

Maritime Applications of Nuclear Energy

Dinka Lale, Nora Miljanić

Faculty of Electrical Engineering and Applied Computing, University of Dubrovnik
Ćira Carića 4, 20000 Dubrovnik, Croatia
dinka.lale@unidu.hr, nora.miljanic@unidu.hr

Dubravko Pevec, Mario Matijević

University of Zagreb, Faculty of Electrical Engineering and Computing
Unska 3, 10000 Zagreb, Croatia
dubravko.pevec@fer.hr, mario.matijevic@fer.hr

ABSTRACT

We live in a time of great technological change and numerous challenges. These changes affect all aspects of our lives. Unfortunately, their impact on the environment and the resulting pollution is inevitable. Of particular note is atmospheric pollution caused by greenhouse gas emissions. Despite the efforts of the International Maritime Organization to reduce greenhouse gas emissions, in 2024 global maritime transport emissions amounted to 973 million tons of CO₂, representing an increase of 9.4% compared to 2019.

Maritime transport plays a leading role in global transport, carrying more than 80% of goods by volume. Like most technologies, shipping is already experiencing, and will continue to undergo, major changes in the future. It is assumed that seafarers will require skills in the future that are not currently necessary. In order to decarbonize maritime transport, a greater increase in the use of nuclear energy in shipping can be expected in the future. As it is expected that the occupational profile of a seafarer will change in the future and require new and different knowledge, this may include knowledge related to the use of nuclear energy to power ships.

The use of nuclear energy brings with it some additional aspects that require additional attention. These are: high initial costs, increased safety requirements, the crew must have some additional knowledge, the need for additional crew training, the problem of waste storage, and the social acceptability of nuclear energy. Despite these aspects, the use of nuclear energy offers great advantages such as a secure energy supply, low fuel costs, the ability to deliver large amounts of energy, minimal CO₂ emissions, and savings in ship space. For all of the above, additional attention should be paid to the development of the use of nuclear energy in maritime transport. Additionally, from a maritime transport perspective, special attention should be paid to modular nuclear reactors.

Keywords: *maritime transport, zero-emission, nuclear energy, CO₂ emissions, fuel costs*

1 INTRODUCTION

Nuclear energy, as a source of electricity, has great potential in maritime applications because it is an energy source that enables the release of large amounts of energy compared to other energy sources. Ships today require enormous amounts of electricity compared to ships in the past. It is expected that the demand for electricity in ships of the future will constantly increase. Large

merchant ships, passenger ships, ships transporting liquefied gas, Floating Storage and Regasification Units ships, icebreakers, these are all ships that cannot perform their function without using electrical energy. Most of today's new vessels are electrically powered, using electric propulsion. In addition, electricity is used in almost all segments of the ship's operation.

Maritime transport plays a leading role in global transport, with more than 80% of goods by volume [1]. "Navigare necesse est, vivere non est necesse" is a famous Latin phrase that translates to "To sail is necessary; to live is not necessary". Today's trade depends on maritime transport. Like most technologies, shipping is already experiencing, and will continue to experience, major changes in the future.

A huge amount of electricity is needed by today's large ships that use electricity for propulsion, the life of people on board, and all the main and auxiliary systems such as the alarm system, communication system, fire protection system, navigation system, water intrusion prevention system, power management system, automation system, and other, relatively speaking, less important systems. Diesel generators are the main source of electricity on most modern ships [2], [3].

Current alternatives for powering ships include methanol, hydrogen, liquefied petroleum gas (LPG), ammonia, liquefied natural gas (LNG), nuclear, biofuel, and electric. Nuclear energy has great potential among all of them [4].

The use of nuclear energy in maritime transport is not new. The first nuclear-powered merchant ship (NS), launched in 1959 by the United States, was the NS Savannah. It was a key element of President Eisenhower's Atoms for Peace program. The NS Savannah operated from 1962 to 1965 in experimental service. The NS Savannah continued in demonstration service as a cargo ship until 1970 [5]. In addition to the NS Savannah, two commercial nuclear-powered demonstration ships were built: the NS Otto Hahn (1968) and the NS Mutsu (1972) [6].

