Digital technology on the IEA's energy roadmaps

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Abstract:
The International Energy Agency (IEA) has drafted roadmaps for the next four decades in collaboration with public and private producers and consumers of energy. These roadmaps indicate the key elements for compliance with the Paris Climate Agreement's objectives for each type of energy. They emphasize the role of digital technology, in particular smart grids, in the transition toward a "smarter" energy system. The conditions necessary for successfully transforming this sector are mapped out, while attention is called to the risks inherent in this transition.

The digital revolution started in the energy sector four decades ago, at first in production and then in the distribution of energy before gradually affecting end-users (individual consumers, local authorities, industries/services).[1] To take an example, the concept of "digital oil fields" emerged in the early 1980s owing to technological developments such as three-dimensional seismic testing and horizontal drilling (Offshore Technology, 2015). Since then, using digital technology upstream in the petroleum industry has improved several key indicators about, for example, discovery and recuperation rates, or operational security. In the electricity industry, a growing percentage of current must be uploaded from renewable sources subject to two new conditions that require using digital technology: the variability of production and the diversity of the units for generating electricity. On the side of consumption, the installation of smart meters is opening the way toward a literal revolution in customer-supplier relations.

Given the ambitious objectives set by the 2015 Paris Climate Agreement and the need to speed up the energy transition, questions arise about how digital technology will come into play on both the supply and demand sides of energy. How to draft roadmaps for moving toward a low-carbon energy sector?

The IEA's energy scenarios

Since the early 1990s, the International Energy Agency (IEA) has made mid- and long-term projections using models that take account of the worldwide consumption and production of energy. Two types of products are proposed: *World Energy Outlook* and *Energy Technology Perspectives*. In both cases, simulations are made for limiting global warming to less than 2°C; and this "2DS scenario" is then compared with more conventional scenarios corresponding either to current policies or to the policies expected from the national commitments made under the Paris Climate Agreement.

[1] This article has been translated from French by Noal Mellott (Omaha Beach, France).

Figure 1 compares projections of CO_2 emissions under the 2DS scenario and under a 6DS scenario (i.e., a six-degree increase in global temperatures, the trend corresponding to current policies). The major energy-consuming sectors that can help us shift toward a low-carbon economy are (in decreasing order): electricity (a potential reduction of 39% in total CO_2 emissions) followed by industry, transportation and the building trade. Achieving the 2DS scenario calls for an unprecedented marshaling of technological and financial resources. The IEA's *Energy Technology Perspectives 2017* presents a scenario for limiting global warming to much less than 2°C, which would require greater efforts than the 2DS scenario.

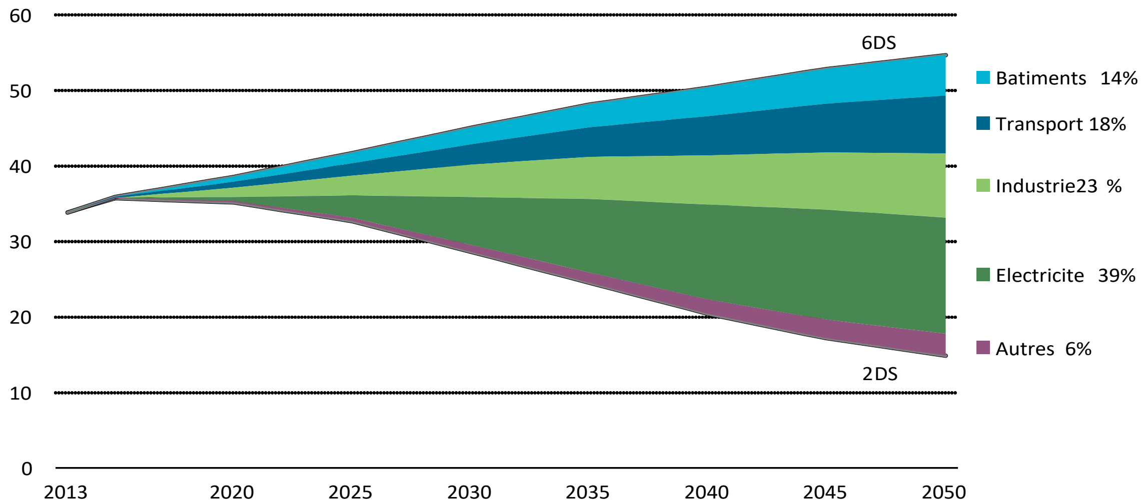

Figure 1: Comparison of the projections of CO_2 emissions under the 2DS scenario (a two-degree increase in global warming) and a 6DS scenario (a six-degree increase, which corresponds to the pursuit of current policies).
Source: IEA, *Energy Technology Perspectives 2016*.

