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Expanding Analyses of Path Creation: Interconnections between Territory and Technology

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abstract

Theoretically and conceptually, evolutionary economic geography has paid little attention to technological characteristics when explaining the emergence of new industries. Building on the literature on technological innovation systems, the article develops a framework for investigating interconnections between territorial dynamics and technological characteristics in path creation processes. The theoretical argument is operationalized in an analytical framework that is applied in empirical investigation of two green technologies and their linkages to the region of southwestern Norway, namely, carbon capture and storage and maritime battery technology. As illustrated by the empirical investigation, territorial dynamics or technological characteristics alone do not explain path creation. Rather, interconnections between the two and how interconnections play out in time and space are considered focal.

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In general, the point of departure of evolutionary economic geography (EEG) has been how territorial, typically regional, capabilities influence future development trajectories, with a focus on, for example, knowledge sharing, support structures, and industrial policy (e.g., Hassink, Isaksen, and Trippl 2019). EEG contributes an analytical palette for investigating the emergence of new industries and the time–spatial dynamics of such processes, but we believe that EEG lacks convincing theoretical and analytical clarity regarding technology and its linkages to industry development. Drawing on the literature of technological innovation systems (TIS), this article examines the interconnectedness between territorial dynamics and technological characteristics in shaping how new industries emerge in regions. Moreover, though much EEG work has investigated the emergence of new industries, far less attention has been directed toward *green* industrial development and industry emergence processes, that is, how (new) technology and industrial activity can contribute to a reduction in environmental burdens.[1] In other words, EEG is a literature that "in principle is agnostic about the greenness of the developed industries" (Grillitsch and Hansen 2019, 15), inadequately linking to recent debates on how society can move toward sustainability through green path creation (Tödtling and Trippl 2018; Trippl et al. 2020).

This article seeks, in part, to address this gap through an analysis of the interconnections between territorial dynamics and technological characteristics in path creation by incorporating insights from the literature on TIS. In doing so, we pose the following research questions:

- How does EEG explain the emergence of new industries?
- How can the TIS literature inform EEG-inspired analyses of path creation in regions?

In addressing the first question, we discuss the EEG literature and its approach to path creation, before the second research question investigates what the TIS literature offers EEG through its

[1] Green industry is here understood as industry where "growth in income and employment should be driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services" (UNEP 2011, 2).

focus on technological characteristics. This leads to development of a theory-informed analytical framework that is exemplified by empirical investigation of two green technologies; carbon capture and storage (CCS) and maritime battery technology (MBT), and their linkages to path creation processes in southwestern Norway. Finally, conclusions and areas for future research are outlined.

Theoretical Background

A central finding in the EEG literature is that relatedness between activities in a region influences the success (or lack thereof) of new industrial activities (Neffke, Henning, and Boschma 2011; Cooke 2012). Among several definitions of path creation, we adhere to that by MacKinnon et al. 2019a, 3) who define path creation as "the emergence of new development trajectories in a region based upon the growth of new industrial sectors or new products, techniques and forms of organisation." This process may occur "through inward investment, the sectoral diversification of firms through path branching or the establishment of new firms and spin-offs" (MacKinnon et al. 2019b, 3). This implies that new industries are latent in already existing regional activities (Aarset and Jakobsen 2015). This definition of path creation is less radical than that proposed by, for example, Grillitsch, Asheim, and Trippl (2018), who define new industries as radical changes in existing industrial structures, often resulting from groundbreaking scientific research and new knowledge. Similarly, Hassink, Isaksen, and Trippl (2019) consider path creation to involve a high degree of novelty and radicality, arguing that path creation represents novelty to the world.

EEG and Path Creation

Martin (2010) distinguishes between *preformation, path creation*, and *path development* as phases in the evolution of a (new) industry. In the *preformation* phase, economic resources, technological solutions, policy initiatives, and purposeful agents are in place, but the potential for *path creation* is yet to be realized. The shift to path creation is characterized by purposive experimentation, technology development, and competition between agents leading to the emergence of a new path. Following this, the *path development* phase is characterized by increasing returns, new entrants, and expansion into new markets and niches; thereby, a new industry is created. Several studies have been conducted on how paths evolve in regions, and, of interest to this article, how paths are created. Our review of the literature finds that EEG identifies four key topics toward path creation: *regional capabilities, multiscalar dynamics, actors and agency*, and *policy*.

In EEG, explanatory weight has largely been placed on *regional capabilities* to explain industrial development, where empirical research, for example, has shown how regional industries are reproduced over time and that related variety (or the lack thereof) in regional settings explains innovation outputs (or the lack thereof) (Neffke, Henning, and Boschma 2011; Aarstad, Kvitastein, and Jakobsen 2016). Thus, EEG holds that industrial development trajectories are linked to choices made in the past and that the scope of action and contingencies is largely conditioned by former practices and choices taken in spatial, typically *regional*, contexts (Martin and Sunley 2006; Boschma and Frenken 2011). Similarly, it has been argued that regional contexts can both trigger and hinder new industry activity (Isaksen et al. 2018). For instance, among the few contributions that approach green path creation quantitatively, Corradini (2019) builds on data from 900 NUTS3 regions spanning fifteen European countries in an investigation of green technology entry. The study emphasizes the role of regional capabilities in explaining the emergence of green innovators, showing that new green innovators "are more likely to develop in regions defined by higher levels of technological activity underlying knowledge spillovers and more dynamism in technological entry"; furthermore, regions "whose innovation activity is defined by cognitive proximity to environmental technologies support interactive learning and knowledge spillovers underlying entrepreneurship in this specific area" (Corradini 2019, 845). In other words, Corradini (2019) finds that green path creation is more likely to take place in regions with the right capabilities. However, the core EEG argument that relatedness, and more recently *un*related variety (Grillitsch, Asheim, and Trippl 2018), influences (future) innovation propensities and (new) industrial development paths (Frenken, van Oort, and Verburg 2007) struggles to explain how novelty is introduced, leading to interest on the role of multiscalar dynamics and agency in emergence of new industries in a region.

