Entrepreneurial Business and Economics Review

2025, Vol. 13, No. 1

10.15678/EBER.2025.130106

Sustainable industrial transformation through entrepreneurial ecosystem governance: The case of Polish energy clusters

Marta Gancarczyk, Damian Tomczyk, Jacek Gancarczyk

A B S T R A C T

Objective: The article aims to expand the concept of regional industrial transformation to sustainable industrial transformation (SIT) and explain the role of ecosystemic governance in SIT on conceptual and empirical grounds based on Polish local energy clusters.

Research Design & Methods: We surveyed energy cluster initiatives in Poland, which we supplemented with a secondary data analysis and semi-structured interviews with the clusters' administration. The survey raised a final sample of 43 observations of active energy cluster initiatives in Poland. The analytical technique was qualitative comparative analysis, an approach between qualitative and quantitative data treatment.

Findings: We identified governance characteristics associated with the different levels of sustainable energy industrial transformation (SEIT). We revealed two governance patterns conducive to high-transformative energy clusters and two patterns of low-transformative cluster initiatives.

Implications & Recommendations: We provide empirical evidence of SEIT on an under-researched local level and identify the ecosystemic governance types favourable for and impeding this industrial transformation, with conclusions and recommendations relevant to economic policy and future research.

Contribution & Value Added: This research contributes by expanding the conceptual framework of regional industrial transformation to SIT based on socioeconomic governance, with the adoption of co-evolutionary and entrepreneurial ecosystem approaches. Moreover, it corroborates and advances the concept of SIT on the empirical ground of Polish local energy clusters.

Article type:	research article
Keywords:	sustainable industrial transformation; entrepreneurial ecosystem; governance; cluster initiative; energy cluster
JEL codes:	025, P28, R11

Received: 9 August 2024 Revised: 15 November 2024 Accepted: 2 December 2024

Suggested citation:

Gancarczyk, M., Tomczyk, D., & Gancarczyk, J. (2025). Sustainable industrial transformation through entrepreneurial ecosystem governance: The case of Polish energy clusters. *Entrepreneurial Business and Economics Review,* 13(1), 95-118. https://doi.org/10.15678/EBER.2025.130106

INTRODUCTION

Environmental and climate challenges demand industrial transformation, that is, the change in industrial structure and related public policies in the multiscalar context of international, national, regional, and local environments (Ashford *et al.*, 2007; Chembessi *et al.,* 2024; Coenen & Truffer, 2012; Schwabe, 2024). We addressed three research and policy gaps in studies of these transformative processes. Firstly, among the referred multiscalar territorial levels of research and policy, the local context remains under-explored due to the predominant search for the sustainability-oriented consensus among the EU, regional, and national authorities and societies (Chembessi *et al*., 2024; Schwabe, 2024; Szewranski *et al.,* 2019). However, these efforts should be complemented by a build-up of the local sustainability-oriented microstructures of clusters or renewable energy communities (Deutz *et al.*, 2024; Loorbach & Rotmans, 2006; Lowitzsch *et al.*, 2020). At the local level, through direct stakeholder interaction, such as business, local governments, and academia, these social and economic clusters or communities can be advanced to entrepreneurial ecosystems for industrial transformation toward renewable energy sources (Jasiński *et al.,* 2021; Micek *et al.*, 2021; Mucha-Kuś *et al.*, 2021; Surwillo, 2022). Secondly, industrial transformation to renewable energy should inevitably reconcile economic and social responsibility goals for the safety of communities and environmental well-being (Andersen *et al.*, 2020; Ashford *et al*., 2007; Coenen & Truffer, 2012; Loorbach & Rotmans, 2006). This calls for an advancement of the conceptual lens towards sustainable industrial transformation (SIT) that would integrate economic efficiency with social and environmental responsibility. The achievement of sustainable energy industrial transformation (SEIT) requires adequate socio-economic governance, as sets of institutions (rules, norms, behaviour patterns) that affect the efficiency of a particular system, such as the ecosystem of an energy cluster (Colombelli *et al.*, 2019; Colombo *et al.,* 2019; Lowitzsch *et al*., 2020). Although existing research points to technical and legal governance for the energy transition, socioeconomic governance in this area remains under-researched (Dragan, 2020; Mucha-Kuś *et al*., 2021; Surwillo, 2022; Wiseman, 2023). Thirdly, industrial transformation represents a coevolutionary and context-dependent process that calls for empirical evidence on its pathways and development stages in different territories (Gong & Hassink, 2019, 2020; Smith *et al.*, 2004). This evidence is still scarce, but we should consider it conducive to further comparative generalisations and place-based policies.

Against these three research gaps, we aimed to expand the concept of regional industrial transformation to sustainable industrial transformation and explain the role of ecosystemic governance in SIT on conceptual and empirical grounds based on Polish local energy clusters. Our theoretical framework drew on the coevolutionary approach to regional industrial transformation (Gancarczyk *et al.,* 2024; Gancarczyk *et al*., 2023; Hassink *et al.*, 2019; Oinas *et al*., 2018) and the concept of entrepreneurial ecosystem governance (Colombo *et al*., 2019; Gancarczyk & Konopa, 2021a; Spigel, 2017, 2022).

We surveyed energy cluster initiatives in Poland, which we supplemented with a secondary data analysis and semi-structured interviews with the administration of the energy clusters. The final sample of clusters included 43 observations, representing 60% of active energy cluster initiatives in Poland. The analytical technique we employed was qualitative comparative analysis (QCA). It addresses the specificity of a small number of observations and an extensive set of variables that describe the governance of the entrepreneurial ecosystem. It enabled a configurational approach and the identification of governance characteristics associated with the different levels of SIT advancement. In particular, we identified two governance patterns conducive to high-transformative energy clusters and two patterns of low-transformative cluster initiatives.

Our article provides contributions relevant to research and policy. The first contribution consists of expanding the conceptual framework of regional industrial transformation to SIT based on socioeconomic governance, with the adoption of co-evolutionary and entrepreneurial ecosystem approaches (Asheim, 2019; Colombo *et al*., 2019; Hassink *et al*., 2019; Oinas *et al*., 2018). Secondly, the article corroborates and advances the concept of SIT on the empirical ground of Polish local energy clusters (Chembessi *et al*., 2024; Schwabe, 2024). Thirdly, we provide empirical evidence of SEIT on an under-researched local level and identify the ecosystemic governance types conducive for and impeding this industrial transformation, with conclusions and recommendations relevant to economic policy (Chembessi *et al*., 2024; Coenen & Truffer, 2012; Loorbach & Rotmans, 2006; Schwabe, 2024; Smith *et al*., 2004).

In the following sections, we will provide the conceptual background of energy clusters in Poland and the governance of energy entrepreneurial ecosystems, as well as a research framework to guide empirical analysis. Then, we will report the methodological approach and the findings. We will follow it with a discussion of the results and contributions.

LITERATURE REVIEW AND RESEARCH QUESTIONS DEVELOPMENT

Energy Clusters in Poland: Overview of Policies and Development

European Commission (2021) considers energy clusters crucial for energy security and effective energy transition of EU member states toward a zero-emission economy. The Polish Strategy for Responsible Development (Ministry of Development, 2017) also acknowledges this goal. As a measure to implement the transition to a low-carbon economy, the Just Transition Fund was established under the EU cohesion policy for 2021-2027 (European Commission, 2020). Furthermore, the resolution of the General Assembly of the United Nations (UN) on 25 September 2015 (UN, 2015) emphasises that clusters are tools for sustainable development policies, such as reducing energy poverty, improving access to clean energy and education, and increasing innovation based on collaboration with research entities (UN, 2016).

Polish legislation defined energy clusters in 2016 with the amendments of the *Act of 20 February 2015 on Renewable Energy Sources*, which determined the substantive, legal, and spatial scope of these initiatives. After the latest amendment to this law, active from 1 January 2024, an energy cluster is defined as a cooperation agreement in the area of a generation, storage, demand balancing, distribution, or sale of electricity or fuels or heat to provide economic, social, or environmental benefits to the parties or to increase the flexibility of the electricity system, whereby the parties in this agreement include at least one territorial government unit or a capital company established by territorial government or a capital company which owns more than 50% of the share capital or stocks or shares of a capital company established by a territorial government. Energy cluster initiatives are often based on public-private partnerships and primarily target individual consumer needs (Mataczyńska & Kucharska, 2020).

Public entities supporting the development of clusters in Poland include the ministries of energy, economy, development, science, and higher education, the Polish Agency for Enterprise Development, and the Industrial Development Agency (Kraska, 2018). Moreover, the Ministry of Energy and the Energy Regulatory Office govern the establishment, operation and licensing of cluster initiatives (KAPE, 2017; Tauron Polska Energia, 2024). Regarding cluster financing, European Union funds dominate, supplemented by national funding, as reflected in national and regional operational programs (Kraska, 2018). Energy clusters can also apply for financing from the Just Transition Fund under the Cohesion Policy 2021-2027. Other sources include the income of the clusters from operations, membership fees, and own funds (KAPE, 2017). Moreover, energy cluster initiatives can benefit from financial relief upon their registration by the Energy Regulatory Office (Energy Regulatory Office, 2024).

The place-based approach to industrial transformation, including the turn of renewable energy, demands policy and research approaches in various transition contexts, such as Central and Eastern European economies (Coenen & Truffer, 2012; Li *et al.*, 2020; Liu, 2020; Luken & Castellanos-Silveria, 2011; Smith *et al.*, 2004). Many of these economies, including Poland, feature energy-intensive industries that have a harmful effect on the environment (Campos-Romero *et al.*, 2024). Their policies oriented toward local energy clusters are at the initial stages in terms of ecosystemic governance structures and industrial technological transitions (Dragan, 2020; Elzen & Wieczorek, 2005; Grigore & Dragan, 2020; Mirowski & Kubica, 2016).

Poland has an energy-intensive industry that uses predominantly traditional sources of electricity and heating systems (Dragan, 2020; Manowska *et al.*, 2017; Mirowski & Kubica, 2016; Mucha-Kuś *et al*., 2021; Sołtysik & Kozakiewicz, 2018). This increases the perception of high transition costs and requires not only legal and technical but also socioeconomic governance, which is the focus of this study (Mucha-Kuś *et al*., 2021; Sołtysik & Kozakiewicz, 2018; Szewranski *et al*., 2019; Uddin & Taplin, 2015). Consequently, energy cluster initiatives and communities are in the nascent stage, with a predominance of community agreements and contracts rather than actively operating ecosystems (Jasiński *et al*., 2021; Surwillo, 2022). Existing research emphasises weak organizational forms of energy clusters and the impediments to their growth, including limitations of the energy infrastructure, unproven business models, instability of the legal system, and limited public trust (Dragan, 2020; Micek *et al*., 2021; Surwillo, 2022; Wawrzyniak *et al.*, 2021). The strategic document of *Polish energy policy until 2040* reported 66 entities in the first half of 2020, compared to the declared 300 units by 2030 (Ministry of Climate and Environment, 2021). Therefore, we can treat the Polish energy ecosystems as early-stage phenomena and use the lens of evolutionary entrepreneurial ecosystem governance to theorise about their characteristics conducive to energy-focused SIT.

