*Energy and climate change: challenges and policies**

Final draft

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1. Introduction

Key Facts for infographic page

- Scotland set a target to reduce emissions by 80% (compared to 1990 levels) by 2050 and an interim target of 42% by 2020. The figure fell by 26.4% between 1990 and 2012
- Energy supply is the biggest source of emissions (30%), followed by transport (13%) and agriculture and related land uses (12%)
- Scotland's carbon footprint grew between 2009 and 2010 suggesting that Scotland's contribution to global warming is more than that accounted for by emissions only.
- Progress has been made towards 2020 renewables targets but there is still considerable way to go and uncertainty over their achievement.
- Nuclear and renewables respectively are the largest sources of electricity generation in Scotland.
- Fuel poverty and extreme fuel poverty are rising, as are fuel prices

As Cairncross (1955, p22) argued "Power, transport and communications are the nerves of modern industry and if they stop functioning, industry is immediately paralysed." This observation remains at least as valid today as it was in 1955. The biggest change since then has been recognition of the impact of energy use and economic activity on the world's environment. A particular concern is the contribution of carbon emissions generated by the burning of fossil fuels.

Energy policies around the world, including in the EU, the UK and Scotland, acknowledge the policy "trilemma" of: improving the environment; ensuring security of energy supply and enhancing energy affordability. The environmental goal reflects a desire to reduce carbon emissions and lower the threat of global warming. Security of supply is often expressed in terms of "keeping the lights on", although the phrase should be understood to include keeping communications and industry functioning. Affordability relates to the price of energy, which affects the ability of consumers to maintain a comfortable lifestyle and also industrial competitiveness.

Why are the three policy goals regarded as a *trilemma*? Essentially because they may be difficult to secure simultaneously: there are likely to be some trade-offs among them. For example, as we shall see, energy policy in Scotland has sought to encourage replacing traditional fossil-fuel technologies with renewables. This contributes to the environmental objective, but it also raises the cost of generating electricity – at least initially while renewable technologies are still in the development phase - and so adversely affects affordability. In fact the challenge for Governments is likely to be even greater than a consideration of the trilemma suggests, since they invariably have other, potentially conflicting, policy objectives. A primary one is economic growth.[1]

Over the long-run, economic growth significantly enhances living standards. However, increases in economic activity are typically associated with increased energy use and carbon emissions. While the recent prolonged recession proved an effective way of limiting emissions, few would recommend it as a means of achieving environmental objectives. Recognition of the environmental objective has led to an emphasis on growth that is *sustainable*: that is growth that is compatible with

[1] Fuel, and more generally energy, poverty is also a matter of concern to Governments, as is the social acceptability of some technologies/ potential energy developments.

the environmental objective (perhaps through the development and adoption of "green" technologies).[2]

A further objective of Scottish energy policy is to use the development of renewable energy (and particularly electricity) as a means of supporting growth: to "reindustrialise Scotland through renewables" (Scottish Government, 2011). The emphasis on the economic development potential of renewables has been greater in Scotland than in the UK as a whole because of the perceived natural advantage Scotland has as a source of wind and marine energy. Renewables appear to offer a way of overcoming the traditional trade-off between economic activity and the environment: in principle, increasing renewables promises simultaneously to increase economic activity whilst reducing emissions and possibly also improving security of supply by reducing dependence on imported fuels. So it is not surprising that one of the distinctive features of Scottish energy policy, since the creation of the Scottish Parliament in 1999, has been its promotion of renewables. Furthermore, successive Scottish Governments have also adopted a distinctive "no new nuclear" stance for electricity generation, effectively precluding one low-carbon source of electricity generation capable of providing base load electricity. However, Scotland's electricity system is fully integrated with that of the rest of GB, so that extensive trading occurs. Currently, Scotland is a significant net exporter of electricity on an annual basis, but this may change as fossil fuel and nuclear power stations come to the end of their useful lives.

Much of energy policy, including regulation, was reserved to Westminster in the original devolution settlement that established the Scottish Parliament in 1999. This limits the nature and number of energy policy instruments over which the Scottish Government has control. Furthermore, the implementation of the Scotland Act 2012 and the Scotland Act 2016 resultant from the Smith Commission include additional fiscal powers that might have important ramifications for some of the issues discussed here. In particular, the 2016 Act makes provision for transferring the responsibilities of the Crown Estates, which previously owned the waters around the Scottish shoreline, to the Scottish Government. This would involve transferring revenues from many offshore renewable developments (McHarg, 2015).

Additionally, it should be recognised that the UK is bound by EU energy policies. In particular, Scotland is committed to meeting its share of the UK's 20-20-20 targets for 2020: a 20% reduction in emissions (relative to 1990 levels); a 20% share of renewables in the overall energy mix (not simply the electricity generation mix); and a 20% cut in overall energy consumption though the promotion of energy efficiency improvements.[3]

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[2] This is quite distinct from *fiscal sustainability*, which refers to the feasibility of government maintaining the public sector deficits and debt levels implied by a given growth path.

[3] The 20% renewables target for the UK is interpreted as implying around a 30% target for renewables in the generation of electricity, given the likely constraints on renewable penetration of heat generation. The multi-level structure of governance is a further complicating feature in the energy domain. For example, reductions in emission in the sectors "covered" by EU ETS – which includes the power generation sector – do not contribute to the UK's emissions targets. However, reducing these emissions is important for de-carbonising the sector, and allowing reductions in emissions elsewhere, notably in transport and heating. (See e.g. McGregor and Swales (2013).

In subsequent sections of this paper we explore Scottish energy policy in some detail and assess how successful it has been in achieving its stated objectives.

