Mitigating the maritime Belt and Road Initiative's environmental impacts

Solution overview for shipping companies

December 2022

Written by

Ali ABDUL SATER
Aurélie BRUNSTEIN
James CHEN
María Fernanda CORREA PEREIRA
Manuella FELTRE
Pietro MANTOVANI
Elsie NAKHLE
Likhwa NDLOVU
Jade ZHOU

MINES PARIS | PSL | ISIGE

INTRODUCTION

The shipping sector is going through a period of great transformation. Even if it is broadly considered the least polluting form of transport, ecological pressures are increasing more and more, having consequences on various levels, including both on the environment and on human communities.

The Belt and Road Initiative, being an extensive project intended to intensify and further increase global trade through massive infrastructure investments, is expected to exacerbate such impacts.

In order to effectively tackle these issues, we wrote the following White Paper, addressed to the major shipping companies involved in the Belt and Road Initiative. The intention is to provide them with some concrete solutions to face the challenges illustrated in the report.

We have selected shipping companies as the recipients because of their global presence. They benefit from a privileged point of view of the market, as they are in a position to have concrete impacts on the BRI maritime routes (globality is probably the most illustrative characteristic of the BRI). Furthermore, due to their core economic activity, shipping companies incorporate a lot of information and different environmental standards applied worldwide, allowing them to be the real game changers in the market, both at ports and at open sea level.

After a brief overview of environmental and human outcomes via our DPSIR methodology, we, therefore, illustrate some strategic, operational, and technological solutions to these corporates. The intention is to provide concrete tools for the creation of a more sustainable shipping industry, that should go through protecting the environment and oceans, as well as local communities and more broadly all the stakeholders involved. Some business benefits from their application are also included in this White Paper, in order to make the implementation of such solutions more economically attractive for shipping companies. Nevertheless, we acknowledge that economic incentives shouldn't be the major force of change for these corporates, as a greater effort is needed that goes beyond the business logic of profit and a "short-termism" mindset. That is why we concluded our White Paper with a final call to action.

SHIPPING OUTCOMES ON ENVIRONMENT

We decided to use the Driver-Pressure-State-Impact-Response methodology to address the subject of China's Belt and Road initiative's impact on the environnement and inevitably on humans.

Drivers

- Ports building and extension
- Ports activity
- Ships lifecycle
- Shipping

Gwadar port

BRI maritime roads

Lamu port

- Noise
- Species migration disturbance
- Intrusion in marine eco-systems
- Dredging and dumping
- Disturbance and abrasion of seabed
- Coastal land use change
- Transfer of non indigenous species and aquatic pathogens
- GHG and air pollutants emissions
- Ballast, black, grey waters and other discharges from ships
- Antifouling components leaching
- Marine litter from ships and port (oil, lubricants)

Pressures

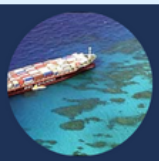
- Masking of marine species acoustic communications
- Establishment & spread of non-indigenous species
- Climate change
- Acid rains & oceans' acidification
- Increased levels of NOx, SOx, PM and ground level ozone in the air
- Collision with species and coral reefs
- Increase of nitrogen level in the water
- Increase of litter and pollutants in the sea
- Increase of suspended matter in the ocean, burial of benthic organisms
- Change in seabed substrate and morphology
- Coastal abrasion
- Destruction of mangroves ecosystem & seagrass habitat
- Increase of noise level in ports areas

Dredging & dumping

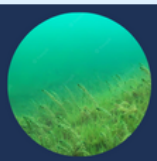
Ballast water discharge

Emissions & pollution

State changes



Coral reef damage



Suspended matter

Accoustic disruption

- Extreme weather event and others climate change outcomes
- Coastal Erosion
- Eutrophication
- Loss of seabed habitat and ecosystem
- Behaviour change, injuries, increased stress and death of local species
- Decrease of indigenous species populations
- Change in the trophic chain
- Change in ecosystem balance

Impacts

AND ON HUMANS

Jobs creation (port related or indirectly)
E.g COSCO is estimated to create 125,000 jobs in Port of Pireus until the new concession agreement expires in 2052.

Local economy boost for port cities
E.g. Gwadar Smart City Master Plan estimated local population growth from 200 thousand to 2 million in the coming years.

