Friends of the Earth Scotland

The Power of Scotland Explained:

debunking the myths about renewable energy and the security of our electricity supply.

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The Power of Scotland **Explained**

This is a myth-busting pamphlet about renewable energy and the security of our electricity supply

It is based on the research of one of the UK's leading energy consultants, Garrad Hassan[1]. They looked at how the renewable sector is likely to grow over the next two decades, and how electricity needs in Scotland are likely to change. They also looked at what measures would be needed to ensure a secure electricity supply, even if the wind stopped blowing, the water levels in rivers were too low to run any hydro turbines, and the sea was completely still, for a period of several days.

They found that by 2030 it will be possible to phase out all coal, nuclear and gas in Scotland, keep the lights on and boost the Scottish economy by selling surplus renewable energy. In other words Scotland can have its cake and eat it. Don't believe it? Then read on…

1 The full technical report, and a detailed summary, is available at www.foe-scotland.org.uk/power-secured

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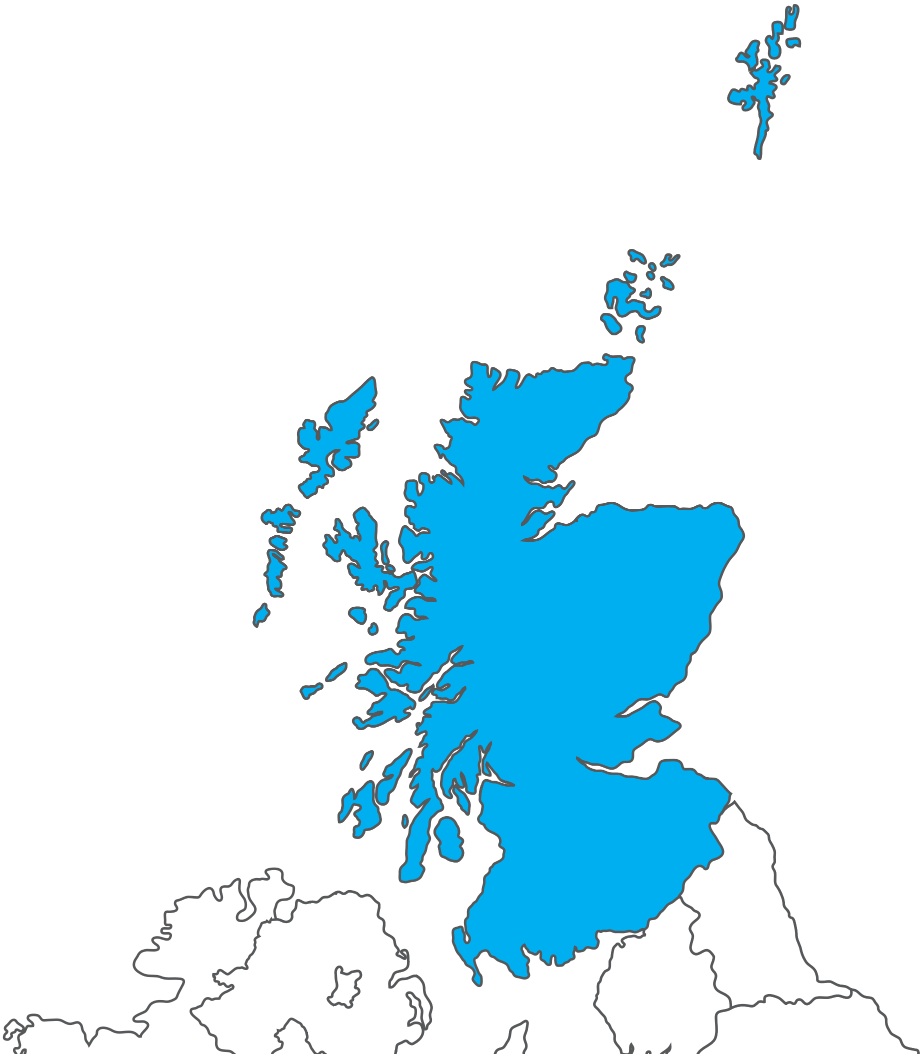
The juicy stuff



THE BACKGROUND

Mega whats?! If you don't know your joules from your jewels then you might find it helpful to start with our dummies guide to electricity, pages 2 – 7.

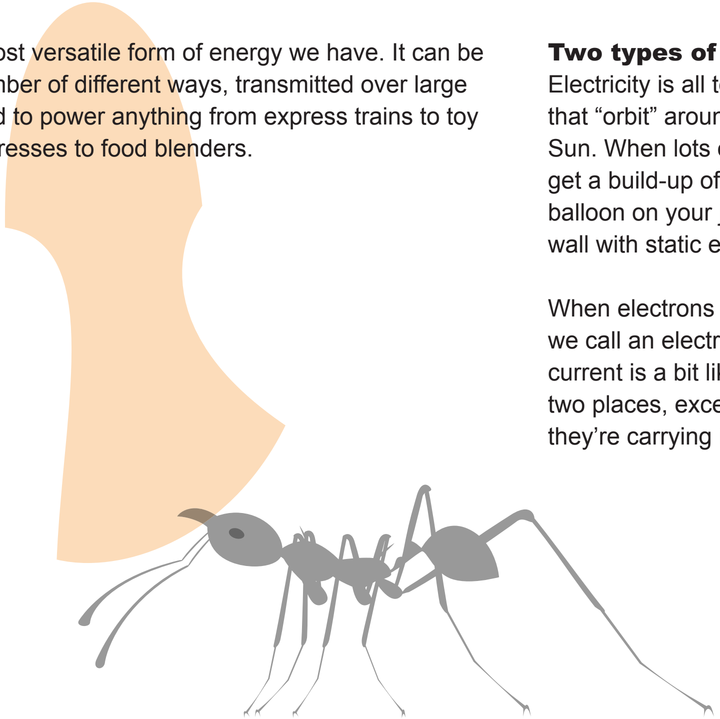
If you want to know how to make electricity from cow dung, or get twice as much energy out of a power station, try our introduction to renewable energy on page 8.

If you think the continental shelf is something you can buy in Ikea, and you've never heard of gas-fracking, then may we recommend pages 10 – 13.

If you're a right clever clogs and this is all old news, then skip straight to the juicy bits, starting on page 14.

What is electricity?

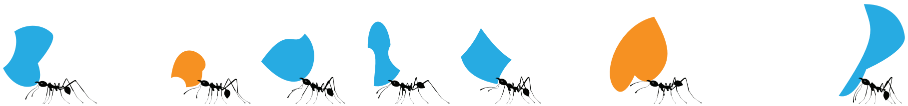
Electricity is the most versatile form of energy we have. It can be generated in a number of different ways, transmitted over large distances and used to power anything from express trains to toy cars and printing presses to food blenders.



Two types of electricity

Electricity is all to do with electrons, those tiny charged particles that “orbit” around the nucleus of atoms like planets around the Sun. When lots of electrons gather and stay in one place, you get a build-up of electric charge or **static electricity**. (Rub a balloon on your jumper and you can make the balloon stick to a wall with static electricity).

When electrons flow from one place to another, they form what we call an electric current or **current electricity**. (An electric current is a bit like a little line of ants carrying leaves between two places, except you have electrons instead of ants and what they’re carrying is electrical energy.)



Static electricity is easy to convert into current electricity. That's what happens during a lightning strike when the huge static charge built up in rainclouds zaps to the ground in a sudden flash of energy – a brief but spectacular electric current.

