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Veröffentlichungsversion / Published Version
Zeitschriftenartikel / journal article

TATuP Zeitschrift für Technikfolgenabschätzung in Theorie und Praxis
Journal for Technology Assessment in Theory and Practice

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RESEARCH ARTICLE

The politics of models: Socio-political discourses in modeling of energy transition and transnational trade policies

Titus Udrea*[, 1], Leo Capari[2], Anja Bauer[3]

Abstract • In this article, we discuss the (re)production of socio-political discourses in two modeling communities, energy transition and transnational trade. Methodologically, we build on bibliometric and qualitative analyses of academic articles. Our analyses show how models structure epistemic communities and are closely linked to specific discourses. The modeling of the energy transition is driven by and contributes to discourses on mitigating climate change and access to energy. Different trade models address either multilateral or regional trade, yet in each case favoring international trade. Overall, we illustrate how the 'politics of models' does not only concern their use at the science-policy interface, but is already inscribed in their development, application, and scientific exploitation. These analyses may help experts, policy makers, and the public to better assess the knowledge claims and evidence politics of computer modeling.

***Die Politik der Modelle**: Soziopolitische Diskurse in der Modellierung der Energiewende und transnationaler Handelspolitiken*

Zusammenfassung • *Wir untersuchen die (Re-)Produktion soziopolitischer Diskurse in zwei Modellierungsgemeinschaften, der Energiewende und dem transnationalen Handel. Methodisch stützen wir uns auf bibliometrische und qualitative Analysen akademischer Artikel. Unsere Analysen zeigen, wie Modelle epistemische Gemeinschaften strukturieren und eng mit spezifischen Diskursen verbunden sind. Die Modellierung der Energiewende wird von Diskursen über die Eindämmung des Klimawandels sowie dem Zugang zu Energie angetrieben und prägt diese. Verschiedene Handelsmodelle befassen sich entweder mit multilateralem oder regionalem Handel. Wir zeigen somit, dass die ‚Politik der Modelle' nicht erst bei der Verwendung an der Schnittstelle zwischen Wissenschaft und Politik sichtbar wird, sondern bereits in ihre Anwendung und Verwertung eingeschrieben ist. Diese Analysen können Expert*innen, Entscheidungsträger*innen und der Öffentlichkeit helfen, die Wissensansprüche der Computermodellierung besser zu beurteilen.*

Keywords • *policy modeling, discourses, energy transition, trade policy*

This article is part of the Special topic "Modeling for policy: Challenges for technology assessment from new prognostic methods," *edited by A. Kaminski, G. Gramelsberger and D. Scheer. https://doi.org/10.14512/tatup.32.1.10*

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https://doi.org/10.14512/tatup.32.1.49
Received: 26. 08. 2022; revised version accepted: 17. 01. 2022;
published online: 23. 03. 2023 (peer review)

Introduction

Energy policy and transnational trade policy are two main areas of 'modeling for policy'. Both areas are highly relevant for the economic performance of countries, leading to increasing demand for 'usable' knowledge about the effects of international trade or the energy provision of a country. In these contexts, computational models fulfil various functions, from identifying and analyzing societal problems to examining different policy instruments (e.g., energy mixes and energy savings) and assessing the impacts and costs of planned and implemented policies. They also serve to justify and legitimize public action, e.g., when models legitimize free trade agreements based on projected growth scenarios. In this role, models are not neutral tools, providing orientation and answers to (exogenously given) societal or political questions, but models are simplifications that

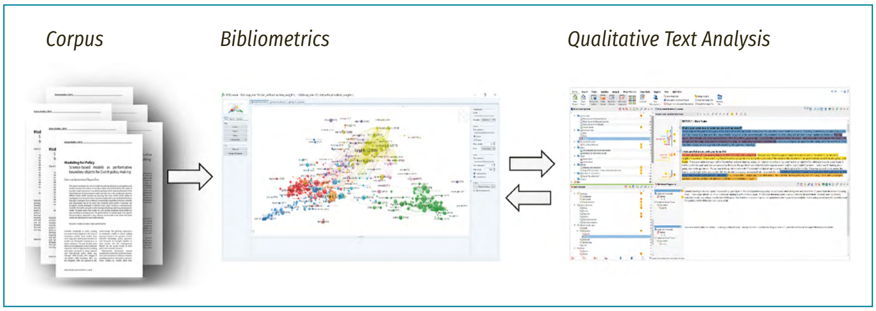

Fig. 1: Research design. *Source: authors' own compilation*

embed and are embedded in specific ideas, assumptions, paradigms, framings, discourses, or representations.