2. Environment

Since the inception of climate change policy in the UK, its operation in Scotland has been devolved to the Scottish Government. This is reflected in the Scottish Climate Change Act (2009), in which Scotland is free to set its own targets. However, climate change is a global problem and the Scottish and UK Governments have willingly participated in a number of international initiatives including Kyoto and the EU's Emissions Trading Scheme (ETS).[4] We return to consider international agreements below, but for now focus on Scottish policy.

Scotland set a target to reduce emissions by 80% (compared to 1990 levels) by 2050 and an interim target of 42% by 2020.[5] The UK originally set a 60% reduction target for 2050 but this was increased to 80% in the Climate Change Act (2008) on the advice of the UK Climate Change Committee.

Figure 1 summarises the pattern of recent Scottish CO2 emissions ((millions of tons equivalent of, Mt CO2 e) and also indicates the 2020 and 2050 target levels.[6] Clearly there is a favourable downward trend in emissions. However, part of that reduction is accounted for by a shift in the structure of production away from manufacturing and in favour of services and was little to do with policy. Furthermore, in recent years emissions have been limited by the effects of the recession. Nevertheless, emissions have exceeded annual targets for every year since the Climate Change Act was passed.[7] For example, in 2013, the last year for which data are available (EU-ETS-adjusted) emissions fell from 57.8 to 49.7 MtCO2e, but the target for 2013 was to 48.0 MtCO2e. In general, this pattern could ultimately undermine the credibility of the Scottish Government's commitment to emissions, with a potentially adverse impact on private sector investment in low carbon technologies. However, without recent improvements to the measurement of emissions (which have increased estimated emissions significantly) the Climate Change Committee judge that it was likely Scotland would have met its targets. There is therefore no immediate threat to credibility, although further action is required for Scotland to meet its 42% target for 2020.

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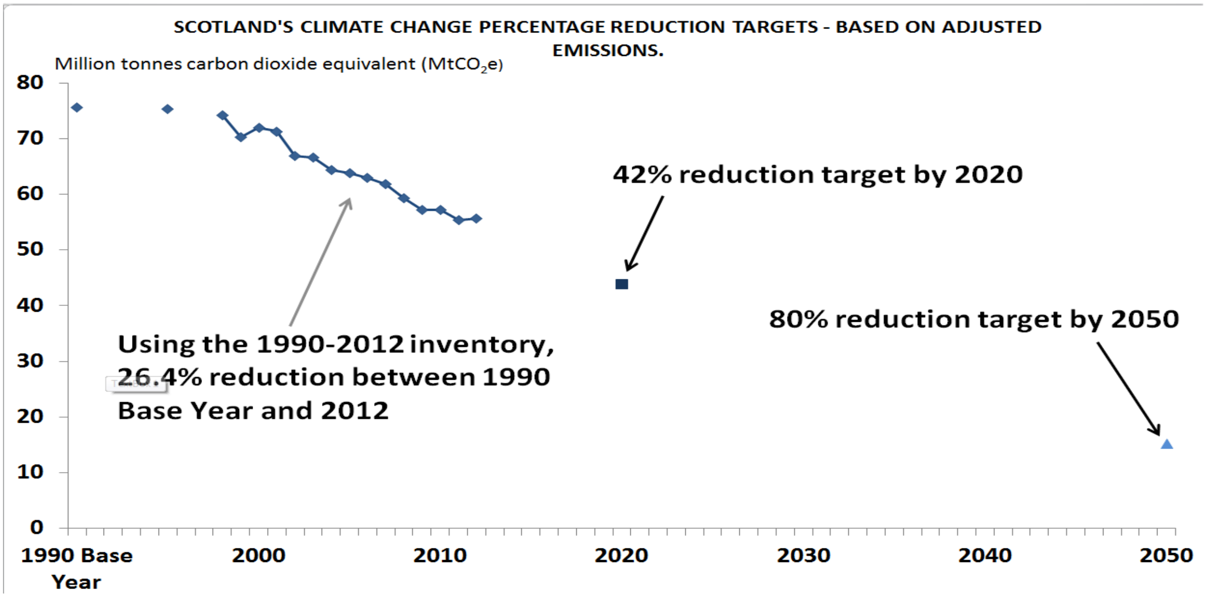
[4] Scottish emissions are tiny relative to global emissions. The Scottish Government's targets reflect a desire to provide leadership in the area, perhaps in part acknowledging Scotland's past contribution to emissions.

[5] The Scottish Government has also adopted a target of "largely decarbonising" the electricity generating sector by 2030 (80% reduction relative to 1990). The target is to achieve emissions of 50 grams CO2 per kilowatt hour. (In 2010 the figure was 347 grams.)

[6] Scottish emissions here for those companies covered by EU ETS reflect Scotland's share of the UK's EU ETS. The EU ETS impact on targets is explained in McGregor and Swales (2013). The carbon content of all Green House Gases allows them to be converted to CO2 equivalents.

[7] Changes to EU measurements have had the effect of tightening the targets relative to those originally set.

