Socio-technical conditions for an energy transition in Norwegian shipping

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NTRANS
Norwegian Centre for Energy Transition Strategies

Research

- Greening the Fleet -project and FME NTRANS (RA2)
- Qualitative socio-technical analysis of energy transition in Norwegian coastal shipping
- Primary data collection in 2015-2020
  - 74 semi-structured interviews
  - Survey with 287 Norwegian shipowners

Socio-technical transitions

- **Fundamental changes** in the patterns of production and consumption in different sectors
- Transitions as interlinked processes of **novel innovations** (niches) **changing established technologies, rules and practices** (regime), influenced by **wider societal and political developments** (landscape)
- Highlights the **systemic** nature of transitions, role of **path dependence** in hampering change, and "**windows of opportunities**" for transitions
- Insights on the **feasibility** of transition scenarios

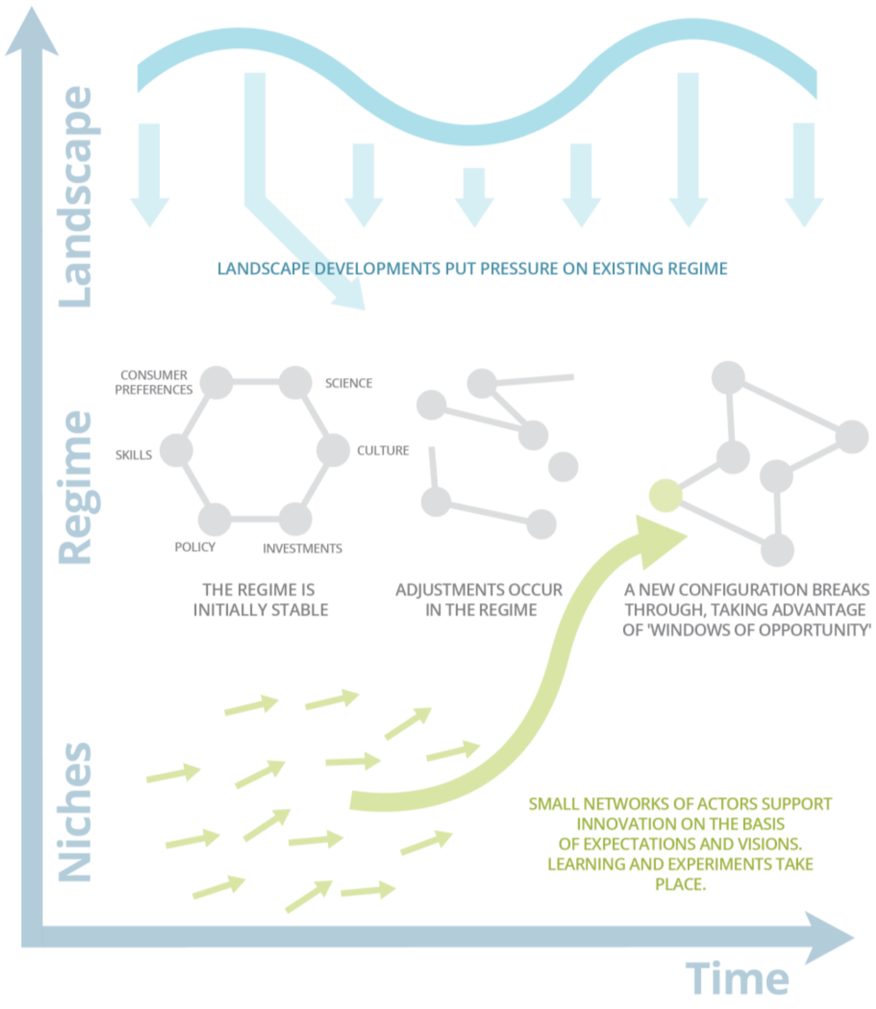

Figure: EEA, based on Geels 2002

Current regime in shipping

- Environmental focus earlier on local pollutants (NOx, SOx, spills, etc.), recently increasingly on carbon (goal of 50% by 2030)
- Path dependence on current fuels (MGO/MDO, HFO, LNG)
  - Cheap, available, trusted, high energy density, embedded in current practices, sunk investments, etc.
  - Limited financial margins and knowledge among shipowners and operators
- Pressure from e.g. new tendering requirements and increasing carbon fees

