Decarbonising The Maritime Shipping Industry

International shipping: Decarbonization Challenges

The problem defined

International maritime shipping is a major contributor to climate change. We live in a globalized world which fundamentally relies on international shipping to deliver our consumer goods and staple foods. Maritime shipping represents the biggest global low cost international freight transport service, and international shipping carries around 80 percent of global trade by volume and over 70 percent by value. According to the International Maritime Organization (IMO), international shipping accounted for approximately 2.6% of annual global carbon dioxide (CO2) emissions from 2007-2011. While shipping is comparatively less emissions intensive than other forms of intercontinental transport (air freight), the economic and energy developments in the future could grow CO2 emissions from international shipping by 50–250%.[1] While the urgency of the IPCC Special Report on 1.5 degrees reveals a pressing need to reduce all sources of carbon emissions in the next decade, a number of interlocking political, economic, technical, social and legal challenges challenges complicate the rapid decarbonisation of the international shipping industry.

Why examine maritime shipping?

Maritime shipping represents a highly significant source of sectoral emissions left unaddressed by the Paris Agreement. Although we examined decarbonisation of various

[1] Raucci, Carlo. "The potential of hydrogen to fuel international shipping", PhD diss., University College London, (2017): 4.

industries in APSC 498, we did not discuss international shipping. The final project was an opportunity to gain a high-level understanding of the challenges and opportunities of decarbonising the maritime shipping industry.

Defining the system

As maritime shipping operates largely in international waters, it was impractical for this report to approach the decarbonisation of shipping from one geographical location. Instead, examined how the activities of large ships interact with international institutions, agreements and consumer forces. Key nodes within our system include the International Maritime Organisation, major shipping corporations, the flag state in which a vessel is registered, the type of ship, fuel used, distance traveled, speed and consumer demand. We identified external regulatory, social and economic pressures which shape activity *within* our system. External forces include carbon-pricing regimes, international pollution regulations, pressure from exporters of raw materials and finished goods, and demand created by patterns of mass-consumption.

The Problem Landscape

There are a number of interlocking political, social, economic and technological challenges in decarbonising the shipping industry. We will examine each of these challenges in greater detail in the sections below. The primary issues we identified are as follows:

- Heavy Fuel Oil (HFO) often used in maritime shipping vessels is an inexpensive, environmentally destructive fuel (in terms of its carbon emissions).[2]
- The IMO has not developed a formal industry-wide emissions reduction strategy.

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[2] Aki Kachi et al., “NewClimate MBM for Maritime Emissions”, NewClimate Institute (2019): 4-5. Accessed April 1, 2019 at https://newclimate.org/wp-content/uploads/2019/03/NewClimate-MBM-for-Maritime-Emissions.pdf

- Any price increase in shipping or reduction in shipping activity could adversely affect Canadian and global economies. For Canada alone, the national economic impact of marine shipping is equal to approximately 1.8% of the Canadian economy, or about $30 billion.[3]
- Measurement and monitoring of on-vessel emissions makes establishing a baseline and ensuring compliance a challenge.
- Long life-cycles of maritime vessels- 25 years, on average- mean that vessels cannot be rapidly replaced or adapted.
- Renewable energy technologies tend to be costly and are in varying stages of development- each comes with variable supply-chain emissions and the potential for unintended social and ecological side-effects.
- Many energy-efficiency initiatives and renewable fuels options will affect vessel operations (decreased fuel efficiency, increased transport time, etc.)
- Measures which increase the cost of international shipping would adversely impact the developing nations most reliant on exports through maritime trade (e.g agroexport nations like Ghana or Indonesia).

Fuel

Currently, cargo and freight ships use fuel referred to as Heavy Fuel Oil (HFO) or "bunker oil", which is a heavy, byproduct from the extraction of gasoline, diesel and other hydrocarbons during the refinery process.[4] Most bunker oil is very toxic and hazardous to aquatic

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[3] Council of Canadian Academies, "The Value of Commercial Marine Shipping to Canada", Ottawa (ON): The Expert Panel on the Social and Economic Value of Marine Shipping to Canada, (2017): 12. Accessed April 1, 2019 at https://www.scienceadvice.ca/wp-content/uploads/2018/08/ValueMarineShipping_fullreport_EN.pdf page 2.
[4] Aki Kachi et al., "NewClimate MBM for Maritime Emissions", NewClimate Institute (2019): 4-5.

life and human life while also emitting large amounts of CO_2. The oil is very thick that it can spread over large distances and is very hard to evaporate, leaving long term contaminants if any spills occur. The reason this type of bunker oil is used is because of the cost; the dirt-cheap oil makes shipping internationally very cheap, which consumers appreciate even if they are not aware of the environmental outcome. The low price of HFO gives little financial incentive to explore costly renewable fuels.

