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Energy model, boundary object and societal lens: 35 years of the MARKAL model in the UK

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ABSTRACT

Technical energy models operate within social systems and those that perform particular social as well as technical functions are more likely to be used. We illustrate this with the example of the MARKAL energy system model in the UK, a model that is also widely used internationally. In the UK, MARKAL modelling has a long history helping underpin government energy and climate policy. We trace the use of the model from its initial development in the mid-1970s to the present day, highlighting attributes that contribute to its role as a successful 'boundary object' for different but interconnecting energy policy communities. We suggest that changing images of the energy policy problem have enabled MARKAL to shift from an initial role in identifying technologies to reduce oil dependency to playing a key role in target-oriented climate policy. Furthermore, we argue that the ability of MARKAL to perform different roles for different groups has served to embed and institutionalise the model in the energy policy community. Moreover, the capacity of the model to represent detailed technology options has accorded with a technological focus that has suited prevailing, shared conceptions of the energy-climate policy problem.

1. Introduction

The MARKAL energy system model was originally developed under the auspices of the International Energy Agency (IEA) in the late 1970s and is arguably one of the most successful energy models of recent decades. In 2001, Seebregts et al. took the view that: "*The MARKAL family of models is unique, benefiting from application in wide variety of settings and global technical support from the international research community. Implementation in more than 40 countries and by more than 80 institutions, including developed, transitional, and developing economies indicates wide acceptability*" [1, pp. 75–76]. Since then, application of the model has continued to increase and today it is used in nearly 70 countries [2] and has provided underpinning analysis for more than 90 peer-reviewed journal articles in the period 2004 to 2014. The United Kingdom (UK) Government and its agencies have been longstanding users of the MARKAL model and, in recent years, MARKAL modelling has been used extensively to inform UK energy and climate policy. Results from MARKAL have provided inputs to documents including the *2003 Energy White Paper* [3], the *2007 Energy White Paper* [4], the *2011 Carbon Plan* [5] and the Committee on Climate Change reports *Building a Low-carbon Economy* [6] and *The Fourth Carbon Budget* [7].

In this paper, we describe the use of MARKAL in the UK and provide an account of its enduring appeal to academic and policy communities by reference to the concept of a boundary object [8,9]. Drawing on the authors' collective experience of MARKAL, we interrogate its role in shaping UK energy and climate policy, with a particular focus on the period from 2001 to 2011. Our interest is not so much in MARKAL's technical characteristics or policy application per se, but rather in how MARKAL has successfully served the differing but intersecting needs of academic and policy communities over a sustained period of time, helping to rationalise major and innovative climate and energy policy commitments. We suggest that MARKAL has brought together mutually supportive epistemic communities across academic and policy worlds, helping to develop and maintain a networked and influential community

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with shared assumptions and goals in which economic and technical models are privileged.

Our motivation is to add to the body of work that understands energy system analysis as in need of social as well as technical contextualisation, but our findings also have relevance to other topical areas of energy social science, including communication and persuasion, social psychology and politics and political economy [10]. In short, we suggest that the particular characteristics of the MARKAL model – highly specialist, cost-based, technology-rich – have allowed it to span the differing but related logics of government and academia and sustained its use by these communities over several decades.

We further reflect on how the model has both been advantaged by changing understandings (images) of the energy policy problem, as climate objectives have increased in importance, while also playing a role in policy path creation, supporting significant climate policy commitments. Seeking to explain the above, we connect literatures on (a) scientific models as active boundary objects in policy development and (b) the way in which changing images of a policy problem can allow new analytic and policy options to enter the political and policy space. We observe how MARKAL has played a transformative role in this context, while itself also being transformed, as the MARKAL modelling process has become target-oriented. Finally, we note how the use of MARKAL to support the policy process has not gone unchallenged.

2. Theory

2.1. The MARKAL energy systems model

The MARKAL energy model was originally developed as part of a programme of energy technology systems analysis and strategy development initiated in 1976 by IEA countries, in the aftermath of the 1973/74 oil embargo by the Organization of Petroleum Exporting Countries (OPEC). In 1980, this programme became an Implementing Agreement of the IEA known as the Energy Technology Systems Analysis Programme and continues to support and promote the use of MARKAL to this day.