Electric circuits

To do anything useful with electricity, like boiling your kettle or powering your microwave, you have to make a path between a source of electricity (something like a battery) and whatever it is you want to power (maybe the bulb in a torch). A path like this is called an **electric circuit**: instead of a simple straight-line, a circuit is a loop that allows electrons to carry energy from the power source (e.g. a battery) to the thing you're powering (e.g. a bulb) and then go back again for more.

It's worth noting that it takes energy just for an electric current to move around a circuit. Even excellent conductors like copper have **resistance**, which means some energy is always wasted as heat as current flows through them. The longer the circuit, the more energy is wasted. As we'll see shortly, that has big implications for the way we generate electricity and transmit it to our homes.

How is electricity generated?

Power stations use ingenious but *dated* technology: they've worked pretty much the same way since Thomas Edison opened the first commercial station in Pearl Street in the heart of New York City in 1882. You feed fuel (such as coal, gas, oil or wood) in at one end and get electricity out at the other end. What happens in between?

First of all the fuel is burnt in a furnace so it releases heat, boils water, and produces high-pressure steam. Then the steam is piped through a **turbine**, which is a series of wheels with windmill-like vanes attached, enclosed inside a large pipe. As the steam whistles past the vanes, the turbine wheels spin very quickly.

The turbine is connected to an **electricity generator** which turns that movement into electricity. To understand how, we need to look at the relationship between magnetism and electricity.

Electricity and magnetism

We often think about electricity and magnetism as though they're two separate things, but you never get one without the other: they're completely interconnected.

When current flows through a wire, it creates an invisible pattern of magnetism all around it (a 'magnetic field'), which you can detect if you put a compass needle near the wire. And just as electricity can make magnetism, so magnetism can make electricity.

When 19th-century scientists such as Englishman Michael Faraday and Scotsman James Clerk Maxwell fathomed out the links between electricity and magnetism, the science of **electromagnetism** was born. It was this huge scientific breakthrough that allowed people both to turn the energy in the fuel into electrical energy (using **electricity generators**) and then use that energy to power machines (using **electric motors**).

Electric motors and generators are almost identical, but they work in opposite ways. An electric motor is a large coil of copper wire that spins inside a magnetic field. Pass current through the coil and it becomes a temporary electromagnet, pushing against the magnetic field, so it spins around, and drives any machine you care to hook it up to – from washing machines to vacuum cleaners.

In a generator, the opposite happens. The turbine makes the coil spin in a magnetic field, creating a current in the coil.

Of course, you don't have to use steam to turn your generator. You can also use the movement of wind, water flow, waves or tides. More on this later.

Inefficiencies

One of the problems with burning things to make electricity is that a lot of heat energy is wasted: in a conventional power station more than half of the energy in the fuel vanishes straight up the cooling towers.

Once electricity has been produced, it has to be sent (or 'transmitted') to the places where people need it, via wires hanging from pylons in a gigantic power-supply system (called the '**grid**'). Around 8% of the original energy is wasted, as heat, along the way.

This figure could be reduced by having electricity produced on a smaller scale, more locally, so that the electricity has less far to travel.

Taken together, the fundamental ineffiencies of a power station and its transmission lines mean that about two thirds of the energy produced is wasted before it gets anywhere near your home.

How is electricity measured?

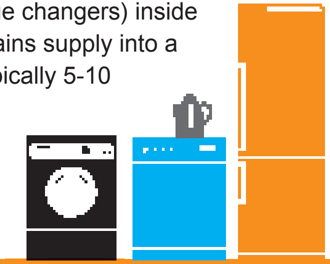
There are lots of ways of measuring electricity and four are particularly important.

Current

This is the amount of electrical charge that flows through an electric circuit in a given amount of time. It's the rate of the flow, and it is measured in amps, A. If you need lots of energy, you need a bigger current to deliver it or you can use a smaller current for longer. That's why a little travel kettle, with a small current, takes longer to boil the same amount of water as a normal kettle with a larger current: a cup of water takes the same amount of energy to boil however you do it, but a kettle using a bigger current can deliver that energy faster.

Voltage

This is the electrical "force" (measured in volts, V) that pushes a current through a circuit, a bit like the water pressure that pushes water through pipes. In any given circuit, if you increase the voltage, the current will increase. In British homes, the voltage of mains appliances is pretty much fixed at around 220-240 volts. Appliances like kettles or washing machines all use 220-240 volts, but use currents of different sizes to deliver the amount of energy they need at the rate they need it. Small appliances (such as mobile phone chargers or CD players) have transformers (voltage changers) inside them that convert the 240 volts mains supply into a more suitable, smaller voltage (typically 5-10 volts).



Watts

The power rating of a computer screen might be 50W; a low energy light bulb, 10W; an old fashioned bulb, 60W.

Kilowatts

The kilowatt is equal to one thousand watts. A typical kettle might use 2 kilowatts (kW), while a tumble dryer might use 4kW.

Power

Together, voltage and current give you electrical power. The bigger the voltage and the bigger the current, the more electrical power you have. We measure electric power in units called watts, W.

Something that uses 1 watt uses 1 joule of energy each second. Something that produces 1 watt of power produces 1 joule of energy each second.

Energy

It takes a certain amount of electrical energy (measured in joules, J, or in kilowatt hours, kWh – see below) to do a certain job, such as boiling a kettle, drying a load of wet laundry, or charging a mobile phone. Using a tumble dryer for an hour requires far more energy than using a kettle for a couple of minutes – even if the kettle and the tumble dryer have the same power rating.

Since power is energy per second, you can work out the amount of energy something uses by multiplying its power rating (in watts, kilowatts, or whatever) by the total time you use it for. That's why electricity companies bill us in "kilowatt hours" (kilowatts times hours), which are actually units of energy.

Megawatts

The megawatt is equal to one million watts. Wind turbines typically produce 1-3 megawatts (MW). The Eurostar consumes more than 12MW.

Gigawatts

The gigawatt is equal to one billion watts, or one thousand megawatts. A large fossil-fuelled power station might produce 1 gigawatt (GW).

What is renewable energy?

Renewable energy is energy harnessed from the wind, the movement of the seas and directly from the sun. Generating electricity from the sun, wind, or sea today won't affect how much you can generate tomorrow. Once you've built the infrastructure – the hydro systems, the photovoltaic panels, the wind turbines – this sort of energy is free, except for the cost of maintaining and repairing equipment.

Fossil fuels like oil, coal and gas are non-renewable because there's only so much of them in the ground. **When we burn them, they are used up. Eventually they will run out.** The same is true for uranium which is used in nuclear reactors. Mining these fuels and transporting them around the world is costly and polluting. But trying to cope with the waste products – like carbon dioxide from coal and gas power stations, and radioactive waste from nuclear reactors – is even more costly, not to mention very dangerous.

Biomass

Energy from burning wood (or biomass) is not strictly renewable energy because it is possible to 'run out' of wood if we cut down forests at a rate faster than they can grow back. This is exactly what we're doing all around the world right now. In fact Europe's growing demand for biomass is driving rapid deforestation and land-grabbing in places like Africa[i].

But *if* the biomass (wood) is sourced from carefully managed local woodlands, where the rate of harvest does not exceed the rate of growth, then it can have many of the same benefits as renewable energy. In this pamphlet we refer to biomass as a 'renewable' source of energy, but just so it's absolutely clear: we mean small scale sustainable use of biomass in efficient wood burners or Combined Heat and Power plants (CHP).