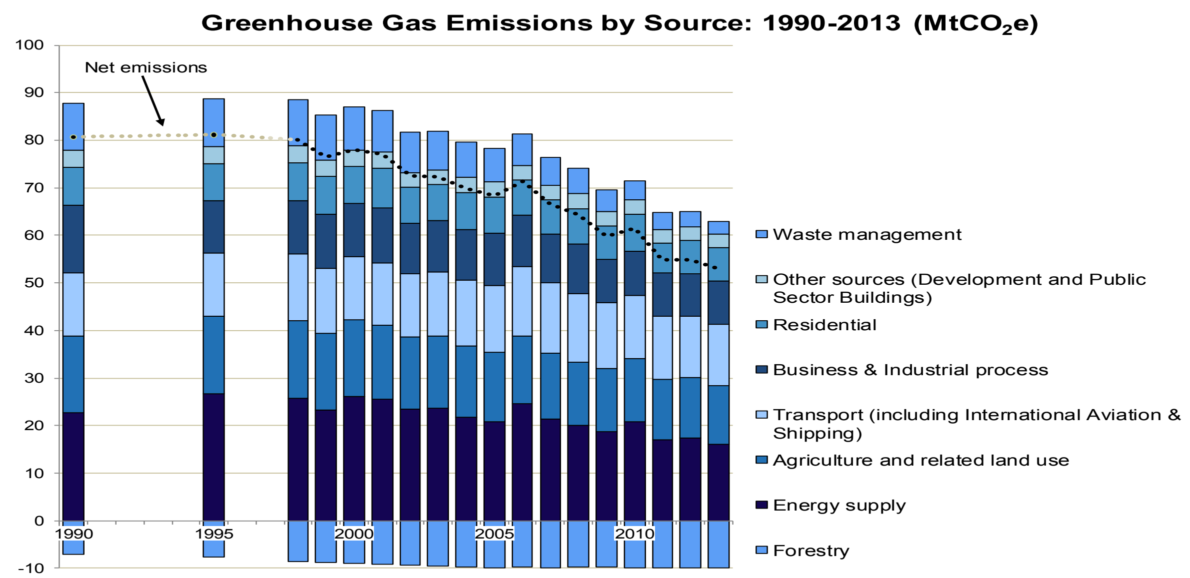
Figure 1: MtCO2e Scottish emissions, 1990 to 2012 and adjusted emissions targets to 2050



Source: Key Scottish Environmental Statistics 2014, Scottish Government

Figure 2 summarises the source of emissions. First, note that the ***net*** emissions are indicated by the dashed line. These are emissions net of any *carbon sinks*, which remove carbon from the atmosphere e.g. through afforestation. The only sector for which net emissions are negative – indicating net removal of carbon – is Forestry. The biggest single source of emissions in every year is the energy supply sector (30.2% of the total in 2013), which includes the generation of electricity. The general downward trend in emissions from energy supply primarily reflects the move away from conventional fossil fuel technologies, but there are considerable fluctuations reflecting climate and relative fuel price changes (that induce more or less use of fossil fuels).

Figure 2: Greenhouse gas emissions by Source: 1990-2013 (MtCO2e)



Source: Key Scottish Environmental Statistics 2015, Scottish Government

Transport is the next biggest source of emissions, accounting for 24.4% of Scottish greenhouse gas emissions in 2013. Recent reductions have largely reflected lower emissions from cars due to improved fuel efficiency and a switch to diesel from petrol, although that has created other environmentally damaging emissions that are giving rise to serious health concerns, particularly in urban environments. Emissions in the Agriculture and related land use sector (23.4% of total in 2013) have fallen gradually, in part due to declining numbers of sheep and cattle. The Business and industrial Process sector (17.2%) exhibited significant declines largely between 1995 and 2000, reflecting the move away from manufacturing and iron and steel making. (SGGE, 2013). Other significant sources include Residential (13.2%), which largely reflects emissions from combustion for heating and cooking.

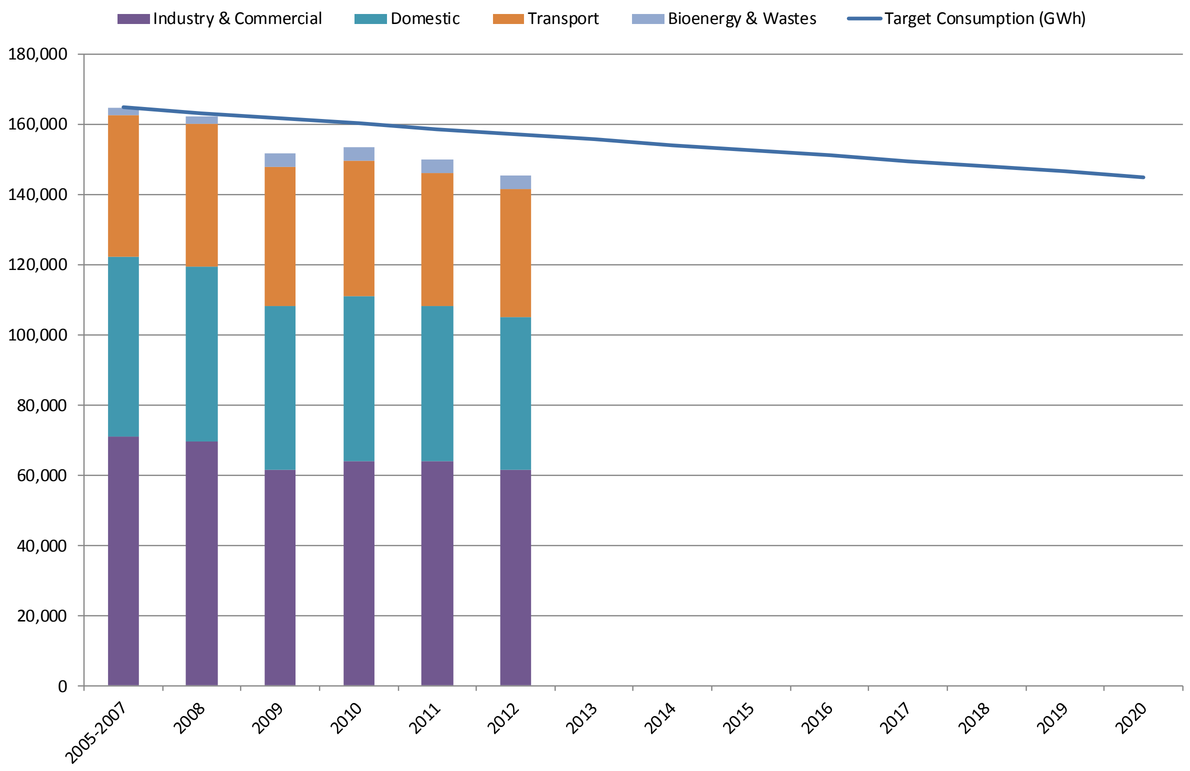
It is clear why decarbonisation of the electricity generating sector is a major priority of the Scottish Government, although since this sector is covered by EU ETS, this will not contribute directly to *adjusted* emissions, which reflect the EU emissions cap. However, decarbonisation of the sector is important since it would facilitate further decarbonisation of two other big sources of emissions: the transport sector (through electrification) and the residential sector (through substitution of renewable electricity for gas in domestic heating).

