UK Energy Research Centre

Energy Modelling in the UK

Briefing paper 4: Decision making in government and industry

Pei-Hao Li and Neil Strachan

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Introduction

Energy models are a great short-hand way to combine different methods from different disciplines to address the complexity of the energy system. Modelling of the energy system has underpinned decision making since the oil shocks of the 1970s. Over the last decade, the legislation of long-term decarbonisation targets (to net zero emissions by 2050) has substantially boosted the need for modelling. Some elements of any energy transition have better data and more established tools such as physical flows of energy, technology characteristics, economic costs and benefits, environmental impacts etc. but others are more challenging to model such as societal trends, feasible policy landscapes, long-term uncertainties etc.

Hence, energy models provide the underpinning evidence to support decision makers across policy, industry and civil society to understand strategies and trade-offs in the energy transition. Decision-makers need to understand what is in any given model:

- How does it solve, how does it deal with time and space, what sectors and technologies does it cover?
- What are the model's inputs and outputs?
- What external drivers it uses, what key insights it gives, what impacts has it had?

A key part of enabling this understanding is the transparency of energy models, so both technical and senior decision makers can understand a model, have confidence in its outputs, recognise its limitations and appropriately apply its insights to specific questions. The UKERC Modelling Hub defines transparency in three levels:

1. Open Description models: concise methodological summary, outline documentation and link to outputs and applications;
2. Open Access models: as 'open description' plus full documentation, data sets, and a user group for access and shared responsibility for model development;
3. Open Source models: fully transparent and accessible models available for any user to download, reproduce, enhance, and apply.

To gain an understanding of what energy models the UK has, UKERC's Energy Modelling Hub coordinated a ground-breaking survey of all the energy models in the UK. This is advised by a Steering Group of key policy stakeholders.[1] As of 1st April 2021, there are 76 UK energy models reported into our database.[2] This is much more comprehensive than past reviews that relied only on models with accessible published information. But there will still be potential gaps and biases.

1 UK Research and Innovation (UKRI), UK Government (BEIS), Scottish Government, Northern Ireland Government, Committee on Climate Change, Energy Systems Catapult, and the National Infrastructure Commission

2 The survey remains open for additional modelling entries, or for updates to existing model entries

This policy brief (#4) is the fourth of four from UKERC's Modelling Hub survey. The first brief on the UK energy modelling landscape, detailed the diversity – across academic, government and consulting firms – of who hosts and runs models, their methodologies and coverage, and their major outputs. The second brief on the strengths and weaknesses of UK energy models highlighted the inevitable trade-offs – in terms of temporal and spatial disaggregation, the coverage of technologies and infrastructures, and the treatment of individual behaviour change and broader societal trends – in any individual energy model. The third brief on the construction, maintenance and transparency of models discussed the project-by-project nature of model development, the hidden effort of model updating, calibration and documentation, and the current low level of transparency in UK energy models.

This final policy brief completes the findings from this first iteration of the UKERC survey of UK models and focuses on how models have underpinned decision making on the transition of the energy system.