What is a Combined Heat and Power plant?
When we burn fossil fuels or wood to generate electricity, we produce a lot of heat. In conventional centralised power stations, much of this heat is wasted: on average only 40% of the energy in the fuel actually reaches our homes as electricity (see page 5). Combined Heat and Power (CHP) plants, by contrast, are designed and located so that the heat produced during the generation of electricity can be put to good use. For example, many CHP plants are connected to 'district heating systems' which provide heat via insulated underground pipes to hundreds of homes. This means that CHP plants have an overall efficiency of typically up to 80%.

Energy from Waste

Energy can be recovered from biodegradable wastes, like cow manure, through a process called '**anaerobic digestion**': when waste gets broken down by microorganisms without air the process produces methane, a greenhouse gas twenty times more powerful than carbon dioxide. Instead of releasing this methane into the atmosphere, we can use it in homes, or burn it to generate electricity in a power station, just like natural gas. The nutrient-rich leftover sludge (digestate) can be used as fertilizer.

It is also possible to burn biodegradable and non biodegradable waste in incinerators to generate electricity. At the moment Scotland generates 100MW in this way, which is a tiny fraction of our over all electricity supply (less than 0.5%). Again, it is not strictly renewable energy, because the waste (and the resources and fossil fuels that have gone into its production) can 'run out'. But for the sake of simplicity we've included it in our 'renewable' category, but only as a stop-gap solution: the feedstocks for such power plants should decline as a result of Scotland's waste reduction policies.

Why should we aim to generate all of our electricity from renewables?

In the long term renewable energy is the only safe, clean and secure option:

1) Climate Change
At the moment, we rely on fossil fuels like oil, gas and coal to generate most of our electricity, to power our vehicles and to heat our buildings. Burning fossil fuels releases CO_2, which is causing climate change: more frequent storms and floods, droughts and famines, sea level rise and loss of habitat for important species.

If Scotland is to pull its weight in the international effort to halt climate change, then we will need to reduce our CO_2 emissions by at least 42% by 2020, and 80% by 2050, and that is what the Scottish government has committed to do.

Fortunately we have the technology and the know-how to generate electricity from renewable resources. The Scottish Government has set a target of producing 80% of electricity from renewables by 2020, and research shows that we could go much further (see pages 16-19).

At the moment electricity meets only a quarter of our nation's energy needs. But if we also started to use renewable electricity to heat our buildings[2] and power our cars, instead of using oil and gas, this would cut emissions very dramatically indeed.

Carbon Capture and Storage aims to reduce the climate impact of burning fossil fuels by capturing CO_2 from power station smokestacks and disposing of it underground. However, CCS involves a suite of technologies which haven't been tested on a commercial scale: any part of the process – the capturing, the transporting or storing – could prove commercially unviable. In any case CCS does nothing to address the social and environmental impacts of fossil fuel extraction (see page 13).

CCS is worth testing out on existing power stations, in case it can prove useful in the long term, for capturing emissions from the cement and steel industries for example, which can't easily be powered renewably. But it is unlikely that the technology will be ready in time to help us meet our 2020 emissions reductions targets, and it should certainly not be used as justification for building new polluting power stations.

2) Energy Security

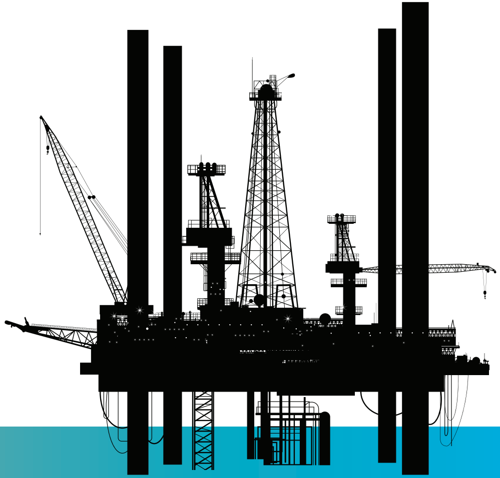
The UK's oil and gas production has halved since 1999, as oil and gas from the UK continental shelf become depleted. The 2007 Energy White Paper predicted that – with current policies – we could be looking to import around 80% of our natural gas needs (and 75% of our coal) by 2020. This dependency on supplies from abroad leaves us extremely vulnerable to shortages and price rises.

By contrast, there is no shortage of renewable energy in Scotland. In fact we have some of the best renewable resources in the world: enough to meet all our energy needs several times over (see pages 16-18).

Renewable energy also lends itself to being decentralized, which adds resilience to the system: if one wind turbine fails, it will have very little impact on overall supply. By contrast, the inherently centralised nature of fossil fuel and nuclear power makes us more vulnerable to power cuts caused by freak weather events or terrorist attack.

2 There are, of course, ways of using 'renewable' energy directly to generate heat, rather than turning it into electricity. For example, by burning sustainably harvested wood in a stove, or using biogas from anaerobic digestors (see page 9). But these solutions won't be practical for many households in Scotland.

The UK Continental Shelf is the region of waters surrounding the United Kingdom, principally the North Sea, underneath which there are large, but rapidly disappearing, reserves of oil and gas.



3) Employment

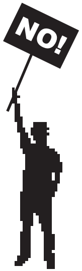
Research shows that that the energy efficiency and renewables sectors create more jobs per unit of energy, than conventional fossil fuel and nuclear power[ii]. In Scotland, the Government estimates that 26,000 green jobs can be created in renewable energy alone, while the Offshore Valuation report found that using just one third of the UK's wind, wave and tidal resource could create 145,000 new UK jobs. Scotland's position at the forefront of renewable technology development has already enabled it to attract significant foreign investment. If renewables grow in line with industry and government aspirations, and proper investment is made in transmission capacity, then by 2030 Scotland could be exporting over 20,000 GWh of electricity per year (worth £20 million, according to DECC's central long term electricity price forecasts[iii]).

By contrast, the construction of a new fleet of nuclear power stations would provide very little economic benefit for the UK economy, as we would need to rely on overseas suppliers offering standardised designs and uranium.

It pays to be at the forefront of renewable technology development. In just the last few months, Iberdrola, the Spanish energy company that owns Scottish Power, has announced £42 million investment and the creation of 300 jobs in the establishment of an offshore wind technology centre in Glasgow; Mitsubishi announced up to £100 million investment in an offshore wind research and development centre in Edinburgh, and acquired Loanhead-based Artemis Intelligent Power; and ABB, the Swiss-Swedish multinational, took an £8m stake in Aquamarine Power, an Edinburgh-based company developing its Oyster wave energy technology.

Deep water drilling

As easily accessible oil wells dry up, the industry is forced to drill deeper under dangerous conditions to feed our increasing oil addiction. The risks involved in this have been dragged into the spotlight following the recent BP Deepwater Horizon disaster in the Gulf of Mexico, where 11 workers lost their lives and many more were injured. Impacts locally were devastating, with cleaning costs running into billions. Even before the investigations into BP's Gulf of Mexico disaster had finished the UK government granted 144 deep water drilling licenses in the area to the west of Shetland, despite industry bodies admitting that the region was hampered by a "hostile marine environment, extreme weather and the shortage of infrastructure" making projects "high risk and technically challenging"[iv].



