# Exploration and Synchronization of Greening of Shipping by Means of Retrofit: The SYNERGETICS Perspective

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**Abstract.** The "greening" of shipping remains a challenge despite the development of technologies aiming at decarbonisation and reduction of air-pollutant emissions. Considering a wide variety of ship types and applications, the choice of the most adequate greening solution for a ship of certain size, type, and operational profile is not straightforward. SYNERGETICS is a Horizon Europe Innovation Action which aims at supporting the greening of inland and coastal shipping by addressing the potentials of retrofit technologies. This paper presents first findings of SYNERGETICS which aim at establishing the synergies between the knowledge available from previous and ongoing research ("Exploration") and the experiences gained from past and ongoing pilot projects ("Synchronization"). A comprehensive database of pilot projects containing 115 inland vessels and 50 coastal ships was created and analysed to establish and explain the trends in greening of inland and coastal shipping. It was found that most of the pilots in inland navigation are conducted on vessels with relatively low power demands and/or with low variations of operational profiles, while coastal shipping features a relatively low number of pilots. This increases the certainty for shipowners but limits the possibilities for scaling up the greening of shipping.

**Keywords:** inland vessels · coastal ships · retrofit · decarbonization · air pollutants reduction · SYNERGETICS

## 1 Introduction

SYNERGETICS (Synergies for green transformation of inland and coastal shipping) is a Horizon Europe Innovation Action in support of the greening of inland and coastal shipping by addressing the potential of retrofit technologies. In context of SYNERGETICS, the "greening" implies the application of innovative technical (design) measures on ships in efforts to achieve decarbonisation and reduce the emissions of air pollutants. In view of uncertainties related to the impact of the innovations on the ship operation


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and/or the absence of adequate regulatory framework, such measures are realized in "pilots" – the vessels which provide insights into operational aspects and potentials for scaling up of the solutions to the fleets.

Establishing synergies with past and ongoing greening pilots as a means of learning from practical experiences gained in their deployment and operation is carried out within "Synchronization", one of the activities performed in the first phases of SYNERGETICS. To facilitate synergizing with the pilots, a comprehensive Pilot database was created with information on 115 inland and 50 coastal shipping pilots performed in period 2008–2026. Using the information from the Pilot database, it is possible to establish trends in greening of ships, such as the technologies most commonly used depending on the ship type, the evolution of the greening efforts considering the time of the pilot deployment, etc.

The observed trends may be driven by a range of factors (e.g., maturity and feasibility of the technologies, policy incentives and supportive financial instruments, development of the necessary infrastructure, etc.). The knowledge which could explain the identified tendencies is fragmented and dispersed over numerous research projects. Harvesting and integration of such knowledge is performed within "Exploration", a SYNERGETICS activity which runs in parallel with "Synchronization".

## 2 Synchronization: Identification of Trends in Greening of Ships

An entry to the SYNERGETICS Pilot database contains information on the project (project name and coordinator, funding program, location, start and end date of the project), the pilot itself (location, starting date and duration) including the technical specifications (type of vessel, type of innovation applied, type of alternative energy system, onboard storage and bunkering method), etc.

**Table 1.** Types of inland vessels and coastal ships represented in the Pilot database.

| Inland vessels | | Ferries | 19% |
|---|---|---|---|
| Motor vessels ($L < 80$ m) | 6% | Large cabin vessels | 1% |
| Motor vessels dry cargo (80m $\leq L <$ 109 m) | 7% | Coupled convoys | 2% |
| Motor vessels liquid cargo (80 m $\leq L <$ 109 m) | 1% | Push boats ($P <$ 500 kW) | 3% |
| Motor vessels dry cargo ($L \geq$ 110 m) | 9% | Push boats (500 $\leq P <$ 2000 kW) | 3% |
| Motor vessels liquid cargo ($L \geq$ 110 m) | 10% | Push boats ($P \geq$ 2000 kW) | 2% |
| Day trip and small cabin vessels | 37% | Workboats | 1% |

| Coastal ships | | Cruise ships | 2% |
|---|---|---|---|
| Tugboats | 14% | Fishing vessels | 4% |
| Offshore supply vessels | 18% | Dredgers | 4% |
| Ferries | 26% | Pilot boats | 2% |
| Cargo ships | 28% | Workboats | 2% |