Business and trading opportunites for BRI countries.
World bank estimates that BRI transport projects could increase trade between 1.7 and 6.2 percent for the world, increasing global real income by 0.7 to 2.9 percent.

Populations displacements and dispossession
E.g. Project conflicts with local communities in Lamu, Kenya; Piraeus, Greece.

Loss of eco-tourism income

Loss of fishing income

Unsafe marine food supply

Air pollution

Destruction/pollution of marine coastal habitat, disruption of trophic chain and eventually fishing yields.
E.g. the depositing of polluted sediment in the Saronic gulf by COSCO

Noise disturbance from ports for nearby residents.
E.g. noise complaints in ports of Malte and Marseille

Potential fossil-fuel-based energy plants developed for increasing energy demand
E.g Chinese fossil fuel investments pre-2021, like in Lamu Kenya.

Accrued Risk of Debt
E.g. Growing accumulation of domestic debt in China leading to a decrease in FDI. 60% of China's overseas loans in 2022 are held by countries in financial distress, versus 5% in 2010. Increased debt abroad resulting in long-term land concessions (99 year lease in Colombo port in Sri Lanka).

STRATEGIC SOLUTIONS

To better address our maritime environmental concern highlighted with our DPSIR analysis with strategy planning answers, the focus of this part will raise the topic of cooperation with stakeholders as a main solution to implement within shipping companies' strategy, vision and environmental goals definition. This aforementioned cooperation strategy can be tailored around three scopes local communities with port authorities, international agency and multi stakeholder initiative groups.

Local communities include various stakeholders, mostly at regional scale, that have close business, political and economical links with shipping companies activities in their active location. Surveying and integrating them into the decision making process and monitoring process, especially considering the harmonisation of business activities and communities demands regarding corporate and social responsibilities. The latter can be approached from both upside and downside perspective with companies seeking better exposure and also competitive advantage from going beyond rules and regulation with leading management systems. This would help consolidate the brand and employee loyalty, adhering to profit sharing policies with profit redistribution to NGOs like Save Lamu in Kenya for instance, increasing transparency and consistency in both internal and external reporting and information sharing of highly market competitive ESGs. These strategies also include the major stakeholder that port authorities constitute by their regulatory weight with their governance over Portugal land, terminal operators and other service providers. More inclusive joint strategies will help improve port' performance with the goal for shipping lines to be satisfied in their needs (capacity, time, etc), streamlining port operations within shipping companies' transport chain and the possibility to solve environmental issues together. This can be possible with cooperation in resource sharing with mutual costs benefits and risk reduction for new infrastructure projects such as BRI. Better cooperation between those active stakeholders also contribute to reducing destructive competition.

IMO, as the global authority for international shipping regulation, works to implement environmental performance policies but the process is long as maritime conventions are not binding until it is enforced after countries ratifications. The minimum of state ratifications is also coupled to a requirement regarding the percentage of the world's merchant fleet that they represent: entry into force of a convention IMO usually takes several years following its adoption. On the scope of GHG emissions for instance, IMO targets are estimated to be not ambitious enough: in November 2022, as according to its strategy the objective is to reduce the carbon intensity from shipping by at least 40% by 2030 compared with to 2008. Shipping companies are therefore expecting more ambitious targets, as well as more stringent policy instruments supporting strategies. This would help them to stabilize future market standards and trends, leading to possible gain of competitive advantage by the time new policies become effectively enforced. Such anticipation practices are therefore supported and should become a main subject from collaboration between shipping companies and IMO.

These dynamics can be the key to the implementation of new technologies and alternative fuels that are already available on the market but not at the industrial scale since their implementation does not align with short-term economic benefits yet. With the market shifting slowly but surely toward a more sustainable scope, new economic opportunities and environmental benefits can result from pioneer positioning in those markets such as fleet updates. Furthermore, a relevant flagship in the sustainable development field is the EU policymakers. Their legislation is often characterized as being leading, more ambitious, and more restrictive than IMO's own directives making the application of their directives a good anticipation of IMO's future conventions. This action will also leverage the widespread global presence of European major shipping companies, already familiar with EU directives.