4) Justice

The effect of fossil fuels is not just about carbon emissions. Deadly impacts stretch right back to the start of the supply chain, to the oil wells, the tarsands, the gas-fracking sites and open cast coal mines, which cause widespread respiratory ill-health and toxic contamination of water supplies. All around the world, from Columbia to Indonesia, from Canada to Nigeria, the fossil fuel extraction industries are associated with environmental destruction and human rights abuses.

Meanwhile the demonstrated risk with nuclear is that a small accident can have disastrous consequences for human health. On top of this, there is still no long term solution for storing high level radioactive nuclear waste which remains dangerous for over 100,000 years. The latest attempt to find a permanent storage solution in the Yucca Mountain in the United States had to be brought to an end by the Obama administration despite $1bn spent on a 6,000 page site characterisation plan. This casts some serious doubts as to whether a long-term geological storage solution will ever be developed.

Tar sands

The process of extracting of oil from 'tar sands' has been described as the most destructive industrial project on earth. Vast quantities of fresh water and energy are required to inject the sands with high pressure steam to separate out the oil from the sand, leaving behind a mix of toxic chemicals, salt, water, silt, clay and hydrocarbons. In the tarsands of Alberta Canada, an area of pristine Boreal forest larger than England has already been impacted. Rates of cancer and immune related illnesses have increased and high levels of toxins have been found in local rivers that many indigenous people rely on for hunting, trapping and fishing[v].

Gas Fracking

Fracking is the process of extracting natural gas by drilling a well and pumping it full of a highly pressurized mixture of water and chemicals. The liquid causes rock to fracture, releasing natural gas for companies to collect. The process is becoming increasingly controversial, due to evidence of contamination of drinking water supplies[vi].

How much electricity will Scotland need by 2030?

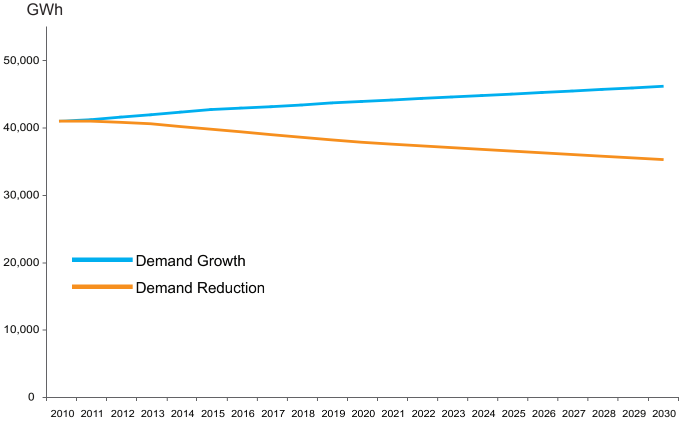
The graph below shows two different scenarios, developed by Garrad Hassan, for how Scottish electricity demand might change between now and 2030.

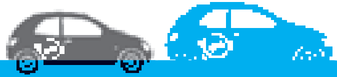
The blue line shows what would happen to electricity demand if we did very little to try and reduce it. The orange line shows what would happen to electricity demand if we make some moderate effort to try and reduce it.

It's important to remember that we could cut our energy use even more than this. Certainly the Scottish Government is aiming to make more ambitious cuts, and the Committee on Climate Change anticipates larger cuts for the UK as a whole.

But let's assume, for the sake of argument, that our base electricity demand lies somewhere between 45,900 GWh and 35180 GWh by 2030.

Figure 1: Energy Demand in Scotland





Heat pumps use the same technology as fridges or air-conditioning units, but instead of taking heat out of the house, they bring heat in from the outside air or from the ground. They need to be sized correctly, combined with good insulation, and powered with renewable energy if they are to be cheaper and more environmentally friendly than gas.

Now, what if we decided to replace some of our cars with battery powered cars? And replace some of our gas boilers with electric heat pumps?

This would cause our electricity demand to increase. But if the electricity comes from a renewable source it would help to cut carbon emissions, and if petrol and gas prices keep rising, it would save people money too.

Say we want to cut carbon emissions from passenger car traffic by 70% by 2030, and carbon emissions from heating by 60% by 2030, in line with Scottish Government targets[vii]. This would increase our electricity demand by 20 – 25%[viii].

The dotted lines on the graph opposite show how this partial electrification of the heat and transport sectors pushes up our overall projected electricity demand.

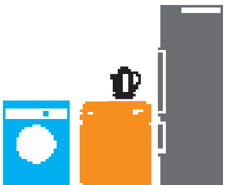
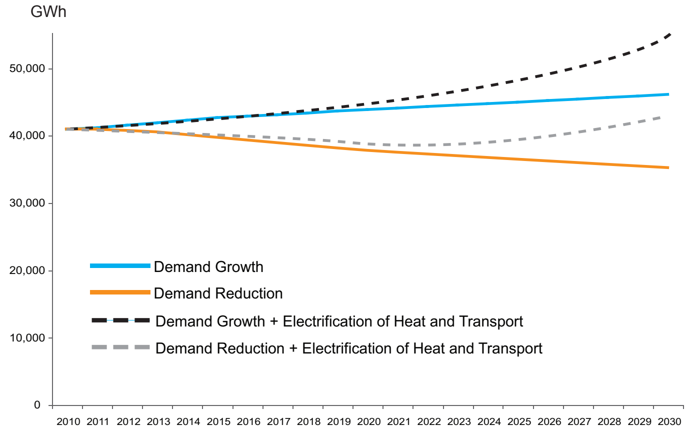


Figure 2: The effects of electrification of heat and transport on total energy demand



The next section looks at how much of this electricity demand we can generate from renewables.

How much electricity can realistically come from renewables by 2030?

The graphs opposite show two different possible scenarios for the growth of the renewable energy sector in Scotland until 2030[3].

In the **Low Renewables Scenario (figure 3)** renewables continue to expand, though at a relatively conservative rate, roughly in line with current build rates.

The **High Renewables Scenario (figure 4)** assumes more optimistic consent and build rates more in line with current industry and Government aspirations.

Microgeneration

The potential electricity supply from community and household scale microgeneration projects has not been included in the graphs opposite. In practice, with the benefits of feed-in-tariffs (FITs) and the renewable heat incentive, microgeneration can be expected to make a significant contribution to both overall supply, and security. Based on estimates from the Energy Savings Trust, microgeneration in Scotland could supply 7000GWh of electricity annually by 2030, equivalent to 15% of total demand in the demand growth scenario. Microgeneration projects can also deliver additional positive impacts in terms of heightened energy efficiency awareness and economic benefits for the local area[ix].

