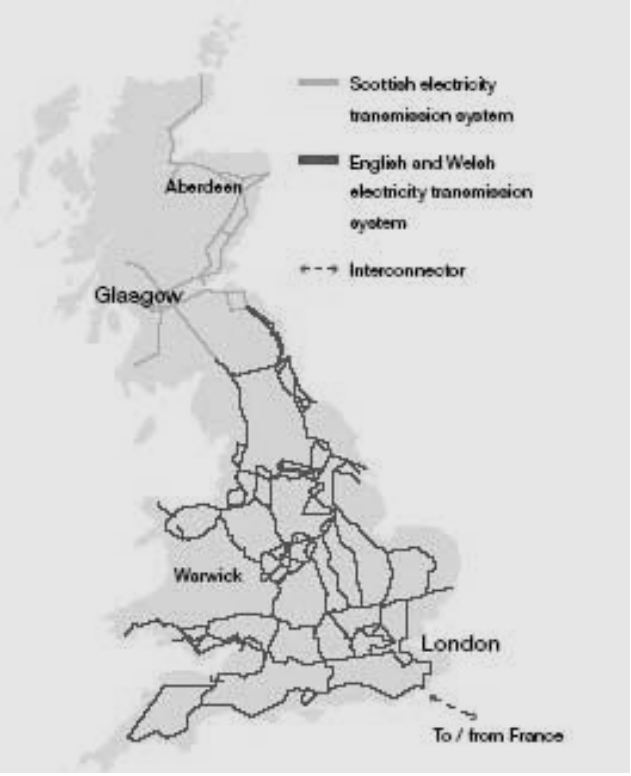
Upgrading the national electricity grid

Many of the electricity supply companies offer so called ‘green’ tariffs. Some claim that the electricity they sell to us is generated by renewable sources. But of course, all electricity comes from a mixture of wind, solar, natural gas, bioenergy, hydroelectric, nuclear or coal. Wherever it comes from, it gets fed into the national grid. What the green suppliers mean is that they have contracted with electricity generating companies that operate wind turbines and solar PV panels. The national grid is designed to distribute power from where it is generated to where it is used. Managing the grid is getting more complicated as more renewable power generation comes on line.

The national grid was designed to distribute power from a relatively small number of power stations, which were originally coal-fired. The Central Electricity Generating Board (CEGB) was formed in 1926 to link the main power stations and the national grid was created in 1935. Previously, the supply network was local to each power station. As demand increased, the capacity of the grid had to be increased. The CEGB transmission operations were transferred the National Grid Company plc in 1990, which was listed on the London Stock Exchange in 1995. Since 2002, National Grid has been a subsidiary of National Grid USA.

In 2020, the UK produced 43 % of its electricity from renewables and in mid-May 2023, we produced the trillionth (1000,000,000,000) kilowatt hour from renewables (National Grid plc). This figure will increase as part of the drive to net zero. But there’s a problem. We can build wind turbines, solar farms and other renewable power stations but the national grid has trouble handling inputs from so many sources and needs upgrading. Wind farms are located at sea and in upland areas where the wind is strongest. Similarly, solar farms are distributed across the land and on buildings. Each installation has to have new transmission lines in order to connect to the grid. So the grid is getting more and more complex and the way it is managed is changing. At present, the grid doesn’t have the capacity to cope with all the



The national electricity grid – England, Wales and Scotland (Utility Search)

demands being put on it. Not only are there many sources of power but there are significant challenges from the intermittency of generation. Unfortunately the wind doesn't blow constantly and no power is generated from solar panels at night.

National Grid is upgrading the network to cope with the changes in supply and the increase in demand for electricity. Demand is expected to increase by 50 % by 2025 and double by 2050. The increase is driven by changes in heating and transport – more buildings (homes and industry) are switching from gas, oil and solid fuel to electricity and the number of electric vehicles is increasing. New transmission lines are being built to meet these demands and existing ones are being upgraded where possible. This does mean that we are likely to have more new pylons across the countryside. National Grid predicts we need to build five times more transmission structures than we have for the last 30 years. Inevitably that will have an impact on the landscape but it also means there will be many new jobs across the whole of the UK.

