Abstract submission to:

International UCL-CIRED workshop, 26-27 March 2014, London, "Innovative techniques for Quantitative SCenarios in ENergy and Environmental research (IQ SCENE)"

A systematic approach for analysing the robustness of a UK low carbon energy future using uncertainty analysis

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In its recent review of the 4th Carbon budget (CCC 2013), the Committee on Climate Change (CCC) reiterated the need for early action to reduce emissions out to 2030, to ensure the UK was on a pathway to meeting the longer 2050 target. It concluded that the budget should be kept at the level provided in its original advice to Government (CCC 2010), rather than tightened, but that the aim should still be to achieve early decarbonisation of the power sector, in addition to strong action across other sectors. The CCC deem this critical if the UK is to follow a cost-effective path towards decarbonisation, and avoid the additional costs associated with delayed action.

However, key uncertainties exist around the delivery and cost of the 4th carbon budget and longer term 2050 target, such as economic growth and structural change, delivery capacity (including financing), technology costs and behavioural change. The uncertainties are of fundamental importance, given the large investments will be required to fund this transition, and these investment decisions will result in long term consequences around the direction of the transition.

Much of the policy development on long term target setting from an integrated energy systems perspective has been supported by MARKAL modelling, with recent work synthesised in Ekins et al. (2013). While of key importance in UK climate policy, a limitation of this modelling is that it fails to address the uncertainties surrounding many aspects of the transition to a low carbon system in an integrated and systematic manner (Usher and Strachan 2012). Applying a deterministic methodology to a complex and multi-faceted area of strategy development that is inherently uncertain is problematic. Three key issues are highlighted with simple sensitivity analysis – i) the probability of an input value cannot be quantified, ii) disparate sensitivity scenarios make policy insights more difficult to determine and iii) the cost of uncertainty is unknown (Usher and Strachan 2012).

Given this context, other approaches to exploring the impact of uncertainties more systematically are needed. This paper describes one such approach, exploring the impact of uncertainty of technologies critical to delivery of a lower carbon energy system, using the Energy Systems Modelling Environment (ESME), developed and licensed by the Energy Technologies Institute (ETI). This model provides a framework for systematic analysis of multiple uncertainties, using a probabilistic approach, on target delivery and technology pathways, out to 2050. The first step comprises the selection of key uncertain parameters that can affect the model resolution. The second step is to use statistical techniques to uncover the sensitivities of these uncertain parameters, including multivariate regression analysis, sensitivity to the output mean and Spearman rank correlation coefficients.

In our analysis, the focus of uncertainties is on the cost and uptake of key technologies, crucial for mitigation action in the mid-term, and necessary to meet the longer term 2050 target. Specifically, we consider the following issues –

- The likelihood of meeting or missing emission reduction targets under a given set of carbon prices.
- The downside or upside risks of lower / higher carbon prices on achieving the targets, providing insights into the sensitivity of target delivery based on changes in carbon prices.
- The characteristics of technology-fuel combinations that are most prevalent across simulations, through exploration of model outputs and sensitivity analysis.

The paper highlights a range of interesting insights from the analysis. Firstly, the future carbon price levels derived from deterministic pathway models may not be sufficient to deliver the ambition levels in the long term. This is of course dependent on the extent to which policy makers want to mitigate uncertainty around target delivery. The additional cost in £/tCO_2 to mitigate uncertainty is much higher in the longer term (2050) than in the mid-term (2030). In addition, the carbon price in 2030 is extremely sensitive in the model, highlighting that setting the right level is crucial to meeting the target but that the additional cost in £/tCO_2 to mitigate uncertainty is low. The analysis also points to the critical role of technologies and fuels to meeting targets, particularly mid-term power sector decarbonisation, and the strong role of nuclear and gas with CCS. In the longer term, the model is very sensitive to biomass availability, as this strongly influences the role of biomass use in CCS technologies, a key mitigation technology in 2050.

The key input uncertainties influencing the output metrics analysed (costs and emissions) are hydrogen and electric cars, and biomass availability. Other metrics that appear to influence the results to a less extent are also fossil resource costs (particularly gas and liquid fuels) and nuclear power plant capital costs.

Key methodological issues are apparent from the analysis, which require further consideration. Critically, how can we pre-determine our uncertainty focus (in terms of nature, location and level) more systematically, prior to propagating them through the energy system model? Our focus has been on supply side uncertainty; however a range of other factors may be as critical such as demand side and behavioural drivers, public acceptability, investment environment. It is evident that our focus is often determined by the capacity of the tools we use and our own preconceived ideas around uncertainty. Nevertheless, the insights gained through this analysis provide a useful basis from which to start exploring key uncertainties, and improving methods.

<u>References</u>

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