Lack of International Regulations

There are currently no legally binding international agreements to reduce CO_2 emissions in the shipping industry.[5] Existing conventions which regulate marine pollution, like MARPOL regulate certain marine pollutants, however, MARPOL does not identify GHGs as a marine pollutant, nor does it specify that shipping corporations' are responsible for minimizing vessel emissions.[6] In the Paris Climate Agreement, the maritime shipping industry were not included in NDCs. Responsibility for developing regulations, targets, and measurement plans rests largely with the International Maritime Organization (IMO).[7] The IMO has been slow to develop an emissions reduction plan.[8] A tentative industry action plan was only tabled by the IMO's Marine Environment Protection Committee (MEPC) in April, 2018.[9] The voluntary agreement aims to reduce shipping emissions by 50% below 2010 levels by 2050. However, there is a lack of clarity about 'Measuring, Reporting, and Verification (MRV)'- it is unclear who will enforce

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[5] Wan, Zheng, Abdel el Makhloufi, Yang Chen, and Jiayuan Tang. "Decarbonizing the International Shipping Industry: Solutions and Policy Recommendations." *Marine Pollution Bulletin* 126, (2018): 430.
[6] Mia Mahmudur Rahim, "Regulating Global Shipping Corporations' Accountability for Reducing Greenhouse Gas Emissions in the Seas." *Marine Policy* 69, (2016): 161.
[7] Wan, "Decarbonizing the International Shipping Industry: Solutions and Policy Recommendations." *Marine Pollution Bulletin*,(2018): 428-435.
[8] Wan, Zheng, "Decarbonizing the International Shipping Industry: Solutions and Policy Recommendations." *Marine Pollution Bulletin* 126, (2018): 428-435.
[9] International Maritime Organisation Press Center, " Low carbon shipping and air pollution control", October, 2018. Accessed April 1, 2019 at http://www.imo.org/en/MediaCentre/HotTopics/GHG/Pages/default.aspx

compliance with emissions reductions targets, and *how* they will be enforced.[10] The IMO itself does not currently have a strategy to assess corporate performance in GHG emissions reduction for the shipping trade, making assessment of any kind extremely difficult.[11] The IMO's tentative emissions strategy will only be revised and formalized in 2023.[12]

Monitoring challenges

Any plan to decarbonise the shipping industry relies on the ability to establish an emissions baseline for the industry, and to regularly and reliably receive data to evaluate compliance with emissions reduction targets. However, while at sea, vessels are not required to report their speeds and routes, two factors which increase the amount of carbon emitted. Currently, the disclosure of emissions data from major international shipping companies is very poor. The world's top eight shipping corporations- Maersk, MSC – Mediterranean Shipping Company. COSCO – China Ocean Shipping Company. CMA-CGM. Hapag-Lloyd. ONE – Ocean Network Express. Evergreen Line. PIL Pacific International Line- do not include emissions data on their yearly reports.[13] The numbers that are given are not offered in a "user-friendly format such as the Global Reporting Initiative (GRI)". For policy makers and academics, the absence of publicly accessible data poses an enormous challenge for decarbonising the shipping industry, as establishing baselines is essential for creating reductions

[10] Kachi, Aki, Silke Mooldijk, and Carsten Warnecke. "Carbon Pricing Options for International Maritime Emissions." Newclimate.org. April 04, 2019. Accessed April 05, 2019. https://newclimate.org/2019/03/19/carbon-pricing-options-for-international-maritime-emissions/.https://newclimate.org/2019/03/19/carbon-pricing-options-for-international-maritime-emissions/

[11]Mia Mahmudur Rahim, "Regulating Global Shipping Corporations' Accountability for Reducing Greenhouse Gas Emissions in the Seas." *Marine Policy* 69, (2016): 169.

[12] International Maritime Organization, "MARPOL ANNEX VI: RESOLUTION MEPC.304(72)", (2018): 5. Accessed April 1, 2019 at http://www.imo.org/en/OurWork/Documents/Resolution%20MEPC.304(72)%20on%20Initial%20IMO%20Strategy%20on%20reduction%20of%20GHG%20emissions%20from%20ships.pdf

[13] Mia Mahmudur Rahim, "Regulating Global Shipping Corporations' Accountability for Reducing Greenhouse Gas Emissions in the Seas." *Marine Policy* 69, (2016): 163.

plans and evaluating compliance relies on this flow of information, which is currently unmeasured by vessels.

