Industrial Ecosystem Collaboration in EV Battery Materials Value Chains: The Case of Kokkola Industrial Park

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The global environmental and geopolitical situation is affecting the energy transition in business and society. The Arctic region has critical materials that are valuable for the EU in the green transition. In response to geopolitical instabilities and to secure access to energy transition materials, the EU is aiming for European and Arctic resource extraction and related value chains. As a result, electric vehicle battery value chains will concentrate in smaller geographical areas with diverse industrial backgrounds within Europe. The purpose of this paper is to examine: What enables environmentally, socially, and economically successful regional circular industrial ecosystem collaboration? A regional industrial ecosystem with symbiotic synergies requires collaborative efforts and value creation from many actors, varying from the government to regional, business, and local actors. We present an intensive qualitative case study on an industrial ecosystem with a long history of operations in the Nordic region: Kokkola Industrial Park (KIP) in Finland. With the current movement of the developing energy transition and of EV battery materials value chains in Europe, it is important to examine local ecosystem flows and the ways in which they connect to global value chains. The data comprises semi-structured interviews with various ecosystem actors and secondary research material, such as reports, documents, social media, and news articles. With interpretative qualitative analysis, we scrutinize and detail the actors, the collaborative practices and activities of an industrial ecosystem. We elaborate on shared interests, and analyze the environmental, social, and economic value creation of the process. The results of this study contribute to our understanding about the role and importance of ecosystem flows in value creation. The results can be utilized in planning and establishing new industrial ecosystems for energy transition and EV battery materials in the Arctic region in Europe.

Introduction

Ecosystems have become a central focus in sustainability transition research and policymaking. There is a call for research on the emergence and evolvement of circular ecosystems (Aarikka-Stenroos et al., 2021; Pietrulla, 2022) and industrial symbiosis (Neves et al., 2020). In more detail, what is of interest are the enablers and barriers for the emergence and evolvement of circular ecosystems (Pietrulla, 2022), their agency and governance (Kanda, 2023) as well as collaborative activities and interactions among the actors of the circular ecosystem, such as ecosystem orchestrating (Parida et al., 2019), data sharing (Serna-Guerrero, 2022) and the triple-bottom-line value creation in industrial symbiosis in regional settings (Neves et al., 2020; Uusikartano et al.,

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2020). Sustainability transition requires a transition from the current, linear, take-make-waste extractive economic model to a circular model that seeks to reduce the use of energy and keep materials creating value for as long as possible (Lehtimäki et al., 2023). Building on systems-change theory and multilevel perspectives, researchers argue that this transition entails extensive and radical change in the prevalent societal, economic, and business systems (Creed et al., 2022; Geels & Schot, 2007; Kivimaa et al., 2021; Lehtimäki et al., 2023; McPhearson et al., 2021). Transformation toward a sustainable market economy calls for examining ways of organizing innovation from fresh perspectives to understand how actors from different industrial sectors, public institutions, research facilities, and user, consumer, and other stakeholder communities get together and shape evolving innovations and business ecosystems. We contribute to the rising research orientation on ecosystems supporting sustainability transitions with a focus on regional industrial ecosystems of electric vehicle (EV) battery materials.

We recognize that regional industrial ecosystems of EV battery materials require attention due to three parallel reasons. First, electric mobility is a response to the demand for carbon neutrality in the quest to prevent and mitigate the effects of climate change. However, electric mobility is more metal intensive than the conventional internal combustion engine mobility (Kleijn et al., 2011; Valero et al., 2018). The demand for metallic materials increases rapidly not only because of electric mobility—but also the transition to carbon neutrality at large—increases the demand, as wind and solar power also use these materials. The limited resources of metallic materials, global industrial politics on sourcing the materials, and the increased demand for these materials in sustainable energy and material transition calls for exploring the application of the principles of the circular economy (CE) into the EV battery value chain (Lehtimäki et al, 2024).

