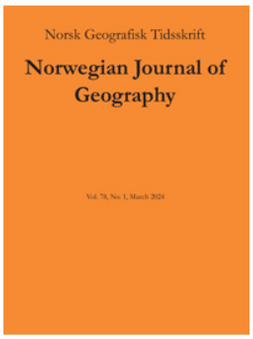

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Behind the scenes of industrial change – Change agency and system function linkages

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ABSTRACT

Green transformation of industry and society is high on the research and policy agenda. The article presents a proposal for a theoretical framework for studying technological change based on the employment of system functions drawn from the literature on technological innovation systems in conjunction with existing theorisation on regional restructuring and change agency. The empirical focus of this article is on the Grenland region in Norway, a thick and specialised region that focuses on the 'greening' of traditional industries. The empirical data were gathered through an in-depth case study of the ongoing restructuring process in Grenland and further by adopting a path tracing methodological approach building on interviews held with key actors, in addition to desk research. The findings revealed how the restructuring process in Grenland can be broken down and understood by empirically examining links between different types of change agency and the utilisation of system functions. The author concludes that the findings provide important insights into the theoretical debate on how agency on a micro-level relates to institutional evolution and structural change.

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Introduction

As the world faces grand societal challenges, such as climate change, there is a need for a green restructuring of the economy on many levels. Even though climate change has triggered low carbon targets, public and private actors are also recognising that a 'green shift' offers possibilities for a sustainable, competitive, and more resilient economy in the future (Gibbs & O'Neill 2017). As with restructuring in general, innovation activity is regarded as crucial for green industrial restructuring. Furthermore, studies have pointed out that this activity needs to be understood and performed at multiple levels (Essletzbichler 2012): by actors in firms, in production networks, and in innovation systems ranging from on the regional scale to the global scale. In particular, the important role of agency and leadership in innovation-based industrial restructuring has been pointed out as an aspect that demands more theoretical and empirical work (Sotarauta & Beer 2017; Chaminade et al. 2019). Although environmental and social challenges may be highly global in nature, they also demand actions at the regional level, including changes in regional industries and policies (Tödtling et al. 2022). Hence, the focus of this article is on the linkages between different types of agency and utilisation of system resources for shifts/green shifts in regional industries.

Analysing and explaining the green restructuring of industries is challenging. The literature on regional innovation systems has embraced an institutional tradition in terms of region-specific formal and informal institutions but is less focused on processes playing out on the firm level. Addressing societal challenges implies leading the innovation process in certain directions, where the traditional regional innovation systems (RIS) approach is focused on 'fostering economic competitive advantage' (Tödtling et al. 2022, 5). Furthermore, regional

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innovation systems are mainly geared towards supporting industrial path extension and path upgrading (Isaksen et al. 2019). This means that the RIS approach can particularly help to explain how a RIS supports the greening of existing regional industries (e.g. through cleaner process technology). However, green restructuring also includes the development of new 'green' industries through path diversification and path creation. In this regard, the technological innovation system (TIS) approach may contribute to the analysis of green industrial restructuring, as it has been acknowledged as 'particularly useful for understanding path creation' (Njøs et al. 2020, 270). Although the approach often includes specific technological developments on both a national and global scale, the system functions derived from various strands of literature are general in nature. As actors within RISs also can utilise extra-regional resources (on different scales), system functions may to different extents be regionally strengthened, and constitute central activities for regional industrial restructuring. Hence, system functions may be applicable to the regional level with the aim of enhancing our understanding of the processes of regional industrial restructuring.

Actors and human agency are at the core of social processes such as innovation activity, and Musiolik et al. (2012, 1) suggest that innovative actors have to develop 'supportive structures which legitimise and stabilise the emerging technology' within a TIS. Furthermore, Musiolik et al. (2012) argue that such innovative actors aiming to implement sustainable technologies in society are mainly individual entrepreneurs. While acknowledging that entrepreneurs play an important role, I suggest that a more 'fine-grained' typology of agency is suitable when analysing such micro-processes of change. Such a typology can be found in the approach of trinity of change agency (TCA) (Grillitsch & Sotarauta 2020), which includes Schumpeterian innovative entrepreneurship, institutional entrepreneurship, and place-based leadership. Drawing on insights from the literature on TIS and its system functions, I focus on the contribution of each system function to industrial development/green industrial development and link each function to the facilitating role of different types of agency. The employment of TIS functions in conjunction with existing theorisation on change agency may be useful in analyses of the process of regional industrial development, as the functions represent a way of how such processes can be 'broken down' and understood. This possibility is further elaborated on in the 'analytical framework' section.

Thus, this article contributes to an increased understanding of regional industrial development/green regional industrial development by coupling the three types of change agency with the system functions drawn from the literature on TISs. More specifically, the article will contribute to the literature through an analysis of the extent to which different types of agency can be linked to different system functions throughout the regional industrial development process.

In this article I study the greening of the manufacturing industry in the Grenland region, in the county of Telemark in south-eastern Norway, by using the theoretical framework developed in the next section ('Theoretical underpinnings'). Grenland holds a thick and specialised RIS, as it is characterised by strong industrial specialisation based on nearly 100 years within the traditional process industry, such as in smelteries and other energy-intensive forms of production. Such RISs are important parts of the industrial structure in Norway, where city regions are dominated by either one or a few related industries that tend to be both energy-demanding and polluting. Furthermore, thick and specialised RISs may have limited endogenous transformative capabilities due to the limited diversity of actors (Chaminade et al. 2019), which makes them an interesting unit to analyse within the scope of this article.