3 The scenarios are based on known volumes of projects under development, estimates of available resource and constraints, stated targets, and achievable construction rates. For details of specific sources, see the original report by Garrad Hassan: Paul Gardner (Sept 2010), *Options for Coping with High Renewables Penetration in Scotland*, available at www.foe-scotland.org.uk/power-secured

Figure 3. Annual Production of Renewable Electricity: Low Growth Scenario

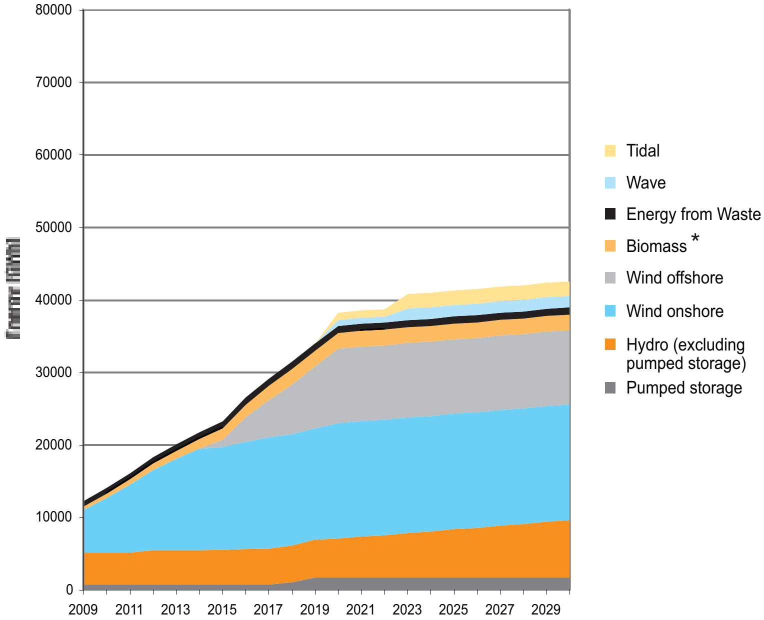
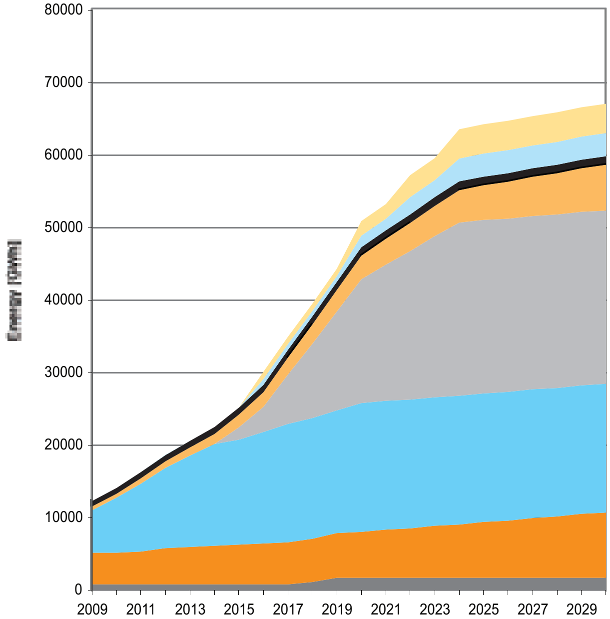


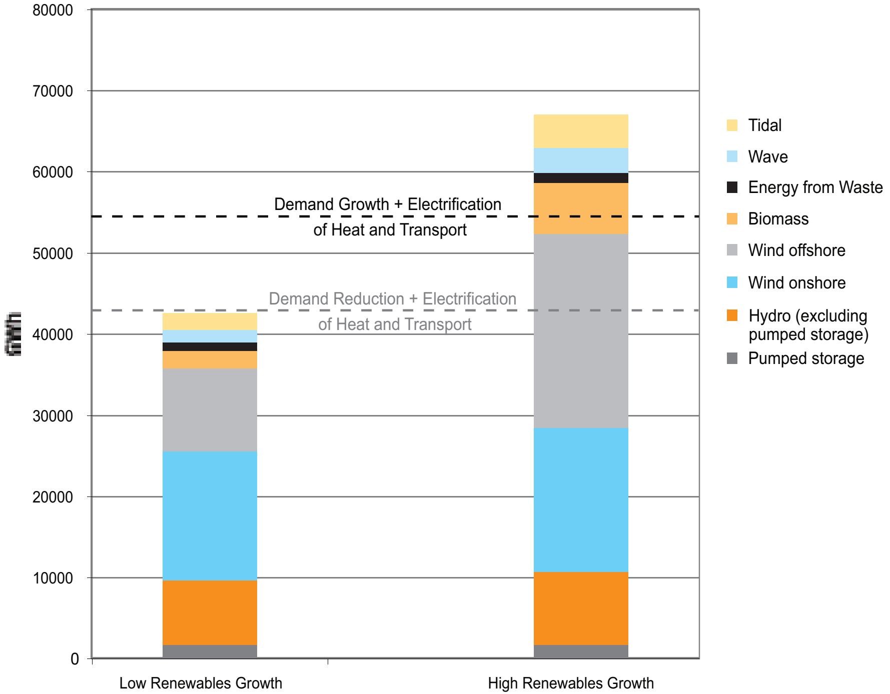
Figure 4. Annual Production of Renewable Electricity: High Growth Scenario

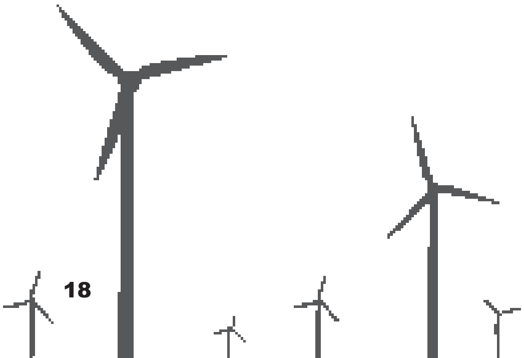


* In order to be considered a sustainable, or indeed 'renewable' resource, feedstocks for biomass projects must besourced from local and well-managed forests. The availability of such biomass is limited, and projects which assume sustainable supplies can be imported may not be justifiable.

In figure 5 the dotted lines show the upper and lower estimates for how electricity demand will develop to 2030, as outlined in the last section, next to the power that will be coming from each renewable source.

Figure 5: Renewable electricity supply in 2030 compared to demand





As you can see from figure 5, even in the worst case scenario (of slow renewables growth and electricity demand increase), almost three quarters of our electricity demand could be met by renewables over the course of the year.

With moderate demand reductions and more ambitious investment in renewables, we could meet all our electricity needs renewably, and have a significant surplus to export.

However, so far we have only considered total (or 'gross') amounts of electricity used over the course of a whole year, and total amounts of electricity generated over the course of a whole year.

What matters from the point of view of keeping the lights on, and maintaining a secure supply, is not only how much electricity you produce and consume over the course of the year, but whether you have enough electricity at any given moment, to meet demand.

Electricity demand varies enormously over the course of a day.

And the electricity that can be generated by the sun, the sea and the wind, will fluctuate too.

Protecting Scotland's wild places

It is assumed that only 26% of the onshore wind projects currently at 'planning', 'appeal' or 'scoping' stage go ahead, compared to a 60% success rate for applications to date. In other words, we assume that the desire to protect environmentally sensitive areas – such as peat bogs – will prevent unsuitable projects from going ahead.

We are clear however, that the greatest threat to the countryside as we know it comes from climate change.

This has led some people to argue that we have no choice but to put up with dirty and risky fossil fuel or nuclear power stations to 'back up' our renewable energy sources.

But there are other ways of making sure that we have a secure electricity supply. And that's what the next section looks at.

Is the variability of renewable energy a problem?

