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A participatory exploratory modelling approach for long-term planning in energy transitions

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ABSTRACT

Energy transitions are complex transformation processes, which involve different actors and unfold in a deeply uncertain future. These features make the long-term planning of energy transitions a *wicked problem*. Traditional strategic planning approaches fail to address this wickedness as they have a predictive, deterministic, and reactive standpoint to future issues. Modelling approaches that are used within conventional contexts are perceived to be inadequate too. They often simplify the qualitative characteristics of transitions and cannot cope with deeply uncertain futures. More recently, new ways of qualitative participatory planning, as well as new approaches to quantitative modelling have emerged to enable policy analysis under deep uncertainty. We argue that qualitative participatory and quantitative modelling approaches can be complementary to each other in different ways. We operationalise their coupling in the form of a practical approach to be used for long-term planning of energy transitions. The suggested approach enables energy decision makers to test various policy interventions under numerous possibilities with a computational model and in a participatory process. We explain our approach with illustrative examples mostly from transitions in electricity sectors. However, our approach is applicable to different forms of energy transitions, and to the broader context of transition in any societal system, such as water and transportation.

1. Introduction

The ratification of the 2015 Paris Agreement—in keeping the global temperature well below 2 °C above pre-industrial level—requires signatory countries to commit to the long-term goal of near zero net greenhouse gases (GHGs) emissions in the second half of the century. Several independent transition efforts exist, at the level of individual countries, for decarbonisation [1–3]. In the UK, for instance, the Climate Change Act was legislated in 2008, setting binding targets to reduce emissions till 2050 by 80% relative to the 1990 baseline. In a different socio-economic context, India enacted the National Action Plan on Climate Change (NAPCC) in 2008 as a high-level policy framework for climate change mitigation and comprising eight national missions for emissions reduction. These decarbonisation processes can be realised through different pathways. They can be achieved through transitions in electricity generation systems with different mixes of renewable (e.g. wind, solar, biomass) and low-carbon non-renewable (natural gas) options. They can also be realised through energy efficient heating provision in buildings or through low-carbon transportation systems with a mix of hybrid, electric and fuel cell vehicles.

Governments use planning approaches to draw visions and targets with a set of strategies and policies to drive and to support these transitions [1,4]. Several examples of such planning approaches can be found in both developed and emerging economies. For example, in the UK's decarbonisation process, an independent committee of experts advises five-year carbon budgets [5], and several collaborative research initiatives, such as 'Realising Transition Pathways' project [6–8], support government bodies to plan for the required actions to implement these budgets. India's Jawaharlal Nehru National Solar Mission (JNNSM) is another example which aims to achieve 100 GW on-grid solar PV by 2022 and plans for a range of policy interventions in the light of the country's decarbonisation [9–13].

While the need for and the relevance of long-term planning in energy transitions is widely acknowledged, the design of a robust, proactive and implementable plan is challenging and is identified as a *wicked problem* [14]. Energy transitions incorporate non-linear interactions between natural, technical, societal and economic systems. They are influenced by multi-level determinants from within the established fossil fuel systems (e.g. the availability of resources and infrastructure), from emerging renewable systems (e.g. price of

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renewable energy technologies) and from the external environment (e.g. governmental interventions). Energy transitions unfold in a deeply uncertain future, surrounded by surprises and shocks around techno-economic and socio-political factors (e.g. investment costs, political coalitions, global fuels price, investors' preferences). They also involve different actors (e.g. manufacturers, investors, utility companies, consumers, etc.) implying that an effective decision making requires their consensus and a compromise between their conflicting values and divergent solutions (see [1]).

Conventional strategic planning approaches cannot adequately address the wickedness in long-term planning of energy transitions. Conventional planning often take a *predict-then-act* approach [15]. This means that planning for the future relies on historical trends or a limited number of future scenarios. The future plan is then developed to fit those trends or those few scenarios [16]. An example of this is the use of population growth trends, and more recently population growth scenarios, as the basis of infrastructure planning in the past many decades. In cases where the reality did not match the projections, this has led to problematic infrastructure decisions with high costs and/or lock-in effects [17]. Conventional planning also takes a reactive standpoint in most cases: planning is often carried out to respond to changing circumstances, rather than to proactively prepare for change (cf. Robust Decision making) [18]. It also does not systematically address *contingencies*, and therefore cannot represent the diversity of possible futures. New approaches to long-term planning and policy analysis have emerged more recently that introduce new ways of thinking about the future [19–23]. They acknowledge that the projection of historical trends and a handful of scenarios would not be very helpful in the context of highly dynamic change processes and ever-increasing uncertainties. Instead, they try to enable *exploratory thinking* among decision makers, by challenging their well-established assumptions and frames of references, and investigating numerous possibilities for how the future could unfold [24]. They also aim to produce proactive and anticipatory actions for unforeseen circumstances that could emerge over time [25]. Under the new planning approaches, long-term plans are designed in a participatory process, involving actors with different views, in order to develop actions which are widely supported and easier to adopt.

