

# The New Electricity Age

Electricity is becoming more and more important for the development of a secure and sustainable energy system. From imposing forests of wind turbines rising out of our seas, to serried ranks of photovoltaic cells moving in unison to catch the sun's rays, to electric cars as capable of injecting power into the grid as they are of drawing it out – there is dynamism in the energy market now in a way not seen in many decades.

By Daniel Whitaker

We should put our current progress in context: The way we find and use energy is an instructive way of measuring human development. For 90 percent of our evolutionary history, we relied on muscle power, later supplemented with fire and early tools. Then, 8,000 years of harnessing draft animals and using water- and wind-driven mills improved agriculture enough to usher in the first cities: Civilization was born. Almost three centuries ago, steam engines were invented, followed by the beginnings of electrical power. These new technologies led to industrialization and urbanization. In the 20<sup>th</sup> century, centralized electrical grids were built, run by public or private monopolies. Each stage was revolutionary, accelerating the velocity of change. Now we are moving into yet another electricity age, its pace and details unpredictable. The integrated and smart grid

will be its hallmark, though other key features include the cultivation of renewable power. As with each other stage, there is a “pull” factor of improving technology. But there are also “push” factors. The first of these lies in human demography and economic expansion. Global population is expected to grow from 6.8 billion today to 9.1 billion by 2050. The increase will be concentrated in urban areas in developing countries – often in “megacities,” where energy use is growing fastest. At the same time, despite the recent financial crisis, demand for energy, especially electricity, is increasing. The International Energy Agency (IEA) expects primary energy demand to be 40 percent higher in 2030 than in 2007, which means an annual increase of 1.6 percent. But the demand for electricity will even be stronger. It is expected to increase annually by 2.3 percent, a

clear indicator how important electricity is. The second driver is the scarcity of energy resources – especially oil and gas, concentrated in a few countries, which further stimulates price fluctuations. Knud Pedersen, Vice President for R&D at Denmark’s Dong Energy, points out that his country began its path towards wind energy immediately after the 1970s oil crisis, when 90 percent of Danish oil imports were from the Middle East (see also “Wind Power” article on page 20). The third, most pressing force, is climate change. As is now well known, without a change in policy, global temperatures could rise by up to 6° C, with catastrophic consequences for our climate. The increase is mainly caused by greenhouse gases like CO<sub>2</sub>, released when burning fossil fuels like coal (e.g., for electricity) and oil (e.g., in transportation). To avoid the

“Developing countries can often drive new policies forward faster.”

Fatih Birol, IEA Chief Economist

## Forecasting the Future of Energy

*Living Energy’s* Daniel Whitaker asked the energy experts who were interviewed for this article a few pointed questions about the new energy age specific to their areas of expertise.

### Fatih Birol, Chief Economist, International Energy Association (IEA), Paris

**Are we entering a New Electricity Age?** Yes, but let’s not forget the many millions around the world who still have no access to electricity, which is vital for social development.

**Where will we see the fastest progress?** Developing countries can often drive new policies forward faster than OECD countries.

**What about carbon capture and storage?** It’s a crucial technology to win the battle against climate change, but it faces three challenges: technological (e.g., leakage), economic (it will require a significant carbon price), and regulatory (determining who is responsible for storage sites).

**What’s the future of electric cars?** 90 percent of growth in oil demand is for transport, so electrification of mobility is vital.



Photos: Private, Wellcome Images

“The technology is being created, but change will be much slower than expected.”

Prof. Vaclav Smil, Manitoba University

most severe weather and sea level rise, greenhouse gas concentration needs to be stabilized at around 450 ppm CO<sub>2</sub>-equivalent to limit the temperature increase to about 2° C. Despite the failure of the Copenhagen Summit to produce binding limits, there will be constant pressure to reduce emissions.

Though alternative, renewable energy sources – solar, wind, biomass, geothermal – are rapidly expanding, fossil energy will remain the major fuel source for the next decades. Vaclav Smil, Distinguished Professor in the Faculty of the Environment at Manitoba University in Canada, describes how in each of the last six years, China has built coal plants with production greater than all of France, with hundreds more such plants planned both there and in the USA.

