UKERC, 'Pathways to a Low Carbon Economy' (2009)

1. Purpose of the activity

The core aims of the UKERC Energy 2050 project were to generate evidence relevant to meeting the UK's principal long-term energy goals as described in the 2007 Energy White Paper:

i. achieving deep cuts in carbon dioxide emissions by 2050, taking the then current 60% - 80% reduction goal as a starting point;
ii. developing a 'resilient' energy system that ensures consumers' energy service needs are met reliably.

A range of scenarios explore specific features of the energy system, including carbon reduction, resilience, accelerated technology development, environmental sensitivities and energy lifestyles.

The outputs described below draw predominantly on the 'Pathways to a Low Carbon Economy: Energy System Modelling' report, and focus on the low-carbon 'core', or CAM, scenario which has 80% reduction (on 1990 levels) in CO_2 emissions by 2050, with 26% reduction by 2020.

2. Model / scenario description

a) timespan and region	2050, UK
b) scenario type	Backcasting, quantitative, normative, expert, whole energy system
c) what the approach has been designed to achieve	To provide a systematic tool to explore the trade-offs and tipping points between alternative energy system pathways, and the cost, energy supply and emissions implications of these alternative pathways. The model gives different plausible outcomes from a range of input parameters and modelling assumptions. A first set of scenarios focus on carbon ambition levels of CO_2 reductions (in 2050) ranging from 40% to 90%, with intermediate (2020) targets of 15% to 32% reductions. These scenarios investigate increasingly stringent targets and the ordering of technologies, behavioural change and policy measures to meet these targets. A second set of scenarios undertake sensitivities around 80% CO_2 reductions with cumulative CO_2 emission targets, notably focusing on early action and different discount rates. These scenarios investigate dynamic tradeoffs and path dependency in decarbonisation pathways.
d) description of modelling method	Uses MARKAL-MED. MARKAL is a widely applied bottom-up, dynamic, linear programming (LP) optimisation model. MARKAL optimises (minimises) the total energy system cost by choosing the investment and operation levels of all the interconnected system elements. The participants of this system are assumed to have perfect inter-temporal knowledge of future policy and economic developments. Hence, under a range of input assumptions, which are key to the model outputs, MARKAL delivers an economy-wide solution of cost-optimal energy market development. MARKAL-MED is the implementation of an elastic demand version to account for the response of energy service demands to prices and it minimises total welfare cost.

e) references, links	The UKERC 2050 project is described, with supporting papers, at http://www.ukerc.ac.uk/support/tiki-index.php?page=Energy+2050+Overview. The UKERC research report 'Pathways to a Low Carbon Economy: Energy System Modelling' is available from http://www.ukerc.ac.uk/support/tiki-index.php?page=UKERC2050PathwaysLowCarbonEconomy Documentation on the UKERC MARKAL model[1] is available from http://www.ukerc.ac.uk/support/tiki-index.php?page=ES_MARKALModelFamily&structure=Energy+Systems. The UK Energy Data Centre holds full scenario data[2], available from http://data.ukedc.rl.ac.uk/cgi-bin/dataset_catalogue/view.cgi.py?id=12.

3. Key Assumptions

a) carbon & energy prices	EU ETS is imposed with price of €20/tCO_2 from 2010 in electricity and industrial sectors. Governmental resource supply curves[3] are translated into higher cost supply steps and imported refined fuel costs.
b) final energy demand	Model meets demands for energy services derived from standard UK forecasts covering transport, buildings and business.[4]
c) economic conditions	GDP growth 2% per annum.
d) social conditions	Energy service demands incorporate a range of demographic, economic and social aspects.
e) learning rates	Exogenous learning curves derived from an assessment of learning rates[5].
f) technology costs	Future technology costs are based on expert assessment of technology vintages, or for less mature electricity and H_2 technologies via exogenous learning curves derived from an assessment of learning rates combined with global forecasts of technology uptake[6].
g) policies	All 2007 Energy White Paper policy measures are implemented (e.g., renewable obligation at 15%, energy efficiency commitment). The (then) proposed EU renewable energy target of 15% of UK final energy demand and the zero carbon homes requirements are not implemented.

[1] Kannan, R., Strachan, N., Pye, S., Anandarajah, G., Balta-Ozkan, N., 2007. UK MARKAL Model Documentation.
[2] Strachan N., Anandarajah G., Hughes N., and Ekins P. (2010), 'UKERC Energy 2050 energy systems scenario data, UKERC Energy Data Centre
[3] Updated energy projections, Department of Business Enterprise and Regulatory Reform, February 2008.
[4] Residential buildings (Shorrock and Uttley, 2003), transport (DfT, 2005), the service sector (Pout and Mackenzie, 2006), and industrial sub-sectors (Fletcher and Marshall, 1995). Generally these sources entail a projection of low energy growth, with saturation effects in key sectors.
[5] McDonald A., and Schrattenholzer L., 2002, 'Learning curves and technology assessment' International Journal of Technology Management, 23 (7/8) 718-745.
[6] European Commission, 2006, 'World Energy Technology Outlook – WETO H2', Report No. EU22038, Directorate General for Research, Brussels.

