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Assessment of impacts from accelerating the uptake of sustainable alternative fuels in maritime transport

Final report

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Table of Contents 5

Executive summary

The European Green Deal and the 2030 Climate Target Plan aim to reduce GHG emissions by at least 55% in 2030, relative to 1990, and achieve climate neutrality in 2050. All sectors should contribute to this target, including maritime transport. Ships in the scope of the EU MRV emitted about 140 Mt CO_2 in 2018 and 2019. One of the reasons for these emissions is the reliance of maritime transport on fossil fuels. Over 99% of marine fuels used globally were either petroleum-based or natural gas-based in 2018, and the situation in the EU is similar.

The low uptake of renewable and low-carbon fuels by ships calling at EU ports complicates reaching the ambition of the European Green Deal and, more in general, makes it more difficult to achieve the temperature goal of the Paris Agreement. In addition, ships at berth in EU ports emit significant quantities of air pollutants because of the use of fossil fuels at berth.

These problems have five drivers:

1. the regulatory framework determines the fuel choice of new ships. Uncertainty about the changes to the regulatory framework may result in more dual-fuel engines being installed, and while this would improve the versatility of the fleet, it would probably also mean that the most cost-effective renewable and low-carbon fuels will seldomly be used on these ships;
2. Most renewable and low-carbon fuels which are suitable for use onboard ships have a low technical maturity. In most cases, the bunkering infrastructure and in some cases the energy conversion on board are immature. This constitutes a high risk for first movers;
3. The production costs of renewable and low-carbon fuels are two to fifteen times more expensive than conventional fuels, depending on the type of fuel and the production pathway. In addition, some fuels require dedicated bunkering infrastructure and modifications to ships, which increase the costs of using these fuels. The cost difference per tonne of CO_2 reduced (equal to the carbon price required to make the fuels cost-competitive) currently ranges from around EUR 150 to several thousand euros;
4. Some renewable and low-carbon fuels are so-called drop-in fuels, meaning that they can be used in existing ships without modifications to the fuel sytem or engine. These fuels can be used occasionally by existing ships. Other fuels, however, require significant changes to ships and dedicated bunkering infrastructure. These fuels include methanol, ammonia and hydrogen, which are amongst the most cost-effective e-fuels. For these fuels, there is an interdependency between supply and demand: the costs of the bunkering infrastructure are only surmountable when there is sufficient demand for these fuels, and conversely, demand will only increase when there is a reliable supply of fuels;
5. Ships have a significant degree of freedom in choosing the place of bunkering. In many cases, they can bunker anywhere along the route they are sailing.

A problem tree is shown in Figure ES1.

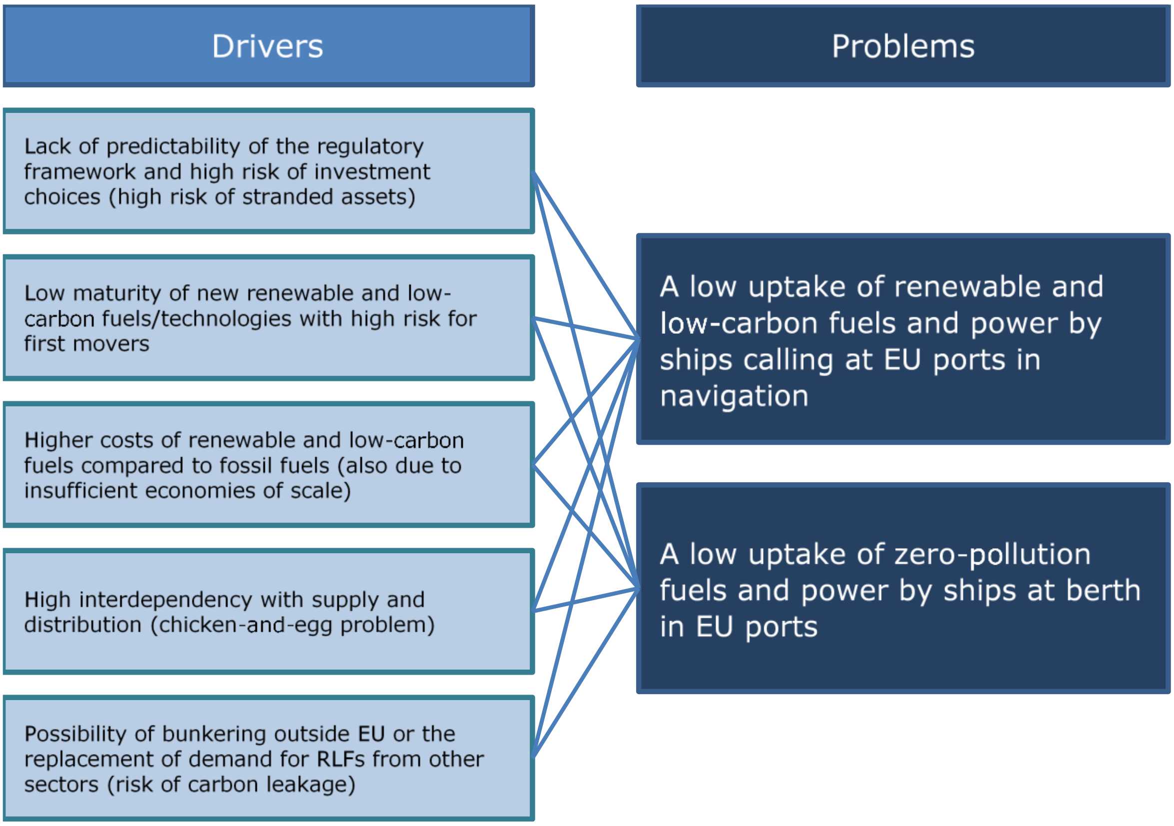

Figure ES1 Problem tree

In the absence of policy action, the problems are unlikely to diminish. Although there are voluntary initiatives to gain experience with renewable and low-carbon fuels, they are unlikely to result in a significant uptake of these fuels because shipping companies using these fuels on a large scale would jeopardize their competitiveness. Existing or future EU policies may provide an incentive for reducing CO_2 emissions from shipping, but that incentive is unlikely to become sufficiently large to overcome the price gap between fossil and renewable fuels and compensate for the risk of using alternative fuels. Member State policies are mainly targeted at R&D and pilot projects. While the Initial IMO Strategy on Reduction of GHG Emissions from Ships explicitly recognises that the global introduction of alternative fuels and/or energy sources is necessary, the consideration of global policies is in the initial stage.

Hence, in order to address the problems, European policy action is required. Because of the possibility of bunkering outside the EU, the policy should target fuels used on voyages to and/or from EU ports, rather than fuels sold in the EU. Also, because the lack of demand for renewable and low-carbon fuels is the main problem, the policy should aim demand for fuels rather than supply. Based on these considerations, this study has identified the following policies:

Table ES1 Policy options

Option	In navigation and at berth	In addition at berth
1 - Prescriptive approach on the choice of technology	Minimum shares of specific fuel types (established ex-ante) would be established and would increase over time.	The use of on-shore power supply will be mandated for the most polluting ships in ports, unless they can prove the use of equally performant alternative.
2 - Goal-based approach on	A maximum limit on the GHG	As above

Option	In navigation and at berth	In addition at berth
technology	content of energy used by ships in navigation (e.g. CO2eq/MJ or kWh) would be established and will be made more stringent over time.	
3 - Goal-based approach on technology and reward mechanisms for overachievers	The maximum limit on the GHG content of the energy used by ships in navigation would be combined with the possibility to pool compliance with other ships / operators, either on a voluntary basis or through transferrable credits. Also, when establishing the ship's performance in achieving the yearly target, higher weight will be attributed to zero-emission technologies.	As above

There are differences between the options in fuel choice and in administrative tasks, as summarised in Table ES2.

Table ES2 Impact of policy options on fuel choice

Option	Likely fuel choice in navigation
1 - Prescriptive approach on the choice of technology	Ships are incentivised to use the cheapest compliant drop-in fuel. These are bio-diesel (HVO or FAME) for ships sailing on liquid fuels and liquefied biogas for ships sailing on LNG.
2 - Goal-based approach on technology	Ships are incentivised to use the most cost-effective drop-in fuel. These are bio-diesel (HVO or FAME) for ships sailing on liquid fuels and liquefied biogas for ships sailing on LNG.
3 - Goal-based approach on technology and reward mechanisms for overachievers	Pools of ships are incentivised to use the most-cost-effective fuels. These are liquefied biogas, biodiesel, bio-methanol, and bio-ethanol. E-fuels are currently less cost-effective. However, if bonuses are given for e-fuels e-ammonia and e-hydrogen could become attractive.

In order to address the reliance of shipping on fossil fuels, the European Commission launched the FuelEU Maritime initiative with the aim to create clear pathway for the demand of renewable and low-carbon fuels and power in maritime transport.

List of Abbreviations

AFID	Directive on Alternative Fuels Infrastructure
BAF	Bunker Adjustment Factor
BDN	Bunker Delivery Notes
BR	Better Regulation
CAPEX	Capital expenditure
CGT	Compensated Gross Tonnage
CNG	Compressed natural gas
DWT	Dead Weight Tonnage
EC	European Commission
ECA	Emission Control Area
EMSA	European Maritime Safety Authority
ESPO	European Sea Ports Organisation
ESSF	European Sustainable Shipping Forum
ETS	Emissions Trading System
EU	European Union
FQD	Fuel Quality Directive
GBER	General Block Exemption Regulation
GHG	Greenhouse Gas
GoO	Guarantees of Origin
GT	Gross Tonnage
GVA	Gross Value Added
HFO	Heavy Fuel Oil
IA	Impact Assessment
IGF Code	International Code of Safety for Ships using Gases or other Low flashpoint Fuels
ILUC	Indirect land use change
IMO	International Maritime Organization
LNG	Liquid Natural Gas
LSMGO	Low Sulphur Marine Gas Oil
NECPs	National Energy and Climate Plans
NPFs	National Policy Frameworks
MACC	Marginal Abatement Cost Curve
MBM	Market Based Measure
MCA	Multi-criteria analysis
MDO	Marine Diesel Oil
MFO	Medium Fuel Oil

MGO	Marine Gas Oil
MoU	Memorandum of Understanding
MRV	Monitoring, Reporting, Verification
NGO	Non-Governmental Organisation
NPV	Net Present Value
ONCC	Other Non-Cargo Carrying vessels
OPC	Open Public Consultation
OPEX	Operational expenditure
OPS	Onshore power supply
PSC	Port State Control
R&D	Research and development
RED	Renewable Energy Directive
RED II	Renewable Energy Directive – recast to 2030 (Directive 2018/2001/EU)
RES-T	Renewable Energy in Transport
RFNBO	Renewable fuels of non-biological origin
RO	Recognised Organisation
RoW	Rest of the World
RSB	Regulatory Scrutiny Board
SAF	Sustainable alternative fuel
SAPS	Sustainable Alternative Power for Shipping
SCM	Standard cost model
SOLAS	International Convention for the Safety of Life at Sea
SSS	Short Sea Shipping
SWD	Staff Working Document
TEN-T	Trans-European Transport Network
TEU	Twenty Foot Equivalent
ToR	Terms of Reference
TSA	Transpacific Stabilization Agreement
UCO	Used cooking oil
ULSFO	Ultra-Low Sulphur Fuel Oil
UNCTAD	United Nations Conference on Trade and Development
VLSFO	Very Low Sulphur Fuel Oil
WTO	World Trade Organisation

1. Introduction

The European Green Deal and the 2030 Climate Target Plan aim to reduce GHG emissions by at least 55% in 2030, relative to 1990, and achieve climate neutrality in 2050. All sectors should contribute to this target, including maritime transport. Ships in the scope of the EU MRV emitted about 140 Mt CO_2 in 2018 and 2019. One of the reasons for these emissions is the reliance of maritime transport on fossil fuels. Over 99% of marine fuels used globally were either petroleum-based or natural gas-based in 2018, and the situation in the EU is similar.

In order to address the reliance of shipping on fossil fuels, the European Commission launched the FuelEU Maritime initiative with the aim to create clear pathway for the demand of renewable and low-carbon fuels and power in maritime transport.

The wider context of this initiative is the Paris Agreement, which aims to hold the temperature increase well below 2°C above pre-industrial levels while pursuing efforts to limit it to 1.5°C. To that end, the Paris Agreement aims to reach global peaking of emissions as soon as possible, let them decline rapidly after the peak in order to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century.

Following the adoption of the Paris Agreement, the IMO adopted the Initial IMO Strategy on Reduction of GHG Emissions from Ships, which aims, amongst others, at a reduction of global greenhouse gas emissions from shipping by at least 50% in 2050 compared to 2008, and recognises that 'the global introduction of alternative fuels and/or energy sources for international shipping' is necessary to achieve the strategic targets.

This report presents a study supporting the European Commission's Impact Assessment of the FuelEU Maritime Initiative.

1.1. Aim of the study

In line with the Better Regulation Guidelines, this study aims to provide a robust evidence base in support of the Commission's Impact Assessment of the FuelEU Maritime Initiative. In particular, the study:

- Analyses the current pattern of fuels and power used in maritime transport and in ports; the current regulatory framework relevant for fuel demand; and the European maritime sectors;
- Analyses the problems and their main drivers as well as the likely development of the problem and the drivers in the absence of regulation;
- Lays out policy options to address the problems and meet the policy objectives; and
- Assesses and presents the impacts of the options.

The study comprises a report on the Stakeholder Consultation and a number of case studies, both as deliverables and as an input to the study.

1.2. Outline of the report

Chapter 2 describes the current state of play with regards to fuels and power used in the maritime sector; the regulatory context; and the European maritime sector. Chapter 3 analyses the problem, develops a problem tree and assesses how the problem will evolve in the absence of EU action. Chapter 4 presents the policy options. Chapter 5 assesses the impacts resulting from the different policy options.

In Annex I the sources used are indicated. Annexes II to VII accompany Chapter 5 on the assessment of impacts. Annex VIII contains the case studies. Annex IX contains the stakeholder consultation report.

2. Current state of play

In 2018, ship traffic to or from ports of the European Economic Area (including the UK) was responsible for more than 142 million tonnes of CO_2 emissions (EU Monitoring, Reporting and Verification (MRV) data - Ships in the scope of the MRV Regulation). This represents around 11% of all EU transport CO_2 emissions and 3-4% of total EU CO_2 emissions.

2.1. Overview of maritime fuel use

The energy demand of maritime shipping is currently almost entirely covered by the use of fossil bunker fuels. Four major fuel types can thereby be distinguished:

1. Marine residual fuels (HFO);
2. Marine distillate fuels (MGO);
3. Liquefied Natural Gas (LNG); and
4. Methanol.

In 2018, the world fleet was powered for 66% by Heavy Fuel Oil (HFO), 30% distillates (MGO), 3% LNG and 0.04% methanol. A detailed overview is provided in Table 2.1.

Table 2.1 Energy use by fuel type for the world fleet (GJ)

Fleet sector	Fuel	2012	2013	2014	2015	2016	2017	2018
International shipping	HFO	7800	7600	7500	7100	7500	7700	7600
	LNG	300	300	300	300	300	400	400
	MGO	900	900	1000	1600	1600	1600	1500
	METHANOL	0	0	0	0	4	5	5
	Total	**9000**	**8800**	**8800**	**9000**	**9400**	**9600**	**9600**
Domestic navigation	HFO	1500	1500	1400	1200	1300	1400	1400
	LNG	0	0	0	0	0	0	0
	MGO	1300	1500	1600	1900	1900	2100	2100
	METHANOL	0	0	0	1	1	1	1
	Total	**2900**	**3000**	**3100**	**3200**	**3300**	**3600**	**3600**
Fishing	HFO	0	0	0	0	0	0	0
	LNG	0	0	0	0	0	0	0
	MGO	500	500	500	500	500	500	500
	METHANOL	0	0	0	0	0	0	0

Fleet sector	Fuel	2012	2013	2014	2015	2016	2017	2018
	Total	**500**	**500**	**500**	**500**	**600**	**500**	**500**
Total	HFO	9300	9100	8900	8300	8800	9100	9000
	LNG	300	300	300	300	300	400	400
	MGO	2700	2900	3100	4000	4000	4200	4100
	METHANOL	0	0	0	1	5	6	6
	Total	**12400**	**12300**	**12400**	**12700**	**13300**	**13700**	**13700**

Source: Fourth IMO GHG Study.

In the global fleet, distillates were predominantly used in auxiliary engines and main engines of smaller ships. Main engines of large ships ran on HFO. Most of LNG was used by LNG and gas carriers, and methanol was used by one RoPax and a few chemical tankers (IMO 2020).

Although there has been an increase in the amounts of LNG and methanol used, petroleum-based fuels remain dominant at about 96% between 2012 and 2018.

From 2018 onwards, commercial cargo and passenger ships larger than 5000 GT calling at EEA (including UK) ports have to report their fuel use emissions under the MRV Regulation.[1] In 2018, these ships had a similar pattern of fuel use as globally. According to the 2019 Annual Report on CO2 Emissions from Maritime Transport,[2] over 72% of the fuel consumed in 2018 was HFO, 24% MGO and other distillates and 3% LNG.

The shares of LNG (3%) and HFO (70%) used by ships in the scope of the EU MRV Regulation resemble the global shares of these fuels. This reflects the fact that the fleet in Europe resembles the world fleet (SWD(2020) 82 final) and that two thirds of the emissions are on inbound and outbound voyages, while it is likely that the emissions on intra-EEA voyages are also partly from ships that engaged in international voyages, as for example container ships often call on multiple EU ports and tramp ships may be chartered to pick up cargo in a port near the port of discharge.

2.1.1. Location of emissions

Ships in the scope of the MRV Regulation emitted 6% (8 million tonnes) of their CO2 at berth and the remainder at sea in 2018 (SWD(2020) 82 final). Assuming that most of these emissions are from Marine Gas Oil (MGO) (in ports, ships use their auxiliary engines which often run on MGO and a sulphur limit of 0.10% m/m applies), and applying the emission factors used in the Fourth IMO Greenhouse Gas Study, estimates of other emissions at berth are shown in Table 2.2.

1 Regulation (EU) 2015/757.

2 SWD(2020) 82 final.

Table 2.2 Estimates of emissions at berth in 2018 (tonnes)

Species	Emissions at berth (tonnes)
Carbon dioxide (CO_2)	8 000 000
Methane (CH_4)	120
Nitrous oxide (N_20)	450
Sulphur Oxides (SOx)	3 400
Nitrogen oxides (NOx)	140 000
Carbon monoxide (CO)	6 500
Non methane volatile organic compounds (NMVOC)	6 000
Particulate matter (PM)	2 200
Fine particulate matter ($PM_{2.5}$)	2 100
Black carbon (BC)	950

The emissions of NOx amounted to about 2% of emissions reported by EU28 under the National Emission Ceilings Directive (EEA 2020). Note that the geographical scope of the data in Table 2.2 is the EEA rather than the EU28. Emissions of $PM_{2.5}$, SOx and NMVOC amounted to 0.2%, 0.2% and 0.1% respectively.

2.1.2. Detailed information on the use of alternative and renewable fuels

Renewable and/or alternative fuels are used in trials, pilots and small-scale projects. Table 2.3 presents an overview of recent initiatives of the use of biofuels in maritime shipping.

Table 2.3 Recent initiatives of the use of non-fossil fuels in maritime shipping

Fuel type	Fuel type properties	Trials at least since	Ship types	Estimates of fuel share	Sources
Biofuels	Drop-in fuels: generally no tank or engine modifications required. HVO, hydrogenated fats, FAME	2009	Navy ships Cargo ships Dredgers Cruise ships Research vessels	The Port of Rotterdam reports that 0.5% - 2% of fuels sold were biofuels or a biofuel mixture in 2019. This would amount to more than 100 kilotons	Port of Rotterdam 2020[3] CE Delft and Technopolis, 2018
Methanol	Currently often of fossil origin, but can be made sustainably	2015	RoPax Chemical tankers	160 kilotons in 2018	Fourth IMO GHG Study
Hydrogen	Requires tank and engine modifications	2019	Trials, amongst others on a ferry: Hyseas And on a research vessel: Maranda	zero	https://www.hyseas3.eu/ https://projectsites.vtt.fi/sites/maranda/
Ammonia	Requires tank and engine modifications	2020	Engine trials: Wärtsilä four-stroke engine tested in Norway; MAN two-stroke engine tested in Denmark.	zero	https://www.wartsila.com/media/news/30-06-2020-world-s-first-full-scale-ammonia-engine-test---an-important-step-towards-carbon-free-shipping-2737809 https://shippingwatch.com/suppliers/article12336077.ece

3 https://www.portofrotterdam.com/en/news-and-press-releases/2019-demand-in-rotterdam-bunker-port-more-sustainable.

The most widely used type of renewable fuels used in shipping is biofuel, of which there appears to be a quantity sold which is comparable to methanol, i.e. much less than a percent of global fuel used. In addition, methanol from fossil sources is used by some ships. Several fuel types are undergoing trials at ship-scale, such as hydrogen (both in internal combustion engines and fuel cells) and ammonia.

1.1.1.1.OPS Infrastructure Characterization.

According to the European Alternative Fuels Observatory European Alternative Fuels Observatory, there are currently 34 high-voltage OPS installations in maritime ports in Europe, of which 9 are in comprehensive TEN-T ports and 15 in core TEN-T ports. Most installations (21) are intended for ferries, RoRo and RoPax vessels. The maximum power output of the installations ranges from 0.5 to 10 MW. In addition, there are 30 low-voltage OPS installations in maritime ports, also mainly (17) for ferries and RoPax vessels. Their maximum power output ranges from 50 kW to 4 MW.

2.2. Current policies affecting fuel choice in maritime transport

As shown in Section 2.1, the share of renewable fuels in shipping is still limited. Several policies are in place that have an impact on fuel choice. In the next paragraphs we discuss the main initiatives.

2.2.1. EU Framework: Alternative Fuels Infrastructure Directive and Renewable Energy Directive

Existing EU policy measures to support alternative fuels currently focus on the supply and deployment of necessary infrastructure.

Relevance of the AFID

The Directive on Alternative Fuels Infrastructure (AFID) was adopted on 29 September 2014 (2014/94/EU) and requires Member States to develop national policy frameworks for the market development of alternative fuels and their infrastructure. In addition, the Directive foresees the use of common technical specifications for recharging and refuelling stations in order to improve harmonisation and the single market and also include provisions on appropriate consumer information on alternative fuels both on vehicle compatibility as well as on price differences. The AFID prescribes development of an infrastructure for electricity for vehicles, CNG (compressed natural gas), LNG for vehicles, maritime vessels and inland shipping vessels. There is a strong link with the TEN-T core network: for both maritime and inland shipping it requires coverage of maritime ports with mobile or fix installations to enable the circulation on TEN-T Core Network. For vehicles LNG refuelling infrastructure is required at least every 400 km on TEN-T Core Network. For hydrogen refuelling infrastructure is recommended every 300 km on the TEN-T network. The infrastructure for alternative fuels has to be put in place by 2025.[4]

4 https://www.fuelcellbuses.eu/wiki/policy-framework/eu-directive-alternative-fuels-infrastructure.

The Directive also requires that Onshore Power Supply[5] shall be installed as a priority in ports of the TEN-T Core Network by the end of 2025 unless there is no demand for OPS and the costs are disproportionate to the benefits, including the environmental benefits (Article 4.5).

As the infrastructure in ports is crucial for an uptake of renewable fuels, the AFID and any revisions of it will play a crucial role in the further developments of renewable fuels as means to decarbonisation maritime shipping.

With regards to OPS, the fact that it is not required in case there is no demand for OPS or the cost are too high, also shows the dependency on strong demand policy measures. The stakeholder consultation shows that ports are reluctant to invest when there is uncertainty about future demand. Any policy measures increasing the demand for OPS will benefit the development of OPS in ports.

The ongoing revision of the AFID is relevant for FuelEU Maritime, both with regards to the types of fuels supplied in ports and to the provision of OPS.

Renewable Energy Directive (2018/2001)

Within the European policy framework growth should come from advanced biofuels and renewable fuels of non-biological origin. If we look at the definition of advanced biofuel in the RED II, the Directive provides the following definition for advanced biofuels: biofuels that are produced from the feedstock listed in Part A of Annex IX (lignocellulosic energy crops, waste and residues). This is the same definition that is also used for the sub target of advanced biofuels of at least 0.2% in 2022, at least 1% in 2025 and at least 3.5% in 2030. Biofuels produced from feedstocks from Part A of Annex IX are also allowed to count twice towards the target.

Based on the stakeholder consultation for the review of the Renewable Energy Directive, conducted from 17 November 2020 to 09 February 2021, there seems to be no widespread agreement as to the extent to which biofuels based on food and feed crops should be able to contribute towards the decarbonisation of shipping and how fuels from low indirect land use change (ILUC) crops should be treated in other policy initiatives.

On the other hand, the European Renewable Energy Directive II (and I) requires that any obligations or financial support for biofuels are compliant with sustainability criteria set out in the Renewable Energy Directive (RED II), even if these fuels are not counted towards targets of the RED II. The sustainability criteria of the RED II cover GHG savings, land use, biodiversity and forest carbon stocks. Later on, we will further discuss the sustainability framework, after discussing the more general provisions of the RED II.

Option to use renewable fuels in maritime shipping under the RED

With respect to renewable fuels in maritime shipping the RED allows Member States to count those fuels towards their RES-T target of reaching at least 14% renewable energy in final energy consumption in transport by 2030. Renewable energy in transport could consist of biofuel, renewable fuels of non-biological origin (RFNBO) and may include recycled carbon fuels. At all times the sustainability requirements should be met. Article 27 describes the calculation rules with regard to the minimum shares of renewable energy in the transport sector. The article states:

(a) for the calculation of the denominator, that is the energy content of road- and rail-transport fuels supplied for consumption or use on the market, petrol, diesel, natural gas,

[5] The term used in the Alternative Fuels Infrastructure Directive is ‘‘shore-side electricity supply’.

biofuels, biogas, renewable liquid and gaseous transport fuels of non-biological origin, recycled carbon fuels and electricity supplied to the road and rail transport sectors, shall be taken into account;

(b) for the calculation of the numerator, that is the amount of energy from renewable sources consumed in the transport sector for the purposes of the first subparagraph of Article 25(1), the energy content of all types of energy from renewable sources supplied to all transport sectors, including renewable electricity supplied to the road and rail transport sectors, shall be taken into account. Member States may also take into account recycled carbon fuels.'[6]

Renewable fuels in the maritime sector can be taken into account in the numerator, but are not included in the denominator. This implies renewable fuels in the maritime and aviation sector can opt in to contribute the 14% transport target and will make it easier to meet the target, because the scope of the numerator is broader compared to the denominator.

According to Article 27, the fuels applied in maritime shipping are however not counted towards the denominator, but only towards the numerator to calculate the contribution to the target.

So far, the REDI have not resulted in a significant contribution of maritime shipping in the numerator. The impact assessment of the RED II observed an additional challenge in the maritime sector (compared with other transport modalities) given the split incentives between ship owners and operators, which does not stimulate the deployment of renewable fuels. The IA mentioned the need to introduce dedicated measures for the maritime sector in the form of a specific incorporation obligation for advanced renewable fuels.[7] The final recast of the RED does not include such specific incorporation obligation. Overall, the RED does not oblige Member States to account for the use renewable fuels in shipping, but fuels supplied in maritime shipping (and aviation) shall be considered 1.2 times their energy content (except for fuels produced from food and feed crops) when demonstrating compliance with the target for renewable energy in the transport sector. This provision is meant to boost the uptake of renewable energy in these sectors. Biofuels produced from feedstocks listed in Part A and Part B are allowed to count double towards the target. This has implications for the impact of the 20% extra counting when used in aviation and maritime: in this way less fuel volumes are required to meet the target and might impact the GHG emission reduction in practice.

The Netherlands have opted-in maritime fuels in the RED and have witnessed a sharp increase in the supply of biofuels to shipping.[8]

Although not specifically focussing on maritime shipping the RED II also includes some other provisions which could interact with policies especially targeted at maritime shipping. These provisions only apply to fuels counted towards the targets (Article 3 and Article 25) and include:

- the cap on food and feed crops of 1% above MS level in 2020 or max. 7%;

6 Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.

7 Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.

8 Regeling van de Staatssecretaris van Infrastructuur en Waterstaat van 14 december 2020, nr. IENW/BSK-2020/239573, tot wijziging van de Regeling energie vervoer in verband met het wijzigen van de uitslag tot verbruik van vloeibare biobrandstof aan zeeschepen en de verkrijging van exploitatiereductie-eenheden over het kalenderjaar 2021, https://zoek.officielebekendmakingen.nl/stcrt-2020-65200.html

- the cap on high ILUC biofuels at MS level in 2019 and decreasing from 2023-2030 to 0%;
- the cap on biofuels produced from feedstocks listed in Part B Annex IX of 1.7%, which includes for example used cooking oil (UCO). Member States might modify this cap based on the availability of the feedstock. Part B Annex IX biofuels can count twice;
- the sub target for advanced biofuels produced from feedstocks from Part A of Annex IX, which includes lignocellulosic energy crops, waste and residues. The contribution should be at least 0.2% in 2022, at least 1% in 2025 and at least 3.5% in 2030 (shares are after double counting which is allowed for these feedstocks).

National implementation at MS level of RED and FQD

IA RED stated that national measures alone will be not be sufficient to reach the EU 2030 target.[9] A binding measure at EU level was mentioned as more likely to achieve economies of scale for sustainable alternative fuels. The REFIT evaluation concluded that the 10% target set by the RED was very effective. For the RED I, most member states have chosen to impose an obligation on fuel suppliers in order to meet the target. Germany has introduced in 2015 a GHG emission reduction obligation on fuel suppliers, stemming from the FQD target and Sweden has done the same in 2018. Germany and Sweden thus solely depend on GHG reduction targets. In 6 other Member States ((HR, CZ, MT, RO, SK, SL) do use a combined approach steering both a volumes uptake and GHG reduction. In the Netherlands, fuel suppliers comply with the 6% FQD target via the RED annual energy obligation. In 2020 this obligation is 16.4% which is higher than the 10% RED target: due to the high share of double counting biofuels actual volumes will be lower. This might be problematic in the light of the realisation of the FQD target and national agreements on actual volumes of biofuels might not be met when applying a 10% target.

The case of Germany

While most EU Member States are implementing RES-T obligations by a volume based system (in line with the RED), Germany uses a GHG reduction system to oblige fuel suppliers to meet the obligations for the fuels they put on the market, which is comparable to the FQD methodology, accompanied by high penalties for non-compliance. The reduction was fixed at 3.5% in 2015, 4% in 2017 and was elevated to 6% in 2020, hereby following the requirement of the FQD. But while the FQD requirements for EU Member States remain (for now) at 6% after 2020, the provisions stemming from the RED II were being sharpened. Hence, German fuel suppliers need to fulfil the national obligations based on a GHG reduction quota but they will also need to comply with the RED II requirements.

The divergent German system has sparked trans-border trade of feedstocks to places of the highest relative profit. In Germany it has led to a decrease of crop-based biofuel consumption (GHG saving of 65%) and an increase in consumption (and prices) of waste and residual based biofuels (like UCO) that have GHG savings of almost 90%. There was a movement of less performing biofuels in terms of GHG reduction potential to countries using the volume-based RED approach (Dusser, 2019).

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[9] COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT Accompanying the document Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast). SWD/2016/0418 final - 2016/0382 (COD) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52016SC0418.

Conclusions on how policies could interfere

The opt-in for renewable energy in maritime shipping under the RED implies that renewable energy used in maritime shipping affects the targets for other transport modes. The more renewable fuels are used in shipping, the fewer will be used on road transport. because maritime transport emissions are not in the EUs NDC, this could impact the commitments of the EU under the Paris Agreement.

2.2.2. IMO Framework: Initial IMO Strategy on Reduction of GHG Emissions from Ships

In 2018, the Marine Environment Protection Committee (MEPC) adopted the Initial IMO Strategy on Reduction of GHG Emissions from Ships MEPC.304(72) which has the vision to 'reduc[e] GHG emissions from international shipping and, as a matter of urgency, aims to phase them out as soon as possible in this century'.

The Initial Strategy specifies four goals or levels of ambition, viz:

1. let the carbon intensity of the ship decline through more stringent design efficiency requirements;
2. reduce the operational carbon intensity of shipping by 40% in 2030 relative to 2008;
3. Peak GHG emissions from international shipping as soon as possible; and
4. reduce them by at least 50% by 2050 compared to 2008 levels on a pathway consistent with the Paris Agreement temperature goals.

The Initial Strategy notes that 'the global introduction of alternative fuels and/or energy sources for international shipping will be integral to achieve the overall ambition'.

In order to meet the levels of ambition the Strategy lists a number of candidate measures, on which negotiations are ongoing. The so-called short-term measures all aim at improving the energy efficiency and will not result in an uptake of low- and zero-carbon fuels, according to their impact assessment. These measures are currently in the final stage of negotiation and could be agreed upon as soon as the MEPC can reconvene after the COVID-19 pandemic.

A short-term measure that has been adopted is the resolution 'to encourage voluntary cooperation between the port and shipping sectors to contribute to reducing GHG emissions from ships' (MEPC.323(74)), which invites IMO Member States 'to promote the consideration and adoption by ports within their jurisdiction, of (…) Onshore Power Supply (preferably from renewable sources)'. While this resolution is non-binding, an EU initiative to require the use of shore-side electricity could be considered an implementation of this resolution, especially when the power is from renewable sources.

A second short-term measure has been agreed at MEPC 75, namely mandatory goal-based technical and operational measures to reduce carbon intensity of international shipping (MEPC 75/18/Add.1).

Although the development of 'robust lifecycle GHG/carbon intensity guidelines for all types of fuels' is also amongst the candidate short-term measures mentioned in the Initial Strategy, consideration of this issue has not resulted in guidelines yet.

The so-called mid- and long-term candidate measures that are mentioned in the Initial Strategy contain measures that will incentivise the use of low- and zero-carbon fuels, although their current description is very general and their design will be subject to negotiations:

- implementation programme for the effective uptake of alternative low- and zero-carbon fuels, including update of national actions plans to specifically consider such fuels;
- new/innovative emission reduction mechanism(s), possibly including Market-based Measures (MBMs), to incentivise GHG emission reduction; and
- pursue the development and provision of zero-carbon or fossil-free fuels to enable the shipping sector to assess and consider decarbonisation in the second half of the century.

2.2.3. Relevant non-GHG policies: Sulphur directive, MARPOL Annex VI, ECA, Mediterranean ECA

Until recently, alternative fuels for maritime shipping have mainly been developed and researched due to air pollution regulation, primarily SOx and PM.

MARPOL Annex VI Regulation 13 and Regulation 14 set requirements for the NOx and the SOx emissions of seagoing ships.

Regulation 13 sets requirements for the NOx emissions from engines of new seagoing vessels. These requirements have been tightened over the years, which is why a distinction is made between Tier I to Tier III ships. Tier I ships were built between 2000 and 2010; Tier II between from 2011; and Tier III) only applies to the engines of ships that operate in a NOx-Emission Control Areas (ECAs). Ships built after 2016 must meet Tier III requirements if they operate in the North American NOx-ECA. Ships built after 2021 must also fulfil Tier III requirements if they operate in the North and Baltic Sea NOx-ECA. Should other waters, such as the Mediterranean Sea, also be designated as a NOx-ECA, then new ships also operating in these waters would also have to meet Tier III requirements from the application year of the new NOx-ECA onwards.

The strictest Tier III requirements can be met by either using conventional/alternative bunker fuels in combination with end-of-pipe technologies, like for example Selective Catalytic Reduction systems, or by using specific alternative fuels, like for example LNG, (see Figure 2.1).

Ships built before 2000 do not have to meet a NOx standard and are colloquially refered to as Tier 0 ships, although this designation is not made in MARPOL.

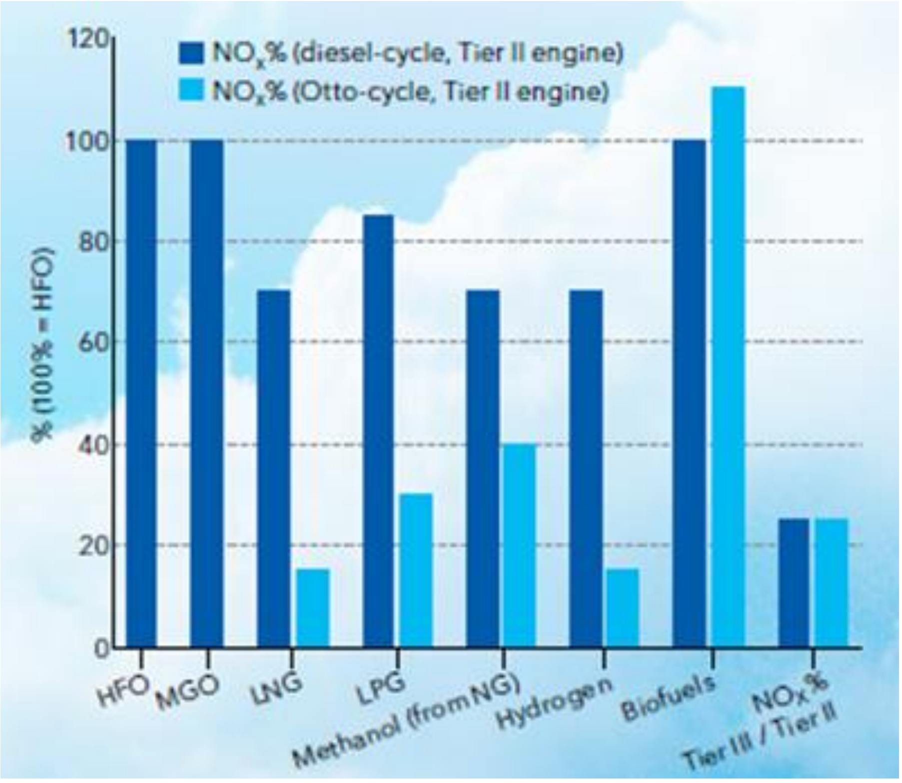

Figure 2.1 NOx emissions depending engine type, alternative fuels compared to HFO.

Source: (DNVGL, 2018).

According to IMO Regulation 14 and EU Directive 2016/802, ships sailing outside a SOx-ECA shall, since early 2020, only use fuel with a maximum sulphur content of 0.50% by mass and ships sailing inside a SOx-ECA shall, since early 2015, only use fuel with a maximum sulphur content of 0.10% by mass.

In addition, EU Directive 2016/802 requires ships at berth in Union ports not to use marine fuels with a sulphur content exceeding 0.10 % by mass already since 2010.

To comply with Regulation 14 and EU Directive 2016/802, ships can either sail on the compliant low sulphur fuels or they are allowed to take measures leading to equivalent SOx emissions, such as a combination of high sulphur fuel and an exhaust gas cleaning system, as long as the SOx emissions do not exceed the emissions of compliant fuels.

2.3. Overview of the current maritime sector

2.3.1. The size of the European shipping industry

Irrespective of the final alternative fuel choice and policy option chosen, the current legislative initiative will certainly impact the (European) maritime sector. Therefore, it is important to gain insight into the size of the industry, especially the number of companies, their flags and the number of ships per company. Obtaining such data is a challenge, as none of the public sources provides a detailed overview of such data. Below, information from various sources is outlined further.

In their Statistical Publication, ISL published figures on the main ship-owning countries in the EU. Table 2.4 presents an overview of the European Member States and the number of vessels, number of 1000 DWT and number 1000 TEU that are controlled by companies registered in their country. Figures on the number of vessels of <5000 GT were not published. It should be noted that the figures only include propelled seagoing vessels of 1,000 GT and above. This means that smaller seagoing vessels, as well as vessels operating on the port area, are not included in the figures below.

Table 2.4 Overview of EU fleet by countries of control as of 1st January, 2019

Country of control (dwt-rank)		1000 dwt	1000 TEU	Number of vessels
1	Greece	380,281	2,161	4,850
2	Germany	95,511	4,394	2,790
3	Italy	48,043	1,403	1,100
4	Denmark	45,745	2,446	927
5	Belgium	28,103	80	247
6	France	15,964	1,154	313
7	Netherlands	11,542	264	873
8	Sweden	6,462	11	293
9	Cyprus	5,209	55	153
10	Spain	3,204	10	194
11	Poland	2,549	8	110
12	Croatia	2,446	-	82
13	Finland	1,949	11	103
14	Ireland	1,734	10	98
15	Bulgaria	1,572	3	72
16	Portugal	1,213	7	42
17	Romania	898	16	85
18	Malta	828	-	46
19	Luxembourg	759	-	9
20	Estonia	388	15	82
21	Latvia	245	9	48
22	Lithuania	213	9	49
23	Austria	39	3	5
24	Slovenia	8	-	3
	Total	**654,905**	**12,069**	**12,574**

Source: ISL (2019) 'Shipping statistics and market review 2019'.

The Euro-maritime website provides anoverview of the shipping companies per EU country. It should be noted that the term shipping companies is defined rather broadly. Besides companies owning vessels larger than 1,000 GT (as presented in the table above), the list also includes tug operators, dredging companies and other shipping companies. Figure 2.2 presents the main countries; no data were included for Hungary and Luxembourg.

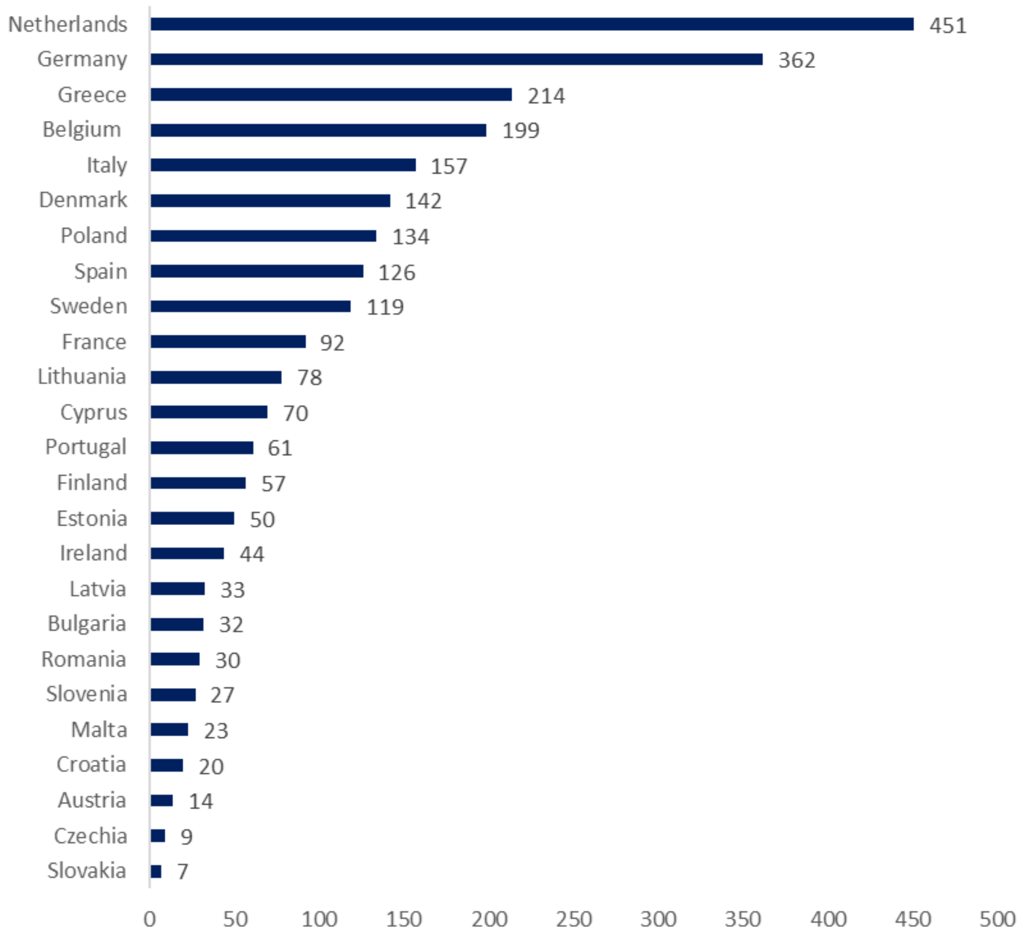

Figure 2.2 Number of shipping companies per EU country (2020)

Source: https://www.euro-maritime.com/index.php/shipping-directory/shippingcompanies

2.3.2. The current position of shipping carriers calling EU ports

In order to assess the current and future competitive position of shipping carriers calling EU ports, it is important to distinguish between several sub-segments as each segment has a different competitive position and will be influenced differently by the legal initiative. Therefore, we distinguish between intra-continental freight transport, intra-continental container transport, short sea shipping, cruise vessels, ferries and vessels operating in or near the port area.

For each of these segments, the current competitive position is described.

Intra-continental freight transport

Intra-continental freight transport[10] refers to different types of cargo, i.e. coal transport between South America and Europe, or oil transport between the Middle-East and Europe. One of the main characteristics of this type of transport is that the goods have Europe as a final destination. Under all conditions, the goods need to be delivered somewhere in Europe. As the goods are often voluminous and the quantities shipped are

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10 In this case only the origin or destination lies within the EU, while the other end of the journey lies outside the EU.

large, it is difficult to opt for a transport mode other than maritime transport. Not only is the capacity on other modes limited, the alternative options are often too expensive to compete with maritime transport. In addition, these commodities often do require dedicated infrastructure in ports, which is not always available everywhere. Especially hinterland pipeline connections can only be found in some European ports. The commodities are therefore captive, meaning that they are not able to shift easily between different ports. It also means that small price increases do not lead to different choices in the logistical chain.

As a result, the market position of intra-continental freight transport is rather steady and changes in the position result mainly from more general supply and demand of goods shipped to Europe.

Intra-continental container transport

A second important category is intra-continental container transport, for example, from China to Europe. Similarly in this market, Europe is often the final destination of the cargo. However, compared to intra-continental freight transport, the container market is more volatile and containers are easier to reroute. Many ports offer the possibility to load and unload container vessels.

Although maritime shipping is often the cheapest option for transporting containers, especially compared to air and rail transport, containers can be brought easier to a nearby non-EU port (e.g. in North-Africa) where containers are then loaded on smaller vessels that will distribute the containers to European ports. This would mean that larger container vessels are less likely to call in European ports. One barrier for changing port of call might be the fairway conditions[11] as not all ports can accommodate the largest of container vessels. Whether or not this will actually happen depends on the cost impact the chosen policy option will have on transport costs and freight rates.

Short sea shipping

Short sea shipping (SSS) refers to short distance sea transport. This could either be from one European port to another or to/from an European port to/from a port located in the Baltic area (Russia), the Black Sea area (e.g. Georgia and Ukraine) and the Mediterranean area (e.g. Morocco and Libya).[12] SSS is in competition with other transport modalities, such as road transport, rail transport and transport through pipes.[13] At the time of the introduction of the SOx Emission Control Areas, several studies forecasted a potential modal backshift from sea to land, due to the higher prices of MGO compared to HFO. However, such transition did not materialized.[14]

If the availability of the zero-carbon fuels is unreliable, the service quality of SSS will be negatively impacted. If fuel costs, and consequently, freight rates, increase

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[11] The fairway is the entrance to the actual port. In some cases, the fairway is short and deep, while in other cases the fairway is long and depth is restricted. For example, the guaranteed fairway depth leading to the port area of the port of Rotterdam is 23 to 24 metres, while the guaranteed fairway depth leading to the port area of the port of Antwerp is 15 metres.

[12] See definition used by Eurostat: https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Short_sea_shipping_(SSS).

[13] DG MOVE, COWI (2015) – analysis of trends in EU shipping and analysis and policy support to improve the competitiveness of short sea shipping in the EU.

[14] Holgrem et al (2014). Modelling modal choice effects of regulation on low-sulphur marine fuels in Northern Europe. Transportation Research Part D: Transport and Environment, 28, 62–73 and Notteboom (2011). The impact of low sulphur fuel requirements in shipping on the competitiveness of roro shipping in Northern Europe. WMU Journal of Maritime Affairs, 10(1), 63–95.

simultaneously, a shift from sea to land may be expected. This is under the assumption that no other specific policy measure for road transport will be taken, which is unlikely.

Cruise shipping

A fourth important market is the cruising industry. In 2019, around 30 million people worldwide undertook a cruise journey.[15] Most popular destinations are the Caribbean (34.4%), followed by Europe (28.4%) and Asia (9.2%). Within Europe, the share of cruises in the Mediterranean is higher than that of other cruises, particularly to Norway and the Baltic Sea. Compared to earlier years, both the Caribbean and European destinations have lost some of their market share to Asian destinations. In 2014, the market share of Caribbean destinations was 37.3% and that of European destinations was 30%. Asian destinations attracted 4.4.%.

Important trends in the cruising industry are related to experiences and achievements[16] of the passengers. Cruise passengers prefer to take trips where they can visit 'must see' areas, including historic cities and heritage sites, and where they can have unique experiences.[17] In addition, the traditional cruise season is extending. Traditionally, the peak time in the European cruise season was during summer, where passengers could enjoy the warmer weather and touristic destinations. More recently, the winter season has also become increasingly attractive, especially the Christmas period, with different lighting festivals. As a result, the cruise product has broadened and become more popular. Competition between regions does change, however the European market share (see above) seems to be less affected than, for instance, the Caribbean market, as especially the Mediterranean has a unique offer as cruising destination.

Ferries

The ferry market can compete, similar to short sea shipping, with other modes of transport. Depending on the location of the ferry, the ferry line might compete with airlines. For some ferry services, especially those between mainland Europe and Ireland / UK, competition from airlines might be an issue as rather cheap flights are offered to those destinations as well. In case of changes in the price of a ferry ticket, passengers might opt for a flight instead of a ferry journey, which in turn might lead to changes in the competitive position of ferry operators. In other European areas, ferries can be the only way to access an island. Especially in Greece, a ferry is often the only option the traveller has. As a result, a price increase will have a lesser impact on the ferry service as the traveller needs to take the ferry in any case to reach the desired destination.

Vessels operating in or near a port

Vessels operating in or close to a port are, for example, tugs and tow boats, pilot vessels and work boats. The majority of these vessels do have a direct link with the port in which they are active and are therefore not in direct competition with their counterparts in other (European) ports. However, their position might change when activities in their port change. For instance, when fewer vessels do call in to port, there is less need of tug boats, as the demand for their services drops. This category of vessels is linked to other parts of the maritime industry. When changes occur in those parts, the vessels operating in or near the port area can be affected as well.

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15 CLIA (2020), 2020 State of the cruise industry and outlook.

16 Achievements are seen as actions on someone's bucket list, such as climbing Machu Picchu.

17 See CLIA (2020) '2019 Cruise trends & industry outlook' and Santos, M., Radicchi, E. and Zagnoli, P. (2019) 'Port's Role as a Determinant of Cruise Destination Socio-Economic Sustainability'.

2.3.3. The current position of the European shipbuilding industry

The competitive position of the European shipbuilding industry has been under pressure for several decades.[18] Following the second world war, European shipyards were the leading yards in the world, but since the 1950's Asian yards gradually took over the market and have become important market players. Despite the fact that the European orderbook measured in million CGT is moderate, the value of the ordered newbuilt ships is high. By the end of 2019, the value of the European orderbook amounted to almost $80 US billion.[19] Worldwide the value of the orderbook amounts to approximately $235 US billion. The EU share equals 34% and chiefly originates from orders for passenger vessels and other non-cargo carrying (ONCC) vessels. Such vessels are more complex to build.