Sustainable Industrial Transformation and Energy Cluster Ecosystems at the Local Level

The territorial industrial transformation is a change in the territorial industrial structure (Hassink, 2010; Hassink *et al*., 2019; Isaksen *et al.*, 2019; Martin & Sunley, 2015). This change can be oriented towards industrial path renewal or new path creation or exposed to lock-in when obsolete and environmentharming standards and products predominate (Asheim, 2019; Grillitsch, 2015; Hassink *et al*., 2019). Considering the sustainability imperative, we conceptually expand the idea of industrial transformation into sustainable industrial transformation (SIT) as a change in the territory's industrial structure that not only meets the economic goals but reconciles economic efficiency with environmental and social goals (Ashford *et al*., 2007; Loorbach & Rotmans, 2006; Smith *et al*., 2004).

In turn, we may treat the sustainable energy industrial transformation as a case of sustainable industrial transformation for balanced and renewable energy sources. Consequently, we may approach SEIT as an industrial change featuring a relatively high share of renewable energy sources compared to traditional sources, whereby relative share refers to the entities considered as reference points, such as local energy cluster initiatives or communities. Moreover, SEIT naturally meets the sustainability challenges by linking economic savings of small prosumers (households, companies, local governments), environmental protection through renewable energy sources, and social benefits of energy security (balanced and distributed energy sources), as well as health protection and life quality.

Due to their nature as specialised industrial agglomerations of interrelated enterprises and business environment organizations, clusters are considered to be the focal settings for territorial industrial transformation (Bohatkiewicz-Czaicka & Gancarczyk, 2024, 2025; Götz, 2021; Howell, 2020; Karlsen *et al.*, 2023; Porter, 2011; Porter, 2001). The actors' proximity centred on regional specialization enables interactions and relational contracts to improve radical innovation (Apa *et al.*, 2021; Howell, 2020). However, technical and organizational knowledge exchanges are a crucial but not sufficient condition for industrial transformation since transformative changes require social consensus and collaboration (Broadstock *et al.*, 2020; Karlsen *et al*., 2023; Timeus & Gascó, 2018). Clusters are also relevant phenomena and concepts in this regard, since they represent governance structures that raise collaborations and gather the key actors around mutual interests and objectives (Götz, 2021; Howell, 2020; Karlsen *et al.*, 2023). Our study focuses on industrial clusters as a policy concept rather than an original theoretical approach and phenomenon of spatial and industrial concentrations (Bohatkiewicz-Czaicka & Gancarczyk, 2024; 2025). As a policy approach, clusters directly correspond with the contemporary idea of entrepreneurial ecosystems, treated as a reconceptualization of industrial agglomerations for policy purposes. This reconceptualization retains the focus on spatial governance formed by key participants of enterprises, local government, and academia within a particular industrial domain, such as energy production and distribution. However, this understanding is released from the necessity of spatial industrial concentration. Clusters and their contemporary policy-driven reconceptualization to entrepreneurial ecosystems are conducive to animating the socioeconomic structures to implement complex projects (Brown & Mason, 2017; Lowitzsch *et al*., 2020; Stam, 2015; Stam & Van de Ven, 2021). Moreover, they ensure a unique grounding to catalyse ideas and reconcile the interests of various stakeholders (Colombo *et al.*, 2019; Gancarczyk & Konopa, 2021b). Furthermore, the cluster and ecosystem approach to industrial transformation in energy supply is relevant due to the place-based and evolutionary nature of SEIT (Gancarczyk *et al*., 2023).

Furthermore, SEIT is necessarily local and requires renewable energy communities and a niche-building approach (Bui, 2021; Cantner *et al.*, 2021; Lowitzsch *et al*., 2020; O'Shea *et al.*, 2021; Schwabe, 2024). This transformation is also local in technical terms due to the capacity of small-scale producers, prosumers, and cooperatives that form this system (Coenen & Truffer, 2012; Elzen & Wieczorek, 2005; Peñate-Valentín *et al*., 2021). As such, it is strongly embedded in the relationships of cross-sectoral and proximate actors (Andersen *et al.*, 2020; Ashford *et al*., 2007; Loorbach & Rotmans, 2006; Smith *et al*., 2004).

However, international, national and, to a lesser extent, regional authorities have been responsible for leading energy industrial transformation, which resulted in a top-down agency of change (Ghobakhloo *et al.*, 2021; Li *et al.*, 2020; Luken & Castellanos Silveria, 2011). There are also bottom-up initiatives promoted as complementary and parallel to these policy actions (Chembessi *et al*., 2024; Deutz *et al*., 2024). The expected outcomes of these actions are the local microstructures of the balanced energy supply and the societal consent for the necessary investment to increase safety, environmental, and economic benefits in the future. The local bottom-up initiatives are nascent in terms of business and economic policy actions, and they are understudied in terms of research agenda (Andersen *et al*., 2020; Chembessi *et al*., 2024; Deutz *et al*., 2024; Ghobakhloo *et al*., 2021; Ghobakhloo *et al*., 2023). These policy and research gaps justify the focus of this paper on the local level of energy industrial transformation.

Entrepreneurial Ecosystem Governance Oriented on the Energy SIT: A Research Framework

Sustainable industrial transformation is necessarily embedded in socioeconomic governance, which is a regulatory, institutional structure, including rules, norms, and behaviour patterns that affect the performance and dynamics of a particular system, such as a cluster or an entrepreneurial ecosystem (Cho *et al.*, 2021; Colombelli *et al.*, 2019; Colombo *et al.*, 2019). Entrepreneurial ecosystems are a contemporary, policy-driven reconceptualization of clusters, representing the sets of outcome-oriented and interrelated actors and factors from the business, social, and public spheres in a given territory (Brown & Mason, 2017; Gancarczyk & Konopa, 2021b; Mason & Brown, 2014; Spigel, 2017, 2022; Stam & Van de Ven, 2021; Wojnicka-Sycz, 2020). Therefore, ecosystemic governance in clusters is a construct oriented on an outcome, such as industrial transformation toward sustainability. Various types of ecosystemic governance are assumed to be defined by interactions or mutual influences with relevant stakeholders, the density of the actors involved, the type of leading tenants, and the explorative or exploitative approach to new business areas or opportunities.

According to the literature on industrial transformation, co-evolutionary processes based on *interactions between key stakeholders*, including industry, government units, and academia drive the transition to a new industrial structure (Cantner *et al*., 2021; Colombo *et al*., 2019; Ter Wal & Boschma, 2011). *Interactions or mutual influences* among key actors, in particular, the intensity of their collaborations, form an important element of the local governance for socioeconomic transformation (Cai *et al.*, 2024; Granovetter, 1985; Putnam, 1992). These collaborations are conducive to a social consensus and to innovative products that initiate new prospective industries (Gong *et al.*, 2022; Gong & Hassink, 2019). To improve exploratory processes and avoid rigid or lock-in specializations, the infusion of external resources, including knowledge, is recommended (Gancarczyk & Gancarczyk, 2018; Hassink, 2010).

One of the conditions for social interactions is density, which denotes the number of entities involved (Amin & Thrift, 1995; Zukauskaite *et al.*, 2017). The density of cluster participants forms a buzz or creative atmosphere that enhances new ideas, which is particularly important for the early stages of cluster or ecosystem evolution (Brown & Mason, 2017; Cantner *et al*., 2021; O'Shea *et al*., 2021; Ter Wal & Boschma, 2011).

Dense and interactive ecosystems do not usually emerge spontaneously but rather develop around central or *lead tenants* (Acs *et al.*, 2017; Brown & Mason, 2017; Mason & Brown, 2014; Thompson *et al.*, 2018). Entrepreneurial ecosystems are centred around private actors, whereas in social entrepreneurial ecosystems, social or governmental actors play a dominant role (Gancarczyk *et al*., 2024; Thompson *et al*., 2000; Thompson *et al.*, 2018). The leading tenants imply the expected purposes and outcomes of the ecosystems. Entrepreneurial ecosystems are predominantly oriented toward productive entrepreneurship that integrates enterprise growth with technological transformation and social and environmental responsibility (Acs *et al*., 2017; Spigel, 2022; Stam & Van de Ven, 2021). Social entrepreneurial ecosystems primarily seek to achieve social and environmental goals through projects with relevant stakeholders (Gancarczyk *et al*., 2024; Gancarczyk & Rodil-Marzábal, 2022; Lai, 2016; Leyshon, 2020; Thompson *et al*., 2000; Thompson *et al*., 2018).

Successful governance of clusters and ecosystems requires the pursuit of both the exploitation of existing capabilities and the entrepreneurial exploration of opportunities in new economic areas (entrepreneurial discovery and expansion). However, the early-stage ecosystem should demonstrate a predominance of exploration to create a niche toward industrial renewal (Foray *et al*., 2015; Gancarczyk *et al*., 2023; Grillitsch, 2015). The overreliance on exploitation can lead to rigid specialization and lock-ins (Hassink, 2010; Martin & Sunley, 2015). Explorative activities include developing innovations, financing research and development, and partnerships with R&D organizations (Cantner *et al*., 2021; Mason & Brown, 2014; Ter Wal & Boschma, 2011). Industrial transformation is enhanced by funding for innovation processes (De Guevara & Maudos, 2009; Gancarczyk & Rodil-Marzábal, 2022; Mason &

Brown, 2014). Innovations such as new products, services, and business processes are direct drivers of industrial transformation, including the turn to renewable energy technologies (Asheim, 2019; Elzen & Wieczorek, 2005). The participation of companies in the financing of R&D favours applied research and innovation development (Mason & Brown, 2014). However, the exploration of new economic areas requires the infusion of technical knowledge from specialised R&D providers, such as technology-based companies, research institutes, and academia (Apa *et al.*, 2021; Foray *et al.*, 2015).

The above characteristics of ecosystem governance form configurations or patterns associated with different outcomes in terms of SEIT advancement, as highlighted in the research framework (Figure 1). We based the framework on the above theory and empirical evidence from cluster literature. It points to the universal components of cluster governance as antecedents of industrial transitions to sustainability (Brown & Mason, 2017; Mason & Brown, 2014; Stam & Van de Ven, 2021). It guided our empirical investigations in energy cluster pathways to SEIT.

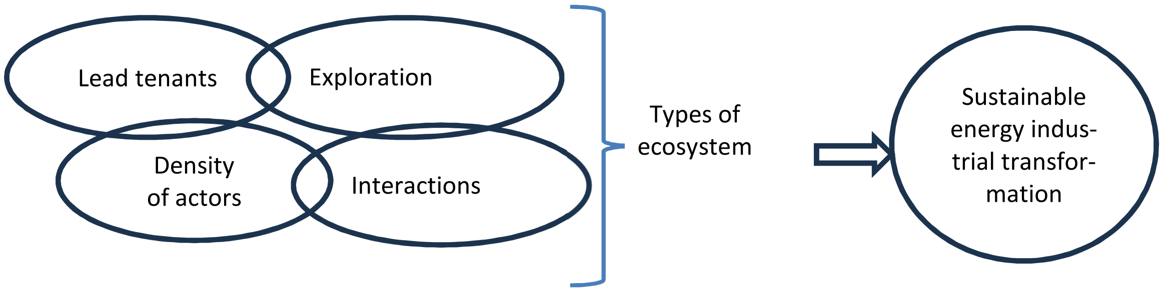

Figure 1. Research framework
Source: own elaboration.

Our research framework assumed that SEIT in cluster initiatives is determined by the types of ecosystem governance. We classified the governance types according to lead tenants, density of cluster participants, interactions of a cluster with key stakeholders, and explorative vs. exploitative approach.

Following the research framework, we posed two questions for our empirical investigations:

RQ1: How does the advance of SEIT differ in various energy cluster ecosystems?

