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Insights into Scotland's climate and energy policies from energy systems modelling

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Energy system models are powerful tools for examining the dynamics of a transition to a sustainable energy system. Here, we report the first application of a two-region version of the UK MARKAL energy system model that explicitly represents Scotland and the rest of the UK as distinct regions. We use this model to examine the implications of Scotland's carbon and renewable energy targets, in the context of the targets legislated for the UK as a whole.

Climate and renewable energy targets in Scotland and the UK

Both the UK and Scotland have legislated long-term targets for the reduction of greenhouse gas emissions. Through the Climate Change Act (2008) the UK has committed to reducing emissions by 80% from 1990 levels by 2050, with an interim target of 34% by 2020. In Scotland, the Climate Change (Scotland) Act 2009 sets out a similar target of 80% by 2050[1] and a deeper 2020 target of 42%.

Renewable energy is an important means of reducing emissions, and both the UK and Scotland have established renewable energy targets, both to drive emissions reductions and because renewable energy is associated with other benefits. Under the European Renewable Energy Directive, the UK has signed up to a target that 15% of final energy must be renewable by 2020, across heat, power and transport. This is likely to mean that at least 30% of UK electricity must be renewable by this time. Scotland's targets are more ambitious, aiming to produce renewable electricity equivalent to 100% of Scottish electricity consumption in 2020.

In this modelling exercise, we examine the implications for the Scottish energy system of both UK and Scottish climate and renewable energy targets.

Modelling Scotland's energy system: development of two-region MARKAL

The UK MARKAL model is a well-established analytic tool that has been used to support a number of UK energy policy processes, including the 2003 and 2007 Energy White Papers and the Committee on Climate Change's suggested carbon budgets and the government's responses to them. MARKAL was developed by the International Energy Agency in the 1970s, and the UK version of the model was mainly developed by the modelling team now at the UCL Energy Institute in the years since 2003 as part of the work programme of the UK Energy Research Centre (UKERC), building on an earlier version of the model, which was also used for policy analysis.

MARKAL is an optimization model of the entire energy system. It includes explicit representation of the UK's energy resources (such as oil and gas, and bioenergy resources), imports, and over 5000 technologies including conversion and processing technologies (power stations, refineries etc), infrastructures (gas and electricity grids) and end-use technologies (spanning vehicles, household appliances, industrial energy use, and energy-efficiency measures). The model is given a set of forecasted energy service demands, and it calculates the least-cost[2] way of meeting those demands based on the technologies and resources available in the model database, subject to constraints such as carbon targets.

The two-region version of the model was developed by disaggregating UK MARKAL into two regions: Scotland and 'rest of the UK'. Data on the Scottish energy system was largely derived from the Scottish Energy Study (Scottish Government, 2006). The model is described in more detail in working papers on the UKERC website[3], while more details of the modelling work reported here are contained in a paper that is currently being reviewed for publication in an academic journal.

Results: Carbon targets

We ran a scenario in which the UK meets UK-wide carbon targets[4] at least cost. In this scenario, Scotland reduces emissions faster and deeper than the rest of the UK, making reductions beyond both UK and Scottish 2020 targets (See Figure 1). Adding Scotland's targets as an additional constraint on the model makes no difference to the decarbonisation trajectory of either region, as the Scottish target is satisfied when the model meets UK targets at least cost. Our results therefore suggest that Scotland's emissions targets may not imply any additional abatement activity beyond that which would be required if the UK were to meet UK-wide targets in the most cost-effective way.

The cheaper abatement opportunities in Scotland arise partly because of planned closure of existing fossil fuel plant (such as Cockenzie power station, due to close in 2013), and partly because Scotland has a large portion of the UK's lowest cost renewable energy potential. Cheap early abatement in Scotland in the model is also in part a result of our allocation to Scotland of offshore oil and gas resources and emissions, which are in decline (see 'upstream' emissions, which include emissions from offshore oil and gas, in Figure 2)[5].