Heavy fuel oil (Photo: Glasbruch2007)

Development of niche innovations

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Implementing maritime battery-electric and hydrogen solutions: A technological innovation systems analysis

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ARTICLE INFO

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Norway
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ABSTRACT

Maritime transport faces increasing pressure to reduce its greenhouse gas emissions to be in accordance with the Paris Agreement. For this to happen, low- and zero-carbon energy solutions need to be developed. In this paper we draw on sustainability transition literature and introduce the technological innovation system (TIS) framework to the field of maritime transportation research. The TIS approach analytically distinguishes between different innovation system functions that are important for new technologies to develop and diffuse beyond an early phase of experimentation. This provides a basis for technology-specific policy recommendations. We apply the TIS framework to the case of battery-electric and hydrogen energy solutions for coastal maritime transport in Norway. Whereas both battery-electric and hydrogen solutions have developed rapidly, the former is more mature and has a strong momentum. Public procurement and other policy instruments have been crucial for developments to date and will be important for these technologies to become viable options for shipping more generally.

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Blending new and old in sustainability transitions: Technological alignment between fossil fuels and biofuels in Norwegian coastal shipping

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Green shipping
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Maritime policy

ABSTRACT

Facing increasing pressure to decarbonize, innovation within the shipping sector has turned to low-and zero carbon solutions. In this paper we investigate how the development and implementation of biodiesel and liquefied biogas (LBG) in Norwegian coastal shipping has been influenced by the technological alignment with fossil fuels. We understand this influence to emanate from the (mis)match of biofuels with the structure of coastal shipping (e.g. infrastructure, knowledge, institutions, actors) which has been shaped by fossil fuels. This way we contribute to the development of Technological Innovation Systems (TIS) framework by discussing the effect of sectoral cross-technology externalities on the functionality of a TIS. Our core data consists of semi-structured interviews, supported by a firm survey with Norwegian shipowners.

Our results show that the technological alignment provides the biodiesel and LBG TISs with several benefits, such as access to established markets and infrastructure, which suggests that Norway to some extent has good conditions for maritime biofuel markets to form. However, two major barriers for implementation of biofuels are fuel availability and cost. Considering the competition with battery-electric and hydrogen solutions, the positive externalities of the interchangeability between fossil and biofuels are insufficient to make biodiesel and LBG competitive contenders for coastal shipping. In order to upscale implementation of biofuels in the Norwegian coastal shipping sector, which is needed to reach national and international emission targets, there is a need for strengthened policy interventions. To establish market formation, subsidies for biofuels and feed-in targets would be crucial policy instruments.

Performance of battery-electric and hydrogen innovation systems

Innovation processes	Battery-electric (BE)	Hydrogen (h2)
Knowledge development and diffusion	+ Strong collaboration - Need for further technological development	+ Increasing number of R&D projects - Weak knowledge base
Engagement of actors	+ Clear political goals + Public incentives	+ Political goals and ambitions - Competition against other alt. fuels
Legitimation	+ Success rate of implemented BE	+ Important actors engaging - Lack of rules and regulations
Market formation	+ Emission regulation, public procurement	- High fuel prices and limited availability of h2
Resource mobilization	+ Substantial public and private investments	+ Increasing access of capital

Weak performance	Intermediate performance	Strong performance

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Performance of biofuel innovation systems