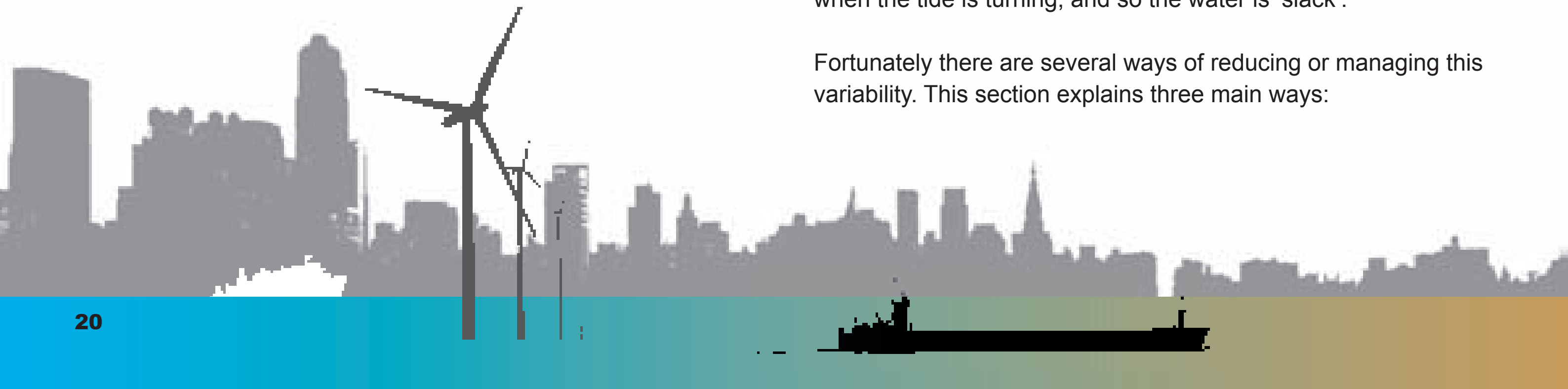
We've seen that Scotland could have more than enough renewable power to cover its electricity needs over the course of a whole year. But the challenge is to make sure that the supply of electricity matches the demand for electricity at any one moment.

This is tricky for two reasons:

Firstly, electricity demand varies enormously over a 24 hour period, and over the course of the year, 'peaking' in weekday late afternoons in winter. Big variations in demand make it very difficult to guarantee energy security in an efficient way because the whole system has to be designed to ensure that the lights stay on during 'peak' demand, even if that means you have excess generation capacity for the rest of the day.

Secondly, electricity generation from renewables can vary more than from conventional power stations. There are times when the wind isn't blowing, when the rivers don't have enough water in them to run turbines, when waves on the sea are gentle, and when the tide is turning, and so the water is 'slack'.

Fortunately there are several ways of reducing or managing this variability. This section explains three main ways:



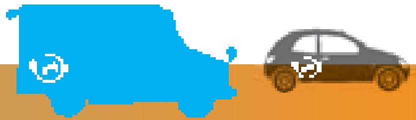
1) Make more use of 'deferrable' demand

Electricity demand which can be postponed or deferred for a few hours, or even days, is called deferrable or interruptible demand.

Power system operators already make extensive use of interruptible demand, usually through industrial customers who are contracted to be able to reduce their demand substantially at short notice, and for short periods only.

But there is the potential to make much greater use of deferrable demand. 'Smart meters' will be installed in homes and businesses across the UK by 2020. These will be able to communicate electricity prices to electricity-consuming devices, like fridges and freezers, so that they vary the level and timing of power consumption according to availability on the grid.

In other words, 'smart' appliances will be able to turn themselves down or shut themselves off if they don't really need to be on (for example, a freezer that is cold enough already), and come on again later when electricity is cheap and plentiful.



Freezers are just one example of an appliance that doesn't necessarily need to have constant electricity supply. If our buildings and hotwater systems were very well insulated, and heated using electric heat pumps for example, they would also be able to vary their power use according to the availability of electricity on the grid, whilst maintaining the temperature above a comfortable threshold.

The same is true for electric cars that are plugged in to charge. You could specify when you need the car to be fully charged again, and the 'smart' charger could choose the cheapest time to charge.

In this way, 'smart meters' could help to address fuel poverty, as well as significantly smoothing out the peaks and troughs in demand.

Did you know that the market price of electricity changes every half hour?
When demand is high but supply is low, electricity is expensive for suppliers to buy. When demand is low, but supply is plentiful, it's cheap.

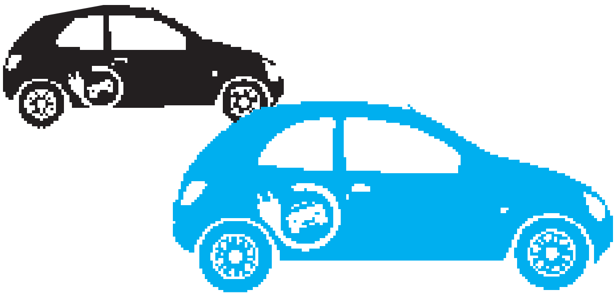
2) Store more energy

One way to manage variability in electricity *supply* is to store energy in a form that can later be turned into electricity.

For example, when electricity is plentiful and cheap, you can use it to pump water up hill into a reservoir. When electricity is expensive and not readily available, you can release that water through hydro turbines. This is known as 'pumped storage'. We already have 740MW of pumped storage capacity in Scotland – roughly half the power output of Cockenzie coal fired power station – and *Scottish and Southern Energy* are developing schemes for two new 600MW pumped storage plants in the next decade.

If battery technology improves as expected, then the batteries of electric vehicles offer another opportunity for storing energy. The maximum theoretical storage capacity of Electric Vehicles in Scotland is estimated to be around 2 to 3 times that of a pumped storage plant, depending on levels of traffic growth. Whilst only a small fraction of this full amount can be expected to be available at any given time, nonetheless the storage capacity of electric vehicles in the 2020s could be a very useful addition to pumped storage.

Combined Heat and Power (CHP) plants (see page 9) offer another opportunity to manage variability in electricity supply if they are built alongside centralized heat storage. When there is a shortage of electricity from renewables the CHP plant could prioritise generating electricity over heat. When there is surplus of renewable electricity, it could be used to charge the heat stores, using heat pumps. CHP systems like this have helped Denmark to cope with variability from wind power.



A grid is a large network of cables, like a complex circuit, connecting up different sources of electricity with all the homes and businesses that use it.

3) Improve interconnection

Interconnection between different grid systems, or improving transmission between different parts of the same grid, helps to reduce variability in both supply and demand

Smoothing demand

In different regions, people tend to have slightly different patterns of electricity use: they put the kettle on at different times, do their washing at different times, turn the lights out at different times. So 'peak' demand occurs at different times in different regions. One reason for this is that darkness falls at different times for different geographical regions. For example, in winter it gets dark in the North of Scotland before it does in the South of England, and it gets dark in Norway, before it does in Scotland. Improving the transmission between Scotland and the rest of the UK grid, or even connecting to other grids on mainland Europe, would, in effect, increase the number of customers in different regions sharing the same grid. This would help to reduce the total variation in demand. If it is not immediately obvious why, look at the two graphs to the right. The blue 'spikey' lines show the variation in electricity demand in ten different EU countries. The orange line shows the variation in their total demand. As you can see is the orange line is much 'smoother'.