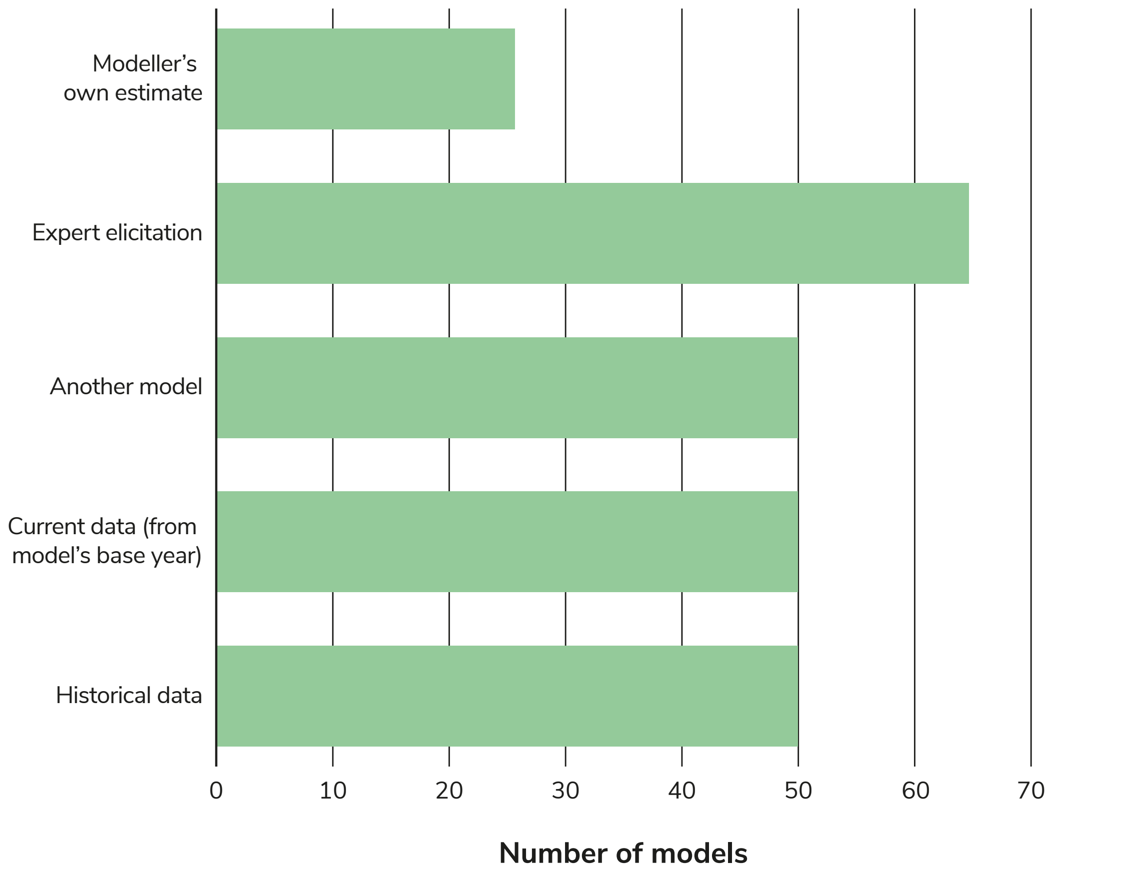
Initial findings

Over three-quarters of models have combined inputs

Key inputs

Models are not just a great short-hand way to combine different methodologies, they are also a mechanism to combine and utilise different sets of external information. As shown in Figure 1, these inputs are extensive and multiple inputs are required for most models. Most models are anchored in past data, either from a single calibration point and/or from a time series of historical data. Of course, the further forward in time a model projects, the less applicable historical data generally becomes. Other key sources for model parameters include other models (as an example, many models take forecasts of future oil and gas prices from the International Energy Agency's modelling suite), especially if these parameters need to be derived from specialised calculations that are not the focus of the model being used. Recognising the large uncertainties in the energy system, expert elicitation – either asking experts individually or via group exercise – is a commonplace for parameters and "known unknown" quantities. Finally, many models have numbers in them that come from their team's own internal calculation, estimates and judgement. This reliance on self-modeller expertise re-emphasises the importance of transparency and in structured uncertainty analysis around these inputs.

Figure 1 Source categories for external inputs

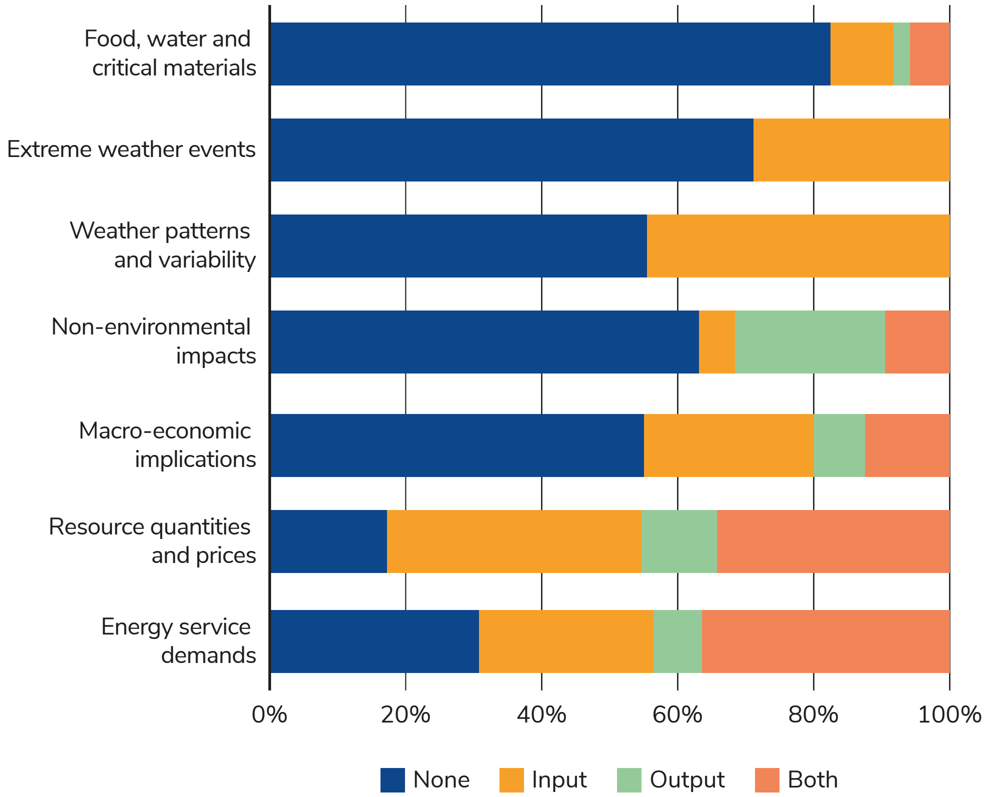


Model inputs are not just individual numbers, values, parameters or constraints. Over three-quarters of models have combined inputs into a coherent scenario exercise to drive a model and give context to a particular model run. Such scenarios can be relatively simple and indicate the broad states of the world the energy system operates in (e.g. one with high or low economic growth), or they can be fleshed out into highly detailed and nuanced narratives as modellers seek consistency over a wide set of inputs. Again, transparency is key in this process to enable buy-in from model users.

