UKERC

UKERC Energy Research Landscape: Energy Systems Modelling

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1. Overview

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Characterisation of the field

The scope of energy system analysis is broad, and fits within an integrated energy modelling approach. This is inherently interdisciplinary, with particular contributions from economics and engineering. Other social science insights (e.g., political science, international relations, sociology and policy analysis) and natural science (e.g., environmental studies, atmospheric chemistry) are incorporated as appropriate. The empirical focus of the model can be the whole energy system (economy-wide), particular elements of the 'energy chain' (either upstream or downstream) or on key sectors (electricity, residential etc).

Energy modelling holds a key position within interdisciplinary research owing to the central role of energy projections in policy decision-making and the political importance of modelling results in policy debates. A particularly notable area of activity is the development and quantification of scenarios relevant to the assessment of energy policy.

In modelling, a broad distinction is usually drawn between top-down and bottom-up models:
Top-down models (both computable general equilibrium [CGE] and macro-econometric) analyse aggregate behaviour using historically derived economic indices of prices and elasticities. Top-down models are more suitable for studying economy-wide responses to energy policies and other drivers, and can generate insights into income, GDP, and competitiveness impacts. Technological detail and real-world constraints on investment and use are aggregated.
Bottom-up models, notably optimization or simulation approaches, can focus at the system or sectoral level, and may accommodate a wider range of policy options. Bottom-up models are more suitable for studying specific technical opportunities and their energy, cost and emission implications, although exogenous forecasts of economic activity may be used. Bottom-up models typically require extensive data sets and necessitate a difficult compromise between the realism of high levels of disaggregation and the constraints of data availability.

A particularly important difference is that top-down models tend to be more pessimistic than bottom-up models about the costs of energy policies. This is related to the difference in the scope and potential for energy efficiency improvements as well as the treatment of technological change. Partly to address these issues and partly to attempt to glean the best out of each modelling framework, a number of hybrid approaches are under development to link the macro and technological approaches to energy modelling.

A third key metric is micro-economics and complementary approaches to model behavioural change. This can be embodied in terms of energy supply, including oligopolistic or monopolistic behaviours, or in terms of energy demand with regards to price responses, heuristics in energy use and diffusion of new technologies.

Furthermore a range of complementary approaches in energy modelling include greater temporal or spatial detail, explicit treatment of institutions, a systematic treatment of uncertainty, a focus on individual sectors or networks, and integrated assessment with environmental or social systems. These models often involve 'soft-linking' different types of models to investigate particular areas of interest (e.g., Geographic Information Systems (GIS) for spatial characteristics).

Research Challenges

Historically, issues related to energy system costs and security of supply have dominated energy modelling. However, in recent years the assessment of environmental issues (notably climate change and CO_2 reductions), have become equally important.

Such assessments of restructuring towards low carbon energy systems have produced a range of analytical challenges, including the assessment of long-run technological change, realistic modelling of behavioural responses, wider environmental and sustainability concerns, the accurate depiction of policy, and the relationship between the energy sector and economic drivers. As a result, energy model types are similarly broad to meet specific research questions, as detailed in the table in Section 2.

Fundamental research challenges include the interdisciplinary nature of the energy system and the resultant need to balance detailed representation of technical systems with regulatory, political, economic and social processes. Data availability for the UK is comparable to other OECD countries, with generally good coverage on traded energy commodities, end-user prices and technology inputs. Less data is available on behavioural responses to energy prices, as well as social and institutional factors in energy decision making. Long-term projection and analysis is problematic in how consumer preferences and technology development may evolve.

Quantitative energy modelling presents a difficulty in translating complex modelling into useful outputs for policy makers. A key challenge is encapsulating and emphasizing uncertainty in modelling outputs.