Multi-stakeholder initiatives, such as the Sustainable Shipping Initiative (SSI), regroup ambitious and like-minded leaders driving change through cross-sectoral collaboration to contribute to and thrive in a more sustainable maritime industry. Collaborating through joining such an initiative would help maintain communication and discussion between the members such as Maersk, WWF, Swire Shipping, etc. A consistent and collaborative schedule can be set regarding best practices both on the economic and environmental side of the business, with "good students" leading the others. SSI can therefore pilot shipping companies towards green shipping, where management and technology can be accomplished. Considering inter-shipping companies collaboration is substantial for management and implementing shipping companies technologies for opposing greater impact such as environmental ones.

New collaborative strategies developed will create a context for information-sharing tools to be developed with mutual funds such as private or public cloud-based platforms as an example multi beneficial result from increasing information sharing between all the aforementioned stakeholders. Therefore, implementing those strategies or strengthening them within the shipping company's vision will be key to addressing the environmental dilemma.

OPERATIONAL SOLUTIONS

Reducing the negative impact of Maritime BR shipping on ecological resources requires a combination of strategic and technical solutions. Due to the lower cost and logistical approach, often strategic solutions are ideal achievable steps to take before investing in new technology. Some of the strategies listed below are already being implemented, by shipping giants like COSCO, whilst others are still in development. In reducing CO2 emissions each strategy also has the potential to reduce operational costs and to benefit planned far furans in 2022 and companies in anticipating a carbon credit/ offset scheme (as planned for Europe in 2023 and possibly expanding globally)

Solution Type	Methods and Measures	Impacts
Maintenance and Human Factors	**Climate Conscious Management** • Improving employee understanding of energy-saving knowledge through operations • Potential employee incentives to encourage energy saving behaviors	✚ Increased employee understanding and investment in energy saving can reduce CO2 emissions between 1-10% ✚ Increases potential for further ideation from employees on saving energy ✚ Low implementation cost compared to alternatives
	Hull cleaning and propeller polishing • Periodic fouling of the hull and propeller • Improvement of ship condition monitoring systems, diagnosis systems, energy consumption monitoring systems	✚ Optimized hull and propeller maintenance can reduce CO2 emissions between 2-8% ✚ Regular maintenance ensures awareness of problems that affect the vessel's speed and power. and overall performance.
Port Services	**Reducing the time in anchorage** • Integrated planning to improve loading/unloading efficiency • Stronger coordination with the Port Authority optimize port maneuvers.	✚ Provides space for slower and more fuel-efficient sailing speed offering ~ 10-40% fuel gain ✚ Reduction of unproductive time through faster document processing and improved loading/unloading efficiency - Requires intensive coordination and planning with port
	Port Cold Ironing • Strong regulatory framework and national financial support • Strong coordination with port authorities to manage complex operations • Shoreside electricity is preferably sourced from low to no-carbon sources	✚ Reduces GHG emissions between 3-10% and reduces engine noise/ noise pollution ✚ Benefits the coastal ecosystem and the health of local communities ✚ Low retrofitting costs for shipping companies and potential port-specific incentives - High initial expenses of installation for ports - The reduction of emissions depends on the type of renewable energy generation in each country
Crusing and Maneuvering	**Increase CO2 measuring capacity/transparency** • Readily publicize company and ship emission data through ship engine and fuel consumption	✚ Allows companies to visualize their carbon emissions and opt to integrate clean energy sources (either renewables or higher-grade fuels) ✚ Potentially benefit companies: ESG scores and allows consumers to prioritize their investments in shipping companies
	Speed reduction (Slow steaming) • Management of voyage time with cargo handling • Decrease speed within engine limits to preserve function	✚ Safe solution, no additional burden for crew ✚ Air, and water pollution reduction by (~10%) ✚ Noise pollution reduction by ~ 1 to 6 dB ✚ Fuel consumption and CO2 reduction by 20–40% safe and easy solution to implement ✚ Increased transportation time - Negative engine impact from operating at off-design conditions
	Voyage optimization • Improved weather routing • Efficient path selection • Just-in-time/Green Approach • Intelligent Energy Efficiency Management • Automation and autopilot	✚ Weather routing improves safety with avoidance of blue corridors and contributes ~1-6% reduction in CO2 ✚ Automation can potentially result in a < 10% fuel gain ✚ Avoidance of blue corridors to decrease collision risk - Accurate multi-objective weather routing optimization technology is still under development - Green Approach can conflict with ports' prioritization of ships

TECHNOLOGICAL SOLUTIONS

Shipping companies, as main customers of shipbuilding companies, have the power to incentivize R&D (EEDI, CII and EEXI optimization) and eco-design when expressing technical requirements. They can also require shipbuilders to follow IMO non-binding regulations such as the guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life. Indeed, environmental regulations are tightening over time. Requiring ship disruptive technologies development will not only help shipping companies to be ahead of future regulations, but will also allow them to remain competitive and significantly decrease their environmental impact.

