the power of Scotland secured

Summary for policy makers

Friends of the Earth Scotland

RSPB

WWF

Based on research conducted for Friends of the Earth Scotland by GL Garrad Hassan.

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Summary written by Beth Stratford

Executive Summary

Scotland has been widely praised for its climate change legislation, which commits us to cutting greenhouse gas emissions by at least 80% by 2050, and by at least 42% by 2020. Decarbonising our electricity supply will be key to meeting that challenge.

Friends of the Earth Scotland commissioned GL Garrad Hassan to examine credible scenarios for electricity demand and supply in Scotland up to 2030, in order to determine appropriate paths for electricity decarbonisation, and necessary measures for ensuring reliable supply with high levels of renewable generation[1].

The analysis indicates that:

Without endangering important environmental interests, renewable electricity generation in Scotland can grow to comfortably exceed our electricity needs, bring in substantial export revenue, and also allow for significant electrification of heat and transport sectors.

By 2020, renewables could be providing over 100% of Scotland's electricity needs, and 185% by 2030. By combining this level of renewable electricity production in 2030 with moderate efficiency measures, Scotland could decarbonise at least 50% of our total energy needs.

Moreover, with improved interconnection[2] and moderate investments in storage and deferrable demand, Scotland could potentially phase out all conventional thermal generation capacity before 2030 and still deliver a secure and reliable electricity supply.

1 The full technical report by GL Garrad Hassan is available at www.foe-scotland.org.uk/power-secured. This summary sets out implications and conclusions for policy makers as understood by FOES, WWF and RSPB.

2 The interconnection capacity required for a secure electricity system is two to three times smaller than the capacity which would be economically justified by the value of electricity exports.

Scotland therefore does not need to risk unnecessarily extending the lives of ageing nuclear plants. Nor need we take the financial and climate risks of new coal powerstations. We can still help commercialise carbon capture and storage through demonstrations on existing power stations.

The overall costs, and consumer prices, in such a system are comparable to those in conventional approaches, and the additional costs of interconnection are economically justified by electricity exports. Significant electrification of heat and transport could reduce household ‘triple fuel’ bills below those in conventional scenarios.

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

Section 1 outlines the electricity demand scenarios.

Section 2 examines the scope for electrification of heat and transport, and considers how this would affect overall demand.

Section 3 assesses the extent to which realistic renewable generation scenarios can meet those demands, and provide exports.

Section 4 addresses the critical question of supply security, and also draws conclusions, regarding the future of thermal generation in Scotland.

Section 5 offers a set of policy recommendations designed to pave the way towards a clean and secure renewable future for Scotland.

1. Electricity demand

Reducing electricity demand, particularly ‘peak’ demand, is by far the cheapest way to contribute both to security of supply, and to emissions reductions.

This section outlines the underlying electricity demand scenarios defined for this study. They are expected to bracket a range of possible outcomes, whilst erring on the conservative side[3].

In the **Demand Growth scenario**, demand begins to grow again in 2011 as the recession is assumed to end, and then continues to increase, resulting in gross electricity consumption reaching 45,900 GWh in 2030 - a net increase of 12.2% (on 2010 levels).

In the **Demand Reduction scenario**, demand begins to contract in 2012, reflecting government policy, resulting in a gross electricity consumption of 35,180 GWh by 2030 - an overall reduction of 14% (on 2010 levels). Likely extra demand created by the partial electrification of the heat and transport sectors is integrated into the analysis subsequently (see section 2) rather than being included at this stage.

Further demand reduction is possible

The Demand Reduction scenario is in line with the long-term trend shown in the European Climate Foundation’s Road Map 2050 study[4], but greater demand reductions may be feasible here in Scotland, and are certainly desirable. The UK Committee on Climate Change (CCC) anticipates significantly more rapid demand reductions for the UK (20% by *2020* and 46% by 2050)[5]. The Scottish Government’s energy efficiency action plan also sets a more ambitious goal of an absolute reduction of 12% across all energy sectors by *2020* (on 2005-7 levels).

3 A deliberately conservative Demand Reduction scenario has been chosen, in order to avoid the conclusions of this study being seen as entirely due to dramatic demand reduction assumptions.

4 A 29% reduction for all of Europe by 2050.

5 Compared with 2007 levels. The latter figure has been extrapolated from CCC assumptions in University of Surrey and Imperial College London (March 2010), *Building a road map for heat*, March 2010, http://www.chpa.co.uk/building-a-roadmap-for-heat---2050-scenarios-and-heat-delivery-in-the-uk_161.html

The potential for reducing peak demand

The above figures are for annual electricity consumption. It is important also to consider peak electricity demand, as a measure of the maximum level of electricity generation or interconnection capacity that must be available for security. Peak demand is also currently disproportionately met by high carbon generation.

One way to smooth out the peaks and troughs in energy demand, and thereby contribute to 'security of supply', is through increasing the scale of 'deferrable' or interruptible demand - electricity usage which can be shifted in time by a few hours.

'Smart meters' will be installed in domestic and commercial premises across the UK by 2020. These will have the capability to communicate electricity price signals to electricity-consuming devices, such as freezers or washing machines, so that they vary the level and timing of power consumption to deliver the required services, according to availability on the grid.

The effect on peaks will likely be very significant. Smart metering may also help reduce overall household energy use, and enable more effective delivery of social tariffs to help address fuel poverty.

Electrification of the transport and heat sectors could also contribute to security of supply by offering deferrable demand and energy storage potential: this is discussed in Section 2.

However, as we shall see in Section 4, even if peak demand remains unchanged, Scotland will be able to achieve secure supply with a high level of renewable generation. Any reduction in peak demand achieved through the measures described here will simply make the task easier.

2. Electrification of heat and transport

Heating and transport together account for roughly 80% of Scotland's energy use[6].

Using low carbon electricity to heat our buildings and power our vehicles, instead of oil and gas, would cut carbon emissions dramatically.

With a modest increase in our total electricity demand (of no more than 20-25%), it would be possible to achieve substantial decarbonisation of the transport and heat sectors in line with Scottish targets, and contribute to the overall security of the system, through increased deferrable demand and heat storage.

Transport

To assess likely demand for electricity from transport we have used existing passenger traffic scenarios[7], which calculate the levels of electrification needed to achieve 70% emissions reductions in passenger car traffic by 2030[8]. (This is equivalent to around a 40% emissions reduction in the surface transport sector as a whole).

If traffic is allowed to grow in line with Government forecasts to 2020, all internal combustion engine (ICE) vehicles must be replaced with hybrid or electric vehicles (EVs) by 2030 in order to meet the target emissions reduction. This would require almost 3,800GWh of electricity annually equivalent to 11% of the total in the 'demand reduction' case set out above.