The use of nuclear energy as a source of propulsion in ships is particularly prominent in special purpose vessels and military vessels. For example, by 1962 the US Navy had 26 nuclear submarines operational and 30 under construction. Today it operates over 70 nuclear-powered submarines and 11 aircraft carriers [7].

In addition to its use in military vessels, nuclear energy is used for special purpose vessels, such as icebreakers. The world's only nuclear icebreaker fleet designed to meet maritime transportation objectives in the Arctic based on the application of advanced nuclear technology is owned by Russia [8].

Among all the relatively new alternative sources, nuclear energy is a safe and reliable source. The following chapters of the paper will discuss the comparison of nuclear energy as a power source in the maritime sector in relation to other energy sources. The energy density, Greenhouse Gases (GHG) emissions, prices of different types of fuel as well as regulations will be discussed.

Initial investments in nuclear facilities are high, exceeding those for all other energy sources, but small modular reactors are being developed today. We believe that the start of serial production will reduce the cost of production of such systems in the foreseeable future.

International cooperation and joint production of knowledge necessary for strategic planning and decision-making in the field of international relations are needed [9].

2 NUCLEAR POWER ADVANTAGES

We have already analysed the advantages of nuclear energy compared to other energy sources in electric energy production [10] [11] [12]. However, when it is used on ships, the situation is somewhat different and even favours the use of nuclear energy sources compared to others.

2.1 The energy density

Energy density differs for different types of fuel.

Table 1 demonstrates the comparison between energy density for the same amount (1 kilogram) taken for each energy source, with the density being displayed in MJ/kg. In addition, the type of reaction is listed in a column 3, and the typical use in a column 4. The data presented in this table were adapted from Reference [13].

Table 1: The Energy Density of a Variety of Different Fuels by Mass [MJ/kg]

Fuel Type	Energy Density [MJ/kg]	Reaction Type	Typical Uses
Wood	16	Chemical	Space heating, Cooking
Coal	24	Chemical	Power plants, Electricity generation
Ethanol	26.8	Chemical	Gasoline Mixture
Biodiesel	38	Chemical	Automotive engine
Crude oil	44	Chemical	Refinery, Petroleum Products
Diesel	45	Chemical	Diesel engines
Gasoline	46	Chemical	Gasoline engines
Natural Gas	55	Chemical	Household Heating, Electricity generation
Uranium 235	3 900 000	Nuclear	Nuclear reactor, Electricity generation

Nuclear energy as a source of electrical energy in the maritime sector has great potential because it is an energy source that enables the release of large amounts of energy in a short time compared to other energy sources.

For comparison, we will cite another source and Table 2, which lists the energy density for various marine fuels, in MJ/kg [14].

These are fuels used on large ships, which are classified into two categories. Special mention is made of large ships because they use the largest amount of fuel and thus cause the greatest impact on the environment. These are: Ultra Large Container Vessels (ULCVs) and Very Large Crude Carriers (VLCCs). The fuels they use are: Heavy Fuel Oil (HFO), Very Low Sulphur Fuel Oil (VLSFO), Liquefied Natural Gas (LNG), Marine Diesel Oil (MDO), and Marine Gas Oil (MGO). The electricity needs of ULCVs and VLCCs are on average 50 to 70 MW. When talking about medium ships, these amounts are from 20 to 40 MW. Small ships are those whose needs are from 5 to 20 MW [14]. This is why we focus specifically on fuels used by large and very large ships. It is to be assumed that just such, very large ships, which require the largest amounts of electricity, will begin to introduce the use of nuclear energy in the future.

Table 2 provides an overview of energy efficiency and energy content for fuels that could be used by large ships in the future, since the use of alternative fuels that have a lower sulphur content and do not pollute the atmosphere is encouraged. The data presented in this table were adapted from Reference [14].

Table 2: Fuel Type and Energy Density

Fuel Type	Energy Content [MJ/kg]
Methanol	20
Ammonia	18.6
Liquid Natural Gas	50
Hydrogen	120
Biofuel	38

Energy density has been shown to be a major advantage over using nuclear energy. Nuclear sources have an energy density of 3 900 000 MJ per kilogram, as demonstrated in Table 1. Furthermore, nuclear power plants provide a safe and reliable supply of electricity [15].

2.2 Fuel costs

It is known that the initial costs of building nuclear plants are high. However, the price of uranium as a fuel is low compared to the price of other energy sources.

