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Scaling mechanisms of energy communities: A comparison of 28 initiatives

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ABSTRACT

Energy communities have mushroomed over the past decades. These initiatives have scaled, that is replicated their experiences, expanded membership, and diversified involved actors and technologies. The picture existing literature paints is hopeful that the scaling of local-scale action may translate into global-scale impact and thus effectively contribute to combating climate change. However, important gaps remain in understanding the (combinations of) conditions which are necessary for scaling with this goal in mind. This article pushes the boundaries of knowledge further by examining and comparing 28 energy communities through a fuzzy set Qualitative Comparative Analysis (QCA) and by identifying the necessary conditions of actionable scaling mechanisms. Our analysis identifies a high number (8) of necessary (combinations of) conditions for scaling. Addressing a strong need amongst policy makers to facilitate broader scaling of community initiatives, this article offers concrete insights on mechanisms that need to be in place to scale energy communities. Insights are developed on – for example – the type of capacity support needed, support structures and the tools needed for connecting communities with each other. These insights help corroborate empirically, for the first time the crucial leverage points that will support strategies for upscaling the impact of energy communities, and will enable them to flourish as an essential element of the global climate governance system.

1. Introduction

Small- and local-scale initiatives targeting climate mitigation have mushroomed over the past decades. The increasingly dominant climate governance narrative is about a multitude of actors, initiatives, and technologies and about how these may develop into a coordinated, timely, and effective impact for mitigating climate change. An illustrative case of this story is that of energy communities: they are blooming in numbers across the globe, replicating experiences and expanding in membership, diversifying in terms of involved actors and technologies, and aiding in the acceleration of the transition towards renewable energy (Blasch et al., 2021). In the European Union (EU), which is a frontrunner in institutionalizing energy communities to-date 2 million citizens are involved in over 7000 such communities (Smarten, 2022). Considering that empirical proof for the scaling of such communities is ample, in this article we examine what the necessary (combinations of) conditions are for their scaling. In effect we also hope to illuminate how local-scale initiatives are being institutionalized and how they contribute to global imapact.

Blasch et al. (2021) define energy communities as “associations of actors engaged in energy system transformation through collective, participatory and engaging processes, seeking collective outcomes” (p. 3). Such an understanding captures the complex nature of the concept where recent developments – particularly pushing towards decentralization, digitalization, and the democratization of energy systems – have led to two distinct outcomes. First, a growing number of technologies are used in communities (production, storage, demand response, etc.), and an increasing number of actors (municipalities, companies, etc.) are engaged in their emergence and operation. Second, a growing number of energy community models are no longer concentrated around local development.

With the proliferation of scholarly research on energy communities, as well as the above detailed tendency towards technological and membership heterogeneity, the question surfaces as to what encompasses such a community in more broad terms. In general, they build on the REScoop model, building on cooperative principles including ownership by citizens, who collectively participate in various renewable energy and energy efficiency projects (REScoop, 2023). Their purpose and benefits are manifold as they help maintain value in local

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economies, foster the social acceptance of renewable energy, keep investments affordable, contribute to more affordable utility bills, and build the local sense of community (EC, 2023).

According to Walker and Devine-Wright (2008), the heterogeneity can be best underpinned by open & participatory processes and local & collective outcomes. The EU has codified them as Renewable Energy Communities and Citizen Energy Communities (EC, 2023). The former focuses on geographical proximity with a promotion of renewable energy sources, whilst the later takes a broader definition with open membership, market elements and a diversion from the locality. The past years have marked a phase of energy community development involving the interaction of different types of actors (such as community, state and the private sector) (Creamer et al., 2018) resulting in institutional complexity, where cooperative logic meets other types of logics (Bauwens et al., 2022). In effect studying the European context is ripe for understanding how scaling feeds into this process of early institutionalization and resulting (institutional) complexity.

Two strands of the academic debate have emerged over the past decade that can aid in understanding how local action translates into a global impact. Of these, Elinor Ostrom (2010) perhaps provides the best understanding of the implications of community action, as she brought insights from her multi-decade-long research program on the effective management of a common-pool resource dilemmas to bear on the discussion on global climate governance. Ostrom's work suggested local action at multiple places can lead to a groundswell of action and productive interactions between localities, thus unleashing a huge transformative potential. However, the key issue she raises is that the groundswell of action is composed of these individual initiatives working in seamless unison. Here questions arise as to how such a polycentric system may most effectively be governed – and how the cogs and wheels of such a system may move in unison allowing for an effective polycentric climate governance system.

In a similar vein, the field of transition studies has been pre-occupied with finding a better understanding of how *niche* innovation and transformative change in socio-technical systems emerge (Loorbach et al., 2020). One of the key issues this literature is concerned with is how *niches* at the local scale turn into global *niches* (movements of initiatives with transformative potential (Schot and Geels, 2008)). These linkages are dependent on the existence of translocal networks of initiatives (Loorbach et al., 2020), which help connect individual initiatives, and disseminate learning capacity.

A challenge for both strands of the academic debate remains the more concrete specification of how one goes from single local initiative, or a set of such initiatives, to the 'groundswell' of initiatives that speak to and learn from each other and manage to affect transformational impacts. We specifically see a need to better understand the necessary (combinations of) conditions for the growth and replication of initiatives, since the necessary (combinations of) conditions are the ingredients that need to be in place for the anticipated transformation to start. Identifying such conditions can in-effect allow for a more concrete understanding of the mechanisms at the disposal of decision makers to scale energy communities. In our understanding mechanisms entail tools available to decision makers, which can trigger processes, dependent on conditions, leading to given outcomes. Hereby, we are "able to identify and provide sets of social mechanisms that can explain the link between causes and effects." (Biesbroek and Candel, 2020, p. 64.). Based on the necessary (combinations of) conditions, we can also identify a number of actionable mechanisms, which can contribute to the scaling of energy communities.

To identify the necessary (combinations of) conditions, we use Qualitative Comparative Analysis (QCA). QCA is a set-theoretical method (e.g., Schneider and Wagemann, 2012; Mello, 2021) that is well-suited for identifying necessary (combinations of) conditions – despite a bias toward the analysis of sufficiency (Schneider, 2019). To this end, we first explore the theoretical accounts of how local innovation can best be governed for the sake of global-scale impact. This is followed by an introduction of our cases: 28 different energy communities that produce or store energy on a community basis, primarily located within the European Union. Most of these initiatives are cooperatives (i.e., one member = one vote), and hence align with the broad definition of energy communities set out above. Our QCA-analysis of necessity reveals eight (combinations of) conditions necessary for scaling. We explore these conditions, also discussing them in light of actionable mechanisms. The final section focuses on the utility of cross-fertilizing literature and the wider implications of our study.

2. Theory: scaling local scale initiatives in climate governance

In 2010 Elinor Ostrom published a paper, which remains an influential paper until today on the effective governance of climate change (Ostrom, 2010). Her paper summarizes thinking on social dilemmas and the potential consequences of failure to build trust among citizens for their resolution in the case of a multi-scale dilemma. Ostrom's decades-long research program has resulted in a clear set of design principles for the resolution of such dilemmas in the domain of local-scale environmental governance; however her thinking on polycentric governance which is about connections between various forms of local action, their cross fertilizations, and 'automatic' adjustments in scale of operation if required, was still incomplete at the moment of her untimely death (Aligica and Tarko, 2012).

The sheer confusion surrounding GHG accounting and the responsibilities around emissions illustrates the complexity of the problem. Questions emerge regarding who is expected to act and what mechanisms help coordinate this action. Even if one assumes the best-case scenario where all actors involved have ambitious climate targets, questions of responsibility (both in terms of a lack and conflict) arise (Savini and Giezen, 2020). Is it public authorities' responsibility to pressure the private sector operating within their jurisdictional limits to reduce their emissions? Is it companies that should leverage utility providers? Should utilities aim to purchase more clean energy and default on their long-term power purchasing agreement? Should governments cooperate in phasing out fossil fules?

What becomes clear is that to resolve the complexity of the dilemmas surrounding effective climate governance one should aim to effectively connect both the various scales of (in)action, the numerous actors involved, and their domains across these scales (Ostrom, 2010). In coordinating these efforts, much is to be learned from existing success stories through posing two questions regarding GHG mitigation activities at the local scale: How can local-scale action most effectively contribute to resolving a global-scale dilemma? And can the benefits of such initiatives span past simply the mitigation of GHG emissions – i.e., are there other positive externalities to these initiatives?