Countering the common notion of computational models as neutral representations, social science scholars have conceived of models as 'techniques of futuring' (Hajer and Pelzer 2018; Oomen et al. 2022), 'boundary objects' (van der Heide 2020; Zeiss and van Egmond 2014) or 'performative devices' (Svetlova 2012). Such conceptions emphasize the social role of models in coordinating different actors (including modelers, other scientists, policy-makers and stakeholders), in contributing to shared understandings and imaginaries about socio-political issues and futures, and in rendering these understandings and imaginaries into 'authoritative orientations for action' (Oomen et al. 2022; van der Heide 2020; Zeiss and van Egmond 2014). Hence, models do not simply inform policy-making; they have performative power by making and shaping the socio-political discourses and worlds in which they are embedded (van der Heide 2020; Zeiss and van Egmond 2014). Against this background, the article explores how scientific computer-based modeling is embedded in and (re)-produces socio-political discourses in the two domains, energy transition and transnational trade. Following Hajer (1997, p. 44), a discourse is a "specific ensemble of ideas, concepts, and categorizations that are produced, reproduced, and transformed in a particular set of practices" (in our case modeling) and which give meaning to social or physical phenomena.

The analysis suggests that energy modeling is strongly connected to two main discourses, the mitigation of global climate change and energy access and security.

Research design

Models coordinate actors and shape discourses in different sites, inter alia, policy processes, scientific debates, or media communication. In this article, we focus on the socio-political discourses that are reproduced in scientific modeling communities by analyzing the respective scientific literature in the two domains. Of course, scientific articles alone do not produce socio-political discourses; they are first and foremost communications within the scientific community. However, by analyzing scientific modeling literature, we seek to trace how socio-political narratives become dressed in techniques and how policy options become potentially narrowed down by rendering certain questions and "trajectories of action possible and maybe even logical" while excluding others (van der Heide 2020, p. 125).

In the following, we give an overview of the main steps of our research design that combines bibliometric and qualitative text analyses (Figure 1). For more detailed accounts, please consult the supplementary research data material.

First, using the Scopus database, we constructed a corpus for each domain, consisting of scientific journal articles that deal with computational modeling. We then applied several bibliometric analyses to each corpus individually. The Scopus analysis tool provided a first overview of the corpora, including publications per year, sources of publication, geographic and institutional hotspots, and authorship frequency. For our main analysis, we used the software tool VOSviewer, which facilitates the creation and visualization of various bibliometric networks. Bibliometric networks consist of nodes representing authors, articles, publications, or key terms and their relations (van Eck and Waltman 2014). We explored several bibliometric relations (term co-occurrences, co-citation, and bibliographic coupling), each providing a distinct way to structure and contextualize the bibliographic information of the corpora (see supplementary 'Research Data'). For the present discussion, however, we draw only on the citation networks. While not presented in this paper, complementary bibliometric analyses validated our interpretation of the citation networks. The citation network identifies key corpus publications (number of citations) and article clusters (articles linked by citations). We adjusted the clustering parameters and resolution, following van Eck and Waltman (2013), to fit the research question and the purpose of providing broad examples within the two domains. Clusters of linked articles indicate similar research foci; however, clusters are not rigidly separated and isolated, but their borders are fuzzy and are connected by intermediating authors and sub-clusters. In this article, we focus only on the main clusters as an exemplary basis for the qualitative analysis of the respective discourses.

The citation network alone does not reveal information about the modeling approaches or discourses. Therefore, we first characterized clusters by screening the titles, abstracts, and key-words of core publications. We particularly looked for the stated modeling approaches and models as well as the themes, topics and problems addressed in the titles and abstracts. Secondly, to enrich our discussion of the socio-political discourses, we selected 20 key articles from each domain for an in-depth qualitative analysis. We analyzed the texts along dimensions such as modeling approach, socio-political contextualization, and policy recommendations. For the purpose of the present discussion, we reconstructed the dominant problem and solution narratives in the selected articles. Problem narratives refer to the construction of the underlying problem or question for which the modeling activities are applied and its embedding in wider socio-political issues and debates. Solution narratives consist of those statements that link the modeling results to (actual or potential) socio-political actions.