Recent research has emphasized that regional economic activity is highly influenced by *multiscalar dynamics*, particularly the interactions between different spatial scales and geographies that can influence foreign direct investments or the operations of multinational companies within territories (Binz, Truffer, and Coenen 2016; Trippl, Grillitsch, and Isaksen 2017). Expanding the strong focus on regional settings, Essletzbichler (2012) focuses specifically on renewable energy technology and how regions in the UK can support industrial formation linked to it. He argues for the importance of focusing on multiscalar dynamics and policy, claiming that the emergence of industries for renewable energy technology is impossible to understand without also looking at the UK as a whole and in comparison with other countries. Similar arguments are made by Afewerki, Karlsen, and MacKinnon (2019), Chlebna and Simmie (2018), MacKinnon et al. (2019b), and Miörner and Trippl (2019) who discuss how path creation is influenced by multiscalar dynamics and not just by regionally contained institutional settings.

Recent EEG research has emphasized the importance of *actors and agency* in shaping the evolution of regional industries (Boschma et al. 2017; Miörner and Trippl 2017). For instance, it has been argued that different agents respond differently to similar regional systemic settings (Zukauskaite, Trippl, and Plechero 2017). Linked to this, it is argued that agency can—and should—be performed by both firm and nonfirm actors, if it is to result in real changes to industrial activities in a region (Binz, Truffer, and Coenen 2016; Isaksen et al. 2018; Steen and Hansen 2018; Kyllingstad and Rypestøl 2019). This means that to change an industry or path, different types of actors, (Smith, Rossiter, and McDonald-Junor 2017) and their actions, for example, Schumpeterian entrepreneurship, institutional entrepreneurship, and path advocacy (Grillitsch and Sotarauta 2019), should be taken into consideration. For instance, Simmie, Sternberg, and Carpenter (2014) investigate the emergence of the British and German wind energy industries. They highlight that actions performed by purposeful actors operating in these two different territories provided different potentials for new path creation, in turn explaining why the introduction of new technologies for wind energy started earlier in Germany compared with the UK. This not only illustrates how the *mindful deviation* (Garud and Karnøe 2001) of actors is an important dimension of new path creation but also that actors and their actions are influenced by territorial context (Simmie, Sternberg, and Carpenter 2014). However, it is also argued that *how* a path evolves may impact different spheres of society differently (MacKinnon et al. 2009), meaning that EEG is increasingly concerned with the roles of broader sets of actors (e.g., policy makers, nongovernmental organizations [NGOs], system actors) than just commercial entrepreneurs (Dawley et al. 2015; Isaksen et al. 2018; MacKinnon et al. 2019a).

Recent contributions have argued that *policy* is critical for path creation and that EEG should pay more attention to its influence on the directionality of industrial development (Tödtling and Trippl 2018; Grillitsch and Hansen 2019). Although the role of policy is discussed in several studies, a particularly useful approach for understanding policy strategies for path creation is that by Garud and Karnøe (2003). The distinction between *bricolage* and *breakthrough* approaches to policy in the processes of path creation is pedagogical and useful. The bricolage approach gives policy a role in developing competence and capabilities across a wide population of (firm and nonfirm) actors, while the breakthrough strategy involves the focusing of resources and efforts on few, and often large, players or initiatives (Garud and Karnøe 2003). A bricolage approach promotes distributed agency, embedded involvement, and bottom-up processes, and implies a gradual development of new technologies through incremental steps (Bugge and Bloch 2016), thereby stimulating interactive learning between the involved actors. The bricolage perspective is especially valuable when markets are characterized by fragmentation or niches and when new products require customization to customers or groups of customers (Berchicci 2009). For instance, a study of the *policy mix* for wind energy in Spain illustrates that "national and regional governments play a key role in the sector development by providing market signals, financial support and mechanisms to articulate different actors and their capacities" (Matti, Consoli, and Uyarra 2017, 661). Conversely, the breakthrough approach favors leapfrog advances and downplays the role of collective learning and adaptiveness (Garud and Karnøe 2003). In some cases, the strategy is based on overconfidence in one or a few technological solutions; the strategy emphasizes the revolutionary characteristics of innovation and that preferred technology solutions should be able to penetrate different markets (Berchicci 2009).

Considered more broadly, EEG's approach to innovation and its inherent policy advice have been criticized for stimulating *any* innovation, and not necessarily innovations that can contribute toward development in a given, for example, green direction (Tödtling and Trippl 2018; Sjøtun and Njøs 2019). It has, therefore, been argued that EEG is neutral toward policy in the sense that it encourages industrial development per se, and not necessarily green industry development and the emergence of new green industries (Grillitsch and Hansen 2019; Sjøtun and Njøs 2019). In addition, the role of technological characteristics in enabling/hindering path creation have been less explicit in the EEG literature (exceptions include, e.g., Binz, Truffer, and Coenen 2014, 2016). In general, technology is treated as an output and typically read off from regional capabilities and dynamics, meaning that technological characteristics have largely been considered *ex post* rather than *ex ante* in EEG. However, as the TIS literature argues, "the innovation itself [is] a part of the system" (Markard and Truffer 2008, 599), implying that technology as an artifact should be given explanatory weight (Bergek et al. 2008; Suurs et al. 2010).