Consumer Behaviour

There is no question that our current economic system is dependent on a well functioning global trade network. If production specialization is the basis for macroeconomic theory, then the massive structure that is the global maritime shipping industry is the crux of our modern economic paradigm. In her well defined list of places to intervene in a system, Meadows suggests that paradigm shifts are the most effective ways to change a system.[14] A paradigm shift of this magnitude may indeed be the most effective, but also the most difficult. In the case of a globalized economy and shipping industry, a paradigm shift would mean a radical shift in consumer behaviour. After careful design and continuous management by a powerful marketing and media system, consumerist behaviour is heavily ingrained in culture, lifestyles. The level of entanglement between human daily life and a globalized trade system makes it difficult to imagine a world without easy, cheap, and reliable shipping. It doesn't help that current global trends of development only point toward an increase in consumerism as populations grow in GDP.[15]

Equity issues for export-oriented nations

Many solutions to GHG emissions in the shipping industry could disproportionately impact 'developing' nations. Some developing countries, particularly small developing island

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[14] Meadows, Donella. "Leverage Points-Places to Intervene in a System." (2015).
[15] Gehlhar, Mark, and William Coyle. "Global food consumption and impacts on trade patterns." Changing structure of global food consumption and trade (2001): 4-13.

states, (SDIS) have expressed concern about the unknown ripple effect and economic impact of an emissions cap on the competitiveness of their marine shipping reliant export sector.[16]

The Solutions Landscape

Existing solutions

Operational and Design Regulations to Increase efficiency

Existing regulatory solutions consist largely of energy efficiency measures. In 2018, the IMO rolled out a new *legally binding* set of regulations on efficiency.**[17]** The legislation adopted an Energy efficiency design index (EEDI) which specifies that ships adopt more energy efficient (less polluting) equipment and engines. The legislation also requires ships to have an energy efficiency management plan (SEEMP) for operating and improving the energy efficiency of their ships. However, some scholars suggest that the modest reductions stemming from the Energy Efficiency Measures under Annex VI (of the IMO) will not result in any reduction of total CO2 emissions for shipping from 2010 levels, as the anticipated growth of world trade cancels any emissions reduction gains made through EEDI and SEEMP.[18]

Slow-steaming

Slow Steaming is an operational strategy which slows down of cargo ships to emit less GHG emissions. Lowering a cargo ships' speed by 5-7 knots could reduce the emissions by half

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[16] Aldo Chircop et al., "Shipping and Climate Change International Law and Policy Considerations", *Center for International Governance Innovation*, (2018): 15. Accessed April 1, 2019 at https://www.cigionline.org/sites/default/files/documents/Shipping%27s%20contribution%20to%20climate%20change%202018web_0.pdf

[17] Carlo Raucci, "The potential of hydrogen to fuel international shipping", PhD diss., University College London, (2017), 4.

[18] Mia Mahmudur Rahim, "Regulating Global Shipping Corporations' Accountability for Reducing Greenhouse Gas Emissions in the Seas." *Marine Policy* 69, (2016): 170.

or more depending on the size of the cargo ships.[19] However, this would mean slower shipping processes so larger or more frequent shipments would have to be used to meet export agendas and consumer demand. In 2011, >50% of global container vessels used slow-steaming, yet, slow steaming will not considerably reduce GHG emissions as trade liberalization and production offshoring is continually increasing demand.[20] It must be coupled with changes to vessel fuel source.

Fuel Switching to Liquified Natural Gas (LNG)

LNG-powered vessels have lower direct exhaust emissions than comparable vessels using petroleum based fuels. A study funded by NGVA Europe, an association which promotes the use of natural gas in vehicles and ships, concluded that LNG as a bunker fuel provides a 21% well-to-wake reduction in GHG emissions compared to convention fuel oil.[21] However, a 2016 study found that the relative GHG emissions benefits of LNG versus conventional fuel oil on a "well-to-wake" basis was highly dependent upon fugitive methane emissions in the LNG supply chain. LNG switching would be an ideal place to start as it would be one of the cheaper options without changing much of the ship's anatomy or parts to fit the fuel type. However, in the absence of on-board CCS, LNG offers a "limited opportunity to reduce greenhouse gas emissions" when accounting for fugitive emissions as the growth of the industry itself.[22] LNG is

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[19] The Geography of Transport Systems, "Fuel Consumption by Containership Size and Speed", Transport Geography, https://transportgeography.org/?page_id=5955 (accessed April 1, 2019)
[20] Cariou, Peter. "Is Slow Steaming a Sustainable Means of Reducing CO2 Emissions from Container Shipping?" Transportation Research Part d-Transport and Environment 16, no. 3 (2011): 260-264.
[21] Congressional Research Service, "LNG as a Maritime Fuel: Prospects and Policy", (February 5, 2019):9. Accessed April 1, 2019 at https://fas.org/sgp/crs/misc/R45488.pdf.
[22] Gilbert, Paul, Conor Walsh, Michael Traut, Uchenna Kesieme, Kayvan Pazouki, and Alan Murphy. "Assessment of Full Life-Cycle Air Emissions of Alternative Shipping Fuels." Journal of Cleaner Production 172, (2018): 855-866.

not a long-term strategy to meet the IMO's provisional climate goal of a 50% reduction in shipping emissions below 2010 levels.

