Energy Research & Social Science 47 (2019) 69–77

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

How modelers construct energy costs: Discursive elements in Energy System and Integrated Assessment Models

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ARTICLE INFO

Keywords:
Energy models
Integrated assessment models
Discourses
Constructivism
SKAD

ABSTRACT

Energy system and integrated assessment models (IAMs) are widely used techniques for knowledge production to assess costs of future energy pathways and economic effects of energy/climate policies. With their increased use for policy assessment and increasing dominance in energy policy science, such models attract increasing criticism. In the last years, such models – especially the highly complex IAMs, have been accused of being *arbitrary*. We challenge this view and argue that the models and their assumptions are not arbitrary, but they are normative and reflect the modelers' understanding of the functioning of the society, the environment-societal relations and respective appropriate scientific tools and theories – in short: models are shaped by discursive structures, reproducing and reinforcing particular societal discourses. We identify 9 distinct paths, all relating to crucial model decisions, via which discourses enter models: for each of these decisions, there are multiple "correct" answers, in the sense that they can be justified within a particular discourse. We conclude that decisions of modelers about the structure and about assumptions in energy modeling are not arbitrary but contingent to the discursive context the modeler is related to. This has two implications. First, modelers and consumers of model output must reflect on what a model and its assumptions *represent*, and not only whether are they *correct*. Second, models hardly need to add more (mathematical) complexity, but rather be reduced and simplified so that they can continue to fulfill their main function as formalized and powerful instruments for thought experiments about future energy pathways.

1. Introduction

How much does decarbonization of the energy system cost? Hundreds of researchers have tried to answer this fundamental question in the last decades. With the rise in computing power, a whole new scientific branch of energy system models and integrated assessment models (IAMs) has arisen, and today scientific energy system and policy analysis without models is unthinkable [1–4]. Such models are used for energy and climate policy advice on all political levels, be it global [5], European [6,7] or national [8,9]. The central output of these models are costs, technology mixes and impacts of different possible future energy pathways, examining the effect of changes in a wide range of parameters, such as input costs; different global, regional or national climate change mitigation policies; or specific national or regional energy policies [4,10,11]. Their results are widely used in politics and public debates as they are often presented as an *objective* basis for decision-making [12].

However, energy system models and especially IAMs have also been criticized of being "inescapably subjective" [13], as being neither theory-driven nor empirically sound [14,15] and of creating their own worlds in which basic scientific standards such as falsification is impossible [16,17], especially since both the models and the used data are often intransparent [18]. Modelers have started to counter this criticism by explicitly framing their research as exploring an unknown future to avoid misinterpretation of models as projection tools. Model evaluation and intercomparison projects [2,3,19] are other ways modelers take to improve the "appropriateness, interpretability, verifiability, credibility, and usefulness" of models [20] and "reduce model uncertainty" [21]. Still, models – especially IAMs – are criticized for creating "a perception of knowledge and precision that is illusory and can fool policymakers into thinking that the forecasts the models generate have some kind of scientific legitimacy" [14] (see also [22,23]). Pindyck further accuses modelers of *arbitrarily* deciding both the functions of the system and the single parameters, including decisive ones like discount rates, damage

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https://doi.org/10.1016/j.erss.2018.08.021
Received 20 June 2018; Received in revised form 23 August 2018; Accepted 24 August 2018

functions or technology cost, making the entire model and its output arbitrary [14].

In this article, we scrutinize this statement. By applying a social constructivist notion of knowledge, going beyond the positivist fact-value dichotomy, we challenge the view that assumptions and parameters in energy models and IAMs are "arbitrary" and seek the discursive determinants of modelers' decisions for how their models are built and the input data is generated. Specifically, we investigate what kind of discursive elements can be found in the models and where these elements enter the models.

We do not investigate whether particular assumptions of model structure or input data are – in a positivist sense – *correct* or *realistic*; further, we do not explain which specific discourses are present in specific modeling teams – we identify whether and where entry points for discourses in energy models and IAMs exist.

2. Literature review and theoretical foundation

Research about possible energy futures is a hot topic in climate and environmental studies. Especially the social and societal implications of different energy futures, the stories and narratives behind energy policies and visions and the social context of energy related behavior has gotten further attention [24,25]. However, regarding the process of energy modeling the vast amount of research has been related to the development of *better*, more *coherent* and even more *complex* – and hence seemingly more *accurate* – modeling techniques. In recent years, researchers have started to reflect on modeling techniques and some criticized them as being arbitrary and non-falsifiable [14,26]. The modeling community responded to this by increasing the complexity of modeling techniques, involving stakeholders for data input or scenario evaluation, or run modeling intercomparison projects to determine "best practices" and to compare the specific features of the models and their effects on the results [2,3,19,27,28]. Also researchers from non-modeling communities have started to investigate specific non-technical aspects of modeling such as the epistemic modes of modeling [29], the objectives [1], the archeology of models [30], the effects on policy recommendations of different modeling narratives [31], the theoretical perspectives on knowledge generation of IAMs [32] or the impact of models on policy advise [12]. Further, there are nascent attempts to better integrate modeling with socio-technical transitions analysis [33]. A discourse-analytical understanding of energy models and IAMs is however still lacking.