Insights from the TIS Approach

It has been argued that the TIS approach is particularly useful for understanding path creation given that it is "an analytical framework for understanding the complex nature of the emergence and growth of new industries and [focuses] on analyzing obstacles to this process" (Bergek et al. 2015, 52). Taking into consideration a range of socio-technical dimensions (Carlsson and Stankiewicz 1991), TIS research typically focuses on specific technologies (Bergek et al. 2008; Suurs et al. 2010) and analyzes the emergence of new technology by heuristically applying seven empirically derived functions encompassing a range of hard and soft indicators. A TIS can be defined as "a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology and/or a new product" (Markard and Truffer 2008, 611). Building on empirical research of, normally, new technologies, the perspective holds that the development and successful (or unsuccessful) implementation of new technologies rely on the interplay between different key processes—*functions*—in dynamic systems, in which the structural components are actors, networks, and institutions (e.g., Bergek et al. 2008). These functions are (Schumpeterian) *entrepreneurship, knowledge development, knowledge diffusion* (through networks), *guidance of the search, market formation, resources mobilization*, and *creation of legitimacy/counteracting resistance to change* (Hekkert et al. 2007).

Importantly, TIS research explicitly focuses on technological characteristics and materiality (e.g., infrastructures) by examining, in part, how new technology is framed, lobbied, legitimated, and/or supported by directed policies and policy mixes (Markard, Suter, and Ingold 2016; Normann 2017) and how multiscalar processes influence technological development (Binz and Truffer 2017; Bauer and Fuenfschilling 2019). For instance, building on EEG and TIS, Binz, Truffer, and Coenen (2016) emphasize that attention should be given to key resource formation processes in path creation, that is, market development, knowledge generation, financial and human resource mobilization, and technology legitimation. Additionally, it should be noted that the TIS approach has typically been applied to studies of green technologies, where it is crucial to build legitimacy and demand for new markets (Markard, Raven, and Truffer 2012; Markard, Wirth, and Truffer 2016).

As discussed, the focus of EEG in studies of path creation has been on regional capabilities, multiscalar dynamics, agency, and policy. Although this focus resonates with four of the functions in TIS (entrepreneurial activity, knowledge development, knowledge diffusion, and resource mobilization), we believe that recent research in EEG offers more fine-grained explanation and less instrumental approaches to these functions by nuancing their contextual underpinnings (Coenen, Benneworth, and Truffer 2012; Coenen 2015; Binz et al. 2020). Both EEG and TIS emphasize the role of policy, but much EEG work has, as discussed, been criticized for promoting neutral innovation policies (Tödtling and Trippl 2018; Sjøtun and Njøs 2019). Within TIS, there is explicit focus on policy advice for green industry development (Lovio and Kivimaa 2012; Reichardt et al. 2016). For instance, it is argued in the TIS literature that green technologies are new and challenge existing industrial practices, markets, and regulations, and that new technology must typically be supported by public actors and policy (Markard, Suter, and Ingold 2016). Moreover, as EEG is a perspective that, in general, has overlooked the role of technological characteristics in explaining path creation, the TIS functions *guidance of the search, market formation*, and *legitimation* contribute to advancing and nuancing the EEG approach. In addition, the TIS literature contributes insight to EEG regarding how functions are dynamically interconnected and how one or several functions may hinder or drive path creation.

Integrating TIS Functions into EEG

In TIS, the *guidance-of-the-search* function relates to those activities associated with a (new) technology "that can positively affect the visibility and clarity of specific wants among technology users" (Hekkert et al. 2007, 423). In most cases, resources for technology development are limited, and when there are different competing technologies, one or a few technologies may succeed in attracting further investment, for example, because of a focus on a particular technology by government representatives, technology producers, and/or technology users. In turn, this provides clear guidance for further support and development, that is, a direction for further development.

TIS studies are explicitly concerned with *market formation* dynamics that are essential for technological development and diffusion. As stated by Martin, Martin, and Zukauskaite (2019, 4) with respect to EEG “it seems fair to state that the current literature on new regional industrial path development has left the notion of demand largely unconsidered” (see also MacKinnon et al. 2019a). It is often difficult for new technologies to compete with established and embedded technologies. The size of a market is often limited and a (new) technology’s price performance may be poor (Bergek et al. 2008). Thus, especially in the early phase of market creation, there is a need for market nursing through governmental initiatives such as protected space for new technologies or specific tax regimes. Market nursing allows for an increase in technology producers and technology users toward the development of cost-efficient and competitive technology solutions.

In TIS, *legitimation* is about overcoming barriers from existing technologies/industry activities, for example, through lobbying activities by advocacy coalitions working toward broader acceptance of a technology (Hekkert et al. 2007; Markard, Suter, and Ingold 2016). To mobilize sufficient resources for further development, a technology needs to be considered appropriate by the government, research milieus, and industry actors (Bergek et al. 2008). Legitimation can be considered a social process explaining the acceptance or not of, for instance, a new technology or industrial activity, meaning that legitimation for a technology can vary between spatial contexts or be more or less universal (Johnson, Dowd, and Ridgeway 2006; Binz and Truffer 2017). If a technology lacks legitimation/acceptance in society, this can be a barrier for its emergence; however, since legitimation is a social process, it can be altered or strengthened, for example, by positive media reports or demonstration projects (Sjøtun 2018). In other words, successful diffusion and implementation of technologies demands (strong) legitimation among broad sets of societal actors, for example, policy makers, finance institutions, and other stakeholders.

The integration of these TIS functions into EEG frameworks, leads us to seven analytical dimensions that should be taken into consideration when studying path creation in regions (Table 1). The framework is also inspired by MacKinnon et al.

Table 1

Analytical Framework and Operationalization of Dimensions: EEG and TIS Combined

		Operationalization
Analytical dimensions emphasized by EEG	**Regional capabilities**	*Existing economic activities and how/if they are linked to a support system; focus on, e.g., dynamics, knowledge flows, interaction, skills, labor mobility, spin-offs*
	Multiscalar dynamics	*Interactions across space involving, e.g., intangible flows of ideas, practices, knowledge, etc.*
	Actors and agency	*Firm and nonfirm actors and their actions; Schumpeterian and institutional entrepreneurs and path advocates*
	Policy	*Bricolage (policy mixes) and breakthrough approaches*
Analytical dimensions from TIS informing EEG	**Guidance of the search**	*Momentum, i.e., a direction, for further support and development; i.e., selection processes under which (new) technologies operate*
	Legitimation	*Perceptions regarding a technology; acceptance and resistance*
	Market formation	*Commercial opportunities and market demand, e.g., by public subsidies*

(2019a) who suggest that regional and extraregional assets, actors, mechanisms, market construction, and the institutional environment are key to understanding path creation. In contrast to this approach, however, our framework is more concerned with discussing the interconnectedness between territorial dynamics and technological characteristics, something that is elaborated on below.