Proposed solutions

Regulatory and Market based measures

Carbon tax

Currently, shipping fuels are not taxed. While many nations and states worldwide have imposed carbon taxes or cap and trade mechanisms (such as Denmark, the flag state of shipping magnate Maersk), emissions from the shipping industry are not tracked or taxed by the flag state. As crude oil bunker fuel is so cheap, there is little economic incentive for shipping corporations or vessel owners to invest in green technology. Creating a climate levy, which would place a set price on each tonne of GHG emitted by ships, would be a way to account for externalized carbon. [23] A carbon price could be implemented through an international convention of the UNFCCC and IMO.[24] Compared to an emissions trading scheme (cap-and-trade), a price per ton of CO2 sends consistent price signals, encouraging investment in low-carbon technology. Revenue from a carbon-pricing scheme could fund further research and development in zero-emissions fuels or fund ship retrofitting programs. One approach to tax this industry is to treat the shipping sector as if it were a sovereign nation that contributes fair and proportionate to

[23] Aki Kachi, Silke Mooldijk, Carsten Warnecke, "NewClimate MBM for Maritime Emissions", https://newclimate.org/wp-content/uploads/2019/03/NewClimate-MBM-for-Maritime-Emissions.pdf

[24] Shi, Yubing. "Reducing Greenhouse Gas Emissions from International Shipping: Is it Time to Consider Market-Based Measures?" Marine Policy 64, (2016): 123-134.

emissions budgets.[25] As with the NDC's of the Paris Agreement, a climate levy could incorporate the principle of 'Common but differentiated responsibility ``(CBDR).This price could operate under principles of common but differentiated responsibilities to minimize the economic impact on least developed countries (LDC's) and island nations, where developed nations agree to offer "financial, technological and capacity-building support" (MPEC, 2012).[26] The comparatively high cost of renewable fuels (biofuel, hydrogen) is one factor which discourages vessel owners from retrofitting their ships. A price on carbon could kickstart research and investment into existing technologies like hydrogen fuel, and fund retrofits for innovations like solar assistance. However, any emissions pricing scheme must be palatable to member states of the IMO.

Alternative Fuel Landscape

The crux of decarbonising maritime transport has to do with drastically reducing or eliminating high-carbon bunker fuels. There are several alternatives to HFO on the market, however, many alternative sources require research and development, trials at scale, and industry investment before they are commercially competitive.

Hydrogen fuel

Hydrogen power is currently being researched for shipping applications because of its potential to reduce emissions on ships. There have been tests for small scale hydrogen ships, such as the 'water-go-round' ferry in San Francisco slated to sail in Fall, 2019 and carry 84 passengers for two days without refueling. Larger applications of hydrogen power are not market-ready, but module-based designs such as the HYON/PowerCell model - which is

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[25] Bouman, Evert A., Elizabeth Lindstad, Agathe I. Rialland, and Anders H. Strømman. "State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping–A review." Transportation Research Part D: Transport and Environment 52 (2017): 408-421.
[26] Wan, Zheng, Abdel el Makhloufi, Yang Chen, and Jiayuan Tang. "Decarbonizing the International Shipping Industry: Solutions and Policy Recommendations." *Marine Pollution Bulletin* 126, (2018): 428-435.

expected to produce 100 kW to multi-megawatt fuel cell power systems- have the potential to power large-scale international shipping, cruise vessels, workboats and offshore vessels.[27] There are several major challenges to hydrogen implementation for maritime transport, such as developing the hydrogen infrastructure, improving storage and fuel cell technologies, and reducing overall cost.[28] Hydrogen production processes will need to improve, as currently, there are still significant emissions from steam-reforming, the major hydrogen production route.[29] Hydrogen fuel costs are also higher, potentially by an order of magnitude, than conventional fuels, but this gap should decline as electrolysers fall in cost.[30] Research and development, along with **carbon pricing** could incentivize a shift towards hydrogen power as a supplement or replacement for oil.[31] Receipts collected from a per/ton carbon price could be diverted to hydrogen fuel subsidies, ship retrofits, and onshore hydrogen infrastructure development.

Biofuels

The overall amount of woody and non-woody biomass is limited and the maritime transport sector is not the only industry interested. Due to the Low-Carbon Fuel Standards already in place in many countries, there is high competition for biofuels. Growing more crops to fuel the shipping industry could intensify existing land-use debates over food or fuel.

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[27] Fuel Cell & Hydrogen Energy Association, "Shipping Propulsion", October 22, 2018, Accessed April 1, 2019 at http://www.fchea.org/in-transition/2018/10/23/shipping-propulsion

[28] The potential of hydrogen to fuel international shipping, Carlo Raucci UCL Energy Institute, University College London, A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy, February 1, 2017, 5-6.

