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ELECTRICITY IN THE UK

Electricity generation accounts for around 30% of UK carbon dioxide (CO_2) emissions. In the next decade, many coal and nuclear plants will close, leaving the UK increasingly dependent on imported gas. Government sets out two priorities in its Energy Review[1]: security of energy supply and emissions reductions. This POSTnote discusses challenges facing electricity networks in the light of these priorities, such as connecting renewable generators in remote areas, and incorporating small-scale generation. It discusses barriers to progress, and policy options such as planning reform and incentives.

Background

The electricity supply industry has three components[2]:

- **Generation** is dominated by large power stations (Box 1). A typical large station has a maximum electrical power output in the range 0.1 to 4 'GigaWatts' (GW). 1GW is enough to power ten million 100W lightbulbs.
- The **transmission** network or **Grid** transmits electricity across the UK from power stations, via ~25,000 km of 'high-voltage' overhead lines (Fig 1). High-voltage transmission minimises energy loss over distance.
- Regional **distribution networks**: Over 800,000 km of overhead lines and underground cables deliver lower voltage power (132kV and below) from Grid 'supply points' to consumers. There is potential for 'distributed generation' where small-scale generators feed power directly into the distribution networks (p 4).

Much of the Grid was built in the 1950-60s, when it was deemed efficient to build large coal-fired plants, mainly close to mines, and transmit electricity to where it was needed. Consequently, the Grid is heavily reinforced in former coal-mining regions. By contrast, there are no high voltage transmission lines in many areas suitable for renewable electricity generation (like North West Scotland where wind speeds are high, or Mid-Wales). The net flow of electricity is from North to South. There are bottlenecks limiting the total power that can be transmitted. For example, flow from Scotland to England is limited to 2.2GW. The Grid is linked to France and Northern Ireland via high-voltage undersea cables.

Box 1. Trends in electricity generation

In 2006, most of the UK's electricity was generated by gas, coal and nuclear stations. Thirty large (>1GW) power stations meet the majority of electricity demand , which is ~40GW at a typical point in time and ~60GW at peak. The contribution from coal and nuclear plants will fall as stations close, leaving a 'gap' of ~15GW by 2015.[3] This will be filled in the short-term by new gas and wind generation. In 2006:

- **Gas** provided 39% of electricity. This figure has grown from 1% in 1990 and is predicted to grow further. Gas is also used to heat approximately 70% of homes.
- **Coal-fired** stations provided one-third of the UK's electricity, down from two-thirds in 1990. Around one-third of existing stations will close by 2015 to comply with European law restricting emissions of sulphur dioxide.
- **Nuclear** stations provided a fifth of electricity; but, most existing UK nuclear plants are due to close in the next decade.
- **Renewable energy** provides a small (4.2%) but growing proportion of electricity. There is also growing interest in Combined Heat and Power (CHP), which involves, for example, making use of the heat which arises as a by-product of electricity generation.

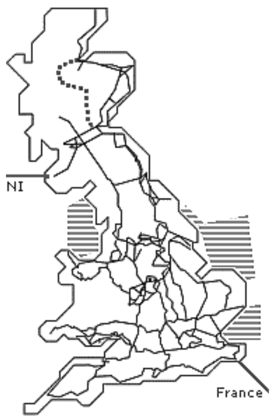


Fig 1. High-voltage Network

The figure shows high-voltage network (lines of 275 kilovolts (kV) or above where one kV=1000 Volts). The dotted line is a proposed upgrade, between Beauly and Denny in Scotland. Interconnectors with France (2GW) and Northern Ireland [NI] (0.5GW) are shown. Three offshore development zones (striped) are marked. The extensive distribution networks (comprising 0.8 million kilometres of overhead lines and underground cables) are not shown.

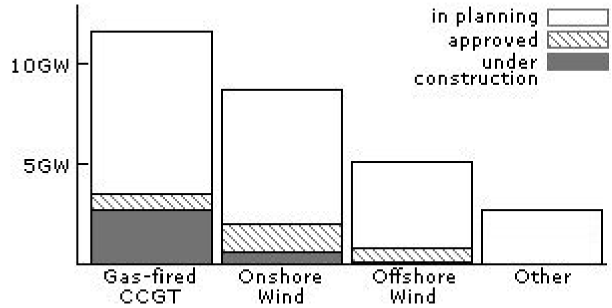
Industry Organisation

The British (GB) electricity industry was privatised in 1990. There are numerous stakeholders: generators, suppliers, network companies, and a System Operator, all overseen by the regulator Ofgem (Box 2).[4]

Box 2. GB electricity industry: main stakeholders
1. **Ofgem** regulates the gas and electricity markets in GB.
2. **Generators** own and operate large power stations.
3. **Suppliers** purchase electricity from generators and sell to business/domestic customers. Under British Electricity Trading and Transmission Arrangements (BETTA) suppliers may purchase from anywhere in Britain.
4. **Network Companies** maintain, operate, and reinforce the electricity networks. They are:
- **Transmission Network Owners (TNOs)**. National Grid is the TNO in England & Wales; Scottish Power (SP) and Scottish and Southern (SS) are TNOs in Scotland.
- **Distribution Network Operators (DNOs)**. The fourteen regions in GB are managed by seven companies (EDF Energy; Central Networks; CE Electric; Western Power Distribution; United Utilities; SP; and SS).