Considering Martin's (2010) path-as-process perspective and the TIS argument that dynamics between system functions evolves over time (Suurs et al. 2010), the dimensions emphasized in Table 1 are necessarily dynamically interconnected. This means that one dimension can influence one or several others, that there can be particularly important interconnections between two or several of the dimensions, or that one or several of the dimensions may hinder the emergence of new industries. Moreover, as Martin (2010) argues, there are different phases in path creation processes (see also Bergek et al. 2008), and certain dimensions and/or interconnections may be particularly important in different phases and, not least, different *places*. For instance, Binz, Truffer, and Coenen (2014, 139) argue that "tracking the activities of core actors over time, processes like knowledge creation, entrepreneurial experimentation or market formation can be related to specific spatial setups." In other words, though some key resource formation processes must be present (Binz, Truffer, and Coenen 2016), territories and technologies come together differently in different contexts (Binz and Truffer 2017).

While EEG places particular emphasis on the regional level and its role in facilitating networking, access to resources, knowledge sharing, etc. in our framework (Table 1), it is not territorial dynamics (EEG) or technological characteristics (TIS) alone that explain path creation but, rather, their interconnectedness. Thus, it is difficult a priori to ascribe importance to one dimension over another in our analytical framework. For instance, both the EEG and TIS literatures emphasize the role of policy in the preformation phase, but, simultaneously, policy is often influenced by purposeful agency by actors either directly or indirectly through lobbying efforts aiming to strengthen the legitimacy of a new technology or industrial opportunity (Markard, Suter, and Ingold 2016; Normann 2017; Sjøtun 2018). Similarly, Steen and Hansen (2018) focus on spatial context in their study of barriers to industrial path creation of offshore wind technology. They find that the potentially emerging industry experiences barriers from other existing industries (i.e., established paths), suggesting that resources to and the legitimacy of offshore wind technology have decreased due to changes in the context in which it is evolving (i.e., Norway). Thus, it can be argued that territorial dynamics may not only enable emergence of new industries but can also be a barrier to path creation.

In sum, the analytical framework developed here emphasizes the dynamic interconnectedness between territorial dynamics and technological characteristics for explaining path creation, but also that such interconnections must be investigated empirically in order to find out which dimensions and/or interplays between dimensions are particularly important where, when, and why. We now illustrate the framework's utility through two case studies of green technologies in southwestern Norway.

Methodology and Data Collection

Given EEG's strong focus on regions and the literature's emerging interest in green economic development, we apply our framework to investigations of the interconnections between a regional setting and two green technologies that are in different phases of development. Given that EEG emphasizes territorial, and particularly regional, dynamics in explaining the emergence of new industries, we should expect that the two technologies are similarly influenced given they are in the same territorial context. The two cases—CCS technology and MBT—have received considerable attention and support both in the media and in the (Norwegian) policy landscape given, in part, that they represent industrial diversification opportunities for southwestern Norway. Moreover, these industries can contribute to a reduction in environmental burdens, thus representing examples of potential green path creation.

Methodologically, we adhere to George and Bennett's (2005, 5) approach in which case studies are a "detailed examination of an aspect of a historical episode to develop or test historical explanations that may be generalizable to other events." Literature reviews and previous studies provide information on the two technologies (see, e.g., van Alphen et al. [2009] for CCS and Steen et al. [2019] for MBT). However, importantly, we have gathered primary data to shed light on the interconnections between territorial dynamics and technological characteristics in the two cases.

In the case of CCS, fourteen interviews were conducted (2018–19). Although some of the informants are located in the region, the majority are located elsewhere in Norway. Interviews were conducted with six commercial actors, two representatives of research and development (R&D) organizations, three representatives from the public sector, one NGO, and two industry developers. Informants cover a wide spectrum of expertise, from firms and technology developers to regulators, judicial expertise, R&D, and industry facilitators. In the case of MBT, twenty-three interviews were conducted (2012–18), mainly in the region, with commercial actors, representatives from maritime consulting/classification and regulation, the public sector, politics, cluster and interest organizations, and NGOs. Interviews focused on various themes on the barriers and enabling factors for the development of environmentally friendly maritime technologies in the region and beyond. Data were also collected through participation in various maritime conferences, seminars, and workshops. For both cases, a large amount of secondary data was surveyed and categorized over time, particularly from the news media and reports (by consultants, interest organizations, regional development agencies, etc.).

We also collected data on the southwestern Norway region (Figure 1), which is defined here as the counties of Hordaland (505,000 inhabitants) and Rogaland (473,000 inhabitants). Due to its proximity to the North Sea, the region is the most important area for the Norwegian petroleum industry, with an employment of approximately 58,000 person-years in 2015 (Economics Norway 2017). In addition, the region has a strong position in the maritime, marine, and other energy industries. However, given the region's strong anchoring in the petroleum industry, recent oil price fluctuations, and increased awareness of the negative environmental impact of oil and gas, several initiatives toward a greener and more sustainable economy have arisen, including CCS and MBT. To gain insights into the dynamics and capabilities of the region, we conducted interviews with fifteen regional stakeholders, including public actors, (environmental) NGOs, R&D organizations, industry development agencies, and, in particular, influential firms and industry representatives. The interviews revolved around topics such as regional development, emerging green technologies, and the potential for green path creation.

