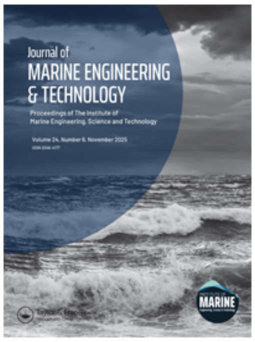

Taylor & Francis
Taylor & Francis Group

Journal of Marine Engineering & Technology

ISSN: 2046-4177 (Print) 2056-8487 (Online) Journal homepage: www.tandfonline.com/journals/tmar20

Moses 2023 special issue: modelling and optimisation of ship energy systems

Andrea Coraddu & Gerasimos Theotokatos

To cite this article: Andrea Coraddu & Gerasimos Theotokatos (02 Mar 2026): Moses 2023 special issue: modelling and optimisation of ship energy systems, Journal of Marine Engineering & Technology, DOI: 10.1080/20464177.2026.2633820

To link to this article: https://doi.org/10.1080/20464177.2026.2633820

Published online: 02 Mar 2026.

JOURNAL OF MARINE ENGINEERING & TECHNOLOGY
https://doi.org/10.1080/20464177.2026.2633820

Taylor & Francis
Taylor & Francis Group

Moses 2023 special issue: modelling and optimisation of ship energy systems

Andrea Coraddu [a] and Gerasimos Theotokatos [b]

[a]Department of Maritime and Transport Technology, Delft University of Technology, Delft, The Netherlands; [b]Department of Naval Architecture, Ocean & Marine Engineering, University of Strathclyde, Glasgow, UK

1. Introduction

The global maritime sector is entering a period of unprecedented transformation, driven by the dual imperatives of deep decarbonisation and enhanced operational resilience. Stricter international regulations, rapid technological advancements, and increasing societal expectations are driving the transition towards cleaner and more efficient ship propulsion and energy systems. As a result, shipowners, designers, and operators increasingly seek solutions that simultaneously reduce greenhouse gas emissions, improve fuel and energy efficiency, and ensure reliable vessel performance across diverse and unpredictable operating conditions.

The *4th International Conference on Modelling and Optimisation of Ship Energy Systems (MOSES 2023)* was held at Delft University of Technology, The Netherlands, on 26–27 October 2023. The *MOSES 2023 Special Issue: Modelling and Optimisation of Ship Energy Systems* brings together a curated selection of high-quality research contributions presented during the event. The published works span a wide range of topics, including alternative and renewable fuels, hybrid-electric propulsion architectures, high-fidelity numerical modelling, thermal and electrical system integration, advanced power and energy management strategies, and uncertainty-aware design methodologies. Together, these studies strengthen the scientific foundations required to support the maritime energy transition and to guide the development of next-generation ship energy systems.

Beyond advancing technical understanding, this Special Issue highlights the importance of integrated approaches that combine thermodynamics, power and energy systems engineering, hydrodynamics, control theory, optimisation, and data-driven modelling. Such interdisciplinary integration is essential for addressing the complexity of modern ship energy systems and for ensuring that emerging solutions are robust, scalable, and adaptable to evolving regulatory and operational contexts. The MOSES community continues to play a central role in this transformation by fostering collaboration between academia, industry, classification societies, and policymakers, thereby supporting the development of cleaner, smarter, and more resilient maritime technologies.

2. Background

The MOSES community has progressively established an interdisciplinary foundation for the analysis, modelling, and optimisation of ship energy systems. Since the early thematic collections that formalised this research area (Frangopoulos et al. 2020), the field has expanded to include advances in energy conversion technologies, digital methods, optimisation tools, and alternative fuels. The present Special Issue reflects this broadening scope and highlights the growing need for integrated, multi-domain approaches to support the maritime energy transition.

The sector-wide push towards decarbonisation, reinforced by the revised IMO GHG Strategy and long-term projections, has intensified interest in new fuels and energy carriers. Hydrogen-based solutions are now being examined for both near-term and long-term deployment scenarios, supported by comparative analyses of carrier pathways and ship integration strategies (van Rheenen et al. 2025).