From inputs to outputs

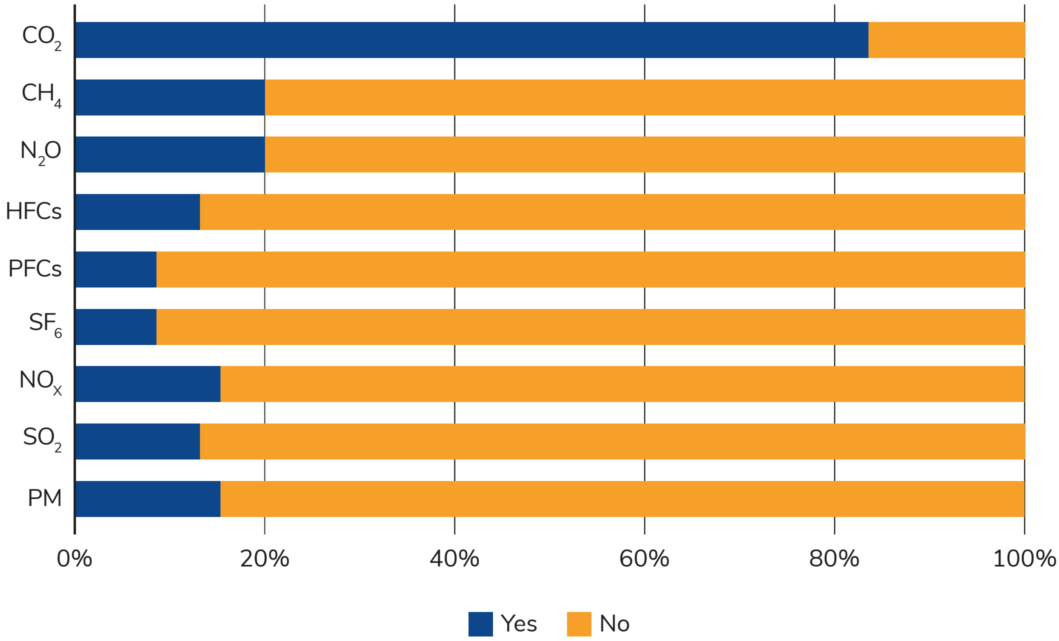
Energy models do not exist in isolation – as well as taking external inputs from different sources they produce outputs for decision making or for further input into other models. Sometimes they do both. Figure 2 shows these input and output categories for the UK energy models in our survey. From the extremes of the energy systems spectrum, the downstream demands that consumer and firms have for energy services, and the upstream supply and price of resources (e.g. oil, biomass etc.) are the most common quantities for inputs/outputs to/from most models. On the other hand, only a specialised subset of energy models consider food, water and critical materials, while weather and climate are a similarly specialised model input.

Figure 2 Model input and output categories



Focusing on the links between energy models and the broader environment, Figure 3 shows the emission outputs of the surveyed models. CO_2 is by far the most common output – this makes sense both as decarbonisation has been the most high-profile energy policy issue in the UK, and as CO_2 is straightforward to calculate from overall flows of energy. Fewer models also capture other greenhouse gases (GHGs) as these require more detail on agricultures and specific industrial sectors, while only a specialised subset of energy models focus on local air pollutants and its health impacts.