Empirical Investigation

CCS is a collective term for technologies intended to remove and sequester CO_2, whereas carbon capture and *utilization* is a collective term for technologies and

Figure 1. Norway. Studied region in grey, showing the two largest cities in southwestern Norway and the capital Oslo.
Source: Wikipedia/CC BY-SA 2.5, modified by Emil Tomson Lindfors.

processes applying CO_2 for different purposes (see, e.g., Pires et al. 2011; Markewitz et al. 2012). The European Commission, the International Energy Agency (IEA), and the Intergovernmental Panel on Climate Change (IPCC) consider CCS central to attaining the objectives of the Paris Agreement. According to the IEA, to achieve the targets, CCS technology must account for around 14 percent of the required emission cuts, meaning that over 2,500 large-scale CCS facilities must be in operation by 2040 (Global CCS Institute 2018). As of 2018, eighteen CCS facilities are in operation, five are under construction, and twenty are in various stages of development worldwide. Together, these facilities will capture and store about forty million tons of CO_2/year (Global CCS Institute 2018). Studies of CCS technologies from a TIS perspective (see, e.g., Lai et al. [2012] for CCS in China and van Alphen et al. [2009] for Norway) point out that governmental support is crucial for the success of the technologies (Kern et al. 2016) and that entrepreneurial activities, market formation, and, in some contexts, legitimation and guidance of the search are necessary for the technology to gain a foothold (van Alphen et al. 2009; Lai et al. 2012; Markusson et al. 2012).

MBTs are those technologies designed for implementing fully electric or hybrid battery and fossil fuel energy systems on ships, and/or charging technology supplying ships with electrical power.[2] The development of MBT has been driven by the global car manufacturing industry, which saw a 50 percent increase in global sales of electric vehicles (EVs) from 2016 to 2017 (IEA 2018). Battery cells used in EVs are mostly produced by major firms in Asia (e.g., Samsung, Panasonic, and Toshiba), and the scale of production of these firms has caused a sharp drop in the price of lithium-ion batteries, which are by far the most dominant and commercially viable battery technology today (International Energy Agency 2018). Furthermore, the storage and lifetime capacity of batteries is continuously increasing due to innovation pressure in the car industry, leading to new generations of batteries. This has also had implications for the maritime industry; from having almost no battery ships in 2009–10, there are now around three hundred battery-driven ships in commercial traffic around the world (Maritime Battery Forum 2019) either already sailing or under construction. In the discussion that follows we assess, for each case, the seven dimensions or factors shaping path creation processes for CCS and MBT in southwestern Norway. Table 2 summarizes the results.

CCS Technologies

Southwestern Norway has a strong oil and gas industry; inter alia, the area is known for its leading expertise in subsea technology. Several large multinational oil and gas companies operate in the region, which is characterized by its strength in ocean-related industrial activities (petroleum, maritime, marine, and renewable energy) (Njøs 2018). Informants argue that petroleum companies have the expertise required for the transportation and storage of CO_2, and that they can utilize *regional capabilities* in this task. Moreover, informants argue that CCS represents potential for other industrial activities such as clean hydrogen production from natural gas.

The region hosts Technology Centre Mongstad (TCM), an advanced test facility for CCS, which was funded by the Norwegian government and cost approximately 7.4 billion Norwegian krone (NOK) (Atkins and Oslo Economics 2016), and is today run as a collaboration between the Norwegian state, Equinor (Norway's biggest oil company), Shell, and Total. TCM has been in operation since 2012 and is according to informants recognized as a global leader in its field, with (commercial) actors from all over the world coming to the facility to test and further develop capture technology. However, TCM has sparked surprisingly little commercial activity in the region, for example, spin-offs and start-ups, nor has it served as a guidance of the search for existing economic activities. In other words, although southwestern Norway possesses latent capabilities for CCS, particularly regarding transportation and storage of CO_2, industrial activity is yet to emerge. We believe this can be explained particularly by national-level processes and technological characteristics.

Norway is one of the pioneers in CCS (Markusson et al. 2012). Triggered by commercial considerations and the introduction of a CO_2 tax in 1991, at the Sleipner (from 1996) and Snøhvit (from 2007) gas fields, about 1.7 million tons of CO_2/year are injected into subsea reservoirs after removing it from extracted natural gas (Atkins and Oslo Economics 2016). Sleipner was the world's first commercial CCS project, while

[2] This can refer to both land power, which ships without batteries also can take advantage of, and battery charging technology, which supplies ships' batteries with electrical power when they dock.

the world's first offshore pipeline for CO_2 transportation was built at Snøhvit (see van Alphen et al. 2009). In 2007, former Prime Minister Stoltenberg announced that CCS represented a huge opportunity to address global environmental challenges, referring to CCS as Norway's *moon landing* (see Haarstad and Rusten 2016). Most prominently, this led to the building of TCM. However, in 2013, plans for a full-scale CCS facility at Mongstad were abandoned by the national authorities, symbolizing, at least in the media, the end of the moon landing project. However, the Paris Agreement has triggered renewed interest in CCS, both globally and nationally (see below), demonstrating the importance of *multiscalar dynamics* in shaping the industry's potential emergence.

Interviews and secondary data show that although regional *actors and their agency* have played a role in the history of CCS in Norway (e.g., in the processes leading to the building of TCM), they have yet to mobilize orchestrated efforts toward CCS. Large global oil and gas players like Equinor, Total, Shell, and Aker Solutions are involved in CCS in the region (as throughout Norway), but there are few companies dedicated to CCS, particularly to capture technology. This is not surprising given that CCS is an immature and highly expensive technology solution. Regarding institutional entrepreneurship and path advocates, we find few visible and powerful actors in the region that can be ascribed such roles, and it appears that CCS is currently a matter of supraregional circumstances (Normann 2017).