#### Storage and Transmission: New Challenges

Despite these challenges, technological progress may also be part of the solution. All parts of the energy conversion chain are undergoing radical change. As the only major company active in every part of this chain, Siemens can engage with the full range of New Electricity Age challenges, and has the chance to apply knowledge gathered in one segment to issues in another. With coal remaining a leading input for power generation in the medium term, technologies that can capture and store the carbon emitted when it is burned may be vital – an area where Siemens has great competence. Nuclear power is also seen by many as another such “interim technology” until renewable generation can meet all of our needs. But both technologies still face challenges, especially regarding the question of where residues may be stored without environmental hazards. Another new frontier is the ocean floor. It holds much-needed hydrocarbons that might reduce the political danger of dependence on oil production from a few countries, especially gas, which represents a cleaner, less carbon-emitting alternative to coal in electricity

generation. Fatih Birol, IEA Chief Economist, agrees that deepwater reserves are huge, but are also costly to extract. Drilling rigs currently require their own inefficient power generation (oil and gas extraction has the highest electricity demand of any industry), and struggle to deal with the ever-increasing depths and hostile environments where reserves are found. A solution is emerging in unmanned, robotic seafloor exploration and drilling systems. These can operate more than 2 kilometers under the sea, drawing their power from a high-voltage direct-current (HVDC) cable connecting them to an onshore grid (see also “Subsea Power Grids” article on page 30).

These same HVDC connectors are revolutionizing long-distance power transmission. The world’s largest CO<sub>2</sub> emitter is China, whose industries are located mainly close to the coalfields feeding its power plants. Now, Siemens is building several 800-kV connections that will span distances up to 2,000 kilometers (twice the voltage and many times the length of anything in Europe). This means Guangzhou or Shanghai coastal factories can be powered by hydroplants in the west of the country. This is relevant to climate change, given that the IEA estimates a quarter of the CO<sub>2</sub> emission reductions needed over the next decade will have to come through Chinese en-

Prof. Vaclav Smil, Distinguished Professor in the Faculty of the Environment, Manitoba University, Manitoba, Canada

**Are we entering a New Electricity Age?** The technology is being created, but change will be much slower than expected. It’s important to be skeptical of the forecasts of large organizations. The IEA, Siemens, and others are overoptimistic. There are also key aspects that are underappreciated, such as the growth of LNG. We are still a fossil fuel society.

**Where will we see the fastest progress?** Europe can more easily implement a smart grid, with its good existing interconnections and high population density. North America is the opposite: The US grid is shambolic, and investors there will want to keep making profits on its immense oil-related infrastructure. China, however, might shift from a coal basis towards LNG and electric cars relatively quickly.

**How is subsea hydrocarbon exploration progressing?** Here again,



there is excessive optimism in energy circles, as BP’s current problems show. It took 50 years to learn how to drill in just 1.5 kilometers of water.

**What are the greatest obstacles to change?** The ignorance of people, who overestimate the risks of nuclear power and wish to overconsume. China and India seem intent on surpassing the Americans in overconsumption – which is frightening.

Photos: Wellcome Images, Private

## John Shine, Deputy Chief Executive, Electricity Supply Board (ESB), Dublin, Ireland



**Are we entering a New Electricity Age?** It's a new era for electricity, due to decarbonization, but it needs leadership from all of the main players – manufacturers, utilities, government – as well as investment and coordinated R&D.

**What's the status of smart meters?**

We are currently running the largest behavioral study ever on these, seeing how consumers respond to different tariff scenarios; whether meters operate best using power lines, GPRS, or radio; and whether gas and possibly water can be incorporated.

**What are Ireland's advantages in this area?** Meters are part of the distribution system, so upgrade investment can be made quickly, and costs can be incorporated into the system charge and amortized over a long period. Also, many large IT players are based in Ireland and want to play a role in smart grid development, with major IT investment already having occurred; wind is already well integrated, and electric vehicle infrastructure rolling out.

ergy policy and activity (see also "UHV DC Guangzhou" article on page 50). The same new transmission capability is opening up great possibilities in renewable generation for Europe. The Desertec project is a massive renewable generation initiative involving offshore wind generation along the European and North African Atlantic coasts, together with hydro, geothermal, photovoltaic and biomass units. But the central element of Desertec is a massive array of solar fields mainly in North Africa. HVDC lines from the Sahara into Europe make the project technically feasible, though economic and regulatory issues remain. The large consortium involved in Desertec (including German, French, Spanish and North African entities) is driven by the fact that all of Europe's power needs could be generated by solar panels in a relatively small area of the northern Sahara.