Figure 1: Shows the emissions pathways for Scotland, the rest of the UK (England, Wales and Northern Ireland), and the UK as a whole to meet UK and Scottish targets. 100 = 1990 emission levels

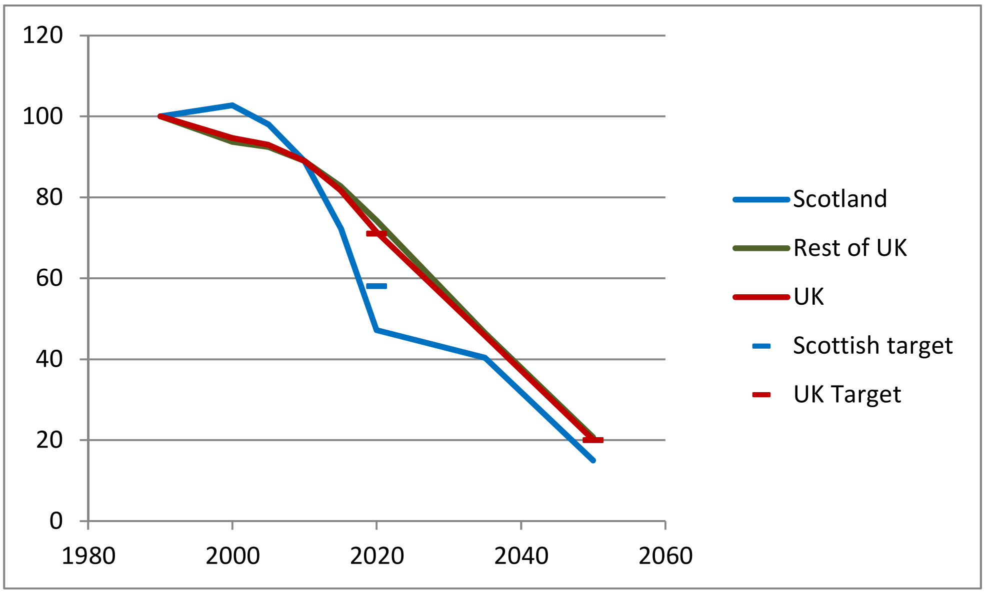
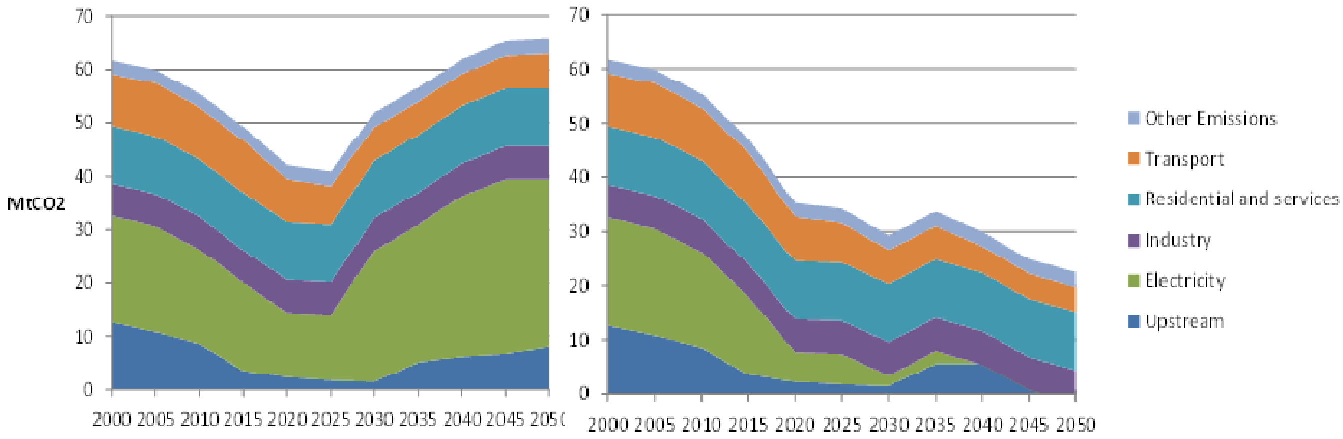


Figure 2. Scottish CO2 emissions in the reference case in which no carbon targets are applied (left panel) and the low-carbon case (right panel)



