UK Energy Research Centre

Energy Modelling in the UK

Briefing paper 1: The modelling landscape

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Introduction

Analysis of the energy transition has drawn heavily on energy modelling, which has been taking place since the oil shocks of the 1970s. The topic lends itself well to quantification due to a number of factors including the physical flows of energy, costs and benefits, different technology characteristics and environmental impacts. Alongside this, as energy is a truly interdisciplinary subject, models are a great short-hand way to combine different methods from different disciplines.

Debate has focused on making models transparent so they qualify as "true science"

Modelling of the energy transition takes place alongside empirical analysis and qualitative research methods. Models therefore underpin decision making – across policy, industry and civil society – to enable the energy transition, with UK energy modelling based across academia, government and consulting firms. All these modellers wrestle with the same key issues:

- what type, how complex, and what strengths their model should have;
- how to fund, maintain and apply that model to decision making;
- how transparent to make its inputs and outputs?

In academia a debate has raged[1], focusing on energy model transparency with a view to making models transparent so they qualify as "true science" where others can understand, verify and replicate the research.[2]

The UK government has led a parallel effort to make all the models it uses transparent and quality assured via the guidance in the Aqua Book.

To investigate these issues, UKERC's Energy Modelling Hub coordinated a ground-breaking survey[3] of all the energy models in the UK. This is advised by a Steering Group of key policy stakeholders.[4]

As of 1st April 2021, there are 76 UK energy models reported into our database, the survey remains open for additional entries and updates to existing entries.

This briefing paper is the first of four to focus on results from UKERC's Modelling Hub survey. In this brief we cover the UK energy modelling landscape. These initial findings detail who hosts and runs models, their methodologies and coverage, and their major outputs.

[1] Pfenninger, S. 2017. Energy scientists must show their workings. Access here.

[2] DeCarolis, et al. 2017. Formalizing best practice for energy system optimization modelling. Access here.

[3] Access the survey here.

[4] 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

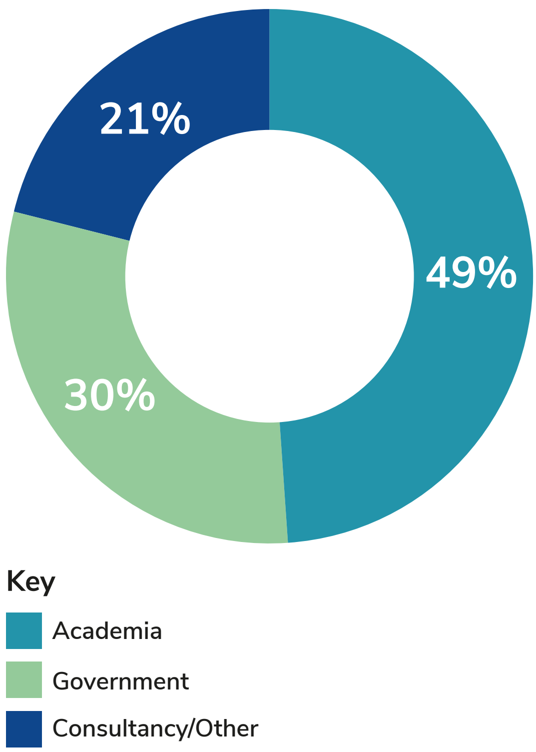
Initial findings

Host organisations

Energy modelling capacity in the UK is spread over many types of organisations (figure 1). Universities are a key player, but very significant expertise is held in-house by government departments, both in Westminster as well as the devolved administrations.
A third key player are those organisations that either sell modelling services (consultancies) or provides specific advice (public bodies) to policy and industrial decision making.