In answering these questions, scholars researching polycentric climate and energy governance have shifted their focus onto the aggregate impact of individual initiatives (Jordan et al., 2018; Petrovics et al., 2022a). Next to this, zooming in on specific innovations and exploring what is necessary for their strategic management has also gained traction over the past decade (Hargreaves et al., 2013; Ruggiero et al., 2018; Smith et al., 2016).

Polycentric governance thinking (PGT) helps shift the analytical focus of global governance to the individual interactions of initiatives and the culmination of the climate governance system as the aggregate of these initiatives' effective interactions. Similarly, another strand of the debate, regarding Strategic Niche Management (SNM), connects local innovation to global *niche* formation through networks (Geels and Schot, 2007; Schot and Geels, 2008). This means that conceptually analyzing a *niche* should not only take place at the scale of an individual initiative but should also consider how these initiatives build networks and, thereby, raise their capacity for system change. Here SNM literature focuses on broad and deep networks, meaning the involvement of a wide variety of stakeholders and the capacity to mobilize resources, respectively (Schot and Geels, 2008). Despite commonalities, the two strands provide variegating insights, and they in fact complement each other to a degree. This is primarily true in terms of the scale they focus on, the type of ontological entry point they take and the conceptual methods they utilize. Table 1 summarizes this.

Table 1
Summary of Theoretical Entry-points.

	Strategic-Niche Management (SNM) approach	Polycentric governance thinking (PGT)
Scale of focus	Meso and macro: how *niche* innovation challenges existing *regimes* and *landscape* pressures affect this process (Geels, 2004; Geels & Schot, 2007).	Multi-scalar: interested in how innovation can be organized at the local scale of actor interactions and how cooperation at "appropriate" scales subsequently develops (Ostrom, 1999, 2010).
Ontological point of entry	Structural conditions of transitions, and how actors are constricted in steering change (Loorbach et al., 2017).	Actor interactions and agency in building coalitions and institutions with potential to alter structural conditions (Aligica, 2013; Aligica & Tarko, 2012).
Conceptual method	Suitable for *ex-post* evaluations of past transitions, and deducing learnings from these processes (Patterson et al., 2017). In certain cases works with (*ex-ante*) scenario building towards desired outcomes (Sondeijker et al., 2006).	Resolution of (common pool resource) dilemmas and building forward from these actor interactions in building institutions (Jordan et al., 2018; Nagendra & Ostrom, 2012; Ostrom, 2010).

PGT in the context of the climate crisis suggests that a more diverse and multilevel approach is possible, building on cumulative positive externalities of local, bottom-up initiatives that may or may not have been initiated out of climate concerns (co-benefits of climate action such as clean air are also seen as important; see Ostrom, 2010). The empirical applicability of the conceptual framework is receiving growing attention with applicability to how a global system should be designed, governed, monitored, and improved. To this end, Jordan et al. (2018) reconceptualized the climate crisis as an issue resolvable by effective climate governance where empirical research is needed on local action, mutual adjustment of governing units, experimentation, trust, and overarching rules.

The SNM approach posits that technological artifacts, related innovation, and the systems in which they are found are inextricably linked to society and the individuals who interact with them. It heavily relies on the multi-level perspective (MLP) that differentiates between three distinct analytical levels. The *regime* entails the *status quo* constellation of policy, science, markets, culture, technology, and industry (Geels, 2002, 2019). This *regime* faces challenges from *niche*-level innovation, which can topple or change the *regime* in a multitude of manners (see, for example Geels and Schot (2007) for a typology of pathways). This process is exacerbated or slowed by *landscape* pressures, which are the overarching dynamics of a system.

These strands of the academic debate enable a useful framing of scaling local scale initiatives. PGT makes propositions on how to govern local-scale action for global-scale impact. The SNM approach outlines what is needed to protect innovation for it to thrive. The two approaches in combination allow for a better understanding of how various scales connect and, most of all, what may describe an effective climate governance system where local-scale activities are connected into movements of initiatives, where learnings can freely be dissipated between governing units, and where the various cogs and wheels of the governance machine move in unison. The questions remain as to what mechanisms may be at play in such a system? What is needed for individual initiatives scattered around the globe to gel into an effective movement of initiatives? How exactly do they grow and replicate? All these questions are effectively about scaling, and so we pay some more attention to the meaning of this term.

As can the scaling strategies of initiatives be diverse (Bauwens et al., 2020), so is the overall understandings of the term scaling. Studies that work with the concept examined how movements grow (Seyfang and Haxeltine, 2012), how transitions accelerate (Ehnert et al., 2018), how *niches* can be protected (Smith and Raven, 2012), or how the impacts of individual initiatives can be amplified (Lam et al., 2020).

In our understanding what underlies these definitations can be distinguished as *horizontal* and *vertical* up-scaling (van Doren et al., 2018). These two types describe the outcomes of scaling processes, in horizontal terms entailing more and bigger initiatives, and in vertical terms pointing towards institutional change. It is important to outline that this framework does not isolate vertical and horizontal pathways – it treats them as potentially self-reinforcing processes. When assessing energy communities, in operational terms, these pathways entail that an initiative may expand both in technical capacity and membership and may replicate its experiences. Moreover, studying and comparing the empirical realities of these processes as they take place in real life (and scale up to greater or lesser degrees) could potentially enable the conditions that matter by informing decision-makers as well as energy community practitioners on where to look for the leverage points available for successful scaling.

This scaling framework has productively been examined in relation to PGT (Petrovics et al., 2022a) as well as the SNM approach (Petrovics et al., 2022b). None of this work has to-date been cross-examined, or in other words, the two approaches have not as of yet been brought into a dialogue when examining scaling. The theoretical contribution of this paper lies here. As a useful operationalization of the two theories, Petrovics et al. (2022a, 2022b) identify 23 potential conditions for scaling energy communities through a literature review. They suggest that empirical testing of the conditions is needed to substantiate pathways towards scaling energy communities. As is outlined in detail in Table 2, these conditions can be grouped in three categories.

Firstly, some can be considered internal conditions to a community's functioning. Here we find conditions to do with the way members interact with eachother and how they define operational procedures for the functioning of the community. Secondly, there are conditions at the level of interactions between initiatives; they may build networks and

Table 2
Conditions for Scaling Energy Communities (Petrovics et al., 2022a, 2022b).

Dimension of Condition	Condition
With-in Community	Actors communicate amongst themselves Simple rules and procedures Ease of engaging citizens in initiative Space to experiment Common vision and set of goals Community members have the capacity to mobilize resources Leadership roles within initiative Sense of co-ownership Financial frameworks serve members Formalized and professionalized organization
Between Communities	Initiatives interact externally Presence of intermediaries Initiatives learn from each other Establishing networks Transferring knowledge and best-practices
In the Context of Communities	Democratized distribution of knowledge Monitoring and evaluation frameworks pointing towards learning Context for entrepreneur-led experimentation Support for local innovation Supportive financial frameworks Innovation focused policy Reliability of technology and policies Local participatory process

may learn from other initiatives. As mentioned, this dimension is key in connecting local *niches* with global *niches* and driving the effective functioning of a polycentric governance system. Finally, some conditions can be identified at the level of the context. These conditions primarily link to the broader support structures at the disposal of policy and decision-makers to support energy communities. This being said action must come from multiple sides including citizens.

As is spelled out below, these conditions serve as a useful baseline to better understand what is needed to scale energy communities as well as to refine both PGT and the SNM approach through empirical examples. Albeit numerous, these conditions may hold the key to better understanding what conditions are necessary for specific energy communities at the local-scale to grow in terms of their membership or their technical capacity. Next to this, these conditions may also hold the key to better understanding how energy communities as an overall movement at the global scale may replicate their experiences. The coming sections aim to enhance our understanding of this by closely analyzing a number of energy communities, by using Qualitative Comparative Analysis (QCA).

3. Methodology

This paper uses Qualitative Comparative Analysis (QCA) as its principal method to identify the necessary (combinations of) conditions for scaling. We compare 28 diverse energy communities across 14 jurisdictions. They are diverse in terms of the technologies they utilize, the actors involved in their emergence and the models they base their operations on.