The basic economics metric for any generating plant is the levelized cost of electricity (LCOE). It is the total cost to build and operate a power plant over its lifetime divided by the total electricity output dispatched from the plant over that period, hence typically cost per megawatt hour. It takes into account the financing costs of the capital component (not just the 'overnight' cost). The economics of new nuclear plants are heavily influenced by their capital cost, which accounts for at least 60% of their LCOE [16]. The share of initial investments can reach up to 70% of the LCOE for certain systems [17]. Fuel costs, on the other hand, are a relatively small factor in a nuclear plant's LCOE (less than 20 percent) [17].

The LCOE for nuclear power plants is generally lower than for all fossil fuel plants. In [10], the mean LCOE for nuclear power plants and for fossil fuel power plants was calculated. Of course, these are onshore plants. But we emphasize the large difference between the two values. We calculated average LCOE for nuclear power plants, and it is 44.7 USD/MWh. Also, average LCOE for fossil fuel power plants is 92.6 USD/MWh [10]. The average LCOE for marine nuclear power plants is difficult to calculate due to the lack of available data.

The LCOE for a nuclear-powered ship is generally considered uneconomical for standard commercial shipping compared to traditional bunker fuel, primarily due to exorbitant capital costs, despite providing reliable, low-carbon power. Nuclear-powered cargo ships using Small Modular Reactor (SMR) technology are projected to cost 3–5 times the value of a conventional ship [17].

Compared to other energy sources, nuclear energy has a cheaper fuel advantage. The paper [18] describes the concept of Offshore Floating Nuclear Plants that can be built entirely inside a floating platform in a shipyard, providing great economies of mass production.

All ships with large fuel consumption may be good candidates for nuclear power [6]. Large cargo ships are one such type of ship. Especially because nuclear-powered ships could reach speeds even higher than today's maximum [6].

2.3 GHG emissions

In the conference paper [10] and in the PhD thesis [12], the specific GHG emissions for different energy sources were analysed separately. As already emphasized, the production of electricity from nuclear sources gave amounts that are among the smallest specific GHG emissions in relation to all other energy sources.

International Maritime Organisation (IMO) has a very rigid decarbonisation strategy. This Strategy sets clear targets and actions to decarbonize international shipping: Net-zero GHG emissions from international shipping are expected by close to 2050 [19].

