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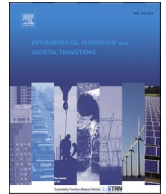
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Research article

The dynamics of participation: A complex adaptive systems perspective

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ABSTRACT

Participatory processes in the energy transition rarely stay within the boundaries of the meetings, practices, and methods in which they are designed. They interact, accumulate, and resonate within and across institutional, spatial and temporal boundaries. Recent scholarship has begun to recognise this, developing systemic perspectives on participation. While these richly describe *what* these interactions look like in practice, we require additional conceptual tools for explaining *how* their adaptive dynamics unfold. This paper addresses this gap by conceptualising a collection of participatory processes as a Complex Adaptive System (CAS). We develop a framework that empirically applies CAS concepts – nestedness, coupled fitness landscapes, path dependence and emergence – to a collection of participatory processes in the Netherlands. Our results from 21 interviews show how participatory processes are nested within multiple spatial, temporal, institutional and social scales and domains, both within and beyond the energy sector. Furthermore, participatory processes continuously learn from and respond to each other. We observed an interaction with two main emergent patterns in the system as a whole: the development of a milieu of learning on participation and the institutionalisation of participation. Finally, we observed processes of self-reinforcing behaviour and path dependence. Our CAS perspective provides conceptual and methodological tools to better understand the complexity, interdependencies, and change implications of participatory governance in sustainability transitions. Our findings underline the need for (normative) reflexivity in designing and evaluating participatory processes as dynamic components of larger, evolving systems.

1. Introduction

Participatory processes in the energy transition rarely stay within the boundaries of the meetings, practices, and methods in which they are designed. A local project can be determined by national renewable energy targets and policies, affect the expectations of citizens in neighbouring areas, and trigger new approaches to participation in the municipality. Participation, in practice, is less of a sequence of discrete events, and more like a dynamic, interconnected system.

Recent scholarship has begun to recognise this, moving away from studying the effects of participation at the level of individual, localised projects through single or comparative case studies (Lelieveldt and Schram, 2023; Upham et al., 2015; Wahlund and Palm,

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2022). Rather, there has been a recent academic move towards more systemic understandings of participation focusing on the relational, co-productive, and systemic nature of participatory processes in the energy transition (Chilvers et al., 2018; Pallett et al., 2019).

For instance, authors like Avelino et al. (2020) explored empowerment across translocal networks, connecting local to transnational processes, while Gottschamer and Walters (2023) advocate for the need of a more temporal understanding of interacting participatory processes. Additionally, a group of scholars including Chilvers et al. (2021) have convincingly conceptualised participation as part of a dynamic, evolving system of processes that shape and respond to each other over time. For instance, Chilvers et al. (2018) propose understanding participatory processes as an “ecology of participation” to understand the relationality of interacting participatory practices, which produce and are produced by the wider systems in which they are embedded. While the ecologies of participation framework is an incredibly useful contribution to understanding participation, richly describing *what* a relational, co-productive system of participation looks like in practice, we require additional conceptual tools for explaining *how* their adaptive dynamics work. To address this, we conceptualise a collection of participatory processes as a Complex Adaptive System (CAS), providing a basis of dynamic, processual concepts to make the behaviour of the system, i.e. the adaptive dynamics, nested structures and emergent properties, more explicit. We therefore ask: From a Complex Adaptive Systems perspective, what are the mechanisms that explain the systemic behaviour of a collection of participatory processes in the energy transition?

To answer this question, we conceptualise participatory decision-making processes as a collection of contextually dispersed, place-based processes that interact within the boundaries of a shared policy system — in this research, the Dutch national energy policy context. We understand these interactions as constituting a CAS in which participation is not a series of isolated events, but part of a dynamic, evolving system of processes that shape and respond to each other over time.

The paper is structured as follows. In Section 2, we develop a theoretical foundation applying a CAS perspective to participatory decision-making. Section 3 contains an overview of participatory decision-making in the Netherlands, setting the national context for this study and introducing the Environment and Planning Advisory Council (‘Omgevingsadviesraad’ in Dutch; OAR), a specific model of participatory decision-making which is the empirical focus of this study. We present our methodology of semi-structured interviews in Section 4. Section 5 reports our empirical application of participatory decision-making in the Netherlands as a CAS. Section 6 reflects on the implications of viewing participation through a CAS lens. Finally, Section 7 concludes the paper.

2. Complex adaptive systems approach to participation

In this paper, we conceptualise the collection of participatory processes as a CAS. CAS comes with many definitions, concepts, frameworks and applications (Labanca et al., 2020). In its most basic understanding, a CAS is a system that consists of a large number of elements (Section 2.1) that interact with each other as well as with their environment (Cilliers, 1998; Derkenbaeva et al., 2022; Holland, 2006; Holling, 1994; Oughton et al., 2018). These elements form the foundation on which the system’s dynamics emerge.