Following this introduction, the theoretical research question addressed in this article is: *How can green regional industrial path development be approached by combining understandings of change agency and system resources?* To help to answer this question I include the following empirical research question: *How can the green industrial development process in the Grenland region be understood through the application of a TCA-TIS framework?*

Theoretical underpinnings

Grillitsch & Hansen (2019) argue that recent studies of innovation offer new opportunities for combining the fields of innovation studies and economic geography. One example is the increasing interest in the development of green industries within various regions, where the RIS approach can contribute to the understanding of regional green path development (Grillitsch & Hansen 2019). The theoretical discussion of this article starts by presenting the RIS and TIS approaches, and is followed by a discussion on how system functions can be linked with different types of change agency. The discussion is summarised in an analytical framework and thereafter the activities related to the greening of the manufacturing industry in the Grenland region are discussed and the conclusions presented.

Innovation system approaches

Since the early 1990s, the innovation system approach has been widely recognised as a proficient way to

study industries' innovation processes in their contexts and to formulate policies to strengthen innovation activities in firms and industries (Lundvall 1992; Edquist 1997). From the original national innovation system approach (Lundvall 1992; Nelson 1993), various strands of literature have emerged with the aim of explaining different elements in the creation of innovation capacity and performance, such as regional innovation systems and technological innovation systems approaches. An increased understanding of innovation processes is important as a basis for policymaking, as societal challenges, such as climate change, put more pressure on firms and society for sustainability and efficiency. Such societal challenges need innovation of various types, performed by many kinds of actors, including organisations, governments, and civil society. This complexity has proved that singular strands of innovation literature are insufficient when it comes to analysing the green restructuring of regional industries (Tödtling et al. 2022).

The context of the empirical part of this article is a region characterised by an organisationally thick and specialised RIS (Isaksen & Trippl 2016). A RIS consists of three core elements – actors, institutions, and networks – and concentrates on the nature of relationships between these three elements (Asheim et al. 2019). Isaksen et al. (2022) argue that regional innovation systems tend to support existing industries and technologies, and that they need to be reconfigured to stimulate regional industrial restructuring. By contrast, the TIS approach focuses on the demand side through the functions of market formation and legitimacy in the creation of new technology. For example, legitimation can be seen as belonging to the demand side, as it contributes to the fact that new industries, technologies, products, and services are accepted by, for example, stakeholders in a region and a nation and by potential customers. Hence, bringing in system functions will help the gaining of insights into how RISs can support and contribute to the greening of a region's industry.

TIS offers insights into how regions and RISs can change to be more able to support the 'green restructuring' of regional industries (Hekkert et al. 2007). The TIS approach is used to analyse the development and diffusion of technologies, particularly new and 'green' technologies. This strand of literature appeared largely in the mid-2000s and has since grown to become an important framework for studying technological change, especially within sustainability solutions, such as green energy production. A TIS consists of actors, institutions (regulations and norms), and networks that influence the diffusion of emerging technologies (Suurs et al. 2009). Compared with the RIS approach, it has a stronger focus on both the dynamics between actors and the institutions guiding their behaviour. The research field further addresses sociotechnical system transitions, based on the fact that the field has emerged from a growing awareness that technological development is both reflected in and determined by the social, cultural, and economic context in which it is embedded (Geels 2002; Geels et al. 2008; Truffer 2008; Markard et al. 2012).

In order to distinguish between drivers of innovation that are endogenous and exogenous to a region there is a need to delineate between systems of innovation and their environment (Coenen & López 2010). According to Edquist (2005) such delineation can be drawn (1) geographically, (2) based on technological fields, (3) based on product areas, or (4) based on activities. Whereas the RIS approach is an example of a concept with geographical boundaries, the TIS approach, even though originating from the same theoretical family as RISs, is based on specific technological fields (Binz et al. 2016a). It does not follow territorial boundaries, 'but follows actors, networks, and institutions to wherever the analysis may lead' (Binz et al. 2016a, 179).

System functions: dynamic elements of innovation systems

The system function framework has proven to be a useful tool when assessing TIS performance and is based on the integration of technology-specific elements with elements from sectoral, regional, and national innovation systems (Bergek 2019). With its focus on the establishment or adaption of institutional structures and networks through actors and their agency, the framework is well suited for analysing and understanding change, as well as the development of new growth paths. The functional approach of the TIS literature proposes seven system functions that ensure a dynamic system view of technological development (Bergek et al. 2008; Suurs et al. 2009). Studying processes of regional restructuring through a TIS perspective is appropriate, as the structural features within different regions to a large extent influence processes of technological development and diffusion (Rohe & Chlebna 2021).

The system functions contribute to explaining and describing shifts in technology-specific innovation systems and industrial growth paths. The first function that contributes to technological development crucial for industrial restructuring is entrepreneurial activities, simply because, according to the TIS approach, a well-functioning innovation system cannot exist without entrepreneurs. To reduce uncertainty, experimentation in entrepreneurial activities is important because a TIS without experimentation is bound to stagnate (Bergek 2019). The second and third functions are knowledge development and

knowledge diffusion, which capture the depth and breadth of the knowledge base of the TIS, how the knowledge base evolves over time, and how knowledge is combined and diffused throughout the system as a whole (Bergek et al. 2008). The fourth function is guidance of search, which revolves around the fact that there must be a specific focus on the choices for investment in the innovation system. Because markets for new technologies can be either greatly underdeveloped or not even exist, there is a need for market formation, which forms the fifth function (Hekkert et al. 2007; Bergek et al. 2008). This is based on the fact that new technology often struggles to compete with already existing and embedded technologies. Function six revolves around the mobilisation of resources, as resources in different forms are essential inputs to every activity within an innovation system (Hekkert et al. 2007). The seventh and final function concerns how legitimacy is created, as new technology must either become part of or even overthrow an existing technological regime; hence, it will be opposed by parties with conflicting interests (Hekkert et al. 2007). Hekkert et al. (2007) argue that legitimacy is a prerequisite for the formation of both new industries and TISs, but it is not given. On the contrary, it is formed and shaped by conscious actions by relevant actors and organisations through institutional entrepreneurship.

