

## Power generation fuel trends past, present and future

The massive increase in power demand, forecast to double to 30,364TWh a year by 2030, poses a huge challenge in terms of constructing new power plants, transmission and distribution facilities. Developing the fuel and energy resources to generate the large increase in electricity supply also presents many challenges, as countries try to change their energy strategies to ensure that development of sustainable power supplies can continue in the future.

**Below:** One of the 30 2MW wind turbines at the North Hoyle offshore wind farm in the UK, 4-5 miles off the coast of north Wales, between Rhyl and Prestatyn.

The mix of primary fuels used for power generation has changed markedly during the past two decades as electricity consumption has surged in many parts of the world. The reasons for the changes in the fuel mix are various. While fuel price has been a major factor, government policies also affect choice, as do growing international efforts to reduce global warming and encourage sustainable energy development. This has promoted new fuel choices that previously attracted little attention.

During the past two decades, high international oil prices have encouraged a shift from oil-fired generation to nuclear power and natural gas, at the same time reinforcing coal's importance. Recent record oil price levels combined with growing concern about environmental damage from greenhouse gas emissions have caused renewed interest in nuclear power and renewable energy as alternatives to coal and natural gas for electric power generation.

According to statistics published by the International Energy Agency (IEA), coal is the largest single primary fuel source used for power generation. In 2005, coal-fired generation accounted for 40.3% of the world's total 18,235TWh electricity output (not including electricity produced by pumped storage schemes), slightly more than double the share of the second largest fuel source for power generation, which was natural gas (representing a one fifth fuel share).

Hydroelectric power was

the third largest source, accounting for one sixth of all electricity generated worldwide in 2005, followed very closely by nuclear power. Oil is the other significant fuel source with plants generating more than 10% of all electricity produced in 2005. The balance was generated by geothermal plants and renewable fuels including solar, wind, combustible renewables and waste.

Although the importance of other fuels has changed over the years, the share of coal in the global electricity generation fuel mix remains largely the same as in the early 1970s. In 1973, just as the first oil crisis occurred, coal-fired power stations accounted for 38.3% of global electricity generation totalling 6116TWh. While coal's share of power generation has remained broadly stable over the past 35 years, the share of other generation fuels has changed, with nuclear power and natural gas increasing and oil-fired and hydroelectric power declining.

The nuclear power share of global electricity generation rose almost five-fold from 3.3% in 1973 to 15.2% in 2005. The natural gas share increased about two-thirds from 12.1% to 19.7%; and generation by geothermal power stations, those using renewable energy and other fuels sources grew from 0.6% to 2.2%.

Oil-fired generation has experienced the largest decline as a source of power. In 1973, oil-fired power stations produced 24.7% of global power, but by 2005 the share had dropped to just 6.6% of total output. This is followed by hydroelectric power, which has declined from 21% to 16% of global power output in 2005.

According to a report by the US government's Energy Information Administration, global electricity generation is expected to increase 2.4% annually from 16,424TWh in 2004 to 30,364TWh in 2030. A large share of this additional generation will occur in non-OECD countries, the report forecasts, as emerging nations' electricity demand grows at 3.5% annually. This compares with 1.3% in countries with more mature economies. Non-OECD countries produced 26% less electricity than OECD nations in 2004, but by 2030 non-OECD electricity generation is projected to exceed OECD electricity output by 30%.

The forecast assumes that the populations of OECD



Image supplied by npower renewables.



nations will grow slowly or even decline in the decades up to 2030, while their already well-developed electricity systems will require less additional capacity to cope with future electricity demand growth. However, non-OECD nations are expected to experience faster power demand growth as their expected higher rate of economic development will result in higher living standards and a corresponding rise in the use of electrical home appliances and further office automation. Forecasts suggest that commercial buildings will increase demand for electricity more than residential buildings worldwide, including office buildings, hospitals, hotels, schools, government buildings and other institutions.

### Meeting demand

Meeting future electricity demand growth will require huge investment in new power stations along with transmission and distribution networks. According to IEA forecasts, some 4800GW of new power station capacity will be needed in the period up to 2030 to meet projected demand and to replace ageing infrastructure. OECD countries are expected to require almost 2000GW of new generating capacity as more than one third of the current installed capacity in OECD countries is likely to be retired over the next 25 years. The remaining 2800GW of new generating capacity will be needed by non-OECD nations.

The cost of this investment will be huge and is estimated at a combined US\$9 trillion for OECD and non-OECD countries. OECD members will need to invest more than US\$2 trillion in building new power stations and a further US\$1.8 trillion in new transmission and distribution networks. Funding is essential to meet these targets. Energy market reform in many OECD countries is helping establish an industry structure capable of attracting the necessary funds and building new infrastructure efficiently.