RQ2: What are the types and characteristics of the energy cluster ecosystems that lead to or impede SEIT?

RESEARCH METHODOLOGY

Material and Method

We focused on one country setting, *i.e.,* Poland, to ensure a coherent regulatory and economic framework and a challenging country context for the energy SIT. The main research methods included a survey among energy cluster initiatives in Poland, supplemented by a secondary data analysis and semi-structured interviews with the administration of the energy clusters. We approached two major associations of cluster initiatives, including the Polish Chamber of Energy Clusters (PCEC) and the Cluster Coordinator (CC). Officially, PCEC associates 93 energy cluster initiatives, while The Cluster Coordinator registers 63 entities. We administered the first survey wave among the PCEC members from November to December, 2023. The PCEC's authorities supported it with a cover letter to strengthen the importance and practical implications of the research. We also conducted semi-structured interviews by telephone and online communication with a manager and a staff member to understand the context, the structure of their association, and the validity and responsiveness of the registered members. We preceded the questionnaire distribution with a pilot study and a questionnaire check by PCEC's management, one staff, and three cluster initiatives. The pilot study resulted in some minor formal changes to improve the transparency and accuracy of the questions. We used PCEC email contacts to distribute an online survey questionnaire.

Due to the limited response rate (at the level of 7%), one of the researchers and a PCEC staff contacted all the listed cluster initiatives by phone for a concise interview. The telephone contacts sought to explain the purpose of the investigation, motivate the respondents, and learn about their opinions and attitudes regarding opportunities and barriers in the pursuit of their projects. Another reason for the phone contacts was to check the proportion of initiatives that are actually operating. This query revealed that around 50% (47 cluster initiatives) of the registered entities could be considered inactive (telephone feedback; nonvalid telephone numbers). The final sample achieved 24 responses, representing approximately 52% of 46 cluster initiatives that were found to actively operate, based on phone checks and confirmed experience from PCEC's staff.

We conducted the second research wave between December 2023 and March 2024 and addressed the members of the Cluster Coordinator group with the use of an online questionnaire. We followed a similar procedure, including four telephone orientation interviews with the members of the CC board. The CC board members who were closely involved with the cluster initiatives checked the questionnaire's accuracy and approved this tool without any changes. Next, we administered the survey by email using an online questionnaire. The response rate was only 5% from the official CC register. The follow-up telephone contacts revealed nonvalid or inactive initiatives at the 60% level (38 entities) of the registered population, leaving 25 active entities (40% of the registered cases). Since CC gathers local governments who should respond to official inquiries through an online system of public information, we also used this system. These efforts resulted in 19 completed questionnaires, representing 80% of actively operating cluster initiatives gathered in CC. The CC's manager reported a similar experience with respect to the low cluster responsiveness.

Our final sample embraced 43 complete survey questionnaires, which is 60% of the active clusters in PCEC and CC altogether. We also collected interview material of approximately 30 normalised pages of notes from the semi-structured interviews with the PCEC and CC administration. Furthermore, we reviewed secondary sources, such as websites of the energy clusters associated with the two entities and reports on the development of the energy cluster initiatives in Poland, a material comprising around 1200 normalised pages.

Our research was explorative and used a new, ecosystemic and co-evolutionary perspective on the role of governance in energy-focused SIT (Gong & Hassink, 2019; 2020; Martin & Sunley, 2015; Oinas *et al.*, 2018). Considering the research framework (Figure 1) with a set of theoretical variables and a small number of 43 cases, the qualitative comparative analysis is an appropriate technique to explore our two research questions (Finn, 2022; Ragin, 2009; Ragin, 2019). The QCA method is between qualitative and quantitative approaches and attempts to attain scientific rigour by processing and structuring a large set of antecedents that are treated as causal conditions (factors) (Legewie, 2018; 2013). It enables both the understanding of the complex context with many explanatory factors and a configurational approach, in which the causal combinations (configurations, patterns, solutions) reveal similar, the same, or divergent outcomes (Douglas *et al.*, 2020; Finn, 2022). The QCA addresses the specificity of research objects that are neither stable and developed nor well recognised, representing several alternative solutions rather than one, average combination of explanatory variables leading to expected outcomes (Nicolas Legewie, 2013; Rizova, 2007; Thomas *et al.*, 2014). The QCA technique shows how equifinal patterns lead to the same outcome and, hence, it acknowledges the observed heterogeneity. These characteristics resonate well with the energy cluster population that we study.

However, when applied as the only treatment, QCA can lead to a loss of nuanced but relevant information. We expanded our QCA results and highlighted them by additional methods, including secondary data analysis and semi-structured interviews with key informants. These supplementary sources were important to understand the context of the observations and interpret the causalities in the governance patterns discerned from the survey material.

Variables and Measurement

The survey questionnaire embraced the characteristics of ecosystemic governance and cluster characteristics as control variables. Table 1 presents a theory-driven set of variables reflecting the advancement of SEIT and ecosystem governance characteristics, their meaning and conceptual foundations, as well as the corresponding observed variables and their measurement.

Table 1. Variables describing SEIT advancement and ecosystem governance

Variables and their symbols	Meaning and conceptual foundations of variables	Observed variables	Types of variable; measurement
Energy SIT (SEIT)	Renewable energy-oriented industrial transformation (Chembessi *et al.*, 2024; Schwabe, 2024)	Share of renewable energy sources in overall energy production by a cluster	Binary; percentage ranges of renewable energy sources in the total energy production in a cluster; 0%–20% – 0; 21% or more – 1
Lead tenants (LEAD)	Private or public leadership (Broadhurst *et al.*, 2021; Thompson *et al*., 2000)	Cluster led by local government or enterprise s	Binary; enterprise leaders – 1 or local government leaders – 0)
Density (DENS)	Density of cluster participants (Brown & Mason, 2017; Cantner *et al.*, 2021; O'Shea *et al*., 2021; Ter Wal & Boschma, 2011)	Number of key actors forming a cluster – 3 items: (1) overall number of cluster participants, (2) number of enterprises, (3) number of research entities	Ordinal; Likert 1-5 (low number – high number of actors) based on the number of actors reported
Interactions (INTER)	A cluster's collaborations with key external stakeholders (other than participants of a cluster agreement) (Cantner *et al*., 2021; Colombo *et al*., 2019; Gong & Hassink, 2019)	Intensity of collaborations – 4 items: intensity of collaborations with (1) local government, (2) enterprises, (3) R&D entities (universities, research institutes, specialised R&D enterprises) and (4) international sources of technological and organizational knowledge	Ordinal; Likert 1-5 (low – high intensity of collaboration with each stakeholder group)
Exploration (EXR)	Exploration of new technological opportunities vs. exploitation of the existing knowledge base (Foray *et al*., 2015; Grillitsch, 2015)	Pursuit of explorative activities – 3 items: (1) innovation pursuit, as the participation of a cluster in innovation activities, (2) partnerships in innovation activities with R&D entities (universities, research institutes, academic enterprises, specialised R&D enterprises), (3) investment of cluster enterprises in environmental technologies	Binary; item 1: involvement in innovation activities – 1, lack of involvement in innovation activities – 0, item 2: partnership in innovation with any of the R&D entities – 1, lack of partnership in innovation with R&D entities – 0, item 3: cluster enterprises invest in environmental technologies – 1, cluster enterprises do not invest in environmental technologies – 0

Source: own study.

The control variables describing the characteristics of the clusters included areas of activity, geographic scope, number of inhabitants, cluster age, and installed energy power (Table 4). Moreover, we asked respondents to indicate the major resource constraints they face, evaluate legislatures on energy clusters, and provide open-response recommendations to improve the economic and legal environment for energy clusters.

Table 2 indicates the characteristics of the outcome and the conditions used in QCA. The aggregate latent variables of DENS, EXPR, and INTER demonstrated adequate levels of Cronbach's alfa, a feasible reliability test for the small N available. Chi-square and Spearman's correlations proved that SEIT and its conditions are not independent, and the positive correlations were either moderately strong (LEAD, DENS, EXPR) or strong (INTER).

The QCA method bases on combinatory logic that requires that all research variables be standardised into binary values: either 1 as present (confirmed in the research) or 0 as absent (rejected in the research). Since our variables were theoretically driven constructs, including both binary and complex latent conditions expressed with the sets of observed variables on binary and ordinal scales, we used a fuzzy-set analysis (Ragin, 2009; Rihoux & Ragin, 2009). This approach requires qualifying a particular nonbinary factor as fully present (completely in), fully absent (completely out) or in-between (a cross-over point). We assigned adequate thresholds to the latent conditions (Appendix 1). We used a theory-driven and observation-based calibration of crossover points rather than the quantitative structuration of the sample, such as percentiles. Our approach is justified by the data that do not comply with any standard distributions and small N with a minor fraction fulfilling the criteria of presence (membership) for the outcome and conditions. As reflected in the frequencies (Table 3), we may explain these characteristics by the nascent stage of the energy cluster initiatives, which forces a reduction of the thresholds of presence, absence, and in-between, and hence recognises even incremental efforts to improve the outcome and conditions. To enhance the comparability of our small N data expressed on different scales, we standardised these data.

Table 2. Characteristics of the outcome and its conditions

Symbol	Item type	Scale	No. of items	Mean	Median	SD	Cronbach alfa**	Chi-square; Spearman rank R***
SEIT	Outcome	0;1 binary	1	0.21	0	0.41	N/A	N/A
LEAD	Condition	0;1 binary	1	0.56	1	0.50	N/A	p=0.03; 0.34**
DENS	Condition	1-5 Likert	3	1.40*	1*	0.79*	0.83	p=0.02; 0.39**
INTER	Condition	1-5 Likert	4	1.86*	1.66*	0.86*	0.85	p=0.00; 0.62**
EXPR	Condition	0;1	3	0.40*	0.33*	0.39*	077.	p=0.03; 0.45**

Note: * – descriptive statistics for the mean values of variables, ** – p<0.05; Chi square and Spearman correlations between SEIT and conditions.
Source: own study.

Moreover, QCA requires that the data be calibrated to assign them with values corresponding to the states on the scale from 0 to 1 (Ragin, 2019). We adopted a dedicated software for QCA, the FZQCA4.1 version, for calibrating, structuring, and processing data. The QCA rules allow that the data falling exactly at the cross-over point are not discarded but retained in the sample by adding a value of 0.001. We applied this procedure.

RESULTS AND DISCUSSION

Research Sample Characteristics

Table 3 presents the characteristics of the research sample of energy clusters, including the percentage of renewable energy sources versus other properties as control variables.

The research sample of 43 energy clusters included 13 entities covering one county, whereby the county is the largest unit of Poland's local administration, 14 entities including 4-5 communes, and 16 entities operating in 3-4 communes. Eleven clusters operate on the territories with a population of more than 100 000; eight organizations cover less than 20 000 inhabitants, and 24 initiatives represent a population between 20 000 and 100 000. Their activities focus predominantly on electricity production, distribution, and trade (37 clusters), energy storage and balancing (14 clusters), and steam heat production and distribution (7 clusters). Only four cluster initiatives have power installed exceeding 50 MW, while 10 organizations operated between 5 and 50 MW and 29 subjects were below 5 MW. The history of operations was no longer than eight years; 21 clusters were established between 2016 and 2018, and 22 clusters originated in the years 2021-2023. Renewable energy sources represented 0-20% in 34 clusters, and only 9 clusters reported renewable energy of 21% or more.