CAS evolve across *coupled fitness landscapes* (Section 2.2), where system elements continuously and dynamically adapt to each other. Participatory processes thus unfold not in isolation but in interdependence, shaping and being shaped by each other. Additionally, CAS are characterised by *nestedness* (Section 2.3), where systems are composed of subsystems, and are themselves part of larger systems. By adopting this perspective, we understand participatory processes as systems in itself, operating within larger systems. Furthermore, CAS have a history, meaning they are shaped by past interactions and behaviours and have impact on future interactions. Path dependence (Section 2.4) can occur, indicating that past interactions have made system elements so pervasive that it is increasingly difficult to change them. Finally, CAS are constantly evolving, with change emerging from the interplay of many factors. Overall system behaviour cannot be predicted solely by the summed-up behaviour of individual elements and interactions over time can give rise to emergent properties. *Emergence* (Section 2.5) implies that the interaction among system components may give rise to the appearance of novel, unexpected patterns, structures or behaviours at a broader system level (Loorbach et al., 2017). Studying these driving mechanisms of a CAS is crucial in understanding the complex adaptive nature of participation in energy transitions.

2.1. System elements

A collection of participatory processes in the energy transition viewed as a CAS involves understanding participatory processes not just as events or techniques, but as dynamic patterns of interaction among interconnected system elements (Yuan et al., 2024). We distinguish three main categories of system elements (Fig. 1), based on sustainability transitions research (Andersen and Geels, 2023;



Fig. 1. System elements.

Köhler et al., 2019). These include the stakeholders and actors involved in participation, such as policymakers, industry, citizens and communities, NGOs, and academics, and the way their identities, capacities and relationships with each other influence how the participatory practice unfolds. Secondly, it involves institutions, the formal rules, regulations and policies influencing participatory processes, as well as the informal norms and values legitimising and constraining modes of participation (de Looze and Cuppen, 2023; North, 1990; Tang, 2011). Materialities is the third category of system elements, including the energy technologies, the infrastructure, and the broader physical living environment that configure the conditions under which participation can unfold. These system elements are not introduced as analytical categories to be examined in their own right, but to provide the backdrop against which the system's dynamics unfold. Participatory processes arise from the dynamic interplay and repeated interactions of these elements. These elements do not remain confined within individual processes: actors move between settings, materialities bridge multiple contexts, and institutional standards travel and accumulate across scales. As a result, each participatory process is composed of its own configuration of system elements and interactions, while also being externally connected to the broader system and to other processes. This interconnectedness provides the basis of understanding a collection of participatory processes as a CAS.

Our CAS framing aligns with other relational approaches to participation, such as the ecologies of participation approach (Chilvers et al., 2018), which recognises and describes the interrelations and mutual influence of participatory practices within their wider spaces of participation and material and institutional contexts. The CAS perspective we propose in this paper builds on this line of thinking and extends it by offering a more explicit account of the adaptive mechanisms underlying these interactions.

2.2. Coupled fitness landscapes

To understand what drives the interaction between system elements, we use the concept of coupled fitness landscapes. Actors within the system operate within their own 'fitness landscape' in which they strive for certain goals (Kauffman and Johnsen, 1991).

A fitness landscape represents an actor's or collection of actors' ability to achieve their desired goals. These goals are subjective and may differ per actor and alter over time and space. For instance, a citizen collective in a participatory process might strive for as little nuisance and as much local economic profit of an energy project as possible. A civil servant, in turn, might aim for a smooth and fast process. These goals impact the behaviour of actors. With every interaction and change in the system, the ability of these actors to achieve their goals shifts, i.e., their fitness landscape changes, and they adapt their subsequent actions accordingly.

The system interactions change the way in which actors position themselves and what their optimal outcomes are, i.e. the characteristics of one system element provide input to the others with which they interact (Kauffman and Johnsen, 1991). The fitness landscapes are therefore *coupled*. Adaptations in one fitness landscape consequently affect the option space and adaptation for other actors, creating a dynamic, constantly evolving system (van Dam et al., 2013).

In this line of thinking, participatory processes also affect the landscapes of other participatory processes. Scholars conceptualising participatory processes in an interconnected way have claimed that "it is often the case that multiple models [...] of participation co-exist and affect each other at particular sites" (Pallett et al., 2019, p. 608). Cuppen et al., for instance, have conceptualised controversy (as a form of self-invited participation) as being shaped by and shaping other controversial projects (Cuppen et al., 2020). In this sense, a coupling occurs across processes and subsystems, in which experiences in one project influence the dynamics in another, either directly or indirectly. The effects on the overall system can be very unexpected when something that happened somewhere affects the fitness landscapes and thereby influences how people act elsewhere in the same system. Identifying these unexpected, emergent outcomes is at the core of our investigation.

2.3. System nestedness

Not only are participatory processes interconnected, but they are also always embedded in their regional, national and global context (Cuppen, 2018; Cuppen et al., 2020). This means that (historical and contemporary) contextual elements impact how a participatory process is designed, what role it plays, who is involved in it, what changes it can induce, etc., (Pesce et al., 2017) and how it evolves over time. In CAS terms, contextuality is defined as the 'environment' in which agents are positioned, consisting of all the information, structure and space that is affecting and affected by agents (van Dam et al., 2013).

