Technological Forecasting & Social Change 166 (2021) 120595

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

# Diverging pathways to port sustainability: How social processes shape and direct transition work

Kristin Ystmark Bjerkan [a,b,*], Marianne Ryghaug [b]

[a] SINTEF, Dept. of Mobility and Economics, Postboks 4760 Torgarden, 7465 Trondheim, Norway
[b] Norwegian University of Science and Technology, Dept. of Interdisciplinary Studies of Culture, 7491 Trondheim, Norway

ARTICLE INFO

*Keywords:*
Expectations
Learning
Networks
Port
Sustainability transition

ABSTRACT

To counter climate change, societies are under pressure to transform energy and transport sectors. Considering the crucial node position of ports in the intersection between energy and transport systems and their connecting of numerous sectors, markets, and values chains, they have hitherto received surprisingly little attention as potential sites for whole system thinking and deep transition. Their heterogeneity suggests that ports are likely to follow different transition pathways. This study explores two Norwegian frontrunner ports to demonstrate how social processes are part of the fabric that constitutes transition pathways in ports. The transition pathways in the two ports diverge according to how they are shaped by deep learning, resource capacity and the collective action of their wider networks, as well as the specificity of expectations. The study complements existing research on transition pathways by focusing on social processes beyond the niche level and by suggesting inter-process and inter-level dynamics to be decisive for the direction of transition work. Contrary to earlier findings, the paper demonstrates how broad and diversified networks may also represent a challenge to the directionality of transitions work. Ports can, however, promote transition work by aligning expectations to port sustainability with expectations in specific value chains.

## 1. Introduction

Societies, sectors, and systems are under pressure to reduce climate emissions and build more sustainable communities. A well of research has delved into the premises for making such a transition (see Köhler et al., 2019; Sovacool et al., 2020 for recent overviews), focusing on how sociotechnical systems could be nudged, lured or forced onto more or less disruptive pathways towards sustainability. Research on socio-technical transition pathways has also been sparked by the recognition that transitions are context dependent and unfold differently under highly different circumstances (Lindberg et al., 2019).

This study focuses on a transition site where a variety of contexts and circumstances clearly shape presumably similar transition cases in different directions, namely ports. Ports are important nodes in the intersection between energy and transport systems, ensuring the shifting of goods and passengers between sea and land transport. In connecting a number of sectors, markets and value chains, ports can promote whole system thinking (McMeekin et al., 2019) to ensure deep transitions (Geels et al., 2017). However, the complexity represented by the conglomerates of actors and activities in ports, also suggests that each port represents a unique transition context. Among other, transition potentials in ports depend on geographical contexts, port characteristics and capacity, ownership strategies, local history and culture (Damman & Steen 2021). Previous research has studied the port of Rotterdam, focusing on the symbioses between the port and industrial activities in the region (Baas, 2008); the role of partnerships in moving the urban port towards sustainable co-existence with the city (Frantzeskaki et al., 2014); and how transition management may be employed to destabilize the fossil fuel regime of the port (Bosman et al., 2018).

Overall, however, the scientific literature on sustainability transitions has largely overlooked ports as transition sites and thereby also the multitude of transition pathways that could emerge (and diverge) in ports. This paper will contribute to fill that gap by exploring emerging transition work in two Norwegian ports. These two ports are placed in seemingly similar transition contexts, but are nonetheless on diverging transition pathways. Thus, by studying these two cases we can know more about how pathway creation occurs in this domain. More specifically, we seek to demonstrate how emergent transition pathways in these two ports appear to diverge by studying social transition processes that the port actors engage in. This shows not only how these processes

* Corresponding author at: SINTEF, Dept. of Mobility and Economics, Postboks 4760, 7465 Trondheim, Norway.
*E-mail addresses:* Kristin.ystmark.bjerkan@sintef.no (K.Y. Bjerkan), Marianne.ryghaug@ntnu.no (M. Ryghaug).

https://doi.org/10.1016/j.techfore.2021.120595
Received 30 March 2020; Received in revised form 11 November 2020; Accepted 8 January 2021
Available online 26 January 2021

enable transition work altogether, but also how port actors operating in these two ports shape the direction of transition work. The purpose of this study is therefore to demonstrate how social processes are part of the fabric that constitutes transition pathways. More specifically, we ask, *how can social transition processes shape transition pathways through enabling and directing transition work?*

Answering this question allows us to understand how social processes build transition work and thereby promote (or impede) transition. By emphasizing processual characteristics, we also go beyond most scholars, who stress technological components of transition pathways. Social processes are considered essential in driving transitions forward (e.g. Schot et al., 2016; Naber et al., 2017; Schot and Geels 2008; Söderholm et al., 2019; Borup et al., 2006), and are in literature on sustainability transitions often thought to revolve around networks, expectations and learning. The production of *expectations* contributes to align perceptions and produce shared realities which build legitimacy and protective spaces for emerging niches. Building *social networks* that support emerging niches and collaborations can destabilize incumbent regimes, especially when networks draw on diverse stakeholders that commit resources. *Learning* has proven important for modification and improvement of niches, as well as modification of assumptions and interpretations upon which the stability of incumbent regimes is built.

By exploring emerging transition work in two ports, this study addresses *uncomplete transitions*. Such an approach is crucial to identify factors that might tilt a potential transition in one direction or the other. Studying emergent transitions calls for targeting cases that are at an early phase of transition, or cases that might eventually evolve into transition. Should research on sustainability transitions be able to contribute to accelerate transitions, understanding failures, struggles and factors that hamper emerging transitions is just as important as studying successful transitions. As such, this study could also increase understandings of acceleration, a phase of transitions which is relatively under-explored (e.g. Valkering et al., 2017), but which depends on the enrolment of new actors like, for instance port actors, into transition processes.

Studies of sustainability transitions need to look beyond niche developments and focus more on institutional and organizational contexts (Truffer et al., 2017). Unlike most studies of social processes within sustainability transitions research that typically relate to a particular niche (e.g. Pedersen and Nygaard, 2018; Falcone and Sica, 2015), this study therefore explores the orientation of port actors within the place specific and spatial contexts they are situated. This is an important endeavor, as understanding how networks, expectations and learning constitute such contexts also shed light on geographies of transition (Hansen and Coenen, 2015; Binz et al., 2020) which overcut regimes that the heterogeneous mass of port actors is part of. This means that our study does not explicitly aim to explore constitutive aspects of social processes, i.e. how these processes are maintained and (re)produced, but rather aims to understand the current *functions* of the social processes in shaping transition work.

The remainder of this article is structured as follows. The next section gives an overview of existing literature on transition pathways and how they could be shaped by networks, expectations, and learning. Section 3 presents methods and data used to understand the role of social transition processes in the two case ports. The next four sections present the case ports, and ways in which their transition pathways are shaped by social transition processes. Finally, Sections 8 and 9 provide discussions and summaries of the study.

## 2. Theorizing transition pathways and social processes

A central issue in transition studies is the prospects of socio-technical systems and how they over time evolve onto different pathways. Socio-technical transition pathways "(..) are concerned with the multiple and interlocking causal processes involved in transitions" (Rosenbloom, 2017). Part of the transition literature is thus dedicated to understanding how transitions evolve and by what types of processes systemic renewal occurs. In their early work, Geels and Schot (2007) suggested a typology of four transition pathways, based on whether pressure from niche and landscape levels were disruptive or reinforcive, and whether innovations were sufficiently mature. Others have suggested other typologies, emphasizing pressures and resources (Smith et al., 2005), coordination and resources (Berkhout et al., 2004), or degrees of sustainability and disruption (Lindberg et al., 2019).

Geels and Schot's (2007) systemic approach to transition pathways has received criticism for under-acknowledging the role of agency. As a response, nuance was added to their typology (Geels et al., 2016:901), arguing that transitions do not just emerge as a result of struggle and pressure on the regime level, but that transitions can also be non-linear and enacted, stressing that "(…) shifts between transition pathways are influenced by a range of developments: changing composition and strength of actor coalitions; learning processes and on-the-ground experiences (..) [and]; landscape developments (…)". In line with this, sustainability transitions scholars have highlighted the roles of agency and actors in shaping transition pathways, for instance, stressing that system-level change, by definition, is "enacted through the coordination and steering of many actors and resources, whether these are intended or emergent features of transformation processes" (Smith et al., 2005:1492). Others have claimed that understanding transition pathways calls for an analytical approach that goes beyond the regime-niche dichotomy (Berggren et al., 2015). Building on these insights, this study emphasizes the need to understand actors and agency beyond the niche-regime dichotomy should we be able to identify emergent features of transformation processes and pathways.

The discussion above also points to the tendency of transition research to study transitions either from a systemic (regime) perspective (e.g. Köhler et al., 2020) or a niche perspective (e.g. McDowall, 2014; Mirzania et al., 2020). Granted, studies focusing on the niche level have been more attentive to the role of actors and agency. In studying low-carbon electricity in the UK, for instance, Foxon et al. (2010) and Fox (2013) describes different sets of actor logics that can produce different transition outcomes. Yang et al. (2020) describe institutional activities in niche and regime actors to demonstrate divergencies between pathways in solar PV. Many studies also discuss how expectations, networks and learning shape how transitions evolve, for instance, talking about how actors build networks to reinforce their 'logic' (Foxon et al., 2013) and suggesting that visions and expectations hold several functions for shaping transitions, such as mapping possibility spaces and providing narratives for mobilizing resources (Smith et al., 2005). There are also studies of transition pathways targeting social transition processes specifically, presenting the theoretical underpinnings for understanding these processes that remain at the core of this study.

