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Ship electrification as a pathway to decarbonize shipping: The case of Perama-Salamina line

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Abstract. Ship electrification offers a promising pathway to decarbonise maritime transportation, especially for short-sea shipping, and activities within port areas. This paper examines the viability of using hybrid or fully electric vessels on a coastal route in the Aegean Sea, with the goal of assessing the positive impact on the environmental footprint. The reduction of greenhouse gas (GHG) emissions and air pollutants impacting human health and climate is estimated through emission inventories and atmospheric modeling. The line Perama – Salamina was selected for study since it is a busy line in terms of ship itineraries. Considering the current technologies in batteries the distance of the line (1.62 nm) makes it ideal for full ship electrification. Preliminary photochemical modelling results from the environmental assessment for a winter period of the year 2019 showed that by zeroing-out the shipping emissions, the maximum difference in the mean daily concentrations of pollutants such as NO_2 could be up to -15.5%. Public consultation revealed support for electrification but noted key barriers like funding, regulation, and incentives; national strategy recommended. In general, the study highlights the potential of ship electrification as a solution to the decarbonisation of coastal shipping.

Keywords: Electric ships, short-sea shipping, net-zero emissions, photochemical modelling, citizen laboratory

1. Introduction

The International Maritime Organization (IMO), in its 2023 strategy, has mandated net-zero emissions for the shipping industry by 2050 (IMO, n.d.). Complementing this, the EU's Fit for 55 package sets ambitious interim targets, requiring a 55% reduction in GHG emissions by 2030 and introducing key regulations impacting the maritime sector (EC, n.d.). While various technological solutions and alternatives to fossil fuels are under development, none are currently fully deployable. Ship electrification offers a promising pathway to decarbonize shipping, especially for short-sea routes, inland waterways, and port operations, while also improving local air quality.

This paper investigates the GHG and atmospheric pollutant emissions and impact on air quality of hybrid or fully electric vessels on a short coastal route in the Aegean Sea, employing emission inventories, and atmospheric modeling. Furthermore, it details the organization of a workshop designed to gather stakeholders' opinion on this topic.

2. Methodology

Emission estimations of GHG from the ships serving the Perama – Salamina line were derived using a detailed bottom-up methodology, incorporating ship's technical and operational data along with the updated set of load-dependent emission factors developed by Grigoriadis et al., 2021. For the atmospheric pollutants, emissions from the CAMS-REGv6.1 emissions database (Kuenen et al., 2021; Kuenen et al., 2022) were used in the WRF-CAMx model simulations, while bottom-up estimated shipping emission data from the FEIGREGAA inventory (Fameli and Assimakopoulos, 2016) were used to isolate Perama– Salamina shipping emissions for the zero-out scenario. The WRF-CAMx modeling system was applied at a 6 km resolution to simulate photochemical atmospheric conditions for January 2019, assessing the air quality impacts of ship electrification on the route.

A public consultation with stakeholders from the maritime industry, ports, energy providers, local community and academia was held on March 2025 to record and analyse the views, challenges and possible solutions of the participants regarding the introduction of electric ships to the Perama-Salamina line. The process included a presentation of the key elements of the short ferry lines, the challenges and solutions for electrification, followed by 2 rounds of discussions to identify the commonly accepted challenges and voting for the solutions in order to build consensus.

3. Results and discussion

The Perama-Salamina ferry route (Figure 1(a)), just 1.62 nautical miles long, is ideal for full electrification due to its short distance, high frequency, and low energy demands. The fleet includes over 20 open-type RoPax vessels, each with more than 1 MW power output and completing over 1,000 annual trips, operating on low-sulfur MDO (0.1%). The route's operational profile supports efficient electric ship deployment with the current battery technology. Frequent sailings and short turnaround times allow rapid recharging, maintaining schedule reliability. These factors make the route a strong candidate for a pilot project in coastal shipping electrification, supporting global decarbonization efforts.

The total annual GHG emissions (CO_2, CH_4 and N_2O) from the fleet in this route estimated at about 4414 tonnes CO_2e (GWP100). Regarding air pollutant emissions profile in the surrounding area (dark blue cell, Figure 1(b)), the contribution from the Perama-Salamina route to the total anthropogenic emissions profile was found 71.0% for NOx, 81.2% for $PM_{2.5}$ and 69.0% for CO in 2019, based on data from the FEIGREGAA emission inventory. Local anthropogenic emission sources at the above-mentioned cell include shipping, road transport and residential heating. It should be noted that the area is not densely populated, mainly covered by low vegetation, thus emissions from shipping activities predominate.

The simulations of the WRF-CAMx modeling system showed maximum mean daily NO_2 reductions of up to -15.5% in winter at the grid cell corresponding to the Perama-Salamina route (dark blue cell, Figure 1(b)), pointing out measurable air quality improvements from ship electrification. Figure 1(b) presents absolute differences in mean daily NO_2 levels on 18 January 2019, the day with the largest reduction in NO_2 levels in January, with reductions reaching up to 4.6 μg/m^3. The air quality improvements extended beyond the immediate area, also affecting nearby maritime zones of the Saronic Gulf and adjacent densely populated coastal regions.

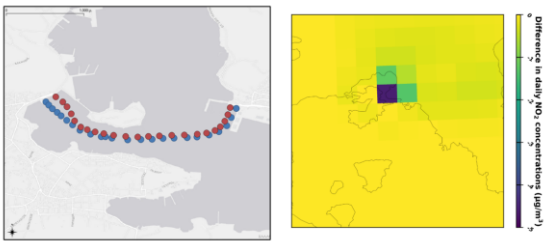

Figure 1. (a) The Perama-Salamina ferry line, (b) Absolute differences in mean daily NO_2 concentrations (μg/m^3) due to ship electrification along the line on 18 January, 2019.

The public consultation highlighted significant obstacles and possible solutions for the transition to electrification on the Perama- Salamina line. While the majority of participants recognise the great importance of electric ships, the feasibility of the transition within five years remains questionable, mainly due to the lack of incentives, regulatory framework and funding. The solutions put forward focus on the creation of a national strategy, financial mechanisms and supporting policies to facilitate the transition to sustainable shipping.

4. Conclusions

This study assesses greenhouse gas emissions and air quality impacts of electrifying ferries on the Perama–Salamina route in the Aegean Sea using emission inventories and atmospheric modeling. Results show significant pollution reductions and suitability for full electrification. A public consultation revealed strong support but highlighted challenges such as insufficient policy, funding, and incentives, stressing the need for a national strategy for sustainable shipping.

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