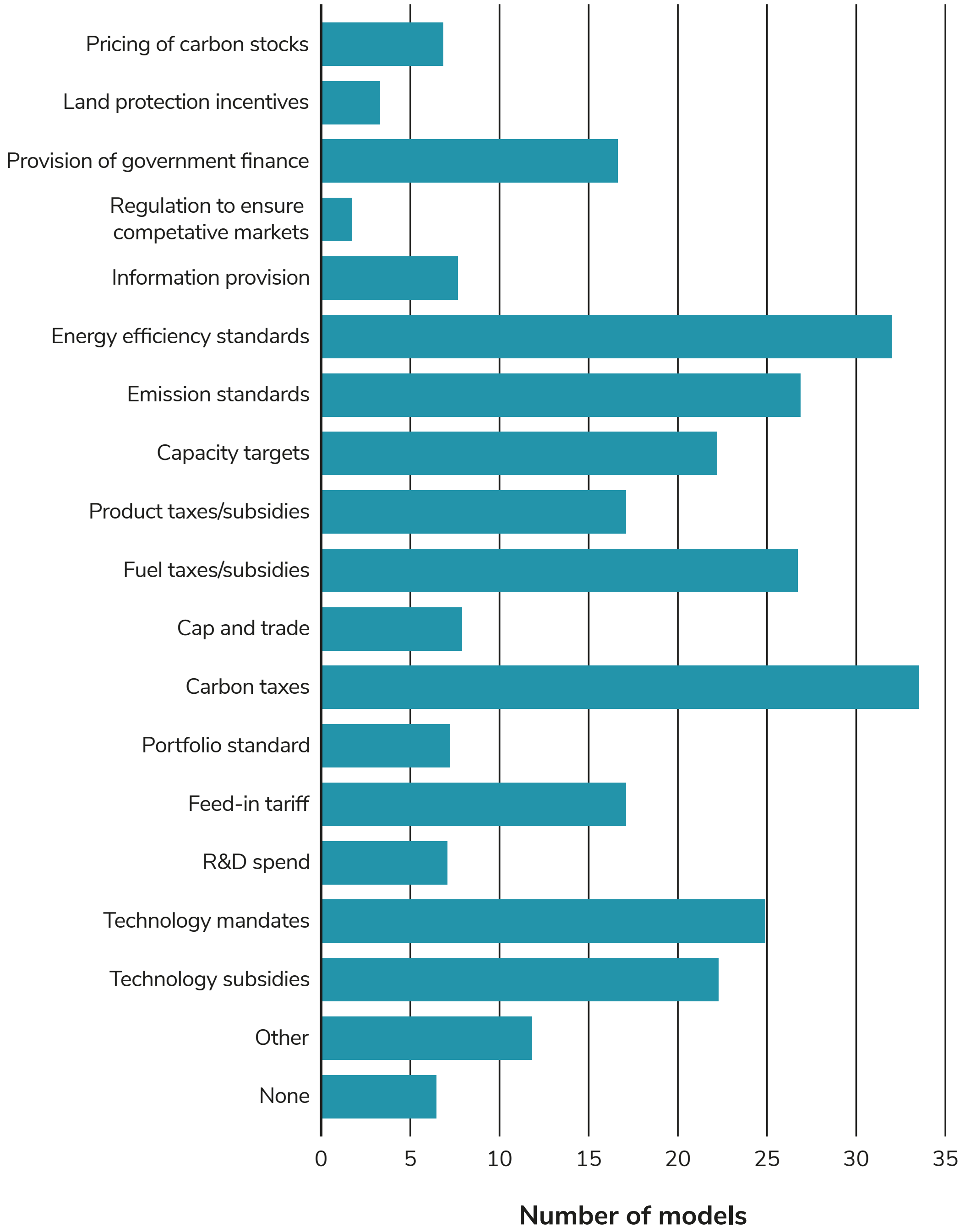
Figure 3 Environmental focus of model outputs



Underpinning decision making

The diversity of energy policy options that models can address reflects both the complexity of the energy system and the range of UK energy model types (Figure 4). This ranges from technology support mechanisms, through pricing options, to standards for efficiency and emissions. Relatively fewer models directly address wider energy policies – R&D spend, information, regulation and finance – both due to a relative lack of data and less obvious methodologies to capture these drivers.

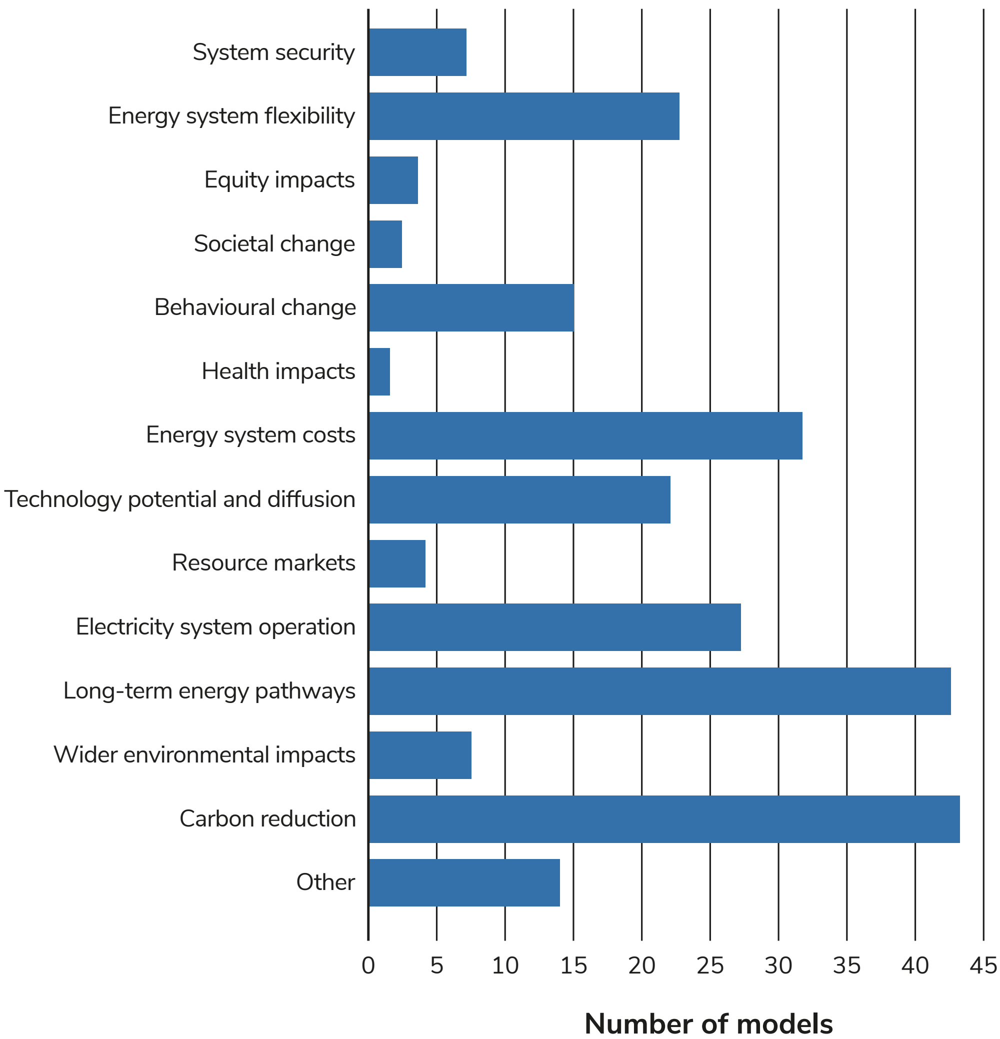
Figure 4 Capacity to model key policy options