The Pilot database comprises both the pilots implemented by retrofitting existing ships and the pilots realized on newbuilt vessels. Newbuilds make 63% of pilots on inland vessels; as for coastal ships, the share of newbuilt pilots is lower, but still high (54%). The database includes all major types of inland vessels and coastal ships (see Table 1). (In context of SYNERGETICS, "coastal ships" are seagoing ships which operate in ports, along coastlines, between islands and in marginal seas.) Most of the pilots in inland waterway transport (IWT) are implemented on small passenger ships ("day trip and small cabin vessels") and ferries (37% and 19% respectively), while the least number of pilots is conducted on push boats (8% considering all push boat categories). Cargo ships (28%) and ferries (26%) dominate the coastal pilots.

Three types of innovations are reported in the database: electrification of the main propulsion plant, use of alternative fuels, and energy-efficiency measures. The identified alternative energy systems comprise hydrogen in fuel cells ($H_2$-FC) and in internal combustion engines ($H_2$-ICE), methanol in fuel cells ($CH_3OH$-FC) and in internal combustion engines ($CH_3OH$-ICE), liquefied natural gas (LNG), compressed natural gas (CNG), and ammonia in fuel cells ($NH_3$-FC) and in internal combustion engines ($NH_3$-ICE). Energy-efficiency measures include design interventions (other than electrification or utilization of alternative fuels) leading to decreased fuel consumption, primarily the hydrodynamic improvements of propulsor and/or hull.

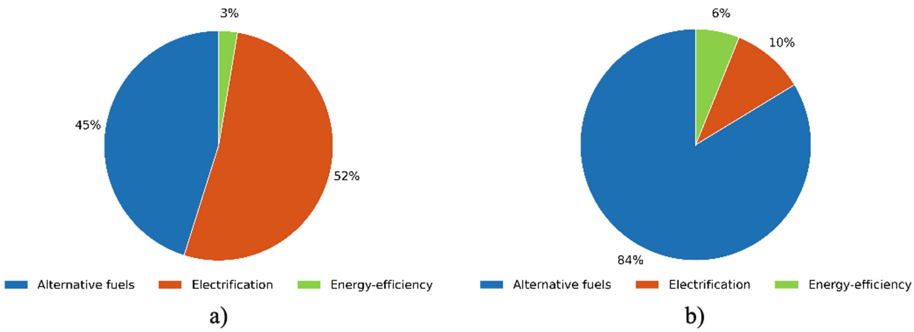


**Fig. 1.** Innovative technologies used in greening pilots on a) inland vessels and b) coastal ships.

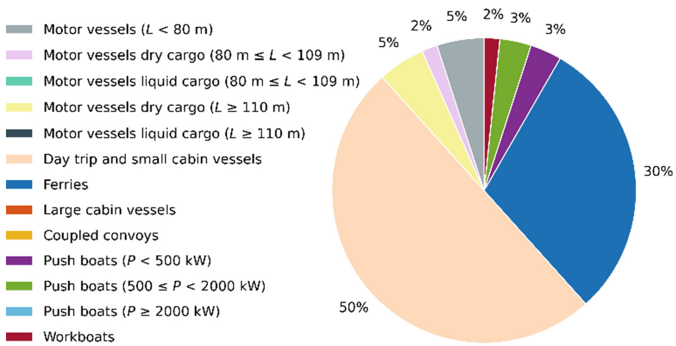


**Fig. 2.** Electrification pilots on inland vessels; breakdown by ship type.

Regarding the choice of innovative technology used (Fig. 1), electrification and alternative fuels are almost equally represented in greening of inland vessels (52% vs.

