Driving Emission Out of Shipping

A race against time

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1. Background

1.1 Shipping as GHG emitter

Green-house-gas (GHG) emissions from shipping have until recently received little scrutiny or regulatory attention. They were left out of the Paris agreement on climate change[1], which sets out a global action plan to keep global warming well below 2°C, requiring reduction commitments by individual nations. Because overall global temperature rise depends on cumulative global CO_2 emissions, the Paris temperature range can be translated into a 600 Gt budget of CO_2 emissions that are still permissible, but requires global and drastic cut-downs by all sectors, including all actors within the shipping sector.

Although shipping is the most energy-efficient transport mode to move large volumes of cargo, in a business as usual scenario with an annual estimated growth rate of three (3) percentage and no actions taken to cut CO_2 -emissions, an increase by nearly a quarter (23 % equalling 1090 tonnes is projected by 2035[2]). Reducing emissions on a global scale presents significant challenges to all industry sectors, including sea freight. Figure 1 shows that the sooner the process of reducing emissions is commenced, the more time there will be to switch to low-emission operations in a sustainable manner. If the process for reducing emissions is not commenced within the next few years, the world faces significant warming and drastic measures[3].

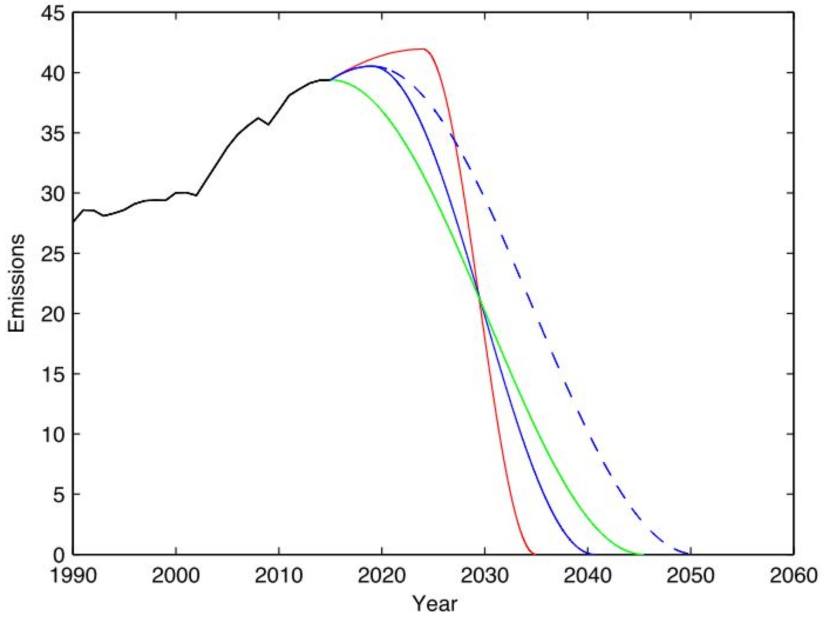

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Figure 1 Three illustrative scenarios for spending the same budget of 600 Gt CO_2, with emissions peaking in 2016 (green), 2020 (blue) and 2025 (red), and an alternative with 800 Gt (dashed)[4].

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[1] Except from the global carbon budget.

[2] OECD/ITF (2018)

[3] Revill and Harris (2017)

[4] Ibid

Sea freight emits approximately 1 GT of GHG emissions which translates to 2% of global emissions and 12 GT of the carbon budget. Although sea freight is the most energy-efficient transport mode to move large volumes of cargo, in a business as usual scenario with an annual estimated growth rate of three (3) percentage and no actions taken to cut CO_2 -emissions, an increase by nearly a quarter (23 % equalling 1090 tonnes is projected by 2035[5]). In 2018 the International Maritime Organization committed to halving GHG by 2050 compared to 1998 levels. This decision was taken after much discussion, but although the decision is in the right direction it still represents a path (black dotted line) which is twice as high as the emission budget would allow (yellow line) as is evident from Figure 2.

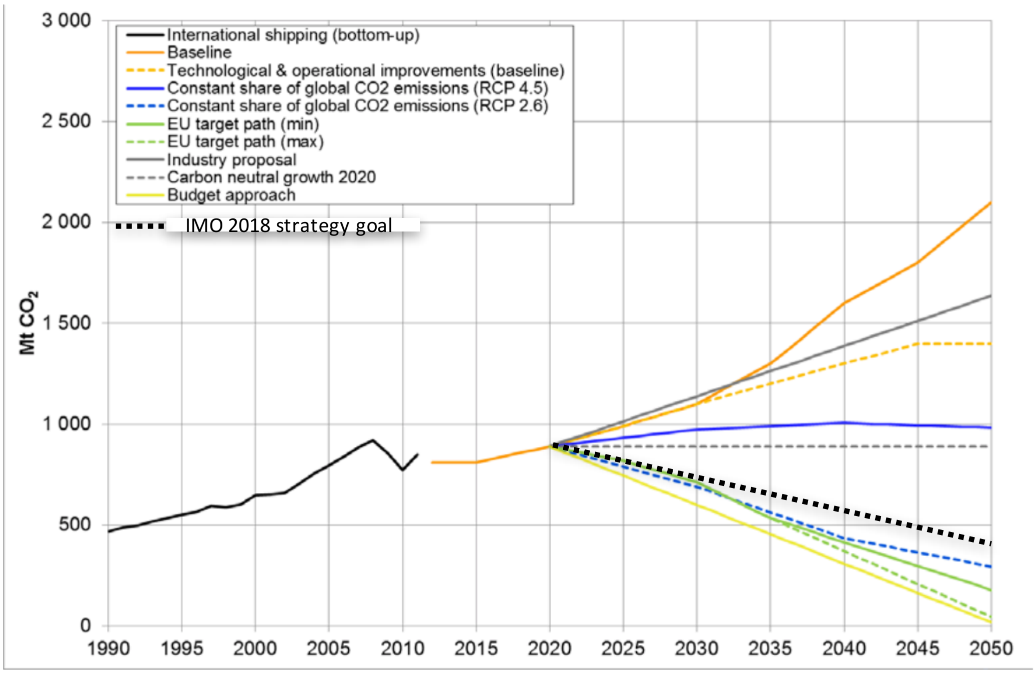

Figure 2 Alternative scenarios for CO_2 emission development[6]