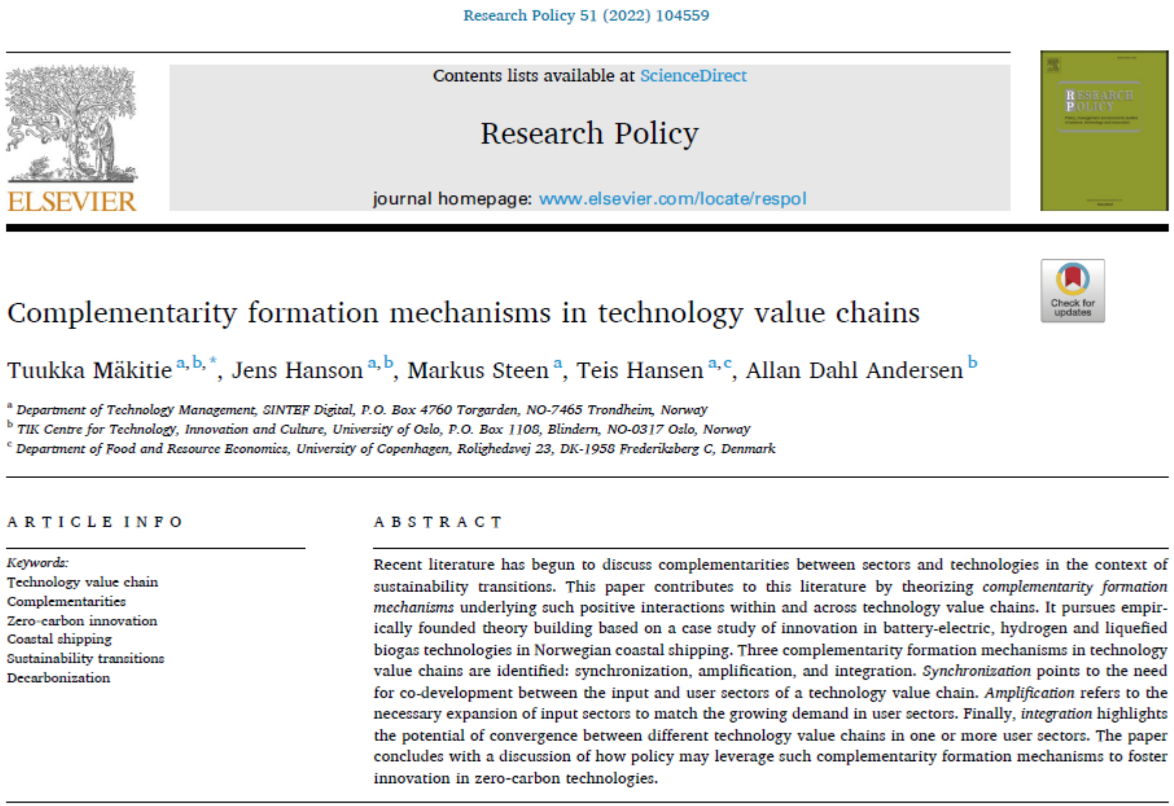
Innovation process	Biodiesel	Liquefied biogas (LBG)
Knowledge development and diffusion	- Little technical development - Little focus on shipping	- Little focus on shipping
Engagement of actors	- High price, - Pessimism among shipowners	+ Emission reduction policies + Synergies with road-based transport
Entrepreneurial experimentation	- Few experiments	- Few experiments in shipping
Legitimation	- Unclear environmental benefits - Fuel vs. food controversy - High price	- Uncertainty of LBG availability - Lower sustainability score in procurement programs
Resource mobilization	- Public R&D programs not favorable to biodiesel	+ Available LNG/LBG infrastructure

Weak performance	Intermediate performance	Strong performance

Condusiveness of the value chains of novel fuels

	Features
Battery-electric	+ Existing power production and distribution + Enough power supply in Norway - Inadequate grid capacity in remote regions
Hydrogen	+ Potential scalability - Yet non-existing value chain - Chicken and egg problems
Liquefied biogas	+ Interchangeability with LNG - Limited production - Low scalability

Weak	**Intermediate**	**Strong**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Complementarity formation mechanisms in technology value chains