As part of the moon landing project, the agency Gassnova was established by Norwegian authorities. Gassnova is a publicly owned agency that is part of the policies and initiatives to support CCS. Together with the Research Council of Norway, Gassnova contributes to CCS R&D through the Norwegian RD&D CCS Programme (granting about two hundred million NOK annually to CCS projects). In addition, Gassnova lead the development of a full-scale demonstration project and the state's interests in the TCM. Furthermore, the policy scheme Centres for Environment-friendly Energy Research (FME), run by the Research Council of Norway, has played an important role in the development of R&D expertise in CCS (Atkins and Oslo Economics 2016). The FME tool grants financial support to research on and the industrialization of environmentally friendly technologies (eight to twenty million NOK annually over eight years). Two CCS research centers were supported from 2009 to 2017, one of which (focusing on CO_2 storage) was hosted by an R&D institution in southwestern Norway. A third CCS research center was granted funding from 2016. In other words, (public) R&D efforts have been substantial and long term; thus, the national *policy* strategy resembles a breakthrough strategy focusing on technical issues and the creation and diffusion of R&D knowledge (see van Alphen et al. 2009).

There is consensus among informants that CCS, together with other green technologies, is needed for mitigating climate change. From an analytical perspective, it can be argued that the development of TCM and the substantial activities of oil and gas companies in the region give the search for CCS technology clear *guidance*. However, for reasons discussed above, the search for cost-efficient CCS technology currently lacks momentum, but this may change in the future. Interestingly, the topic of CCS is now returning to the policy and media agenda in Norway, since a full-scale demonstration project for capture, transportation, and storage of CO_2 is being planned. Informants are very optimistic toward the project, which is led by Gassnova.

In the project, the plan is to capture CO_2 at two industrial facilities in eastern Norway. Captured CO_2 will be transported to interim storage near a natural gas processing facility in southwestern Norway, before being injected through pipelines into geological formations in the North Sea. The intended infrastructure will be the world's first to handle CO_2 from different emission sources and will capture about 800,000 tons annually. However, the potential infrastructure will be able to handle far larger amounts of CO_2, making it possible to receive CO_2 also from other emission sources and other countries.[3] According to an opportunity study conducted by industrial actors in 2016, it was estimated that the project would cost 7–12.6 billion NOK (Ministry of Petroleum and Energy 2016). The project is currently awaiting a governmental decision on funding (expected in 2020–21), and according to media reports, the initial cost estimation has increased since 2016. However, informants argue that the project is crucial for the development of cost-efficient CCS technology, to showcase the technology's functionality, and to contribute to learning and experience (see also Atkins and Oslo Economics 2018). Thus, in light of our analytical framework, it can be argued that the project is important for establishing a clear *guidance of the search* to which actors can respond.

Informants argue that the CCS technological solution has strong *legitimation* in Norway, a country with a long history in offshore petroleum activity. Several informants and media reports point out that the full-scale project and new infrastructures may represent commercial opportunities for southwestern Norway, inter alia, as a diversification opportunity for companies. In particular, informants argue that the potential development of physical infrastructures can trigger opportunities for other green technologies and industries such as clean hydrogen production from natural gas. From an analytical perspective, this serves as an example of the growing legitimacy for CCS technology. There are few critical voices against the technology in itself, but public discourse (as is also evident in discussions in the media) typically portrays the moon landing as a failure. Public skepticism exists regarding the high investment costs of CCS and the potential full-scale project, and informants argue that this can be a barrier for its realization. Hence, regional, national, and international companies are currently thought to be sitting on the fence and awaiting the decision regarding the full-scale project.

Although several public and commercial actors are working toward the further development and large-scale implementation of CCS, we find that a number of obstacles prevent *market formation* with respect to the technology (see also Markusson et al. 2012). Most urgently, it appears that the current price structure of CCS makes it too expensive, and informants argue that commercial actors (e.g., in the process industry) have few, if any, incentives to implement it. There is currently no market for capturing and storing CO_2, and, of crucial importance to the future of CCS, it is reasonable to claim that technological development and market formation are key to achieving widespread implementation (Størset et al. 2019).

To summarize, technological challenges (e.g., infrastructure development) and the lack of commercial incentives, among other issues, has prevented CCS path creation in southwestern Norway. However, as also exemplified by the increasing number of positive media reports, one recent optimistic study estimated that a future CCS industry in Norway could contribute to tens of thousands of new workplaces by 2050 (Størset et al. 2018). Similar topics are also on the agenda globally; a study conducted on CCS on the east coast of the UK found that CCS could potentially lead to the creation/retention of about 225,000 jobs by 2060 (Summit Power 2017). Therefore, an interesting question concerns if—and how—southwestern Norway can utilize existing

[3] See https://www.regjeringen.no/en/topics/energy/carbon-capture-and-storage/ccs-in-norway/id2601471/for information about the project.

capabilities to capitalize on a potential industrial opportunity that is latent in existing regional capabilities. However, as evidenced by the moon landing project, the building of TCM, and possibly the full-scale project, new infrastructures by themselves may not be sufficient for green path creation (cf. Binz and Truffer 2017). Hence, returning to the theoretical discussion above, it emerges that in the case of CCS, beneficial territorial dynamics are not sufficient for the emergence of a new green path in the region and that technological characteristics of CCS are important for explaining the current situation.

MBT

The maritime industry in southwestern Norway is known for its strong willingness to adapt to changing economic circumstances, as exemplified by the various risk-taking shipping companies in the region. These firms have a history of operating in the ferry and offshore markets and, over the past decade, they have utilized their experience and knowledge to drive development further toward maritime cleantech solutions. Our analysis shows that strong, *regional capabilities*, in particular world-leading competence in power electronics and automation and power production, and, recently, maritime battery integration, has led to green path creation in the region. A large number of firms in the region, for example, shipyards (Fjellstrand, Westcon), suppliers (Wärtsilä, Norwegian Electric Systems, Rolls Royce, Servogear), and shipping companies (Eidesvik, Solstad, Østensjø, Norled), are now considered world leaders in producing and operating car ferries and offshore supply vessels that use battery technology instead of diesel fuel technology (Andersen et al. 2019). This development has been supported by ongoing and increasing R&D activities, in which regional R&D institutions and new initiatives are increasingly focused toward MBT. Examples include a newly created test center for maritime clean technology, the Sustainable Maritime Norwegian Catapult Centre.