Carbon capture on board

Adsorption approach
(Seabound)

+ Captures up to 95% of CO2 emissions
- Reduction of the cargo capacity (1-5%)

Solvent-based approach

- Filters sulphur, ultra-fine particulates and CO2

+ Plug and play system
100% circular solution
- Not scaled for big trading ships yet

Antifouling

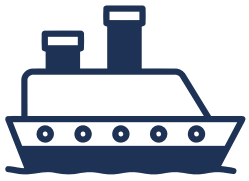
Physical (Finsulate)

- Using spiney surfaces to prevent organisms from clinging to the hull of a boat.

+ No chemical release in the ocean
100% recyclable
5 years lifespan
- Maintenance needed
Hasn't prooven to work perfectly

Non-biocidal lower roughness antifouling coating

+ 63.6 t of CO2 emission reduction per route for bulk carrier (~5400$ savings)*
Return on investment ~ 1.5 - 3 years
No leaching of toxic compounds
- More research needs to be done



Ship & propulsion design

Advanced materials

+ Weight reduction, reducing up to 22% CO2*
Noise reduction
- Price

Free or reduced ballast ships

+ Up to 10% CO2 reduction*, smaller risk of non indigenous species spread
- Not scaled for big trading ships yet

Waste Heat Recovery (Rankine cycle)

+ Energy consumption reduced by valorising heat exchanges of exhaust gas and cooling water

Hull Hydrodynamics (design, forms, coating, air film lubrification)

+ Speed increase, less resistance
Up to 30% CO2 reduction*
Noise reduction

Water rotationnal energy recovery systems
(stator-fins, contrarotationnal propeller, contracted & loaded tip propeller)

+ Up to 10% CO2 reduction*
Improve overall ship efficiency
Reduce cavitation, vibration & noise
Reliable and low-cost retrofit

Advance sewage system

+ Anticipating future MARPOL convention strenghtening.

Alternative energy

Alternative fuels

+ **Green Ammonia:** no carbon footprint when combusted
- Ammonia is very toxic and has a high environmental impact when leaked. Nitrogen dioxide and NOx are byproducts of combustion (but avoidable if a fuel cell is used).

+ **Green Hydrogen:** potential for the lowest emissions from the combustion process
- Fuel prices are extremely high and hydrogen requires a very low storage temperature

+ **Methanol LNG:** biodegradable, clean-burning fuel type. Up to 30% reduction in GHG compared to HFO. Technology is readily available.
- Methane leaks from methane slip contribute to 4x higher GHG potential than CO2.

+ **LPG**: comply with IMO's new sulfur regulations from 2020. 20% reduction in GHG emissions. LPG is an ideal transition fuel with readily available technology
- Safety concerns with lower combustion temperature of LPG

+ **Nuclear propulsion**: reducing emissions such as CO2 and replacing fossil fuels.
- Radiation hazards pose a safety concern and require highly trained personnel.
- Obstacles to overcome with international and local nuclear regulations

Wind power (OcenBird, AirSeas)

- Rotor sails or flattener rotors are spinning cylinders that use the changes in air pressure to propel the vessel

+ Reduction of fuel consumption (from 10 to 20%) & air, water and noise pollution
- Intermittent energy source

*due to fuel savings

BUSINESS BENEFITS

Shipping companies may benefit from some advantages for the company growth and development if they apply these different measures: strategic, technological and operational solutions. Moreover, this will consequently mitigate the shipping intensification due to the BRI development.

In the previous part, several types of solutions have been introduced. They all represent possible paths to reduce shipping environmental and human impact: short or long-term, reliable or risky, and low-cost or expensive investment solutions.

Shipping companies face many challenges in integrating low-carbon policies and limiting their impact on biodiversity. A combination of some of the proposed solutions above, over a long range of time, is the solution for a more sustainable industry. However, shipping companies will have interested in implementing these changes in the near future.

Indeed, some solutions provide cost savings in the short or long term, competitiveness, and help gain a positive reputation.