System nestedness entails that adaptive and coevolutionary systems are composed of other sub-systems (van Dam et al., 2013). Systems can be nested through multiple scales and domains, such as in time, space, social relations and institutions (Holling, 2001; Köhler et al., 2021; van Dam et al., 2013). In transitions literature, the idea of nestedness has been central in describing how socio-technical change unfolds, for instance in the multi-level perspective literature (Geels, 2002, 2004, 2019; Grin et al., 2010), and in geographical approaches such as Avelino et al. (2020) on translocal networks, and Binz et al. (2025) on the role of place, scale and territorial embeddedness. In this paper, we relate to this established work but apply a more focused analysis, namely that of the domain of participatory practices. For instance, a local case on participatory decision-making can be viewed as a system embedded in temporal dynamics with fast, event-level decisions interacting within slower processes such as long-term policy shifts (time nestedness), situated within a larger spatial system shaping material conditions and possibilities (physical space nestedness), shaped by social relationships at multiple levels, such as interpersonal trust and community networks (social relations nestedness), and structured by decision-making frameworks spanning from local to (inter)national governance (institutional nestedness).

Nestedness can provide instability as well as stability. Because subsystems are interdependent and constantly adapting to changes across levels, disruptions in one part of the system can cascade throughout the system and drive change (Cuppen et al., 2020; Mariani et al., 2019). At the same time, the larger-scale system often provides a relatively stable context or nest within which the subsystems operate and the interdependence across levels can reinforce structures that absorb shocks and resist change (Mariani et al., 2019).

2.4. Path dependence

Interactions among system elements can become bolstered and established in such a way that it is increasingly difficult to alter or revoke them, and past choices and contextual heritage can have long-term impacts on the system in shaping the option space of subsequent choices and future developments (Sorensen, 2015). Due to this path dependence, decisions or events in the past strongly influence and constrain the options available for future action. Once certain pathways are taken, they tend to become self-reinforcing, thereby limiting flexibility and steering the system toward specific outcomes, making it increasingly difficult to reverse or change course (David, 1994; Derkenbaeva et al., 2022). Path dependence can be understood as emerging from the interplay of temporal nestedness – where system elements and processes evolve across multiple, interconnected timeframes – and stability, which reinforces established structures and behaviours. This can lead to lock-ins into path dependent trajectories, in which stability increases, the system becomes overconnected, and the interactions among system elements become so robust that they constrain future possibilities for change and make shifts away from established trajectories increasingly difficult (Holling, 1994; Macgill, 2011). While transitions scholarship uses path dependence to explain incumbent power (Hawxwell et al., 2024; Pacini and Bauknecht, 2025) and technological and institutional lock-in mostly at the regime level (Bours et al., 2026; Geels, 2004; Miorner et al., 2026), here, we apply the concept to participatory processes themselves and how repeated participatory routines and expectations can become stabilised over time, making certain forms of participation more likely than others.

2.5. Emergence

To fully understand system behaviour, the focus should be both on system components, as well as on their extensive interactions and processes of emergence over time (Derkenbaeva et al., 2022; van Dam et al., 2013; Yuan et al., 2024). Emergence refers to the new patterns, behaviours or system properties that arise through ongoing interactions and feedback loops among system elements (Watson, 2012). It entails that some macro-level phenomena cannot be attributed to micro-level causalities (Fromm, 2005; Yuan et al., 2024). It is the process of pattern formation over time through system interactions, resulting in outcomes and changed system properties that cannot be understood by simply examining individual system components (Basu and Bale, 2023; van Dam et al., 2013).

It is important to note that emergence can mean both the arising of macro-level processes of change, as well as the consolidation of stability of the system (Yuan et al., 2024). In addition, processes of emergent stability and change can alternate depending on the timeframe, and combinations of short-term positive feedback and long-term negative feedback frequently arise (Fromm, 2005). Emergence should be understood as an ongoing, dynamic process within a CAS, continuously shaping and being shaped by the interaction of system elements. Emergence is therefore not an end state, but rather a phenomenon to be observed, analysed and understood in relation to the evolving system elements and their interactions (Fromm, 2005; Yuan et al., 2024).

Together, the concepts of coupled fitness landscapes, nestedness, path dependence and emergence provide a conceptual framework to explore participatory decision-making as a CAS. They help make sense of *how* multiple participatory processes co-evolve, adapt to one another, and contribute to and interact with broader patterns of continuity and change. This CAS lens thus offers a way to move beyond isolated analyses of local participation, towards a more systemic understanding of how participation behaves as a collective, adaptive, evolving phenomenon.

3. Participatory decision-making in the Netherlands

To empirically apply our conceptual framework, we focus our attention on a collection of participatory processes in the Netherlands. The Netherlands makes an interesting focus country due to its longstanding tradition of participatory decision-making in the energy transition. We narrow down participatory processes to one specific type of participation: the Environment and Planning Advisory Council ('Omgevingsadviesraad' in Dutch; OAR; Section 3.2) to allow for an in-depth, coherent analysis of the interactions across participatory processes and the system dynamics at play.

3.1. The Netherlands: participation in the energy transition

For years, the Netherlands has been involved in the transition to renewable energy with an explicit focus on onshore wind and solar projects to reach renewable energy targets and reduce the environmental impact of the Dutch energy demand. In the past, many energy projects in the Netherlands have faced local resistance due to their perceived negative impacts on the local environment (Cuppen, 2018; de Looze and Cuppen, 2023; Schram et al., 2024). This is in line with a general sentiment of local resistance to energy projects in Europe and beyond, but has been especially fierce in the Netherlands due to the scarcity of space and the immediate local nuisance citizens experience as a consequence (van de Grift and Cuppen, 2022). These conflicts have repercussions for current-day projects that operate within the same local environment, representing a path-dependent system in which negative sentiments, distrust, and fear increasingly influence stakeholder interactions.