Linking agency and system functions

Within existing literature and theorising there are still few studies of how different types of change agency may affect system functions. However, exploring potential linkages is relevant, as agency has been highlighted in recent studies as a determinant of development processes. Grillitsch & Sotarauta (2020, 705) point out that 'there is a dearth of knowledge about what actors do to create and exploit opportunities in given contexts'. Drawing on different types of agency such as innovative entrepreneurship, institutional entrepreneurship, and place-based leadership, the TCA concept was developed as a tool for analysing agency in emerging regional growth paths (Grillitsch & Sotarauta 2020).

While exact knowledge of how agency relates to the various system functions is somewhat of an 'empirical black box', theoretical arguments for relevant linkages can be proposed. For example, innovative entrepreneurship is a crucial engine of regional industrial development, by triggering path-breaking innovations. While searching for new economic opportunities, innovative entrepreneurs do not shy away from financial or personal risks and they may exploit both emerging and existing opportunities (Sotarauta et al. 2021). As innovation processes, including radical ones, involve high degrees of experimentation, innovative entrepreneurship may thus be linked to the system function 'entrepreneurial experimentation'. By taking a Schumpeterian view of such entrepreneurship, the innovative entrepreneur challenges and may overthrow incumbents, which in turn may foster economic development and growth (Malerba 2020). These processes of experimentation and development of new solutions have the potential to transform the regional industrial 'status quo', which implies either the development of new existing knowledge bases in a region or the alteration of such bases, thereby also potentially drawing a link between innovative entrepreneurship and the system functions 'knowledge development' and 'knowledge diffusion'.

New technology and ideas produced by innovative entrepreneurs are leading to innovations diffusing into markets, which may be underdeveloped or even non-existing (as pointed out in the preceding section, '*System functions: dynamic elements of innovation systems*'). Thus, innovation-based industrial development and growth will require institutional changes such as the creation of new markets (e.g. sheltered niche markets) and shaping of existing markets on different scales. Such changes can be initiated by opportunity-oriented and risk-taking institutional entrepreneurship, potentially linking institutional entrepreneurship to the system function 'market formation'. However, as markets usually are developed through feedback loops between entrepreneurs (companies) and their customers, this system function may also be influenced by innovative entrepreneurs (Binz et al. 2014).

The system function 'guidance of search' is impacted by the variety of choices emerging from specific processes of knowledge creation; hence, it can be influenced by innovative entrepreneurs, as well as by knowledge organisations such as research institutes and universities. However, the possible variety for 'guidance of search' is also determined by institutions such as long-term policy goals and regulations. Institutional entrepreneurs can be defined as 'individuals or groups of individuals but also organisations or groups of organisations that originate change processes contributing to the creation of new institutions and/or transformation of existing ones' (Grillitsch & Sotarauta 2020, 711). Based on this definition, institutional entrepreneurship may have an indirect influence on 'guidance of search', but also on the innovative entrepreneur itself, by determining the 'rules of the game'.

As new technology often is in conflict with existing technology with institutional support, such as norms and regulations, it needs to overcome a process of technology legitimation (Binz et al. 2016b). According to Binz et al. (2016b), such legitimation process can be confronted in two ways: by technology adaptation to

comply with the existing institutional framework, or by adjusting the rules to fit the requirements of the new technology. Accordingly, there are two types of agency that can be argued to be relevant for the system function of 'legitimation'. Adapting the characteristics of the new technology, seems to be a result of entrepreneurial experimentation; hence, innovative entrepreneurship becomes relevant. By contrast, adjusting the institutional framework is a task that reasons with efforts made by institutional entrepreneurs.

Lastly, processes of regional industrial development are made possible through the joint efforts of multiple actors; hence, there is a need for place-based leadership that coordinates activities, resources, and powers for the benefit of both individual objectives and the broader region. Thus, the function 'resource mobilisation' may be influenced by place-based leadership to a large extent.

Analytical framework

While both innovative and institutional entrepreneurship, and place-based leadership are agency roles that matter for industrial development (and theoretical linkages can be drawn), there is little empirical evidence of such agency link up of each of the system functions. Moreover, such linkages may be context dependent, meaning that specific change agency may affect different system function in distinct regions and RISs. To identify agency-system function linkages, a proposed matrix for completion, based on evidence from an empirical enquiry into the industrial development process in Grenland, is provided Table 1. The characteristics of the Grenland region are described in the next section.