As a result of increased competition and specialisation at East-Asian yards, European yards also became more specialised. Nowadays, the main focus of European yards is on highly specialised and complex vessels, such as vessels used in the offshore industry, arctic shipping and dredging vessels. In addition, European yards still have a competitive advantage in building cruise vessels, with several large yards located in Finland, France, Germany and Italy.

A recent study published by the European Commission shows that the economic importance of the European shipbuilding industry, including repair activities, has increased.[20] The gross value added (GVA) of the shipbuilding and repair industry amounted to € 12.8 billion in 2009. In 2017, the GVA increased to € 14.8 billion. This equals a 15.6% increase in GVA. The gross profit increased further, from € 2 billion in 2009 to € 3.6 billion in 2017. This equals a 75.9% increase. The study also shows that it is likely that the positive trend will continue. The profits and number of jobs in the sector for new build vessels and floating structures are likely to increase. The same goes for yards active in ship repair and ship maintenance.

2.3.4. The current position of the European marine equipment industry

The initiative to accelerate the uptake of renewable and low-carbon maritime fuels mainly impacts the engine manufacture and manufacture of propulsion systems (e.g. power trains). Other parts of the marine equipment industry are not at all, or to a far lesser extent, impacted. For example, the producers of radar equipment or ballast water management system do not seem to be impacted by this initiative. Therefore, the analysis focuses on engine manufacturers and manufacturers of propulsion systems (from now on referred to engine manufacturers).

The production of engines is the largest sub-market within the overall marine equipment industry. The total production value of the engine manufacturers in Europe is about 18% of the total production value of the European marine equipment industry.[21] Measured in number of enterprises, about 13% of all marine equipment suppliers are involved in the production of engines.

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18 See for example Ecorys (2009) 'Study on Competitiveness of the European Shipbuilding Industry' and Ecorys and CE Delft (2012), Green growth opportunities in the EU shipbuilding sector.

19 SeaEurope (2020) Annual report 2019.

20 European Commission (2020) The Blue Economy Report 2019.

21 BalanceTechnology (2014) Competitive position of European marine supply industry.

The market for marine engines consists of only a few key players, who are mainly based in Europe and North-America. The market for engines is structured as follows:

- Low-speed marine diesel engines: major players are MAN, Wärtsilä, and Mitsubishi Heavy Industries;
- Medium-speed marine diesel engines: major players are Wärtsilä, MAN, and Caterpillar and in 2017, they held a combined market share of 86%;
- High-speed marine diesel engines: major payers are MTU, Deutz, MWM, SACM, Pielstick, Ruston, and Paxman.

In China, marine diesel engines are mainly produced through patent licensing by MAN, Wärtsilä and MTU.[22]

The above overview shows that the current market is served by a limited number for larger companies. As many marine equipment companies do not solely work for the shipbuilding industry (e.g. engine manufacturers including Rolls Royce, MAN, Wärtsilä all serve other markets such as land transport, power stations, etc.), they have the ability to make use of knowledge gathered in other industries and transfer this to the shipbuilding industry.[23] For example, experiences with alternative fuels in land-based transport can be transferred to the maritime sector as well. They are able to create spill-over effects. This will strengthen their position on the engine market, also in the development of engines suitable for alternative fuels. It seems unlikely that new players will enter the market as the research and development effort to develop engines suitable for alternative fuels is high and the capital needed to develop and produce such engines is high as well. In addition, engine buyers have a strong preference for products of known market players and will not easily switch to the product of a newcomer.

2.3.5. The current position of the fuel suppliers and bunkering facilities

The last group of stakeholders that will be impacted by the legal initiative are the fuel suppliers and bunker facilities. Current fuel suppliers are the refineries that actually produce the fuels. Often these refineries are part of the global oil companies, such as Shell, Total and BP. As the majority of marine fuels is still fossil fuel, these oil companies and their refineries are the main suppliers. These companies extend the products offered and are currently also producing biofuels. In addition, some of them are taking steps to produce LNG.

There are 72 refineries located within the European Union (see Figure 2.3).[24] Each refinery produces a mix of fuels for different transport modes. Rough estimations show that about 5% of all fuels produced by these refineries is produced for the maritime sector. These 72 refineries have a joint capacity to produce 598.4 million tonnes per year. On average, around 30 million tonnes is produced for the maritime sector. This amount is not only consumed in Europe. Europe is producing more marine fuels than is required and as a result, is a net exporting market for marine fuels.

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22 https://www.researchandmarkets.com/research/rhflcv/global_marine?w=5.

23 CE Delft (2012), Green growth opportunities in the EU shipbuilding sector.

24 FuelsEurope (2020) Statistical report 2020.

COUNTRY	Number of refineries	COUNTRY	Number of refineries
Austria	1	Ireland	1
Belgium	3	Italy	10
Bulgaria	1	Lithuania	1
Croatia	2	Netherlands	5
Czechia	2	Poland	2
Denmark	2	Portugal	2
Finland	2	Romania	3
France	7	Slovakia	1
Germany	11	Spain	8
Greece	4	Sweden	3
Hungary	1	United Kingdom	6
EU TOTAL: Refineries = 78			
Norway	2		
Switzerland	1		
TOTAL NO + CH: Refineries = 3			
TOTAL: Refineries = 81			

Figure 2.3 Number of refineries in Europe (2019)

Source: FuelsEurope (2020) Statistical report 2020.

The bunker facility market is organised in a different way. Where the number of fuel suppliers is highly concentrated with several large global players, the market for bunker facility companies is highly fragmented. Most companies only have a few vessels they can use to deliver the fuel to the vessels. In some cases, a company owns a single vessel and is only active in one port. Due to the small size of the bunker facility companies, their investment potential is limited. Rough estimations show that initial investments for a bunker vessel delivering fossil fuel are around USD 4 million or € 3.5 million. However, the investment costs for a vessel to deliver LNG as fuel are much higher. Estimations are that the price is about four to five times the price of a traditional bunkering vessel.

3. Problem definition

3.1. Problem definition

Ships in the scope of the EU MRV emitted 142 Mt CO_2 in 2018 and 145 Mt in 2019 (EMSA, 2020).[25] These are cargo and passenger ships over 5000 GT on voyages to and from EEA ports (including in 2018 and 2019 the UK), as well as at berth in an EEA port. Taking into account that there are ships below 5000 GT as well as ship types that are not in the scope of the EU MRV, it has been estimated that the emissions of ships sailing to and from EEA ports are about 10% higher (EC 2020).

The total CO_2 emissions of the 28 EU Member States in 2018 amounted to 3598 Mt, excluding international shipping but including international aviation (EEA Greenhouse Gas Data Viewer). Hence, shipping emissions accounted for 3.8% of total emissions including shipping in 2018.

The European Green Deal and the 2030 Climate Target Plan aim to reduce GHG emissions by at least 55% in 2030, relative to 1990, and achieve climate neutrality in 2050. All sectors should contribute to this target, including maritime transport. Because the scope for additional energy-efficiency improvements in shipping is limited, a transition from fossil fuels to renewable and low-carbon fuels is required for maritime transport to contribute to the goals of the Green deal.

Marginal abatement cost curves (MACC) of maritime transport indicate how the maritime sector could reduce its emissions and what the associated costs are. We are not aware of recently published MAC curves for the EU or EEA fleet, but two MACCs have been published for the UK international fleet (i.e. ships calling at UK ports on international voyages) and the world fleet. Both have been developed using different techno-economic assessments of measures so they present a range of marginal abatement costs. The two MACCs are presented in Table 3. and Figure 3.1, respectively. Table 3.1 shows that energy-efficiency options are more cost-effective than renewable fuel options. In this analysis, all options except for solar panels are more cost-effective than renewable fuels. Figure 3.1 distinguishes between several groups of emission reduction technologies, indicated by different colours. The grey data points indicate renewable fuels; the orange and yellow data points energy-efficiency options and slow steaming, respectively. Although the cost-effectiveness of individual options is different in both analyses, they both indicate that, in general, energy-efficiency improvements and slow steaming are cheaper than renewable fuels. The two analyses show that efficiency improvements in the order of 20% - 30% are possible and are more cost-effective in reducing CO_2 emissions than using renewable fuels.

The cost-effectiveness of using of renewable fuels is estimated to range from USD 260 – 420 per tonne of CO_2 in the global analysis and from GBP 100 – 220 per tonne of CO_2 in the UK analysis. This report presents values of a similar order of magnitude in Section 3.1.3.

Table 3.1 Marginal Abatement Costs of technologies for the global fleet, 2030

Technology group	MAC (USD/tonne-CO_2)	CO_2 abatement potential (%)
Optimization water flow hull openings	-119	1.64%
Steam plant improvements	-111	1.30%

25 The emissions in 2018 have been published in SWD(2020) 82 final. The emissions in 2019 have been retrieved from the database version 103, dated 24 November 2020.

Technology group	MAC (USD/tonne-CO_2)	CO_2 abatement potential (%)
Propeller maintenance	-102	2.20%
Hull maintenance	-92	2.22%
Reduced auxiliary power usage	-61	0.40%
Hull coating	-53	1.48%
Auxiliary systems	-41	0.87%
Main engine improvements	-35	0.25%
Wind power	6	0.89%
Speed reduction	17	7.38%
Propeller improvements	21	1.40%
Super light ship	54	0.28%
Waste heat recovery	69	1.68%
Air lubrication	105	1.35%
Use of alternative fuel with carbons	258	5.54%
Use of alternative fuel without carbons	416	0.10%
Solar panels	1,186	0.18%

Source: Fourth IMO GHG Study.

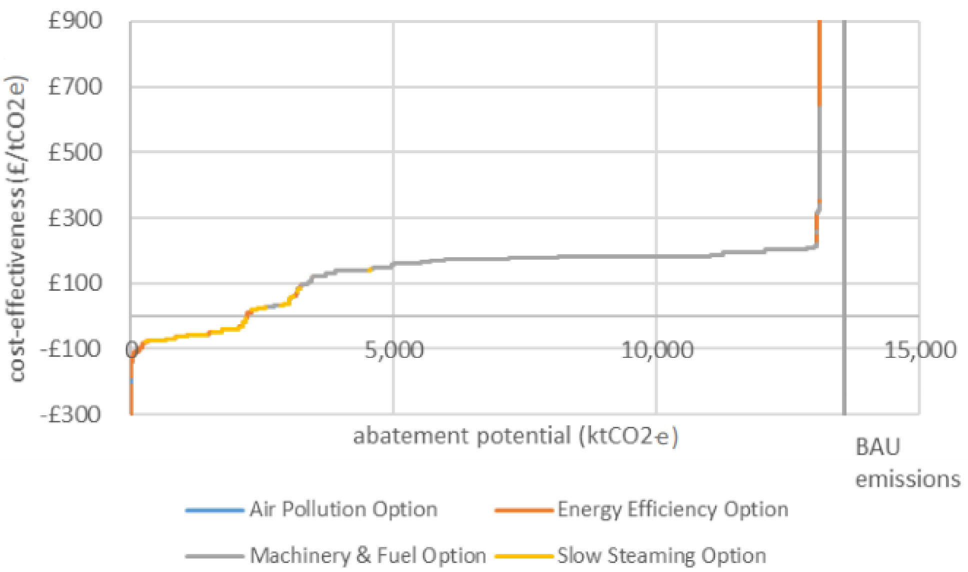

Figure 3.1 Marginal Abatement Cost Curve for UK International shipping, 2030

Source: UMAS, CE Delft, E4Tech and Frontier Economics, 2019

First, if the instrument to address GHG emissions from shipping is a financial incentive, it will not result in a transition to renewable fuels unless the projections are that the prices will rise to several hundred euros per tonne of CO_2, in order to account for higher fuel costs as well as the risks involved in switching to non-standard fuels. This means that including shipping in the EU ETS will not result in a fuel transition in the coming decade, because allowance prices have been between EUR 20 and 30 for most of 2020[26] and are projected to increase to EUR 32 – 65 when the EU Climate Target Plan is implemented.[27] (The fact that biofuels are sold to ships in the Port of Rotterdam can be explained by the

[26] Ember Climate, https://ember-climate.org/data/carbon-price-viewer/, accessed 26 November 2020.

[27] SWD(2020) 176 final, table 10.

opt-in of maritime fuels in the RED in The Netherlands, which apparently results in carbon shadow prices in excess of the EU ETS prices).

Second, that a policy that results in the uptake of alternative fuels will result in an efficiency improvement of ships, because it results in an increase in the average fuel price and therefore makes energy-efficiency options more cost-effective. Moreover, as Hicks (1932) pointed out, innovation is often aimed at reducing the input factor which has increased in price.

As a consequence, the low uptake of renewable and low-carbon fuels and power by ships calling at EU ports is a problem that needs to be addressed in order to achieve the goals of the European Green Deal on top of addressing GHG emissions reduction coming from technical or operational energy efficiency improvements. Because of the different technical options to address this problem and because of the impact of emissions at berth on air quality in port cities, the issue can be broken down in two problems:

1. A low uptake of renewable and low-carbon fuels and power by ships calling at EU ports in navigation; and
2. A low uptake of zero-pollution fuels and power by ships at berth in EU ports.

These problems have five drivers:

1. Lack of predictability of the regulatory framework and high risk of investment choices (high risk of stranded assets);
2. Low maturity of new renewable and low-carbon fuels/technologies with high risk for first movers;
3. Higher costs of renewable and low-carbon fuels compared to fossil fuels (also due to insufficient economies of scale);
4. High interdependency with supply and distribution (chicken-and-egg problem); and
5. Possibility of bunkering outside EU or the replacement of demand for RLFs from other sectors (risk of carbon leakage).

A problem tree is shown in Figure 3.2.

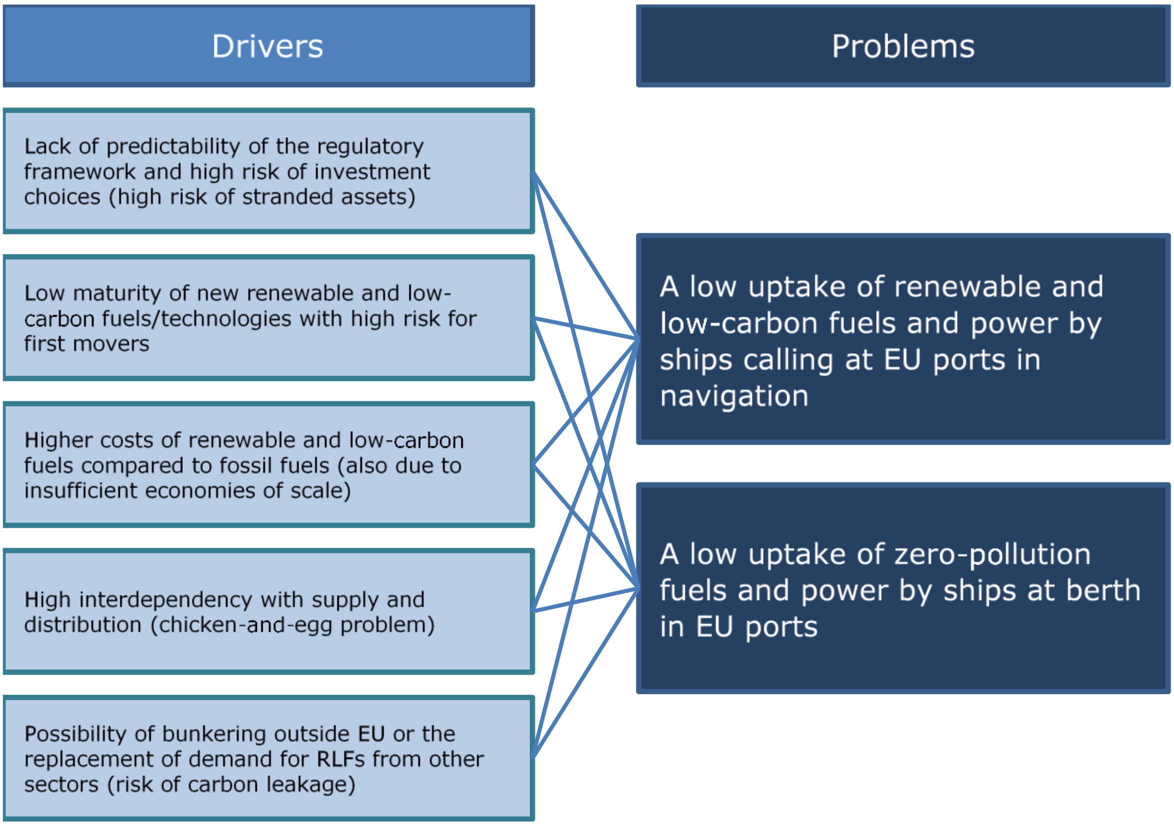

Figure 3.2 Problem tree

Each of these drivers is described in detail in the following sections.

3.1.1. Lack of predictability of the regulatory framework (long lifetime of ships) and high risk of investment choices (high risk of stranded assets)

The average ship in the scope of the EU MRV in 2018 was 11 years old which is relatively young compared to the 20.5 years of the average ship globally (EC 2020). There are significant differences between ship types, which passenger ships and RoPax vessels being the oldest vessels, on average, in the EU.

Ships have a lifetime of several decades. Depending on the ship type the average demolition age between 2005 and 2018 varies between 23 to 45 years (Table 3.2). Ships may not operate their entire life in the same geographical area, as suggested by the difference in the average age of the European and the global fleet.

Table 3.2 Average demolition age between 2005 and 2018

Ship type	Average age at demolition
Bulkers	29
Chemical tankers	29
Combos	25
Containerships	26
Crude tankers	23
Cruise ships	45
Dredgers	39
Ferries	39
General cargo ship	36
LNG tanker	38
LPG tanker	30
Multi-Purpose Vessel	29

Ship type	Average age at demolition
Offshore vessel	35
Oil tanker	28
Other non-cargo ship	39
Pure car carriers	29
Product tanker	30
Reefers	31
Ro-Ro ship	31
Special tankers	33
Tugs	43

Source: CE Delft analysis of Clarkson Research Portal, 2020.

The long lifetime of ships means that fuel and design choices made now will have an impact for several decades. Ships designed to sail on conventional fossil fuels may switch to drop-in fuels like biofuels and biodiesel during their lifetime, but it is harder to switch to methanol and even more expensive to switch to gaseous fuels like liquefied methane and ammonia. This matters because ammonia is amongst the cheapest e-fuels, cheaper than drop-in e-fuels.

When a ship owner decides to order a new ship which is able to run on an alternative fuel, he should already consider which type of fuel and corresponding technology is most suitable during the entire lifetime of the ship. The fuel and engine system of a ship are an integral part of the design and are strongly linked to each other. While engines may be renovated, it is very rare for engines to be replaced because in most cases this would require cutting the ship open. A number of dual fuel engines are commercially available which allow for some flexibility on the fuel, e.g. either liquid petroleum fuels or LNG, or MGO/methanol. The design of the fuel system and bunker tanks depends on the fuel type(s) which will be used on board. Petroleum-derived fuels can be stored under atmospheric pressure and normal temperature in bunker tanks on board. Methanol can also be stored under atmospheric pressure and normal temperature, but has a low energy density compared to fossil fuels. This means that larger bunker tanks are required on board or that more bunker operations need to be carried out compared to the use of fossil fuels. In addition, measures need to be taken to avoid the build-up of an explosive methanol-air mixture in the tank. Other alternative fuels such as liquefied natural gas, hydrogen or ammonia need to be stored in liquid or compressed form under pressure and/or at low temperature. Special cryogenic tanks are necessary to store these type of fuels (CE Delft, 2020).

Which fuel and which technology is most suitable depends on several factors such as the ship type itself, the operational profile of the vessel, the propulsion system, the power demand and the fuel availability in the area where the ship will operate. A number of these factors such as the ship type, the operational profile and the power demand will likely have already been determined before the fuel type and technology have to be selected. Other factors such as the region in which the ship will be operated and the fuel availability in that region are not always known before the ship is built and in operation. However, despite the fact that it is difficult to predict how the fuel production, the fuel availability and new technologies will develop on the market in the coming decades, the decision on which fuel types and technologies will be used on board during the complete lifetime of the ship, has to be made before the ship is built.

Currently, internal combustion engines are installed on virtually all self-propelled vessels. Almost all vessels currently use petroleum-derived fuels and this technology has been well established for decades. This implies that if they want to use renewable or low-carbon fuels, they either are restricted to drop-in fuels or have to modify their engines and/or tank and piping.

In addition to the application of alternative fuels in internal combustion engines, research and development is also being conducted into the use of fuel cells and batteries for the propulsion of the ship. Fuel cells and batteries are not yet available in the power ranges typically required for ships; the largest fuel cells are currently a few megawatts, while ship engines are typically tens of megawatts.

The costs of modifying the fuel system of a ship can be large. An example of a modified ship is the Stena Germanica, a methanol fuelled ferry which operates between Gothenburg (Sweden) and Kiel (Germany). It was the first ship in the world running on methanol. The ferry was converted to run on methanol and modifications were done to the bunkering line, tanks, pump room, pumps, piping and automation system. The existing fuel tanks and part of the ballast tanks were converted into methanol tanks, enabling no loss of commercial space for the ferry. Although the conversion from HFO to methanol is relatively simple, the costs for the modification amounted €13 million, part of which was funded by the EU. (The newbuilding costs of this ship have not been disclosed; a new RoPax vessel may cost between € 35 and 230 million, depending on the size, speed, and accommodation (Bilen *et al*., 2018)[28]).

In sum, the regulatory framework determines the fuel choice of new ships. Uncertainty about the changes to the regulatory framework may result in more dual-fuel engines being installed, and while this would improve the versatility of the fleet, it would probably also mean that the cheapest zero-carbon e-fuels, ammonia and hydrogen, cannot be used on these ships.

3.1.2. Low maturity of new sustainable alternative fuels/technologies with high risk for first movers[29]

Low maturity of new sustainable alternative fuels/technologies with high risk for first movers

The value chain of bunker fuels consists of roughly five stages: production, storage in port, bunkering, storage and energy conversion on board ships, with transport/distribution infrastructure linking these different stages. Each stage is highly technology dependent and is still mainly aimed at conventional fossil bunker fuels. The introduction of an alternative, non-drop-in fuel would require adaptation in practically all stages. The level of maturity of the value chains of the new sustainable alternative bunker fuels thus plays an important role in the uptake of the fuels by the sector, with first movers being exposed to the potential risk of technical failure and/or availability shortfalls.

In the following, we will briefly describe the level of maturity of the value chains of the following (potential) bunker fuel types:

- hydrogen;
- methane;

[28] Ümran Bilen et al., 2018, Market Analysis, Deliverable 1.1 of the Project Holistic Optimisation of Ship Design and Operation for Life Cycle, https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5b85b131d&appId=PPGMS).

[29] This section is based on the following sources: https://www.cedelft.eu/en/publications/2431/availability-and-costs-of-liquefied-bio-and-synthetic-methane. https://ceproject.cedelft.eu/projecten/7-M92/Documents/CE_Delft_7M92_Greenhouse_gas_emission_reduction_targets_for_international_shipping.Def.pdf. https://ceproject.cedelft.eu/projecten/200249/Documents/Literatuur/2020_MKC-TNO-TU-Delft_alt-fuels-for-shipping-final-report-310120.pdf.

- ammonia;
- methanol;
- ethanol;
- diesel-like fuels.

The analysis of the supply chain is thereby split into the supply chain after the production of the fuels and the production of the fuels as such. This is to account for the fact that a fuel type can be produced in different ways (e.g. methanol as e-methanol or as biomethanol), but once produced does only require one type of infrastructure in the rest of the supply chain.

The maturity levels of the fuels' supply chains are subsequently visually summarised.

Maturity level – supply chain of fuels after production

General aspects

The six (potential) bunker fuel types analysed can, in principle, either be used in internal combustion engines or in fuel cells, since methane, ammonia, methanol, ethanol and diesel are also hydrogen carriers.

Hydrogen, methane and ammonia are gaseous and methanol, ethanol, and diesel-like fuels liquid at ambient temperature. Gaseous fuels need to be liquefied to be used in internal combustion engines, whereas liquid fuels to be evaporated for use in fuel cells.

The energy density (in terms of MJ/litre) of the different alternative bunker fuels is lower compared to conventional liquid bunker fuels. Hydrogen, methane and ammonia need to be liquefied and/or compressed to reduce storage space on board ships.

Hydrogen

Due to its low energy density, hydrogen needs to be liquefied and/or compressed to be stored as fuel on board ships. Compressed gaseous hydrogen requires more space than liquid hydrogen, and both options require significantly more space per unit of energy compared to conventional fuels. Storage of compressed hydrogen is an established market ashore. The small number of ships (inland ferries) that have used hydrogen so far used pressurized tanks, but concepts for (inland) shipping can still be considered under development (e.g. NPROXX (n.d.)).[30] Liquefaction of hydrogen is an energy intensive process, since hydrogen has a boiling point of -253°C which is even lower than the boiling point of methane (-162°C). Liquefied hydrogen has to be stored in cryogenic tanks. There is some experience with cryogenic storage of liquefied hydrogen, but it was so far reserved for certain special applications, in high-tech areas such as space travel (Air Liquide, n.d.).[31] A first hydrogen carrier is however currently being built as part of the HySTRA demonstration project. The vacuum insulated storage tank has been installed beginning 2020 and the ship is expected to be ready for testing in 2021.

At this stage, there are no hydrogen-fuelled internal combustion engines available for ships and the technology readiness level of hydrogen marine internal combustion engines can be considered the lowest compared to the other alternative fuels. Hydrogen is however the prime candidate when it comes to fuel cells. Due to the high efficiency of fuel cells, the storage space required for hydrogen onboard tanks might be less than for comparable ships equipped with an ICE and thus might allow hydrogen to be applied to

30 https://www.nproxx.com/hydrogen-powered-heavy-duty-vehicles/shipping-maritime/.

31 https://energies.airliquide.com/resources-planet-hydrogen/how-hydrogen-stored.

more ships, but the size of the fuel cells, might prevent fuel cells to be used by large ships. And both the lifetime of fuel cells in non-stationary applications and the costs of the fuel cells are still a major issue.

A few (demonstration) projects with hydrogen-fuelled ferries, cruise ships and workships have been announced,[32] all of which applying fuel cells and some of which working with liquid hydrogen onboard storage systems.

Hydrogen bunker facilities are not available yet and are still under development. A design for a liquefied hydrogen bunker vessel has been developed (Wilhelmsen, 2019),[33] but an actual vessel has not been built yet. Containerized pressure vessels which could be loaded and unloaded in ports could also be an option, at least for smaller vessels. This is considered a more advanced option.

Since carriage of liquid hydrogen by trucks is an established technology, truck-to-ship bunkering is also considered (SWZ Marine, 2020).[34] Here you could also build on the experience gained from truck-to-ship LNG bunkering, but the volume of hydrogen that can be bunkered with this technology is limited.

Methane

Renewable methane can highly rely on the existing technologies and infrastructure of natural gas, which mainly consists of methane. Methane can be transported in both gaseous and liquid form: it can be injected into the gas grid or, after liquefaction, be transported by ships or trucks. Locations with favourable conditions for the production of renewable methane (in terms of inputs) are not as a rule close to a gas grid, which might make transport by ships or trucks necessary. Since methane-fuelled ships equipped with an internal combustion engine require methane to be stored as a liquid anyway, liquefaction of methane is an inevitable part of the supply chain. Liquefaction of methane, which has a low boiling point (-162°C), is an energy intensive process and therefore costly, but can be considered a fully mature process.

LNG bunkering infrastructure is technically mature and commercially available, although still limited in capacity compared to traditional fuels.

LNG-fuelled ship systems and engines can be considered technically mature and are commercially available. As of mid-September 2020, on a global basis, 584 LNG-capable and 203 LNG-ready vessels were in the fleet and 368 LNG-capable and 52 LNG-ready vessels had been ordered (Clarksons Research, 2020).[35]

Ammonia

Ammonia is currently not used as marine bunker fuel at all. Fossil ammonia is however transported by tankers as cargo. This means that there is knowledge about and experience with the storage of ammonia both on board and ashore as well as with the handling of ammonia.

32 HySEAS III, NORLED's hydrogen fuelled ferry, Havila's hydrogen fuelled cruise ship, Ulstein's construction support vessel.

33 https://www.wilhelmsen.com/media-news-and-events/press-releases/2019/new-design-makes-liquefied-hydrogen-bunker-vessels-a-reality/.

34 https://www.swzmaritime.nl/news/2020/09/09/bunkering-facility-not-a-must-to-get-liquid-hydrogen-on-board-a-ship/?gdpr=accept

35 LNG-capable ships are ships that can be LNG-fuelled. LNG-ready ships can relatively easily be converted to LNG-capable ships.
Shipping Market Overview, September 2020.

To reduce storage space, ammonia will have to be stored as liquid ammonia on board ships. Ammonia has, compared to hydrogen, the advantage that its boiling point is relatively high (around -33.40°C) which means that it can become liquid at relative low pressure and does not require cryogenic storage. Pressurised storage tanks can be used instead. Disadvantage is that tanks of fully-pressurised ships are extremely heavy. If transported as cargo, large quantities of ammonia are therefore transported by fully-refrigerated gas carriers.[36] For the transport of hydrogen, its conversion to ammonia is discussed in the literature.

Ammonia can cause severe skin burns and eye damage, is toxic if inhaled (ECHA, 2020) and can be lethal to humans at 2,700 ppm when exposed for a duration of 10 minutes (Vries, 2019) it is also very toxic to aquatic life (ECHA, 2020). The use of ammonia as marine fuel thus requires careful management of these risks.

A marine internal combustion engine for ammonia is not available yet, but the development of a two-stroke dual fuel ammonia engine is estimated to take two to three years (MAN, 2018).[37] The actual development of the engine would however only be started if a market for the engine developed (MAN, 2018). In addition, Wärtsilä announced (Wärtsilä, 2020)[38] that in the first quarter of 2021, a consortium will commence a long-term, full-scale laboratory test using ammonia as a fuel in a marine four-stroke combustion engine. When ammonia is used in internal combustion engines, increased NOx emissions might require the use of aftertreatment technologies.

Concept designs for ammonia-fuelled ships with an ammonia internal combustion engine have been and are being developed[39] and it has recently been announced that an offshore vessel will be retrofitted with an ammonia fuel-cell as part of a demonstration project (Equinor, 2020)[40].

Methanol

Methanol is liquid at ambient temperature and is therefore associated with relative low transportation and storage costs compared to hydrogen, methane, and ammonia. Its energy density is also higher than for liquid ammonia and liquid hydrogen, but lower than for liquid methane, ethanol and conventional liquid bunker fuels.

Currently, a small number of ships are operating on methanol worldwide (Methanol Institute, 2020)[41] and methanol dual-fuel internal combustion engines can be considered a proven technology.[42] It has also been demonstrated that a ship and its engines can be retrofitted to operate on methanol. Methanol's very low viscosity, its poor lubrication and its corrosiveness towards certain metals have thereby to be accounted for.

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36 https://www.wartsila.com/encyclopedia/term/gas-carrier-types.

37 Ship Operation Using LPG and Ammonia As Fuel on MAN B&W Dual Fuel ME-LGIP Engines: Using low carbon ammonia fuel.

38 https://www.wartsila.com/media/news/30-06-2020-world-s-first-full-scale-ammonia-engine-test---an-important-step-towards-carbon-free-shipping-2737809.

39 https://www.ammoniaenergy.org/articles/ammonia-fueled-ships-entering-the-design-phase/.

40 https://www.fch.europa.eu/press-releases/major-project-convert-offshore-vessel-run-ammonia-powered-fuel-cell.

41 https://www.methanol.org/marine-fuel/.

42 Spark ignited engines running on100% methanol are also being tested: https://greenmaritimemethanol.nl/green-maritime-methanol-consortium-starts-engine-test-programme/.

Methanol fuel cells have been tested on marine ships in a small number of projects (Pa-X-ell project, METHAPU project) and the concept is used on a structural basis on a small inland passenger ferry (MS Innogy) only.

There is hardly any methanol bunkering infrastructure available in ports and ships that are currently methanol-fuelled are either methanol carriers using their cargo as fuel or ships that make use of tank-to-ship bunkering. Lloyd's Register has however developed different methanol bunkering guidelines (Methanol Institute, 2020a)[43] and since fossil methanol is traded on a large scale worldwide, onshore storage and methanol handling can be considered proven technologies/processes. According to the Methanol Institute (2020b), fossil methanol is available in over a 100 ports today.

Ethanol

Compared to methanol, ethanol has a higher energy density and is less toxic. A 2-stroke dual-fuel marine engine, which allows the use of ethanol is commercially available, but to our knowledge there is currently no ethanol-fuelled ship in operation or has been ordered. According to SSPA and LR EMEA (2016),[44] the fossil ethanol price has consistently been higher than the fossil methanol price. This might explain why the use of ethanol has been less attractive and why ethanol has not been tested in demonstration projects on maritime ships so far. The design of an ethanol-fuelled ship can however be expected to be similar to a methanol-fuelled ship, due to the similarities in the properties of the two alcohols. According to A.P. Møller-Mærsk and Lloyd's Register (2019)[45] Maersk and Lloyd's Register (2019), ethanol and methanol is fully mixable in a vessel's bunker tanks, which would allow for fuel flexibility.

In road transportation, blends of bioethanol and gasoline are already common practice and (bio)ethanol is transported by chemical tankers on a large scale. Onshore storage and ethanol handling can therefore be considered proven technologies/processes.

Diesel-like fuels

There are different diesel-like alternative fuels, like for example e-diesel, biodiesel (FAME), renewable diesel (HVO) or advanced liquid biofuels. These fuels can, to a certain degree, be blended into the conventional liquid fossil bunker fuels or can fully replace them.

FAME and HVO are miscible with marine distillate fuel (Oak Ridge National Laboratory, et al., 2018).[46] HVO can replace MGO (DNV GL, 2018) and FAME can be blended into MGO without adjustments to the engines. ISO 8217:2017 currently allows up to 7% of FAME to be blended into marine distillate fuels. Straight vegetable oil (SVO) can substitute HFO (DNV GL, 2018), but cannot, just as FAME, be produced as an advanced, second generation biofuel.

Second generation liquid biofuels that are miscible with marine distillate fuels are renewable diesel (advanced HVO), Fischer-Tropsch-diesel, upgraded pyrolysis oil (hydrogenated pyrolysis oil) or upgraded bio-oil from hydrothermal liquefaction of biomass.

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43 .https://www.methanol.org/marine-fuel/

44 https://eibip.eu/wp-content/uploads/2018/01/Study-on-the-use-of-ethyl-and-methyl-alcohol-as-alternative-fuels.pdf.

45 https://www.maersk.com/news/articles/2019/10/24/alcohol-biomethane-and-ammonia-are-the-best-positioned-fuels-to-reach-zero-net-emissions.

46 https://info.ornl.gov/sites/publications/files/Pub120597.pdf.

These fuels thus have the advantage that, after production, they can use the existing infrastructure in the rest of the supply chain or only require minor modifications to the infrastructure.

Summary

Table 3.3 visually summarises the above analysis of the technology readiness levels of the different supply chain stages of the (potential) bunker fuels.

	Storage	Bunkering infrastructure	Onboard energy conversion
Hydrogen			Fuel cells
Ammonia			
Methane			
Methanol			
Ethanol			
Diesel-like fuels			

Fully matured/commercially available at large scale	
Fully matured/commercially available at small scale	
Mature/available at very small scale	
Maturing/could relatively easily be developed based on experience from other sectors	
Immature/demonstration level	
Immature/design level	

The table shows that only for diesel-like fuels the infrastructure is fully mature in each of the stages of the value chain. For hydrogen the infrastructure is the least developed for each of the stages. The maturity of the bunkering infrastructure differs highly between the fuels and is a major barrier to the uptake of the alternative fuels.

Maturity level – production

Regarding the production process, two main categories of alternative fuels can be distinguished:

1. E-fuels, also referred to as Power-to-Gas (PtG)/Power-to-Liquid (PtL) fuels; and
2. Biofuels, liquid or gaseous fuels transport produced from biomass.

Either production pathway or both production pathways are relevant for the six potential bunker fuel types considered here.

The e-fuel pathways have in common that hydrogen, produced by means of water electrolysis using renewable electricity, is required. Independent of the specific fuel type, the upscaling of the hydrogen production and the renewable electricity production are thus key for a wider application of e-fuels.

Biofuels can be produced by means of very different biomass feedstocks and via different conversion routes, depending on the specific biomass used. The bottleneck for a wider application of biofuels are the disclosure of the sustainable feedstock potentials and the advancement and upscaling of the production process of advanced biofuels. Some biofuels (like for example bioethanol) are already used by other sectors (like road transport) which means that the use in shipping might be less attractive due to competition from other sectors.

In the following, the production processes of the different fuel types are discussed in more detail.

Hydrogen

Green or renewable hydrogen can be produced by means of water electrolysis, using freshwater and renewable electricity as inputs. Two main types of electrolysis can be distinguished: low-temperature and high-temperature electrolysis. Two well established technologies for low-temperature electrolysis are Alkaline water electrolysis and Polymer electrolyte membrane (PEM) electrolysis. High-temperature electrolysis (Solid oxide electrolysis) is more efficient than low temperature electrolysis, but requires a constant high-temperature supply, is significantly less dynamic in operation and less mature than low-temperature electrolysis. To date, only about 2-4% of global hydrogen supply is produced via electrolysis (IEA, 2019) (IRENA, 2018).

Ammonia

The synthesis of ammonia via the Haber-Bosch process is a well-established industrial process and is applied on a large scale in the chemical industry today, for example for fertilizer production. The process requires nitrogen and hydrogen as inputs. Nitrogen is thereby gained from air separation and hydrogen is currently typically produced from fossil hydrocarbons, like natural gas or coal. This fossil hydrogen must be replaced by hydrogen from renewable sources (i.e. water electrolysis with renewable electricity) to decarbonise the production of ammonia. An alternative technique for the production of ammonia is the direct Solid State Ammonia Synthesis (SSAS). Ammonia is thereby directly synthesized from a source of hydrogen (water) and nitrogen (air) without intermediate steps. Many variations of this technology are being developed around the world, but there is no SSAS system commercially available today.

Ammonia is not being produced as e-ammonia yet. In Saudi Arabia, however, a plant for e-ammonia production, using wind and solar power, is currently being built to be operational by 2025 (NEOM, 2020). And in some other countries, like for example Australia, New Zealand (AEA, 2020) and Chile (Enaex, 2019), e-ammonia production projects have also been initiated.

Methane

To produce e-methane, a catalytic (thermochemical) methanation process using renewable hydrogen and CO2 as inputs can be applied. The production of renewable hydrogen and CO2 is just as described above. The methanation (Sabatier) process is an exothermic reaction which, next H2 and CO2, does not require additional energy. Instead, waste heat is released which could, for example, be used to extract carbon dioxide from the air.

Globally, very few commercial methanation plants have been built so far, the number of pilot and demonstration plants, however, is rapidly increasing (see Thema, et al., 2019) for an overview).

Essentially, all types of biomass feedstock could be used for the production of biomethane.

There are two main types of conversion routes for the production of biomethane from biomass: anaerobic digestion and gasification.

Gasification systems typically use dry, woody (lignocellulosic) biomass, whereas anaerobic digestion systems use wet feedstock types. However, supercritical water gasifiers can process all types of feedstocks, both woody and non-woody. These gasifiers require wet feedstocks, which means that dry biomass must be mixed with water.

Anaerobic digestion is a collection of processes in which microorganisms break down biomass feedstocks in the absence of oxygen. The feedstocks sometimes undergo a pre-treatment step to increase the moisture content to the required level. The anaerobic digestion processes result in biogas, which is a mixture of methane, carbon dioxide (30-50%), and other gasses such as hydrogen sulphide. In an upgrading step, the carbon dioxide is separated from the (bio)methane.

Gasification is a process in which biomass feedstocks react at high temperatures (> 700°C) with a certain amount of oxygen and/or steam and are converted into syngas (short for synthesis gas), which is a gas mixture that consists mainly of hydrogen and carbon monoxide. In a preceding pre-treatment step biomass is dried and reformed by means of pyrolysis (Sikarwar, et al., 2016). After gasification, gas cleaning and conditioning, the syngas is fed into a methanation process.

Global biomethane production is rapidly growing. According to CEDIGAZ (2019) there were around 1,000 plants beginning of 2019 and global production was around 3 billion cubic meters in 2017 (CEDIGAZ, 2019).[47] The potential global supply of feedstocks for the production of biomethane is confidently higher than the highest estimate of demand of the shipping sector in 2030 as well as 2050 (CE Delft, 2020).[48] Whether the according feedstocks will be used to produce biomethane and whether it would become available for the shipping sectors remains however to be seen.

Methanol

One way to produce methanol is a two-step process: the production of synthesis gas (often referred to a syngas) followed by methanol synthesis. Alternatively, the syngas can also be fermented to directly produce methanol.

Today, syngas is primarily produced using fossil fuels such as coal, oil or natural gas. Alternatively, the syngas could:

- **e-methanol**: be produced via the reverse water-gas shift (RWGS) reaction from e-hydrogen and renewable CO2 or via co-electrolysis in a single step process;
- **bio-methanol**: be produced via gasification of biomass or via anaerobic digestion of biomass with biomethane as intermediate product. Different kinds of biomass feedstock could be used to this end.

In addition, methanol in pulp mill condensates can also be segregated and purified.[49]

Another method to produce e-methanol is the one-step process or direct methanol synthesis. In this process, CO2 is directly converted into methanol and water. This process also requires H2 as an input.

Methanol synthesis from syngas in a well-established process, whereas the RWGS reaction, required for the production of the syngas, is not established for large scale production yet. The co-electrolysis process has been successfully demonstrated,[50] but has also not been applied on a large scale yet. The first European commercial plant to produce e-fuels in Norway is however designed to apply co-electrolysis on a larger scale.[51]

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47 https://www.cedigaz.org/global-biomethane-market-green-gas-goes-global/.

48 https://www.cedelft.eu/en/publications/2431/availability-and-costs-of-liquefied-bio-and-synthetic-methane.

49 https://www.andritz.com/products-en/group/pulp-and-paper/pulp-production/kraft-pulp/evaporation-plants/methanol-plants.

50 https://www.sunfire.de/en/company/news/detail/breakthrough-for-power-to-x-sunfire-puts-first-co-electrolysis-into-operation-and-starts-scaling.

51 https://fuelcellsworks.com/news/norsk-e-fuel-is-planning-europes-first-commercial-plant-for-hydrogen-based-renewable-aviation-fuel-in-norway/.

E-methanol is produced on a small scale in Iceland (Carbon Recycling International) applying the direct methanol synthesis.[52] The application of the process at a larger scale is however still to be demonstrated.

And the development of an industrial-scale production facility in Denmark has recently been announced (Maersk, 2020b). The latter intends to provide e-hydrogen for zero-emission heavy-duty trucks, e-methanol for marine vessels and e-kerosene for airplanes.

According to the Methanol Institute, in 2018 five companies produced biomethanol worldwide.

Ethanol

Bioethanol is already widely applied in land-based transportation where it is often blended with petrol. Bioethanol is currently mainly produced from wheat, corn and sugarcane.[53] To a limited extent, bioethanol is also produced as second-generation biofuel, mainly from lignocellulosic fractions. The recalcitrance of cellulosic biomass however poses a challenge to realising the potential of lignocellulosic bioethanol. [54]

In 2017, around 85 billion litres of bioethanol have been produced globally.[55]

Diesel-like fuels – e-diesel

E-diesel can, just as e-methanol be produced via syngas. In contrast to the production of methanol, the syngas is however converted into syncrude by means of the Fischer-Tropsch process. The syncrude can subsequently be refined into various fuel grades, like e-diesel r e-kerosene.

Currently, syncrude and according different e-fuel grades (like e-diesel and e-kerosene) are produced in a small number of demonstration plants,[56] with the first European commercial plant being planned in Norway.[57]

The Fischer-Tropsch synthesis can be considered an established technology, whereas the RWGS reaction, required for the production of the syngas, is not established for large scale productions yet.

Biofuels

Conventional, first generation biofuels are biodiesel (FAME), renewable diesel (HVO), and Straight Vegetable Oils (SVO)/Pure Plant Oil (PPO) produced from oil crops.

Since the use of edible crops for the production of biofuels can lead to indirect land use change (ILUC) and to an increase in food prices, the focus has shifted to the second generation biofuels, also called advanced biofuels. These biofuels are produced from

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52 Marlin et al (2018) Process Advantages of Direct CO2 to Methanol Synthesis.

53 https://www.eubia.org/cms/wiki-biomass/biofuels/bioethanol/.

54 https://iopscience.iop.org/article/10.1088/1755-1315/475/1/012081/pdf https://www.bioenergyconsult.com/production-cellulosic-ethanol/.

55 https://worldbioenergy.org/uploads/191129%20WBA%20GBS%202019_HQ.pdf.

56 https://www.audi-mediacenter.com/en/press-releases/fuel-of-the-future-research-facility-in-dresden-produces-first-batch-of-audi-e-diesel-352; https://www.cleanenergywire.org/news/german-pilot-project-produces-kerosene-sunlight-water-and-co_2-first-time.

57 https://fuelcellsworks.com/news/norsk-e-fuel-is-planning-europes-first-commercial-plant-for-hydrogen-based-renewable-aviation-fuel-in-norway/.

agricultural and forestry residues, organic waste and in some cases non-food or feed energy crops (IRENA, 2016).[58]

Second generation liquid biofuels relevant for maritime shipping are for example renewable diesel (advanced HVO), Fischer-Tropsch-diesel, upgraded pyrolysis oil (hydrogenated pyrolysis oil) or upgraded bio-oil from hydrothermal liquefaction of biomass.

The third generation biofuels use engineered energy crops such as algae as energy source. They possess the highest sustainability criteria while holding a very low GHG intensity, but their production is still in its infancy and not implemented at industrial scale. Renewable diesel can be produced from algae too.

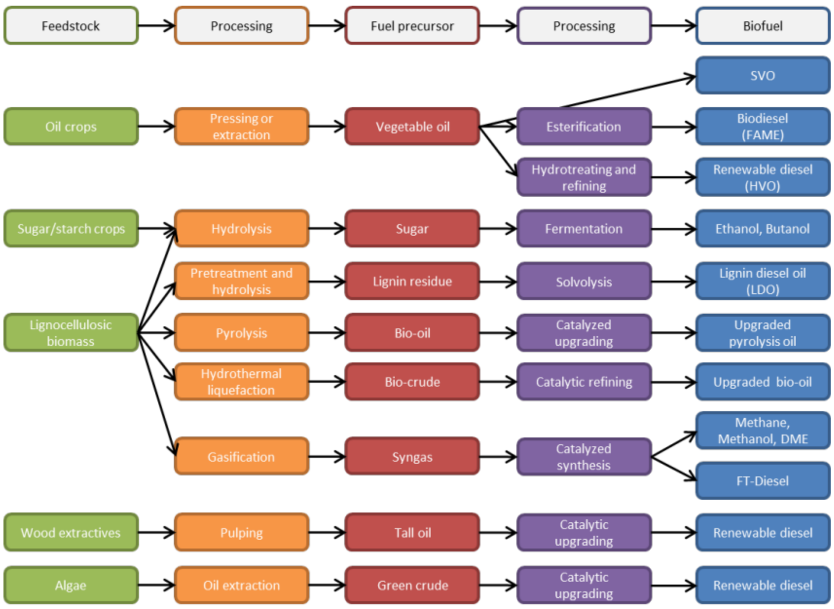

Figure 3.3 Overview of different feedstock conversion routes to marine biofuels including both conventional and advance biofuels.

Source: IRENA (2017). [59]

Summary

The analysis above has shown that there are various production processes for the different fuel types which vary highly in terms of maturity. Table 3.4 gives an overview of the technology readiness levels of the energy carriers and some of the production processes as developed in the context of the EESF. If different conversion routes are conceivable, the according route is specified in the first column, together with the fuel type.

Table 3.4 Overview of the maturity levels of the technologies and systems for the production of alternative bunker fuels

Fuel type	Technology readiness level in 2020
Biodiesel (HVO, from palm oil)	8

58 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Innovation_Outlook_Advanced_Liquid_Biofuels_2016.pdf.

59 http://task39.sites.olt.ubc.ca/files/2013/05/Marine-biofuel-report-final-Oct-2017.pdf.

Fuel type	Technology readiness level in 2020
e-methane (CO_2 from flue gas)	7
e-methanol (CO_2 from direct air capture)	7
biomethanol (from glycerine as waste product)	7
Biomethane (from organic waste)	6
e-hydrogen	5
e-ammonia	5
e-diesel (CO_2 from flue gas)	3

Source: Marin (2020)[60].

The above analysis has also shown that the current production levels of e-fuels are negligible. The production levels of some biofuels, especially first generation biofuels that feature a high technology readiness level, are already significantly higher. These biofuels are however mainly used in other sectors due to according policy incentives. Production of the biofuels would just as for e-fuels have to be scaled-up to provide significant volumes for maritime shipping. The bottleneck for a wider application of biofuels are the disclosure of the sustainable feedstock potentials and the advancement and upscaling of the production process of advanced biofuels. Key to the upscaling of the e-fuel production is, independent of the fuel type, the upscaling of the hydrogen production and the renewable electricity production.

3.1.3. Higher costs of alternative fuels compared to fossil fuels[61]

Contribution to the problem

An important reason for the low uptake of zero-emission fuels and power by ships calling EU ports is that the costs of these fuels are generally higher than the costs of fossil fuels. This section quantifies the difference and explores how prices may react to growing production volumes and other parameters. It quantifies the cost-effectiveness of fuels in reducing CO_2 emissions from shipping and places this in the perspective of carbon prices and renewables certificate prices in order to quantify the level of the carbon price or the renewables certificate required to achieve price parity between renewable and zero-carbon fuels on the one hand and fossil fuels on the other. Finally, the section identifies the main drivers for the costs of fuels.

Note that various studies have different estimates of the costs of renewable fuels. One of the causes of the variation between studies is that many fuels are not produced at a large scale (because there is no or little demand) so market prices are not available. Instead, studies frequently use engineering estimates with different assumptions about the costs of various cost components, about economies of scale and about production location. Another source of the variation, especially for e-fuels, is the variation in assumptions about the price of renewable electricity. For biofuels, the price of biomass is a major component for which the assumptions vary considerably.

Fuel categories

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60 https://sustainablepower.application.marin.nl/.

61 This section is based on the following sources, except where other sources are cited:
CE Delft, 2020. Availability and costs of liquefied bio- and synthetic methane: The maritime shipping perspective.
IRENA, 2019. Navigating the way to a renewable future: solutions to decarbonise shipping.
Lloyd's Register, 2017. Zero-Emission Vessels 2030. How do we get there?
Maritime Knowledge Centre, TNO and TU Delft, 2020. Final Report: Assessment of alternative fuels for seagoing vessels using Heavy Fuel Oil.