is by far the most common output as it is straight forward to calculate

The above foci of models mirror the recently implemented (and proposed) policy options in the UK electricity, transport and building sectors. Figure 5 details the three major applications of the surveyed models. The models' primary capacities (technology support mechanisms, pricing options, standards for efficiency and emissions), translate into an application focus on carbon reductions, long-term pathways, technology diffusion and energy system costs. However there has been a wider application of models to other key energy issues, notably; ensuring electricity system operation and flexibility, understanding wider environmental impacts, and trying to harness consumer behavioural change.

Figure 5 Application to key policy issues



Policy-industrial-academic use of models

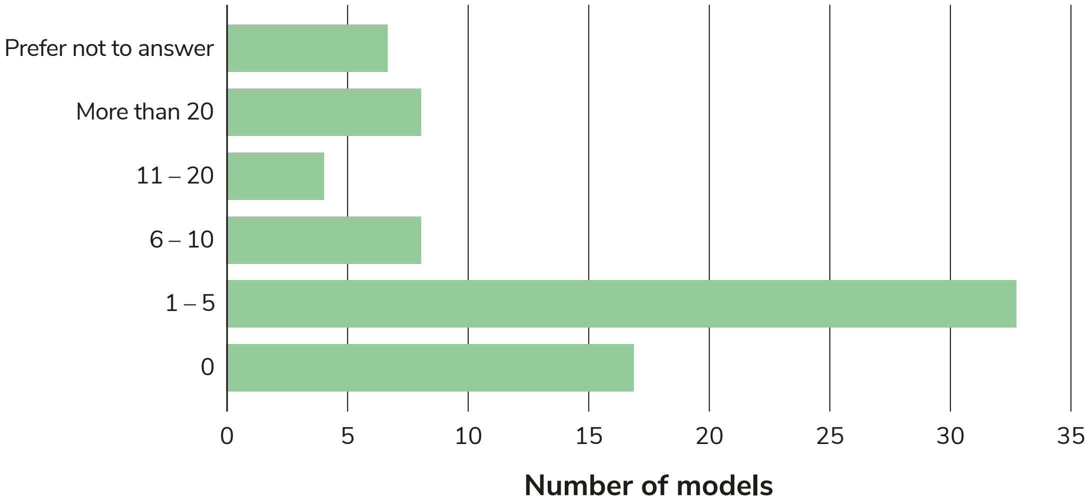
However, although UK energy models have this diversity of capacities and applications, their actual use to support key policy and industrial decisions is not uniform (Figure 6). Many models are applied in the same year they were developed, other require 1 to 3 years until they underpin a policy/industry decision There is also a divergence between a set of models that have been applied to specific decision making (with this application increasing in frequency in recent years), vs. a set of models that are not (yet) directly linked to policy or industrial strategic choices.

Figure 6 First use for policy or industrial decision-making support

	2000	2006	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	N/A
2000	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006		0	0	0	1	0	0	0	0	1	0	0	0	0	0	1
2008			1	1	0	0	0	0	0	0	0	0	1	0	0	0
2009				0	1	0	0	1	0	0	0	0	0	0	0	0
2010					1	1	1	0	0	0	0	0	0	0	0	0
2011						0	1	0	0	0	0	0	0	0	0	1
2012							2	0	0	0	1	0	0	0	0	0
2013								4	1	0	0	0	0	0	0	2
2014									2	1	0	1	1	0	0	0
2015										1	0	0	1	0	0	1
2016											2	2	1	0	0	3
2017												1	2	1	1	3
2018													5	1	1	1
2019														1	0	3
2020															4	7

Of the set of models commonly used for strategic decision making, only a minority (37%) are used for a repeating and regular purpose – i.e. maintained for an annual report, a statutory policy assessment etc. The majority of models are applied to policy via a less regular and more responsive process – this may be driven by completion of major academic projects, by calls for evidence, or by specific commissioning of analysis. Figure 7 shows how if a model's key reports are disseminated to policy makers this is most commonly for only 1-5 instance per model. This is understandable for decision-makers who are constantly seeking the best modelling insights and also a variety of approaches, but is a challenge for modelling teams in the continuity of funding and hence utility of their models (as discussed further in Modelling Hub policy brief #3). A smaller set of models are heavily utilised for repeated policy input.

