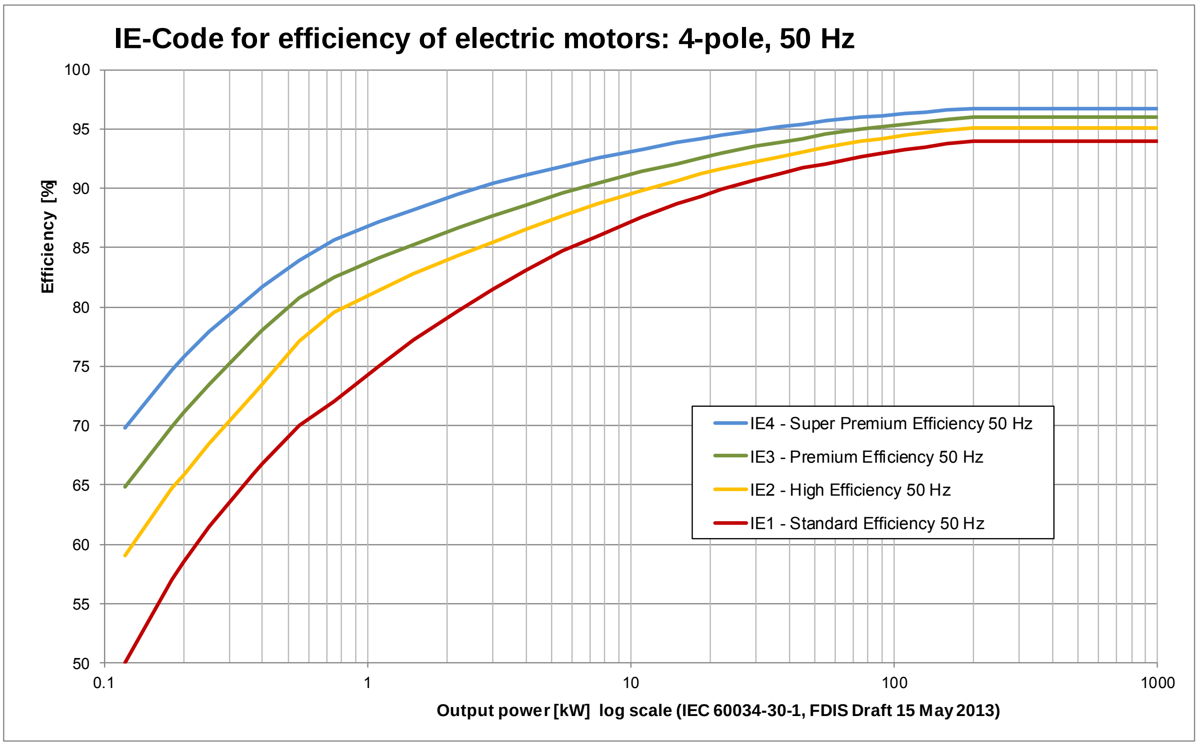

Figure 4 Motor energy efficiency classes at 50 Hz (Source: data from draft FDIS IEC 60034-30-1, 2013)

d) The IEC motor systems standards: With the description available for the performance of the key motor component of an integrated electric motor system, now the need starts to include also various other components into the efficiency classification of a complete drive system. The efficiency measurement standard for motors driven by VFDs (IEC/TS 60034-2-3, 2013) and their efficiency classification (IEC 60034-30-2, 2014) are well under way. The new project of a standard for the systems efficiency of a motor plus VFD in IEC 61800-9 (2016) is a start into this direction (see Figure 5).