3.1. Why QCA is appropriate for studying the scaling of energy communities

QCA is a set-theoretic approach, which builds on the conception that societal phenomena can be described through set relations (Mello, 2021; Ragin, 2008; Schneider and Wagemann, 2012). This enables the identification of necessary and sufficient (combinations of) conditions for an outcome. While relationships of necessity and those of sufficiency are both relevant from a set-theoretical perspective, applied QCA research tends to focus most of the analysis of sufficiency (cf. Schneider, 2019). There has been more attention paid to the analysis of necessity in QCA in methodological studies (e.g., Bol and Luppi, 2013; Rohlfing and Schneider, 2013; Vis and Dul, 2018). However, to date, this has not been picked up much in applied research, perhaps except for also reporting SUIN conditions. These conditions are "a sufficient but unnecessary part of a factor that is insufficient but necessary for an outcome" (Mahoney, 2008, p. 419). This bias towards analysis of sufficiency is unfortunate, both because many theories in the social sciences include claims of necessity – as the numerous examples by Goertz and Starr (2003) show, and because empirically necessary (combinations of) conditions are essential for the occurrence of an outcome. This is especially important when a study's goal is (also) to make policy recommendations, like this one's.

QCA is also appropriate because a growing number of papers in the field of environmental studies adopt it as a method. These include studies comparing renewable energy target adoption (Bergero et al., 2021), assessments of climate policy ambitions (Tobin, 2017), early-stage experiments for radical climate interventions (Low et al., 2022), sub-national (German) success conditions of energy communities (Martens, 2022) or leadership in energy policy-planning (Crawford, 2012). Albeit being manifold, these studies tend to focus on relationships of sufficiency. Our focus, conversely, is explicitly focused on the conditions or combinations thereof that are necessary, because these are crucial ingredients enabling scaling.

3.2. Data collection and calibration

This study's raw data comes from a survey conducted in 2021, which contained 37 (7-point Likert scale) statements corresponding to the 23 conditions identified by Petrovics et al., (2022a, 2022b) (see Table 2). Each of the statements in the survey was followed by an open-ended question, providing respondents the opportunity to offer further qualitative information.

Due to the explorative nature of our study during the data collection process, we followed a non-probability sampling approach. In selecting our cases, we considered the following. We looked for prominent examples of energy communities in diverse jurisdictions, most of which are expected to transpose the EU's definitions of energy communities. These definitions stem from directives targeting the formalization of energy communities throughout the European Union (Renewable Energy Directive 2018/2001 and Internal Electricity Market Directive 2019/944). The requirement for member states to transpose these directives has created a fertile ground for identifying empirical examples across the EU of successful initiatives. As such, we aimed to balance the diversity of empirical examples with the umbrella catchment of a broader institutional setting – i.e. the European Union with one case in Turkey that replicated Belgian experiences. Despite a difference in technology, size and location we consider the growth and replication of experiences the focus of our study and the included cases. As such, through the QCA we aim to explore the necessary ingredients of scaling across successful initiatives.

We approached 200+ energy communities and 50+ gatekeepers (academics working in the field, umbrella organizations, etc.), which resulted in 30 responses from representatives of communities. Two of these have been excluded due to incomplete survey responses resulting in a total pool of 28 cases. As mentioned, the cases included in our analysis utilize diverse technologies and differ in size and location however are embedded with-in the EU's framing of energy communities. For a high-level overview of the cases see Table 3; for a detailed one, see Methodological Appendix 1 (section 1.2).

To conduct an analysis of necessity using QCA, raw data needs to be *calibrated* (see Oana et al., 2021). This means that a case can have full membership (=1), full non-membership (=0), and partial membership (<0.5<) in a set. Considering the conditions follow Likert-scale responses, these can be considered 'pre-calibrated' (i.e., the responses are already comparable). Therefore, membership in the various conditions is calibrated as 6.5 <fully in, 4.0 cross-over point and <1.5 fully out. Certain data points were skewed, which we have accounted for in the Methodological Appendix 1 (sections 3.2 and 4.2).

The outcome (high degree of scaling) is measured by assessing three separate factors: change in technical capacity, change in membership, and replication of experiences. Change in technical capacity is measured by comparing the degree of change for production in MW and for storage in Ah compared to the base year (founding of the community). Similarly, change of membership is measured by the growth rate of membership compared to the base year. These factors have been compiled in a composite index for comparability and more straightforward calibration. This was done by scoring the degree to which scaling took place in terms of a.) growth in technical capacity, b.) growth in membership and c.) replication of experiences. These scores were in effect weighed as Scaling Outcome = 0.2 x A + 0.4 x B + 0.4 x C. These weights were chosen to reflect the fact that energy communities not only carry the opportunity to enhance the process of deploying renewables but also carry a potential to democratize energy grids. Hence, the conscious choice was made to weigh change in membership and replication more heavily. This is also based on the assumption that expansion in membership as well as the replication of activities will implicitly carry a change in technical capacity.

To validate the responses past the survey we also utilized further methods and tools to enhance the quality of our data. Upstream this includes literature reviews for validating the examined conditions, the aforementioned non-probability sampling approach, correction of skewedness of certain data points as well as qualitative interviews with energy community practictioners and representatives of some of the

Table 3
Overview of Cases.

Case	Country	Date of Founding
LEC Steyr	Austria	2020
Ecopower	Belgium	1991
Mega Watt Puur	Belgium	2019
Noordlicht	Belgium	2019
Novi Otok Korčula Coop	Croatia	2015
DWATTS	France	2016
Plaine Énergie Citoyenne	France	2018
SCIC Midi Quercy Energies Citoyennes	France	2017
PowerZone	Germany	2018
Hyperion Energy Community	Greece	2020
Sifnos Energy Community	Greece	2013
Aran Islands Energy Coop	Ireland	2012
Villanovaforru Energy Community	Italy	2021
Coopérnico	Portugal	2013
GoiEner Coop	Spain	2012
Monachil's River Energy Community	Spain	2020
Som Energia	Spain	2010
Viure de l'aire	Spain	2009
Röstånga energikooperativ ekonomisk förening	Sweden	2000
Blijstroom	The Netherlands	2012
Duurzaam Assen Energy Coop	The Netherlands	2016
Ecostroom	The Netherlands	2014
Energiecoöperatie Zuiderlicht	The Netherlands	2013
Reduzum Coop	The Netherlands	1994
Toer	The Netherlands	2019
Vereniging Aardehuis Oost Nederland	The Netherlands	2011
Troya Renewable Energy Cooperative	Turkey	2017
Egni Coop	United Kingdom	2013

cases. These interviews have explored specific experiences of cases and overall trends in the European energy community field. Downstream we work with case illustration as well as a detailed discussion of the necessary conditions to enhance the theoretical and practical validity of our findings, as is outlined in the discussion section. To this extent, these approaches allow for the triangulation of the survey data and a better grounding of the results in empirical reality.

3.3. Analysis of necessity

To conduct the analysis of necessity using QCA, we place the 23 conditions identified by Petrovics et al., (2022a, 2022b) into three categories based on what happens within an initiative, between initiatives, and in the contexts (see Table 2). This allowed us to pragmatically approach the vast qualitative differences across the conditions examined. The three categories allow for presorting the conditions and to identify the necessary (combinations of) conditions within each of them. We utilize two R packages for our analysis from Dusa (2019) and Oana and Schneider (2018) and have conducted our analysis in the 2022.07.2 Build 576 version of RStudio. We utilize a consistency level of 0.9, which is common for analyses of necessity (Dusa, 2019). This measure indicates the degree of necessity of a condition. We furthermore report on coverage necessity and relevance of necessity, which allows to measure the triviality of conditions past their necessity. For more information on this process and the detailed results per model, see the Methodological Appendix 1 (sections 1.3, 2, 3, and 4).

The necessary conditions resulting from these models can take two forms: single necessary conditions and SUIN conditions; the latter are conditions that are "a sufficient but unnecessary part of a factor that is insufficient but necessary for an outcome" (Mahoney, 2008, p. 419). To establish if empirically identified SUIN conditions are also theoretically valid, the researcher needs to examine if said conditions form a higher-order concept (Ibid.). Such a higher-order concept can be treated as a necessary condition if they do. Based on this process we identified 4 necessary conditions and 4 SUIN conditions, which are also detailed below.

4. Results: identifying necessary conditions to scaling

This section outlines the key results of the three analyses of necessity. To summarize, we identified eight different necessary conditions to scaling, including several necessary SUIN conditions. A detailed overview of the resulting conditions of scaling marked with condition number (C#) is outlined in Fig. 1 below.

4.1. Descriptive results of analysis of necessity

Four of the conditions set forward by Petrovics et al., (2022a, 2022b) are necessary for scaling, which include formalized organization, leadership roles within an initiative, initiatives interacting externally and initiatives learning from each other. The results supporting these findings are outlined in Table 4 below.