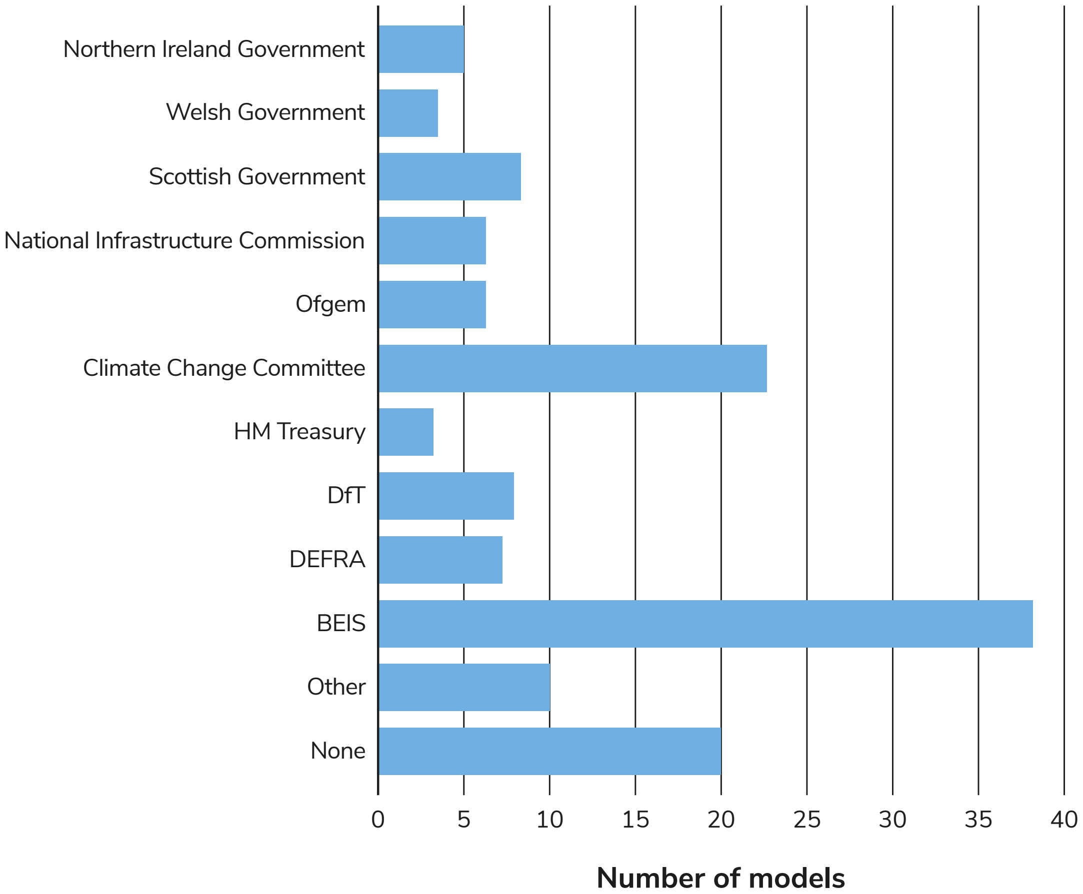
Figure 7 Repeated policy application of models



In terms of the policy users (or "customers"), this is dominated by the Department of Business, Energy and Industrial Strategy (BEIS) and the Committee on Climate Change (CCC), with further Westminster departments, devolved governments, and public bodies as listed in Figure 8.

The focus on BEIS and the CCC for modelling evidence ties back into an application focus on carbon reductions, long-term pathways, technology diffusion and energy system costs as major recent policy debates.

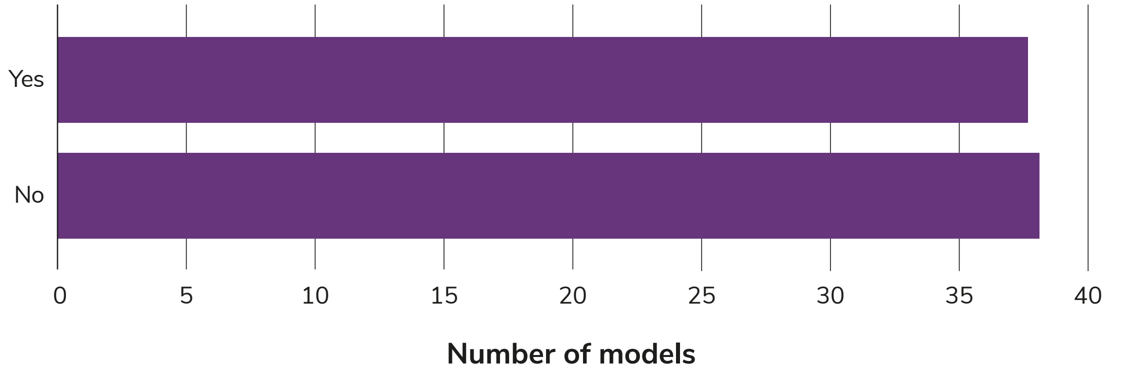
Figure 8 Policy "customers" of models



only 37% of models are used for a repeating and regular purpose

Of course, in the same way that models are developed and run by academic, consultants and government itself, the use of modelling for underpinning evidence goes well beyond policy uses. Around 50% of models have been applied to a business decision for specific firms or industrial organisations (Figure 9).