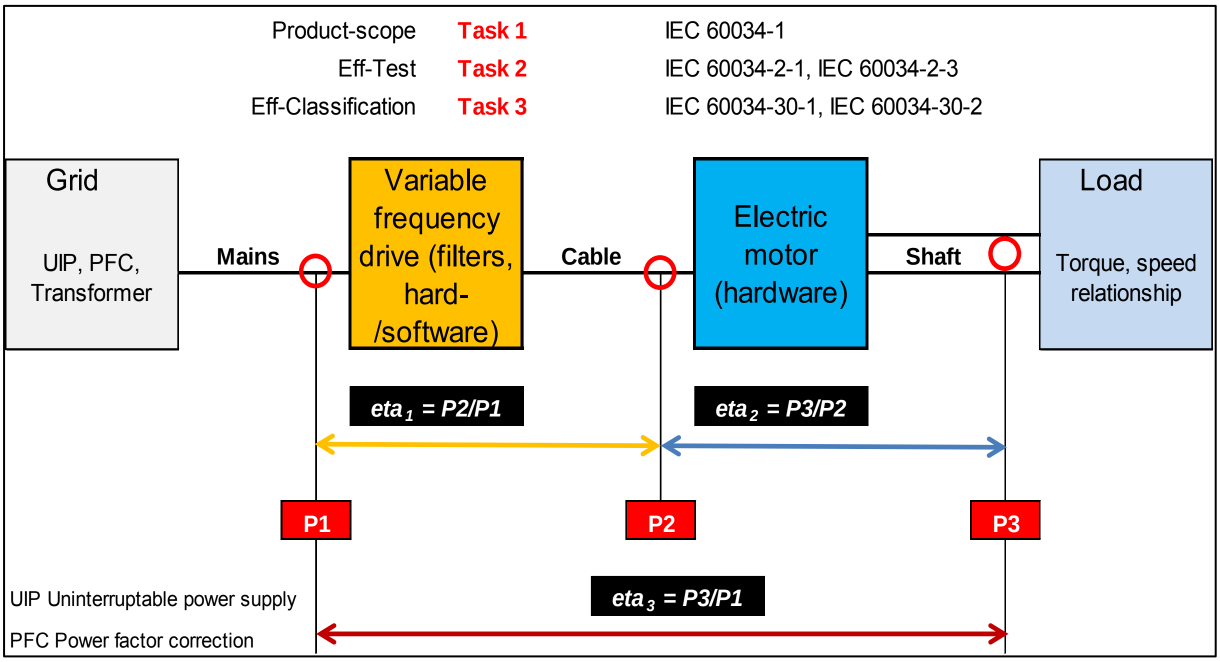

Figure 5 **The scope for measurements and efficiency classes electric motors and variable frequency drives (Source: IEC 61800-9, draft 2013)**

e) IECEE certification and labeling: Based on the clear product scope (a), its standardized method of determination of losses and efficiency (b), and an agreed efficiency classification (c) the next logical step requested by industrial product users and government regulation agencies includes a certification system that also issues a label for products that comply with all the necessary requirements. An important element still to be clarified is the product registration. Several countries have introduced as part of their MEPS policy, a registration system that requires each manufacturer (like in the USA) or even each product group (like in Australia) to register its product and show the respective number on the rating plate. The use of RFID (radio frequency identification) or bar codes can facilitate access to the respective data set on the plate or at a manufacturers' database.

10. Lessons learned for other electrical products

Many of the lessons learned from the motor standards could, if all relevant stakeholders were prepared to agree, readily be adapted to many other electrical products like lighting (lamps, ballasts, and luminaires), household appliances, consumer electronics, office equipment, transformers, etc.

The key element is to prepare a coherent set of global measurement and performance standards that can be easily used later as base for national MEPS [14] [15]. Previously, inclusion of efficiency classification performance standards had been resisted by a number of Governments who felt that IEC's role was to determine the measurement methodology only - the setting and amending efficiency performance levels being seen by some Governments as their responsibility. After all, this was the fundamental delivery tool for their policy. On the other hand, in the last decade several IEC TCs have refrained to include efficiency classifications into their standards out of fear of overstepping their competence into the field of national legal requirements. This is clearly not the case: IEC standards can set efficiency classes, national governments are free to adopt the levels thy see fit for their economies at a given point in time.

On the other hand, if standards for measurements and bands of graduated performance standards are globally harmonized and national MEPS enforced, then the burden for manufacturers for additional testing and product certification is diminished. Their global marketplace expands as a level playing field for domestic and imported products, based solely on the product performance. Additionally, those Governments that work together to adopt exactly the same performance standards, are then in a powerful position to leverage improved performance standards through their harmonizing the adoption of future more demanding standards.

