Advancing the fit between behavioural theory and decision style in agent-based energy transition models

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Abstract. For the energy sector, drastic changes like the heating transition and electrification are in progress that affect everyone. To make these system transitions successful we need behaviour change on all levels. Capturing system behaviour that emerges out a plurality of choices of individuals requires anticipating what individuals perceive, how they consider the context and how they interact. We notice that these aspects are typically not included in agent-based energy transition models (ET ABM's). In an explorative review we find that when behavioural aspects are included in a model, the fit of theory with the behaviour of interest lacks solid argumentation and needs more in-depth elaboration. We also find an underrepresentation of 'use' behaviours like cooking or load shifting (where energy use is shifted to another part of the day in order to prevent peak-use of electricity) in ET ABM's compared to adoption behaviours (like buying a heat pump or an electric vehicle). To explore ways ahead, we deem interdisciplinary and team science crucial.

Keywords: behavioural theory, ABM, energy transition, decision model, theory fit, review

1 Introduction

To reach climate goals such as those set in the Paris Agreement, we need behaviour change on all levels [1]. In the energy sector, drastic changes are coming that affect everyone, such as the heating transition, hydrogen, or electrification.

Energy policies are informed by models and scenarios that typically capture the techno-economic optimum, assumptions regarding the availability and costs for energy infrastructures and technological developments. Such scenarios, however, assume that a plurality of choices by individuals, households, companies, and other stakeholders will (or can) make this a reality supported by policy interventions. Capturing the system behaviour that emerges out of this plurality of choices requires anticipating what individuals perceive, how they consider their context and how they interact.

These aspects are typically not included in models and scenarios. While including behaviour in models is important as even small differences in the representation of behaviour can lead towards different model results [2], we think that the specific fit of the theory with the behaviour of interest is the next step ahead. For instance, one can use

the Theory of Planned Behaviour by Ajzen [3] and implement social norms (copying what others do) into the decision logic of an agent, but if the behaviour in question is motivated by giving feedback on energy consumption, one should better zoom into the difference between *descriptive norms* (perceptions of the behaviours performed by others) and *injunctive norms* (perceptions of what behaviours are (dis)approved of by others) that shape behaviour.

Several reviews discuss how behavioural aspects are integrated in energy system models. Huckebrink & Bertsch [4] for instance structured their review along (all) modelling around *acceptance, adoption and use* of specific technologies like large-scale renewables (e.g. wind and solar farms) and microgeneration of renewables (e.g. residential heat pumps and solar panels). Hesselink & Chappin [5] focussed on ET ABM's that discussed *adoption* behaviours (e.g. buying electric vehicles or solar panels) and use behaviours (e.g. feedback on energy consumption) of households, discussing how policy measures are aligned. While these reviews provide a valuable insight on the state of the art of behavioural representation in ET ABM's, we extend by reviewing the fit of behavioural theory and the behaviour in question.

Our work aims to understand the current practice of argumentation behind the fit of a theory and the behaviour in question in energy transition ABM's. Based upon this, we hope to draw conclusions on how to improve our practice.

2 Preliminary findings

We examined the papers that were reviewed by Huckebrink & Bertsch [4] and Hesselink & Chappin [5] and assessed the arguments brought forward to support the choice of the behavioural theory that was used for the decision logic of agents, if given at all. Because we found a lack of attention to 'use' behaviours in these reviews, we extended our search to ET ABM's that regarded load shifting behaviours (where energy use is shifted to another part of the day in order to prevent peak-use of electricity).

Preliminary findings show that if a behavioural theory is used to support the decision logic of an agent and is argumented for, most argumentations contain some form of 'ease of operationalizability' of the theory. Either the behavioural theory has clear building blocks (like the Theory of Planned Behaviour) or it is easily translated into formulas or assumptions . We also find that incorporating behavioural theory into ET ABM's is mainly done at technological institutes and that in-depth behavioural analysis is rarely done beforehand,

3 Ways forward

To understand the fit of behavioural theory and the behaviour of interest further, we aim to build upon and extend our explorative review. We will dive more into how empirical research is grounded in the research to corroborate theory and findings, and will explore how heterogeneity of agents is dealt with precisely.

To explore ways ahead, we deem interdisciplinary and team science crucial. Psychology and social science in general study human behaviour and offer an extensive

knowledge base on behavioural theory as well as specifications on when which theory might be applicable. This knowledge is however very broad and not easily digestable within a modelling project.

Specific challenges for modelling behaviour are i.) identifying relevant theory and justifying its fit [7], ii.) filling in gaps that the theory might not explain [8], and iii.) formalizing the often ambiguous description of theory into rules and formulas that can be translated to modelling code [9]. Collaboration between modellers and social scientists such as psychologists can help to address those points and give the representation of behaviour in ET ABM's a more solid base.

Interdisciplinary team work is not always straightforward though [10], and formalization can be specifically challenging [9]. Allowing sufficient time and resources for discussion can help to facilitate this process, as well as learning to understand each other by identifying how words, concepts, and models are used in each discipline [11].

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