In the UK, uncertainties in the funding environment throughout the 1990s and early 2000s created difficulties for developing and maintaining modelling expertise within UK universities. Most models require extensive and long-term investment to construct and maintain, with much of this expertise embodied in teams of researchers. While short-term consultancy funding can be obtained for using models to address particular market or policy questions, this is insufficient to maintain modelling capacity. Over the last decade a sustained growth in funding spearheaded through the Research Councils (initially the Towards a Sustainable Energy Economy (TSEC), followed by the RCUK Energy Programme) is partially addressing this.

Like other interdisciplinary social science research, energy modelling falls between different academic departments and research networks. Coherence is aided through the co-ordination of international networks (including the IAEE, EMF and ETSAP), publication in a core set of academic journals (Energy Journal, Energy Economics, Energy Policy), and a growth in dedicated energy research groups and departments (e.g. at the Universities of Leeds, Sussex, Cambridge, Imperial and UCL).

2. Capabilities Assessment

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As detailed in section 3 there is a broad range of energy models and modelling institutions. These encompass the range of top-down, bottom-up, hybrid and complementary approaches. UK modelling capacity is now building up through significant research council investments and supplemented by applied funders, all linked to increased interest in environmental, cost, and security of supply implications of energy supply and use.

The UK has a limited number of examples of energy modelling areas where it is very strong and world leading. The majority of UK energy modelling lies in the medium category illustrating competence and comparable expertise to other G8 countries. That the UK has relatively few weaknesses is a testament to the quality of UK modellers, and the positive impact of recent funding increases.

The unit of focus tends to be the UK as a whole. Aggregation into European or global models and disaggregation to regional or local models is becoming more prevalent, but is still in a minority of models.

In terms of specific modelling gaps in the UK, these include sectoral analysis (notably industry energy use), the impact of global drivers (i.e., resources, emissions trading, technological change), a better treatment of uncertainty via sensitivity and probabilistic assessments of model structure and parameter uncertainty, an enhanced understanding of the macro-economic implications of structural changes in the energy sector, and a deeper assessment of the role of behavioural change in energy use.

Note, that the concept of market potential is not applicable to these underlying strategic analytical tools.

Table 2.1: UK Capabilities

UK Capability	Area	Market potential
High	Macro-econometric	N/A
Medium	Optimisation - systems	N/A
Medium	Macro-economic	N/A
Medium	Integrated assessment	N/A
Medium	Optimisation - sectoral	N/A
Medium	Network / infrastructure	N/A
Medium	Simulation - Buildings	N/A
Medium	Simulation - Transport	N/A
Medium	Micro-economic	N/A
Medium	Cost benefit	N/A
Medium	Econometric	N/A
Medium	Environmental input-output	N/A
Medium	Spatial (GIS)	N/A
Medium	Stochastic	N/A
Low	Simulation - Industry	N/A
Low	Behavioural	N/A
Low	Agent based	N/A
Low	Resources	N/A

3. Basic and applied strategic research

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All UK activity is covered in this section as all energy modelling can be considered as basic/applied strategic research (from the Frascati (2002) definition of R&D).

UK capabilities in the energy modelling domain are arrayed between a number of academic departments, but also through government departments, and consultancies.

Energy modelling and analysis is one area where internal governmental resources have been maintained and even built up. This includes the DECC energy model and DECC pathways calculator. Sectoral-specific public expertise is seen via the National Transport Model, while the National Housing Model is currently under development.

A core set of academic modelling institutes exist that have a critical mass to undertake energy modelling and maintain and fund these analytical developments – these broadly align with the major UK centres of social science energy research. Major players include the University of Cambridge, University College London, University of Oxford, University of Leeds, Imperial College London, and University of Strathclyde. More isolated pockets of expertise exist in a range of other institutes.

Significant modelling expertise is retained in consultancies. These include former government research institutes (BRE and AEA) as well as a range of dynamic specialist firms (including Cambridge Econometrics, OXERA, Pöyry and Redpoint).

Additionally, major energy companies undertake a significant amount of model development and application (e.g., EON UK) but much of this is not in the public domain.