Context and method

The case of Grenland

The Grenland region, which consists of 6 municipalities, encompassed a population of c.118,000 people in 2021 and contained the largest concentration of process industries in Norway (Helgersen 2021), primarily focused on production of petrochemicals, metals, and cement. The development of hydropower in the region sparked the start of the modern Norwegian manufacturing industry, and power companies are still among the largest actors in the region after several traditional manufacturing companies. The core of the manufacturing industry in Grenland is located in the industrial park on Herøya and covers 1.5 km, and has c.80 tenants with c.2500 employees (Herøya Industripark n.d.). The overall export share from the firms in the park is 85%, and the park has a well-developed infrastructure, including a 1.5 km port line with 6 individual ports, access to process water, tank terminals, and railways, and an electricity net with a total capacity of 680 MW (Herøya Industripark n.d.).

In an RIS context, Grenland has become highly specialised, building on over 90 years of traditional heavy industrial activities. Furthermore, the region is responsible for over 20% of Norway's greenhouse gases from the manufacturing industry alone: c.2.5 million tons out of a total of 11.19 million tons of CO_2 equivalents in 2015 (Herøya Industripark n.d.). To avoid a potential lock-in, the Industrial Green Tech (IGT) cluster was formed in 2018, with the aim of developing new smart technology and more eco-friendly solutions for the manufacturing industry. Based on this aim, the cluster organisation developed the ambitious vision of becoming the world's first climate-positive industrial region by 2040. Thus, although the Grenland region can be characterised as a 'dirty region', it has ambitions and several actors are working towards a green industrial transition. This makes Grenland an interesting case for testing the relevance of the analytical framework of this article (i.e. what type of agency has been central to the process, and what system functions have been activated).

Table 1. Open analytical framework for identifying agency-system function linkages

System functions	Innovative entrepreneurship	Institutional leadership	Place-based leadership
Legitimation			
Entrepreneurial experimentation			
Resource mobilisation			
Guidance for search			
Knowledge development			
Knowledge diffusion			
Market formation			

Methodology and data collection

The greening of 'dirty' industries in a region holding a thick and specialised regional innovation system was chosen as a case because it is a possibly good context for identifying preconditions and agency that can lead to green transformation of a 'dirty region'. Still, the presented framework is expected to be applicable to regions in general. A case study is suitable for testing the relevance of the analytical framework and potentially adjusting it according to the findings of the empirical analyses. The analysis is based on 22 qualitative interviews, document analyses, and a brief review of recent studies. The interviews were conducted during early

Table 2. Interviewed informants in the Grenland region, Norway

Informant number	Type of actor
1	Cluster manager (departing)
2	Cluster manager (incoming)
3	Leader of the science park (public/private)
4	Business manager (municipality 1)
5	CEO* (intermunicipal company)
6	Marketing manager (private technical company)
7	Industrial counsellor (county municipality)
8	Site manager (large industrial actor 1)
9	Department manager (private technical support company)
10	Mayor (municipality 1)
11	Mayor (municipality 2)
12	CEO (energy supplier)
13	Factory manager (large industrial actor 2)
14	Director of climate and environment (large industrial actor 3)
15	Director of operational excellence (private service provider)
16	Regional manager (labour union)
17	Science leader (local research institute)
18	Counsellor for business development and entrepreneurship (municipality 1)
19	R&D** manager (large industrial actor 4)
20	Port director (public)
21	Technical manager of a port (public)
22	Head of development and application (large industrial actor 5)

*chief executive officer; **research and development

autumn in 2021 with 22 key regional actors in Grenland (hereafter, also referred to as interviewed informants) and one interview was held with each informant (Table 2).

Path tracing methodology

The study on which this article is based used a mixed methods approach, influenced by theorisation on 'path tracing' (Sotarauta & Grillitsch 2023). One critical step in path tracing is defining the starting point of the analysis, which may proceed from a singular event, as the interviewed informants perceived. Another central question revolves around which actors should be in focus. Such actors can be identified by their capabilities to deviate from the current industrial path, and to search for future visions (Sotarauta & Grillitsch 2023). Thus, these actors will not be selected based on their office or decision-making bodies, but on the influential agency they may perform. In this article, the first interviewed informants, important actors, were chosen through desk research and newspaper reviews that revealed who supposedly took the initiative for the green restructuring process in Grenland. Then followed a sequence of 'snowballing', meaning that subsequent interviewed informants were chosen based on the information gathered from the first interviewed informants. The data collection process further involved trying to unravel potential critical junctures, including the starting point of the analysis and what type of agency led up to such junctures. Central questions in this regard were what actors had been active in this specific context and the characteristics of their influence.

All interviewed informants in the study were representatives from the leading industrial firms, a trade union, regional authorities, and the industrial green tech cluster organisation. A semi-structured interview guide was used, which emphasised key actors, coordinating roles, key system functions, and regional competitive advantages for green restructuring. The interviews lasted between 30 minutes and 1 hour, and they were recorded and transcribed. The data were then categorised within key topics drawn from the analytical framework on which the interview guide was based. In addition, desk research was conducted, which involved studying relevant articles, laws and regulations, and strategic plans by both public and private sectors in Grenland.

Green industrial development in Grenland

To discuss the linkage between different types of change agency and utilisation of system resources, there is a need for information regarding how green industrial development evolves in the case of Grenland. This section therefore focuses on important and relevant projects and contributions towards the greening of Grenland's industry.

The process of becoming climate-positive through green restructuring is evolving in many directions in Grenland. Still, the pioneer examples of work towards a green industrial transformation in Grenland are two large ongoing projects that involve electrifying production processes in the production of green ammonia and carbon capture and storage (CCS), which, because of their wide impact on the regional industry, are in focus in this article.