Second, while the existing business ecosystems for the supply of critical raw materials of electric mobility have a strong global character due to their reliance on primary production, it is expected that future sustainable CE business ecosystems will have a strong regional emphasis with opportunities for new business opportunities and interwoven local value chains of secondary raw material streams, as well as new process concepts and technologies. Europe's Arctic region plays a crucial role in the EU's energy transition because of its renewable energy resources and reserves of critical minerals, and the increased focus of the European Union (EU) on energy security in Europe. The established and regional industrial ecosystems in the Artic region offer chances to explore ways to develop eco-innovative ways of operating, and new green energy ecosystems are being set up. Our case study provides valuable insights from a long-operating regional ecosystem of process industry in energy transition and EV materials to other ecosystems operating in the Arctic region.

Third, the CE of EV battery materials are only emerging. There are not yet enough materials to recycle; the regulation is still taking form; and there are several technological barriers—for example batteries are not always optimally designed to be recycled, labor intensity in recycling, and recyclability of battery chemicals (Rönkkö et al., 2024). What makes regional circular industrial ecosystems important is that the green energy transition requires cross-industrial, collaborative efforts that connect different actors for shared, systematic value creation (Aarikka-Stenroos & Ritala, 2017; Adner, 2017; Pietrulla, 2022).

In this study, we examine actors and the interdependencies between them in a regional circular industrial ecosystem in the northern context. We argue that to increase knowledge about the CE ecosystems of EV battery materials requires a close examination of regional ecosystems that seek to achieve system-level outcomes through collaboration due to spatial proximity of a variety of public and private stakeholders who pursue their interests that are not only local but also national and international. The research question is: "What enables environmentally, socially, and economically successful regional circular industrial ecosystem collaboration?" Specifically, we ask the following: (1) What actors are there in the regional circular industrial ecosystem? and (2) How do material, knowledge and value flows occur in a regional circular industrial ecosystem?

With an intensive qualitative case study (Eriksson & Kovalainen, 2016), we examine the ecosystem actors and their connections and the related material, knowledge, and value flows (Aarikka-Stenroos et al., 2021) to increase our understanding about the impacts of ecosystem collaboration. The research material comprises 14 in-depth interviews, a workshop, and seminars as primary material—and reports, documents, social media and news articles as secondary material. Interpretative content analysis (Mantere & Ketokivi, 2013) was used as a method of analysis.

The results of our analysis uncover actors and flows in a regional circular industrial ecosystem of EV battery materials in Central Ostrobothnia in Finland, on the Gulf of Bothnia. This study brings new knowledge about the connection between regional ecosystem collaboration and sustainable CE value creation in the global ecosystem. This study contributes to research on ecosystems in two ways. First, our elaboration on the variety of actors and the intertwinement of resource flows in the regional ecosystem brings new knowledge about the contextual factors that shape the flows and the collaborative aspects of the circular ecosystem of EV battery materials. Second, our analysis of the connection between the ecosystem collaboration and sustainable CE value creation in the ecosystem increases knowledge about the global process of systemic value creation (Aarikka-Stenroos et al., 2021) in the CE ecosystems of EV battery materials.

The paper is structured as follows. In the theoretical background section, we will first review the ecosystem concept and elaborate on the research gap we are addressing in this paper. In the methodology section, we describe the intensive case study method and explicate our method of data collection and analysis. In the findings section, we provide a rich description of the actors and the flows in this regional industrial ecosystem in a northern context. We conclude with a summary of the findings and a discussion on the implications of the findings for northern developments in energy transition.

Theoretical background

In previous research, the concepts of industrial symbiosis, industrial ecosystems, eco-industrial parks, CE ecosystems, and circular industrial ecosystems have been used to frame ecosystems. While the definitions have differences, they have also been used in parallel with each other. For instance, the concept of an ecosystem is often used interchangeably with concepts such as systems (Kanda, 2023), industrial symbiosis, and eco-industrial parks (Pietrulla, 2022). These concepts have roots in varied literature such as anthropology, biology, and industrial ecology (Moore, 1993; Lowe & Evans, 1995; Kanda, 2023). They all belong to the same family of concepts, as they all depict cross-sectoral collaboration and ways to advance sustainable processes and production—and they all have been used to increase understanding about systemic changes in the sustainability transition. In this research, we follow the definition of circular ecosystem as "an aggregation of economic actors whose activities need to be coordinated to create value" (Kanda, 2023: 3) — and more specifically, as "a regional community of hierarchically independent, yet interdependent, heterogeneous set of actors who sustainably produce industrial goods and services in symbiotic collaboration and resource use." (Aarikka-Stenroos et al., 2021: 266).

