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The role of regional innovation systems in mission-oriented innovation policy: exploring the problem-solution space in electrification of maritime transport

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ABSTRACT

The innovation literature increasingly addresses grand challenges and transformative change. However, the issue of to what extent transformative change can build upon the resources, actors and institutions of existing innovation systems has not received sufficient attention. Against this background this paper aims to advance our understanding of the geographies and continuities of transformative change, by exploring the role of regional innovation systems in mission-oriented innovation. Based on an in-depth case study of electrification of ferries in Western Norway, the paper finds that the accomplishment of the mission was in large part due to the fact that it created new regional economic opportunities and built upon and mobilized existing regional resources, actors and structures. This mission re-orientation of an existing regional innovation system was characterized by (a) limited contestation, low complexity and low uncertainty about the technological battery-driven solutions pointed at, (b) multi-actor and multi-scalar agency and finally (c) asset modification of strong and pre-existing RIS structures, institutions and regulatory context.

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1. Introduction

Innovation studies is undergoing a 'normative turn' associated with an increasing interest in the direction of innovation and the factors shaping it (Nelson 2011; Foray, Mowery, and Nelson 2012; Tödtling, Trippl, and Desch 2021; Uyarra, Ribeiro, and Dale-Clough 2019). This change manifests in discussions about how innovation can help address grand societal challenges. Setting direction for innovation or directionality is typically understood as the strategic formulation of collective priorities and the creation of shared visions (Weber and Rohracher 2012). The normative aspects of setting direction draw attention to the role OF political struggles, contestations and uncertainty in innovation (Schlaile et al. 2017). Within this context the notion of mission-oriented innovation policy (MOIP) has been revitalized and extended as researchers try to capture

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

the diverse nature of challenges and possible solutions (Mazzucato 2018; Kattel and Mazzucato 2018; Diercks, Larsen, and Steward 2019; Wanzenböck et al. 2020; Janssen et al. 2021; Bugge and Siddiq 2021).

It is generally argued that radical or transformative change is required to sufficiently address grand challenges including disrupting the established sociotechnical trajectories and actors that created the problems in the first place (Weber and Rohracher 2012; Schot and Steinmueller 2018). This leads to proposals for broader involvement of new actors in innovation and strong directionality via policies. Combined these issues present a novel way of thinking about innovation and innovation policy broadly referred to as a transformative change agenda.

However, while proponents of this new framing are explicit about disruption and the 'new' elements needed to address societal challenges, there is so far limited systematic thinking about what the role of existing elements such as established knowledge bases, industrial specialization of regions and incumbent firms could be in transformative change (Alkemade, Hekkert, and Negro 2011; Fagerberg 2018; Giuliani 2018). There is thus a need for a better understanding of how transformative change promoted by MOIP relate to existing systems of innovation (Janssen et al. 2021). It is important to address this gap for two reasons; First, as technological development is largely path dependent while allowing for related diversification (Hansen and Coenen 2015), actors and resources of established innovation systems can act both as vital prerequisites or obstructions for transformative change. Second, as knowledge and industry specialization is 'sticky', the relationship between transformative change and existing innovation systems influences the potential for value – and jobs creation in particular regions. Policies that address societal challenges while creating economic uncertainty typically encounter strong popular resistance and low political feasibility (Vona 2019). Successful implementation of policy for transformative change – such as MOIP – depends on widespread legitimacy. Therefore, a degree of continuity in transformative change in the form of building on existing actors and resources in particular places may be central (Andersen et al. 2020; Foxon 2018).

Against this background we explore the role of existing innovation systems in transformative change in general and in MOIP in particular. We do so by drawing on and integrating two distinct literatures.

First, we build upon the problem-solution space approach to MOIP which understands MOIP as addressing societal problems in socio-technical systems through a matching process between mission problems and mission solutions. Depending upon contextual characteristics, these processes may vary according to degrees of contestation, complexity and uncertainty (Wanzenböck et al. 2020). The approach thus highlights the heterogeneity of societal challenges and argues that the design and implementation of MOIP must be understood in light of mission-specific properties to be successful. However, the framework gives little explicit attention to the role of existing industry specialization of and incumbent firms in the spatial context.

Second, we draw on the recent literature on regional green path development – i.e. transformative change towards sustainability – to elaborate on the role of existing actors and resources in formulating mission problems and finding mission solutions. While it seems clear that regions differ in the capacity to develop new green technologies and industries, reflecting to a large extent previous industrial specializations (Santoalha and Boschma 2020; Trippl et al. 2020), relatively little is known about how green path development processes unfold in different kinds of regions (Capasso et al. 2019; Grillitsch and Hansen 2019). We draw explicitly on Trippl et al. (2020) that distinguish between different dimensions that may condition the type and pace of green regional path development; (a) pre-existing RIS structures, (b) asset modification and (c) firm level and system level agency.

We combine these theoretical elements into a novel analytical framework to make sense of how the dynamics of the problem-solution space targeting a given sociotechnical system are influenced by an existing RIS. We apply the framework to an in-depth case study of electrification of maritime transport in Western Norway. In this greening process, car passenger ferries have been the ‘spearhead’, driven by public procurement (Bach et al. 2020). By 2022 more than 60 ferry routes along the western coast of Norway will be electrified in part (i.e. hybrid) or full as part of an ambition to reduce CO_2 emissions in the transport sector with 40% by 2030. The case is relevant because it constitutes a successful mission where existing regional actors and resources have played an important and pro-active role.

The paper makes three key contributions. First, we provide a conceptualization of the role of regional innovation systems in transformative change, by exploring the problem-solution space and the relationship between innovation systems and its surrounding socio-technical system. In this sense the paper emphasizes the spatial prerequisites for mission-oriented innovation policy at the regional level. Second, we show how existing industry actors and resources can be drivers for transformative change if mission problems can be solved with solutions that provide economic opportunities. Third, our case draws attention to the importance and many facets of mission agency performed by a diverse set of distributed actors operating at multiple levels.

The paper proceeds as follows. Chapter 2 outlines the main conceptual building blocks for the framing of the case study. Chapter 3 presents the research setting and methods. Chapter 4 presents and analyses the case. Chapter 5 discusses main findings from the case and finally chapter 6 concludes.

2. Theoretical framework

2.1. The problem-solution space in mission-oriented innovation policies

Mazzucato (2018) makes a distinction between old and new forms of mission-oriented innovation, where the old were defined by a small and centralized group of experts, oriented towards specified technology development, and where wider diffusion was of less importance. Current mission-oriented innovation typically addresses complex societal challenges, and requiring that broader sets of actors are involved in defining the mission problem, and setting direction. Contemporary missions tend to have both technical and societal objectives, and the diffusion of solutions is considered paramount.

Issues related to normativity and complexity of sociotechnical change such as contestations, political struggles and wickedness of problems and solutions are central to the new type of missions. Moreover, these issues are likely to change during implementation via various feedback mechanisms that may differ across missions involving different sectors, technologies and places (Diercks, Larsen, and Steward 2019). In order to capture such nuances Wanzenböck et al. (2020) outlined a problem-solution typology. In this perspective, the challenge of MOIP is to match problems and solutions in a way that contributes to advance societal missions. The framework distinguishes between the degrees of wickedness in different missions by sorting these according to levels of *contestation*, *complexity* and *uncertainty* in their problem framing and solution space, respectively.

The *degree of contestation* or legitimacy depends on the extent of divergent claims, values and conflicts of interest from heterogeneous actors. This can manifest as diverging views on the feasibility of solutions or importance of problems.

The *degree of complexity* indicates the difficulty of the governance challenge. It is typically higher if the required policy mix involves coordination across multiple scales, dimensions, sectors and policy domains. If a particular solution requires a series of changes in existing sectors to be implemented, complexity rises.

The *degree of uncertainty* depends on availability of shared knowledge about a problem or a solution e.g. clarity about causes and consequences of a particular action. High uncertainty about the potential of a solution can reduce its legitimacy.

In this perspective, MOIP is successful once problems and solutions are matched in a process which, ultimately, is leads to low contestation, complexity and uncertainty. Ideally, MOIP should from the outset be designed according to social and technical characteristics of the particular mission.

However, this framework pays little explicit attention to the role of existing industry specialization and incumbent firms in the context of missions in relation to the three categories, yet these may strongly influence the potential for change processes in a particular territory. In terms of solutions, we know that new innovations mainly draw on existing knowledge specialization, i.e. it is recombinant and largely follows path-dependent evolutionary trajectories. In terms of problems, incumbent firms often proactively work against policy processes that may disrupt their business (e.g. Wesseling et al. 2014), but they may also contribute to accelerating change if they see a new opportunity related to existing knowledge and assets (e.g. Hockerts and Wüstenhagen 2010).

Problem-solution dynamics are therefore likely conditioned by and affect (local) economies and existing systems of innovation. This issue is pointed out by Janssen et al. (2021) who explicitly distinguish between sociotechnical systems (providing e.g. maritime transport) where 'problems' often reside, on the one hand, and innovation systems, on the other, that may be mobilized to develop solutions to problems. These two types of systems have different actors, institutions, knowledge bases and policy domains. The interface between them is therefore at the heart of understanding problem-solution dynamics in missions. It allows for a systematic understanding of the roles of firms, existing knowledge assets and industry specialization in the context where missions are implemented. Although the innovation system in the present paper is at the regional level, it should be considered porous with extra-regional linkages. Similarly, the socio-technical system of maritime transport in the region should be regarded as nested within broader national and international systems.

The distinction between sociotechnical and innovation systems has implications for our understanding of transformative change. Transformative change is generally understood as structural change (e.g. creation of new trajectories, technologies and practices) such as transitions in sociotechnical systems (Schot and Steinmueller 2018; Wanzenböck et al. 2020). In our case, electrical ferries (E-ferries) constitute transformative change in the sociotechnical system in the form of e.g. technological substitution, new fuel infrastructure and institutional change in procurement and operation of transport services. However, transformative change may also happen in the associated innovation system developing and producing the new technology. A mission can thus be transformative in the sociotechnical system and/or the innovation system (Andersen and Gulbrandsen 2020). Indeed, as we shall see in the case study, for the RIS developing new ferries, electrification to a large extent constitutes a continuation of existing industrial trajectories. In this way, the case is an example of continuity in the innovation system in combination with transformative change in the sociotechnical system (OECD 2021).

2.2. The role of regional actors and resources in conditioning transformative change and MOIP

Developing building blocks for a normative route of change in RIS, Trippl et al. (2020) distinguish between different dimensions that may condition the type and pace of green regional path development; (a) pre-existing RIS structures, (b) asset modification and (c) firm- and system-level agency.

First, *pre-existing RIS structures* refer to the pre-existing industrial base and actors, its degree of industrial diversification, the regional policy apparatus and institutional set-up, the entrepreneurial climate in the region and to the inter-regional and international linkages and connections (Bathelt, Malmberg, and Maskell 2004). In sum pre-existing RIS structures are seen to either enable or hamper transformative change ('green path development') in the region.

Second, *asset modification* refers to the adjustments or reorientation of existing assets in a green direction and may include (i) natural assets (resources), (ii) infrastructural and material assets (buildings, machines, networks and infrastructure), (iii) industrial assets (technology and firm competencies), (iv) human assets (labour skills, costs, knowledge) and (v) institutional endowments (rules, routines, norms, values and culture). Green path development through asset modification processes may take place through either re-using existing local assets, creating new local assets or by destroying old local assets. The importance and relevance of these different forms of asset modification processes depends upon the pre-existing RIS structures and the regional assets available. Not least will the possibilities of asset modification depend upon the direction in which pre-existing RIS resources are drawn.

Third, *agency* refers to deviating from past practices and implies a conscious action or intervention to generate particular effects. Agency may either be forwarded by individual firms and entrepreneurs in Schumpeterian innovative entrepreneurship or by multiple and non-firm systemic or collective agency through public policy (Holmen and Fosse 2017) or institutional entrepreneurship (Sotarauta and Mustikkamäki 2015) consisting of the removal of identified systemic barriers to new path development. In our case collective agency is primarily present through innovative public procurement (Uyarra et al. 2020; Bach et al. 2020). In this sense it is distinguished between firm-level and system-level agency, which can both initiate asset modification processes (Trippl et al. 2020). Indeed, they are strongly interdependent and may be mutually reinforcing (Holmen and Fosse 2017).

2.3. Summary of analytical framework

Against this background, we seek to advance our understanding of how MOIP addressing challenges in sociotechnical systems is influenced by existing regional innovation systems. Anchored in the literatures on the problem-solution space in MOIP and conditioning factors for green regional path development, our framework to analyze and understand the present case of electrification of maritime transport is summarized below (Figure 1).

In the analysis we explore how the mission problem and – solution are being 'interpreted' and 'articulated' through the lens of the existing RIS. We analyze how the relationship between the mission problem and -solution process related to a particular socio-technical system is conditioned by pre-existing RIS structures and various types of agency that in different ways results in asset modification.

3. Research setting and methods

3.1. The maritime industry in Norway

The maritime industry is one of Norway's oldest and largest industries, currently employing ca. 87,000 people and having an annual turnover of ca. NOK 175 billion annually (Jakobsen and Helseth 2021). Throughout the last 10–20 years the maritime supplier industry (i.e. yards, ship designers, equipment suppliers) has become more concentrated in regional and specialized industry clusters notably in Western and Southern Norway (Regjeringen 2015; Menon 2015). Four main types of industry actors can be distinguished: (1) shipowners (deepsea, shortsea, offshore and drilling), (2) shipyards (shipbuilding, maintenance, repairs and modifications), (3) maritime equipment suppliers (mechanics, electronics and operating control systems) and (4) maritime services

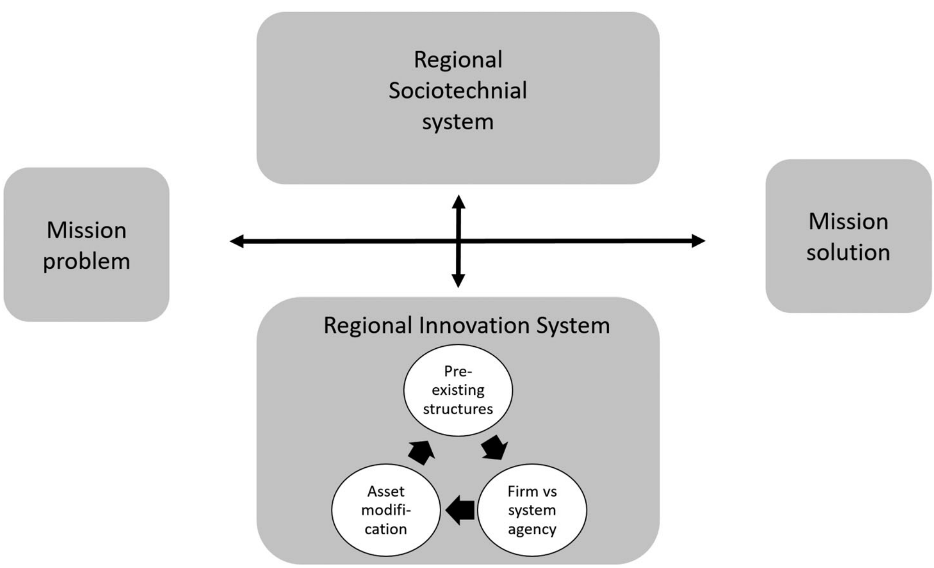

Figure 1. Analytical framework.

(design, brokering, finance, engineering, classification, R&D and logistics) (Jakobsen and Espelien 2011). All four groups are relevant to understand how the process of electrification unfolds.

Norway has a long tradition of shipping and ocean-based economic sectors (fisheries, offshore petroleum, aquaculture) are crucial for the economy. These sectors have articulated sophisticated demand for various ships and vessels, a demand that in large has been met by a highly innovative national maritime cluster. Norway is one of the few high-cost countries that still builds and outfits ships. These are often high-tech and advanced, which is an important competitive advantage for both shipyards and maritime equipment suppliers (Andersen et al. 2019).

Of particular relevance to this paper is that the Norwegian maritime sector has been at the forefront internationally in the development and use of cleaner energy solutions, such as liquefied natural gas (LNG) and battery-electric systems (Jakobsen and Helseth 2021; Steen et al. 2019). The maritime industry is currently experiencing the early phases of a sustainability transition, with a shift away from traditional fossil fuels towards low- and zero-carbon energy solutions, and in adopting a stronger environmental profile in general (Steen 2018). In Western Norway, this reorientation process owes substantial debt to a cluster project focusing on 'green' solutions that was initiated around 2010 by a regional development agency along with a small group of companies in the region (Holmen and Fosse 2017). With support from the Norwegian national cluster programme, this initiative has developed into a 130-member strong National Centre of Expertise (NCE)[1] Maritime CleanTech. The cluster members comprise mainly regional firms and non-firm actors, but also extra-local firms, R&D institutions and public agencies.

While the quest to reduce greenhouse gas emissions from shipping is not entirely new (e.g. LNG was introduced already in the early 2000s), it is fair to say that it is only since around 2014–2015 that the greening of maritime transport has been properly on the agenda of politicians and industry alike, which we outline in more detail in the sections that follow. And it is notably within the ferry segment of shipping that niche market dynamics have occurred. This is mirrored in Figure 2, which illustrates the number of media cases in the 2005–2019 period on 'electrification maritime', 'hydrogen maritime' and 'electrical ferries'. The status and sophistication of the Norwegian maritime industry makes this a highly relevant case to study transformative change.

Passenger ships is the category of vessel types that has the highest share of emissions in Norwegian waters (Steen et al. 2019). This category is broad and comprises many types of vessels ranging from ocean-going cruise ships to small ferries operating in city harbours. As stated previously, this paper focuses on a particular segment of vessels within this category, namely car passenger ferries (hereafter referred to as ferries). Due to Norway's coastal topography and relatively distributed settlement pattern along the coast (including islands), ferries are a vital part of the country's transport infrastructure. Approximately 120 ferry crossings exist in the country, as part of either national/European or county roads. The Norwegian Public Road Administration (NPRA) is responsible for ferry crossings on national roads, whereas counties are responsible for crossings on county roads. Ferry services are procured by either NPRA or counties from private operators, typically on 10-year contracts, following highly competitive tendering processes. A

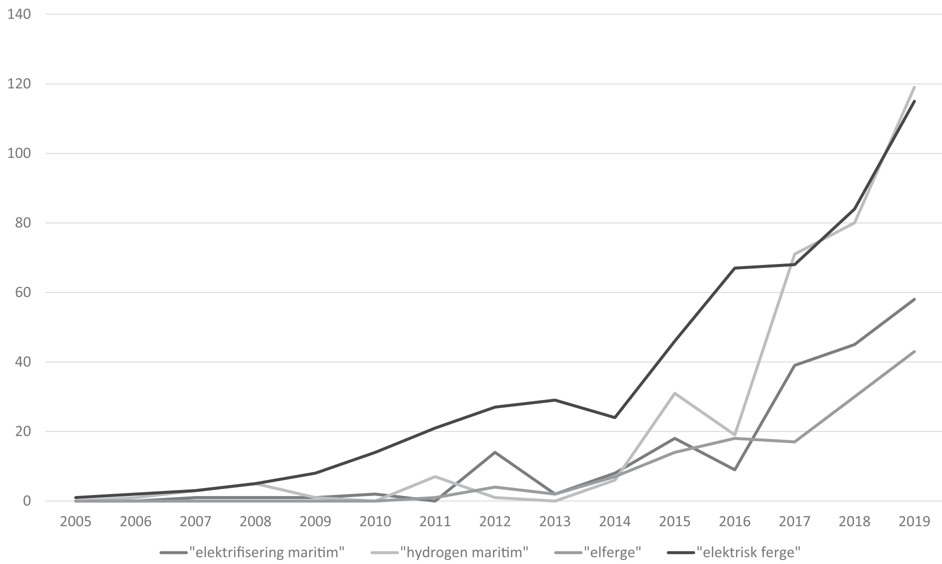

Figure 2. Media analysis. Source: Retriever.

typical tendering process starts about five years prior to the start of a contract to operate, providing shipowners sufficient time to adapt, retrofit or build new vessels.

3.2. Delineation of the case

The case study specifically targets electrification of ferries which should be seen as a sub-mission of broader objectives related to decarbonization of transport and achieving national and international climate targets for Norway (Meld. St. 41 2016–2017). Our selection of electrification limits our scope to analyse how targeted and delineated missions can be successfully organized and under which conditions this can take place. Moreover, the case study has a pronounced regional focus on the county of Hordaland in Western Norway, which since 2020 forms part of Vestland county together with Sogn og Fjordane. We also understand the counties of Rogaland and Møre og Romsdal to be part of the region of Western Norway, and our delineation of the RIS thus incorporates three (previously four) political-administrative regions. Maritime electrification appears to be a particularly good case for studying MOIP as the process has largely been directed by ambitious policies on CO_2 emission reductions and innovative public procurement policies (Bach et al. 2020). Moreover, the empirical study object of the maritime industry in Western Norway constitutes an established innovation system (Njøs et al. 2020), enabling us to explore the interlinkages between directional mission-oriented innovation policies and an existing RIS.

The case comprises different types of actors across the RIS and the socio-technical system of maritime transport. This includes core RIS actors from the regional industry (e.g. shipowners, equipment suppliers, shipyards, cluster organization, industry association), regional county municipalities, state bodies (e.g. NPRA), actors from the power sector and finally also other actors such as environmental non-governmental organisations (NGOs) that have worked to promote more sustainable maritime transport.

3.3. Methods

The data collection for the case study consists of document analysis, participation at policy-and industry seminars and interviews.

The document analysis comprised White Papers (e.g. Meld. St. 33 2016; Meld. St. 41 2016–2017), the governmental maritime strategy (Regjeringen 2015), industry reports (e.g. Mellbye, Helseth, and Jakobsen 2018), transport strategies (e.g. UNCTAD 2016) and climate strategies (Hordaland 2014; Bergen 2016; IMO 2015a; DNV-GL 2016; Klimakur 2020). The document analysis also included searches in the media archive Retriever, which helped give an understanding of the field as well as illustrating the relevance of the case in Figure 2.

We also participated in two national conferences organized by NGO ZERO targeting especially electrification of maritime transport in Norway, which gave a good understanding of the industry and policy context for the case study. Finally, we accomplished 40 semi-structured interviews with respondents representing public administration (at national, regional and local levels), interest and industry organizations, shipowners, shipyards, maritime equipment suppliers and maritime services. We also interviewed actors from the power sector (electricity generation, grid infrastructure). All interviews revolved around drivers and barriers for decarbonizing maritime transport, with a particular focus on the greening of ferry operations in Western Norway. The bulk of interviews were carried out face-to-face in the period from May 2018 to April 2019. Some interviews were done on video conference or telephone. All interviews were recorded and transcribed. The interview transcripts were subsequently read through by all the three authors, particularly identifying and categorizing key analytical categories such as 'mission problem' and/or 'solution', 'pre-existing RIS structures', 'type of agency' and 'type of asset modification'. Preliminary findings were discussed at two seminars; one with Nordic policy practitioners and including the Hordaland region in 2018, and one with NCE Maritime Cleantech cluster in March 2021.

4. Case study and analysis

In this chapter, we analyse the case study. First, we present the mission problem of reducing CO_2 emissions and its political process. Second, we address how pre-existing RIS structures, asset modification and firm- and system-level agency affected the quest towards a mission solution. As part of this, we elaborate on the contestation, complexity and uncertainty of mission problem and solution processes.

4.1. The mission problem: reducing CO_2 emissions in maritime transport

In the Paris Agreement in 2015, countries set goals for reduction of national CO_2 emissions. Norway initially aimed at a 40% reduction of CO_2 emissions by 2030. In February 2020 this emission reduction target was increased to 55%. These overall targets have been operationalized at sectoral and regional levels. For the Norwegian transport sector, the goal is to reduce CO_2 emissions by 35–40% by 2030 compared to 2005 (Meld. St. 41 2016–2017). While shipping accounts for approximately 3% of all global greenhouse gas (GHG) emissions (IMO 2015b), shipping in domestic waters is ca. 10% of Norway's total CO_2 emissions (Mellbye et al. 2016). More generally, shipping has been a laggard in addressing GHG emissions. The Norwegian Shipowners Association made a resolution in 2017 aiming for a 50% reduction in CO_2 emissions from shipping by 2050, and carbon-neutrality by 2100 (Hovland 2017). In 2018 the International Maritime Organisation (IMO) followed suite with a similar target for global shipping by 2050. This can be interpreted as decreasing contestation (Wanzenböck et al. 2020) over GHG emissions from the maritime sector being a problem that needs to be addressed.

Regarding concrete policy requirements for reducing CO_2 emissions nationally, the Norwegian Parliament made a resolution in 2015 that called for county municipalities to request low- or zero-emission energy technologies for new ferry tenders where feasible (Otterlei and Raunholm 2015). Political parties from more or less the entire right-left spectrum of Norwegian politics supported this resolution, indicating broad political agreement on the mission problem and also signalling a way forward in finding solutions. Intense lobbying by industry actors and NGOs such as ZERO appear to have played a decisive role in influencing this political decision. It is also clear that an additional motivation for these new requirements was to create market demand for the maritime industry, which was struggling at the time, especially due to a downturn in the offshore petroleum industry. A member of Parliament commented 'This means lower climate gas emissions and sorely needed jobs in Norwegian shipbuilding industry (…). This is a win-win situation' (Otterlei and Raunholm 2015).

This linking of emission reductions from maritime transport with economic opportunities for the domestic maritime industry via innovation has been clearly stated in practically all key policy documents in recent years. For instance, the Government's 2015 Blue Growth strategy explicitly mentioned procurement of ferry services as a way of stimulating environmental innovation, which, as we will demonstrate in what follows, has also been central in the Norwegian context (NFD 2015). The logic of combining environmental and industry development ambitions also applied when LNG was introduced (with relative success) as a shipping fuel in the late 1990s (Interview NPRA, 2016). The prospect of achieving both increased sustainability and new green jobs was critical for the political feasibility of imposing stronger environmental standards on the sector (Interview ZERO, 2018). This greening process was furthermore stimulated by various policy instruments providing R&D grants, investment support and funding for pilot and demonstration projects (Steen et al. 2019).

The national targets are complemented by regionally formulated emission reduction targets. In Hordaland (now part of Vestland County), the regional authorities aim to reduce CO_2 emissions with 22% by 2020 and 40% by 2030 compared to 1991 (Hordaland 2014). Because many ferry routes are the responsibility of county municipalities, and fossil fuel driven ferries have high CO_2 emissions, they became prime candidates for counties addressing their mission problem. Both regional and national non-firm actors were heavily involved in institutional work to make both the NPRA and regional counties set high emission reduction targets for ferry tenders.

To summarize, there has overall been limited contestation about the mission problem, and agreement appears to have increased over time. Most notably, there was broad political alignment across political parties and levels of governance. Several factors have contributed to this. Early anchoring of the mission problem in industry appears to have been important, and industry actors also pushed for stronger environmental regulations. NGOs and other system-level actors contributed by building networks and establishing arenas to discuss the problem. Addressing emission reductions from established sectors tends to be complex, as it indeed is also for shipping. Multiple levels and sectors often need to converge on problem framing. However, in this case, the problem had long antecedents, and actors were already converging. Another characteristic of the ferry segment of shipping is that there is strong scope for public governance, with commercial terms set by public actors (NPRA and county municipalities).

As we shall see in the section that follows, the principal solution that emerged – the development and implementation of battery-electric energy solutions for ferries – required considerable asset modification and involvement of many types of actors. Still, this solution was relatively uncontroversial from the maritime industry's point of view.

4.2. The mission solution: electrification of ferry transport

It is generally agreed that no silver bullet exists for reducing emissions from shipping (DNV GL 2016). In addition to battery-electric systems, key technologies include biofuels, hydrogen and LNG. In general, the feasibility of these different technological options depends on a range of factors, including operational patterns (fixed or flexible routes, sailing distances etc.) and institutional aspects such as particular safety regulations for specific vessel types. Battery-electric systems are seen as particularly relevant for small- and mid-sized vessels that typically operate on short and fixed routes (such as ferries), or have very variable power demand (such as e.g. offshore supply vessels) (Bergek et al. 2018).

In principle, all the above-mentioned candidates for mission solutions are relevant for ferries. Indeed, LNG has been used since the early 2000s, whereas biofuels (both biodiesel and to some extent biogas) also has a long history (Bach et al. 2021). Hydrogen is seen as an important solution for ferries operating long routes, yet remains immature with substantial uncertainty related to supply and infrastructure development (Steen et al. 2019). In the greening of ferries to date, therefore, electrification has been the main solution. Also, the availability of renewable energy and a well-developed grid infrastructure provides suitable basis for electrification in Norway.

A statement from a representative of NPRA (2015) in many ways illustrates how battery-electric systems for shipping are conceived: 'Electrification is relatively cheap, (…) and there is nothing more energy-efficient than taking electricity straight from the grid into a battery (…) Next generation batteries will be far lighter, take much less space, and be much cheaper'. It is important to note that commercial ferry tenders, including those requiring low- or zero-emission energy solutions – are technology neutral. This means that the mission solution that grew forth was never dictated top-down but must be understood as an outcome of collective entrepreneurship and distributed agency from the RIS and beyond.

The first steps towards E-ferries began around 2010 with feasibility studies of electrification, R&D hybridization projects involving members of (current) NCE in 2011, and a development contract from NPRA aiming to stimulate the development of low- or zero-emission energy solutions (Sjøtun 2018). The latter, which resulted in the world's first fully-electric ferry *MF Ampere* in 2014, was of particular importance in demonstrating technological feasibility and also in mobilizing the maritime industry, notably because all four main Norwegian ferry operators with consortia of equipment suppliers took part in the competitive tendering process. It was also of key importance to the Parliamentary resolution passed in 2015 because it was now obvious that to request low- or even zero-carbon solutions was feasible.

In NPRAs' development contract (2011), environmental requirements were used actively as an award criterion for the purchase of ferry services, and environmental performance was weighted up to 30%. Succeeding this development contract, the NPRA has continued the same type of innovative procurement for regular ferry tenders on 11 routes, and this also inspired counties (that are responsible for most ferry routes in Norway) such as Hordaland to set higher environmental ambitions in their ferry tenders.

While being technology neutral, the way tenders have been specified has benefited electrification in two ways. First, in one county municipality the tender for new ferry contracts was announced with two timetables, where bidders with a hybridization rate above 30% could use an 'alternative timetable which allowed for longer docking time for charging. (…) And that was done to give an extra push for electrical solutions'. Second, this county municipality also took on the 'construction contribution cost' to grid companies, a potentially high fee that is difficult to calculate in advance of grid improvements, and hence represents a substantial economic risk to ferry contract bidders. Indeed, there are concerns about how adaptive grid regulation will be to needs of electrifying sectors and energy transition more broadly (Bauknecht, Andersen, and Dunne 2020).

In addition to the important role of NPRA and county transport administrations, other public actors have contributed substantially to the mission solution. These include notably the Norwegian Maritime Authority (NMA) and Enova. The NMA is the body that ensures that Norwegian ships and foreign ships follow regulations. Typically, NMA will grant approval to new or retrofitted ships after engineering etc. is completed. However, in recent years the NMA has taken on a more proactive role, being involved in the early phase of developing ships with new energy solutions. Enova grants investment support to reduce GHG emissions and/or improve energy efficiency. In this context, Enova has supported innovation projects in new electric ships and charging infrastructure. In addition, several non-public organizations (e.g. DNV, the Shipowners' Association) and NGOs (e.g. ZERO, Bellona) have acted as system-level intermediaries in developing networks and arenas for collaboration across different types of actors and sectors, for joint reflexivity and learning.

Next we turn to how characteristics and strengths of the maritime RIS has contributed to finding a solution to the mission problem.

4.3. Mobilizing the RIS

In addition to a strong state setting the direction for the greening of maritime transport in general and publicly operated ferry routes in particular, the industry actors (in the existing RIS) have proactively engaged to develop solutions within electrification. According to a representative of an NGO (interview, 2019), 'actors in the market were very proactive and very clear in their communication that this was something they could deliver'. As mentioned in the previous section, members of NCE Maritime CleanTech were involved in a 2011 feasibility study of electrification, and in the 2014–2017 period the cluster had substantial focus on battery-electric solutions. According to a cluster representative, the broad asset base of the cluster (covering the entire maritime value chain) proved highly valuable in bringing forth these novel energy solutions due to the need for optimizing battery-electric systems vis-à-vis vessel types and operational requirements: 'the entire logistical structure needs to be optimised to achieve as energy-efficient systems as possible (…) propellers, ship design, material technology'. By mobilizing a variety of actors within the RIS, who brought along existing knowledge and experience and contributed to adapting those assets to new circumstances, uncertainty was reduced around the mission solution. Compared with many other types of maritime vessels, ferries are also suitable for electrification due to their operational patterns, and because their design and architecture often allows for retrofitting with battery-systems and charging devices (Bach et al. 2020).

Firm actors indicate strong support for the ambitious environmental targets and procurement process organized by NPRA:

> I think this is the best innovation driver, setting 'hairy goals'. (…) I'm sure that all new contracts we will win now have electrification in part or full, so that 90% of our fleet will be electric by 2030. (…) There is a lot of risk in this, but the ferry fleet needs renewal, so this is absolutely right. (Interview, shipowner 2017)

In general, electrification has not been perceived as disruptive to the bulk of the maritime industry. On the contrary, developing new and advanced vessels and integrating various types of systems is the Norwegian maritime RIS's competitive edge. Many of the large and established equipment suppliers (e.g. Wärtsila, Siemens, ABB, Rolls-Royce) were quick to contribute to asset modification by developing and launching products and solutions for electrification of ships, sometimes in collaboration with new entrants such as battery manufactures or R&D institutes.

Institutional and strategic agency by policy actors at national and regional levels via public procurement has also been highly instrumental in arranging for the mission solution. The NPRA paved the way for innovative public procurement in the ferry market, and the knowledge and experiences from this front-runner role has subsequently trickled down to procurement in the county administration in Hordaland and other counties. As stated by an informant in the Hordaland county administration, MF Ampere 'opened the door for us and others to follow'. Dialogue between NPRA and the industry has been a vital part of the procurement strategy, both for the procurer and the bidders, reflecting a process-oriented dynamic in the problem-solution space. As argued by an NPRA (2019) representative, the dialogue-based procurement process 'has been a very good way to reduce risk on behalf of the bidders. (…) And when risk is reduced, technology is taken even further'. At the same time, learning across policy actors, both across different policy levels and in-between county municipalities has reduced both complexity and uncertainty in tendering.

It is not a given that actors in the Western Norway maritime RIS would be able to secure contracts for developing and building E-ferries. While ferry tenders are open to the EU market, and no market discrimination is allowed, the twin benefit of emission reductions and regional industry development has been important for policy makers and public agencies. As argued by one informant, 'it is clear that politically, that way of thinking has been dominant. (…) You set an (environmental) ambition level knowing what competencies you have. This benefits the industry'. Another informant stated that 'of course, within public procurement regulations, and the EEA-agreement, there isn't much space. But the dialogue processes, which are open, result in Norwegian actors being a little bit more updated on what to expect'. By engaging with industry actors, policy makers were moreover able to understand what technological solutions that could actually be feasible.

In addition to reducing uncertainty, this way of organizing the procurement process contributed to broad mobilization of existing maritime industry actors, with all the main ferry operators with their suppliers and sub-suppliers taking part. As noted by a representative of NPRA (2019) the resulting competition not only acted as a 'strong [innovation] driver', but 'really contributed to technological diffusion' and thereby amplifying uncertainty reduction.

As highlighted by one of our informants (NPRA, 2016), the real strength of public procurement as a key innovation driver has been in tandem with other policy instruments, indicating a low degree of complexity in the support system. These other instruments include notably different types of investment support (Enova, the NOx-fund) and innovation and R&D grants (Innovation Norway, the Research Council of Norway). In sum, 'this has created the momentum that we need' as expressed by one informant, and helps explain why the Norwegian Government in November 2020 signalled that from 2023, all new public tenders for ferry transport services are expected to require low- or zero-emission solutions (Norum and Molde 2020).

Figure 3 sums up the main events at both national and regional levels associated with the electrification of ferry transport along the Western coast of Norway.

Although there has been limited contestation over the mission problem-solution in the case of decarbonizing ferry operations, there are tensions that remain to be fully resolved. Most notably, the institutionalization of high environmental standards in procurement for all ferries did not specify how added costs with E-ferries (and necessary infrastructure) would be financed. Since then, many regional governments have complained about significant financial burdens, and in the absence of state support, they

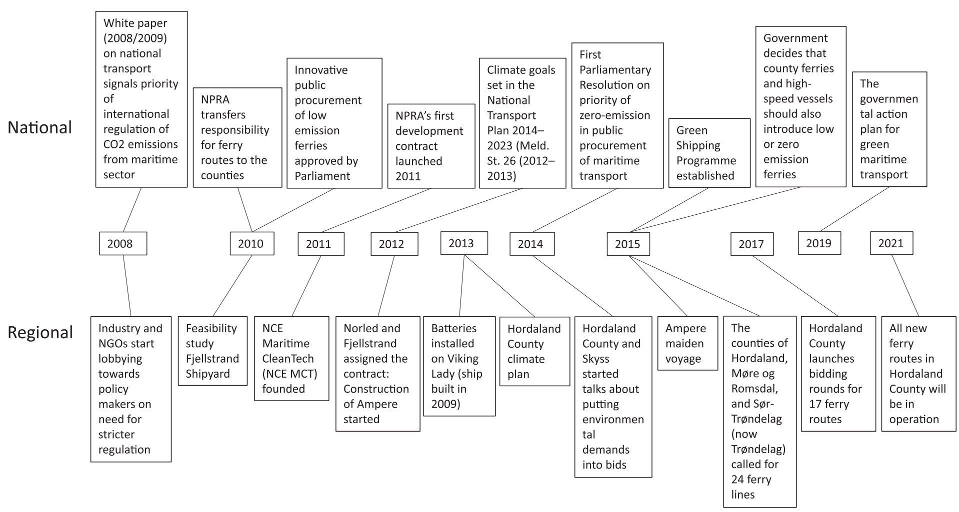

Figure 3. Timeline of main events.

may have to cut expenditure in other areas or raise taxes. Indeed, in some regions this has resulted in significant ferry price increases, a social outcry and resistance to electric ferries (Lambertsen, Helness, and Lysvold 2021).

5. Discussion

The case study presented in the previous section suggests a case of mission-oriented transformative change with relatively limited contestation, and low complexity and uncertainty in the mission problem-solution space. This, we suggest, reflects that pre-existing RIS structures provided an enabling context for change, where multiple types of agency were involved in asset modification processes that to a limited extent were disruptive. In this section we reflect on the role of existing actors and resources in transformative change in general and MOIP in particular.

5.1. Pre-existing RIS structures, asset modification and agency

Pre-existing RIS structures can be enabling or constraining for transformative change (Trippl et al. 2020), depending on industrial structure, organizational support structure and institutional set-up. The maritime RIS in Western Norway features strong collaborative (and competitive) traditions across the value chain, with a sophisticated organizational support structure (knowledge-intensive business services, financing institutions, R&D, education etc.) and an institutional set-up that has been adapted or modified to support and accommodate new energy solutions, thus enabling more environmentally friendly maritime transport.

While we have focused on a particular RIS, extra-local actors and factors have been important for the transformative change processes observed. As such, the clear directionality introduced by politically set emission reduction targets at both regional and national (and international) levels have been key to changes in procurement requirements for ferry services, and thus pivotal for creating market opportunities and reducing risk for companies. In sum the sequence of and feedbacks between decision-making and priority setting across different actors and spatial scales provide an interesting case of MOIP driven by distributed agency in the context of an ongoing sustainability transition.

The adaptation of the existing RIS has been supported by regional and extra-regional actors in the *organizational support structure*. Especially NCE Maritime CleanTech (see also Holmen and Fosse 2017) has been centre-stage in initiating various projects that have enrolled industry (and non-firm) actors to work on both particular technological problem-solving within different application domains, and exerted strong institutional pressure on policy makers to set high ambitions for emission reductions. This cluster is based on key RIS actors at its core, but has also evolved by enrolling non-local firms and non-firm actors that complement and strengthen the cluster network and asset base. This is for instance visible in collaboration with various regional, national and international universities and R&D institutes in different projects. Other national cluster organizations and networks have also contributed to the mission solution (Steen et al. 2019).

In terms of the institutional set-up, the changes that have allowed for electrification of ferries have been driven by multiple types of actors regionally and nationally. It has also involved various institutional changes, ranging from requirements in procurement contracts to necessary regulatory changes for approval of energy solutions on ships. Two other aspects are however more striking.

One is that institutional change has come about through seemingly collective and highly interactive processes. This is apparent for instance in the dialogue-based process with NPRAs development contract, and in the involvement of the Norwegian Maritime Authority in the early innovation stages of developing electrification solutions for shipping. The other is that incumbent RIS industry actors, often found to resist transformative change (Penna and Geels 2015), have embraced and acted pro-actively towards electrification not only by being in the forefront in developing new technologies (mission solution), but also by doing institutional work as in pushing for high ambitions for emission reductions in ferry contracts. This push reflects that RIS actors have perceived themselves as being well positioned to deliver the solutions needed to address the mission problem. It confirms the importance of (potential for) local value creation as legitimizing transition policies. The insights and experiences generated from development within the 'ferry niche' has also paved the way for further greening of the maritime industry (Sjøtun 2018; Steen et al. 2019).

These agentic processes have driven the asset modification needed for the mission solution which in this case was electrification of ferries. The knowledge building for the mission solution seems to have been complementary with existing RIS assets. It is also important to note that ships are complex products, of which the energy solution is but one albeit an important part. Therefore, while the energy solution may imply radical innovation, many other components and services do not change. Importantly, capabilities have been enhanced through collective processes, ranging from project work to broader networking and creation of new arenas for sharing of experiences, such as those organized by NCE Maritime CleanTech, ZERO and others.

5.2. Limited contestation, low complexity and low uncertainty

Following Wanzenböck et al. (2020), the transformative change processes associated with E-ferries in Western Norway can be characterized as having low contestation (until recently), complexity and uncertainty. Various actors across geographical scales have acted seemingly in alignment to provide directionality in the problem-solution space. This has occurred in a broader sectoral context with general agreement that the socio-technical system of maritime transport needs to reduce its dependence on fossil fuels and implement alternative fuels and energy carriers (Steen et al. 2019). While there certainly is some resistance towards greening, sustainability ambitions are relatively high among Norwegian shipowners in general (Sæther, Eide, and Bjørgum 2021). Electrification of ferries has not been particularly challenging technologically. Although there have been issues to solve, especially related to charging solutions and infrastructure, these have not reduced the legitimacy of battery-electric power as a suitable option for ferries (see also Bergek et al. 2018).

Seen from the perspective of established RIS actors, one reason for the limited contestation over the mission solution is that E-ferries have not required asset destruction. For example, since many ferries are hybrids, conventional combustion engines remain relevant. Moreover, ferries only represent a small part of the total market for most of the actors in the RIS, and in most other segments conventional solutions still dominate. Finally, conventional combustion technology is likely to remain relevant also in a low-carbon future, with substitution of fossil fuels with for instance biofuels (Bach et al. 2021). Therefore, deployment of battery-electric energy solutions in the maritime sociotechnical system is in many ways welcomed as a new market opportunity by a RIS that is at the global forefront in terms of equipment, design and engineering. While not addressed in the analysis, the relatively stable political and institutional context of Norway may also have contributed to limited contestation around the mission problem.

Due to a low degree of contestation over future solutions and with limited conflicts of interest between existing and new actors distributed across the sociotechnical system and the RIS, it was possible to reorient the strong existing RIS. Interestingly, the mission solution (electrification, battery-electric systems) emerged more rapidly than some actors (e.g. NPRA) thought was possible. Due to the ways in which development contracts and commercial procurement has been organized, many types of maritime industry actors were mobilized. Subsequently, agreement over the solution as appropriate for ferries appears to have grown. Contestation rather seems to be a more recent phenomenon that has surfaced with soaring ferry prices. Regardless, compared with other low- and zero-carbon solutions, electrification proved superior in terms of cost-efficiency, yet also clearly benefitted from the strong weighting of environmental requirements in the procurement contracts.

6. Conclusion

The paper set out to explore the role of RIS in transformative change and mission-oriented innovation policy, using the case of electrification of car passenger ferries in Western Norway. In doing so, we have sought to improve our understanding of the role of existing actors and resources in transformative change. While the debate on transformative change and mission-oriented innovation has paid limited attention to the role of existing actors and assets (Janssen et al. 2021), economic geographers (e.g. Trippl et al. 2020; Grillitsch and Hansen 2019) emphasize how existing assets and RIS may be central pillars of transformation processes. This paper seeks to contribute to this agenda and can be seen as a response to the call for operationalization and application of the framework proposed by Trippl et al. (2020) in different regional contexts, which highlights pre-existing RIS structures, asset modification and firm- and system-level agency to better understand the geographical underpinnings and conditions for mission-oriented innovation and transformative change.

The transformative change that has occurred in the socio-technical system of Norway's car/passenger ferry transport can be understood as an outcome of limited contestation and successful alignment between policy ambitions at multiple levels around mission problems, and the delivery of mission solutions by existing innovation system actors via strategic agency and asset modifications. As such the case study can be perceived as *mission-re-orientation* of a strong existing RIS. The paper further illustrates how processes of transformative change may be multi-scalar and how they are conditioned and embedded by their geographical underpinnings (Truffer, Murphy, and Raven 2015). This includes political regulation and priorities at various levels, innovative public procurement, initiatives by public administration, public support schemes for research and innovation, technical advice and consulting, networking, lobbying and dialogue and strong industry involvement in both mission framing and identification of mission solution.

While the case study demonstrates the importance of innovative public procurement in stimulating transformative change, these procurement practices should also be understood as operationalizations of politically set targets at different levels to reduce GHG emissions. However, the case illustrates that actors such as NPRA and county municipalities have used their relative autonomy in operationalizing targets via procurement to simultaneously emphasize environment and provide new opportunities for the regional/national maritime industry. The seemingly successful outcome of this process may reflect that transformative change in a green direction is perceived by both policy makers and industry actors alike to be strengthening rather than threatening the long-term international competitiveness of the maritime industry. The paper has shown how asset modification of pre-existing RIS structures and both firm- and system-level agency have co-evolved and mutually enforced each other. In this sense the case demonstrates how mission-oriented innovation can be accommodated and strengthened when there is a fit between mission solution and the existing regional knowledge base and industrial specialization. These findings also indicate that even in cases of low contestation, strong pre-existing RIS structures and alignment with new economic opportunities, pro-active agency and direction appears crucial for unleashing the potential of industrial re-orientation.

Note

1. NCE is an abbreviation for Norwegian Centre of Expertise. It is one (and second in terms of sophistication/maturity) of the cluster categories in the official Norwegian cluster programme, the other categories being ’Arena’, ’Arena Pro’, and ’Global Centres of Expertise’.

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