CHAPTER 11

Rethink Energy System Models to Support Interdisciplinary and Inclusive Just Transition Debates

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Policy Highlights To achieve the recommendation stated in the chapter title, we propose the following:

- Policymakers should demand more open and inclusive energy modelling processes to ensure that stakeholders can meaningfully contribute to the process.
- Policymakers should recognise the critical role of the Social Sciences and Humanities (SSH) in complementing energy modelling to receive a more holistic viewpoint on just pathways to climate neutrality. Both Science, Technology, Engineering and Mathematics

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(STEM) and SSH research is needed to transform our energy system to a just, climate-neutral future.
- Policymakers should establish cross- and transdisciplinary debates for incorporating more diverse voices into energy modelling.

Keywords Participatory modelling · Climate change mitigation · Energy justice · Just transition · Energy policy

11.1 Introduction

The goal of a just transition to climate neutrality is high on the political agenda. Just transition refers to "a fair and equitable process of transition to a post-carbon society" (McCauley & Heffron, 2018, p. 2). The concept has been recognised in the IPCC's latest mitigation assessment

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and the European Green Deal. The European Union has set stringent net-zero greenhouse gas emission targets, while also declaring it will leave no person and no place behind.

The dominant tools for understanding the energy transition are energy system models (Süsser et al., 2021a). The most prominent whole system approaches—Energy System Optimisation Models (ESOMs) and Integrated Assessment Models (IAMs)—are important policy tools. These provide a representation of current and future emissions across different scales; pan-EU, national, and regions or cities. While they have great value in providing techno-economic least-cost pathways for decarbonisation, we argue that their ability to reflect the real-world energy transition is limited. Two critical gaps we see are that, firstly, the models are not designed to reflect important aspects of fairness and inclusion, and secondly, they tend to assume very little or no changes to social and political institutions (e.g. future energy demand is generally based on projecting continuous GDP growth).

Consequently, current modelling practices are often incompatible with the goal of a just transition. The models, optimising for least cost, are unlikely to produce equitable outcomes, and modelling teams have tended not to focus on equity or just transition issues (Sonja & Harald, 2018). Recently, there has been some interest in ways to incorporate broader societal considerations into modelling tools (Krumm et al., 2022; Lonergan et al., 2023). This includes using existing models to scrutinise narratives, intensifying collaboration across scholars, or structurally modifying and building new models to integrate Social Science research (Holtz et al., 2015; Trutnevyte et al., 2019). Nevertheless, more effort is needed to increase inclusive participation in modelling processes and to integrate aspects of fairness or justice in energy modelling (Lonergan et al., 2023; McGookin et al., 2021).

The arguments made in this chapter stem from the context of three EU-funded research projects, SENTINEL, SEEDS and JustWind4All, as well as on an online discussion between the author team (September 2023) (McGookin et al., 2024a), a joint workshop with the International Renewable Energy Agency (IRENA) on stakeholder-driven scenario development for just transitions to climate neutrality (November 2023) (Süsser, 2024; Süsser & Goussous, 2024), and feedback from a presentation at the Behave 2023 conference (November 2023). At the workshops and discussions, both Social Scientists and Computer Engineers were present, who work in research, practice, and policy, including

governmental authorities, international development agencies and the energy industry. We discussed current gaps in modelling practices and solutions to improve tools and modelling processes. By building on these combined insights, we argue that integrated and complementary energy modelling and Social Sciences research are crucial to enable equitable pathways to climate neutrality. Policy would benefit from insights based not only on modelled techno-economic pathways, but also on the results of debates with the stakeholders[1] and citizens. To achieve just transitions, models must be complemented with Social Science research, including Policy Research, Psychology and Human Geography, to open up debates and enable better informed decision-making.

11.2 Insights on Modelling Gaps and Ways to Improve and Complement Energy Modelling

In this chapter, we apply a justice lens to energy modelling (Table 11.1). This is done using three energy justice principles: *distributional justice*, which focuses on the equitable distribution of costs and benefits; *procedural justice*, which refers to transparent decision-making processes and adequate representation; and *recognitional justice*, which acknowledges past injustices and ongoing risks of underrepresentation (Jenkins et al., 2016; Walker & Day, 2012).

11.2.1 What Are the Limitations of Models and Modelling Approaches?

A key limitation of current energy models is their grounding in techno-economic worldviews that prioritise total costs rather than distributions, and which obscure procedural and recognitional dimensions of justice. Models are navigated through modellers' frameworks, norms, and values, which often remain inherently ambiguous (Silvast et al., 2020). A narrow techno-economic lens pushes into the background alternative perspectives that might challenge foundational assumptions. Models are shaped by

[1] We define stakeholders as all those affected by or interested in the energy transition, including policymakers, the energy industry and civil society organisations.