Challenges remain though, including the installation of sufficient reserve generating capacity to prevent blackouts, such as those which affected the US in 2003

and 2004. Developing countries are expected to require US\$5.2 trillion of investment to build power stations, transmission and distribution networks to meet demand. Many developing countries are faced with the prospect of increasing investment in power well above current levels if they are to meet targets for economic growth and social development. In many cases, electricity sector reform will be needed to attract the private sector investment essential to future development and to establish an electricity industry structure that assists efficient operation and management.

### Coal

Coal is expected to remain the single most important power generation fuel for the next 25 years and beyond, due to its continuing price competitiveness and the large coal reserves that remain in many parts of the world. EIA forecasts that coal-fired generation worldwide will increase by 2.8% annually up to 2030, when coal-burning power stations will produce 45% of total world electricity output, up from 2004's 41%. Sustained high oil and gas prices will, among other factors, make coal-fired generation more economically attractive, particularly in countries with large coal reserves that include China, India and the US. The projected growth in coal's market share is second only to natural gas, which is expected to rise by 3.3% annually to 2030.

Coal's share of power generation will be highest in China, India and the US, and will remain so in the future. Currently, 75% of all electricity generated in China is produced by coal-burning stations, while in India about 60% of electricity output is from coal-fired plants. Electricity produced by coal-fired stations in the US and Canada represents about 46% of North America's total electricity generation. Elsewhere, about 47% of all electricity generated in Africa is from coal-fired stations, though coal use is restricted to a small number of coal-producing nations, particularly South Africa. In Europe, coal represents around 29% of power generation among European OECD member countries and 28%

**Above:** Cowes power station, a 140MW open cycle gas turbine power plant capable of achieving full load in five minutes.



**Above:** Shushenskaya hydroelectric dam in Russia. Hydroelectric power's global energy contribution is expected to fall to about 12% over the next 25 years.

**Below:** Mile Island nuclear power plant in the US.



of total power generation in East Asia (Japan, South Korea and Taiwan). Russia is another important coal burner with coal-fired stations representing around 19% of electricity output.

Most countries and regions reliant on coal will require a larger amount of coal-fired generation in future. The share of coal-fired generation in East Asia, for example, is forecast to grow by more than half by 2030, when it will generate about

49% of electricity consumed in Japan, South Korea and Taiwan. However, while coal-fired generation will grow worldwide, it is expected to show a small decline as a proportion of total electricity output due to the forecasted increase in natural gas-fired generation. In North America, coal's share of generation will fall by about 6% to account for 40% of total power generation in 2030, according to IEA forecasts, while the coal share of generation among OECD countries in Europe is likely to drop about 5% to 24%. In China, the development of natural gas-fired generation and other fuels is expected to push the share of coal-burning stations' output down 5% to 72%, while in India coal-fired generation as a proportion of total generation will ease about 6% points to 54%. The fall in coal-fired generation share of electricity will be largest in Africa, where an 18% drop is expected, leaving coal-burning stations with a 29% share of electricity supplies in 2030.

The growth in coal-fired generation is due to be accompanied by greater use of environmental protection equipment at coal-burning stations to remove NOx and SOx. Installation of scrubbers and other facilities to remove emissions will depend on governments and power company budgets. Less developed countries are likely to permit the use of less effective equipment or set looser pollution emission control standards, as at present, due to government decisions to balance the need for new generation capacity with provisions to control pollution emission. But, carbon dioxide emissions will grow as coal-fired generation increases. IEA

forecasts that carbon-dioxide emissions from power plants in developing countries will treble over the next 25 years. In 2030, coal-burning plants in developing countries will produce more carbon dioxide than the entire OECD electricity industry.

**Natural gas**

International concern to reduce pollution emission from power generation has been one of the major factors supporting the development of natural gas for

power generation during the past two decades. The development of combined cycle gas-fired power plants has further promoted the use of gas as a generation fuel due to combined cycle stations' fuel efficiency and operating flexibility, which allows for fast start up times compared with coal-fired and some other stations. Other benefits from combined cycle stations are lower investment costs and shorter construction times.

Gas-fired generation as a share of total generation rose from 12.1% in 1973 to 19.7% in 2005, while the amount of electricity generated worldwide grew threefold during the same 32 year period. Gas-fired generation is expected to more than double from 3592TWh in 2005 to 7423TWh in 2030, though electricity output from gas-fired stations will still be half that of coal-burning stations.

Since the 1980s, a number of countries have become heavily reliant on gas-fired generation, often because natural gas is their most plentiful indigenous fuel resource. Pakistan, Bangladesh, Thailand, and Malaysia are among those where gas is the major power generation fuel accounting for more than 70% of electricity generation. Gas-fired generation is also well developed in the Middle East, particularly among Arabian Gulf state, where it is expected to grow quickly in future both to produce electricity for distribution as well as for water desalination plants.