In terms of research funding, a welcome return to viability of undertaking long-term modelling capacities has been spurred by the sustained support of the RCUK Energy Programme. This has been supplemented with applied funding from European institutions, the Energy Technologies Institute (ETI), DECC and the Committee on Climate Change (CCC). However much of these latter funding streams remains generally ad hoc and short term.

Table 3.1: Research Funding

Program	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
UK Energy Research Centre Phase II	RCUK Energy Programme	This is the flagship of the RCUK energy programme, providing a whole systems interdisciplinary approach to energy research. The Energy Systems research theme, run by University College London coordinate systems models at the UK and global scales. This is supplemented by detailed sectoral, network and environmental models in other themes.	£18.5M in total for all activities	2009-2014	£200K for energy modelling
SUPERGEN	RCUK Energy Programme	SUPERGEN consists of 14 consortia, and takes a new approach to supporting research into sustainable power	£98M in total for all	14 ongoing	£200K for energy

		generation and supply. The initiative aims to help the UK meet its environmental emissions targets through a radical improvement in the sustainability of power generation and supply. Researchers work in multidisciplinary partnerships between industry and universities, focused on major programmes of work.	consortia and all activities since 2003	consortia	modelling
Electricity Policy Research Group	RCUK Energy Programme	Interdisciplinary, but with a core economics focus. EPRG focuses on the following areas: Regulation and Markets; Technology and Innovation; Governance and Politics; Climate Change Policy			£50K for energy modelling
ITRC	RCUK	UK Infrastructure Transitions Research Consortium; inform the analysis, planning and design of national infrastructure, through the development and demonstration of new decision support tools, and working with partners in government and industry			
Research Councils responsive mode		Responsive funding for policy analysis using existing models, or targeted updates		Respon-sive	
ETI		The Energy Technologies Institute aims to demonstrate technologies, develop knowledge, skills and supply-chains, inform the development of regulation, standards and policy, and so accelerate the deployment of affordable, secure low-carbon energy systems from 2020 to 2050.		Ongoing	£100K for energy modelling
Tyndall Centre	Various	An ongoing programme to address the climate change research agenda via: 1) To identify and analyse the opportunities, benefits and social, technical and economic challenges associated with different greenhouse gas stabilisation pathways at different temporal and spatial scales; and 2) To explore, evaluate and facilitate sustainable routes for adapting to climate change through policy, behavioural and technological innovation and robust decision-support tools.		Ongoing	£100K for energy modelling
DECC	Central Government	Maintenance of core government energy models, plus responsive funding for policy analysis using existing models, or targeted updates. Includes support of Energy Act and Climate Change Bill implementation, through the Low Carbon Transition Plan		Rolling & respon-sive	£100K for energy modelling

CCC		Responsive funding for policy analysis using existing models to underpin emission budget and other reports			£50K for energy modelling

Table 3.2: Key Research Providers

Name	Description	Sub-topics covered	No of staff	Field
DECC	DECC energy model includes econometric modelling of public, commercial and industrial energy demand, vehicle stock modelling for the transport sector, and a optimisation model for electricity generation. DECC 2050 Pathways calculator, an accounting tool to explore scenarios to match energy supply and demand	Econometrics Accounting	5	Government
DfT	National Transport Model (NTM) as an analytical and policy-testing tool, providing a systematic means of comparing the national consequences of alternative national, or widely-applied local, transport policies.	Simulation Network	<5	Government
University College London, Energy Institute	UK MARKAL Family; TIAM UCL; OSeMOSYS A family of energy systems optimisation models, at alternate scales (London, UK, Global), with macro, elastic demand, stochastic and other variants CaRB: domestic and non-domestic buildings stock models Bayesian Belief Network modelling SEEScen: Society, Energy Environment Scenario	Energy systems Optimization Simulation Behavioural	7	University
University of Cambridge, 4CMR; Judge Business School; EPRG	MDM-E3; E3MG UK and global macro-econometric models that provide an integrated tool for energy and environmental forecasting. The macroeconomic model uses econometric equations to project disaggregated energy demand and iterative changes in economic variables PAGE 2009 Integrated assessment of energy, economic and climate variables, all in a detailed probabilistic environment Integrated Planning Model Optimisation of the electricity network	Macro-econometric Stochastic Integrated assessment Simulation Optimisation	5-10	University
University of Leeds:	SATURN: Traffic network assignment model, including	Behavioural	<5	University