Construction industry 14%
Transportation 18%
Industry 23%
Electricity 39%
Others 6%

The IEA's technological roadmaps

Accelerating the development of low-carbon technology is urgent if we are to cope with the challenges of a secure supply of energy, economic growth and the limitation of climate change. In 2008, the ministers of the G8 countries, meeting in Japan, asked the IEA to propose technology roadmaps for making the necessary innovations faster. In response to the G8's request, the IEA drafted, with the support of member states, a series of roadmaps for the major forms of energy technology. The drafting of these roadmaps benefitted from the participation of both the private and public sectors (firms and associations as well as state authorities, officials in education and research). In addition, 39 of the IEA's technology collaboration programs took part in collecting information and diffusing "good practices".

These roadmaps seek to reduce greenhouse gas emissions to a level compatible with limiting global warming to less than 2°C. Each roadmap has come out of an international consensus about the principal steps for developing technology: the need for regulations, the efforts required for public relations and communication campaigns, and the requirements of international cooperation. The IEA has released the following roadmaps on its website:[2] *Bioenergy for Heat and Power*; *Biofuels for Transport*; *Carbon Capture and Storage*; *Carbon Capture and Storage in Industrial Applications*; *Cement*; *Chemical Industry via Catalytic Processes*; *Electric and Plug-in Hybrid Vehicles*; *Energy-Efficient Buildings: Heating and Cooling Equipment*; *Energy-Efficient Building Envelopes*; *Energy Storage*; *Fuel Economy of Road Vehicles*; *Geothermal Heat and Power*; *High-Efficiency, Low-Emissions Coal-Fired Power Generation*; *Hydrogen and Fuel Cells*; *Hydropower*; *Nuclear Energy*; *Solar Photovoltaic Energy*; *Solar Thermal Electricity*; *Smart Grids*; *Solar Heating and Cooling*; and *Wind Energy*. The agency has also drawn up national roadmaps in collaboration with certain countries, for example: on wind power in China or the production of cement (with a reduction in CO_2 emissions) in India.

Digital technology plays a key role In several of these roadmaps. I shall illustrate its importance in the roadmap devoted to smart grids (IEA 2011).

Digital technology in the roadmap for smart grids

With more than 50 million kilometers of lines on the planet (enough to go from the Earth to Mars), electricity grids form a very complex infrastructure. They used to be managed in a single direction, from the supply-side of the electricity that, generated in power plants, was to be delivered to end-users — but with very little participation by consumers on the demand-side.

The girds have become "smarter" over the past three decades, a trend that has recently picked up speed. Data flows produced by electricity systems are doubling every two years. Meanwhile, the costs of remote control devices and computer technology have, on the average, been decreasing every thirty months over the past twenty years. Had light-weight vehicles improved at the same rate since 1996, they would have achieved in 2016 an autonomy of 200,000 miles (more than 320,000 km)! Information and communications technology (henceforth ICT) and the energy sector, though evolving at quite different speeds, must increasingly interact.

An energy system that is smarter because of digital technology is emerging from current trends. To maximize its potential, accelerate the trend and attenuate the risks inherent in this transition, efforts must be put into making stakeholders more aware and more involved. Smart energy systems require new installations on the end-use infrastructure (electricity, gas or heating systems in urban areas) and for the generation of electricity. Current installations will have to be equipped with electronic devices such as sensors and integrated in ICT systems. This smarter system calls for interconnections via high-speed communication networks using standardized protocols, thus bringing the worlds of ICT and energy together.

The roadmap for smart grids assesses the global impact by 2050 of smart technology and of ICT on electricity grids. It evaluates the issues, obstacles and steps necessary for a timely roll-out of this new technology and thus gauges the options of decision-makers for managing the energy transition.

The transition toward a smarter, more digitized energy system rests on three main pillars:

— DATA FROM SENSORS AND METERS. Sensors placed throughout the grid (from the smart electricity meters in homes to the sensors in power stations or on big industrial equipment) will generate an enormous volume of data.

— CONTROL OVER MORE OF THE ENERGY SYSTEM. Two-directional communications will allow for remotely controlling a large number of machines and equipment in the energy sector.

[2] https://www.iea.org/roadmaps/

— THE ANALYSIS BIG DATA. By analyzing big data, both raw data and data from applications, our learning capacity will grow along with our intelligence for designing, managing and operating energy systems more efficiently.

Whenever these three factors come into play together in a sector or application, appropriate regulations can be adopted that allow for the emergence of new business models and solutions that: *a)* increase the use of current assets; *b)* decrease costs while increasing efficiency; and *c)* open toward integrating new sources of energy (such as the electricity stored in electric vehicle batteries, the distributed generation of current, smart heating and smart cooling systems, or "sober" household appliances). The *Smart Grids* roadmap identifies the principal fields where the use of digital technology has a great potential during the period covered by the IEA's scenarios. Figure 2 depicts the passage from the concentrated single-direction electricity systems of the past to the smart, distributed, multidirectional systems now being set up.

