The energy and climate challenge

The world is facing serious energy-related challenges, key issues being how to secure supplies in the face of fast-growing demand, increasing supply risks, and how to mitigate the environmental harm caused by rising consumption.

Rising energy prices and concerns about climate change have brought energy issues to the top of the agenda in business, politics and public debate.

Leaders of the G8 group of countries in June 2007 agreed to take “strong and early action” to tackle climate change. European Union leaders in March 2007 agreed to cut energy consumption by 20 percent by 2020 compared with projected demand.

The EU commission estimates that realizing the target will cut the annual energy consumption of member states by 390 million tons of oil and reduce CO_2 emissions by 780 million tons. This is more than twice the reductions agreed to by the EU under the Kyoto Protocol, an international treaty than runs until 2012. Using available technology and changes in behavior will be key to achieving the targeted reductions.

In 2004, the most recent year for which global figures are available, energy produced worldwide was equivalent to about 11.2 billion tons of oil. This includes the energy used to generate more than 17 million megawatt-hours of electricity. Global energy consumption resulted in CO_2 emissions of ca. 26 billion tons.

Energy demand has been rising steadily and by 2004 was almost twice what it was 30 years earlier. The International Energy Agency (IEA) forecasts demand will grow by a further 53 percent between 2004 and 2030. Others predict even faster growth. The McKinsey Global Institute (MGI) expects demand to rise 45 percent by 2020.

The IEA says global electricity consumption is set to grow nearly twice as fast as overall energy demand and will almost double by 2030. China alone is expected to more than triple electricity consumption. As a consequence, electricity’s share of total end-user consumption will grow from 16 to 21 percent.

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The continued strong growth in energy demand is mainly driven by the rapid economic development in emerging markets, especially in China, India, eastern Europe and the Middle East. Developing countries will account for more than 70 percent of the growth in energy demand until 2030, the IEA predicts.

CO_2 emissions will grow at the same pace as energy demand or even slightly faster because coal-fired power plants will account for a growing share of production. Until 2030 global CO_2 emissions are estimated to increase by 55 percent. Emerging markets will account for 75 percent of the increase in CO_2 emissions as they continue to rely more heavily on fossil fuels.

The world's leading emitters of CO_2 in 2004 were the United States and Europe and China will overtake both of them by 2010, according to a 2006 study by McKinsey's MGI. China will probably generate 24 percent of global CO_2 emissions by 2020, accounting for 38 percent of emissions growth in that period, it estimates.

Massive further investments in energy infrastructure

The rising demand for energy will require massive new investments in global energy supply infrastructure. According to the International Energy Agency, more than $20 trillion in cumulative investments will be needed between 2005 and 2030 to build up new energy infrastructure.

Some 60 percent of this will be spent in emerging markets on modern power networks including power exploration, generation, transport, transmission and distribution.

Investments in the development of alternative energy solutions will play a key role in increasing and broadening the power supply.

Energy efficiency – achieving energy savings and curbing energy demand

The most immediate, practical and cost-efficient solutions to address the increasing energy and environmental challenges are the opportunities for energy savings that come from using energy more efficiently with available and proven technology.

The potential for energy savings is enormous. Today, some 20 percent of energy is wasted. This corresponds to 64 million barrels of oil per day, or almost 150 percent of the U.S.'s energy consumption in 2005.

Using the potential of energy-efficient technologies would reduce growth in energy demand by some 50 percent by 2020.

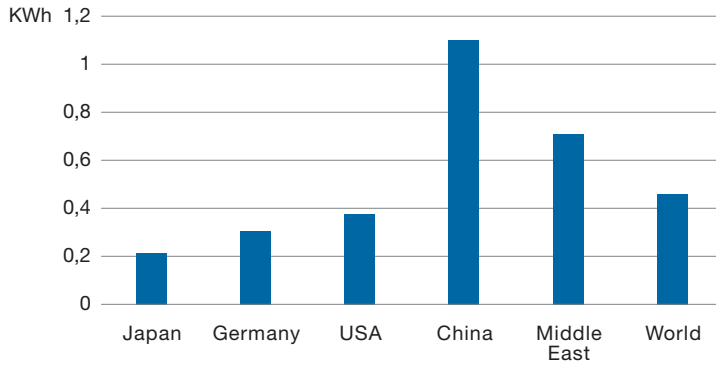
The key advantages of using energy-efficient technology are that savings can be achieved immediately and that savings in energy costs typically offset the initial investments. With attractive payback times, these investments pay for themselves and have the potential to increase profitability. Seizing opportunities to use energy more efficiently gives fast-growing emerging markets the chance to save energy and reduce environmental impact without compromising their economic development.

Energy efficiency varies widely across economies, reflecting the degree of penetration of energy-efficient technology and the share of gross domestic product generated by energy-intensive industries.

The savings potential is particularly large in emerging markets, where the forecasted growth rate of energy demand will be highest (see chart).

Energy efficiency differs strongly between countries

Amount of energy used in 2004 to produce $1 GDP



International Energy Agency, 2006

China, for example, used five times as much energy per unit of gross domestic product as Japan. Using energy-efficient technologies will offer an opportunity to substantially curb the additional energy demands and CO_2 emissions from these countries.

Sources: ABB, International Energy Agency, McKinsey Global Institute

Background information
Energy efficiency

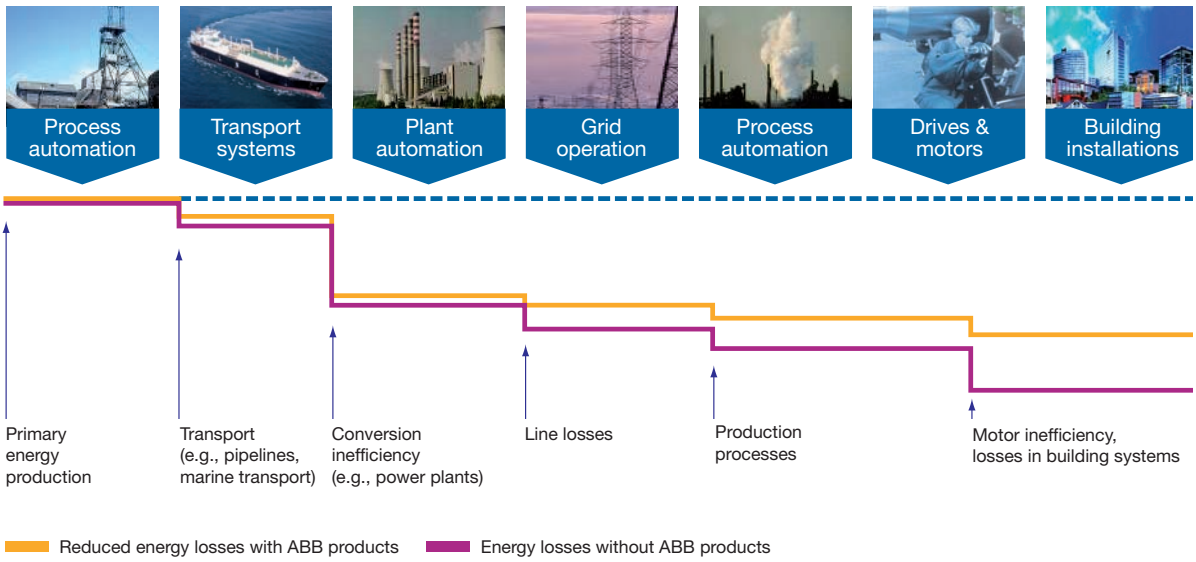
ABB and energy efficiency

Only 20 percent of the available energy creates economic value along the entire electricity value chain. The rest is lost in the process of burning the fuels, transmitting electricity and using power inefficiently.