Addressing climate change

Over a decade of regulatory action to cut GHG emissions from shipping

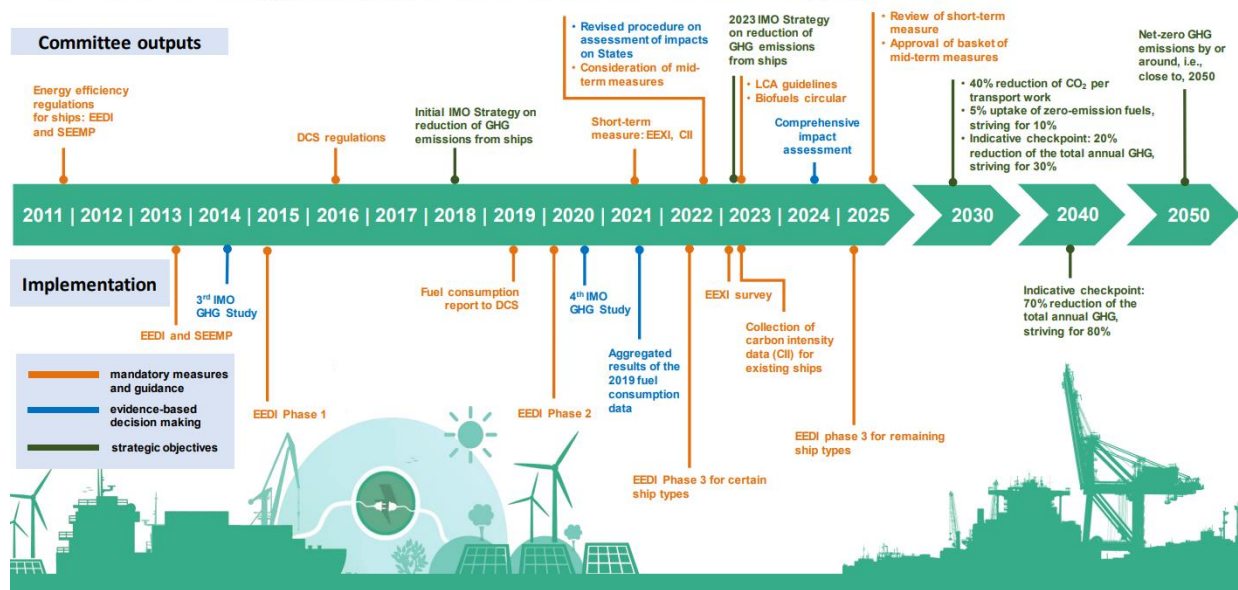


Figure 1. A Regulatory Action to cut GHG Emissions from Shipping [20]

Figure 1 shows graphically all the actions that need to be done in order to fulfil the given goal. To achieve it, it is necessary to use alternative fuel. The first concrete actions were taken in 2011 when energy efficiency regulations for ships were introduced. MARPOL Annex VI introduces mandatory technical and operational measures for the energy efficiency of ships. A total of 3 phases of introducing systematic energy efficiency measurements for all types of ships were implemented, namely in 2015, 2022 and the last in 2025. IMO Data Collection System (DCS) regulations were introduced in 2016. The Initial IMO Strategy on reduction of GHG emissions from ships was adopted in 2018 and expanded in 2023. Beginning in 2023, the collection of carbon intensity data for current ships is being implemented. The goal of net zero emissions will be achieved through detailed verification of data in 2040.

There is a certain amount of literature that discusses various methods of decreasing GHG emissions. In the most of them nuclear energy plays a very important role [21]. Older ships can reduce the emission index by simply slowing down the engine [22]. Due to economic reasons, it is not possible nowadays to decrease the speed of ships to reduce GHG emissions.

The most frequently used fuel in today's ships is diesel. Diesel engines normally emit CO emissions between 100 and 500 ppm in exhaust gases, or 0.1 to 0.5 g/kWh of energy produced [23]. On average, a diesel generator produces between 0.6 kg and 0.8 kg of CO₂ per kWh of electricity generated [24]. Medium nuclear lifecycle GHG emission intensity is 29 tonnes CO₂e/GWh in an older paper [25]. Today's results range from 8 to 64 gCO₂e/kWh. According to Reference [26], these values correspond to average results obtained using three different life cycle assessment (LCA) approaches for the European Pressurised Reactor (EPR): Process-based LCA (16.97 gCO₂e/kWh), Input-Output LCA (24.89 gCO₂e/kWh), and Hybrid LCA (27.63 gCO₂e/kWh). These values represent averages obtained from multiple scenarios within each method. Estimated values for SMR-based marine propulsion systems generally range from approximately 5–20 gCO₂e/kWh, depending on the study. Regardless of whether older or newer results and calculations are observed, the use of nuclear energy has a great advantage over conventional sources of electricity on ships from the point of view of GHG emissions. The IMO strategy has ambitious plans, as can be seen in Figures 1 and 2. If a ship does not meet the regulations of the IMO strategy, it will have to pay fines or penalties.