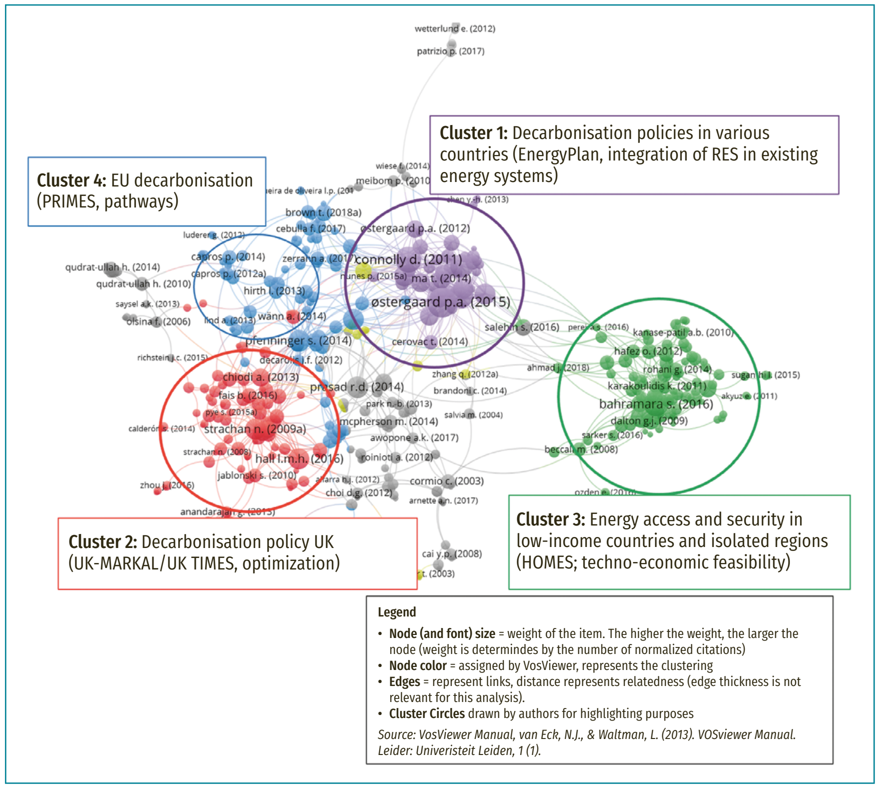

Fig. 2: Energy transition modeling: core citation network. *Source: authors' own compilation*

Modeling the energy transition: between combatting climate change and ensuring energy security

Energy system models have been entangled with energy policies since the 1950s and 1960s to calculate countries' energy demand and respective energy provisions. In the last decades, models have increasingly been developed to address the transition of energy systems from fossil fuels to renewable or hybrid energy sources. Our corpus on modeling the energy transition includes 1.242 articles (1974–2018), with a steady increase in publications from the early 2000s. Figure 2 shows the core citation map[1] with the most cited and linked articles grouped into clusters. We restrict the following discussion to the four most relevant and distinct clusters – in terms of number of articles, citations, links, as well as modeling approaches and socio-political issues.

The citation map provides first insights into the modeling community: Cluster 1 (C1, violet) mainly focuses on the model EnergyPLAN in different geographic contexts (e.g., Ireland, Denmark, Hong Kong) to simulate the potential for the transformation to renewable energy systems. Cluster 2 (C2, red) mainly revolves around the UK energy system decarbonization and discusses MARKAL, times, and hybrid modeling approaches. In Cluster 3 (C3, green), the model HOMER is applied to optimize hybrid renewable energy systems in rural regions, less industrialized countries, and emerging economies. Cluster 4 (C4, blue) focuses on PRIMES to explore decarbonization pathways of the EU.

We observe a dominance of a few modeling tools with community structuring effects, i.e. citation networks built around them. Most importantly, the analysis suggests that energy modeling is strongly connected to two main discourses, the mitigation of global climate change and energy access and security. The discourse on climate change mitigation is dominant (C1, C2, C4). The transition of regional and national energy systems from fossil fuels to renewable energies is presented as a key solution to decarbonize economies and reduce green house gas (GHG) emissions. This societal relevance is not only invoked abstractly, but modeling is deeply contextualized in specific policies, aims or strategies, such as the EU climate targets (C4), the UK decarbonization strategy (C2), or, as the following quote illustrates Hong Kong's climate ambitions:

> „Climate change, the defining challenge of our time, brings about more severe weather and affects each and every one

1 Core citation map includes only those articles with at least 10 citations and further excludes isolates. The core citation map contains 410 articles.