In connecting ecosystem management and value creation, previous research has directed attention to the orchestrator as a focal organization that advocates an ecosystem value proposition to other actors (Thomas & Ritala, 2022), configurations of activity in the ecosystem as defined by a value proposition (Adner, 2017), and the common goal of competitive advantage as a value outcome for actors in the ecosystem (Clarysse et al., 2014). Previous literature has drawn attention to the roles of actors, such as orchestrators, complementors, users, and external actors in ecosystem interaction (Thomas & Ritala, 2022). Some of the previous research has shown that ecosystems can be managed to some extent (e.g., Iansiti & Levien, 2004; Hannah & Eisenhardt, 2018), while others have argued that ecosystems are self-organizing collectives (Clarysse et al., 2014; Wilhoit & Kisselburgh, 2015). Some researchers have emphasized the role of ecosystem orchestrators in coordinating and overseeing diverse interests, ensuring alignment among ecosystem partners, and enforcing the rules of the game and ensuring that other partners adhere to the rules (Parida et al., 2019).

Ecosystem theorizing builds on a notion that value is a result of ecosystem actors collaborating, coevolving and competitive support, crossing the industry and actor disciplines (Moore, 1993). Recent research has argued that value is (co-)created in a systemic way by diverse collaborating actors who join in providing an offering (Aarikka-Stenroos & Ritala, 2017; Adner, 2017). Thus, a shared value proposition of an ecosystem is expected to stem from a combination of technological, economic, and cognitive interdependencies and the interactions between various participants (Thomas & Ritala, 2022). Participation in the ecosystem is expected to provide a competitive advantage for each actor in the ecosystem (Adner, 2017). Our research adds to this discussion by examining the ways in which ecosystem actors join in creating value at the ecosystem level and the ways in which interdependencies organize the value creation. We examine the relational dynamics in ecosystem value creation (Kujala et al., 2017; Kanda et al., 2021) and seek to increase understanding about the ways in which relational dynamics and collaboration organizes value creation.

Methodology

We present an intensive qualitative case study (Eriksson & Kovalainen, 2016) of a regional industrial ecosystem. This methodology was chosen because it enables a rich contextual description essential to understanding the phenomenon and theory generation (Ketokivi & Choi, 2014). Our case study, Kokkola Industrial Park (KIP) in Kokkola, Finland, is the largest inorganic chemical industry ecosystem in Northern Europe and a pioneer in the circular economy in Europe. The site was selected as it enabled a fruitful setting for studying an established regional circular industrial ecosystem.

Our primary research material consists of 14 semi-structured interviews (Brinkmann, 2014) with ecosystem actors collected between August 2022 and March 2024. The research team organized a workshop (in November 2022) where actors in the ecosystem discussed CE activities and best practices in the local ecosystem. Both interviews and group discussions from the workshop were recorded and transcribed. The research team attended local seminars (two seminars in 2022 and 2023) where the ecosystem actors presented their activities, developments, and plans to a national audience. Notes were taken by the researchers participating in these seminars. The secondary research material involves reports and documents (including an innovation ecosystem agreement between the city and the Finnish government), policies, strategy documents, sustainability reports of ecosystem actors, media coverage, and social media posts.

Interpretative content analysis (Mantere & Ketokivi, 2013; Eriksson & Kovalainen, 2016) was applied as the method of analysis. The analysis process was a cyclical research process that included several rounds of analysis of the empirical research material with reading theory on the topic and further analysis of the material. This allowed us to explore themes, patterns, and meanings in the text. Both authors participated in the analysis to allow for a deeper analysis of the interdependencies and co-evolvement of relations in the ecosystem. A visual mapping tool Kumu (https://kumu.io/) was used to visually illustrate the roles and connections between the actors in the ecosystem.

Findings

In this section, we will first depict the actors in the ecosystem. Next, we will provide an in-depth analysis of the resource flows that include materials and energy, knowledge flows that involve education and informal knowledge sharing among the actors, and value flows that include social, environmental and economic values. The analysis of the ecosystem flows will include depictions of the actors and their roles in the ecosystem and the interdependencies between the actors. The analysis of the aforementioned aspects underlines the collaborative nature of the ecosystem.