4. Outputs

(a) final energy demand overall

Final Energy demand by Sector (PJ)	2000	2035-CAM	50-CAM
Agriculture	51	48	49
Industry	1,473	1,321	1276
Residential	1,961	1,666	891
Services	850	624	647
Transport	1,855	1,935	1511
Total	**6,189**	**5,594**	**4374**

(b) how demands were met by fuel

Final Energy demand by fuel (PJ)	2000	2035-CAM	2050-CAM
Electricity	1,176	1,234	1632
Gas	2,391	2,170	1148
Petrol	872	784	311
Diesel	1,164	792	103
Ethanol/Methanol	-	232	393
Bio diesels	-	73	338
Biomass	28	148	176
Other	558	161	273
Total	**6,189**	**5,594**	**4,374**

<5%: jet fuel, LPG, fuel oil, coal, manufactured fuels, H2, heat

(c) power generation by technology

Electricity generation mix (PJ)	2000	2035-CAM	2050-CAM
Coal	396	-	0
Coal CCS	-	797	816
Gas	487	50	0
Nuclear	282	245	764
Wind	3	160	189
Imports	52	88	103
Marine	-	-	64
Other	68	56	71
Total	**1,288**	**1,396**	**2,007**

<5%: oil, solar PV, storage, gas ccs, hydro, biowaste and other

(d) role for bioenergy

Biomass/Biofuel in final energy (PJ)	2000	2035 - CAM	2050 - CAM
Residential	8	88	0
Service	0	29	146
Transport	0	306	731
Total	**8**	**423**	**876**

Very large amount of biomass is selected to reach the mitigation targets set in CAM. Biomass is mainly imported and heavily used in the transport sector, along-with the residential and service sector at a smaller scale.

(e) role of enabling technologies

MARKAL has limited temporal disaggregation, so that the model cannot be used to explore such issues as the daily supply-demand balancing of electricity, heat and other energy carriers.

(f) Decentralised energy and role of CHP

Electricity generation by CHP drops from 3.5% of total supply in 2000 to less than 0.5% from 2035 in CAM scenarios.

(g) costs of achieving goals	The marginal price of CO2 emissions in CAM rises steeply after 2030 (when it is about £25/tCO_2) to £170/tCO_2 in 2050. The undiscounted energy system cost in CAM is £225bn in 2035 and £276bn in 2050, against base case costs of £227bn and £259bn. Discounted costs (at 10% discount rate) for CAM are £6.8bn in 2035, and £2.0bn in 2050, in the base case they are £7.0bn and £1.9bn respectively.

5. Key messages

From the Executive Summary of the UKERC 2050 synthesis report, which draws conclusions from across the range of scenarios employed by the UKERC 2050 project:

- Achieving a resilient low-carbon energy system is technically and economically feasible at an affordable cost.
- There are multiple potential pathways to a low-carbon economy. A key trade-off across the energy system is the speed of reduction in energy demand versus decarbonisation of energy supply. There is also a number of more specific trade-offs and uncertainties, such as the degree to which biomass, as opposed to electricity and perhaps hydrogen, is used in transport and other sectors.
- Deploying new and improved technologies on the supply side will require substantially increased commitment to RD&D, the strengthening of financial incentives and the dismantling of regulatory and market barriers. A major increase in efforts to accelerate the development of emerging low-carbon energy supply technologies promises significant reward, in terms of more affordable decarbonisation pathways, in the long term.
- Increasing the uptake of existing and cost-effective energy efficiency and conservation technologies will reduce the welfare costs associated with demand reduction.
- A resilient energy system needs a range of measures, but reducing energy demand is key. This will reduce our exposure to energy price shocks and could help us to ride out major disruptions to infrastructure.
- Lifestyle changes that reduce energy demand would enhance energy system resilience and reduce the costs of CO_2 reduction. Further work is needed to assess how such changes might be induced and the role that policy could play.
- If public concern about specific technologies prevents their deployment, the cost of meeting CO_2 targets will significantly increase, and a greater burden will be imposed on demand side responses.
- Reducing CO_2 will broadly lead to improvements in other environmental areas, but regulatory attention may be needed in some areas (air quality, water stress) where there are potentially adverse effects.

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