The key elements for this standard format for IEC standards see Table 6:

1	Clear scope	Standard with clear definition of product scope: which products and conditions included, which ones excluded. No loopholes for exploitation by less scrupulous suppliers.
2	Measurement standards	Energy efficiency (defined as output/input) requires measurement standards with high accuracy and repeatability, including the definition of a preferred method. In some products with high efficiencies (>> 90%) the segregation of losses instead of an output/input measurement is necessary to avoid the inaccuracies coming from division of two similarly large numbers. Definition of measurement tolerances. In non-motor products the definition of the output can require more detail to understand and describe the energy service delivered clearly: i.e. televisions where measurement standard disagree on the definition of the output as the readability of the produced image.
3	Efficiency classification	Efficiency classification scheme with clear thresholds set between classes including maximum allowable tolerances (measurement and product quality). The open scale should allow for further improvements. This allows national decisions on the classifications for energy labels and performance tiers for MEPS. Large freedom of national speed to upgrade the tiers to higher performance levels. The formerly stated fear that an IEC standard could not set efficiency classes is based on the confusion of IEC standards and government MEPS.
4	No technology bias	No bias for various technologies in delivering a certain output, instead an open competition between different technologies to succeed in better performance and cost effectiveness. Market conditions, and the need to comply with the ever more demanding regulated energy efficiency levels, will give the better products a better chance of success in the market.
5	Tools for users	Provide tools for users like the Motor Systems Tool (MST) to design and optimize complex systems.
6	Global certification	Globally recognized certification scheme operated by renowned international agencies like IECEE.

Table 6 Key words for standard format of IEC standards, applicable for other products

While leaving from the field of Rotating Machines in IEC TC2 to apply the lessons learned to many other types of electrical equipment like lamps (TC34), appliances (TC59), and TVs (TC110) the definition of energy efficiency becomes more complex. In the underlying equation

$$\text{Efficiency} = \text{Output / Input}$$

the "output" definition needs more specific attention. While the mechanical output of an electric motor can be defined as torque and rotational speed, the output of lamp, a refrigerator or a TV is much more complex to describe (see Table 7). Nevertheless, this added complexity in non-mechanical applications of electrical equipment should not hamper the use of the future standard format for IEC standards.

Process	Equipment	Output	Side effects
Lighting	Lamp (plus auxiliary equipment: ballast, luminaire)	Light (lumen), distribution of wave length (color), color rendition, light distribution (concentrated or diffuse)	Start-up time with color change, decay (loss of lumen and color change)
Refrigeration	Refrigerator and freezer	Hermetically enclosed volume for foodstuff at lower than ambient temperature, fixed inside temperature with small deviations, different temperature per compartment, speed to cool stored material down to cooling temperature.	Noise, equal temperature distribution within compartment, icing and defrosting, condensation, stand-by for displays
Image	TV, monitor	Image (size, brilliance, contrast, color rendition),	Sharp image with moving pictures, start-up time, stand-by loss
Washing	Laundry washing machine, dish washer	Volume (weight) of clean laundry or dishes, residual water content after wash	Noise, textile damage, detergent use
Drying	Laundry dryer	Water content of laundry	Noise, textile damage, fibers clog filters
Cooking	Oven	Enclosed volume at higher than ambient temperature, fixed temperature with small deviations, different temperature per compartment, speed to heat stored material to hot temperature.	Noise, coagulation of fat, cleaning procedure, equal temperature distribution within compartment
Print & copy	Printer, copier, facsimile, scanner	Printed paper (per second), black/white or color, paper size, image density/quality (dpi), color rendition, time to first page	Time to have image dry, stand-by loss, printed image margin, image input (scan, data file)
Compute	Personal computer	Calculations per second (Flops: floating point operations per second)	Storage capacity, communication capabilities
Data transfer	Router	Data rate (bps bit/s)	Storage capability

Table 7 Output definitions for various types of electrical equipment

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