IEC

Coping with the Energy Challenge
The IEC's role

Smart electrification – The key to energy efficiency

Summary and Recommendations

September 2010

Executive summary

The International Electrotechnical Commission (IEC) is the world's leading organization that prepares and publishes International Standards for all electrical, electronic and related technologies – collectively known as "electrotechnology".

IEC International Standards cover a vast range of technologies from power generation, transmission and distribution to home appliances and office equipment, semiconductors, fibre optics, batteries, nanotechnologies, solar energy and marine energy converters, to mention just a few. Wherever you find electricity and electronics, you will find the IEC supporting safety and performance, the environment, electrical energy efficiency and renewable energies. The IEC also manages Conformity Assessment Systems that certify that equipment, systems or components conform to its International Standards.

The demand for energy is growing fast, and for electricity even faster. Current energy production methods are unsustainable for both resource and environmental reasons. The IEC believes that smart electrification, the intelligent and economic use of electricity as a major energy source, will be one of the most significant factors in addressing the energy challenge. Electricity is the most versatile and controllable form of energy, the easiest and most efficient to distribute. At the point of use it is practically loss-free and essentially non-polluting, and it can also be generated cleanly.

The IEC has identified key areas where significant emission reductions and efficiency increases can be achieved without holding back economic development. This requires both efficient generation and economy of use. Economy of use depends crucially on the systems perspective, allowing efficiencies that are not available when considering only one product at a time. Accordingly, the IEC intends to change its orientation so as to emphasize the standards needed to achieve systemic efficiencies, and specifically to develop a set of specifications giving minimum acceptable performance rules and options for the operation of smart electric grids.

As a major strategy for the future, the IEC intends to strengthen its ties with a range of relevant international and governmental organizations and invite them to join forces with it in an effort combining both policy and technology to progress smart electrification. Relying on the IEC's technical competence and ability to involve all relevant stakeholders is one factor among many that will allow the global community to build a better future.

1. Clean, efficient energy to satisfy growing demand

Every day the range and quantity of activities needing energy is increasing. Nevertheless, 1.6 billion people still have no access to electricity, and by 2030 another 1.7 billion people will have been added to the world's population, with a corresponding increase in the need for energy. Added to this challenge is the fact that most of today's methods of energy production and use are unsustainable, because they are either exhausting the earth's resources or disrupting the climate. These unacceptable effects will only be intensified with the increases in the number of users of energy and in the amounts they use. We therefore need more efficient ways of meeting our energy needs.

Within the overall increase in energy demand, the requirement for electricity will grow even faster and is on the way to tripling by 2050. As we will see below, this is not necessarily bad news. However, it does underscore the importance of producing the needed electricity without unacceptable environmental impact and of making the electricity produced go as far as possible.

This paper outlines the ways the IEC, with its partners, can contribute some of the new methods needed for this.

2. The strategic importance of electricity

Electricity is the most versatile and easily controlled form of energy. At the point of *use* it is practically loss-free and essentially non-polluting. At the point of *generation* entirely renewable methods are available, such as the use of wind, water and sunlight, and these may be completed by techniques and capital investments that are relatively economical in their use of resources and produce little pollution. Electricity is the form of energy which is the easiest and most efficient to distribute, and also the only major form which lends itself to "two-way" distribution where consumers may also be producers. All in all, electrical energy is the most flexible, and it would be difficult to imagine solutions to the energy challenge which did not involve a major role for electricity.

Electrification – conversion from using another form of energy to using electricity – is a central tool. In particular, the electrification of vehicle transport, only an insignificant proportion of whose energy is electrical today, promises to allow enormous reductions in greenhouse gas emissions if advantage is taken of "clean" generation opportunities. Electrification also promises improvements in other major uses, such as heating and cooling, largely because the timing and quantity of energy used can be controlled intelligently and waste reduced.

We can conclude that one essential strategy for meeting the energy challenge is to concentrate on the generation and use of electricity. A two-pronged approach is required.

- First, the most efficient [1] and least damaging methods of producing electricity must be developed and applied. This will be built on renewable production, large increases in the efficiency of fossil-fuel-based generation (including carbon capture), and advanced nuclear power, as well as on optimizing the electricity delivery chain.