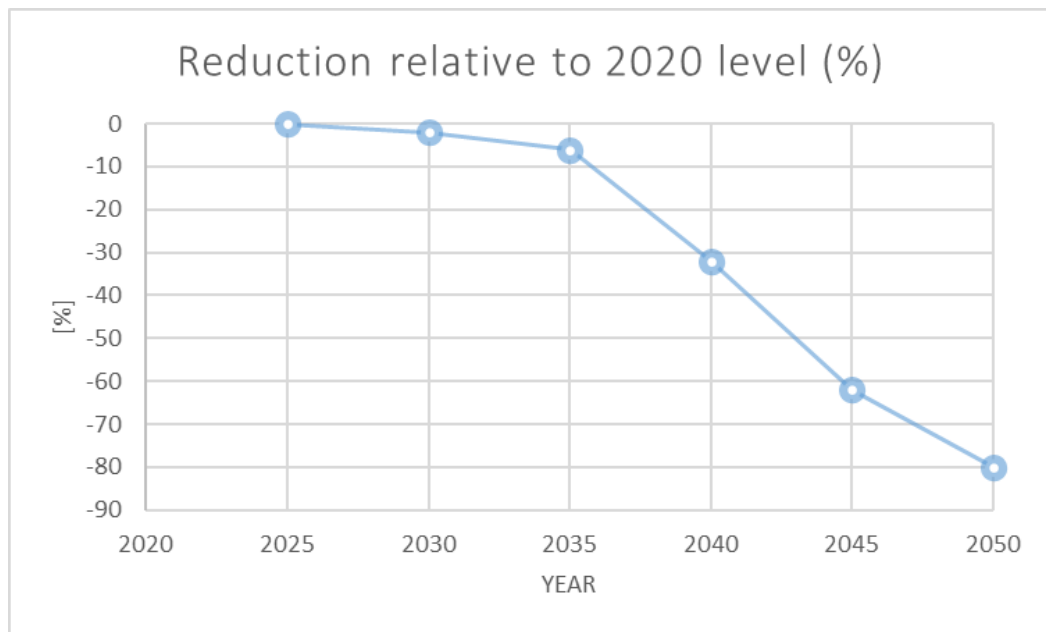


Figure 2. Reduction in GHG Emissions Used on Board from 2020 Levels (%) [4]

It can be assumed that the use of alternative fuels with low GHG emissions will be more and more profitable.

2.4 Regulations

Maritime transport plays an extremely important role in world trade. It is estimated that around 80% to 90% of world trade is carried out by ship according to the World Trade Organization [27]. The maritime system needs to be decarbonized due to the requirements of the IMO and environmental organizations. One way is to switch part of the ship's propulsion to nuclear energy. Besides the IMO, there are other maritime societies that have laws, regulations, and recommendations that are respected globally. The most significant among them are: Lloyd's Register of Shipping, Bureau Veritas, Registro Italiano Navale, Germanischer Lloyd and Det Norske Veritas (DNV). Many classification societies have agreements on mutual recognition of classification and supervision of shipbuilding and repairs. In addition, there are agreements whereby one classification society carries out material inspections in its own country on behalf of another foreign classification society. The fact that their regulations for shipbuilding and material inspections do not differ significantly, makes it possible for one Register to recognize classes and perform work on behalf of another Register [27]. DNV particularly highlights the advantages of using nuclear energy over other sources of electricity and considers the possibilities of using nuclear energy in maritime applications [28]. In addition, the expert opinion of the DNV company is more important because it is an international company that is an accredited parent and classification company based in Høvik, Norway. DNV provides services to several industries, including maritime, oil and gas, renewable energy, electrification and healthcare. It is assumed that the IMO and the already mentioned class societies will have a major role in the drafting of regulations related to civil nuclear ships as well as large offshore ships.

The regulations related to nuclear power ships mostly refer to ships used for military purposes. Military submarines and aircraft carriers are mostly nuclear powered. Decision makers have realized that the regulations regarding civilian nuclear-powered ships need to be changed. The first revision of the existing regulations began in 2025 and continued into January 2026. Then it was decided that the final revision related to the nuclear power ship would be made in 2030, as can be seen in Table 3 [29]. For easier understanding of Table 3, abbreviations are Maritime Safety Committee (MSC) and Ship Design and Construction (SDC).

Table 3. IMO work plan for final changes to existing regulations

Technology/Year	2026	2027	2028	2029	2030
Nuclear (revision of the Nuclear Code and amendments to SOLAS chapter VIII)	MSC 111 to approve the work plan				SDC 16 Finalization MSC 117 Approval MSC 118 Adoption
Wind (interim guidelines)				SDC 15 Finalization MSC 116 Approval	
Li-ion batteries (amendments to SOLAS II-1/41)		SDC 13 Finalization MSC 113 Approval	MSC 114 Adoption		
Swapable traction batteries (containerized swapable batteries)			SDC 14 Decision: unified interpretation or guidelines, on design and installation		

As can be seen from Table 3, the plan is to have a final regulation in 2030 for civil nuclear power ships. Cooperation between the IMO and IAEA (International Atomic Energy Agency) will be necessary to create a harmonised regulatory system for nuclear powered ships. The shipping industry has relatively limited experience with the operation of nuclear-powered merchant ships; most marine experience is with naval vessels that use older reactor types which are not suitable for commercial shipping. Chapter VIII of the International Convention for the Safety of Life at Sea (SOLAS) gives the basic requirements for ships provided with a nuclear power plant, creating a framework encompassing design, construction, operation, maintenance, surveying, salvage, and decommissioning of nuclear reactors on ships, including as a means of propulsion [4].