By contrast, if a goal of stabilising total car km at 2001 levels by 2021 is attained, and ICE efficiencies improve to the extent that the UK Committee on Climate Change forecasts, then the numbers of battery electric and plug-in hybrid numbers need only grow to make up 17.9% and 42.9% of the car population respectively by 2030, requiring 1,700GWh, or 5% of total consumption.

The difference between the two scenarios clearly highlights the fact that reducing the total distance traveled by car is the key to reducing transport emissions cost-effectively.

6 AEA Technology (2006), *Scottish Energy Study: Volume 1: Energy in Scotland: Supply and Demand,* for the Scottish Executive. This breaks down energy use in 2002 as 54% heat, 27% transport fuel and 19% electricity.

7 WWF Scotland (2010), *Watt Car*, based on work by Element Energy, available at: http://scotland.wwf.org.uk/what_we_do/tackling_climate_change/electric_vehicles/

8 This figure is in line with the emissions reduction required from the entire transport sector described by the Scottish Government, June 2009, *Scottish Climate Change Delivery Plan (CCDP)*. The calculations assume a grid intensity of 193 gCO2/kWh in 2020 and 80gCO2/kWh

Electric Cars as energy stores

A further benefit of phasing in the use of electric vehicles is that, when connected up to their charging supplies, EVs could help to smooth the peaks and troughs in demand: the charging process can be deferred by several hours if demand is high, and with expected improvements in battery technology it will be possible for energy to be drawn from the batteries to help cope with temporary shortages of generation. Moreover, vehicle batteries are likely to be charged overnight, when renewable electricity supply can be expected to exceed demand.

The theoretical storage capacity of EVs in Scotland is estimated to lie in the range of 19-32GWh depending on the degree of traffic growth. For comparison, Cruachan pumped storage facility has a total stored energy capacity of 10GWh. Whilst typically only a small fraction of this full amount can be expected to be available at any given time, nonetheless the storage capacity of EVs in the 2020s could be a very useful adjunct to pumped storage.

It should also be noted that the running cost of EVs are significantly lower than the running costs of ICE vehicles.

Heating

If gas and oil prices rise, and if domestic and public buildings are better insulated, it is possible that electricity could be used extensively for heating, purely on economic grounds. However, in this study, to give a guide as to the additional electricity demand that could be created through electrification of heating, it is assumed – in line with existing Scottish government targets - that just 11% of heat demand will be met by renewable sources by 2020, increasing to 40% by 2030[9].

Using electric heat pumps to contribute to the renewable heat target in this way would increase Scottish gross electricity consumption in 2030 by about 14% and would cut carbon emissions from heat by up to 60%[10].

Electricity from heat pumps would be deferrable over periods of hours, thus helping manage daily peak demand. Given improved levels of insulation in line with energy saving targets, in winter there could be at least several hundred megawatts of deferrable electric heating demand in Scottish homes.

This is because, with very well-insulated buildings or hot water systems, it is possible that cooling times will be long enough to match the longer-term weather-related variations in output of wind and wave plant[11], allowing heating use to contribute to deferrable demand over a period of days. The benefits of having deferrable demand capable of contributing on these timescales are potentially great, and this issue merits further detailed study in a Scottish context.

9 40% is assumed here as a reasonable interpretation of the target set out in the Scottish Climate Change Delivery Plan of 'significant progress' towards large-scale decarbonisation by 2030.

10 This assumes electricity supply is decarbonised, and heat demand falls in line with Europe-wide estimates produced for the ECF Roadmap 2050, such that total demand in 2030 is 37,500GWh. Meeting 40% of this (15,000GWh-thermal) with heatpumps (assumed to operate at only a 3x coefficient of performance in Scottish conditions) would require 5,000GWh-electrical. The combined reduction in carbon emissions from heat resulting from demand reduction and electrification is estimated at 60%.

11 DECC suggests that domestic space heating could be time-shifted by up to 12 hours in well-insulated houses, and water heating by up to 24 hours. DECC, July 2010, *2050 Pathways Analysis*. www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/2050/2050.aspx

Anaerobic Digestion as a renewable heat source

Another way to increase the contribution of renewables to heat energy is to use biogas from anaerobic digestion (AD) plants. This gas could be injected into the gas grid or used locally, reducing the contribution required from renewable electricity to meet overall renewable energy targets[12]. This could be very significant in scale. The National Grid has suggested that 18.5 billion cubic metres of biogas could be produced by 2020 in the UK (equivalent to 48% of forecast residential demand or 18% of total UK demand).

Although AD has not been included in the renewable generation scenarios, it could also be used to produce electricity, most logically as part of Combined Heat and Power (CHP) schemes, which make efficient use of the excess heat generated.

Flexible use of Combined Heat and Power[13]

CHP systems – however fuelled - also offer another opportunity to manage variability in electricity supply if developed alongside heat storage. In Denmark, which has a very high level of CHP district heating systems, heat storage has been identified as an important measure to allow high integration of wind energy.

Adding centralised heat storage to these systems allows the CHP stations to prioritise electricity production over heat production when there is low wind, and would allow surplus electricity production from wind generation at other times to be used to charge the heat stores, using heat pumps.

While there are not yet extensive district heating networks in Scotland, 'package' CHP systems for individual buildings, incorporating heat storage, could also be used in this way without the need for heating networks.

12 See National Grid (January 2009), *The potential for Renewable Gas in the UK*, available at http://www.nationalgrid.com/NR/rdonlyres/9122AEBA-5E50-43CA-81E5-8FD98C2CA4EC/32182/renewablegasWPfinal1.pdf

13 CHP schemes supply the heat produced by thermal electricity generation to industry or space heating. Depending on design, the ratio of heat output to electricity output can be varied at will.

3. The Renewable Future

For this study, two scenarios for growth in renewable generation have been developed, as credible potential lower and upper bounds on what may be achieved[14]. Comparing these with the two electricity demand scenarios already outlined, shows that renewable production could significantly exceed our annual electricity consumption by 2020. Even allowing for extra electricity demand from the heat and transport sectors, electricity exports could be increased significantly by 2030.