Single necessary conditions only resulted from models # 1 and # 2. The four necessary conditions all reflect a high degree of consistency (with a Cons.Nes threshold of >0.9) and have relatively high coverage scores (with a Cov.Nec threshold of >0.7). The varying degrees of Relevancy of Necessity (RoN) can be verified through plotting the results for which more supporting evidence is provided in Methodological Appendix 1 (sections 2.2, 3.2, and 4.2).

Based on our analysis four higher order (SUIN) conditions also emerged, which are similarly necessary. These include the presence of bonding capital, the presence of bridging capital, openness to novelty, and the continuity of support structures. The results supporting these findings are outlined in Table 5.

Each of the three models resulted in SUIN conditions, with model #3 producing two such conditions. The high inclusion scores (inclN > 0.9) and relatively high coverage scores (covN > 0.7) suggest that following theoretical validation the resulting higher order concepts can be considered necessary for the outcome. For more details on how these concepts were reached, please see Methodological Appendix 1 (sections 2.2.1, 3.2.1, and 4.2.1).

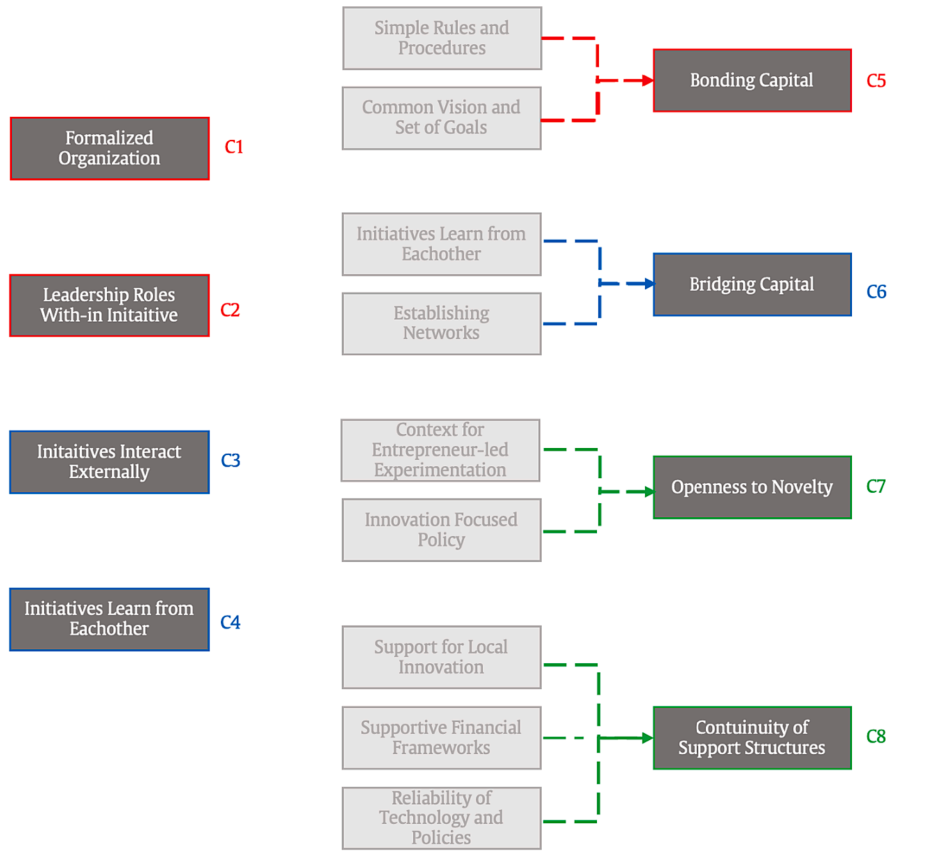

Fig. 1. Results of three analyses of necessity with Condition # (red = analysis 1, blue = analysis 2, green = analysis 3).

Table 4
Results of Analyses of Necessity.

Model #	Condition	Cons. Nec	Cov. Nec	RoN
1	Formalized Organization (C1)	0.944	0.742	0.354
1	Leadership roles with-in initiative (C2)	0.901	0.787	0.559
2	Initiatives interact externally (C3)	0.933	0.772	0.471
2	Initiatives learn from each other (C4)	0.962	0.758	0.374

Table 5
SUIN Conditions and Higher-order Necessary Conditions.

Model #	Conditions	Higher order concept	inclN	RoN	covN
1	Simple Rules and Procedures **AND** Common Vision and Set of Goals	Bonding Capital (C5)	0.903	0.512	0.771
2	Initiatives learn from Each other **AND** Establishing Networks	Bridging Capital (C6)	0.908	0.505	0.771
3	Context for Entrepreneur-led Experimentation **AND** Innovation Focused Policy	Openness to Novelty (C7)	0.915	0.552	0.792
3	Support for Local Innovation **AND** Supportive Financial Frameworks **AND** Reliability of Technology and Policies	Continuity of Support Structures (C8)	0.903	0.501	0.767

4.2. *Empirical examples of necessary conditions*

The four necessary conditions and four higher-order (SUIN) conditions that emerged from the empirical analyses are discussed in more detail below, whereby we illustrate them with examples from our cases.

First, our cases are mostly formalized (C1) by inscribing the community as a cooperative at the relevant business or commercial authority; in a handful of cases, there is special legal standing created for energy communities as legal entities (see, for example, the Greek Law on Energy Communities (4513/2018). Next to this, communities such as Toer (Tzum) attach a foundation to their community with broader goals of driving sustainable development at the local-scale and ensuring any surplus value is captured in the immediate surroundings of the community. In a handful of cases the communities are founded as a company (e.g. PowerZone). Interestingly, formalization was not found to have a strong relationship with the scalability of these cases implying that the one-actor-one-vote principal of cooperatives has a stronger influence on scalability. The emergence of this type of energy community may signify a *landscape* resulting from the revised Renewable Energy Directive 2018/2001 and revised Internal Electricity Market Directive 2019/944 of the EU, which set out for the active involvement of municipalities and private sector actors in *renewable energy communities* and *citizen energy communities* respectively.

Second, strong leadership roles within the cases (C2) manifested primarily in the citizen-led cooperatives. In the municipal-led case of the Villanovaforru Renewable Energy Community and the private company-initiated PowerZone this condition is less present. It can be extrapolated from these cases that their alternative institutional logic (i.e. non-cooperative approaches) can help bypass the necessity of strong leadership. A notable example among the cooperative cases is Zuiderlicht in the Netherlands, which not only has committed leadership in the community as a whole but also invests resources in training further project leaders to set up and run specific installations and further initiatives.

Third, the cases interact externally (C3) primarily by engaging with umbrella organizations such as Energie Samen in The Netherlands, the Swedish Renewable Energies Oranization (SERO) in Sweden, or REScoop, the European Federation of Energy Communities. Next to this, they maintain regular contact with other energy communities and with municipal-scale public authorities and energy utilities. Such interactions have helped communities observe common challenges, identify enabling conditions and share experiences in open fora. Next to this, it has also allowed our cases to identify relevant skills and knowledge from further initiatives and individuals.

Fourth, the cases have learned from other initiatives (C4) primarily via REScoop. This federation has assisted a number of newcomers to the field with relevant knowledge and connected various initiatives with each other. The means are diverse – ranging from coaching programs on the International Cooperative Alliance's cooperative principles, regular meetings with other cooperatives, recruiting experienced individuals as board members, and running joint projects with sister organizations (energy communities).

As mentioned, four higher-order SUIN conditions also emerged from our analysis. Here, we discuss the logic of reaching these conditions and give some empirical examples. First, simple rules and procedures within a community alongside a shared vision and goals point to the higher-order concept of *bonding capital* (Putnam, 2000) (C5). Putnam (Ibid.) describes this type of social capital as one that allows for communities to 'get by' through building strong ties in a horizontal manner resulting in thick trust. This links to the inward looking focus on how actors utilize their social capital to engage with each other.

Generally among the cases, it is during the founding stages that the long-term goals and the rules for the functioning of the community are set. At this stage it is commonplace for members to participate in iterative and participatory processes, which result in statutes and founding documents. At a later stage of the communities' lifespan members generally contribute to short-term goal setting and the overall processes of the community are generally discussed face-to-face. It is also commonplace for substantial issues to be raised at General Assembly meetings, which tend to be enshrined in broader decision-making processes.

Second, learning between communities happens directly between communities or with the help of intermediaries (Warbroek et al., 2018), suggesting the necessity of *bridging capital* (Putnam, 2000) (C6). This type of social capital mirrors the capacity of communities (and their overall) movement to build on connections they make externally with other essential actors. As mentioned, key actors in these processes are national umbrella organizations and REScoop in particular, which can assist communities in developing and utilizing their bridging capital.