3 SOME SPECIFICS TO SAVE SPACE

Ships as means of transportation and systems that house the propulsion and all necessary devices for safe navigation and maintaining safe navigation conditions have some specific characteristics. One of the specificities of a ship is its limited space. Therefore, when choosing the propulsion and all necessary systems, the volume they occupy plays a major role. Saving space is exactly one of the segments that was present when electric propulsion started to be introduced in ships, apart from other advantages that it brings. Figure 3 shows how ship space is saved by using electric propulsion instead of conventional diesel propulsion [30]. Figure 3 a) shows diesel-mechanical propulsion. Figure 3 b) shows diesel-mechanical propulsion with gearboxes. Figure 3 c) and d) show electric propulsion with built-in propulsion electric motors and under-hull thrusters.

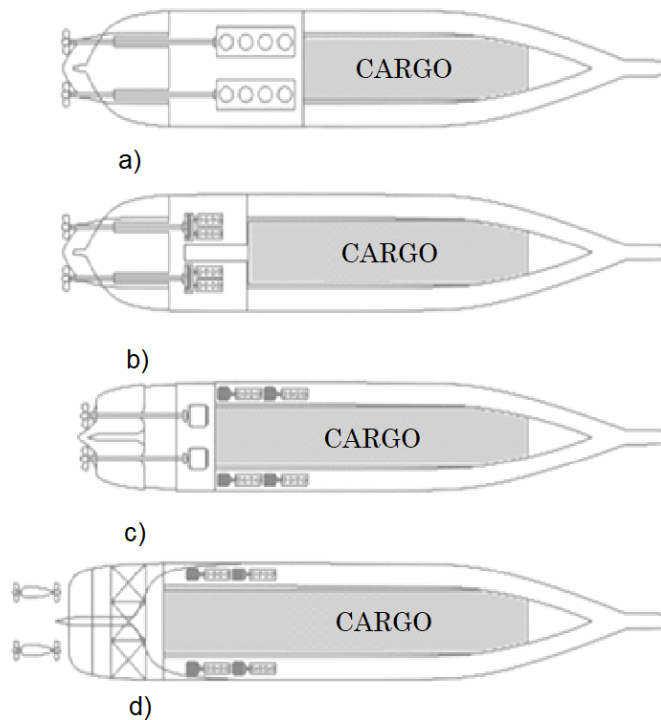


Figure 3. Utilization of Ship Space with Different Propulsion Concepts

If electric propulsion is used, a large onboard electrical energy source is required, making a nuclear power source one possible solution. This saves space even more because electric propulsion is used, which in itself saves space (Figure 3), and a nuclear source of electricity is also used, which has the highest energy density (thus it takes up little space and produces a large amount of energy).

4 DISCUSSION

The paper analyzes and describes the specific advantages of using nuclear energy for ship propulsion. In addition to the advantages of the highest fuel density, lower fuel prices, reduced GHG emissions and saving space, which is very important for a ship, it is important to mention that it is a safe and stable source of energy.

The introduction of nuclear power to commercial ships may be slowed down by high initial costs, lack of legal regulations, and a negative community opinion. For example, in addition to limited economic viability, the vessel Otto Hahn faced restrictions on access to certain ports. Mass production of small nuclear reactors could reduce initial costs. Today there are many modern small reactors under development, and many of these aim to provide very simple-to-operate solutions, safe operations and lower cost than we have lately seen in nuclear [6]. The Norwegian NuProShip project is evaluating three Generation IV technologies for potential commercial marine application. During their voyage, ships traverse several countries, and each country has its own laws and regulations. In addition to the already mentioned regulations by IMO, SOLAS, MARPOL, and IAEA, an independent non-governmental organization was established called the Nuclear Energy Maritime Organisation (NEMO). NEMO provides a forum with broad, cross-section competence, intended to facilitate dialogue and coordination between traditionally separate domains through the participation of classification societies, industry stakeholders, and academic institutions [6].