Figure 9 Industrial application of models



Academic outputs are also important, both as a key metric of a university team's output (and hence funding), to showcase and compare UK expertise on an international stage, and for non-academic models to engage with their research counterparts in analytical methods.

Similar to policy applications (Figure 7), most models have only a few (or even none) academic journal papers, with a sub-set of models being highly productive in terms of their pure research output (Figure 10).

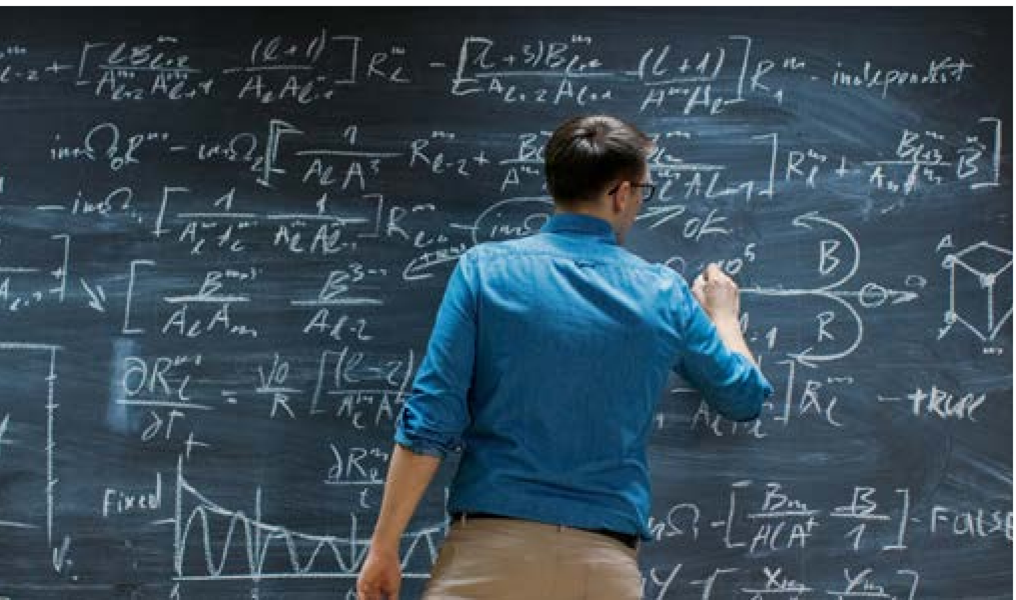
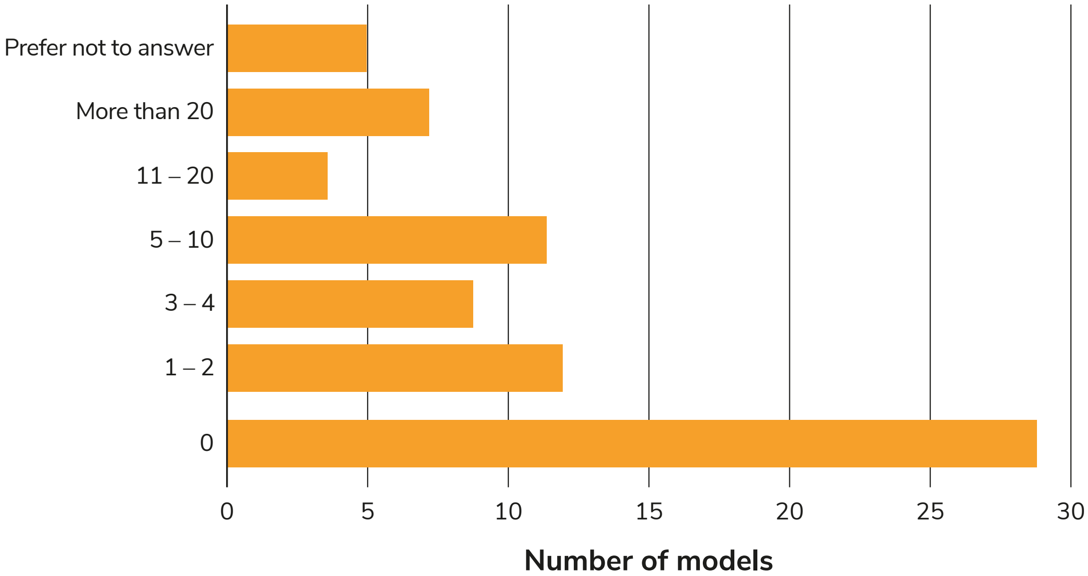


Figure 10 Academic output of models



In terms of any type of outputs for energy models there are no systematic trade-offs by developer or by methodology. Perhaps unsurprisingly, universities' models are more likely to be applied to academic papers (48% of models with more than five journal papers), but both government and consultancy models feature in the academic literature. Higher shares of consultancy's models (38%) are applied to industry decisions but again all three organisations' models are utilised.