Our analysis finds that technological developments in MBT have been driven by *multiscalar dynamics* related to the global car industry and general improvements to battery technology. In developing and implementing batteries for maritime application, of central importance has been the formerly Canadian-owned maritime battery firm Corvus—now majority-owned by Norwegian companies—which today controls over 50 percent of the maritime battery cell market. Corvus recently opened its new main battery factory in southwestern Norway, and Rolls Royce Norway has also opened a factory for maritime battery production in the region. However, historically, technological development has mainly taken place globally or nationally (e.g., in the highly acclaimed research institute SINTEF in Trondheim, and the Institute for Energy Technology and DNV GL in the Oslo region). However, this situation has changed recently, and battery technology is now strongly embedded in southwestern Norway, as evidenced by a number of demonstration projects and commercially viable innovations originating from the region that are now being pursued elsewhere nationally and globally. Hence, initially occurring outside the region, southwestern Norway has become a hot spot for MBT. This has been driven by bottom-up processes in which regional capabilities have been aligned with proactive actions by regional actors supported at the national level.

Through the interviews it becomes clear that visionary and purposeful regional *actors and agents* have seized global opportunities arising from battery development in the car industry, in turn anchoring MBT to the region. Overall, MBT has become an influential strategic orientation of several leading maritime firms in the region (e.g., Norled, Eidesvik, Fjellstrand, and Wärtsilä) (Holmen and Fosse 2017; Sjøtun 2018). Paralleling this, the cluster facilitation initiative NCE Maritime CleanTech (NCE MCT) was set up in 2011. The cluster has stimulated experimentation with and cooperation on MBT between regional actors, for example, through specific demonstration projects involving several influential sectors. Informants argue that the cluster has played an important role in realizing and embedding MBT regionally by linking global technology development to regional capabilities through demonstration projects and lobbying, both by individuals in firms (e.g., engineers and business leaders) and by the cluster administration. For instance, the push to change regional and national policies and regulations to become more favorable to inducing green technological solutions (e.g., lobbying for green public procurement) in the maritime industry has been heavily supported by NCE MCT, as well as by major industry actors in the region (Holmen and Fosse 2017; Sjøtun 2018); national, public, and NGO actors have been important allies in this regard. Finally, the influential regional power company BKK recently revised its strategy toward focusing on electrification of the maritime sector, exemplifying how other regional actors also are responding to opportunities arising in MBT.

Particularly influential in stimulating the emergence of MBT in southwestern Norway have been initiatives and *policies* sponsored by the public body Enova. Enova has (partly) funded several maritime battery or electrification projects, and the NOx Fund, a fund into which member firms pay an emission tribute instead of paying the state via, for example, taxes or fees. Furthermore, the Norwegian Public Roads Administration, together with several county council administrations, has started to demand low- or zero-emission standards in procurements for new ferry contracts (Sjøtun 2018). Although new tenders are technology neutral, battery technology is becoming the main response from shipping companies. Finally, as exemplified above, public cluster policy has also been important for the emergence of MBT. Taken together, a mix of policies has influenced the development of MBT in southwestern Norway, representing a bricolage approach.

The orientation toward MBT is the result of several *guidance-of-the-search* factors. First, our analysis finds that current and perceived new green national/regional procurement policies and International Maritime Organization (IMO) regulations have necessitated the change toward MBT in the maritime industry. As informants argued, this change has been strengthened by the establishment of NCE MCT, which has served to amplify and spread a regional consciousness and increase collaboration and the strategic orientation of firms toward MBT. Moreover, while the ferry sector has attracted more activity due to the decline in oil prices in 2014, as well as new green public procurement, the offshore supply vessel market now represents another market beginning to incorporate maritime battery solutions for similar reasons. This is partly driven by Equinor, which demanded, in a recent charter, battery technology for offshore supply vessels. Here, however, battery solutions are pursued primarily not only for energy-demanding offshore operations (e.g., dynamic positioning) but also due to safety concerns in the sector.

MBT has a strong degree of *legitimation* in the region in the sense that the technological solution is considered efficient and safe. In recent years, several technological demonstration projects have proved the viability of battery technology on ships, particularly in the ferry and offshore supply market. Although there has been discussion in the media regarding the public costs of implementing MBT, the technological demonstration has had a positive effect on industrial actors' perception of MBT as well as on (regional) political authorities. This is also shown in a recent report that

Table 2

Empirical Findings

	Regional Capabilities	Multiscalar Dynamics	Actors and Agency	Policy	Guidance of The Search	Legitimation	Market Formation	*Outcome in Western Norway*
MBT	Strong capabilities residing in firms with world-leading competence in power electronics and automation and power production, and, recently, maritime battery integration; several risk-taking regional (shipping) companies	Global technological developments, national policies and instruments; purposeful action by regional actors toward national policy makers	Proactive regional response; several actors (firm and nonfirm) lobbying for change; establishment of maritime cleantech cluster; bottom-up processes	Bricolage through a mix of policies; proactive regional policy makers	Global development and maritime adaptation/ application of mature, established technology; implementation in new applications (maritime); declining oil sector; current and perceived future green regulations	Confidence in the technological solution; considered important for greening and industrial development	Creation of (new) market(s) and market niches; public procurement important	**Green path creation**
CCS	Strong oil and gas competence and strong related industries; leading expertise in subsea technology; dynamic regional innovation system	National and international networks/ arenas are important; top-down processes	Reactive regional response; few dedicated CCS actors	Breakthrough strategy targeting R&D and large-scale technology development	Actors currently awaiting decision on full scale demonstration project	Technological solutions with relatively few opponents; infrastructure requirements and large investment costs met with resistance	Currently no market; no commercial demand for CCS	**Preformation**

concludes that electrifying the Norwegian maritime industry will have a huge potential for an increase in export revenues (Menon Economics 2019).