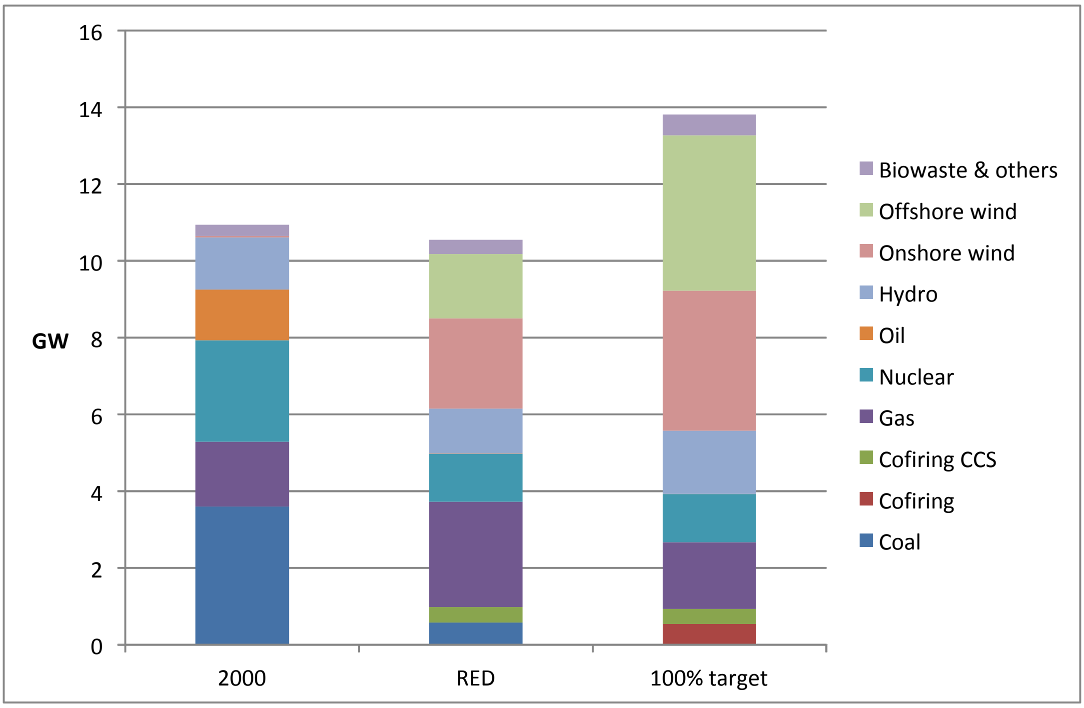
Results: Scotland's renewable targets

We ran two scenarios to examine the implications of renewable energy targets in Scotland. First, we ran a scenario in which the UK meets its obligations under the Renewable Energy Directive (RED) at least cost, with the model free to deploy renewable energy in Scotland or the rest-of-the-UK depending on where the cost is lowest. Second, we ran a scenario that meets the RED targets and also meets Scotland's 100% renewables target. Both of these scenarios are also required to meet carbon targets.

The effects of Scotland's targets on the Scottish power generation mix in 2020 are shown in Figure 3. From the figure, one can see that the 100% target drives greater uptake of both onshore and offshore wind compared to the RED scenario, and also drives replacement of coal generation with biomass co-firing.

In the RED scenario the proportion of renewable energy in Scotland as a share of Scotland's final electricity consumption is 55%. This clearly misses Scotland's 100% target. In the second scenario we require the model to meet Scotland's 100% target, in addition to meeting UK-wide RED targets. The result is that there is no increase in overall renewable energy across the UK. Instead renewable energy investment and deployment is shifted from the rest of the

Figure 3: Installed power generation capacity in Scotland in the year 2000, and in two 2020 scenarios. In the RED scenario, the UK deploys renewable energy at least cost to meet the UK's obligations under the Renewable Energy Directive. In the 100% target scenario, Scotland produces renewable electricity equivalent to 100% of its consumption



UK to Scotland. Requiring the model to meet Scottish renewable energy targets in addition to UK RED targets adds to the overall costs of the energy system, equivalent to a total discounted cost of about £15 per person in the UK, assuming that the additional costs are spread across all UK consumers.

An important assumption underlying this finding of higher costs is that the policy actions of the Scottish government make no difference to the actual installed costs of renewable energy. It does not take into account, therefore, the fact that a more favourable planning system in Scotland for onshore wind, for example, could reduce the costs associated with renewables deployment. Nor does it account for the possibility that, with the higher targets in Scotland, the renewables supply chain there might develop and reduce its costs more quickly. Either of these factors could reduce the costs we have calculated.