As for analytical frameworks, the predominant use of econometrics models has been for policy (perhaps illustrating the need for near- and medium-term forecasts), while the most common use of environmental life cycle models has been in academia (perhaps illustrating the research debate on trade-offs in energy transition pathways). But again, different methodologies are all applied by model consumers in policy, industry and academia.

Summary

This policy brief has focussed on how energy models provide the underpinning evidence to support decision makers across policy, industry and civil society to understand strategies and trade-offs in the energy transition.

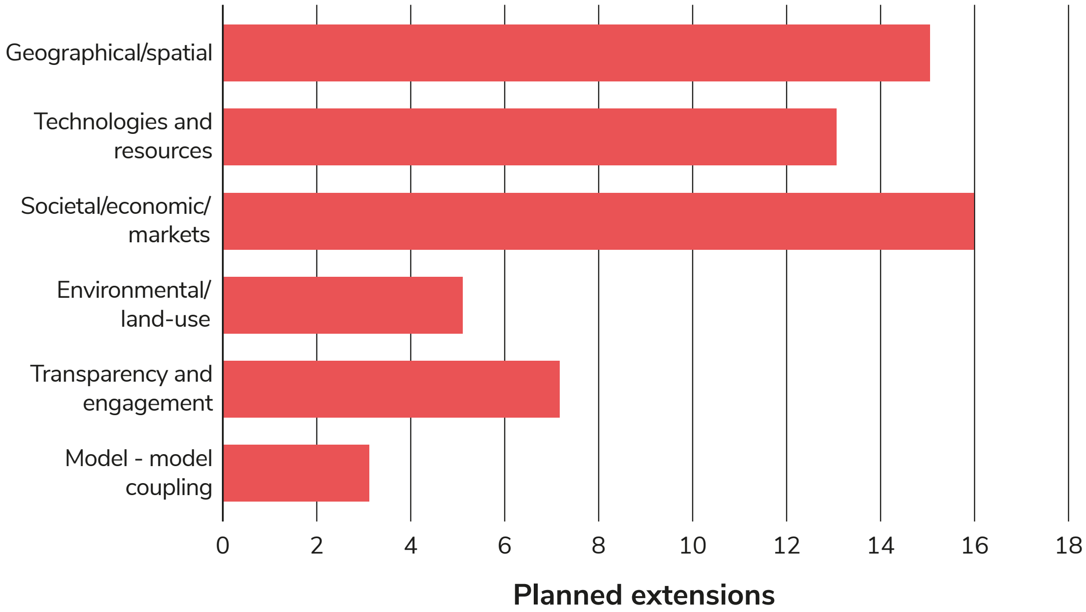
Models rely on historical data, data from other models, expert opinion from stakeholders, and calculation by modellers themselves all as key inputs. Indeed, models do not exist in isolation, and rather form a chain from external inputs to produce outputs for decision making or for further input into other models.

Many UK energy models' primary capacities (technology support mechanisms, pricing options, standards for efficiency and emissions), translate into an application focus on carbon reductions, long-term pathways, technology diffusion and energy system costs. This reflects the current landscape for policy and industrial decision makers. However there has also been a wider application of models to other energy issues (e.g., electricity system flexibility, wider environmental impacts, and consumer behavioural change).

UK energy models are both built by academic, consultants and government modellers and applied to policy, business and research questions. However, the actual use of UK energy models to support key policy and industrial decisions is not uniform, with a subset of models being employed repeatedly while other remain focused (for now) on pure research questions.

In an optional question in the survey, 30 modellers responded on the planned extensions to their models. A major element of these critical development pathways for their analytical tools is improving their applicability to the insights that decision makers require (or will require in the future). Reflecting the diversity in modelling tools, different teams are pursing different improvements which both build on strengths and acknowledge/respond to weakness from iterations with decision makers. Reflecting the prior discussion on model strengths and weaknesses in policy brief #2, the first four categories in Figure 11 span across the complexity of the energy systems and its transition to net zero emission whilst meeting costs, security, equity and other environmental goals.

Figure 11 Planned extensions / development of models



The final two categories in Figure 11 focus on developments of improved transparency and engagement which recognises the importance of iterative participation with model users (both senior decision makers and technical staff) across government and industry. This links back to our call in policy brief #3 to further improve the transparency of energy models (stepping from open description to open access to fully open source models as appropriate). And the effort to better connect and couple different models brings us full circle to the first policy brief in our series which highlighted how no model can cover the full scope and complexity of the energy system.

Authors

Pei-Hao Li, University College London
Neil Strachan, University College London

Reference

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Contact

T: +44 (0)20 3108 7564
Email: UKERC@ucl.ac.uk
Website: www.ukerc.ac.uk
: @UKERCHQ
: www.linkedin.com/company/uk-energy-research-centre

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UK Energy Research Centre,
Central House, BSEER,
14 Upper Woburn Place,
London, WC1H 0NN