Figure 6: Demand variation over the year

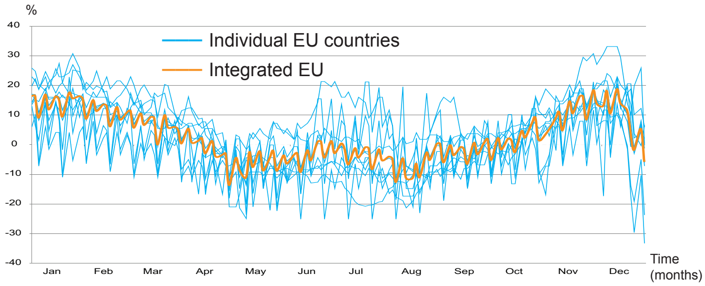
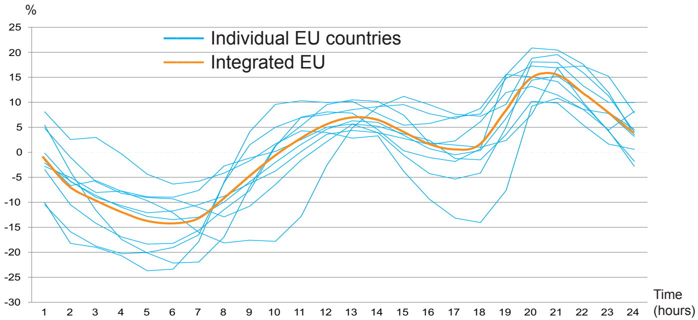


Figure 7: Demand variation over the day



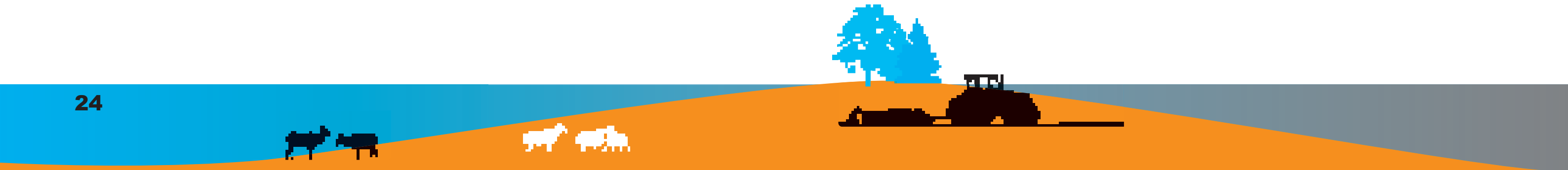
Source: The European Climate Foundation, Roadmap 2050

Smoothing supply

Exactly the same thing can be said about our renewable electricity supply: the greater the number of renewable suppliers on the grid the less the variation in supply. By improving interconnection between different grid systems you effectively ‘pool’ together the power from different renewable resources in different geographical regions, which helps to ‘smooth’ out the supply curve: if the wind is not blowing in Scotland, we can be fairly certain that across Europe there will still be plenty of power from hydro, solar, wave, tidal and geothermal.

Sharing Reserve

Interconnection has the added bonus of allowing different grid systems to share what’s called ‘reserve’ power. To be considered secure each grid system must have ‘back up’ or ‘reserve’ generators, like 'pumped storage' plants (see page 24), which can be brought ‘online’ (turned on, or connected to the grid) at very short notice in case a major generator fails unexpectedly. But it would be very unlikely for two major generators to fail at exactly the same time in two grids, so interconnection provides backup for both systems.



Do we need some coal, gas and nuclear in Scotland to keep the lights on when the wind drops?

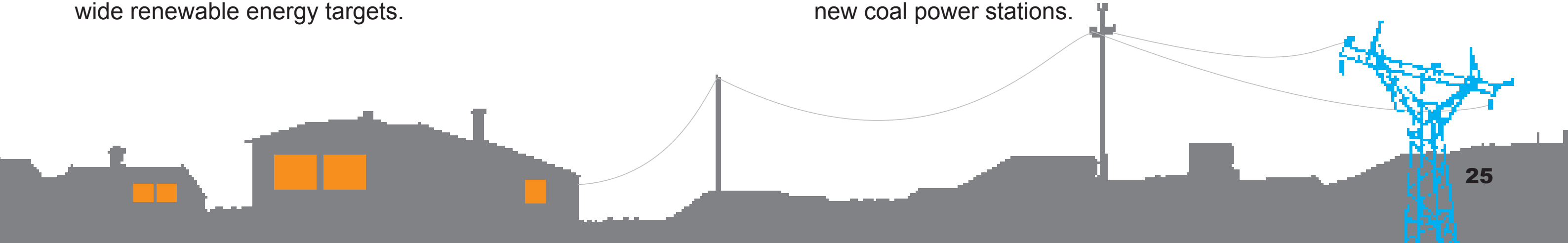
We've already talked about several different methods for managing the variability of renewable electricity supply (pages 20-24). This section takes just one of these methods – improving transmission to the rest of the UK grid or to Europe – and shows that this method alone would allow Scotland to phase out all its coal, gas and nuclear power stations, and still maintain a secure electricity supply.

What do we mean by secure?
In this research Scotland's electricity system is considered 'secure' if it can still supply enough electricity to meet 'peak demand' even if *both* of the following unlikely events occur:
1) there is absolutely no electricity coming from *any* of our onshore or offshore wind farms, from run-off hydro, wave or tidal generators
AND
2) two of our main transmission lines to the rest of the UK grid, or Europe, were to fail simultaneously.
It is of course extremely unlikely that such a situation would ever come about, but it's good to be prepared for the absolute worst case scenario.

Improving interconnection would mean laying down new transmission lines to allow more electricity to be transported from Scotland to the rest of the UK grid when we have a surplus, and to allow more electricity to be imported when we don't have enough. It would be a big engineering project, but the cost of doing it would be small compared to the amount of revenue that could be generated by *exporting* renewable electricity when there's plenty of it.

Doing this would allow Scotland to fulfil its potential as a world leader in renewable energy and contribute to UK and European-wide renewable energy targets.

It would also mean that we don't have to risk extending the lives of ageing nuclear plants or take the financial and climate risks of new coal power stations.



Perhaps this all sounds a little far-fetched. So let's actually look at the figures. To work out if we can have a secure electricity supply without relying on any coal, gas or nuclear power, we need to know three things:

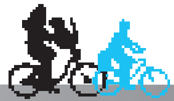
1) What is peak demand?
Currently peak demand in Scotland is 6000MW. Again, to be on the safe side, let's assume that we don't manage to reduce peak demand at all. (In practise, with demand reduction measures and greater use of deferrable demand as set out on page 21, peak demand could decrease significantly, making the objective of system security much cheaper and easier to achieve.)

2) What renewable generation capacity will still be available in the worst case scenario?
In other words, how much electricity will we be able to produce if the wind stops blowing, the water levels in rivers are too low to run any hydro turbines, and the sea is completely still, for a period of several days? At the moment the answer is 2300MW, because at the moment the *existing* generating capacity from pumped storage, reservoir hydro, biomass and energy from waste plants is 2300MW.

Transmission capacity is the amount of electricity that the transmission cables can carry to or from a given location – in this case, to and from Scotland. The more/bigger/better transmission cables you install, the greater your transmission capacity.

3) What 'transmission capacity' will still be available in the worst case scenario?
In other words, how much electricity will we be able to import if the two biggest transmission lines were to fail simultaneously?

By 2014/15 there will be at least 4000 MW of transmission capacity, which means that we will have the ability to import up to 4000 MW of electricity from England.



How much additional transmission capacity should we build? Well, if the renewable sector continues to grow at current build rates (see pages 16-17), the level of transmission capacity which it makes sense to build from an economic point of view is likely to reach 15-20,000 MW. In other words, the cost of building the ‘wires’ to carry 15,000-20,000 MW will be easily offset by the revenue that we could earn by exporting our renewable energy.

If renewable build rates increase in line with Government and industry aspirations then the transmission capacity which is economically justified is likely to reach 20-25,000 MW.

As we’ll see from the scenarios over the page this is much more than is necessary to guarantee a secure electricity supply for Scotland.