The production of green ammonia project partly involves strengthening of existing regional pathways, whereby 17 firms from the manufacturing industry and technology, logistics, and research organisations are collaborating on establishing a complete value chain within hydrogen production based on renewable energy sources in Grenland. In this regard, one important part of the 'greening' process involves the use of new non-fossil based raw materials in the production of important products. For example, Grenland currently hosts Norway's only factory that produces ammonia based on hydrogen, also known as 'green ammonia'. This type of ammonia is produced entirely without the use of any fossil fuels and is important for more

sustainable production processes, as it can be used in the same way as standard ammonia, which is a central element in nitrogenous fertiliser and is currently being tested in fuel cells (Informant 13). The project, which received 283.25 million NOK in funding from Enova[1], has cut 45% of the factory's CO_2 emissions since 2005 and has committed to cutting a further 30% by 2030. In this case, petroleum gas will be substituted with renewable energy sources in hydrogen production, and this example within one firm alone is estimated to cut CO_2 emissions by c.41,000 tons per year. As the case of green ammonia in Grenland is seen to become the world's first large-scale production of low-carbon fertiliser, it will contribute to reducing the climate footprint, not only nationally but also globally (Lorentzen 2021).

The second project that involves a greener production process is in the production of cement, where 60% of coal usage has been replaced with biofuels and industrial waste since 2013, with the resulting ashes ultimately used in the finished product. In addition to producing more efficiently and using alternative energy sources, the cement factory in Grenland is currently involved in Norway's largest project within CO_2 reduction, financed by Northern Lights JV DA (a cooperation between the commercial parties of Equinor, Shell, and Total) and the Norwegian government (Informant 22), which eventually could lead to a 'CCS path' focusing on Grenland. The CCS facility in Grenland is planned to be completed by 2024 and will play an important role in the local industry's goal of becoming emission-free before 2030. CO_2 resulting from Norwegian gas production has been stored below the ocean since 1996, and the only two functioning CO_2 handling projects in Europe are based in Norway (Ministry of Energy & Norwegian Offshore Directorate 2024). Even though CCS technology is being developed and tested in several locations around the world, Norway can be argued to have built a solid knowledge base concerning this technology, based on three decades of handling CO_2.

In addition to the most readily apparent efforts towards a climate-positive Grenland at the firm level, several contributions have been made within the provision of infrastructure., The industrial park on Herøya not only focuses on its own emissions but also acknowledges that CCS and hydrogen are 'big issues' within the manufacturing industry in Grenland (Informant 3). As a result, the industrial park's managers are working on how to make the park more attractive to regional and external actors within the two aforementioned fields by focusing on a 'plug and play' concept. For example, there is an ongoing project regarding the capture of the rest of the annual CO_2 emissions from the industry in Grenland (c.1.2 million tons remaining after the larger CCS project has removed 0.4 million tons and the green ammonia has removed 0.8 million tons per year). The project was initiated by the industrial park's management team together with the IGT cluster, individual firms, and a local research institute. According to the project plan, this will be a joint facility for receiving and separating CO_2 from the manufacturing industry, to which all firms located on Herøya can connect (Informant 3).

Based on the elaboration above, I see that the green restructuring process in Grenland is mainly taking place through firms focusing on the use of more eco-friendly raw materials in existing production processes and through the use of cleaner energy, such as biofuels instead of coal. Still, the project on CCS technology has the potential for new path development, as it is maintained that CCS will be important worldwide in order to fulfil the United Nation's climate goals (NHO n.d.).

Discussion

Agency and system functions – the story line

The empirical research question discussed in this section is: How can the green industrial development process in the Grenland region be understood through the application of a TCA-TIS framework?

Legitimation of a new vision

According to Grillitsch & Sotarauta (2020), finding common ground that stimulates collective industrial development efforts is often hard because the various actors participating in regional industrial development efforts are pursuing their own interests. This is deemed to be the case also in Grenland, but when comparing the current green development efforts with other grand industrial changes in Grenland in the past, 'something is different', according to several interviewed informants – different in the sense that previous processes of restructuring have been uncoordinated, while the current process concerns a joint development project for the manufacturing industry in Grenland as a whole. This statement is supported by the fact that there have been several attempts to form a regional industrial cluster project in Grenland, based on three industrial networks that have existed there for decades. Still, the

[1]Enova is a state enterprise owned by the Ministry of Climate and Environment.

cluster initiative was not successful until the IGT cluster organisation was formed and gained Arena Pro[2] status (i.e. it became a member of the Norwegian Innovation Clusters (NIC) programme, owned by Innovation Norway, Siva, and the Research Council of Norway) in 2018. The region was also described as consisting of several 'chieftains' after the disintegration of the large core firm Hydro, a resolution that contributed to a segmented and heterogenic industrial culture (Informant 1). Assumedly, IGT managed to accomplish the difficult task of formulating a shared vision, which, to a high degree, is embedded in the regional organisations, industry, the vocational school, the local university, and the public sector. In other words, the cluster organisation performed *institutional entrepreneurship* that contributed to the *legitimation* in Grenland through actions aimed at fulfilling the ambitious vision of becoming climate-positive before 2040. These actions, performed at by institutional entrepreneurs at the micro-level, thus influenced the system function 'legitimation' at the meso-level (regional level), by having an impact on the existing institutional framework. While the road towards more sustainable production methods was already started in the early 1980s, the vision may still be argued to have been the start of the ongoing green development process, since according to several interviewed informants, the process evolves across more dimensions, altering the ways of working and cooperating in the regional industry industrial structure at a far more rapid speed than before. This implies that the development of the vision can be argued to serve as a critical juncture, and it serves as the starting point of my analysis.

