Institution: University College London

Unit of Assessment: 16 – Architecture, Built Environment and Planning

Title of case study:

Energy-economic modelling of long term decarbonisation pathways: The policy impacts of the MARKAL-TIMES model family

1. Summary of the impact

The family of MARKAL-TIMES energy models have successively underpinned every major recent UK government energy policy document on long-term decarbonisation pathways. Enabled by the interdisciplinary critical mass of the UCL Energy Institute, a ground-breaking research programme by Strachan, Ekins et al has taken the UK's energy systems analytical capacity from near zero to world-class. Specific examples of policy impacts include assessment of decarbonisation costs in the DECC Carbon Plan, and the quantification of electricity sector decarbonisation as an essential enabling step to meet the targets set by the Committee on Climate Change (CCC) in the legally adopted UK carbon budget periods.

2. Underpinning research

An interdisciplinary research team at the UCL Bartlett Faculty of the Built Environment Energy Institute, led by Professor Neil Strachan and Professor Paul Ekins (both at UCL since 2009) – with support from lecturers Gabrial Anandarajah (since 2009) and Ilkka Keppo (since 2011) – has developed the family of MARKAL-TIMES energy models. As a multi-year multi-person endeavour, the development, maintenance and analysis of the MARKAL-TIMES model has been enabled via dedicated energy systems modelling funding of around £3 million from 2009 through to 2013. This has been anchored by the UK Energy Research Centre (NE\G007748\1), of which the Energy Systems theme has been led by Professor Paul Ekins since 2009, with additional sources of income from UK Research Council projects, government departments such as the Department of Energy & Climate Change (DECC), statutory governmental bodies (Committee on Climate Change), regulators (Ofgem), energy utilities (EON, EDF), European Commission (FP7) and NGO funding.

The MARKAL-TIMES model family is an integrated energy system, technology-rich optimisation framework. Some elements of this research programme – notably the model code and software interfaces – came from an international collaboration with a range of premier research institutes via an implementing agreement of the International Energy Agency (IEA). From 2005, Ekins and Strachan had led elsewhere the multi-institution development of the UK MARKAL model. Since both moving to UCL in 2009, the critical mass within the UCL Energy Institute enabled a step-change in the scope and sophistication of successive model variants, including the evolution from the MARKAL to the TIMES model platform, plus the development of UK, EU and global model versions. Furthermore, UCL's interdisciplinary modelling capacity allowed a range of interdisciplinary models to be developed to provide a rich diversity of insights. These insights included the interactions between technological and behavioural change (MARKAL Elastic Demand), geographical drivers (MARKAL-GIS), multi-regional impact (MARKAL England-Scotland), decision making under uncertainty (Stochastic MARKAL), life-cycle analysis (TIMES-LCA), and interactions with global drivers (ETM-UCL, TIAM-UCL).

This ground-breaking research programme has taken the UK's energy systems analytical capacity to a world-class level. Key research insights emerging from the UCL enhancements to research are as follows:

- Analysis with the UK MARKAL elastic-demand model demonstrated the necessity of all sectors to contribute to carbon mitigation efforts, underscoring the value of an energy systems approach. The early and key role of the electricity generation sector in decarbonisation efforts was a particularly striking finding **[a]**.
- Analysis with the global TIMES model (TIAM-UCL) quantified the critical role of global learning on the UK energy system's potential transition to an alternately fuelled transport system **[b]**.
- Analysis carried out using the UK MARKAL stochastic model quantified the range of potential

costs of a radical energy system decarbonisation that requires an immediate and consistent implementation of carbon pricing rising to a 10th to 90th percentile range from £100–400/ tCO_2 by 2050 **[c]**.

- Analysis carried out using the UK Elastic Demand MARKAL model demonstrated the value of energy service demand reductions as an immediate decarbonisation response, hedging against both future high costs of decarbonisation as well as security of supply issues **[d]**.
- Analysis reported to the Scottish Executive has illustrated the opportunities and costs of decarbonisation pathways for a devolved or independent Scotland **[e]**.