Few countries are as reliant on nuclear power as natural gas for the major share of their electricity supplies. France, which has few indigenous fuel resources, relies on nuclear power for 79% of total domestic electricity generation while the Ukraine obtains 48% of electricity supplies from nuclear stations, Sweden 46% and South Korea 38%. The US is the world's largest generator of nuclear energy producing 29.2% of the total global 2768TWh nuclear power output in 2005 followed by France which generated 16.3% and Japan 11%.

**Nuclear**

The nuclear share of total world generation grew quickly in the 1970s and 1980s, though there has been little expansion in nuclear generating capacity in the past decade. Nuclear energy represented 3.3% of global generation in 1973. In 2005 the proportion stood at 15.2%. Prospects for further development of nuclear energy have improved in recent years, as governments seek to develop clean energy strategies to comply with the Kyoto Protocol commitments. With renewable energy being costly and slow to develop due to the small size of individual power plants, nuclear energy could provide part of the solution for environmentally friendly generation.

High capacity utilisation rates are being reported for many existing nuclear power plants and most existing nuclear stations in OECD countries, as well as non-OECD Europe and Russia, are expected to receive extensions to their operating lives. The Energy Information Administration is forecasting a 1.3% annual increase in generation from nuclear facilities over the next 25 years with nuclear generation expected to reach 3619TWh in 2030, up 34.5% from 2005. The geographi-

cal growth of nuclear energy remains to be seen and will depend on how issues relating to plant safety and radioactive waste disposal influence public opinion in different countries.

China and India are expected to take a lead in nuclear power development as part of their efforts to meet fast growing energy needs. China, for example, is forecasting a 7.7% annual increase in nuclear generation until 2030, while India is planning an even higher 9.1% annual growth. Only OECD Europe is expected to see an overall decline in nuclear generation in future due mainly to some countries such as Belgium and Germany planning to phase out nuclear power entirely.

### Renewable energy

Meanwhile, renewable electricity generation, including hydroelectric power, is forecasted to show the next highest growth rate after coal-fired and gas-fired generation in the years up to 2030. The US Energy Information Administration projects electricity generation from hydropower and renewable energy resources will increase at an average annual rate of 1.7% from 2004 to 2030. High oil and natural gas prices that are likely to persist in the mid-term will encourage greater development of these sources of power, which has the added attraction of being clean. Government policies and incentives in many OECD countries are also encouraging the development of renewable energy even when it cannot compete economically with fossil fuels.

Lowering renewable energy costs is an issue for many countries. In a bid to lower the cost of renewable energy and other energy resources including biofuels, the European Union is preparing to launch a study looking into energy co-operation with non-EU neighbouring countries in North Africa, the Middle East and some former Soviet republics. Plans include the import of low cost renewable energy including solar and wind power that neighbouring non-EU countries could produce more cheaply.

Although electricity generation from renewable energy and hydropower will increase, the renewable en-


ergy share of generation is expected to fall over the next 25 years, due largely to the declining share of hydroelectric power. The hydroelectric share is expected to fall to about 12% over the next 25 years. High cost, lengthy construction and growing social and environmental difficulties associated with large dam construction schemes are some of the factors limiting the future growth potential of hydropower.

The share of hydroelectricity in total global power generation declined from 21% in 1973 to 16% in 2005, while non-hydro renewables increased their share from 0.6% to 2.2% during the same period. World production of hydropower reached 2994TWh in 2005. China is the largest hydropower generator accounting for 13.3% of global generation followed by Canada 12.1%; Brazil, 11.3%; the US, 9.7%; and Russia, 5.8%.

Although China is the largest generator of hydroelectricity, hydropower represents 15.9% of China's total generation while Norway relies on hydropower for 98.9% of its electricity supply. Other countries heavily dependent on hydropower are Brazil where hydroelectricity is 83.7% of total generation; Venezuela, 73.9%; Canada, 57.9%; and Sweden, 46%.

### Oil

Meanwhile, with oil prices expected to be about US\$59/bbl (in real 2005 dollars) at the end of 2030, the expected rate of increase in oil-fired power generation will be the slowest among all energy sources. The share of oil-fired generation has been in decline since the 1973 oil crisis when oil-fired power plants generated 24.7% of global electricity supplies.

In 2005, oil-fired power plants produced 6.6% of worldwide electricity supplies. IEA forecasts that oil fired generation will grow by 0.9% annually over the next 25 years. In fact, oil-fired generation is expected to increase only in the oil-rich Middle East, which already relies on oil-fired generation for one-third of total electricity supplies. In OECD Europe, oil-fired generation is expected to decline by 0.3% annually, with use reserved mainly for peak load generation and for back-up supply. 

Below: Causeymire Wind Farm, UK. Image supplied by npower renewables.