The change in regional and national procurement policies regarding new ferry contracts toward low- or zero-emission solutions was instrumental in MBT *market formation*. Specifically, the shift toward batteries in place of diesel fuel technology on car ferries and offshore supply vessels (Sjøtun 2018) created an MBT ferry market that many newcomers have entered. It is anticipated that in 2022 the MBT car ferry market will cover about seventy ferry lines—the majority operating in western Norway—using either only battery or hybrid battery technologies. Although the implementation of MBT has so far mainly taken place in the ferry market, interviews with informants and various media sources reveal that it is finding its way into new markets such as the offshore supply market and other short sea shipping markets. For instance, Corvus recently won a contract to install one of the world's largest battery packs on four Norwegian cruise ships sailing in the fjords of western Norway. New unorthodox maritime actors are also becoming more important in the growing MBT industry. Firms and industries are looking for commercial opportunities in MBT, for example, power and utility companies and suppliers of charging technology are playing a major role through the development of new infrastructures, namely, fast-speed charging stations, land power infrastructure, and a general upgrade of the power grid.

Taken together, MBT represents green path creation in southwestern Norway. Considering the analytical framework discussed above, we find that interconnections between territorial dynamics and technological characteristics explain the observed outcome. Southwestern Norway possesses strong technoindustrial competence in MBT, in which new technology opportunities within the global battery industry have been seized by regional actors. Public procurement policies have contributed to the formation of a new market for green maritime technologies, and through the showcasing of new technology solutions, the broader public has become aware of the positive environmental and, interestingly, economic effects of MBT. Table 2 summarizes and compares the results for the case studies of CCS and MBT.

Discussion and Conclusions

In this article, we departed from EEG (e.g., Dawley et al.'s 2015) understandings of regional path creation processes by focusing on green industries and by contributing to the literature regarding the role of technological characteristics in path creation. This was achieved through the integration of concepts from the TIS literature. Our TIS-informed EEG framework for path creation emphasizes four dimensions purported by EEG (regional capabilities, actors and agency, multiscalar dynamics, policy), in addition to three TIS functions: guidance of the search, market formation, and legitimation. We argue that these seven analytical dimensions explain interconnections between territorial dynamics and technological characteristics more effectively than the extant EEG literature.

The analytical framework was applied in empirical investigation of two green technologies in different phases of path creation (CCS and MBT) and their linkages to southwestern Norway (see Table 2). In the case of CCS, we found that the technology is evolving top-down to the region (multiscalar dynamics), where, in particular, national-level policy and global environmental concerns influence technology development. In addition, as a currently highly expensive technology carrying few or no incentives for implementation by commercial actors, the commercial demand for CCS technology is very weak (market formation). However, this may change, for example, if new innovations are introduced or if national and/or international policy encourages large-scale implementation of CCS. Nevertheless, policies and subsidies must also support massive investments in physical infrastructures and CCS facilities (guidance of the search) and the development of a commercial market (market formation); these are factors that, in turn, may materialize as green path creation in southwestern Norway, given this region's capabilities and already existing CCS infrastructures. However, it is unlikely to be sufficient to rely on top-down initiatives if the aim is to encourage path creation.

In contrast, the case of MBT shows how strong regional technoindustrial competence and a risk-taking culture (regional capabilities), coupled with global developments in battery technology in the car industry (multiscalar dynamics), are being capitalized on by regional actors responding through orchestrated bottom-up efforts (actors and agency). Proactive regional agents have been affected by and have influenced regulations (through lobbying), such as public procurement (policy), in which regional firms have been guided by current and anticipated future regulations (e.g., new national/regional public procurement and IMO regulations). These developments have been particularly influenced by the cluster NCE MCT, which has established the direction for regional actors toward MBT (guidance of the search) as well as toward politicians in order to create a market for green maritime technologies in Norway (market formation). Several technological demonstration projects have been vital in showcasing new technology solutions and making the broader public aware of the positive environmental and economic effects of these new technologies (legitimation). In addition, we also observe that the MBT green path seems to be supported by narratives aligned with and framed by regional actors. Observed narratives focus on the environmental and economic superiority of solutions developed in the region and appear to be influential in explaining the discussed change in regional industrial practices. A focus on narratives is an area that neither EEG- nor TIS-inspired work has looked at (Steen 2016; Fløysand and Jakobsen 2017; Hassink, Isaksen, and Trippl 2019), and we believe that more research is needed on this topic and how it fits into our framework.

Overall, we found that the analytical framework is appropriate for analyzing path creation and, in this study, green path creation in southwestern Norway. We have explained successful path creation, as in the case of MBT, but we have also discussed why a green path is still in a preformation phase, as in the case of CCS. The cases examined show that path creation can be explained through analyzing interconnections between regions and technology (MBT) but also that the regional level can be less influential than EEG leads us to expect (CCS). More specifically, the framework appears as helpful for investigating processes that may *block* the emergence of new industries, as illustrated by CCS where technology-specific explanations rather than regional dynamics appear as crucially important. Regarding CCS, we found that substantial national, public investments in physical infrastructures and technology development support are still needed to promote potential market creation and cost-efficient CCS solutions. Hence, linked to the analytical framework, changes in policy, guidance of the search, and market formation appear critical for path creation to take place. However, it remains to be seen which actions are taken and whether they can also influence other dimensions. Conversely, MBT exemplified path creation resulting from interconnections between territorial dynamics and technological characteristics.

In addition to looking into the role of narratives, we believe future research should look further into the dynamic interplay between the seven dimensions in the analytical framework to better explain how the different dimensions (positively and negatively) influence each other; which dimensions that are particularly important when and where; and, not least, investigate more in-depth if there are qualitative differences between such interplays in processes of *green* path creation compared to the emergence of traditional industries. Such investigations should, however, further nuance EEG's theoretical and conceptual apparatus, not merely provide empirical accounts of green path creation (see Binz et al. 2020). This article has been an early attempt at doing so.

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