As the global leader in power transmission and distribution technology and a leading automation company, ABB can help to achieve energy savings at each step of the energy chain, from the harvesting of primary energy to its transportation and ultimate end-use.

The application of ABB technologies can reduce waste along the electricity value chain by 20 to 30 percent.

ABB technology reduces losses along the energy chain



ABB's automation and power technologies can help to achieve energy savings, either by reducing power consumption and losses, improving productivity or better management of equipment.

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Moreover, ABB is the market leader for key energy-saving technologies in emerging economies, where the energy-efficiency potential is the largest. In China and India, ABB is the market leader for power transmission and distribution technology and a leading supplier to the fledgling industrial sectors.

Our customers are mainly utilities in power generation, transmission and distribution. We are also a leading automation and power technology supplier to all industries including the transportation sector.

Energy efficiency in primary energy production

The production and transport of primary energy such as oil, gas and coal consumes considerable amounts of energy in itself. ABB's products, services and solutions help producer industries to optimize their operations and use less energy to extract resources from the ground and deliver it to power plants and industrial processes.

In 2006, ABB supplied automation and power technologies and services worth more than $1 billion to the oil and gas industry alone.

Companies like BP, Norsk Hydro, Shell and Statoil have all selected ABB to supply comprehensive power and automation solutions for offshore platforms, transport and production projects.

A standard liquefied natural gas (LNG) process plant powered by ABB electric drives saves almost $100 million a year in costs compared to the conventional alternative of gas turbines. With such significant cost savings coupled with improved energy efficiency, maintenance cycles, uptime and significantly lower emissions, it is perhaps not surprising that so many oil and gas companies are making the switch to electric drive systems. An LNG plant with a capacity of 6.25 million tons a year would reduce its annual CO_2 emissions by 360,000 tons.

At Statoil's Troll A gas platform in the North Sea, ABB provided a 70-kilometer underwater power link to deliver electricity from the mainland grid. This solution removed the hazard of local power generation on the rig, saved valuable space and provided access to a reliable supply of emission-free power from Norway's hydroelectric plants.

By providing a high-efficiency transmission link using ABB's HVDC Light technology, as well as high-efficiency motors to drive gas delivery equipment, ABB helped Statoil to cut CO_2 emissions by 130,000 tons per year.

Energy Efficiency in transport

Besides the use of oil and gas pipelines to transport fossil fuels, deliveries by sea have gained in importance. Western Europe and North America are increasingly importing liquefied natural gas (LNG) in tankers. Exports of LNG are expected to triple by 2030.

For the transport of oil and gas in pipelines or ships, ABB technology can make important contributions to lower energy losses and reduce CO_2 emissions.

ABB is the world's leading supplier of power and propulsion systems for the marine industry and also supplies high-voltage power connections that provide grid electricity to vessels in port. This allows ships to shut down their own, less efficient generators, which would otherwise produce CO_2 and other emissions in the port.

ABB's high-efficiency Azipod propulsion system reduces the fuel consumption of large ships by about 15 percent. The ABB Azipod propulsion systems help cruise and cargo vessels to save more than 125,000 tons of fuel annually.

ABB is a global leader in the manufacture of high-performance diesel engine turbochargers. More than 50 percent of the world's tankers, container ships, diesel power stations and mining vehicles are fitted with ABB turbochargers to help them increase the power output of their engines by up to 300 percent.

Turbochargers are cost-effective, providing 75 percent of an engine's power for only 10 percent of its cost.

Pipeline operators use ABB instruments to manage flows and detect leaks. ABB is a leading supplier of technology for pipeline compressor and control systems, providing energy-efficient solutions for pumping the gas over thousands of kilometers. For the Yamal pipeline from western Siberia to western Europe, ABB built five compressor stations and supplied control, automation, and electro-technical systems.

Energy efficiency in power generation

As energy moves along the chain, some power losses are inevitable. The laws of physics limit the amount of thermal energy that can be transformed into mechanical energy. As a consequence, most of the losses in the energy chain are – and always will be – in the process of power generation.

There are steady improvements in power generation technology, including turbine technology, combined cycle plants, as well as better control processes. Technology can bring the losses closer to the theoretical limit.

Since 1970, the average efficiency of coal-fired power plants has been improved by approximately 20 percent. The average transformation efficiency for power generation is now 40 percent and the latest technology achieves an efficiency grade of 60 percent, when power and heat are generated at the same time.

ABB is a market leader for power-station automation, supplying all the electric and automation equipment for power plants except for the turbine and boiler.

ABB's power combustion optimization software and precise boiler control systems are helping to minimize the losses and make better use of primary fuel sources.

ABB's Optimax Boilermax solution automatically calculates the optimum start-up strategy for steam generators. The underlying idea is to optimize fuel consumption and time during the boiler start-up process without exceeding the maximum thermal ratings of critical system components. With this technology, the process can be operated very close to its limits. This allows an improvement of up to one percent in efficiency as well as lower emission values.

ABB's commitment to efficiency in power generation is illustrated by its involvement in the new 750-megawatt "Walsum 10" power plant, the first hard-coal fired power plant to be built in Germany for 11 years.

ABB will supply the entire package of electrical and automation systems for the plant. This includes turbine control, boiler protection, metrological and analytical equipment, as well as medium and low-voltage substations, and all the associated engineering, construction, commissioning and operator training.

When it goes live in 2009, Walsum 10 will be the most efficient hard-coal fired power station in Germany, thanks in part to ABB's optimized equipment and monitoring systems. These will help it feed more electricity into the grid than other generating units that use the same amount of fuel.

Energy efficiency in power transmission

The electrical energy generated by power plants needs to be transported via a network of interconnected transmission lines to end users that are often hundreds or thousands of kilometres away. Transmission losses are typically 6 to 8 percent and can be as high as 10 percent.

Available power technology allows for substantial energy savings. In addition, they can increase the actual electrical power transportation capacities of transmission and distribution networks by 16 percent. The potential to improve energy efficiency directly through loss reduction in transmission and distribution is higher than 1 percent of total generated energy.

The EU commission estimates that network losses in the European Union can be cut by up to 48 million megawatt-hours annually. This equals the power consumed by 13 million EU households.

In the United States, about 200 million megawatt-hours were lost in the transmission network in 2005.

With a market share of about 20 percent and annual sales of more than $12 billion, ABB is the recognized global leader in power transmission and distribution. ABB's sophisticated power transmission technologies, such as high-voltage direct current (HVDC), and highly efficient power and distribution transformers allow significant reductions in power losses.

With their widespread application and long life span, distribution transformers that help channel power from substations to millions of end users make up a considerable fraction of total losses in power transmission and distribution systems. ABB is the market leader and supplies more than 400,000 of these transformers per year. Using ABB's modern transformer technology allows actual transformer losses to be cut by at least 15 percent.

Power transmission networks are the heavy-duty highways of the electricity grid.