Methanol has similarly emerged as a promising marine fuel, with growing attention to system-level integration, performance uncertainties, and safety considerations. Recent studies have highlighted the impact of variations in thermal management, storage, and reforming on the viability of methanol-powered architectures (Souflis-Rigas et al. 2025). Additional research into methanol-specific spray processes has provided deeper insight into injection behaviour, evaporation dynamics, and combustion readiness (Karvounis and Theotokatos 2025; Zoumpourlos et al. 2025).

Beyond conventional fuels, broader assessments of hydrogen and ammonia underscore their potential as fully decarbonised alternatives, while also outlining key engineering, regulatory, and cost challenges (McKinlay et al. 2021). Collectively, these studies emphasise that fuel choice will increasingly depend on a vessel's mission profile, operational constraints, and life-cycle environmental targets.

The evolution of propulsion architectures has been equally transformative. Battery-electric and hybrid power systems are now entering mainstream adoption, especially for short-sea, ferry, and coastal applications. Demonstrations of heat-pump-assisted energy efficiency improvements on battery-electric vessels illustrate how thermal subsystems can significantly enhance overall performance (Brötje et al. 2025). Meanwhile, system-level modelling of hybrid ferry powerplants has shown how batteries, engines, and auxiliary subsystems interact across different operating conditions (Balestra and Schjølberg 2021).

The rapid adoption of electrified propulsion has been enabled by advancements in power electronics and DC-based architectures. Foundational studies on DC shipboard power systems have clarified the behaviour of converters, storage elements, and hybrid power distribution (Xu et al. 2021). Subsequent reviews of maritime fuel-cell integration highlight how these systems influence power quality, reliability, and hybrid architecture design (van Biert et al. 2016). Together, these developments underscore how hybrid solutions offer a flexible platform for integrating batteries, fuel cells, and future alternative fuel technologies.

Energy management remains a central theme in MOSES research, driven by the need to optimise fuel use, emissions, and operational efficiency. Early efforts in voyage optimisation demonstrated

CONTACT Andrea Coraddu a.coraddu@tudelft.nl

that data-enabled routeing and power management could significantly reduce energy consumption at the fleet level. More recent reviews have consolidated the state of knowledge in modelling and optimisation, charting methodological advances from physical modelling to machine learning and hybrid approaches (Coraddu et al. 2021; Mylonopoulos et al. 2023).

Operational data analysis has become increasingly important for improving ship performance, particularly as high-frequency onboard measurements become more accessible. Data-driven frameworks have been proposed to enhance model calibration, identify inefficiencies, and improve predictive accuracy in operational settings (Vasilikis et al. 2025). These developments reinforce a growing industry trend towards real-time, data-enabled operational decision support.

Digitalisation has become one of the defining shifts in maritime energy research. Hybrid digital twins, which integrate physics-based models with live sensor data, now enable real-time optimisation of propulsion systems and dynamic decision support during mixed operating profiles (Brötje et al. 2025). These tools rely on advances in simulation fidelity and solver efficiency, enabling the multi-domain coupling of hydrodynamics, power systems, thermal behaviour, and control mechanisms.

High-fidelity thermal interaction models are also becoming central to the analysis of integrated power systems. For example, investigations combining batteries, fuel cells, and heat pumps have demonstrated how thermal management constraints influence hybrid-system performance in transient and off-design scenarios (Zhang et al. 2023). Such insights reinforce the need for holistic, system-level modelling approaches in future ship design. The electrification of ships has increased interest in modular, scalable DC microgrids.

Reviews of DC architectures highlight the importance of converter dynamics, communication structures, and storage integration in ensuring safe and reliable operation (Xu et al. 2021). In parallel, advanced control methodologies have been developed to support power sharing, fault resilience, and dynamic stability under diverse loading conditions (Jin et al. 2017).

Recent contributions in this area include the application of virtual-impedance control for stability enhancement, which enables improved decoupling between fuel cells and battery subsystems (Xu et al. 2021). Experimental and simulation-based investigations demonstrate how virtual impedance can support safe operation under rapid load changes and converter nonlinearities, thereby improving the robustness of hybrid DC networks. Advances in frequency-decoupling solutions for modular fuel-cell/battery architectures further reinforce the practical value of these methods (Kopka et al. 2025).