For the discussion of the production costs of different alternative fuels for maritime shipping it is useful to distinguish between the following fuel categories:

- **Biofuels:** Fuels, both liquid and gaseous, that are produced on the basis of biomass feedstock. Included in this category are biomethane, biodiesel, biomethanol, bio-ethanol;
- **E-fuels**: Fuels that are produced by means of the electrolysis of water into hydrogen and oxygen. The hydrogen can be used as a feedstock for the production of other e-fuels than hydrogen. It includes (green) hydrogen, e-diesel, e-ammonia, e-methane, e-methanol and e-ethanol. If renewable electricity and CO2 from renewable origin is used, the e-fuels are renewable fuels. However, if the electricity and CO2 are from fossil origin, the associated CO2 emissions may be higher than for fossil fuels (van der Giesen, Kleijn, & Kramer, 2014);
- **Fossil fuels**: Fuels that are produced on the basis of oil, natural gas or coal. Includes marine fuel oil (MFO),), heavy fuel oil (HFO) and liquid natural gas (LNG);
- **Recycled carbon fuels**: These fuels can be used to fulfil renewable energy targets for transport as part of the RED. They are defined as “liquid and gaseous fuels that are produced from liquid or solid waste streams of non-renewable origin which are not suitable for material recovery” (EC, 2018). Because of the lack of data on production costs and emissions of recycled carbon fuels, they are not included in this discussion and comparison.

Definition of costs

‘Costs’ refers here to the production costs of (sustainable) alternative fuels. Thus, distribution costs and profit margins (which are included in fuel prices paid by ship operators) are not considered in this section. These costs can be relatively small for drop-in fuels, but much larger when a dedicated infrastructure is required. CE Delft and TNO (2017) estimate that the bunkering infrastructure costs for LNG amount to 0.4 – 1.6 EUR/GJ if bunkering by bunker vessels is possible (representing a mark-up of 6% - 23% of the fuel costs), and around 3 EUR/GJ if ships had to be supplied by trucks (a 40% mark-up). For other fuels, the figures may be different depending on the energy density of the fuel and the needs for refrigeration or compression.

From the perspective of ship operators, the additional costs of engines and fuel systems may add to the costs of switching from fossil fuels to a sustainable fuel. These costs are not considered here either. For drop-in fuels no retrofitting is needed. CE Delft and Technopolis (2018), for example, conclude for biofuels in general that “retrofitting requirements for ships seem to be very limited and therefore will not form the main cost barrier”. For other fuels, e.g. liquefied gas, ammonia and hydrogen, new ships will be more costly than ships designed to sail on conventional fuels. The price difference of ships depends on many factors and reliable estimates are only available for fuels that are currently used in the market. CE Delft and TNO (2017) estimate the additional newbuilding costs for LNG vessels to be 6% to 40% of the price, depending on the ship type and size.

Furthermore, the energy efficiency of converting the fuel to useful mechanical energy (work) in the ships is not taken into account here. If fuel-technology combinations are compared, more energy-efficient propulsion systems will result in lower costs of useful work.

Production cost of alternative fuels

We have conducted a literature study of the production costs of fossil fuels, biofuels and e-fuels for maritime shipping, using various sources ((E4tech, 2018); (Hydrogen Council, 2020); (IEA, 2020); (IEA Bioenergy, 2020); (Maritime Knowledge Centre, TNO and TU Delft, 2020)). The resulting overview of fuel production costs is shown in Figure 3.4.

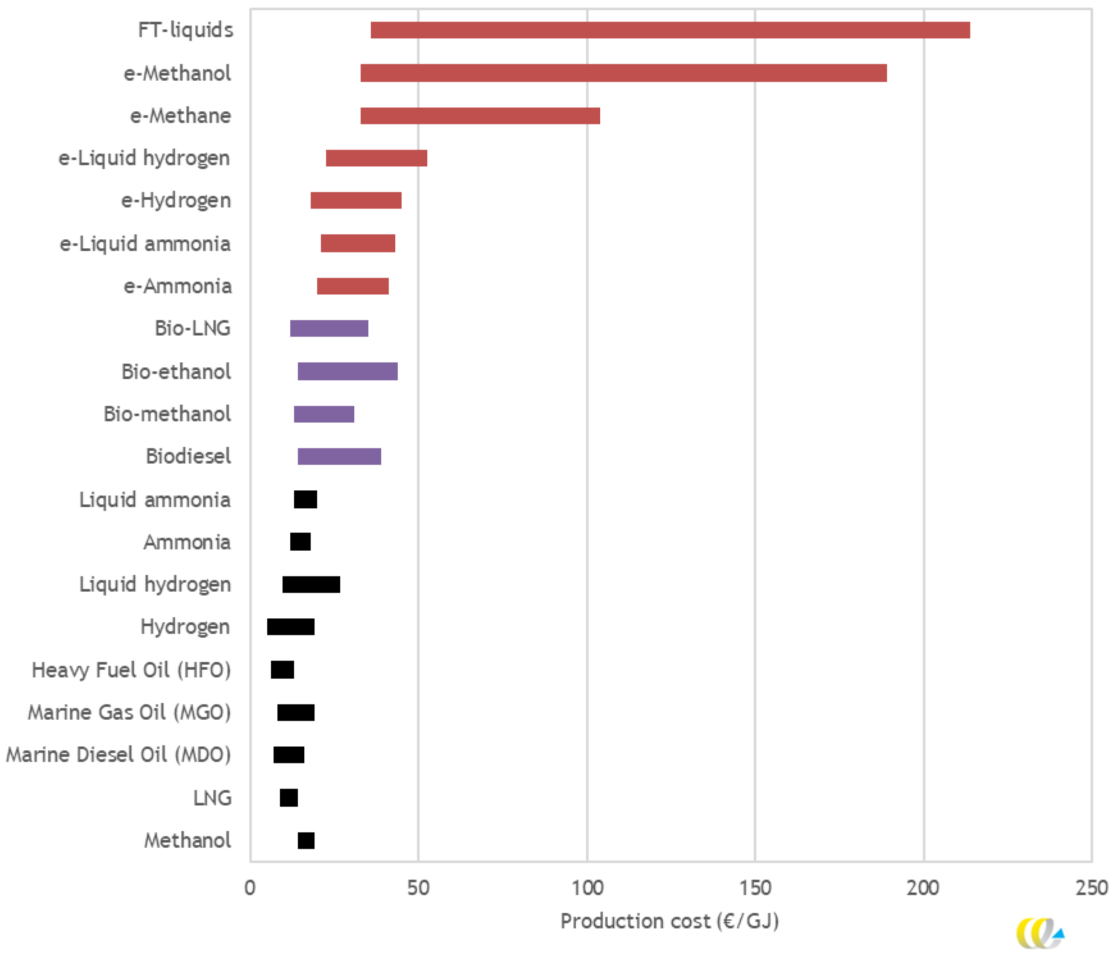

Figure 3.4 Current production cost of sustainable alternative fuels vs. fossil fuels for maritime ships (black: fossil fuels of fossil-fuel based; green: biofuels; blue: e-fuels with renewable electricity)

Source: authors, based on literature study. Fischer-Tropsch (FT) liquids are defined here as liquid fuels that are produced using electrolysis.

This figure confirms that, in general, renewable maritime fuel production costs are currently higher than those of fossil fuels. However, there is some overlap between the production cost ranges, suggesting that, under specific circumstances, biofuels and e-fuels may already be able to compete.

The production cost ranges of biofuels and e-fuels are larger than those of fossil fuels. For a part, this is caused by the fact that production systems for biofuels and e-fuels have a shorter history and are subject of on-going research, which is likely to bring learning effects. For biofuels, this also relates to the variety of biomass feedstocks and feedstock prices and the variety of production technologies in existence. For e-fuels the large ranges also relate to the uncertainty about renewable electricity costs, which are linked to electricity market price developments. The electricity costs form a major part of the production costs of e-fuels. This becomes apparent from the analysis of the current levelised costs of e-methane by (ENEA, 2016), which is shown in Figure 3.5. They have estimated the share of electricity costs in e-methane production at 47%.

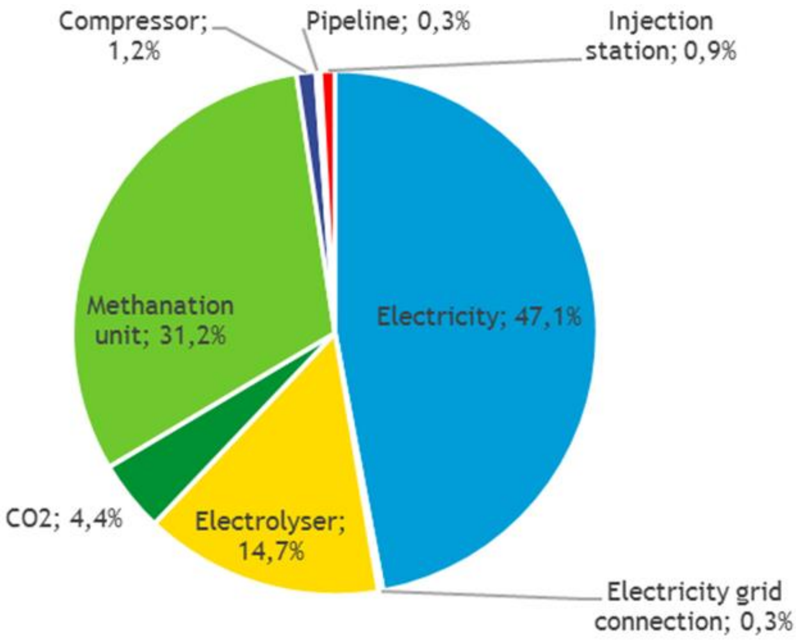

Figure 3.5 Cost-break down of levelised cost of e-methane

Source: ENEA (2016)

Future development of fuel production cost

The current costs of renewable and low-carbon fuels are much higher than those of conventional fuels. However, some projections show that the gap may decrease.

- IRENA (2019) projects that biofuels (both bio-alcohols and diesel substitutes of biological origin such as HVO and FAME) may become 30% cheapter in 2050 compared to 2018. The price development crucally depends on the biomass feedstock price. IRENA (2019) indicates that when there is much competition for biomass, the price reduction may be smaller or may not occur at all.
- E-fuels will become cheaper driven by lower prices of renewable electricity (wind and solar-PV). IRENA (2019) projects that prices in 2050 may be up to 70% lower than in 2018 for e-methanol, e-ammonia and e-liquefied hydrogen. This projection crucially depends on further reductions in the costs of renewable electricity.

The projected production cost reductions are dependent on increased demand for inputs and fuels. Without increases, learning effects which bring down costs will not be realised.

Even with these cost reductions, renewable and low-carbon fuels are still projected to be more costly than fossil fuels currently are.

Production cost per ton of CO2 reduction

Sustainable fuels are generally more expensive, but also result in lower direct and indirect greenhouse gas emissions. The estimation of the production cost of alternative fuels per ton of CO2 reduction provides insight in the costs for the maritime shipping industry to reduce its CO2 emissions. To carry out this estimation, we have executed the following steps:

- Collection of emission factors: We have collected from various sources well-to-wake (WtW) CO2 emissions of fossil and alternative fuels for maritime shipping, which are expressed in gram CO2-equivalents per MJ of fuel;
- Selection of reference fuel: To calculate CO2 reduction values, a reference fossil fuel needs to be selected. Because very low suplhur fuel oil (VLSFO) is currently

the dominant fuel in global maritime shipping, we have chosen VLSFO as the reference fuel;

- Calculation of reduction in CO2 emissions: For each alternative fuel, we have calculated the CO2 reduction (in g/MJ) by taking the difference between the WtW emission factor of the alternative fuel and that of the reference fuel. To simplify the estimation, we assume that conversion efficiencies of the fuels are the same. We have calculated a range, taking into account the emission factor ranges. The used emission factors for e-fuels are based on the assumption that renewable electricity is used;
- Calculation of the production cost per ton of CO2 reduction: The production cost values per ton of CO2 reduction (in €/ton) are calculated by dividing the fuel production cost values (in €/GJ) by the CO2 reduction values (in g/MJ) and multiplying by thousand. We have calculated the full range, taking into account the production cost and CO2 reduction ranges.

The outcome of the estimation is given by Figure 3.10.

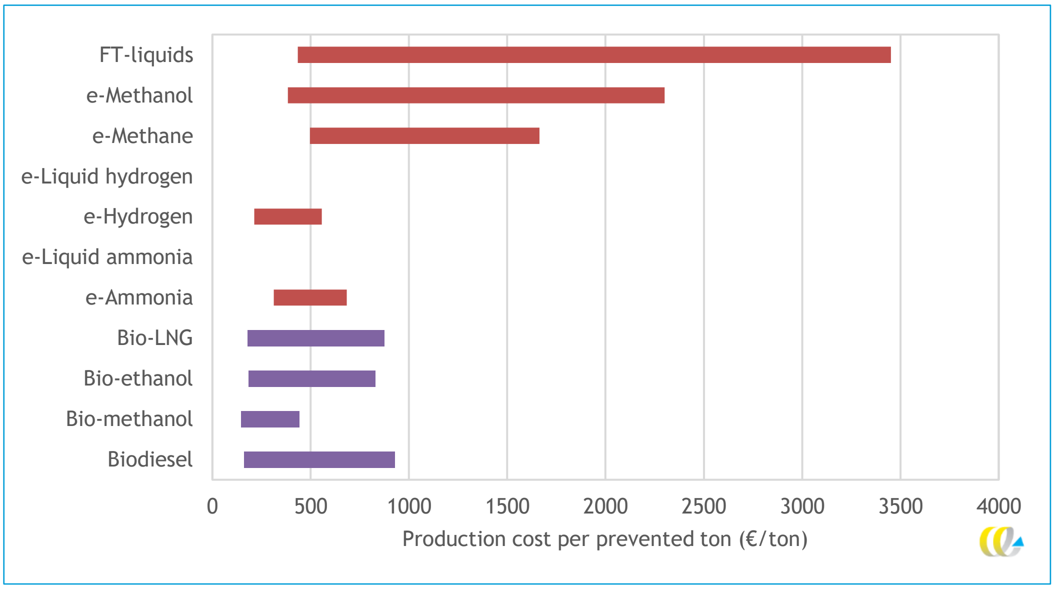

Figure 3.10 Current production cost per ton of CO2 reduction for alternative marine fuels

Source: authors, based on literature study

We can observe that the production cost per ton of CO2 reduction are high, compared to recent EU ETS carbon prices, which were in the range of 25 €/ton. For biofuels, the lowest values of the ranges are 150 to 180 €/ton and the highest values are as high as 800 to 900 €/ton. For e-fuels, the lowest value calculated is about 200 €/ton (for e-hydrogen) and the highest value is almost 3,500 €/ton (for FT-liquids). The highest values are based on the highest production cost estimates and the lowest CO2 emission reduction estimates. The production cost values have the highest influence. Considering that production costs can drop significantly over time due to mass production and economies of scale, the maximum values will decrease over time.

Carbon-adjusted production costs

If maritime fuels become part of the EU ETS system, fuel costs will be increased with a cost component related to the purchase of EU emission allowances to cover the CO2 emissions associated with the fuel consumption. As sustainable fuels have lower CO2 emissions, this cost component will be lower for sustainable fuels than for fossil fuels. It is interesting to assess if projected ETS carbon prices will be able to close the gap between the cost of fossil fuels and alternative fuels.

To estimate the 'carbon-adjusted' production cost of different marine fuels, we first need to assume an ETS carbon price range. Market analysts have reduced their forecasts of average ETS carbon prices due to the corona crisis, to 22 €/ton in 2020 and 29 €/ton in 2022.[62] The International Emissions Trading Association (IETA) forecasts an average carbon price of 32 €/ton "throughout the 2020s".[63] The European Green Deal projects prices ranging from 32 to 65 EUR/tonne CO2 by 2030 (EC 2020). Considering this, we have assumed a carbon price range of 30 to 60 €/ton.

The carbon-adjusted production costs are calculated as follows. For each fuel, the CO2 emission factor (in g/MJ) is multiplied by the carbon price (in €/ton) and divided by thousand. The resulting carbon cost component (in €/GJ) is added to the production cost. An overview of the carbon-adjusted production cost of different fuels is provided in Figure 3.11.

When we compared this overview with that of the production costs without carbon cost component from Figure 3.4, we see little change in the relative height of production cost of fossil fuels versus alternative fuels. Although the overlap between the cost ranges of the fossil fuels on the one hand and e-hydrogen, e-ammonia and biofuels has increased visibly, alternative fuels are still generally more costly to produce than fossil fuels.

62 https://www.reuters.com/article/us-eu-carbon-poll/analysts-cut-eu-carbon-price-forecasts-as-coronavirus-causes-demand-slump-idUSKCN2261GO.

63 https://www.edie.net/news/6/EU-carbon-price-set-to-rise-to-EUR32-by-2030--but-experts-say-EUR81-necessary-to-achieve-net-zero-in-the-UK/.

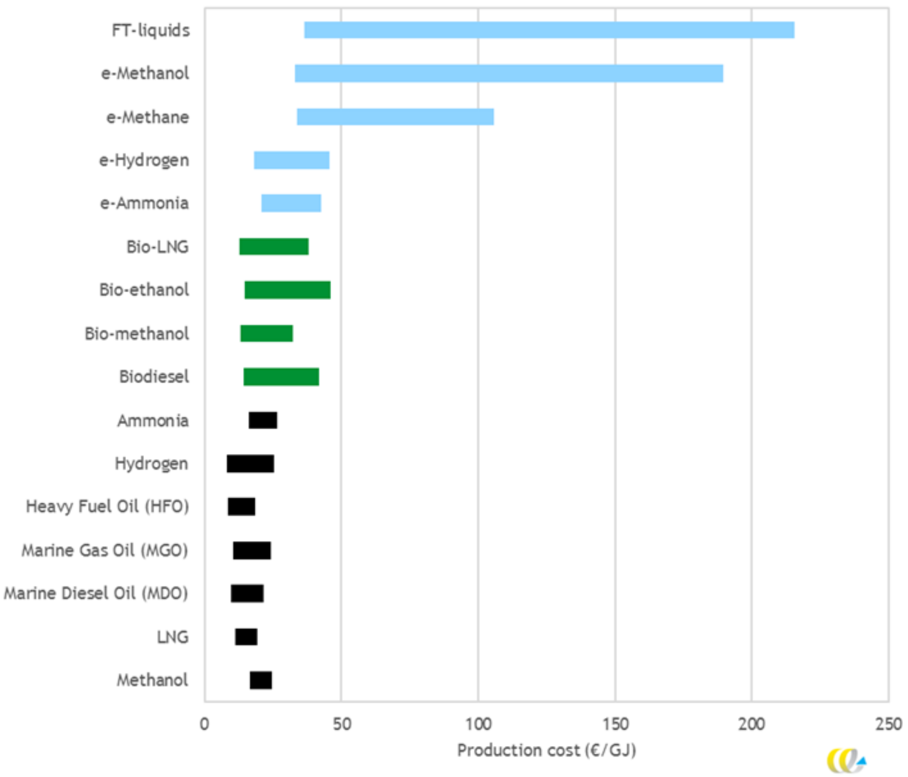

Figure 3.11 Carbon-adjusted production cost of marine fuels, assuming a carbon price of 30 to 60 €/ton

Source: authors

Effect on biofuel certificate prices

The European Commission has given Member States the possibility to initiate a market for biofuel certificates (biotickets), which can be traded between fuel suppliers in order to prove compliance with both the Renewable Energy Directive and the Fuel Quality Directive (EUROPIA, 2017). Various EU countries have set up such a markets, but these are national and young markets. Biofuel certificates are traded bilaterally between producers, traders and suppliers. As a result, biofuel certificate prices are volatile. For the same reasons, prices are not published, and price data is hard to find. In the Netherlands, the tradable renewable energy units (called 'Hernieuwbare Brandstofeenheid', or 'HBE') was worth between 5.5 and 8 €/GJ in the period 2015-2016 (Groengas Nederland, 2016).

Prices of biofuel certificates are determined by supply and demand of renewable fuels and the price difference between renewable fuels and fossil fuels (Groengas Nederland, 2016). This is because fossil fuel suppliers that choose to buy certificates instead of producing renewable fuel themselves will be willing to pay up to the difference between the production cost of the renewable fuel and the fossil fuel for those certificates. Thus, the prices of tradable renewable energy units can be expected to approach the difference between fossil fuel prices and renewable fuel prices.

If we take the difference between the carbon-adjusted production cost of alternative fuels and that of a reference fuel, we obtain an indication of the height of biofuel certificate prices. Again, we take HFO as the reference fuel, being the main marine fuel used. In Figure 3.12, the estimated biofuel certificate prices are depicted.

We can see that under favourable conditions, such as a high carbon price and low renewable energy production costs, the required biofuel certificate price is zero. Under unfavourable conditions, however, certificate price could reach 30 €/GJ, or even much higher values, in case of e-methane, e-methanol and Fischer-Tropsch liquids.

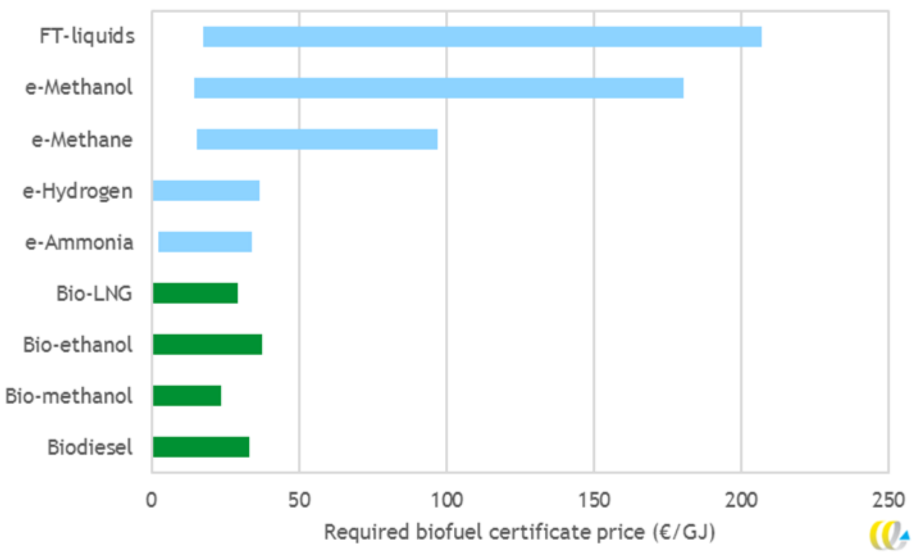

Figure 3.12 Required biofuel certificate price to bridge the gap with the cost price of the reference fuel and alternative fuels

Source: authors

Prioritisation of alternative fuels

Based on the above production cost analysis of alternative fuels, biofuels are most likely to become competitive with fossil fuels. E-fuels are currently more costly to produce, with production cost levels being more uncertain. On the shorter term, biofuels appear the more cost-effective alternative to fossil fuels in maritime shipping. On the longer term, the development of supply of and demand for biomass feedstock and renewable electricity play a major factor in the relative financial attractiveness of biofuels and e-fuels. We go into more detail on production cost drivers below.

Drivers of production costs

The table below provides an overview of drivers of production costs of fuels, which are described below per fuel category. These drivers apply to the production of fuels in general; they are not unique for maritime shipping fuels.

Table 3.5 Overview of cost drivers for the production of different fuel categories

Fuel category	Cost driver
All fuels	Capital cost of fuel production technologies
	Operation and maintenance cost
	Process energy cost
	Scale of production
Biofuels	Biomass feedstock prices
	Availability of sustainable biomass
E-fuels	Renewable electricity price
	Electrolyser load factor and price
Fossil fuels	Oil and natural gas prices
	Carbon price

All fuels

- **Capital cost of fuel production technologies**: The production cost of a fuel consists of two main components: the purchase cost of the main energy input (which varies between fuel categories and are therefore described below) and the capital cost of the fuel production system. The capital costs need to be earned back over the lifetime of the production system. The level/amount of the capital cost component in the fuel production cost depends on the annual production volume, system lifetime and the purchase, and installation cost of the production system. The production system may consist of different production facilities that are used to execute different conversion steps. For immature technologies, capital costs are relatively high. This is currently true for electrolysers and biomass gasification technologies;
- **Operation and maintenance cost**: Newer technologies may be subject to higher maintenance costs. Complicated production processes that require a lot of human operation and monitoring will have higher operation cost;
- **Process energy cost**: Different fuel production systems require different levels of auxiliary electricity and heat input. This process energy could be produced using (intermediary) production of the own production process, which lowers the fuel production volume, produced within the compound of the production location (e.g., solar panels, geothermal energy) or purchased. High-temperature heat is generally more expensive than low-temperature heat;
- **Scale of production**: Most if not all fuel production systems benefit from economies of scale: with larger installations the capital cost of the production system increases less than the produced volumes, resulting in lower capital cost per unit of fuel produced. This effect is smaller for scalable production systems.

Biofuels

- **Biomass feedstock prices**: The biomass feedstock prices are a major cost component in the production of biofuels. The prices of residual biomass types such as agricultural plant residues and manure are generally lower than those of wood from forests or energy crops. Sustainable biomass, which is proven through sustainability certificates, is more expensive than unsustainable or non-certified biomass. Biomass feedstock prices are influenced by global supply and demand developments;
- **Availability of biomass feedstock**: The demand for sustainable biomass is expected to rise as countries and industries strive to meet renewable energy and carbon emission reduction targets, but the availability of sustainable biomass is limited. The amount of land available for growing energy crops and wood for bio-energy is scarce, and bio-energy production should not go at the expense of food production. The potential of algae production in oceans is immense in theory, but yet unproven on a large scale (CE Delft, 2020).

E-fuels

- **Renewable electricity price**: The cost of electricity is a major part of the e-fuel production cost. To produce sustainable e-fuels, the electricity should originate from renewable energy sources such as wind and solar. Wind and solar energy have become much cheaper in the last two decades, along with increasing penetration levels. Wind and solar power are expected to gain a dominant market share in the future, which may further reduce renewable electricity prices. However, if subsidies are lifted, price-setting fossil fuel plant leave the market, and balancing costs are paid by the market, the prices may not drop as much as originally expected;
- **Electrolyser load factor**: Although the capital costs of electrolysers are expected to decrease with increasing uptake, low electrolyser load factors will still result in a high capital cost value per unit of fuel. Many studies have shown that a high load factor is essential for cost-competitive production of e-fuels. However, higher load factors result in higher electricity purchase prices. Thus, a trade-off exists between a high electrolyser load factor and low electricity costs. For isolated, integrated wind/solar-electrolyser systems, the load factor is limited by the hour-by-hour energy production of the wind/solar park.

Fossil fuels

- Oil and natural gas prices: Oil and natural gas prices are influenced by global supply and demand developments (including financial and health crises), geo-politics, discovery of new reserves, and development of extraction technologies.
- Carbon price: A price on the emission of carbon in the process of production and/or consumption of fossil fuels could result in higher oil and natural gas prices. Therefore, this driver is related to the previous one. Carbon prices for maritime shipping fuels do not yet exist. Their introduction could improve the cost-competitiveness of sustainable fuels, but there is a risk of carbon leakage if the carbon price is not introduced in the rest of the world.

3.1.4. High interdependency with supply and distribution

Not all fuels are fully fungible with existing ships. Some fuels require specific investments in tanks, piping or engines. Table 3.6 provides an overview of the modifications required by ships when switching fuels.

Table 3.6 Modifications required by existing ships to be able to sail on sustainable fuels

	HFO/MGO-fuelled ship	LNG-fuelled ship	Diesel-electric driven ship
e-methanol	Minor modifications in engine, tanks and piping, including provision of inert gas to tanks Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of methanol	Major modifications to tank, piping and engines Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of methanol	Minor modifications in engine, tanks and piping, including provision of inert gas to tanks Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of methanol
e-methane (liquefied)	Major modifications to tank, piping and engines Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of methane	No modifications required	Major modifications to tank, piping and engines Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of methane
e-hydrogen (compressed or liquefied)	Major modifications to tank, piping and engines Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of hydrogen	Major modifications to tank, piping and engines Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of hydrogen	Major modifications to tank, piping and engines Possibly replacement of generator by of fuel cell Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of hydrogen
e-ammonia (compressed or liquefied)	Major modifications to tank, piping and engines Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of ammonia	Minor to moderate modifications to tank, piping and engines Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of ammonia	Major modifications to tank, piping and engines Possibly replacement of generator by of fuel cell Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of ammonia
Bio-methane (liquefied)	Major modifications to tank, piping and engines Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of methane	No modifications required	Major modifications to tank, piping and engines Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of methane
Bio-ethanol	Minor modifications in engine and piping	Minor modifications in engine and piping	Minor modifications in engine and piping
Bio-methanol	Minor modifications in engine, tank and piping, including provision of inert gas to tanks Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of methanol	Major modifications in engine, tank and piping Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of methanol	Minor modifications in engine, tank and piping, including provision of inert gas to tanks Changes in cargo capacity or bunkering frequency because of lower volumetric energy density of methanol
Biodiesel	No or minor modifications required	Major modifications to tank, piping and engines	No or minor modifications required

If the investments result in a ship requiring a certain fuel (e.g. because the new tanks will be contaminated or piping clogged if other fuels are used), a shipowner will want to have certainty that the fuel is available in all the port a ship visits.

Some ships can use the existing storage and bunkering infrastructure, while others require dedicated infrastructure or a separate bunkering system because of the physical or chemical properties of the fuels. Biodiesel and e-diesel can probably be blended and used in existing bunkering infrastructure. Methanol and ethanol are soluble in lighter petroleum-based fuels, up to a limit, but may cause instability when blended with heavy fuel oil. For that reason, a dedicated infrastructure could be required. This is also the case for hydrogen, ammonia and liquefied biomethane and e-methane, which all need to be cooled and/or compressed. For hydrogen and ammonia, explosiveness respectively corrosiveness and toxicity need to be managed.

Table 3.7 summarises the extent to which existing storage and bunkering infrastructure can be used for renewable and low-carbon fuels.

Table 3.7 Modifications to port storage and bunkering infrastructure required for renewable and low-carbon fuels

	HFO/MGO-bunkering infrastructure	LNG-bunkering infrastructure
e-methanol bio-methanol bio-ethanol	Minor modifications to infrastructure; possibly larger storage needs	Not suitable
e-methane (liquefied) bio-methane (liquefied)	Not suitable	No modifications required
e-hydrogen (compressed or liquefied)	Not suitable	Major modifications in order to store at lower temperatures, keep pressurised
e-ammonia (compressed or liquefied)	Not suitable	Major modifications required to account for corrosiveness and toxicity
Biodiesel	No or minor modifications required	Not suitable

Sources: TNO 2020[64]; Alfa Laval et al., 2020[65].

This means that in addition to the investment in ships, a transition to zero-carbon fuels requires significant investments in production of those fuels as well as ships as in a supply chain and in bunkering infrastructure. UMAS (2020) estimate the investments required for transitioning to e-ammonia amount to USD 1.4 to 1.9 trillion, depending on whether ammonia is produced from natural gas with CCS or from e-hydrogen.[66] Between 85% and

64 TNO 2020 Green Maritime Methanol: Operation aspects and the fuel supply chain, TNO Report R11105.

65 Alfa Laval, Hafnia, Haldor Topsoe, Vestas, and Siemens Gamesa 2020 Ammonfuel – an industrial view of ammonia as a marine fuel, https://www.topsoe.com/hubfs/DOWNLOADS/DOWNLOADS%20-%20White%20papers/Ammonfuel%20Report%20Version%2009.9%20August%203_update.pdf.

66 UMAS 2020, Aggregate investment for the decarbonisation of the shipping industry, https://www.globalmaritimeforum.org/content/2020/01/Aggregate-investment-for-the-decarbonisation-of-the-shipping-industry.pdf.

89% of this investment is required for assets to produce, transport and supply fuels and the remainder for ship- and engine modifications. Hence, the capital costs for shipping companies would amount to approximately USD 200 billion globally in the period up to 2050. A fuel producer or supplier that makes the investment will want to ensure that there is sufficient demand for the fuel he produces or supplier, in order to make a return on investment.

Hence, demand and supply are closely interconnected.

The development of the LNG-fuelled fleet and the LNG bunkering infrastructure is a case in point. LNG requires ships with special tanks, piping and engines. It is most cost-effective to supply LNG to these ships with a bunker vessel, but this requires a significant investment which can only be earned back when there is sufficient demand. When bunker vessels are not available, LNG is often delivered by trucks (CE Delft and TNO, 2014). Table 3.8 shows that it has taken about half a decade before the increase in the number of LNG-fuelled ships resulted in the deployment of LNG bunker vessels in ports. Note that throughout this period, LNG was cheaper than HFO per unit of energy, except for in 2016 (DNVGL (2020), Alternative Fuels Insight) and significantly cheaper than MGO for the entire period.

Table 3.8 Development of the LNG-fuelled fleet and the LNG bunkering infrastructure globally

Year	LNG ships	LNG bunker vessels
2010	18	0
2011	22	0
2012	32	0
2013	43	1
2014	53	2
2015	70	2
2016	88	2
2017	105	5
2018	130	10
2019	162	13
2020	171	16

Source: DNVGL (2020), Alternative Fuels Insight.

3.1.5. Split incentives with respect to investments in clean technologies and the possibility of bunkering outside the EU

A large share of the fleet is owned by a different party than the one that pays for the fuel in operation (Stopford 2009). Ships can for example be on a time-charter where the company operating the fleet and paying for the fuel charters the ship from the owner. This potentially creates a split incentive with regards to investments in fuel efficiency. If a ship owner orders a more fuel-efficient ship or invests in her ship to make it more fuel-efficient, she does not benefit directly from its lower fuel consumption. Indirectly, she may benefit if she can command higher charter rates for a more fuel-efficient ships.

The literature on the split incentive suggests that only a share of the benefits of lower fuel consumption are passed on to the owner: Angolucci et al. (2014) found that in panamax bulk carriers, about 40% of the value of fuel savings was passed on in charter rates. Ådland *et al*. (2018) found that more efficient ships command higher prices on the second-hand market. Hence, it appears that a share of the benefits is passed through in the value of the ship, but not all. This means that MACCs and other techno-economic analyses portray a too optimistic picture of the cost-effectiveness of emission reductions, or, conversely, that financial incentives for efficiency improvements will not result in the efficiency improvement suggested by the MACC. Regulatory efficiency improvements do not suffer from the split incentive if they require ships to use fuel with a certain quality or meet a certain fuel- or carbon-efficiency standard.

CE Delft *et al*. (2012) estimates that 70%-90% of ships are on time charter and that half of the costs of investments can be recouped by the owner.

All policies addressing the fuel choice of ships must take into account that ships can sail up to six or eight weeks on a bunkering. This depends on many different parameters, such as the size of the tanks, the speed at which the ship sails, whether the ship is loaded or in ballast, et cetera. However, it is clear that ships engaged in voyages to and from destinations outside the EU have the choice to bunker in non-EU ports. Policies aimed at fuels in EU ports which result in higher bunkering costs in the EU will therefore suffer from carbon leakage. An indication of the sensitivity of bunkering location to prices is given by the experience in California, which introduced a fuel tax on marine fuels in the 1990s which coincided with a decline in bunkering volumes. LOA (2001) finds that at least a part of the decline was due to the fuel tax.

The size of fuel tanks varies significantly, even for ships with a similar size. Figure 3.13 shows this for bulk carriers. For example, the bunker fuel tank size for bulk carriers of around 180,000 dwt varies from 3000 m3 to 8300 m3. In general, larger ships tend to have larger fuel tanks.

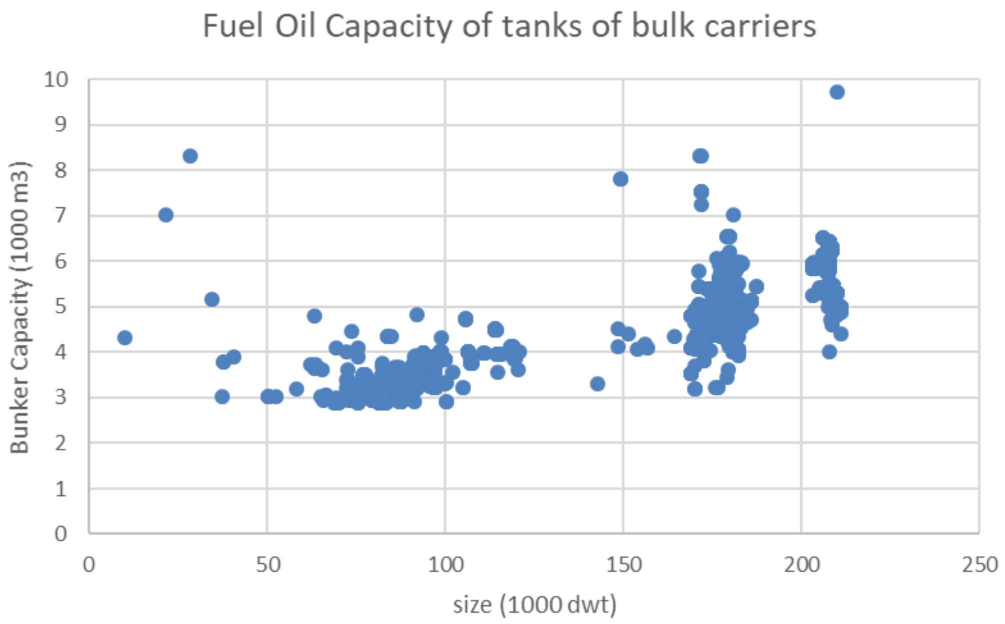

Figure 3.13 Bunker fuel tank size of bulk carriers

Source: Clarksons World Fleet Register.

We have compared the average size of the fuel tank with the average annual fuel consumption that ships had in 2018 and the distance they sailed. Table 3.9 shows how far selected ship categories can sail on a fuel tank. For most ships, this is well in excess of 20,000 nm, which allows them to reach important bunkering ports like Fujairah (7000 nm from the main bunkering port in the EU, Rotterdam), Singapore (9300 nm from Rotterdam) and Houston (6200 nm from Rotterdam).

Table 3.9 Distance that can be sailed on a full bunker fuel tank

Ship type		Unit	Distance on one fuel tank (1000 nm)
Bulk carrier	0-9999	dwt	51
Bulk carrier	10000-34999	dwt	33
Bulk carrier	35000-59999	dwt	31
Bulk carrier	60000-99999	dwt	31
Bulk carrier	100000-199999	dwt	33
Bulk carrier	200000-+	dwt	35
Container	0-999	teu	38
Container	1000-1999	teu	32
Container	2000-2999	teu	33
Container	3000-4999	teu	31
Container	5000-7999	teu	30
Container	8000-11999	teu	33
Container	12000-14499	teu	38
Container	14500-19999	teu	46
Container	20000-+	teu	50
Oil tanker	0-4999	dwt	16
Oil tanker	5000-9999	dwt	13
Oil tanker	10000-19999	dwt	10
Oil tanker	20000-59999	dwt	11
Oil tanker	60000-79999	dwt	14
Oil tanker	80000-119999	dwt	17
Oil tanker	120000-199999	dwt	19
Oil tanker	200000-+	dwt	28

In addition to the distance that ships can sail on one bunkering, we note that about two thirds of the fuel used on ships in the scope of the EU MRV was on voyages from an EEA-port to a non-EEA port or vice versa. These ships do not have to make a detour to bunker outside the EEA. This means that ships engaged in international voyages have ample opportunities to bunker at non-EEA ports.

In sum, because of the split incentive shipping companies cannot be expected to pass on all the cost increases associated with renewable fuels to their clients. In particular, the capital expenditures may not be fully recoupable. Because of the possibility to bunker outside the EU, policies aiming to address the fuel choice of ships should focus on fuel used on voyages to and from EU ports rather than on fuel supplied in EU ports and waters or by EU-registered fuel suppliers.

3.2. How would the problem evolve – the baseline scenario

This section analyses how the problems would develop in the absence of EU policy. It first analyses the impacts of respectively voluntary initiatives in the shipping sector (Section 3.2.1); national policies (Section 3.2.2); EU policies (Section 3.2.3); current (Section 3.2.4) and future IMO policies (Section 3.2.5). Section 3.2.6 concludes on the future uptake of renewable fuels in the absence of additional policies.

3.2.1. The impact of voluntary initiatives on the problem drivers and the problems

The shipping sector knows several voluntary initiatives aiming at reducing emissions or incentivising the uptake of renewable or low-carbon fuels.

1. Individual trials of renewable and low-carbon fuels. CE Delft and Technopolis (2018) counted 14 trials of biofuels between 2004 and 2018 and Annex II includes four case studies of other fuels;
2. Group initiatives and pledges (UNEP 2020).[67] Getting to Zero Coalition of the Global Maritime Forum: a collaboration of approximately 140 corporations focused on achieving the goal of there being scalable zero carbon energy solutions for international shipping available from 2030 and a pledge of major shipping companies to deploy zero-emission ships from 2030. Poseidon Principles: a commitment to transparent annual reporting of portfolio operational carbon intensity relative to an interpretation of the IMO's Initial Strategy by financiers representing approximately 30% of the capital invested in international shipping. Sea Cargo Charter: a commitment to transparent annual reporting of scope 3 / supply chain operational carbon intensity relative to an interpretation of the IMO's initial strategy by charterers and cargo owners.

These initiatives (when involving renewable and low-carbon fuels) are important to build experience with these fuels, both technically and operationally. They help develop class rules and technical requirements for storage on board and handling of these fuels. They sometimes involve building supply chains and developing commercial contracts for the supply of fuels.

However, because of the high costs of renewable and zero-carbon fuels (see Section 3.1.3), these initiatives cannot result in a significant uptake of renewable fuels by themselves. The Getting to Zero Coalition recognises in its communication the need for both 'market-based incentives' and the right 'regulatory environment' by the mid-2020s in order to achieve the aim of having commercially viable zero-emission vessels on deep sea trade routes by 2030. One of the coalition's members, Trafigura, calls for the introduction of a worldwide USD 250 – 300 carbon levy.[68]

This is supported by the stakeholder consultation. Most stakeholders who responded to the survey agreed that policies aiming to increase the demand for sustainable or low-carbon fuels are very relevant or relevant.

In sum, voluntary initiatives can address the barrier of the low maturity of fuels and reduce technical and operational risks. They cannot, however impact the costs of renewable and zero-carbon fuels, the predictability of the regulatory framework or the interdependency between supply and demand.

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[67] UNEP 2020 Emissions Gap Report.

[68] Jose Maria Larocca and Rasmus Bach Nielsen, 2020, Time for a carbon levy on shipping fuel, Financial Times 25 September 2020, https://www.ft.com/content/6647bd84-0d2b-4c14-b62c-e6bd80ff40e4.

3.2.2. The impact of national policy initiatives on the problem drivers and the problems

There are several national policy initiatives in EU Member States which could have an impact on the fuel choice of ships. These fall into two broad categories:

1. National policies implementing EU law, in particular;
2. Policies initiated in the context of the Alternative Fuels Infrastructure Directive (2014/94/EU);
3. National Energy and Climate Plans in the context of the Regulation on the governance of the energy union and climate action (EU/2018/1999); and
4. Other national policies aimed at addressing the environmental impacts of shipping.

Each of these groups of policies will be discussed below and the impacts on future fuel choices will be analysed.

National policies implementing EU law

The directive on the deployment of alternative fuels infrastructure (AFID) includes requirements for the construction of the infrastructure necessary for the use of alternative fuels of the maritime sector. AFID requires Member States to construct a LNG bunkering network which covers the TEN-T core network. Also, member states must ensure the deployment of Onshore Power Supply (OPS) in the TEN-T core network ports unless 'there is no demand and the costs are disproportionate to the benefits, including environmental benefits' (EC, 2014). As part of the implementation of AFID, all EU members have formulated National Policy Frameworks (NPFs), in which they have stated both the present state and 2025 targets. AFID does not include requirements for the infrastructure of renewable and low-carbon fuels.

Based on an analysis of the NPFs, it is clear that the majority of EU members intends to offer LNG bunkering at TEN-T core ports in 2025. However, not all countries formulated goals and the ambitions do not seem to cover the entire TEN-T core network. In Section 2 the current situation as well as the 2025 targets for LNG bunkering at maritime ports are shown.

Many countries have investigated the economic viability of OPS infrastructure at specific ports (EU Member States, 2016/2017). For multiple countries the results of these studies were a reason not to formulate targets for OPS infrastructure. Some of the barriers which were mentioned were economic viability, low demand from ships and insufficient local power. Also, some countries still were waiting for the results of feasibility studies at the time of reporting. Since the AFID allows Member States not to deploy OPS in case it is not economically viable the realisation of OPS infrastructure, three Member States have formulated goals for 2025, and these goals do not always specify whether the OPS is low- or high-voltage and whether it is for inland or sea-going ships. Also, no distinction is made between the amount and type of vessels that can make use of the OPS.

With respect to other low-carbon marine fuels,[69] most countries did not formulate concrete targets. In most NPFs, alternative fuels for maritime shipping were not mentioned. Some

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[69] Such as biofuels, batteries, methanol, methane, hydrogen and ammonia. For all of these fuels it is important to note that they are only low-carbon when they are produced sustainably form renewable sources.

countries indicated that they have built one or more low-carbon seagoing vessels, but the corresponding infrastructure requirements were mostly lacking from the discussion.[70]

Based on these findings, it seems likely that, without additional EU policy, OPS infrastructure will only be realised in specific clusters such as the Baltic Sea.[71]

The National Energy and Climate Plans (NECPs) outline how Member States intend to address energy efficiency; renewables; greenhouse gas emissions reductions; interconnections; and research and innovation. The greenhouse gas emission reductions are linked to the EU's nationally determined contribution (NDC) under the Paris Agreement, which excludes emissions from maritime bunkers. Consequently, NECPs do not contain references to maritime transport.

National policies aimed at addressing the environmental impacts of shipping

In recent years, after AFID was implemented, some individual countries have formulated national strategies for the decarbonisation of the maritime sector. We have identified strategies from The Netherlands, Sweden, Norway and the UK, while several other countries have indicated that they are working on national strategies and may publish them later in 2020.[72] In these country plans, more information about low-carbon fuels is included. The Netherlands aims for at least one zero-emission seagoing vessel in 2030 and 70% absolute reduction in carbon emissions from maritime shipping relative to 2008 in 2050 (Dutch state and stakeholders, 2019). The UK aims that all newly built ships are suitable for zero-emission propulsion technologies and that 'zero emission vessels are in operation in UK waters' from 2025 onwards. With respect to bunkering, the UK strives that 'low or zero emission marine fuel bunkering options are readily available across the UK' (Department for Transport, 2019). Norway formulated the target to 'reduce emissions from domestic shipping and fisheries by half by 2030 and promote the development of low- and zero- emission solutions for all vessel categories' (Norwegian Government, 2019).

It can be concluded that, without additional EU policy, it is unlikely that zero-emission marine fuels will be adopted at a larger scale than today in the next decade. The example of LNG infrastructure shows that even with an EU policy framework it takes a long time before the necessary infrastructure is in place. Since both OPS and all low-carbon marine fuels are at the moment not cost-competitive, it is unlikely that without additional policy the required transition will happen in time.

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70 Specifically, the Finnish NPF mentions that at least four vessels under the Finnish flag could use biofuel, with the ambition to increase the ship use of biofuels by four or five times by 2021 with respect to the time of writing. Also, it was mentioned that a couple of electric vessels are operating in Finland, with plans to expand the electric fleet (Finnish government, 2017). The Swedish NPF mentions the Stena Line, which was converted so that the engines run on Methanol (Swedish Government, 2016).

71 The ports of Tallinn, Stockholm, Helsinki and Turku have signed a Memorandum of Understanding aiming for a common approach for OPS.

72 We are also aware that the Italian government has published 'Guidelines for Energy and Environmental Planning Documents of the Port System Authorities (DEASP)', which is to be a framework for the decarbonization of Italian ports. As the documents are in Italian, we are currently analysing the precise content (Government, 2019).

3.2.3. The impact of EU policies on the problem drivers and the problems

EU Emissions Trading System

The European Union Emission Trading System (EU ETS) was set up in 2005 and is a tool from the European Union to reduce the emissions of man-made greenhouse gases which are responsible for warming up the planet and causing climate change. It is the world's first international emission trading system.

The EU ETS works on the 'cap and trade' principle. A cap is set on the total amount of greenhouse gases that can be emitted by installations which are covered by the system. The cap is reduced over time so that the total emissions will decline. Companies receive or buy emission allowances, which they can trade with each other in case needed. There is also an option to buy limited amounts of international credits from emission-saving projects around the world. The limit on the total number of available allowances ensures that they have a certain value. Each year the companies must surrender enough allowances to cover all their emissions. When a company has a lack of allowances fines are imposed. In case a company reduces its emissions, it can keep the spare allowances to cover its future needs or sell them to another company that is short of allowances. This approach gives companies the flexibility they need to cut their emission in the most cost-effective way. (European Commission, 2020) (European Commission, 2016)

By the introduction of the EU emission trading system, a carbon price is created. This system increases the expenditure, while income remains constant for the same amount of transport and greenhouse gases. In this way, the system promotes the investment in clean and low-carbon technologies. There are plans to include the shipping industry in the EU Emission Trading System, but this is not yet the case.

The current Commission announced a proposal to include shipping in the EU ETS. In the event that the EU ETS will be applied to the shipping industry, ships need to surrender allowances for their emissions in the scope of the system and this will add to the costs of using fossil fuels. As shown in Section 3.1.3, the cost prices of renewable and low-carbon fuels are higher than the prices of fossil fuels. The difference ranges from 150 to 3450 EUR/tonne CO_2 reduced (see Table 3.10). It is possible that the price difference reduces in the future as a result of learning effects in the production of these fuels, but these learning effects depend on the demand for these fuels which, in the absence of regulation, is unlikely to increase.

Table 3.10 Costs of fuels per tonne of CO_2 emission reduction

Fuel	Cost-effectiveness (EUR/tonne of CO_2 reduced)	
	Low estimate	**High estimate**
Biodiesel	160	930
Bio-methanol	150	440
Bio-ethanol	180	830
Bio-LNG	180	880
e-Ammonia	310	680
e-Hydrogen	210	560
e-Methane	500	1660
e-Methanol	380	2300
FT-liquids	430	3450

Source: authors, based on literature study. See Section 3.1.3. Fischer-Tropsch (FT) liquids are defined here as liquid fuels that are produced using electrolysis.

The price difference is at least 2.3 times as high as the highest estimate of ETS allowance prices in 2030, which range from 32 to 65 EUR/tonne CO2 (EC 2020). The cost-effectiveness in Table 3.10 does not take the costs of ship modifications or the higher newbuilding costs into account. Hence, it can be considered as a low estimate of the carbon price required to incentivise a fuel switch at present. In the future, when cost prices are expected to decrease, the carbon price required to incentivise the uptake of low- and zero-carbon fuel may be lower. Consequently, it can be concluded that the ETS may reduce the price gap between fossil fuels on the one hand and renewable and low-carbon fuels on the other, but will not bridge the gap.

EU Monitoring, Reporting and Verification (MRV) of CO2 emissions

The European Union MRV Regulation (Regulation (EU) 2015/757 on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport, and amending Directive 2009/16/EC) entered into force on the 1st of July 2015.

As from the 1st of January 2018, ships over 5,000 gross tonnage loading or unloading cargo or passengers at ports in the European Economic Area (EEA) are required to monitor their CO_2 emissions, fuel consumption and other parameters, such as travelled distance, time at sea and amount of cargo carried on a per voyage basis, so as to gather annual data into an emission report submitted to an accredited MRV shipping verifier.

As from 2019, at the latest by 30st of April of each year, companies shall, through THETIS MRV, submit to European Commission and to the Flag States in which those ships are registered a verified emission report for each ship that has performed maritime transport activities in the European Economic Area in the previous calendar year.

As from 2019, at the latest by 30st of June of each year, companies shall ensure that all their ships which have performed cargo operations in the previous reporting period and are visiting ports in the European Economic Area carry on board a document of compliance issued by an accredited verifier in THETIS MRV. This obligation might be subject to inspections carried out by Member States' authorities.