Table 3. Characteristics of the research sample: Polish energy clusters (N=43)

Characteristic	N	%	Characteristics	N	%
Size – geographical scope			**Year of establishment**		
Medium (1 county)	13	30.23	2016-2018	21	48.84
Small (4-5 communes)	14	32.56	2021-2023	22	51.16
Very small (1-3 communes)	16	37.21			
Scope – activity areas*			**Renewable energy sources**		
Electricity production, distribution, and trade	37	86.05	0%-20%	34	79.07
Energy storage and balancing	14	32.56	21%-60%	2	4.65
Steam heat production and distribution	7	16.28	61%-100%	7	16.28
Others	7	16.28	**Population covered**		
Power installed			<20 000	8	18.60
<5 MW**	29	67.44	20 000-50 000	12	27.91
5-50 MW	10	23.26	50 000-100 000	12	27.91
>50 MW	4	9.30	>100 000	11	28.58

Note. * – frequencies from multiple-response questions; ** – MW (megawatt).
Source: own study.

The Advancement of SEIT in Various Energy Cluster Ecosystems

Following the QCA technique, we sought the configurations of factors that are necessary and/or sufficient for SEIT to occur (Legewie, 2013; Ragin, 2019). The sufficiency of solutions or factors means that they produce the outcome but are not the only antecedents leading to it (Ragin, 2009). The necessity of a condition or a factor implies that they are indispensable to generate the outcome. The necessary condition is the only antecedent of the outcome. The necessary factor is a widely shared antecedent of the outcome, or it appears in all the solutions relevant to the outcome (Ragin, 2023). In this research, factors or conditions are central tenants (LEAD), density of actors (DENS), exploration activities (EXPR), and a cluster's interactions with key stakeholders (INTER) (Tables 1 and 2).

Before we identified the necessary or sufficient solutions, we determined the necessary conditions. Table 4 reports this analysis, including both the set-theoretic factors versus the presence of SEIT and their counterfactuals approached through negation, meaning the absence of factors and SEIT (a lack of or low levels of the factors and SEIT).

Table 4. Analysis of the necessary conditions for the presence or absence of SEIT

Conditions	SEIT (presence)		~SEIT (absence)	
	Consistency	Coverage	Consistency	Coverage
LEAD	0.91	0.39	0.51	0.70
~LEAD	0.57	0.68	0.56	0.95
DENS	0.57	0.68	0.15	-0.56
~DENS	0.63	0.68	0.92	0.87
INTER	0.65	0.54	0.24	0.64
~INTER	0.56	0.19	0.82	0.88
EXPR	0.77	0.39	0.44	0.72
~EXPR	0.44	0.20	0.62	0.90

Note: ~ – negation mark.
Source: own study.

Analysis of necessary conditions (Table 4) reports the consistency and coverage values, whereby consistency reflects the extent to which a factor covers an outcome (similarly to the correlation coefficient in classical regression), and coverage indicates the extent to which a condition conforms to an outcome (Legewie, 2018; 2013). A condition can be considered necessary if its consistency and coverage exceed 0.9 and 0.5, accordingly (Legewie, 2013). Our findings did not indicate necessary conditions for SEIT since a highly consistent factor of central tenants (LEAD) did not meet the coverage criterion. However, we find support for the lack of actor density (~DENS) as a necessary condition for the absence of SEIT.

To identify the patterns conducive to SEIT, in the next step of the analytical procedure, we constructed a so-called truth table that presents the results that show all the possible configurations of factors (Ragin, 2019). We may treat these configurations or solutions as patterns of the governance of the ecosystem of energy clusters related to SEIT (Appendix 2). We determined two relevant and equifinal configurations leading to SEIT in Appendix 2 based on cut-offs' frequency and consistency.

Our empirical material provided more evidence of a low or absent energy clusters' sustainable transformation (34 cases) than evidence supporting it (9 cases), which also justifies an investigation of the counterfactual, *i.e.* the relationships between the set conditions and the absence of SEIT (Appendix 3). We identified four relevant and equifinal configurations that hinder SEIT and bolded them in Appendix 3, while data covered nine configurations (Ragin, 2019; Rihoux & Ragin, 2009).

Identifying the Final Patterns of Energy Cluster Ecosystem Governance Leading to SEIT and Impeding SEIT

Next, we minimised the procedure to identify the final sufficient governance patterns for SEIT. The minimization procedure consisted of combining solutions that differed in only one condition and removing this condition did not change the required outcome (Ragin, 2009). Table 5 presents the final governance patterns according to their share in all observations that achieved SEIT (unique coverage) and consistency with the SEIT outcome.

Table 5. Final patterns of the ecosystemic governance for the presence of SEIT and for the absence of SEIT

Condition	Patterns of ecosystem governance			
	SEIT (presence)		SEIT (absence)	
	Transformative social entrepreneurial ecosystem: local government-led, not dense, but interrelated, and explorative ecosystem	**Transformative entrepreneurial ecosystem**: dense, interrelated, explorative, and enterprise-led ecosystem	**Embryonic social entrepreneurial ecosystem**: local-government-led, not dense and not interrelated ecosystem	**Embryonic entrepreneurial ecosystem**: not explorative and not dense enterprise-led ecosystem
LEAD	◯	●	○	●
DENS	○	⬤	○	○
INTER	⬤	⬤	○	
EXPR	●	●		◯
Consistency	0.94	0.71	0.98	0.89
Raw coverage	0.25	0.44	0.54	0.21
Solution consistency	0.71		0.95	
Solution coverage	0.49		0.69	

Note: ⬤ – core causal condition (present); ◯ – core causal condition (absent); ● – contributing causal condition (present); ○ – contributing causal condition (absent); blank space – not relevant condition.
Source: own study.

Two patterns revealed a transformative capability to produce SEIT. We also identified two patterns to be impeding or unsuccessful in this regard. We treated these causalities as alternative governance patterns conducive to sustainable energy industrial transformation (transformative ecosystem governance) or less developed and causing a lack of or a low level of SEIT (embryonic ecosystem governance) (Brown & Mason, 2017; Mason & Brown, 2014; Thompson *et al.*, 2018). Since the patterns differed in the type of central tenants, being either local governments or enterprises, we also differentiated them as social entrepreneurial or entrepreneurial ecosystems. Consequently, the results pointed to the favourable governance of a transformative social entrepreneurial ecosystem and a transformative entrepreneurial ecosystem, and at the unfavourable governance of an embryonic social entrepreneurial ecosystem and an embryonic entrepreneurial ecosystem (Brown & Mason, 2017; Stam & Van de Ven, 2021; Thompson *et al*., 2018).

We may capture the transformative social entrepreneurial ecosystem as a local government-led, not dense, but interrelated and explorative governance pattern successful in SEIT. It represents a favourable governance defined by two core causal conditions of local government leadership (LEAD absent) and strong collaborations with key stakeholders (INTER present) (Thompson *et al.*, 2018). Two contributing causal factors are a low number of cluster participants (DENS absent) and an exploratory approach to industrial transformation (EXPR present). Meanwhile, the transformative entrepreneurial ecosystem is also a successful governance for SEIT that we may describe as a dense, interrelated, explorative, and enterprise-led ecosystem. It is defined by two core causal conditions of a high number of cluster participants (DENS present) and strong collaborations with key stakeholders (INTER present). Two contributing causal factors are enterprise leadership (LEAD present) and the exploratory approach to industrial transformation (EXPR present).

The embryonic social entrepreneurial ecosystem is a local government-led, not dense, and not interrelated ecosystem. It represents unfavourable governance which is not defined by any core conditions, but only three contributing conditions of local government leadership (LEAD absent), low number of cluster participants (DENS absent), and lack of collaborations and interactions (INTER absent) (Gancarczyk *et al*., 2024; Thompson *et al*., 2018). Exploration remains a nonrelevant condition in this pattern. The embryonic entrepreneurial ecosystem constitutes an alternative unsuccessful governance for SEIT, a not explorative and not dense enterprise-led ecosystem. It is defined by one core causal condition of nonexploratory approach to industrial transformation (EXPR absent) and two contributing conditions of enterprise leadership (LEAD present) and a low number of cluster participants (DENS absent), while interactions with stakeholders (INTER) represent a nonrelevant factor in this instance (Cho *et al*., 2021; Ter Wal & Boschma, 2011).

Table 8 also indicates the unique levels of consistency and coverage for the identified solutions, which individually met the consistency threshold of 0.70. The overall solution consistency and coverage for the favourable and unfavourable patterns also conform to the standards. The strength of the relationship between the favourable solutions (solution consistency) exceeded 0.70 (0.71), and these solutions represented 49% of the energy cluster cases raising SEIT (at least 25% is recommended) (Legewie, 2013; Ragin, 2019). The relationship between unfavourable solutions was even stronger (0.95) and they formed 69% of the energy cluster cases that did not produce SEIT.

Discussion

Identified governance patterns represent causalities, that is, combinations of causal conditions that should be explained as interrelated, mutually influencing, and complex antecedents rather than individual SEIT determinants (Finn, 2022; Ragin, 2019). We will discuss these antecedents based on the survey data, but to deepen this analysis, we will also use the secondary data analysis and semi-structured interviews indicated in the method section. The inference of causalities governing the four ecosystems can be as follows.

The transformative social entrepreneurial ecosystem features extensive collaborations with such stakeholders as enterprises, local governments, R&D providers universities, research institutes, specialised R&D enterprises), and international sources of technological and organizational knowledge (Wawrzyniak *et al.*, 2021; Andersen *et al*., 2020; Ashford *et al*., 2007; Loorbach & Rotmans, 2006; Smith *et al*., 2004). This highly interactive approach is crucial to a low density of cluster participants and compensates for the low number of entities forming the cluster (Cantner *et al*., 2021; Colombo *et al*., 2019; Ter Wal & Boschma, 2011). It can also enhance the explorative approach present in this ecosystem. The latter contributes to SEIT through participation in innovation activities, partnerships with R&D entities (universities, research institutes, academic companies, specialised R&D enterprises), and investment by enterprises in environmental technologies. Existing case-based reports emphasis the mutual benefits of collaboration between an energy cluster and R&D entities (Micek *et al.*, 2021; Wawrzyniak *et al*., 2021). The benefits for the cluster include the influx of high-quality technical and management standards, as well as educational and dissemination assistance. The advantages for the

R&D entity are access to the cluster's infrastructure that enables research activities (Micek *et al.*, 2021, p. 45). In addition to these hard and direct effects on SEIT, energy clusters appreciate the creation of a network to reconcile the interests of diversified stakeholders and collaborate for future innovative energy technologies (Micek *et al.*, 2021, p. 64).

As an alternative governance pattern favourable for SEIT, the transformative entrepreneurial ecosystem relies both on the density of its participants and on extensive collaborations with a wide range of key stakeholders nationally (Gancarczyk *et al*., 2024; Thompson *et al*., 2000) and with international sources of technological and organizational knowledge (Gancarczyk *et al*., 2023; Gong & Hassink, 2019; Hassink, 2010). This dense and interactive governance is supported by enterprise leadership and an explorative approach to industrial transformation (Broadhurst *et al*., 2021; Gancarczyk *et al*., 2024; Thompson *et al*., 2000). We may treat the explorative approach as a direct enabler of the transition to renewable technologies (Foray *et al*., 2015). However, it does not act in isolation but is reinforced by the leadership of companies that channel an R&D investment to practical outcomes (Brown & Mason, 2017; Mason & Brown, 2014; Spigel, 2017). Moreover, a creative buzz from the density of participants and interactions with key stakeholders also enables exploration (O'Shea *et al.*, 2021) that can provide access to complementary resources. As our interviewees underlined:

> The large scale of simultaneous projects makes the cluster a partner for all major global suppliers of RES [renewable energy sources] technology. Without an energy cluster, no single investor stands a chance. Therefore, we are blazing a trail (an interviewee cluster manager).
>
> 'The cluster should become the leading organization that brings together entities for the joint production and distribution of electricity, acting as a model not only for the region but also for the whole country. Innovative and efficient solutions in energy distribution should encourage local governments and investors to become more involved in RES, so that the cluster cannot only meet local needs, but, over time, also generate increasing profits from exporting energy outside the county (an interviewee cluster manager).