Actors and relations in the ecosystem

Our research focuses on the EV battery materials ecosystem in the area of Kokkola, Finland. Kokkola is a city located in Central Ostrobothnia that is historically known as a trade center, due to its port and seafaring. Since the 1940s it has had industrial manufacturing facilities in the Kokkola Industrial Park (KIP), which is the industrial park where the ecosystem is sited. The KIP area was historically divided into two parts: KIP South, which used to run the Kemira chemical factories; and KIP North, where the Outokumpu metal production factories were located. An interesting point to note is that none of these original manufacturing facilities, inherited from the Finnish state-owned manufacturers Kemira and Outokumpu from the 1940s and 1960s, have been closed. Instead, they have got new owners who have made further investments in the area. The city has good logistical connections within and outside Finland through the Port of Kokkola, as well as railways, highways and an airport. KIP boasts decades-long cooperation and maintaining an industrial symbiosis. The manufacturers in the area benefit from many levels of synergies, such as utilization of the process industry's side streams, centralized service production, and the joint development of business culture— especially with regard to the environment and health, safety, and quality factors that have been established between companies.

Image: KIP Area (https://kip.fi/en/area/introduction-to-the-area.html)

KIP is identified as an industrial ecosystem, which has strong and increasing focus on EV battery material production. EV battery material manufacturing and processing actors in the area include the chemical, mining and metal production industries. KIP South houses the Sibanye-Stillwater Keliber lithium project. This project, which is under construction at the time of this study, aims to develop operations to produce battery-grade lithium hydroxide—an essential component in lithium-ion batteries. The second major owner of this project is the Finnish government, through Finnish Minerals Group, with 20% ownership. The Keliber project includes a mine near Kokkola, a concentrator near the mining sites, and a lithium refinery in the KIP South area. Both the concentrator and the refinery are under construction with the aim of being fully functional in 2025 or 2026. Boliden operates their sulfuric acid plant in KIP South. In the KIP North area is the second Boliden site with their zinc plant. This zinc plant is the second largest zinc plant in Europe. KIP North also houses Umicore, with their variety of operations—mainly around cobalt and battery precursory cathode material (pCAM) production. There is also Jervois, with the biggest cobalt refinery outside of China. The identified end customers of the manufacturers are mostly battery producers or car producers outside of Finland. Mining companies, where materials to the manufacturing companies mainly come from, are connected to the ecosystem through the manufacturers.

The KIP Registered Association (KRA) is a regional developmental organization of the KIP area, focusing on developing and improving the area. The KRA promotes collaboration between businesses and improves the operating conditions of the park's businesses. The KRA is governed by a board of directors with 25 members from the different organizations in the park, including the city of Kokkola through Kokkolanseudun Kehitys Ltd (KOSEK). The members have volunteered and applied to be part of the association in order to have a say in the developmental activities within the industrial park. The KRA includes various active working groups on the environment, energy, safety, HR, ICT and marketing. The working groups are platforms to further enable collaboration, communication, and support of the core activities in the area. The KRA has been defined as a "soft areal developer."

A variety of service operators were identified as part of the KIP ecosystem with the aim of supporting the core manufacturing activities. KIP Service Limited is the collaborative, multiservice organ of the industrial park. It provides environmental services, security services, and services related to real estate and infrastructure, such as maintenance, human resources services and consulting, training and development, and a variety of other supportive services such as postal services. KIP Service Limited was defined to be the active and action-oriented "practical areal developer."

KIP Infra Limited, in turn, deals with the infrastructure of the industrial park through not only management of the land areas, buildings and roads, but also through ownership of railways, sewage, and pipe bridges in the area—all of which are required to maintain and develop the activities of the manufacturing facilities. Other services and machinery and utility providers of the KIP area include consulting companies, water and energy companies, logistics companies, and machinery, automation, and ICT providers. These ecosystem actors complement the services that KIP Service Limited provides with more detailed and directed support to the manufacturers. Some examples of these are Kokkolan Teollisuusvesi Limited, which is responsible for the water supply and management of the area; Kokkolan Energia Limited, which deals with the energy of the area; and Sweco, which supplies consulting, development, and project management-related services.