> of us. […] Hong Kong has set a target to achieve a reduction in energy intensity of at least 25 % by 2030 corresponding to the APEC (Asia-Pacific Economic Cooperation) target and a reduction of carbon intensity by 50–60 % by 2020 corresponding to the Copenhagen Accord […]" (Ma et al. 2014, p. 301).

Such policy targets not only serve as a motivation for modeling but are central reference points to model respective trends, strategies, or scenarios. Modeling provides knowledge on strategies and measures to reach these targets (e.g., the optimal energy mix), the associated costs, uncertainties, sensitivities, and challenges (e.g., in terms of flexibility). Optimization models like TIMES or MARKAL (C2) calculate the optimal technology mix to meet the energy demand at minimum costs. Other models, such as EnergyPLan (C1), explore the potential for national renewable energy system (RES) transformation and respective CO_2 reductions by simulating and comparing energy scenarios. They also explore the integration and optimal combinations of renewable energy sources into the existing electricity or transport sectors.

In most cases, modeling results are intended to inform policies, yet with varying roles, ranging from general orientation and insights into developments and uncertainties, to supporting or challenging policies with concrete recommendations. In the following illustrative quote, the modeling results support UK's decarbonization strategy:

> "For UK policy makers an important message from this modelling exercise is that deep long-term CO_2 emission reductions are feasible" (Strachan and Kannan 2008, p. 2961).

The authors further highlight the role of Carbon Capture and Storage as a critical zero-carbon technology, thereby influencing the narrative on potential solutions. In other cases, modelers challenge government policies:

> "[…] However, it is obvious that the RE scenario is much better than the governmentally proposed scenario in terms of climate change, availability, and long term sustainability" (Ma et al. 2014, p. 307).

Hence, modeling not only draws on the common problem narrative of climate change but actively contributes to solution narratives by supporting or challenging policies. The second socio-political discourse revolves around energy access and security (C3). The stated problem is that many people in rural, low-income countries or geographically isolated regions have little or no access to electricity, hindering their economic and social development:

> "[…] access to electricity is fundamental in advancing the well-being of any society and promoting economic growth […] Like most countries in sub-Saharan Africa, access to electricity in Ghana is low compared to more advanced countries" (Adaramola et al. 2014, p. 284).

In this discourse, the transition is a solution not primarily because GHG emissions can be reduced but because RES are cost-effective, decentralized, and stable and can provide energy access to energy-poor people and regions.

> "In isolated areas, the high cost of transmission lines and higher transmission losses are encouraging the use of green sources of energy. Combining two or more renewable energy sources […] gives a stable energy supply in comparison to non-renewable energy systems" (Hafez and Bhattacharya 2012, p. 7).

In these contexts, modeling provides insights into the technical and economic feasibility of hybrid renewable energy systems in specific geographical contexts (countries, regions, islands). The dominating modeling tool is HOMER, which, in contrast to the optimization models introduced above, does not primarily focus on CO_2 reductions but cost-effective energy provision and security. Therefore, the modeling may also result in solutions that combine fossil fuel and renewable energy sources:

> "Therefore, any government policy that aid decreasing the cost of diesel fuel can reduce the operating cost of hybrid power system in remote and semi-urban area of the country" (Adaramola et al. 2014, p. 291).

In sum, energy system transition and respective modeling activities are motivated by two underlying problems: climate change and energy poverty. As a result, modeling activities have different foci, particularly apparent in optimization models, searching for cost-effective solutions to reduce a certain amount of GHG or secure a certain level of energy security. The discourses also have clear geographic foci. While the climate change discourse is strongly linked to industrialized countries, the energy security discourse is linked to less industrialized countries and rural areas.

Trade modeling: between favoring bilateral and multilateral trade agreements

Trade policy was among the first domains to use computational models. Modeling entered mainstream policy-making in the 1970s at the UN, as a way to scientifically and empirically validate macroeconomic policies (Estrada and Park 2018). Since then, "macroeconomic modelling has become an almost mandatory part of assessing the impacts of a new (trade) policy" (Pollitt 2018). Our corpus (1834 documents, 1966–2018) reflects this, showing a steady increase in publications since the late 1980s.

 https://doi.org/10.14512/tatup.32.1.49

Figure 3 shows the core citation network[2] of the trade modeling corpus. For the purposes of this paper, the largest two clusters are considered as the basis for the further qualitative analysis. The first cluster (blue) revolves around computable general equilibrium (CGE) modeling, multilateral trade agreements and trade effects-related topics. The second cluster (red) is dominated by gravity models and research topics such as regional markets, bilateral and domestic trade effects, welfare and labor. CGE and gravity models, as well as the underlying economic schools of thought, have been used for trade policy analyses for over 50 years (Piermartini and Teh 2005).