The embryonic social entrepreneurial ecosystem represents an unfavourable governance that fails to produce SEIT. This is a less developed ecosystem both in terms of few participants and lack of collaboration (Bessagnet *et al*., 2021; Brown & Mason, 2017; Cho *et al*., 2021). We can assume that, if led by local governments, energy clusters miss SEIT due to low participation and isolation from the key stakeholders who might have served as sources of knowledge and other intangible and tangible assets (Gancarczyk *et al.*, 2024; Lai, 2016; Leyshon, 2020; Thompson *et al*., 2000; Thompson *et al*., 2018). A 'lack of development and coordination activities' (a local government respondent) represents an important barrier to the necessary resources, primarily access to financial capital, land, and facilities. Legislatures often fail to provide incentives for integrating clusters with the existing energy system and building the crucial interrelations between producers, prosumers, distributors, and consumers, as exemplified by 'the legal conditions of establishing energy cooperatives by towns and cities' (a local government respondent) (Dragan, 2020; Kuciel & Proszek, 2001; Mataczyńska & Kucharska, 2020). One of the necessary partners, from strategic and operational angles is energy distributors. However, as the local government respondents highlighted in the survey material:

> 'Currently, we observe the reluctance of incumbent energy operators to cooperate with energy clusters, although the clusters are essential for the proper functioning of the system. … Lower distribution fees [required by energy operators] for renewable energy infrastructures developed by energy clusters' [would improve the efficiency of energy clusters].

According to our findings, these crucial drawbacks overshadow the exploration of new technological opportunities and remove it from consideration as a driver of SEIT in local government-led energy ecosystems.

The embryonic entrepreneurial ecosystem constitutes alternative unsuccessful governance for SEIT. Unlike the local government-led governance, this enterprise-centred ecosystem fails to produce SEIT primarily due to a nonexploratory approach. When led by companies, energy clusters do not reach SEIT if they are not involved in innovation, investment in environmental technologies, or R&D partnerships (Foray *et al*., 2015; Gancarczyk *et al*., 2023; Grillitsch, 2015). Regardless of the level of interaction and collaborations (a nonrelevant factor in this governance pattern), a lack of explorative approach is detrimental to clusters with enterprise leadership (Acs *et al*., 2017; Spigel, 2022; Stam & Van de Ven, 2021). The survey respondents emphasised not only financial and tangible capital shortages (*e.g*., facilities) but also deficiencies in technological and human resources as the main impediments to the growth of these ecosystems. Moreover, they underlined considerable problems with financing that rest on membership fees and EU funds whose infusion is being either postponed or held up, as reported below.

> 'Despite the proposals of legal amendments from PCEC, these changes are either delayed or unsatisfactory.'
> 'There is no financial support to implement the projects; the support declared for the pre-investment and investment phases was not provided. Consequently, we are in the phase of participant agreement and awaiting pre-investment support for strategy development.'
> 'We lack regulation that would remove the obligation of public procurement for the sale and distribution of energy within the cluster (in particular, between local governments and companies). The freedom of energy exchange and the release of fees for energy exchange within a cluster [among cluster participants] are crucial. New amendments to the laws on public procurement and energy are needed, as the recent amendments did not meet the expectations of the cluster communities.'

Modest participation, a contributing factor in this ecosystem pattern, also weakens the potential for a sustainable industrial transition.

> 'There are legal impediments that prevent the optimal structure of the cluster participants that would gather local governments, municipal companies, R&D entities, and private companies (*i.e.*, legal barriers to establish partnerships or associations of local governments and companies). … We need better collaboration with the local government to build structures and dialogue within the cluster' (a respondent from an enterprise-led cluster).

CONCLUSIONS

This research achieved its objective on theoretical and empirical grounds by expanding the concept of regional industrial transformation with sustainability outcomes and explaining the role of ecosystem governance in SIT, based on Polish local energy clusters. The implementation of this purpose enabled responses to research questions that guided the empirical study.

Regarding RQ1, we analysed and described the advancement of sustainable energy industrial transformation in various energy cluster ecosystems while quantifying SEIT as a share of renewable energy sources in the overall energy supply of a cluster. Adopting the QCA technique, we classified the governance of energy clusters into eight entrepreneurial ecosystems related to SEIT, finding only two types that produced the expected outcomes out of the eight patterns covered by the empirical material. Within the sample study of 43 units, only nine energy clusters produced the threshold outcome, while the majority of the units revealed only low or no SEIT. This finding indicated a low advancement in sustainable energy transformation among Polish clusters and qualified this SEIT as an early-stage evolution. In response to RQ2, we discerned the types and characteristics of the energy cluster governance that led to SEIT and impeded it. Above, we described and discussed the two types of entrepreneurial ecosystem governance sufficient for SEIT and the two types sufficient to prevent SEIT.

This article provided research and policy-relevant contributions. First, we expanded the conceptual framework of regional industrial transformation to a sustainable industrial transformation based on socioeconomic governance with the adoption of coevolutionary and ecosystemic approaches (Asheim, 2019; Colombo *et al.*, 2019; Hassink *et al*., 2019; Oinas *et al*., 2018). The concept of SIT bases on the expected outcomes or goals of industrial transformation that should aim at reconciling social and environmental goals. To empirically highlight SIT, we focused on its particular case, namely the energy SIT.

Seeking an explanation of the antecedents of SEIT, we adopted the theoretical perspectives of coevolution and entrepreneurial ecosystems (Gong & Hassink, 2019; Martin & Sunley, 2015). Furthermore, the conceptual framework guiding our empirical investigations (Figure 1) was based on the theory and empirical evidence from cluster and ecosystem literature, and this general framework proved relevant in explaining the antecedents of sustainable energy industrial transformation. This contributes to a wider generalization of the cluster ecosystem components as derived from the existing evidence and corroborated in the spatial and industrial context of our study. Our empirical results support the theoretical underpinnings of coevolutionary perspective to industrial transformation, such as interactions of key stakeholders and explorative approach (Gancarczyk *et al*., 2024, 2023). Moreover, they suggest the relevance of the antecedents of successful clusters, such as density and the leadership role (Amin & Thrift, 1995; Broadhurst *et al*., 2021; Zukauskaite *et al*., 2017). However, considering the small N and the method we applied, the results are analytical generalization rather than statistical generalization (Silverman, 2015; Yin, 2018). This analytical generalization does not confirm or reject individual variables, but it translates their configurations into causalities or ecosystem governance patterns that produce SEIT or impede SEIT (CC Ragin, 2019).

Second, the article advances the concept of SIT and corroborates it on the empirical ground of Polish local energy clusters, with a focus on a particular case of SEIT (Chembessi *et al*., 2024; Schwabe, 2024). In this empirical setting, SEIT is at the nascent stages. Therefore, our results add to the research on an early-stage industrial transformation (Bessagnet *et al*., 2021; Brown & Mason, 2017; Chembessi *et al*., 2024; Cho *et al*., 2021). We advance this research by pointing to driving and impeding causalities or governance patterns. Unlike the majority of existing research that uses a case study method or tests isolated determinants to come up with one average pattern, we propose a configurational perspective of QCA and discern alternative solutions both for the success and failure in SEIT. This research approach addresses the complexity, variety, and emerging patterns of the initial stage of industrial transformation (Brown & Mason, 2017; Schwabe, 2024). Based on this lens, we can treat the energy communities organised into clusters as niche-builders who can proliferate their behaviours through imitation and diffusion to a wider socioeconomic system. The referred mechanism strengthens the importance of the investigations focused on industrial niches as relevant to research and practice (Schwabe, 2024).

Thirdly, we provided evidence of SEIT on an under-researched local level, with conclusions and recommendations relevant to economic policy regarding energy communities (Chembessi *et al*., 2024; Coenen & Truffer, 2012; Loorbach & Rotmans, 2006; Schwabe, 2024; Smith *et al*., 2004). Since the antecedents of SEIT were discerned at the initial development stage as emerging patterns, a recommendation is to further improve the conditions forming the successful governance in SEIT and avoid failed governance patterns (Spigel, 2022). We identified the transformative and embryonic ecosystems as either local government-led or enterprise-led. Therefore, our findings also raised practical recommendations for these two types of central tenants initiating and organizing local energy clusters (Broadhurst *et al.*, 2021). The lead tenants can identify themselves with adequate patterns and understand the current position. Furthermore, leading entities can target a successful governance pattern that best suits their specificity to enhance industrial change. The referred benchmarking, simulations and adjustments of cluster leaders vis-à-vis the governance patterns can enhance the upgrading of ecosystem governance, acknowledging their unique characteristics (Gong & Hassink, 2020). Our findings are also informative for the upper levels of policy since the local level is always dependent on the multiscalar context. This research evidence calls for regulation that enhances the integration of local energy communities with the country's energy system (Dragan, 2020; Kuciel & Proszek, 2001; Surwillo, 2022). We can achieve this by improving access to finance, supportive public procurement, and freeing internal energy exchanges of the cluster from excessive charges. By referring to the upper levels of public choices, we also contribute to a wider context of industrial policy, in particular, to the concept of New Industrial Policy that recognises a bottom-up and place-based perspective on designing the public intervention in support of industrial transitions (Gancarczyk & Ujwary-Gil, n.d.)

Our article is not free from limitations, which we will justify, explain the way of addressing them, and use as a basis for future research directions. The small N research sample and analytical rather than statistical generalizations are disadvantages resulting from the nature of the phenomenon studied. We addressed these limitations with a tailored QCA technique, which is specifically recommended for this type of empirical material. The value of QCA was to produce analytical generalization in the form of causalities (patterns of ecosystem governance). This analytical generalization can further be used to develop research hypotheses tested on large samples for statistical generalization.

Another drawback refers to the limited evidence of successful SEIT against the absence of SEIT in our sample and a threshold (*i.e.,* 0.70) rather than strong (*e.g.,* 0.85) consistency of the empirical evidence supporting successful ecosystems. Recently, Ragin (2008, 2019, 2023) emphasised the researcher's judgment based on theory and empirical knowledge and proposed 0.70 (Ragin, 2023) as a cutting point for solution inconsistency. We followed this recommendation as justified by an emerging and poorly defined phenomenon studied. Moreover, we derived a final sample from the entire population of energy clusters. A predominant approach in QCA is a small N purposeful sampling that focuses on the best-performing clusters, thus leading to better consistency. Our sampling embraced a considerable share of active cluster initiatives, giving a broader and more accurate picture than selective sampling. Furthermore, this evidence is valuable for highlighting the governance of SEIT in its initial phase. As energy communities grow in number and their structures advance, future studies can build on this research to verify its findings on larger datasets.