Public sector actors were identified as integral in the KIP industrial ecosystem. These include the city of Kokkola, through its ownership of some infrastructure and memberships in associations such as KIP Services Limited and KIP Infra Limited. KOSEK is the regional development company owned by the city of Kokkola and the city of Perho with an aim to develop the business environment of the region further. KOSEK focuses on promoting collaboration between regional actors, cities, and businesses through free development and advisory services to businesses of all sizes—and they do this with in a wider regional perspective rather than focusing only on the area of Kokkola and KIP. Educational institutes such as the University of Oulu and Centria University of Applied Sciences were identified to be integral in providing a knowledgeable and well-trained workforce to the ecosystem actors of KIP area. Collaboration between companies and educational institutions spans research, development, and innovation activities. Educational institutes were stated to be currently one of the most important actors of the Finnish battery value chain.

Ecosystem reach is wider than just regional proximity, due to connection and collaboration with governmental institutions, national organizations and networks, and international partners. The actors and parties involved in this ecosystem benefit from the Innovation ecosystem agreement signed between the city of Kokkola and the Ministry of Economic Affairs and Employment of Finland (TEM). This agreement brings the city and the KIP ecosystem financial and status-related benefits. KIP is also part of the Finnish network for eco-industrial parks, which allows for exchange of knowledge and information with other ecosystems present and emerging in Finland. KIP is the only Finnish and Nordic member of the European Chemical Site Promotion Platform focusing on European-wide collaboration and promotion of European chemical markets to possible future investors.

The ecosystem actors were also linked through diverse interdependencies. All the manufacturers were located physically close to each other with a structured and supported infrastructure. This spatial proximity allowed for physical interconnectedness which is required for industrial symbiosis. Technological complements and business links were identifiable and integral for maintaining a well-working ecosystem. Ecosystem governance with a leadership structure and defined responsibilities for the industrial park governance was identified to maintain coordination mechanisms among the actors, accompanied by the regional government.

Interdependencies and co-evolutionary interactions

The material and energy flows, knowledge flows and value flows created interdependencies and co-evolutionary interactions among the ecosystem actors. We will describe each of these flows in the following section.

First, material and energy flows included resources mostly from outside Finland through the Port of Kokkola. Materials that the manufacturers in the KIP area utilize are mined elsewhere (e.g., Asia, Canada, the Democratic Republic of the Congo) and then transported to be further processed at the KIP plants. In some cases, the materials received include a level of recycled material, but these levels are still quite low. The geographically stipulated context of KIP enabled energy and material flows between the manufacturers of the ecosystem. Due to proximity to each other, energy and materials could be easily distributed among the various actors through pipes to be directly utilized further rather than transporting them elsewhere. The efficient resource flows between actors were stated not to be possible would the actors be more dispersed. The actors were defined to be highly connected through resource flows "in good and in bad" (interview KOF-1). This was explained to mean that the actors benefit from the synergies, but if one of them fell out for any reason or their production stops, for example due to downtime, it might cause major issues elsewhere.

The resource flows were in part historically defined, partially due to the demand and supply of the actors present. In the 1960s Kemira and Outokumpu had their manufacturing facilities built so that they could benefit from each other's side streams. Later, when new actors started to come to the area, discussions were conducted to see how and where the new entrants could benefit but also contribute to the synergies and the symbiosis. The main resource flows were specified to include sulfuric acid, hydrochloride acid, ammonia, gases, and energy. These resources flow between the actors mainly through pipes and pipe-bridges connecting the actors. When planning a new manufacturing plant for the KIP area, placing the pipes is carefully considered to ensure that not only current residents but also possible future residents are provided for. The chemicals and materials produced at KIP are mostly exported through the Port of Kokkola.