As with the Kyoto agreement, the emissions targets are expressed in terms of emissions directly generated through production or fuel use within Scotland's borders. One concern about these *territorial* emissions targets is that they could be met by a relocating its carbon-intensive production abroad and/or importing carbon-intensive goods from countries that are not bound to emissions targets ("carbon leakage"). Clearly such a process could frustrate the intended (global) impact of the targets, and could even worsen total emissions if technologies elsewhere are more carbon intensive than they are in Scotland.

Carbon "footprints" attempt to deal with this problem. Emissions embodied within imports consumed in Scotland are added to production measures and those emissions attributable to exports from Scotland are subtracted (since they are attributed to those who consume the exports). The Scottish Government publishes a measure of Scotland's carbon footprint. This has always been greater than the production measures presented above. For example, in 2010, the footprint was estimated at 82.2 MtCO2e, which represented an increase on 2009 (Scottish Government, 2014). The implication is that Scotland's contribution to global warming is greater than conventional measures of emissions imply, and also that these might be rising, not falling.

3. Energy and renewable energy

Figure 3: Total final energy consumption (GWh) by consuming sector, Scotland, 2005 to 2012 and targets to 2020

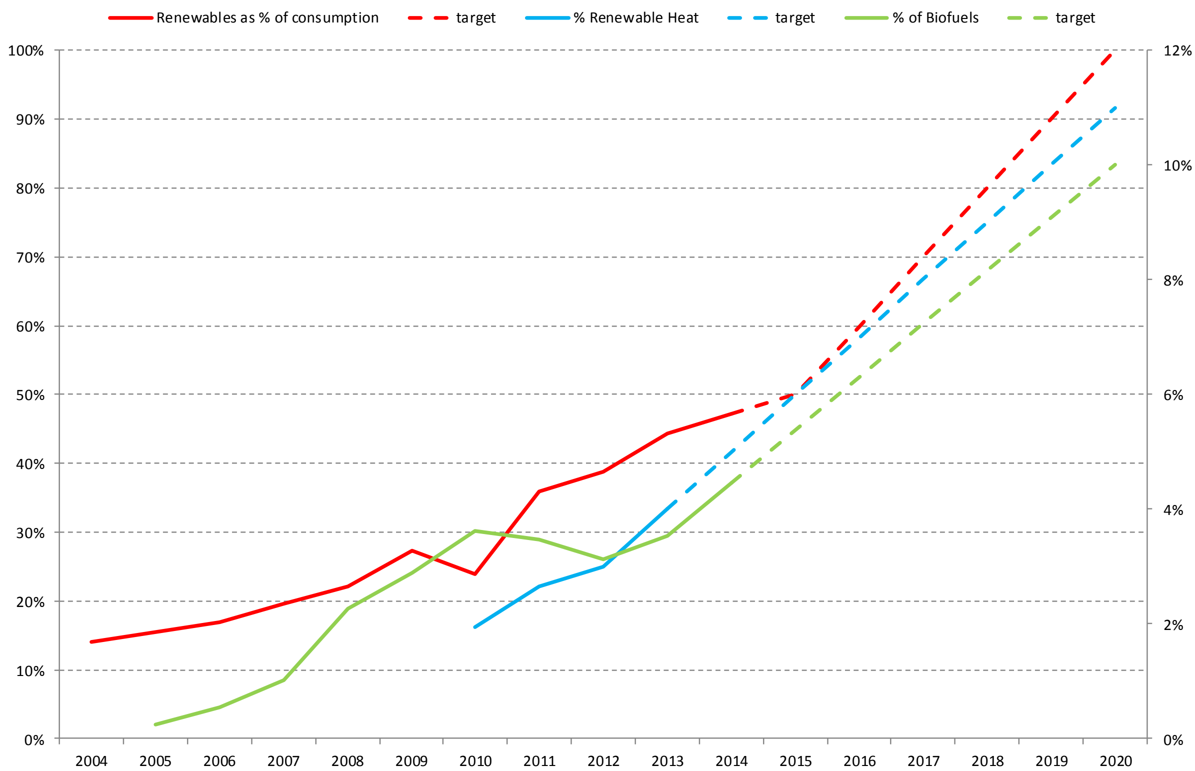


Source: Energy in Scotland 2015, Scottish Government (Figures 1.7 and 2.4)

The Scottish Government uses the 2005-2007 total final energy consumption as the base for the target cut of 12% of total energy consumption by 2020. Figure 3 shows that actual consumption has been below the target trajectory in every year to date with total energy consumption 11.8% below the benchmark in 2012. The bulk of final energy consumption is for heat (55% in 2012), transport (24%) and electricity (21%). Total final energy consumption varies, reflecting its dependence on factors such as the weather and the state of the economy. All consuming sectors have reduced their total final energy consumption relative to the 2005-2007 base, but this is most marked in the domestic sector (-15%) and least in transport (-10%).