In parallel and complementary to Desertec, Siemens joined the French solar energy initiative Transgreen in May 2010. This project develops ideas for the European transmission grid connecting the future centers of major renewable generation, using lines under the Mediterranean Sea to bring the solar energy from the Desertec project to Europe. While Desertec is developing step-by-step, other renewable generation has been mushrooming. This has been stimulated by "feed-in laws" in more than 60 jurisdictions offering guaranteed grid access, long-run contracts, and cost-based tariffs. Extensive investment is under way in wind generation – especially offshore, where wind speeds are greater and the huge turbines are less obtrusive. As with solar power, the absence of emissions and the factor of marginal cost are strong attractions. Since these offshore sites

are located far from grid-based transmission infrastructure, the HVDC technology is once again needed. The upper ceiling for utility-owned wind farms is steadily increasing, with over 1 GW at the UK's London Array site, for example. But regulatory incentives in many countries are also giving rise to increasing numbers of small wind generation projects, as with solar power and cogeneration in industrial and commercial sites.

Another related key aspect of the New Electricity Age is decentralized generation of power. Gone are the days when monopoly electricity utilities would establish a few large power plants and simply link them up with the main cities and industries. The new grids have to accept power feed-in from many points of varying sizes and (especially in the case of wind and solar) fluctuating generation levels. Given that some connected entities (a factory with a cogeneration unit, a house with solar panels) are now "prosumers" that can either produce or consume power, the new grid must be able to cope with bidirectional as well as strong fluctuating power flows. The monitoring and control needs of such a grid are immensely more complex than in the past. What's more, customers have increased informational expectations. Smart meters should give the consumers access at all times not only to data on usage, but also to current energy prices (which will be highly variable, given changing decentralized generation and demand). Smart meters also let consumers change their energy consumption with ease. This is even more important for "prosumers," who will effectively trade energy by deciding at each price level whether they will consume or generate. At the same time, "unbundling" of transmission and distribution services in the USA and the EU means that many more commercial entities are involved in each section of the grid.

Clearly, major market participants will have to demonstrate both engineering and IT capabilities, as well as a flexi-

ble organizational structure to address crosscutting issues. Siemens is already experiencing this, and employs more software engineers than does Microsoft. But much work remains to be done on connecting a system based on moving electrons with one based on moving digital information. The world of electricity and the world of IT need to come together.

### On the Road Again – Emission-Free

Electricity generation is a major source of carbon emissions, and the fastest-growing one, but it is of course by no means the only important one. Vehicle transport will be another locus of great change in this new age. The first signs are already here. John Shine, Deputy Chief Executive of the Irish utility ESB, explains that his company has agreed with Renault-Nissan to build 3,500 charging points by 2011, or one per 1,200 citizens. In China, more than 60 million electric bikes are already on the road, complementing electric buses and LNG-fueled taxis. The bikes use lead batteries that can be recharged from a wall socket. China's electric bikes haven't required any subsidy. The electromobility boom there is due to rapid urban growth and a lack of already existing oil-based infrastructure, as throughout much of the developing world. But the Chinese government has been promoting renewables more forcefully than is often appreciated, with massive wind and solar investments planned. Due to the scale of developments in China, the New Electricity Age may be most visible there, though many other countries (Denmark, Ireland, Israel) and cities (San Francisco, USA, and Masdar/Abu Dhabi, UAE) are pioneering other aspects of transition.

Electromobility will play a central role in the New Electricity Age everywhere, however. Challenges remain both inside electric cars – mainly regarding batteries, power electronics and lightweight materials – and with the infrastructure that will surround

**"It's a new era for electricity, but it needs leadership from all main players as well as investment and coordinated R&D."**

John Shine, ESB Deputy Chief Executive

them. A key question is whether to exchange vehicle batteries at recharge stations or include permanent batteries – if the latter becomes the norm, plug standardization is needed to avoid the incompatibility problems seen with mobile phones. Mobile telephony may offer a positive example for billing, however, as its roaming and remote billing concepts could be applied to the electricity business. Beyond reducing carbon emissions and fuel dependency, electromobility offers another great advantage: a solution to the New Electricity Age's storage problem. The fluctuation that wind, solar, and decentralized generation bring means that the new smart grid must be able to store excess energy when it enters the system as well as having surplus on tap when needed. Already in Germany, such fluctuations sometimes produce a negative energy price (so anyone prepared to take electricity will be paid to do so), and the total German electricity storage capacity (in water pumping facilities) totals less than 30 minutes of load. What electric vehicles offer is a massive, decentralized storage capacity. Drivers could double as "prosumers," informed of energy market developments by mobile phone or similar. If the grid carried too much energy, electric cars could buy it up cheaply and

store it in their batteries. When the price went again, they could sell it back – always saving enough electricity to power their drive into work, of course (see also "Electromobility" article on page 26).