3. References to the research

This research stream has generated over 15 peer reviewed journal and book chapters, and has been presented in over 30 major international conferences, and over 100 UK forums to a wide range of stakeholders. Selected publications include:

[a] Strachan N. & Usher, W. (2012) 'Failure to Achieve Stringent Carbon Reduction Targets in a Second-best Policy World'*, Climatic Change*, 113 (2): 121–139. [DOI: 10.1007/s10584-011-0267-6]

[b] Anandarajah, G., McDowall, W. & Ekins, P. (2013) 'Decarbonising Road Transport with Hydrogen and Electricity: Long Term Global Technology Learning Scenarios', *International Journal of Hydrogen Energy*, 38 (8), 3419–3432. [DOI: 10.1016/j.ijhydene.2012.12.110]

[c] Usher W. & Strachan, N. (2012), 'Critical Mid-Term Uncertainties in Long-Term Decarbonisation Pathways', *Energy Policy*, 41: 433–444. [DOI: 10.1016/j.enpol.2011.11.004]

[d] Strachan N. (2011) 'Business As Unusual: Existing Policies in Energy Model Baselines', *Energy Economics*, 33 (2): 153–160. [DOI: 10.1016/j.eneco.2010.10.009]

[e] Anandarajah, G. & McDowall, W. (2012) 'What are the costs of Scotland's climate and renewable policies?', *Energy Policy*, 50, 773–783. [DOI: 10.1016/j.enpol.2012.08.027]

4. Details of the impact

It is difficult to overstate the importance of having a sophisticated and transparent set of state-of-the-art energy systems models for proactive and responsive engagement with the UK policy community. Models are the integrating language of policy and provide the key numbers and insights that form the backbone of the debate and resultant policy impacts. This is particularly true in the highly topical and fast moving area of energy policy, and especially the key goals of energy system decarbonisation and energy security.

The Department of Energy and Climate Change (DECC), in its *2009 UK Low Carbon Transition Plan* **[1]**, accepted the MARKAL elastic demand model's finding (as described in **[d]**) of the critical role of the electricity generation sector to enable wider decarbonisation efforts in buildings and transport. Resultant electricity decarbonisation policy mechanisms have been implemented as a key government priority with latest efforts being support mechanisms under Electricity Market Reform as legislated in the 2013 Energy Bill.

A continuing impact of the MARKAL-TIMES modelling effort for UK government policy making has been in demonstrating the economic feasibility of decarbonisation pathways (as described in **[a]**), including the critical interplay between technological and behavioural change (via energy service demand reductions). UK MARKAL-TIMES has constituted the key technical reports on this topic for DECC's 2011 Carbon Plan **[2]**.

The quantification of electricity sector decarbonisation using MARKAL models is an essential enabling step to meet the targets set by the Committee on Climate Change (CCC). The CCC's carbon budget reports (2009–13) outline the framework for legislated UK carbon budgets, with successively commissioned MARKAL-TIMES modelling projects providing long-term energy and emission scenarios. In 2011, the UK government accepted the CCC's 4th budget period recommendation **[3]** for a 50% reduction (from 1990 levels) in carbon emissions by 2025, with underpinning technical appendices from the UK stochastic MARKAL model **[c]**.

Dr David Joffe, the Head of Modelling for the Committee on Climate Change, has since stated: '*Since 2009, UCL's family of MARKAL/TIMES energy systems models have been heavily utilised*

by the CCC to explore the costs and trade-offs between different long-term decarbonisation pathways. This underpinning research – published in successive CCC reports – has been invaluable in the CCC's assessment of the appropriate level of the 2050 target, what this means for measures required in the medium term within the UK's carbon budget periods, and the policy framework to deliver these.'

Placing UK decarbonisation efforts in a global context **[b]**, the TIAM-UCL model provided the key underpinning technical appendix to the CCC's 2010 international aviation and shipping review **[4]**, which advocated including international transport emissions in the UK's legislated carbon budgets for a fully comprehensive mitigation response to climate change.

Such has been the authoritative benchmark of MARKAL-TIMES that UCL has been instrumental in developing complementary energy modelling tools for key stakeholders. This has included Strachan serving as a strategic advisor on the development of the ESME energy systems model of the Energy Technologies Institute from 2010, illustrating how UK industry has adopted an energy systems modelling approach. In a parallel development, Ekins and Strachan have successfully argued for the incorporation of cost metrics (derived explicitly from MARKAL) to be incorporated into the DECC Calculator **[5]** – the UK government's highly popular policy engagement tool, which is downloaded by 10,000 UK users each month and has been adapted into the nationally utilised My2050 schools classroom toolkit released in November 2012.