5. National Grid (NG) acts as **System Operator**, responsible for balancing electricity supply with demand (POSTnote 203). Over times scales of up to a few hours, NG use fast-response services like the hydro-electric facility at Dinorwig to do this. For long term fluctuations (such as increased demand during cold winters) 'back up' generation is needed.

Box 3. Proposed New Generation
- In the next **five years**, new generation will mostly be gas-fired plants and wind, with some CHP (Box 1), coal gasification, waste incineration, biomass and hydro-electric power.



- In the next **fifteen years**, companies like E.On, EDF, and British Energy would like to build large new coal or nuclear stations. Other companies suggest marine renewables (wind, wave, tidal) and gas fired CHP as alternatives. In 2006, E.On applied to build the first UK coal plant in 20 years.

Network Costs and Revenues
Network companies raise revenue by levying three broad types of *network charges* on generators and suppliers:
- *Use of System charges*. To pay for network reinforcement, maintenance and renewal, paid by generators and suppliers, broadly in proportion to their use of the network. Charges are highest for generators in remote regions, far from demand.
- *Connection charges*. To cover costs of infrastructure required for new connections, paid by generators and customers wishing to connect.
- *Balancing charges*. To meet costs of matching supply with demand, and providing reserve generation, paid by large generators and suppliers.

Ultimately, charges are passed to electricity consumers. Transmission and distribution costs make up around 4% and 17% of the average domestic bill, respectively. The Network Companies are regulated monopolies. To prevent overcharging, Ofgem sets caps on revenues every five years, through 'Price Control Reviews'. Reviews of transmission and distribution were recently completed.

Issues
Networks face two key challenges. First is **renewal**: much of the Grid infrastructure, built in the 1950s and 60s, is nearing the end of its design life. Second is **reconfiguration**: adapting the existing network to incorporate low-carbon generation, for several reasons:
- High gas prices mean household electricity bills have risen by 45% since 2003;
- Under EU Emissions Trading companies can benefit financially from reducing their CO_2 emissions;
- Government has set targets to reduce emissions, such as 10% of UK electricity from renewable energy by 2010; a 60% reduction in CO_2 emissions by 2050.

In recent Price Control Reviews Ofgem approved capital expenditure of up to £3.7 billion on transmission, and up to £5.7 billion on the distribution networks, for their next five year periods. This represents an increase of 126% and 48%, respectively, on the previous five-year periods.

Transmission Issues
Planning Reform
The next two decades are likely to see more investment in Grid infrastructure than the previous two, because of new power stations and network upgrades (Box 3,4). The last major addition to the Grid (a 96 km line in Yorkshire, completed in 2003) was referred to two public inquiries. It took nine years to gain planning consent. Construction of overhead lines above 20kV requires ministerial consent and a public inquiry is often held. The proposed upgrade to the Beauly-Denny line (Fig 1) went to inquiry in 2006. This runs 220 km through the Scottish Highlands and the plans have drawn much opposition. Any delays will impede progress towards renewable energy targets: until the line is complete, the Grid in Northern Scotland will not have the 'capacity' to transmit power from all proposed new plants (see below).

Government is concerned by the length of inquiries for large energy projects (3 years on average). It will address this in the 2007 Energy White Paper. The Energy Review proposes changes to inquiries:
- pre-hearings to define/restrict scope of inquiries;
- inquiry timetables, with deadlines set by Ministers;
- concurrent sessions held by a number of Inspectors;
- joint inquiries, which consider generation and Grid works as part of the same project.

The Barker Review of land use planningrecommends that Government sets out Strategic Objectives, but suggests that decisions on individual applications should be taken independent national Planning Commission, to ease the workload of ministerial departments.[5]

Renewable Generators and Transmission
Connection dates and planning permission
Over 150 Scottish generation projects (mainly wind) have been proposed. A long queue of connection requests (Box 4) has arisen. National Grid awarded connection dates on a first-come, first-served basis. Some projects have early connection dates, but no planning consent. Others

have planning consent but cannot obtain a timely connection. An extreme example is the Drummuir wind project, which is consented but is not guaranteed a connection until 2015. Of the consented projects, around one quarter are unable to connect before 2010, by which time their five-year planning permission will have lapsed.