1.2 New regulations and policies

The establishment of regulatory framework for shipping emissions has been slow, scattered and insufficient, but is starting to show indications of improving actions. The International Maritime Organisation (IMO) has committed to make the environmental regulations of international shipping more stringent, but the emphasis has at least so far been primarily on technology driven solutions and energy efficiency of ships.

In May 2018, IMO adopted a GHG reduction strategy for shipping industry with the aim to reduce carbon dioxide emissions by at least 40% by 2030 and 70% by 2050 and halve the total annual GHG emissions by 2050. In 2015, IMO implemented designated control areas (Baltic Sea, North Sea, East and West coasts of the United States and the Caribbean Sea) with SO_x and NO_x emission limits for ocean-going vessels. The fuel oil used on board must not have a sulphur content exceeding 0.10%. These Emission Control Area (ECA) regions will be enlarged in 2020 to cover other coastal areas of major trading areas.

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[5] OECD/ITF (2018)

[6] Adapted from European Parliament (2015)

In 2013, IMO implemented and put into effect two mandatory energy efficiency measures, namely, the Energy Efficiency Design Index (EEDI) for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for the existing fleet, to increase the energy efficiency and mitigate the CO_2 emissions of shipping. The EEDI sets compulsory energy efficiency standards for new ships built after 2013. EEDI is a specific measure for an individual ship design, expressed in grams of CO_2 per ship's capacity-mile. The formula is calculated based on the technical design parameters for a given ship. The CO_2-levels are made more stringent on a five-year interval. The Ship Energy Efficiency Management Plan (SEEMP), on the other hand, is an operational measure that requires existing ships to improve their energy efficiency in a cost-effective manner[7][8].

On EU level, the European Commission presented a legislative proposal in 2013 to set up a CO_2-monitoring, reporting and verification (MRV) system for ships calling at EU ports. The proposal was adopted by the European Council and Parliament in 2014, came into force in 2015 and will apply to port calls from 2018 onwards[9].

1.3 Purpose and structure of this white paper

A number of new regulations and policies have or are coming into force. There are also a number of technological developments supporting and enabling ship owners and operators to meet them. However, shipping also suffers from a row of systemic inefficiencies that among others hinders or slows down the adoption of new technologies. Perhaps most notably, the relationship between policy makers and ship owners is a lock-in, where the current problems in the shipping industry hinders policy makers from asserting more stringent sustainability criteria on ship operations. Therefore, there are concerns as to whether the shipping industry can meet the new targets fast enough.

Currently the shipping industry is not represented under EIT's Climate-KIC organization. Being part of the Climate KIC would direct more focus on the systemic problems in the industry and could eventually help solving them. Hence, the main purpose of this document is to lay the foundation for an action program that can be included as an own new area of focus under the Climate-KIC.

The paper is organized as follows. We start by highlighting some common inefficiencies and lock-ins in the shipping industry using the short sea freight sector in the Baltic Sea as a case in point. Next, we present potential part-solutions to the listed inefficiencies and evaluate their impact on the combat against climate change. There is an abundance of CO_2 reducing solutions on offer in the maritime sector, the majority of which are technical ones, which often are too expensive and complex an investment compared to gained benefit with regard to the ship´s life cycle and earning capability. We then look and compare, from an investment prioritising view, at a number of different alternative solutions that are sustainable and tenable, and which could be applied immediately and with a wide-scale effect. We conclude with a list of proposed actions and potential consortium members.

2 Inefficiencies and lock-ins of the short sea freight sector

The existing world fleet is in many segments large and from a technical and hence a climate perspective, outdated. The situation is aggravated by the existing imbalance between ship supply and demand, with

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[7] IMO (2018)

[8] Cames et al. (2015)

[9] Ibid.

ship capacity greater than the demand. Additionally, an inadequate degree of cargo co-ordination and oversupply in cargo capacity results in downward pressure on freight rates and revenue. The absolute majority (95%) of shipping companies are small and they operate a fleet of less than five ships. This essentially means a formation of a vicious circle in the value chain where the ship operators or shipping companies lack the opportunity to invest in GHG reducing solutions in a scale and speed needed to reduce emissions.

Shipping is a broad industry consisting of many specialized sub-trades such as: tankers, container ships, dry bulk cargo ships, cruise ships, RoPax, RoRo, icebreakers, service vessels and fishing boats. The sub-trades differ in volume, operational profile, and impact on climate change. In this paper, we will not focus on giving a comprehensive picture of the entire industry. Instead, we pinpoint inefficiencies identified in short sea shipping, which is a significant polluter when it comes to sea-borne intra-continental transportation. Many similar inefficiencies are, however, found also in the ocean going (deep sea) traffic. These are, for obvious reasons, not only in the hands of decisions taken at an EU level.