### 2.1. Social networks

There is an abundance of research on the role of social networks in sustainability transitions. As we focus on the functions of networks in shaping transition work, we find it useful to draw on the resource based perspective on networks as presented by Musiolik et al. (2012). We consider the functions carried by social networks in shaping transition work to be inherently tied to the capacity of network actors to establish and apply the resources available in these social networks. Musiolik et al. (2012:1033) refer to resources as shaped by the "broader resource space" of networks, arguing that cyclically pooling available resources between networks of actors provides direction and a sense of control. They define resources as "assets which are strategically developed, used and transformed by actors (…)" (Musiolik et al., 2012:1034). Thus, developing transition pathways not only depends on resources such as financial assets and economic or human capital, but also resources embedded in culture, trust, goals, and reputations. Building on this, networks can successfully progress transition if able to draw on the variety of resources available to them.

Transition scholars have suggested several ways for actors to promote transition through building on their resource spaces. For instance, producing and exchanging resources such as knowledge and experience within niches can increase the ability of networks to or modify innovations, demands and preferences (Schot et al., 2016), and thereby impacting the diffusion of innovations. Further, resources are crucial for enabling actors to take *collective action*, that is collectively engaging each other with regard to promoting new technologies and to accelerate their production, use and diffusion (Markard and Truffer, 2008). Collective action is particularly effective when supported by formal networks (Musiolik et al., 2012), in which actors are bound to draw on complementary resources to coordinate strategies and objectives.

Drawing on resources in vast networks may also allow actors to *create protective spaces* for emerging niches (Naber et al., 2017; Smith and Raven, 2012). In particular, wide networks with a wide set of complementary resources (i.e. broad networks) and networks in which actors are committed to pool their resources (i.e. deep networks) are likely to support and promote the successful breakthrough of niche innovations (Schot et al., 2016). Thus, networks that efficiently promote transitions tend to be broad and deep, i.e. include different groups of stakeholders that express multiple perspectives and that mobilize resources and commitment (Schot et al., 2016; Schot and Geels, 2008). This could be translated into network performance (Newell et al., 2017; Provan and Kenis 2007; Klijn, 2005), which in the literature is considered the product of high *actor diversity*, high *level of integration* and high degree of *stability* in the network (Söderholm et al., 2019). In contrast, underperforming networks might impede transitions, particularly by imperiling niche development, and previous research has seen several examples of emerging transitions being obstructed by weak social networks (Giurca and Metz, 2018) or unproductive network composition (Falcone and Sica, 2015; Normann, 2017).

The network compositions in ports are likely to vary from one port to another and to consist of heterogeneous sets of actors, activities, technologies, and institutions. As transition work at ports involves wide networks that cut across sectors and value chains, ports are in position to encourage deep transitions, which requires fundamental shifts in directionality and logic across sectors (Schot and Kanger, 2018). This renders ports interesting sites for studying how differences in network complexity, integration and stability contributes to shaping coherent or diverging transition pathways.

### 2.2. Expectations

Transitions could also be shaped by expectations, which are real time representations of future situations (Borup et al., 2006; Budde et al., 2012). The evolution and diffusion of innovations rely on widely shared perceptions of future prospects (Schot et al., 2016), particularly in early phases of transitions (Hoogma et al., 2002; Skjølsvold, 2014). Expectations could also provide direct and indirect guidance in innovation searches (Budde et al., 2012; Bakker, 2014) and encourage investments to realize societal and collective goals (Schot and Geels, 2008; Borup et al., 2006).

Several studies discuss the definition and role of expectations in transitions (e.g. Berkhout, 2006; Geels and Smit, 2000; Konrad, 2006; Van der Voorn and Quist, 2018; Hansen and Bjørkhaug, 2017). Summarizing this research, Alkemade and Suurs (2012) provide a useful distinction between four functions of expectations. Firstly, expectations can serve to *coordinate and align* actors and activities, so that expectations shape decision making (Van Lente and Rip, 1998) and cognitive frames (Schot and Geels, 2008). This is particularly salient when expectations are shared by many actors (e.g. Naber et al., 2017). Second, expectations can *build legitimacy* around emerging technologies and create *protective spaces* that allow technologies to mature in peace (Schot et al., 2016). The agency of actors is therefore essential to diffuse visions and innovations (Van der Voorn and Quist, 2018). Third, expectations can motivate actors to *mobilize and dedicate resources* to new technologies (Alkemade and Suurs, 2012) through mutual commitment (Borup et al., 2006), especially when they suggest urgency and imminent change (Schot et al., 2016). The mobilizing effect is particularly fierce when expectations are tested and confirmed by empirical observation (Schot and Geels, 2008; Bakker, 2014). Finally, expectations can contribute to *reduce perceived risks* and uncertainty (Borup et al., 2006; Alkemade and Suurs, 2012), especially in early phases of transition when innovations are immature and uncertainties are high (Budde et al., 2012).

The potential of expectations to shape transition pathways lies particularly in their ability to balance stability and flexibility. Stable perceptions can more easily be placed within larger sociotechnical narratives (Schot et al., 2016) and thereby linked to other expectations (Budde and Konrad, 2019) which may reinforce their legitimacy and validity. A challenge, however, is balancing stability with the need to adjust according to experiences that may dismiss or modify expectations (Schot and Geels, 2008). Expectations are therefore contingent on a temporal dynamic, often characterized by hype-disappointment cycles (e.g. Borup et al., 2006; van Lente et al., 2013; Verbong et al., 2008; Dedehayir and Steinert, 2016). Thus, expectations can also slow transitions down, and lack of shared visions (or directionality) is known to be a potential transformation failure (Weber and Rohracher, 2012). Lack of expectations to an emerging niche could for instance obstruct actors from engaging in that niche (Budde et al., 2012; Budde and Konrad, 2019) or actors might withdraw their support if developments are expected to change (Bakker, 2014). Transitions could also halt if expectations are inconsistent and not shared between actors within a niche (Hansen and Bjørkhaug, 2017; Alkemade and Suurs, 2012) or between different governmental levels (Mutter, 2019; Tidwell et al., 2018).

Given the complexity and context laden nature of ports, it is likely to assume that the multitude of actors and markets interacting in ports are also reflected in a multitude of expectations. This could pose a challenge in uniting actors around common visions, but could also represent an opportunity for enhancing our understanding of how expectations and co-production of visions shape transition pathways.

### 2.3. Social learning

From the transitions literature on actors, agency and local specificity, we know that social learning is essential to realize sustainable development (Van Poeck et al., 2018). The main function of learning in progressing transition is to allow *modification of innovations, expectations and sociocultural perceptions* (Naber et al., 2017). This includes learning about innovations and their exogenous aspects (Schot et al., 2016), as well as fundamental assumptions that may guide interpretations and behaviors (Argyris, 1976; Argyris and Schon, 1974). It is therefore useful to distinguish between different types of learning in transition work.

*Broad learning* (first order learning) implies learning about the technology at hand, but also external aspects such as regulations, societal, cultural and environmental impacts, market potential and user preferences (Schot et al., 2016). The diffusion of such knowledge could be instrumental in producing radical transition pathways, as it has been argued that one area of expertise alone does not have sufficient "problem-solving capacity" (Van Poeck et al., 2018). However, broad learning can mostly produce incremental changes (Pahl-Wostl et al., 2013). In contrast, *deep learning*, or second order learning, implies fundamental changes to assumptions that guide interpretations and behaviors. Deep learning therefore often allows for more radical changes (Argyris, 1976; Argyris and Schon, 1974). It may resembles "triple loop learning" (Pahl-Wostl et al., 2013), where revisiting, scrutinizing and potentially altering, underlying values, beliefs and world views are considered necessary for structural transformation. Questioning what is taken for granted and institutionalized (i.e. "unlearning", Baas, 2008) has proven to allow for creatively producing new perspectives, skills and practices (Van Poeck et al., 2018). Furthermore, deep learning can occur both at the individual and group level (Sengers et al., 2019), and can be

**Table 1**
Summary of functions and reinforcive characteristics of social processes in transitions. Authors' composition.

| | Social networks | Expectations | Learning |
|---|---|---|---|
| **Dimensions** | Create collective action<br>Build protective spaces<br>Diffuse knowledge and technology | Coordinate/align<br>Build legitimacy/ protective space<br>Mobilize resources<br>Reduce risk perception | Modify innovation<br>Modify expectations<br>Modify sociocultural perceptions |
| **Reinforcive characteristics** | Diversity<br>Integration<br>Stability | Shared<br>Specific<br>Confirmed | Broad<br>Deep |

achieved through actual use of innovations when users reflect around assumptions they take for granted (Schot et al., 2016). Experiments that confirm or contradict expectations are therefore essential in this kind of learning processes (e.g. Brown et al., 2003; Rosenbloom et al., 2018; Berkhout et al., 2010).

Considering the many technologies and innovations that are relevant in transitioning ports towards sustainability (Bjerkan and Seter, 2019), substantial broad learning is likely to be crucial for the ability of port actors to identify and select technological components of their transition work. The strong incumbency of many of these actors could also indicate that deep learning (or even unlearning) could be cardinal for transitions to evolve in ports.