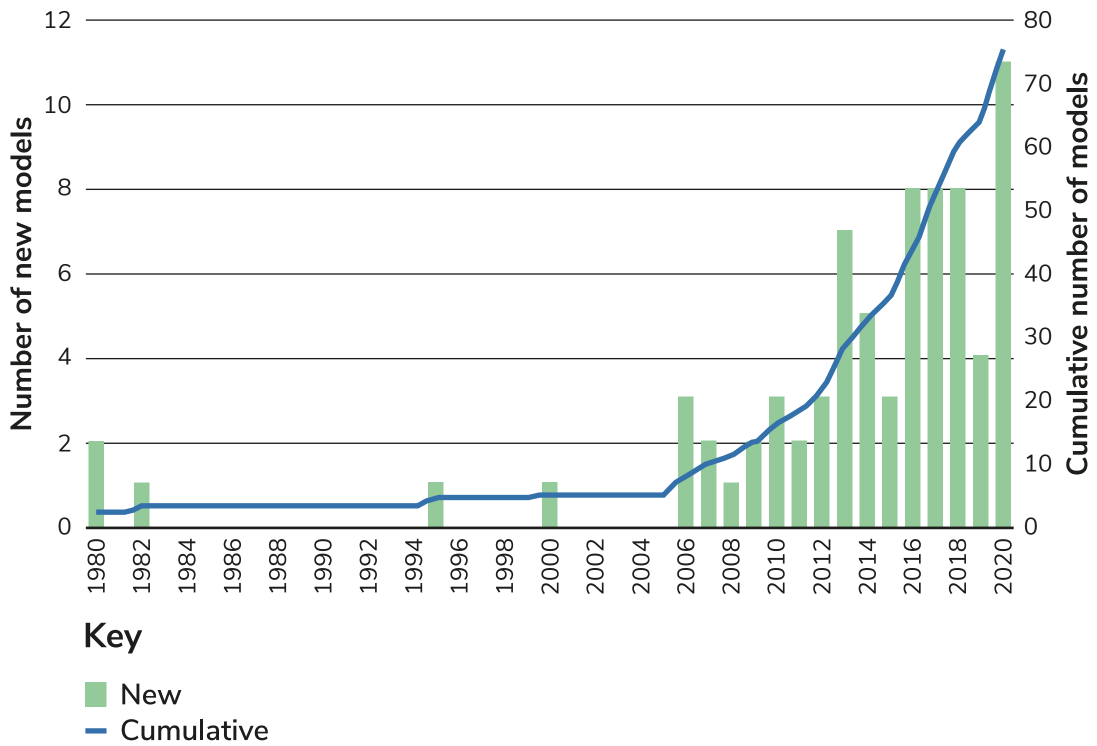
UKRI is the largest funder of academic models. However, government not only develops its own models but is a second major funder for all model developers. It is also common for all organisations to develop (at least initially) models using their own institutional resources.

Figure 1: UK energy models by host organisation



A handful of models have a very long life-span (20 or even 40 years old), indicating a continual analytical output and continued investment in data, software and staff expertise of these legacy models (figure 2). However, of the current generation of energy models, their founding coincides with the rise of the energy transition as a fundamental policy question and hence also as a company strategy issue. The landmark Climate Change Act in 2008 legislated for carbon reduction targets, which were later strengthened to zero carbon by 2050. In the last five years, the trend for model development has further accelerated, with around six new models developed every year.