Table 11.1 How Social Sciences can contribute to filling modelling gaps on energy justice

Justice dimensions	*Gaps in modelling*	*Contributions of Social Sciences to close gaps*
Recognition: Whose worldviews are represented and excluded?	The techno-economic perspective in models limits potential for recognition of diverse groups	Challenges worldviews and link them to policy goals; opens-up processes to diverse perspectives
Procedure: Who is involved in the modelling process? What models are used? How is modelling used to inform decisions?	Models can reduce the space for debate and dissent, excluding marginalised voices and 'de-politicising' debate The process of model development is rarely transparent Public rarely participates in modelling processes	Challenges the assumptions behind models and what is missing from them; raises new questions; provides participatory research expertise; communicates model uncertainties and outcomes
Distribution: How are distributional impacts assessed? Who will be the (local/regional) winners and losers of the transition?	Models typically explore distributional consequences as second-order concern, if at all	Investigates local and regional transition impacts; documents people's lived experience of the energy transition; includes human behaviour and responses

certain societal discourses, which are reproduced and reinforced (Ellenbeck & Lilliestam, 2019). As such, models may become engines of injustice and exclusion themselves.

Models can 'depoliticise' debates, undermining procedural justice. They do this first by narrowing the frame of debate, as they provide only a simplified representation of reality. In doing so, they push excluded perspectives into the background, privileging some issues and perspectives over others. There is a basic trade-off here: such narrowing is important for tractability and 'closure' around a particular problem framing, but this comes at the cost of respect for plural perspectives (Stirling, 2008). Second, models often have power in debate (Aykut et al., 2019). Their purported accuracy, technical complexity, and association with 'objective science' lend them strong credibility (Porter, 2020), even when it is not clear what the knowledge claims arising from a given model might be. The risk is that the space for political dialogue is removed: the apparently objective model, which only few are competent to critique, both frames

the debate in ways that exclude certain perspectives and obscures many of the normative and political judgements that underpin the conclusions.

Model development processes are not transparent and are rarely informed by co-design or participation, further limiting procedural fairness. Despite calls for the opening up of energy system models (Morrison, 2018; Pfenninger, 2017), the assumptions that determine modelling outputs remain opaque. Progress with open modelling has reduced this concern in recent years, but it remains true that relatively few people have the skills required to unravel the assumptions underpinning certain findings and be able to challenge them. This leaves a significant amount of control over the framing and the logic within the modelling team. Moreover, modelling processes are rarely opened-up to wider participatory and co-design processes (McGookin et al., 2021). We argue that only if different stakeholders are part of the modelling process, they can influence it, and thus, ways to build-in stakeholder perspectives can be explored.

Models overlook transition impacts. Some modelling studies do account for distributional impacts, such as which regions stand to benefit or lose from the transition (Caulfield et al., 2022; Li et al., 2016; McDowall et al., 2023). However, they typically focus on economic vulnerabilities and examine distributional issues as a consequence of least-cost pathways, implying that distributional issues are secondary in importance to total costs (for a rare exception, see Sasse & Trutnevyte, 2020). They contribute to a frame in which difficult distributional impacts are seen as the unfortunate, but necessary, consequence of the least-cost transition path, rather than opening a conversation about society's prioritisation of inequitable outcomes.

11.2.2 How Can Social Sciences Address Modelling Gaps?

Recognitional Justice

Social Sciences can challenge dominant worldviews by discussing mental models behind the computer-based models. Models are built from assemblages of theory, data and (often tacit) social norms about how the world 'works'. Insights from Behavioural Science, Political Science and other fields can unpack those assumptions, and thus open up the possibility for model-based explorations of more radical or emancipatory futures. A recognitional justice lens demands that analyses recognise diverse perspectives, values, and aspirations by "engag[ing] with other knowledge systems as active contributors of solutions" (Rubiano Rivadeneira &

Carton, 2022, p. 8). For example, visioning documents developed at the community-level have been shown to provide context-based nuance that challenges the techno-managerial "indexification of poverty" (Kiely & Strong, 2023, p. 1758)—i.e. the use of statistical indices to measure poverty—and provide alternative ways of building energy poverty models. Such approaches can contribute to public debates on possible and desirable energy futures, and systematically rebalance existing power relations within the energy system, promoting 'recognitional' and 'procedural' justice. This can be crucial not only to improve public participation in climate and energy policymaking, but also to increase trust in the policy outcomes.

