# Decarbonization in Shipping Industry

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## Definition

Decarbonization in Shipping Industry might be achieved through alternative fuels (nuclear, hydrogen, ammonia, methanol), renewable energy sources (biofuels, wind, solar), the maturity of technologies (fuel cells, internal combustion engines) as well as technical and operational strategies to reduce fuel consumption for new and existing ships (slow steaming, cleaning and coating, waste heat recovery, hull and propeller design).

## 1. Introduction

The shipping sector is crucial for international trade (~80–90% of the global trade occurs through shipping) and hence vital to the world economy [1]. Due to the scale of the sector, shipping represents ~3% of the total global green house gas (GHG) emissions [2], therefore strict environmental regulations around $NO_x$, $SO_x$ and $CO_2$ emissions are set to cause major technological changes in the industry [1][3]. For example, Liquefied Natural Gas (LNG) can improve the performance, and on the other hand, with methane slip, the benefits are reduced [1]. Other fuels and/or other technologies such as biofuels, hydrogen, nuclear and carbon capture and storage (CCS) could all decarbonize the industry, but each have significant barriers regarding cost, resources and social acceptability [1]. In addition, fuel consumption can be improved by various efficiency improvements (such as hull design and cleaning, and propeller design, to name a few). It is obvious that numerous problems/issues must be tackled in order to achieve deep decarbonization of the shipping industry. Thus, there is "no single route and a multifaceted response is required" [1] from different sectors of the industry.

Moreover, demand for shipping is likely to grow over the next three decades [2]. Market surveys conducted in order to understand the current market trends [4] show that the market and industry are considering decarbonization as part of their business strategy over the coming decades, in line with the International Maritime Organization's ambition to reduce $CO_2$ emissions from shipping by at least 50% by 2050 compared with a 2008 baseline [5].

Deep decarbonization will require financial incentives and policies at an international and regional level given the maritime sector's ~3% contribution to GHG emissions [1][6]. Maritime emission and reduction measures are commonly divided into two main categories: technical (ship size, ship–port interface, etc.) and operational (lower-speeds, waste heat recovery, etc.) [7][8]. The International Transport Forum recognizes additional separate routes to achieve decarbonization, which is the use of alternative fuels (sustainable biofuels, hydrogen, ammonia), electrification of ships and wind assistance, albeit these could be argued to fall under the technical measures' category [8].

## 2. Future Trends and Challenges in Shipping Industry Decarbonization

There has been increased interest from the shipping sector's important stakeholders regarding deep decarbonization. However, deep decarbonization will require financial incentives and policies at an international and regional level given the maritime sector's 3% contribution to GHG emissions [1][6].

Shell and Deloitte conducted a market survey in order to understand the current market trends [4] and it has been realized that the majority of the stakeholders considered decarbonization an important or top priority for their organizations [4]. This, therefore, shows that the market and the industry are considering decarbonization as part of their business strategy. For example, Maersk (the world's largest shipping container company) has announced its intentions to be net-zero carbon by 2050, with carbon-neutral vessels commercially viable by 2030 [9]. The IMO has introduced measures for new and existing ships (SEEMP, EEDI and the fairly recent EEXI), which combine operational and technical measures to help ship operators achieve reductions in emissions.

The relative advantages and disadvantages of alternative fuels, in terms of cost, technical difficulties and maturity, were presented. Shell's view on future pathways involves a "poly-fuel scenario", in other words, the use of different fuels [10]. Japan's report on "Roadmap to Zero Emission from International Shipping" mentions that pilot concepts are based on two possible emission reduction pathways: (1) LNG, provided that LNG transitions to carbon-recycled methane, and (2) adoption of hydrogen/ammonia as fuel [11]. Although hydrogen/ammonia fuels are a very promising solution to achieve deep decarbonization, there are still issues to be resolved in order for them to be a commercially viable solution. Issues of storage, transportation, safety, toxicity and cost are the prime inhibitors for these alternative fuels. LNG is a very promising solution to achieve short-term decarbonization, with existing ships already deploying LNG (mostly as a drop-in-fuel, blended with existing fuels in marine sector).