An important item is also what type of reactor would be used in future commercial nuclear-powered ships. We believe that these will be light water reactors or thorium reactors. Large cargo ships are likely to use these reactor farms. Smaller ships with power requirements in the range of 5 to 20 MW may consider very compact Gas Cooled reactors [6].

5 CONCLUSION

The paper analyzes the most important advantages of the use of nuclear energy compared to the use of other energy sources on board. These are: fuel price, GHG emissions, energy density, and saving space on board.

The biggest problem with the use of nuclear technology in shipping is the large initial investments and the fear of an accident. As is the case with all technologies, when serial production is started, then production costs are also reduced. In addition, limits on the use of polluting fuels due to fines for excessive GHG emissions will make nuclear energy sources more economically attractive. Besides that, another problem with the civilian use of nuclear energy is its negative connotation. In order to solve this problem, systematic and permanent education of the population is needed. The aim is to change attitudes towards the use of nuclear energy for electricity through education that covers the general population.

Nuclear energy offers great advantages such as a secure energy supply, low fuel costs, the ability to deliver large amounts of energy, minimal CO₂ emissions, and savings in ship space. The use of nuclear energy for ship propulsion in the maritime industry seems promising for the future.

REFERENCES

- [1] Review of Maritime Transport 2024, Navigating maritime chokepoints, 2025, UN Trade and Development
- [2] Z. Bei, J. Wang, Y. Li, H. Wang, M. Li, F. Qian, W. Xu, Challenges and Solutions of Ship Power System Electrification, *Energies*, Vol. 17, 3311, 2024, DOI 10.3390/en17133311
- [3] K. Valkeejärvi, The ship's electrical network, engine control and automation, *Marine Technology*, Wärtsilä Corporation, Rozal Belgian Institute of Marine Engineers, 2009.
- [4] Fuel for thought: Nuclear, Loyd's Register Group Limited, 2024
- [5] San Francisco Maritime National Park Association, Tour of NS Savannah, Version 1.21, 25 May 2020
- [6] E. Hagen, Nuclear power in commercial ships, *International Journal for Nuclear Power*, atw, 2026, vol. 71, ISSN: 1431-5254 (Print), eISSN: 2040-6668 (Online)
- [7] World Nuclear Association, "Nuclear-Powered Ships", update 4th February 2025, accessed: 20th of March 2026, <https://world-nuclear.org/information-library/non-power-nuclear-applications/transport/nuclear-powered-ships>
- [8] State Atomic Energy Corporation Rosatom, "Nuclear Icebreaker Fleet", accessed 20th of March 2026, <https://rosatom.ru/en/rosatom-group/the-nuclear-icebreaker-fleet/>
- [9] C. Rodrigues Correa, T. Pepe de Medeiros, G. A. Guimaraes, The future of nuclear energy and maritime power relations, *Brazilian Journal of Radiation Sciences*, 2020, ISSN: 2319-0612
- [10] D. Lale, D. Pevec, M. Matijević, An Economy Aspect of Different Nuclear Energy Development, Proceedings of the 14th International Conference of the Croatian Nuclear Society, Zadar, Croatia, June 9 – 12, 2024
- [11] D. Lale, D. Pevec, V. Knapp, M. Matijević, A Comparison of the Radioactive Waste Produced for Different Nuclear Energy Development Scenarios, In Proceedings of the 13th

International Conference of the Croatian Nuclear Society, Zadar, Croatia, 5-8 June 2022, pp 118-1 (for a paper in the conference proceedings)