While both clusters are firmly embedded in the mainstream free trade discourse (i.e., positive framing of free trade as central for welfare), the two clusters and respective modeling approaches include different foci and relate to distinct policies, i.e., multilateral versus regional free trade.

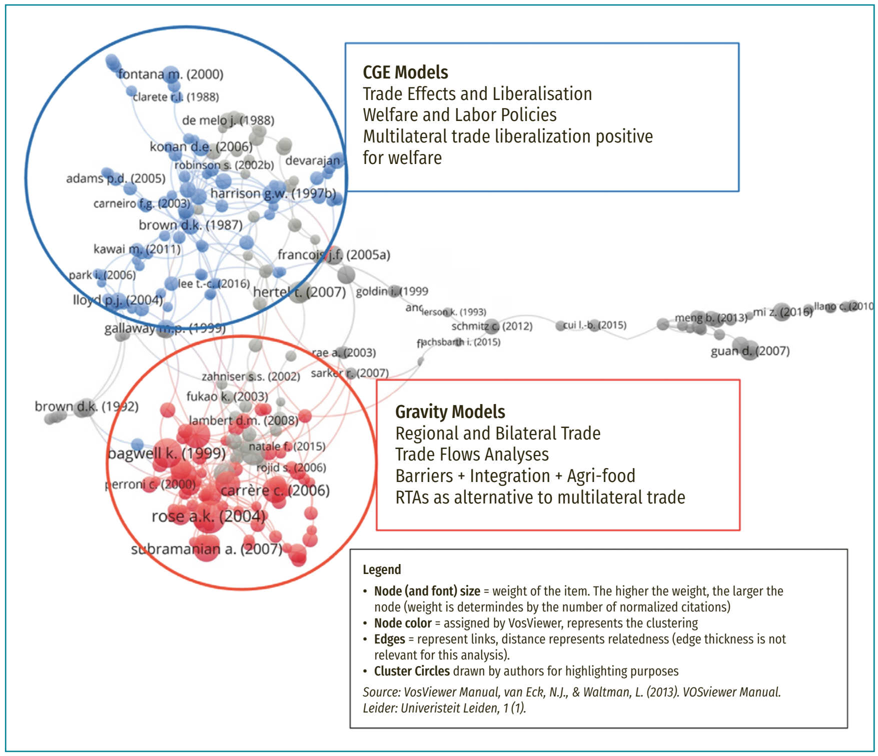

Fig. 3: Trade core citation network and focus clusters. *Source: authors' own compilation*

The first cluster is dominated by CGE models, which calculate economy-wide impacts and welfare effects of trade liberalization across sectors, either ex-post (after the agreement) or ex-ante (before the agreement). Modeled welfare effects include, e.g., gross domestic product, growth or sector-specific effects, such as wages and labor dynamics. CGE models by their design (built on mainstream economic theory that trade liberalization, in the long run, always increases welfare) provide a generally positive outlook of trade arrangements. With a broad economic scope, CGE-based analyses tend to conclude (as well formulate policy recommendations) that multilateral trade arrangements are the most conducive to welfare increases. Multilateral trade refers to the global trade system and broad international frameworks, e.g., the World Trade Organization (WTO) with more than 150 members. Several studies in our sample specifically compare regional and multilateral trade arrangements and recommend the former as the better policy alternative:

> "[…] while regional and bilateral FTAs may be welfare enhancing for the member countries directly involved, these welfare gains are considerably smaller than those resulting from multilateral trade liberalization, and, in any case, accrue in absolute terms primarily to the large industrialised countries" (Brown et al. 2003, p. 826).

Turning to the second cluster, where, along gravity models, topics involve regional trade agreements and regional economic integration, e.g., The North American Free Trade Agreement (NAFTA), The Association of Southeast Asian Nations (ASEAN), African Union. Regional trade arrangements are also compared to multilateral arrangements (e.g., WTO) in terms of trade flows. Bilateral agreements are also included here, and new large regional trade frameworks, such as the proposed TTIP (Transatlantic Trade and Investment Partnership) between the US and EU, or the 16-member TPP (Trans-Pacific Partnership), which blur the lines between multilateral and regional trade. There is a stronger geographic focus evidenced by the presence of regional items and specific countries, such as 'Middle East', 'South Asia' (e.g., Bangladesh), 'East Asia', 'Africa' (e.g., Tunisia, Morocco), 'South and East Africa'.