Whilst the Scottish Government wishes to reduce energy consumption in Scotland, it wants to simultaneously increase activity in the renewable energy sector. There are four current renewable energy targets in Scotland, covering the three major sources of energy use. All of these targets relate to the year 2020. First, there is a target for generating the equivalent of 100% of Scottish electricity demand from renewable technologies in Scotland. Second, there is a similar target to meet 11% of heat demand using renewables. Third, there is a target for 30% of overall energy demand to come from renewables. This implies that renewable fuel use in transport will increase to 10% of fuel demand in Scotland over the same period. Figure 4 shows the progress towards these targets over the coming years, and the required (dotted) pathway to reach the stated targets by 2020.

Figure 4: Renewable energy targets, % equivalent of electricity demand in Scotland from renewables (left-hand axis) and % of heat and transport fuels from renewable sources (right-hand axis)

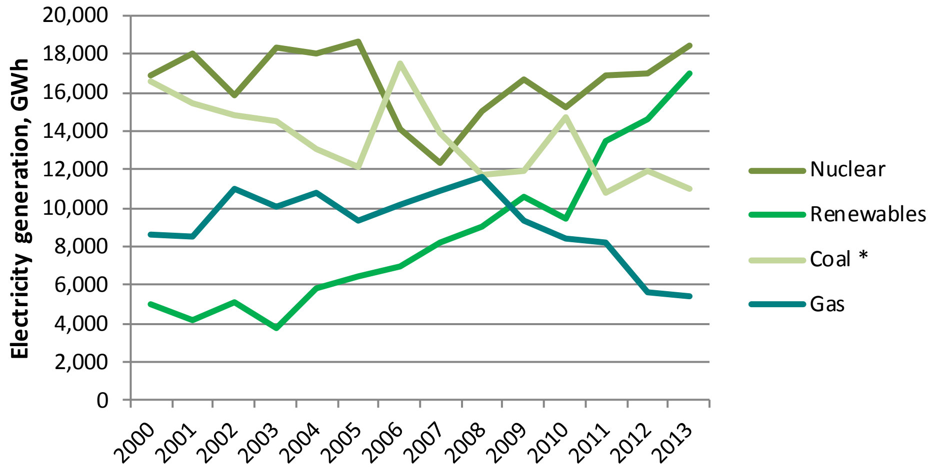


Source: Energy in Scotland 2015, Scottish Government, Figures 1.4, 1.5 and 1.6

Figure 4 shows that whilst all the indicators have been moving in the right direction, there is still a considerable way to go to meet the 2020 targets. The recent (November 2015) shift in the UK Government's stance to reduce support for wind technologies seems likely to make the renewables targets harder to meet.

Figure 5 summarises the total amount of electricity generated in Scotland by source. Note the marked rise in the contribution of renewables and the declining contributions of coal and gas. The last of Scotland's coal generation facilities – Longannet – ceased activity in March 2016, following the earlier closure of Cockenzie in 2013, so that Coal's share in Scottish electricity generation is currently zero. However, Figure 5 also highlights the fact that nuclear has typically been the most important single source of electricity generation over the period and this important source of base load is due to disappear in Scotland (but not in the rest of the UK) as existing nuclear power stations reach the end of their useful lives (see below).

Figure 5: Electricity generation by fuel (GWh) Scotland 2000-2013



Source: Energy in Scotland 2015, Scottish Government (Figure 3.2)

What is critical for the future shape and scale of the Scottish electricity generation mix is the level of investment and its distribution across the different technologies. Two points are worth stressing:

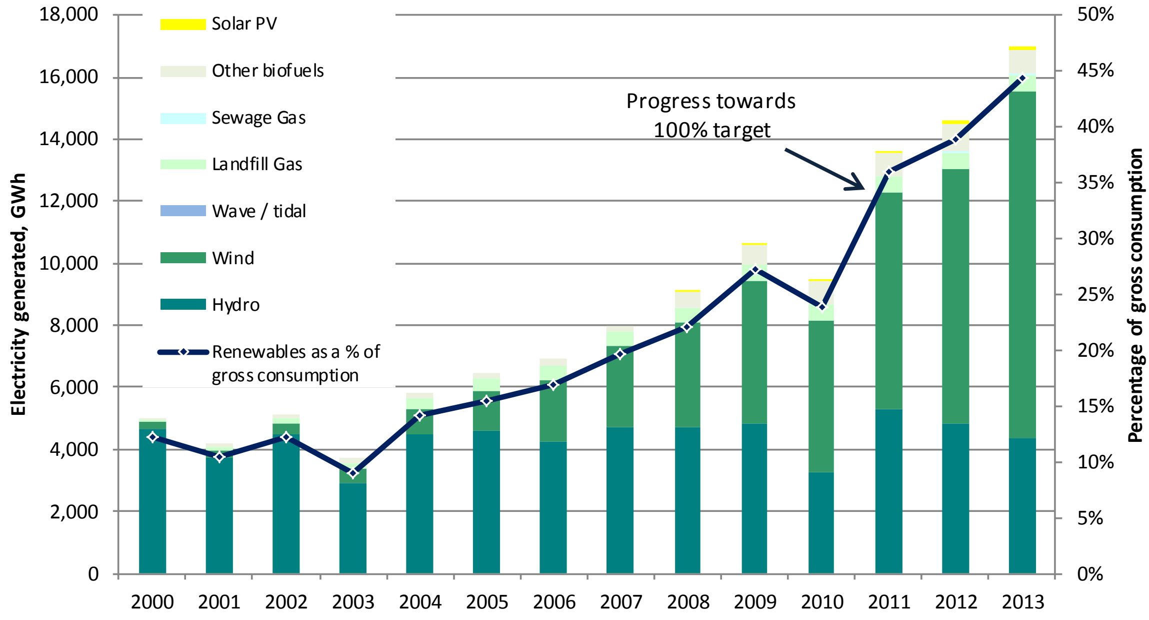
- The generation mix in use today reflects the priorities and aspirations of policy makers and engineers at previous points in Scotland's economic history.