Building up our renewable generation and transmission capacity like this does not just make sense financially. It will make sense from the perspective of enabling the rest of the UK to meet its renewable energy and emissions reductions targets. If we don’t make the most of Scotland’s renewable resources, it will be difficult for the UK as a whole to decarbonise its electricity supply in line with advice from the Committee on Climate Change and our legal obligations as part of the European Union.

The following three scenarios are plausible options for the development of transmission capacity in Scotland.

Scenario 1:
Total transmission capacity = 9400MW
Required generation capacity = 200MW

Three additional 1800 MW HVDC sub sea transmission lines are built: one on the east coast and one on the west coast as is already planned, and a third, which might go to England, or possibly even to Norway or the Netherlands. In this scenario, if the two largest lines were to simultaneously fail, then we'd need 200 MW of generation capacity in Scotland to have a secure system. Good news – we already have eleven times that capacity!

Scenario 2:
Total transmission capacity = 7600MW
Required generation capacity = 2000MW

Only the east and west coast transmission lines are built. If both of these were to fail, we'd need 2000 MW of generation capacity in Scotland. We already have 2300MW!

HVDC stands for high voltage direct current, which is a way to transport large amounts of electricity over long distances without losing as much electricity along the way as you would with traditional lower voltage 'alternating current'.

Scenario 3:
Total transmission capacity = 5800MW
Required generation capacity = c.3000 MW

Finally, consider the possibility that only the planned 1800 MW sub sea HVDC transmission line is built on the West coast. If this were to fail along with the second biggest transmission line, we would need around 3000MW of generation capacity in Scotland, which we don't yet have. But we do know that SSE are planning two new 600MW pumped storage plants, which would bring our generation capacity in Scotland to 3500MW.

This analysis shows that the variability of renewable energy in Scotland needn't pose a risk to energy security. In fact the transmission capacity that it makes economic sense for us to install, to fulfil our renewable export potential, is three or four times that which is needed to guarantee a secure electricity supply.

These conclusions depend on only moderate efficiency and conservation achievements, below the targets set by the Scottish Government. **More ambitious energy demand reductions and demand management across all sectors would make system security and emissions reductions far easier and cheaper to deliver, and would reduce household fuel bills.**

The costs of a 100% renewable grid

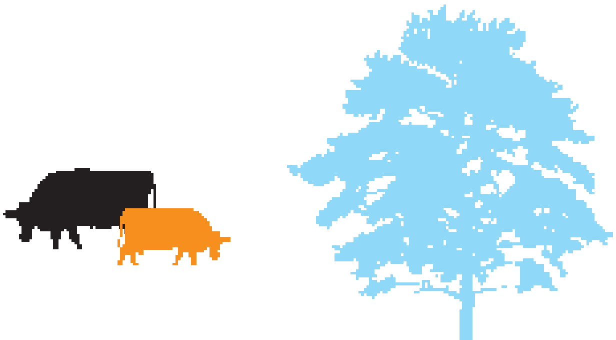
The overall costs of the system outlined above are likely to be similar to the costs of maintaining a secure supply with a more ‘business as usual’ approach. In fact, as the price of oil, coal and gas rises over the coming years, and costs of renewable technologies fall, using renewable electricity for heat and transport would mean that household’s ‘triple bills’ (for electricity, heat and transport) are likely to be cheaper than in conventional scenarios.

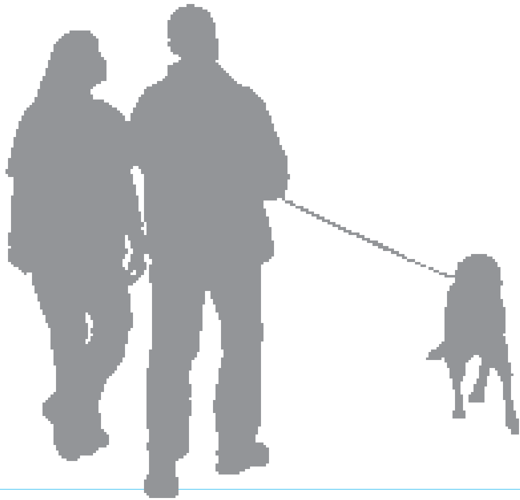
But the economic benefits don’t stop there. As shown on page 12, being at the forefront of renewable technology development will bring enormous employment and investment opportunities in Scotland.

Similar conclusions have been found at the European level. The European Climate Foundation’s (ECF) Roadmap 2050 study[x] found that substantial reinforcement and extension of Europe’s transmission infrastructure was economically justified to allow the ‘pooling’ of electricity from renewable sources like wind, solar and hydro; and the costs of improving this infrastructure only formed a relatively small part of customers’ final electricity bill.

The study also concluded that with such improved interconnection, a future European energy system relying entirely on renewable energy was technically feasible, no less secure and only around 10% more expensive than other options for decarbonising the power sector.

It is inevitable that there will be competition in the future between the fossil fuel, nuclear and renewables industries for scarce resources, including transmission capacity, finance and skilled labour. When faced with such investment decisions, the Scottish Government should remember that renewables and efficiency are the best option for employment, for the environment and for long-term energy security. We hope that this briefing will have given you the confidence and background knowledge to make that case to your own representatives.





i Africa: Up for grabs, August 2010, Friends of the Earth Europe and Africa
ii Daniel Kammen, Kamal Kapadia, and Matthias Fripp, April 2004 (updated January 2006), "Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Create?" UC Berkeley: Renewable and Appropriate Energy Laboratory (RAEL), 12; see also José Goldemberg, The Case for Renewable Energies, Thematic Background Paper: International Conference for Renewable Energies, Bonn 2004
iii DECC, January 2010, 'Valuation of Energy Use and Green House Gases (GHG) Emissions for Appraisal and Evaluation'
iv Platform, 2010, "Off the deep end: Foreign policy, 'energy security', and the desperate dash for offshore oil", available at: http://www.platformlondon.org/offthedeepend.pdf
v Platform, 2010, Cashing in on Tar Sands: RBS, UK banks and Canada's "blood oil", available at http://foe-scotland.org.uk/tarsands-report
vi Ian Urbina, February 26, 2011, "Regulation Lax as Gas Wells' Tainted Water Hits Rivers", New York Times
vii The Scottish Government has a target of reducing emissions 40% from the entire transport sector by 2030, and of meeting 40% of heat demand renewably by 2030.
viii If you want to know exactly how this is calculated you'll have to read the more in-depth report available at www.foe-scotland.org.uk/power-secured
ix Across the UK microgeneration could produce 220TWh of combined heat and electricity by 2030, according to Energy Saving Trust, E-Connect and Element Energy (2005) Potential for Microgeneration Study and Analysis, for the UK Department of Trade and Industry. For Scotland that would imply perhaps 15TWh of heat energy and 7TWh of electricity. In Germany, FITs have already stimulated more than 500,000 solar photovoltaic installations, generating more than 10000GWh of electricity each year.
x Roadmap 2050: A Practical Guide to a Prosperous, Low-Carbon Europe, European Climate Foundation, April 2010, http://www.roadmap2050.eu/downloads. See Executive Summary to Volume 1.

Friends of the Earth Scotland exists to help people in Scotland look after the planet for everyone's future. Our vision is of a world where everyone can enjoy a healthy environment and a fair share of the earth's resources. Friends of the Earth Scotland is an independent Scottish charity, number SC003442.

This community briefing is based on research conducted by GL Garrad Hassan. The full technical report is available at www.foe-scotland.org.uk/power-secured