Short sea shipping is the movement of cargo and passengers over short distances, typically a domestic or international journey enduring 3-5 days, along coast lines without having to cross an ocean. This paper uses the Baltic Sea as a trade region example within the European Short sea shipping sector. The European Short sea shipping sector is considerable and the Baltic Sea one of its busiest trading areas as can be seen in Figure 3. Hence, short sea shipping plays a major role in intra-continental transportation and can more readily be affected through EU-level policies.

The EU has a strategic interest in ensuring the continuous economic and environmental performance short sea shipping, which is in the forefront of EU:s transportation policy that in addition to emission reductions among others aims at moving the shift of 30% of road freight over 300 km to other modes (notably the sea) by 2030[10].

Other large short shipping markets outside Europe can be found among others in the U.S., Canada, China, and the Philippines. The challenges of EU short shipping market are likely to be shared also by other short shipping markets and to even the deep sea market. Europe could thereof function as the "flagship" in sharing and disseminating effective governance models and policies for driving emissions out of shipping on a global scale.

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[10] European Commission (2018)

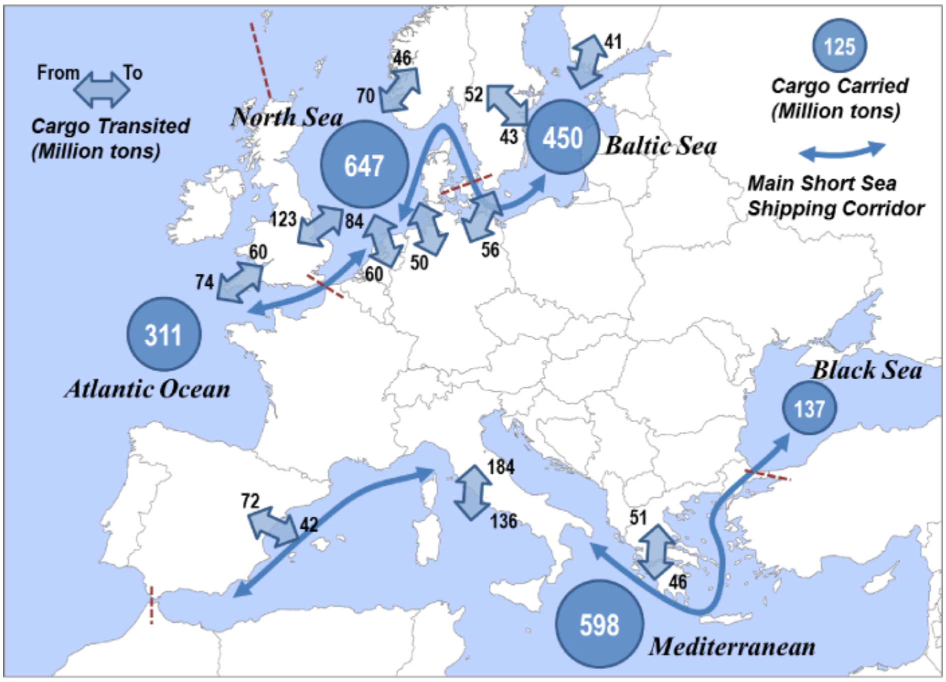


Figure 3 Short sea shipping areas and volumes in Europe

3 Problem area 1 - Non-optimal speed profiles

3.1 'Rush to wait'-port arrivals

Today, there are two interrelated problems or reasons why ships sail faster than needed and cause more emissions than necessary:

1. The 'first-come, first-served' queueing principle at the ports
2. Freight agreements that demand ships to reach the destination port at a specific point in time.

Many ports lack a slot system that would allow booking in advance a certain time for the vessel to arrive, load and unload, even if the arrival was known days in advance and could be pointed out with accuracy during the ship's voyage. As a consequence, vessels often speed up and rush during the voyage because of the "first come, first served" slot allocation principle many ports apply. This indeed leads to queue formation and idle time while waiting for the berthing permission, stevedoring and other shore services as is evident from Figure 4, which illustrates the median speed profile of dry bulk and general cargo vessels having to wait to enter the ports in the Baltic Sea. The diagram clearly demonstrates a waiting time of closer to 40 hours outside the port in anchorage, before a permission to enter was given. The median waiting time is calculated by taking the difference between the date-time stamps of ships' AIS positions whilst in standstill doing 0 knots.

Closer to 60% of all dry bulk and general cargo vessel arrivals in the Baltic Sea exhibit this kind of speed profile as shown in Figure 4. Port policies as well as freight contracts are the main reasons for irrational speed profiles. Needless to say, a more even speed profile would have allowed for slow steaming and less emissions.

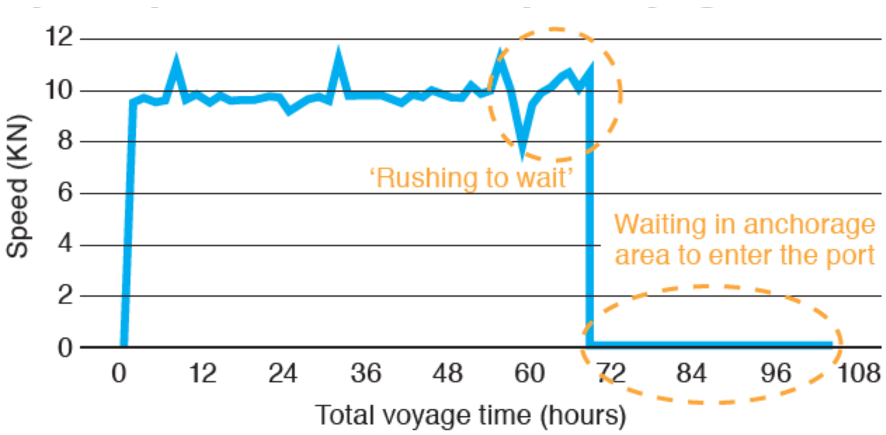


Figure 4 A typical "rush to wait" sailing speed profile in the Baltic Sea

3.2 Towards better voyage optimisation and smart port arrivals

With IMO´s decision to reduce shipping CO_2 emissions with 50% by 2050, quick and efficient measures need implementing. One of the fastest decarbonising methods in the short term is to optimise the operations of the existing fleet. Operational efficiency can for example be achieved through following measures:

- Route optimisation
- Ship-to-ship route exchange
- Port call synchronisation
- Port call optimisation

These systems along with others could a form a central communication platform supporting voyage optimization, port arrivals and timely cargo handling since all stake holders are given a right to access real-time information about shipments.

Once vessel operations can be more predictable through enhanced communications and information sharing between key actors, real-time voyage execution plays a crucial role in ensuring an energy and cost-efficient voyage. A system for voyage optimization installed onboard serve two vital functions:

1. Adjust sailing to dynamic conditions such as changing routes due to weather conditions, while ensuring optimal fuel consumption
2. Record ship performance during voyage (including speed profiles, fuel consumption, time sailed on route etc.), thereby enabling the gathering of knowledge and continuous optimization as part of the entire logistical chain.

Figure 5 illustrates the potential impact of voyage optimization on speed and waiting time profile of a vessel *en route* to its destination port.

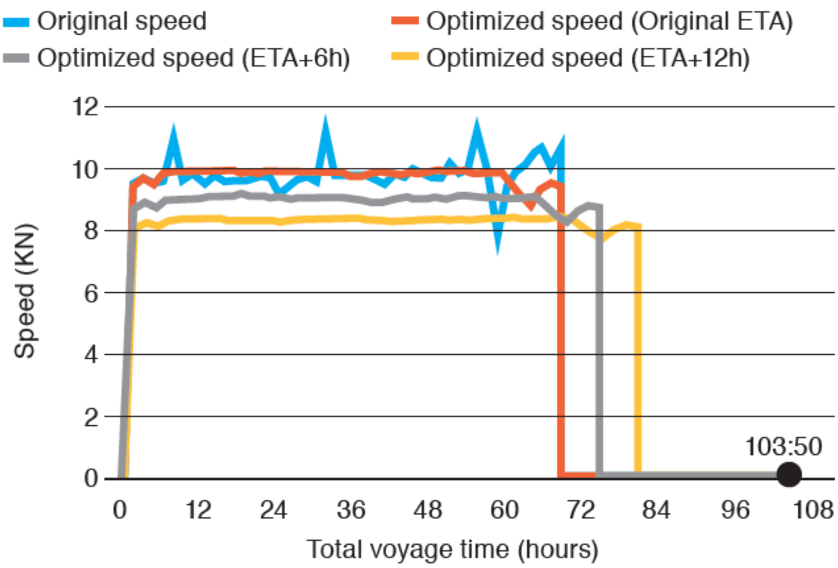
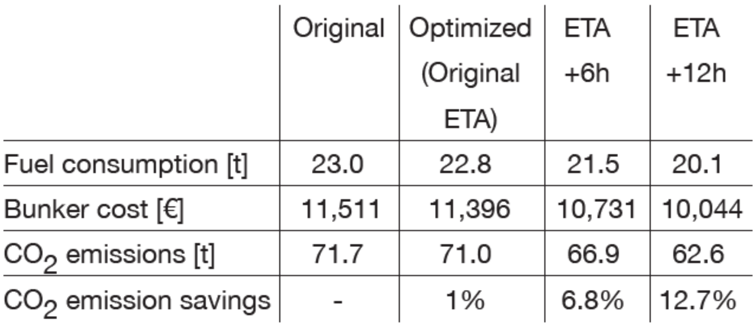


Figure 5 Retro-optimised marching speed profile for navigation speeds for meeting the original ETA, ETA +6 h and ETA + 12 h[11].

3.3 Benefit

As a result of enhanced communications and information sharing between all relevant system actors, including cargo owners, ship operators and ports, cargo handling and pick-up times can be with precision and hence no rushing or queueing in ports would longer be necessary. Thereby the voyage could be executed at an appropriate and even speed, which means reduced fuel consumption and emissions. Table 1 translates the different speed profile scenarios shown in Figure 5 to fuel consumption and emissions according to adjusted sailing speeds and arrival times.

Table 1. Fuel consumption and CO_2 emissions for the original and retro-optimised scenarios



	Original	Optimized (Original ETA)	ETA +6h	ETA +12h
Fuel consumption [t]	23.0	22.8	21.5	20.1
Bunker cost [€]	11,511	11,396	10,731	10,044
CO_2 emissions [t]	71.7	71.0	66.9	62.6
CO_2 emission savings	-	1%	6.8%	12.7%

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[11] The figure is based on historical data obtained from European Maritime Safety Agency for a voyage between Sillamäe, Estonia and Lübeck, Germany. The retro-optimisation was carried out utilizing NAPA voyage optimization tools.