45%). In case of coastal ships, however, electrification comprises just 10% of pilots (five ships, three out of which are ferries) while alternative fuels are being implemented in as much as 84% of pilots. Energy-efficiency measures appear to be seldom used (2% in inland vessels pilots and 6% in coastal ships pilots). In inland navigation, electrification is mostly used on day trip and small cabin vessels and ferries (50% and 30% respectively), see Fig. 2.

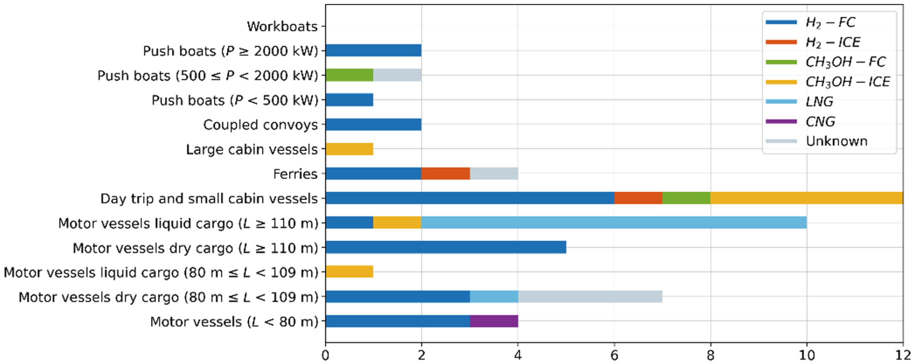


**Fig. 3.** Alternative fuels pilots on inland vessels.

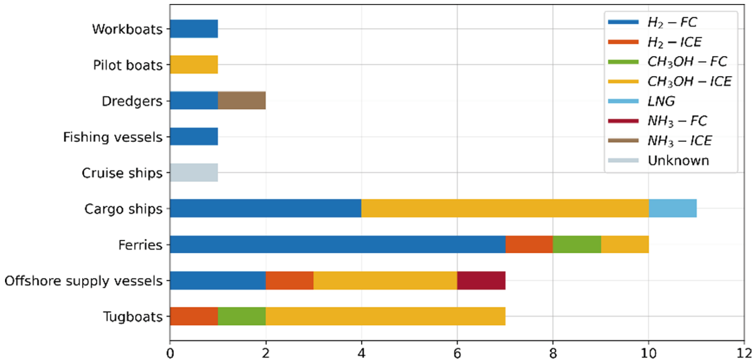


**Fig. 4.** Alternative fuels pilots on coastal ships.

The utilization of alternative fuels is more equally spread across the types of inland vessels, Fig. 3. In fact, self-propelled dry and liquid cargo vessels with $L > 80$ m comprise some 45% of the alternative fuel pilots. The most prominent types of alternative energy systems used in inland navigation pilots are $H_2$-FC, i.e., almost half of the pilots (49%), followed by LNG (17%)[1] and $CH_3OH$-ICE (14%). In coastal shipping, $CH_3OH$-ICE and $H_2$-FC have equally prominent roles (both 40%); the principal alternative fuels pilots are the major ship types (tugboats, offshore supply vessels, ferries, and cargo ships), Fig. 4.

[1] LNG pilots comprise early applications and/or applications with a specific learning potential, not all inland and coastal ships powered by LNG.

Another prominent feature of coastal pilots is the use of $NH_3$ (which, so far, found no pilot application in IWT), albeit in two pilots only.