The European Commission publishes every year a report to inform the public about the CO_2 emissions and energy efficiency of the monitored fleet. (European Commission, 2020) (European Commission, 2020)

The EU MRV is a monitoring and reporting system and does not specify any limits on the amount of CO_2 emissions or fuel consumption. Since the EU MRV does not set any limits, it is not expected that the EU MRV will lead to more use of alternative fuels or shore power by both existing and newbuilding ships. However, the amount of annual CO_2 emissions of every ship above 5,000 gross tonnage which load or unload cargo or passengers in ports in the European Economic Area are published online and is free available for everyone (EMSA THETIS MRV, 2020). There is a possibility that this publicity lead to pressure on shipping companies to reduce CO_2 emissions. Besides the use of alternative fuels, there are also other ways to reduce CO_2 emissions. This possible pressure from outside does not necessarily lead to the use of alternative fuels.

3.2.4. The impact of existing IMO policies on the problem drivers and the problems

Several existing IMO policies can be considered to have an impact on the fuel choice of ships. These are:

- IMO Sulphur regulation under MARPOL Annex VI Regulation 14; and
- The Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan.

This section analyses the impacts of these policies on fuel choice.

IMO Sulphur Regulation

SOx and particulate matter emission controls apply to all fuel oil combustion equipment and devices on board, which include main and auxiliary engines together with items such as boilers and inert gas generators. A difference is made between the limits of SOx and particulate matter inside and outside so-called Emission Control Areas (ECAs). The fuel oil sulphur limits have been subject to a series of step changes over the years, which are shown in Table 3.11, ECAs are in the North- and Baltic Seas, as well as along the US and Canadian coast.

Table 3.11 Overview of sulphur limits outside and inside the ECA

Outside ECA	Inside ECA
4.50% m/m prior to 1 January 2012	1.50% m/m prior to 1 July 2010
3.50% m/m on and after 1 January 2012	1.00% m/m on and after 1 July 2010
0.50% m/m on and after 1 January 2020	0.10% m/m on and after 1 January 2015

Source: IMO (2020).

The increasingly strict sulphur limits both inside and outside the ECAs have led to a shift in fuel consumption. Before the 1st of January 2020, most ships used HFO with a maximum limit of 3.50% sulphur outside ECAs and MGO with a limit of 0.10% sulphur inside ECAs. Some ships installed Exhaust Gas Cleaning Systems, and some opted for LNG. Since the 1st of January 2020 there is a maximum sulphur limit of 0.50% sulphur outside ECAs. This has given a boost to the number of ships equipped with exhaust gas cleaning systems while the increase in the number of LNG ships continued. By mid-2020, a little over 1.5% of the world fleet by dwt was capable to sail on LNG, while just under 18% was equipped with a scrubber.

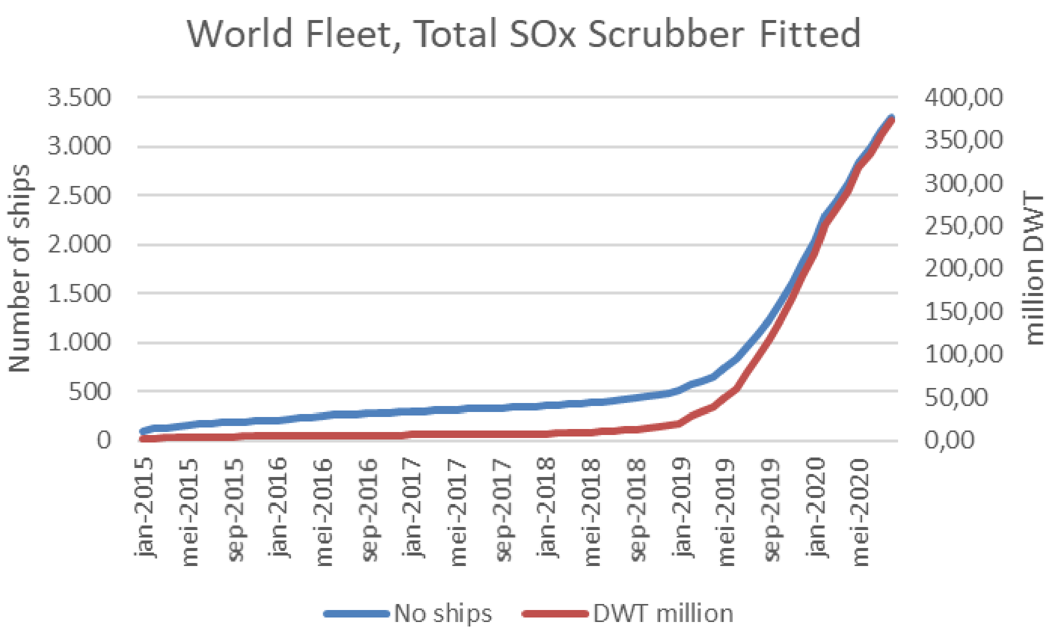

Figure 3.14 SOx scrubber fleet

Source: Clarksons Shipping Intelligence Network

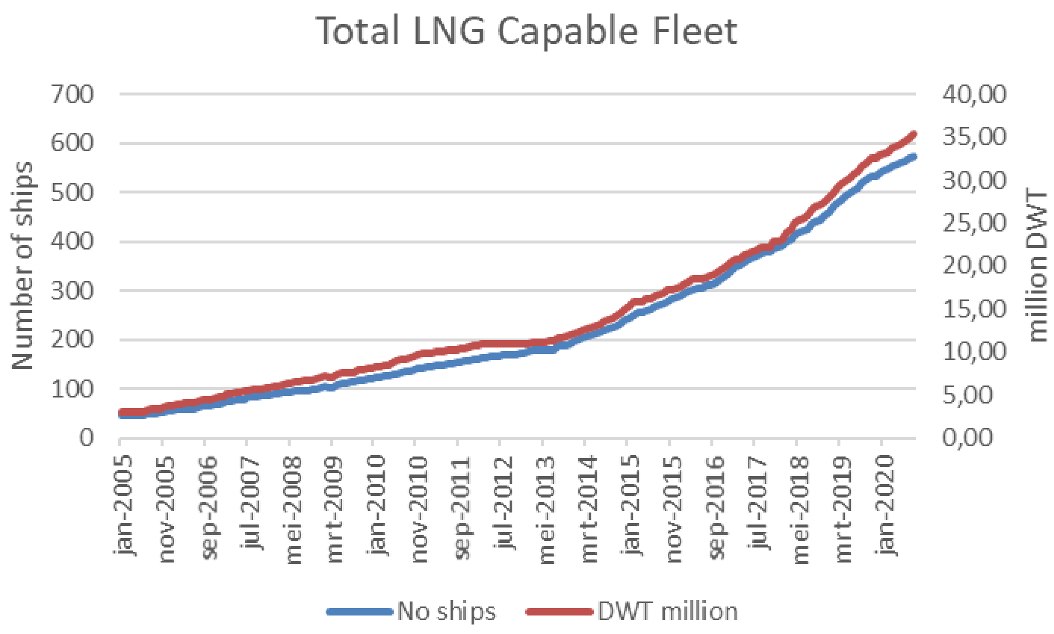

Figure 3.15 LNG Capable fleet

Source: Clarksons Shipping Intelligence Network.

While other fuels also have lower sulphur and PM emissions, the number of ships capable to sail on other fuels has not increased as much. There are, for example, currently just over 10 ocean-going ships capable of sailing on methanol (Methanol Institute 2020).[73]

In sum, the Sulphur regulation has primarily resulted in a reduction of the sulphur content of petroleum-based fuels and to the installation of after-treatment. The number of ships shifting to other fuels has remained limited despite the fact that LNG, methanol and other fuels are generally recognised as ways to comply with the sulphur regulation.

Energy Efficiency Design Index and the Ship Energy Efficiency Management Plan

The Energy Efficiency Design Index (EEDI) is an indicator of the energy efficiency of new ships. Tankers, bulk carriers, gas carriers, general cargo ships, container ships, refrigerated cargo carriers, LNG carriers, RoRo, cruise-ships and combination carriers built after the 1st of January 2013 have to meet a minimum energy efficiency level (IMO, 2020). The level was tightened in 2015 and 2020, and a new phase is foreseen for 2022 or 2025 (see Table 3.12).

Table 3.12 Reduction factors (in percentage) for the EEDI relative to the EEDI Reference line

Ship Type	Size	Phase 0 1 Jan 2013 - 31 Dec 2014	Phase 1 1 Jan 2015 - 31 Dec 2019	Phase 2 1 Jan 2020 - 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
Bulk carrier	20,000 DWT and above	0	10	20	30
	10,000–20,000 DWT	n/a	0-10*	0-20*	0-30*

73 https://www.methanol.org/wp-content/uploads/2020/01/Methanol-as-a-marine-fuel-january-2020.pdf.

Ship Type	Size	Phase 0 1 Jan 2013 - 31 Dec 2014	Phase 1 1 Jan 2015 - 31 Dec 2019	Phase 2 1 Jan 2020 - 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
Gas carrier	10,000 DWT and above	0	10	20	30
	2,000–10,000 DWT	n/a	0-10*	0-20*	0-30*
Tanker	20,000 DWT and above	0	10	20	30
	4,000–20,000 DWT	n/a	0-10*	0-20*	0-30*
Container	15,000 DWT and above	0	10	20	30
	10,000–15,000 DWT	n/a	0-10*	0-20*	0-30*
General cargo ships	15,000 DWT and above	0	10	15	30
	3,000–15,000 DWT	n/a	0-10*	0-15*	0-30*
Refrigerated cargo carrier	5,000 DWT and above	0	10	15	30
	3,000–5,000 DWT	n/a	0-10*	0-15*	0-30*
Combination carrier	20,000 DWT and above	0	10	20	30
	4,000–20,000 DWT	n/a	0-10*	0-20*	0-30*
LNG carrier	10,000 DWT and above	n/a	10**	20	30
Ro-ro cargo ship (vehicle carrier)***	10,000 DWT and above	n/a	5**	15	30
Ro-ro cargo ship***	2,000 DWT and above	n/a	5**	20	30
	1,000–2,000 DWT	n/a	0-5* **	0-20*	0-30*
Ro-ro passenger ship***	1,000 DWT and above	n/a	5**	20	30
	250–1,000 DWT	n/a	0-5* **	0-20*	0-30*
Cruise passenger ship*** having non-conventional propulsion	85,000 GT and above	n/a	5**	20	30
	25,000–85,000 GT	n/a	0-5* **	0-20*	0-30*

Source: Resolution MEPC.203(62) (MEPC 62/24/Add.1, Annex 19); MEPC 251(66) (MEPC 66/21, Annex 12).

* Reduction factor to be linearly interpolated between the two values dependent upon ship size. The lower value of the reduction factor is to be applied to the smaller ship size.

** Phase 1 commences for those ships on 1 September 2015.

*** Reduction factor applies to those ships delivered on or after 1 September 2019, as defined in paragraph 43 of regulation 2.

n/a: No required EEDI applies.

As the EEDI is a design measure, it is best suited for fuels that are integral to the design of a ship. For example, LNG, methanol, hydrogen and ammonia require specific tank and engine or fuel cell designs and could, in principle, be taken into account when determining the design efficiency of a new ship. Drop-in fuels like e-diesel and biodiesel are not a part of the design. Similarly, an LNG ship can sail on fossil LNG, liquefied biomethane or liquefied e-methane without changes to the ship design. These fuels cannot be accounted for in the EEDI.

Ships can in principle comply with the EEDI in many ways, including changing fuels. Apart from petroleum fuels, the EEDI Guidelines contain carbon factors for LNG, Methanol and Ethanol (Resolution MEPC.245(66)). Other low- and zero-carbon fuels are currently not included in the EEDI formula, and work on integrating these fuels in the formula is taken up by a correspondence group analysing the options for an EEDI Phase 4 (MEPC 75/INF.8; MEPC 75/6/5), which will likely not enter into force before 2030.

The limited uptake of LNG and Methanol (see above) suggests that changing to these fuels has not been used as a compliance option to the EEDI. It is likely that other compliance options have been sufficient to meet the required EEDI values, in particular improving the hull- and propeller design and in some cases reducing the engine power. Also, many ships exceed the EEDI requirements by a large degree without relying on alternative fuels (CE Delft 2016).[74] This suggests that there are sufficient options to meet future targets.

The Ship Energy Efficiency Management Plan (SEEMP) is a management plan which ships are required to have on board since 2013 (IMO, 2020). The form and content of the plan are not prescribed in the MARPOL Regulation, and plans are not inspected by either Flag or Port States. It is not known how many ships have pro-forma SEEMPs and how many have SEEMPS that include actions. The Guidelines for the development of a SEEMP, which are voluntary in nature, contain a long list of options to improve the fuel efficiency of a ship, such as speed optimization, autopilots, hull maintenance, et cetera, and one sentence on the possibility to reduce CO_2 emissions by changing fuels: ‘The use of emerging alternative fuels may be considered as a CO_2 reduction method but availability will often determine the applicability’ (Resolution MEPC.282(70)).

The SEEMP Guidelines mention the use of energy efficiency indicators such as the EEOI, which in principle could reflect the lifecycle emissions associated with the fuels used. However, the IMO has not agreed on methods to account for lifecycle emissions and hence there are no recognised ways to take renewable and low-carbon fuels into account in the EEOI.

In conclusion, it cannot be expected that the EEDI will create an effective incentive to use alternative fuels in the next decade. There are sufficient other options to meet the required EEDI without changing fuels, changing fuels does not appear to be a preferred option, and there are currently no incentives to use fuels like hydrogen and ammonia. Due to the freedom ships have in developing a SEEMP and the little attention in the SEEMP guidelines for alternative fuels, it is highly unlikely that the SEEMP will create an effective incentive to change fuels.

3.2.5. The impact of future IMO policies on the problem drivers and the problems

In 2018, the IMO adopted the Initial IMO Strategy on Reduction of GHG Emissions from Ships (Resolution MEPC.304(72)). The Strategy envisions to phase out GHG emissions from international shipping as soon as possible in this century. It explicitly acknowledges that ‘the global introduction of alternative fuels and/or energy sources for international shipping will be integral to achieve the overall ambition’.

In carrying out the Strategy, the IMO will adopt measures to reach the goals. The Strategy distinguishes three types of measures:

[74] https://www.ce.nl/index.php?/publicatie/readily_achievable_eedi_requirements_for_2020/1917.

1. Short-term measures which could be finalised and agreed between 2018 and 2023, but need not enter into force in this period;
2. Mid-term measures which could be finalised and agreed between 2023 and 2030, but need not enter into force in this period; and
3. Long-term measures which could be finalised and agreed after 2030.

The candidate short-term measures mostly focus on energy-efficiency improvements or on laying the groundwork for possible future measures aimed at the introduction of new fuels, such as supporting R&D and developing lifecycle carbon-intensity guidelines for all relevant types of fuels. Measures that aim to change the fuel mix are mentioned as candidate mid- and long-term measures, e.g. 'implementation programme for the effective uptake of alternative low-carbon and zero-carbon fuels' and 'new/innovative emission reduction mechanism(s), possibly including Market-based Measures (MBMs), to incentivize GHG emission reduction'.

MEPC 75 approved draft amendments to MARPOL Annex VI concerning mandatory goal-based technical and operational measures to reduce carbon intensity of international shipping. Once adopted, these amendments would require all ships to:

- Meet a required technical efficiency standard (EEXI), regardless of whether it is a new or an existing ship; and
- Calculate an operational carbon-intensity indicator; compare it with the required carbon-intensity indicator and take action if the operational indicator is consistently above the required value; and
- Calculate a carbon-intensity rating indicating how the actual carbon intensity indicator relates to the required value.

The EEXI is an indicator of design efficiency and will not reflect the type of fuel used for the same reasons as the EEDI (see Section 3.2.4). The carbon intensity indicator (CII), however, could in principle reflect the lifecycle emissions of the fuels used in the period over which the CII is calculated. Whether it will actually do so depends on guidelines that will be discussed and possibly agreed at MEPC 76 in 2021.

The required CII of ships shall ensure that the levels of ambition of the initial strategy are met, i.e. a 40% improvement of the carbon-intensity by 2030 relative to 2008, on a fleet-average basis. According to the Fourth IMO GHG Study (IMO 2020), the fleet-average CII in 2018 was 21 - 29% better than in 2008, depending on the indicator used, and a further 23% efficiency improvements are more cost-effective than the use of renewable and low-carbon fuels, in addition to efficiency improvements brought about by deploying larger ships.

Hence, it is unlikely that the agreed amendments to MARPOL Annex VI will result in a significant uptake of renewable and low-carbon fuels by 2030, because other options to meet the objectives are cheaper.

3.2.6. Conclusions

The preceding sections have concluded that neither voluntary initiatives nor current or foreseen policies will by themselves result in a significant uptake of renewable and low-carbon fuels, at least in the period up to 2030, despite the voluntary initiatives and national policies which will, to some extent, improve the maturity of the fuels. Can the combination of policy measures and voluntary initiatives effectively increase demand for renewable and low-carbon fuels?

As shown in Chapter 2, the current demand for renewable and low-carbon fuels is mainly in countries that have implemented an opt-in for marine fuels under the Renewable

Energy Directive. This helps with making the business case for supplying biofuels to ships. These biofuels are predominantly of a lower quality than road diesel. If more Member States would opt-in the marine sector, demand for these fuels could increase. Because road transport fuels are included in Europe's Determined Contribution (DC) to the Paris Agreement and marine fuels are not, this would mean that other sectors would need to do more to achieve the target in the DC.

If maritime transport would be included in the EU ETS in addition to an opt-in under RED, the business case for selling renewable and low-carbon fuels to ships would include more fuels, probably also of higher quality. Based on the analysis of the cost-effectiveness of different fuels in reducing CO_2 emissions, we expect drop-in biofuels to become cost-competitive. It is much less likely that fuel become cost-competitive which require dedicated infrastructure and non-conventional fuel systems and engines.

Hence, unless the opt-in under RED is expanded, it is unlikely that the demand for renewable and low-carbon fuels will increase significantly in the next decade. If more Member States choose to opt-in marine fuels, the demand for the least expensive renewable and low-carbon fuels will increase, but the more expensive fuels as well as electrofuels will not be sufficiently incentivised.

4. Policy options

4.1. Policy options

This report considers three policy options: a prescriptive approach on the choice of technology; a goal-based approach on technology; and a goal-based approach on technology combined with a reward mechanism for overachievers. All approaches would address the choice of the fuel and the electricity used.

Option 1	In navigation and at berth	In addition at berth
Prescriptive approach on the choice of technology	Minimum shares of specific fuel types (established ex-ante) would be established and would increase over time in line with the expected penetration rates resulting from the 2030 Climate Target Plan Ships using zero-emission energy sources as a primary source of energy will be exempted from the blending obligation in order to reduce the risk of lock-in. The performance of fuel is established ex-ante and demonstrating sufficient blending levels would be necessary to prove compliance. Additional rules should be established for this purpose, including for monitoring, reporting and verification of consumption of alternative fuels in the context of the EU MRV and to harmonise Port State Control (PSC) procedures.	The use of on-shore power supply will be mandated for the most polluting ships in ports, i.e. containerships, passenger ships and ro-pax ships, unless they can prove the use of equally performant alternative (e.g. batteries, zero-pollution energy sources, etc.) A phased-in implementation is planned in order to gradually extend the requirements to the entire fleet.

Option 2	In navigation	At berth
Goal-based approach on technology	A maximum limit on the GHG content of energy used by ships in navigation (e.g. CO_2eq/MJ or kWh) would be identified in line with the expectations of the 2030 Climate Target Plan and will be made more stringent over time. Ships need to remain below the maximum limit on average over the compliance period.	The use of on-shore power supply will be mandated for the most polluting ships in ports, i.e. containerships, passenger ships and ro-pax ships, unless they can prove the use of equally performant alternative (e.g. batteries, zero-pollution energy sources, etc.) A phased-in implementation is

Option 2	In navigation	At berth
	The performance of the fuel is not established on-board but needs to be document on annual basis for the total energy generated on-board. Additional rules should be established for this purpose, including for monitoring, reporting and verification of consumption of alternative fuels in the context of the EU MRV and to harmonise Port State Control (PSC) procedures.	planned in order to gradually extend the requirements to the entire fleet.

Option 3	In navigation	At berth
Goal-based approach on technology and reward mechanisms for overachievers	General approach: A maximum limit on the GHG content of energy used by ships in navigation (e.g. CO_2eq/MJ or kWh) would be identified in line with the expectations of the 2030 Climate Target Plan and will be made more stringent over time. Ships need to remain below the maximum limit on average over the compliance period. This policy option also integrates specific measures to foster over-achievements and encourage the development of more advanced, zero-emissions technologies. These concern specifically the possibility to not only average compliance on a yearly basis (as in PO2) but also pool compliance with other ships / operators, either on a voluntary basis or through transferrable credits. Also, when establishing the ship's performance in achieving the yearly target, higher weight will be attributed to zero-emission technologies. The performance of fuel is established ex-ante and demonstrating sufficient blending levels would be	The use of on-shore power supply will be mandated for the most polluting ships in ports, i.e. containerships, passenger ships and ro-pax ships, unless they can prove the use of equally performant alternative (e.g. batteries, zero-pollution energy sources, etc.) A phased-in implementation is planned in order to gradually extend the requirements to the entire fleet.

Option 3	In navigation	At berth
	necessary to prove compliance. Additional rules should be established for this purpose, including for monitoring, reporting and verification of consumption of alternative fuels in the context of the EU MRV and to harmonise Port State Control (PSC) procedures.	

Common elements and characteristics of the policy options:

- All options will be in line with the expectations of the 2030 Climate Target Plan;
- Emissions considered in the goal-based approach are GHG emissions (i.e. CO2, CH_4 and N_2O). Benefits should also be evaluated on the air pollution performance;
- Policies will include the same ships and the same emissions as the EU MRV (Regulation (EU) 2015/757);
- The regulated entity will be the ship;
- The time horizon for assessment would be 2025-2050.

4.1.1. Position on the different policy options according to the stakeholder consultation

By means of the open public consultation, the targeted consultation, the ESSF Roundtable discussion on September 18th and the stakeholder interviews, different stakeholder groups have had the chance to communicate their view on the different policy options as stated above. In this Paragraph, a brief discussion of how the stakeholders think about these policy options is included. A more in depth analysis is included in the stakeholder consultation report, which is a separate deliverable of this impact assessment.

First of all, it is clear from all sources of stakeholder consultation that a goal based approach for ships in navigation is preferred over a prescriptive approach. The answers to the open public consultation, which have been analysed for each stakeholder group with more than ten responses separately, show that there is a consensus between the different groups of stakeholders that a goal-based approach is preferable over a prescriptive approach(see Table 4.1). This is supported by the findings in the stakeholder interviews and the targeted consultation. An often mentioned reason for why not to opt for a prescriptive approach are that it is still very unclear what fuel(s) will be most promising in the future (see Section 3.1.2). A second argument is that there is a great diversity of situation for different vessels and ports for each of which a different technological solution might be preferable. Another argument that was heard against a prescriptive approach is that there is no guarantee that the rest of the world will converge to the same technologies. This could lead to high risks of stranded assets (see Section 3.1.2).

Table 4.1 How should requirements for the use of sustainable alternative fuels and power be set for ships in navigation? (OPC)

	number of contributions	Performance requirements based on carbon-intensity	Requirements on the share of alternative fuels	Other	No opinion
National public authorities	13	69%	0%	23%	8%
Ship owning and ship management	37	65%	14%	11%	11%
Short sea shipping	24	63%	13%	17%	8%
Ports management and administrations	13	38%	15%	23%	23%
Port terminal operator or other port services	13	38%	15%	15%	31%
Inland waterways sector	8	50%	0%	25%	25%
Shipbuilding and marine equipment manufacturers	10	80%	20%	0%	0%
Academia, research and innovation	12	50%	17%	33%	0%
Energy producers and fuel supply	37	49%	22%	24%	5%
Interest organisations	13	31%	15%	31%	23%

With respect to policy at berth, a goal based approach also is preferred by most stakeholders but not to the same extent as for fuels used in navigation (see Table 4.2). An often heard reason not to mandate the uptake of OPS is that the business case for this, which is in practice always poor, very much depends on the specific circumstances at a port. It is therefore argued that mandating the uptake of OPS in ports could lead to large and inefficient investments in places where this is no good option. On the other hand, an argument in favour of prescriptive regulation at berth is that this could help provide certainty about both supply and demand for OPS which could increase the usage rates.

Table 4.2 How should requirements for the use of sustainable alternative fuels and power be set for ships at berth? (OPC)

	number of contributions	Performance requirements based on the	Requirements on the share of sustainable	Other	No opinion
National public authorities	13	54%	23%	15%	8%
Ship owning and ship management	36	53%	25%	14%	8%
Short sea shipping	23	52%	13%	26%	9%
Ports management and administrations	13	31%	31%	23%	15%
Port terminal operator or other port services	13	31%	31%	31%	8%
Inland waterways sector	7	43%	0%	29%	29%
Shipbuilding and marine equipment manufacturers	9	67%	33%	0%	0%
Academia, research and innovation	12	33%	42%	25%	0%
Energy producers and fuel supply	34	50%	21%	21%	9%
Interest organisations	13	23%	23%	15%	38%

There was broad agreement amongst the stakeholders that emissions should be measured on a well-to-wake basis (Table 4.3) and that all relevant greenhouse gases and air pollutants are included in the framework (Table 4.4). An important point to be made here is that a solid certification system is needed to ensure that the emissions are correctly accounted for and that double counting is avoided.

Table 4.3 How should emissions be calculated? (OPC)

		On a "tank-to-wake" basis	On a "well-to-wake" basis	Other	No opinion
National public authorities	12	33%	67%	0%	0%
Ship owning and ship management	27	44%	56%	0%	0%
Short sea shipping	18	22%	78%	0%	0%
Ports management and administrations	9	11%	89%	0%	0%
Port terminal operator or other port services	9	33%	67%	0%	0%
Inland waterways sector	6	17%	83%	0%	0%
Shipbuilding and marine equipment manufacturers	10	10%	90%	0%	0%
Academia, research and innovation	11	9%	91%	0%	0%
Energy producers and fuel supply	27	7%	93%	0%	0%
Interest organisations	9	11%	89%	0%	0%

Table 4.4 What emissions should be included? (OPC)

		CO2 emissions	CO2 emissions and emissions of other greenhouse gases	Greenhouse gas- and air quality emissions	No opinion
National public authorities	14	21%	7%	71%	0%
Ship owning and ship management	37	27%	32%	38%	3%
Short sea shipping	24	21%	29%	46%	4%
Ports management and administrations	13	23%	15%	62%	0%
Port terminal operator or other port services	13	23%	31%	46%	0%
Inland waterways sector	9	0%	11%	78%	11%
Shipbuilding and marine equipment manufacturers	10	20%	10%	70%	0%
Academia, research and innovation	12	0%	17%	83%	0%
Energy producers and fuel supply	37	5%	43%	51%	0%
Interest organisations	14	0%	14%	86%	0%

With respect to policy for ships in navigation, there is reasonable consensus that it should apply to all ship types (see Table 4.5).

Table 4.5 To whom should these requirements apply?

	number of contributions	To all ships	To certain ship types	Other	No opinion
National public authorities	13	69%	8%	23%	0%
Ship owning and ship management	38	61%	16%	13%	11%
Short sea shipping	24	46%	29%	13%	13%
Ports management and administrations	13	69%	23%	0%	8%
Port terminal operator or other port services	12	58%	17%	17%	8%
Inland waterways sector	9	56%	22%	11%	11%
Shipbuilding and marine equipment manufacturers	9	78%	22%	0%	0%
Academia, research and innovation	12	83%	17%	0%	0%
Energy producers and fuel supply	37	51%	16%	22%	11%
Interest organisations	13	77%	15%	8%	0%

An aspect about which there is no agreement is the right scope of the policy. Based on the open public consultation results, there clearly is no preference to apply the policy to ships bunkering in the EU, since this could lead to carbon leakage (see Table 4.6). However, about equal shares of stakeholders are in favour of a policy that applies to either ships calling at ports of the EU or ships sailing in the territorial waters and Exclusive Economic Zones of the EU. A significant share or respondents also indicated that they would prefer a combination of the three previously mentioned options.

Table 4.6 What would be an appropriate scope of these measures?

		Ships calling at ports of the European Union	Ships bunkering in ports of the European Union	Ships sailing in the territorial waters and Exclusive Economic Zones of EU	Other	No opinion
National public authorities	13	38%	0%	15%	38%	8%
Ship owning and ship management	37	32%	0%	30%	32%	5%
Short sea shipping	24	29%	0%	29%	38%	4%
Ports management and administrations	13	46%	0%	38%	15%	0%
Port terminal operator or other port services	13	38%	0%	23%	38%	0%
Inland waterways sector	9	0%	0%	67%	11%	22%
Shipbuilding and marine equipment manufacturers	9	22%	0%	33%	22%	22%
Academia, research and innovation	12	58%	0%	33%	8%	0%
Energy producers and fuel supply	35	29%	6%	26%	34%	6%
Interest organisations	12	25%	0%	67%	8%	0%

Another point about which a significant amount of comments was made is the role of the IMO. On the one hand, some stakeholders argued that none of the above options are suitable because action can only be taken whilst preserving the level playing field if this is done at the IMO level. On the other hand there were stakeholders who are in favour that the EU should create a policy framework, but stress that this should be done in close cooperation with the IMO to ensure that the regulation is in line with future IMO policy.

With respect to policy for ships at berth, there is no consensus about what ship types the policy should apply to. In the open public consultation, there were five specified options for this question as well as the possibility to choose ‘other’. All five options gained a significant amount of votes, without one option clearly being the favourite (Table 4.7). However, the two options with the highest votes (apart from ‘other suggestion’) were a policy that addresses all ship types and a policy that prioritizes the highest emitters. In the category ‘other’, the most heard remarks were that a combination of these options should be chosen and that a Cost Benefit Analysis should be at the basis of any decision for measures to reduce emissions at berth. Based on an analysis of the survey results per stakeholder groups, it also is apparent that different types of stakeholders have a very different opinion about this. This conclusion is supported by the stakeholder interviews. It will therefore be challenging to formulate a policy for ships at berth which will satisfy all groups of stakeholders.

Table 4.7 Do you have any views on how these requirements for ships at berth should apply?

		Addressing all ships at berth	Prioritising the ships and the ports already equipped with zero-emissions	Prioritising the highest emitters	Taking action once infrastructure is available in majority of EU ports	Other	No opinion	
National public authorities	13	23%	0%	15%	8%	46%	8%	1,0
Ship owning and ship management	36	17%	19%	19%	25%	19%	0%	1,0
Short sea shipping	24	8%	13%	25%	25%	25%	4%	1,0
Ports management and administrations	13	23%	8%	15%	15%	31%	8%	1,0
Port terminal operator or other port services	13	8%	0%	15%	31%	38%	8%	1,0
Inland waterways sector	9	22%	11%	44%	0%	0%	22%	1,0
Shipbuilding and marine equipment manufacturers	9	33%	11%	22%	22%	11%	0%	1,0
Academia, research and innovation	12	50%	25%	8%	8%	0%	8%	1,0
Energy producers and fuel supply	35	17%	9%	31%	3%	26%	14%	1,0
Interest organisations	14	50%	14%	14%	7%	0%	14%	1,0

Apart from these aforementioned results of the stakeholder consultation, there were some remarks that were heard often.[75] First of all, it was both in interviews and the open public consultation often stressed that any policy should be flag-neutral. Also, a significant share of stakeholders indicated that policy should be technology neutral. Some special attention should be given to the role of LNG and biofuels in this respect. In the stakeholder position papers and interviews, multiple stakeholders indicated that there should be (a transitionary) role for LNG and biofuels. However, there were also stakeholders who argued that policy should not be aimed at promoting intermediate solutions. A third specification that was heard from different stakeholders was that a policy should apply to the whole fleet rather than the individual ship. This could allow for more flexibility with respect to choices for how to comply with sustainability targets.

4.2. Options for pooling compliance and rewarding overachievers in policy option 3

Policy option 3 integrates measures to foster over-achievements and encourage the development of more advanced, zero-emissions technologies. These concern specifically the possibility to pool compliance with other ships, either on a voluntary basis or through

75 For these remarks, no conclusion can be made about whether a majority of stakeholders agrees with these views.

transferrable credits. Also, when establishing the ship's performance in achieving the yearly target, higher weight will be attributed to zero-emission technologies.

Policy option 3 integrates measures to foster over-achievements and encourage the development of more advanced, zero-emissions technologies. These concern specifically the possibility to pool compliance with other ships, either on a voluntary basis or through transferrable credits. Also, when establishing the ship's performance in achieving the yearly target, higher weight will be attributed to zero-emission technologies.

This section discusses how both elements of the measure could be designed. It first discusses pooling compliance in Section 4.2.1 and then analyses how higher weights can be attributed to zero-emission technologies in Section 4.2.2.

4.2.1. Ways to pool compliance

Pooling compliance could either be achieved by ships voluntarily forming pools governed by private-law and submitting both a ship-specific and pool-specific compliance report to the competent authority; or by a baseline-and-credit scheme established by the competent authority under public law.

In a voluntarily formed pool, ships that do not comply are allowed to pool their compliance with ships that overcomply, as long as all the ships in the pool meet the obligation to use energy sources which, on average, have emissions lower than the maximum limit on the GHG content of these energy sources. In addition to the ship-based reporting under the EU MRV, the pool of ships would need to report collectively on the total amount of fuel used (i.e. the sum of the fuel reported in the EU MRV) and the total amount of RLF used or the average GHG emissions intensity of the fuel. The collective report would need to be verified.

When ships choose their compliance strategy and consider forming a pool, it can be assumed that they will want to have certainty about:

1. The amount of overcompliance of the overcompliant ship(s); and
2. The amount of undercompliance of non-compliant ship(s).

After all, if there is overcompliance in the pool as a whole, the compliance costs are higher than they need to be. If the pool does not comply, there will be penalties.

The fuel use of a ship cannot always be predicted accurately because it depends on factors like where a ship is put to service, weather and currents, the amount and type of cargo, idling, repositioning, and a range of other factors. Therefore, ships will want to have contingency plans covering situations like unforeseen higher or lower fuel use by members of the pool, resulting in common over- or undercompliance. These plans could include for some ships to change their fuel plan, adding ships to the pool or expulsing them from the pool, et cetera.

Hence, participants in the pool need to draft contracts under private law covering, at least:

1. The obligation each party to the pool has;
2. Definitions of non-compliance, force majeure;
3. Remedies for missing the obligation;
4. Contingency plans; and
5. Governance of the pool.

The competent authority needs to decide how to enforce the compliance of pools. If a ship is part of a pool and fulfils its contractual obligations, but the pool as a whole does not comply, will the regulator enforce against the ship? And if a ship complies individually, but the pool to which it belongs does not comply, will that ship be penalised?

Voluntary pooling leads to additional administrative tasks by the competent authority and by the regulated entities as indicated in Table 4.8.

Table 4.8 Additional administrative tasks with voluntary pooling

Administrative tasks regulator	Administrative tasks responsible entities
Check compliance of each ship in a pool	Collective reporting
Enforce non-compliance in case the pool is non-compliant	Verification of the collective report
Register compliance / issue Statement of Compliance	Negotiating contracts for the pool

A baseline-and-credit scheme would allow ships to use energy credits to comply when the energy that a ship has actually used has GHG emissions in exceedance of the limit value. Credits would be granted to ships that overcomply, i.e. which have emissions below the GHG limit value. A credit would represent a unit of energy with a certain amount of emissions. So for example, if the applicable limit is 80 g CO_2eq/MJ energy, and a ship uses 1 TJ of e-methanol with WTW emissions of 8 g CO2eq/MJ, it has emitted 72 million grams CO_2 less than it would have if it would have sailed on compliant fuel. Consequently, it could apply to receive 72 million credits with a value of 1 g CO2eq. A ship that uses 6 TJ MGO with WTW emissions of 92 g CO_2eq/MJ (12 g CO_2eq/MJ above the limit) could use these 72 million credits to comply.

One way of looking at a baseline and credit scheme is that it is a voluntary pool, potentially comprising the entire fleet (although ships can also comply individually) and governed by the regulator instead of by private contracts.

In order to organise the baseline and credit scheme, the regulator would need to develop a system to issue credits to overcompliers and set up a registry for credits, thus ensuring that redit scan be used only once and that the ownership of the credits is determined.

An overcomplier would submit its emissions report together with a request for credits. If he meets the criteria (i.e. when the consumption of RLF is above the limit or the average GHG emissions intensity of the fuel is below the limit value), the regulator would issue credits. In order to receive credits, the overcomplier needs to register.

The regulator does not need to organise a market, that can be left to the private sector as long as the ownership of credits is well defined and credits are transferable.

Table 4.9 Additional administrative tasks with a baseline and credit system

Administrative tasks regulator	Administrative tasks responsible entities
Set up register	Register
Issue credits	Apply for credits
Enforce compliance of individual ships	

4.2.2. Assigning higher weights to zero-emission technologies

In order to incentivise the use of innovative technologies, higher weights could be assigned to fuels that have very low or zero emissions. This can either be done by setting thresholds or by applying a continuous function as shown in Table 4.10:

Table 4.10 Ways to assign higher weights to low-GHG technologies

	Threshold	Continuous function
Voluntary pooling	Fuels with emissions lower than 10	Fuels with specific emissions of

	g CO_2eq/MJ[76] count for twice the amount of energy Fuels with emissions lower than 5 g CO_2eq/MJ[77] count for four times the amount of energy	x g CO_2eq/MJ (x<20) count for 20/x the amount of energy
Baseline and credit	Fuels with emissions lower than 10 g CO_2eq/MJ qualify for 2 times the amount of credits Fuels with emissions lower than 5 g CO_2eq/MJ qualify for 4 times the amount of credits	Fuels with specific emissions of x g CO_2eq/MJ (x<20) qualify for 20/x the amount of credits

4.3. Impacts of policy options on fuel choice

The different policy options have a different impact on the choice of the fuel used to comply with the requirement. The prescriptive option A sets a minimum share of eligible fuels which would increase over time as well as a minimum share of OPS, with alternative means of compliance for certain fuel types. Because ships have to comply individually on an annual basis (i.e. on average over the period of one year), ships have the following options as long as the share is less than 100%:

- Ships will use a compliant blend of fuels continuously. This blend will be composed of the conventional fuel (which can be VLSFO, ULSFO, HFO, MGO or LNG, depending on the engine of the ship, its compliance option for the Sulphur regulation and the region in which the ship is sailing) with the cheapest compatible renewable or low-carbon fuel that can be blended in. According to Section 3.1.3, the drop-in fuels with the lowest production costs (in €/GJ) are liquefied biogas and biodiesel, although the actual compatibility will need to be assured in every specific case;
- Ships will use a conventional fuel for a share of the time and bio- or electro-liquids or gases (including hydrogen and ammonia) for the remainder of the time, thus achieving compliance on average across the year. This would be preferable to the previous option when, for example, a ship is not able to bunker compliant blended fuels when bunkering outside the EU. In this case, a ship would also opt for the cheapest compliant fuel, either unblended or in a higher blend, and would need to switch over from one fuel to the other. According to Section 3.1.3, the fuels with the lowest production costs (in €/GJ) are liquefied biogas and biodiesel, although the actual compatibility will need to be assured in every specific case;
- Ships will use a compliant fuel for some equipment, e.g. one or more auxiliary engines or boilers, and conventional fuel for the other engines. Also in these cases, ships will opt for the cheapest compliant fuels. The benefit compared to the previous compliance option is that a fuel switch is not necessary.

Under policy option 2 three similar choices would be available. The difference is that in this option, the market would not choose for the cheapest fuels, but for the most cost-effective in terms of euro per unit of GHG emissions per GJ in a total cost of ownership perspective. According to Section 3.1.3, the most-cost-effective fuels in terms of cost-price of production are liquefied biogas, biodiesel, bio-methanol, bio-ethanol and e-hydrogen.

76 E.g. e-methane.
77 E.g. e-ammonia, e-hydrogen.

Other e-fuels are currently less cost-effective, although the order may be different if bunkering costs and capital costs of ships are taken into account.

In policy option 3 ships can collectively comply. This means that another option becomes available in addition to the three options listed above, viz.:

- A ship sails continuously on an eligible low- or zero-carbon fuel. This would probably be the most cost-effective fuel from a total cost of ownership perspective. According to Section 3.1.3, the fuels with the best cost-effectiveness (in €/tCO_2eq/GJ) are liquefied biogas, bio-ethanol, bio-methanol, biodiesel and e-ammonia. Hence, in addition to the compliance per individual ship, one could expect a larger uptake of bio-methanol and bio-ethanol. Since compliance would be pooled, some ships in a pool can sail continuously on conventional fuels and others continuously on eligible fuels, thus removing the need for a fuel switch and/or engine adjustments.

Under, policy option 2 the same compliance options would be available.

Table 4.11 summarises the impact of policy options on fuel choice.

Table 4.11 Summary of the impact of policy options on fuel choice

Policy option			Compliance options
A	In navigation and at berth	Minimum shares of specific fuel types (established ex-ante) would be established and would increase over time in line with the expected penetration rates resulting from the 2030 Climate Target Plan	Run one or more (auxiliary) engines on compliant fuels, either all the time or part-time. The market will opt for the cheapest compliant fuels. If fuels are used in the main engine, the market will opt for the cheapest drop-in fuels. According to Section 3.1.3, the fuels with the lowest production costs (in €/GJ) are liquefied biogas, bio-ethanol, bio-methanol and biodiesel. Biodiesel and LBG are drop-in fuels for diesel- and LNG engines, respectively. The production costs of these fuels overlap with the cheapest e-fuels, e-hydrogen and e-ammonia. However, as the latter require significant modifications to a ship, the total costs of ownership for ships able to run on those fuels are likely to be significantly higher.
	In addition at berth	The use of on-shore power supply will be mandated for the most polluting ships in ports, i.e. containerships, passenger ships and ro-pax ships, unless they can prove the use of equally performant alternative (e.g. batteries, zero-pollution energy sources, etc.)	Ships will opt for OPS when that is cheapest, and for fuels when that is cheapest. This depends on how often they come at ports that require OPS, how OPS is accounted for, the costs of linking to OPS, et cetera. When opting for fuels, the market will opt for the cheapest compliant fuels.
B	In navigation and at berth	A maximum limit on the GHG content of energy used by ships in navigation (e.g. CO_2eq/MJ or kWh) would be identified in line with the expectations of the 2030 Climate Target Plan and will be made more stringent over time. Ships need to remain below the maximum limit on average over the compliance period.	Run one or more (auxiliary) engines on compliant fuels, either all the time or part-time. The market will opt for the most cost-effective compliant fuels in terms of €/CO_2eq/MJ or kWh). If fuels are used in the main engine, the market will opt for the most cost-effective drop-in fuels.. According to Section 3.1.3, the most-cost-effective fuels are LBG, biodiesel, bio-methanol, bio-ethanol and e-hydrogen. Other e-fuels are less cost-effective. Of these fuels, biodiesel and LBG are drop in fuels for diesel- and LNG engines, respectively. The production costs of e-fuels are projected to decrease in the coming decades. Hence, it is possible that the most cost-effective fuel will become an e-fuel in the coming decades.
	At berth	The use of on-shore power supply will be mandated for the most polluting ships in ports, i.e. containerships, passenger ships and ro-pax ships, unless they can prove the use of equally performant alternative (e.g. batteries, zero-pollution energy sources, etc.) A phased-in implementation is planned in order to gradually extend the	Ships will opt for OPS when that is cheapest, and for fuels when that is cheapest. This depends on how often they come at ports that require OPS, how OPS is accounted for, the costs of linking to OPS, et cetera. When opting for fuels, the market will opt for the most cost-effective compliant fuels.

Policy option			Compliance options
		requirements to the entire fleet.	
C	In navigation and at berth	A maximum limit of the GHG content of energy used by ships in navigation (CO_2eq/MJ or kWh), which would be made more stringent over time	Have a few ships sail continuously on compliant fuels in order to minimise the risks associated with fuel-switching and so that a supply chain can be contracted. The market will opt for the most cost-effective compliant fuels in terms of €/CO_2eq/MJ or kWh).
	At berth	The use of on-shore power supply will be mandated for the most polluting ships in ports, i.e. containerships, passenger ships and ro-pax ships, unless they can prove the use of equally performant alternative (e.g. batteries, zero-pollution energy sources, etc.) A phased-in implementation is planned in order to gradually extend the requirements to the entire fleet.	Ships will opt for OPS when that is cheapest, and for fuels when that is cheapest. This depends on how often they come at ports that require OPS, how OPS is accounted for, the costs of linking to OPS, et cetera. When opting for fuels, the market will opt for the most cost-effective compliant fuels.

4.4. Impacts of policy options on administrative requirements

Table 4.12 Summary of the impact of policy options on administrative requirements

Policy option			Compliance options
1	In navigation and at berth	Minimum shares of specific fuel types (established ex-ante) would be established and would increase over time in line with the expected penetration rates resulting from the 2030 Climate Target Plan	Ships need to report: The total amount of fuel used in year X in MJ (currently not required under the EU MRV); and The amount of compliant fuel used in year X in MJ (currently not required under the EU MRV). Fuel producers need to certify that fuels are compliant. The regulator needs to check compliance of ships and enforce if necessary
	In addition at berth	The use of on-shore power supply will be mandated for the most polluting ships in ports, i.e. containerships, passenger ships and ro-pax ships, unless they can prove the use of equally performant alternative (e.g. batteries, zero-pollution energy sources, etc.) A phased-in implementation is planned in order to gradually extend the requirements to the entire fleet.	Ships need to report: The total amount of energy used at berth in year X in MJ (currently not required under the EU MRV); The amount of electricity consumed at berth in year X in MJ (currently not required under the EU MRV); and The amount of compliant fuel used at berth in year X in MJ (currently not required under the EU MRV).
2	In navigation and at berth	A maximum limit on the GHG content of energy used by ships in navigation (e.g. CO2eq/kWh) would be identified in line with the expectations of the 2030 Climate Target Plan and will be made more stringent over time. Ships need to remain below the maximum limit on average over the compliance period.	Ships need to report: The total amount of fuel and electricity used in year X in MJ (currently not required under the EU MRV); and For each fuel or electricity: the GHG content (currently not required under the EU MRV). Fuel supplier/producer has to certify GHG content of the fuel
	At berth	The use of on-shore power supply will be mandated for the most polluting ships in ports, i.e. containerships, passenger ships and ro-pax ships, unless they can prove the use of equally performant alternative (e.g. batteries, zero-pollution energy sources, etc.) A phased-in implementation is planned in order to gradually extend the requirements to the entire	If the limit at berth is the same: see above. If the limit at berth is more stringent than in navigation: The total amount of fuel and electricity used at berth in year X in MJ; and For each fuel or electricity: the GHG content.

Policy option			Compliance options
		fleet.	
3	In navigation and at berth	A maximum limit on the GHG content of energy used by ships in navigation (e.g. CO2eq/kWh) would be identified in line with the expectations of the 2030 Climate Target Plan and will be made more stringent over time. Ships need to remain below the maximum limit on average over the compliance period. This policy option also integrates specific measures to foster over-achievements and encourage the development of more advanced, zero-emissions technologies. These concern specifically the possibility to not only average compliance on a yearly basis (as in PO2) but also pool compliance with other ships / operators, either on a voluntary basis or through transferrable credits. Also, when establishing the ship's performance in achieving the yearly target, higher weight will be attributed to zero-emission technologies.	See option 2 above In addition, optionally, if ships choose not to comply on an individual ship basis, either a compliance report for the voluntary pool or credits from a baseline and credit scheme.
	At berth	The use of on-shore power supply will be mandated for the most polluting ships in ports, i.e. containerships, passenger ships and ro-pax ships, unless they can prove the use of equally performant alternative (e.g. batteries, zero-pollution energy sources, etc.) A phased-in implementation is planned in order to gradually extend the requirements to the entire fleet.	See option 2 above

5. Assessment of impacts

5.1. Introduction

In this chapter, the impact of the proposed policy options is assessed in more detail.[78] It is important to note that the impact of the legal initiative, irrespective of the policy option chosen, already has a large effect. The fact that a legal act will be adopted which stimulates the uptake of alternative fuels in maritime transport, leads to an increased use of alternative fuels and accompanying impacts. The impact of the legal act *per se* is much larger than the different impacts resulting from the individual policy options.

Another important note is that much is still unknown. In the available literature and reports, there is only little evidence on the impact of the different policy options. Also, stakeholders find it difficult to assess the impact of the different options. Information on the impact of accelerating the uptake of maritime fuels could be found and stakeholders do have a clear view on how alternative fuels will impact their business, in terms of costs, compliance and competitive position. However, assessing the differences between a prescriptive option and a goal-based option turned out to be more difficult, as many stakeholders indicated that the ultimate impact of the policy options will depend on the details of the new legal act. As a result, they were able to provide some indication, but many assumptions had to be made.

Overall, eleven different impacts are considered. In Section 5.2, the five economic impacts are discussed. Section 5.3 elaborates on social impacts, and section 5.4 discusses the environmental impacts.

5.2. Economic impacts

The economic impacts consist of the direct impacts, such as the regulatory impacts for the economic actors (e.g. ship operators, fuel plants, etc.) and administrative impacts for enforcement authorities. Other possible impacts might be less direct. Examples are the impact on third countries and the competitiveness of the maritime sector. Nevertheless, these impacts also need to be considered.

5.2.1. Administrative impact: compliance costs and administrative burden for economic actors

The main objective of the compliance and administrative burden assessment is to analyse to what extent the policy options will impact the compliance costs and administrative burden on market actors, such as alternative fuel producers, bunker companies and shipping companies. The assessment in the section above focussed on the CAPEX and OPEX costs, this assessment will include all other costs and investments borne by economic actors to be compliant with the legal initiative and the resulting information obligations.

[78] It is also important to note that in accordance with the ToR not all impacts of the proposed initiative are covered in this support study. Some of the impacts were assessed by the Commission and are therefore only included in the SWD.

In order to assess the significance of the compliance costs and administrative burden, a step-by-step approach is followed aligned with the EC Better Regulation Guidelines and toolbox Tool #60. The following definitions are used:

Definition compliance costs

Compliance costs encompass, according to tool #58, 'those investments and expenses that are faced by businesses and citizens in order to comply with substantive obligations or requirements contained in a legal rule.'

Definition administrative burden

Administrative burden encompasses, according to tool #58, 'those costs borne by businesses, citizens, civil society organisations and public authorities as a result of administrative activities performed to comply with information obligations included in legal rules.'

In an impact assessment, it is common to develop a dedicated standard cost model (SCM) in order to assess the impact of the policy options on different economic actors. In the current impact assessment, however, it is difficult to develop a full SCM as future impacts are highly uncertain. Nevertheless, the methodology described to develop an SCM is followed as much as possible.

The compliance regime of the FuelEU Maritime initiative will be based on reporting and verification of GHG intensity of the energy used on board. In the EU MRV Regulation, there are already reporting requirements for time spent at sea, fuel consumption and CO2 emissions. Figure 5.1 shows the compliance cycle introduced for the EU MRV Regulation, including the obligations of several stakeholders. A similar compliance cycle could be introduced in the legal initiative, as the aim is to rely as much as possible on the already existing reporting requirements in the EU MRV Regulation. However, the legal initiative will include additional emissions (such as well-to-tank and CH4 and N20 emissions). Therefore, the information obligations of the EU MRV regulations are not sufficient for compliance with the policy options.