Indeed, the proposed solutions are not all costly and don't require important investments. For example, new propeller technologies and LNG-fuel engines are reliable technologies, and they allow the reduction of CO2 by 30% and fuel saving in a short-term vision. They do not represent any financial or technical risk other than those existing for basic fuel engines.

Shipping companies are encouraged to anticipate changes in the new regulation. IMO is intensifying its efforts to decarbonize the shipping sector. New mandatory rules were introduced in November 2022 to reduce the carbon intensity of international shipping by at least 40% in 2030 compared to 2008 levels. Therefore, shipping companies will need to adopt disruptive technological solutions to be in line with the regulation under penalty of sanctions or to pay the bill of technological delay later. Besides, regional emission trading schemes, such as the EU and China, are considering the inclusion of the shipping sector into their schemes for carbon emissions. Shipping companies could benefit by planning an optimal investment strategy to anticipate the rise of the carbon price. This will lead to changes towards environmentally sustainable emission-free solutions with a positive net present value, the possible payback time for the investments should be short as well.

As the general public becomes increasingly aware of the deleterious impacts of shipping on the environment, through oil spills, nearby port inhabitants' discontent and organized cetaceans strikes, implementing eco-friendly measures in shipping companies' business could help to get a better reputation from civil society but also customers.

Besides, the implementation of new technologies will allow a decrease in chemical pollution in the oceans. The companies will benefit from a favorable public opinion and that will improve their visibility and attractiveness. Investing in new technologies will also lead to less atmospheric pollution in port cities, which is a good attribute for public opinion. It should also be noted that the setup of tools to allow noise reduction may have a positive impact on marine species' behavior. This is a good thing to attract customers who are kind on biodiversity matters and therefore enhance the good reputation of the company.

Also, many social studies have demonstrated the increasing need in society to find meaning and impact in their job position. It is always more fulfilling to work in a modern company whose strategy is oriented toward solving social and environmental issues. Thus, implementing solutions for a less carbonized and biodiversity-harmful industry will convince new talents to join shipping companies or current employees to pursue their careers within the company.

Finally, the improvement of communication among the different maritime trade stakeholders is equally fundamental. However, it depends on a well-functioning process and the quality of the interactive process. The relevance of enhanced networking on technical and procedural issues plays a key role in the management of environmental issues throughout the entire process. It, therefore, contributes to a better way to do business. Besides, greater transparency and better cooperation will lower the reputational risk of the company.

SUMMARY

This White Paper has been written with the intention of assisting our main recipient, the shipping companies, to minimize the impacts that have previously been discussed.

The solutions that have been proposed have been made with the thought in mind of not only presenting potential monetary savings for the shipping companies and improving their public perception but also, more importantly, finding ways to protect the environment. These solutions have been divided into strategic, operational, and technological.

The strategic solutions focus on highlighting the importance of shipping companies to increase cooperation with other stakeholders whether they are international or local groups. The operational solutions are targeted at the maintenance and human factors, port services, cruising, and maneuvering aspect. The technological solutions proposed are carbon capture on board, ship and propulsion design, antifouling, and alternative energy implementation.

These types of solutions should be implemented and intertwined with each other in order for shipping companies and the environment to benefit from these measures. Some of these suggestions can be easily implemented while some are more challenging, some of them are low cost while some are expensive, and some of them can show results in the short-term while others in the long-term.

However, regardless of the many factors a company might need to consider before implementing any change to its way of doing business, we strongly believe that it is in the best interest of the shipping companies to start and keep making the proper adjustments to be on track with the decarbonization and mitigation path not only because they have to follow regulations from the IMO but also because of the sense of responsibility that we owe to our common home.

CALL TO ACTION

“Fight now for a new dawn.”

Fight now for the world, human health, sea life, and nature. Fight now for a brighter future for your beloved people. We have the power, ability, and will to make our beloved ones live better without natural or health disasters. It’s time to start adaptation and mitigation for a healthy and free-of-disaster life before it’s too late. We present you a variety of solutions to reduce the impacts of the maritime Belt and Road Initiative on biodiversity, climate, and humans. For more information on the ways and solutions, please contact one of the ENVIM students.