Table 1: A breakdown of the Low and High Renewables Scenarios

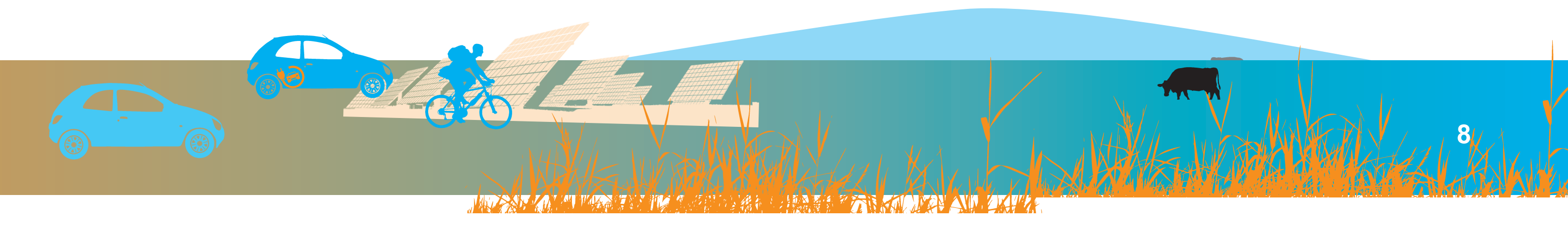
	Current	Low Renewables	High Renewables
Onshore Wind	1918MW	6738MW (achieved by 2020) Projects already approved, and 20% of projects at planning, appeal or scoping stage go ahead (compared to 66% historically). The aggregate capacity factor* is assumed to fall from 35% to 27%.	7500MW (achieved by 2020) Assumes a 26% success rate, and a growth rate of 360MW per year. The aggregate capacity factor is assumed to fall from 35% to 27%.
Offshore Wind	180MW	3000MW (achieved by 2020) Assumed capacity factor of 39%	7000MW (achieved by 2024) 5000MW installed between 2015 and 2020, then slower expansion
Hydro	1387MW	2200MW (achieved by 2030) Based on a growth rate of roughly 50MW per year starting in 2017	2500MW (achieved by 2030) Based on a growth rate of 50MW per year from 2011
Wave and Tidal	Negligible	1260MW (achieved by 2023) Comes online from 2020 and grows until 2023 (based on projects already in development). Capacity factor of 30% for wave, 35% for tidal.	2520MW, of which 1320MW is tidal (achieved by by 2024) Comes online from 2016 and grows more rapidly to 2024. Capacity factor of 30% for wave plus 35% for tidal.
Biomass**	79MW	355MW (achieved by 2018) Projects already approved, and 40% of projects at planning, appeal or scoping stage go ahead	1030MW (achieved by 2030) Growth of 50MW per year from 2014, with no constraints to supply of biomass
Energy from Waste***	100MW	125MW (achieved by 2015) Growth rate of 5MW per year	150MW (achieved by 2020) Growth rate of 5MW per year

* The capacity factor is a measure of the proportion of the notional total generation capacity that is utilised in practice to generate electricity. For renewable sources it typically reflects the proportion of time the resource (wind, waves, tides) is available.

** In order to be considered sustainable, feedstocks for biomass projects must be sourced from local and well-managed forests. See page 11.

*** FoES, WWF and RSPB only consider some forms of energy from waste (such as anaerobic digestion) to be 'renewable'. In accord with industry practice however, these scenarios include all forms.

14 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



In the **Low Renewables Scenario** renewables continue to expand, though at a relatively conservative rate, roughly in line with current build rates. The **High Renewables Scenario** assumes more optimistic consent and build rates more in line with current industry and government aspirations. Figures 1 and 2 opposite show the forecast levels of electricity generation to 2030 in the two scenarios.

Thermal generation in the scenarios

In the Low Renewables scenario, Longannet, Peterhead and Fife CCGT are assumed to continue in operation[15], and for the purposes of the scenario, the proposed new coal plant at Hunterston is assumed to commence operation in 2018[16],[17]. The 'gas turbines and oil' category, which is understood to contain mainly standby generators, is assumed to continue unchanged, except that in 2019 projects totalling 500 MW are added in line with National Grid expectations.

In both scenarios Cockenzie, Hunterston B and Torness are assumed to close at the end of 2015, 2016 and 2023 respectively.

In the High Renewables scenario no new or replacement thermal capacity is added. The likely capacity factors of the remaining thermal plant are considered under section 6.

Microgeneration

As a conservative estimate, no electricity supply from microgeneration has been included in this analysis. In practice, with the benefits of feed-in-tariffs (FITs) and the renewable heat incentive, community and household microgeneration projects can be expected to make a significant contribution to both overall supply, and security.

Based on estimates by the Energy Saving Trust (EST)[18] microgeneration in Scotland could supply 7TWh of electricity annually by 2030, equivalent to 15% of total demand in the demand growth scenario. In Germany, FITs have already stimulated more than 500,000 solar photovoltaic installations, generating more than 10TWh of electricity each year[19] Microgeneration projects can also deliver additional positive impacts in terms of heightened energy efficiency awareness and economic benefits for the local area.

15 Longannet is 2400MW capacity, and Fife (Cardenden) 123MW. The Peterhead plant (1840MW capacity) is assumed to be indefinitely limited to 1180MW by grid restrictions.

16 The scenarios include 1600MW capacity for this plant, although subsequent to the analysis commencing, the formal application raised the capacity to 1852MW (albeit with a 100MW parasitic load for the proposed CCS demonstration).

17 As with all specific developments mentioned, inclusion in the scenarios cannot be taken to imply any endorsement of the development by FoES, WWF or RSPB. In this case all these groups explicitly oppose the Hunterston coal development, but believed it would be interesting to include a new development in the modelling exercise to better understand whether there is any need for one, and what its impacts on the wider system might be.

18 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.

19 Based on industry estimates reported at http://www.renewableenergyworld.com/rea/news/article/2010/10/germany-adds-nearly-1-of-electricity-supply-with-solar-in-eight-months