As a response to ongoing conflict, and with the explicit intention of making the transition more just and appreciative of the values and wishes of local communities, citizen and stakeholder participation started to play a more prominent role in decision-making. Although there are ongoing discussions on whether participation actually contributes to achieving a more just and democratic energy transition (Hendriks, 2009; Michels, 2006), there has been an increase in citizen participation in decision-making procedures in the Netherlands, especially over the past 20 years (de Looze et al., 2024).

The integration of citizen participation into decision-making procedures started off mostly as an informal adaptive strategy by civil

servants and project developers to achieve more local acceptance and to improve procedural justice of energy projects (de Looze and Cuppen, 2023; Enserink et al., 2024; Kemp et al., 2025). However, it gradually became codified in laws and policies such as the 2024 Environment and Planning Act (Omgevingswet) and stimulated with the establishment of the Regional Energy Strategies (RES) in 2019. The RES decentralised renewable energy planning to thirty energy regions, making these regions responsible for investigating onshore renewable energy possibilities (Haarbosch et al., 2026). While the thirty regions do not constitute a formal layer of government, they are nested within national policies and energy targets, linking local decision-making to broader climate targets and policy frameworks (de Looze and Cuppen, 2023; Lelieveldt and Schram, 2023). This nested structure means that decisions made at one level reverberate across other levels, creating a dynamic system in which actors continuously adapt to shifting constraints and opportunities.

3.2. OARs

One participatory format that emerged within this evolving system is the Environment and Planning Advisory Council ('Omgevingsadviesraad' in Dutch; OAR). Despite local differences in design, these formats have a number of characteristics in common:

- They include frequent and structured interaction with a set group of stakeholders.
- Frequently involved actors are: (independent) chair, secretary, project developer, competent authority, citizens or representatives of a citizen platform, activist groups, NGOs, tourist industry, landowners, agricultural representatives.
- They span a longer period of decision-making, mostly on a municipal level, at least a couple of months and sometimes a couple of years.
- Frequent topics of agreement during the process are: size, location, spatial planning, nuisance agreements, compensation schemes, ownership, and/or monitoring of the renewable energy project.

Unlike previous participatory models in which citizen participation was often limited to sporadic contributions of usual suspects, OARs were founded in the Netherlands with the aim of creating more balanced and inclusive collaborations. They seek to provide formal representation for citizens, ensuring more equal weight to their perspectives, balancing it with the other invited stakeholders who all have formal representation.

The first OAR was introduced around 2014 in the midst of an increase in participatory decision-making in the system as a whole. The format of OARs spread throughout the country, as its potential to result in a more constructive dialogue was appreciated. Initially, the establishment of OARs was shaped by an organisation representing citizen interests. As the approach gained traction and was more frequently adopted, demand outpaced the capacity of this organisation. In response, the organisation produced a guidebook with which other stakeholders could initiate and manage OARs independently. Currently, OARs – and OAR-like participatory formats with diverse names such as dialogue table and advisory group – are adopted regularly all over the country.

4. Methodology

In this research, we apply the CAS framework to the empirical context of the collection of OARs in the Netherlands. We investigate the mechanisms that explain the systemic behaviour of a collection of participatory decision-making processes in the energy transition, in order to understand participation as part of a dynamic, evolving system of processes that shape and respond to each other over time.

4.1. Data collection

We conducted interviews, as they provide rich, contextualised insights into participatory processes, which allowed us to interpret how the properties of a CAS – coupled fitness landscapes, nestedness, path dependence, and emergence – manifest in practice. We decided to exclusively focus on interviews, because they provide the most direct access to understanding the dynamics of interacting and interrelated participatory processes, which are not readily accessible through documentary sources reflecting more formalised accounts of participation. We conducted semi-structured interviews of 45–90 minutes with 21 actors involved in OARs or working on participatory decision-making on a national level. The interviews were used first of all to provide background information on what this collection of OARs entails and to distinguish the system elements that build up the CAS. In addition to this, we had four main goals with our empirical data collection: 1) to understand how OARs interact with each other and act as coupled fitness landscapes; 2) to learn how OARs are nested in time, physical space, social relations and institutions; 3) to find out whether there is any path dependence fixating participatory processes; and 4) to discover emergent patterns.

To achieve these goals, we aimed to interview a diverse set of interviewees. The interviewees involved in OARs were selected through a grey literature document search of OARs. We conducted an online search of OAR meeting notes and final agreements, and derived names of actors and organisations involved in the OARs. Rather than aiming for a representative sample of all OARs, we focused on capturing a broad diversity of perspectives by including interviewees occupying different roles and organisational positions, many of whom were or had been active in multiple OARs throughout their professional career. This led us to interview a variety of actors, including municipal civil servants (CS; 5); project developers (PD; 3), independent chairs (IC; 4), and citizen representatives (CR; 2). The national-level interviewees were selected through online searches for employees at ministries (M; 4) or ministry-related organisations (M-r; 3) with a focus on participation within their work. Whereas the interviews with the actors involved in OARs mostly helped define system boundaries and shed light on the system interactions, the national-level interviewees helped reflect especially on

nestedness and emergent patterns.