With a focus on spatial interaction, gravity models investigate regional trade flows and the effects of trade agreements on economic growth. Usually employed in ex-post analyses, gravity models are used to assess the role of trade deals for trade and economic growth:

> "During the last 10 years, regionalism has re-emerged as a major issue in the policy agenda [listing several agreements; the authors …]. The effect of this 'second wave' of regionalism on trade is still an open question. Do they really increase trade among members? Do they contribute to further trade liberalization with nonmember countries or

2 Core citation map includes only those articles with at least 10 citations and excludes isolates. The core citation map contains 253 articles.

undermine it? Do they harm nonmember countries?" (Soloaga and Winters 2001, p. 1).

Often, the focus is on specific sectors, particularly agriculture (as a function of interregional trade effects). Newer literature, using gravity modeling, generally shows positive effects of regional trade and presents bilateral, regional trade as an alternative to multilateral trade. Especially for the agricultural sector, regional trade is seen as a more pragmatic approach to trade liberalization: "RTAs may be an attractive alternative to promote agricultural trade. […] While the GATT/WTO has not made significant progress in agriculture, regional trade agreements offer countries the opportunity to liberalize and increase members' agricultural trade. This may be a fundamental explanation for the aggressive pursuit of regionalism over the past two decades" (Grant and Lambert 2008, p. 765).

Regarding policy recommendations, the takeaway is that regional trade is the alternative because multilateral arrangements are complicated to establish and maintain (yet not because the welfare effects would be higher).

Conclusions

In this article, we have illustrated how modeling approaches are entangled with specific problem framings, analytical foci, and geographic regions, and support different policies: Modeling energy system transitions refers to the climate change discourse but also to energy access and security discourses in poor energy access regions. The two dominant trade modeling approaches refer to distinct policies, i.e., multilateral versus regional free trade. A limitation of this contribution is the cursory (and exemplary) presentation of the various bibliometric and qualitative analyses due to word limits. Nevertheless, our analyses offer valuable insights on the socio-political nature of models. Analyzing how models discursively present policy problems and solutions exemplifies their roles as 'technologies of futures' or 'boundary objects' and how they might reinforce, consolidate or transform the possible repertoires for action (Oomen et al. 2022). Broader socio-political aims and specific policies frequently serve as the motivational background of modeling and directly feed into modeling, e.g., by serving as endpoints for which optimized solutions are sought. Moreover, the different policy discourses feature a geographic component in both modeling domains. The geographic foci include a strong political component linked to questions of welfare, poverty and equality (trade) or energy security (energy), respectively. This raises questions about the political implications of this geographic imbalance, particularly when considering that less-industrialized countries are frequently the object of modeling in energy transition and trade policy, while respective models have been developed in the Global North. In line with previous research, we thus observe how "agendas, commitments, goals [and strategies] of policy communities are referred to in scientific communities as justifications" for modeling approaches and how, in return, these scientific commitments might cement the policy goals that motivated them initially (Demortain 2017, p. 147; Shackley and Wynne 1996, p. 221).

Energy system transition and respective modeling activities are motivated by two underlying problems: climate change and energy poverty.

Overall, with our analysis of scientific modeling discourses, we illustrate how the 'politics of models' does not only concern their use at the science-policy interface; modeling communities frequently make "authoritative claim[s] to policy-relevant knowledge" (Knorr-Cetina 2007, p. 365) already in the modeling process. The insights may serve both TA academics and policy experts to assess knowledge claims and epistemic communities. It is not only technical questions regarding the modeling algorithms, data, validity, uncertainties etc., that are of relevance for their use and assessment but also their discursive embedding and power. TA has long been active in analyzing political and societal debates and discourses on technologies, including respective visions and expectations.

Funding • This article is based on research conducted in the project 'CoMoPA – Computational Modelling for Policy Advice' funded by the Austrian Academy of Science Innovation Fund 'Research, Science and Society' [no. IF_2017_13]
Competing interests • The authors declare no competing interests.

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Research Data

https://epub.oeaw.ac.at/ita/ita-papers/the_politics_of_models_supplementary.pdf

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