Biofuels look marginally more competitive than fuels derived from renewable electricity or from natural gas with carbon capture and storage. However, biofuels have challenges in terms of sustainability and availability, thus, in the mid–long-term, they may be uncompetitive due to sustainability restrictions and price volatility [12]. Because fuel price is the dominant factor that determines the total cost of operation, a fuel derived from natural gas or from a renewable energy source "may offer longer term benefits" compared to biofuels if the future growth in energy global demand and the aforementioned sustainability and availability issues of biofuels are taken into account [12].

Various renewable energy sources that are available or currently under development for shipping. Promising technologies (for existing or new ships) such as wind (via the use of kite sails, Fletnner rotors, fixed sails), solar (PV) and biomass will help the shipping sector reduce the $CO_2$ emissions. However, these technologies are still not mature enough to achieve deep decarbonization on their own.

Marine diesel ICEs are the dominant technology to provide a ship power for propulsion and for its ancillary and auxiliary needs. Given the ICEs dominance in the shipping sector, they are not expected to be replaced any time soon. Hence, it is evident from the research and market trends that the use of combusting blended fuels (e.g., blending hydrogen/ammonia/biofuel with marine diesel fuel) in ICE marine diesel engines is the way forward, at least in the short term. There are existing ships that use hydrogen as a drop-in-fuel, such as Hydroville by CMB. The technology is a hybrid engine that allows it to run on diesel and hydrogen [13]. In addition, the CMB technology is building several hydrogen-powered vessels.

Fuel cells with hydrogen or ammonia as fuels is a promising technology, especially green hydrogen and green ammonia, because not only do they reduce/eliminate GHG emissions, but they also eliminate pollutants ($NO_x$ and $SO_x$). However, fuel cells in shipping applications have lots of issues to resolve, but there are exciting projects underway to test and validate this technology. Projects such as ShipFC, a project funded by Fuel Cells and Hydrogen Joint Undertaking (FCH JU) under the EU's Horizon 2020 research and innovation program, will install a maritime fuel cell that will be powered by green ammonia [14]. The use of hydrogen in fuel cells has attracted lots of commercial interest. Recently, a Danish–Norwegian project aimed to build and test a ferry, the Europa Seaways operated by DFDS ferries, powered by a hydrogen fuel cell. The project recently gained EU funding and aims to have Europa Seaways operational by 2027. Note that this project attracted several key players in the shipping and energy sectors, who joined forces to build a ferry that will be able to transport 1800 passengers [15].

Various $CO_2$ abatement options can help the shipping industry to reduce CO2 emissions. In essence $CO_2$ abatement options are strategies and techniques that can help reduce fuel consumption, such as slow steaming, vessel and propeller design, waste heat recovery and even cleaning and coating of the hull's surface. These techniques reduce fuel consumption by either reducing the ship's resistance, improving propulsion or utilizing the wasted heat energy from the ship's engine for auxiliary and ancillary power needs. With WHR technologies, the most promising concepts are to reduce fuel consumption and thus $CO_2$ emissions. Steam and organic Rankine Cycles seem to be the most promising technologies, as they are mature. Other technologies, such as the Kalina Cycle, require further research, especially in terms of techno-economic feasibility if this technology is to compete with the more mature steam and organic Rankine Cycles. Note that the techniques are short-term measures to achieve reduction of $CO_2$ emissions, but will not achieve complete decarbonization on their own because the main source of energy is fossil-based fuels.

The IMO's targets will be achieved via a radical technology shift together with the aid of social pressure, financial incentives and regulatory and legislative reforms at the local, regional and international levels.

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## Keywords

decarbonization;hydrogen;ammonia;biofuels;fuel consumption;slow steaming