Figure 1: Annual electricity production, Low Renewables scenario

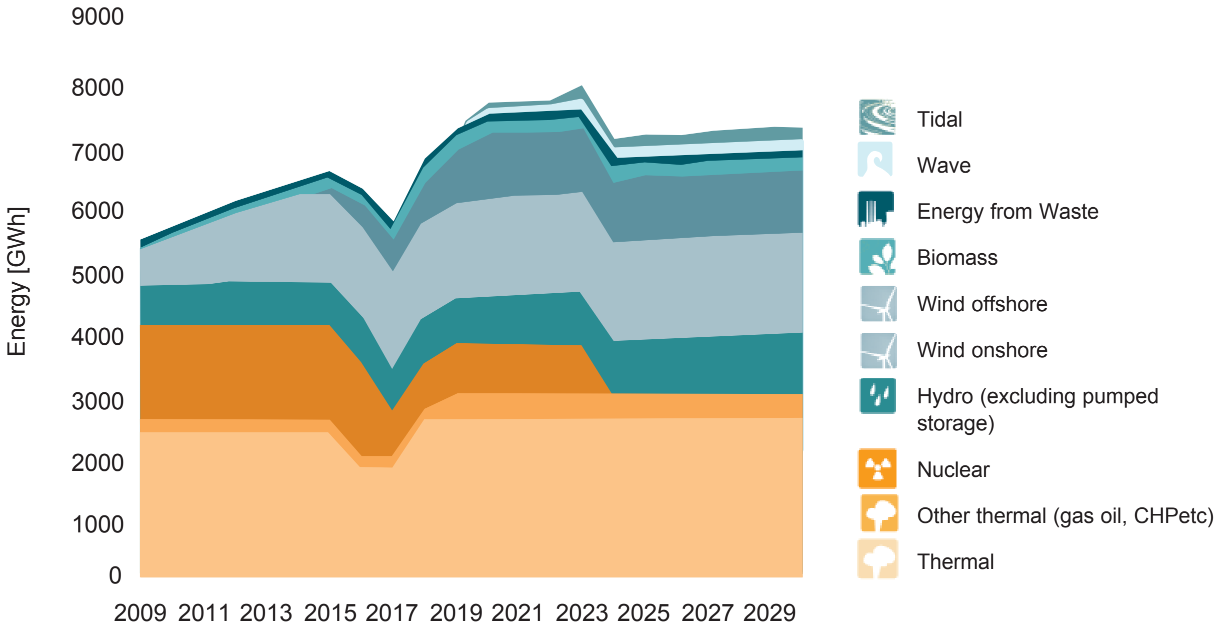
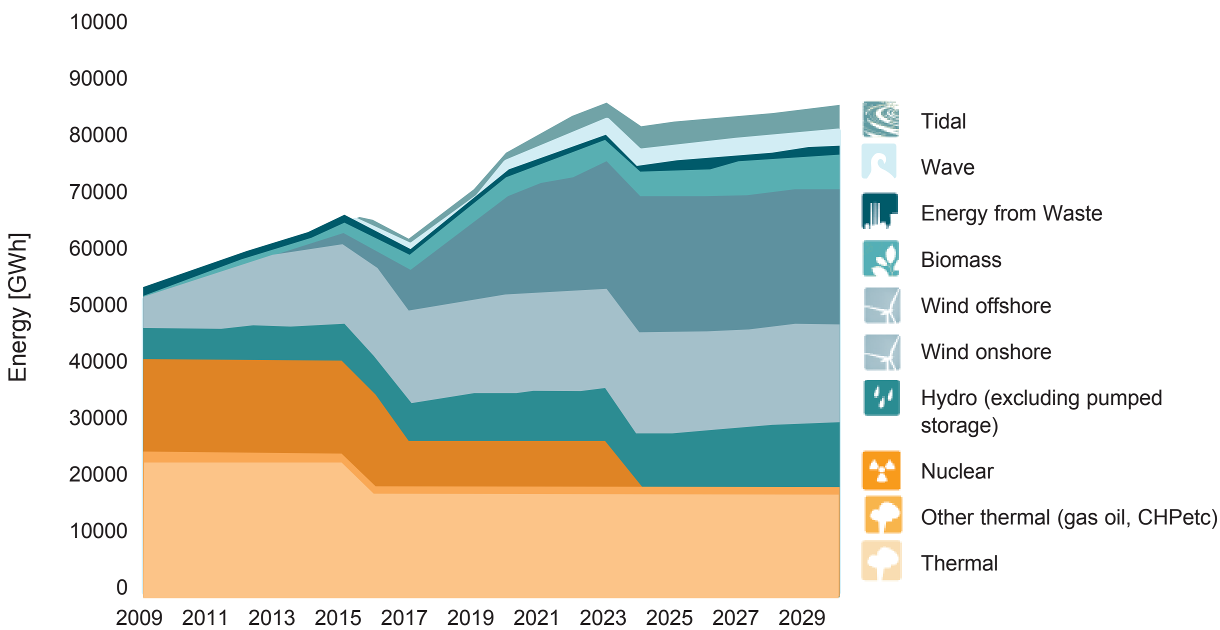


Figure 2: Annual electricity production, High Renewables scenario[20]



20 The dips in energy production in 2016 and 2017, as shown in Figures 1 and 2, do not represent a technical problem, since Scottish electricity consumption is much lower than production, much of which is exported. The 'dips' are insignificant in the context of electricity supply for the entire GB system.

Sustainable renewables

Both scenarios allow for constraints on wind, wave and tidal projects to ensure protection of nationally and internationally designated landscapes and habitats. Limits on the availability of waste for energy use have also been considered, and a limit on sustainable supply of biomass is included in the low renewables scenario.

However, the constraints to the supply of resources for biomass or energy from waste may be more limiting than foreseen in the scenarios. In order to be considered a sustainable, or indeed 'renewable' resource, feedstocks for biomass projects must be sourced 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.

The most logical use of Scottish biomass is for small-scale heating or CHP systems sized according to the local heat demand. Similarly, the most sustainable methods of waste management are reduction and recycling. Feedstocks for energy from waste plants should decline as a result of Scotland's Zero Waste aspirations. Energy is better recovered from green wastes through anaerobic digestion.

However the relative levels of generation from biomass and energy from waste in the scenarios are very small. Even if sustainability constraints reduce such capacity substantially it would not alter the general conclusions of this study.

Scope to meet annual demand

Even in the most pessimistic case shown in the tables opposite (Low Renewables generation, combined with Demand Growth), renewables production in 2030 is 89% of gross consumption. In all other cases, renewables production exceeds 100% of gross consumption, achieving decarbonisation of consumption.

Virtual decarbonisation of electricity *supply* could be achieved if all remaining large scale fossil fuelled generation were closed down by 2030, or were fully fitted with carbon capture and storage technology[21]. Section 4 considers the interconnectivity and energy storage capacity that would be needed to deliver security of supply in this context.

Figure 3 and table 4 overleaf shows that substantial electrification of heat and transport can be easily accommodated within the higher renewables case, and is even possible with low renewables as long as demand management is also actively pursued. The figures emphasise the importance of demand management in all forms of energy consumption, and imply that to both maximise the opportunities for decarbonisation of all energy supply in Scotland and to enable a significant level of renewable export, we should activity pursue the higher renewable case.

21 This, of course, depends upon CCS technology proving both technically effective and economically feasible, which is by no means given.