This critical juncture was in evidence throughout the interviews, when it became obvious that everyone interviewed was familiar with the vision; it did not make a difference whether the interviewed informant was a member of the cluster project. The enthusiast behind the cluster initiation was pointed out as an essential individual in this work and can be argued to have taken the role of a *place-based leader*, since her actions appear to have impacted the regional industry as a whole. The impact is underlined by the following quote, which describes what happened after the decision to initiate the cluster project was made:

> This wild vision came up, and visions alter behaviour, so it forced these large firms to have an opinion. We went to the process leader council and said, 'Listen! You are responsible for these large emissions. You have to do something' and the CEOs said 'OK'. (Informant 7)

Experimentation and mobilisation of resources

The obligations the process leader council took on after committing to the goal of becoming climate positive within 2040 included allowing firms' chief engineers to spend time on what could be done and how to fulfil the vision. As this implied the deliberation of various industrial resources for one specific purpose, I see that place-based leadership leads to, and can be directly linked, to the system function, namely *mobilisation of resources*.

The mobilisation of resources further contributed to the creation of fertile ground for *innovative entrepreneurship* which is important for experimenting with and identifying feasible projects to help realise the common vision. The mobilisation of resources also became important for enabling the initiation of projects in need of critical inputs, such as human labour and finance. One example is when the cluster management involved a research institute and the local university in developing a roadmap towards becoming climate positive (Informant 17).

Knowledge development

In addition to recognising and dividing between efforts that are climate positive and climate neutral, the roadmap leading to becoming climate positive in turn led to the idea of the creating a centre for climate-positive technologies in Grenland, which was launched during an annual industrial seminar in the autumn of 2021. The centre marks a step beyond the system function entrepreneurial experimentation to *knowledge development* through the refinement of new technologies and the alteration of existing technologies. As the roadmap was, according to the interviewed informants, the initiative that led to the centre, it can be regarded as another critical juncture. Three partners are behind the roadmap that in turn was behind the centre: Herøya Industripark, the IGT cluster, and the local university. In addition, a local digitalisation centre in Grenland will take responsibility for applying to public programmes for funding projects. The cluster management acted as a place-based leader through the initiative for the roadmap and the coordination of resources that further led to the development of the centre for climate-neutral technologies.

Direction of search

I see that innovative entrepreneurs performed entrepreneurial experimentation that contributed knowledge concerning what projects could be feasible in Grenland.

[2]Arena Pro is one of three status levels within the Norwegian cluster programme, and aims to stimulate the clusters' strategic importance.

Hence, this type of agency can be directly linked to the system function, *direction of search*. This system function is, however, also influenced by actors who orchestrate the public funding programmes available for the manufacturing industry, as such actors, for example, focus on specific technologies. Hence, agency in shape of institutional entrepreneurship is also somewhat indirectly linked to the direction of search function in the Grenland case.

Mobilisation of human resources and legitimation

In addition to the cluster management and leaders from the process industry in Grenland, the process leader council includes the leader of the industrial park and representatives from the labour union clubs, thus ensuring that the industrial employees receive information first-hand, such as information regarding structural changes. Information and decisions made in the process leader meetings are then shared and distributed, not only to cluster firms but also to local politicians, thereby ensuring legitimation beyond the manufacturing industry itself. According to one of the club leaders, employees in the industry in Grenland have gone 'silently' through previous restructurings, and they have the highest salaries for manufacturing industrial workers in the country (Informant 16). Based on this, it is reasonable to claim that union clubs, too, have performed agency, and thus contributed to the place-based agency that has been important for the mobilisation of human resources and the alteration of informal institutions linked to the legitimation of new technology.

Supportive versus institutional entrepreneurship

To accomplish large restructuring processes, such as the ongoing process in Grenland, supportive actors that provide infrastructure and other assets, such as knowledge and technical support, are essential. As maintained in the section '*Knowledge development*', actors that work within the infrastructure are playing important roles within the ongoing green restructuring process in Grenland, but the interviews pointed to typical 'supportive actors' (Sotarauta et al. 2021) as taking on roles that went beyond being supportive. For example, the industrial park is supporting changes within the manufacturing industry by providing upgraded infrastructure for production with new raw materials, such as hydrogen and green ammonia, and is contributing to the structural design of new power cables, which are essential for several of the ongoing 'green' projects in Grenland. However, according to several interviewed informants, the leader of the industrial park also contributed to the vision of becoming climate positive together with the initiator of the cluster organisation. The leader seemed to have taken an active role in establishing formal connections between the local university and the manufacturing industry (hence, institutional entrepreneurship links up to knowledge diffusion), and the industrial park was investigating and initiating projects that were going beyond the initiatives taken by the industry, of which the joint CCS project serves as an explicit example. Whereas Sotarauta et al. (2021) define supportive actors as actors that do not 'play the game' themselves, the leader of the industrial park was not only implementing actions based on ideas generated in the industry but was also generating and implementing his own ideas; hence, he was also 'playing the game'. This shows that supportive actors can equally well put on the 'institutional leadership hat' and contribute to essential institutional change for green restructuring processes.