[29] Office of Energy Efficiency & Renewable Energy, "Hydrogen Production: Natural Gas Reforming", https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming (accessed April 1, 2019)

[30] Balcombe, Paul, James Brierley, Chester Lewis, Line Skatvedt, Jamie Speirs, Adam Hawkes, and Iain Staffell. "How to Decarbonise International Shipping: Options for Fuels, Technologies and Policies." Energy Conversion and Management 182, (2019): Pages 72-88.

[31] Raucci, Carlo. "The potential of hydrogen to fuel international shipping", PhD diss., University College London, (2017):5.

Additionally, while biofuels are lower carbon,(than LNG) they can have highly variable supply chain emissions depending on the biofuel feedstock and processing methods.[32]

Electrification

Current electric ships are very limited in travel and would be mainly used for short distance shipping application. Electric ship applications will expand as battery research and development advances and cost are driven to more competitive prices.[33] Additionally, ship electrification relies on a large onshore supply of power. For electrification of maritime transport to have any climate benefit, an onshore power supply (OPS) must come from clean energy sources. To enable the electrification of fleets, it is crucial to decarbonize domestic power supplies in major port cities, and to install much more clean power generating capacity than is necessary for residents of the city.

Solar

Solar power is being considered for on board electricity generation as a supplement to electrical ships and for onboard hydrogen generation through electrolysis. It is estimated that onboard solar generation for assisted power could reduce emissions by 0.2 to 12%; and when combined with wind power, the fuel savings could be between 10 to 40%. Problems with onboard solar power could occur when faced with the harsh salty environment of ocean ships.[34]

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[32] Balcombe, Paul. et al.,"How to Decarbonise International Shipping: Options for Fuels, Technologies and Policies." *Energy Conversion and Management* 182, (2019): 72-88.

[33] Balcombe, Paul, James Brierley, Chester Lewis, Line Skatvedt, Jamie Speirs, Adam Hawkes, and Iain Staffell. "How to Decarbonise International Shipping: Options for Fuels, Technologies and Policies." *Energy Conversion and Management* 182, (2019): 79

[34] Balcombe, Paul, James Brierley, Chester Lewis, Line Skatvedt, Jamie Speirs, Adam Hawkes, and Iain Staffell. "How to Decarbonise International Shipping: Options for Fuels, Technologies and Policies." *Energy Conversion and Management* 182, (2019): 80

Wind Assistance

Wind Power is also being considered for onboard energy as a supplement to other options. Wind sails could help the ship keep moving at operational speeds while reducing fuel use, and technologies such as rotor could generate onboard electricity. Wind assistance would work better for slower speeds and smaller ships and have the potential to reduce fuel consumption by up to 60% with sails at slower speeds. [35]

Models and Designs

Some concept designs for zero-emission ships have been proposed by big environmental companies as well as shipping conglomerates. The shipping conglomerate Wallenius announce a concept design for their 'E/S Orcelle' zero-emission ship. It would use wave energy from fins below the water, solar energy from photovoltaic cells on the roof, wind energy from sails which can be folded or rotated to better capture the wind, and finally, hydrogen fuel cells would be used to supply electricity to the engine was well. Several other concept designs are being drafted such as the 2030 NYK super-eco ship which is designed to reduce carbon emissions by 70% for large scale vessels by reducing ship weight, new loading concepts, efficient cargo storage, and new propulsion system with an efficient power plant system using fuel cells, solar and sail power.[36] Hydrogen power is a common theme with these concept designs and the 'Container Feeder Vessel ZERO' predicts that using a double bunker loading system, the hydrogen can be filled up in three hours and last up to 10 days. Many of these concepts also include route planning, to

[35] Balcombe, Paul, James Brierley, Chester Lewis, Line Skatvedt, Jamie Speirs, Adam Hawkes, and Iain Staffell. "How to Decarbonise International Shipping: Options for Fuels, Technologies and Policies." *Energy Conversion and Management* 182, (2019): 79-80

[36] Anish, "Top 5 Zero Emission Ship Concepts Of The Shipping World", Marine Insight, 24 Oct 2017, https://www.marineinsight.com/green-shipping/top-5-zero-emission-ship-concepts/ (accessed April 1, 2019)

maximize the sun exposure the solar panels or catch the right winds, and other techniques to reduce emissions.

GHG Monitoring

Requiring reports on GHG emissions reduction performance is one tool to improve corporate accountability. Through the legislation of flag states in which ships are registered, it is possible to legislate that ships collect and disclose this sensitive information.[37] Regular disclosure of information on the emissions reduction performance of shipping corporations would increase their accountability to greenhouse gas emissions reduction commitments. Direct emissions monitoring would provide a wealth of standardized data that could inform future policy.[38]

Levers for change

We compiled a list of 4 actionable areas, each involving a unique lever of change. Although there is no simple solution to this 'wicked' problem, within this structure, various sectors can contribute and steer the maritime industry towards decarbonisation.