Second, the knowledge flows occurred between educational institutions, the manufacturers, and the service facilitators. On a regular basis, the educational institutions visited the KIP area to learn about the manufacturers and the service providers, and the work they did. Visiting and learning how the area and the businesses work allows collaboration regarding student work placement, project work, and possible future employment opportunities. In 2023 KIP received approximately 11,000 visitors. These visitors came from the region, elsewhere in Finland and abroad—and represented interested parties from, for example, educational institutes, companies, city governments, and developmental organizations. Also, knowledge flows involved organizational support through the KRA that was stated to be integral in maintaining the formal and informal knowledge flows within the ecosystem. The meetings—both general meetings and with the working groups—ensured that the different actors gathered to discuss important topics. Coming together as representatives of various ecosystem actors, whether in person or online, allowed for knowledge sharing through discussions that might not otherwise occur. Stakeholder magazine *SERVIS,* published by KIP Services Limited, was stated to be an important way to reach more of the different stakeholders of the ecosystem. This magazine was published in Finnish approximately three times a year and is available online and in printed form. Knowledge also flowed through the SSG On site app that was utilized for communication, as well as in a variety of memos to site employees and on screens in all cafeterias and on roadsides. A lot of informal knowledge sharing was said to happen in cafeterias in the KIP area, where employees from the various companies and with different functions meet for lunch and coffee breaks. Governance in the ecosystem was identified to happen mainly through the KRA and KIP Services Limited. They provide services for projects both inside and outside KIP, and thus, also "tie these different companies together better" (interview KOC-1).

Third, the value flows included social, environmental, and economic value. As dimensions of social value, we identified being a part of the area, part of the city, and part of the country as important to the ecosystem actors. Also, the industrial history of the area was mentioned as an aspect of social value in operating the industrial park It was intertwined with identity building: "We know what we are doing; we have been doing this for a long time; we are the example.". The importance of trust, openness, contact and connection, and the acknowledgement that one is not alone but a part of a larger ensemble was highlighted. Being part of the area and the city was expressed, for example, through supporting the local sports and cultural events and organizations.

We detected the environmental value in the discussion about raw-materials mining and transportation. The discussion involved pondering about paradox of doing good for the environment (climate) while contributing to its degradation (mining of raw materials). The CE was defined as something inherent to the processing industry, something that was built into its activities—so deeply so that the interviewees did not realize at first what was meant by CE. The efficient use of raw materials and the strengthening of the various resource flows was quoted "to be natural" (interview KOF-1) to the ecosystem. Already historically, in the 1960s, the manufacturing facilities that originated in the area were built to accommodate utilization of each other's side streams. Innovations regarding circularity and expansion of the resource flows to a greater extent were seen as possible development points to further enable sustainable value proposition to customers, investors and collaborators nationally and internationally.

The economic value was depicted in the discussion about investments. Industrial investments were seen to require long-term commitment— "decades long long-term investments" (interview KOE-1) and a lot of money. Lack of available domestic capital had led to investments mainly from international private businesses. The Finnish government was, however, participating within its abilities—as, for example, identified in the case of Keliber, where the majority owner is the South African miner Sibanye-Stillwater, with Finnish government as a partial owner (20%) through Finnish Minerals Group (FMG). Interviews showcased anticipation of the growth of the area due to increasing interest from companies wanting to establish their business in the area. Water, energy and the existing infrastructure were identified as factors of importance to possible investors to the area. Permits—and more specifically environmental permits—were seen as a possible obstacle to the further growth of the area. Also, the geopolitical situation and uncertainty related to future investments (e.g. the Inflation Reduction Act, or IRA) raised concerns. Economic value came also to the surface when interviewees talked about synergies. One responded stated "*they [actors] benefit from this collaboration and synergies, even to an economically significant extent.*" (interview KOF-1).

Value was seen to be created locally in the industrial park, regionally and nationally. An increase of over 1,000 employees was stated to be expected in the next coming years. A Kokkola Works advertising campaign was created to attract people to work in the area. Many of these new recruits would not be coming alone but with their spouses and families. This meant that careful planning was required in the local municipality to include the employment of spouses, schooling, daycare centers and housing.

Discussion

Our study contributes, first, to the ecosystem perspective on CE by elaborating on agency and the interdependencies among the ecosystem actors. The CE in this industrial area comprises the circulation of raw materials that includes the efficient use of raw materials, side streams and water, and the reduction and use of waste materials. Resource efficiency in processes, closed-loop water use, and carbon dioxide capture and storage are also part of the circular economy in the area. The area has also various sharing platforms, product-as-a-service models and extended life-cycle services to enhance operational efficiency in the area.