Box 4. New connections to the Grid

To obtain a connection from a new power plant to the Grid:

- An application is made to National Grid (NG). Planning consent for the plant itself is not required at this stage;
- NG respond (within three months) with an offer outlining terms of connection, charges, and the **connection date**. Then, the relevant TNO applies for planning consent for the Grid works.

An accumulation of connection requests can 'trigger' deeper Grid reinforcements, to increase capacity at bottlenecks. By waiting for requests, NG can show planning authorities that new lines are needed. It also avoids paying for uneconomic lines. However, this approach leads to long delays in cases where 'strategic works' are needed. Recognising this, Ofgem recently approved £560m for 'Transmission Investment for Renewable Generation', including:

- £330m to upgrade the 'Beauly-Denny' line in Scotland to 400kV.
- £168m to upgrade the twin England-Scotland lines.

Further upgrades, such as a connection to the Western Isles, are under consideration. Some suggest that Ofgem should identify "strategic works" at an earlier stage, to stimulate renewable deployment and avoid long delays.

Reform of Connection Terms

Many small renewable developers are dissatisfied with the connection terms offered by National Grid (NG). For example, NG requires financial guarantees from new generators to underwrite the costs of Grid upgrades. At present, Grid costs are calculated on a project-by-project basis. Where a project 'triggers' a large Grid upgrade (Box 4), it faces a big liability. While small projects can join together to share this burden, in the worst case, a single developer faces the entire liability ("final sum") if the others drop out. To improve the situation, NG has proposed a simpler alternative, where liability is based only on project size and geographical region.

Variability and Intermittency

All generators are 'intermittent' to some extent due to shutdowns for maintenance, or breakdowns. But some renewable energy sources are also 'variable'. For example, the output of a wind turbine depends on wind speed. Variable sources add to the cost of balancing supply with demand (Box 1). Opinions differ over how much electricity should come from variable sources and what the additional costs would be. For example a UK Energy Research Council report concluded that, if the amount of wind power in the UK rose to ~20% (from the existing figure of 2%) the extra costs of balancing and of 'back up' generation would add ~2% to domestic bills.[6] Some say this is small compared with rises in gas prices. Others say an assessment of the extra costs should consider many factors, such as engineering constraints, not just backup generation.

Offshore Connections

Government hopes that large offshore wind (and, later, wave) projects will help meet renewables targets. The Crown Estate has allocated three areas of seabed (Fig. 1). Four 'Round 1'" wind projects are in operation; over 7GW of larger 'Round 2' projects (further offshore) are proposed. In 2006, the first of these plants were granted planning consent. Ofgem and the DTI are consulting on licensing options for transmission for Round 2 projects.[7] A decision will not be taken until 2008, meaning a delay in construction until 2011 for most Round 2 projects.

Managing Grid Capacity

Generators awarded "guaranteed access rights" from National Grid (NG) receive compensation if their connection is lost or if NG disconnects them. The Energy Review says that up to 2GW of renewable generation could be advanced by 2-3 years, if the conditions under which "guaranteed access rights" were awarded, could be modified. Although this might be technically possible, NG says the transmission system is already "full" and could accommodate the additional renewable generation only by reducing output from power stations already connected. Those stations would then need to be compensated, ultimately raising costs to the consumer.

Future nuclear stations

New or replacement nuclear plants would require extra Grid infrastructure. NG estimate that replacing the fleet at existing sites would require Grid investment of £850m to £1400m. Estimates depend on siting decisions, and the size of new plants. British Energy suggest the first new plant could be constructed by 2017.

Interconnection with Europe

In the EU there is a desire to increase interconnection: the capacity of member states to import/export electricity. An EU Green Paper suggests a target of 10% of installed production capacity. This figure is currently 3% (2.5 GW) for the UK. NG is working towards connections with the Netherlands; discussions are underway about an Ireland – Wales interconnector. Irish company Airtricity proposes an offshore North Sea grid, to connect the UK, Germany and Holland with giant offshore wind projects.

Distribution Network Issues

Whereas large plants connect directly to the Grid, smaller plants can connect directly to the distribution network. This is called **Distributed Generation** (DG) and describes over 12 GW UK generation including:

- Medium-scale (~100MW) gas-fired generation;
- Industrial scale CHP)schemes;
- Wind and small-scale hydro power;
- Landfill, biomass and waste incineration generation.

Though over half of all DG uses fossil-fuels, there has been a rapid growth in electricity from wind (1.1GW of all DG) from biomass (0.4GW) and from waste (1.3GW). More small low-carbon generators could bring benefits such as emissions reductions and greater competition. However some generators face problems obtaining a connection, and a "fair reward" for their electricity (Box 5).