As ship energy systems become more complex, the ability to quantify and manage uncertainty has emerged as a key research priority. Studies on uncertainty quantification for marine energy systems demonstrate how variations in component performance, environmental conditions, and mission profiles can influence both design decisions and operational performance. Complementary investigations into system-level design uncertainties, from fuel reforming to energy conversion and subsystem integration, highlight the need for robust, uncertainty-aware design frameworks in early-stage engineering (Souflis-Rigas et al. 2025). The broad set of methodologies showcased across the MOSES community reflects a common aim: to develop energy systems that are efficient, resilient, and adaptable to future fuels and operational requirements. By uniting research on alternative fuels, hybrid-electric architectures, microgrid control, optimisation, and digitalisation, this Special Issue provides a comprehensive overview of the state of the art and a forward-looking perspective on next-generation ship energy systems.

3. Research in this special issue

This Special Issue showcases five published research articles, each advancing the science and practice of ship energy systems through distinct, rigorously developed investigations:

(1) **A Case Study of Enhancing Energy Efficiency in Battery-Electric Ferries Through Low-Temperature Heat Pump Integration**: Brötje et al. present a pioneering investigation into the integration of low-temperature heat pumps aboard battery-electric ferries. Their research quantifies reductions in electrical demand and demonstrates extended vessel endurance, providing practical strategies for realising zero-emission passenger transport on waterways (Brötje et al. 2025).
(2) **Comparative energy analysis of hydrogen carriers as an energy source on ships**: van Rheenen et al. present a comparative analysis of three hydrogen carriers, liquid hydrogen, LOHC, and ammonia, assessing their techno-economic and energy profiles within an integrated modelling framework. This comprehensive evaluation offers strategic guidance for ship designers and decision-makers considering hydrogen-based propulsion technologies (van Rheenen et al. 2025).
(3) **Virtual Impedance-based Frequency Decoupling for Modular Fuel Cell-Battery DC Shipboard Power Systems**: Kopka et al. present a novel control strategy for modular fuel cell-battery shipboard DC microgrids. By employing virtual impedance-based frequency decoupling, their research enhances stability and load sharing, a crucial advancement for next-generation hybrid and all-electric vessel architectures (Kopka et al. 2025).
(4) **Characterisation of methanol power and energy systems' uncertainty propagation in ship design**: Souflis-Rigas et al. deliver an in-depth uncertainty-propagation framework for evaluating methanol-powered ship designs. Their methodology enables shipbuilders and designers to quantitatively assess the reliability and environmental performance of methanol energy systems, strengthening robust decision-making in the adoption of alternative fuels (Souflis-Rigas et al. 2025).
(5) **Methanol Sprays in Marine Engines: CFD Modelling of Port Fuel Injection Systems**: Zoumpourlos et al. present a high-fidelity computational analysis of methanol spray formation and combustion processes in marine engines. Their results provide engineers with actionable insights for cleaner and more efficient combustion strategies, advancing the development of low-emission propulsion technologies (Zoumpourlos et al. 2025).

4. Outlook

The contributions gathered in this Special Issue delineate a clear and compelling trajectory for maritime research and innovation. As vessels increasingly adopt hybrid propulsion architectures, integrate clean and alternative fuels, and deploy sophisticated energy management strategies, advanced modelling and optimisation techniques will play an increasingly central role. Looking ahead, the fusion of physics-based models with data-driven and AI-enabled approaches is poised to revolutionise the development of next-generation digital twins, predictive control systems, and real-time optimisation frameworks. Furthermore, lifecycle assessment and techno-economic analyses will become indispensable tools for informing both new-build designs and retrofit decisions. The methodological advances showcased here demonstrate that the MOSES community is exceptionally well-positioned to support the maritime sector's transition towards cleaner, smarter, and more sustainable ship-energy systems.