In China, ABB's high-voltage direct current technology will help cut consumption of raw coal by 40 to 50 million tons a year and eliminate 100 million tons of carbon dioxide emissions.

Power for Shanghai, for example, is generated more than 1,000 kilometers away at the Three Gorges hydropower station in central China and is sent to the city over two transmission lines. Using ABB's efficient HVDC transmission technology it was possible to save enough energy to power more than 150,000 households per power line.

ABB's latest ultrahigh-voltage direct current (UHVDC) technology will allow for savings of some 30 percent for very long power transmission distances above 1,500 kilometers. This technology was developed to transport bulk power from remote hydro-power stations in emerging markets like China, India and Brazil to the industrial centers with growing energy requirements.

Energy efficiency in industry

In 2004, industry accounted for 32 percent of total end-user energy demand and consumed some 40 percent of the electricity generated. Most energy is used in the cement, chemical, iron and steel industries.

ABB supplies virtually every industry with a broad range of products to increase productivity, safeguard quality and lower costs. Our automation technologies serve the automotive, building, chemicals, consumer, electronics, life sciences, manufacturing, marine, metals, minerals, pulp and paper, petroleum, transportation and utility industries.

The vast majority of ABB's industrial product range enables energy savings by helping to run factories more productively or equipping them with state-of-the-art control systems and electrical equipment.

Key technologies include controls, enterprise software, instrumentation, low-voltage products, drives, motors, robots and turbochargers.

The energy and cost-saving potential in industry remains substantial. The largest energy consumers are the hundreds of millions of electric motors that account for about 67 percent of all electrical energy used in industry.

Every year millions of motors are added worldwide. These motors are the workhorses of industry, driving machines, compressors, fans, pumps or conveyors in virtually all industrial sectors.

ABB is the world's largest maker of electric motors and of motor-control devices known as variable-speed drives. These devices help to cut energy consumption of electric motors by up to 70 percent by adjusting their speed to the required performance. The energy savings potential is enormous: more than 90 percent of industrial motors either can not adjust their power consumption or use only very crude methods to do so. Many always run on full speed regardless of the actual output requirement. In many applications, energy use can be cut to one-eighth just by adjusting the motor speed to one-half.

ABB has delivered more than 2.5 million energy-efficient motor-control devices.

The installed base of low-voltage ABB drives alone saved about 130 million megawatt-hours of electricity in 2006, equivalent to the consumption of about than 32 million average EU households (the average consumption is about 3800 kWh per household in the 27 countries of the EU).

In CO_2 terms, the savings are about 100 million tons, more than the yearly emissions of Finland.

Energy efficiency in commercial and residential buildings

Commercial and residential buildings account for some 38 percent of global end-user energy demand, mainly for heating, cooling and powering electric appliances.

In the European Union some 280 million tons of oil equivalent, or 26 percent of end-user energy consumption, is used for residential buildings. The EU commission estimates that around 27 to 30 percent of the energy can be saved.

Adjusting the heating temperature, lighting and the energy consumption of electric appliances to the actual requirements offers a substantial energy-saving potential without compromising comfort or quality of life.

Every day, ABB ships one million products for the commercial and residential building sector and is a leading producer of low-voltage devices and automated control and building automation systems that can help to achieve savings mainly in three areas:

- Temperature control can save up to 30 percent
- Lighting control can save up to 50 percent
- Building automation can save up to 60 percent

Electric motors: a huge potential for savings

Electric motors are the workhorses of industry. They are so widespread they use about two-thirds of the electricity used in industry, which is 25 percent of global power consumption.

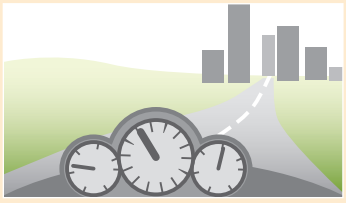
Virtually all industrial activities use electric motors. They run machines, fans, pumps, conveyors and compressors in industries as varied as pharmaceuticals, chemicals, cement, mining and electronics, to name just a few.

The savings potential for motors is enormous. Most of them run at full speed, even when they don't need to. The speed of some motors is controlled by "throttling," but this is like controlling the speed of a car by stepping on the brake while the other foot is on the accelerator. It not only wastes energy, it also causes excessive wear on the equipment.

A far more efficient approach is to regulate the power delivered to the motor with a variable-speed drive (VSD), which adjusts the motor's speed to the task at hand. Energy savings of about 50 percent are achieved in a typical application, meaning an investment in variable-speed drives will often pay for itself in less than a year.

Control the engine speed instead of breaking

The importance of speed control has been always clear in cars. You can imagine how difficult it would be to manage a car by keeping your foot on the accelerator and controlling your speed with the brakes. It is much easier to change to a lower gear and reduce engine revs. With a medium size (100 kW) car:



- Energy saving: about 25'000 kWh/year
- Reduction in CO_2 emissions: 12'500 kg/year
- Other benefits:
  Improved savety, easier to control, reduced maintenance cost

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ABB estimates that equipping all the motors sold worldwide in 2006 with variable-speed drives would have reduced carbon dioxide emissions by 200 million tons, more than the annual emissions of the Netherlands.

Using high-efficiency motors in combination with drives is even more effective. The energy savings quickly add up because the energy used to run a motor over its lifetime costs 100 times more than the motor itself.

ABB is the world's largest maker of electric motors and variable-speed drives. More than 2.5 million ABB drives are in use worldwide, achieving savings of 130 million megawatt-hours in 2006, which is equivalent to the power generated by 16 nuclear reactors.

Reducing losses in power transmission

About 6-8 percent of the electricity that leaves power stations never reaches the consumer. The loss comes from resistance in the power lines that causes them to heat up and dissipate the heat into the atmosphere. The further electricity is transported, the higher the losses.

Yet today, we are becoming more reliant on power from remote sources such as off-shore wind farms, isolated hydroelectric dams and international power trading schemes. The need for efficient long-distance transmission systems is increasing.

The most efficient technology for this purpose is high-voltage direct current (HVDC). Developed by ABB more than 50 years ago, it has lower losses than conventional alternating current (AC) transmission.

Expensive technology is needed to switch power to DC and back to AC for its distribution to consumers, so HVDC is economically viable only over distances of more than 600 kilometers for overhead lines and 50 kilometers for underwater cables.

Over long distances, however, the savings are considerable. A 500-kilovolt power line carrying 3,000 megawatts over a distance of 1,000 kilometers will lose about 7 percent of the energy using AC. This will shrink to just 3.5 percent when using DC technology, representing a 50-percent saving.

Environmental benefits

HVDC is also environmentally friendly for other reasons. Fewer cables are needed to transport the same amount of power, which reduces the amount of land that has to be cleared, and they can be buried underground, avoiding the need for steel pylons across the countryside.

Electricity can flow both ways, providing further environmental benefits. The 580-kilometer link that ABB is building between Norway and the Netherlands will allow the Netherlands to

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import “green” hydropower from Norway during the day, when demand is high, and export excess capacity from its thermal power stations during the night when demand is low. These measures are expected to yield a reduction in CO_2 emissions of almost 1.7 million tons per year.

Visions of harvesting solar power in the Sahara depend on HVDC technology.

ABB is the world leader in power transmission and distribution technology and has won some 55 percent of HVDC orders around the world.