Procedural Justice

Social Scientists can help challenge the assumptions behind models. To enable cross-disciplinary dialogues, modelling processes must be transparent. This is not simply a matter of open code, open data, and good documentation—important though these are. Modelling data and assumptions should be discussed within interdisciplinary teams, and also with stakeholders, to create a better understanding of the importance of assumptions and uncertainties in modelling (McGookin et al., 2024b). Transparency must be an ongoing process that ensures models are continually being explained, challenged and critiqued. Social Sciences can thus help to redress the power imbalances created by complex modelling tools.

Modelling perspectives can be expanded with Social Science research to better understand social aspects, such as attitudes towards different energy futures or lived energy experiences. This was attempted, for instance, in the SEEDS project, where stakeholder needs were used to expand the default outputs provided by models, to better reflect stakeholder concerns. Furthermore, Behavioural Science and Psychology can provide theories and evidence on behavioural change or people's preferences, which can be used in modelling tools. An example is provided by the SENTINEL project, where social-political storylines based on different governance logics and social and political observations (Süsser et al., 2021b) constrained feasible net-zero configurations of the European energy system (Mayer et al., 2024). Using models alongside other processes can ensure that broader perspectives are included in the analysis (McDowall, 2014).

Social Scientists can provide participatory research and communication expertise to modellers. Instead of modellers re-inventing the wheel, they should seek to work with these experts through transdisciplinary approaches. Visualisations of modelling results can facilitate policy dialogue, and the communication of model uncertainties and assumptions is critical to create an understanding among modelling users, including policymakers, what model outcomes mean and what they do not mean. Moreover, Social Scientists can provide insights into participatory methods and how to plan effective public engagement processes as an integral part of modelling. For example, the community engagement in the modelling work by McGookin et al. (2022) benefited greatly from Social Science perspectives. The research team implemented a broader engagement process to explore what a sustainable future for the area would look like, resulting in several important local projects.

Distributional Justice

Social Science can contribute to a better understanding of how positive and negative impacts of the transition are distributed. Regions and communities will be affected differently by the transition, depending on their social and geographic circumstances, the current status of the transition, and capacities to respond, among others. This requires models to account for existing regional differences and potential underlying injustices in the energy transformation. For example, a modelling study by Mayer et al. (2024) showed that positive employment effects could lead to higher welfare levels, which would otherwise have been neglected if only the costs of energy system configurations had been considered. Local and regional analyses could be used to assess the impact of transitions, including costs and benefits, and provide important insights to complement modelling tools.

11.3 Achieving Our Recommendation

As per the title of this chapter, our core recommendation is that policy should: *rethink energy system models to support interdisciplinary and inclusive just transition debates*. This recommendation is underpinned by three sub-recommendations:

First, *policymakers should demand more open and inclusive energy systems modelling processes.* Diverse perspectives can contribute to a critical reflection of current injustices in the energy transition and their anchoring in

models. Addressing existing injustices and ensuring fairness and inclusiveness in the energy transformation is critical to achieve the energy policy goals for a just transition to climate neutrality. Thus, policymaking should require open, transparent, participatory modelling processes from the modelling community and work with institutes that align with this standard. Such processes should facilitate a critical engagement with and around modelling tools, as well as building a better understanding of the 'power' of model assumptions and model limitations. Policymakers should initiate and/or fund research programmes that require the formation of interdisciplinary research teams with diverse expertise, the convening of participatory modelling processes, or stakeholder-based committees or partnerships.

Second, *policymakers should recognise the critical role of the Social Sciences in complementing energy systems modelling to receive a more holistic viewpoint on just pathways to climate neutrality.* A constructive critique of models and modelling processes is required, which may highlight injustices or lack of attention to justice issues. This requires the EU funding of research and practice projects that produce critical socio-psychological and institutional insights, such as how to meaningfully engage the public in energy infrastructure projects, or perceptions and needs for transitions away from coal and carbon-intensive industries. This would contribute to the achievement of policy goals to accelerate the expansion of renewable energy, in line with the 'Fit for 55'-package, and to support regions that are most vulnerable to the transition under the Just Transition Mechanism.

Third, *policymakers should establish cross- and transdisciplinary debates for incorporating more diverse voices into energy systems modelling*. There is not only one energy future; visions, values, and aspirations of researchers with different backgrounds, as well as those from diverse stakeholders and citizens, can inform the development of alternative storylines and scenarios. McGookin et al. (2024b) have suggested best practice guidelines for incorporating diverse voices into energy modelling. However, modelling projects are often restricted by funders' requirements, which may prevent engagement in deliberative activities. Policymakers—and in particular funders of modelling—should create spaces for cross-disciplinary and participatory dialogue to open up modelling. In deliberative dialogues, models can function as 'exploration tools'—helping to foster debate, rather than replace it.

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