We asked questions about if and how OARs are connected to each other, what the connecting or isolating factors are, if and how actors and OARs adapt to each other over time, in what ways OARs are nested in time, physical space, social relations and institutions, and whether interviewees observed any path dependent processes. Additionally, we asked about emergent patterns of participation in the Netherlands.

4.2. Data analysis

After each interview, we transcribed the interview and coded it using ATLAS.ti. We based our coding scheme on our conceptual framework as presented in Section 2. We coded for system elements and macro-system interactions, coupled fitness landscapes, nestedness, path dependence, and emergence.

We analysed our data by manually looking through the coded sentences and paragraphs per concept. Based on this, we empirically described the collection of OARs as a CAS. We did this through analysing the coded excerpts to understand the presence or absence of nestedness (Section 5.1), coupled fitness landscapes (Section 5.2), emergence (Section 5.3) and path dependence (Section 5.4).

5. Results

5.1. Nestedness

First of all, we observed physical space nestedness. Rather than being local, isolated cases, interviewees mentioned that OARs have influence beyond their local context. Multiple interviewees discussed the “meaning [of local projects] for the energy transition in a broader sense” (M-r). Rather than zooming in on local dynamics and impacts, they raise the question of “what does it mean for the rest of the Netherlands?” (M-r) and understand local projects as physically nested within wider regional and national energy systems, where their contribution to renewable energy targets – or lack thereof – affects grid capacity and the physical space available for developments elsewhere. They would therefore not just operate within their OAR and local context but act as part of a wider network connecting these physical spaces: “there are six municipalities within our region. The six of us actually have regular consultations and then all these kinds of themes come up” (CS).

We additionally observed social relations nestedness. Almost all of our interviewees mentioned that they were part of a network within their own actor group, such as an industry association, a collective of municipalities, or a citizen interest group. Most of our interviewees also mentioned being involved in cross-sector networks, such as learning platforms on participation (beyond energy projects) and innovation networks within local regions. The goal of many such networks is “to let the knowledge that is there about participation flow in the whole network” (M-r). In addition, employee turnover with actors bringing experiences and knowledge from one job to another and individuals being involved in multiple OARs running at the same time or after each other strengthened social relations nestedness. Social relations nestedness also played an important role in the perceptions of local inhabitants towards new projects due to dynamics of distrust inherited from previous projects with “a history of injustice” (M-r) or a history of political instability in the area.

Finally, we observed institutional nestedness. Interviewees mentioned how their OARs were being shaped by and adapting to decision-making that occurred on a higher level. One interviewee mentioned: “you interact at all kinds of levels ... How is your energy system structured and what international or European agreements do we have?” (M-r). Furthermore, some interviewees mentioned how “it is much broader than just energy” (CS). They regarded OARs in the context of a wide set of national and regional assignments that impact the living environment, including energy provision, housing, and infrastructure. “Everything is interconnected, I would say. [...] Building wind turbines is never just about the turbines themselves. It is also about aviation, farmers, citizens, housing, ecology. And all these policy areas – at all these administrative levels – have to coordinate different participation processes” (M-r).

5.2. Coupled fitness landscapes

We observed coupled fitness landscapes in the collection of OARs and the way in which individual OARs adapted to each other over time. Every process shaped the way for future processes again, successful methods were duplicated and lessons learned were shared across OARs: “the information you gain from one [OAR], you take with you to the next. Those are really learning processes. Just in terms of better reporting, for instance, or methods for productive working sessions. So, you definitely take that information and experience with you” (PD). Another interviewee commented that “we are continuously asking ourselves: How did this work out? How would we do this another time? We continuously learn and evaluate what to do” (M). This continuous, iterative interaction of OARs and adaptations over time resulted in a collection of fairly homogeneous OARs in which the interaction space and the opportunity for adaptations is limited by the agreed-upon institutions and participatory directives.

Nonetheless, in this search for the ‘most successful’ participatory model, there would usually be room for slight local variations. Success is a subjective value of which different actors in different times and contexts have a different understanding. This means that even when one process went extremely smoothly for all parties involved, replicating this in a different context did not mean all actors would achieve their desired goals in this specific situation. Most interviewees and the people they worked with were aware of this: “It is always context specific. Ultimately, you approach it in the same way, but if there is a lot of resistance, you follow a different process. Or if there is a lot of political pressure in an environment at a certain moment, then the process also proceeds differently. Every project is different” (PD).

The adaptations and interactions between the OARs and their fitness landscapes did not just occur randomly but relate strongly to the nestedness of the OARs. Interviewees mentioned that the decentralisation of decision-making through the Regional Energy Strategies (RES) has resulted in increased regional coordination and continuous adaptation to other regions' strategies. This is related to institutional nestedness (Section 5.2) and explains why the energy regions continuously co-evolve and respond to energy-related decision-making in other regions. Because "there is no national direction" (IC) on what participatory activities ought to look like, local decision-making bodies adapted their behaviour to "become more fluid [...] and talk to each other" (IC) to learn from each other's experiences, join forces on participatory projects that cross their region's borders, and negotiate region-wide effects of participatory projects "because we cannot avoid getting into each other's way" (M-r). However, interviewees did mention that they continuously perceive pressure for quick solutions and decisions, leaving little room for orchestrating system interactions, knowledge exchange and learning processes. "In the implementation of projects, you are assessed on two things: being on time and within budget. And everything else distracts from those two main goals" (M-r). This influences actors' room for engaging in knowledge exchange and participatory activities. Interviewees mentioned that they see the value of knowledge exchange: "we can learn a lot from them, and they can learn from us too. But no time" (M-r). The pressure for quick solutions therefore altered the fitness landscapes, limiting the ability to achieve desired interactions and learning across OARs.