MARKAL belongs to a class of bottom-up energy systems models. These models aim at a solution that satisfies the demand for energy services through a disaggregated and technology-oriented approach to modelling energy supply and demand. In the case of MARKAL, the solution is usually represented as a set of technologies that represents the least cost configuration for an energy system that meets both the exogenously specified demands and any additional constraints, such as those on emissions. Using this approach it is possible to identify the potential contributions of different energy supply and demand technologies under a wide range of future possible scenarios, as well as the costs involved.

The original objective of the model was "*to assess the long-term role of new technologies in the energy systems of the participating countries and thereby provide focus for current research-and-development (R&D) support*" [11, p. 353]. Specifically MARKAL was designed to help in understanding [ibid, pp. 353–54]:

(a) "*the relative attractiveness of existing and new energy technologies and energy resources in satisfying plausible future demands for useful energy*;
(b) *the time evolution of the introduction of and investment costs for new technologies and resources and the time evolution of the decline in use of existing resources, especially imported petroleum*;
(c) *the sensitivity of future energy systems to different goal choices and ordering, with system cost, the amount of imported petroleum, and the relative contributions of nuclear, renewable, and fossil resources being the criteria of interest; and*
(d) *the long-range effect of conservation and efficiency improvements on the energy system*."

In recent years, MARKAL has been used by a wide-range of organisations in many different countries to model energy systems at a variety of spatial scales from global applications, through regional and national models, to the local-level, such as a single city [12–18]. These studies have also ranged in focus from analysing changes to the entire energy system to examining the prospects for particular sectors or technologies. New variants of the model have also been developed that have arguably increased its usefulness and relevance in both policy and academic circles, as we show in Section 4.

2.2. Models, policy images and boundary objects

In this section, we connect the idea of scientific models and their output as boundary objects to the theory of changing policy images (beliefs and values) as a facilitator of policy change. In this regard, external pressures can raise the political and policy salience of particular issues, enabling and driving change [19]. We also see the theory of policy change as punctuated equilibrium as particularly relevant. This perspective views policy change as taking the form of relatively long periods of stasis being 'punctuated' by shorter periods of change [20,21] (c.f. Kingdon's concept of a time-limited 'policy window' [22]). Policy stasis is explained by the dominance of closed groups of policy experts, which can be interrupted by a changing image or understanding of the nature of the policy problem [19]. Driving these changes are competitive processes, both between government departments and in wider society, in which actors seek to achieve policy change that is consistent with their agendas [21].

Our argument is, firstly, that MARKAL's changing use through the period circa 1990–2011 reflects a change in the prevalent image of the energy policy problem. This has been from one in which the UK government saw its primary role as setting a framework within which the market could deliver the energy needs of the country, to a policy image of a climate-constrained world in which radical changes to the UK energy system would be required, with the attendant need for more active government involvement to identify how this low carbon transition could be achieved and which technologies might require support. MARKAL has been well positioned to allow consideration of new goals and configurations for the energy system; moreover, the changing use and nature of MARKAL offer an insight into the changing perceptions of energy policy, as this became integrated with climate policy

Secondly, that this changing use has been strongly supported by the way in which MARKAL and its output have successfully functioned as a boundary object, simultaneously connecting and meeting needs in different communities, providing and supporting shared understandings of the changing image of the policy problem. As van Egmond and Zeiss [21] observe, the idea of the boundary object has proved useful in explaining the hybrid nature of scientific models used in policy – that is, the way in which such models are not only based on mathematical representations of the world, but are also shaped by, and play a role in shaping, the social world in which they are embedded [21,23]. Science and policy scholars have previously studied the relationship between modelling practices and policy practices [24–27], in general observing that models play a role in co-ordinating policy practice. This is not just in the rhythm of modelling runs and policy use of modelling output, but more specifically in terms of the way in which models provide 'discursive spaces' in which shared understandings are