Figure 2: Development of UK energy modelling capacity

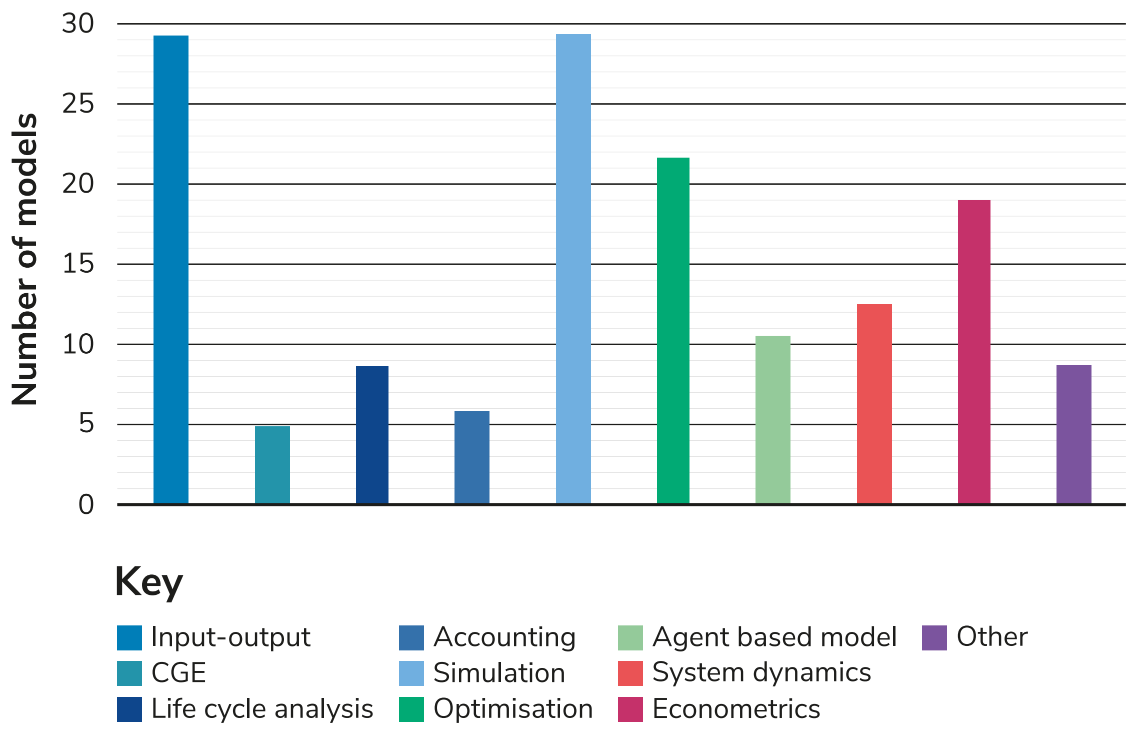


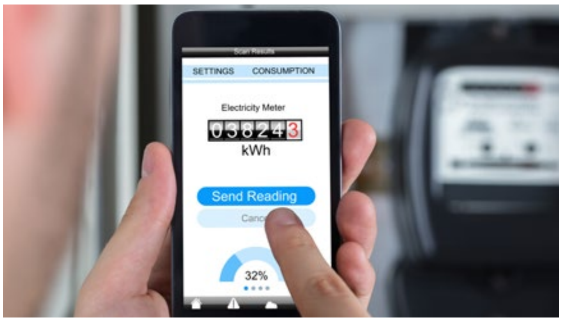
Analytical methods

There is a wide range of analytical methodologies employed in the spectrum of UK energy models (figure 3), likely reflecting the heterogeneity of different energy sectors, the interdisciplinarity of modellers themselves and the lack of a dominant theoretical approach. Figure 3 sums to many more than the 76 discrete models in the database, illustrating that many models use a combination of methods – for example in formulating energy demand and energy supply separately – showcasing the frequency of systems-wide modelling approaches.

The multi-disciplinarity of the energy systems field has also shown how different modellers have a different interpretation of modelling terms (this is despite the survey being iterated and tested via a set of in-house models at the UCL Energy Institute). Specifically, a common category was input-output which is a specific model type in academia and energy economics, but this has a much broader interpretation in engineering as well as in government.

Figure 3: Analytical methods of UK energy models





In the last five years, the range of analytical approaches has widened; including agent-based, system dynamics, and econometrics models (figure 4). Part of this trend is due to the need to capture distributed decision making, as well as feedbacks (intended and unintended). While another factor is the increased availability of energy demand data
in how people and firms consume energy.

Figure 4: Analytical modelling methodology through time

	Pre-2008	2008 – 2014	2015 onwards
Input-output	5	8	18
CGE	2	0	3
Life cycle analysis	1	4	4
Accounting	1	2	3
Simulation	6	8	17
Optimisation	1	10	12
Agent-based model	1	1	9
System dynamics	2	2	9
Econometrics	5	5	10
Other	2	2	5

Coverage of sectors and vectors

Figure 5 details the sectoral coverage of models and again shows the drive for integrated systems approaches which cover a range of end-use sectors (via their competition for fuels, and interlinkages via finances and policy). Of course, there are also a set of highly detailed, single-sector energy models as part of the UK capacity. The relative paucity of agricultural models is due to analysis of this sector having much broader environmental and societal drivers/impacts than just energy. The same applies for transport (especially road transport) where a number of transport models that focus on other policy priorities (congestion, air pollution, safety etc.) are likely missing from this energy modelling database.