Research has been used to provide evidence to policy makers and thus contribute to informed political debate. On 24 May 2011, Strachan was invited to give parliamentary oral evidence based on his modelling expertise to *The UK's Energy Supply: Security or Independence* review by the House of Commons Energy and Climate Change Select Committee. Following the publication of his review of modelling exercises using the UCL MARKAL model from 2009–2013 **[6]**, all of which were directly used in policy support as discussed above, Ekins made two presentations in the Houses of Parliament. At the House of Commons on 26 February 2013, Ekins presented a paper at a UKERC policy briefing on 'The UK Energy System in 2050: Comparing Low-Carbon, Resilient Scenarios' to a number of MPs and their researchers, which fed directly into the then current debate on the Energy Bill about the need to decarbonise the UK electricity system. On 1 May 2013, Ekins then presented in the House of Lords on 'The Role of Gas in a Low-Carbon UK Energy System: Insights from Modelling', which has informed the current debate about the role of shale gas from 2020 in the UK energy system.

In terms of sub-national energy policy-making, a multi-regional version of the UK MARKAL model was presented to senior Scottish government and industry representatives on the potential role of Scotland in meeting its own and the wider UK's renewable energy targets, and subsequently submitted as supporting evidence to the Scottish Parliament's Economy Energy and Tourism Committee **[7]**.

The reach of the MARKAL-TIMES research impact extends also to international energy policy. As research lead on the Japan-UK research project on international modelling on low carbon societies, UCL led an international effort that contributed to the declaration and reaffirmation through 2009–13 of a global long term target of a 50% reduction in greenhouse gas emission in 2050. Furthermore the UCL team served as expert reviewers and contributors to the International Energy Agency's flagship Energy Technology Perspectives publications **[8]**. And on the basis of his research at UCL **[a, c, d]**, Strachan was appointed as lead author on the 'Energy System' chapter under Working Group III of the Intergovernmental Panel on Climate Change 5th Assessment Report, with interim reports in 2011–12 and the final report to appear in April 2014.

To demonstrate how UCL's systems modelling research has resulted in a sea-change in how the UK now funds and uses energy models to underpin policy making, the EPSRC has funded (as of 1 July 2013) a £5.7 million whole energy systems modelling (wholeSEM) consortium (EP/K039326/1) as a centrepiece of the Research Council's energy portfolio. Furthermore, a memorandum of understanding was agreement in September 2013 between UCL and DECC to utilise UK TIMES as the principal model for long-term UK Government energy analysis.

5. Sources to corroborate the impact

[1] DECC (2009), *The UK Low Carbon Transition Plan*, London: Department of Energy and Climate Change [http://webarchive.nationalarchives.gov.uk/20121217150421/http://decc.gov.uk/en/content/cms/emissions/emissions.aspx]

[2] DECC (2011), *The Carbon Plan*, London: Department of Energy and Climate Change [www.gov.uk/government/publications/the-carbon-plan-reducing-greenhouse-gas-emissions--2]

[3] CCC (2010), *The Fourth Carbon Budget - Reducing emissions through the 2020s*, London: Climate Change Committee 4th budget report [http://www.theccc.org.uk/publication/the-fourth-carbon-budget-reducing-emissions-through-the-2020s-2/; see in particular the supporting evidence in Chapter 3]

[4] CCC (2010), International Aviation & Shipping Review, London Climate Change Committee, London [http://www.theccc.org.uk/publication/international-aviation-shipping-review/; see the supporting evidence in Chapter 3]

[5] DECC (2011), *2050 Pathways: Exploring how the UK can meet the 2050 emission reduction target using the web-based 2050 Calculator. Updated model as of March 2011*, London: Department of Energy & Climate Change [http://www.gov.uk/2050-pathways-analysis]

[6] Ekins, P., Keppo, I., Skea, J., Strachan, N., Usher, W. & Anandarajah G. (2013), 'The UK Energy System in 2050: Comparing Low-Carbon Resilient Scenarios', UKERC Research Report (UKERC RR/ESY/2013/001), February 2013, London: UK Energy Research Centre [http://www.ukerc.ac.uk]

[7] McDowall, W., Anandarajah, G. & Ekins, P. 2012 'Insights into Scotland's energy and climate policies from energy systems modeling', *Fraser Economic Commentary*, Special Issue No. 3, University of Strathclyde, Glasgow, pp. 5–8 [Available at http://www.scottish.parliament.uk/S4_EconomyEnergyandTourismCommittee/General%20Documents/FRASER_OF_ALLANDER_INSTITUTE.pdf, PDF]

[8] IEA (2012), *Energy Technology Perspectives 2012: Pathways to a Clean Energy System*. Paris: International Energy Agency [http://www.iea.org/etp/]