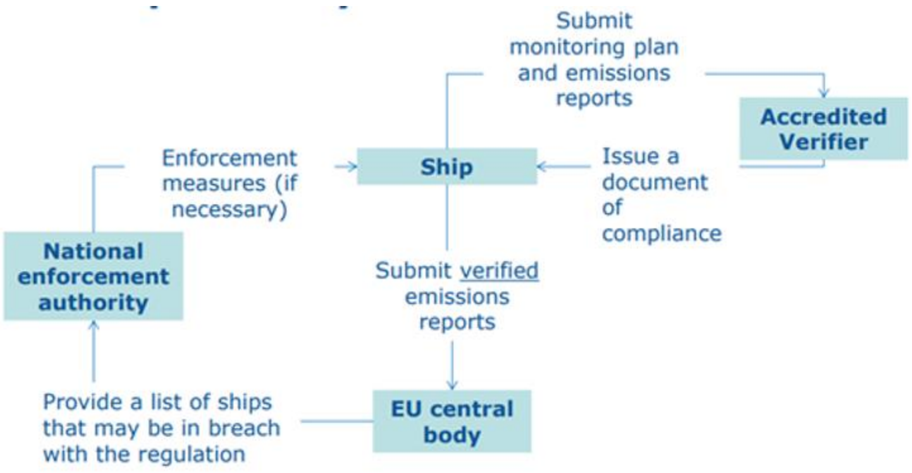

Figure 5.1 Compliance cycle EU MRV Regulation

Source: European Commission, 6th EU ETS Compliance Conference 5 November 2015, Brussels.

As a first step, the study team identified all the respective additional information obligations of economic actors to authorities. Besides the information obligations all actions needed to comply with the legal initiative were identified. Various literature sources which describe the current information obligations (e.g. other impact assessments and evaluation studies, like the EU MRV Impact Assessment) were used. At a regulatory level, changes in the draft International Code of Safety for Ships using Gases or other Low flashpoint Fuels (IGF Code)[79] and proposed amendments under SOLAS in the light of different chemical characteristics of alternative fuels (e.g. low flashpoint, volatilities,

[79] The IGF Code is currently only holding LNG.

energy content per unit mass and toxicity) are useful.[80] Literature findings were supplemented, to the extent possible, with findings from interviews.

It should be noted that not all of the administrative costs from switching to alternative fuels can be contributed fully to the legal initiative. Switching to alternative fuels will have to happen, as it will be one of the ways to reach the climate goals set out by the Paris Agreement. For instance, several large energy/oil companies[81] have already committed to (near) carbon neutrality in 2050. A recognised organisation recently indicated that their clients (shipowners) are motivated to switch to alternative fuels, as long as they can be certain that these fuels have a clear pathway to carbon neutrality on a life cycle basis.

Ship owners/operators

All policy options focus primarily on ship owners and operators, as shipowners have to comply with the regulation and are also responsible to prove their compliance. The regulation will likely be in place the earliest in 2025.

The ships covered under the legal initiative are the same as in the EU MRV regulation, namely ships with a GT above 5,000. In 2019, the EU MRV regulation covered 12,114 vessels.[82] The number of vessesl under the EU MRV regulation will be linked to the evolution of the stock of vessels under the policy options, with an expected number of 13,502 vessels falling under the scope of the initiative in 2025 and 19,412 vessels in 2050.

All of these ships already have experience with the reporting requirements and the use of the THETIS-MRV database. An analysis has been performed by the European Commission (2018 data) on the number of voyages performed by 80% of the ships in the MRV monitored fleet.[83] These 9,924 ships together performed over 400,000 voyages, of which 65% were EEA-related voyages. Extrapolating this number to the 2019 MRV monitored fleet would suggest that roughly 317,900 voyages were performed, falling under the EU MRV Regulation. The number of voyages will be linked to the predicted evolution in freight transport activity. This means that in 2025 there will be 455,365 voyages and in 2050 there will be 582,875 voyages falling under the scope of the initiative.

In the following text, the administrative costs resulting from each identified information obligation is discussed individually.

1. **Annual energy compliance plan**

Each vessel has to prepare an annual compliance plan, which describes which fuels and technologies the ship is planning to use. This plan resembles the EU MRV Monitoring plan. However, the new plan is more extensive, as monitoring is only a part of the new obligation.

Administrative action: Prepare and submit annual energy compliance plan

80 Several other guidelines and standards are upcoming. IMO guidelines for methyl/ethyl alcohol have been finalised, IMO guidelines for Fuel Cells are under development. Additionally, ISO is requested for a series of necessary standardization efforts with respect to the use of different fuels as marine fuels.

81 These include Shell, Repsol, Total, Equinor, BP.

82 Thetis-MRV 2019 CO2 Emissions Report, https://mrv.emsa.europa.eu/#public/emission-report.

83 2019 Annual Report from the European Commission on CO2 Emissions from Maritime Transport.

In the EU MRV Impact Assesment Part 2[84] a time of 40 hours per ship was estimated for the prepartation of the Monitoring Plan. The same amount of time will be used in this impact assessment for the annual energy compliance plan. This will lead to a total annual administrative cost of around €21.1 million (40 hours * 13,502 ships * €39.1 labour costs per hour[85]) in 2025, with increasing costs till 2050 as the costs are linked to the number of vessels. Based on the experience with the implementation of EU MRV Regulation, it is likely that such a cost would be highest in the first year and significantly decrease afterwards. Therefore these costs are only incurred once every 10 years.

2. Annual energy report

The annual energy report is the calculation of the annual energy consumption of the vessel. It should be broken down to different energy sources/types of fuel. This report resembles the EU MRV Annual energy report, but is more extensive as well-to-tank, non-CO_2 emissions and OPS consumption are included as well. Also, the exact amount of each fuel used should be reported. This leads to several additional actions.

Administrative action: Collecting additional information

In the targeted survey 8 out of 9 respondents indicated that for ship owners, the reporting time would increase two hours at most, per voyage. Only 1 respondent indicated that the time would increase more than 2 hours, but did not specify with how much. This additional reporting time predominantly would be spent on submitting the bunker delivery notes and on making additional calculations for CH_4 and N_2O emissions, gathering and the well-to-tank CO_2 emissions from bunker delivery notes. As there will be 455,365 voyages yearly in 2025 the total annual administrative costs in 2025 are €22.3 million (2 hours * 317,900 voyages * €24.5 labour costs per hour). The number of voyages is linked to the evolution of transport activity, which is expected to increase with 28% in the period 2025-2050. So the costs of collecting information will also increase. However, it is to be expected that shipping companies will implement systems to automate the reporting, thus reducing the administrative burden.[86]

It can be assumed that specific information on the use of OPS is already included in this reporting. For every port call, the arrival time, connection time, disconnection time and departure time have to be documented. This information can be supplied by the electricity supplier.

3. Proof of compliance

Each ship has to prove that they are compliant with the legal initiative. In order to achieve this, the ship has to carry a document of compliance and cooperate during Port State Control inspections and show this document of compliance. The following is the additional burden for each of these two actions:

Administrative action: Carry document of compliance:

This will not impose any additional administrative costs, as the document is supplied by the Recognised Organisation, and thus only has to be stored.

Administrative action: Cooperate during Port State Control Inspections

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84 DG CLIMA, MOVE (2013) – Impact assessment part 2 Accompanying the document Proposal for a Regulation of the European Parliament and of the Council on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport and amending Regulation (EU) N° 525/2013.

85 Eurostat (LC_LCI_LEV) Labour costs index EU27, Professional, scientific and technical activities (M).

86 Eurostat (LC_LCI_LEV) Labour costs index EU27, Transportation and storage (H).

The only action required is to retrieve the document of compliance and present it to the inspector. The additional administrative costs of this will be a maximum of 15 minutes per inspected ship. The total number of Paris MoU PSC Inspections in 2019 was 15,494 (excluding Canada and the Russian Federation).[87] Assuming that each ship that falls under the scope of the initiative (expected total: 13,502 in 2025) will be inspected every year, the maximum amount of annual administrative costs in 2025 are approximately €83,000 (€24.5 labour costs per hour[88] * 0.25 hours * 13,502). The number of ships is linked to the growth in vessel stock, so the maximum costs will increase in the period 2025-2050.

Only in policy option 3, a system needs to be set up in which over-compliance is rewarded. Still several options are under examination. In this assessment, the option in which credits are awarded to ship in case of over-compliance is considered, as this is regarded the best alternative. This could be a system similar to ETS, but independent of it. Credits could be transferred from over-complying ships to under-complying ships. It should be recognised that this still might give bigger companies an advantage, as there will probably not be enough credits available to set up a proper market system. Ships can also keep their credits, to use them as a means of compliance in the following year. The actions following from this are:

Administrative action: Register to baseline-and-credit system

If a ship wants to trade credits, it can register to the baseline-and-credit system, which is set up by the European Commission. There will likely be a small impact related to registering and trading credits. However, as ships do this on their own volition, these costs will not be regarded as an administrative burden.

4. Safety procedures

In switching to alternative fuels, attention should also be paid to the safety of the fuels. The characteristics of some of the alternative fuels are very different than those of traditional fossil fuels. These challenges are not easy to overcome. Guidelines and protocols must be developed to guarantee the safety level as alternative fuels are introduced. The following actions are needed, by shipowners, to safely use alternative fuels:

Administrative action: Training of crew to safely handle alternative fuels

A shipping company indicated that two entire crews need to be trained per ship, when LNG is used as fuel. The size of a crew depends on the size and complexity of the vessel. In Table 5.1 the average crew size for different vessel types are shown. The training needs are dependent on the level of the crew. For instance, officers and engineers require more extensive training than ratings.

Table 5.1 Crew size per vessel type

Vessel type	Crew size
VLCC	24-26
Suezmax	22-24
Aframax	21-24
Panamax bulker	20-24
Handy bulker/reefer	20-22
LNG/LPG	15-24
Product tanker Automated	20-24

Source: Deloitte (2011) – Challenge to the industry: Securing skilled crews in today's marketplace.

87 Paris MoU (2019) – Annual Report.

88 Eurostat (LC_LCI_LEV) Labour costs index EU27, Transportation and storage (H).

The mandatory training needs for LNG are either the IGF Code Basic Training, or the IGF Code Advanced Training.[89] These trainings take between 2 and 4 days per crew member, with a fee of around €400 per day,[90] or €50 per hour.

However, training is very specific to the technical features of the fuels. As there is little to no experience with the other alternative fuels, neither in maritime shipping, nor in other modes of transport, training needs of other alternative fuels might exceed those of LNG.

Furthermore, we assume that training for alternative fuels will become standard in training programs for new seafarers in 2035. This means that only the ships switching to alternative fuels (*not* including LNG) before 2035 would need to invest in additional training. We assume that not the entire crew will be trained at once, but that the training will be spread over 10 years. This has the implication that we assume that the largest part of the crew will only be trained after the vessel starts using the alternative fuel.

According to the results of the PRIMES modelling, under policy option 1, the share of alternative fuels (not including LNG) in the energy mix will increase from 3% in 2025 to 15.7% in 2035. For policy options 2 and 3 this will be from 3% to 16.1%. We assume that the number of ships using alternative fuels are equal to share of alternative fuels in the energy mix.

Combining these numbers the total annual cost in 2025 will be €3.3 million (2 crews * 22/23 members per crew * 3 days * 8 hours * (€24.5 labour costs per hour[91] + €50 fee per hour) * 13.502 ships in 2025 * 3% affected) / 10 years). These costs would only be incurred between 2025 – 2035. As both the number of ships and the uptake of alternative fuels will increase, the costs will increase to around €19.0 million in 2035.

Bunker suppliers and fuel producers

The underlying assumption of the legal initiative is that there will be sufficient supply to realise the demands. However, energy companies are very much focused on economy wide energy transitions. In the case that shipping requires unique fuels (i.e. ammonia), there is no guarantee that there will be sufficient supply, as energy companies will focus on multi-purpose alternative fuels first. The fact that fuel producers have to react to an uncertain demand, makes this risk even greater. In an interview, it was indicated that it takes fuel producers at least 5 years of a concerted effort to get ready for small scale implementation of an alternative fuel and at least another 5 years to build a market for it.

Bunker suppliers and fuel producers are not the main stakeholder group targeted in this initiative. However, they are affected as they have to change their operations in order to accommodate the shipowners to be compliant. For bunker suppliers and fuel producers to accommodate ship owners to prove their compliance, the following information obligations are introduced:

1. **Certification of fuel and upstream emissions**

Fuel producers already have experience with certification of biofuels under the Renewable Energy Directive, so there is already experience. When a new (bio)fuel needs to be certified, for instance, under the International Sustainability & Carbon Certitification (ISCC) Scheme, the entire supply chain has to be certified. This means that either all suppliers

89 https://www.ilent.nl/onderwerpen/bemanning-zeevaart/trainingen-igf-schepen.

90 Based on duration of IGF Code training for LNG (RelyOnNutec: IGF Basic Training (2 days, fee: €800), STC Training & Consultancy IGF Training (Advanced 4 days, fee: €1,765 – Basic 2 days, fee: €730).

91 Eurostat (LC_LCI_LEV) Labour costs index EU27, Transportation and storage (H).

and other stakeholders need to cooperate in the certification, or are themselves already ISCC certified..

The certification occurs in several steps:

- Step 1: Firstly, the producers select a recognised certification body to conduct the external audit;
- Step 2: Secondly, the producer must register to ISCC (or any other certification scheme). Certification schemes mostly have one-time registration fees that vary between €50 and €500,[92] so these are one-off costs.

Then an audit is performed in two stages:

- Step 3: In the first stage, an internal audit is conducted. Costs for this will be dependent on the amount of time spent on it. These are yearly costs. Fuel producers were not able to indicate the time needed;
- Step 4: In the second stage, the certification body performs an external audit. The producers must provide all necessary proofs, documents, data and access to relevant locations.[93] The certification has to be renewed every year. Annual fees per certificate vary from €50 to €500 as well. Finally, fees have to be paid per quantity of material declared as sustainable. These fees range between €0.03 and €0.10 per metric ton. The costs of an external audit can range from €800 to €2,000 per day.

The efforts needed to also certify upstream emissions are greater. An option is to use default values, which only have to be certified once every several years. The question remains as to how this could be introduced outside of the European Union. Monitoring the exact emissions constantly is expensive and would introduce serious costs to the fuel producers. Several fuel producers have been interviewed, but none were able to make an estimate of the effort needed for certification. However, the effort needed for policy option 1 where only the type of fuel needs to be certified is significantly lower than for policy option 2 and 3, where the exact amount of emissions is needed.

Administrative costs for port authorities

Administrative action: Establishing bunkering guidelines for alternative fuels with ports

Ports want to be certain that the bunkering operations in their port are safe. As there is little to no conventional experience with alternative fuels yet, setting up guidelines and developing procedures can take a long time. Firstly, movers in the bunker supplier market have to invest significant time in setting up guidelines. There is also no guarantee that ports will accept guidelines introduced in another port, especially if it is a port in a different country, so this process has to be repeated for each individual port. Sometimes vessel designs even have to change.

A bunker supplier indicated in an interview that at the first port where they wanted to introduce LNG the whole process of setting up guidelines to getting a license to sell LNG in that port took 5 years. Currently, in new ports, the process can be repeated in a months' time. We assume that 1 FTE is busy with setting up this guideline during this month. This

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92 https://www.iscc-system.org/process/registration-for-certification/iscc-fee-structure/. https://rsb.org/wp-content/uploads/2020/07/20-07-06-Bio-based-and-Advanced-Liquid-Fuels-for-web.pdf. http://www.betterbiomass.com/wp-content/uploads/2020/02/Better-Biomass-Tariff-sheet-2020.pdf.

93 https://www.iscc-system.org/process/overview/.

same progress can be expected for other alternative fuels. If new guidelines have to be established for six fuel categories (LNG, e-liquids, e-gas, hydrogen, ammonia and methanol) in the 160 medium and large-sized ports (470 ports * 34%) in Europe (see section 5.2.4 Impact on Ports), the total annual administrative costs will be €170,000 (160 hours * €28.1[94] labour costs per hour * 470 ports * 34% affected * 6 fuel types / 25 years).

Another complication is that there are no international standards for alternative fuels yet. A biofuel supplier indicated that the ISO 8217 standard only applies to fossil production and that there is no ISO standard for the production of bio versions of the fuels. Therefore, no insurance is possible and discussions need to be held with engine manufacturers and the flag State directly in order to be granted an exception. This is a complicated and lengthy process. Unfortunately, stakeholders could not indicate a range of the time spent on the discussion. One supplier has been in contact with the NEN[95] and they do not expect any change in the ISO 8217 standard in the coming 3 to 4 years. There will also be an impact for ISO, since they have to develop new international standards for alternative fuels.

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94 Eurostat (LC_LCI_LEV) Labour costs index EU27, Industry (except construction) (B-E).

95 NEN is the Dutch organization for standardization, they also facilitate the management of certification schemes.

Annual administrative costs

All the costs for these different information obligations and stakeholder are summarised in Table 5.2. As an example the costs for the year 2025, not discounted, are calculated. For most categories the costs will increase, as the number of vessels will increase with 44% in the period 2025-2050 and the number of voyages with 28%.

These are only the additional costs resulting from the legal initiative. The costs per policy option are calculated by multiplying the frequency per year, with the time needed in hours, with the tariff per hour, with the number of entities and the percentage of entities affected per policy option.

Table 5.2 Administrative costs in 2025 (not discounted)

Information obligation	Administrative action	Frequency (per year)	Time (hours)	Tariff (per hour)	Number of entities	Entities affected per policy option	Annual administrative costs (PO1)	Annual administrative costs (PO2)	Annual administrative costs (PO3)
		(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6) = 1*2*3*4*5(PO1)**	**(7) = 1*2*3*4*5(PO2)**	**(8) = 1*2*3*4*5(PO3)**
Administrative costs of ship owners									
Annual energy compliance plan	Prepare and submit annual energy compliance plan	0,1 (to spread costs over 10 years)	40[96]	39.1[97]	Vessels under EU MRV Regulation: 13,502 (in 2025); linked to the evolution of the stock of vessels in the policy options	PO1, PO2, PO3: 100%	€ 2,11 million	€ 2,11 million	€ 2,11 million
Annual energy report	Collecting additional information (per voyage)	1	2	24.5[98]	Number of voyages under EU MRV Regulation: 455,365 (in 2025); linked to the evolution of transport activity over time in the policy options	PO1, PO2, PO3: 100%	€ 22,3 million	€ 22,3 million	€ 22,3 million
Proof compliance	Cooperate during PSC inspection	1	0.25	24.5[99]	Vessels under EU MRV Regulation: 13,502 (in 2025) linked to the evolution of the stock of vessels in the policy options	PO1, PO2, PO3: 100%[100]	Upper bound: € 82,000	Upper bound: € 82,000	Upper bound: € 82,000
Safety procedures	Crew training	4.5[101] (to spread costs over 10 years)	24[102]	24.5 (wages) + 50 (fee)	Vessels under EU MRV Regulation: 15.027 (in 2025) linked to the evolution of the stock of vessels in the policy options	Uptake of RLF in each option (in 2025) PO1: 3% PO2, PO3: 3%	€3.3 million (in 2025)	€3.3 million (in 2025)	€3.3 million (in 2025)
Administrative costs for port authorities									
Guidelines in ports	Set up guidelines in ports	0.24[103] (to spread costs over 25 years)	160	28.1	Number of ports in the EU: 470[104]	A, B, C: 34%[105]	€170,000	€170,000	€170,000

96 DG CLIMA, MOVE (2013) – Impact assessment part 2 Accompanying the document Proposal for a Regulation of the European Parliament and of the Council on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport and amending Regulation (EU) N° 525/2013.

97 Eurostat (LC_LCI_LEV) Labour costs index EU27, Professional, scientific and technical activities (M).

98 Eurostat (LC_LCI_LEV) Labour costs index EU27, Transportation and storage (H).

99 Eurostat (LC_LCI_LEV) Labour costs index EU27, Transportation and storage (H).

100 Assuming that each vessels under EU MRV Regulation is inspected every year, by Paris MoU PSC. Total inspections under Paris MoU PSC 15,494 in 2019(excluding Canada and the Russian Federation).

101 Per vessel two entire crews (40-50 people) that need to be trained once between 2025 and 2035.

102 Based on duration of IGF Code training for LNG (RelyOnNutec: IGF Basic Training (2 days, fee: €800), STC Training & Consultancy IGF Training (Advanced 4 days, fee: €1,765 – Basic 2 days, fee: €730).

103 Assuming that guidelines only need to be set-up once between 2025 and 2050, for each of the following six fuel categories (LNG, e-liquids, e-gas, hydrogen, ammonia and methanol).

Source: Own calculations (2020).

[104] 470 European ports have registered throughput statistics, see section 5.2.4 (impact on ports).

[105] Assuming the ports classified as large and medium (see section 5.2.4 (impact on ports)) will set up guidelines and the small ports will use those guidelines.

In Table 5.3 the net present value for the period 2025-2050 is given, for each stakeholder group. A yearly discount rate of 4% is used, starting from 2020. As can be seen there is little difference between the three policy options, as most of the costs come from switching to alternative fuels and there is little difference in the uptake of alternative fuels between the three policy options.

Table 5.3 Total administrative costs period 2025-2050 (million €'2015)

	PO1	PO2	PO3
Administrative costs of ship owners	**439.0**	**439.4**	**439.7**
Prepare and submit annual energy compliance plan	32.8	32.8	32.8
Collecting additional information (per voyage)	335.3	335.3	335.3
Cooperate during PSC inspection	1.0	1.0	1.0
Crew training	69.8	70.2	70.5
Administrative costs for port authorities	**1.8**	**1.8**	**1.8**

Source: Ecorys(2020)

5.2.2. Regulatory and enforcement costs for public administrations

In order to assess the regulatory and enforcement impact for public administrations, the cost of compliance is identified per stakeholder group that is directly targeted or involved in reaching compliance with the regulations. The regulatory and enforcement impact mostly lies with Member States and regulatory organisations.

Member States

Member States are primarily responsible for the enforcement of compliance. The inspection can be carried out during Port State Control inspections.

Port State Control

"Port State Control (PSC) is the inspection of foreign ships in national ports to verify that the condition of the ship and its equipment comply with the requirements of international regulations and that the ship is manned and operated in compliance with these rules." IMO

The maritime authorities of the European Union, the United Kingdom, Canada and the Russian Federation have an official agreement under the Paris Memorandum of Understanding on Port State Control (Paris MoU) to implement a harmonised system of PSC. In this system, ships are selected for an inspection based on a risk scheme. Control checks for the compliance of the FuelEU Maritime initiative can be included in this risk scheme. Ships have to submit an annual emissions report to the EU competent authority, after the verification is completed and the ship has received its Document of Compliance. If the EU competent authority has not received this report in time, the ship will be placed on the high-priority list. In this way, non-compliant ships can be targeted efficiently.

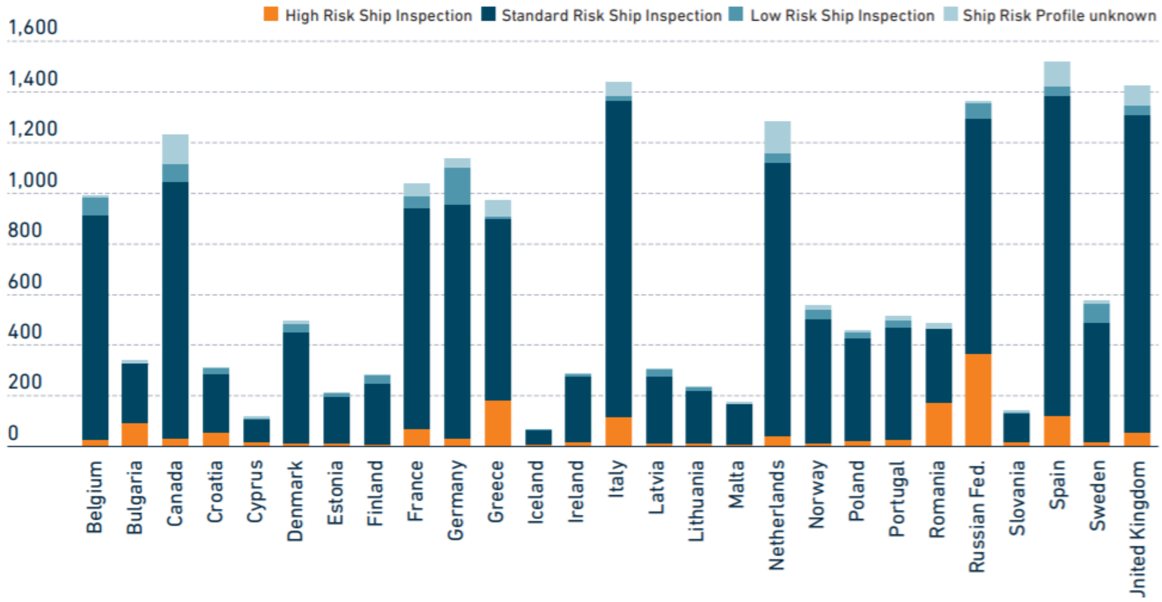

Figure 5.2 Number of inspections per Member State of the Paris MoU

Source: Paris MoU Annual Report 2019

Figure 5.2 shows the number of inspections per Member State of the Paris MoU. When only including the Member States of the European Union 15,494 inspections were carried out in 2019. As the Port State Control Officer only has to determine whether the Document of Compliance is aboard, a negligible burden of 15 minutes per inspection is assumed. If the FuelEU Maritime initiative allows the use of electronic certificates, there will be no need for a physical check at all, and it would allow for checking every ship. Member States are also responsible for imposing penalties to the shipping companies, when the Document of Compliance is missing.

Recognised organisations

In the EU-MRV Regulation, recognised organisations (RO) verify the documents supplied by shipping companies. As many documents that demonstrate compliance to the FuelEU Maritime initiative are similar to the ones used for the EU MRV Regulation, it might be reasonable to expect that the same RO will verify both regulations. The additional tasks for the RO will be the following:

- Verify annual emissions report: To verify the annual emissions report the RO has to check all the calculations and all the Bunker Delivery Notes;
- Approve annual compliance plan: The RO has to check if the fuels and technologies that the ship is planning to use are enough to meet the obligation.

In the first policy option (policy option 1), the RO has to determine which fuels were actually used on voyages that fall under the scope of the Regulation. Particularly for deep sea shipping, this might prove to be difficult, as fuel is bought in large quantities and used for multiple trips. More information on individual voyages is needed than what is available in the current database. Each bunker delivery note (BDN) must also be considered. Most BDN are not available in electronic format, so it becomes a paper-based exercise. However, if electronic BDN's are mandated, ships and bunker suppliers have to invest in acquiring an appropriate IT system and in certification of the electronic BDN.

As the verification is for compliance, the standard of verification increases quite significantly compared to the EU-MRV Regulation, as penalties for non-compliance are considered to be quite high. The RO assumes that several hours are needed for the verification of the annual emissions report of a single ship, in policy option 1.

For policy option 2 and 3, the most efficient way to evaluate the upstream emissions it to use default values for upstream emissions. However, it must be reflected in the default values that processes and supply chains can be very different for the same product in different parts of the world. If all these supply chains would have to be verified separately, this would take a lot of time. Also, it is not clear whether the EU has the authority to verify supply chains outside of the EU. The time needed for the verification in policy options 2 and 3 is similar to policy option 1, a few hours, as all BDN's still have to be checked. Instead of calculating the fuel percentages, now the GHG emissions have to be calculated. The calculation methodology for the emissions per voyage should be defined in the regulation, such that all shipowners will follow the same approach.

Finally, the RO indicated in an interview that if the EU has a regulatory requirement that needs to be verified, the RO will step up to meet the challenge. However, making the regulatory requirement as efficient and easy as possible would be good from everybody's perspective, as the likelihood of a mistake is reduced.

European Commission

Furthermore, the European Commission would have to adapt the THETIS IT eco-system (THETIs, THETIS-EU and THETIS-MRV). It should support PSC officers and EU flag states inspectors in their work and should accommodate new functionalities for the additional information requirements. Developing the tool are one-off costs, estimated at €300,000, based on experience with THETIS-EU modules. PO3 would need an additional tool to support the tool to trace and, whenever necessary, balance over- or under-compliance. This tool is estimated to cost €200,000.

The annual enforcement costs in 2025 are approximately €5.3 million. These costs are specified in Table 5.4. These costs will increase in the period 2025-2050 as they are linked to the number of vessels falling under the scope of the initiative.

It total costs correspond to a net present value of €83.3 million for policy options 1 and 2 and €83.5 million for policy option 3 in the period 2025-2050, with a discount rate of 4% from 2020, including the once-off costs of developing the IT system.

Table 5.4 Regulatory costs in 2025, not discounted

Action	Frequency per year	Time (hours)	Tarif (per hour)	Number of entities	Percentage of entities affected (per policy option)	Total administrative costs (PO1)	Total administrative costs (PO2)	Total administrative costs (PO3)
Verify annual emissions report	1	5	39.1[106]	Vessels under EU MRV Regulation: 13,502 (in 2025); linked to the evolution of the stock of vessels in the policy options	PO1, PO2, PO3: 100%	€ 2.6 million	€ 2.6 million	€ 2.6 million
Approve annual compliance plan	1	5	39.1	Vessels under EU MRV Regulation: 13,502 (in 2025); linked to the evolution of the stock of vessels in the policy options	PO1, PO2, PO3: 100%	€ 2.6 million	€ 2.6 million	€ 2.6 million
Additional time during audits/inspections	1	0.25	39.1	Vessels inspected in Paris MoU PSC, excluding Canada, the Russian Federation: 15,494 (in 2019); linked to the evolution of the stock of vessels in the policy options	PO1, PO2, PO3: *unknown*% of vessels inspected that fall under scope of EU-MRV regulation	Upper bound[107]: € 75,000	Upper bound: € 75,000	Upper bound: € 75,000
Adaptation to the EU system	Once-off					€ 300,000	€ 300,000	€ 500,000

Source: Own calculations (2020).

106 Eurostat (LC_LCI_LEV) Labour costs index EU27, Professional, scientific and technical activities (M).

107 Assuming that each vessels under EU MRV Regulation is inspected every year, by Paris MoU PSC.

5.2.3. Impact on ports to provide the necessary infrastructures and resources for each policy option

The uptake of alternative maritime fuels in maritime transport will require several actions from ports. The main action is that ports need to ensure that vessels are able to bunker the alternative fuels by providing bunkering facilities or use OPS while being at berth in the port area. This means that ports will need to invest in the adequate infrastructure facilities for alternative fuels. The costs of investing in new infrastructure may be substantial and it is questionable whether these investments are feasible within every port (not only for financial reasons, but also for other reasons, including spatial allocation). In order to assess the impact of the proposed legal initiative several steps have been taken. These steps are discussed in more detail below.

Port size: European port throughput

In the first step, the port size (measured in annual port throughput) is analysed on the basis of Eurostat 2018 statistics.[108] While there is no harmonised and accepted definition to classify small, medium and large ports, the most common method readily available is to use annual throughput of goods handled by ports.

For the purpose of this study – assessing the impact of alternative fuels on ports – the port classification threshold that is used will be somewhat broader than the one used in the TEN-T guidelines,[109] in order to clearly indicate the various impacts. The following definition is applied:

- A large-sized port is a port with a total annual traffic volume of more than (or equal to) 50 million tonnes of freight (e.g. Rotterdam or Barcelona);
- A middle-sized port is a port with a total annual traffic volume between 5 and 50 million tonnes of freight (e.g. Bilbao or Bari);
- A small port is a port that does not meet the criteria of categories A and B, but are situated in island, peripheral or outermost regions (e.g. Esbjerg or Marsaxlokk).

Figure 5.3 presents the geographical concentration of ports and the associated port classification. More than 730 ports are registered in the Eurostat database of which 470 have registered throughput statistics. Roughly 4% of these 470 ports are classified large, 30% is a medium port and 66% is a classified as a small size port. In terms of throughput, the large-sized ports (4%) are responsible for almost 40% of the annual port throughput in Europe, while the medium- and large-size ports are responsible for respectively 50% and 10% of the European throughput.

[108] Eurostat [mar_go_qmc], http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=mar_go_qmc&lang=en.

[109] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52007SC0313.

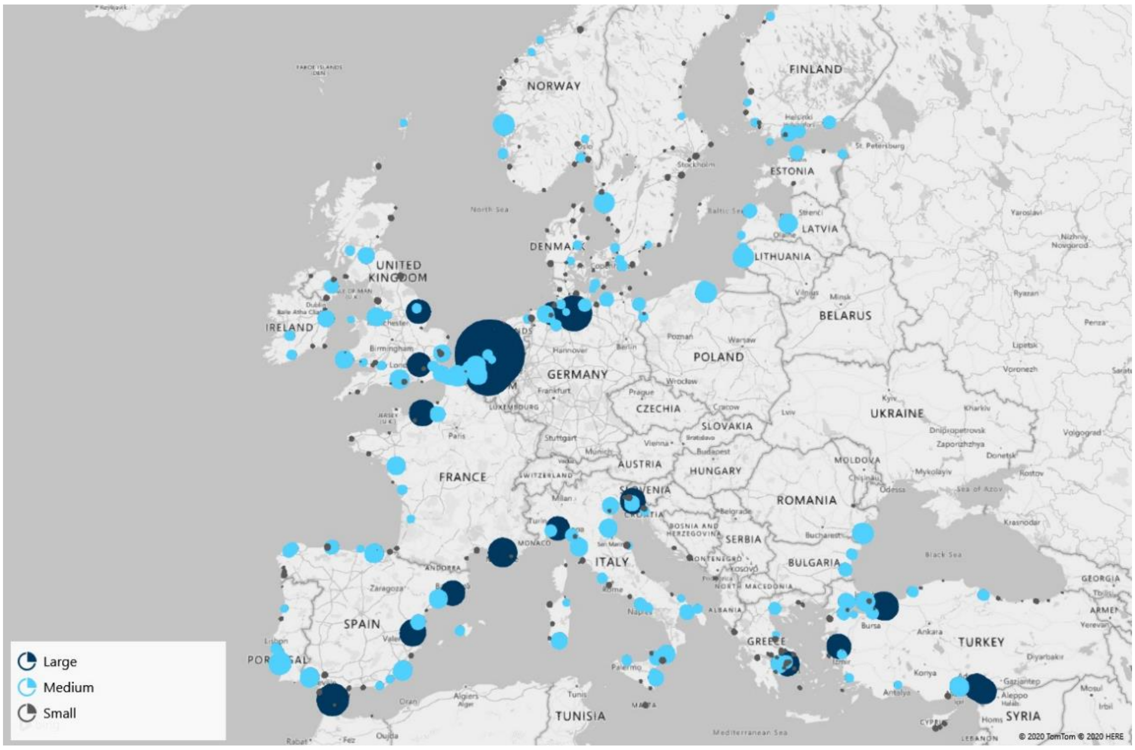

Figure 5.3 European port throughput and size – distribution across Europe

Source: Eurostat [mar_go_qmc] (modified by author)

Port size: European maritime transport of passengers

In addition to the selection of representative ports based upon port throughput, a separate sub-assessment has been performed for maritime passengers' traffic. Three representative port regions will be selected on the basis of maritime passenger movements (see Figure 5.4), from where the impact on these regions will be assessed.

- The 13 largest regions in Europe (measured in terms of maritime transport of passengers) cover roughly 50% of the total maritime transport of passengers. Each port receives around 10 million passengers per year. These 13 regions will be classified as large in the context of this study;
- Almost 40 regions in Europe have a maritime transport of passengers close to the European average. They cover roughly 40% of the total European maritime transport of passengers. Each port receives between 1.5 and 10 million passengers on an annual basis. Therefore they are classified as medium in this study;
- The 100 smallest regions (in terms of maritime transport of passengers) cover roughly 10% of the total European maritime transport of passengers. Each port receives less than 1.5 million passengers per year. These 100 regions will be classified as small in this study.

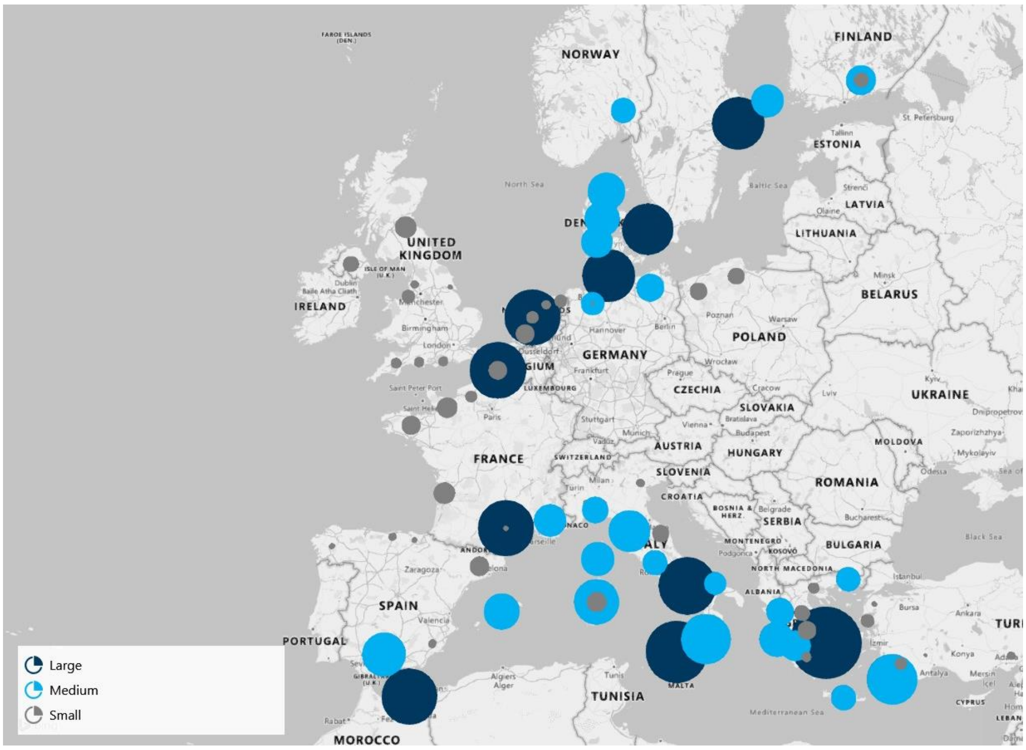

Figure 5.4 Maritime transport of passengers by NUTS 2 regions

Port type: port characteristics

While the previously discussed port size is an essential factor in order to determine the impact of alternative fuels on ports, the investments in port infrastructure also depends on the type and functioning of the port. In this second step of the analysis the different port types have been defined and data has been collected.

Some ports function as a gateway and facilitate hinterland transport towards their captive hinterland market(s). Other ports focus to a great extent on their transhipment function and facilitate distribution towards smaller ports in the region (often via short sea shipping). These different ports characteristics also impact the necessity to facilitate (and thus investments in) the necessary infrastructure. Therefore, the project team has used the following distinction (in line with Notteboom *et al*, 2019) in order to assess the impact for the following port types:[110]

- Gateway ports: these ports have a high focus on hinterland-bound flows and handle a relatively small amount of transhipment flows;
- Mixed ports: handle a balanced mix of hinterland-bound and transhipment flows;
- Transhipment ports: they focus mainly on being transhipment hubs.

After defining the different port types, data has been gathered to quantitatively assess this classification in the European port industry. Firstly, throughput per port is categorised between the following commodities: liquid bulk goods, dry bulk goods, large containers, RoRo and other cargo.[111] Secondly, information on the type of vessels is retrieved from Eurostat, which makes a distinction between liquid- and dry bulk carriers, container ships,

[110] Notteboom et al, 2019.

[111] Eurostat [mar_go_qmc], Gross weight of goods handled in main ports by direction and type of cargo.

cruise and passenger ships.[112] Thirdly, other port/region specific characteristics: such as maritime passenger movements in the region and core or comprehensive classifications.[113] The results are presented in Annex II.

European port categorization: port matrix

In step 3, the results from previous steps are confronted in a matrix. The matrix consists of the port size (x-axis) and port type (y-axis) derived from the results in step 1 and 2 respectively. In step 1, the ports are classified as either small, medium and large ports on the basis of total throughput, whereas the ports are classified as a gateway, mixed or transhipment port in step 2 of the analysis. On the basis of these two classifications, a port matrix framework has been constructed in order to assess the impact on ports to provide the necessary infrastructure (Figure 5.5).

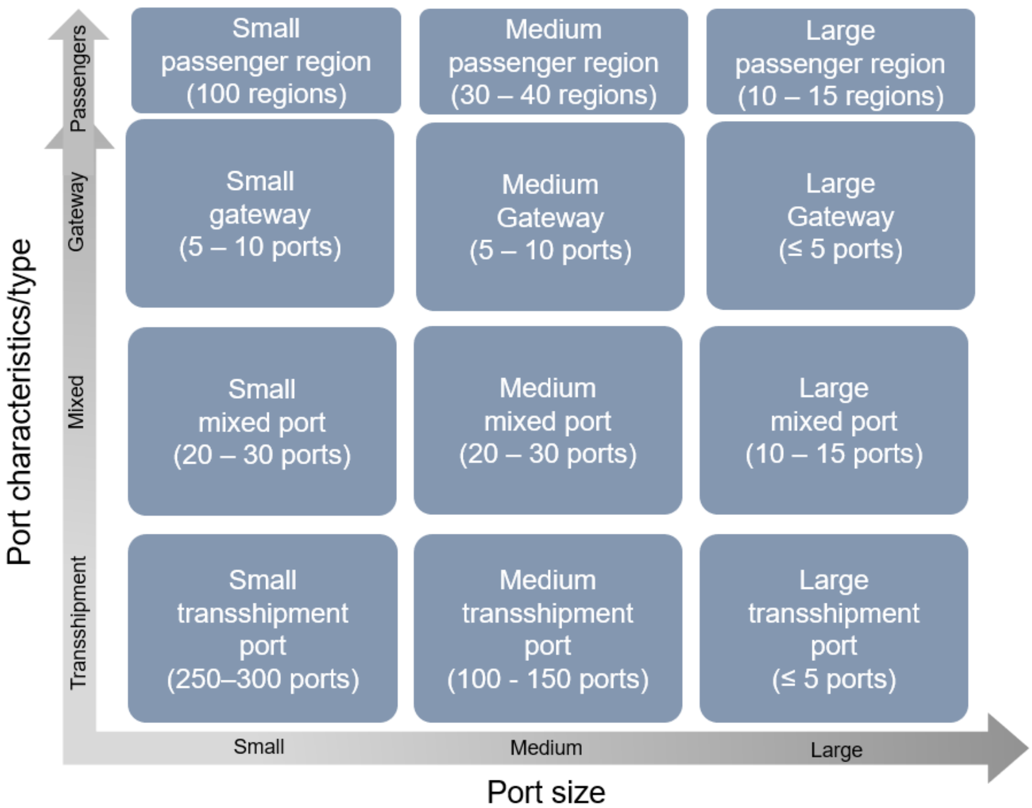

Figure 5.5 Port matrix – framework

Most European ports in Figure 5.5. are classified as small transhipment ports (roughly 250 – 300 ports). These smaller European ports often have a relatively small captive hinterland for which they function as the (main) gateway. However, the majority of the cargo handled in these ports will be distributed to other ports in the region.

The other side of the matrix represents the largest gateway ports in Europe. These large gateways have a relatively large captive hinterland and are able to compete on contestable markets further away in the hinterland, because they are the first- and/or last port of call in Europe.

[112] Eurostat [mar_tf_qm], Vessels in main ports by type and size of vessels.

[113] Eurostat [mar - list of ports].

After having assessed the port matrix framework (see Figure 5.5.), the impacts of the port categories are assessed in step 4, by describing the impact for representative port examples. These potential representative ports are depicted in Figure 5.6.

Figure 5.6 Port matrix – representative ports

Infrastructure investment needs of European ports

On the basis of the previous steps (step 1 – 3) a solid basis has been constructed to focus more in depth on the impacts on ports (related to infrastructure investment). In this step, the impacts of the port categories will be assessed by analysing (among others) the following aspects:

- European, but also the (regional) competitiveness between gateway, mixed and transhipment port;
- Infrastructure investment needs of these port types (i.e. gateway, mixed and transhipment) and the investing actor (e.g. port authority or port operating companies).

To provide an aggregated view of European port infrastructure investments the results of the port investments survey (held by ESPO in 2016) are retrieved. In this survey the results of close to 400 investment projects are analysed (see Figure 5.7). The approximated size of the investment pipeline of these port projects is equal to €32 billion in the EU-27 until 2027. After extrapolation, based upon throughput, ESPO concluded that the total investment pipeline in the EU-27 will be €48 billion until 2027 (equal to around €5 billion per year).

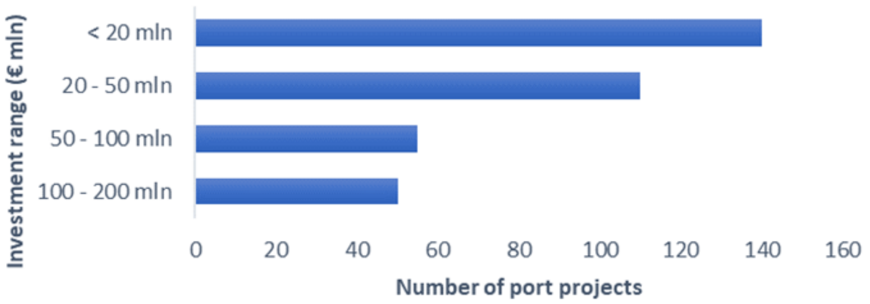

Figure 5.7 Number of project per investment range

Source: ESPO (2018), Port investments survey

Gateway port

Gateway ports often function as a hub to transport goods to or from the hinterland. These ports want to attract vessels and cargo as the demand for these goods comes from a market in the hinterland area (so called captive markets). Often, gateway ports are also adding value to the goods (e.g. manufacturing, assembly, etc) destined for hinterland (captive and contestable) markets. The willingness or incentive for gateway ports to provide the necessary infrastructure that allows using alternative fuels will therefore be relatively high. By means of a representative example, a short description of a gateway port will be provided.

Port of Rotterdam: functions as a large gateway

The Port of Rotterdam is the largest port in Europe with a total freight throughput of close to 470 million tonnes in 2019. In 2019 the Port of Rotterdam handled 8.8 million containers (equal to 153 million tonnes. Next to containerised cargo, Rotterdam has a strong position liquid and dry bulk segment (respectively 165 and 68 million tonnes).[114]

The Port of Rotterdam Authority also invests annually in their port complex. These investments accounted to roughly €408 and €340 million in 2018 and 2019.[115] [116] In addition, a non-limited list of the largest infrastructure projects and investments in the Port of Rotterdam between 2013 to 2018 are presented in Table 5.9. Most of these infrastructure projects are (co)funded by the Dutch Ministry.

Table 5.5 Investments in the Port of Rotterdam port infrastructure (between 2013 – 2018)

Infrastructure projects	Investments (in €)
Deepening the ‘nieuwe waterweg’ (part of development mainport R’dam)	€35 million by the Dutch Ministry of infrastructure
Railway connection Maasvlakte II	€222 million by the Dutch Ministry of Infrastructure
Theemswegtrace (shifting 5 km of railway line)	€160 million by the Dutch Ministry of Infrastructure €96 million by the Port of Rotterdam Authority €62 million by the European Commission (Ten-T

[114] Port of Rotterdam (2020), Facts and Figures.

[115] Port of Rotterdam (2019), Annual Report 2018.

[116] Port of Rotterdam (2019), press release 2019 throughput.

Infrastructure projects	Investments (in €)
	funcs)
Contribution to the maintenance of the Maasvlakte II	€4,3 million per year (between 2018-2023) by the DG of Public Works and Water management

Source: Erasmus & Decisio (2020), Level Playing Field Northwest European seaports.

In addition, the Port of Rotterdam is also exploring the potential possibilities of alternative fuels. For instance, a study has been performed on alternative maritime power in the Port of Rotterdam, in which they analyse the feasibility of using shore-side electricity for containerships at the Euromax terminal. The estimated installation cost for a shore-side power system are estimated at €28.5 million. The largest investment aspects are the power connection to grid (€7 mln), conduits (€5 mln), transformers and outlets (both €3 mln) and a frequency converter (2,5 mln). The annual costs of operating such as shore-side power system are estimated at €3,25 million (incl. depreciation, maintenance, personnel). [117] Next to that the Port of Rotterdam Authority supports the investments in a green hydrogen plant by realising new pipeline infrastructure.

Concluding, a large gateway port (such as the Port of Rotterdam) has a high willingness to explore and invest in alternative fuels. Strengthened by its leading position as a large gateway and the large financial possibilities (often supported by public bodies).

Port of Ghent (part of North Sea Port): functions as a (medium) gateway

The Port of Ghent has a high focus on dry bulk and increasing importance of bio-based cargo streams and production of biofuels. Import and export cargo stream have a local destination. The port also has Volvo car and a Volvo Trucks assembly plant, as well as a steel mill of Arcelor Mittal. According to EU freight statistics, the port has a strong position in the dry bulk segment (66%) and containers (16%).[118]

In addition, the Flemish government invested roughly €1.400 million (between 2009 – 2018) in port infrastructure (i.e. Port of Antwerp, Ghent, Zeebrugge and Oostende). Ghent in particular receives close to €15 million per year.[119]

North Sea Port as a whole leads several important initiatives concerning the transition of the port cluster towards a sustainable port cluster. In 2018, the Bio Base Europe Pilot Plant (BBEPP) was officially launched. With co-funding of the EU IMPACT programme an investment of more than €9,4 million will be made.[120] More recently (early 2020), the North-C-Methanol project has been launched. The project consists of two large-scale demo plants and supporting infrastructure that will produce methanol. The total project investment, beared by both private and public partners, represent €140 million.[121]

In short, a medium gateway port (such as the Port of Ghent) has the willingness to explore and invest in alternative fuels. However, due to its focus on particular cargo segments and moderate financial possibilities (especially compared to large gateways) these type of ports will be careful in their investment decisions.

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[117] Port of Rotterdam (2006), alternative maritime power in the port of Rotterdam.

[118] Eurostat [mar_go_qmc], Gross weight of goods handled in main ports by direction and type of cargo.

[119] Erasmus & Decisio (2020), Level Playing Field Northwest European seaports.

[120] http://www.bbeu.org/pilotplant/impact/.

[121] North CCU Hub (2020), North-C-Methanol.

Port of Split: classified as a small gateway

The port of Split functions, in terms of cargo, as a small gateway. The main activity in the Port of Split is related to cruise vessels. The expected number of cruise vessel visits in 2020 and 2021 is respectively 84 and 350. Meanwhile, the Port of Split is involved in several European projects, such as SUSPORT, MIMOSA, INTESA and Charge. The latter, Charge, aims to promote efficient and sustainable investment for infrastructural development of ports.[122]

In short, a small gateway (e.g. the Port of Split) still has the willingness to explore and invest in alternative fuels. In the case of Split, it would be particularly relevant to adapt to the demand in the cruising market. In general, the financial strength of these smaller ports will be limited. Still, several initiatives (e.g. studies, project or pilots) can be developed.