Figure 5: Sectoral coverage of energy models

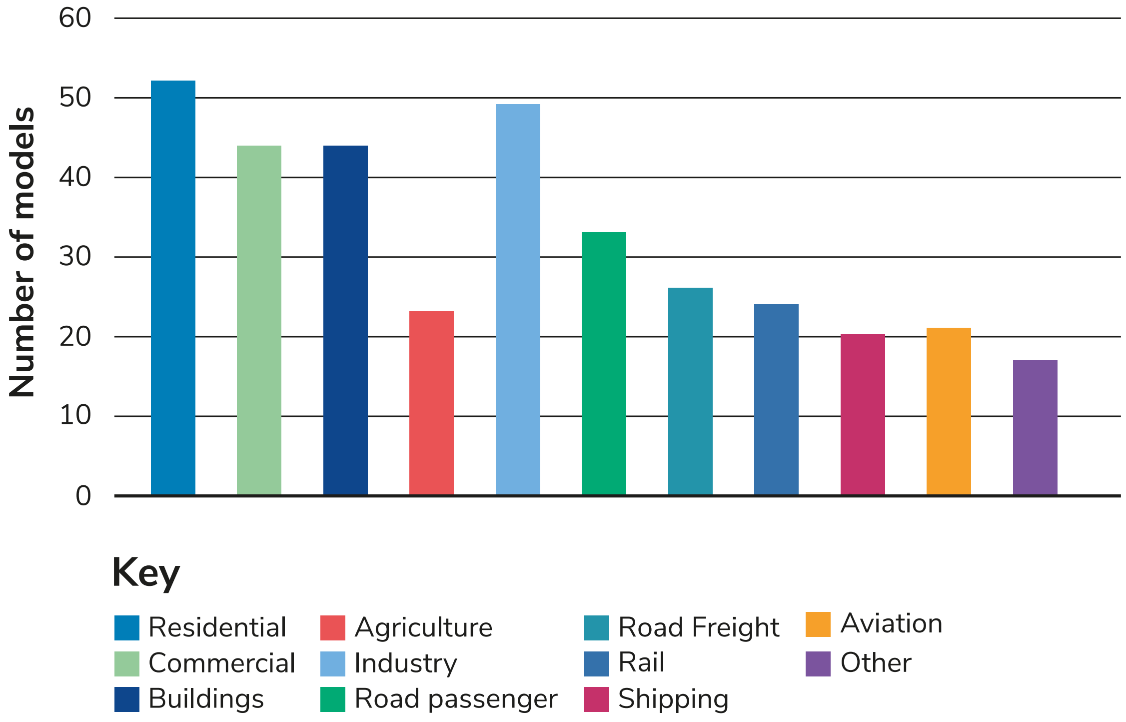


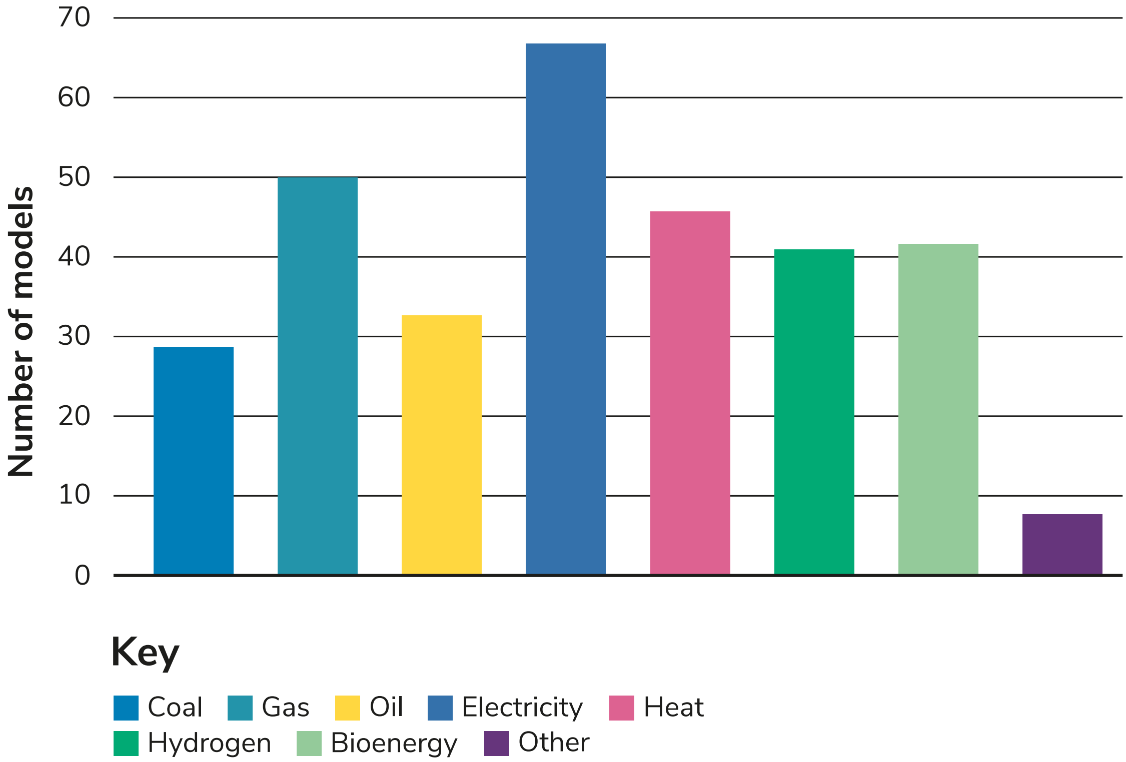
Figure 6 shows that all types of modelling organisations cover the full spectrum of modelled end-use sectors. This is logical given the range of departments and the policy/regulatory priorities that governments must cover, the many different foci due to the absence of a dominant academic discipline in energy modelling, and that consultancies are marketing their expertise to a full range of public bodies and private firms.

Figure 6: Sectoral energy modelling by organisation type

	Government	Academia	Consultancy/Other
Residential	13	23	16
Commercial	12	18	14
Buildings	11	18	15
Agriculture	8	9	6
Industry	13	22	14
Road passenger	7	15	11
Road freight	7	11	8
Rail	5	12	7
Shipping	6	9	5
Aviation	6	10	5
Other	8	9	0

The commonality of integrated systems approaches is again shown in how many models encompass multiple energy vectors (figure 7). However, the most covered energy vector is electricity (88% of all models), followed by gas (66%) and heat (61%). This is understandable as those vectors have played a key role in the UK's energy system, and electricity especially is expected to play an even larger role in a decarbonised future energy system. In recent years more models have additionally included hydrogen and bio-energy as these vectors have been touted as low carbon carriers for transport modes and industrial sub-sectors.