Acknowledgements

The Guest Editors extend their sincere gratitude to all authors who contributed to this Special Issue and to the reviewers whose constructive evaluations strengthened the final manuscripts. Appreciation is also expressed to the MOSES community for its continued engagement, and to the editorial staff of the *Journal of Marine Engineering & Technology* and the Taylor & Francis production team for their professional support.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Andrea Coraddu http://orcid.org/0000-0001-8891-4963
Gerasimos Theotokatos http://orcid.org/0000-0003-3547-8867

References

Balestra L, Schjølberg I. 2021. Modelling and simulation of a zero-emission hybrid power plant for a domestic ferry. Int J Hydrogen Energy. 46(18):10924–10938. https://doi.org/10.1016/j.ijhydene.2020.12.187

Brötje S, Mühmer M, Schwedt T, Tran AP, Ehlers S.. 2025. A case study of enhancing energy efficiency in battery-electric ferries through low -temperature heat pump integration. Journal of Marine Engineering & Technology. 1–10. https://doi.org/10.1080/20464177.2025.2567723

Coraddu A, Kalikatzarakis M, Theotokatos G, Geertsma RD, Oneto L.. 2021. Physical and data-driven models hybridisation for modelling the dynamic state of a four-stroke marine diesel engine. In: Agarwal AK, Kumar D, Sharma N, Sonawane U, editors. Engine modeling and simulation. Springer; p. 145–193.

Frangopoulos CA, Theotokatos G, Baldi F. 2020. Special issue dedicated to MOSES2019: 2nd international conference on modelling and optimisation of ship energy systems. Energy. 198:117363. https://doi.org/10.1016/j.energy.2020.117363

Jin Z, Meng L, Vasquez JC, Guerrero JM. 2017. Frequency-division power sharing and hierarchical control design for DC shipboard microgrids with hybrid energy storage systems. In: 2017 *ieee applied power electronics conference and exposition (APEC)*, 3661–3668. IEEE.

Karvounis P, Theotokatos G. 2025, April 1. Parametric optimisation of diesel–methanol injection timings of a dual-fuel marine engine using CFD. Appl Therm Eng. 264:125433. https://doi.org/10.1016/j.applthermaleng.2025.125433

Kopka T, Coraddu A, Polinder H. 2025. Virtual impedance-based frequency decoupling for modular fuel cell-battery DC shipboard power systems. Journal of Marine Engineering & Technology. https://doi.org/10.1080/20464177.2025.2489313

McKinlay CJ, Turnock SR, Hudson DA. 2021. Route to zero emission shipping: hydrogen, ammonia or methanol? Int J Hydrogen Energy. 46(55):28282–28297. https://doi.org/10.1016/j.ijhydene.2021.06.066

Mylonopoulos F, Polinder H, Coraddu A. 2023. A comprehensive review of modeling and optimization methods for ship energy systems. IEEE Access. 11:32697–32707. https://doi.org/10.1109/ACCESS.2023.3263719

Souflis-Rigas A, Pruyn J, Kana AA. 2025. Characterization of methanol power and energy systems' uncertainties and evaluation of their impact on layout design. Journal of Marine Engineering & Technology. https://doi.org/10.1080/20464177.2025.2462387

van Biert L, Godjevac M, Visser K, Aravind PV. 2016. A review of fuel cell systems for maritime applications. J Power Sources. 327:345–364. https://doi.org/10.1016/j.jpowsour.2016.07.007

van Rheenen ES, Padding JT, Kana AA, Visser K. 2025. Comparative energy analysis of hydrogen carriers as energy source on ships. Journal of Marine Engineering & Technology. https://doi.org/10.1080/20464177.2024.2448057

Vasilikis N, Geertsma R, Coraddu A. 2025. A multi-objective optimisation framework for the design of ship energy systems under uncertainty. Appl Energy. 402:126829. https://doi.org/10.1016/j.apenergy.2025.126829

Xu L et al. 2021. A review of DC shipboard microgrids – Part I: Power architectures, energy storage, and power converters. IEEE Trans Power Electron. 37(5):5155–5172. https://doi.org/10.1109/TPEL.2021.3128417

Zhang N, Lu Y, Kadam S, Yu Z. 2023. Investigation of the integrated fuel cell, battery, and heat pump energy systems. Energy Convers Manag. 276:116503. https://doi.org/10.1016/j.enconman.2022.116503

Zoumpourlos K, Bekdemir C, Geertsma R, van de Ketterij R, Coraddu A. 2025. Methanol sprays in marine engines: CFD modelling of port fuel injection systems. Journal of Marine Engineering & Technology. https://doi.org/10.1080/20464177.2025.2473184