Third, a context for entrepreneur-led experimentation and innovation-focused policy suggests the necessity of *openness to novelty* (C7) where experimentation is embraced by communities themselves and where a supportive institutional context, which allows communities to do so is created by decision makers. Amongst the cases the following examples are present. In the ZEZ Coop in Croatia, support from local authorities helped citizens get involved in projects that install solar PV in their households and assisted them in applying for government subsidies to install the systems. This model has also been replicated in several different cities in Croatia. In the Basque country, the GoiEner Coop builds on individual ideas from all members as long as they are well elaborated and developed. This allows for all members to act as entrepreneurs. Finally, in Catalonia, in the Viure de L'aire initiative, their'cooperative's knowledge is complemented by collaborating with other engineering coops to implement technologies such as batteries within their projects. What underlines these activities is a general aptitude towards experimentation and innovation, which is accentuated by the space and opportunity to do so.

Finally, the condition of *continuity of support structures* (C8) entails support for local innovation, supportive financial frameworks and reliability of technology and policies. Next to general policies that focus on innovation, local-scale support is also needed. Among the cases, examples include the calling of EU funds through inter-municipal partnerships (Interwaas) in support of energy communities in Belgium, feed-in tariffs in a number of countries, as well as provincial-level subsidies for energy communities, as in the case of Friesland (The Netherlands).

4.3. Towards sufficient combinations of conditions

Our main focus with QCA has been on identifying the (combinations of) necessary conditions for scaling. To take a first step to also identify which (combinations of) conditions are sufficient for the outcome, a QCA analysis of sufficiency is required. Given the high number of conditions, a full-fledged analysis of sufficiency using QCA is unlikely to yield meaningful results. Instead, we use QCA's truth table to summarize the data, the latter being one of the uses of QCA (Berg-Schlosser et al., 2009). A truth table includes all possible combinations of conditions (k), with the number of rows in the truth table being 2^k. We produced a truth table of necessary conditions (individual or SUIN ones).

Table 6 presents the truth table rows, i.e., combinations of necessary conditions, that represent one or more cases. The scores '1' indicate the presence of given condition, whilst '0′ indicate the absence. Each row of a truth table "linked to the outcome can be interpreted as a statement of *sufficiency*" (Schneider and Wagemann, 2012: 334, emphasis in original, see also Ragin, 2008). The measure of fit "incl" (inclusion, also known as consistency) indicates the degree to which cases that share a specific combination of conditions also display the outcome. We use a conventional inclusion cutoff of 0.8. PRI, also displayed in Table 6, which stands for Proportional Reduction in Inconsistency and is a measure to identify simultaneous subset relations—the, problematic, situation where the same combination of conditions is sufficient for both the presence of the outcome as well as its absence (see e.g., Mello, 2021: ch. 6).

For the rows with the presence of the outcome (#1 through #9) there are no major gaps between the PRI scores and the inclusion scores, which is suitable for a meaningful analysis of sufficiency. Similarly, in the case of the outcome, '1′ means the complete presence of the given outcome whilst '0′ entails the complete presence of the negation of the outcome for a sufficiency relationship. The truth table thus presents the varied combinations of conditions — in this case, of the conditions identified as necessary — that are sufficient for the outcome, without necessarily involving the presence of all necessary conditions. A number of points stand out in the truth table in Table 6. Firstly, a high number of cases (n = 12) display the same combination of (necessary) conditions (in row #9), which jointly are sufficient for the outcome: *the presence of the conditions* Formalized Organization AND Leadership Roles With-in Initiative AND Initiatives Interact Externally AND Initiatives Learn from Eachother AND Bonding Capital AND Bridging Capital AND *the absence of the conditions* Openness to Novelty AND of Continuity of Support Structures. Note that this descriptive finding is intended only as a first step towards a full-fledged analysis of sufficiency. For one, it likey includes conditions that are redundant, i.e., not core ingredients of a sufficient path to the outcome. Moreover, it is a complex finding, including a high number of conditions as well as the presence of SUIN conditions.

Secondly, row #5 is the configuration in which all individually necessary and SUIN conditions are present. As is plausible theoretically, most cases with this configuration indeed have the outcome (n = 4). One case, conversely, Stichting TOER, has not scaled. This indicates that there is a bottleneck that hampers producing the outcome, something that is interesting to explore further in in-depth case analysis. However, this so-called deviant consistency in kind does no invalidate the findings regarding necessity.

Finally, row #11 suggests that there is one case where all conditions

Table 6
Truth table.

Row #	Formalized Organization	Leadership Roles With-in Initiative	Initiatives Interact Externally	Initiatives Learn from Eachother	Bonding Capital	Bridging Capital	Openness to Novelty	Continuity of Support Structures	Outcome (Scaling)	n	incl	PRI	Cases
1	1	1	1	1	0	1	1	0	1	2	0.926	0.888	Energiecoöperatie Zuiderlicht, Blijstroom
2	1	1	1	1	1	1	1	0	1	1	0.909	0.849	Egni Coop
3	1	1	1	1	1	0	1	0	1	1	0.900	0.795	Ecostroom
4	1	1	1	1	0	1	0	0	1	2	0.872	0.799	Som Energia, Duurzaam Assen Energy Coop
5	1	1	1	1	1	1	1	1	1	5	0.869	0.817	Mega Watt Puur, Toer, LEC Steyr, DWATTS, Plain Énergie Citoyenne
6	1	1	1	1	1	1	0	1	1	1	0.858	0.795	Reduzum Coop
7	1	1	1	1	0	0	1	0	1	1	0.855	0.697	Novi Otok Korčula Coop
8	1	1	0	1	1	1	1	1	1	1	0.842	0.711	Villanovaforru
9	1	1	1	1	1	1	0	0	1	12	0.835	0.777	Viure de l'aire, Coopernico, Hyperion, Aran Islands Energy Coop, Sifnos Energy Community, Troya Renewable Energy Cooperative, SCIC Midi Quercy Energies Citoyennes, Noordlicht, GoiEner Coop, Röstanga, Ecopower, Monachil's River Energy Community
10	1	0	1	1	1	1	0	0	0	1	0.786	0.546	Vereniging Aardehuis Oost Nederland
11	0	0	0	0	0	0	0	0	0	1	0.638	0.309	Powerzone

are absent and as expected, given that these conditions are necessary indeed so is the outcome. This is the case of PowerZone. This community is particular in that it has been initiated with the absence of cooperative principles in place, serving as a neighbourhood pilot project from the company E.On. Being a pilot may underline why the community has not scaled and the fact that it is run by a company may explain the absence of the various conditions drawn from literature primarily examining cooperatives.

5. Discussion: towards actionable scaling mechanisms of local-scale initiatives

This section makes five key arguments regarding the empirical reality of necessery conditions of scaling energy communities and concludes as to what scaling mechanisms may be at the disposal of decision-makers.

First of all, PGT and the SNM approach highlight different aspects of the scaling of energy communities and empirical testing confirms the importance of some aspects contributed by each. The necessity of *openness to novelty* (C7) underpin the SNM approach's focus on protecting the *niche*. It becomes clear that a context that provides space for innovators to innovate is a must, and if specific initiatives have an internal driver behind this (i.e. strong leadership) chances for scaling are even higher. Here decision-makers could set out with policies that allow for training more leaders in the energy community space building on the existing experiences of initiatives (see the example of Zuiderlicht above).

Rules and rule setting are an important element in PGT. Nonetheless, it has been suggested that a critical examination is indeed needed to better understand the central needs of an efficient design of a polycentric climate governance system (Dorsch and Flachsland, 2017). For this reason, cross-fertilization from other types of thinking may be beneficial. The particular focus the SNM approach places on articulating expectations and visions to a certain extent, may fill this gap. Ensuring internal stakeholders are engaged and on the same page by ensuring they share expectations and that actionable guidance is available is key here.

Secondly, the two approaches overlap and completement each other in a number of ways. PGT puts great emphasis on the importance of overarching rules (Jordan et al., 2018). Our identification of the continuity of support structures (C8) as a necessary condition highlights a key point here. This condition shows that energy community practitioners can only operate in a regulatory setting where public support schemes enabling the financial viability of given initiative can be expected to stay in place for the coming decade or two. This means that overarching rules set out in a polycentric governance system may constitute *niche-external* dynamics complementing the *internal* ones in the language of the SNM approach (Schot and Geels, 2008).