Name	Description	Sub-topics covered	No of staff	Field
Institute for Transport Studies; School of Earth and Environment	emissions and energy use across the network VMM: Simulation stock model for passenger and road freight transport, MRIO: Multi regional input output modelling	Network Simulation Input-Output		
Imperial College: Centre for Transport Studies, ICEPT	Travel behaviour and transport modelling, including survey design and data analysis, travel demand modelling Simulation model of energy systems and innovation	Statistical Micro-economic Simulation	<5	University
ECI, University of Oxford and associated depts	UKDCM, UKNDCM, UKTCM Stock simulation models for the residential, commercial and transportation end-use sectors respectively	Simulation	3	University
University of Strathclyde	AMOS, AMOS-ENVI Economy-energy-environment computable general equilibrium (CGE) modelling framework parameterised for Scotland or the UK	Macroeconomic	3	University
Surrey Energy Economics Centre	Econometric modelling and forecasting of (aggregate and disaggregate) energy demand across all sectors of the UK	Econometric	2	University
University of Cardiff	WASP and CGEN Combined gas and electricity networks electricity models	Optimization Network simulation	2	University
Oxford Brooks University	DECoRuM model A GIS-based domestic energy, carbon counting and carbon reduction model	Spatial Cost-benefit	1	University
London Business School	Econometric and agent-based models of the electricity sector	Econometric Agent based modelling	1	University
Institute for Energy Research and Policy University of Birmingham	Electricity model suite to study issues of market power, efficient pricing	Microeconomic Cost benefit	1	University
UEA	CIAS: Integrated assessment modelling under the Tyndall Centre	Integrated assessment	1	University
Cambridge Econometrics	MDM-E3; E3MG (See University of Cambridge, 4CMR entry)	Macro-econometric	5-10	Consultancy
OXERA	OXERA Wholesale Electricity Model	Simulation	2	Consultancy
Oxford Economics	Global Macro Model	Macro-economic	3	Consultancy

Name	Description	Sub-topics covered	No of staff	Field
Redpoint	Set of electricity dynamic and other market analysis model	Optimisation; Simulation	3	Consultancy
IPA Energy	ECLIPSE: Power system economics	Micro-economic	2	Consultancy
Pöyry Energy	ILEX emissions trading and electricity models	Simulation Optimisation	3	Consultancy
NERA	European Electricity System Model (EESyM)	Micro-economic	2	Consultancy
AEA Technology	UK MARKAL family (see UCL entry) ENUSIM: Energy Use Simulation Model: An engineering model of energy use in the industrial sector.	Optimisation Simulation	2	Consultancy
BRE	BREHOMES, NDEEM Simulation stock models for energy use in the domestic and non-domestic sectors.	Cost benefit Simulation	5-10	R&D science & engineering Consultancy
ETI	ESME: Energy systems model	Optimisation	2	R&D science & engineering
Policy Studies Institute	UK MARKAL family (see UCL entry)	Optimisation	1	Research institute

4. Applied Research and Development
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Not applicable – see section 3.

5. Demonstration Funding
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Not applicable – see section 3.

6. Research Facilities and Other Assets
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Not applicable – energy systems analysis requires conventional computing power and good data sets rather than large capital equipment

7. Networks

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Energy modelling in the UK has no dedicated network. Instead, researchers interact through sector specific or discipline specific networks. UKERC's NERN network is the major cross discipline information platform. With some researchers not attached to major modelling groups, there is likely to be a number of practitioners getting less interaction with potential collaborators.