Table 2: Results for electricity production, consumption and export in 2030

Renewables production as % of gross consumption	**Low Renewables, Demand Growth**	**High Renewables, Demand Growth**	**Low Renewables, Demand Reduction**	**High Renewables, Demand Reduction**
Total generation capacity	21,388 MW	26,308 MW	21,388 MW	26,308 MW
Fossil, nuclear and pumped storage capacity	*7,707 MW (36%)*	*5,607 MW (21%)*	*7,707 MW (36%)*	*5,607 MW (21%)*
Renewables generation capacity	*13,681 MW (64%)*	*20,701 MW (79%)*	*13,681 MW (64%)*	*20,701 MW (79%)*
Total electricity production	71,815 GWh	86,174 GWh	71,815 GWh	86,174 GWh
*Fossil, nuclear and pumped storage production**	*30,955 GWh (43%)*	*20,837 GWh (24%)*	*30,955 GWh (43%)*	*20,837 GWh (24%)*
Renewables production	*40,860 GWh (57 %)*	*65,337 GWh (76%)*	*40,860 GWh (57 %)*	*65,337 GWh (76%)*
Gross consumption**	46,049 GWh	46,049 GWh	35,316 GWh	35,316 GWh
Potential Net export	25,766 GWh	40,125 GWh	36,499 GWh	50,858 GWh
Net export (% of total production)	36%	47%	51%	59%
Year	**89%**	**142%**	**116%**	**185%**

* With high volumes of output from renewables generators, it is highly likely that (if they continue to generate) the coal, gas and nuclear generators will produce less than is estimated here. See page18.

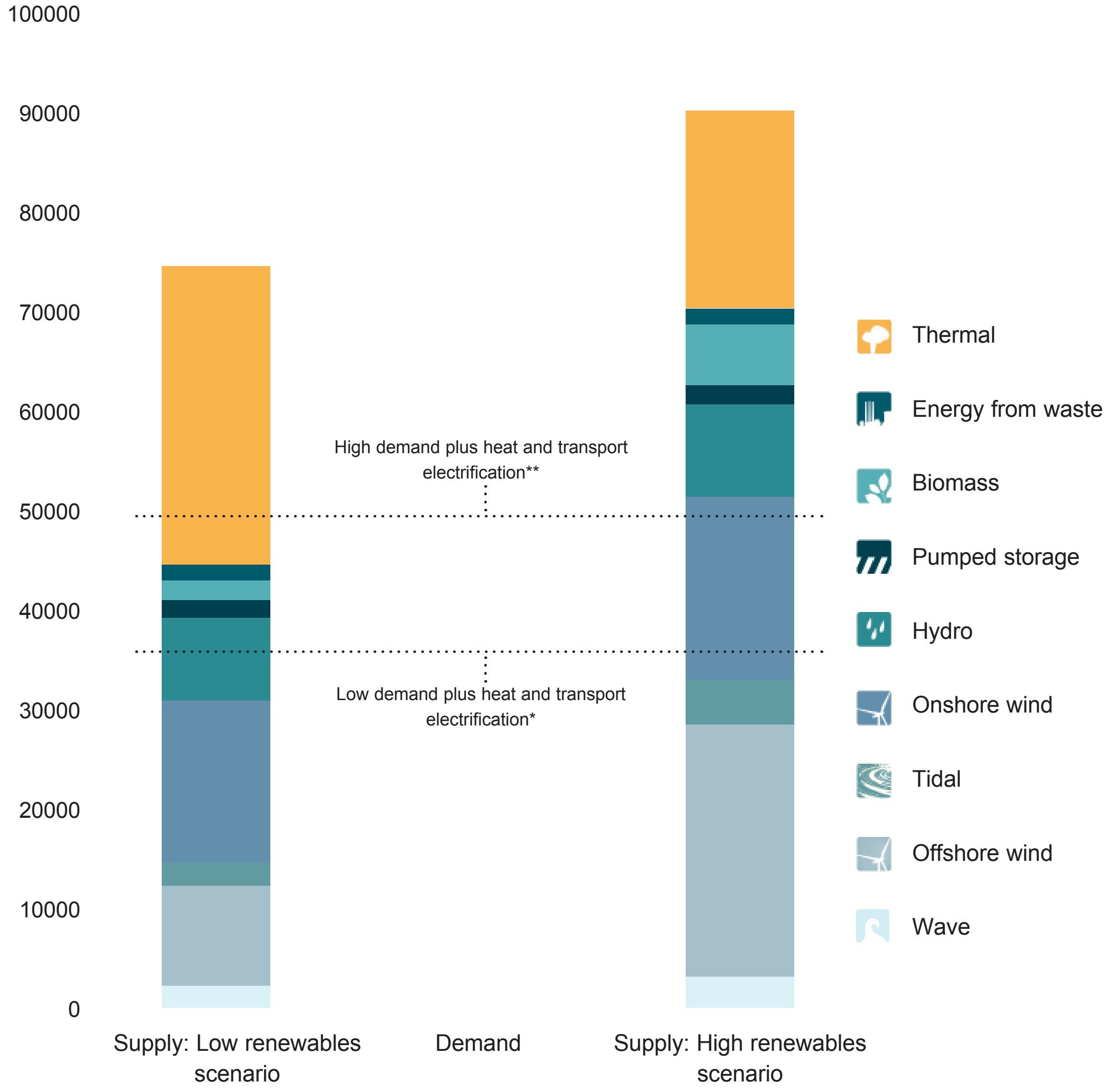
** A small correction has been added to the Gross Consumption figure in order to allow for the increased energy consumption for pumping caused by the increased Pumped Storage capacity.

Table 3: Renewables production: growth between 2010 and 2030

	Renewables Production as % of gross consumption			
Year	**Low Renewables, Demand Growth**	**High Renewables, Demand Growth**	**Low Renewables, Demand Reduction**	**High Renewables, Demand Reduction**
2010	33%	33%	33%	33%
2015	53%	57%	57%	62%
2020	83%	112%	96%	130%
2025	88%	139%	108%	171%
2030	89%	142%	116%	185%

Figure 3: Electricity supply 2030, compared with demand scenarios

Figure 3 graphically contrasts the generation scenarios for 2030, showing how renewable supply exceeds likely demand



* In the low demand scenario we include the lower transport electrification figures based on traffic management (1700GWh).

** In the high demand case we include the higher transport electrification figure based on traffic growth (3800GWh).

Table 4: The effects of extra demand for renewable electricity in heat and transport in 2030

	Renewables production as % of gross consumption	
	low renewables case	**high renewables case**
Low demand base case	116%	185%
Low demand plus electrification of heat and transport*	97%	156%
High demand base case	89%	142%
High demand plus electrification of heat and transport**	74%	119%

* In the low demand scenarios we include the lower transport electrification figures based on traffic management (1700GWh).