Carbon Pricing:

An industry-wide price per ton of CO2 emitted could drive innovation and investment in clean shipping fuels technology. A major barrier to the adoption of low-carbon fuels sources, such as hydrogen is its inability to compete with the cost of crude oil bunker fuels. A carbon

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[37] OECD, "International Trade and the Transition to a Circular Economy", Resource Efficiency & Circular Economy Project, (2018), accessed April 1, 2019

[38] European Union Ministry of Transport, "Towards a strong and reliable ship emissions monitoring system", Mobility and Transport policy brief. December, 2012, accessed April 1, 2019 at https://www.verifavia-shipping.com/bases/resource_pdf/23/2012-12-Emission-monitoring-briefing.pdf

price at an appropriate level could send consistent market signals to industry, incentivising research and development into clean fuels. The economic burden of carbon intensive vessels may also lead to retrofits during the five year maintenance cycle of ships, a window when vessels could install zero-emission alternatives – batteries, fuel cells or new tanks for ammonia for example.

Decarbonising onshore power

A decarbonization of onshore power would significantly reduce oil tanker traffic. In 2018, the global oil tanker fleet had a capacity of around 561 million deadweight tonnage (a measure of how much weight a ship can carry). In terms of tonnage, oil tankers account for around 29.2 percent of global seaborne trade.[39] As a decarbonised economy will not rely on oil imports, it is reasonable to assume a decline in oil tanker traffic in relation to the increasing portion of domestic energy coming from renewable sources. Thus, onshore decarbonisation of energy supplies will reduce oil tanker traffic, which accounts for a significant portion of maritime trading vessels. It is reasonable to assume a decline in oil tanker traffic as growing shares of domestic energy come from renewable sources.

Changing patterns of consumption and production

As stated earlier, a change in global consumption habits has the potential for a massive paradigm shift which could greatly affect the global shipping industry. In theory, if consumers were to require less goods then we would have a reason to reduce global shipping, and therefore emissions. However, a change in consumer habits is more complex than just reducing consumption. A plausible redesign of systems of consumption is seen in developments into the

[39] "Global Seaborne Trade - Oil Tanker Capacity 2018 | Statistic." Statista. Accessed April 1, 2019. https://www.statista.com/statistics/267605/capacity-of-oil-tankers-in-the-world-maritime-trade-since-1980/.

concept of a circular economy. On one hand we will see the rise in Product as a Service business models; essentially a reimagination of consumption where the service of use is paramount to the mere ownership of the material good. On the other, in a circular economy the value in the material resource will be preserved as the useful life is extended and end of life considerations are taken into design. With these points in mind, we know that greater regional trade and economic circularity may lead to a decrease in import of primary and secondary materials in some jurisdictions.[40] However, as new markets of re-manufacture and reprocessing are created, shipping may actually increase in certain industries and regions as well.[41] Unless we radically localize these systems of remanufacturing and reprocessing, we will continue to depend on the original manufacturers. In this case reverse logistics and systems in which the same material can flow back and forth between economies will probably prevail, making it unclear as to the net reduction in shipping that may take place.[42] Overall, a shift in consumption patterns away from an overly materialist society should be welcomed, but more study is needed to be able to accurately predict the extent of the effect that a circular economy will have on global shipping.

Reforming IMO structure

One of the nodes with most potential for structural change is the regulatory framework of the IMO. The IMO's mandate is to, "create a regulatory framework for the shipping industry that is fair and effective, universally adopted and universally implemented."[43] However, despite

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[40] Technopolis Group and Wuppertal Institute, "Regulatory barriers for the Circular Economy Lessons from ten case studies", Final report, 13 July 2016, accessed April 1, 2019 at http://www.technopolis-group.com/wp-content/uploads/2017/03/2288-160713-Regulary-barriers-for-the-circular-economy_accepted_HIres.pdf

[41] Yamaguchi, Shunta. "International Trade and the Transition to a More Resource Efficient and Circular Economy." (2018).

[42] Yamaguchi, Shunta. "International Trade and the Transition to a More Resource Efficient and Circular Economy." (2018).

[43] IMO, www.imo.org/en/About/Pages/Default.aspx, accessed 2/04/2019

the fact that the IMO has been tasked with reducing shipping emissions since the 1997 Kyoto Protocol, it was only in April 2018, after much international pressure, that a plan to reduce emissions by 50% by 2050 was released. This goes to show that there are many structural flaws in the IMO's governance that could prove to be problematic in achieving emissions reductions. A 2018 report released by Transparency International outlined the challenges that the IMO still faces in hoping to reduce emissions. Of those the most outstanding were highlights into how there are uneven member state and private interests engrained in the structure of the IMO. For example, there are cases where member states, in a highly intransparent process, select members of private shipping companies as country delegates in what Transparency International deems as a "partial privatisation of inter-governmental policy-making in shipping."[44] Another key obstacle to change is the unbalanced funding structure of the IMO where ten states provided 65% of global contributions.[45] In a matter which is global in nature, and where the consequences of wrongdoing affect the majority of the global population, there needs to be more assurance that certain interested parties are not buying influence. Some key improvements would then be to require public declarations of conflict of interest of member state delegates and provide more transparency into how funding requirements are formulated.