5.3. Emergence

Viewing the collection of OARs in the Netherlands through a CAS lens, we observed two main patterns of emergence: 1) the development of a milieu of learning on participation; and 2) the institutionalisation of participation. Rather than being direct outcomes of specific system interactions, these patterns of emergence should be understood as part of the wider system behaviour, co-evolving through the ongoing interactions among OARs and the structures they are nested in. The two patterns of emergence are thus not an endpoint but a dynamic property of the system in itself, which continues to influence system interactions and participatory processes.

5.3.1. Milieu of learning on participation

The first emergent pattern we observed is the development of a milieu of learning on participation. Interviewees observed that over the years, participation has developed as a "craftmanship" (M). Rather than being a side issue or introduced to decision-making as an afterthought, participation has now become a real, standalone field of expertise, across all levels of governance. This has been a self-reinforcing loop of learning, with participation experts and consultancies nowadays teaching people to train others on how to do participation, a ripple effect referred to as "*particileren*" (M; *partici-learning*) by one of the interviewees. Interviewees mentioned that this milieu of learning on participation is reflected in the increase of participation experts and in the founding of knowledge and learning platforms that enhance knowledge exchange about participation. One interviewee mentioned that participation has become such a well-known aspect of decision-making that people increasingly recognise its importance and seek out learning opportunities. Events and knowledge sessions are then used "to familiarise people with participation. And then there is a kind of seed planted" (IC). When the need for participation comes up, there is a wide range of information, guidelines, and case studies to be easily found and learned from, both online and within people's networks. One interviewee additionally mentioned that the fact that the national government is also appreciating and actively supporting this milieu of learning on participation is benefiting and reinforcing its existence, because "once you have a vision that you want to work towards, you can also work on material that will support that" (IC).

5.3.2. Institutionalisation of participation

The second emergent pattern that we observed is institutionalisation of participation. Interviewees mentioned that participation has gradually become formally embedded in all kinds of decision-making procedures and institutionalised, broadened and professionalised across all levels of decision-making: "We have grown from being only concerned with formal participation procedures to actually serving the entire playing field of participation" (M). Rather than being a 'nice-to-have' aspect of renewable energy projects, it has now become a mandatory part of decision-making in many cases. To strengthen this push, participation has become "anchored in law" (M), for instance through the 'Environment and Planning Act' and the 'Act on strengthening participation at a decentralised level'. These acts institutionalise participation but keep space for different participatory approaches. "We have seen a development towards more and diverse forms of participation. And the Environment and Planning Act now also states that this is free of form. So, it indicates that you must involve the local environment well, but it does not prescribe how exactly you should do that" (M). The dynamic interaction between the two emergent patterns of institutionalisation of participation and the creation of a milieu of learning about participation ensures that, despite this free form of participation, many formats, handbooks, and guidelines have been developed on how to best engage citizens and other stakeholders in decision-making.

Some interviewees were content with the system interactions and the occurrence of the two emergent patterns. They agreed that modes of participation have improved over the years, as a consequence of an improved milieu of learning on participation. The continuous exchange of knowledge, best practices, and mistakes has enabled initiators of participation to better include citizens and their perspective, which enhances procedural justice of decision-making processes. In a similar fashion, the institutionalisation of participation gives more legal obligations to participation and has helped make participation a key part of decision-making, in the energy transition and beyond. Interviewees were generally positive about these developments and their contributions to more just and inclusive decision-making for the energy transition.

5.4. Path dependence

Nonetheless, not everyone agreed that the interactions observed are always desirable. Interviewees warned against path dependent processes and over-stabilisation of the emergent patterns. We found that the presence of personal networks, although connecting OARs and fostering a milieu of learning on participation, reinforces established paths of knowledge exchange. “The energy sector in the Netherlands is quite small in that respect” (CS), meaning that certain organisations and individuals within these organisations continuously strengthen existing knowledge paths and create an ‘in-crowd’. A lack of diversity in knowledge contributions, especially when OARs were a newly found approach, meant that knowledge and participatory approaches were very much linked to individuals who dominate the participatory landscape: “I think they were the only one in the Netherlands who were involved in that” (CR). Interviewees mentioned that this resulted in a lock-in of a certain model of participation. They argued that at some point, the dominant approach was seen as the only way forward: “In this land of the blind, the one-eyed man is king” (IC) and “all the ideas come from them ... their role was particularly big” (CR). This sometimes led to an OAR being the chosen approach, at the cost of other ideas and “it was never a question of: is this a good approach?” (IC), even when the project might have benefited more from other participatory models.

Moreover, some interviewees argued that the emergent trend of knowledge sharing has become dysfunctional and undesirable, explaining that it has reached a point of diminishing returns. They described that the overload of general, untailored guidebooks on how to do participation sometimes actually counteracts system interactions and learning: “I really hate guidelines. I get a guideline sent to me around once a week. And then I read it and think, it is too general for me, or it does not help me” (M). This results in an attitude of apathy towards these documents, ultimately weakening the system interactions they were meant to support.