** In the high demand cases we include the higher transport electrification figure based on traffic growth (3800GWh).

Exports and interconnection

The above scenarios see Scotland becoming a major exporter of electricity – a role that would have economic and employment benefits for Scotland, as well as helping the rest of the UK to meet its renewables obligations. With high renewables development, and demand reduction offsetting increased use of electricity for heat and transport, electricity exports would increase from less than 13,000GWh now, to over 20,000GWh in 2030 even if all non-renewable generation were closed down.

The European Climate Foundation's (ECF) Roadmap 2050 study[22] found that substantial transmission system reinforcement and interconnection infrastructure was economically justified to allow long-distance transmission of the electricity from variable renewable sources like wind, solar and hydro; and transmission costs in these cases formed a relatively small part of the total cost to consumers.

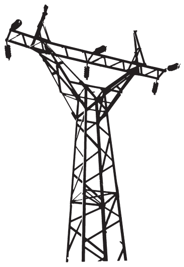
The study also concluded that with such interconnection, a future European energy system with a generation baseload comprising 100% renewable energy was technically feasible, no less secure and only around 10% more expensive than other pathways to decarbonise the power sector.

In practice, export levels from Scotland are likely to be somewhat constrained by transmission capacity. There is unlikely to be an economic case to install transmission capacity capable of exporting all surplus electricity when renewable production is at a maximum, and consumption at a minimum in Scotland. Such circumstances would be too infrequent to justify that level of investment. However the level of transmission capacity which is economically justified by export potential is likely to reach 15-20,000 MW in the Low Renewables case, and 20-25,000 MW in the High Renewables case. As shown below, in section 4, this will be well in excess of what is needed for system security.

A logical next step for Scotland is to understand the economics of interconnections for export of renewables production, especially to Norway, the Netherlands and Germany.

22 European Climate Foundation (April 2010), *Roadmap 2050: A Practical Guide to a Prosperous, Low-Carbon Europe,* http://www.roadmap2050.eu/downloads. See Executive Summary to Volume 1.

4. System Security



This section considers alternative scenarios for achieving reliability of electricity supply in the context of a 100% renewable energy production.

There are four main ways to provide or contribute to 'security of supply':

1) Backup

Backup generation is generation available to start (or to increase its output) at will, on various timescales. True 'backup' generation such as standby diesel generators, or open-cycle gas turbines typically has low capital, but high running costs, and runs only in rare circumstances[23]. Other conventional generation capacity may also provide a back-up function[24].

2) Deferrable 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. There is growing potential to increase the amount of electricity demand which is deferrable as outlined in section 2.

3) Energy storage

In Scotland, the main opportunities to store energy in forms that can then be turned back into electricity are pumped storage, and electric vehicles. *Scottish and Southern Energy* are already developing schemes for new pumped storage plant[25].

4) Interconnection

Interconnection between systems can help increase security of supply in three ways:

Sharing reserve: failures of major generators on interconnected systems are unlikely to occur simultaneously, so interconnection provides backup for both systems.

Smoothing demand: demand peaks in northern Europe in winter occur in late afternoons, for example, so the peak in Germany occurs before those in the Netherlands and France.

Smoothing supply: with variable renewables, interconnection also allows the variability to be 'smoothed' over a larger geographical area and wider mix of renewable sources.

23 For example simultaneous high electricity demand, low renewables production, and perhaps also failure of some conventional generation.

24 The ECF study found that in a well interconnected European energy system with a 100% renewable energy base, up to 270GW of backup generation would be required (about 15% of total generating capacity) but it would operate with a load factor (i.e. a utilisation rate) of no more than 8%.

25 And for conversion of an existing hydro station to provide additional pumped storage capability

The optimum solution for Scotland will contain some elements of deferrable demand and energy storage, but interconnection is likely to provide the greatest contribution to a secure electricity supply with high renewables penetration[26].

As noted above, the transmission capacity which is economically justified for export is at least 15,000 MW. The scenarios below show that this is well in excess of what will be needed for system security. Increasing the interconnection[27] capacity to around 8-10,000 MW (from the 4,000 MW existing or already under development) would comfortably allow all coal, gas and nuclear generation in Scotland to be closed without threatening security of supply. This assumes that, at times of very low renewables production Scotland would import electricity from England and Wales, or elsewhere in Europe[28].

Further connections from Scotland to other European systems may be justified at high renewables penetrations for export purposes, but are not essential to provide a secure system.

While the cost of interconnection and other means of dealing with high volumes of variable renewables is large in absolute terms, it has a very small impact on overall consumer electricity prices. With high fuel and carbon costs such decarbonised pathways provide cheaper electricity[29].

Interconnection Scenarios

Electricity supply for Scotland can be considered 'secure' if peak demand can still be met, assuming concurrent failure of the two largest elements of interconnection capacity, *combined* with zero output from onshore wind, offshore wind, wave generation, run-off river hydro, and tidal[30] over a multi-day period.Table 4 shows three different highly conservative interconnection cases, ranging to as little as one-third of the capacity that could be justified by exports. The cases are based on the total 4000 MW interconnection capacity planned for 2014/15, plus a number of additional 1,800 MW HVDC connections, as intended for the planned west and east coast subsea connections[31].

For each case, the last column shows the generation that would be required in Scotland in order to ensure peak demand is still met. This generation is assumed to be made up of pumped storage, reservoir hydro, biomass and energy from waste plants, which together already total around 2,300MW capacity. If two further 600 MW pumped storage sites are developed this would bring the total generation capacity to 3500MW which, as the table below shows, is in excess of the output that would be required in all three scenarios.

It is assumed here – also very conservatively - that peak demand remains effectively unchanged to 2030, in line with National Grid forecasts. In practice, with demand reduction measures and greater use of deferrable demand as set out in section 2 above, peak demand could decrease significantly, making the objective of system security much cheaper and easier to achieve.

26 Generation and transmission in Scotland is effectively part of the GB system, and all formal assessments of system security have to be done on this basis. Providing a secure electricity system in Scotland without considering the connections to the rest of the GB system would be possible, but would result in a significantly more expensive system.

27 Technically much of what is considered here is not interconnection, as the term refers to linkages between systems, while the GB grid is designed and operated a single system. The connections discussed here are technically just reinforcements to the GB transmission system.

28 Cold, clear weather in winter would be most likely to necessitate import of electricity. Estimates suggest several such events a year, reaching 10-20% of the year.

29 The ECF Roadmap study found that with carbon prices above €20-30 per tonne, or fuel costs increasing faster than the baseline projection of 1% pa, decarbonised pathways resulted in lower levelised costs of electricity.