Table 7.1 Networks

Network	Established	Description	Membership	Activities
BIEE	1990	British Institute of Energy Economics, part of the International Association for Energy Economics (IAEE)	Energy economists in academia, government and industry	Publication of the Energy Journal, annual national and international conferences
UKERC NERN	2004	UK Energy Research Centre free network	All organisations and individuals involved in energy research who can make a contribution towards energy R&D in the UK	Free informational resource to develop the coherence and capacity of UK energy research modelling, with regular newsletters, blogs etc
SDRN		Sustainable Development Research Network	Open to all interested researchers and analysts	Newsletter and events to contribute to sustainable development in the UK by encouraging the better use of evidence and research in policy-making
HEEDNET		Heterodox economics for environment and development network	Development and policy analysts, with a focus on economics	Dialogue on current environmental and sustainable development policy issues, seminars and occasional papers

8. UK Participation in EU Activities

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There is a considerable investment in energy systems analysis and modelling at the EU level. However UK participation in this is lower than that of other countries. One reason for this is the lack of UK access to and use of major European energy modelling tools, including POLES, PRIMES, GEM-E3 and PET-TIMES

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual spend
ATEST Analysing transition planning and systemic energy planning tools for the implementation of the energy technology information system	Review models/tools used in the European Countries, taking in mind what is used outside Europe; and what are the requirements of the SETPlan). Identify and recommend common tools to be used in all countries and in the Energy Technology Information System, and gain consensus on these models. Identify and recommend existing technology databases and provide a roadmap for the development of these databases on a European and on a regional basis.	FP7-ENERGY	Coordination (or networking) actions	University of Westminster	Centre for Renewable Energy Sources and Saving, Greece Plus 8 partners	€1.3M	€0.9M	Start date:2009-10-01 End date:2012-03-31	€0.36M
PLANETS Probabilistic long-term assessment of new energy technology scenarios	The goal of PLANETS is to devise robust scenarios for the evolution of energy technologies in the next 50 years. This is achieved by means of an ensemble of quantitative and analytical tools that are designed to foresee the best technological	FP7-ENERGY	Small or medium-scale focused research project	University of Manchester	Fondazione Eni Enrico Mattei, Italy Plus 8 partners	€1.92M	€1.54M	Start date:2008-01-01 End date:2010-06-30	€0.62M

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual spend
	hedging policy in response to future environmental and energy policies								
AMPERE Assessment of Climate Change Mitigation Pathways and Evaluation of the Robustness of Mitigation Cost Estimates	The project AMPERE is aiming for a broad exploration of mitigation pathways and associated mitigation costs under various real world limitations, while at the same time generating a better understanding about the differences across models, and the relation to historical trends.	FP7-ENVIRONMENT	Small or medium-scale focused research project	MET Office	Potsdam Institut, Germany Plus 20 partners	€4.26M	€3.15M	Start date:2011-02-01 End date:2014-01-31	€1.26M
EXIOPOL A new environmental accounting Framework using externality data and input-output tools for policy analysis	1-To synthesize and develop comprehensive estimates of the external costs for Europe of a broad set of economic activities; 2-To set up a detailed environmentally extended (EE) Input-Output (I-O) framework, with links to other socio-economic models 3-To apply the results of the external cost estimates and EE I-O analysis for the analysis of policy questions of importance, as well as to evaluate the impact of past research on external	FP6-SUSTDEV	Integrated Project	University of Bath, UCL, Queens University Belfast, University of Edinburgh, IEEP	Fondazione Eni Enrico Mattei Plus 33 partners	€6.59M	€5.00M	Start date:2007-03-01 End date:2011-10-31	€1.07M