Ultimately, our study is limited to one country setting. We justified this setting as a challenging and emerging context for SEIT and discussed it against a relevant socioeconomic and regulatory background. A particular territorial context is also relevant to designing and implementing place-based policies as demanded by the New Industrial Policy Paradigm. However, future studies should provide a comparative view of countries with varied advances in the energy transition to better understand the governance that is conducive to it. Here, we can recommend future studies comparing the experience among mature and nascent contexts of the energy transitions.

REFERENCES

Acs, Z.J., Stam, E., Audretsch, D.B., & O'Connor, A. (2017). The lineages of the entrepreneurial ecosystem approach. *Small Business Economics*, *49*(1), 1-10. https://doi.org/10.1007/s11187-017-9864-8

Amin, A. & Thrift, N. (1995). *Globalization, institutions, and regional development in Europe*. Oxford University Press. Retrieved from https://www.academia.edu/81780444/Globalization_institutions_and_regional_development_in_Europe on July 10, 2024.

Andersen, A.D., Steen, M., Mäkitie, T., Hanson, J., Thune, T.M., & Soppe, B. (2020). The role of inter-sectoral dynamics in sustainability transitions: A comment on the transitions research agenda. *Environmental Innovation and Societal Transitions*, *34*, 348-351. https://doi.org/10.1016/j.eist.2019.11.009

Apa, R., De Marchi, V., Grandinetti, R., & Sedita, S.R. (2021). University-SME collaboration and innovation performance: The role of informal relationships and absorptive capacity. *The Journal of Technology Transfer*, *46*, 961-988. https://doi.org/10.1007/s10961-020-09802-9

Asheim, B.T. (2019). Smart specialisation, innovation policy and regional innovation systems: What about new path development in less innovative regions?. *Innovation: The European Journal of Social Science Research*, *32*(1), 8-25. https://doi.org/10.1080/13511610.2018.1491001

Ashford, N.A., Hafkamp, W., Prakke, F., & Vergragt, P. (2007). *Pathways to Sustainable Industrial Transformations: Cooptimising Competitiveness, Employment, and Environment*. Retrieved from https://dspace.mit.edu/handle/1721.1/41844 on July 13, 2024.

Bessagnet, A., Crespo, J., & Vicente, J. (2021). Unraveling the multi-scalar and evolutionary forces of entrepreneurial ecosystems: A historical event analysis applied to IoT Valley. *Technovation*, *108*. https://doi.org/10.1016/j.technovation.2021.102329

Bohatkiewicz-Czaicka, J., & Gancarczyk, M. (2024). *Ewolucja koncepcji klastrów a uwarunkowania ich globalnej pozycji*. Wydawnictwo UJ. https://doi.org/10.4467/K7563.5/24.24.19345

Bohatkiewicz-Czaicka, J., & Gancarczyk, M. (2025). *Industrial clusters in international value chains: Conceptual advancement and empirical evidence from European ICT clusters*. Taylor & Francis. https://doi.org/10.4324/9781003494423

Broadhurst, K., Ferreira, J., & Berkeley, N. (2021). Collaborative leadership and place-based development. *Local Economy*, *36*(2), 149-163. https://doi.org/10.1177/0269094221103255

Broadstock, D.C., Matousek, R., Meyer, M., & Tzeremes, N.G. (2020). Does corporate social responsibility impact firms' innovation capacity? The indirect link between environmental & social governance implementation and innovation performance. *Journal of Business Research*, *119*, 99-110. https://doi.org/10.1016/j.jbusres.2019.07.014

Brown, R. & Mason, C. (2017). Looking inside the spiky bits: A critical review and conceptualisation of entrepreneurial ecosystems. *Small Business Economics*, *49*(1), 11-30. https://doi.org/10.1007/s11187-017-9865-7

Bui, S. (2021). Enacting transitions—The combined effect of multiple niches in whole system reconfiguration. *Sustainability*, *13*(11), 6135. https://doi.org/10.3390/su13116135

Cai, W., Polzin, F., & Stam, E. (2024). Mitigating local bias in equity crowdfunding: A financial ecology perspective. *Journal of Economic Geography*, lbae009. https://doi.org/10.1093/jeg/lbae009

Campos-Romero, H., Rodil-Marzábal, Ó., & Gómez Pérez, A.L. (2024). Environmental asymmetries in global value chains: The case of the European automotive sector. *Journal of Cleaner Production*, *449*, 141606. https://doi.org/10.1016/j.jclepro.2024.141606

Cantner, U., Cunningham, J.A., Lehmann, E.E., & Menter, M. (2021). Entrepreneurial ecosystems: A dynamic lifecycle model. *Small Business Economics*, *57*(1), 407-423. https://doi.org/10.1007/s11187-020-00316-0

Chembessi, C., Bourdin, S., & Torre, A. (2024). Towards a territorialisation of the circular economy: The proximity of stakeholders and resources matters. *Cambridge Journal of Regions, Economy and Society*, rsae007. https://doi.org/10.1093/cjres/rsae007

Cho, D.S., Ryan, P., & Buciuni, G. (2021). Evolutionary entrepreneurial ecosystems: A research pathway. *Small Business Economics*, 1-19. https://doi.org/10.1007/s11187-021-00487-4

Coenen, L. & Truffer, B. (2012). Places and spaces of sustainability transitions: Geographical contributions to an emerging research and policy field. *European Planning Studies*, *20*(3), 367-374. https://doi.org/10.1080/09654313.2012.651802

Colombelli, A., Paolucci, E., & Ughetto, E. (2019). Hierarchical and relational governance and the life cycle of entrepreneurial ecosystems. *Small Business Economics*, *52*, 505-521. https://doi.org/10.1007/s11187-017-9957-4

Colombo, M.G., Dagnino, G.B., Lehmann, E.E., & Salmador, M. (2019). The governance of entrepreneurial ecosystems. *Small Business Economics*, *52*(2), 419-428. https://doi.org/10.1007/s11187-017-9952-9

De Guevara, J.F., & Maudos, J. (2009). Regional financial development and bank competition: Effects on firms' growth. *Regional Studies*, *43*(2), 211-228. https://doi.org/10.1080/00343400701808907

Deutz, P., Jonas, A.E., Newsholme, A., Pusz, M., Rogers, H.A., Affolderbach, J., … & Ramos, T.B. (2024). The role of place in the development of a circular economy: A critical analysis of potential for social redistribution in Hull, UK. *Cambridge Journal of Regions, Economy and Society*, rsae002. https://doi.org/10.1093/cjres/rsae002

Douglas, E.J., Shepherd, D.A., & Prentice, C. (2020). Using fuzzy-set qualitative comparative analysis for a finer-grained understanding of entrepreneurship. *Journal of Business Venturing*, *35*(1), 105970. https://doi.org/10.1016/j.jbusvent.2019.105970

Dragan, D. (2020). Legal barriers to the development of energy clusters in Poland. *European Energy and Environmental Law Review*, *29*(1), 14-20. Scopus. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85086926877&partnerID=40&md5=da28a6bbe85121e4629aed89dac33344 on July 12, 2024. https://doi.org/10.54648/eelr2020002

Elzen, B. & Wieczorek, A. (2005). Transitions towards sustainability through system innovation. *Technological Forecasting and Social Change*, *72*(6), 651-661. https://doi.org/10.1016/j.techfore.2005.04.002

Energy Regulatory Office. (2024). *RES: The President of ERO publishes a template application for entry in the register of energy clusters*. Retrieved from https://www.ure.gov.pl/pl/urzad/informacje-ogolne/aktualnosci/11586,OZE-Prezes-URE-publikuje-wzor-wniosku-o-wpis-do-rejestru-klastrow-energii.html on July 19, 2024.

European Commission. (2020). *Proposal for a Regulation of the European Parliament and of the Council establishing the Just Transition Fund. Brussels, 14.1.2020 r. COM(2020) 22 final 2020/0006 (COD).* Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020PC0022 on July 19, 2024.

Finn, V. (2022). A qualitative assessment of QCA: method stretching in large-N studies and temporality. *Quality & Quantity*, *56*(5), 3815-3830. https://doi.org/10.1007/s11135-021-01278-5

Foray, D., McCann, P., & Ortega-Argilés, R. (2015). Smart specialization and European regional development policy. *Oxford Handbook of Local Competitiveness*, 458-480. https://doi.org/10.1093/oxfordhb/9780199993307.013.26

Gancarczyk, M. & Gancarczyk, J. (2018). Proactive international strategies of cluster SMEs. *European Management Journal*, *36*(1), 59-70. https://doi.org/10.1016/j.emj.2017.03.002

Gancarczyk, M., Gancarczyk, J., & Reichel, M. (2024). Revitalizing Forgotten Spaces through local leadership and social entrepreneurial ecosystems: The case of Muszyna commune. In *European Regional Policy and Development* (pp. 105-134). Routledge. https://doi.org/10.4324/9781003256281-9

Gancarczyk, M. & Konopa, S. (2021a). Exploring the Governance of Entrepreneurial Ecosystems for Productive High Growth. *Foresight and STI Governance*, *15*(4), 9-21. https://doi.org/10.17323/2500-2597.2021.4.9.21

Gancarczyk, M. & Konopa, S. (2021b). Exploring the Governance of Entrepreneurial Ecosystems for Productive High Growth. *Foresight and STI Governance*, *15*(4), 9-21. https://doi.org/10.17323/2500-2597.2021.4.9.21

Gancarczyk, M., Najda-Janoszka, M., Gancarczyk, J., & Hassink, R. (2023). Exploring Regional Innovation Policies and Regional Industrial Transformation from a Coevolutionary Perspective: The Case of Małopolska, Poland. *Economic Geography*, *99*(1), 51-80. https://doi.org/10.1080/00130095.2022.2120465

Gancarczyk, M. & Rodil-Marzábal, Ó. (2022). *Fintech framing financial ecologies: Conceptual and policy-related implications*. https://doi.org/10.7341/20221841

Gancarczyk, M. & Ujwary-Gil, A. (2020). *Revitalizing industrial policy through smart, micro-level and bottom-up approaches*. Retrieved from https://www.researchgate.net/publication/344494550_Revitalizing_industrial_policy_through_smart_micro-level_and_bottom-up_approaches on July 16, 2024.