30 The contribution from tidal would only be zero if the other failures also coincided with the time of slack water for all tidal capacity.

31 The interconnection with Northern Ireland is ignored in this discussion, assuming that if Scotland is short of generation due to low output from renewables, Ireland may well be in the same position.

Table 5: Effect of low interconnection capacity on generation required within Scotland

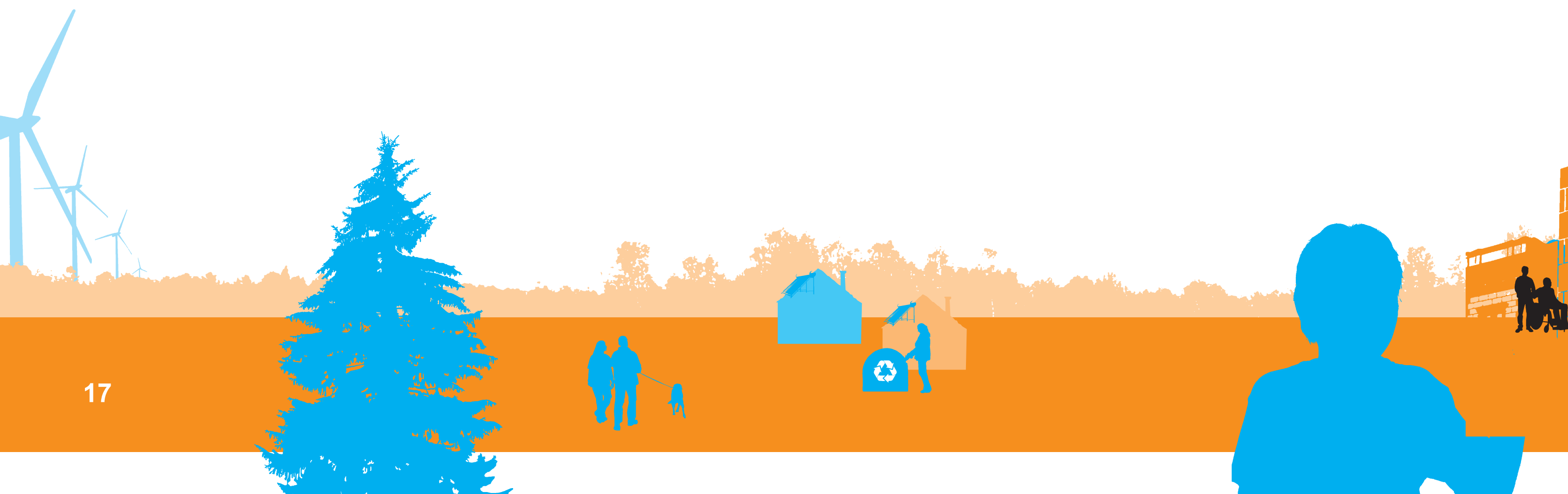
Case	Total interconnection capacity [MW]	Interconnection capacity assuming failures of two largest elements [MW]	Peak demand [MW]	Required output of generation in Scotland [MW]
1	9,400	5,800	6,000	200
2	7,600	4,000	6,000	2,000
3	5,800	~3,000	6,000	3,000

Case 1 is secure, as long as the combined Great Britain system remains secure. This case includes the planned west and east coast subsea interconnectors (each 1,800MW), and a further unspecified interconnector of the same size. Even with the loss of the two largest interconnections, it is only necessary to be able to generate around 200 MW within Scotland at the time of peak demand. This could be met three times over by *existing* pumped storage plant, recharged overnight.

Case 2 assumes only the east and west coast interconnectors are added. In this case, at the time of peak demand, it is necessary to be able to generate around 2,000 MW within Scotland. Current pumped storage capacity is 740 MW, but there are proposals for a further 2 x 600 MW. With *existing* reservoir hydro, biomass and energy from waste, this option can also be considered secure.

Case 3 assumes only the planned west coast interconnector is added. In this case, at the time of peak demand, it is necessary to be able to generate around 3,000 MW within Scotland. If pumped storage capacity is increased to 1,940 MW as proposed, this option may also be secure, but detailed study of possible causes of concurrent 'failure' of some of the pumped storage, reservoir hydro, biomass and energy from waste plants would probably be necessary. A substantial amount of deferrable demand would also be of assistance.

In each case the pumped storage capacity would need to be recharged overnight when electricity surpluses could be assumed to exist in the interconnected systems.



The future of thermal generation

In practice, even if no new thermal capacity is added to the Scottish system, existing capacity will continue to operate for some time. This section considers the implications for such capacity in a high-renewables future.

Competition for interconnection

As more variable renewables are added, it is very likely that the operating capacity factors of fossil and nuclear generating plants in Great Britain will fall[32]. The effect is likely to be more extreme in Scotland, as so much of the output is likely to be exported south, and interconnection capacity is likely to cause constraints for economic reasons. It is much more likely that thermal generation will be constrained (because at least the fuel costs are saved) than wind, wave, tidal or run-of-river hydro (where in contrast the 'fuel' is effectively wasted).

If the capacity factor of a fossil or nuclear plant declines sufficiently, it will eventually be closed on economic grounds, unless it can remain economic as a 'peaking' plant (i.e. running only at the times of highest electricity prices), or if it receives payment for providing other services such as backup.

Early closure of existing power stations will become even more likely if the proposed Hunterston coal plant or the Cockenzie gas plant proceeds. Under these circumstances, the most likely candidate for closure is Longannet.. As will be shown below this would undermine ambitions for Scotland to contribute in a timely and effective way to the development of carbon capture and storage (CCS) technology.

32 i.e. the plant will operate less frequently, or at a lower percentage of its maximum capacity.

Towards a rational Carbon Capture and Storage (CCS) policy

As demonstrated in this report, in the medium to long term there is no need to rely on coal for our energy security. Similar conclusions have been reached for electricity systems elsewhere in the world. However, the potential value of CCS for accelerating decarbonisation in countries such as China means that as a good global citizen, Scotland should seek to contribute to overcoming the considerable risks and uncertainties surrounding the technical and economic feasibility of CSS.

In particular, Scotland has the scope with the existing infrastructure and skills in the North Sea, to demonstrate progress and develop exportable expertise in the transport and storage parts of the CCS chain. However, to achieve this does not require new fossil-fired power stations, but can be done, and more quickly, with a trial of retrofit CCS on an *existing* power station, as proposed at Longannet[33]. There are also sound arguments that globally, demonstrating the commercial and technical viability of *retrofit* CCS will make most difference to cumulative emissions[34].