The CE of energy transition and EV battery materials industry is still in its early stages in Europe. Currently, the recycling rate of key elements of EVs is below 1 % (UNEP, 2013; EC, 2018). In addition to policy and regulatory frameworks to address recycling across the entire EV battery lifecycle—from raw-material supply to end-of-life (Lehtimäki et al., 2024)—voluntary action of companies is needed to develop CE of energy transition and EV battery materials. As a contribution to developing CE ecosystems, our study shows that ecosystem interdependencies in material, knowledge and value flows support the interest of companies in engaging in CE activities.

Second, our case study contributes to the northern development in the global context by showing how the regional ecosystem collaboration provides value to the actors involved and how it supports building continuous competitive advantage in the unpredictable global market and regulatory environment. The value chains of energy transition and EV battery materials are global and face problems of material demand, trade, regulatory frameworks, and logistics (Barman et al., 2023). There are several complexities and wickedness of interwoven sustainability tensions regarding resource sufficiency, geographical distribution of raw materials, and the global value chains, global, national, and regional regulations and policies and the emerging novel battery technologies (Lehtimäki et al., 2024). Our case study shows how a regional industrial ecosystem in the northern context is a part of the global value chains through upstream and downstream material flows, ownership structures, and investments. This regional ecosystem has little negotiation power to influence the decision making on investments by globally operating companies or the geopolitical decisions of China, the USA, or the EU. However, the well-functioning industrial symbiosis provides the benefits of optimizing the use of resources, improving energy efficiency, identifying synergies in collaboration, and fostering knowledge sharing—and thus improves the strategic resilience of the regional ecosystem. Therefore, we conclude that the regional social, environmental, and economic outcomes build resilience and sustainability for the industrial ecosystem to anticipate potential changes and risks involved in the global value chains of which they are a part.

Conclusions

The results of our analysis elaborate on the interdependencies between the ecosystem actors in an industrial area in a northern context closely involved in the global energy transition. We identified infrastructural, technological, economic, cognitive, and social alignments among the actors in the industrial ecosystem as important in creating collaborative advantages needed for staying competitive in the global value chains. A regional ecosystem involves locally based knowledge flows and globally spanning material and value flows. Simultaneously, in the global ecosystem, geopolitics and protectionism in the energy transition, risks in the supply of raw materials, and competition in battery industry investments between nations and regions create strategic risks of value destruction.

Our findings show that in the regional ecosystem of energy transition and EV battery materials, the public and private sector actors join the ecosystem with their value propositions and delivery and expectations of value capture, and thus, create ecosystem level value capture without centralized control. Previous research has emphasized the role of orchestrators and centralized control of the ecosystem (Iansiti & Levien, 2004; Hannah & Eisenhardt, 2018; Parida et al., 2019). This study shows that the interaction and the relational dynamics among actors both inside and outside of the regional ecosystem—i.e., national and international constituencies—are important in the governance and organizing of ecosystem-level value creation. The value network that the local actors create includes industrial actors, service providers, educational institutions, and ecosystem facilitators. It also involves an extended network of global suppliers, customers, partners, investors and collaborators. Thus, a regional ecosystem of energy transition and EV battery materials involves operational and strategic interdependencies among the network actors in the regional area while simultaneously cutting across several national and international value networks of which many of the regional actors are a part.

This case study indicates that a high-level coordination among the ecosystem actors is important in managing risks in the global value chains. In this regional industrial ecosystem, the strengths of relational dynamics build on long history of collaboration in the local area, trust among the actors, joint interests in value capture, and an ability to collaborate in industrial processes, knowledge sharing, and capacity building. Understanding how this complex network of regional and globally spanning activities is organized is particularly important for understanding the drivers and barriers in developing a sustainable CE value creation on EV battery materials in the global value chains of the future.

The Arctic region has critical materials that are valuable for the EU in the energy transition. In response to the geopolitical instabilities and to secure access to energy transition materials, the EU is aiming for local, European-wide, and Arctic resource extraction and related value chains. It is anticipated that electric vehicle battery value chains will concentrate in smaller geographical areas with diverse industrial backgrounds within Europe. Our study shows that a regional industrial ecosystem with symbiotic synergies builds on collaborative efforts of heterogeneous actors—including governmental and regional public sector actors, third-sector organizations, and local and global business actors. The coevolutionary processes in a regional ecosystem create mutually beneficial adaptations that support thriving in the face of economic and political changes in the global value chains.

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