- Secondly, the delivered electrical energy must be made to go as far as possible; that is, all its uses must be made highly efficient [2] and effective. A realistic aim is a 30 % reduction in the short term in the energy needed to accomplish any one task and, longer term, much greater improvements. The latter will be based on rethinking the tasks themselves, coupled with advances due to research and development along lines that can already be mapped out today.

1 In electricity generation, efficiency applies both to the output productivity, where it means maximum electricity generated for a given input of primary energy, and to the side effects, minimizing the greenhouse gases and other pollutants emitted.

2 In the use of electricity, efficiency has two complementary aspects: minimizing the power needed to accomplish a given task, and changing or reducing the tasks deemed to be necessary so that less energy is needed.

3. The systems perspective

Most of the products and applications of today's world were developed one by one as the need and technology for each became apparent. Their use today, however, presents in practically every case a *systems* problem, which requires all the parts of the complex to be considered together. Examples include the Internet; the electricity grid; industrial infrastructure and the intelligent enterprise; and, increasingly, the home, with its requirement for coordinated functioning of appliances and electronics.

The resulting systems perspective is one of the main levers for electrification and efficiency. When a system is considered as a whole, techniques present themselves which reduce the overall need for energy but which are not available if only individual components are considered. A good example is use of intelligent software to control which rooms in a building need heating (or cooling) and for how long, as a function of occupancy and the use of other rooms. This whole-system approach is to be contrasted with optimizing the heating or cooling of a single room.

Perhaps the most obvious opportunity for efficiency and systems rethinking is the end use of energy. Electrified vehicle systems, whether individual cars, public transport or freight, will allow large savings in emissions and also probably in net energy use as well, especially in combination with "intelligent" roads. An essential precondition for the effective use of electrical vehicles (and many other system optimizations as well) is advances and investment in electricity storage. New battery technology will increase the range and decrease the charging time of vehicles, and more generally help balance the supply and demand for electricity everywhere. Thus at moments when extra generated electrical energy is available it may be stored, in storage installations or even in the batteries of individual vehicles which are not being used. Then, at times of peak use, the stored energy can be released.

The result is less total need for generated electricity and for peak capacity together with the relevant infrastructure. Large-scale storage systems are also an essential component of most renewable energy opportunities, whose generation capacity is intermittent (e.g. wind and solar).

4. Further potential for energy efficiency

The electrical energy chain from generation to final use is one vital system which presents opportunities for efficiency in all its aspects. Large-scale centralized generation using fossil and nuclear fuels will continue to have a key role in the production of electricity. But of the theoretical energy in the fuel, two-thirds is today lost in generation and another 9 % in transmission/distribution, so that of the primary energy consumed only about 30 % is available as electricity at the point of use (see Figure 1). Technologies exist which can be developed to improve thermal generation efficiency by at least 10 percentage points, and at the same time considerably decrease emissions from fossil-fuel generating plants (potentially with large-scale carbon capture and storage). High-capacity centralized generation, including renewable-resource power plants, will coexist with decentralized generation of lower unit capacity but with a large number of installations.

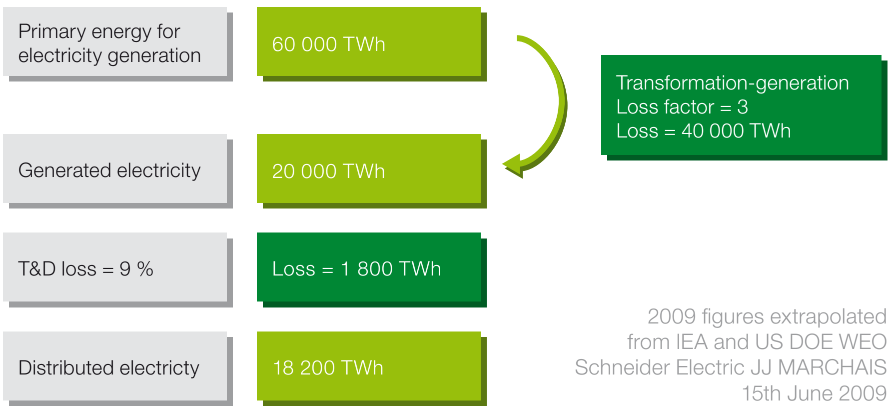

Figure 1 – Losses in current energy chain

Renewable generation must be developed to the maximum extent possible since it produces little or no net greenhouse gases. Figure 2 shows the three principal scenarios for electricity-related CO_2 emissions[3]:

1) Do nothing ("business as usual"): this leads to an unacceptable warming of the climate.

2) Apply current technologies, making products or vehicles more efficient and extending current types of renewable power generation: this implies a smaller increase in emissions, but an increase is still unacceptable.

3) Apply planned but not yet fully ready technologies. This involves innovations such as the Smart Grid (see below), carbon capture, and manufacturing systems integrated for efficiency, bringing a decrease in emissions which may sufficiently limit climate change.

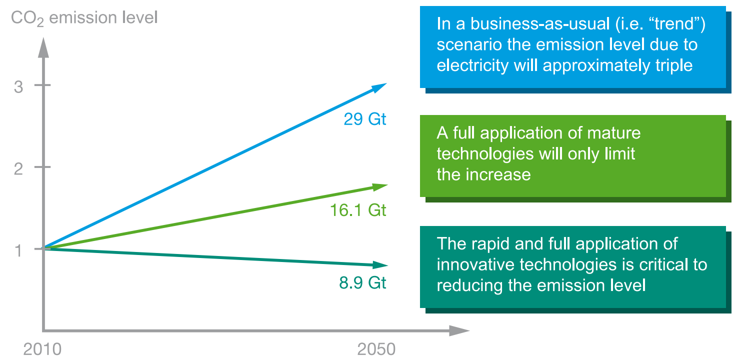

Figure 2 – Schematic of the effects of applying different technology levels

3 The business-as-usual scenario is based on the projections made by the International Energy Agency in its *Energy Technology Perspectives 2008* and a reasonable forecast for the proportion of electricity in the energy mix; the current technology scenario relies on a 30 % efficiency improvement and the IEA's forecast for renewables; and the innovative technologies option uses the IEA's *450 Policy Scenario* and the IEC's projection for the technology potential.

For transmission, strategies may be applied to decrease the loss by two or three percentage points. With greater and greater distances potentially separating the generation and the use of electricity, this is significant in absolute terms. Technologies such as ultra-high voltage transmission and superconducting cable may help achieve this. In distribution the contribution of distributed small producers of power – even individual consumers – will be significant, not only as a source of electricity but also as actors in a complex, “smart” electricity grid (see Section 5).

Technology is already available to reduce consumption of electricity by individual devices, such as household appliances and industrial installations, by around 30 %. Needed are systemic approaches which may eliminate some tasks entirely and globally optimize others. Electric motors, which may represent as much as 70 % of the electricity used in industry, are a good example of both. Investment in known technology will improve the performance of individual motors, and the energy optimization of factories and other plants can lead to significant system redesign for both less energy and use of cleaner forms. Heat pump systems, another excellent example, use a small amount of electricity for the pump and manage to heat and cool buildings efficiently. In short, rethinking what needs doing when – and especially taking advantage of electricity’s controllability and flexibility to electrify more functions – will lead to overall savings.

5. Reference architectures and the Smart Grid

The three greenhouse-gas emission scenarios in Figure 2 demonstrate the need to go beyond the current approaches and aggressively apply developing technologies. This depends on significant changes in the overall design of the energy chain, as well as many interactions between end use and generation. Like any complex design task, energy chain redesign and its various sub-designs require competent planning, which by analogy with the design of buildings we refer to as “architecture”. To achieve a useful end result the architecture must be mapped piece by piece on to a real-world implementation, and the term “*reference* architecture” expresses this link between each part of the design and the corresponding implementation step carried out in reference to it. The approach using reference architectures may be understood as putting the systems perspective into practice.