### 2.4. Summing up dimensions of social processes that shape transition work

Table 1 summarizes dimensions of social processes that can enable and shape transition work, as presented by the literature referenced above. The table distinguishes between i) different dimensions of social processes and ii) characteristics that might provide momentum in the transition work. The latter refers to aspects of social processes that may impact the forcefulness of transitions. For instance, expectations that are shared, specific and confirmed, and heterogeneous, tight networks, are considered to effectively drive transitions forward.

The dimensions and characteristics displayed in the table will be used throughout the following analysis to demonstrate how social processes shape transition pathways in the two ports. However, before demonstrating how social processes can produce diverging transition pathways in ports, we will first elaborate on how data was collected and how the analysis was carried out .

## 3. Methods

### 3.1. Data collection and sample

The paper is based on data from interviews with 25 actor representatives in the Norwegian ports of Oslo and Kristiansand between October 2018 and February 2019. The representatives were identified through purposive sampling (Berg, 2001; Tongco, 2007) in collaboration with key port contacts. Actors considered to play active roles in sustainability efforts in and around ports were explicitly targeted. Some informants were also suggested by other informants (i.e. snowballing, Goodman, 1961).

The port literature provides several categorizations of port actors (e.g. Rodrigue et al., 2010; Lam et al., 2013; Hall et al., 2013), which typically encompass actors in the port area (terminal operators, goods owners, warehousing, piloting and towage, waste collection etc.), actors in the transport domain (transport users, providers, agents and operators), and community actors (authorities, NGOs and interest organizations, port authority, residents etc.). This study applied a similarly broad approach, thereby encompassing the variety of actors that might engage in and shape transition work in the two ports.

**Table 2**
Port and transport roles covered by actors interviewed.

| Interviews in Port of Oslo ($n$=10) | Interviews in Port of Kristiansand ($n$=10) |
|---|---|
| Local authority* | Local authority |
| Port authority | Port authority |
| Terminal operator | Regional authority |
| Energy supplier | Terminal operators |
| Goods owners | Energy suppliers |
| Vessel/vehicle owners | Goods owners |
| Transport service providers | Vessel/vehicle owners |
| Transport buyer | Transport service providers |
| | Transport buyers |
| | National Rail Authority, regional division |
| **Interviews related to both ports ($n$=5)** | |
| Norwegian Coastal Administration | |
| Norwegian Port Association | |
| Vessel/vehicle owners | |
| Transport providers | |

*The City of Oslo is both local and regional authority.

Interviews were based on a semi-structured interview guide which allowed the informant to narrate freely around each question and address issues that were not defined in advance. Table 2 gives an overview of interviews with port actors. The sample included representatives from transport companies, forwarding agents, terminal operators, industrial companies, local, regional, and national authorities, port authorities, port association, and energy suppliers. Energy suppliers provided hydropower electricity, LNG, biogas and hydrogen. The sample also included organizations that conducted several types of business and have several roles in the port and the transport system. The same organization may for instance be a transport provider, a forwarding agent, and a terminal operator. All industrial companies in the ports were further goods owners. Thus, the sample comprised non-exclusive categories of informants with several roles in ports and transport systems.

The interviews were conducted on telephone and lasted between 30 and 60 minutes. The researchers took notes continuously throughout the interviews. Upon completion of the data collection, all notes were loaded into text processing software for coding and analysis.

### 3.2. Data analysis

Data was explored through conventional content analysis (Hsieh and Shannon, 2005) based on codes in Table 3. These were defined with reference to theory and previous research on social processes within the sustainability transitions literature described in Section 2. The data gave an overview of the actors' main network connections and the character of these connections. The accounts of the informants also described relations to actors that were not interviewed in this study (e.g. universities, environmental organizations). Such relations were also included in the analysis. The network relations were further analyzed with regard to actor diversity (i.e. number of different actors and sectors in network) and integration (i.e. degree of formalized relations). The analysis also identified how actors engaged in and/or pursued collective action, how they worked individually or collectively to build protective spaces around niches, and whether specific niches and technologies were adopted by the actors in the network.

The analysis of expectations included mapping the informants' expectations about the future and assessing whether these expectations were shared between port actors, specific and confirmed. This included expectations about the organization itself and its surroundings, possible future market developments, regulation and incentives, innovations, and technologies. The mapping allowed us to assess whether expectations served to coordinate/align actors and activities, build legitimacy and niches, mobilize actors and resources, and reduce risk perceptions.

The analysis of learning processes included identifying the attempts

**Table 3**
Description of codes applied in data analysis. Authors' definition.

| Code | Summarized description |
|---|---|
| Networks | The informant talks about formal and informal networks their organization is (not) part of and dialogue/cooperation they do/do not engage concerning sustainability issues. |
| Expectations | The informant describes their imagined future. The informant talks about their organization's expectations and visions for the future, how and to what degree they expect having to change. The informant talks about innovations expected to emerge. |
| Learning | The informant talks about his/her knowledge about innovations and external aspects which do or do not foster diffusion of innovations (first-order learning). The informant further talks about the assumptions that underlie his/her organization's motivations, priorities and decision-making (second-order learning). The informant talks about his/her perception of what the port is and should be (second-order learning). |

of the actors to gain knowledge about innovations and preconditions for use. It also included identifying changing assumptions about innovations, expectations and sociocultural perceptions.

## 4. Two case ports in emerging transitions

This study addresses social transition processes in two Norwegian frontrunner ports to demonstrate how such processes are part of the fabric that constitutes transition pathways. The Port of Oslo is located in the heart of the Norwegian capital and is a hub in the national transport system. The Port of Kristiansand is located at the southern tip of Norway, closely located to continental Europe. The ports are similar in many respects. Their goods traffic is dominated by container transport, tanker, and bulk transport, although with higher volumes in Oslo than in Kristiansand (Fig. 1). Both ports are served by cruise ships and ferries. During the first nine months of 2019, 1,8 million international (cruise) ferry passengers passed through the Port of Oslo, and 1 million through the Port of Kristiansand (Statistics Norway, 2019a). A lot of the goods transported to the port in Oslo is connected to the industrial activity in the port area, whereas the offshore and supply sector is a prominent port user in Kristiansand.

Despite belonging to a group of progressive Norwegian ports in terms of sustainability and technology implementation, the two ports differ in ways that make them interesting contrasting cases for studying emerging transition pathways. The Port of Oslo is a Norwegian frontrunner port when it comes to sustainability ambitions and endeavors, with explicit and ambitious sustainability goals. The port is owned by the City of Oslo, which aims to reduce the city's greenhouse gas emission by 95% within 2030 (City of Oslo, 2016). This implies substantial reductions in the port area as well. The port is therefore explicitly included in the city's ambitious climate policy, with an ambition to reduce 85% of $CO_2$ emissions from the port within 2050. The port has also appointed a Director of Environment, and the large port organization (at least in a Norwegian context) has employees with specific competences on technology, business development, policy, and governance. The port provides high voltage shore power to international ferry lines, and its terminal operator is moving towards automation and full electrification. This is in line with the port's zero emission action plan, which also emphasizes charging facilities and biofuel infrastructure for local passenger ferries. The Port of Kristiansand is one of several Norwegian ports who ambitiously implement technologies and innovations to improve own sustainability. It could be considered a frontrunner because of its position as an early mover in implementing high and low voltage shore power and installing solar power on rooftops. It also aims to become an environmentally friendly transport hub in the region. The port organization in Kristiansand is less specialized than the one in Oslo, and the 30 employees form a lean organization that hires needed competence from the outside.

Thus, the two ports share certain similar transition contexts. They belong to the same geopolitical and macroeconomic realities; they are publicly owned and located in the city centers; they have similar traffic; are progressive in making use of new technologies and innovations; and are engaged in research and development to strengthen own sustainability efforts. Exploring these similar cases is useful to identify factors that promote progress in one case or impede it in another. The port organization could for instance draw actively on its social network in one case but not engage in network building in the other, or expectations could be aligned in the latter but divergent in the former. Hence, this study investigates the two cases' emergent transition pathways by exploring how social processes shape their transition work. These explorations are analyzed in the following.