REFERENCES

- Michele Acciaro, Peter Nyegaard Hoffmann and Magnus Strandmyr Eide,(2013) The Energy Efficiency Gap in Maritime Transport, JSOE Volume 2, Number 1-2, 2013
- Evert A. Bouman a, Elizabeth Lindstad b, Agathe I. Rialland b, Anders H. Strømman. (2017) State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping – A review,
- Yunlong Wang et al, (2022) Analysis on the Development of Wind-assisted Ship Propulsion Technology and Contribution to Emission Reduction. 2022 IOP Conf. Ser.: Earth Environ. Sci. 966 012012.
- Deloitte, (2022) ESG in the shipping sector, The role of ESG in the evaluation of shipping companies, Retrieved from: https://www2.deloitte.com/content/dam/Deloitte/gr/Documents/consumer-business/gr_esg_in_the_shipping_sector_noexp.pdf
- Min Wua, Kevin X. Lib, Yi Xiaoc, Kum Fai Yuen, (2022). Carbon Emission Trading Scheme in the shipping sector: Drivers, challenges, and impacts.
- Henry Schwartz, Magnus Gustafsson, Jonas Spohr. (2020) Emission abatement in shipping e is it possible to reduce carbon dioxide emissions profitably? Retrieved from: www.elsevier.com/locate/jclepro
- International Maritime Organisation. (2022) Note by the International Maritime Organization to the fifty-seventh session of the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA 57) Sharm El Sheikh, Egypt, 6 to 12 November 2022, Retrieved from : https://unfccc.int/sites/default/files/resource/IMO%20submission%20to%20SBSTA%2057.pdf
- Xing, H., Spence, S., & Chen, H. (2020). A comprehensive review on countermeasures for CO2 emissions from ships. ELSEVIER, 3-11.
- China Communication Construction Company and China Aid for Shared Future. (2019). The integrated Gwadar Smart Port City Master Plan Report
- Yeo, S., Kim, J., & Lee, W. (2022). Potential economic and environmental advantages of liquid petroleum gas as a marine fuel through analysis of registered ships in South Korea. Journal of Cleaner Production, 330, 129955. doi:10.1016/j.jclepro.2021.129955
- Issa, M., Ilinca, A., & Martini, F. (2022). Ship energy efficiency and maritime sector initiatives to reduce carbon emissions. Energies, 15(21), 7910. doi:10.3390/en15217910
- Lindstad, E., Lagemann, B., Rialland, A., Gamlem, G. M., & Valland, A. (2021). Reduction of maritime GHG emissions and the potential role of E-fuels. Transportation Research Part D: Transport and Environment, 101, 103075. doi:10.1016/j.trd.2021.103075

Operational Solutions

- Lee Jones Reader in International Politics. (2020, October 01). 4. Sri Lanka and the BRI Debunking the Myth of 'Debt-trap Diplomacy'. Retrieved December 8, 2022, from https://www.chathamhouse.org/2020/08/debunking-myth-debt-trap-diplomacy/4-sri-lanka-and-bri
- Pariotis, Efthimios & Zannis, Theodoros & Yfantis, E.A. & Roumeliotis, Ioannis & Katsanis, John. (2016). Energy Saving Techniques in Ships.
- Wang, K., Wang, J., Huang, L., Yuan, Y., Wu, G., Xing, H., . . . Jiang, X. (2022). A comprehensive review on the prediction of ship energy consumption and pollution gas emissions. Ocean Engineering, 266, 112826. doi:10.1016/j.oceaneng.2022.112826
- Wu, Z. (2022). Configuration generation method of ship end program for Ship Energy Efficiency Management Platform. Wireless Communications and Mobile Computing, 2022, 1–7. https://doi.org/10.1155/2022/7742088
- Xing, H., Spence, S., & Chen, H. (2020). A comprehensive review on countermeasures for CO2 emissions from ships. Renewable and Sustainable Energy Reviews, 134, 110222. https://doi.org/10.1016/j.rser.2020.110222
- Bergqvist R. & Monios J. (2019). Green Ports in Theory and Practice. doi: 10.1016/B978-0-12-814054-3.00001-3. Retrieved from: https://www.eblueeconomy.com/wp-content/uploads/2021/05/eBlue_economy_Green_ports.pdf
- The Editorial Team. (2020, October 5). Do you know what Cold Ironing is? Safety4Sea. Retrieved from: https://safety4sea.com/cm-do-you-know-what-cold-ironing-is/
- Identifying the unique challenges of installing cold ironing at small and medium ports – The case of Aberdeen. Retrieved from: https://www.researchgate.net/figure/Ports-using-cold-ironing-WPCI-2017_tbl1_323959405
- Dunkerque Port. (2020, January 8). CMA CGM AND THE PORT OF DUNKIRK INAUGURATE A "COLD IRONING" SYSTEM ALLOWING SHIPS TO PLUG INTO ONSHORE ELECTRICITY. Retrieved from: http://www.dunkerque-port.fr/en/press/news/2020-01-07-cma-cgm-and-the-port-of-dunkirk-inaugurate-a-cold-ironing-system-allowing-ships-to-plug-into-onshore-electricity-en-62965.html
- Cold Ironing. Suaridaz Group. Retrieved from: https://www.suardiaz.com/innovation/cold-ironing/?lang=en
- About Cold Ironing. TEC Shore Power. Retrieved from: https://tec-shorepower.com/
- The Editorial Team. (2019, March 18). Cold Ironing: The role of ports in reducing shipping emissions. Safety4Sea. Retrieved from: https://safety4sea.com/cm-cold-ironing-the-role-of-ports-in-reducing-shipping-emissions/#:~:text=In%20fact%2C%20because%20of%20the,95%25%20of%20NOx%20and%20particulate