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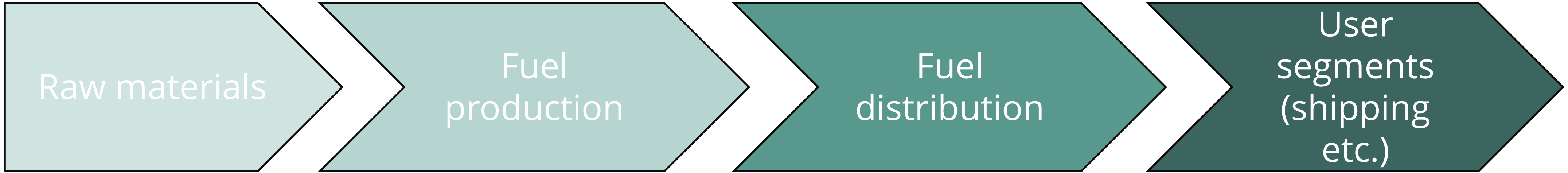
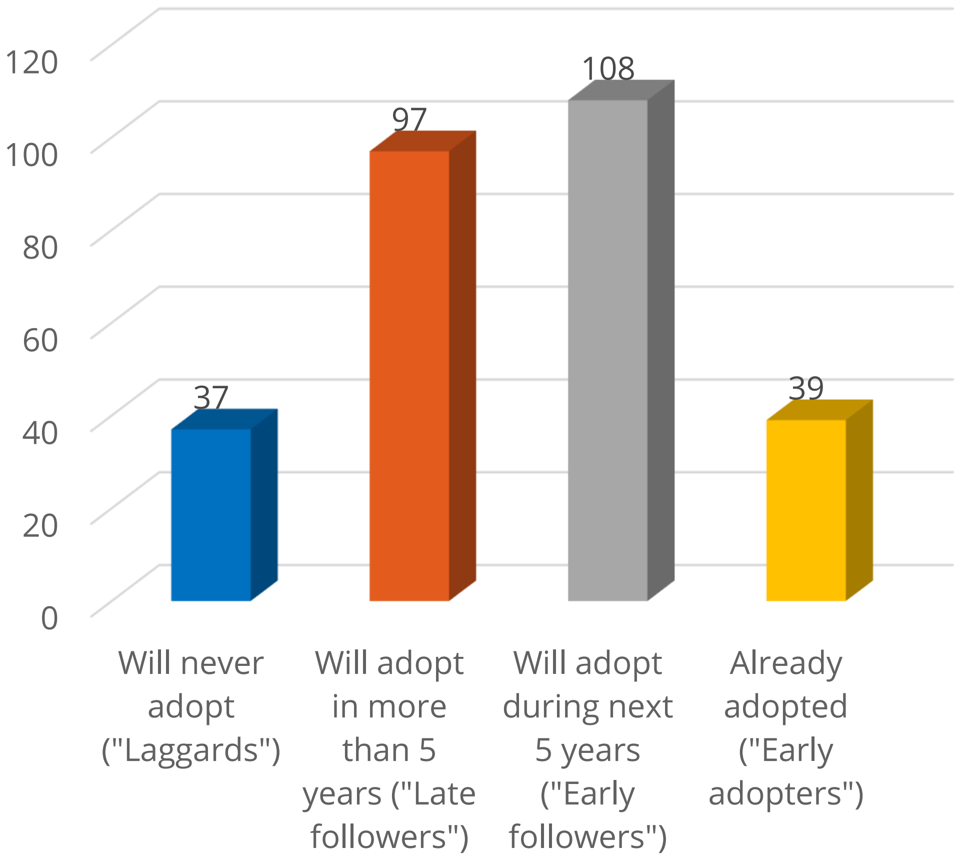
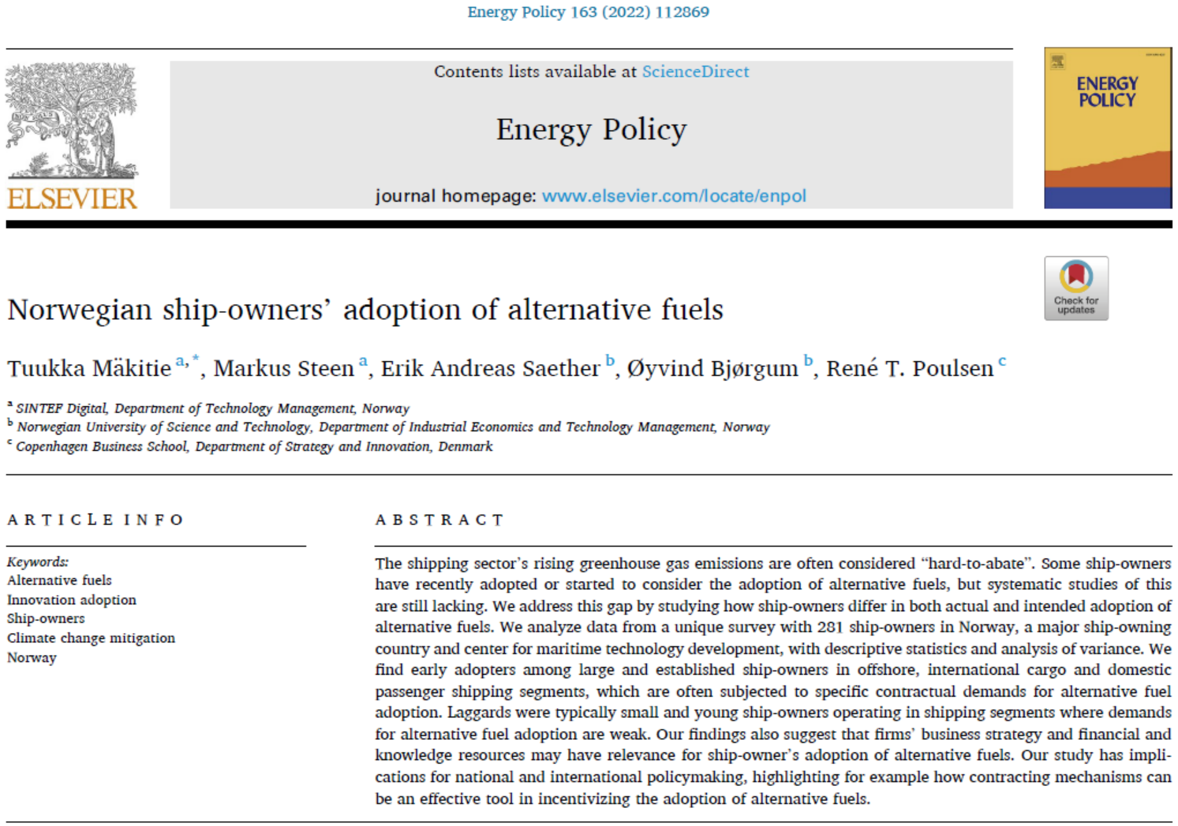
ABSTRACT