4 Problem area 2 – Low ship utilization rates

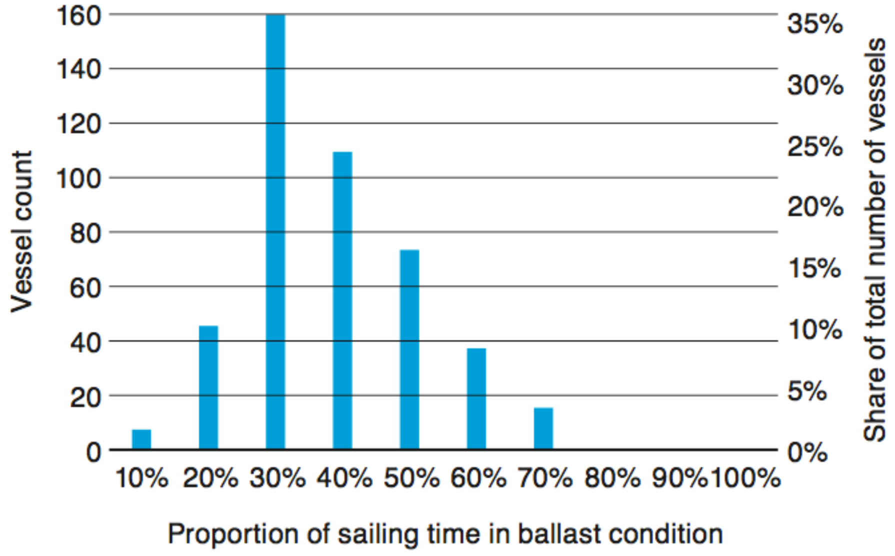
4.1 A non-integrated supply chain

With advanced logistic functions and operations integration, the management and efficiency of logistics chains have developed markedly over the past decades. Sea logistics, on the contrary, constituting an important and often necessary link in the logistics chain, has not followed this general development, but operates more or less as an isolated function. The detachment hampers, for example, the operational planning of industrial organisations as well as the ship operators' capacity capability to direct their operation so that the vessel capacity could be utilized maximally. This, in turn, means higher freight rates and unnecessary emissions.

The roots of shipping go far back in history and its established procedures and practices sit tight, still today. In other words, the shipping industry has not capitalized on the full potential of modern world technology and communication. Non-integrated logistics and production processes, as well as the lack of transparent and timely information availability means that ship operators have a limited ability to foresee and plan their operations so that the cargo loads could be maximised and ships sailing with high utilisation rates with optimal speed profiles, not to mention fewer CO_2-emitting ships transporting the same amount of cargo.

The dry bulk and general cargo ships plying the Baltic Sea, sail on average 34 % percent of their sailing time in ballast, that is, without cargo onboard[12]. As illustrated in Figure 6, more than half of the vessels sail empty at least 40% of their sailing time. The reason for this is that the coordination of ships and cargo flows is still manually by multiple brokers. Industry, the cargo owners, also do not coordinate their supply chains in such a way that would ensure that a ship arrives and leaves with cargo.

The above-mentioned utilization rate is a conservative figure. It does not include deck space which is often unused because freight contracts that prohibit the ship operator from taking other cargo owners' goods on unutilised deck space.



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[12] Gustafsson et al. 2015. Positioning report: Revolutionizing short sea shipping, Åbo Akademi University.

Figure 6 Proportion of vessels in the Baltic Sea (2013-2014) sailing in ballast condition[13]

The high number of actors in a supply chain[14] can delay and/or obstruct the information flow restricting the actors and stakeholders and especially the cargo owner´s possibilities to analyse, measure and track each individual actors´ CO_2 footprint in the transport chain easily and collectively. Tracking the CO_2 footprint throughout the supply chain seems at present to be a major challenge.

4.2 Cargo coordination and supply chain integration

The data and information flow in the current sea shipping business is old-fashioned and there is a lack of transparency, centralized coordination and interoperable data exchange in the ship-interface and between various port actors and ports themselves, which would enable an efficient sea logics chain.

Introducing dynamic real-time integrated production and logistics planning enables coordination of supply chain operations in such a way that logistic resources, ships, ports and trucks, are used optimally and can be connected to an exchange platform for electronic trading of freight slots. This transparency enables cargo owners to better plan their shipments. By planning shipments so that fit when demand and thereby prices are low.

4.3 Benefit

Analyses show real-time coordination of production and logistics planning would increase the utilization of bulk ships from 34% to 43%. This in turn would reduce freight costs 30-35% and emissions 25-30%.

5 Problem area 3 – Time spent in ports

5.1 Inefficient loading operations and cargo handling

As mentioned earlier, many ports lack a slot system that would enable a targeted arrival time at the port. Therefore, the planning of a timely commencement and completion of loading procedures in the port is difficult to determine. The main reason is attributable to a communication failure, at the ship-shore interface and between various port actors, such as stevedores, shore services, and authorities. The communication failure can be a result of lacking information transparency, sharing, inaccessibility or quality, that all prolong the planning and preparation of efficient operations among actors in the port. As a result, half of the dry cargo vessels and general cargo vessels in the Baltic Sea short sea sector spend at least 40% of their time in ports making no revenue[15] as illustrated in Figure 7.

Another factor increasing the time spent in ports is the slow loading and unloading process taking usually two days or more for the aforementioned vessel types. This, in turn, is often related to the type and low value of cargo carried, such as raw materials and semi-finished products shipped as bulk and handled often with inefficient and outdated cargo handling infrastructure. High-value cargo transports and flows, on the other hand, are often constituting parts of industrial production chains and

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[13] Ibid.

[14] Gustafsson et al (2015) identified 16-19 different actors involved in delivering a freight consignment.

[15] Gustafsson et al. (2015)

transport/distribution networks. They require precise timing and are often scheduled to arrive in due time for each day's production.