- [12] D. Lale, "Estimation of nuclear fuel supply sufficiency in the case of significant nuclear energy contribution to the solution of the global warming problem", doctoral thesis, University of Zagreb, Faculty of electrical engineering and computing, 2020
- [13] I. Hore-Lacy, "Future Energy Demand and Supply," in *Nuclear Energy in the 21st Century*, 2nd ed., London, UK: WNUP, 2011, ch.1, sec.6, pp.9
- [14] E. Curcio, A Comparative Analysis of Alternative Fuels for Sustainable Maritime Shipping, Ship and Bunker, January 2025, accessed: 31st of March 2026, <https://shipandbunker.com/news/world/527976-insight-a-comparative-analysis-of-alternative-fuels-for-sustainable-maritime-shipping>
- [15] A. Rayhan, Abu, Nuclear Power as Renewable Energy: A Comprehensive Analysis, 2024, 10.13140/RG.2.2.20985.89447
- [16] M. J. Barasa Kabeyi, O. A. Olanrewaju, The levelized cost of energy and modifications for use in electricity generation planning, *Energy Reports*, Volume 9, Supplement 9, 2023, Pages 495-534, ISSN 2352-4847, <https://doi.org/10.1016/j.egy.2023.06.036>.
- [17] Encyclopædia Britannica, Inc., Publishing company, Nuclear Power – Economic, Safety, Environment, accessed: 24th of March, 2026, <https://www.britannica.com/technology/nuclear-power/Economics>
- [18] Buongiorno, J.; Jurewicz, M.G.; Todreas, N., The Offshore Floating Nuclear Plant Concept, *Nuclear Technology*, 194, pp. 1-14, 2016
- [19] International Maritime Organisation, 2023 IMO Strategy on Reduction of GHG Emissions from Ships, Resolution MEPC.377(80), (adopted on 7 July 2023), MEPC 80/17/Add.1, Annex 15
- [20] International Maritime Organisation, 2023 IMO Strategy on Reduction of GHG Emissions from Ships, accessed on 31st of March 2026, [https://www.imo.org/en/mediacentre/hottopics/pages/cutting-ghg-emissions.aspx#:~:text=The%20International%20Maritime%20Organization%20\(IMO\)%20has%20adopted,measures**%20*%20**Technical%20elements**%20*%20**Economic%20elements**](https://www.imo.org/en/mediacentre/hottopics/pages/cutting-ghg-emissions.aspx#:~:text=The%20International%20Maritime%20Organization%20(IMO)%20has%20adopted,measures**%20*%20**Technical%20elements**%20*%20**Economic%20elements**)
- [21] New Energies Coalition, The role of nuclear in shipping decarbonization, Bureau Veritas, CMA CGM, April 2025], [Final Report of the Nuclear Propulsion for Merchant Ships I Project, 2025
- [22] M. Hero, P. Vidmar, P. Vlacic, M. Perkovic, Limiting greenhouse gas emissions in the maritime transport sector, *Transportation Research Procedia*, Volume 83, 2025, Pages 157-164
- [23] S. Babamohammadi, A.R. Birss, H. Pouran, J. Pandhal, T. N. Borhani, Emission control and carbon capture from diesel generators and engines: A decade-long perspective, *Carbon Capture Science & Technology*, Volume 14, March 2025, 100379
- [24] U.S. Energy Information Administration (EIA). (2022). Carbon Dioxide Emissions Coefficients. Washington, DC: EIA

- [25] World Nuclear Association Report, Comparison of Lifecycle Greenhouse Gas Emissions of Various Electricity Generation Sources, 2012
- [26] F. Pomponi, J. Hart, The greenhouse gas emissions of nuclear energy – Life cycle assessment of a European pressurised reactor, *Applied Energy*, Volume 290, 15 May 2021, 116743
- [27] Pomorski promet. Hrvatska enciklopedija, mrežno izdanje. Leksikografski zavod Miroslav Krleža, 2013. – 2026. Accessed: March, 17th, 2026.
<https://www.enciklopedija.hr/clanak/pomorski-promet>
- [28] DNV, Maritime Publications, Maritime nuclear propulsion – Technologies, commercial viability, and regulatory challenges for nuclear-powered vessels, accessed: 19th of March 2026,
https://www.dnv.com/maritime/publications/maritime-nuclear-propulsion-download/?utm_source=web&utm_medium=pr&utm_campaign=ma_25q4_glob_publ_maritime_nuclear_propulsion_whitepaper&utm_id=701bH00000UAmQMQA1
- [29] IMO, Sub-Committee on Ship Design and Construction (SDC 12), 19-23 January 2026, accessed 31st of March 2026,
<https://www.imo.org/en/mediacentre/meetingsummaries/pages/sdc-12.aspx>
- [30] D. Vucetic, I. Cekada, Eksploatacijske prednosti električne propulzije, *Pomorstvo*, god. 20, br. 1 (2006), str. 129-145