The dominant approach of formal energy models [26–28], which are developed primarily based on the neoclassical assumptions of rational choice, cost-benefit analysis, and profit maximisation, are perceived to have critical limitations too [29]. They are critiqued for limited attention to the qualitative characteristics and underpinning social processes of transitions [6]. The dominant approach tends to design an ultimate model or multiple models, which feature high-levels of technical details, but do not necessarily reflect the diversity of actors' views. The dominant approach of techno-economic models in general is also critiqued for the treatment of uncertainty, when it tends to manage deeply uncertain futures with few limited scenarios or when it makes a simplistic assumption that the probability distribution of uncertainties, which are by nature irreducible to probability distributions, can be known [30,31]. Emerging approaches to energy systems modelling [8,32–34] (and also to the broader topic of long-term transformation modelling [35–37]) have moved towards the inclusion of socio-technical factors into energy models. An emerging area of research, known as *exploratory modelling* [19,38], has made the multiplicity of future possibilities explicit and enabled decision makers to assess their candidate policies, or strategies, under a large range of potential circumstances. Robust Decision Making is one of the prominent examples of contemporary decision analysis approaches [19]. It uses exploratory modelling—as opposed to the conventional predictive modelling—to identify robust strategies that can cope with a wide range of conditions, moving away from optimising outcomes for a narrowly defined set of projections.

While different qualitative planning and quantitative modelling approaches have been discussed in the scholarship in isolation [19,39,40], a medium which can couple them and take advantage of their interactions to support energy transition processes has been rarely addressed [8,41–43]. Trutnevyte et al. [8] explained how highly detailed storylines and energy models should be linked to each other for studying transition pathways scenarios. They explained how storylines can harmonise model assumptions and how modelling results can correct underestimates and overestimates of storylines. Li et al. [29] criticised the limited attention to the co-evolution of society and technology in energy systems models and reviewed those models which had already addressed this co-evolution to different extents. Robertson [43] presented an integrated quantitative and qualitative analysis of low carbon transition scenarios, where the Life Cycle Assessment and the Socio-Technical Scenario were quantitative and qualitative tools. From a broader and more generic perspective, the importance of bridging between analytical approaches from different disciplines has also been emphasised strongly in the broader community of low-carbon transitions [44,45].

This paper aims to create a new medium for coupling qualitative and quantitative approaches in a complementary way from a new perspective: a participatory exploratory modelling approach to sustainability transitions. We develop an approach for policy analysis in long-term planning of energy transitions. Our proposed approach uses *exploratory transitions modelling* to assess policies under numerous future scenarios. This modelling process is underpinned by concepts from the *sustainability transitions* literature to better capture the underlying social processes of change. The modelling process is also enhanced by a qualitative *participatory approach* to include the diverse perceptions, assumptions, expertise and experiences of actors regarding the past and the future of energy transitions. Our proposed participatory exploratory modelling approach helps decision makers in energy transitions to (i) specify conditions under which presently less competitive energy options become viable, (ii) identify the vulnerabilities of various policy interventions, (iii), plan for coping strategies against these undesired circumstances and (iv) deliver robust policy packages that can realise the desired vision across numerous possible scenarios.

We describe our proposed approach in the context of electricity transitions. Transition in electricity generation sectors—from fossil fuels towards renewable sources—is critical in the decarbonisation process [46]. In addition to emissions reduction, it can also have significant impact on energy security, energy equity and job creation [47–49]. We use several examples from previous applications of the introduced tools and techniques (of each individual step of the approach) in real-world energy and electricity systems in order to demonstrate their practicality and to enhance the conceptual clarity of our arguments. It should be noted that although the context and examples are related to electricity sectors, the approach and introduced techniques are quite generally applicable to different forms of energy transitions and to the broader context of transition in any societal systems (such as water and transportation).

The rest of the paper is organised as follows. Section 2 elaborates on the conceptual underpinnings of the approach. The outline of the approach with its different phases is explained in Section 3. Section 4 discusses the contributions and limitations of the approach and concludes the paper.

2. New approaches to long-term planning in the context of sustainability transitions

This section explains the conceptual underpinnings of our proposed approach. It introduces new approaches from social sciences, such as sustainability transitions, which are used to capture the qualitative aspects of transitions for their long-term planning. It also introduces modelling approaches which can better address the complexity of long-term transformational changes.