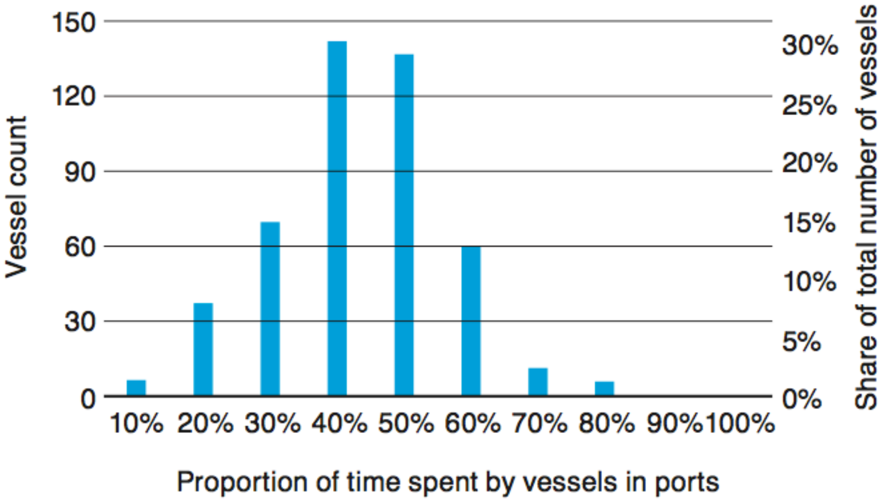

Figure 7 Time spent in ports for vessels in the Baltic Sea (2013-2014)[16]

Approximately 5% of shipping emissions are directly generated in ports. However, the indirect impact of ports on shipping emissions is much higher as the inefficiencies in cargo handling leads the fact that more ships are needed to maintain the same capacity and the ships' room for optimization manoeuvres diminishes.

5.2 Towards optimised and automated loading operations and cargo handling

As evidenced in the previous chapter, there is a number of factors impeding seamless information flow over the ship-port interface, which would allow shipments to flow efficiently and in a timely manner from ship to shore. One of the biggest challenges that slows down and hinders smooth cargo transactions (causing unnecessary waiting outside ports and long port times) is unintegrated information systems and transmission. Equally important is a modern and efficient cargo handling infrastructure with increasingly higher degrees of automation.

Both type of measures, however, require considerable capital investments that the current owner structure of many smaller ports seems uncapable of or unwilling to make. Increasing privatization of ports may gradually change this *status quo*.

6 Problem 4 – Lack of incentives for offering environmentally friendly freights

6.1 Non-sustainable freight procurement behaviour

Socially and environmentally responsible companies, and in particular those with established brands and reputation, are feeling a growing pressure from the society and various stakeholders to reduce their carbon footprint, although so far, the effects have been globally measured modest.

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[16] Ibid

By and large, this inefficiency echoes the general call for seeing logistics and sea transportation as part of the overall supply chain of goods and materials.

6.2 Creating incentives for sustainable freight services

In the pursuit of measurable shipping CO_2-reductions, companies and cargo owners should take increasingly a stronger role and responsibility in cargo co-ordination and the management of the footprint of the entire global logistics chain, including shipping. Cargo owners have the power and responsibility to manage and direct their procurement of freight contracts and logistics service providers in a manner that reduces the overall CO_2 footprint. Cargo owners are in the position to choose the preferred and "greenest" sea carriers with the best environmental performance including routing, scheduling and energy efficiency.

6.3 Benefits

Not only does such "green procurement criteria" result in emission reduction, but also to considerable cost cutting, as emission monitoring tends to prove profitable. This, in turn, can improve the financial performance of the company and enable the release of capital for other $C0_2$ reducing investments.

7 Problem 5 – Lack of investments in new vessels and better technology

7.1 Slow turnover and update of existing fleet

A number of new sustainable technologies are already available that could significantly reduce fuel consumption and emissions. Such technologies include, for example:

- Structural features such as
    - sleeker hull designs,
    - the use of new lighter materials such as metal alloys or composites to improve the hydrodynamic qualities or to make the ship lighter (Car carrier "Cicero"[17]), for instance.
- A transition from traditional marine fuels to alternative ones, such as
    - LNG is currently taking place.
    - Other potential fuel alternatives include the use of LPG, biofuels, methanol.
- New propulsion technologies
    - batteries
    - fuel cell systems
    - partial aid solutions such as wind-assisted propulsion (e.g Maersk tankers[18] and Viking Line ferry[19]).

The installation of new green technology on existing vessels is, however, costly and takes place with a delay, as the retrofit is usually carried out following a docking scheme with a recurrence interval of typically years. The existing fleet will also renew itself slowly as, depending on the ship type and trade, a vessel typically has a life span of 20-30 years. Moreover, research show that vessels are on average owned by three different owners. For a typical bulk carrier, the first owner owns the vessel for ca 10 years. After that the time of ownership goes down to five years and successively shortens. This means

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[17] CompositeWorld (2018)

[18] Maersk Tankers, Norsepower and Energy Technologies Institute (2018)

[19] Viking Line and Norsepower (2018)

that after ten years the economic incentives and feasibility to invest in an update of the vessel significantly decreases. This is also a consequence of the current overcapacity on the market.

Table 2 Average period of retention before sale for bulk carriers[20]

First owner	10.2 years
Second owner	5.5 years
Third owner	4.3 years
Fourth owner	3.3 years
Fifth owner	3.1 years
Sixth owner	1.3 years

New technology and new solutions are easier to design and incorporate sustainably in newbuilds. When a newbuild is being designed and constructed, the owner's focus and incentive is, however, often in minimising the capital expenditure. Lesser attention is given to the cargo flexibility or operational adaptability of the ship, that brings efficiency and maximizes the earnings potential throughout its lifecycle, given the rather frequent shifts in ownership of a vessel. In other words, the operational performance is not prioritised during the design and construction stages. Consequently, we end up in a situation where ships are managed, operated and controlled differently from what it was designed for. This leads often to a situation, where the vessel operation and management of systems (trim, sailing speed etc.) deviate from the actual and optimal design parameters, as well as the customer needs and requirements. A typical example is when a ship in trade is knowingly sailed at a different speed than what it was optimised for. Design speed is the optimal speed for a given vessel with the lowest fuel consumption.