CCS should not be used to justify the building of new coal-fired power stations and Scotland should not rely on this as yet untested technology to meet carbon reduction targets. However, support for retrofit demonstration projects, especially on plants likely to continue operating in the 2020s – such as Longannet and Peterhead – is clearly desirable.

33 In fact Longannet is now the only contender left in the UK competition for CCS demonstration funding, but the plan may not go ahead if the plant has an uncertain economic future over the coming decade as a result of excess thermal capacity on the Scottish system.

34 Palle Bendsen and Kim Ejlertsen (2010), *An assessment of cumulative CO2 reductions from carbon capture and storage at coal fuelled plants in a carbon constrained world*, NOAH Friends of the Earth Denmark, available at http://ccs-info.org/cumulative_co2.pdf; See also Chalmers, H., J. Gibbins and M. Lucquiaud (2009) "Retrofitting CO2 capture to existing power plants as a fast track climate mitigation strategy" in *Proceedings of ASME 3rd International Conference on Energy Sustainability*, San Francisco, USA, July 2009.

5. Conclusions

1. **Without endangering important environmental interests,** renewable electricity generation in Scotland can grow to comfortably exceed our electricity needs, bring in substantial export revenue, and allow for significant electrification of heat and transport sectors.

2. **By 2020, renewables could be providing over 100%** of Scotland's electricity needs, and 185% by 2030. By combining this level of renewable electricity production with moderate efficiency measures, Scotland could decarbonise at least 50% of our total energy needs by 2030.

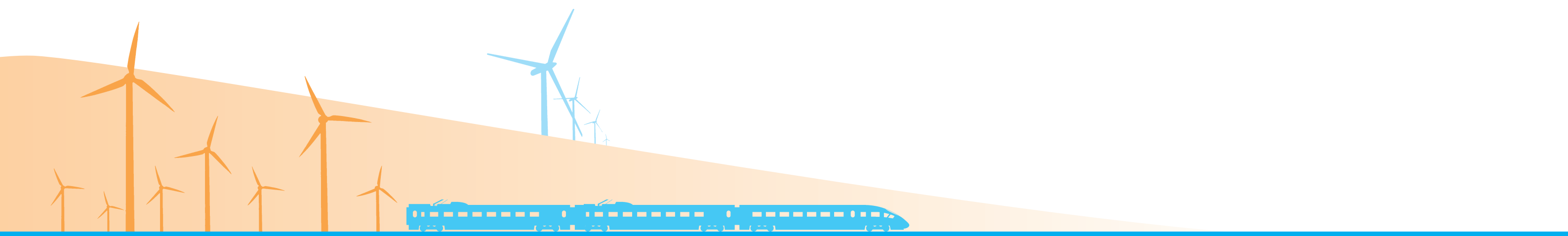
3. **With improved interconnection and moderate investments** in storage and deferrable demand, it would be possible to phase out all conventional thermal generation capacity in Scotland by 2030 and still deliver a secure and reliable electricity supply.

4. **The interconnection capacity required for a secure electricity system** is two to three times smaller than the interconnection capacity which would be economically justified by the value of electricity exports.

5. **The overall costs of such a system are comparable** to those in business as usual approaches. In fact, with significant electrification of heat and transport, overall household 'triple fuel' bills could be lower than in conventional scenarios.

6. **Scotland does not need to risk** unnecessarily extending the lives of aging nuclear plants. Nor do we need to take the financial and climate risks of new coal plant. We can help commercialise carbon capture and storage through demonstrations on existing power stations.

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



Recommendations

In order to meet Scotland's widely lauded emissions reductions targets, it vital that the government put in place a coherent enabling policy framework to support the right development of renewable energy in the right places; to deliver demand management; and to provide the infrastructure which will ensure security of supply. In particular, we recommend the following ten steps:

Demand management

1. Aggressively pursue and exceed the energy-saving targets in the Energy Efficiency Action Plan – thus maximising the potential to deliver renewables targets ahead of schedule.

2. Raise target levels of ambition for renewable heat and power for transport in line with the availability of additional renewable electricity.

3. Ensure the rapid roll-out of smart metering in Scotland, and other infrastructure and technologies to maximise deferrable demand.

Securing the supply

1. Robustly pursue a fair UK grid charging regime for electricity which recognises the decentralised nature of renewable generation.

2. Support the further development of transmission capacity within, and from, Scotland to get Scotland's renewable electricity to other markets in the UK and the EU, including completion of Beauly-Denny and sub-sea connections on both the east and west coasts.

3. Encourage and approve additional proposals for large scale energy storage such as pumped storage.

The supply mix

1. Ensure a stable regime of financial support for renewable generation which rewards householders, communities and companies adequately to stimulate rapid deployment and commercialisation of existing and new technologies.

2. Set a deadline of 2030 for the achievement of a 100% renewable electricity generation mix in Scotland (not just 100% of Scottish consumption), delivering full decarbonisation of the Scottish electricity sector on schedule to meet our climate targets.

3. Establish a clear and rational policy for demonstration of carbon capture and storage (CCS) on existing generating plants (and non-energy sector carbon sources), rather than supporting the construction of new fossil fired power stations on the grounds that they might demonstrate CCS.

4. Reject proposals for new fossil-fired thermal capacity such as those at Hunterston and Cockenzie, and maintain opposition to new nuclear capacity or life extensions of existing nuclear stations.

We also recommend that the government undertake research into:

1. The economics of transmission connections between Scotland and Norway, the Netherlands and Germany for export;

2. The level of electric vehicle battery storage capacity that may become commercially available in Scotland;

3. Renewable heat options specifically for Scottish conditions, and the impact of heat pumps on peak demands; and

4. The economics of using building heat loads as deferrable demand over a period of days in a Scottish context.

Postscript

It is inevitable that there will be competition in the future between fossil fuel, nuclear and renewables industries for scarce resources, including interconnector capacity, finance and skilled labour. When faced with such investment decisions, policy makers should remember that renewables and efficiency are the best option for employment, for the environment and for long-term energy security.

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.

RSPB Scotland is part of the RSPB, the UK charity that speaks out for birds and wildlife, tackling the problems that threaten our environment. The Royal Society for the Protection of Birds (RSPB) is a registered charity: England and Wales number 207076, Scotland number SC037654

WWF Scotland is part of the largest environmental organisation in the world. WWF's global network is in action around the clock, working to find solutions to environmental problems to help people and nature. WWF-UK is aregistered charity number 1081247 and registered in Scotland number SC039593.

The Power of Scotland Secured is a summary of research conducted by GL Garrad Hassan.
The full technical report is available at
www.foe-scotland.org.uk/power-secured

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