Mixed port

Mixed ports have both a gateway and transhipment function. Some of these ports are competing with gateway ports to offer the most economically viable supply chain solution towards the hinterland. Part of their traffic volume focusses on facilitating transhipment connections. The (relative) willingness to invest and facilitate alternative fuels for these ports might be lower than for gateway ports. On the basis of a representative example, the dynamic between mixed ports and potential investments will be described.

Port of Hamburg: classified as large mixed port

The Port of Hamburg handled between 2013 and 2018 roughly 135 million tonnes of throughput. Hamburg is, measured in TEU, still the third largest container port in Europe (handling 8.73 million TEU per year). While their main cargo segment is containerised cargo, they handle roughly 45 million tonnes of bulk on a yearly basis.[123]

The Port Hamburg Port Authority (HPA) launched an investment programme, which states that the HPA will be investing close to €3 billion in infrastructure (e.g. expansion and maintenance of terminals, railway track and quays) on the medium term. In addition, the total funding from public bodies to the Port of Hamburg varied between 2016 and 2018 between €118 and €143 million.[124]

In short, a large mixed port (similar to the Port of Hamburg) has the willingness and financial possibilities to explore and invest in the infrastructure related to alternative fuels (supported by national and local public bodies).

Port of Zeebrugge: classified as a medium mixed port

In terms of throughput, the majority of cargo in the Port of Zeebrugge is in the Ro-Ro segment (60%). In this cargo segment, Zeebrugge has strong connections towards the United Kingdom and Scandinavia. In combination with the function as transhipment and export port, the Port of Zeebrugge also provides multimodal hinterland connections (both train and inland waterways) to consumer markets.

The Flemish government invests roughly €1.400 million (between 2009 – 2018) in their four ports (i.e. Port of Antwerp, Ghent, Zeebrugge and Oostende). The port of Zeebrugge receives over the 10 year period roughly €31 million per year.[125]

[122] Split Port Authority (2020), EU projects (https://portsplit.hr/en/).

[123] Hamburg Port Authority (2019), Annual Report.

[124] Erasmus & Decisio (2020), Level Playing Field Northwest European seaports.

[125] Idem previous.

Since 2018, the Port of Zeebrugge's started processing the first shipments of LNG in order to supply the demand for LNG in North West Europe. In addition, the Flemish government invests (between 2009 and 2018) over 30 million euro per year in the port infrastructure.[126]

To conclude, a medium mixed port (such as the Port of Zeebrugge) has the willingness to explore and invest in alternative fuels, but with a clear focus on either their competitive position in the region or the added value in particular cargo segments. In addition, a medium port will have slightly lower financial possibilities (especially compared to large ports). As a result, these ports will be careful in their investment decisions.

Port of Iraklion: classified as a small mixed port

The port of Iraklion is the third largest place of passenger traffic in Greece as it serves more than 1.6 million passengers and more than 300,000 vehicles annually, which makes and is the main transport gateway for the Region of Crete. In terms of throughput, the port has a high focus on Ro-Ro traffic (+80%). The port is directly integrated into the life of the city of Heraklion, which not only facilitates ship and cruise passengers but also ensures activity and movement throughout the year in important parts of the port area.

The Port of Iraklion is, in terms of investments, dependent on funding from Europe. Currently, there are several projects that focus on the maritime connectivity and multimodality (under the project: North Road Axis & Ports of Crete), such as an upgrade of pier V at Heraklion Port against a total estimates cost of €75 million.[127] In addition, the European Commission co-financed a project (called Poseidon Med II) that aims to provide a roadmap to widen the adoption of LNG. Several objectives of the project are to facilitate LNG bunkering (e.g. new techniques for bunkering operations and a regulatory framework for LNG bunkering).[128]

In short, a small mixed port (such as the Port of Iraklion) still has the willingness to explore and invest in alternative fuels, but lacks the financial possibilities to do so itself. By means of support from public bodies (e.g. national government and/or the European Commission) several initiatives can be developed, which mainly focus on alternative bunkering facilities.

Transhipment port

(Pure) transhipment ports have contestable nature as the cost of switching ports is relatively low. Compared to gateway- or mixed ports, these ports are experiencing a high throughput volatility, which makes it complex to facilitate alternative fuels. The (relative) incentive to invest and facilitate alternative fuels might be somewhat lower than gateway/mixed ports. In the following section, a short description of a transhipment port will be provided on the basis of a port example.

Port of Algeciras: functions as large transhipment port

In 2019, the Port of Algeciras handled over 100 million tonnes of cargo. The vast majority of the cargo handled is containerised (roughly 70%), of which roughly 50 million tonnes is international transit traffic and almost 7 million tonnes is national transit traffic. This makes the port an excellent example of a large transhipment port.[129]

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[126] Idem previous.

[127] European Commission (2020), North Road Axis & Ports of Crete.

[128] Motorways of the Seas (2015), https://www.onthemosway.eu/poseidon-med-ii/.

[129] Algeciras Port Authority (2020), Stats.

The Port Authority of Algeciras (APBA) has approved investment of €233 million for the coming four years. In 2020 APBA will invest roughly €63 million in their port.[130] In that light, the Algeciras is Spain's largest bunkering port and is therefore also exploring the use of alternative fuels. The port is mainly exploring (and investing) in the supply of LNG. Recently, the port allocated €27 million from CEF funds in order to develop two new projects to supply LNG.

In short, a large port focused on transhipment volumes (e.g. Port of Koper) has a strong willingness to invest and remain and/or increase their competitive position for transhipment traffic. These larger ports have the financial strength to explore and invest in the infrastructure related to alternative fuels.

Port of Koper: functions as a medium transhipment port

Total throughput in the Port of Koper was in 2019 equal to 23 million tonnes of which 9.5 million consists of containerised cargo (equal to 1 million TEU). The Port of Koper is also specialised in handling of cargo. In 2019 they handled over 0.7 million cars.[131]

When it comes to infrastructure investment related to alternative fuels the Port of Koper explores the possibilities of refuelling LNG. However, in the National Spatial Plan there is no fixed LNG infrastructure foreseen in the port. Within the GAINN4 MOS project the experiences and (technical) possibilities are shared.[132]

In short, a medium transhipment port (e.g. Port of Koper) has the willingness to invest and remain competitive for transhipment traffic and attract traffic for their captive hinterland. Although, in combination with the moderate financial possibilities to explore and invest in infrastructure related to alternative fuels, the port will be hesitant to make large investment decisions.

Port of Marsaxlokk: functions as small transhipment port

Malta is located in the centre of the Mediterranean Sea just south of Sicily. The geographical location, near the main sailing route, strengthens the role of these Mediterranean ports as transhipment nodes. Dynamar (2018) indicated that there are nine ports in the Mediterranean, with an average transhipment share of almost 80%.[133] Maritime activity in Malta centres around the two main Malta ports, Valletta and Marsaxlokk. The latter is one of the main transhipment ports in the Mediterranean and has connections to 128 ports worldwide (of which 75 are throughout Europe, North Africa, the Black Sea and the Middle East) according to ESPO.[134]

When it comes to investments in port infrastructure, there are major investments needed to deal with climate change. Particularly important for Malta and the Port of Marsaxlokk are the rise of water levels and the extreme weather. Malta has, according to the Malta Maritime Forum, a strong position as a bunkering centre. However, with the high investment cost of bunkering barges, the transition towards alternative fuels will be closely monitored.[135]

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130 PortSEurope (2019), Algeciras port plan to will €233 million in four years.

131 Port of Koper (2019), Maritime Throughput in 2018.

132 Safety4Seas (2017), Port of Koper explores possibilities to LNG-fuelling.

133 Dynamar (2018), Transhipment & Feedering (2018).

134 https://www.espo.be/news/port-of-the-month-maltese-ports-valletta-and-marsa.

135 https://mmf.org.mt/maritime-services/bunkering/.

In short, a small transhipment port (such as the Port of Marsaxlokk) has the willingness to explore and invest in alternative fuels. In the case of Malta, they even have a strong bunkering position due to their strategic location close to the main sailing routes. However, the financial possibilities of these smaller ports are limited. By means of support from public (e.g. national government and/or the European Commission) and private bodies several initiatives can be developed. Often, these investments will focus on bunkering barges.

Passenger ports

(Maritime) passenger regions have a slightly different functioning and dynamic than the previously described port examples. These maritime regions want to attract maritime passengers, and in order to remain attractive for vessels (e.g. ferries and cruises) to call at their port, the infrastructure should facilitate bunkering alternative fuels especially as ferries and cruises are often scheduled in 'closed' services.

Three representative port regions (Sicily, Oslo and Valencia) are on the basis of maritime passenger movements selected to identify differences in the infrastructure investment needs. Where Sicily has an active cruise market, Oslo transports relatively high volumes of maritime passengers via ferries.

A challenging requirement, when it comes to cruise vessels, is the (potential) need of high power shore-side electricity for vessels at birth. In particular, when multiple cruise vessels arrive at the same point in time. This could limit the implementation of onshore power supply.[136]

Overview of infrastructure investments

On the basis of findings from desk research, an overview of infrastructure investments in alternative fuels is provided in Table 5.6.

Table 5.6 Overview of infrastructure investment costs per fuel type

Alternative fuel	Port	Investments
Onshore power supply	Case study: Port of Gothenburg	Total investments in terminals vary between €0,7 and €1.4 million
	Case study: Port of Rotterdam, Euromax terminal[137]	Investments in shore-side electricity equal €28.5 million Operational costs are estimated at €3.25 million
	Case study: Port of Rotterdam, Beneluxhaven and Hook of Holland[138]	Investments in shore-side infrastructure vary from €4.3 to €5.3 million Operational costs vary between €2.7 to €2.8 million per year
	Case study: Port of Bergen,	Investments in grid connection

[136] Port of Rotterdam (2006), alternative maritime power in the port of Rotterdam.

[137] Port of Rotterdam (2008), Shore Connected Power for the ferry / RoRo vessel in the Port of Rotterdam.

[138] Idem as previous.

Alternative fuel	Port	Investments
	Hamburg, Rostock, Talinn and Helsinki[139]	and shore power installation vary between €10.0 (Hamburg) and €25.6 million (Rostock)
Liquified Natural Gas (LNG)	Analysis of the LNG market in Europe (CE Delft, 2017)	Investments in LNG bunkering terminal vary from €15 to €137 million. Operational costs vary between €3 to €17 million per year.
	Case study: Port of Bergen, Hamburg, Rostock, Talinn and Helsinki	Investments in LNG power barge is estimated at €16.2 million
	Case study: Nynäshamn (Sweden)	Installation costs for an LNG terminal is approximately €50 million
Hydrogen (H2)	Case study: North Sea Port[140]	The infrastructure investment for a green hydrogen plant are budgeted at €35 million (for phase 1). After which they are expected to rise to more than €100 million
Methanol	Port of Zeebrugge: North-C-Methanol project[141]	The investments in the North-C-Methanol project (consist of two large-scale demo plants and supporting infrastructure that produce methanol) are €140 million.
	Case study: Stena Germanica[142]	Installation costs of a small methanol bunkering unit (truck) are estimated at around €0.4 million
Ammonia (NH3)	Case study: Iberdrola and Fertiberia[143]	Investments in a green hydrogen plant for industrial use is estimated at 150 million euros and production of ammonia starts in 2021

Impact on European ports

[139] Interreg (2018), Assessment of opportunities and limitations for connecting cruise vessels to shore power.

[140] North Sea Port (2020), https://en.northseaport.com/volth2-signs-cooperation-agreement-with-north-sea-port-for-the-development-of-a-green-hydrogen-plant.

[141] https://www.northseaport.com/miljoenenproject-transformeert-co2-tot-groene-grondstof-in-north-sea-port.

[142] Stefenson (2015), Methanol: The marine fuel of the future.

[143] https://www.ammoniaenergy.org/articles/solar-ammonia-available-in-spain-from-2021/.

To conclude, the costs of infrastructure investment are highly port specific. Although they are intertwined with the specific characteristics of the port, such as size and often type, a back-of-the-envelope calculation can be made (see Annex VII).

Firstly, it is expected that at least the largest 25 freight ports (5 gateway, 15 mixed and 5 transhipment ports) will invest in multiple types of alternative fuels as they have both the willingness and financial possibilities to invest. At the same time, OPS installation will not have to be limited to passenger ports, but are more widely adopted. Therefore, one could expect that the larger European ports will invest in OPS infrastructure. For investments in OPS infrastructure, in particular, the assumption is made that all the European core ports (equal to 88 ports) will invest in onshore power supply infrastructure.

Secondly, by consulting the impact of the policy options (compared to the baseline scenario) the main demand for alternative fuels comes from LNG, bio-LNG, e-liquids, e-gas and hydrogen. Although LNG and bio-LNG will be the main alternative fuels, the investment in LNG infrastructure is not a direct result of this new legal initiative. Already under the AFID, ports do have an obligation to invest in LNG infrastructure.[144] Besides investments in infrastructure for alternative fuels, the large ports are also expected to invest in the infrastructure needed for onshore power supply. The following infrastructure investments are based upon the overview in Table 5.10:

- Investments in a hydrogen plant are highly case specific and are budgeted between €35 million to more than €100 million;
- The average investments per onshore power supply installation vary between €1 and €25 million (dependent on the size and complexity). The investment bandwidth in principle includes the OPS needs for the passenger ships, RoPax and containerships. However, onshore power infrastructure varies per ship type. Where tankers, cruise vessels and RoRo ships berth at the same dock/quay, connection to the shore is easier. Container vessels do not always berth at the same dock/quay, which increases the need for more connection points at container terminals.[145]

A back-of-the-envelope calculation shows that, given the numerous caveats and simplicity of the assumptions, the total estimated investments in alternative fuels would vary between €1 and €4.6 billion over the period 2025-2050.[146] The policy option projections are consulted in order to derive the expected timing of investments in hydrogen en onshore power supply.

For hydrogen, the first fuel cell engined ships will arise to the market in 2040 according to the policy option projections. The infrastructure investments in hydrogen are therefore expected to take place from 2035 onwards. These investments are assumed to take place

[144] See for example: https://www.fuelcellbuses.eu/wiki/policy-framework/eu-directive-alternative-fuels-infrastructure#:~:text=The%20Directive%20on%20Alternative%20Fuels,The%20Directive%20%3A&text=Paves%20the%20way%20for%20setting,and%20sound%20price%20comparison%20methodology.

[145] ICCT (2015), Costs and Benefits of Shore Power at the Port of Shenzhen.

[146] The minimum and maximum port investments in hydrogen and onshore power supply vary between respectively €35-€100 mln and €1-€25 mln. Not all ports will invest in alternative fuel infrastructure. It is expected that at least the largest 25 freight ports will invest in hydrogen infrastructure and the European core ports (88 ports) will invest in OPS infrastructure. Multiplying the investments with these expected number of ports results in an investment bandwidth of €1.0 and €4.6 billion. See Annex VII for a detailed overview of the calculations.

gradually over a 15 year period (in line with the gradual development of alternative fuels in the stock of vessels). The average yearly investments vary between €60 and €160 million.

For onshore power supply, the first electric ships will enter the market in 2030. Together with the current development (and usage) of onshore power supply in ports, it is expected that investments in onshore power supply take place from 2025 onwards. These investments are assumed to take place gradually over a 25 year period. The average yearly investments vary between roughly €3 and €85 million.

Considering the expected timing of investments, the total estimated net present value (NPV) of investments in alternative fuels is calculated over a 25 year period (between 2025 – 2050) and with an annual interest rate of 4%. The NPV varies between €0.5 and €2.6 billion.

In the final (fifth) step, the impact on European ports will be classified per port category. Table 5.7 presents the estimated infrastructure investment per port category.

Table 5.7 Estimated infrastructure investment in European port

Port size / characteristics	Small port	Medium port	Large port
Gateway	• Small/medium willingness to invest (due to local importance) • Small financial possibilities	• High willingness to invest (due regional/local distribution function) • Medium financial possibilities	• High willingness to invest (due to national importance) • Large financial possibilities
Mixed	• Medium willingness to invest (due to local distribution function) • Small financial possibilities	• Medium willingness to invest (due to mixed function of the port) • Medium financial possibilities	• Medium willingness to invest (due to regional/ national importance) • Large financial possibilities
Transhipment	• Low willingness to invest (due to pure distribution function • Small financial possibilities	• Low willingness to invest (due to mixed function of the port) • Medium financial possibilities	• High willingness to invest and remain attractive for transhipment traffic • Large financial possibilities

Impact on policy options

As highlighted above, the willingness to invest in port infrastructure for alternative fuels differs per port type and port size. Besides willingness to invest also the possibilities will differ. During interviews, stakeholders indicated that not all EU ports will be able to invest in infrastructure needed for alternative fuels as the investment costs are high and it is questionable what the demand for alternative fuels will be. Especially in smaller ports limited demand for alternative fuels might exist, as vessels have large tanks onboard and do not have to bunker in each and every port they reach.

It is therefore likely that the larger ports will invest in infrastructure for alternative fuels. They are able to invest in different facilities, due to their port size, and would therefore be able to offer different types of alternative fuels, such as biofuels, LNG and ammonia. Smaller ports are mostly likely to offer the cheapest option. As not all ports seem to be required to have all the infrastructure, smaller ports might opt for OPS, while fuels using navigation are not or only limitedly supplied. The strategy will be followed for all policy options. With regard to the impact on ports, the three policy options do not seem to have a distinct impact.

This findings seem to be confirmed by the respondents to the targeted survey, who indicated that the actual impact of different policy options will be unclear. Roughly 60% of the respondents indicated that they do not know the impact of mandatory use of alternative fuels on various port types (ranging from very large to very small). 20% perceives that the mandatory use of alternative fuels will have no impact with regard to competitiveness. Only several respondents indicated that the competitive position will either improve (10%) or worsen (10%).

5.2.4. Competitiveness of the European Maritime Cluster

Besides impacts on European ports, the European maritime cluster will also be impacted by the shift to alternative fuels. Differences in competitive positions will occur. The competitiveness is mainly determined by the maritime and hinterland connectivity and efficiency of port operations.[147] However, the competitiveness of the European maritime cluster could also change from multiple perspectives as a result of sustainable alternative fuel policies.

In order to assess the competitiveness of the European maritime cluster, it is important to indicate which actors are part of this cluster. Based upon earlier work and market studies, the main actors in the maritime cluster are:

- Shipping carriers calling at EU ports;
- The European shipbuilding industry, including ship repair and maintenance yards;
- The European marine equipment suppliers, especially the engine manufacturers;
- The fuel suppliers, those supplying conventional and/or alternative fuels, active on the European market as well as bunker facilities in EU ports.

The current situation of the main actors was described in Section 2.3. Based on these descriptions it is possible to assess how these competitive positions change, considering the policy option chosen. It should be noted that the analysis of the competitive position focuses on the industry itself. Impacts on the number of jobs in each of the subsectors will be analysed separated in section 5.3.1.

Competitive position of shipping carriers calling at EU ports

Based on the analysis in Section 2.3 different shipping segments will respond differently to the new legal initiative. As highlighted, some segments, especially the intercontinental container transport and short sea shipping might see changes in their current competitive position. For container vessels it is relatively easier to choose a different port outside the EU to unload their cargo. Via a feeder network containers could be distributed to EU ports. With regard to short sea shipping it is important to see whether similar initiatives will be taken for rail and road transport. In the (unlikely) case this does not happen, these modes might become more attractive and a reversed modal shift might occur. For the other segments (intercontinental freight transport, cruise vessels, ferries and vessels operating near or in ports) the impact seems small as each of these segments does have a distinct competitive position which enables operators in these sectors to hold on to their positions.

During the targeted survey, stakeholders were asked whether they think the competitive position of the European shipping sector will change as a result of the accelerated uptake

[147] Arvis et al, (2018) Connecting to Compete 2018: Trade Logistics in the Global Economy.

of alternative maritime fuels. Altogether, 32 stakeholders responded to the target survey. A total of 22 of them either indicated that they do not know how the competitive position will change or they did not answer the question.

Out of the group of ten respondents that did provide an indication, one stakeholder indicated the position of the EU shipping sector will not change, four indicated that the competitive position will improve, while five indicated that the position will worsen. Especially shipping lines and fuel operators are of the opinion that the competitive position of the EU shipping sector will worsen. The main reason provided for this is that all current options for alternative fuels are more expensive than the current fossil fuels. This means that the total fuel costs will go up, which might influence freight rates (for more information on the freight rates, please refer to section 5.3.2). As the current margins in the sector are already small, stakeholders fear that the margins might further decrease and some companies might even be forced to leave the shipping business. [148]

Stakeholders that do think that the competitive position of the EU shipping industry might improve highlight that European shipping companies can become the first movers, especially when the legal framework in place provides the right incentives. Given the current debates on meeting stricter climate goals, shipping companies shifting to alternative fuels, will have a greener image which could have a positive impact on their market position. Shippers who would like to contribute to positive climate change might be more willing to pay a little extra to ensure that their goods are transported by a more environmentally friendly operator. In such cases, EU ships (when using alternative fuels) might be placed in a better position to accommodate these shippers.

Stakeholders seem to agree that the actual impact of the introduction of alternative fuels on the competitive position of the EU shipping sector will depend on the specific policy option chosen as well as the flexibility of the chosen system. The more flexible the system is, e.g. by allowing for a free choice on how to reduce emissions, the larger the positive impact. Both in policy options 1 and 3, ship owners are of the opinion that they have slightly more options available to meet the targets set by the new legal initiative. This larger freedom of choice will allow them to opt for the best suitable option per vessel. In addition, ship operators are in favour of a system that awards the over performers (policy option 3). They indicate that rewarding vessels that perform better than the required standards, will create a positive impulse to choose for solutions that would support zero emission vessels. Based on the provided argumentation by the stakeholders, policy options 1 and 3 have a slightly more positive impact than option 2 as options 1 and 3 provide more flexibility to vessels operators on how to meet the goals set and in additional policy option 3 provides the possibility to award the overachievers.

Competitive position of the European shipbuilding industry

As indicated in Section 2.3, European shipbuilders are specialised in highly advanced and complex vessels as well as cruise vessels. Vessels using alternative fuels, especially vessels near zero emissions, are complex vessels to build. European shipbuilders are developing designs for such vessels and several vessels have been built already. By developing these more complex vessels, European shipbuilders could strengthen their current market position. This finding is confirmed by different stakeholders.

During the targeted survey, stakeholders were asked how they think the current policy initiative will impact the competitive position of the shipbuilding industry. Sixteen respondents did not provide an answer or were not able to assess the impact. Out of the other sixteen respondents, thirteen indicated that the competitive position of the EU

[148] Targeted stakeholder survey, question 42.

shipbuilding industry will improve, one indicated that the position will worsen, while the remaining two indicated that the position will not change.[149]

In particular, shipyards are of the opinion that the competitive position will improve as a result of the policy initiative. They highlight the importance of first movers. Yards have the knowledge in-house to facilitate the use of alternative vessels and move towards zero-emission vessels. One of the pre-conditions to speed up these developments is to have a legal framework in place. Currently, there is no strong obligation to reduce the emissions, which results in ‘a wait and see’ approach in the shipping sector. However, when there is an obligation, European shipyards are able to facilitate the production of cleaner vessels which enable ship owners to meet the new climate targets. Such developments fit in their current specialised portfolio and they would be able to further strengthen this. Several stakeholders stated that financial support, in the form of subsidising ship owners, might accelerate the adoption of zero emission vessels further.

Nevertheless, respondents also highlight that the impact of a flexible system, creating multiple options to use different fuels will yield better results as such a system will increase the demand for zero emissions ships. As it is quite complex to retrofit existing ships to zero emission ships, stakeholders indicate that the demand for new vessels will increase. In case of a more restrictive policy option (option B), it is expected that the majority of vessels will opt for bio-fuels. In such a case, retrofitting existing ships is relatively easy and, as a result, stakeholders expect that the demand for additional new ships will be limited. A more prescriptive option will not improve the competitive position of the shipbuilding sector in Europe. As a result, the impact of option 2 on the competitive position of the European shipbuilding industry will be limited, while options 1 and 3 might strengthen the competitive position.

Competitive position of the European marine equipment industry

The European marine equipment industry has a strong competitive position. The industry is able to further strengthen this position as they, together with European yards, are developing techniques needed to use alternative fuels. Especially the engine and propulsion systems needed for alternative fuels are currently developed by leading EU companies. As a result, the legal initiative might be a stimulus for these developments which will positively impact the competitive position of the marine equipment industry in Europe. This finding is confirmed by different stakeholders.

During the targeted survey, stakeholders were asked how they think the EU marine equipment industry will be impacted as a result of the policy initiative. Fifteen respondents to the targeted survey did not respond or did not know the answer to the question. Out of the seventeen remaining respondents, fifteen indicated that the competitive position of the EU marine equipment industry will improve. One thought the position would worsen and one thought the position would remain the same. [150]

Again, the majority of respondents which are of the opinion that the competitive position will improve are ship yards and equipment manufactures. They provided the same comments as for the shipbuilders. Again, they highlighted the importance of the first movers, potential subsidy programs and the wish for a goal-based approach. As a result, the impact of option 2 on the competitive position of the European marine equipment sector will be limited, while options 1 and 3 might strengthen the competitive position.

Competitive position of the fuel suppliers and bunker facilities active in Europe

As explained in Section 2.3, the number of fuel suppliers is relatively limited as the main suppliers of fuel are the large oil companies. These companies are currently extending

[149] Targeted stakeholder survey, question 42.

[150] Targeted stakeholder survey, question 42.

their products, and besides fossil fuels, they also produce biofuels. Some of them are currently already producing less carbon intense fuels for marine shipping, such as LNG. The large players, such as Shell, also have internal strategies to develop (near) zero emission fuels for the marine sector.[151] As these large companies are already working towards the production of zero emission fuels, it seems their market position will remain the same. The number of producers will remain limited and as they are advancing towards alternative fuels, not many newcomers are expected. The competitive position of the fuel suppliers remains the same or might slightly improve.

The shift to alternative fuels might have different impacts on the bunker facility companies. As indicated in Section 2.3, the market of bunker facilities consists of many small players. Some of these players are only active in one port and with one vessel only. The bunker vessels used are currently equipped to transport fossil fuels. In case, the demand for biofuels increases, the current vessels can still be used, when minor changes to the vessel are made. However, when the demand for LNG or other alternative fuels increases, these fuels cannot be transported with the current bunker vessels and new vessels would be needed. Such vessels are four to five times more expensive than the current bunker vessels. Many companies might not be able to invest in those new vessels. Stakeholders interviewed suggested that the market for bunker facility companies will consolidate and that some of the bunker vessels might become part of the fuel suppliers as these large companies do have the capability to invest in more expensive vessels. The number of independent bunker facility companies might drop.

As the legal initiative will apply to vessels of more than 5.000 GT, all vessels smaller than 5.000 GT fall outside the scope of this initiative. These vessels are still allowed to use fossil fuels, and the bunkering facilities could still supply to those vessels. So for a part of the current market, it will remain the same.

During the targeted survey, stakeholders were asked whether they think the competitive position of the European fuel suppliers and bunker facilities will change as a result of the policy initiative. The majority of stakeholders (23 out of the 32) did not answer the question or was not able to give an indication. Out of the nine remaining stakeholders, seven indicated that the competitive position will improve, while one indicated that the position remains the same and one believes the position will worsen.[152] Although the opportunity was provided to elaborate on their choice, stakeholders did not take this opportunity.

When considering the different policy options, the impact on fuel producers will be more or less similar. The shift to alternative fuels will increase their competitive positions, as most of them are already in the process to develop alternative fuels. A goal-based option might stimulate the introduction of zero-emission vessels and this would create the required demand for the fuel suppliers.

For the bunkering facility companies policy option 1 seems to have the least impact. Many stakeholders expect that vessels will opt for biofuels. As indicated earlier, the current bunkering vessels can relatively easy also supply biofuels. Their market share will remain more or less the same. In options 2 and 3, it seems more likely that also other alternative fuels will be chosen by the shipping sector. When the sector moves to the use of LNG, hydrogen or another fuel, the current bunkering vessels will not be able to transport the requested fuels. In such a case high investments are needed to buy new vessels and it is uncertain whether the small companies can make them. It is likely that bunker companies will disappear form the market.

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[151] See for example: https://www.shell.com/business-customers/trading-and-supply/trading/news-and-media-releases/shell-sets-course-for-net-zero-emissions-shipping.html.

[152] Targeted stakeholder survey, question 42.

Summary on competitiveness

For each of the segments above, an assessment is made of the possible impact of the policy options on the competitiveness of the different parts of the maritime sector. The table below provides a summary of this assessment. As the most likely alternative fuel in option 2 will be biofuels, the impact on the competitive position of the different segments in the maritime sector will be limited. Policy options 1 and 3 lead to a small improvement in the competitive position of the shipping, shipbuilding and marine equipment sectors as well as fuel suppliers, compared to today's situation. Especially as more (near) zero-emission vessels will enter the market, a need for highly specialised ships, equipment and fuel is needed, something the EU industry can supply. For bunker facilities, policy options 2 and 3 most likely create a negative impact on their competitive position as they will not be applied to invest in alternative bunker vessels.

Table 5.8 Estimated impacts on competition of the EU maritime sector

Stakeholder category	Policy option 1	Policy Option 2	Policy option 3
Shipping industry	Small positive	No change	Small positive
Shipbuilding industry	Small positive	No change	Small positive
Marine equipment industry	Small positive	No change	Small positive
Fuel suppliers	Small positive	No change	Small positive
Bunker facilities	No change	Negative	Negative

Source: Ecorys.

5.2.5. Impact on third countries

A measure that incentivises the uptake of alternative bunker fuels can be expected to have different economic impacts on third countries.

Firstly, the policy measure can be expected to have an economic impact on the bunker fuel producer, the bunkering sector and on fuel infrastructure supplier: The policy measure will incentivise the production of alternative fuels and these fuels will have to be made available to the sector. On the other hand, demand for conventional fuels can be expected to decrease compared to the baseline.

In 2012, refinery production of marine HFO was dominantly located in Asia, but also at a relatively high level (>= 10 Mt per year) in Europe, Middle East, North America, Latin America, and Russia & CIS. Refinery production of MGO was mainly located in Asia and Europe (Table 5.9).

Table 5.9 Regional Refinery Production (2012) - million tonnes per year

	Africa	Asia	Europe	North America	Latin America	Middle East	Russia + CIS	Global
Marine HFO	7	95	52	21	18	25	10	228
MGO	3	31	15	7	6	1	2	64

Source: CE Delft et al. (2016)[153]

153 https://www.cedelft.eu/publicatie/assessment_of_fuel_oil_availability/1858.

The production of the alternative fuels can, but does not necessarily have to emerge in countries that currently produce conventional fossil bunker fuels, since different feedstocks and input factors are required. Countries with favourable conditions for the production of renewable electricity could, for example, be attractive production locations for e-fuels.[154]

Currently, major bunkering ports outside Europe are Singapore, Fujairah, Hong Kong, Busan, Gibraltar, Panama, Algeciras and Los Angeles/Long Beach (Maritime Fairtrade, 2019)[155] and thus also candidates when it comes to supplying the bunkers required under the policy measures.

Secondly, the policy measure can also be expected to have an economic impact on the shipbuilding and ship equipment industry: The policy measure gives an incentive to improve the efficiency of the ships and for non-drop in fuels, ship equipment compatible with alternative fuels has to be developed, produced and integrated into ship designs.[156] Current ship designs would still be relevant for the use of drop-in fuels and for the use of conventional fuels outside the scope of the measure.

According to UNCTAD (2019),[157] China, Japan and the Republic of Korea represented together 90 per cent of the global shipbuilding in 2018, with China accounting for 40% and Japan and the Republic of Korea for 25% respectively. And Figure 5.8 gives the main suppliers of the shipbuilding industry, which potentially can indirectly profit from an impulse for the shipbuilding industry.

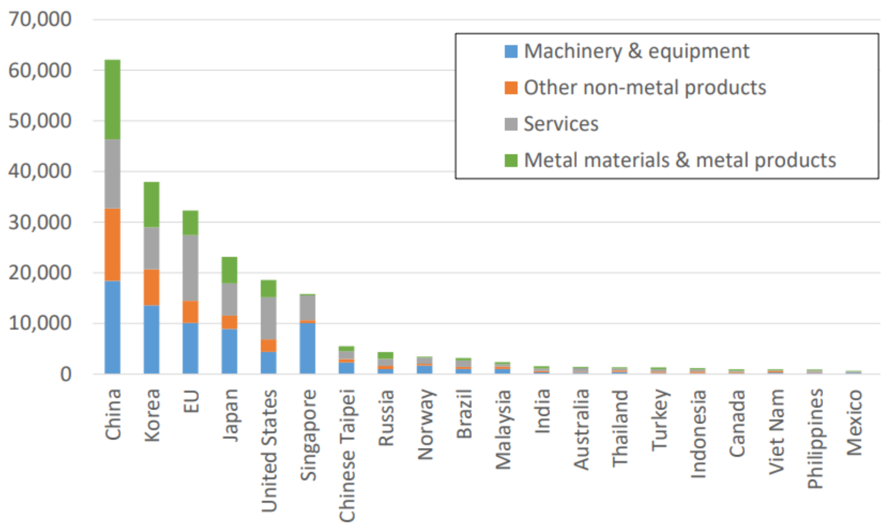

Figure 5.8 2015 sales of supplier industries to the shipbuilding industry [million USD2019]

154 See for example, Ricardo Energy & Environment (2019), Electrofuels for shipping: How synthetic fuels from renewable electricity could unlock sustainable investment in countries like Chile.

155 https://maritimefairtrade.org/top-ten-bunkering-ports/.

156 Note that these newly designed ships will, if they are not flexible with respect to the fuel, probably not be competitive outside the scope of the measure.

157 https://unctad.org/system/files/official-document/rmt2019_en.pdf.

Source: OECD (2019)[158]

Thirdly, a measure that incentivises the uptake of alternative bunker fuels can have an impact on ships' transportation costs. It can therefore also have an indirect effect on trade of third countries:

- Third countries could potentially benefit if exports from the EU became relatively more expensive. This could lead to a loss in market share of EU products outside the EU and to an increase of the market share of products not transported on sea routes from the EU to the third countries (e.g. Japanese cars might gain market share in the US at the expense of German cars);
- And the opposite could hold for imports from third countries if imports from third countries to the EU became relatively more expensive. This could lead to a loss in market share of non-EU products in the EU and to an increase of the market share of products not transported on sea routes to the EU (e.g. gas from Russia that is transported via pipelines could gain market share at the expense of LNG stemming from Qatar).

If there is however relatively little competition between different suppliers of the goods in the countries of destination, higher transportation costs might be passed on to buyers, at least if the goods cannot easily be substituted or are luxury goods characterised by a relatively high elasticity of demand. National economies might thus be adversely affected, especially in countries heavily dependent on maritime transport.

Whether effects on trade and national economies accrue, depends on whether the policy measure will lead to a significant increase of transportation costs and on whether the transportation costs have a significant share in the value of the goods transported.

Ships could, for example, take energy efficiency measures to keep transportation costs low or some goods might only be transported by ship over a relatively short distance or for high-value products, transportation costs might only be a fraction of the overall costs/in the price.

To avoid a prohibitive effect on trades, the design of the policy measure should in any case account for the fact that in some countries alternative fuels might become available only in the medium-/long-run. A mechanism that allows for flexibility between ships and/or years might be solution here.

Figure 5.9 gives the Top 20 extra EU-27 maritime trade flows in terms of cargo volumes, to illustrate the trades that might be affected by the measure.

[158] http://www.oecd.org/industry/ind/WP6-Workshop_Item_1.1.1_OECD_Secretariat.pdf.

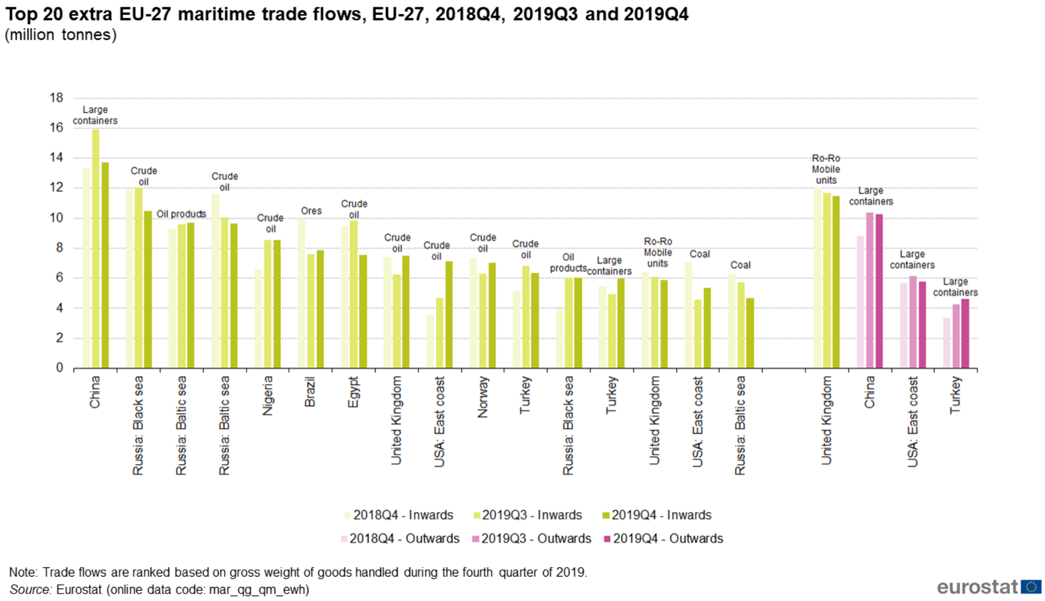

Figure 5.9 Top 20 extra EU-27 maritime trade flows

5.3. Social impacts

The social impacts focus on the second-tier impact, such has employment impacts in the maritime sector, the impact on freight rates and the impact on the islands and outermost regions. The impacts will be described in more detail below.

5.3.1. Impact on jobs in different parts of the maritime sector

As part of the initiative to stimulate the use of alternative fuels in maritime transport, employment may be impacted. It is relevant to make a distinction between segments within the maritime sector. First of all, an increased use of alternative fuels might lead to job creation and/or losses in both the facilities producing those alternative fuels as well as those producing fossil fuels. In addition, different skills and knowledge might be required to handle those alternative fuels during the storage/bunkering process in the ports. Jobs may be created also in the research and innovation domain, as the alternative fuel technology has a potential of evolution.

The crew on board of a vessel might also be affected. It seems unlikely that additional jobs will be created on board of the vessel, however, the required skill-set may change. Another group that might be affected are people working in the bunkering sector. Again, a different skill set might be required once the maritime sector switches to the use of alternative fuels.

Based on the above, two impacts are relevant for employment and have been taken on board in this study. More specifically:

- direct impact on employment (measured in number of jobs) and possible substantiation between employees in the producing industry, transport, ports and feedstock collection;
- indirect impact on employment and related to (additional) training and/or courses.

Direct impacts in employment

To examine the direct impacts of the policy options in the maritime sector, one would need to identify baseline figures of the categories mentioned above, analyse the way each policy option will impact each category and then compare this impact against the baseline. However, baseline information on the number of people employed in the different maritime sectors as identified in our literature review is generally sporadic.

According to the ECSA report on the economic value of the EU shipping industry (2020), the EU shipping industry employs roughly 685,000 people. This even goes up to over 2 million employees when including the entire supply chain.[159] Furthermore, the report estimates that each job in the shipping industry supports 1.9 jobs in another part of the EU economy. Further information is found in the Blue Economy Report(s). The latest version of the report (2020)[160] provides the following figures:

- Ports and water projects (including services) employed 186,987 persons;
- Maritime transport employed 407,825 persons;
- Shipbuilding and repair sectors 318,315 persons.

On the other hand, the final report of the EU-Funded Project "Creating a European Skills Council for the Maritime Technology Sector" (2014 - 2016), [161] estimated the employment in the following sectors:

- Marine equipment 350,000 persons;
- Shipbuilding 175,000 persons;
- Ship Maintenance, Repair and Conversion 45,000 persons.

We were not able to obtain specific figures on persons employed in port bunkering services, while for the fuel production, it is difficult to distinguish the impacts of the shipping sector to the overall demand for such fuel, as at the same time there will be a clear need from other transport modes in the context of the Green Deal. Neither are there clear indications on the number of persons employed in R&D posts relating to the maritime sector.

As seen, the information on people employed in the maritime sector is not detailed enough to proceed with a full analysis, and there are some risks regarding potential overlaps in the sectors. This is a similar finding to that of the 2020 study on social aspects within the maritime transport sector[162] which stated that "the fragmented nature of maritime transport makes it difficult to obtain complete and accurate data on EU/EEA employment in the maritime sector".

One important element to consider is how each possible solution will impact each employee category. Stakeholders from different sectors interviewed (shipping companies, ports, equipment producers, and workers representatives) saw potential benefits in employment brought on by the use of alternative fuels, however, they were not in a position to estimate the effects. Two maritime shipping companies interviewed considered positive impacts in their field, and one of them indicated that it may come from the need to

159 https://www.ecsa.eu/sites/default/files/publications/Oxford%20Economics%20-%20The%20Economic%20Value%20of%20EU%20Shipping%20-%20Update%202020.pdf.

160 https://ec.europa.eu/maritimeaffairs/sites/maritimeaffairs/files/2020_06_blueeconomy-2020-ld_final.pdf.

161 Sea Europe (2020).

162 https://op.europa.eu/en/publication-detail/-/publication/a14413d7-bf30-11ea-901b-01aa75ed71a1.

prepare and deliver additional training. A port representative considered benefits in construction and research, pointing to LNG as an example. Representatives of fuel suppliers indicated that they do not expect an increase in the number of job. They argued that about 5% of all fuel produced in the EU is meant for the maritime sector. Employees of fuel suppliers therefore, not only produce maritime fuels, but also fuels used in other transport sectors. A representative of a European association representing workers considered that on-board jobs would not significantly change in number, but a potential increase may come about if a greener maritime sector encourages a modal shift towards short sea shipping. The stakeholder consultation also did not uncover any information on the differences in employment levels (for example switching from bunkering or traditional fuels to operating an OPS facility).

The table below presents our assumptions based on literature review, the views of the stakeholders and our expert judgement.

Table 5.10 Assumed impact per technology on employment levels

Employment category	Biofuels	Electro-liquids	Hydrogen	OPS
Seafarers	No change in manning levels	No change in manning levels	No change in manning levels	No change in manning levels
Bunker suppliers	No change in employment levels	Possible positive changes depending on size/type/efficiency of facility	Possible positive changes depending on size/type/efficiency of facility	Possible positive changes depending on size/type/efficiency of facility
Equipment suppliers	No change in employment levels	Possible increase in initial stages	Possible increase in initial stages	No change in employment levels
Ship construction and repair	No change in employment levels	Depends on demand	Depends on demand	Depends on demand
Research and development	No change in employment levels	Possible increase in initial stages	Possible increase in initial stages	No change in employment levels

Source: Ecorys.

The seafarers are the category that is expected to be impacted the least, as manning levels should not change under any of these categories. Bunker suppliers will in practice not be impacted in the case of biofuels. However, the impact in case of other fuels will depend on the personnel levels needed for the new installations to functions, where we expect a possible increase. Our assumption here is that (at least the majority of companies) will be able to make the shift to alternative fuels. Suppliers of marine equipment are also not expected to have important changes in their personnel levels, as they are expected to change the type of equipment (and not the overall volume) to be produced. Nevertheless, some initial increase at investment stage may materialise. Ship construction and repair employment would be directly impacted by the number of new vessels ordered in particular for electro-liquids, hydrogen and OPS. However, this is subject to ship-owners decisions as to the rate of replacement of the fleet and any legal limits for changes. Finally, employment in R&D is considered more or less stable in case of biofuels and OPS as these are more advanced compared to the other two categories. Employment could increase for electro-liquids and hydrogen.

Concerning the potential development of employment in the framework of the baseline scenario, the policies analysed earlier in section 3.2, and the information above lead us to the following estimates on the development of employment. The estimation is qualitative as we did not identify individual quantitative impacts upon which numerical estimates could be made.

Table 5.11 Estimated baseline impacts on employment

Baseline element	Expected impact
Voluntary initiatives	Marginal overall impact considered, which will be reflected in employment
National policy initiatives	Minor positive impact through construction of LNG and OPS facilities
EU policies	Marginal overall impact considered, which will be reflected in employment
Existing IMO policies	Positive through construction of LNG and methanol
Future IMO policies	Positive but uncertain as to date of introduction
Possibility for bunkering outside the EU	Unlikely for local/domestic or Short Sea Shipping or long-distance deep sea. Possible for others but questionable as to the likelihood.

Source: Ecorys.

Therefore, under the baseline scenario, given that the expected developments will rely primarily on the use of biofuels and then on a continued trend for uptake of LNG and OPS, it is our conclusion that only small positive impacts will be observed in employment numbers in the bunkering, equipment supply, ship construction and repair sectors. Of course, impacts on employment may come about by other developments and most notably digitalisation.[163] However, this is considered to be out of the scope of this study.

As regards the potential impacts on employment levels in the EU through mandatory use of low carbon fuels, the survey results indicated that stakeholders expected this to lead to job creation clearly in the research and development (17 out of 32 respondents) and the marine equipment industry (13 out of 32 respondents). Less stakeholders expect jobs to be created in the shipbuilding industry (9 out of 32 respondent) and the shipping industry (6 out of 32 respondents). Minor benefits are expected in fuel supply (5 out of 32 respondents and 1 expected jobs to be lost) and much less in the port sector (2 out of 32 respondents). Across the questions there was an important number of respondents who indicated that there are not aware of the impacts or chose not to respond (between 16 and 22 respondent).

Estimating the impacts

In order to estimate the impacts of the different policy options, we need to focus on the characteristics of each option and then identify a) how many people are concerned as a base (for example, administration jobs may need to be excluded or for the R&D sector only for those employed in maritime activities/projects), b) the number of installations/vessels/businesses affected, and c) the exact change that each technology application is bringing about (in terms of increase/decrease in the number of people employed). The expected impact would not be the same across all the sectors and should reflect the views of the stakeholders expressed above.

For this study however, this method cannot be applied as detailed information, as we were not able to identify the necessary information. As such, we proceed with a more qualitative approach.

163 https://commons.wmu.se/lib_reports/58/.

Policy option 1 requires a minimum share of the use of bio- and electro-liquids and gases and hydrogen and a minimum share of OPS. Thus, the actual impact on employment can be assumed to be proportional to the minimum share required (though most likely not applicable to all the jobs) thus could be considered as the upper limit. It would need to be adapted to take into account the expected impacts in each sector. Given that, we expect the impact – always compared to the baseline - to be marginally positive for the seafarers. Equipment suppliers and ship construction and repair should see more positive impacts reflecting an expected increase in investments, and changes in the fleet, equipment, and facilities. For the bunkering sector, on the other hand, the growth may be more restrained as potential increases in the new facilities may be counterbalanced by losses in "older" forms of bunkering. Finally, R&D employment should see a clear increase.

Policy option 2, considers a maximum limit of GHG energy content both at navigation and berth. In terms of employment, this policy option does not differ much from policy option 1. Any differences in employment will come from the changes in the mix of solutions used by the sector.

Policy option 3, being a variant of policy option 2, combines a maximum GHG content in both navigation and at berth with a mechanism that rewards over-achievers. Compared to option 2, impacts on employment seems similar.

Table 5.12 Estimated impacts on employment levels

Stakeholder category	Policy option 1	Policy Option 2	Policy option 3
Seafarers	Small positive	Small positive	Small positive
Bunker suppliers	Small positive	Small positive	Small positive
Equipment suppliers	Medium positive	Medium positive	Medium positive
Ship construction and repair	Medium positive	Small positive	Medium positive
Research and development	High positive	High positive	High positive

Source: Ecorys.

The table above presents out qualitative estimated on the impacts on employment levels in the different sectors. It should be noted that while all policy options bring about benefits, the difference between them is not considered to be important. Furthermore, 11 out 32 participants considered that training would be needed in case low carbon fuels became mandatory.

Indirect impacts

Turning now to indirect impacts, it is clear that the introduction of new technologies will necessitate changes in the skill levels required. We consider though that the use of biofuels requires less training compared to the use of other energy sources (especially in terms of safety). As such, the training needs will depend on the actual use of biofuels. Particularly for seafarers the Skill Sea project[164] finds that new skills need to be developed in terms of optimal operation of the vessel and on the use and handling of different energy technologies (LNG, hydrogen, ammonia handling but also battery packages, and even retractable wind turbines, solar panels, and sails). Important investments in training and certification of seafarers will also be needed, as these are not included in current training

[164] Skill Sea Europe: www.skillsea.eu.

and education programmes, not required by the existing legislation (most notably the STCW Convention).[165]

This view was echoed by a representative of a European association representing workers, who underlined the need for education, but also on-the-job training. The training will also depend on the type of fuel used. The need to upgrading the skills is also a benefit, as from one side in can increase the competitiveness of European employees in the global market, and at the same time improve the image of the sector and inspire more people (younger people as well as women) to opt for a career.

The results of the survey mentioned above indicated training needs would materialise in all sectors. There isn't a clear pointer as to the sector where this will be more needed, as the views are very close. From the answers provided, the need for training was noted in the port sector (8 out of 32 participants), the shipping industry (6 out of 32 participants), the shipbuilding industry (5 out of 32 participants), the marine equipment industry and the fuel supply industry (4 out of 32 participants in both cases). Understandably, no such change in skill levels is expected in the R&D sector.

Given the similarities between the different policies options, we assume that there will be no real differences in the overall number and types of skills that will be needed for each sector. Compared to the baseline, the up-skilling/retraining skills will be increased.

5.3.2. Impact on the freight rates

Alternative fuels in maritime transport come at a different cost than fossil fuels. This potentially impacts the transport price (i.e. freight rates) and could trickle down to consumer prices. Some of these additional fuel costs will probably be internalised by carriers themselves. Another part of these costs will not be internalised and will be included in the price of freight transport (thereby, increasing the freight rates). By means of three steps, these additional costs will be estimated.

Maritime transport cost structure

As a first step, a thorough literature review on the maritime transport cost structure was performed. In order to understand the importance of fuel costs for different market segments, a distinction has been made between ship types.

Several scientific studies and reports have outlined the share of fuel price (in relation to the total costs of shipping) for specific type of vessels or segments. An overview of findings from the literature will be provided in Table 5.13, followed by a brief description of some segments.

Table 5.13 Overview of maritime transport cost – findings from literature

Segment / vessel type	Description	Fuel costs (in %)	Source
General	Bunker costs (incl. container, administrative and cargo handling)	24% - 41%	IRENA (2019)
Tanker (small)	Bunkering costs	35%	UNCTAD (2012)
Container / bulk vessel	Energy costs	53%	European Parliament (2009)

165 International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW).

Tanker vessel	Energy costs	54%	European Parliament (2009)

UNCTAD (2012) estimated the freight rate cost components of a small tanker (see Figure 5.10). The share of bunker costs is, with 35%, the largest cost component of such a small tanker. The other main cost components are crewing (18%) and port charges (10%).