7.2 Vessel investments from an operational flexibility and life-cycle point-of-view

Operating the vessel at its optimum dynamic trim can result in the vessel sailing at a higher speed and/or lower propelling power. This translates to savings in fuel as well as other economic and environmental benefits[21]. The solution to this common misalignment of incentives is in reorganizing the roles and tasks in shipbuilding and operation. The reorganization must lead to an arrangement where both shipbuilding and ship operation strive to construct ships that are optimally designed for their trade and customer needs and which can adapt to maximize their use of capacity throughout their lifecycles. In other words, the actors´ incentives, from the drawing board onwards, must be aligned towards in-use performance.

7.3 Benefits

The list of technical CO_2 -reducing solutions is growing and new innovations such as composite decks have been installed on newbuilds to reduce the weight of the ship, which in turn increases the cargo carrying capacity of the vessel. Figure 8 provides and overview of the CO_2 reduction potential of these technologies and other measures that can be installed both on newbuilds and as existing operational vessels as retrofits.

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[20] Stott (2016)

[21] Abouelfadl & Abdelraouf (2016)

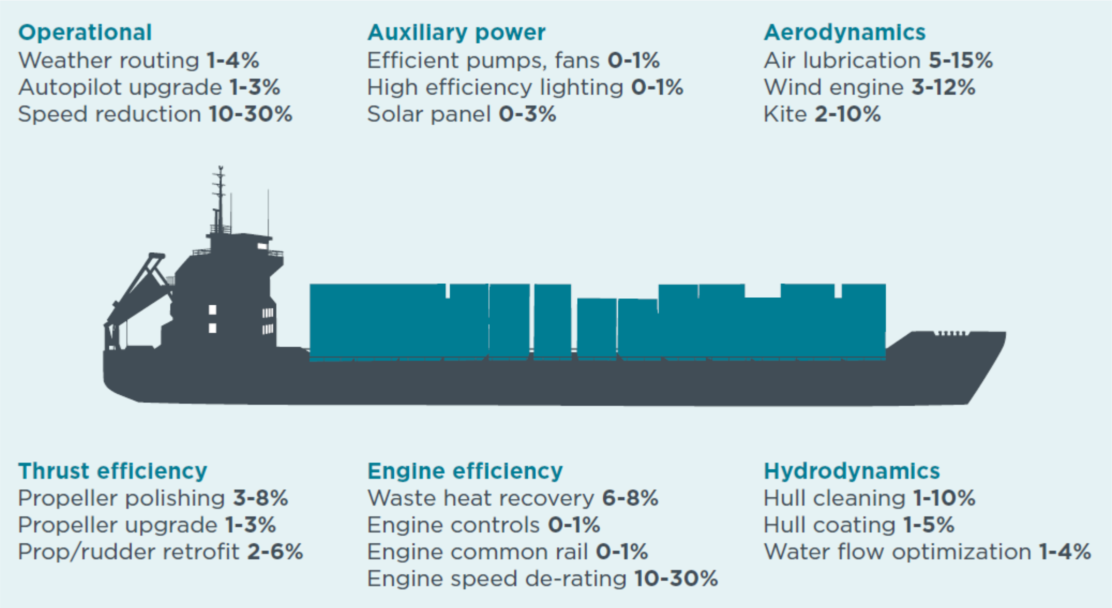

Figure 8 Potential CO_2 *reductions from various efficiency approaches for shipping vessels*[22]

It is, however, to be noted that due to the current overcapacity and the relatively young age of bulk carriers and container ship[23], as well as the short time of ownership of older ships, the needed investments are likely to be realized at such a speed that the combat against climate change cannot solely rely on them.

8 Conclusion - Investment priorities for CO2-cutting measures and solutions

The implementation of regulatory policies is often a sluggish and long-lasting process, not least due to the strong resistance of the shipping sector having to carry out expensive and risky investments in a low-margin business. For policy makers to turn this situation around and succeed in the short-term implementation of new standards and policies, they should rather enforce operation models that, for example, would ban ships from waiting outside the ports.

In this paper, we have drawn the attention to five common problem areas in shipping, notably in short sea operations, that when solved could drastically reduce emissions in the sector. Those are:

1. Non-optimal speed profiles
2. Low utilisation of ships
3. Time spent in ports
4. Lack of incentives to offer environmentally friendly freights
5. Lack of investments in new vessels and better technologies

We have also presented approaches to solving each one of them.

1. Voyage optimisation and smart ports
2. Cargo coordination and supply chain integration in logistics
3. Optimisation and automation of loading and unloading operations

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[23] UNCTAD (2017)

4. Incentives for sustainable freight services
5. Investments promoting operational flexibility over the ship life-cycle

It is, however, to be noted that these measures have to be implemented on a step-by-step basis. Figure 9 presents a proposed a trajectory for reducing shipping emissions that peak in 2020[24]. It shows the relative contribution to emissions reductions from the existing and scalable solutions presented in this document. It also indicates a certain sequence of the various measures and solutions.