- Investment in electricity capacity in the past has typically been "lumpy", rather than gradual, reflecting the economies of scale that characterise traditional fossil fuel and nuclear power plants. The subsequent decommissioning of these facilities also leads to lumpy adjustments to capacity.

Figure 6 reveals the trajectory of renewable electricity generated in Scotland, broken down by technology. From a base of 12% of electricity coming from renewable sources in 2000, comprising almost exclusively hydro power, by 2013 the equivalent of 44% of Scottish electricity demand was met by renewables from a range of technologies[8].

[8] Some of this increase reflects a fall in electricity demand in Scotland, noted earlier. If demand had remained at 2000 levels, the equivalent of 42% of this was produced from renewable sources in the last year.

Figure 6: Electricity generated from renewable sources, Scotland, 2000 to 2013



Source: Energy in Scotland 2015, Scottish Government (Figure 3.19)

Figures available in June 2015 show a total of 13.4 GW of renewable capacity within the planning system. 0.85GW capacity was currently under construction, while consented – but not yet operational – projects constitute 8.2GW of capacity. There was a further 4.3GW seeking planning approval. The 8.2GW capacity of projects awaiting construction is broadly equally split between offshore (4.1GW) and onshore (3.5GW) projects (with 0.5GW from other technologies). However, there are only nine offshore projects, compared to 111 onshore projects, indicating the significantly larger average size of offshore developments. The pipeline of projects without planning consent however is almost exclusively onshore (4.2GW from a total of 4.3GW). This confirms that the development status of existing consented offshore facilities are critical for renewable energy capacity in Scotland; there are no offshore projects currently in the "starting blocks" for their journey through the planning approval and construction process.

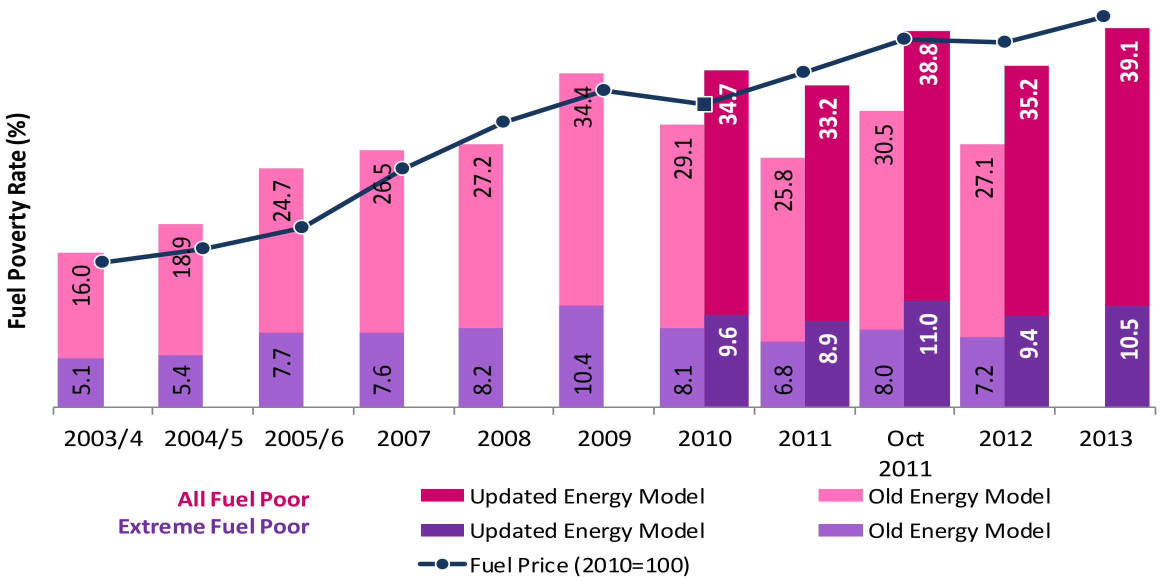
4. Security of supply and energy affordability

Security of supply. This is a complex issue that we cannot deal with in detail here. One concern - in the context of electricity – is simply whether there is adequate generating capacity to meet total demand, and there is some concern that the amount of "excess" capacity has been declining through time. In a Scottish context the closure of Longannet power station in March 2016 and the two lifetime-limited Scottish nuclear power stations have created concerns given the current dependence on these sources of generation (Figure 5). However, Scotland is part of a fully integrated British electricity grid, and it is thought that there will be adequate generating capacity across that grid. It seems likely that in the future Scotland will have further recourse to imports of electricity through interconnectors to RUK, although it unlikely to remain a significant net exporter on an annual basis. Given the increasing penetration of renewables, there has been a move towards "smart" electricity grids, and more distributed generation. Furthermore, there has been increasing emphasis on actively managing electricity demand, so as to shift it away from the "peak" periods, through the roll out of smart meters, for example.

Affordability. The Scottish Government defines fuel poverty, and extreme fuel poverty, as where a household would have to spend over 10%, or 20%, respectively of their incomes on heating to "maintain a satisfactory heating regime". The Scottish Government has very limited control over this. Many energy prices – such as the oil price - are largely determined in world markets and until very recently have tended to grow much more rapidly than households' incomes. Furthermore, the increasing penetration of renewables tends to put upward pressure on fuel bills, given their (currently) higher costs. Modelling for the DECC suggested that about 15% of the price increase for average household fuel bills between 2007 and 2013 was due to energy and climate change policies, while wholesale energy costs and network costs were responsible for 60% and 25% respectively (DECC, 2013). While there have been some fluctuations, there is a general upward trend in both fuel poverty and extreme fuel poverty in Scotland.

Of course, if imperfect competition distorts domestic energy markets there is a role for Government through regulation and industrial policy, but under current arrangements that is an issue for the UK Government. However, the greater fiscal policy autonomy that the Scottish Government is about to enjoy (as a consequence of the Scotland Acts, 2012 and 2016) would give it some ability to influence fuel poverty and income distribution more generally. However, doing so would be costly either in terms of reduced public expenditures elsewhere or increased taxation.