Here the essential mechanism at play is that the local and the higher-order are connected through a set of interoperable but fit-to-purpose rules targeting specific actors at specific scales. This mechanism can be considered to be *regime* derived, where in plain language established actors such as municipalities, regional authorities or even national governments can target innovation with subsidy schemes, or regulate the rights of specific types of entities such as energy communities (if formalized) to connect to the grid (Wainer et al., 2022), to share energy behind the meter, to collectively self-consume power, or to access a feed-in tariff (Brown et al., 2019). In their responses to our survey, a number of the case study communities highlighted their struggle with changing regulatory and support *landscapes*, which do not guarantee the continuity of tools and the safety their initial investments depend on.

Furthermore, trust is seen to build faster if local-scale (self) organization is in place. This links with the conception that a polycentric governance system functions effectively if the various governing units have the capacity to mutually adjust to each other's activities (Jordan et al., 2018). By catering to strong leadership while building and maintaining social capital that allows the effective external interactions of initiatives, our cases suggest that energy communities can build the capacity needed as a movement overall to scale. This process links closely with establishing deep and broad social networks in the SNM approach, where the bonds initiatives build externally are conditioned on the capacity of actors to mobilize resources while also allowing for a multitude of stakeholders to voice their perspectives (Schot and Geels, 2008). This means that, on the one hand, initiatives individually do have a lot to gain from interacting with each other, while on the other hand, the amalgam of these interactions adds up to a different kind of whole, to put it in Elinor Ostrom's words a holon - or a system of systems (Ostrom, 2005).

Similarly, initiatives must interact externally (C3), highlighting a strong emphasis on networks. Considering both a well-functioning polycentric governance system as well as the effective management of *niches* is predicated on a network, it is important to unpack what initiatives themselves can do to leverage this concept well. It is not simply bridging capital as a capacity needed that is at play here; it is the interest of internal actors turning to the myriad of further initiatives past their own doorstep that allows for scaling. Ensuring activities are communicated to the outside world and that by this the engagement of key (*regime*) actors is safeguarded is a must for the movement of energy communities. Here any type of communication capacity support from decision-makers is a support mechanism.

Next to this, learning (C4) is a key condition for the scaling of energy communities. And so, the capacity of a system to enable individual initiatives to learn from each other is the key mechanism at play here. This links to the emphasis PGT and the SNM approach both place on learning. In the former, learning is a key underpinning of the capacity for individual governing units to mutually adjust (Baird et al., 2014; Blasch et al., 2021) while in the later it is the underpinning that allows a system to reflexively transition. Overall, these commonalities highlight that there is fruitful benefit in cross-fertilizing seemingly different theoretical literatures and by this examining the same empirical material from varying perspectives.

Thirdly, bonding (C5) and bridging capital (C6) are concepts that also appear in PGT (Hamilton and Lubell, 2019). From our examination what becomes apparent is that on the one hand bonding capital can inform the building of micro-scale institutions. This is a key underpinning both of what is needed to guard a *niche* from external market forces whilst also of the common's logic underpinning PGT (Ostrom, 2010). It can furthermore be argued that by creating the appropriate legal framing of a given initiative, bonding capital can be linked to the formalization of initiatives. This is a strong mechanism at the disposal of decision makers, which can further strengthen the bonding capital of initiatives.

Bridging capital on the other hand can particularly help in connecting local *niches* with global *niches* and by this help better ground the overall movement of initiatives – in our case the movement of energy communities. Decision makers – and in particular umbrella organizations and intermediaries – have a mechanism at their disposal by creating platforms for initiatives to connect, share experiences and most importantly learn from each other.

Fourth, what also becomes clear from PGT and SNM entry-points is that past the empirical proof of horizontal scaling – notable expansion of initiatives in technical capacity, membership and replication of experiences; the above conditions highlight the qualitative nature of vertical scaling. Considering vertical scaling involves institutional change (van Doren et al., 2018), *niche* initiatives can influence the regime's behavior as well as constellation. This in effect opens the opportunity for further advancement of the *niche*, be that through legal structures that allow the formalization of initiatives (C1), external interactions (with incumbents) (C3), learning from other initiatives (C4) resulting in higher order learning, or through ensuring that support structures enjoy a continuation (C8). It can very well be that this type of institutional effect further drives the horizontal scaling of community energy.

Table 7
Summary of Scaling Mechanisms of Energy Communities at the Disposal of Decision Makers.

Scaling Mechanism	Description
Equip individual citizens with leadership capacity	Considering know-how on leveraging the administrative *landscape* of setting up and running energy communities exists in successful communities, this knowledge should be dissipated. Set out with frameworks that allow for training more project and community leaders in the energy community space based on the experiences of existing initiatives.
Draft rules and allocate responsibilities fit-to-scale and fit-to-purpose	Ensure that rules are interoperable and fit-to-purpose targeting specific actors at specific scales (from local, through regional, to national). Consider what the needs of incumbent actors are (e.g. Distribution System Operators (DSOs)), whilst ensuring citizens have streamlined access to the resources needed for their community initiative to take off.
Build learning capacity	Enhance the capacity of a system to enable individual initiatives to learn from each other. This can be done by supporting their engagement with (existing) networks, which dissipate learnings.
Provide communication capacity support	Assist energy communities in reaching further citizens through communication support and assist energy communities in engaging *status quo* players, such as energy utilities and DSOs.
Formalize initiatives aimed at their functioning	Create a legal framing for energy communities, which can allow for their effective participation in energy governance. Ensure that their formalization allows them grid access, streamlined access to subsidies and tax breaks.
Create peer-to-peer learning platforms	Create platforms for initiatives to connect, share experiences and most importantly learn from each other in a peer-to-peer manner.
Build the capacity of umbrella organizations	Provide support for any type of regional, national or international initiative, which strengthens the connections between energy communities. These umbrella organizations are generally member or community funded, whilst their potential to scale impact through dissipating learnings is tremendous.
Create platforms and processes for communities to engage with incumbent actors	Create platforms where energy community practitioners can engage with *regime* actors such as transmission system operators (TSOs) or DSOs in particular, municipal decision makers or energy policy actors at the national level.

Finally, QCA has helped to understand what (combination of) conditions are necessary for a certain outcome. In the case of our analysis a high number of conditions resulted as necessary – meaning the scaling of energy communities may face a number of bottle necks. This means that these necessary conditions (C1-C8) form the baseline of what has to be in place to successfully scale energy communities but it is important to emphasize that this still is no guarantee for scaling to take place. This being said a future analysis of sufficiency may underline what conditions may lead to scaling without the necessity for all the encompassed conditions to be in place (Table 7).

As for the limitations of our analysis a number of points can be raised. Our cases span diverse contexts, with varying actors and technologies at play suggesting a relatively heterogenous pool of cases. However the breadth of our concepts should allow for the possibility of identifying the common denominator in scaling available to decision makers and energy community practitioners alike. Next to this, we have not in detail explored relationships of sufficiency and have solely focused on identifying those conditions necessary to scaling. Further analyses could illuminate the minimal combinations of (necessary) conditions sufficient to scaling. Furthermore, the above mechanisms primarily outline leverage points available to decision makers, whilst other actors may have further mechanisms at their disposal.

6. Conclusion

By studying the empirical reality of scaling in 28 energy communities our article explored what (combinations of) conditions are necessary for the much-anticipated broader impact of local initiatives. Whilst speculation on the effects of local initiatives on the broader efforts to govern renewable energies is rampant, systematic empirical studies of a larger number of cases have been few and far between. This article takes a step towards filling this important gap.

Assessing the amalgam actions these communities undertake through the lens of PGT and better understanding how this *niche* can best be strategically managed has allowed for a fruitful cross fertilization of diverse strands in the academic literature. The two bodies of literature study very similar subjects and in effect are a neat complementation of one another with potential to bridge debates happening in the field of governance studies (Jordan et al., 2018) and transition studies (Loorbach et al., 2020). Our theoretical contribution draws on this cross-fertilization by shedding light on the benefits of empirically examining local-scale action, better understanding the interactions and interrelations of individual initiatives and overall embedding the concept of community-based action in a global governance system.

We did so by conducting a Qualitative Comparative Analysis. This method has allowed us to focus on the necessary (combinations of) conditions to scaling whilst also examining 28 individual cases. This approach has allowed us to extend exploratory thinking on the governance of energy communities as *niches* into the realm of empirics. Further exploration would benefit this examination, particularly in exploring more detailed cases of successful energy communities.