Box 5 Barriers to small-scale generators

In April 2005, Ofgem introduced various incentives to remove barriers to uptake of DG, including:

- reduced and simplified connection charges for DG;
- financial and other incentives (such as the IFI – Box 6) for DNOs to connect DG.

The Energy Networks Association say these incentives may lead to investment in infrastructure only for *specific* DG schemes and it will not fund "deeper reinforcement". It says additional incentives are needed to "take a holistic view of likely network requirements in the medium to long term".[8]

Micro-generators: small community, business or domestic projects (below ~50kW in size) only account for a minute fraction of all electricity generated. Government has taken steps to encourage uptake including:

- grants of up to 30% of total capital costs;
- legislation (2006) requiring DNOs to provide a "fair reward" for surplus electricity sold back to the network.

At present, it is unclear whether this will be enough to stimulate a mass-market in micro-generation technologies.

The House of Commons Trade and Industry Select Committee inquiry into "Local Energy" (generation by individuals, businesses or communities for their own consumption) concluded that while were no major technical obstacles to local energy generation, it was not a "short term panacea", and that replacing conventional generating capacity and grid upgrades was still a necessity.[9]

Adapting the distribution network

A distribution network resembles a tree. Power flows from a 'root' (a Grid Supply Point), along 'branches' and 'twigs' (high- and low-voltage lines and cables) out to the 'leaves' (consumers). There is little interconnection between branches. The networks have been designed primarily to convey power from Grid Supply Points to consumers ('one way flow'). Incorporating new DG while maintaining reliability presents technical challenges.

Networks must cope with voltage fluctuation, faults, and reverse power flow that may occur as a result of DG. Though the higher-voltage lines are monitored and managed centrally, the lower-voltage parts are not. Most faults still require on-site intervention to restore supply. If DG is to become widespread, improved monitoring and control techniques will be needed, with more automation and more interconnectivity between branches. Many say that the opportunity to incorporate new technologies should be taken now, while aging infrastructure is being replaced. Box 6 describes research underway.

Private-wire networks?

Privately-owned unlicensed networks may operate within existing distribution networks. Advantages include exemption from some licence charges and reduced energy loss in transmission. Ports and large industrial users often operate with private wire networks. Woking Council have shown that private networks incorporating local generation can be used to cut emissions in urban areas. However there is concern that customers on a private network are vulnerable, since they cannot switch suppliers if prices increase, or complain to a regulator. Government is consulting on how to protect customers and preserve competition if private networks continue to expand.

Box 6. Research, Development and Innovation

After privatisation, competitive pressures led DNOs to make substantial cuts in R&D budgets. The Innovation Funding Incentive (IFI), part of Ofgem's incentive package (Box 5), aims to stimulate R&D. It allows DNOs spend an extra 0.5% of their revenue on R&D and encourages collaboration between industry and academia. Companies like EDF Energy and Central Networks plan to test new technologies such as:

- **Battery storage:** large-scale (0.1GW) energy storage to help balance supply with demand.
- **Active network management:** new monitoring and control technologies to manage large amounts of DG; with tests on a real network in S.E England.

Additional work is underway, by the FutureNet consortium, and the DTI's Electricity Network Strategy Group. A new Energy Technologies Institute was announced in 2006, funded by the DTI and major energy companies.

Centralised versus Decentralised Generation (DG)

Proponents of DG argue that generating electricity close to where it is used reduces losses; also, using waste heat delivers efficiency savings. Others say the UK has already invested considerably in a centralised infrastructure and that large power stations are reliable, and provide economies of scale. Most observers agree that for the foreseeable future the UK will retain a centralised network, augmented by increasing amount of DG.

Overview

- The next decade will see increased investment in network renewal and connection of new generation.
- Delays in obtaining connections in Scotland and offshore may impede the connection of renewables.
- Government aims to reform planning law to streamline major electricity projects such as Grid upgrades.
- The effectiveness of government incentives will influence the extent to which distribution networks are adapted to accept more small scale generation.

Endnotes

1 *The Energy Challenge*, Department of Trade and Industry, July 2006.
2 *UK electricity networks,* POSTnote 163, October 2001.
3 Joint Energy Security of Supply Working Group: 7th report, Dec 06.
4 The industry in Northern Ireland is separate. An all-Ireland electricity market is expected to begin in 2007.
5 *Barker Review of Land Use Planning,* HM Treasury, December 2006.
6 *The Costs and Impacts of Intermittenc*y, UKERC, March 2006.
7 *Licensing offshore electricity transmission,* Ofgem, November 2006.
8 Energy Networks Association submission to DTI consultation on Distributed Energy, December 2006.
9 Trade and Industry Select Committee, First Report of Session 2006-2007, *Local Energy – Turning consumers into producers,* HC 257.

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