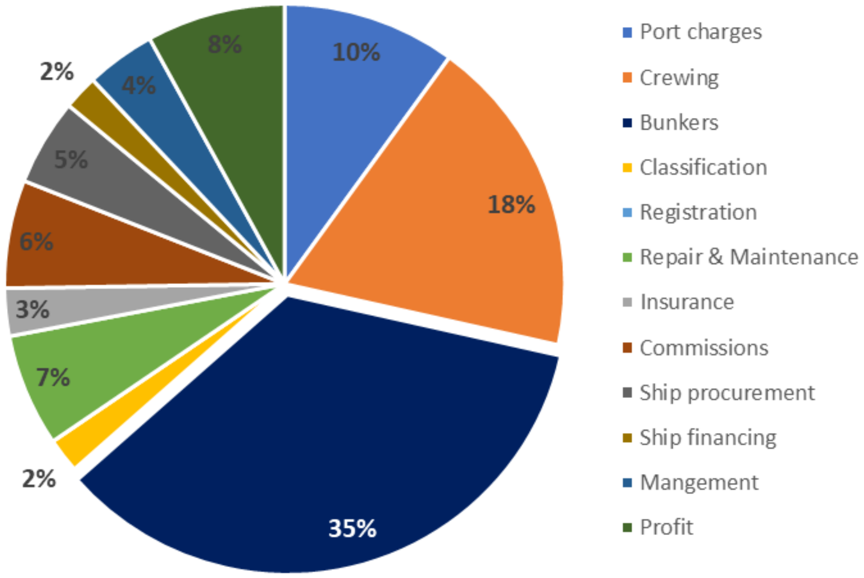

Figure 5.10 Freight rate components of a small tanker (10.000 dwt) with 20 years of economic life

Source: UNCTAD (2012), Review of Maritime Transport

For a container/bulk vessel, the breakdown of total transport cost of short sea shipping is presented in Figure 5.11. The share of energy costs is estimated to be over 50% (53%) for a container/bulk vessel. Roughly the same cost share is assumed for a tanker (54%).[166] These figures cannot be compared directly to these for a small tanker, as the oil price on which Figure 5.10 is based is unknown.

[166] UNCTAD (2012), Review of Maritime Transport.

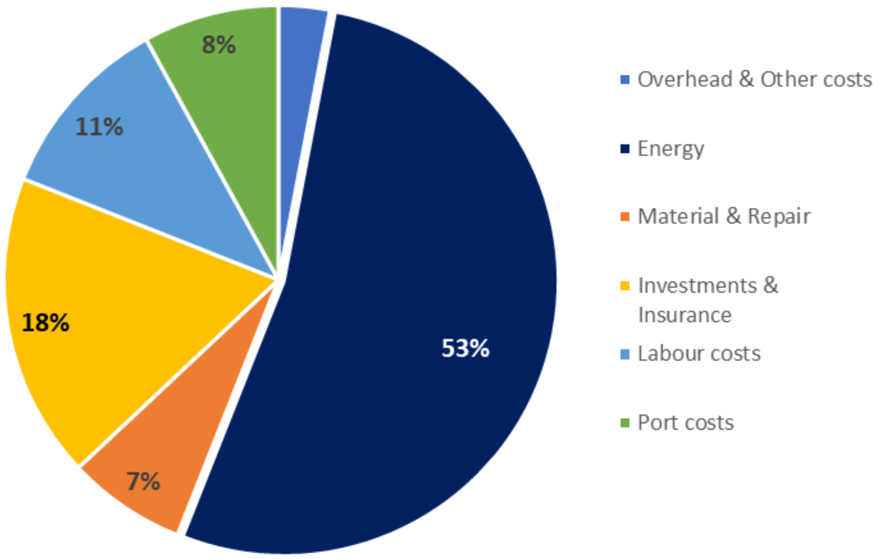

Figure 5.11 Total transport cost of short sea shipping of a container/bulk vessel

Source: EP (2009), The impact of oil prices fluctuations on transport and its related sectors

Finally, according to IRENA (2019), the bunker costs account for approximately 24% to 41% of the total costs of shipping. This is line with the findings from specific cargo segments. To conclude, the share of energy-related costs varies according to the information above, and is between 25% and 50% of the total transport cost. However, the scientific background of these statements is minimal. This is also due to the fact shipping companies could and/or are not willing to provide a break-down of the cost structure during the interviews.

Maritime fuel price increase

Alternative fuels have a different price tag than the main energy source in maritime transport. Nowadays mainly Heavy Fuel Oil and Marine Diesel Oil are used (see Table 2.1 for detailed information). In the second step of this analysis the potential transport cost increase due to the evolution of fuel price(s) will be assessed.

According to IRENA (2019), the production costs for alternative fuels are 3 to 6 times higher than production cost for fossil fuels, especially in the short term. The vessel operator sees the bunker cost increase as a part of the operational cost.

In the third chapter of this study, the costs of sustainable fuel production are elaborately discussed. Main outcomes of the analysis are the substantially higher production costs of (several) sustainable fuels than those of fossil fuels, which is also in line with the findings from the assessment of alternative fuels for seagoing vessels (Maritime Knowledge Centre, *et al*., 2020). At the same time, the projections of production costs of sustainable and fossil fuels are expected to develop towards each other in the future.

The price increase of 'diesel blend' is estimated at around 7% by 2030 relative to the baseline and at 42% by 2050 in all POs. The 'diesel blend' covers diesel blended with biodiesel, e-fuels, hydrogen, ammonia and methanol. The blended diesel which would be mostly decarbonised by 2050 is projected to represent around 51% of the fuel mix used in short sea shipping by 2030 and 36% by 2050 and is therefore relevant in all policy options.

For the theoretical assessment of fuel price increase and freight rates, the assumption is made that sustainable fuel prices will be 7% higher than fossil fuels in 2030 and 42% higher by 2050.

In the next section, the relation between transport costs, freight rates and final consumer prices will be assessed.

Note that not only bunker cost might increase, but the investments made for retrofitting ships might affect freight rates as well. These effects will be incorporated based on the analysis of the CAPEX and OPEX for economic actors.

Maritime transport cost and the effect on freight rates

In the third step, the relation between maritime transport cost, freight rates and final consumer prices will be determined based upon the assumed transport cost increase (retrieved from step 1 and 2). In the first part of the analysis, the relation between fuel prices and freight rates will be presented based upon literature and data analysis. The second part explains the relation between transport costs/freight rates and consumer prices.

In some cargo segments, the additional costs of using alternative fuels trickle down to the freight rates, while in other segments there is a tendency to internalise the additional costs. Therefore, the two fuel prices indexes – Marine Diesel Oil (MDO) and Intermediate Fuel Oil (IFO) 180[167] – are plotted against the following three freight indexes:

- General Freight Index is a combined index of shipping rates;
- The Harpex Shipping Index (HARPEX) is an index that container shipping rates for eight classes of container ships;
- Baltic Dry Index (BDI) is used in the world as a proxy for dry bulk shipping stocks.

In Figures 5.12, 5.13 and 5.14 the indexed fuel price of both Marine Diesel (light blue line) and Fuel 180 CST (dark blue line) correspond to the left y-axis. The General Freight Index (dark grey line), HARPEX (dark orange) and BDI (dark yellow) correspond to the right y-axis. Historical monthly figures between 2013 and 2020 are deducted from the ISL Statistics Yearbook 2019.

Freight rates in general

Comparing the General Freight Index (dark grey line) with the fuel prices indexes (blue lines) (Figure 5.12) reveals a strong correlation of respectively 0.92 and 0.93. A strong correlation implies both variables follow a similar trend and are clearly associated. While a correlation can be seen as the extent of fuel costs passed through to freight rates, correlation is not equal to causation.

From 2014 to 2016, there was a clear downward trend in oil prices, and the same happened to the general freight index. In recent years oversupply in the container market might have increased pressure on freight rates, which made the oil price an even more important element in freight rates.

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167 Marine Diesel Oil (MDO) consists of a blend of heavy gasoil that may contain very small amounts of black refinery feed stocks, but has a low viscosity up to 12 cSt; Intermediate fuel oil (IFO) consists of a blend of gasoil and heavy fuel oil, with less gasoil than marine diesel oil. In particular, IFO 180 has a maximum viscosity of 180 centistokes.

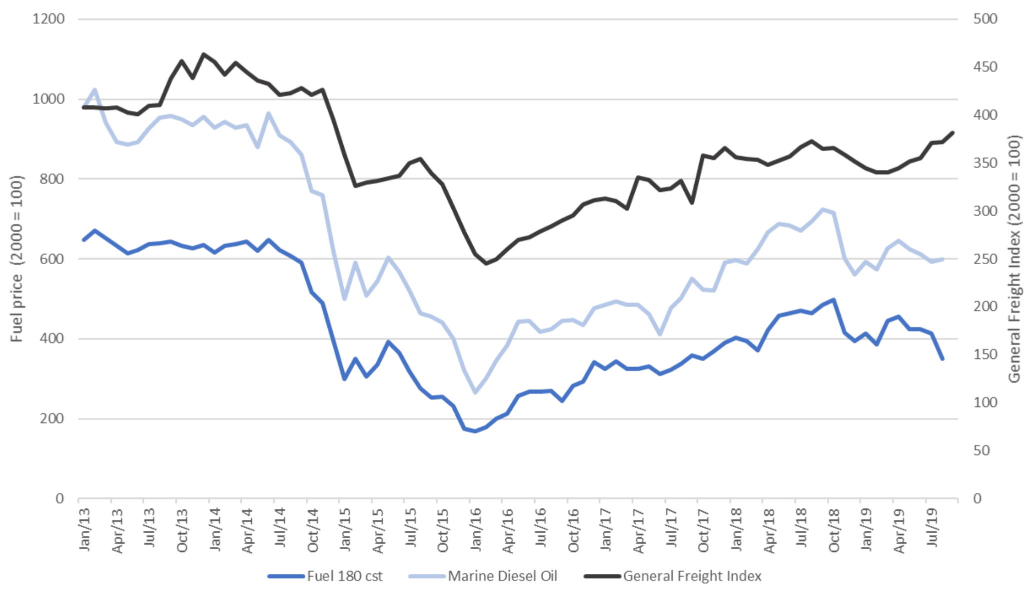

Figure 5.12 Marine Diesel/Fuel 180 CST Index (left axis) and General Freight Index (right axis)

Source: ISL Shipping Statistics Yearbook 2019

Container freight rates

The relation between fuel price and the HARPEX is less strong and differs (dependent on the moment in time) mainly in magnitude. The calculated correlation between HARPEX and marine diesel oil / fuel 180 is equal to respectively 0,74 and 0,68.

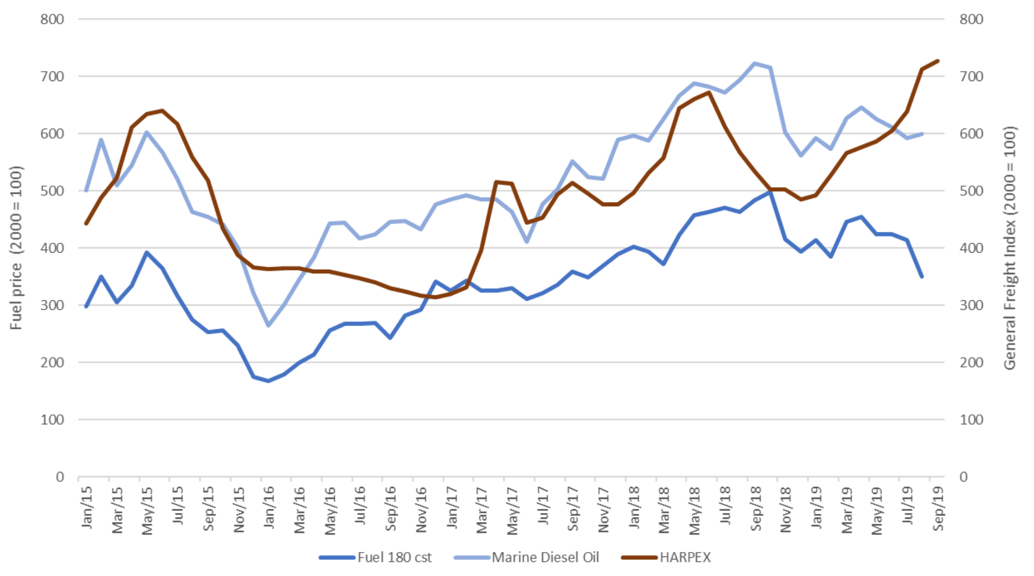

Figure 5.13 Marine Diesel/Fuel 180 CST Index (left axis) and HARPEX (right axis)

Source: ISL Shipping Statistics Yearbook 2019

UNCTAD (2010) estimated the correlation between fuel prices and container freight rates between 1993 and 2008. The estimated elasticity ranged between 0.19 and 0.36. In the same study, it is found that directional container trade imbalances have an even larger impact on container freight rates, with estimated coefficients between 1.9 and 2.1.

Vivid Economics (2010) concludes that the (potential) impacts of a fuel price increase varies across products. The elasticity for freight rates with regard to the bunker price for containerised goods (e.g. low apparel and furniture) are estimated between 0.12 and 0.16. In case the bunker price would increase with 10% this equals a freight rates increase of between 1.2% and 1.6%.

The impacts of an increase in the bunker price vary across product markets, both in terms of magnitude and distribution of impacts. Two general observations can be made: - where cost pass-through is higher, more of the cost is borne by local consumers, the impact on exporters is less negative, and the gains to local producers from increased profit margins are larger; and - product price rises are less than 1 per cent.

Dry bulk freight rates

The European Parliament (2009) indicates that in the dry bulk sector, freight rates are completely decoupled from bunker prices and are mainly influenced by the demand and supply of raw materials, fleet composition and demand and supply of ships. Figure 5.14 offsets the price of fuels against the Baltic Dry Index, which confirms that fluctuations in the price for dry bulk are (for a large part) not directly related to oil price fluctuations.

Shipping lines use the bunker adjustment factor (BAF) as a compensation for fluctuations in fuel prices (IHS Markit et. Al., 2019). It used to be set quarterly by the Transpacific Stabilization Agreement (TSA), but since the disbandment of TSA in 2018, shipping operators set their BAF independently of each other. Recently, there have been complaints that the bunker surcharge formulas are not transparent and lack uniformity. Currently, the bunker surcharge is tied to the price of Brent crude oil, meaning that it might not be relevant for the additional costs of using zero-carbon fuels, if bunker surcharge formulas are not updated.

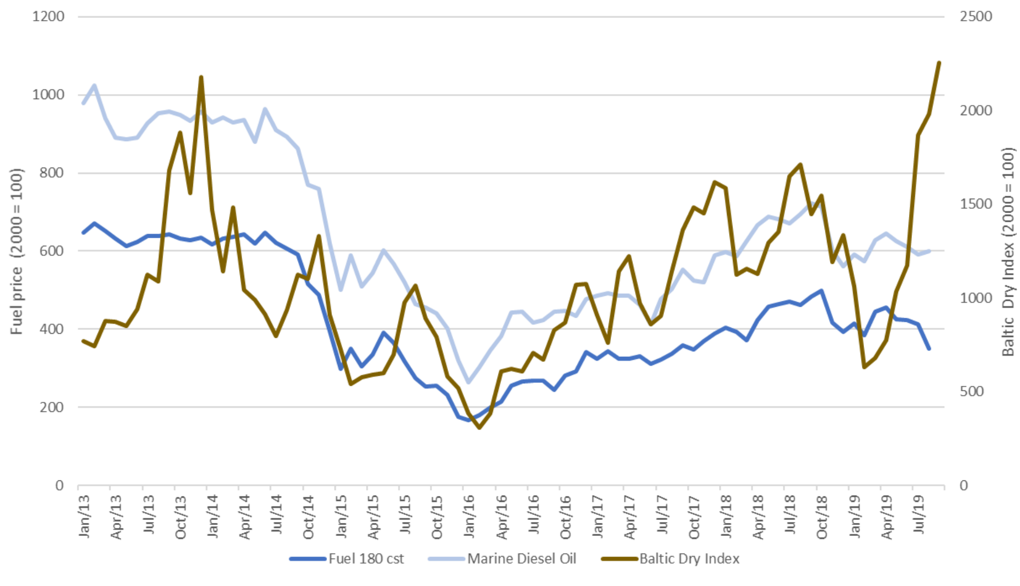

Figure 5.14 Marine Diesel/Fuel 180 CST Index (left axis) and Baltic Dry Index (right axis)

Source: ISL Shipping Statistics Yearbook 2019

Summary

In the context of this study the correlation between fuel price and the General Freight Index (Figure 5.12) and HARPEX (Figure 5.13) are calculated at respectively 0.9 and 0.7. For the dry bulk segment (see Figure 5.14) there is no strong correlation perceived.

In line with these findings are the results from several scientific studies that have derived the relation between fuel prices and freight rates (or even consumer prices):

- UNCTAD (2010) estimated the elasticity between fuel prices and container freight rates between 1993 and 2008, which ranges between 0.19 and 0.36;
- OECD (2008) estimated that the elasticity between freight rates and fuel prices ranges between 0.018 and 0.150;
- Hummels (Hummels, 2007) derived an elasticity between freight rates and oil price ranging from 0.232 and 0.327;
- Mirza and Zitouna (2009) calculated an estimated elasticity between freight rates and oil prices between 0.088 and 0.103 dependent on the origin/destination of the countries.

Table 5.14 presents the key findings from the literature, such as the energy share in the total cost structure, assumed costs increase due to sustainable fuels and freight rate elasticity. Finally, a gross estimate of the impact of sustainable fuels on the freight rate is presented with a bandwidth. The estimated impact ranges from a relatively small effect (+/- 1%) to a potential 12% increase of freight rates.

Table 5.14 Estimated impact on freight rates – key findings

Segment	Energy share (1)	Fuel cost increase (2)	Freight rate elasticity (3)	Total estimated impact (2) * (3)	Segment
				2030	**2040**
General	25% - 50%	7% by 2030 42% by 2050	0.018 to 0.36	0,1% - 2,5%	0,8% - 15,1%
Containers	+/- 50%		0.11 to 0.36	0,8% - 2,5%	4,6% - 15,1%
Dry bulk	35%		0.28	2,0%	11,8%

Maritime transport cost and consumer price

The impact of a universal carbon price on emissions from maritime transport on freight rates and transport costs would depend on several parameters, including market structure, trade routes and cargo type. According to Kosmas and Acciaro (2017) the carrier can pass on the additional cost to shippers in a demand-driven market, whereas this is less true in a supply-driven market.

This is demonstrated by a comparison of market conditions in 2006 – 2007 (characterised by high demand and elevated freight rates) and 2012 – 2013 (characterised by overcapacity in the market). If a hypothetical fuel levy had been introduced in 2006 – 2007 roughly 48% of the levy would have been borne by carriers, and 52% by shippers. In the overcapacity situation of 2012 – 2013, it is estimated that 90% per cent would have been borne by carriers, and 10% by shippers.

VIVID Economics (2010) assessed the economic impact on freight rates from a 10% increase bunker prices for different markets and cargo segments (i.e. containers, grain, oil, etc) and concluded that, except for iron ore, the price increase is estimated to be smaller than 1% and the loss of consumer welfare from reduction in consumption will be negligible.

In short, several studies have investigated oil price fluctuations and consumer prices and many indicate that both are to some extent associated (especially in the long run). However, no substantial impact of historic oil price fluctuations and consumer prices can be derived from the literature.

Impacts on policy options

Overall, a potential fuel price increase of alternative fuels results in an estimated freight rate increase between 1% and 40%. However, several studies indicate that there is no substantial impact found between fuel price fluctuations and consumer prices. Most additional costs are internalised by the carrier or shipper before being transferred to the consumer. The effects on consume welfare are expected to be negligible. The three policy options do not seem to have a distinctive impact when it comes to freight rates and do no lead to different conclusions.

5.3.3. Connectivity of remote islands and outermost regions

Ports located on remote islands or in outermost regions might be impacted more than their counterparts on the mainland. In order to remain attractive for regional (or even international) shipping, the required bunkering infrastructure needs to be established in those ports as well. However, investments in bunkering facilities for alternative fuels might be high, while only a limited number of vessels will use their services. The gap between costs and potential benefits might be large, creating a disincentive to invest in infrastructure. Without the required infrastructure, vessels sailing on the alternative fuels, will no longer call such a port, as they are not able to bunker. As a result, shipping companies will have to consider whether it is still possible to offer the service (both financially and technically). Consequently, islands and outmost regions might become more secluded if ship services are not retained and maritime transport declines.

Islands and outermost regions in Europe

In the first step, the ports on islands and outermost regions in Europe are identified. In Figure 5.15, the European islands (roughly 150 islands) are presented, which already shows that (concerning this impact) specific focus can be applied to certain regions in European (e.g. Baltic, Mediterranean, etc). In addition, the European Union officially counts nine outermost regions:[168]

- French Guiana;
- Guadeloupe;
- Martinique;
- Mayotte;
- Reunion Island;
- Saint-Martin (France);
- Azores;
- Madeira (Portugal),
- Canary Islands (Spain).

[168] European Commission (2020), Regional policy & outermost regions.

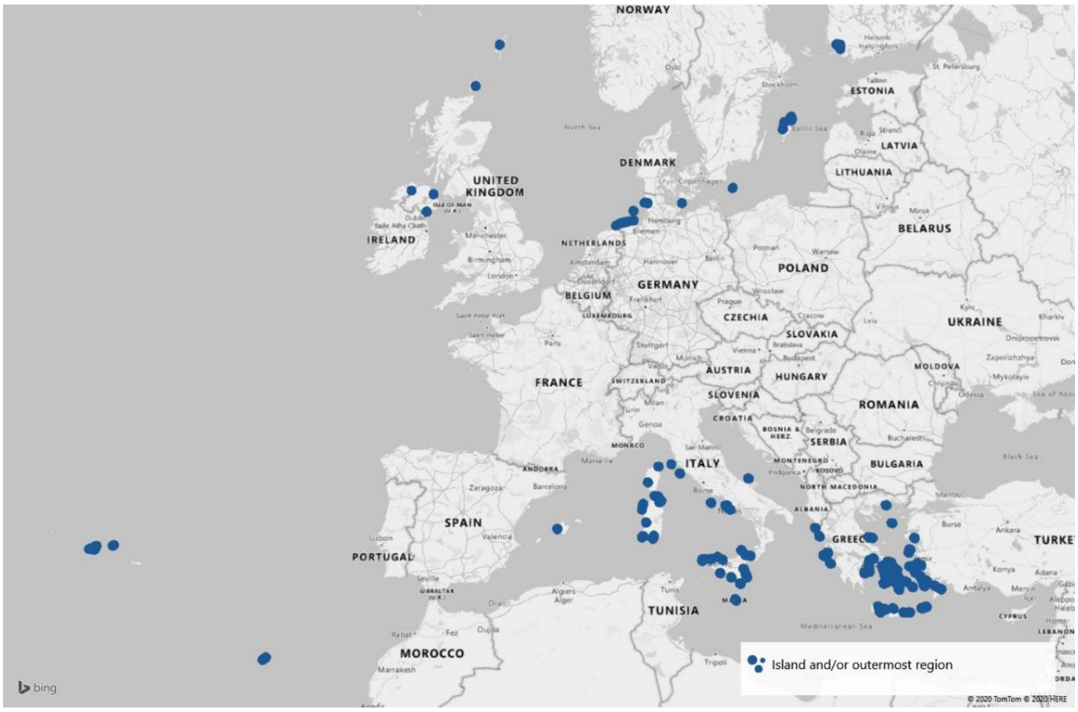

Figure 5.15 Ports on islands and/or outermost regions in Europe

Source: Eurostat - maritime transport (metadata) (modified by author)

Impact on connectivity of islands and outermost regions

The impact on connectivity of these remote islands and outermost regions will be highly dependent on the characteristics of the region. Therefore, in the second step, regional databases are analysed in order to determine the characteristics of the region with a specific focus on certain segments (e.g. focus on passenger transport and cargo segments). Information on the type of port, number of vessel calls and especially current connectivity and frequency is relevant to assess the magnitude of the impact. The data analysis is on several aspects similar to the impact on ports, but with a clear regional focus on islands and/or outermost regions.

Port throughput

Total throughput of the ports on European islands in 2018 is close to 250 million tonnes, which equals 6% of the total throughput in Europe. On the basis of the port size classification used in impact on ports section, roughly 75% (53 ports) of the ports on islands are classified as a small port. Around 25% of ports on islands have an annual traffic volume between 5 and 50 million and are therefore classified as medium ports. Note that more than 80 ports do not have freight statistics available (potentially due to their small size).[169]

At the same time, the total number of vessel calls at these islands equals 640.000 on an annual basis. This equals over 25% of the total number of vessel calls in Europe. The majority of vessels is transported by (small) general cargo vessels (75%) and is destined for the local market.[170] Transportation is mainly done by (smaller) feeder vessels with a fixed sailing route from the (larger) surrounding ports. This is confirmed by presenting a freight connectivity example of the Port of Marsaxlokk (see Table 5.15).

169 Eurostat [mar_go_qmc], Gross weight of goods handled in main ports by direction and type of cargo.

170 Eurostat [mar_tf_qm], Vessels in main ports by type and size of vessels.

The Port of Marsaxlokk is a relatively larger island port, but is clearly included is several fixed sailing services from the main deep- and shortsea carriers active in Europe (CMA-CGM, Hamburg Sud, OOCL, etc). In combination with the fact that a feeder vessel can sail several days without bunkering shows that vessels are able to bunker at one of the larger ports in the fixed schedule. The impact on these islands (in terms of freight connections) will therefore be negligible.

Table 5.15 Freight connectivity example – Port of Marsaxlokk

Origin	Destination	Number of connections	Average time (in hrs)	Carrier
Rotterdam	Marsaxlokk	5	11 – 15	CMA-CGM, Sealand, Hamburg Sud, Freso
Antwerp	Marsaxlokk	7	6 – 11	CMA-CGM, Sealand, Hamburg Sud, Freso
Hamburg	Marsaxlokk	3	7 – 8	CMA-CGM, Sealand, Hamburg Sud
Bremerhaven	Marsaxlokk	3	9 – 10	CMA-CGM, Sealand, Hamburg Sud
Algiers	Marsaxlokk	1	4 – 12	CMA-CGM
Algeciras	Marsaxlokk	6	4 – 20	CMA-CGM, OOCL, Sealand
Valencia	Marsaxlokk	4	10 – 21	CMA-CGM, OOCL, Sealand
Felixstowe	Marsaxlokk	2	12 – 13	Sealand, Hamburg Sud
Catania	Marsaxlokk	1	1	CMA-CGM

Source: Ecorys Intermodal Links Database

Several scientific studies have derived the relation between fuel prices and freight rates (see impact on freight rates description) and concluded that the freight rate elasticity lays somewhere between 0.018 to 0.36. This means that a 10% increase of fuel prices have an expected impact of 0.18% to 3.6% on freight rates, whereas part of these costs will not be passed through to the consumer price. In line with these findings, it can be concluded that the impact on consumer welfare (also for the local market) will be negligible.

Maritime transport of passengers

Where the yearly total number of vessels calling at ports on European islands is equal to 640.000, around 110.000 consists of passengers ships (excl. cruise vessels). This shows that maritime transport of passengers will (often) result in a substantial (economic) activity. The impact on connectivity and/or challenges with regard to maritime passenger transport will be explained. Table 5.16 shows an example of connectivity statistics that is retrieved for passenger transport departing from Las Palmas (Spain), which shows there are 18 fixed connections per week connecting Las Palmas to the surrounding islands and the mainland. These connections are often point-to-point connections (compared to a network of port calls in case of freight transport).

Table 5.16 Passenger connectivity example – Las Palmas

Origin	Destination	Number of connections	Average time (in hrs)	Carrier
Las Palmas	Santa Cruz de Tenerife (Tenerife)	4	3,1	Fred.Olsen Express
Las Palmas	Arrecife (Lanzarote)	4	7,15	Fred.Olsen Express
Las Palmas	Cádiz	1	46	Trasmediterranea
Las Palmas	Huelva	2	37	Canary Bridge Seaways
Las Palmas	Morro Jable (Fuerteventura)	2	2,5	Fred.Olsen Express
Las Palmas	Puerto del Rosario (Fuerteventura)	2	6	Naviera Armas
Las Palmas	San Sebastián (La Gomera)	1	12,5	Naviera Armas
Las Palmas	Santa Cruz de La Palma	2	15	Naviera Armas
		18 (total)	16 (average)	

Source: ferrylines.com.

Multiple pilots and projects have been started to explore the possibilities of using alternative fuels in these point-to-point ferry connections. Several Scandinavian countries have already made the transition towards electric or hybrid ferry (e.g. E-ferry Ellen in Denmark).[171] In Greece, an electric ferry has been developed to connect the Gulf of Corinth and the port of Aigio. The total costs of this pilot are budgeted at €4 to €5 million.[172] In 2018, as part of the Hyseas III research program, hydrogen has been applied as a marine fuel to the ferry fleet of the Orkney Islands. The expected costs are equal to around €12,6 million (of which €9,3 million is funded by the Horizon 2020 program).[173] The transition from ferries powered by fossil fuels towards more sustainable solution is has started.

One of the main challenges, when it comes to electrification of passenger vessels (and especially cruise vessels) is the high demand for shore-side electricity. Electricity problems might arise when large vessels (e.g. cruise vessels) will simultaneous call at a seaport. Theoretically, the energy demand of these vessel, when using OPS, will be higher than the energy demand in the city itself. This could limit the implementation of onshore power supply.[174]

171 https://plugboats.com/worlds-largest-electric-ferry-completes-maiden-voyage/.

172 https://plugboats.com/greeces-first-electric-ferry-announced/.

173 Hyseas III, https://www.hyseas3.eu/the-project/.

174 European Commission (2015), State of the Art on Alternative Fuels Transport Systems in the European Union.

Impact on policy options

The current policy options provide insufficient basis to assess the quantitative impact on the connectivity of remote islands and outermost regions and the economic viability of the individual carriers. Nevertheless, similar to the conclusion drawn for impacts on ports, the shift towards alternative fuels and the impact on the island ports will depend on the willingness and capability to invest. Additionally, findings from the literature have shown that oil price and freight rates are related, but by interpreting the elasticities, the projected impact on consumer welfare is negligible. Finally, The policy options itself do not seem distinctive and will not generate different impacts.

5.4. Environmental impacts

Most environmental impacts were assessed by the Commission to ensure consistency with the overall climate modelling. The study team focused on the risk of carbon leakage through evasion re-routing, and on challenges related to implementations, monitoring and reporting.

5.4.1. Risk of carbon leakage through evasion, re-routing and modal shift

The implementation of a policy measure that incentivises the uptake of alternative bunker fuels on a regional level can potentially incentivise ships to change their operational pattern or shippers to adjust their logistic chains in order to minimise compliance costs. As a consequence, the policy measure might be less effective than expected and, in the worst case, might have a counterproductive effect, i.e. lead to higher emissions.

The geographical scope of the policy measure plays an important role in this context. If the policy measure that incentivises the uptake of alternative bunker fuels has the same geographic scope that holds under the current EU MRV Regulation, then the geographical scope would be defined as follows: “All intra-Union voyages, all incoming voyages from the last non-Union port to the first Union port of call and all outgoing voyages from a Union port to the next non-Union port of call, including ballast voyages, …”. Given this geographical scope, shippers/ship operators might consider changing their operational pattern:

1. by attempting to avoid the measure as such by:
    a. using transhipment at sea instead of calling at a port;
    b. choosing another mode of transport (modal shift).
2. by reducing the distance sailed within the scope of the measure;
3. by making an additional port call at a non-Union port, in order to minimize the in scope-distance between the Union port and the non-Union port;
4. by selecting another port of destination/origin in the Union at a shorter distance to the non-Union port and at the same time increase the distance that is covered by means of hinterland transport;
5. by selecting another port of origin/destination outside the Union at a shorter distance to the Union port and at the same time increase the distance that is covered by means of hinterland transport;
6. by selecting another port of destination/origin just outside the Union and at the same time increase the distance that is covered by means of hinterland transport, to entirely avoid the policy measure;

7. by reducing the fuel consumption on voyages that fall in the scope of the measure;
8. by using relative efficient ships to sail to and from Union ports, whereas relative inefficient ships are increasingly used outside the geographical scope of the policy measure;
9. by sailing relatively slowly within the scope of the measure. This would have a positive effect on the emissions in the scope of the measure, but could potentially lead to a net-increase of a ship's overall emissions if ships sailed at a higher speed outside the scope of the measure to compensate for the time lost due to slow steaming.

The current operational pattern of the ships has been optimised for the current conditions, and whether it would be profitable to change this pattern will depend on the stringency of the policy measure, the associated compliance costs and their impact on the overall transport costs.

Additional port calls can be expected to be associated with relatively high additional costs, at least if the definition of a port call requires cargo handling or (dis)embarkment of passengers as is the case under the current EU MRV Regulation. Not only extra operational costs for the additional distance sailed would then accrue, but also additional port dues and opportunity costs due to the extra time required for the extra port call which highly depends on the capacity of the ports.

Time will probably also play a very important role when considering to cover longer distances by means of hinterland transport or replace shipping by other modes of transport.

In general, ships that sail a relatively long distance within the scope and thus would have relatively high compliance costs, have a higher incentive to avoid the policy measure. The profitability of avoidance tends to be higher in relative weak markets, and appears to be lower for high-price commodities. In addition, a careful design of the measure can contribute to the minimisation of avoidance (CE Delft et al. (2009)[175]).

The definition of a port call is, for example, crucial in this context. It should ensure that pure strategic port calls are ruled out, but at the same time not enlarge the scope of a measure to an extent that might reduce the political feasibility of the measure.

Ricardo-AEA (2013)[176] have assessed the potential impacts of different GHG reduction measures if implemented on EU level. As part of the impact assessment, the policy measures are, amongst other criteria, assessed with regards to their avoidance potential. The outcome of this assessment is relevant for this context too, since both the policy measures assessed by Ricardo-AEA (2013) and the policy measures under consideration lead to an increase of the transport costs of ships sailing to and from EU ports.

Regarding the avoidance potential, Ricardo-AEA (2013) conclude 'that the probability of undermining the environmental effectiveness of a regional system by implementing avoidance or evasion strategies is considered to be very low. On the contrary, the reduction of total costs … [due to an efficiency improvement induced by the policy measures] may lead to modal shift from rail or road to ships, if the savings are passed into the freight rates."

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[175] https://www.cedelft.eu/en/publications/1005/technical-support-for-european-action-to-reducing-greenhouse-gas-emissions-from-international-maritime-transport; Annex H of the report goes specifically into the potential for evasion.

[176] https://ec.europa.eu/clima/sites/clima/files/transport/shipping/docs/ghg_maritime_report_en.pdf.

With regards to a potential modal shift due to a regional measure to reduce GHG from shipping, CE Delft et al. (2009) conclude that:

- If modal shift will occur, it will most likely occur in unitised short sea shipping, including RoRo and LoLo. For intercontinental shipping other modes of transport hardly exist, while elasticity estimates of short sea bulk transport suggest that these are not very sensitive to price;
- Modal shift may result in higher emissions in some cases, yet this need not be true in every case. Small vessels have emissions that are comparable to road transport and higher than emissions of rail transport. So modal shift only results in higher emissions on routes where relatively large ships compete with road transport;
- On routes where unitised cargo is transported and relatively large vessels compete with road transport, modal shift may occur if road and rail transport are not subject to cost increasing climate policies or if the cost increase per unit of CO_2 emissions is the same as in maritime transport. If the cost increase in road and rail transport is higher than in maritime transport, modal shift in unlikely to occur, or may occur in a way that increases the share of maritime transport.

Avoidance options that reduce the fuel consumption on voyages within the scope (listed under 3.) are associated with relatively little extra costs and thus also more likely to occur than the other options.

Another potential source of carbon leakage is related to the ship type/size scope of the potential policy measure. Due to the policy measure, ship types and sizes that fall outside the scope of the measure might, if possible, be used more intensively instead of ship types/sizes within the scope of the measure. If the scope of the policy measure was, for example, aligned with the scope of the EU MRV regulation, then transport work could be shifted from ships above 5,000 GT to ships of 5,000 GT and below; since almost all ship types are included in the EU MRV regulation,[177] a shift of transport work between ship types would, however, be unlikely.

Relatively large ships are normally preferred to relatively small ships, due to economies of scale – relative larger ships are more efficient to use. Shifting transport work to relatively small ships thus comes at a cost (e.g. higher fuel bill, more time in port to handle the same amount of cargo etc.), but depending on the stringency of the measure, a shift to smaller ships cannot entirely be ruled out, at least for coastal shipping and intra-EU shipping, potentially leading to a net increase of emissions of a segment of the in-scope fleet. For ocean-going ships, a shift to ships of 5,000 GT and below is very unlikely.

Finally, requirements related to the emissions of ships at berth could also lead ships to change their operational patterns and to potentially reduce the effectiveness of the policy measure. If ships were obliged to use an OPS system in ports, they might prefer calling at ports which have not installed an OPS system yet. Or if an OPS obligation was implemented gradually over ship types, then transport work might, if possible be shifted from the in-scope ship types to the ship types not yet falling in the scope of the regulation.

For battery hybrid ships it holds, that they might have an incentive to load the batteries outside the scope of the regulation by means of diesel generators and use the batteries in ports falling in the scope of the policy measure. Battery hybrid ships are, at least currently, relatively small ships that can expected to mainly sail within the scope of the system. As such, the effectiveness of the policy measure is probably not compromised, at least if not only at berth, but also in navigation, requirements still apply.

[177] The EU MRV Regulation ‘does not apply to warships, naval auxiliaries, fish-catching or fish-processing ships, wooden ships of a primitive build, ships not propelled by mechanical means, or government ships used for non-commercial purposes.

In parallel with ships' potential adjustments to the policy measure, the emissions (both GHGs and air pollutants) produced by power plants providing electricity in ports related to the use of OPS should also be , (for instance by mandating a more sustainable power generation on land for all electrical power use including OPS) to make the policy measure an effective instrument. CO_2 emissions of power supply, fall under the EU ETS system and are thus effectively capped.

Annex I - Bibliography

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- Eurostat data on maritime transport, international trade, et cetera;
- Ecorys Intermodal Links Database.

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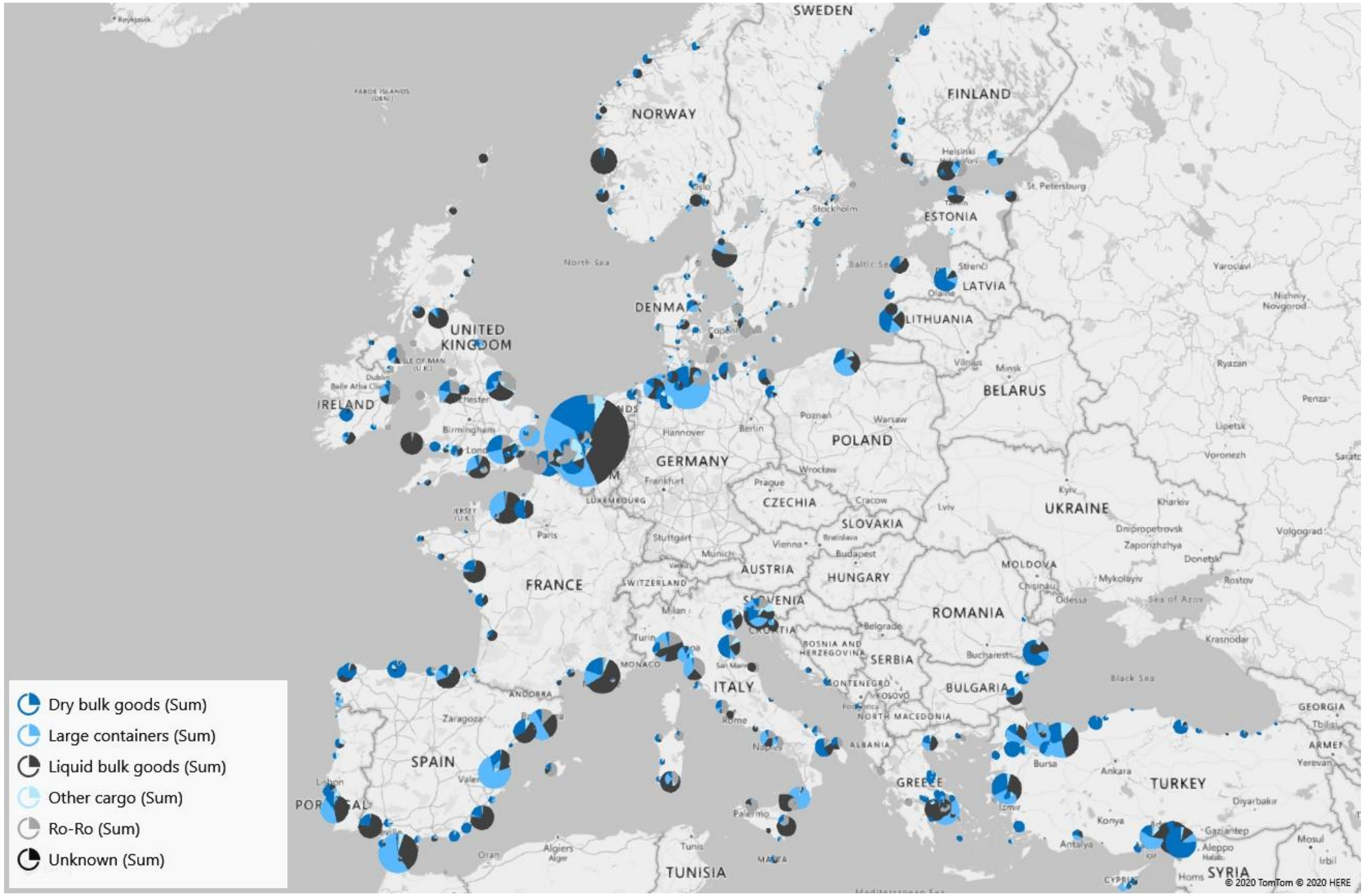
- https://www.shell.com/business-customers/trading-and-supply/trading/news-and-media-releases/shell-sets-course-for-net-zero-emissions-shipping.html;
- https://www.skillsea.eu.

Annex II - Additional information for impacts on ports

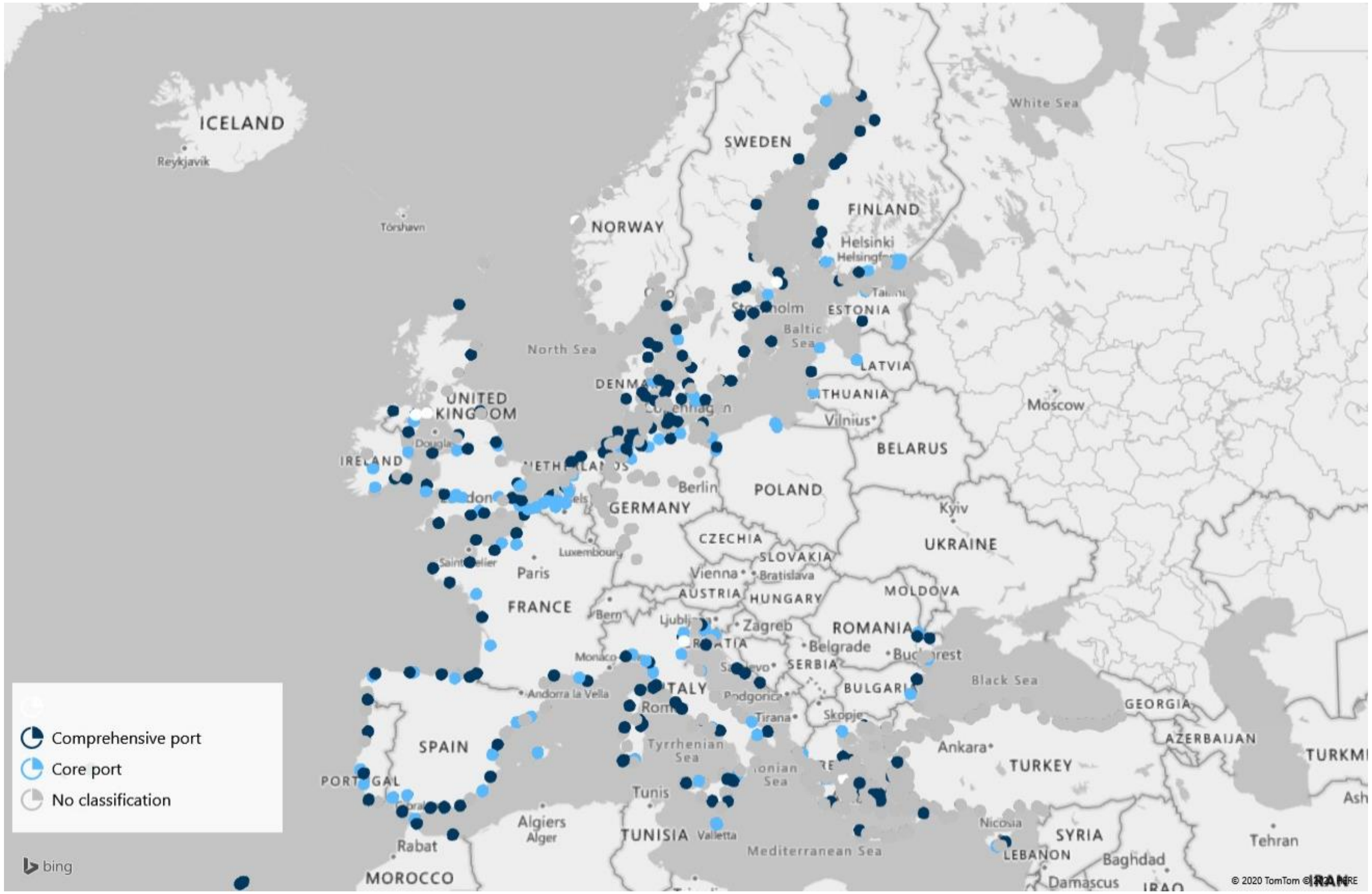
For the analysis of the impact of the different policy options two additional analyses have bene conducted. The results of these analyses can be found in the following two graphs:

- AII.1 Port throughput divided between commodities;
- AII.2 Overview of core and comprehensive ports.



AII.1 Port throughput divided between commodities.

Source: Ecorys (2020).



AII.2 Core/comprehensive ports.

Source: Ecorys (2020).

Annex III - Large-sized ports

Table AIII.1 Largest ports in Europe (classified as large-sized ports)

Port	Port ID	Country	Total throughput (x 1.000 tonnes)
Rotterdam	NLRTM	Netherlands	441.473
Antwerpen	BEANR	Belgium	212.012
Hamburg	DEHAM	Germany	117.625
Amsterdam	NLAMS	Netherlands	99.503
Algeciras	ESALG	Spain	88.640
Marseille	FRMRS	France	75.670
Le Havre	FRLEH	France	64.905
Valencia	ESVLC	Spain	61.975
Trieste	ITTRS	Italy	57.378
Immingham	GBIMM	United Kingdom	55.618
Barcelona	ESBCN	Spain	54.562
London	GBLON	United Kingdom	53.197
Genova	ITGOA	Italy	51.569
Bremerhaven	DEBRV	Germany	51.161
Peiraias	GRPIR	Greece	50.925

Source: Eurostat [mar_go_qmc].

Annex IV - Passenger movements

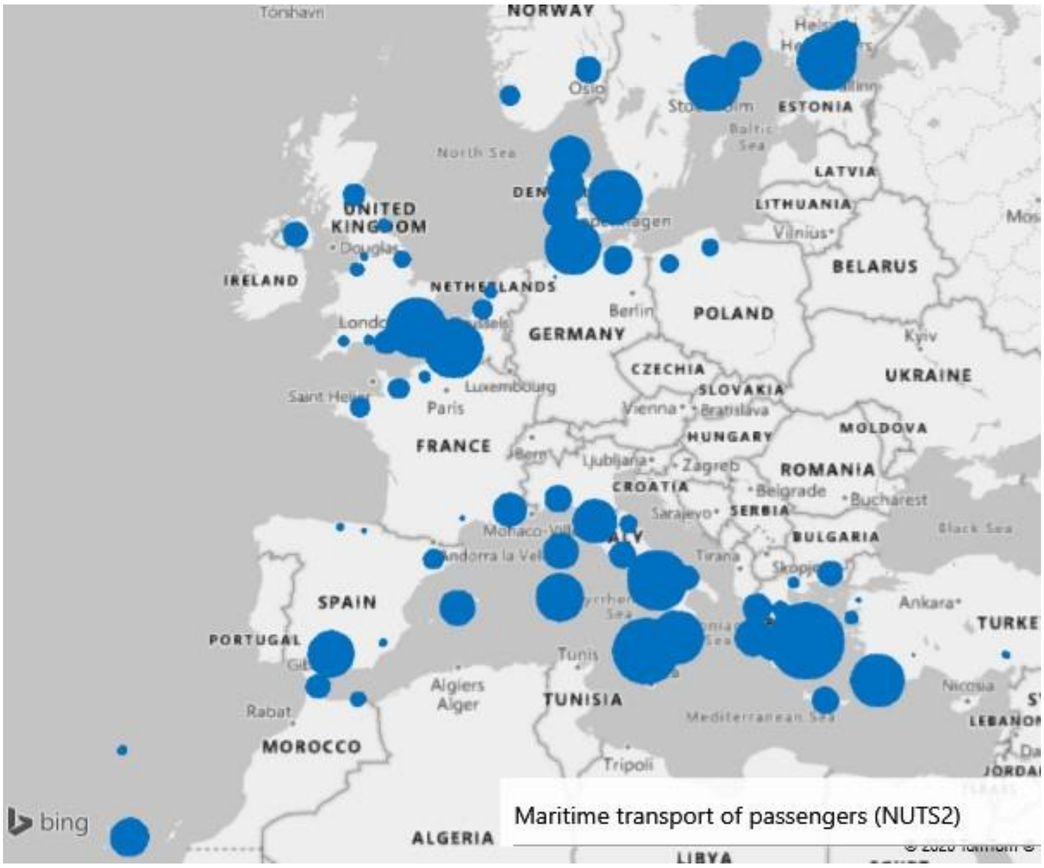


Figure AIV.1 Maritime transport of passengers by NUTS 2 regions.

Source: https://ec.europa.eu/eurostat/databrowser/view/tgs00075/default/table?lang=en.

Annex V - Freight rates and oil prices

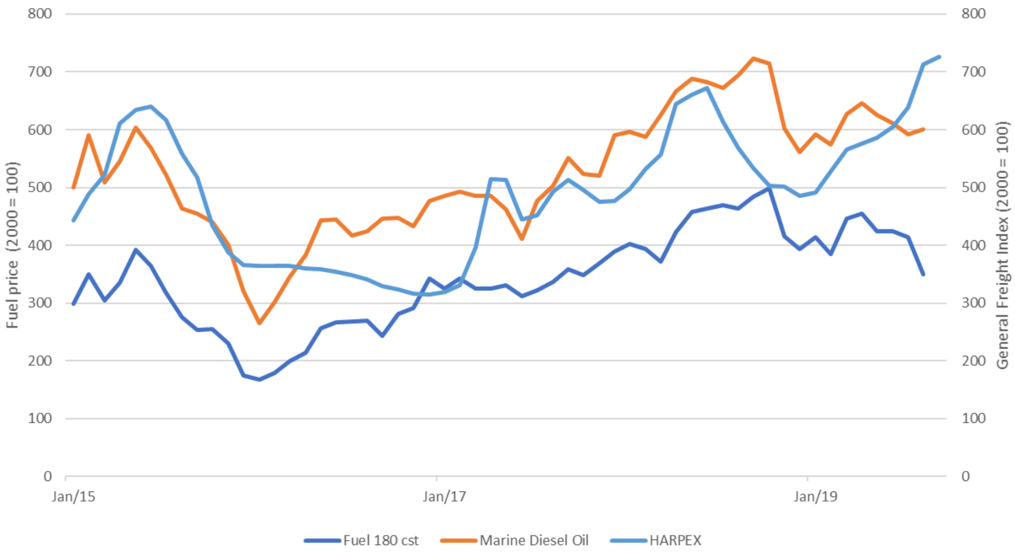


Figure AV. Marine Diesel/Fuel 180 CST Index (left axis) and HARPEX (right axis).