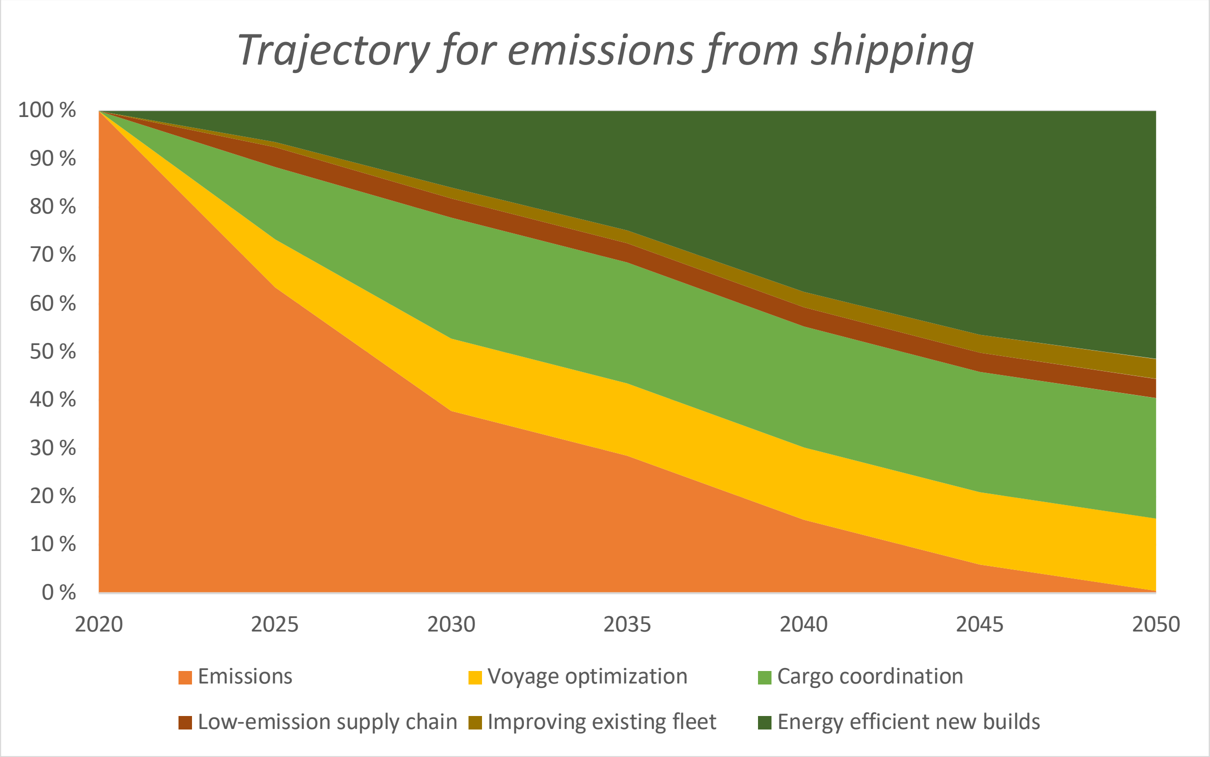

Figure 9 Sequential implementation of emission-reducing measures

The process should start by implementing voyage optimization and cargo flow coordination. From an investment perspective neither of these require a large initial investment. They can both be implemented on a broad scale thereby achieving significant emissions reductions immediately regardless of the age of the fleet. Since both voyage optimization and cargo coordination also reduce freight costs the resistance from the shipping sector should be fairly small. Both measures also release capital that at present are lost to inefficiencies. This capital can be focused on investing in new technologies. They would also create the data needed for cargo owners to better measure the supply chain emission footprint. Figure 9 outlines the potential for reducing emissions in shipping step by step.

Investments into technology, be it upgrades or newbuilds, should be decided on a case by case basis. There are many existing and future potential technical solutions such as lightweight metal alloys, propulsion assisting structures and systems, use of composites, solutions improving the hydrodynamics, amongst other. However, their immediate effect on CO_2-emissions remain in many cases marginal or small if applied individually and as retrofit, if structurally possible to begin with. This is due to the fact that such installations take place with a delay and when ships are docked for overhaul

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[24] Adapted from Global Action Summit (2018)

every five years, for instance. As for newbuilds they can of course include all the latest technologies. However, in practice shipbuilding is constrained by the available shipyards and the fact that as long as industry (cargo owners) do not focus on their supply-chain emission footprint it does not make sense to invest in low-emission technologies.

Reducing emissions in shipping requires a combined approach of policy, new business models and new technologies. Shipping today is locked in a vicious circle of systemic inefficiencies that hinder the introduction of regulations and technologies that could reduce emissions. New technologies require new business models in order for society to fully capitalize on the benefits. Similarly, new business models make room for more stringent policies by showing that it is feasible to be both ecologically and environmentally sustainable – in fact it can be highly profitable. Changes in policy, in turn, support the new, more sustainable business models. To break the vicious circle focus must be put on the systemic inefficiencies. That way a virtuous circle of more competitive business models based on modern technologies and supported by stringent regulation can be created step by step as outlined in Table 3.

Table 3: Interplay of development of policy, business models and new technologies

	2020-2030	2030-2050
Business Models	Real-time dynamic supply chain integration Industry monitors emissions in supply chain	New investment models for low-emission ship lifecycle
Policy	Inefficient sailing banned (no more rush to wait) Financing structures for sustainability upgrades Old-fashioned shipping subsidies are abandoned	Shipping emissions are taxed
Exponential Technology	Renewable diesel for ships Rotary sails and kites	Battery powered coastal shipping Renewable fuels (LNG etc.) Advanced sail technologies Unmanned ships lower operating costs releasing capital for low-emission technologies

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