Some interviewees had critical remarks on the increasing institutionalisation of participation. They criticised the ever-increasing bureaucratisation and locking in of participation as an obligation or a box that ought to be ticked: “I would ask: ‘why do you want people to participate?’ [and they would answer:] ‘because they have to!’” (M-r). Participation is then no longer used as an opportunity to engage in open, place-based and context-specific public encounter to improve decision-making. It also runs the risk of “[organising] citizen consultations for things that people are not interested in at all. And what you get then is indifference and non-receptivity of the people, so people drop out of the participation process” (IC). The consequence of this is a counterproductive situation in which citizens display fatigue and resistance against participation in a system in which participation is evermore required.

6. Discussion

Our results provide an empirical application of a CAS approach to the collection of OARs. We have demonstrated that OARs interact with each other and the broader systems they operate in. These connections are shaped by several interrelated mechanisms. First of all, we found that OARs are nested within multiple spatial, temporal, institutional and social scales and domains, both within and beyond the energy sector. Additionally, we found that OARs continuously learn from and respond to each other through coupled fitness landscapes in which they mutually adjust to each other and pave each other’s way over time. Furthermore, we observed an interaction with two emergent patterns in the system as a whole: the development of a milieu of learning on participation and the institutionalisation of participation. Finally, we found that certain patterns of interaction engage in self-reinforcing behaviour over time, bolstering and becoming established in such a way that it becomes increasingly difficult to revoke them and resulting in path dependence.

We have illustrated that participatory processes are not isolated events, but rather deeply interrelated and continuously adapting to one another and their evolving environments, shaped by – and in turn shaping – historical structures, feedback loops, and broader system dynamics. These findings are in line with previous research on the relational, co-productive, and systemic nature of participatory processes in the energy transition (Chilvers et al., 2018; Pallett et al., 2019). Where previous approaches such as the ecologies of participation framework have contributed the tools to describe what a relational, co-productive system of participation looks like (Chilvers et al., 2018), our CAS framework has refined and deepened this research by going one level more abstract in describing the mechanistic properties that create this structure. This systemic perspective reveals the dynamics that explain why participatory processes extend beyond their immediate contexts, being one of many structural forces within transition processes, collectively contributing to and in turn influenced by emergent system change. Recognising this has important implications for the design, implementation and evaluation of participatory processes, calling for greater sensitivity to socio-cultural, institutional, and historical contexts and system interactions. Where most participatory processes are evaluated based on direct outcome, this perspective unravels the more intangible, unquantifiable values of participation, and it implies that in evaluating participation, the focus should widen from a local output assessment to additionally encapsulate an evaluation of the mechanistic properties determining the complex, multi-directional and collective impacts and constraints of participation.

It is important to note that our findings illustrate that emergence is the result of complex, dynamic interactions that resist standardisation. Because participatory processes are nested in space, time, institutions and social relations and are contingent to unique interactions, timing, feedback loops and actor constellations, it is extremely difficult to accurately recreate or predict system dynamics and patterns of emergence. A CAS perspective on a collection of participatory processes tells us that we cannot and should not try to control everything. This resonates with earlier transitions literature emphasising the need for reflexivity and learning (Pacini and Bauknecht, 2025; van Mierlo and Beers, 2020). Our CAS perspective adds to these literatures by contributing insights on the dynamics that constrain the potential for control and underline the importance of working with these system dynamics. Rather than trying to encapsulate participatory processes into a streamlined framework of guidelines aimed at steering towards a certain goal, it suggests a move towards more soft coordination that recognises and works with the system’s mechanistic properties and collective dynamics. It means considering multi-level effects and constraints arising from nestedness, the continuous reshaping of conditions due

to coupled fitness landscapes, emergent outcomes that cannot be fully predicted, and the influence of path dependence on the possibilities for disruption or reinforcement of system behaviour.

6.1. Normative considerations

In navigating the system dynamics and understanding and evaluating the complex, multi-directional and collective impacts of participation, two important normative questions arise: what kinds of complex interactions and impacts are actually ‘desirable’ and who predominantly exert influence over the CAS? The system interactions and emergent patterns we observed are not neutral, nor are they inherently positive, productive or beneficial. Their occurrence is driven by the values, needs and goals of those in power, and the desirability of the system dynamics depends on whose values, needs and goals it serves. As such, any effort to evaluate participation as a CAS must be accompanied by a critical reflection of its normative premises and implications. We engaged with this question of desirability of system interactions in the interviews and received a nuanced response, with some participants reflecting on the positive impacts of the milieu of learning and the institutionalisation of participation (Section 5.4), and others warning against path dependent processes and over-stabilisation of participatory methods and frameworks (Section 5.4).

In other words, the system interactions and emergent patterns are not automatically something that ought to be stimulated. Even within our relatively small but diverse sample of 21 interviewees, we observed discrepancies in how the complex interactions were normatively evaluated—suggesting that perceptions of desirability vary widely depending on individual perspectives, roles, and contexts. Had we spoken to a broader group of stakeholders, it is likely that these divergences would have been even more pronounced. It is essential to continue normative discussions on the desirability of system interactions and the directionality of change. We recommend further research evaluating CAS interactions’ contributions to reaching normative goals such as energy justice. Such evaluations must remain sensitive to the time- and space-contingent nature of transitions, and to the fact that normative goals themselves are dynamic and subject to change (de Looze et al., 2024).