To identify the social embeddedness of modelers' decisions regarding assumptions and structures in modeling processes, we will first refer to more general concepts how to analyze economic phenomena and will later apply this to the case of energy system models and, especially, IAMs. Berger and Luckmann further developed the view that reality is socially constructed and not detached from societal institutions, experiences, signs and roles [34]. This has been applied to the economic domain, looking at economic knowledge generation and the implications for the perception and interpretation of economic action in different societal fields. Relating to this basic assumption, a large amount of research has been done to analyze the calculative characteristics of economic transactions, economic knowledge generation and risk management [35–38], yet an analysis of energy modeling is lacking. Smelser and Swedberg [39] founded a new strand of economic sociology, based on the assumption that the economy is an integral part of society and must be analyzed with the same methods and assumptions as other societal phenomena, including the examination of social structures, conventions, institutions, identities and the perception of different actors of these categories. Furthermore, special interest has been given to power aspects of economic knowledge generation e.g. the social construction of accounting methods and their influence on perceptions of economic categories and institutions like the "firm", "credit rating", "risks" or "responsibilities" of different agents. Miller for example discusses the permeable and historically contingent character of cost conceptions in accounting by analyzing accounting standards as tools for decision-making, finding that these "different functions of cost accounting called for different concepts of costs." [40]. Common to all these studies is their finding that calculative tools to measure economic phenomena and correlations produce their objects by measuring them. Particularly in the study of finance the reciprocal role of economists and their objects have been analyzed, revealing that results of calculative actions cannot be understood as representations of an objective reality but as determining and constituting the subject to be examined [37,41]. "Reality" is thus not something that can be *measured* – as a positivist researcher would claim – but in a social constructivist sense it can be at best be *understood* by looking at the social construction process and its determinants.

This social constructivist perspective on reality relates to the *archeology of knowledge* concept of Foucault, viewing practices/behavior not as "arbitrary" but "contingent" on discursive structures [42]. Here, we follow this school of thought understanding the act of building complex mathematical-computational models, such as IAMs, as a process that is closely connected to and influenced by societal discourses and institutions, but also as one that can shape reality by reproducing a discourse by calculating it (power effect). Looking at models and their outputs thus means looking at "artefacts" [29] but with power effects: discursive structures are main determinants for behavior – but actors can and do influence these structures, e.g. through discursive battles about dominating narratives.

3. Method

In this article, we analyze how energy model results such as cost statements *are made* by modeling practices – specifically, how and where discursive elements are channeled into the models. For this, we use and extend the SKAD framework, which was designed "to analyze ongoing and heterogeneous processes of the social construction—production, circulation, transformation—of knowledge" [43]. The SKAD links the process orientation of the sociology of knowledge to epistemic assumptions from Foucauldian discourse analysis [38]. To identify the context in which modelers decide for specific parameters and functions, we use this research concept to relate the modes of knowledge production in energy models and IAMs to wider societal discourses.

Discourses are here defined as sense-making units that produce a certain set of practices and assign meaning to objects and social phenomena [43], including norms, worldviews and specific system beliefs. Economic discourses are thus "*collective practices processing economic institutions such as markets and firms*" [43,44]. Discourses are (re)produced and carried by "*epistemic communities"*, understood as networks of "*professionals with recognized expertise and competence*" and an "*authoritative claim to policy-relevant knowledge*" [45]. Actors within an epistemic community share a set of normative beliefs and notions of validity, and perceive that they share a common policy enterprise [45]. Following the SKAD, we do not consider the individual modelers and why they make a particular decision, but focus on the structure in which modelers' assumptions are embedded. We view modelers as carriers of worldviews (consciously or unconsciously), and these worldviews depend on the discourses to which they adhere.

We chose the case of energy modeling and IAMs, as the transformation of the energy system is a field where decisions are urgent and contested, and where they will have far-reaching impacts both on the energy system and its actors and on society. Furthermore, the complexity of the system requires the extensive use of models as policy-advice instruments. Energy is thus a case with a strong model-policy interface, and it is one with a well networked research community and wide range of different models to look at. Hence, we apply our analytical framework to energy, but it would be equally applicable to modeling of other (contested) policy areas, e.g. mobility or tax policy, and we would greatly appreciate seeing such studies in the future.