Recent literature has begun to discuss complementarities between sectors and technologies in the context of sustainability transitions. This paper contributes to this literature by theorizing *complementarity formation mechanisms* underlying such positive interactions within and across technology value chains. It pursues empirically founded theory building based on a case study of innovation in battery-electric, hydrogen and liquefied biogas technologies in Norwegian coastal shipping. Three complementarity formation mechanisms in technology value chains are identified: synchronization, amplification, and integration. *Synchronization* points to the need for co-development between the input and user sectors of a technology value chain. *Amplification* refers to the necessary expansion of input sectors to match the growing demand in user sectors. Finally, *integration* highlights the potential of convergence between different technology value chains in one or more user sectors. The paper concludes with a discussion of how policy may leverage such complementarity formation mechanisms to foster innovation in zero-carbon technologies.



Shipowners' adoption of novel fuels





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Norwegian ship-owners' adoption of alternative fuels

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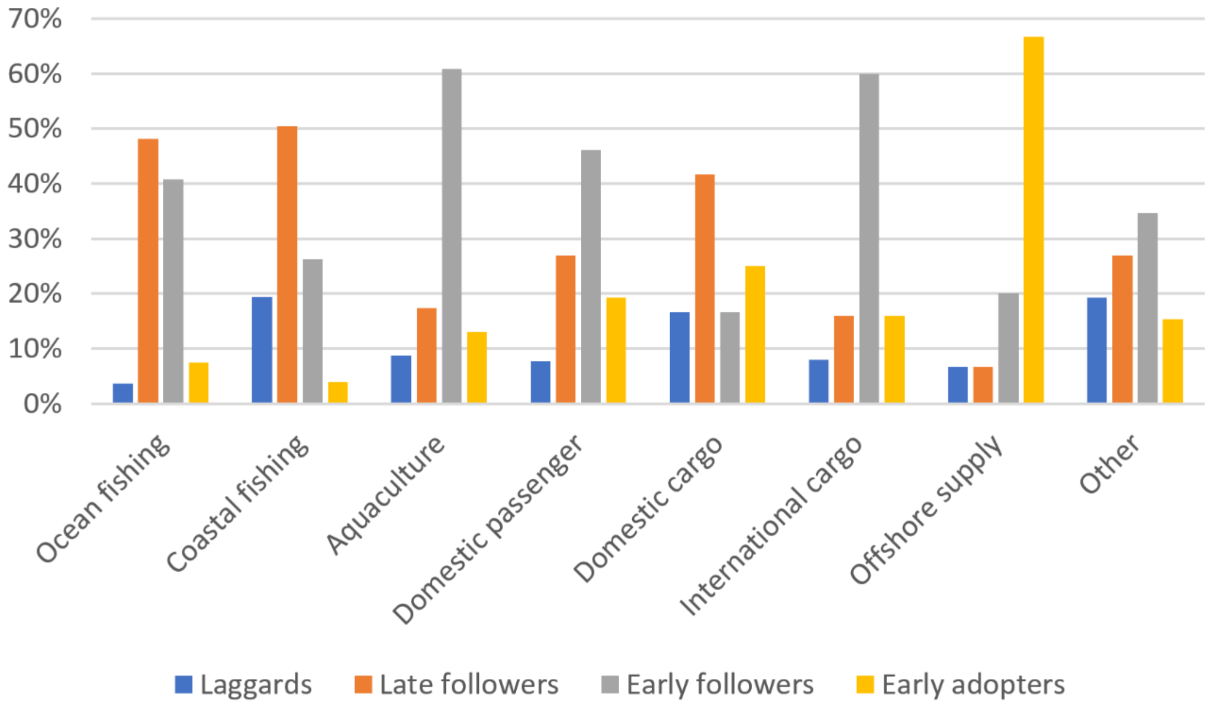
Norway

ABSTRACT

The shipping sector's rising greenhouse gas emissions are often considered "hard-to-abate". Some ship-owners have recently adopted or started to consider the adoption of alternative fuels, but systematic studies of this are still lacking. We address this gap by studying how ship-owners differ in both actual and intended adoption of alternative fuels. We analyze data from a unique survey with 281 ship-owners in Norway, a major ship-owning country and center for maritime technology development, with descriptive statistics and analysis of variance. We find early adopters among large and established ship-owners in offshore, international cargo and domestic passenger shipping segments, which are often subjected to specific contractual demands for alternative fuel adoption. Laggards were typically small and young ship-owners operating in shipping segments where demands for alternative fuel adoption are weak. Our findings also suggest that firms' business strategy and financial and knowledge resources may have relevance for ship-owner's adoption of alternative fuels. Our study has implications for national and international policymaking, highlighting for example how contracting mechanisms can be an effective tool in incentivizing the adoption of alternative fuels.

Early adopters vs. laggards

- **Early adopters** of alternative fuels are typically…
  - from shipping segments such as e.g. **offshore**, **international cargo** and **domestic passenger**
  - **large** and **old shipowners** with relatively **new vessels**
- **Laggards** are typically…
  - from e.g. **coastal fishing**
  - **Small** and **young shipowners** with relatively **old vessels**
- Early adopters report **higher motivations** e.g. in terms of **increased competitiveness**
- **Few differences in barriers**: all groups report e.g. difficulties in terms of investment costs and financing



Conclusion

- Complexity a key socio-technical condition for an energy transition in shipping (A. Bergek, T. Hansen, J. Hanson, T. Mäkitie & M. Steen, under review)
- Heterogeneity of solutions and application domains
  - Many potential technologies with different strengths and weaknesses
  - From small fishing vessels to globetrotting megaships!
  - Long lifetime of vessels requires retrofitting (customization, adaptation) → less mass production
- Interdependencies between technologies, value chains and user segments
  - Novel technologies: competition over resources and investments, potential synergies between battery-electric & hydrogen, biofuels reusing fossil fuel infrastructure
  - Value chains: development of production, distribution and use of novel fuels (like hydrogen) mutually interdependent (possible chicken and egg problems)
  - Knowledge spillovers and synergies between application domains