Overall, our analysis forms an empirical contribution to transition studies and thinking on governance more broadly. Our empirical assessment of necessary (combinations of) conditions of scaling energy communities highlights the focal points those active in the energy community field as well as national and local policy makers may have at their disposal. Next to this, the specific mechanisms resulting from this analysis may form a strong basis for further policy development towards expanding the reach of both renewable energy technologies and their effective governance at the local-scale.

But what is needed for energy communities to scale? Our analysis resulted in 8 specific mechanisms, which are deeply implied in the scaling of energy communities. Several implications for those who are involved in the governance of local initiatives (ranging from the initiators to government actors and beyond) ensue. Our findings point to the importance of capacity support – in terms of leadership, learning, and communication capacity development, but also to the importance of the way in which initiatives are formalized and the manner in which legislation should be drafted fit to scale and purpose. Our findings also suggest the importance of the connections between communities, umbrella organizations and incumbent actors. Ultimately each of these mechanisms should allow for the overall number and size of energy communities to grow and should allow for initiatives to replicate their experiences. Next to this it should allow for innovation to happen within initiatives pointing to a type of formalization, which is not one dependent on one-size-fits-all legal structures; but one that is contextually embedded and creates a level-playing field for energy communities with safeguards from external market pressures to enhance their activities.

There is plenty of opportunity for further research here – in particular when it comes to the study of any type of common pool resource dilemma, which departs from the constraints of the local in its effect but may potentially be governed effectively through the blend of multiple localities across multiple scales. As some of the core assumptions taken in this paper are that there are certain mechanisms at play connecting local-scale initiatives with a global-scale impact it is important to zoom out and underline that there are observable changes undergoing the European Energy system with at least 2 million EU Citizens being involved in over 7000 energy communities (Smarten, 2022). Compared to the overall energy demand of the EU as well as the total number of citizens this may seem small, however from the perspective of *niche* institutionalization it is substantial.

Future research could further examine the rate of growth and the knowledge networks supporting these communities. Next to this, researchers could explore what cross-fertilization of literature may mean for the governing of other types of commons – be those knowledge commons, urban commons or environmental commons. Furthermore, sketching out the detailed working of the various conditions outlined in this article could carry potential. Finally, considering the growing heterogeneity of energy communities it would be relevant to better understand what conditions apply best to various institutional logics (state, market or community).

The coming period will act as a Litmus test to the diffusion of energy communities. Particularly in the case of the front runner - the EU, Member States have space to interpret how *renewable energy communities* and *citizen energy communities* may manifest in their jurisdictions. However, bearing the pressing nature of the climate crisis in mind, policy makers also have a responsibility here to consider what is the most effective approach. Hence transposition should be done with local contexts in mind. Existing regulatory frameworks governing electricity markets, support schemes available for the deployment of renewable energy technologies and overarching targets and goals for the share of renewable energy in national energy mixes should be considered in the process. Decision makers should reflect on how energy communities can best benefit their jurisdiction and what can be done to best incorporate the community-based ownership of renewable energy assets in their jurisdictions.

CRediT authorship contribution statement

Daniel Petrovics: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Visualization, Writing – original draft, Writing – review & editing. **Dave Huitema:** Conceptualization, Writing – original draft, Writing – review & editing. **Mendel Giezen:** Conceptualization, Writing – original draft, Writing – review & editing. **Barbara Vis:** Methodology, Validation, Formal analysis, Writing – review & editing.

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.

Data availability

Data will be made available on request.