Background information
Energy efficiency

The greenest energy is energy saved
ABB white paper

Barely a day goes by without talk of climate change. The latest scientific reports have shown it is happening faster than experts had expected and that human activity is responsible. If we are to move beyond talk and prevarication, we need urgent solutions.

Renewable energy, carbon capture and biofuels are among the main solutions put forward to mitigate climate change. They are valid methods and must be pursued but the truth is that most of the technologies are either not fully developed, still too expensive or have unwanted side effects.

There is a quicker, cheaper and more effective way of reducing carbon dioxide emissions that can be applied right now: energy-efficient technologies that are commercially available and proven. Energy efficiency is the low-hanging fruit in the campaign to protect the environment because the technologies exist and we know the savings they will deliver.

China, for example, has vast energy requirements that alternative fuels are not ready to meet. Coal-fired power generation is expected to increase at an average rate of about 5 percent per year over the next quarter century, not because the country is addicted to coal but because that's the affordable energy source that is available. The issue that needs to be tackled today is how we can help and encourage China to raise the efficiency of those coal-fired power plants to minimize emissions of carbon dioxide.

Similarly in industry, the biggest reductions in emissions in the short term will come from measures to run processes more efficiently. To give one example, about 40 percent of electricity is consumed by industry, and two-thirds of that is used by electric motors. Devices to regulate the speed of a motor can reduce their energy consumption by 50 percent in many applications. Yet less than 10 percent of motors are equipped with such a device.

Fitting them to all the motors shipped in 2006 alone would avoid 200 million tons of carbon dioxide emissions per year, more than the annual emissions of the Netherlands. And there are many more energy saving opportunities like this.

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Climate experts from the Intergovernmental Panel on Climate Change say that if global warming is to be limited to +2°C, carbon dioxide emissions must start to fall by 2015 at the latest. This goal must be achieved using existing technology. Industry can make a huge positive contribution but political will and support are needed to exploit the full potential of energy efficiency.

There are many things politicians can do.

- Raise awareness of the financial benefits of energy efficiency. Payback times can be extremely short but many businesses still focus on the purchase price when buying equipment, instead of considering running costs over its lifespan. The purchase price of an electric motor, for instance, is just 1 percent of what the owner will spend on energy to run the equipment over its lifetime.

- Create incentives for businesses and local authorities to save energy. The fairest would be a global price on emissions through a trading system. This will take time to achieve and in the meantime national governments can use standards, rules for public procurement or other means to promote energy efficient technologies.

- Governments should make energy efficiency a criterion of every project they fund, every treaty they negotiate, every research agreement they support, and every school or hospital they build. Others will follow where governments lead.

- Politicians should also consider legislation. Australia plans to ban conventional light bulbs and the European Union is likely to follow. Although energy efficient bulbs achieve huge savings, governments have decided it is taking too long for them to dislodge cheaper conventional lighting.

Efficiency standards were raised sharply in the 1970s without harming growth. On the contrary, it has made economies more resilient to the surge in fuel prices in recent years and helping energy efficient technologies will further reduce dependence on energy imports. Only fear is holding us back from taking much firmer action.

Political and business leaders must do more than pay lip service to the need for greater energy efficiency. They must be bold enough to set their own countries and companies on a course that will make them models for others to follow.

June 2007

The world in 2015 – trends and drivers

Friedrich Pinnekamp

In the globally networked world of today even slight changes of influencing parameters can have a huge effect on the development of society. With the fast changing political scenery, the soaring economic development and ongoing leaps in technology, a forecast into the future is a risky undertaking. Nevertheless, as the future development of the world's energy is one of the backbones of the global society, the need for reasonable planning is obvious. Utilities need to make long term investment decisions for their power generation portfolio as well as the transmission and distribution infrastructure, providers of alternative energy solutions seek a sound decision platform and, last but not least, industrial groups and their suppliers want to know where market and technological development will lead.

A look into the future is obscured by the fact that disruptive events like pandemics, terrorist attacks and technological breakthroughs may have a significant influence on the development of the world, but they are by nature unpredictable.

Forecasts based on the extrapolation of developed or emerging trends seem to be more reliable within a reasonable time span. As those trends are driven by a few major forces, there is a chance of a meaningful prediction by analyzing these drivers.

ABB has looked at six prominent trends with strong influence on the upcoming needs of people and requirements of the industry. These trends address

- Changes in the global society
- Globalization
- Energy industry restructuring
- Primary energy concerns
- Electrical energy needs
- Environmental issues

Within the next ten years an additional 200 million people will be living in mega-cities, this urban migration being the traditional way for poor people to gain access to better economic conditions.

A rapidly changing global society

Exponential population growth, falling mortality and fertility rates, a shift in the demographic balance between young and old, chronic poverty in much of the southern hemisphere, urbanization and the growth of mega-cities, mass migration within and between countries, the rising influence of religion in some cultures and growing secularism in others, and the worldwide impact of the digital and IT revolutions – these are all factors that are driving societies and individuals towards increasingly rapid change.

With world population currently at 6.5 billion and rising by 75 million a year, changes in the structure, values and relations within and between societies are the driving force behind all other movements that shape the world we live in.

The population problem is exacerbated in the mature economies by the combination of falling birth rates and longer life expectancy. This is creating ageing populations which could, in time, lead to tension between the younger and older generations 1.

Severe poverty in the least developed countries will remain at a high level, even if the ambitious anti-poverty goals of the United Nations are achieved. The number of conflicts sparked by poverty and injustice is likely to grow, leading to increased social and political instability.

Within the next ten years an additional 200 million people will be living in mega-cities (bringing the total to 600 million by 2015), this urban migration being the traditional way for poor people to gain access to better economic conditions.

People living in urban areas or migrating to developed countries have greater access to global communications platforms like the Internet, TV, and mobile and fixed line phones.

These same technologies are aiding the dissemination of knowledge and taking education into a new dimension. While growth levels of higher education in the mature economies are flattening out, those in the rapidly developing economies are rising steeply. The number of well-trained

1 Projected development of world population

engineers in these countries is impressive. In the West, on the other hand, traditional disciplines like electrical engineering have declined resulting in severe shortage of skilled engineers.

With the gradual integration of China, India, and other developing countries into the world economy, hundreds of millions of working-age adults will join a more globally integrated labor market.

Globalization

Globalization is driven by new technologies, new economic relationships and the national and international policies of a wide range of actors, including governments, international organizations, business, the media, labor and civil society.

The impact of globalization on individual societies is multi-faceted. The mechanisms by which the flow of trade, capital, ideas and people cause economies and societies to change are highly complex.

The world economy is projected to grow by about 40 percent between 2005 and 2015, and average per capita income by 25 percent. Large parts of the world will enjoy unprecedented prosperity, and a middleclass population could be created for the first time in some formerly poor countries.