Conclusion

In summary, decarbonisation of the international maritime shipping industry is a 'wicked problem' for a number of interconnected social, technical, political and economic barriers. We have offered a high-level overview of the key challenges and levers for change in the system of

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[44] Transparency International's Climate Governance Integrity Programme. 2018. *Governance at the International Maritime Organisation*. Berlin: Transparency International.

[45] Transparency International's Climate Governance Integrity Programme. 2018. *Governance at the International Maritime Organisation.* Berlin: Transparency International.

international maritime trade. As the potential to use renewable technologies progresses, blind consumerism shifts and international pressure leads to a carbon taxed society with a stricter control on corruption, we will undoubtedly begin to witness a drastic change in the environmental impact of the global maritime shipping industry.

How might we each contribute in our careers?

Antonio, engineering: The fuel problem would be the area of most contribution for people like myself graduating with chemical and biological engineering degrees. The concepts of energy and power generation as well as technologies like hydrogen fuel cells and photovoltaic cells have been integrated into the lectures and projects of this degree. Research and development would be the most prominent field for work as a graduate from this field due to the fact that the technology is not completely reliable yet and many more advancements have to be made for them to be implemented on a large scale.

Katie, History: Once my history degree is completed, I hope to pursue a Masters in Urban Planning. While urban planners are not *directly* involved in the development of policy or technologies to reduce emissions in the maritime shipping industry, the nature of our future cities will indirectly shape consumer demand for goods delivered by maritime shipping. For example, safe and reliable mass-transit systems could reduce the need for overseas vehicle imports, while alterations to zoning regulations to could support urban farming initiatives, reducing the volume of imported food.

David, Global Resource Systems: My degree has been centered around better understanding and planning human use of resources in an attempt to tackle global environmental issues. In this respect, understanding the systems around global trade require me to also place a strong emphasis on understanding the maritime shipping industry. For this I would place my focus on the circular economy and how a new paradigm of consumption of services rather than material things could signal a change in the way we move our resources around the world.

References

Aki Kachi, Silke Mooldijk, Carsten Warnecke, "NewClimate MBM for Maritime Emissions", NewClimate Institute, March 2019 . Accessed online at https://newclimate.org/wp-content/uploads/2019/03/NewClimate-MBM-for-Maritime-Emissions.pdf

Aldo Chircop et al., "Shipping and Climate Change International Law and Policy Considerations", *Center for International Governance Innovation*, (2018): 15. Accessed April 1, 2019 at https://www.cigionline.org/sites/default/files/documents/Shipping%27s%20contribution%20to%20climate%20change%202018web_0.pdf

Allen, M.R., O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M.Wairiu, and K. Zickfeld, 2018: *Framing and Context. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press. Accessed April 1, 2019 at https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chapter1_Low_Res.pdf

Anish, “Top 5 Zero Emission Ship Concepts Of The Shipping World”, Marine Insight, 24 Oct 2017, https://www.marineinsight.com/green-shipping/top-5-zero-emission-ship-concepts/ (accessed April 1, 2019)

Balcombe, Paul. et al.,"How to Decarbonise International Shipping: Options for Fuels, Technologies and Policies." *Energy Conversion and Management* 182, (2019): 72-88.

Balcombe, Paul, James Brierley, Chester Lewis, Line Skatvedt, Jamie Speirs, Adam Hawkes, and Iain Staffell. "How to Decarbonise International Shipping: Options for Fuels, Technologies and Policies." *Energy Conversion and Management* 182, (2019): 72-88.

Bouman, Evert A., Elizabeth Lindstad, Agathe I. Rialland, and Anders H. Strømman. "State-of-the-Art Technologies, Measures, and Potential for Reducing GHG Emissions from Shipping – A Review." Transportation Research Part D 52, (2017): 408-421.

Cariou, P. "Is Slow Steaming a Sustainable Means of Reducing CO2 Emissions from Container Shipping?" Transportation Research Part d-Transport and Environment 16, no. 3 (2011): 260-264.

Congressional Research Service, “LNG as a Maritime Fuel: Prospects and Policy”, (February 5, 2019):9. Accessed April 1, 2019 at https://fas.org/sgp/crs/misc/R45488.pdf.

Council of Canadian Academies, “The Value of Commercial Marine Shipping to Canada”, Ottawa (ON): The Expert Panel on the Social and Economic Value of Marine Shipping to Canada, 2017.