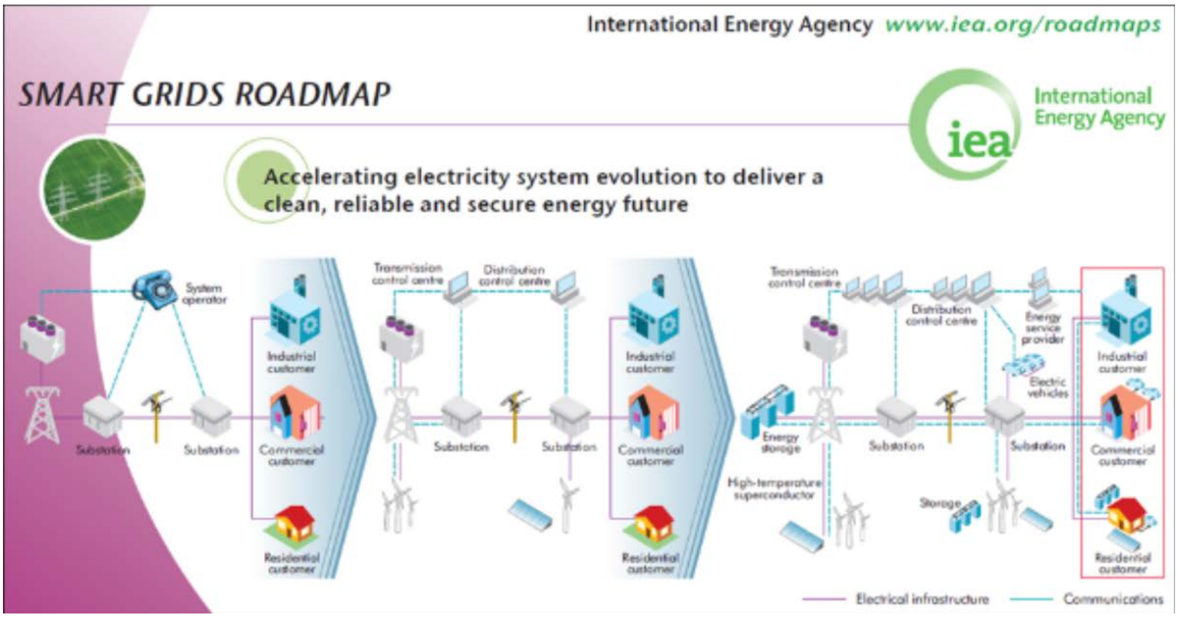

Figure 2: The electricity system and digital technology.
Source: IEA, *Technology Roadmap: Smart Grids*.

In distribution networks at the local scale, energy systems will, as ICT makes them smarter, optimize surveillance and control functions. Thanks to data collection and analysis, in particular, the operations of distribution will be followed up on in real time, thus opening possibilities for predicting breakdowns and for "remote" maintenance. Furthermore, these smarter grids will allow for more control over power stations, as well as other assets, and over the flow of current. They will help us develop better models, foresee variations in demand, predict points of vulnerability on the grid, and react nearly instantaneously to outages.

In transmission networks at a larger scale, high-voltage technology will allow for uploading distributed energy resources and interconnecting grids. As sensors of better quality improve information about the grid's state, smart energy systems will be able to improve the network's physical capacity. Finally, using digital technology in energy networks will reduce the need for laying new electricity lines or investing in other physical assets.

For end-users, the greater opportunities coming from digital technology will revolve around applications on the grid's "edge". Smart energy systems will facilitate consumer participation in managing the systems owing to an improved adaptation to demand, smart devices, the recharging of electric vehicles, etc. At the same time, they will enable consumers to produce and stock larger quantities of current. The flexibility of demand can considerably increase the system's overall capacity for storing electricity from intermittent, renewable sources and other clean forms of energy. It can also create the conditions for running a large number of electric vehicles, for the electrification of heating and cooling systems and of industry, and for an across-the-board reduction of costs.

Nevertheless, the transition toward digital energy systems carries risks that must also be managed. First of all, a major concern is the confidentiality and security of data. Which data will have priority and for which stakeholders or sectors? Who will own the data from meters, sensors, etc.? Who should have access to them? How to best respond to these concerns while weighing the advantages stemming from the new sales models and technical solutions that require processing data from these new sources? Secondly, the paradigm of a smart energy system necessitates a complex ICT system, whence more points of vulnerability and a higher risk of cyberattacks. Strategies must be worked out for cybersecurity from the start to the end of the system. To do this, stakeholders must be made much more aware of cybersecurity issues.

The IEA's *Smart Grids* roadmap also points out a few major risks related to: *a)* the management of applications and procedures for processing huge volumes of data; *b)* the variety of the equipment, protocols and systems that, currently installed on grids, were not designed with interoperability in mind but that have to operate without fail; *c)* the different paces of change in ICT and in energy systems, since the much faster evolution in ICT risks throwing the two out of sync; and *d)* the need for much stronger crossborder coordination in the energy sector than what now exists.

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