The reference architecture of the power networks will have to integrate small power networks based on decentralized generation (basically renewable energies such as photovoltaic, wind and small hydro). This must take place within large-scale power networks connecting centralized power plants. High-performance and flexible interconnections will be needed among the large networks, as well as between these and the small networks. The resulting optimal power grid is widely dubbed the Smart Grid, in view of the extensive incorporation of information and communications technologies to permit intelligent control of the system – for example smart metering, where consumers supply as well as use information on availability and price, and advanced control and protection systems to ensure stability in fluctuating conditions. Reference architectures are also needed for energy and electricity end use: for buildings, for industry and for the home (not only home appliances and electric cars consuming or sometimes storing energy, but also energy-generating equipment).

Issues raised by the future energy chain, which need to be addressed through architectures and innovative technologies, include: the balancing of demand and generation, centralized and distributed; power quality, e.g. voltage fluctuations; prevention of overload conditions which can lead to massive breakdowns; and coordination of control systems between the utilities' grid and decentralized generation.

What is needed to achieve progress, create the reference architectures and apply them to realize the Smart Grid and the required efficiencies? Clearly research, development and massive investment are needed. However, the necessary precondition for the massive investment and deployment is substantial *worldwide agreement* on the "what, where, when and why". The systems approach will only work if there is a coherent global approach – the overall objective is a global one; many of the systems need to involve several countries; development of the required innovations will often need the scale of global markets to justify the risk and up-front cost; the component technologies need to interwork to enable systems approaches in the first place.

This is where standards come in.

6. The role of standards

The role of standards, and therefore of the IEC, is as technical facilitator and a channel for the expression of the collective wisdom on a particular issue. This remains far from guaranteeing that the necessary concrete steps will in fact be taken, or that the energy challenge will be effectively met – indeed, that is not at all the role of the IEC. However, we may characterize standards as absolutely essential, even if not sufficient, for the process of meeting the challenge we all face. This is because no better mechanism exists to reach agreement worldwide, among *all* the relevant stakeholders, on major technical subjects.

In each area where a reference architecture is needed, the relevant worldwide experts should be gathered together to develop it and the result published as an international standard. This would ensure the widest possible consensus and buy-in on the part of stakeholders, whether manufacturing industry, utilities, end-use markets, researchers or regulators. Considerable investment from the engineering community will be required. Architectures are notably needed for industry, for buildings, for homes, and of course for the power grid itself.

An important further benefit is that the standardization process itself is excellently suited to determining the boundaries of the architectures, and notably whether the power grid needs mainly one overall design or several more detailed architectures. It should also be noted that the successful architectures, particularly for buildings and industry, will probably include other types of energy and not just electricity, in order to achieve global optimization.

Once architectures are in place, the job of standards is by no means exhausted. Beyond the many existing standards for electrical and electronic products and smaller systems, major innovations are needed if the architectures are to be applied to provide solutions. This gap between architectures and products is the domain of the applications approach, as shown in Figure 3. An architecture gives major interdependencies and design considerations for its subsystems, but does not specify hard conclusions as to all the future functions of products and subsystems contained in it. These are provided by describing a solution, or application, which is needed to provide a function but may be implemented by a range of possible services, technologies and products. In the standards world this implies a new departure:

- So far, complex systems have been developed as one-off solutions.
- The design and development is typically performed either by the final user of the system, such as a utility, or as in industry by a system integrator company; IT multinationals and consultancies often play a significant role.
- In consequence the market has not so far seen a need for standards for complex systems.
- A certain number of these systems *must now be standardized* in order to achieve optimal energy efficiency.

This follows inescapably from the need for worldwide agreement mentioned in the previous section, at least as regards those characteristics which are shown by the architecture to have an influence on energy use.