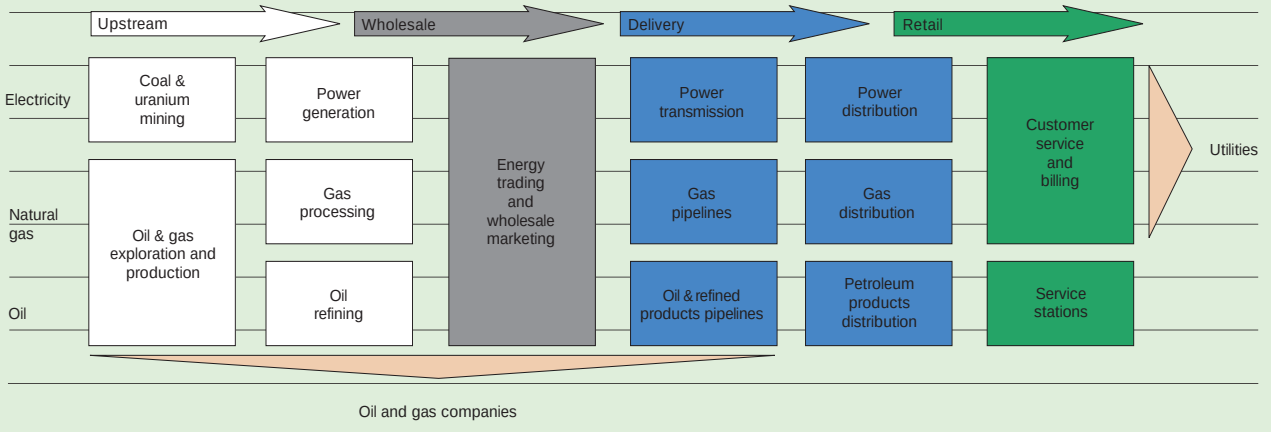
With the gradual integration of China, India, and other developing countries into the world economy, hundreds of millions of working-age adults will join a more globally integrated labor market. Existing patterns of production, trade, employment and wages will be transformed.

The greatest benefits of globalization will accrue to those countries and groups that can access and adopt new technologies. The growing two-way flow of high-tech brain power between the developing world and the West, the increasing size of the computer-literate workforce in developing countries, and efforts by global companies to diversify their high-tech operations will foster the spread of new technologies. Information and communication technology (ICT) is an important driver of globalization, facilitating the borderless exchange of ideas, opinions, and data at high speed. It enables multinational companies to work across time zones and obtain an advantage over companies based in only one location.

Continuous restructuring of the energy industry

The global energy industry is undergoing continuous restructuring. Processes like liberalization and deregulation, market consolidation, the spread of wholesale energy trading and the commoditization of electricity and gas

2 Energy industry value chain



are changing the very nature of energy trading. Large-scale investment in renewable forms of energy by oil and gas majors, the development of enabling technologies for ultra high voltage transmission and the storage of electric power, combined with political intervention by governments to stimulate or discourage trends and technologies are all influencing the energy industry across the entire value chain 2.

A key factor affecting the structure of the world energy industry is the liberalization and privatization of electricity and gas markets. However even after almost 25 years there is still no clear picture of the effects of these actions. Market liberalization is opening up a new era in wholesale electricity trading. European countries are not liberalizing at the same tempo, which means there is considerable variation in power trading arrangements, ranging from central dispatch to exchange-based models. The ultimate objective is a market in which gas and electricity are traded as commodities with flexible and innovative products and services.

Another factor that drives the restructuring of the energy industry is the need for additional investment in energy infrastructure to meet the growing demand for energy services worldwide. Investment is required to replace capacity that is being retired, expand supply where needed, and cover the cost of cleaner energy systems.

Politicians drive restructuring by using subsidies and taxes, supported by corresponding laws and regulations, to develop and encourage the use of renewable energy, increase environmental awareness and promote energy savings.

However, small-scale renewable power generation is unlikely to have a major influence on the structure of the energy industry in the medium term.

Another driving force is the lack of supply reliability that the various blackouts of 2003 revealed. The fact that energy security has many dimensions such as safe energy supply based on market economics; technological, environmental, social and cultural aspects, as well as being of military strategic importance, adds to the complexity of the restructuring process.

The future of primary energy resources

Most forecasts on future patterns of energy see a continuously rising demand for primary energy in the first two decades of this century. This can best be described as an extrapolation of past development, even though consumption is shifting significantly to emerging economies, in particular China and India.

The primary energy resources of oil, coal, natural gas, and uranium will all still be available in 2020 and beyond. The International Energy Agency (IEA) estimates that a total investment of $16 trillion will be necessary over the next three decades to meet the expected surge in demand for energy, of which 60 percent will be required for power plants and transmission and distribution networks.[1)]

The correlation between primary energy and gross domestic product has been strong in the past but is expected to lessen over time with the increasing use of energy-efficient technologies in some regions. Nevertheless, global economic growth as a whole will still proceed hand in hand with a rising demand for energy over the next 20 years.

Covering almost 38 percent of world energy consumption oil is expected to remain the dominant energy source in the next two decades, even though more than 30 percent of the resources required have yet to be discovered. Natural gas remains an important source of energy for power generation (about 30 percent). Because it produces lower CO_2 emissions, natural gas is an attractive choice for greenhouse gas mitigation.

Consumption of coal will increase in almost all countries except Western Europe. The largest increase is projected for China and India, both of which have huge deposits. These two countries will account for 72 percent of the worldwide increase in coal consumption.

Nuclear power may again become popular in the mature economies after a period of stagnation. Other primary energy resources like wind, wave, geothermal or solar energy will become part of the energy mix but are not expected to contribute significantly to global energy supply in the next 15 to 20 years. Many of the alternative technologies to fill the potential gap in energy supply are still at the development stage and might not become economically viable for some time. Energy savings, especially in the transportation sector,

Footnote

[1)] See also ABB Review 4/2004.

could significantly extend the availability of oil. Biofuels of different types will also reduce this sector's dependence on oil.

The growth in new business opportunities is compounded by uncertainty about the future of primary energy resources.

In summary, uncertainty about primary energy resources is driven by:

- Limited accessibility to energy resources for political reasons
- Limited availability of economically viable technologies for exploiting future resources
- Limited availability of alternative energy resources to replace traditional sources to a sufficient extent and at an affordable cost
- Limited use of fossil fuels to prevent impacting the environment and at affordable cost.

Changing electrical energy needs

With demand growing at a constant rate and with most of that growth taking place in developing countries, the regional differences in the way electricity is generated, distributed and used are likely to be accentuated. In the mature economies the ageing infrastructure poses a challenge. In emerging economies new installations have to be constructed and the need for technologies that protect the environment and reduce energy intensity is high on a global scale 3.

Although the energy mix for power generation is not expected to change significantly, those countries that increase the amount of renewable energy in their mix will need to address grid reliability. Transmission and distribution grids in many parts of the world are operating close to their capacity limits and although new grids are being built in the rapidly growing Asian economies, they are not being built fast enough to meet escalating demand.

The top priority for all countries will be to ensure a reliable supply of electric power with the cost of refurbishing existing grids or building new ones being a major challenge.

In China and India, this is leading to the construction of new power plants in remote locations close to primary energy sources. New transmission lines with the capacity to deliver large volumes of power are therefore required.

Many utilities see reliability as one of their most pressing concerns as the impact of poor reliability on society as a whole can be crippling. The blackouts in the United States are estimated to have incurred costs and lost revenues of more than 10 billion dollars, and are attributed to underinvestment in transmission and distribution capacity and the use of outdated technology and incorrect operating procedures.