Ghobakhloo, M., Fathi, M., Iranmanesh, M., Maroufkhani, P., & Morales, M.E. (2021). Industry 4.0 ten years on: A bibliometric and systematic review of concepts, sustainability value drivers, and success determinants. *Journal of Cleaner Production*, *302*, 127052. https://doi.org/10.1016/j.jclepro.2021.127052

Ghobakhloo, M., Iranmanesh, M., Morales, M.E., Nilashi, M., & Amran, A. (2023). Actions and approaches for enabling Industry 5.0-driven sustainable industrial transformation: A strategy roadmap. *Corporate Social Responsibility and Environmental Management*, *30*(3), 1473-1494. https://doi.org/10.1002/csr.2431

Gong, H., Binz, C., Hassink, R., & Trippl, M. (2022). Emerging industries: Institutions, legitimacy and system-level agency. *Regional Studies*, *56*(4), 523-535. https://doi.org/10.1080/00343404.2022.2033199

Gong, H. & Hassink, R. (2019). Co-evolution in contemporary economic geography: Towards a theoretical framework. *Regional Studies*, *53*(9), 1344-1355. https://doi.org/10.1080/00343404.2018.1494824

Gong, H. & Hassink, R. (2020). Context sensitivity and economic-geographic (re) theorising. *Cambridge Journal of Regions, Economy and Society*, *13*(3), 475-490. https://doi.org/10.1093/cjres/rsaa021

Götz, M. (2021). *Clusters, digital transformation and regional development in Germany*. Routledge. https://doi.org/10.4324/9781003005506

Granovetter, M. (1985). Economic action and social structure: The problem of embeddedness. *American Journal of Sociology*, *91*(3), 481-510. https://doi.org/10.1086/228311

Grigore, A.M. & Dragan, I.M. (2020). Towards sustainable entrepreneurial ecosystems in a transitional economy: An analysis of two Romanian city-regions through the lens of entrepreneurs. *Sustainability (Switzerland)*, *12*(15). https://doi.org/10.3390/su12156061

Grillitsch, M. (2015). Institutional layers, connectedness and change: Implications for economic evolution in regions. *European Planning Studies*, *23*(10), 2099-2124. https://doi.org/10.1080/09654313.2014.1003796

Hassink, R. (2010). Locked in decline? On the role of regional lock-ins in old industrial areas. In *The handbook of evolutionary economic geography*. Edward Elgar Publishing. https://doi.org/10.4337/9781849806497.00031

Hassink, R., Isaksen, A., & Trippl, M. (2019). Towards a comprehensive understanding of new regional industrial path development. *Regional Studies*. https://doi.org/10.1080/00343404.2019.1566704

Howell, A. (2020). Agglomeration, absorptive capacity and knowledge governance: Implications for public–private firm innovation in China. *Regional Studies*, *54*(8), 1069-1083. https://doi.org/10.1080/00343404.2019.1659505

Isaksen, A., Jakobsen, S.-E., Njøs, R., & Normann, R. (2019). Regional industrial restructuring resulting from individual and system agency. *Innovation: The European Journal of Social Science Research*, *32*(1), 48-65. https://doi.org/10.1080/13511610.2018.1496322

Jasiński, J., Kozakiewicz, M., & Sołtysik, M. (2021). Determinants of energy cooperatives' development in rural areas—Evidence from Poland. *Energies*, *14*(2). Scopus. https://doi.org/10.3390/en14020319

KAPE. (2017). *The concept of functioning of energy clusters in Poland. Warsaw: Ministry of Energy.* National Energy Conservation Agency, Atmoterm, National Institute of Distributed Energy. Retrieved from https://www.kape.gov.pl/about-us (Accessed 3 August 2024).

Karlsen, A., Lund, H.B., & Steen, M. (2023). The roles of intermediaries in upgrading of manufacturing clusters: Enhancing cluster absorptive capacity. *Competition & Change*, *27*(1), 3-21. https://doi.org/10.1177/10245294211059138

Kraska, E. (2018). *Regional processes of cluster formation and development (on the example of the Świętokrzyskie Voivodeship)*. Kielce: Jan Kochanowski University Press. (Accessed 2 August 2024).

Kuciel, S. & Proszek, M. (2001). The techno-economical and legal conditions for recycling plastic wastes. *Przemysl Chemiczny*, *80*(9), 386-394. Scopus. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-0035594724&partnerID=40&md5=612d419e5cf88ba3750b24cfcf0ba953 on July 27, 2024.

Lai, K.P.Y. (2016). Financial advisors, financial ecologies and the variegated financialisation of everyday investors. *Transactions of the Institute of British Geographers*, *41*(1), 27-40. Scopus. https://doi.org/10.1111/tran.12101

Legewie, N. (2018). Anchored calibration: From qualitative data to fuzzy sets. *ZBW – Leibniz Information Centre for Economics*, *18*(3). Berlin: Freie Universität Berlin. https://doi.org/10.17169/fqs-18.3.2790

Legewie, N. (2013). An introduction to applied data analysis with qualitative comparative analysis. *Forum Qualitative Sozialforschung Forum: Qualitative Social Research*, *14*(3). https://doi.org/10.17169/fqs-14.3.1961

Leyshon, A. (2020). Financial ecosystems and ecologies. In *The Routledge Handbook of Financial Geography* (pp. 122-141). Routledge. https://doi.org/10.4324/9781351119061

Li, W., Chen, G., & Liao, X. (2020). *Countermeasures of Chinese traditional commercial banks to meet the challenges of internet finance based on big data analysis-evidence from ICBC*. *1648*(3). Scopus. https://doi.org/10.1088/1742-6596/1648/3/032066

Liu, Y. (2020). The micro-foundations of global business incubation: Stakeholder engagement and strategic entrepreneurial partnerships. *Technological Forecasting and Social Change*, *161*. Scopus. https://doi.org/10.1016/j.techfore.2020.120294

Loorbach, D. & Rotmans, J. (2006). Managing transitions for sustainable development. *Understanding Industrial Transformation*, *44*, 187-206. https://doi.org/10.1007/1-4020-4418-6_10

Lowitzsch, J., Hoicka, C.E., & van Tulder, F.J. (2020). Renewable energy communities under the 2019 European Clean Energy Package – Governance model for the energy clusters of the future?. *Renewable and Sustainable Energy Reviews*, *122*. Scopus. https://doi.org/10.1016/j.rser.2019.109489

Luken, R. & Castellanos-Silveria, F. (2011). Industrial transformation and sustainable development in developing countries. *Sustainable Development*, *19*(3), 167-175. https://doi.org/10.1002/sd.434

Manowska, A., Osadnik, K.T., & Wyganowska, M. (2017). Economic and social aspects of restructuring Polish coal mining: Focusing on Poland and the EU. *Resources Policy*, *52*, 192-200. Scopus. https://doi.org/10.1016/j.resourpol.2017.02.006

Martin, R. & Sunley, P. (2015). Towards a developmental turn in evolutionary economic geography?. *Regional Studies*, *49*(5), 712-732. https://doi.org/10.4324/9781315667430

Mason, C. & Brown, R. (2014). Entrepreneurial ecosystems and growth oriented entrepreneurship. *Final Report to OECD, Paris*, *30*(1), 77-102. Retrieved from https://research-portal.st-andrews.ac.uk/en/publications/entrepreneurial-ecosystems-and-growth-oriented-entrepreneurship on August 5, 2024.

Mataczyńska, E., & Kucharska, A. (Eds.) (2020). *Energy clusters: Regulation, theory and practice*. Rzeszów: I. Łukasiewicz Institute of Energy Policy. Retrieved from https://www.researchgate.net/publication/343105911_Klastry_energii_Regulacje_teoria_i_praktyka_red_E_Mataczynska_A_Kucharska on June 4, 2024.

Micek, D., Kocór, M., Worek, B., & Szczucka, A. (2021). *Społeczne uwarunkowania funkcjonowania klastrów energii w Polsce: Raport podsumowujący analizę studium przypadku wybranych klastrów: Cz. 3*. Ministerstwo Rozwoju, Pracy i Technologii, Akademia Górniczo-Hutnicza im. Stanisława Staszica w Krakowie, Narodowe Centrum Badań Jądrowych. Retrieved from https://www.er.agh.edu.pl/media/filer_public/66/cb/66cb3fd2-854d-47c5-baaa-c2952fb8e639/raport_spoleczne_uwarunkowania_funkcjonowania_klastrow_energii_w_polsce.pdf on June 4, 2024.

Ministry of Climate and Environment. (2021). *Energy policy of Poland until 2040 (EPP2040)*. Retrieved from https://www.gov.pl/web/climate/energy-policy-of-poland-until-2040-epp2040 on June 4, 2024.

Ministry of Development. (2017). *Strategy for Responsible Development until 2020 (with an outlook to 2030)*. Retrieved from https://www.gov.pl/documents/33377/436740/SOR_2017_streszczenie_en.pdf on June 6, 2024.

Mirowski, T. & Kubica, K. (2016). The role of biomass in energy clusters. *Polityka Energetyczna*, *19*(4), 125-138. Scopus. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85062563272&partnerID=40&md5=3b2a5e2903977190fb25168f4388ff5e on July 8, 2024.

Mucha-Kuś, K., Sołtysik, M., Zamasz, K., & Szczepańska-Woszczyna, K. (2021). Coopetitive Nature of Energy Communities—The Energy Transition Context. *Energies*, *14*(4). Scopus. https://doi.org/10.3390/en14040931

Oinas, P., Trippl, M., & Höyssä, M. (2018). Regional industrial transformations in the interconnected global economy. *Cambridge Journal of Regions, Economy and Society*, *11*(2), 227-240. https://doi.org/10.1093/cjres/rsy015

O'Shea, G., Farny, S., & Hakala, H. (2021). The buzz before business: A design science study of a sustainable entrepreneurial ecosystem. *Small Business Economics*, *56*(3), 1097-1120. https://doi.org/10.1007/s11187-019-00256-4

Peñate-Valentín, M.C., del Carmen Sánchez-Carreira, M., & Pereira, Á. (2021). The promotion of innovative service business models through public procurement. An analysis of Energy Service Companies in Spain. *Sustainable Production and Consumption*, *27*, 1857-1868. https://doi.org/10.1016/j.spc.2021.04.028

Porter, M. (2011). *The Competitive Advantage of Nations: Creating and Sustaining Superior Performance*. Retrieved from https://books.google.pl/books/about/Competitive_Advantage_of_Nations.html?id=CqZzxAxBpfEC&redir_esc=y on July 4, 2024.

Porter, M.E. (2001). The value chain and competitive advantage. *Understanding Business Processes*, *2*, 50-66. Retrieved from https://books.google.pl/books?hl=pl&lr=&id=vNldIVx6BQ4C&oi=fnd&pg=PA50&dq=Porter,+M.E.+(2001).+The+value+chain+and+competitive+advantage.+Understanding+Business+Processes,+2,+50%E2%80%9366.&ots=FDIsmEFK7M&sig=_Lz9-1CqCM-edqegBwIvGBq69HI&redir_esc=y#v=onepage&q&f=false on July 4, 2024.

Putnam, R.D. (1992). *Making democracy work: Civic traditions in modern Italy*. Princeton university press. Retrieved from https://press.princeton.edu/books/paperback/9780691037387/making-democracy-work?srsltid=AfmBOoo9zalmue3JzFi_Xqb0mjKR1J3l-1y6TmLsIWdEZ2SmihU8FDAJ on July 7, 2024.

Ragin, C.C. (2009). *Redesigning social inquiry: Fuzzy sets and beyond*. University of Chicago Press. Retrieved from https://www.researchgate.net/publication/37695154_Redesigning_Social_Inquiry_Fuzzy_Sets_and_Beyond on July 28, 2024.

Ragin, C.C. (2019). *User's Guide to Fuzzy-set/Qualitative Comparative Analysis. 2017*. Retrieved from https://sites.socsci.uci.edu/~cragin/fsQCA/download/fsQCAManual.pdf on July 18, 2024.

Ragin, Charles. (2023). *Research Note: Stepwise Consistency Analysis*. Retrieved from https://compasss.org/blog/2023/08/15/research-note-on-stepwise-consistency-analysis-by-charles-ragin/ on July 28, 2024.

Rihoux, B., & Ragin, C.C. (2009). *Configurational comparative methods: Qualitative comparative analysis (QCA) and related techniques* (Vol. 51). Sage. https://doi.org/10.4135/9781452226569

Rizova, P.S. (2007). Applying Charles Ragin's Method of Qualitative Comparative Analysis (QCA) to the Study of Technological Innovation. Retrieved from *Available at SSRN 1093090* on August 13, 2024.

Schwabe, J. (2024). Regime-driven niches and institutional entrepreneurs: Adding hydrogen to regional energy systems in Germany. *Energy Research & Social Science*, *108*, 103357. https://doi.org/10.1016/j.erss.2023.103357

Silverman, D. (2015). *Interpreting qualitative data*. Sage. Retrieved from https://www.researchgate.net/publication/237068011_Interpreting_Qualitative_Data on July 18, 2024.