In addition to this, it is important to note that the system interactions are themselves shaped and conditioned by existing power relations and dominant norms of ‘desirability’ (Avelino, 2017; Shove and Walker, 2007). A CAS lens helps understand participation in a more systemic, collective, co-evolving phenomenon, but it is crucial to understand these dynamics in light of its uneven playing field – in which some actors have (had) greater capacity to shape interactions, set agendas, introduce norms of desirability and thereby define the CAS and its underlying mechanisms of interaction (Kok et al., 2021). Acknowledging complexity and unpredictability should not lead to passivity or an uncritical acceptance of emergent outcomes: interventions remain possible — and at times necessary — because emergent dynamics are not inherently desirable or neutral, but reflect existing power relations and normative directions. It is therefore crucial to critically evaluate these power dynamics and the directions they produce, making explicit the normative intentions behind any intervention. Future research could build on this by combining theories of power and directionality to examine how intentions are articulated, negotiated, and aligned within and across participatory processes — and how unequal power relations shape whose intentions prevail.

6.2. Academic reflections

This study offers conceptual contributions to both the literature on participation in transitions and the CAS field by developing and applying a novel framework that synthesises these fields. In doing so, it situates and conceptualises a collection of participatory processes within and as a dynamic system. Our approach offers a novel analytical lens for understanding the mechanisms that explain *how* local participatory efforts contribute to system-level effects. Furthermore, the CAS framework we developed offers a vocabulary that can support the connection of participatory governance research to CAS modelling practices, such as agent-based modelling (An et al., 2021; Epstein, 1999). Existing modelling approaches often struggle to apply complex systems thinking to dynamics of participatory processes. The articulation of mechanisms such as nestedness, coupled fitness landscapes, emergence and path dependence in relation to participation literature provides opportunities for translating qualitative, empirical insights from participation and transitions into model components, thereby bridging these disciplinary domains (An et al., 2021). This enables a more systematic and explanatory exploration of *how* participatory processes contribute to, and are influenced by, wider system dynamics, and how interventions may or may not reshape these dynamics and outcomes over time.

While we identified several interactions that shape system behaviour, it is important to note that these represent only a subset of the broader dynamics at play. Many interacting elements fall outside the scope of this research and the two emergent patterns that we observed are likely not the only processes of emergence that are occurring. Rather, they are part of a broader, iterative process in which new interactions, feedback loops and patterns continuously arise and in which the emergent patterns we observed are themselves dynamic properties within the broader energy system and the longer trajectory of energy transitions (van Dam et al., 2013). Moreover, while we have emphasised the interconnectedness of participatory processes in this study, it is important to note that not all sub-systems of participation unfold in this manner. Some local participatory initiatives remain relatively isolated, with limited exchange or alignment with other processes or institutional structures. In other words, the interconnection of participatory processes is not a given. Future research should explore the conditions under which participatory processes become connected or remain disconnected, and what implications this has on their role in the broader system and their contributions to ‘desirable’ change.

Furthermore, the findings are shaped by the interaction of OARs – a very specific subset of participatory processes - within the Dutch governance context. This influences how the CAS mechanisms manifest. At the same time, the mechanisms identified here are likely not unique to the Dutch case or to OARs specifically. Rather, the collection of OARs provides a clear empirical setting in which these complex, adaptive mechanisms become visible. The insights from this study should therefore be understood as empirical

expressions that are contextually grounded, but with underlying CAS mechanisms that are analytically transferable to other contexts.

7. Conclusion

This study contributes to a recent academic move towards a more systemic understanding of participation. We designed a framework to explore participatory decision-making as a complex adaptive system. Through empirically applying the concepts of coupled fitness landscapes, nestedness, path dependence and emergence to participation in the energy transition in the Netherlands, we shed light on the mechanisms that determine how multiple participatory processes co-evolve, adapt to one another, and contribute to and interact with broader patterns of continuity and change. This paper provides an important contribution to existing efforts in transitions literature to achieve a more systemic understanding of participation as a collective, relational, evolving phenomenon, by studying the underlying mechanisms that explain the systemic behaviour of a collection of participatory processes.

When adopting a CAS approach to participation it is essential to recognise its normative implications. Systems are never neutral: they reflect power dynamics and values that are shaped by past interactions but are also continuously subject to change. A more systemic understanding of the impacts of participation should therefore always be accompanied by a continuous reflection on what change is desirable, for whom, under what conditions, and according to whom.

Future research should further explore these normative implications. Additionally, we see a need for further synthesis of CAS theory, transition studies and governance literature, for instance through adopting a critical, value-sensitive lens to modelling approaches that investigate system interactions, while recognising participation as a contested political arena shaped by diverse values and negotiations. Recognising and engaging with the systemic nature of participation through a complex systems lens, these approaches open new pathways for understanding the complex dynamics of change of the energy transition as a whole.

CRedit authorship contribution statement

Annemiek de Looze: Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Eefje Cuppen:** Writing – review & editing, Validation, Supervision, Funding acquisition, Conceptualization. **Antonella Maiello:** Writing – review & editing, Validation, Supervision, Conceptualization. **Igor Nikolic:** Writing – review & editing, Validation, Supervision, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The data that has been used is confidential.

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