Note also that the model does not take into account the possible political constraints on actually installing the lowest-cost renewables in the UK, much of which is onshore wind in England. It is very possible that it will not prove politically feasible to harness much of this resource, in which case the extra installed capacity in Scotland driven by the Scottish renewables targets may make a crucial difference as to whether the UK-wide renewables targets are met or not, or the degree by which they are missed.

Insights for policy

The scenarios examined in this work have generated two principal findings. First, we find that Scottish carbon targets do not lead to additional abatement beyond that which is required under a least-cost path to meeting UK targets. Second, we find that Scotland's renewable energy targets lead to a shift in investment and deployment from the rest of the UK to Scotland, leading to a higher overall cost for the UK as a whole. We discuss the implications of each of these in turn.

Since Scotland reduces emissions beyond its own targets under a scenario constrained only by the UK targets, one might be tempted to draw the conclusion that Scotland's targets are unnecessary. However, we believe that would be a mistake. The value in Scotland's targets is not necessarily that they drive additional effort over and above that which should be happening in response to UK-level targets, but that they play a supporting role, augmenting action to meet the UK target. Several authors have noted the additional value of complementary targets within a multi-level governance regime (e.g. Goulder and Stavins 2010), arguing that complementary targets strengthen investor confidence in future carbon constraints, and bolster the political consensus on the need for action. In the context of Scottish carbon targets, Reid (2009) argues that it was the ambition of Scotland that led to the stringent UK-level carbon targets, highlighting the important role that

Scotland's carbon targets have played even if they can be described as less ambitious in terms of the marginal abatement costs of meeting them, as our model suggests.

The situation with renewable targets is different. Unlike with carbon targets, Scottish renewable energy targets do require additional deployment in Scotland over and above that which would occur in a least-cost pathway to the UK's Renewable Energy Directive target. This additional deployment in Scotland results in additional costs for the UK as a whole, equivalent to a total discounted cost of around £15 per UK citizen. Current policy and market structures mean that this additional cost would be borne by consumers across the UK. We have noted that it is possible that the model overstates the size of this additional cost, because it ignores the fact that the target is accompanied by other efforts to encourage renewable energy which may decrease the costs of deployment (such as streamlined planning approvals). However, assuming that this finding of additional costs is real, one might ask why UK consumers should pay for renewable energy deployment to be focused in Scotland.

One possible justification is that Scottish renewable targets provide greater investor confidence, and in doing so they make it more likely that the UK will actually meet its RED targets. The model does not take into account the possibility that the UK may fail to meet its targets, but in reality we know that this is possible, and perhaps even likely. Given the on-going resistance in many parts of the UK to deployment of onshore wind, one might argue that Scotland's targets act as insurance against the risk that the rest of the UK will fail to deploy renewable energy fast enough to meet targets. Note that failure to meet targets is not cost-free. Aside from the implied political cost of missing statutory targets, and the environmental cost if this results in higher emissions, the European Commission may apply financial penalties to member states that fail to live up to their commitments.

References

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Endnotes

[1]The Scottish target has a broader scope than the UK target, e.g. it includes international aviation and shipping.

[2]The cost that the model minimizes is the total discounted energy system cost. This is the discounted stream of all the fuel costs, investments and operating and maintenance costs required to meet energy service demands from 2000-2050.

[3]See http://ukerc.rl.ac.uk/UCAT/cgi-bin/ucat_query.pl?URadio=P_12&GoButton=Find+Publications

[4]We conducted this analysis before the Government's response to the fourth carbon budget, and hence the model results reflect targets in 2020 and 2050.

[5]In our model, allocation of offshore oil and gas resources, and hence emissions, follows that in the Scottish Energy Study, i.e. resources are allocated to the region in which they are landed. However, in the real world emissions occurring in the UK Continental Shelf are not allocated to Scotland, and reductions here thus do not count towards Scottish targets. Our allocation of emissions was necessary for this work because of the way in which offshore activities are represented in the model, but the result is an overstatement of the ease with which Scotland meets its 2020 carbon targets. However, we believe this overstatement does not affect the overall finding that Scotland meets targets in a UK least-cost decarbonisation scenario.