Figure 7: Energy vector coverage of UK models



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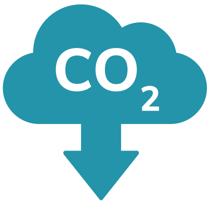
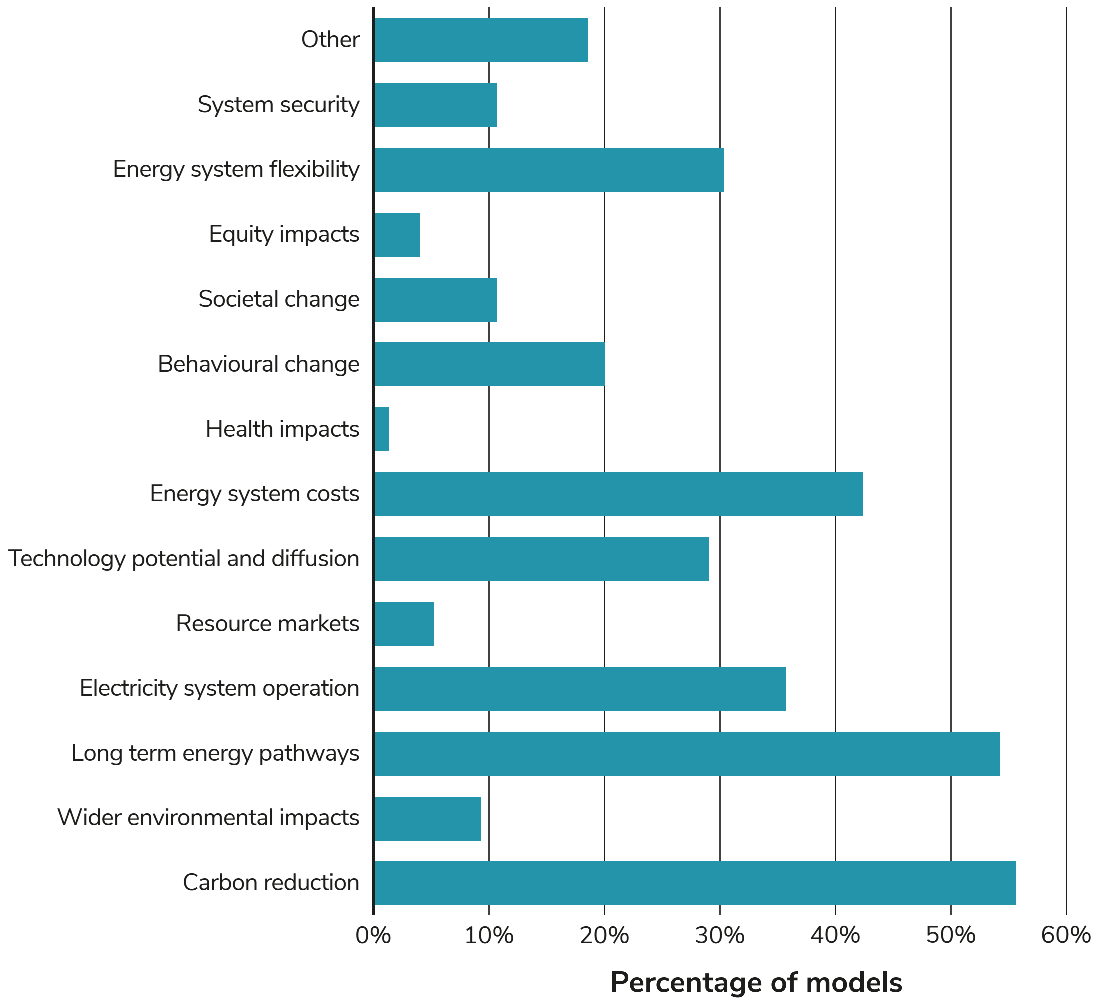