Figure 7: Energy affordability. Fuel poverty, extreme fuel poverty rates and index average (mid-year) fuel prices, 2003/4-2013



Source: Energy in Scotland 2015, Scottish Government (Figure 7.12)

There is a clear upward trend in fuel prices, as indicated in the dotted line in Figure 7 (although this trend will have been interrupted by the recent substantial falls in the price of oil since Autumn 2014). Fuel poverty is estimated with the use of a model of domestic energy consumption (and a new model has been used since 2010). While these estimates have fluctuated, as can be seen in Figure 7, they have also tended to increase over time – both for the fuel poor and the extreme fuel poor.

5. Policy responses and opportunities

The policy responses to the energy policy trilemma (or quadrilemma, if we include economic growth) have taken a number of forms:

- Legislation and/ or international agreement on emissions
- Reforming energy markets and facilitating infrastructure investment
- Influencing the price of carbon
- Encouraging low carbon technologies
- Stimulating energy efficiency

We have already noted the importance of multi-level governance in the energy-economy-environment domain: Scotland has to operate in the context of a global economy in which the EU and Westminster Governments have an important influence on feasible energy policies in Scotland. We consider how the above policy responses are reflected at each level of the hierarchy, starting with the global level.

At the *global level* the biggest challenge remains securing effective international agreements on emissions. The global nature of climate change implies that it is essential to find a global solution, or at least have the world's major carbon emitters commit to restrictions. The difficulties in securing international agreements should not be underestimated, as past experience clearly demonstrates, but there are reasons for optimism given the outcome of the Paris accord, with India being the latest country to commit itself to renewables targets.[9] The main concern is how effective policing of what are essentially voluntary internal targets will prove to be.

At the *EU level*, the 20-20-20 targets and their successors are under consideration, with perhaps an increasing focus on the ultimate objective, reducing emissions, with greater discretion over the means by which individual countries achieve this. The current targets imply a big push on renewables and energy efficiency, and these targets are binding on member states. Financial penalties apply if they are not met. However, there is a suggestion that EU policy is likely to become less prescriptive in precisely how emissions are reduced in individual countries. One major challenge for the EU, however, is whether the EU ETS is capable of delivering a credible long-run price of carbon. This concern underlies the UK Government's Electricity Market Reform's implementation of a carbon price floor and it is conceivable that further devolution might result in the Scottish Government being able to levy a carbon tax.

[9] See e.g. Guardian 5/10/15.

The *UK's policy stance* appears recently to have been shifting away from the blanket encouragement of renewables, particularly for onshore wind which has attracted a great deal of social opposition. Electricity Market Reform has altered the basis of government support of renewables It has simultaneously reduced the effective subsidy to onshore wind, in particular, while providing long-term assurance for the development of new nuclear (although the Scottish Government's position on planning permission effectively precludes any such development in Scotland). As already noted, the reduction in subsidies has led to concerns being expressed in Scotland about the feasibility of meeting its targets for the deployment of renewables.

The *Scottish Government's* policy stance involves considerable emphasis on *renewables*, reflecting a number of considerations. First, Scotland is endowed with substantial renewable resources, notably wind and tidal, so that there seems to be considerable potential. Second, the development of renewables holds out the promise of simultaneously stimulating economic activity through a number of mechanisms including: domestic supply linkages; new renewable technologies stimulating productivity and providing new export markets; additional income flows through partial local ownership. Third, if renewable development occurs at a local community level it may impact upon fuel poverty and income distribution more widely. Fourth, encouraging renewables seems likely to add to security of supply at local and national levels, in the latter case by reducing dependence on imported fuels.

However, renewables present their own challenges. First, like all newer technologies they tend to be associated with higher (levelised) costs than established technologies, but the expectation is that policy support will encourage adoption and deployment and that through learning, these costs will fall – eventually to levels that are competitive with traditional technologies (especially once the costs of carbon are included). Second, at a technical level, the variability of many renewable sources (notably wind, wave and solar) creates challenges for the management of the electricity and wider energy systems, initially developed around large scale fossil fuel generators. Third, the renewable resources are often located far from centres of demand, so that there are issues for the transmission and distribution centres, with higher overall costs.

Additionally, the success of economic development will depend to a degree on the ability to stimulate a domestic supply chain: importing wind turbines from Europe does nothing to stimulate economic activity in Scotland or the UK. Furthermore, successful development at the local level may well depend on appropriate policies and financial incentives, which in turn may depend largely on the pattern of ownership. Finally, currently the incentives to invest in renewable technologies are controlled by the UK Government and this does not seem likely to change soon. So there is little the Scottish Government can currently do to counter the UK Government's shift away from some renewables, although in principle the new fiscal powers from April 2016 would allow some policy differentiation.

Like the other levels of Government, the SG encourages the adoption of *energy efficiency* improvements, although again much of the financial power to stimulate such activity currently lies with the UK Government currently. Energy efficiency improvements essentially reduce the relative price of a unit of effective energy and so actually stimulate the demand for energy measured in efficiency units. The impact on physical energy demand depends on the sensitivity of the system to relative price changes. In general however, there is likely to be some *rebound* effect, so that the reduction in energy demand is less than the proportionate improvement in energy efficiency. Indeed in some circumstances energy demand may actually rise: the case of *backfire*. These cases are not necessarily bad news: they are likely to reflect the fact that the fall in the effective price of energy actually stimulates economic activity, and so contributes to another of the Government's objectives.