As the electromobility market begins to grow, Siemens can proudly point the market's historic roots. The "Electromote," the world's first electric vehicle, was designed and driven by Werner von Siemens 118 years ago near Berlin.

### The Role of Economics and Government Regulation

Technological progress is now moving perhaps at its fastest since the days of Watt, Stephenson's Rocket, and the Industrial Revolution. Change is occurring throughout the energy chain. Intelligent market participants are very open to external ideas, since no single organization will possess all of the portfolio elements needed to meet all smart grid challenges. But two other forces besides technology will also exert influence how the New Electricity Age and smart grid evolve. The first is economics. From an overall perspective, it is clear that smart systems must replace the current energy infrastructure. But the speed of this adaptation will be determined by the profitability of such invest-

ments. For final consumers, for example, smart meters could guarantee a rapid return on outlay, through cost savings and potential gains from energy trading. But the massive capital spending required to develop the rest of the smart grid's infrastructure, including an electromobility charging system, is less straightforward. That spending will be driven by the second major influence: regulation. Governments are already setting the pace of reduction in carbon generation through feed-in laws and emissions trading rules. Subsidies for renewable energy may only be temporary: Costs are continuously falling, and once the technologies break out of niches into a true mass market, costs will plummet still faster. Prof. Smil reminds us that many technologies have benefited from subsidies – oil from road building, nuclear power and gas turbines from military R&D, and computers from NASA investment.

International regulatory accords are needed for the cross-border transmission that would facilitate Desertec and other projects. Design standards must be established for smart grid infrastructure. In particular, data transfer between the many participants in the New Electricity Age requires harmonization of IT protocols and systems.

## Margareth Øvrum, Executive Vice President for Technology and New Energy, Statoil, Oslo, Norway



**Are we entering a New Electricity Age?** Change has been continuous, though it is accelerating. Increasing energy demand, growing difficulty in accessing hydrocarbons, and the spread of awareness about climate change are the main elements.

**What is Statoil's involvement in renewables?** We focus exclusively on offshore wind because that is where our competitive edge lies (from offshore oil and gas experience) and because it

is the most mature renewable source, technologically and industrially. With the other technologies, Statoil is more of an interested follower.

### What about carbon capture and storage?

Statoil was spurred to begin CCS by the UK market requiring lower CO<sub>2</sub> content in gas we sold them (capture) and the Norwegian government introducing a carbon tax (storage). Since 1996, we have captured and stored almost 14 million tons of CO<sub>2</sub> in natural undersea reservoirs. But, as with renewables, an international carbon tax is needed.

### And subsea hydrocarbon exploration and production?

New methods are extending the lives of our 475 current subsea wells. We can drill deeper, use longer tie-backs to production facilities, and cope with colder climates. A range of technological improvements allows for more efficient production of oil and gas, with better compression of gas and more effective control and power transmission and distribution systems. There are similarities to offshore wind, but the direction of energy flow is reversed.

The investment, regulatory and coordination requirements are immense, though the technology is already available. In the light of the enormous (if unquantifiable) threat that climate change poses, the challenges to the advent of the smart grid and mastery of the New Electricity Age may seem extremely daunting. Certainly, progress will not be smooth and easy.

But there are encouraging precedents. In 1868, Werner von Siemens was told he must construct a link from London to Calcutta by telegraph – a technology then far less mature than most elements of the smart grid are today. He had only two years to accomplish this, since the upcoming birthday of Queen Victoria was set as a deadline. Against great odds, the

connection was opened in 1870, and a new era of international communications was underway. Our New Electricity Age has every chance of following in the same way.

*Daniel Whitaker is a London-based freelance journalist who specializes in writing about technology, business and economics. His work has appeared in such prestigious publications as the Financial Times, The Times, The Observer, the Economist and the Daily Telegraph, among others.*

### Further Information

[www.siemens.com/energy](http://www.siemens.com/energy)



## Knud Pedersen, Vice President for R&D, Dong Energy, Copenhagen, Denmark

**Are we entering a New Electricity Age?** It is the start of a fundamental change in the structure of the energy sector. Clearly, electricity will dominate, combining many more facilities and activities. Sectors will also integrate, like transport with electricity.

**What about Desertec?** It's exciting to envision a combination of solar power from the south and wind power from the north, all integrated in a wider European market. The challenge is basic decision making on infrastructure at the EU level.

**What are Dong's priorities?** For us, wind power, with its grid implications, and electric vehicles (especially battery flexibility) are most important.

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