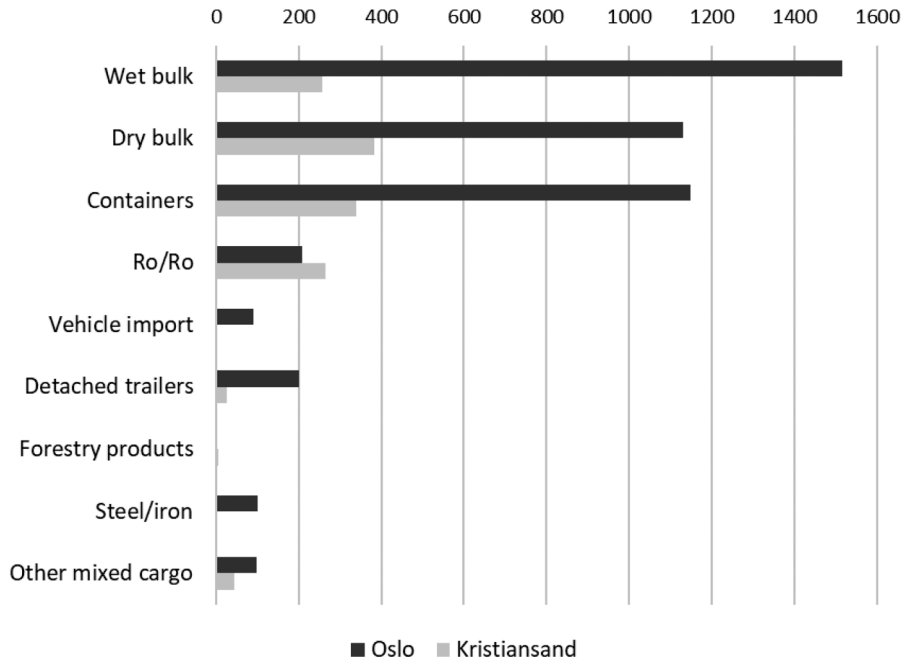


**Fig. 1.** Goods throughput in the two ports Q1–Q3 2019, in thousand tons. Source: Statistics Norway (2019b).

## 5. Producing visions and sharing expectations

Expectations and visions can drive transitions along several dimensions. As described more in detail in the theory section, they serve to coordinate and align actors and activities; they can build legitimacy around and protect innovations; they may mobilize and dedicate resources and reduce perceived risks among actors. The following passages demonstrate how expectations enabled and shaped transition work in the ports of Oslo and Kristiansand.

The largest difference between the two ports related to their agency and scope in facilitating visions. Unlike the Port of Kristiansand, the transition work in the Port of Oslo rested on visions that included the width of port activities and actors, as represented by the Port's 17-point zero emission action plan. The Port envisioned a wide approach to transitioning the port, encompassing a multitude of innovations and stakeholders. The Port further sought to *produce* shared imaginaries among its users and other stakeholders. For instance, the port invited the city and a range of its users to develop a concept for the future zero emission port in Oslo. Not only did this serve to co-create long-term visions, but it also expanded their scope in providing visions for a range of technologies, such as energy production and storage, autonomous vessels, biogas and waste heat, hydrogen and alternative fuels.

In contrast, the Port of Kristiansand did not actively seek to (co) produce visions among its users and stakeholders. Rather, the port's transition work mainly centered around stepwise electrification of port activities, and projects and dialogues with individual users. As such, visions in the Port of Kristiansand were less produced and less encompassing both in terms of scope (technologies) and time perspectives.

Nonetheless, expectations in the two ports also aligned in several ways. Transition work in both ports was supported by the actors' expectations that they must prepare for a green future by reducing emissions and improving energy efficiency. Port actors were as such aligned in working towards more sustainable production, operations, and value chains, and their expectations about a green future drove them to explore sustainable solutions. This motivation seemed to be grounded in an almost promotional strategy. The belief that pressures to transform in a more sustainable direction would increase, raised the legitimacy of nearly any technology or innovation that was expected to improve sustainability issues. This pressure, however, was not perceived to be urgent and port actors did not expect to be penalized by their markets if they did not adjust accordingly. As such, non-change was not associated with high risk. The lack of urgency also related to how the port actors perceived the competitiveness within their sectors. There was a general assumption that no one would pursue sustainability if it implied economic loss, but actors disagreed on whether one could expect to profit from becoming greener or not. Port and local authorities considered sustainability transitions at ports as a viable business opportunity that enhanced their competitive edge, and thus expected green ports to win market shares over less green ones. They therefore mobilized for stricter regulation and greener policies to strengthen the positions of their ports. Conversely, actors enmeshed in port operations questioned the value of green profiling compared to time and cost-effective production.

Further, transition work in both ports was strongly tied to expectations regarding electrification. These were largely the result of clear policies and generous public funding schemes which reduced the actors' risk perceptions and enabled mobilization of resources. Although port actors were unsure of the urgency and profitability of sustainability efforts, many port actors invested in electrification technologies, which reflected their high expectations around electrification. Electrification has been prominent in Norwegian energy policies, as also reflected in the policies of the two ports. Action plans and shore power strategies have built legitimacy to and continued protection of electrification as a viable pathway. Expectations and visions regarding operations that could be electrified were therefore strong, stable, and shared, and continuously confirmed by collaboration projects and practical experience.

Nonetheless, we seem to be witnessing two cases of directionality failure in this study. Previous studies point to collective priorities and technology-specific policies (Weber and Rohracher, 2012) and the alignment of regulation and policy with social discourse as means to avoiding such failure (Yap and Truffer, 2019). In the two ports examined here, transition work and pathways not related to electrification were modest and vague. Technology and innovation expectations were highly unspecific, and few expectations served to legitimate specific innovations or fuels. The difficulty in co-producing expectations beyond electrification might relate to the lack of directionality signaled by authorities and that 'the battle of fuels' was still considered undecided. One actor particularly highlighted the previous confusion related to liquified natural gas (LNG): after being perceived as a viable solution in the early 2000s, new knowledge about the climatic footprint of LNG caused great skepticism and uncertainty (e.g. Gilbert and Sovacool, 2017), not unlike typical hype-disappointment cycles (Dedehayir and Steinert, 2016). Given the lack of political direction and interest, shared and specific expectations beyond electrification failed to mobilize actors, as risks felt prominent, leaving the ports to solve their challenges uncoordinatedly and by themselves.

We found that directionality appeared to be strongly connected to sector-specific expectations. Identifying a clear transition pathway for the entire port can be challenging when expectations are not aligned and coordinated across value chains. The analysis, however, revealed, that expectations of various port actors were very closely related to the specific markets or industries they engaged with. Their actions were first and foremost connected to transformations in their own value chains. Among industrial port actors, for instance, environmental upgrading in value chains was closely connected to expectations regarding their future production. An industrial port actor in the mineral market expected little change in future production and therefore saw no need to change own operations, whereas an industrial port actor in the cement market expected increased production due to new methods for obtaining raw materials and therefore prepared to use larger vessels more suited for emerging technologies. Thus, different actors could favor different transition pathways depending on what value chain they were part of. Given the heterogeneity of actors and corresponding value chains in ports, this could produce a variety of imaginaries that are not necessarily mutually supportive. In turn, this leaves transition work a challenging task for ports, which will have to align and navigate the complex and heterogeneous web of value chains that port actors constitute.

## 6. Mobilizing social networks

Social networks can drive transition along several dimensions. According to the literature, networks can engage actors to collectively act towards a specific end; they can deliberately shield or support innovations; they can contribute to diffuse innovations, knowledge, legitimacy and resources. The following section analyzes and discusses how the mobilization of social networks contributed to initiate transition work in the ports of Oslo and Kristiansand, and how different characteristics of the social networks found in each port contributed to shape the direction of their respective emerging transition pathways.

Actors in both ports were part of extensive, informal networks with relations between public policy (port, local and regional authorities, national transport authorities, national energy transition agency), expertise (consultants, R&D, technology and energy suppliers), interest and support organizations (port associations, environmental and business organizations), and operational port users (goods and vehicle/vessel owners, terminal operators, transport buyers, providers and agents). The two cases differed, however, with regard to i) whether informal networks were converted into formal, collective action, ii) whether they engaged in strategic or ad-hoc use of network relations, and ii) the degree of integration in the port-city relation.

The Port of Oslo demonstrated strategic use of network relations in actively and deliberately drawing on its wide network resources to

define and create support around its own transition work. The Oslo case was therefore characterized by successful collective action between the port and its users, its owner, and environmental organizations. The port engaged all its users in a variety of interactions, spanning from day-to-day discussions to collaboration agreements, and actively facilitated dialogue between port users and the port. The port also strategically involved its network resources to shield and nurture specific technologies, such as shore power, automated solutions, and electric cranes.

For instance, the port authority established a financial support scheme which allowed operational port actors to apply for funds to cover investments in more sustainable solutions. The port also orchestrated its wide range of users (terminal operator, equipment provider, mineral company, import company) and other actors (consultants, energy company, city administration) to develop a joint zero-emission concept for the future port which entailed conceptualizing an innovative energy system for the entire port area. We further saw how the port authority drew on this large and coordinated network when preparing to introduce shore power. In planning the shore power connection for international cruise ferries, the port invited shipowners and a range of technology providers to a dialogue conference to ensure that the shore power solution would be usable and acceptable. The introduction of shore power was further enabled by mobilization across the social network; shipowners modified their vessels, environmental organizations pushed for ambitious policies; the city set ambitious emission targets; the port authority funded and coordinated activities; and the energy supplier and consultants provided technological knowledge.

To increase support and legitimacy around transition work in Oslo, the port and the city further sought collective action and teamed up with environmental organizations, who pushed for stricter regulations and more ambitious environmental policies. Environmental organizations had fiercely promoted sustainability measures in the City of Oslo, and their active lobbying eventually also compelled the port to enter into collaboration agreements to increase mutual understanding and ensure exchange of knowledge and perspectives. In continuing its efforts towards electrification, the Port of Oslo further entered into an intentional agreement with the local energy company to establish a joint enterprise dedicated to construct, operate, and maintain shore power facilities. Thus, we see that specific social networks were formalized, and that collective action was fostered to ensure directionality of the transition pathway in the port.

In contrast to the Oslo case, extensive, informal dialogue in the Port of Kristiansand was to a limited degree converted into collective action. The port authority appeared more focused on providing sustainable services *to* its users (e.g. low voltage power supply) and less focused on developing joint port strategies together *with* its users. Collaboration between actors was often sporadic and project based. One example was the introduction of shore power, where the Port of Kristiansand was among the very early adopters in Norway. Unlike the meticulous process proceeding the shift to shore power in Oslo that involved diverse actors and that had gone on for several years, the introduction of shore power in Kristiansand was a more bilateral response to requests from particular port users and R&D actors. Both passenger ferries and offshore vessels requested it and the port authority was invited into an ongoing research project looking for a port willing to demonstrate their technology. As such, the nurturing of shore power did not result from collective action among actors mobilized in a broad network, but rather resulted from ad-hoc responses to specific requests in the network. Like in Oslo, the strategy was supported by the diffusion of competence and resources in the network, as the port authority relied heavily on competence from research and development, the regional energy company and consultants involved in solving practical challenges.

The two cases also diverged on the level of integration between the ports and their owners: the cities of Oslo and Kristiansand. The direction of the transition work in Oslo was strongly shaped by the close relation between the port and the City of Oslo. The City of Oslo was instrumental in setting ambitious targets for port sustainability (Bjerkan and Seter, 2021) and increasingly wielded its port ownership to steer and accelerate transition work in the port. Hence, the city administration and the port in Oslo kept an extensive, continuous dialogue and collaborated to define shared policies and to jointly implement measures for reducing port emissions.

In Kristiansand there were few examples of deliberate city-port collaboration. Local authorities supported the sustainability efforts of the port, but not very actively. This corresponds with the common approach among Norwegian public port owners (i.e. local authorities), who have tended to take a more laissez-faire approach, not emphasizing their role as port owners and accentuating the port's autonomy as a legal entity (Bjerkan et al., 2021). Thus, in line with most Norwegian ports, the port authorities in Kristiansand, to some extent seemed to neglect opportunities to foster fruitful collective action towards sustainability transitions in the port.

Thus, we clearly see how the transition work in the Port of Oslo was shaped by the mobilization and creation of collective action through building strong and stable networks with interest organizations, experts and port users. Transition work was also shaped by the network building protective spaces around certain technological solutions, such as shore-power, which rested on and contributed to knowledge and resource diffusion within the larger network. Consultants and R&D provided a basis for policy making and enabled public decision makers to understand their surroundings, technologies, and markets. In this way, port authorities gained access to knowledge resources they did not have themselves. This also made it easier for public policy actors such as port authorities to protect and legitimize these technologies. It also helped actors in port operations to select more sustainable technologies (e.g. vehicles or equipment). Thus, we see how the large and diverse social networks that were mobilized in Oslo enabled broad learning among port actors and the way relations in the network also served to diffuse knowledge about each other's operations, perspectives and sustainability efforts, which again made it easier to enter into more formalized and specific collaborations related to sustainability transitions in ports. Already, we therefore see an indication of the important relationship between social networks and social learning, which is further elaborated on in the following section.

## 7. Social learning

As pointed out in Section 2, social learning can drive transitions through modifying innovations, expectations, and sociocultural perceptions. This section discusses how social learning enabled transition work and shaped emerging transition pathways in the two ports. Common for both ports, was the prominence of broad learning (i.e. learning about technologies and innovations). Increased knowledge of and first-hand experience with technologies and innovations enabled port actors to identify and select measures for improving sustainability in own operations and value chains. Given the low maturity of many technologies, these experiences can contribute to modify innovations, and enable port actors to navigate among a range of emerging (and often competing) niches to make more qualified decisions regarding use and non-use.

In the Port of Kristiansand, the port practiced learning by doing through incremental trial and error with specific technologies. The introduction of shore power, for instance, progressed in close collaboration with the regional energy utility and R&D actors. This strategy allowed the port to steadily increase own technology competence, as well as awareness around lacking or needed competences in the port organization and competences it could seek from others.

In Oslo, broad learning increased the port's ability to identify potential paths forward. Broad learning particularly related to the Green Shipping Program as an arena for learning about technologies and solutions for sustainable maritime transport. The program was administered by a renowned consultant company and built around an evolving set of pilots (e.g. autonomous transport, shift cargo from road to sea, environmental port index, alternative fuels) that joined port authorities,

regional and local authorities, goods owners, ship owners, technology providers, R&D, and port and industry organizations. The port actors described the program as a nexus for dialogue and experimentation which allowed them to realize and learn from solutions for green and efficient shipping. The program could also propel transitions as a network of complementary actors that shared resources, and that developed joint expectations and visions. Port actors therefore relied on knowledge from outside the port (e.g. experts and consultants) in broad learning, but also learned about innovations through dialogue between port actors, practical projects, and strategic planning. The previously mentioned dialogue conference on shore power in 2017 for instance educated the port on technical solutions for shore power.

The transition work in the two ports diverged, however, in how port actors engaged in deep learning. Whereas changing role perceptions and perceptions about power distribution characterized the Oslo case, similar processes seemed absent in the Port of Kristiansand. In Oslo, the port's explicit and ambitious transition work was among other the product of deep learning regarding the roles of port and city authorities. Port actors, the port, and the city all questioned the purely commercial orientation of ports and the laissez-faire ownership of cities. The increasing pressure on the city to act on climate change and local pollution, coupled with a green shift in political leadership, appeared to induce more active port ownership in Oslo. This coincided with overall urbanization of port areas and port regulation which strengthened the owners' hold over public ports.

The Port of Oslo was therefore increasingly considered a problem owner when it came to emissions. The port became embedded in local environmental policy and was expected to follow up on the city's ambitions. As such, the port authority experienced new, emerging expectations to become a more active community manager, i.e. joining actors to facilitate collaboration and improve performance. The actors in Oslo considered the port to be a facilitator and uniformly pointed to the port authority as key in progressing port sustainability. Strengthening the port's role as community manager added to the list of competences the port needed and required it to cooperate with external expertise and consultancy to adequately fulfill its commitments. These commitments derived from the perceptions of a new, green reality for ports, suggesting that they should proactively deal with climate and environment to remain relevant and maintain autonomy.

Further, the wide and coordinated transition work in the Port of Oslo derived from changing perceptions about distribution of power among port actors. On one hand, this related to the port's potential reach into energy and transport systems. Historically, ports have been perceived as maritime, but informants stressed that ports needed to orient equally towards landside activities (i.e. port operations and hinterland transport) should they facilitate sustainability transitions. This implied appreciation of the port as a node in entire transport systems and that the Port of Oslo might influence transitions on the landside more than it currently did.

On the other hand, deep learning seemed to modify perceptions about the distribution of power among operational port actors in Oslo. Transport buyers were considered to have more leverage than what is usually recognized in policy making, and port actors argued that the potential of non-maritime actors to induce transitions was underacknowledged. Transport buyers explicitly reflected around own potential to influence the maritime sector, for instance through transport service procurement, which could pressure ship owners and agents in placing requirements to vehicles, vessels, and fuels.

## 8. Discussion

The purpose of this study has been to demonstrate how social processes are part of the fabric that constitutes transition pathways (see Table 4 for an overview). As such, we look beyond technological components of transition pathways, and rather emphasize their social characteristics. The social processes that characterized the Port of Oslo suggested that the port is moving towards a whole-system transition, where port actors transform their understandings of own roles, which might lead to more radical innovations and system wide acceleration. The current social processes in the Port of Oslo suggested that its emerging transition pathway could be labeled *strategic, coordinated and scalable*. It was strategic and coordinated because the Port of Oslo worked strategically with a long-term perspective on sustainable transitions. This reflects one main difference between the two ports' emerging pathways; namely the ways in which they included network resources to progress and define the scope for transition work. The Port of Oslo united its wide network in close and formal collaboration, which allowed co-production of strategies and visions and enabled the port to coordinate joint projects with the city, environmental organizations, the local energy company and a range of its users. The transition pathway can also be considered scalable, because the Port of Oslo took a wide approach in its sustainability endeavors, encompassing a multitude of innovations and stakeholders. This was particularly represented by the Port's active involvement of the city and port users in developing the future zero emission port, which included reconceptualizing the entire energy system of the port area.

Conversely, the emerging transition pathway in the Port of Kristiansand could be characterized as *incremental and niche-oriented*. Here, the lack of formalized relations and a less integrated network implied that the port remained more loosely connected to other actors and mostly engaged in bilateral, ad-hoc projects with its users. Followingly, the port did not deliberately draw on resources available in its network to the same degree as in Oslo. Further, port development did not rest, as in the Oslo case, on visions co-produced between the variety of port users. In Kristiansand, the lack of committing collaboration corresponded with lack of joint vision-making which in turn discouraged coordinated, scalable sustainability endeavors. As in Oslo, the City of Kristiansand focused on emission reduction but did not engage in a similarly strategic collaboration with the port and did not challenge the port's role perceptions. Further, the port's transition work mainly centered around stepwise electrification of port activities.

The above demonstrates the importance of moving beyond studying pathways for specific niches or innovations. In this article we have

**Table 4**
Summary of social processes reflected in the two ports' diverging transition pathways.

| | **Port of Oslo**Strategic, scalable, and coordinated transition pathway | **Port of Kristiansand**Incremental and niche-oriented transition pathway |
|---|---|---|
| **Expectations** | Co-production of visions<br>Prepare for green future<br>Electrification pathway<br>Lack of expectations beyond electrification<br>Sector-specific expectations | Prepare for green future<br>Electrification pathway<br>Lack of expectations beyond electrification<br>Sector-specific expectations |
| **Networks** | Collective action with users, owner and environmental organizations<br>Shield/nurture innovations through strategic involvement of network<br>Knowledge and resource diffusion in wide network<br>Collective action in value chains | Informal, bilateral collaboration<br>Less collective action with owner<br>Knowledge diffusion from R&D and energy sector |
| **Learning** | First order leaning in extensive network<br>Second order leaning: role perceptions<br>Second order learning: perceptions of influence | First order learning by doing<br>Second order learning not prominent |

studied emerging transition pathways of a whole domain, namely *ports*, which comprise many potential niches and innovations which themselves could be tied to specific pathways. The study – and the Oslo case in particular – reflects how transition pathways can transcend the regime-niche dichotomy (Berggren et al., 2015). In the Oslo case there were no obvious niche actors and transition work was mainly conducted by incumbent actors. There were also examples suggesting that transition work was not exclusively found at the niche level: networks that mobilized efforts and resources were closely tied to the regime level; and expectations that shaped transition work were located on the landscape level (e.g. urban restructuring), on the regime level (e.g. developments in value chains) and at the niche level (e.g. the battle of fuels). Further, deep learning among some actors (e.g. port authority, local authority) seemed futile if not followed up by or aligned with similar developments in other actors (e.g. national policymakers).

This study also provides examples suggesting that transition pathways can be shaped by interaction between different social processes. Networks were for instance crucial for broad learning, which was enabled by the mobilization of competence and knowledge of actors in diverse networks and facilitated by the experiments these set up (e.g. though the Green Shipping Program). Networks were further instrumental in co-producing visions and shared imaginaries, like when the Port of Oslo entered into formal collaboration precisely to encourage shared realities and expectations. This study also showed how expectations were shaped by the networks port actors belonged to, particularly those represented by value chains. Sustainability initiatives were often closely related to the value chains port actors were part of, and different expectations existing in different value chains could discourage actors from aligning their endeavors and engaging in collective action. This brings nuance to current research on the role of networks in sustainability transitions, which would assume the diverse and integrated network of the Port of Oslo to represent an advantage in progressing transition work. Based on the above, however, this study suggested that network (e.g. value chain) diversity could also represent a challenge in aligning the direction of the different actors' transition work, and thereby also in aligning transition pathways.

Although this challenges the ability of the port to align transition work across the myriad of value chains in the port, it also indicates that ports could be successful in facilitating and shaping transition pathways *within* value chains. The permeability of value chains suggests that they are suited for scaling up or accelerating transition efforts. Targeting transitions in entire value chains could therefore enable systemic approaches to coordinate actors and activities. Similarly, van Welie et al. (2019) have in a recent study argued that studying value chains is useful to understand systemic preconditions for transition work. However, the fluidity of value chains challenges transition work as each value chain consists of heterogeneous actors situated in own contexts, which are part of potentially distinct regimes and located at different places. This has also been pointed out by others; transition processes in value chains are distributed across different spaces (Hansen and Coenen, 2015). Thus, the place-specificity of ports could thus challenge ports' ability to induce transitions in value chains. Hence, ports can primarily be expected to shape transition work in value chains by facilitating co-production of general expectations to port sustainability, which port actors in turn can translate and integrate with (more or less) aligning expectations in own value chains.

This study also hinted at a hierarchy among social transition processes. It has demonstrated that deep learning (e.g. role perceptions) in the Port of Oslo produced new expectations about what the port should and could do (for the city), and what responsibilities the port should take. This created new knowledge needs in the port, which in turn led it to make active use of the resources and knowledge available in its network. As deep learning produced new expectations which further required more formal and dedicated network relations, one could argue that the divergent transition pathways in the two ports above all derived from deep learning (which characterized the Oslo case but not the Kristiansand case). It could therefore be useful to construct a hierarchy of social processes. In the Oslo case, deep learning appeared to precede modification of expectations and spur collective action. Defining the Port of Oslo as a problem owner and emphasizing the port authority's faciliatory role produced expectations to the port authority which compelled it to engage more actively and formally with its existing network and to draw on the network's competence to (re)develop ambitions and strategies for port sustainability. These strategies in turn provided directionality through specific expectations, thereby reducing perceived risk among port actors. As new perceptions were also tied to greener and more active port ownership on the side of the city, they further disallowed the port authority from opting out of the faciliatory role and continuing their focus on commercial operations.

In contrast, the Port of Kristiansand did not experience similar deep learning because of the laissez-faire approach of the port owner, which in turn placed fewer expectations on the port's role. Hence, the incremental, ad-hoc transition work continued because there was neither internal motivation nor external pressure on the port to engage in formal, more binding collaborations. This kept the port from absorbing resources and knowledge available in its network to develop long-term, strategic and encompassing plans for their transition work.

## 9. Conclusion

This study has set out to demonstrate how social processes are part of the fabric that constitutes transition pathways. To do so, we studied how such processes in different ways shaped transition work in two Norwegian ports. The Port of Oslo is becoming a frontrunner on an international scale. It shares certain characteristics with other international frontrunners (e.g. in Los Angeles/San Pedro, Vancouver, Rotterdam, Hamburg) in being publicly owned and located close to urban citizens, however smaller in terms of transport volumes. Future research should therefore explore if social processes facilitate sustainability transitions in other frontrunner ports in a similar manner. However, as a temperature check on transition work in general, investigating social processes could prove valuable to specify transition strategies also beyond frontrunner ports.

When investigating social transition processes in the Port of Oslo and the Port of Kristiansand, we found that these processes were reflected in their transition pathways. We found that actors in both ports had clear and stable expectations associated with electrification and a green future. Still, the actors struggled with specifying what the green future would look like, which lead them to orient by expectations they had for the markets and value chains they were part of. The two ports diverged, however, in their approach to involving wide networks, and in the degree of deep learning, particularly related to role perceptions.

This study has stressed that the interplay and hierarchy of social processes provide important understandings of how transition pathways could be developed. Future research should seek to elaborate further how such process dynamics might influence transition pathways in other contexts. Given the complexity of ports, as they comprise a number of regimes (port, maritime transport, land transport) and a number of potentially emerging niches (see f.ex. Bjerkan and Seter, 2019), identifying or anticipating one single transition pathway is very unlikely. However, this complexity of ports (including the heterogeneity of port actors) also represents a tremendous potential for aligning compatible sets of transition pathways that could lead to deep and sector-wide transitions. Thus, better understanding how social processes and the dynamics between them induce and hamper transition work and transition pathways is important. Piggybacking on the multifaceted and sustainable future of ports can therefore enhance our understanding of and the drivers for transition efforts in other domains.

## CRediT authorship contribution statement

**Kristin Ystmark Bjerkan:** Conceptualization, Methodology,

Investigation, Formal analysis, Writing - original draft, Writing - review & editing. **Marianne Ryghaug:** Conceptualization, Writing - review & editing, Supervision.

## Declaration of Competing Interest

None.

## Acknowledgments

The authors wish to thankfully acknowledge the financial support for this research from the Research Council of Norway, grant number 281002. We also wish to thank all the informants who have contributed with their perspectives and experiences, and to colleagues Sigrid Damman, Markus Steen and Assiya Kenzhegaliyeva for cooperating with the interviews . Further, we extend our gratitude to Tomas Moe Skjølsvold and the referees for valuable feedback on earlier versions of this paper.

## References

Köhler, J., Geels, F.W., Kern, F., Markard, J., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M.S., Nykvist, B., Onsongo, Elsie, Pel, B., Raven, R., Rohracher, H., Sandén, B., Schot, Johan, Sovacool, B., Turnheim, B., Welch, D., Wells, P., 2019. A Research Agenda for Sustainability Transitions Research: State of the Art and Future Directions. Insititution.

Sovacool, B.K., Hess, D.J., Amir, S., Geels, F.W., Hirsh, R., Rodriguez Medina, L., Miller, C., Alvial Palavicino, C., Phadke, R., Ryghaug, M., Schot, J., Silvast, A., Stephens, J., Stirling, A., Turnheim, B., van der Vleuten, E., van Lente, H., Yearley, S., 2020. Sociotechnical agendas: reviewing future directions for energy and climate research. Energy Res. Soc. Sci. 70 https://doi.org/10.1016/j.erss.2020.101617, 101617.

Lindberg, M.B., Markard, J., Andersen, A.D., 2019. Policies, actors and sustainability transition pathways: a study of the EU's energy policy mix. Res. Policy 48 (10). https://doi.org/10.1016/j.respol.2018.09.003, 103668.

McMeekin, A., Geels, F.W., Hodson, M., 2019. Mapping the winds of whole system reconfiguration: analysing low-carbon transformations across production, distribution and consumption in the UK electricity system (1990–2016). Res. Policy 48 (5), 1216–1231. https://doi.org/10.1016/j.respol.2018.12.007.

Geels, F.W., Sovacool, B.K., Schwanen, T., Sorrell, S., 2017. Sociotechnical transitions for deep decarbonization. Science 357 (6357), 1242–1244. https://doi.org/10.1126/science.aao3760.

Damman, S, Steen, M., 2021. A socio-technical perspective on the scope for ports to enable energy transition. Transportation Research Part D: Transport and Environment 91, 102691. https://doi.org/10.1016/j.trd.2020.102691.

Baas, L., 2008. Industrial symbiosis in the Rotterdam Harbour and Industry Complex: reflections on the interconnection of the techno-sphere with the social system. Bus. Strat. Environ. 17 (5), 330–340. https://doi.org/10.1002/bse.624.

Frantzeskaki, N., Wittmayer, J., Loorbach, D., 2014. The role of partnerships in 'realising' urban sustainability in Rotterdam's City Ports Area, The Netherlands. J. Clean. Prod. 65, 406–417. https://doi.org/10.1016/j.jclepro.2013.09.023.

Bosman, R., Loorbach, D., Rotmans, J., Raak, R.v., 2018. Carbon lock-out: leading the fossil port of Rotterdam into transition. Sustainability 10 (2558).

Schot, J., Kanger, L., Verbong, G., 2016. The roles of users in shaping transitions to new energy systems. Nat. Energy 1, 16054. https://doi.org/10.1038/nenergy.2016.54.

Naber, R., Raven, R., Kouw, M., Dassen, T., 2017. Scaling up sustainable energy innovations? Smart grids in the Netherlands. Energy Policy 110, 342–354. https://doi.org/10.1016/j.enpol.2017.07.056.

Schot, J., Geels, F.W., 2008. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. Technol. Anal. Strat. Manag. 20 (5), 537–554. https://doi.org/10.1080/09537320802292651.

Söderholm, P., Hellsmark, H., Frishammar, J., Hansson, J., Mossberg, J., Sandström, A., 2019. Technological development for sustainability: the role of network management in the innovation policy mix. Technol. Forecast. Soc. Change 138, 309–323. https://doi.org/10.1016/j.techfore.2018.10.010.

Borup, M., Brown, N., Konrad, K., Van Lente, H., 2006. The sociology of expectations in science and technology. Technol. Anal. Strat. Manag. 18 (3-4), 285–298. https://doi.org/10.1080/09537320600777002.

Valkering, P., Yücel, G., Gebetsroither-Geringer, E., Markvica, K., Meynaerts, E., Frantzeskaki, N., 2017. Accelerating transition dynamics in city regions: a qualitative modeling perspective. Sustainability 9 (7), 1254.

Truffer, B., Schippl, J., Fleischer, T., 2017. Decentering technology in technology assessment: prospects for socio-technical transitions in electric mobility in Germany. Technol. Forecast. Soc. Change 122, 34–48. https://doi.org/10.1016/j.techfore.2017.04.020.

Pedersen, M.B., Nygaard, I., 2018. System building in the Kenyan electrification regime: the case of private solar mini-grid development. Energy Res. Soc. Sci. 42, 211–223. https://doi.org/10.1016/j.erss.2018.03.010.

Falcone, P.M., Sica, E., 2015. Explaining biomass niche readiness through network analysis: the Lithuanian case. WIT Trans. Ecol. Environ. 199, 1743–3541.

Hansen, T., Coenen, L., 2015. The geography of sustainability transitions: review, synthesis and reflections on an emergent research field. Environ. Innov. Soc. Transit. 17, 92–109. https://doi.org/10.1016/j.eist.2014.11.001.

Binz, C., Coenen, L., Murphy, J.T., Truffer, B., 2020. Geographies of transition—from topical concerns to theoretical engagement: a comment on the transitions research agenda. Environ. Innov. Soc. Transit. 34, 1–3. https://doi.org/10.1016/j.eist.2019.11.002.

Rosenbloom, D., 2017. Pathways: an emerging concept for the theory and governance of low-carbon transitions. Glob. Environ. Change 43, 37–50. https://doi.org/10.1016/j.gloenvcha.2016.12.011.

Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. Res. Policy 36 (3), 399–417. https://doi.org/10.1016/j.respol.2007.01.003.

Smith, A., Stirling, A., Berkhout, F., 2005. The governance of sustainable socio-technical transitions. Res. Policy 34 (10), 1491–1510. https://doi.org/10.1016/j.respol.2005.07.005.

Berkhout, F.G.H., Smith, A., Stirlingh, A., 2004. Socio-technological regimes and transition contexts. In: Elzen, B., Geels, F.W., Green, K. (Eds.), System Innovation and the Transition to Sustainability. Edward Elgar Publishing Ltd, Cheltenham.

Geels, F.W., Kern, F., Fuchs, G., Hinderer, N., Kungl, G., Mylan, J., Neukirch, M., Wassermann, S., 2016. The enactment of socio-technical transition pathways: a reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions (1990–2014). Res. Policy 45 (4), 896–913. https://doi.org/10.1016/j.respol.2016.01.015.

Berggren, C., Magnusson, T., Sushandoyo, D., 2015. Transition pathways revisited: established firms as multi-level actors in the heavy vehicle industry. Res. Policy 44 (5), 1017–1028. https://doi.org/10.1016/j.respol.2014.11.009.

Köhler, J., Turnheim, B., Hodson, M., 2020. Low carbon transitions pathways in mobility: applying the MLP in a combined case study and simulation bridging analysis of passenger transport in the Netherlands. Technol. Forecast. Soc. Change 151, 119314. https://doi.org/10.1016/j.techfore.2018.06.003.

McDowall, W., 2014. Exploring possible transition pathways for hydrogen energy: a hybrid approach using socio-technical scenarios and energy system modelling. Futures 63, 1–14. https://doi.org/10.1016/j.futures.2014.07.004.

Mirzania, P., Balta-Ozkan, N., Marais, L., 2020. One technology, two pathways? Strategic Niche Management and the diverging diffusion of concentrated solar power in South Africa and the United States. Energy Res. Soc. Sci. 69, 101729 https://doi.org/10.1016/j.erss.2020.101729.

Foxon, T.J., Hammon, G.P., Pearson, P.J.G., 2010. Developing transition pathways for a carbon electricity system in the UK. Technol. Forecast. Soc. Change 77, 1203–1213.

Foxon, T.J., 2013. Transition pathways for a UK low carbon electricity future. Energy Policy 52, 10–24. https://doi.org/10.1016/j.enpol.2012.04.001.

Yang, J., Schot, J., Truffer, B., 2020. Shaping the Directionality of Sustainability Transitions: The Diverging Development Patterns of Solar PV in two Chinese Provinces. Insititution. https://doi.org/10.2139/ssrn.3667900.

Foxon, T.J., Pearson, P.J.G., Arapostathis, S., Carlsson-Hyslop, A., Thornton, J., 2013. Branching points for transition pathways: assessing responses of actors to challenges on pathways to a low carbon future. Energy Policy 52, 146–158. https://doi.org/10.1016/j.enpol.2012.04.030.

Musiolik, J., Markard, J., Hekkert, M., 2012. Networks and network resources in technological innovation systems: towards a conceptual framework for system building. Technol. Forecast. Soc. Change 79 (6), 1032–1048. https://doi.org/10.1016/j.techfore.2012.01.003.

J. Markard and B. Truffer, Actor-oriented analysis of innovation systems: exploring micro–meso level linkages in the case of stationary fuel cells Technol. Anal. Strat. Manag., 20 (4), (2008) 443-464 10.1080/09537320802141429.

Smith, A., Raven, R., 2012. What is protective space? Reconsidering niches in transitions to sustainability. Res. Policy 41 (6), 1025–1036. https://doi.org/10.1016/j.respol.2011.12.012.

Newell, D., Sandström, A., Söderholm, P., 2017. Network management and renewable energy development: an analytical framework with empirical illustrations. Energy Res. & Social Science 23, 199–210. https://doi.org/10.1016/j.erss.2016.09.005.

Provan, K.G., Kenis, P., 2007. Modes of network governance: structure, management, and effectiveness. J. Publ. Adm. Res. Theory 18 (2), 229–252. https://doi.org/10.1093/jopart/mum015.

Klijn, E.-H., 2005. Designing and managing networks: possibilities and limitations for network management. Eur. Polit. Sci. 4 (3), 328–339. https://doi.org/10.1057/palgrave.eps.2210035.

A. Giurca and T. Metz, A social network analysis of Germany's wood-based bioeconomy: social capital and shared beliefs, Environ. Innov. Soc. Transit., 26, (2018) 1-14 10.1016/j.eist.2017.09.001.

Normann, H.E., 2017. Policy networks in energy transitions: the cases of carbon capture and storage and offshore wind in Norway. Technol. Forecast. Soc. Change 118, 80–93. https://doi.org/10.1016/j.techfore.2017.02.004.

Schot, J., Kanger, L., 2018. Deep transitions: emergence, acceleration, stabilization and directionality. Res. Policy 47 (6), 1045–1059. https://doi.org/10.1016/j.respol.2018.03.009.

Budde, B., Alkemade, F., Weber, K.M., 2012. Expectations as a key to understanding actor strategies in the field of fuel cell and hydrogen vehicles. Technol. Forecast. Soc. Change 79 (6), 1072–1083. https://doi.org/10.1016/j.techfore.2011.12.012.

Hoogma, R., Kemp, R., Schot, J., Truffer, B., 2002. Experimenting for Sustainable Transport. The Approach of Strategic Niche Management. Routledge, London.

Skjølsvold, T.M., 2014. Back to the futures: retrospecting the prospects of smart grid technology. Futures 63, 26–36. https://doi.org/10.1016/j.futures.2014.08.001.

Bakker, S., 2014. Actor rationales in sustainability transitions – Interests and expectations regarding electric vehicle recharging. Environm. Innov. Soc. Transit. 13, 60–74. https://doi.org/10.1016/j.eist.2014.08.002.
Berkhout, F., 2006. Normative expectations in systems innovation. Technol. Anal. Strat. Manag. 18 (3-4), 299–311. https://doi.org/10.1080/09537320600777010.
Geels, F.W., Smit, W.A., 2000. Failed technology futures: pitfalls and lessons from a historical survey. Futures 867–885.
Konrad, K., 2006. The social dynamics of expectations: The interaction of collective and actor-specific expectations on electronic commerce and interactive television. Technol. Anal. Strat. Manag. 18 (3-4), 429–444. https://doi.org/10.1080/09537320600777192.
Van der Voorn, T., Quist, J., 2018. Analysing the role of visions, agency, and niches in historical transitions in watershed management in the lower Mississippi river. Water 10 (12), 1845.
Hansen, L., Bjørkhaug, H., 2017. Visions and expectations for the Norwegian bioeconomy. Sustainability 9 (3), 341.
Alkemade, F., Suurs, R.A.A., 2012. Patterns of expectations for emerging sustainable technologies. Technol. Forecast. Soc. Change 79 (3), 448–456. https://doi.org/10.1016/j.techfore.2011.08.014.
Van Lente, H., Rip, A., 1998. Expectations in technological developments: an example of prospective structures to be filled by agency. In: Disco, C., Van der Meulen, B. (Eds.), Getting New Technologies Together. Studies in Making Sociotechnical Order. Walter de Gruyter, Berlin.
Budde, B., Konrad, K., 2019. Tentative governing of fuel cell innovation in a dynamic network of expectations. Res. Policy 48 (5), 1098–1112. https://doi.org/10.1016/j.respol.2019.01.007.
van Lente, H., Spitters, C., Peine, A., 2013. Comparing technological hype cycles: towards a theory. Technol. Forecast. Soc. Change 80 (8), 1615–1628. https://doi.org/10.1016/j.techfore.2012.12.004.
Verbong, G., Geels, F.W., Raven, R., 2008. Multi-niche analysis of dynamics and policies in Dutch renewable energy innovation journeys (1970–2006): hype-cycles, closed networks and technology-focused learning. Technolo. Anal. Strat. Manag. 20 (5), 555–573. https://doi.org/10.1080/09537320802292719.
Dedehayir, O., Steinert, M., 2016. The hype cycle model: a review and future directions. Technol. Forecast. Soc. Change 108, 28–41. https://doi.org/10.1016/j.techfore.2016.04.005.
Weber, K.M., Rohracher, H., 2012. Legitimizing research, technology and innovation policies for transformative change: combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework. Res. Policy 41 (6), 1037–1047. https://doi.org/10.1016/j.respol.2011.10.015.
Mutter, A., 2019. Mobilizing sociotechnical imaginaries of fossil-free futures – electricity and biogas in public transport in Linköping, Sweden. Energy Res. Soc. Sci. 49, 1–9. https://doi.org/10.1016/j.erss.2018.10.025.
Tidwell, J.H., Tidwell, A., Nelson, S., 2018. Surveying the Solar power gap: assessing the spatial distribution of emerging photovoltaic solar adoption in the state of Georgia, U.S.A. Sustainability 10 (11), 4117.
Van Poeck, K., Östman, L., Block, T., 2018. Opening up the black box of learning-by-doing in sustainability transitions. Environ. Innov. Soc. Transit. https://doi.org/10.1016/j.eist.2018.12.006.
Argyris, C., 1976. Single-loop and double-loop models in research on decision making. Adm. Sci. Q. 21 (3), 363–375. https://doi.org/10.2307/2391848.
Argyris, C., Schon, D.A., 1974. Theory in Practice: Increasing Professional Effectiveness. Jossey-Bass Inc. Publishers, San Fransisco.
Pahl-Wostl, C., Becker, G., Knieper, C., Sendzimir, J., 2013. How multilevel societal learning processes facilitate transformative change: a comparative case study analysis on flood management. Ecol. Soc. 18 (4), 28. https://doi.org/10.5751/es-05779-180458.
Sengers, F., Wieczorek, A.J., Raven, R., 2019. Experimenting for sustainability transitions: a systematic literature review. Technol. Forecast. Soc. Change 145, 153–164. https://doi.org/10.1016/j.techfore.2016.08.031.
Brown, H.S., Vergragt, P., Green, K., Berchicci, L., 2003. Learning for sustainability transition through bounded socio-technical experiments in personal mobility. Technol. Analy. Strat. Manag. 15 (3), 291–315. https://doi.org/10.1080/0953732031000160149 6.
Rosenbloom, D., Meadowcroft, J., Sheppard, S., Burch, S., Williams, S., 2018. Transition experiments: opening up low-carbon transition pathways for Canada through innovation and learning. Can. Public Policy 44 (4), 368–383. https://doi.org/10.3138/cpp.2018-020.
Berkhout, F., Verbong, G., Wieczorek, A.J., Raven, R., Lebel, L., Bai, X., 2010. Sustainability experiments in Asia: innovations shaping alternative development pathways? Environ. Sci. Policy 13 (4), 261–271. https://doi.org/10.1016/j.envsci.2010.03.010.
Bjerkan, K.Y., Ryghaug, M., Skjølsvold, T.M., 2021. Actors in energy transitions: transition potentials in the intersection between Norwegian port and transport systems. Energy Res. Soc. Sci. 72, 101868 https://doi.org/10.1016/j.erss.2020.101868. Under review.
Bjerkan, K.Y., Seter, H., 2019. Reviewing tools and technologies for sustainable ports: does research enable decision making in ports? Transp. Res. Part D: Transp. Environ. 17, 243–260.
Berg, B.L., 2001. Qualitative Research Methods for the Social Sciences. Allyn and Bacon, Boston.
Tongco, D.C., 2007. Purposive sampling as a tool for informant selection. Ethnobot. Res. Appl. 5, 147–158.
Goodman, L.A., 1961. Snowball sampling. Ann. Math. Stat. 32 (1), 148–170.
Rodrigue, J.-P., Debrie, J., Fremont, A., Gouvernal, E., 2010. Functions and actors of inland ports: European and North American dynamics. J. Transp. Geogr. 18 (4), 519–529. https://doi.org/10.1016/j.jtrangeo.2010.03.008.
Lam, J.S.L., Ng, A.K.Y., Fu, X., 2013. Stakeholder management for establishing sustainable regional port governance. Res. Transp. Bus. Manag. 8, 30–38. https://doi.org/10.1016/j.rtbm.2013.06.001.
Hall, P.V., O'Brien, T., Woudsma, C., 2013. Environmental innovation and the role of stakeholder collaboration in West Coast port gateways. Res. Transp. Econ. 42 (1), 87–96. https://doi.org/10.1016/j.retrec.2012.11.004.
H.-F. Hsieh and S. E. Shannon, Three approaches to qualitative content analysis, 15 (9), (2005) 1277-1288. 10.1177/1049732305276687.
Statistics Norway, Table 04225: Ferry transport between Norway og international desitnations. Passengers and cargo, by port, direction, statistical variable and quarter, (2019a), downloaded from https://www.ssb.no/statbank/table/04225/, March 4th 2020.
Statistics Norway, Table 08923: Port statistics. Goods, by port, cargo type, direction, statistical variable and quarter (Norwegian only), (2019b), downloaded from https://www.ssb.no/statbank/table/08923/, March 4th 2020.
City of Oslo, 2016. Climate and Energy Strategy for Oslo. Insititution, Oslo.
Yap, X.-S., Truffer, B., 2019. Shaping selection environments for industrial catch-up and sustainability transitions: a systemic perspective on endogenizing windows of opportunity. Res. Policy 48 (4), 1030–1047. https://doi.org/10.1016/j.respol.2018.10.002.
Gilbert, A.Q., Sovacool, B.K., 2017. US liquefied natural gas (LNG) exports: boom or bust for the global climate? Energy 141, 1671–1680. https://doi.org/10.1016/j.energy.2017.11.098.
Bjerkan, K.Y., Seter, H., 2021. Policy and politics in energy transitions. a case study on shore power in Oslo. Energy Policy. Under review.
van Welie, M.J., Truffer, B., Yap, X.-S., 2019. Towards sustainable urban basic services in low-income countries: a technological innovation system analysis of sanitation value chains in Nairobi. Environ. Innov. Soc. Transit. 33, 196–214. https://doi.org/10.1016/j.eist.2019.06.002.

**Kristin Ystmark Bjerkan** is a research scientist in transport research focussing on sustainable mobility. Her research has largely revolved around preconditions for implementing sustainable tools and technologies in transport, and the roles of actors and users in encouraging or discouraging successful implementation. She holds a master in political science, and is conducting a Ph.D. in science and technology studies, in which she studies the potential for sustainability transitions in Norwegian ports.

**Marianne Ryghaug** (Ph.D.), is professor of Science and Technology Studies at the Department of Interdisciplinary Studies of Culture (NTNU-KULT) and is the leader of the research group on Energy, Climate and Environment. She has a long track record of nationally and internationally funded energy projects and is currently leading the expert working group on Transport in the Energy-SHIFTS Forum (2019–2021) funded by H2020 and is appointed as an expert advisor by the European Commission's Scientific Advice Mechanism and the Group of Chief Scientific Advisors, (SAPEA); working group "A Systemic Approach For the Energy Transition in Europe".