Market formation

As the green restructuring process in Grenland mainly involves producing the same products in a more eco-friendly manner (in addition to the development of completely new technology), markets connected to the end products have already been developed and are functioning well. Still, regarding the CCS project, the fact that the Norwegian government committed to investing 16.8 billion NOK was important for a *market formation* process concerning CCS (Informant 3). Even though the project now concentrates on national emissions, it aims to receive and store CO_2 from several locations in Europe in order to achieve the UN's climate targets (Ministry of Energy & Norwegian Offshore Directorate 2024). The Norwegian government is also financially supporting other global CCS projects (e.g. based in China and South Africa) as part of a process of establishing international collaboration for developing and commercialising new technology, thereby contributing to a possible new industrial path. As projects handling CO_2 are costly, the international collaboration concerns, to a large extent, reducing costs, with the aim of resulting in wider implementation and commitment towards this type of technology. Hence, I see that the Norwegian government is performing institutional entrepreneurship through the establishment of international collaboration networks. As these networks aim at commercialising new technology, the agency performed by the Norwegian government is linked to the two system functions technology legitimation and market formation.

Based on the theory-based elaboration of the empirical results of the study presented in this article I have

identified a pattern consisting of agency linked to various system functions. I have also identified critical junctures, including the logical starting point for the analysis.

An overview of events when agency influenced various system functions during the ongoing restructuring process in Grenland is provided in Table 3. The table contains several empty cells, representing the fact that the study did not reveal change agency-system function links relevant for the given cells. For example, as I have suggested in the section '*Linking agency and system functions*', markets may be shaped through feedback loops between entrepreneurs and customers, indicating a link between innovative entrepreneurship and market formation. During the study of Grenland, it became clear that the external demand for greener products and production processes was lower than the sustainability goal the manufacturing industry had set for itself. So the focus on greener products and production processes *was not* initiated due to current feedback from customers to the innovative entrepreneurs (in this case), but through a combination of a future vision/ideological future vision and a belief that the regulatory framework in which the industry operates will lead to such demands in the future. This means that even though there theoretical links can be drawn between a distinct agency type and system function, it does not mean that it will always (or at all times) be empirically present.

Table 3 also contains cells that are filled with information not indicated by the theoretical elaboration in the section '*Linking agency and system functions*'. For example, based on my theoretical elaboration, I have mentioned in the same section that innovative and institutional entrepreneurship as more important types of change agency for the system function 'legitimation'. However, I found that place-based leadership, and its ability to gather and unify resources (including human resources) had a large impact on informal institutions, including the regional industrial culture in Grenland. The resource mobilisation performed by place-based leadership also led to the 'roadmap', which in turn had an influence on the function 'guidance of search', implying that links can be drawn also between this type of agency and system function. These two examples demonstrate that change/agency-function links are highly context dependent and findings relating to them may vary from one study to another. The examples also show how the three different types of change agency are highly dynamic in nature and may

Table 3. Main events influencing the process of green transition in the Grenland region

System functions	Innovative entrepreneurship	Institutional entrepreneurship	Place-based leadership
Legitimation (1)	–	The leader of the IGT cluster came up with, and received approval for the vision among regional actors that legitimised the commitment towards green technologies.	The IGT cluster, together with the Herøya industrial park and leaders from the process industry, included politicians in their forums, aimed at changing the formal institutions to give better support the ongoing development process.
Entrepreneurial experimentation (2)	Chief engineers in the largest firms within the process industry were given time to experiment and search for possible solutions for more sustainable production processes.	–	The Herøya industrial park, where most of the core manufacturing industry in Grenland is located, started working on solutions and joint facilities to capture the remaining CO_2 on the site (i.e. the CO_2 not captured by the larger CCS project.
Resource mobilisation (3)	–	–	The obligations undertaken by the process leader council implied the deliberation of resources for one specific purpose: to become climate positive. The representatives from the labour unions mobilised human resources to support changes in informal institutions.
Direction of search (4)	Entrepreneurial experimentation led to knowledge of what projects where feasible, which in turn influenced the direction of search.	–	The roadmap towards becoming climate positive is functioning as a guide to what projects can or should be initiated, hence influencing the direction of search.
Knowledge development (5)	The centre for climate-positive technologies contributes to the refinement of new and existing technologies. The green ammonia project is building new knowledge and competence concerning hydrogen.	–	–
Knowledge diffusion (6)		The Herøya industrial park has contributed to the institutionalisation of couplings between the local industry and the regional university.	–
Market formation (7)	–	The Norwegian government is directly financing the carbon capture and storage (CCS) project, thereby stimulating market formation.	