Chircop, Aldo. Doelle, Meinhard. Gauvin, Ryan. “Shipping and Climate Change International Law and Policy Considerations”, *Center for International Governance Innovation*, (2018). Accessed April 1, 2019 at https://www.cigionline.org/sites/default/files/documents/Shipping%27s%20contribution%20to%20climate%20change%202018web_0.pdf

European Union Ministry of Transport, “Towards a strong and reliable ship emissions monitoring system”, Mobility and Transport policy brief. December, 2012, accessed April 1, 2019 at https://www.verifavia-shipping.com/bases/resource_pdf/23/2012-12-Emission-monitoring-briefing.pdf

Fuel Cell & Hydrogen Energy Association, “Shipping Propulsion”, October 22, 2018, Accessed April 1, 2019 at http://www.fchea.org/in-transition/2018/10/23/shipping-propulsion

Gehlhar, Mark, and William Coyle. "Global food consumption and impacts on trade patterns." Changing structure of global food consumption and trade (2001): 4-13.

Gilbert, Paul, Conor Walsh, Michael Traut, Uchenna Kesieme, Kayvan Pazouki, and Alan Murphy. "Assessment of Full Life-Cycle Air Emissions of Alternative Shipping Fuels." Journal of Cleaner Production 172, (2018): 855-866.

Halim, RA, L. Kirstein, O. Merk, and LM Martinez. "Decarbonization Pathways for International Maritime Transport: A Model-Based Policy Impact Assessment." Sustainability 10, no. 7 (2018): 2243.

International Maritime Organisation Press Center, " Low carbon shipping and air pollution control", October, 2018. Accessed April 1, 2019 at http://www.imo.org/en/MediaCentre/HotTopics/GHG/Pages/default.aspx

IMO, About us, www.imo.org/en/About/Pages/Default.aspx, (accessed April 1, 2019)

Lambert, Fred. "A new all-electric cargo ship with a massive 2.4 MWh battery pack launches in China", Electrek, 4 Dec 2017, https://electrek.co/2017/12/04/all-electric-cargo-ship-battery-china/ (accessed April 1, 2019)

Mia Mahmudur Rahim, "Regulating Global Shipping Corporations' Accountability for Reducing Greenhouse Gas Emissions in the Seas." *Marine Policy* 69, (2016): 170.

OECD, "International Trade and the Transition to a Circular Economy", Resource Efficiency & Circular Economy Project, (2018). http://www.oecd.org/environment/waste/policy-highlights-international-trade-and-the-transition-to-a-circular-economy.pdf

Office of Energy Efficiency & Renewable Energy, "Hydrogen Production: Natural Gas Reforming", https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming (accessed April 1, 2019)

Penner, Derrick. “What is bunker fuel?”, The Vancouver Sun, 04 Sept 2015, http://www.vancouversun.com/technology/What+bunker+fuel/10958350/story.html (accessed April 1, 2019)

Rahim, Mia Mahmudur, Md Tarikul Islam, and Sanjaya Kuruppu. "Regulating Global Shipping Corporations' Accountability for Reducing Greenhouse Gas Emissions in the Seas." Marine Policy 69, (2016): 159-170.

Raucci, Carlo. “The potential of hydrogen to fuel international shipping”, PhD diss., University College London, (2017).

Shi, Yubing. "Reducing Greenhouse Gas Emissions from International Shipping: Is it Time to Consider Market-Based Measures?" *Marine Policy* 64, (2016): 123-134.

Statista Group, “Capacity of oil tankers in seaborne trade from 1980 to 2018”, (n.d) accessed April 1, 2019. https://www.statista.com/statistics/267605/capacity-of-oil-tankers-in-the-world-maritime-trade-since-1980

Technopolis Group and Wuppertal Institute, “Regulatory barriers for the Circular Economy Lessons from ten case studies”, Final report, 13 July 2016. http://www.technopolis-group.com/wp-content/uploads/2017/03/2288-160713-Regulary-barriers-for-the-circular-economy_accepted_HIres.pdf

The Geography of Transport Systems, "Fuel Consumption by Containership Size and Speed", Transport Geography, https://transportgeography.org/?page_id=5955 (accessed April 1, 2019)

Transparency International's Climate Governance Integrity Programme. 2018. *Governance at the International Maritime Organisation.* Berlin: Transparency International.

Wan, Zheng, Abdel el Makhloufi, Yang Chen, and Jiayuan Tang. "Decarbonizing the International Shipping Industry: Solutions and Policy Recommendations." *Marine Pollution Bulletin* 126, (2018): 428-435.

United Nations Climate Change, "Initial IMO Strategy for Reducing Shipping Emissions Set for Adoption", 10 April 2018, https://unfccc.int/news/initial-imo-strategy-for-reducing-shipping-emissions-set-for-adoption (accessed April 1, 2019)

Yamaguchi, Shunta. "International Trade and the Transition to a More Resource Efficient and Circular Economy." (2018).