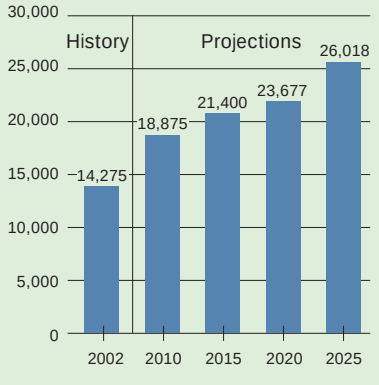
Attempts to reduce system losses are driven by environmental factors as well as the requirement for supply security. Modern transmission and distribution systems tend to lose 6–7 percent of the electricity they transport. Approximately 70 percent of those losses occur in the distribution system, which is more extensive than the transmission system and operates at a lower voltage level.

Not only utilities are keen to reduce losses. Electrical energy savings have a direct impact on the bottom line of industrial plants, commercial businesses and households. This drives the demand for energy-efficient electrical equipment like motors, drives and consumer appliances.

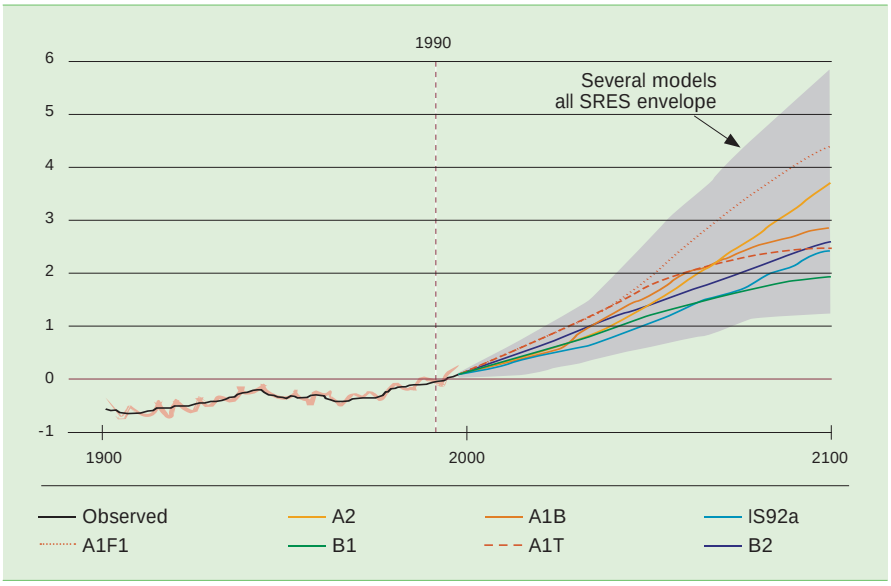
Technology development has opened new ways of managing grids. Progress in static reactive power compensation and power storage technologies enables new sources of electrical energy to be connected to existing grids. Power electronics have made it possible to control grids and new FACTS (flexible AC transmission systems) devices are improving controllability.

Technologies that save energy or improve efficiency are becoming more widespread. Low-loss and energy efficient power semiconductors are reducing losses in the grid. Continuous reductions in energy loss are being achieved by advanced motors and power-electronics-based variable speed drives.

3 World net electricity consumption in billion kilowatthours, 2002-2025. Source: IEA



4 Projected global temperature change from various models.
Source: Cambridge University Press, 2006



R&D initiatives on “smart” or “self-healing” grids that improve supply reliability are also driven by advances in information and communication technology.

The environment as a business factor

Even though the debate on the scale and impact of environmental change is ongoing, there is a consensus that the world has a set of compelling problems to solve like greenhouse gas emissions, climate change, and the depletion of natural resources 4.

The concern, perceived as most pressing in the world today, largely because of the global reach of its potential impact, is the growth in concentrations of greenhouse gases. The increasing importance of emission reducing technologies is a catalyst for new business opportunities. These opportunities lie in zero- and low emission technologies for the power generation and manufacturing industries, and in improving the energy efficiency of industrial processes and equipment by using efficient motors and applying variable speed drives.

The growth in new business opportunities is compounded by uncertainty about the future of primary energy resources. This is likely to intensify research into technologies for generating renewable energy and the use of alternative bio-fuels in the transportation industry. In recent years, the technologies used to burn fossil fuels of all kinds have improved tremendously. This applies to oil, gas and coal as well as to combustion engines in cars.

Nevertheless, the development of new technologies will most likely be driven by the tradeoff between the cost of these technologies and the various benefits they offer – tax breaks, lower emissions, reduced fuel consumption, and longer service life.

The renewed interest in building nuclear power plants may inhibit the spread of alternative forms of power generation. The tradeoff between clean energy restrictions and economic growth is, however, complicating the implementation of measures especially in the rapidly emerging countries.

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Looking back from 2015

An ABB analysis

Friedrich Pinnekamp

This study was conducted based on interviews, written statements and personal discussions with a large number of external experts, opinion leaders, politicians and members of the scientific community.

The majority of these authorities considered that a closing up of national economies is more likely than a move towards a global society. They further believed that the gap between the emerging and mature economies will continue to close, with both groups seeing some growth.

ABB is taking these indications seriously and is preparing for the various possible scenarios. Even though the uncertainty of the future direction is high, there is one overriding concern in all the scenarios – energy efficiency.

In the global and open society with virtually free access to energy for all, it is the general shortage of primary energy and shared environmental concerns that dictate the careful use of energy. If the world turns towards more protectionism, it is the lack of security in its supply that forbids excessive use of energy.

When the development of the emerging economies gathers speed again, it is once more the shortage of resources that hampers their growth. For a stagnating mature society it is simple economic reality that forces a reduction of energy consumption.

So, in the next decade, energy efficiency is the name of the game.

Assumption of growth rate measured at purchased power parity varies from five percent in the first scenario to three percent in the last.

	Open global society	Mature economies become more competitive
Economic growth	Prosperity has been taking hold of most regions over the last decade. Strong trading blocks (for example the European Union) exist, but their purpose is not protectionist – they are well integrated into a global economy.	Growth in the mature industrialized part of the world has been strong for a decade. It has been possible to maintain a balance between high standard of living and international competitiveness. Worldwide growth has not met earlier expectations, hence prosperity has not spread globally.
World characteristics	The world economy is globalized with free flow of goods, labor, technology and finance. The WTO has produced treaties to secure cross-border trade. Multinational companies prosper in this climate.	Governments of the mature countries have benefited from their export strength and secured markets beyond their own economies. Emerging economies have been more protectionist against foreign influence.
Attributes of societies	Societies have become well-integrated into the global market with their flexible labor forces. Most of the world's population has access to knowledge and electricity – both of these are foundations for prosperity.	Strong economic growth has enabled the mature economies to ease the burden of an aging population by attracting young and educated migration workers.
Energy market	Steady price rises for oil and gas have made energy efficiency a global priority. More and more alternative energy sources are becoming economical and the exploitation of previously uneconomical oil and gas finds is gradually being realised.	High energy prices underline conservation and alternative generation is having an impact. Liberalization of the energy market is ongoing. To secure energy in a world of dwindling primary resources, many bilateral agreements have been made between increasingly powerful suppliers.
Power grid	The electricity grid is being expanded all over the world to reach most of the global village. There are no signs of consolidation and power sales remain in the hands of suppliers.	The replacement of outdated infrastructure has had a positive influence on the competitiveness of mature economies. The volume of new grid installations in the developing countries has been lower than expected.
Environment	Climate change, biodiversity and the health of the environment are concerns of more people than ever. Political leaders and large companies in all economies of the world are tackling the issue of energy efficiency and global warming, a concern that has now gathered momentum.	Trading schemes for CO_2 reduction have been established in most mature economies. Fuel for transportation is increasingly being derived from oil-independent sources (which are mainly promoted in mature economies).
Technologies	The opportunity to develop modern grids has provided impetus for the introduction of new technologies such as ultra-HVDC and ultra-HVAC, current limiters, high power circuit breakers and super conductive systems. New methods for energy storage have promoted renewable generation.	The positive economic climate in the mature economies has spurred R&D investments in both the public and industrial sectors beyond expectation.