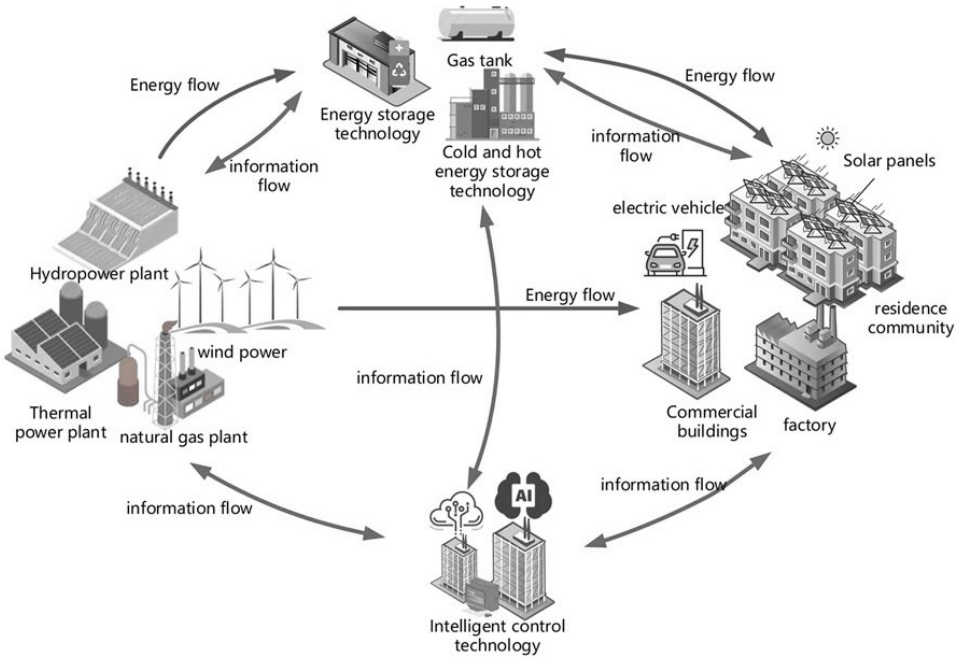
The transmission cables that we see marching across the countryside are made of aluminium. This metal is an excellent conductor and is lighter than the copper used in wiring up buildings. However, even aluminium has electrical resistance, which becomes significant over the long distances that power has to be transmitted. About 5 – 10 % of the total electricity generated is lost in the cables as heat that is caused by the electrical resistance of the metal, exactly the same process as when we boil a kettle. The total loss of power in transmission is 25 terrawatt hours per year and costs £3.75 billion. There is a way to overcome this limitation – superconducting cables.

Research into superconductance has been going on for many years. It holds the promise of being able to send power down a cable with no losses. Unfortunately, superconductance works best at extremely low temperatures, very close to absolute zero or -273 ºC [Absolute zero is the lowest possible temperature, when a system has zero energy and zero electrical resistance]. Recently, it is has been found that cooling certain metal alloys with liquid nitrogen to -196 ºC makes them into superconductors. Researchers at the University of Cambridge have shown that these so called 'high-temperature superconducting' (HTS) cables could be the solution to the problems associated with traditional aluminium cables. According to these researchers, because HTS cables have zero resistance they can carry much more power with minimal losses. They could be buried in the ground so there is no need for pylons and cables to be strung across the countryside. These "low-loss, 'superhighways'" would move the power from wind and solar farms via the national grid to where it is needed. Other countries, including Germany, USA, Japan and China already have demonstration projects that show how effective HTS cables can be. If the UK fails to invest in this technology, it will be left behind and may have to buy it in from abroad later.

The other challenge of renewable power is its intermittency. Part of this will be overcome by the new nuclear power stations that are being built. The development and building of new energy storage capacity will help smooth the delivery of power from renewables.

Battery technology is advancing and lithium-ion batteries are improving continuously becoming more affordable, longer lasting and more environmentally friendly. When they do reach end-of-life, the lithium and other precious components can be recovered and re-used. There is still a question over the safety of lithium batteries so there is lots of interest in other types such as solid-state batteries. These can hold more power in small units (higher energy density) and charge faster. Another way of storing power is to make hydrogen by the electrolysis of water using excess electricity. The gas can used to power fuel cells that generate electricity by making water from the hydrogen and oxygen from the air. Then there are flow batteries which use the energy released when two different liquid chemicals are brought close together either side of a membrane. Electricity is used to recharge the chemical electrolytes so storing power.

As well as upgrading the power network and adding storage systems, the adoption of ‘smart grids’ will improve the management of the distribution of electricity. A smart grid uses digital technology to monitor power generation, distribution and use to optimise supply and demand. We already see the beginnings of this with the smart meters being installed in our homes, which send back usage data to suppliers. In the UK, smart grids haven’t developed very far but elsewhere progress has been better. Canada is investing over £75 million in smart grid technology and the EU plans to invest about £150 billion for smart meters, automated management of the grid and digitising metering and improving field operations. As more people get electric cars, smart grids will be able to integrate their charging into the overall grid. With full integration across the whole of the network, power production and use will become more efficient and less costly.



Schematic of an Integrated Energy System.
From: Dai, N et al., 2022. Editorial: Advanced Technologies for Modeling, Optimization and Control of the Future Distribution Grid. *Frontiers in Energy Research* 25 March 2022 (open access).

With the improvements in the grid for power transmission, better control by making it smart and advanced battery systems, we will be able to take full advantage of renewable power generation in the future. Doing this will help reduce our carbon footprint and protect the environment, Other countries, even China, are already working on improving their grids, building more wind and solar farms. If they can do it, so can we.

Read more:
From gridlock to grid power: how to get renewable energy where it's needed in the UK:
https://www.cam.ac.uk/research/news/from-gridlock-to-grid-power-how-to-get-renewable-energy-where-its-needed-in-the-uk

Wishing you a Very Green and Merry Christmas and Happy New Year.

Richard Marshall

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