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References

Aligica, P.D., 2013. Institutionalism and Polycentricity. The Ostroms and Beyond, In Institutional Diversity and Political Economy.
Aligica, P.D., Tarko, V., 2012. Polycentricity: From Polanyi to Ostrom, and Beyond. Governance 25 (2), 237–262. https://doi.org/10.1111/j.1468-0491.2011.01550.x.
Baird, J., Plummer, R., Haug, C., Huitema, D., 2014. Learning effects of interactive decision-making processes for climate change adaptation. Global Environmental Change 27 (1), 51–63. https://doi.org/10.1016/j.gloenvcha.2014.04.019.
Bauwens, T., Huybrechts, B., Dufays, F., 2020. Understanding the Diverse Scaling Strategies of Social Enterprises as Hybrid Organizations: The Case of Renewable Energy Cooperatives. Organization & Environment. 33 (2), 195–219. https://doi.org/10.1177/1086026619837126.
Bauwens, T., Vaskelainen, T., Frenken, K., 2022. Conceptualising institutional complexity in the upscaling of community enterprises: Lessons from renewable energy and carsharing. Environmental Innovation and Societal Transitions 42, 138–151. https://doi.org/10.1016/J.EIST.2021.12.007.
Bergero, C., Rich, M.J., Saikawa, E., 2021. All roads lead to Paris: The eight pathways to renewable energy target adoption. Energy Research & Social Science 80, 102215. https://doi.org/10.1016/J.ERSS.2021.102215.
Berg-Schlosser, D., De Meur, G., Rihoux, B., Ragin, C., 2009. Qualitative Comparative Analysis (QCA) as an Approach. In: Rihoux, B., Ragin, C. (Eds.), Configurational Comparative Methods. Qualitative Comparative Analysis (QCA) and Related Techniques. Sage, pp. 1–18.
Biesbroek, R., Candel, J.J.L., 2020. Mechanisms for policy (dis)integration: explaining food policy and climate change adaptation policy in the Netherlands. Policy Sciences 53 (1), 61–84. https://doi.org/10.1007/s11077-019-09354-2.
Blasch, J., van der Grijp, N.M., Petrovics, D., Palm, J., Bocken, N., Darby, S.J., Barnes, J., Hansen, P., Kamin, T., Golob, U., Andor, M., Sommer, S., Nicita, A., Musolino, M., Mlinarič, M., 2021. New clean energy communities in polycentric settings: Four avenues for future research. *Energy Research and Social*. Science 82 (August). https://doi.org/10.1016/j.erss.2021.102276.
Bol, D., Luppi, F., 2013. Confronting Theories Based on Necessary Relations: Making the Best of QCA Possibilities. Political Research Quarterly 66 (1), 205–210.
Brown, D., Hall, S., Davis, M.E., 2019. Prosumers in the post subsidy era: an exploration of new prosumer business models in the UK. Energy Policy 135 (August), 110984. https://doi.org/10.1016/j.enpol.2019.110984.
Crawford, S., 2012. What is the energy policy-planning network and who dominates it?: A network and QCA analysis of leading energy firms and organizations. Energy Policy 45, 430–439. https://doi.org/10.1016/J.ENPOL.2012.02.053.
Creamer, E., Eadson, W., van Veelen, B., Pinker, A., Tingey, M., Braunholtz-Speight, T., Markantoni, M., Foden, M., Lacey-Barnacle, M., 2018. Community energy: Entanglements of community, state, and private sector. Geography Compass 12 (7), 1–16. https://doi.org/10.1111/gec3.12378.
Dorsch, M.J., Flachsland, C., 2017. A Polycentric Approach to Global Climate Governance. Global Environmental Politics 17 (2), 45–64. https://doi.org/10.1162/GLEP_a_00400.
Dusa, A., 2019. QCA with R. Springer International Publishing, A Comprehensive Resource.
European Comission (EC), 2023. Energy Communities Repository - Energy Communities. Accessed from: https://energy-communities-repository.ec.europa.eu/energy-communities_en#benefits.
Ehnert F., N. Frantzeskaki, J. Barnes, S. Borgström, L. Gorissen, F. Kern, L. Strenchock, M. Egermann. (2018). The acceleration of urban sustainability transitions: a comparison of Brighton, Budapest, Dresden, Genk, and Stockholm. Sustainability 10:612. https://doi.org/https://doi.org/10.3390/su10030612.
Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. Research Policy 31 (8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8.
Geels, F.W., 2004. From Sectoral Systems of Innovation to Socio-Technical Systems Insights about Dynamics and Change from Sociology and Institutional Theory. 33, 897–920. https://doi.org/10.1016/j.respol.2004.01.015.
Geels, F.W., 2019. Socio-technical transitions to sustainability: a review of criticisms and elaborations of the Multi-Level Perspective. Current Opinion in Environmental Sustainability 39, 187–201. https://doi.org/10.1016/j.cosust.2019.06.009.
Geels, F.W., Schot, J., 2007. Typology of Sociotechnical Transition Pathways. 36 (November 2006), 399–417. https://doi.org/10.1016/j.respol.2007.01.003.
Goertz, G., Starr, H. (Eds.), 2003. Necessary Conditions: Theory, Methodology, and Applications. Rowman and Littlefield, New York.
Hamilton, M.L., Lubell, M., 2019. Climate change adaptation, social capital, and the performance of polycentric governance institutions. Climatic Change 152 (3), 307–326. https://doi.org/10.1007/s10584-019-02380-2.
Hargreaves, T., Hielscher, S., Seyfang, G., Smith, A., 2013. Grassroots innovations in community energy: The role of intermediaries in niche development. Global Environmental Change 23 (5), 868–880. https://doi.org/10.1016/j.gloenvcha.2013.02.008.
Jordan, A., Huitema, D., Schoenefeld, J., van Asselt, H., Forster, J., 2018. Governing Climate Change Polycentrically. Governing Climate Change 3–26. https://doi.org/10.1017/9781108284646.002.
Lam, D.P., Martín-López, B., Wiek, A., Bennett, E.M., Frantzeskaki, N., Horcea-Milcu, A. I., Lang, D.J., 2020. Scaling the impact of sustainability initiatives: a typology of amplification processes. Urban Transformations 2, 1–24.
Loorbach, D., Frantzeskaki, N., Avelino, F., 2017. Sustainability Transitions Research: Transforming Science and Practice for Societal Change. Annual Review of Environment and Resources 42 (1), 599–626. https://doi.org/10.1146/annurev-environ-102014-021340.
Loorbach, D., Wittmayer, J., Avelino, F., von Wirth, T., Frantzeskaki, N., 2020. Transformative innovation and translocal diffusion. Environmental Innovation and Societal Transitions January, 1–10. https://doi.org/10.1016/j.eist.2020.01.009.
Low, S., Baum, C.M., Sovacool, B.K., 2022. Taking it outside: Exploring social opposition to 21 early-stage experiments in radical climate interventions. Energy Research & Social Science 90, 102594. https://doi.org/10.1016/J.ERSS.2022.102594.
Mahoney, J. (2008). Toward a Unified Theory of Causality: *Http://Dx.Doi.Org/10.1177/0010414007313115*, *41*(4–5), 412–436. https://doi.org/10.1177/0010414007313115.
Martens, K., 2022. Investigating subnational success conditions to foster renewable energy community co-operatives. Energy Policy 162, 112796. https://doi.org/10.1016/J.ENPOL.2022.112796.
Mello, P.A., 2021. Qualitative comparative analysis : an introduction to research design and application. Georgetown University Press.
Nagendra, H., Ostrom, E., 2012. Polycentric governance of multifunctional forested landscapes. International Journal of the Commons 6 (2), 104–133. https://doi.org/10.18352/ijc.321.
Oana, I.-E., Schneider, C.Q., 2018. SetMethods: An Add-on R Package for Advanced QCA. The R Journal 10 (1), 507–533.
Oana, I.-E., Schneider, C.Q., Thomann, E., 2021. Qualitative Comparative Analysis Using R. Qualitative Comparative Analysis Using R. https://doi.org/10.1017/9781009006781.
Ostrom, E., 1999. Coping With Tragedies of the Commons. Annual Review of Political Science 2 (1), 493–535. https://doi.org/10.1146/annurev.polisci.2.1.493.
Ostrom, E. (2005). Understanding Institutional Diversity. In *Public Choice* (Vol. 132, Issues 3–4). https://doi.org/10.1007/s11127-007-9157-x.
Ostrom, E. (2010). Beyond markets and states: Polycentric governance of complex economic systems. *Nobel Lectures: Economic Sciences: 2006 - 2010*, *100*(June), 171–176. https://doi.org/10.1142/9789814635585_0004.
Patterson, J., Schulz, K., Vervoort, J., van der Hel, S., Widerberg, O., Adler, C., Hurlbert, M., Anderton, K., Sethi, M., Barau, A., 2017. Exploring the governance and politics of transformations towards sustainability. Environmental Innovation and Societal Transitions 24, 1–16. https://doi.org/10.1016/j.eist.2016.09.001.
Petrovics, D., Huitema, D., Jordan, A., 2022a. Polycentric energy governance: Under what conditions do energy communities scale? Environmental Policy and Governance. https://doi.org/10.1002/EET.1989.
Petrovics, D., Giezen, M., Huitema, D., 2022b. Towards a deeper understanding of up-scaling in socio-technical transitions: The case of energy communities. Energy Research & Social Science 97, 102860.
Putnam, R.D., 2000. Bowling Alone. Simon & Schuster http://bowlingalone.com/.
Ragin, C., 2008. Redesigning Social Inquiry: Fuzzy Sets and Beyond, Illustrated Edition. Fuzzy Sets and Beyond Illustrated Edition. University of Chicago Press, In Redesigning Social Inquiry.
REScoop,, 2023. The REScoop Model. Accessed from: https://www.rescoop.eu/the-rescoop-model.
Rohlfing, I., Schneider, C.Q., 2013. Improving Research on Necessary Conditions: Formalized Case Selection for Process Tracing after QCA. Political Research Quarterly 66 (1), 220–235.
Ruggiero, S., Martiskainen, M., Onkila, T., 2018. Understanding the scaling-up of community energy niches through strategic niche management theory : Insights from Finland. Journal of Cleaner Production 170, 581–590. https://doi.org/10.1016/j.jclepro.2017.09.144.
Savini, F., & Giezen, M. (2020). Responsibility as a field: The circular economy of water, waste, and energy. *Environment and Planning C: Politics and Space*. https://doi.org/10.1177/2399654420907622.
Schneider, C.Q., 2019a. Two-step QCA revisited: the necessity of context conditions. Quality & Quantity 53 (3), 1109–1126. https://doi.org/10.1007/s11135-018-0805-7.
Schneider, C.Q., 2019b. Two-step QCA revisited: the necessity of context conditions. Quality & Quantity 53, 1109–1126.
Schneider, C.Q., Wagemann, C., 2012. Set-Theoretic Methods for the Social Sciences. Cambridge University Press. https://doi.org/10.1017/CBO9781139004244.
Schot, J., Geels, F.W., 2008. Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy. Technology Analysis and

Strategic Management 20 (5), 537–554. https://doi.org/10.1080/09537320802292651.
Seyfang, G., Haxeltine, A., 2012. Growing grassroots innovations: Exploring the role of community-based initiatives in governing sustainable energy transitions. Environment and Planning c: Government and Policy 30 (3), 381–400. https://doi.org/10.1068/c10222.
SmartEn,, 2022. Energy Communities to Increase Local System Efficiency. Accessed from: https://smarten.eu/wp-content/uploads/2022/02/ENERGY_COMMUNITIES_to_increase_local_system_efficiency_02-2022_ONLINE-final.pdf.
Smith, A., Hargreaves, T., Hielscher, S., Martiskainen, M., Seyfang, G., 2016. Making the most of community energies: Three perspectives on grassroots innovation. Environment and Planning A 48 (2), 407–432. https://doi.org/10.1177/0308518X15597908.
Smith, A., Raven, R., 2012. What is protective space? Reconsidering niches in transitions to sustainability. Research Policy 41, 1025–1036.
Sondeijker, S., Geurts, J., Rotmans, J., Tukker, A., 2006. Imagining sustainability: The added value of transition scenarios in transition management. Foresight 8 (5), 15–30. https://doi.org/10.1108/14636680610703063.
Tobin, P., 2017. Leaders and Laggards: Climate Policy Ambition in Developed States. Global Environmental Politics 17 (4), 28–47. https://doi.org/10.1162/GLEP_a_00433.
van Doren, D., Driessen, P.P.J., Runhaar, H., Giezen, M., 2018. Scaling-up low-carbon urban initiatives: Towards a better understanding. Urban Studies 55 (1), 175–194. https://doi.org/10.1177/0042098016640456.
Vis, B., Dul, J., 2018. Analyzing Relationships of Necessity Not Just in Kind But Also in Degree: Complementing FsQCA With NCA. Sociological Methods & Research 47 (4), 872–899.
Wainer, A., Petrovics, D., van der Grijp, N., 2022. The grid access of energy communities a comparison of power grid governance in France and Germany. Energy Policy 170. https://doi.org/10.1016/j.enpol.2022.113159.
Walker, G., Devine-Wright, P., 2008. Community renewable energy: What should it mean? Energy Policy 36 (2), 497–500. https://doi.org/10.1016/j.enpol.2007.10.019.
Warbroek, B., Hoppe, T., Coenen, F., Bressers, H., 2018. The role of intermediaries in supporting local low-carbon energy initiatives. Sustainability (switzerland) 10 (7), 1–28. https://doi.org/10.3390/su10072450.