## 3 Exploration: Analysis of the Observed Trends

Even though the pilots were carried out on all major ship types used in IWT and coastal shipping, the diversification seems to be relatively limited when it comes to inland vessels. The pilots are mostly performed on small passenger ships and (usually small) ferries (see Table 1), that is, on vessels with relatively low power demands, operating in comparatively controlled environments, with low variations in day-to-day operational profiles. Since such ships carry people (i.e., light "cargo") the options for modification of standard designs and mitigation of novel risks (inherent to some of the greening solutions) are greater. Furthermore, such vessels travel over short distances, staying close to the "home port" where they can be readily taken care of in case of technical issues with the novel technologies. These factors limit the risks and diminish the costs associated with the application of innovative technologies. Moreover, a greener passenger vessel may appeal better to the public and, possibly, attract more customers. However, the available data (see [1]) indicate that day trip vessels and in specific, ferries, are not the major emitters in inland navigation. Less than 20% of pilots is performed on large self-propelled liquid and dry cargo ships ($L \geq 110$ m) which are among the greatest emitters in IWT. The total of eight pilots performed on push boats across all power ranges is a consequence of high power demands and constrained space, as push boats are essentially floating engine rooms.

The diversification with respect to ship types used as pilots is greater in coastal shipping (see also Table 1). However, the number of pilots is much lower than in inland navigation despite the rapid growth of the coastal shipping in the period covered by the Pilot database (see [2]). Depending on the size, type, and operational area, coastal ships may be exempt from several international and European environmental regulations (such as EU Emission Trading System and FuelEU Maritime) which is – in combination with high investment costs – disincentivizing the greening efforts.

The low share of electrification pilots on coastal ships (see Fig. 1) is a consequence of the requirements for greater autonomies and/or higher deadweight-to-lightship ratios, which translate to greater power demands and limited space and weight available for batteries. On the other hand, higher share of electricity-based pilots in inland shipping may be explained by the fact that most of them are conducted on small, short-distance passenger ships (Fig. 2) which allow more frequent charging and offer more space and weight for storage of batteries. Measures aimed at reduction of fuel consumption are often implemented as a part of the regular business plans, rather than distinct projects, which may explain the low number of energy-efficiency pilots (Fig. 1). Additionally, as fuel costs are often covered by cargo owners, not by vessel owners / operators, the latter may not be incentivized to invest in energy-efficiency measures unless this would give them a clear competitive advantage in the market.

Numerous hydrogen pilots both in inland and coastal shipping (see Figs. 3 and 4) may be partly explained by the adoption of a number of national and transnational hydrogen roadmaps and related financial instruments which bolstered the hydrogen applications across industries, including shipping. Many policy makers regarded IWT and coastal shipping as sectors which could boost the demand for hydrogen (see [3]), which led to hydrogen-related programmes being placed high in subsidy schemes.

## 4 Conclusions

The paper presents the first findings of the Horizon Europe Innovation Action SYNERGETICS. Initial phases of SYNERGETICS integrate the knowledge from past and ongoing research projects (Exploration) with the experience gained from past and ongoing pilots (Synchronisation) to facilitate the green transition of inland and coastal fleets. A comprehensive database of pilot projects was created which enabled the identification of the trends in greening of inland and coastal ships. To the best of the authors' knowledge, such a database is unique. It is to be noted that even though the greening of ships is a "hot topic" the relevant information is often scarce.

The analysis of the identified trends showed that the shipowners, being faced with large uncertainties linked to implementation of novel technologies, whilst not being sufficiently incentivized, hesitate to engage in greening beyond the pilot applications at the lower risk end. Most of the pilots in IWT are performed on small vessels, with lower power demands. In coastal shipping, the total number of pilots is low, and the developments started later than in inland navigation. Thus, the replicability of pilots and the possibilities for scaling up of greening from single vessels to fleets is limited.

The potentials of retrofit are still largely untapped, considering that most of the pilots are realized on newbuilds. This is particularly important for inland vessels which have much longer lives than seagoing ships. This gap confirms the importance of SYNERGETICS which focuses on potential of greening of ships by means of retrofit.

The Pilot database does not quantify the level of greening attained, e.g., in terms of achieved emissions reduction. A more elaborate assessment would require more sophisticated data, e.g., the information on production of the alternative fuels and the sources of electricity. Therefore, the database registers greening efforts and identifies main directions but does not aim at assessing the achieved environmental performance. This remains the task for the future work of SYNERGETICS.

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