One of the most common model application was carbon reduction

Major applications

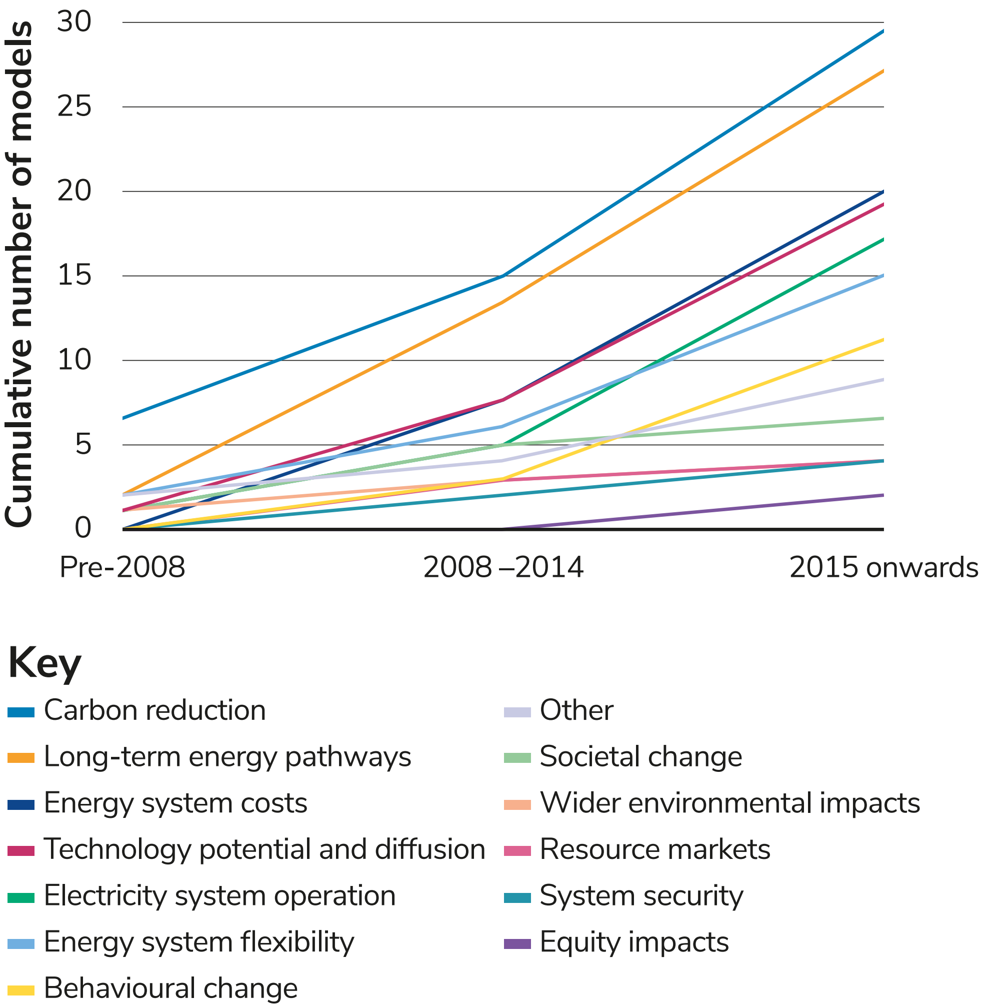
When modellers were asked to list the three primary applications of their UK energy models (figure 8), the most common answers were carbon reduction and long-term energy pathways, mirroring the policy and investment narrative over the last 15 years or so. The significant share of models considering energy system costs (42%) implies that it is critical to consider monetary impacts when evaluating measures to achieve policy targets as well as understand future investment patterns.

Figure 8: Three major applications of energy models

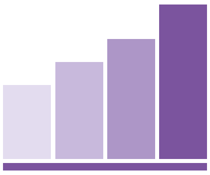


As illustrated by figure 9, in recent years (post 2008) energy system flexibility and electricity system operation have become key applications for UK energy models, responding to the challenge of integrating very large amounts of intermittent generation that has led to a dramatic reduction in unit cost. Even though relatively less common, over the last five years the UK energy modelling capacity has started to consider wider issues; such as societal change, equity impacts, and health impacts. This mirrors a general change in the discourse from predominantly supply-side techno-economic solutions to more inclusive solutions that also consider societal and political factors.

Figure 9: Time trend of major applications of energy models



Summary



76

different energy models in use in the UK

Overall the survey identified 76 different energy models in use in the UK. 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. Interestingly, a survey tells us quite a lot about what energy models the UK has, but not necessarily how good, how sophisticated or how accurate they are.

This first set of findings on the modelling landscape has shown the diversity of UK energy models; across organisation types, across analytical methods, and across a systems coverage of sectors. UK modelling capacity – and its application to key policy and investment decisions – has further grown and diversified in recent years. This has been driven by the legislative processes and new potential business models from the centennial challenge of the energy decarbonisation transition.

The Modelling Hub will continue to analyse the results collated via the survey, and future publications will focus on: #2 Model strengths and weaknesses; #3 Construction, maintenance and transparency and #4 Applications to decision making.

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