It seems clear that the Scottish Government, like the UK Government, would like to see a significant increase in the *price of carbon,* and would support a tightening of EU ETS to that end. However, with greater fiscal autonomy it may also be possible for the SG to impose a Scottish-specific carbon tax. If this is done in a revenue neutral way it may be possible simultaneously to reduce emissions and stimulate economic activity: a *double dividend* in terms of impacts on policy goals (e.g Allan et al, 2014).

The Scottish Government faces a number of additional current and future challenges and opportunities, including impending constitutional change, the introduction of new technologies and the integration of energy systems on an EU-wide basis. We briefly consider each of these in turn.

Constitutional change*.* The Smith Commission and subsequent legislation promises much in the way of further devolution of fiscal powers to Scotland. While little of this is directly in the remit of the present paper, there will be implications. For example, if further fiscal autonomy stimulates further growth, as some claim (though controversially), this will raise further challenges for energy policy, unless the growth is explicitly oriented to low carbon technologies. Furthermore, it currently seems unlikely that the outcome of the Smith Commission will satisfy desires for further Scottish autonomy and that may impact on energy in a variety of ways (McGregor and Swales, 2013).

New technologies. These can have a radical, and sometimes unanticipated, impact on the energy-economy-environment system.

- *Fracking* in the US is partially responsible for the recent sharp decline in the price of oil, with significant consequences for oil producing economies (including Scotland). The potential impact of fracking within Scotland has yet to be fully assessed, although the scale is likely to be fairly modest. While fracking is potentially good news from an affordability perspective – and certainly has been in the US context – and beneficial from a security of supply perspective if it were partly to replace imported fuels - combustion of more fossil fuels (because they are cheaper) is bad news for territorial emissions if consumed domestically, especially if potential renewables output is partially replaced.
- *Carbon Capture and Storage* is a further potential "game changer". If this could be made cost effective and implemented on a significant scale, it would allow combustion of fossil fuels while protecting the environment from the bulk of the resultant carbon emissions. This could be particularly important for Scotland given the storage capacity of former oil fields, and the potential for increasing the recovery rates for oil. So it has the potential simultaneously to enhance security of supply, while improving the environment, but at some cost in terms of affordability at least in the short-run. The UK Government has recently withdrawn support for research into CCS, and this is potentially an area where the SG could choose to invest.
- *Distributed and locally-based energy* is a partial solution to energy security issues, though perhaps with some adverse local environment impacts. However, depending on the

contractual arrangements these can also contribute to improving energy affordability, and indeed to local economic activity. The Scottish Government is keen to encourage community level development of renewables.

- *Smart grids.* The use of new technologies, including smart meters, can be used to manage energy demands, and, in particular to shift the timing of demands during the day, so that less generating capacity is required to service peak loads.
- *Energy storage.* A key feature of many renewable technologies – notably wind and wave – is intermittent generation. This creates problems for managing their incorporation into the system. Energy storage provides a possible answer, with excess electricity generated in, for example, high winds being stored for later use. Currently, the cost of large scale storage is high, restricting the scope for renewable developments.
- *Electrification of transport.* There is increasing penetration of electric or hybrid private cars and commercial vehicles. Again, depending on the learning rates associated with these technologies, the impact could ultimately be transformational. The Scottish Government expects to see significant progress in the decarbonisation of road transport by 2030 in part through wholesale adoption of electric cars and vans.
- *Electrification of heat.* At present domestic heating is primarily generated by gas, but decarbonisation would likely require a shift to electric heating powered by renewable generation.

Social acceptability is potentially an issue for all new technologies. Of course, NIMBYism has been most marked among opponents of onshore wind, and offshore developments have some advantages in that respect (though not all offshore projects are uncontroversial), as do new marine technologies. Importantly, there would be scope for the SG, with enhanced powers, to adopt policies that better reflect Scottish preferences, and to a degree this is already reflected in their attitudes (and policies) towards new nuclear and renewables. However, fracking has proved to be extremely controversial, with focus on the potential adverse local environmental health effects, as well as the global emissions concern. The scope for policy differentiation in Scotland is, nevertheless, set to grow.

Geographical interconnectivity of energy systems. The EU's aspiration to establish an integrated EU electricity market appears still to be a long way off. In principle, however, this is a very important mechanism for helping to enhance security of supply, provided members of the integrated system are themselves reliable and secure. Major interconnectors already aid security of supply in Scotland and the UK, and indeed, provide the means by which Scottish electricity can be exported. This is particularly important for Scotland given its 100% electricity target for renewables. That would necessitate the exporting of electricity when the resource is substantial, but equally the importing of electricity when renewable generation is weak due to a lack of wind, for example. The degree of international integration is set to increase and this should ease the problems of balancing domestic supplies and demand. (For example, links to Norway provide access to a huge storage capacity through massive hydro schemes.)

6. Conclusions

There are major challenges around the simultaneous achievement of the Scottish Government's energy policy goals of: environmental targets, security of supply, affordability and sustainable economic growth. The transformation to a low carbon economy is complicated by the multi-level governance in the energy domain, and the importance of policies formed in Westminster and Brussels, although for some goals at least (including security of supply) there may be significant advantages to setting policy across wider geographic areas.

Particular challenges exist around achieving renewables targets in the context of a UK Government that has reduced the incentives to some types of renewables, and this is also likely to impact emissions targets. Security of supply challenges are also looming given the current importance of nuclear and fossil fuels in meeting Scottish demands for electricity, since the generating plants for these technologies are rapidly coming to the end of their useful lives. The integrated GB electricity market will undoubtedly assist in this respect, although it seems likely that Scotland will more frequently be a net importer of electricity.

Affordability can only partially be addressed by any Government given that some key fuel prices are determined in world markets, although new fiscal powers do raise new options both for addressing distributional issues and perhaps, providing new incentives for renewables. However, increases in tax and public spending here are likely to have wider macroeconomic effects that the Scottish Government will have to take cognisance of (Lecca et al, 2016).

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