Smith, A., Stirling, A., & Berkhout, F. (2004). *Governing sustainable industrial transformation under different transition contexts*. 113-132. Retrieved from https://www.researchgate.net/publication/280153151_Governing_Sustainable_Industrial_Transformation_Under_Different_Transition_Contexts on July 15, 2024.

Sołtysik, M., & Kozakiewicz, M. (2018). Selected Optimization Issues In The Energy Clusters. *Rynek Energii*, *2018*(3), 9-13. Scopus. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85181217766&partnerID=40&md5=1e4b4617d00e840fa18124bc89445277 on July 5, 2024.

Spigel, B. (2017). The relational organization of entrepreneurial ecosystems. *Entrepreneurship Theory and Practice*, *41*(1), 49-72. https://doi.org/10.1111/etap.12167

Spigel, B. (2022). Examining the cohesiveness and nestedness entrepreneurial ecosystems: Evidence from British FinTechs. *Small Business Economics*, 1-19. https://doi.org/10.1007/s11187-021-00589-z

Stam, E. (2015). Entrepreneurial ecosystems and regional policy: A sympathetic critique. *European Planning Studies*, *23*(9), 1759-1769. https://doi.org/10.1080/09654313.2015.1061484

Stam, E. & Van de Ven, A. (2021). Entrepreneurial ecosystem elements. *Small Business Economics*, *56*(2), 809-832. https://doi.org/10.1007/s11187-019-00270-6

Surwillo, I. (2022). Energy clusters in Poland: Towards diffused green energy communities. In *Energy Transition in the Baltic Sea Region* (pp. 185-204). Routledge. Retrieved from https://www.taylorfrancis.com/chapters/oa-edit/10.4324/9781032003092-13/energy-clusters-poland-izabela-surwillo on July 17, 2024.

Szewranski, S., Kachniarz, M., Sylla, M., Swiader, M., & Tokarczyk-Dorociak, K. (2019). *Spatio-temporal assessment of energy consumption and socio-economic drivers in rural areas in Poland*. *18*, 1372-1378. Scopus. https://doi.org/10.22616/ERDev2019.18.N093

Tauron Polska Energia. (2024). *Energy Clusters in the activities of the Ministry of Energy*. Retrieved from https://www.tauron.pl/tauron/o-tauronie/tauron-dla-otoczenia/klastry-energii on July 5, 2024.

Ter Wal, A.L. & Boschma, R. (2011). Co-evolution of firms, industries and networks in space. *Regional Studies*, *45*(7), 919-933. https://doi.org/10.1080/00343400802662658

Thomas, J., O'Mara-Eves, A., & Brunton, G. (2014). Using qualitative comparative analysis (QCA) in systematic reviews of complex interventions: A worked example. *Systematic Reviews*, *3*, 1-14. https://doi.org/10.1186/2046-4053-3-67

Thompson, J., Alvy, G., & Lees, A. (2000). Social entrepreneurship–a new look at the people and the potential. *Management Decision*. https://doi.org/10.1108/00251740010340517

Thompson, T.A., Purdy, J.M., & Ventresca, M.J. (2018). How entrepreneurial ecosystems take form: Evidence from social impact initiatives in Seattle. *Strategic Entrepreneurship Journal*, *12*(1), 96-116. https://doi.org/10.1002/sej.1285

Timeus, K. & Gascó, M. (2018). Increasing innovation capacity in city governments: Do innovation labs make a difference?. *Journal of Urban Affairs*, *40*(7), 992-1008. https://doi.org/10.1080/07352166.2018.1431049

Uddin, N. & Taplin, R. (2015). Regional cooperation in widening energy access and also mitigating climate change: Current programs and future potential. *Global Environmental Change*, *35*, 497-504. Scopus. https://doi.org/10.1016/j.gloenvcha.2015.05.006

UN. (2015). *Resolution adopted by the General Assembly on 25 September 2015 Transforming our world: The 2030 Agenda for Sustainable Development. A/RES/70/1.* Retrieved from https://digitallibrary.un.org/record/3923923?v=pdf on July 16, 2024.

UN. (2016). *Sustainable Development Goals*. Retrieved from https://www.un.org.pl/ on July 16, 2024.

Wawrzyniak, K., Walkowiak, S., & Cetnarski, R. (2021). Elastyczność w sieci OSD jako kluczowy komponent transformacji energetycznej. *Energetyka Rozproszona*, (5-6), 75-90. https://doi.org/10.7494/er.2021.5-6.75

Wiseman, H.J. (2023). Energy governance models. In *Handbook of Energy Law in the Low-Carbon Transition* (pp. 41-64). Scopus. https://doi.org/10.1515/9783110752403-010

Wojnicka-Sycz, E. (2020). *Paradygmat systemowy w innowacyjności: Geneza, ewolucja i ocena*. Wydawnictwo Uniwersytetu Gdańskiego.

Yin, R.K. (2018). *Case study research and applications*. Sage. Retrieved from https://www.scirp.org/reference/referencespapers?referenceid=2914980 on July 17, 2024.

Zukauskaite, E., Trippl, M., & Plechero, M. (2017). Institutional thickness revisited. *Economic Geography*, *93*(4), 325-345. https://doi.org/10.1080/00130095.2017.1331703

Appendix 1: Calibration thresholds and frequencies for the nonbinary conditions

Item symbol and scale	Item values and frequencies	Fully present	In-between (cross-over point)	Fully absent
DENS (1-5 Likert)	1.00- 34 1.50 – 1 2.00 – 4 3.50 – 1 4.00 – 1 5.00 – 1	4.00	2.00	1.50
INTER (1-5 Likert)	1.00 – 11 1.17-2.33 – 2 2.50-4.17 – 11	4.00	2.33	1.00
EXPR (0;1)	0.00 – 15 0.33 – 15 0.66 – 3 1.00 – 10	1.00	0.33	0.00

Source: own study.

Appendix 2: Truth Table with all possible configurations and sets of cases demonstrating the same solution relative to the outcome of SEIT

Solution	LEAD	DENS	INTER	EXPR	N	Raw cons.	PRI cons.	SYM cons.	SEIT (outcome)
1	0	0	0	0	12	0.16	0.02	0.02	0
2	1	0	0	1	9	0.42	0.26	0.26	0
3	**1**	**1**	**1**	**1**	**6**	**0.71**	**0.56**	**0.56**	**1**
4	0	0	0	1	6	0.44	0.09	0.09	0
5	1	1	0	1	3	0.69	0.48	0.48	0
6	1	0	1	1	5	0.55	0.39	0.39	0
7	1	0	0	0	2	0.44	0.19	0.19	0
8	1	0	1	0	1	0.59	0.21	0.21	0
9	**0**	**0**	**1**	**1**	**1**	**0.94**	**0.72**	**0.72**	**1**
10	1	1	0	0	0				
11	1	1	1	0	0				
12	0	1	0	0	0				
13	0	0	1	0	0				
14	0	1	1	0	0				
15	0	1	0	1	0				
16	0	1	1	1	0				

Note: Frequency cut-off – 1; raw consistency cut-off – 0.70; PRI consistency cut-off – 0.5; N – number of energy clusters representing a given solution.
Source: own study.

Appendix 3: Truth Table with all possible configurations and the sets of cases demonstrating the same solution relative to the absence of SEIT

Configur.	LEAD	DENS	INTER	EXPR	N	Raw cons.	PRI cons.	SYM cons.	~SEIT (outcome)
1	**0**	**0**	**0**	**0**	**12**	**0.98**	**0.98**	**0.98**	**1**
2	1	0	0	1	9	0.80	0.74	0.74	0
3	**0**	**0**	**0**	**1**	**6**	**0.95**	**0.91**	**0.91**	**1**
4	1	1	1	1	6	0.63	0.44	0.44	0
5	1	1	0	1	3	0.72	0.52	0.52	0
6	1	0	1	1	3	0.75	0.64	0.64	0
7	**1**	**0**	**0**	**0**	**2**	**0.87**	**0.81**	**0.81**	**1**
8	**1**	**0**	**1**	**0**	**1**	**0.89**	**0.79**	**0.79**	**1**
9	0	0	1	1	1	0.84	0.28	0.28	0
10	0	1	0	0	0				
11	1	1	0	0	0				
12	0	0	1	0	0				
13	0	1	1	0	0				
14	1	1	1	0	0				
15	0	1	0	1	0				
16	0	1	1	1	0				

Note: Frequency cut-off – 1; raw consistency cut-off – 0.86; PRI consistency cut-off – 0.5; N – number of energy clusters representing a given solution.
Source: own study.

Authors

The contribution share of authors is equal and amounted to ⅓ for each of them. Marta Gancarczyk – conceptualization, method, data gathering and processing, writing; Damian Tomczyk – conceptualization, method, data gathering and processing, writing; Jacek Gancarczyk – conceptualization, method, data processing, writing.

Marta Gancarczyk
Full Professor at the Institute of Economics, Finance, and Management, Jagiellonian University in Krakow, Poland. Her research interests include economic governance, entrepreneurship economics, industrial clusters, and public policies for innovation, entrepreneurship, and small and medium-sized enterprises.
Correspondence to: prof. dr hab. Marta Gancarczyk, Jagiellonian University, Faculty of Management and Social Communication, ul. Łojasiewicza 4, 30-348 Kraków, Poland, e-mail: marta.gancarczyk@uj.edu.pl
ORCID https://orcid.org/0000-0003-2078-9320

Damian Tomczyk
Master's degree in Economics at the Institute of Economics, Finance, and Management, Jagiellonian University in Krakow; PhD student in Economics and Finance, the Doctoral School in the Social Sciences, Jagiellonian University in Krakow. His research interests include ecological economics, particularly the energy industry and renewable energy sources.
Correspondence to: Damian Tomczyk, Jagiellonian University, Faculty of Management and Social Communication, ul. Łojasiewicza 4, 30-348 Kraków, Poland, e-mail: damian.tomczyk@doctoral.uj.edu.pl
ORCID https://orcid.org/0009-0008-6592-9562

Jacek Gancarczyk
Adjunct Professor at the Institute of Entrepreneurship, Jagiellonian University in Krakow, Poland. His research interests include innovative ventures, entrepreneurship, industrial clusters, and small and medium-sized enterprises. He is a member of the European Council for Small Business and Entrepreneurship (ECSB).
Correspondence to: Dr Jacek Gancarczyk, Jagiellonian University, Faculty of Management and Social Communication, ul. Łojasiewicza 4, 30-348 Kraków, Poland, e-mail: jacek.gancarczyk@uj.edu.pl
ORCID https://orcid.org/0000-0002-5636-1062

Acknowledgements and Financial Disclosure

This publication was written as part of "The green transition and economic polarization in Europe: a multilevel assessment with Germany and Poland as case studies" research project funded by the National Science Centre Poland (grant no. 2021/43/I/HS5/00538) and German Research Foundation (grant no. 504890580). The publication was also supported by the Institute of Economics, Finance, and Management and the Institute of Entrepreneurship, Faculty of Management and Social Communication, Jagiellonian University in Krakow, Poland. The draft version of the paper was presented at the Regional Studies Association Conference *Driving Regions Forward: Transitioning to Brighter Regional Futures*, London, November 7-8, 2024.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Copyright and License

Published by Krakow University of Economics – Krakow, Poland