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual spend
	costs on policy-making in the EU.								
NEEDS New Energy Externalities Development for Sustainability	Ultimate objective is to evaluate the full costs and benefits (i.e. direct + external) of energy policies and of future energy systems, both for individual countries and for the enlarged EU as a whole.	FP6-SUSTDEV	Integrated Project	University of Bath, University of Newcastle	Istituto Di Studi Per L'integrazione Dei Sistemi, Italy Plus 67 partners	€11.7M	€7.6M	Start date:2004-09-01 End date:2009-02-28	€1.69M
ADAM Adaptation and Mitigation Strategies: Supporting European climate policy	To assess the extent to which existing and evolving EU (and world) mitigation and adaptation policies can achieve a tolerable transition to a world with a global climate no warmer than 2 degrees C above pre-industrial levels, and to identify their associated costs and effectiveness. To develop and appraise a portfolio of longer term strategic policy options that could contribute to addressing identified shortfalls both between existing mitigation policies and the achievement of the EU's 2°C target, and between existing adaptation policy development and implied EU goals and targets for adaptation. To develop a	FP6-SUSTDEV	Integrated Project	University of East Anglia, University of Cambridge	University of East Anglia, UK Plus 25 partners	€18.2M	€12.9M	Start date:2006-03-01 End date:2009-07-31	€3.8M

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual spend
	novel Policy-options Appraisal Framework and apply it both to existing and evolving policies, and to new, long-term strategic policy options.								

9. International Initiatives

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Coherence within UK energy modelling and exposure to state-of-the-art modelling techniques and ideas have been greatly facilitated by increasingly good links with international initiatives. This has facilitated increased journal publications and international conference participation.

Table 9.1: International Activities

Name	Type	Description	UK Contact Point
ETSAP	IEA Implementing Agreement	The Energy Technology Systems Analysis Programme (ETSAP) was first established in 1976. It functions as a consortium of member country teams and invited teams that actively cooperate to establish, maintain, and expand a consistent multi-country energy /economy /environment analytical capability. Its backbone consists of individual national teams in over 35 countries, and a common, comparable and combinable methodology, mainly based on the MARKAL / TIMES family of models, permitting in-depth national, multi-country, and global energy and environmental analyses. ETSAP holds open workshops twice a year, to discuss methodologies, disseminate results, and provide opportunities for new users to get acquainted with advanced energy-technology developments. As part of its outreach activities, ETSAP collaborates with many other research teams throughout the world, participates in various global forums, and makes its Newsletter and its Workshop Proceedings available online to the public at large.	Stephanie Ockenden, DECC
Energy Modelling Forum	International Network	The EMF (Energy Modelling Forum) was established in 1976 to provide a structured forum within which energy experts from government, industry, universities, and other research organizations could meet to study important energy and environmental issues of common interest. EMF studies emphasize the important insights for energy planning and policy that are learned from a comparison of alternative modelling approaches. This focus makes the Forum's conclusions relevant to policy makers and decision makers who are not modelling experts. Operating through ad hoc working groups focused on a particular topic, each study seeks to summarize and synthesize the truly key findings from modelling and related analysis that can better inform policymaking and business strategy.	Limited direct UK involvement in current studies
IAEE	International Network	The IAEE is a worldwide non-profit professional organization which provides an interdisciplinary forum for the exchange of ideas, experience and issues among professionals interested in energy economics. To achieve this goal, it publishes The Energy Journal – a quarterly, academic publication, and holds International	

		American and European Energy Conferences each year.	
IPCC	International Collaboration	The Intergovernmental Panel on Climate Change (IPCC) has been established by WMO and UNEP to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation. Working Group III is concerned with mitigation issues in general and energy in particular. The 4th IPCC assessment reported in 2007 with multiple chapters relevant to energy; the 5th assessment report is due in 2014.	David Warrilow, DECC
LCS-RNet	International Network	A global network for understanding the transition to low carbon societies. Its objectives are: promotion of information exchange and research cooperation; dialogues between researchers and various stakeholders including policy-makers, businesses, citizens; contribution to international policy-making processes on climate change including G8 process by providing research outcomes.	Jim Skea, UKERC