Emerging economies get stronger	Retreat into protectionism
Having failed to reform early in the new century, the mature economies struggle to keep up with the exceedingly exuberant developing nations, primarily in Asia: China, India, South Korea and to some degree the Middle East have capitalized on their increasingly educated but still cheap labor force.	Stagnation in the global economy, including recession in some parts of the world, has lasted for a decade. Global trade has slowed significantly and domestic markets have grown in importance. Western economies have been affected by the slowdown in Asia, an area that could not maintain its past growth rate. International cooperation is limited. Nations are becoming introverted and are seeking self-sufficiency.
Globalization has facilitated the full participation of emerging economies on the global market. WTO treaties were sufficiently effective to promote international trade between most regions. Multinational companies have adapted their global footprint to better make use of the strengths of the various regions.	Asia is affected by social unrest, environmental challenges and over-heated economies. The WTO has failed to provide a foundation for sustained international trade. Disappointed governments have turned to protectionism, resulting in decreasing standards of living even in the mature economies. Movement of people and labor, knowledge and technology is restricted.
As conditions in the developing nations have improved, migration of skilled labor has slowed considerably. Living standards are improving and these nations are driving global consumerism.	A large number of people in the world are still without electricity, a situation unlikely to change due to financial difficulties in these countries and the tough investment climate. Access to information remains restricted in countries with closed societies.
Energy demand has increased beyond what was planned for a decade ago. To meet this great need for primary energy, the development of energy efficiency and alternative energies including nuclear are high on the agenda everywhere. Bilateral energy agreements are sought wherever possible in an attempt to secure access to limited resources.	Global stagnation has reduced the expected energy demand compared to forecasts of 10 years ago. The need for primary energy is still acute, but with protectionism and the desire for self-sufficiency in ascendance, energy efficiency measures, alternative energy and nuclear power are prioritized. Difficulties in securing access to primary energy through long-term bilateral agreements have grown as supplying countries are closing ranks to drive up prices. The risk of war over energy is escalating.
The mature economies have only partially been able to replace their outdated electrical equipment and networks. Large investments in new infrastructure has, however, gone into the emerging economies in an attempt to redress the imbalance between supply and demand in those areas.	In response to the black-outs of ten years ago, the mature economies have squeezed existing infrastructure to its limits without major investments in the electrical grid. Many grid interconnections were planned but only a few implemented. The emerging countries have been installing new grids but not at the pace intended.
Due to environmental awareness in the emerging economies, these have succeeded in implementing the necessary regulations to control their pollution. The latest technologies are playing an important part in making this possible. The global expansion of nuclear power, promotion of renewable energy and energy efficiency measures have reduced the threat of energy shortage.	As global cooperation has crumbled, so has the worldwide initiative related to climate change issues and CO_2 trading. National initiatives driven more by local priorities for clean air than any global concerns have taken their place. Alternative fuels are slowly entering the markets of the mature economies.
The insatiable energy demand of the emerging economies has led to the installation of cutting-edge technologies for high productivity generation and transmission of electricity. Combined with the latest energy efficiency applications in new factories, this has resulted in these young economies gaining further advantages over their more mature competitors.	Only few new technologies for generation, transmission and energy savings have been introduced in the energy sector.

Clean power from the sea

Large wind parks at sea replace new power stations on shore

Eskil Sörensen, Finn Nielsen

About one fifth of the electricity demand in Denmark is covered by wind power, which makes Denmark the leading wind power nation in the world. For many years, new windfarms were located on land, but today more and more of them are located at sea. Two large offshore wind parks, whose output can be compared to medium-sized power stations, now deliver almost four percent of Denmark's electricity demand or 25 percent of its wind power generation. ABB is an important supplier to these parks – providing transmission equipment, generators and low- and medium-voltage products and SCADA[1)] systems.

Wind is in the eye of the storm over global warming and it is becoming increasingly relevant in the fight against CO_2 emissions. Denmark is a leading producer of wind turbines for electricity generation and two of the world's leading companies are based there – Siemens Wind Power (previously named Bonus Energy) and Vestas Wind A/S, the largest wind turbine producer in the world. This has created a knowledge base that other producers are eager to tap into; hence they are locating research units in Denmark. A network of sub suppliers to the wind turbine producers has emerged in the same area. This concentration of know-how and manufacturing skills is essential for the development of wind turbines into larger and larger units: Wind turbines now exist with wingspans of 60 meters and towers reaching a height of close to 120 meters. Parallel to this development is an increasing academic interest, which is reflected in the education and training of expertise at the surrounding universities and wind institutions such as Risö research center.

History of wind

ABB in Denmark is also a member of this knowledge-environment, and has over the last 25 years developed a substantial expertise in the area of power generation from wind. ABB's cables and transformers, generators and motors are but a selection of the products it delivers to the wind turbine manufacturers. Hence, when the Danish-based manufacturers export large wind parks to California or Spain, an important portion of the equipment often comes from ABB. As a matter of fact, wind contributes a large part to ABB Denmark's revenue.

Denmark is a leading producer of wind turbines for electricity generation and two of the world's leading companies are based there.

Just a few years ago, 50 percent of the world's wind turbines came from Danish companies. However, today several other producers have entered the market such as General Electric from America and Suzlon from India. Wind power has become a global business with significant competition; Danish producers control 30 percent of the market. With an annual expansion of around 20 percent during the last few years, this market share is equivalent to a substantial growth in the local Danish wind industry. As a matter of fact, this sector is the Danish industry segment seeing the greatest boom, having grown from $ 500,000 10 years ago to today's figure of $ 4 billion (according to the Danish Wind Energy Association). This implies that the Danish wind industry is constantly in need of new employees. Today 21,000 people are employed by the industry in Denmark and it is getting difficult to find the necessary talents.

The Danish wind adventure commenced during the oil crises of the 70s. At first, small wind turbines were built, often by the local blacksmith. By the 80s the development had become more professional and industrially-produced wind turbines marked their breakthrough with the introduction of 55 kW units. Since these early days, several new generations have been developed and today's turbines are 50 times more powerful. The market offers 2 MW and even 3 MW turbines. The biggest commercially available unit today is 3.6 MW, but larger turbines are already in the pipeline.

Wind turbines at sea

There are good reasons why the energy industry is prepared to face the difficulties of building wind parks offshore. As the wing span and the height of the wind turbine have grown, it has become more and more difficult to find acceptable locations to erect these towers, especially in densely populated countries such as Denmark. There is a limit to how many wind turbines people are willing to accept in their landscape.