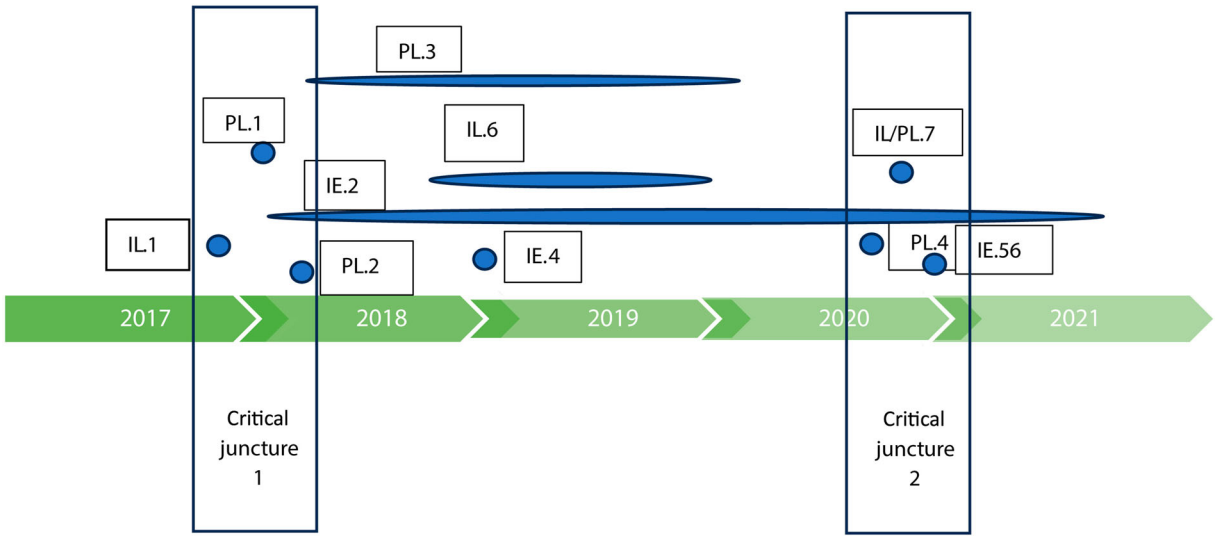

Fig. 1. Timeline of important events that influenced the green transition process in the Grenland region, 2017–2021 (IE – innovative entrepreneurship; IL – institutional entrepreneurship; numbers indicate system functions)

be expanded to encompass more (or less) than what is suggested by existing theory.

The events listed in Table 3 are shown as a timeline in Fig. 1, thus pinpointing how the interplay between several types of agency and system functions contributes to the path development process within the studied manufacturing industry. Based on the timeline of events, the results of the study highlight two critical junctures: the agreement on the vision that marks the starting point for the analysis and a specific point in time where several types of change agency jointly contributed to the realisation of a wide array of projects. These critical junctures are characterised by different types of agents and agency that have a strong influence on the alteration and development of certain system functions.

Furthermore, the empirical analysis has shown how the joint actions of change agents on a micro-level can lead to changes on a more meso-level (regional level) by activating the various system functions. This is shown in Table 4, which provides an overview of agency-function links and the broad influence such links have at the regional level in Grenland. For example, the study revealed how institutional entrepreneurship to a large degree influenced the legitimation of new technological solutions by developing the vision, as well as initiating resource formation, thus forming the regional foundation on which the proceeding parts of the green transformation process in Grenland would be based. These changes on the regional level had an impact at the micro-level through increased investments towards green restructuring among firms.

In the same vein, innovative entrepreneurship at firm level leads to enhanced innovative activity and knowledge flow in the regional innovation system through

Table 4. Overview of agency-function links and both the meso-effects and micro-effects of the links

Type of agency	Linked system functions	Meso-level changes (regional effects)	Micro-level changes (firm-level effects)
Institutional entrepreneurship	1. Legitimation 2. Resource mobilisation 3. Guidance of search 4. Knowledge diffusion 5. Market formation	The creation of the vision stimulating joint actions in the innovation system in order to develop and secure resources aimed at fulfilling the goal of becoming climate positive	Increased investments towards green restructuring at firm level, also potentially increased competitive advantages in new and existing markets
Innovative entrepreneurship	1. Entrepreneurial experimentation 2. Knowledge development 3. Knowledge diffusion	Innovative entrepreneurship contributing to enhanced innovative activity and knowledge flow in the regional innovation system	Increased possibilities for innovation among individual actors and organisations in Grenland through new technological solutions
Place-based leadership	1. Legitimation 2. Resource formation 3. Market formation	Pooling of regional and extraregional resources, and coordinating actions towards fulfilling the widely supported vision	A wide array of resources both supports and adds to the possibilities of firms becoming greener in Grenland (e.g. through easier access to finance and important competence).

entrepreneurial experimentation, knowledge development, and knowledge diffusion. In this regard, the couplings made between the industrial park on Herøya and the local university will contribute to knowledge flow between both sides, ensuring that new employees in the region will hold the right competence for industrial work. This may ultimately also increase number of possibilities for innovation at the firm level.

Lastly, the study findings demonstrate that place-based leadership is important for mobilising important resources, such as human and financial resources. Place-based leadership, together with innovative entrepreneurship triggered a range of experimentation projects among local firms and research institutes, resulting in the 'roadmap' towards achieving the goal of the joint vision, which functioned as a guide towards the commonly agreed actions and resources for achieving this goal. As new technology concerning CCS proved to be successful, one important event was the Norwegian government's decision to provide substantial financial support for the CCS project. The support opened up the possibility for more large-scale testing at firm level, which in turn contributed to knowledge development and diffusion through international collaboration.

Conclusions

In this article I have demonstrated that regional industrial development/green regional industrial development processes are complex and can be understood as interplays between different types of actors that influence system functions. Furthermore, I have demonstrated how such processes can be broken down into regional-specific patterns of change agency-system function constellations. Enhanced knowledge concerning such micro-processes, and how actions by individual actors on a micro-level may influence regional specifications and foundations for future industrial development, may contribute to more 'tailored' policy strategies within different regions.

The framework has proven useful for analysing green restructuring in Grenland, and may thus be regarded as a central theoretical contribution to the literature on green regional industrial development. Additionally, I have suggested avenues for further discussions on how restructuring processes can be broken down and approached by applying the understanding of how actors utilise the seven system functions that ensure a dynamic system view of technological development. Future research could, for example, focus on other types of regions and contexts, and examine to what extent the analytical framework is theoretically generalisable and could possibly be further developed.

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No potential conflict of interest was reported by the author.

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