Technological Solutions

- Marine traffic noise pollution infographic. (s. d.). IFAW. https://www.ifaw.org/international/resources/marine-traffic-noise-infographic
- Seabound. (s. d.). https://www.seabound.co/#news
- Elkafas, A. G., Khalil, M., Shouman, M. R., & Elgohary, M. M. (2021). Environmental protection and energy efficiency improvement by using natural gas fuel in maritime transportation. Environmental Science and Pollution Research International, 28(43), 60585-60596. https://doi.org/10.1007/s11356-021-14859-6
- Value maritime—Filtration reinvented! (s. d.). Value Maritime. https://valuemaritime.com/services/
- Maintaining water quality with sustainable ship antifouling. (2020, juillet 30). Innovation News Network. https://www.innovationnewsnetwork.com/maintaining-water-quality-with-sustainable-ship-antifouling/6338/
- Farkas, A., Degiuli, N., Martić, I., & Vujanović, M. (2021). Greenhouse gas emissions reduction potential by using antifouling coatings in a maritime transport industry. Journal of Cleaner Production, 295, 126428. https://doi.org/10.1016/j.jclepro.2021.126428
- McLellan, A. (s. d.). Back to the future with wind-propulsion. https://www.imarest.org/themarineprofessional/on-the-radar/6363-back-to-the-future-with-wind-propulsion
- Ammonia i future fuels. (s. d.). MAN Energy Solutions. https://www.man-es.com/marine/strategic-expertise/future-fuels/ammonia
- Hydrogen i future fuels. (s. d.). MAN Energy Solutions. https://www.man-es.com/marine/strategic-expertise/future-fuels/hydrogen
- Renewable methanol. (s. d.). METHANOL INSTITUTE. https://www.methanol.org/renewable/
- Schuler, M. (2020, novembre 4). World's first lpg-fueled very large gas carrier completes sea trials. GCaptain. https://gcaptain.com/worlds-first-lpg-fueled-very-large-gas-carrier/
- Jillian. (2021, mai 25). World's first fleet of dual-fuel lpg powered ships. IRI | International Registries, Inc. https://www.register-iri.com/blog/worlds-first-fleet-of-dual-fuel-lpg-powered-ships/
- Explore dsme | dsme. (s. d.). https://www.dsme.co.kr/epub/technology/technology0108_n04.do
- Aakko-Saksa, P. T., Lehtoranta, K., Kuittinen, N., Järvinen, A., Jalkanen, J.-P., Johnson, K., Jung, H., Ntziachristos, L., Gagné, S., Takahashi, C., Karjalainen, P., Rönkkö, T., & Timonen, H. (2023). Reduction in greenhouse gas and other emissions from ship engines : Current trends and future options. Progress in Energy and Combustion Science, 94, 101055. https://doi.org/10.1016/j.pecs.2022.101055
- Furfari, S., & Mund, E. (2022). Advanced Nuclear Power for Clean Maritime Propulsion. The European Physical Journal Plus, 137(6). doi:10.1140/epjp/s13360-022-02980-5