Footnote

[1] SCADA: Supervisory Control and Data Acquisition, a large-scale distributed monitoring and control system

1 The Nysted wind park consists of 72 wind turbines, each with a max capacity of 2.3 MW

The second reason for moving off-shore is related to the fact that the wind is somewhat stronger over the sea, which results in higher electricity production – in the best case as much as 50 percent more.

Countering these benefits is the higher cost associated with wind parks at sea such as constructing the foundation for the tower. The higher salt concentration requires corrosion resistant components. The tall towers are carefully treated with special paint. The machinery is often placed indoors where the humidity can be kept at a level of less than 50 percent. Maintenance cost is also higher since crews have to be flown back and forth with helicopters. The energy utilities are justifying these additional costs for offshore based wind farms by the increased electricity generation.

In Denmark, installed wind turbines produce an aggregated 3100 MW of power, which is equivalent to five large power plants, hence save the equivalent of four million tons of CO_2 annually.

Nysted off-shore wind farm

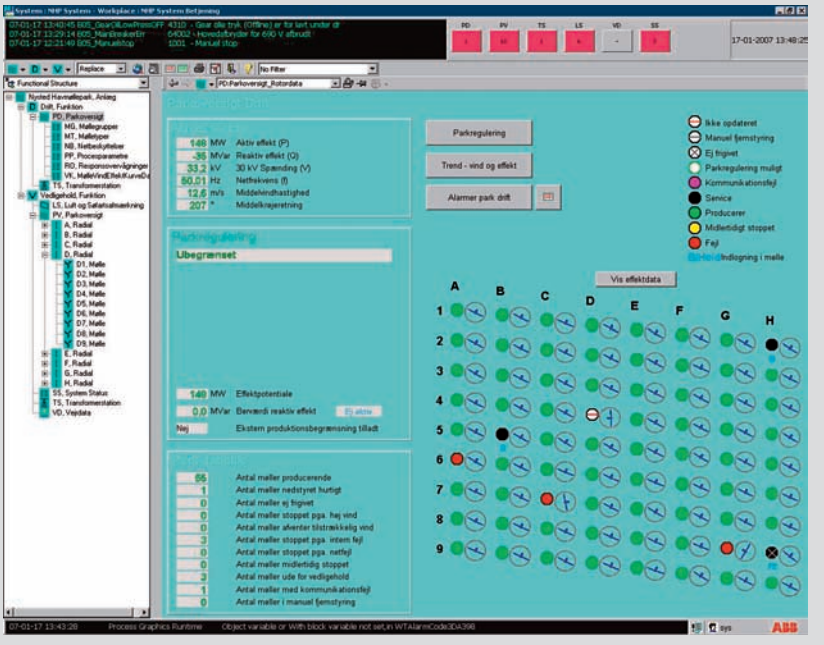
Based on a decision by the Danish Parliament (Folketinget), two large off-shore power parks were constructed as early as 2002 and 2003. Together these parks can meet almost four percent of Denmark's electricity demand. ABB was a supplier of essential equipment to both these installations. The Nysted sea-based wind park for power generation was commissioned in 2003. At that time it was the largest off-shore wind farm in the world 1. The 72 wind turbines produce a maximum power of 165.6 MW; the equivalent of a medium-sized power plant. Each turbine delivers its power to the aggregating center 2 by a 33 kV cable. Here the power is transformed to network voltage levels and delivered to shore by a 132 kV cable. This park can satisfy the power demand of 150,000 households.

The atmosphere is relieved of 500,000 tons of CO_2 annually, equivalent to one percent of Denmark's total CO_2 emissions. This is a significant contribution to the reduction of greenhouse gases. In Denmark, installed wind turbines produce an aggregated 3100 MW of power, which is equivalent to five large power plants, hence save the equivalent of four million tons of CO_2 annually. The Nysted offshore wind park was designed to produce 500,000 MWh annually. This goal has been more than met.

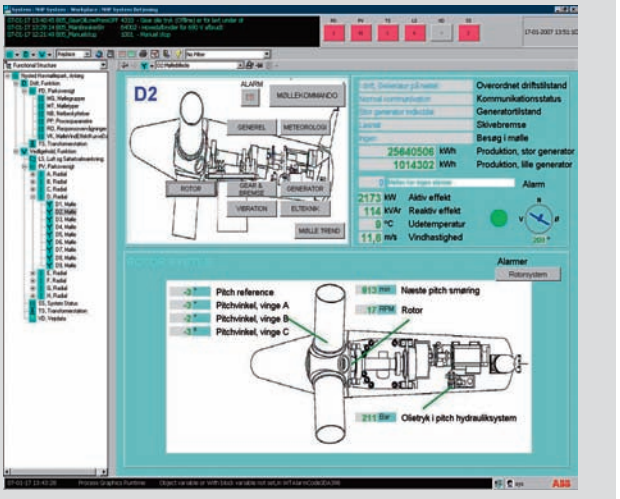
More off-shore wind power is in preparation. The Danish government has recently announced permission to build two new wind parks off-shore. These will be commissioned in 2009

2 Transformer unit for the aggregation of the 72 wind turbines of the park

3 The operators' overview of status information for all 72 wind turbines



4 “Drilling down” to the status details of an individual wind turbine



and 2010. DONG Energy A/S has been appointed to build the park located at Horns Rev and a consortium of DONG Energy A/S and E.ON Sweden AB are the winners for the construction of the park at Rödsand. ABB has already been awarded an order and several more are under way.

Off-shore wind park as power station

A network of 72 towers, such as Nysted offshore wind farm, requires a SCADA system for control and monitoring. The system supplied was based on ABB’s System 800xA with built-in redundancy. The result was a very stable system with high availability. In addition, ABB delivered all 72 transformers and generators and 45 kilometres of 33 kV sea cables to the turbines, which are located 10 to 14 km from land. Also the on-shore cable link, which transports the power to the electricity network, was delivered and commissioned by ABB.

Factbox Nysted offshore wind farm

- 72 wind turbines, each 2.3 MW
- Combined maximum effect: 165.6 MW
- Electricity production: approx. 500,000 MWh, equivalent to the consumption of 150,000 households
- Wind turbines are produced by Bonus Energy, today Siemens Wind Power
- The towers are 69 meters high; the wings are 40 meters long
- The Wind farm was put into operation during 2003
- Owners of the wind farm are: DONG Energy A/S and E.ON Sweden AB

Denmark, with its high percent wind based generation, has already seen situations where the wind power based energy supply has exceeded the electricity demand.

The SCADA system can be used to control the aggregated power generation of the wind turbines just as such a system would control a power plant. Wind turbines obviously generate electricity in relation to how the wind blows; however, the total power can be controlled. If the electrical network calls for 100 MW to be delivered by the park, the SCADA system can regulate the production to match this demand. The operator can easily enter the required production from the park and the SCADA system figures out how many wind turbines have to be taken out of operation (or added) to balance the demand and supply. The current status of the 72 turbines can be shown to the operator as depicted in 3. From this overview, the operator can “drill down” into individual turbines for detailed status information 4. Wind power has permitted the electrical network to reduce the use of conventional power stations. As the availability of wind power increases, situations will increasingly occur where production of clean energy will have to be throttled to avoid overloading the network. As a matter of fact Denmark, with its high percent wind based generation, has already seen situations where the wind power based energy supply has exceeded the electricity demand. Other nations will of course experience similar issues as their power production shifts to variable and unpredicatble sources such as wind and sun.

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