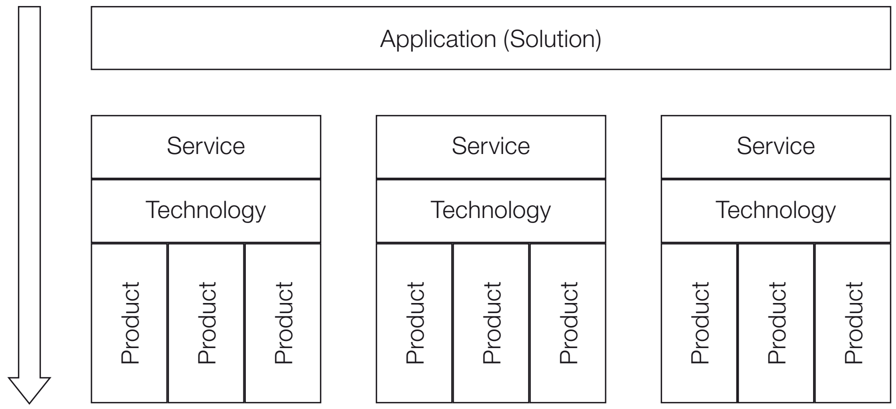

Figure 3 – The applications approach

As examples of the applications approach, we can cite the integrated manufacturing enterprise and the intelligent building. For the first, a reference architecture is needed to describe the “digital factory” from the energy point of view, including heat, cooling and other forms of *energy use*; *sources* of energy including electricity; and elements of *energy storage*. *Applications* or solutions correspond to the major functions such as automated manufacturing stations and transport of parts, and the characteristics of each such application relevant to the reference architecture must be described in a standard (these could be a need for cooling, or production of excess heat available for use elsewhere). Only then can the services needed by each application, and the best technologies to implement these, be chosen and standardized. For the second example of intelligent buildings, an architecture will show the building energy network; one application will be the requirement for minimum and maximum ambient temperatures in various building spaces; and the services (heating, cooling), technologies and products may be standardized as a function of the architectural requirements for energy efficiency.

7. Next steps

To address the challenge described in this paper, the IEC is planning an evolution in its fundamental orientation.

- Traditionally the IEC has concentrated on safety and compatibility.

- Now we intend to move to taking the lead in new areas where a common approach is needed:
  - energy efficiency,
  - productivity,
  - the environment.

- Traditionally we have developed mainly product standards.

- Now we must understand and extend our activity to aim at systems and reference architectures as a basis for global solutions.

The message of this paper is that the thinking must start from the system and go down to the parts, rather than start from the individual products and possibly progress to the system, as is the case today. This must include revisiting existing product standards, where necessary, when new systems standards have been prepared.

Solutions are defined by the market according to its needs, and are not necessarily limited to the IEC’s areas of competence. It is the IEC’s task, first, to listen and put questions to the market, in order to understand and describe the solutions that the market requires and to determine which aspects of these solutions belong to the domain of the IEC.

We intend then to invite all relevant organizations to cooperate in working out the solutions, and finally to define standardization requirements in the IEC's domain for the services and products needed by those solutions.

Specifically for the central problem of electricity transmission, distribution and use, the IEC intends rapidly to develop a full and detailed set of specifications giving minimum acceptable performance rules and a full set of options for the operation of grids. This is conceived as a part of the set of standards needed by Smart Grids. The specifications will allow for the necessary differences in approach and choices made in different countries; thus some of the resulting publications may be non-normative. In order to facilitate implementation, it is proposed that the IEC and the cooperating organizations hold a public symposium on what the necessary specifications and other IEC publications on the Smart Grid should contain.

Progress needs to be made in all the research and development projects involving emerging technologies needed for electrical energy efficiency and decarbonization. It seems to the IEC that all are called upon to achieve this, whether in the domain of technological enablers, policy decisions or provision of funding.

The IEC's energy efficiency solutions may usefully contribute to the political agenda and public incentive plans, to show feasibility and a technically sound approach. Cooperation with regulatory and political authorities is clearly of great importance, in order that electrical-energy-efficient solutions may be implemented in a timely fashion to serve the public interest. For this purpose, the IEC intends to strengthen its ties with a range of relevant international and governmental organizations and invite them to join forces with it in an effort combining both policy and technology to progress smart electrification. Relying on the IEC's technical competence and ability to involve all relevant stakeholders is one factor among many that will allow the global community to build a better future.

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

3, rue de Varembé
P.O. Box 131
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch