GREENING THE FLEET – SUSTAINABILITY TRANSITIONS IN THE MARITIME SHIPPING SECTOR (2017-2020)

GREENFLEET is a research project that aims to analyse the opportunities and challenges associated with a transition from fossil-based fuels to low- or zero-carbon technologies. From previous research we know that such 'sustainability transitions' are complex and lengthy processes. This is due to various barriers (technology, economy, culture etc.) confronting novel technological solutions, that may be of organizational, contextual or systemic nature. That transitions are challenging and lengthy is therefore often not due to technology itself, but rather to other factors such as established conventions and 'rules of the game', that new technologies require protected 'niches' wherein they can develop to commercial level, lacking market demand, high degrees of uncertainty regarding technology choices and so on.

With a 'technological innovation systems' perspective at its core, GREENFLEET will analyse the strengths and weaknesses of three focal low- or zero-carbon energy technologies (battery-electric, biofuels, hydrogen), as well as hybrids of these and conventional energy solutions. Each of these focal technologies constitute a 'technological innovation system' with differing degrees of maturity and complexity. Development and maturation of technological innovation systems has been found to be contingent of seven different processes or functions (with key aspects):

1. Knowledge development and diffusion (different types of knowledge and learning processes)
2. Influence on the direction of search (incentives to enter a technological field)
3. Market formation (rise of demand, public procurement, pilot and demonstration projects)
4. Resource mobilization (human and financial capital, complementary assets)
5. Legitimation (social acceptance)
6. Entrepreneurial experimentation (testing and developing new solutions)
7. Development of external economies (formation of specialized know-how, intermediate goods, knowledge spillovers)

By analysing these functions/processes (using various indicators), GREENFLEET aims to illuminate the strengths and weaknesses of novel 'green technologies' that can contribute to emission reductions in the Norwegian maritime shipping sector. This knowledge will be useful for informing policy makers about framework conditions and policy tools, and may contribute to enhanced grounds for decision-making. It can also shed light on potential synergies across the maritime industry and also other sectors.

Theoretically and conceptually the TIS approach forms the core of the GREENFLEET project. To better understand both context and agency, we complement the TIS approach with perspectives from the broader sustainability transitions literature as well as more actor-oriented approaches from organizational theory and strategic management. GREENFLEET engages with a rather complex empirical field. First, the MSS covers a broad range of vessel types that operate within various domestic and international market segments and are thus subject to different framework conditions and regulations. Second, the new LoZeCs (i.e. emerging TIS) differ in their level of development and diffusion, application contexts, potential in 'hybrid solutions' with other new and conventional energy technologies and fuels, relevance and linkages to other sectors. Our empirical focus will be on three key LoZeC technologies or fuels, thus constituting the focal TIS to be analyzed: biofuels, battery-electric, and hydrogen. Against this background, the main research question in GREENFLEET is:

- What are the systemic, contextual and actor-level drivers and barriers confronting 'green shift' processes in the MSS?

Additionally, GREENFLEET addresses the following sub-questions:

- What is the status of the different focal TISs and what are their particular system strengths and weaknesses? (WP1)

- What firm level strategies and industry dynamics concerning technology development, investment decisions and business models linked to LoZeCs characterize the MSS? (WP2)
- How are the focal TISs affected by 'external' contextual dynamics? (WP3)
- Given the status of focal TISs, contextual conditions and firm level strategies, what future transition pathways can lead towards a sustainable MSS? (WP4)

WP1 TIS analysis (WP leader: Teis Hansen, Lund University)

Objectives: Provide TIS analysis of focal LoZeC technologies, i.e. a mapping of structural components (actors, networks, institutions, value chains) as well as description and analysis of key processes (or functions) of the chosen TISs to unveil system strengths and weaknesses.

Methods & data: WP1 will be based on the scheme of TIS analysis described in Bergek et al. (2008), which includes suggested data sources and indicators for identifying the key structures and actors associated with the relevant LoZeC technologies and analyzing and assessing TIS functions (e.g. for resource mobilization to new technologies). Methodological approaches for TIS analysis vary for different function and include: literature review, bibliometric analysis, document analysis, *ca.* 10 interviews with key informants (industry experts, technical (R&D) experts, officials in key public agencies such as e.g. Innovation Norway or Enova) per focal TIS (30 in total) and a dedicated user panel workshop.

WP2 Firm capabilities and industry dynamics (WP leader: Tone Merethe Aasen, SINTEF)

Objectives: WP2 will be based on perspectives from organizational and innovation theory and the strategic management literature. It will analyze strategies and activities of firms in various value chain segments within (and outside) the MSS involved in the focal TISs, focusing on technology strategies, investment decisions, inter-firm collaboration and business models in the context of a mature industry currently subject to various potentially disruptive technologies. By empirically covering various types of firms (e.g. in buyer-supplier relations) WP2 will also provide insights on emerging LoZeC value chains and prospects for value creation.

Methods & data: Key methods in WP2 include a firm survey, interviews (with industry experts and in firm case studies), participatory observation at industry events and document studies. The survey sample will be based on user partners' (NCE Maritime CleanTech, the Norwegian Shipowner's Association, the (maritime branch of) the Federation of Norwegian Industries). The survey will thus cover various types of firms (shipowners, technology developers/suppliers, shipyards etc.) potentially involved in the focal TISs, and, importantly, also serve to provide a broad overview of how different MSS actors perceive and approach sustainability transition processes. Survey data will be combined with interviews with industry experts, document studies (e.g. technical reports) and participation at industry events. We complement the broad-based survey with case studies of approx. 10-12 companies (tentatively include 4-5 incumbents (i.e. established MSS companies), 4-5 new entrants, and 3-4 firms entering the MSS from other sectors (e.g. battery developers or biogas producers)). Case studies will be based on interviews (2-3 per case) and document studies. Access to firms for these case studies will benefit from assistance from our user panel industry partners. Moreover, SINTEF and NTNU have close interaction with Norwegian industry firms, and based on our experience, access to informants and data should not be problematic.

WP3 Context analysis (WP leader: Olav Wicken, University in Oslo)

Objectives: Provide context analysis for the three focal LoZeC technologies. This includes identifying and analyzing structural coupling and linkages between emerging TIS and the following context structures: 1) Between the different emerging TIS (which may compete, be complementary (in hybrid solutions) etc.), 2) between the focal TISs and the MSS (as well as other relevant sectoral contexts, e.g. the broader energy system, onshore transport), 3) between the focal TISs and the political context, and finally 4) between the focal TISs and geographical contexts. In reality these context are not neatly separated, nor is it necessarily straightforward to distinguish between focal TISs and context structures. Specific delineations are therefore a result of analytical choice and empirical findings. We expect that WP1 and WP2 will provide necessary guidance both to distinguishing between TISs and context structures that influence TIS functioning and to identifying "external" inducement and/or

blocking mechanisms. Whether structural couplings between TISs and contexts are positive or negative can in other words not be determined *a priori*. The key objective in WP3 will therefore be scrutinize the contexts to which inducement and/or blocking mechanisms "belong to". Once these are identified, specific lock-in mechanisms hindering transitions processes can be unpacked.
Methods & data: WP3 draws on the extended TIS-in-context approach (Bergek et al. 2015) and broader sustainability transitions literature. The analysis will build directly on WP1 and draw on WP2, but to larger extent include interviews with other stakeholders (industry associations, policy makers, different government agencies, key actors in other sectors (e.g. utilities or biogas producers) etc.). In addition to approx. 20 interviews, methods include a user panel workshop, literature reviews and document analysis of secondary (archival) data.

WP4 Prospective analysis (WP leader: Markus Steen, SINTEF)
Objectives: Provide roadmaps for 2025 and 2040 for further development, implementation and diffusion of new LoZeC technologies in the MSS. Describe potential transition pathways towards a sustainable MSS and provide guidelines to decision makers in industry and policy on how a green shift in the MSS may be realized.
Methods & data: Drawing on insights gained in WPs 1-3 WP4 will analyze and identify potential technological and organizational development options for possible sustainable transition pathways in the MSS. We will employ a prospective *socio-technical variants analysis* (STVA) to identify future development options taking account of both technological and organizational features (Markard, Stadelmann, and Truffer 2009). For instance, some technologies require substantial capital investments, which thus impacts on the types of firms that are likely to take a leading role in TIS formation. However, this prospective analysis will also demand attention to how contexts may evolve. Foresight activities can help identify promising technological pathways, facilitate the creation of collective expectations and visions, generation of better problem definitions, priority settings and improved innovation system functioning through network development between firms and non-firm actors. A dedicated foresight workshop with user panel members and other invited stakeholders is an important method in WP4.

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