Source: ISL Shipping Statistics Yearbook 2019.

Annex VI - Outermost regions and islands

Table AVI.1 Outermost regions and islands - sample of potential representative regions

Country_name	NUTS region	NUTS2
Germany	Weser-Ems	DE94
Germany	Schleswg-Holsten	DEF0
Greece	Attica	EL30
Greece	North Aegean	EL41
Greece	South Aegean	EL42
Greece	Crete	EL43
Greece	Eastern Macedonia and Thrace	EL51
Greece	Thessaly	EL61
Greece	Ionian Islands	EL62
Greece	Central Greece	EL64
Spain	lles Balears	ES53
Spain	Canaras	ES70
Italy	Campania	ITF3
Italy	Puglia	ITF4
Italy	Sardegna	ITG2
Malta	Malta	MT00

Annex VII - Methodological calculations supporting impacts on ports

Table AVII.1 Methodological calculation – impact on ports

Type of ports		N.o. ports investing in alternative fuels (1)		Average investments (2)	Total Investments (1) * (2)		Total bandwidth
		Hydrogen	OPS		Hydrogen	OPS	
Large EU ports	Gateway	5	-		Min: €875 mln Max: €2.500 mln	Min: €88 mln Max: €2.200 mln	€175 - €500
	Mixed	15	-				€525 - €1.500
	Transhipment	5	-				€175 - €500
TEN-	Core ports	-	88				€88 - €2.200

Annex VIII – Case study fiches

OPS California

The aim of doing this case study is to provide an example of how the use of OPS can be incentivised or regulated, what the barriers to implementation are and what effects the measure has had.

Reason for carrying out the case study

This case study is an example of how to deal with the problem: low uptake of zero-pollution fuels and power by ships at berth.

The following objectives are applicable to this case study:

- *Specific objective 4: create demand from ship operators to bunker sustainable alternative fuels or connect to the electric grid while at berth.* The CARB expects a large part of fleets to use shore power. Fleet operators must fill out spreadsheets with information regarding the usage of shore power which will be checked by the CARB.

General description

Shore power can be installed for all types of vessels of all ages. It has been used for smaller vessels with moderate power requirements (50 – 100 kW) for years. These vessels are capable of making use of normal grid voltage and frequency, and replace the energy from the generators with the shore power with only marginal investments. For larger vessels with higher power requirements (100 kW – 15 MW) however, providing shore power is more costly due to expensive installations both on board and on land. Installations may include upgrading the grid capacity, frequency converters and complex high power connectors. (8)

OPS systems on the land side consist of the following (8):

- High voltage grid to the port
- Frequency and voltage convertors/transformers
- Control panels and connection boxes
- Cable reel and connectors

The ships require installation of the following (8):

- Transformer
- Power distribution system
- Control panel
- Frequency converter (optional for greater flexibility)
- Connectors and cable reel (optional for greater flexibility)

How has the regulation evolved over time

In 2008, the State of California Air Resources Board (CARB) adopted new regulations, requiring reductions of air pollutants emitted from container, cruise, and refrigerated cargo ships docked (at berth) at six California ports:

1. Los Angeles
2. Long Beach
3. Oakland
4. San Diego
5. San Francisco
6. Hueneme

The regulation requires that auxiliary diesel engines are shut down (i.e., instead use grid-based power) for specified percentages of fleet visits. In new regulation the ports and terminals in Northern California will be added to the list in cities such as Stockton, Richmond, Rodeo, Benicia and Martinez. (4)(9)

Vessel operators relying on shore power were/are required to shut down their auxiliary engines:

- 50% of the fleet's vessel visits in 2014
- 70% of the fleet's vessel visits in 2017
- 80% of the fleet's vessel visits from 2020 onwards

The same percentages apply to the reduction of onboard power auxiliary engine power. (4)

At least 70% of the fleet's visits to a port must satisfy the following limit on engine operation: for each visit, the auxiliary engines on the vessel cannot operate for more than three hours during the entire time the vessel is at-berth (14)

(6):

New regulation will involve more ship types and will be applied to more ports and terminals (9):

2023: smaller container, reefer and cruise ships

2025: ro-ro ships

2027 (Los Angeles and Long Beach): tankers

2029 (elsewhere): tankers

Reason why OPS is used

OPS is generally used in ports for vessels in berth to provide electricity for stationary processes at the ship, such as ventilation and heating. Electricity is often obtained from running generators at the ship but can be replaced by electricity from shore (OPS). (8)

In 2008, the State of California Air Resources Board (CARB) adopted new regulations, requiring reductions of air pollutants emitted from container, cruise, and refrigerated cargo ships docked (at berth) at six California ports. The key requirements of the regulation include emission reductions of 50% starting in 2014, 70% starting in 2017, and 80% starting in 2020. Grant funding awarded to the Port requires emission reductions that are higher than those specified by CARB regulations. (5)

Ship types and sizes for which the regulation applies

Implementation as off:

2014: container, cruise, and conventional refrigerated cargo ships

2023: smaller container, reefer and cruise ships

2025: ro-ro ships

2027 (Los Angeles and Long Beach): tankers

2029 (elsewhere): tankers

75% of visits from oceangoing vessels will be covered by this regulation.

(4)(9)

Governance, incentive or enforcement

Incentives may be available to projects that reduce at-berth emissions.

Carl Moyer funding accelerates the turnover of highly polluting engines. The Carl Moyer Program provides grant funding for replacing engines and equipment with cleaner technology. The funding has been awarded for shore-side transformer costs at passenger-vessel terminals and for onboard vessel retrofit costs. Example: Grant funding has been awarded to the port of Oakland requires emission reductions that are higher than those specified by CARB regulations. (10)(5)

Monitoring and reporting obligations for ships

Ship operators must fill out a visit information spreadsheet regarding their visit (15). The information spreadsheet must consist information about the ship and specifically about shore power and must consist the following (16):

- Information about the electricity provider;
- Time auxiliary engines stopped;
- Time auxiliary engines started.

In an advisory of CARB as off January 1 2017, The CARB offers six possible scenarios for regulated entities to satisfy certain provisions under certain circumstances. The objective of the scenarios is to offer flexibility to fleets that have equipped their vessels to use shore power or contracted to use an alternative control technology to comply with at-berth regulation. The scenarios are (14):

1. The vessel visiting the port is equipped to receive shore power, but the terminal's shore power berth is not able to provide shore power;
2. A vessel makes a commissioning visit to a terminal, and during the visit, the auxiliary engines operate longer than three hours;
3. A vessel uses shore power, but fails to meet the three/five-hour time limit for connecting or disconnecting shore power;
4. Vessels are using an approved alternative control technology to comply with the At-Berth Regulation;
5. Fleet participates in testing an alternative control technology with an ARB-approved test plan;
6. A fleet meets the percent reduction requirements for visits, power, or emissions, averaged on an annual basis.

The staff of CARB will review each fleet's efforts to meet the scenario conditions on case-by-case basis. The fleet operator has to provide proof and documentation sufficient to qualify for the scenarios and the CARB's staff may request additional information to verify the fleet's claims. If verification is not possible, the fleet's request to use one or more scenarios will be denied (14).

Costs

Regulatory costs

Regulation would have a total net cost of $2.16 billion between 2021 and 2032 according to estimations from CARB. The estimated unit costs:

- $1,11 per TEU for container or reefer vessels
- $4,56 per cruise passenger
- $7,49 per automobile moved on a ro-ro ship
- < $0,01 per gallon of finished product for product moved by tanker (9)

Costs for ports

The grid power solution and the frequency converters typically represent the costliest elements on the shore side. Depending on the availability of grid power and the power requirements, the cost of installing shore power on the shore side will vary considerably. (8)

Costs depend on type of vessel and the size of the vessel. Range is from: $50.000 for 1000 GT vessels - $750.000 for 100.000 GT vessels (8)

Costs for ships

The financial system is different at each port and thus the costs for ships vary. In general, costs consist of:

- Utility rates for shore power usage (usage rate + maintenance rate + initial vessel commissioning charge)
- Installation onboard facilities

Not all berths at a port are owned or managed by a port but by a terminal operator. In these cases, the terminal operator decides the utility rates.

Example: the port of Oakland

- Usage rate: $267 per hour (plus applicable taxes)
- Maintenance rate: $31 per hour (plus applicable taxes)
- Initial vessel commissioning charge (5)

CO_2 emission savings (if any)

The reduction potential is 50% to 100% in port for the electrical motors on board. (8)

CO2 emission savings rely partly upon the generation mix of power station that supply ports with electricity (12). In the table below the main sources for electricity generation in California are displayed for 2010 and 2019. In both years, the main source was natural gas. However, as becomes clear from the table, the state has invested in the generation of electricity by solar power which results a reduction of CO2 emissions for electricity generation.

Table: Electricity generation in California in GWh (based on (13))

Source	2010	2019
Natural gas	109.682 (53%)	86.136 (43%)
Hydro	34.190 (17%)	38.494 (19%)
Nuclear	32.214 (16%)	16.163 (8%)
Solar	969 (0,4%)	28.513 (14%)
Total	205.657 (100%)	200.457 (100%)

Other environmental benefits

The reduction potential is 50% to 100% in port for the electrical motors on board. (8)

Estimated reduction of air pollutants from ships at berth by 95%. OPS nearly eliminates NOx, PM and SOx. (6)

Potentially elimination of local noise and vibration (8)(11)

Sources:

(1) https://www.freightwaves.com/news/california-plans-to-expand-rules-requiring-ships-to-use-shore-power

(2) https://www.polb.com/environment/shore-power/#shore-power-program-details (oa de factsheet die

hierin genoemd staat)

(3) https://ww2.arb.ca.gov/sites/default/files/2020-04/finalregulation_ADA.pdf

(4) https://www.portoflosangeles.org/environment/air-quality/alternative-maritime-power-(amp)

(5) https://www.oaklandseaport.com/development-programs/shore-power/

(6) https://safety4sea.com/how-does-cold-ironing-affect-the-environment/

(7) httpsbattery://ww2.arb.ca.gov/our-work/programs/ocean-going-vessels-berth-regulation

(8) https://glomeep.imo.org/technology/shore-power/

(9) https://www.freightwaves.com/news/california-plans-to-expand-rules-requiring-ships-to-use-shore-power

(10) https://ww2.arb.ca.gov/resources/documents/berth-faqs

(11) http://www.wpci.nl/docs/presentations/Onshore%20Power%20Supply%20Project%20IAPH%20conference%2018%20November%202009%20Finalt.pdf

(12) https://theicct.org/sites/default/files/publications/ICCT-WCtr_ShorePower_201512a.pdf

(13) https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/electric-generation-capacity-and-energy

(14) https://ww2.arb.ca.gov/sites/default/files/classic//ports/shorepower/forms/regulatoryadvisory2016/regulatoryadvisory110316.pdf

(15) https://ww2.arb.ca.gov/berth-regulation-advisories-and-forms

(16) https://ww2.arb.ca.gov/sites/default/files/2020-04/instructionforvisitinformation_ADA.pdf

OPS China

The aim of doing this case study is to provide an example of how the use of OPS can be incentivised or regulated, what the barriers to implementation are and what effects the measure has had.

Reason for carrying out the case study

This case study is an example of how to deal with the problem: ow uptake of zero-pollution fuels and power by ships at berth.

The following objectives are applicable to this case study:

- *Specific objective 4: create demand from ship operators to bunker sustainable alternative fuels or connect to the electric grid while at berth.* The Chinese government supports the usage of shore power in two ways. 1) By funding shore power infrastructure and 2) By producing vessels with shore power equipment. Additionally, the use of shore power will be checked at vessels within the DECA.

General description

Shore power can be installed for all types of vessels of all ages. It has been used for smaller vessels with moderate power requirements (50 – 100 kW) for years. These vessels are capable of making use of normal grid voltage and frequency, and replace the energy from the generators with the shore power with only marginal investments. For larger vessels with higher power requirements (100 kW – 15 MW) however, providing shore power is more costly due to expensive installations both on board and on land. Installations may include upgrading the grid capacity, frequency converters and complex high power connectors. (2)

OPS systems on the land side consist of the following (2):

- High voltage grid to the port
- Frequency and voltage convertors/transformers
- Control panels and connection boxes
- Cable reel and connectors

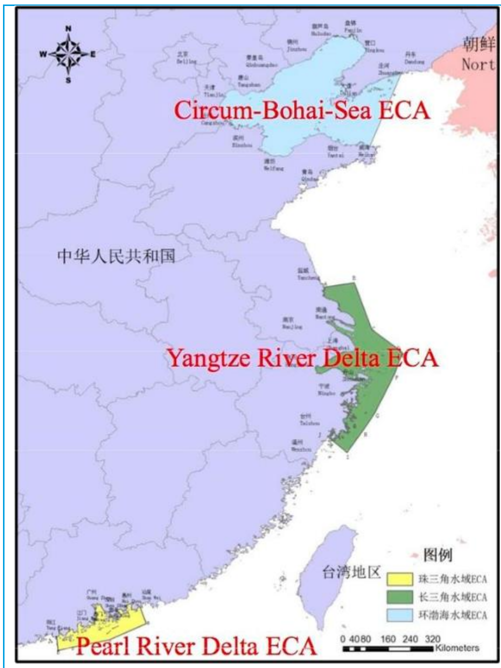
The ships require installation of the following (2):

- Transformer
- Power distribution system
- Control panel
- Frequency converter (optional for greater flexibility)
- Connectors and cable reel (optional for greater flexibility)

How has the regulation evolved over time

In December 2018 the Chinese Ministry of Transport has launched a new regulation to combat shipping pollution. China uses so-called domestic emission control area (DECA). Before the regulation the DECA was limited to three areas, as is displayed in the figure (left) below. In the new regulation the DECA is along China's coastline and extends 12 nautical miles off the coastline, see the figure below (right) (8). Additionally, emission control areas (ECAs) for inland shipping and cover the Yangtze River main line and the Xijiang River main line (8).

Figure source (9) (left) and (8) (right)



In accordance with the new regulation the following applies (8):

- As off 1 January 2019: Ships within the DECA must use fuels with a sulphur content not exceeding 0,5% of the fuel;
- As off 1 January 2020: Oceangoing ships that ply the inland river DECAs must use fuel with a sulphur content not exceeding 0,1% of the fuel;
- As off 1 January 2022: All ships operating inside Hainan waters must use fuel with a sulphur content not exceeding 0,1%.

New regulations start phasing in emission standards for NOx applicable to all China-flagged new-build or rebuilt ships. Also, the regulation sets requirements on the installation and use of onshore power (8):

- From 1 July 2019: vessels should use shore power if berthed for more than 3 hours. This applies to vessels that have the ability to receive shore power engaged on international voyages. Regulation does not apply to tankers and vessels using equivalent measures to reduce emissions. Within an inland control area regulation applies to vessels if berthed for more than 2 hours (5)(6).
- From 1 January 2021: shore power must be used by cruise ships if berthed for more than 3 hours in a berth with onshore power supply capacity (5)(6).

The Chinese Ministry of Transport has additional requirements for vessels to be equipped with ship shore power, per ship types. These are specified below in the section ‘ship types and sizes for which the regulation applies’. Additionally, the Chinese shipping enterprises and operators are encouraged to install shore power system ship-borne devices on vessels other than mentioned below, and to use shore power when getting alongside berth with onshore power supply capacity in the emission control area (7).

Additionally, the Chinese government calls for a review of the feasibility of requiring that (8):

1. All ships plying China’s coastal DECA must burn 0,1% sulphur fuel by 2025
2. All China-flagged ships that are built or have their engines rebuilt on/after 1 January 2025 must meet IMO Tier III standards

Reason why OPS is used

China introduced emissions standard. Sulphur content in must be below 0,5% in DECA (8). OPS nearly eliminates NOx, PM and SOx. OPS is a system which can be used to meet the standards.

Ship types and sizes for which the regulation applies

Usage of shore power

From 1 July 2019: vessels that have the ability to receive shore power engaged on international voyages, except for tankers and vessels using equivalent measures to reduce emissions (5)(6)(7).

From 1 January 2021: shore power must be used by cruise ships if berthed for more than 3 hours in a berth with onshore power supply capacity (5)(6)(7).

Construction

Build on/after 1 January 2019: Chinese public service vessels, inland river vessels and river-coastal vessels shall be equipped with ship shore power system (7).

Build on/after 1 January 2020: Chinese domestic coastal container ships, cruises, ro-ro passenger ships, passenger ships with a gross tonnage of at least 3.000 tons and dry bulk cargo ships with a gross tonnage of at least 50.000 tons shall be equipped with ship shore power system (7).

Build on/after 1 January 2022. The following vessels are required to install shore power system ship-borne device (7):

- Chinese public service vessels, inland river vessels (except for liquid cargo vessels) using single marine diesel engine power output of more than 130 KW but do not meet the Tier II oxynitride emission limits stipulated by MARPOL;
- Chinese domestic coastal container ships;
- Ro-ro passenger ships, passenger ships with a gross tonnage of at least 3,000 tons
- Dry bulk cargo ships with gross tonnage of at least 50,000 tons

Governance, incentive or enforcement

The Chinese government provides funding to subsidize the building of shore power infrastructure. It is expected to have 493 berths equipped with onshore power equipment across the country (8).

Monitoring and reporting obligations for ships

Obligations for ships (11):

- Operate in accordance with relevant safe operation procedure;
- Record information such as the starting and ending time of the use of shore power and the name of the operator in the engine logbook

The China Marine Safety Administration (MSA) will check ships certificates and documents. Specifically the MSA will check (11):

- The ship-borne appliance at ship types in accordance with the dates mentioned before;
- If shore power is indeed used in accordance with regulation;
- If the use of shore power conforms to relevant safety procedures;
- The Engine Logbook regarding starting and ending time for the use of shore power;
- If starting and ending time conforms to regulation.

The MSA will also conduct safety inspection works and will carry out on-site inspection regarding the use of shore power, the use of clean energy or new energy and the installation of exhaust gas after-treatment device. The MSA will verify if the ship meets corresponding emission control requirements (11).

Costs

Based on a research for the port of Shenzen in 2015 (12):

- *Capital costs for vessels:* Estimates by CARB and Environ: modification of a ship to receive onshore power ranges from $500.000 - $2.000.000 (container ships). Capital investment of $172 per TEU capacity (container ships);

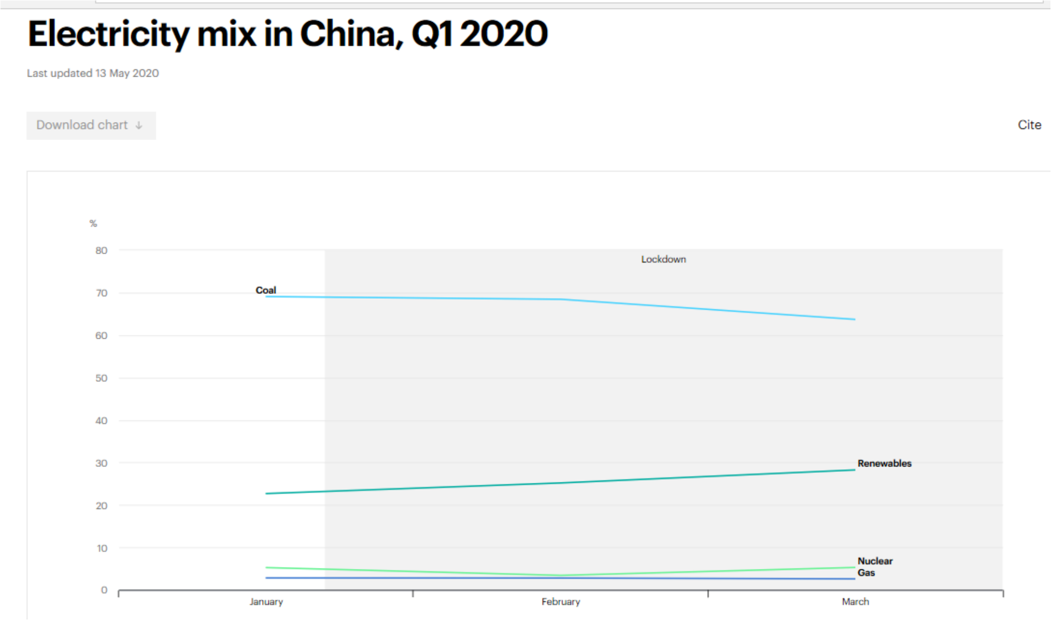
- *Capital costs for berths and terminals:* CARB estimated modification of each berth is about $5.000.000. This does not include additional costs such as the modification of the existing electrical infrastructure. For China this is estimated to be 20% less due to lower labour and raw material costs in China;
- *Electrical infrastructure outside ports:* costs depend on the port. I.e.: in Los Angeles no additional costs were made and in Hueneme $32 million (which was later scaled down) was estimated to adjust infrastructure. For Shenzen $5 million was estimated.
- *Operations and maintenance costs:* based on an Environ study costs are estimated to be annually 12% of total capital investment in shoreside infrastructure;
- *Energy costs:* depends on the electricity rate per port. In the research the assumption was made that the electricity costs for ships are $0.15 per kWh.

Other sources were not found.

CO_2 emission savings (if any)

CO2 emission savings rely partly upon the generation mix of power station that supply ports with electricity (12).

The main source of generation of electricity in China is coal. In the first quarter of 2020 64-69% of electricity was generated from coal, whereas generation from renewables was 23-28%.



Other environmental benefits

The reduction potential is 50% to 100% in port for the electrical motors on board.

Estimated reduction of air pollutants from ships at berth by 95%. OPS nearly eliminates NOx, PM and SOx. (1)(2)

Potentially elimination of local noise and vibration (2)(3)

Sources:

(1) https://safety4sea.com/how-does-cold-ironing-affect-the-environment/

(2) https://glomeep.imo.org/technology/shore-power/

(3) http://www.wpci.nl/docs/presentations/Onshore%20Power%20Supply%20Project%20IAPH%20conference%2018%20November%202009%20Finalt.pdf

(4) https://www.e-ports.com/regulations/5c874e46d52c6e0a00c17867

(5) https://www.nepia.com/industry-news/china-emission-control-areas-update/

(6) China Classification Society (2018)
Technical notice No.57/Total No.383
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(7) https://safety4sea.com/wp-content/uploads/2018/12/Huatai-Circular-Ref-No.-PNI1816-2018_12.pdf

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(11) https://www.skuld.com/contentassets/82a30fd9a3e647b883c33cc5292693fd/china_eca_plan_guideline_2018-english.pdf
Document of P.R. China MSA
HWF [2018] No.555

(12) https://theicct.org/sites/default/files/publications/ICCT-WCtr_ShorePower_201512a.pdf

Comparison OPS California and OPS China

Regulation

In California implementation of regulation started in 2014 and will be implemented over a longer period of time, up until 2029. The last group is tankers from 2027 onwards. In China regulation was adopted from 2019 onwards and tankers do not need to meet regulations for OPS. Adoption of OPS in other ship types started later (in 2019) than in California but becomes fully applicable already in 2022.

Implementation phases in California per port. In China along the entire coastline at the same time.

Governance, incentive

Both California and China have funding available for the adjustment of infrastructure and vessels.

Monitoring and reporting obligations for ships

In California fleet operators are supposed to fill out a spread sheet and are responsible to comply with regulations. California offers scenarios for fleet operators who are not able to meet regulations. The CARB will review the proof and information provided by the fleet operators.

The MSA in China will check the vessel's certificates and documents. The MSA will carry out safety inspection works and on-site inspection.

Both in California and in China ship operators are supposed to write information about shore power in the vessel's logbook. The logbook must contain information about the starting and ending time for the use of shore power.

CO2 savings

The electricity in China is mainly generated from coal (about 65% in the first quarter of 2020). In California electricity is generated from multiple sources. The main sources are natural gas, nuclear, hydro and solar power, together about 84% in 2019.

Costs

Regulatory costs for China are unknown.

Capital costs for vessels are about the same in California and China based on one source.

Adjustments of berths is estimated to be cheaper in China due to lower costs for labour and raw materials.

Energy costs are different for each port, both in California and in China.

Hyseas III

The aim of this case study is to show what is necessary for the successful deployment of hydrogen as a marine fuel

Reason for carrying out the case study

This case study is an example of how to deal with the problem: low uptake of zero-emission fuels and power by ships calling EU ports.

The following objectives are applicable to this case study:

- *Specific objective 2: support technology development and deployment.* The EU has funded the project and has therefore supported the supported the development of new technologies. In HySeas III the selected technology will be tested at site.
- *Specific objective 4: create demand from ship operators to bunker sustainable alternative fuels or connect to the electric grid while at berth.* HySeas is an example of the efficient usage of energy. The local hydrogen is not all used and due to HySeas, this energy will not go to waste.

General description

HySeas III is the final development stage of a three part research program that started in 2013. The three parts of the program are:

- HySeas I: theory of hydrogen powered vessels (2013)
- HySeas II: detailed technical and commercial study to design a hydrogen fuel cell powered vessel (2014 – 2015)
- HySeas III: the aim is to demonstrate the fuel cells can be integrated with a proven marine hybrid electric drive system along with associated hydrogen storage and bunkering arrangements (July 2018 – present)

The HySeas III project is partly supported by the Horizon 2020 framework.

In the HySeas III project a full size drive train will be developed, constructed and tested on land. The hydrogen is produced from local renewable sources to aim for zero emission. Additionally, the aim is to define a business case to make the adoption of the hydrogen vessel commercially viable.

Reason why H_2 is used

The Orkney Islands already produce hydrogen from renewable energy from which not all the hydrogen is currently used. Using the hydrogen in the islands ferry fleet is a solution to reduce emissions and not let the hydrogen go to waste.

Ship types and sizes involved in the project

The consortium of the HySeas III project hopes to deliver the first sea-going hydrogen powered vehicle and passenger ferry (RoPax) with hydrogen produced from local resources.

Size of the prototype (4):

- 40 m x 10 m x 4 m (depth)
- Capacity: 120 passengers
- Rolling payload capacity: 20 passenger vehicles or 2 trucks

Hydrogen ecosystem

In case of the HySeas III the consortium consists of (1):

- Ship designer and builder: Ferguson Marine Engineering Limited (Port Glasgow, UK)
- Fuel cell power systems: Ballard Power Systems Europe A/S (Hobro, Denmark)
- Vessel Systems Integrator: Kongsberg Maritime AS (Kongsberg, Norway)

- Fuelling Infrastructure: McPhy Energy SA (France)
- Vessel and ports owner/operator: Orkney Island Council (Orkney Islands, UK)
- Lifecycle and socio-economic analysis: DLR Institute of Networked Energy Systems (Oldenburg, Germany)
- Dissemination and Communications: Interferry European Office (Brussels, Belgium)

The team is coordinated by the University of St. Andrews (St. Andrews, Scotland)

Monitoring and reporting obligations for ships

-

Costs

Up-front costs are a major barrier to adoption of hydrogen fuel cell ferries. One of the key objectives of the HySeas III project is to look at how the concept can be made commercially viable. (1)

Development

The supported development is expected to cost around 12,6 million euros of which 9,3 million euros is funded by the Horizon 2020 program. (2)(3)

Construction

Scottish Transport have agreed to fund the building of the RoPax ferry should the test be successful. (1)

Usage phase

Unknown

CO_2 emission savings (if any)

CO2 emission savings depend on the energy source used for the production of hydrogen. In case of energy from renewable of nuclear sources, the net emissions are zero (green hydrogen). In case hydrogen is produced with grid mix electricity, the carbon footprint is the same as the grid mix (5)

In case of the HySeas III, production of hydrogen is from local energy sources. Therefore, no transportation of fuels or other energy carriers is needed and thus no emissions come from the transportation of energy carriers.

Other environmental benefits

There are no emissions of SO_x and NO_x when H_2 is used.

H_2 bunkering solution and safety

Hydrogen can be stored physically-based or material-based. Physical storage methods are based on either compression or cooling or hybrid storage, which is a combination of compression and cooling. Material-based storage methods are new technologies that are being investigated. These include solids, liquids and surfaces. In the HySeas III prototype the compressed gas method will be used, see the table below. (6)

Specifications of the powertrain (4):

On-board fuel cell power	600 kW
Type of fuel cells	Proton-exchange membrane fuel cells (PEMFC)
On-board hydrogen storage	600 kg
Type of storage	Compressed gas, 350 bar

On-board batteries	768 kWh
Type of batteries	Li-ion, cell chemistry still to be defined

Hydrogen is used for decades but misperceptions come from lack of knowledge. Hydrogen is highly flammable but being the lightest element in the world, the hydrogen ascends rapidly into the atmosphere and has therefore little time to burn. Hydrogen requires rules of usage like other energy carriers. As for hydrogen in mobility, Toyota conducted series of tests on a hydrogen tank in a vehicle. The series consisted of burst test, bonfire tests, crush test and gunshot test. The tank passed all tests. Hydrogen tanks should be handles with care just like any other flammable fuels. (5)

Sources

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(3) https://www.rivieramm.com/news-content-hub/hyseas-iii-hydrogen-ferry-project-meets-major-milestone-54868
(4) https://elib.dlr.de/132926/1/ELMAR-REGWA%20Paper_v6.pdf
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(7) Edwin Pang , Communication & Dissemination Lead, personal communication

WES Amelie

The aim of this case study is to show what is necessary for the successful deployment of synthetic methane as a marine fuel

Reason for carrying out the case study

This case study is an example of how to deal with the problem: low uptake of zero-emission fuels and power by ships calling EU ports.

The following objectives are applicable to this case study:

- *Specific objective 2: support technology development and deployment.* The Wes Amelie forms an example for marine SNG use. Valuable knowledge and experience with SNG becomes available in this real world usage.
- *Specific objective 3: stimulate production of sustainable alternative fuels on a larger scale and reduce price gap with current fuels.* The WES Amelie will form a testbed for SNG use as a drop in fuel. The SNG is fabricated in the current largest SNG facility, owned by Audi. Increased demand in SNG, when the usage on WES Amelie becomes a success, may form a technological incentive in increasing SNG production facilities. Scale effects in higher demand may lower costs in the long run.
- *Specific objective 4: create demand from ship operators to bunker sustainable alternative fuels or connect to the electric grid while at berth.* By using SNG the vessel now meets both Tier II and Tier III emission requirements set by the IMO. SNG can form an alternative fuel to meet these requirements.

General description

Back in 2017, the 1036 TEU Wes Amelie became the first boxship to be retrofitted with an LNG engine. Currently, a project is unveiled where the Wes Amelie will be retrofitted to operate on liquefied synthetic natural gas (SNG). The project is initiated by German shipping company Wessels marine and engine manufacturer MAN Energy Solutions. Furthermore, Nauticor (LNG supplier) and Unifeeder (charter company) are also cooperating in the project. SNG would be produced from wind energy and be a drop-in fuel. 20 tons of liquefied SNG will be delivered to the vessel and mixed in the vessels single 500 m^3 pressurised LNG fuel tank (6). The fuel mix becomes 20% SNG and 80% LNG (6). Automobile manufacturer Audi's power-to-gas facility will provide the SNG (1).

MARPOL Annex VI is a guideline from the IMO that limites the main air pollutants contained in ships exhaust gas, including SO_x, NO_x and particulate matter and emission control areas (ECAs). Since 2020, the sulphur limit of bunker fuels is 0,5% globally, and since 2015 0,1% in ECA's (7). The North Sea and the Baltic Sea is an ECA, and it is here where the Wes Amelie operates frequently. The project is to showcase the use of SNG as an alternative to fossil fuels.

Reason why synthetic methane is used

SNG describes a variety of natural gas alternatives that are as close as possible in composition and properties to natural gas. SNG can be produced from coal, biomass or synthesised using surplus renewable energy (5). Using biomass or surplus renewable energy to make SNG is referred to as bio-SNG/biogas and e-gas/syngas.

- Thermochemical SNG production (75% efficiency) à bio-SNG
- Biochemical SNG production (80%) à bio-SNG / bio-gas
- Electrolyses by surplus renewable energy (78%) (Power-to-Gas / Power-to-X) à e-gas / syn-gas

Compared to LNG, bio-SNG can be used to even further reduce emissions. The fuel is climate-neutral when created from biomass or renewable sources, and also drop-in (1) in LNG engines.

The advantage of SNG is that it is synthetic and nearly pure methane. Furthermore, SNG has an high methane number which prevents knock and will provide smoother power delivery. Therefore dual-fuel engines will run better, emissions will be lower and wear and tear will be reduced, requiring less maintenance.

Ship types and sizes involved in the project

Wes Amelie is a 1.036 TEU feeder vessel that had originally a 8-cylinder four stroke (MAN 8L 48/60 B) engine. Two years ago, the vessel was converted to a larger 8-cylinder four stroke dual fuelled engine (MAN 51/60 DF). Most of the time the ship operates in the North European emission control area where vessel's need to be run with a fuel that has a sulphur limit of 0,1% (6). With the new engine, the vessel uses LNG. The liquefaction of methane creates liquid SNG which can and will be mixed with normal LNG (20/80) for the Wes Amelie (6).

e-Methane ecosystem

The Power-to-X plant owned by Audi has an output of 6 MW and is the largest in the world. It was built in 2013 in collaboration with MAN Energy Solutions (9).

After the conversion of the Wes Amelie, a governmental support program was set up to aid the conversion of more ships to LNG. If such a program would be set up for SNG, the viability as an marine fuel would be greatly increased, since the fuel is too expensive and not available in sufficient quantities for long-term use (9).

Monitoring and reporting obligations for ships

No information

Costs

The costs comprise the additional costs for synthetic methane.

CO_2 emission savings (if any)

20 of the 120 tons of LNG that the Wes Amelie typically uses per round trip will be replaced by climate-neutral SNG. CO2 emissions are expected to decline by 56 tons in this case (1).

Sustainability of the synthetic CH_4

Other environmental benefits

MAN Energy Solutions reports that the retrofit enabled the Wes Amelie to significantly reduce its SO_x emissions by >99 percent, NO_x by approximately 90 percent. As a result, the vessel now meets both Tier II and Tier III emission requirements set by the IMO (8). These benefits are not specific to synthetic methane by apply to all liquefied methane fuelled ships.

Sources:

(1) https://www.offshore-energy.biz/wes-amelie-to-become-1st-ship-partially-running-on-synthetic-natural-gas/
(2) https://www.wessels-marine.com/en/
(3) https://youtu.be/rcvIMFBPLIQ, North Sea and Baltic sea area emission rules are strict (emission control area ECA)
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Stena Germanica

The aim of this case study is to show what is necessary for the successful deployment of methanol as a marine fuel

Reason for carrying out the case study

This case study is an example of how to deal with the problem: low uptake of zero-emission fuels and power by ships calling EU ports.

The following objectives are applicable to this case study:

- *Specific objective 2: support technology development and deployment.* The Stena Germanica pilots two new innovations which provide knowledge and experience in their respective areas. 1) The Stena Germanica is the first methanol fuelled ship in the world. 2) The Stena Germanica is the first methanol converted ship, indicating a conversion on conventional diesel ships is possible and viable.
- *Specific objective 3: stimulate production of sustainable alternative fuels on a larger scale and reduce price gap with current fuels.* The successful use case of methanol in the Stena Germanica stimulates methanol as a potential alternative fuel. Furthermore, the conversion towards methanol took two months for the first case. Economies of scale will lower conversion prices of conventional ships. This can stimulate a shift towards more methanol conversion, and consequently more methanol demand.
- *Specific objective 4: create demand from ship operators to bunker sustainable alternative fuels or connect to the electric grid while at berth.* The IMO has imposed restrictions on sulphur oxide (SO_x) emissions. As a marine fuel, methanol is compliant with this guideline. Methanol is already available in many major ports in the world. Showing the utilization of methanol in the Stena Germanica, lowers technological barriers for methanol as an alternative fuel.

General description

The Stena Germanica is a methanol-fuelled (24 kW) ferry which operates between Gothenburg (Sweden) and Kiel (Germany). It was the first ship in the world to run on methanol. The ferry was converted to run on methanol in 2015 (1).

The project was known as Pilot Methanol and received support from the EU-TEN-T program. The conversion took less than 2 months, modifications were done to the bunkering line, tanks, pump room, pumps, piping, and the automation system. The existing fuel and part of the ballast tanks were converted to methanol tanks, enabling no loss of commercial space for the ferry (5).

Reason why synthetic methane is used

Since 2020, the IMO has imposed restrictions on sulphur oxide (SO_x) emissions. As a marine fuel, methanol is compliant with this guideline, since SO_x emissions are reduced by 99%. Also Tier III (NOx) of the guideline can be met without exhaust after-treatment (1).

Marine methanol fuel produces no sulphur emissions and very low levels of nitrogen oxide emissions. It is therefore compliant with emission regulations by the IMO in emission control areas (ECA) such as the North Sea (2).

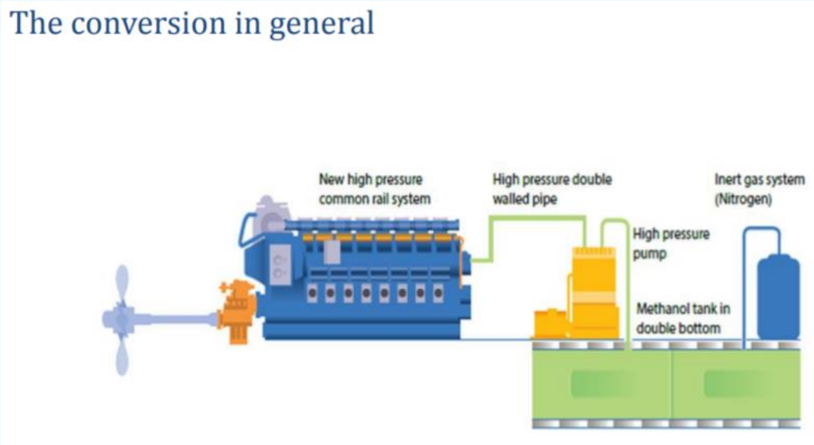
Methanol has a relatively low flashpoint level (11° C) and boiling point (65° C). This means that only incremental changes have to be made to the existing storage, distribution and bunkering of vessels on methanol (2).

With regard to maintenance, the efficiency and lifetime of components will probably be similar or better. (5).

Ship types and sizes involved in the project

The 240-metre ferry has a capacity for 1500 passengers and 300 cars. The vessel was retrofitted with a Wärtsilä 4-stroke engine that can run on methanol or traditional marine fuels (1).

Source (3):



Methanol ecosystem

Methanol is already available at most of the world's largest ports (1).

The methanol for the Stena Germanica is being supplied by Methanex Corporation. Through a wholly-owned subsidiary, Waterfront Shipping, the company operates the world's largest methanol ocean tanker fleet with eleven vessels (1).

Methanol has been shipped globally, handled and used in a variety of uses (2). This means that the knowhow and experience is present with handling procedures and guidelines in place.

The infrastructure of methanol is based on the worldwide distribution by the chemical industry. Although there is widespread availability, additional terminals are needed if methanol is used as a fuel on a wider scale (2). Replacing 5% of the fuel oil used in the Northern European SECA would require 2 million tons of methanol annually (2).

Methanol is a very suitable alternative to marine fuels, considering the number of feedstocks that it can be produced from. Namely gas, coal, biomas and CO2. Methanol is being produced and transported in many areas in the world, resulting in fuel that is widely availible with an already existing infrastructure. In the early stages of introduction of methanol as a marine fuel, the existing production and infrastructure can be used. In later stages, where demand rises, infrastructure will have to be expanded and other (renewable) production methods have to be developed (5).

Monitoring and reporting obligations for ships

Because of the low flashpoint of methanol, a number of regulations and guidelines are in place to mitigate the risk of fire. The IMO Resolution MSC.285(86) interim guidelines on safety for natural gas-fueled engine installations on ships (2).

Costs

Installation of small methanol bunkering unit have been estimated at around 400.000 euro. A bunker vessel can be converted for approximately 1.500.000 euro (2).

Conversion specific costs for the Stena Germanica amounted to 13 million euro. The total project costs were 22 million, which includes a methanol storage tank onshore and the adaptation of a bunker barge. Being the first of its kind, conversion costs of a second vessel would be around 30-40% of the costs (2).

Retrofit cost of a ship from diesel fuel to dual-fuel methanol/diesel has been estimated to be 250-350 Euro/kW (10-25KW). For a ship like the Stena Germanica (24 kW), the conversion costs would come in at 350 Euro/kW (2), since extra installation equipment is needed for a ship on the upper boundary of the class.

Source (2):

5.1.2. New-build of a 10 MW tank ship

For the construction of a ship using two converted 10 MW MAN engines, these are the estimated costs:

- Engine costs: € 825,000
- Work on engine: € 300,000
- Fuel supply system: € 600,000
- Fuel tanks: € 500,000
- Piping etc: € 500,000.

This corresponds to a total of € 270/kW. As with the previous example, this is the first time this kind of engine has been converted to methanol, although these conversions have been carried out on new engines (Sejer Laursen, 2015a).

Project costs Germanica conversion approximatly 450 Euro/kW. (3)

Operational costs (OPEX) account largely to fuel costs. As of 1 July 2020, prices of methanol stand at 235 Euro/MT for European price of methanol. As a comparison, MGO stands at around 300 Euro/MT. (4) The energy density of methanol is half of that of MGO, which has to be taken into account, and makes the required fuel amount twice as high (6). This relates to higher total fuel costs for methanol.

Methanol is cost competative with other emissions abatement measures such as scrubbers and catalysts, and LNG.

CO_2 emission savings (if any)

Methanol has lower tank-to-wake emissions than conventional marine fuels. CO2 emissions drop by 13%, sulpheroxides and nitrousoxides drop by 99% and 80% respectively, and PM with 95% (6).

Other environmental benefits

Methanol dissolves in water and is biodegradable. In case of a large spill, the environmental effects are less than that of fossil bunker fuels (2).

Source (2):

Results from laboratory tests with a Wärtsilä engine show the following results (Stojcevski, 2014):

- NOx 3.5 g/kWh (Low Tier II, no major conversion)
- CO (< 1 g/kWh)
- THC (< 1 g/kWh)
- PM only from MGO pilot (FSN ~ 0,1)
- SOx only from MGO pilot (99% reduction)
- Formaldehyde emissions (~ below TA-luft)
- No formic acid detected in exhaust gases
- No reduction in output and load response unchanged, full fuel redundancy
- Higher efficiency (tests show lower fuel consumption in methanol mode).

Sources:

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(2) http://www.methanol.org/wp-content/uploads/2018/03/FCBI-Methanol-Marine-Fuel-Report-Final-English.pdf
(3) Per Stefenson, (2016), Methanol: The marine fuel of the future, Updates from the Stena Germanica. http://www.methanol.org/wp-content/uploads/2016/07/Updates-from-Stena-Germanica-Per-Stefenson.pdf
(4) https://shipandbunker.com/prices#MGO
(5) Strategies for introducing methanol as an alternative fuel for shipping https://biblio.ugent.be/publication/8583233/file/8583238.pdf
(6) https://www.swzmaritime.nl/news/2020/03/10/waterfront-shipping-methanol-as-a-marine-fuel-works/

Maersk Mette

The aim of this case study is to show what is necessary for the successful deployment of biofuels as a marine fuel

Reason for carrying out the case study

This case study is an example of how to deal with the problem: low uptake of zero-emission fuels and power by ships calling EU ports.

The following objectives are applicable to this case study:

- *Specific objective 2: support technology development and deployment.* The Maersk Mette is an example for the use of biofuels in two ways. 1) Adjustments to the engine of the ship. 2) The successful usage of a biofuel on a large container ship
- *Specific objective 3: stimulate production of sustainable alternative fuels on a larger scale and reduce price gap with current fuels.* Stakeholders involved in the pilot want to show that the shipping industry is ready for innovations to reduce emissions. The use of biofuel at Maersk Mette could be an incentive for other stakeholders to start producing biofuels on a larger scale.
- *Specific objective 4: create demand from ship operators to bunker sustainable alternative fuels or connect to the electric grid while at berth.* The usage of biofuel at Mette Maersk now is a proven concept to reduce CO2 emissions. Ship operators could start using biofuel to get a green image or sustainability certificates.

General description

The Mette Maersk is one of the largest ocean container vessels in the world. The vessel is used in a clean shipping project with 3 key objectives (3):

1. A promising technology that works in practice on a container ship
2. Successful collaboration between stakeholders
3. To send a message to innovators that the shipping industry is eager to try new solutions to decarbonise ocean freight

Collaboration between industry players, carrier, fuel provider and other stakeholders is key in the project. In the project, a fuel mix of regular fuel and biofuel is used.

The Mette Maersk has set sail to Shanghai from Rotterdam on March 25 2019. The ship returned in June 2019. (5) The project was initiated by the Dutch Sustainable Growth Coalition. Multinationals Shell, DSM, Friesland Campina, Heineken, Philips en Unilever wanted to execute a test with biofuel in ocean freight container shipping. The Danish company Maersk was the right partner for the project. (4)

Before the test at the Mette Maersk, Shell conducted fifteen laboratory tests to determine the performance of the bio fuel in combination with the motor of the Mette Maersk. Additionally, tests were executed to investigate the stability of the fuel mix under extreme circumstances and to see if the fuel can still be combusted in the engine after the test from Rotterdam to Shanghai. After the tests in the laboratory, the engine settings of the Mette Maersk were slightly adjusted. (4)

Reason why biofuels are used

Biofuel isn’t the ultimate solution and is used to encourage others to come up with innovative solutions to decarbonize ocean shipping. Bio-fuels are seen as a bridge fuel until fully sustainable solutions are available. (3)(6)

The biofuel used at the Mette Maersk is a second generation biofuel. The biofuel is produced from used cooking oil. This is a high quality biofuel but other biofuels could be considered to optimize the supply chain and to reduce costs. (6)

Ship types and sizes involved in the project

Container ship sailing under the flag of Denmark (2)

Built in 2015

Carrying capacity of 18.000 TEU

Summer DWT: 214733 t

Size: 399,2 m (length) x 59 m (width)

Governance, incentive or enforcement

Incentive is to decarbonize ocean shipping and to encourage others to come up with innovative solutions (3)

Initial tests showed that the fuel blend could already be used today with just a few minor modifications to the ship's engine settings. The crew and the technical fuel crew underlined the excellent performance of the fuel. (6)

Monitoring and reporting obligations for ships

No different for ships with biofuel than for ships with regular fuels

Costs

Beforehand, Maersk set aside substantial financial reserve to cover possible repair costs but this reserve wasn't needed.

The pilot shows that shippers are willing to temporarily pay a higher price per TEU to support green innovations in shipping.

The emission reductions were allocated to 2.000 containers to gain insight into the extra costs. This included the higher price of the bio-fuel and certification of the use of second generation bio-fuel. All companies involved have a CO2 accounting system.

The price of bio-fuel is higher than regular fuels. Shell identified possible supply chain improvements to reduce the price of bio-fuel. This includes upstream processes (for example larger volumes) and using lower quality (biomass) waste as input. (6)

Regulatory costs

None mentioned in literature

Costs for ports

None mentioned in literature

Costs for ships

The temporary solution of blending biofuels with regular fuels does not require a new engine. Therefore, the only additional costs for ships is the higher price of fuels.

Some of the recent developments in (bio)fuels, ammonia, (bio)LNG and (bio)methanol require new techniques and new ships. In literature the additional costs of further development of biofuels is not mentioned (6)

Costs for training the crew (if any)

A technical fuel crew was at the Mette Maersk the entire roundtrip Rotterdam – Shanghai. Extra costs for these crew members was not explicitly mentioned in literature.

CO_2 emission savings (if any)

Fuel bled with 7 – 20% biofuel was used. On the roundtrip CO2 emissions were reduced by 1.500 tons. (6)

In (4) the following numbers are presented. From Rotterdam to Shanghai CO2 emissions will be reduced with:

- 1.500 tons with fuel blend with 7% biofuel
- 4.200 tons with fuel blend with 20% biofuel

A reduction of 80 – 85%. The biofuel used is a second- generation biofuel and was made from used cooking oil. (3)(6)

Other environmental benefits

On the roundtrip Rotterdam – Shanghai the use of the biofuel led to a reduction of 20 ton sulphur emissions. (6)

Sources:

(1) https://www.dsgc.nl/news/fotos-nieuws(1-items/DSGC%20clean%20shipping%20pilot%20results%20rapport.pdf
(2) https://www.marinetraffic.com/en/ais/details/ships/shipid:3369100/mmsi:219631000/imo:9632155/vessel:METTE_MAERSK
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(4) https://www.shell.nl/media/nieuwsberichten/2019/container-ship-mette-maersk-sails.html
(5) https://www.youtube.com/watch?time_continue=57&v=_MSUPbIPaE0&feature=emb_logo
(6) https://www.dsgc.nl/news/2020/dsgc-info-document-clean-shipping-pilot.pdf

Annex IX – Stakeholder consultation report

1 INTRODUCTION

1.1 General introduction

This *stakeholder consultation report* summarises the outcomes of the stakeholder consultation activities for the Impact Assessment of the FuelEU Maritime Initiative.

The project team has undertaken four types of activities to gather vies from stakeholders and collect information for the assessment of impacts. These are:

- open public consultation (OPC) running from 2 July 2020 until 11 September 2020;
- the targeted consultation (TC) survey running from 1 Augustus 2020 until 18 September 2020;
- the stakeholder interview conducted from July through September 2020; and
- a roundtable discussion on 18 September 2020.

While the open public consultation was open to every interested stakeholder, invitations to participate in the targeted consultation were sent out to members of the European Sustainable Shipping Forum, especially the subgroups for Sustainable Alternative Power for Shipping and Ship Energy Efficiency, as well as to members of the European Ports Forum and the ART Fuels forum. Invitees were encouraged to share the invitations with others. The invitation was widely distributed in order to ensure a good participation amongst stakeholder groups. As can be seen in Figure 48, there was a good representation amongst most stakeholder groups with the exception of logistics companies, financial institutions and inland waterway transport companies.

The interviews were conducted with equipment manufacturers, fuel suppliers, shipping companies (both liner and tramp shipping companies), ports, EU Member States, shippers and a trade union. Within each stakeholder group, interviewees have been selected with different characteristics in e.g. company size, type of activities, et cetera.

The responses from the different stakeholder consultations have been analysed with the following three questions in mind:

1. What are the views of the stakeholders on the main problems, their drivers and the policy objectives?
2. Do these views vary between different stakeholder groups and if so, how?
3. What type of policy instrument is preferred by the different stakeholder groups?

In Chapter 2, these questions are answered using specific information from the open public consultation, the targeted consultation, ESSF Roundtable discussion and the stakeholder interviews. The tables and figures including all survey results of the open public consultation are included in Chapter 3. The results of the targeted consultation survey are included in Chapter 4. A list of interview partners is included in Chapter **Error! Reference source not found.**. A list of received position papers is included in Chapter 6.

1.2 Problem definition

The stakeholder consultation shared a preliminary version of the problem tree, as shown on the next page. As can be seen in this picture, two distinct problems are identified:

1. Low uptake of zero-emission fuels and power by ships calling EU ports;
2. Low uptake of zero-pollution fuels and power by ships at berth.

Five drivers were identified, which are shown on this figure on the left, with five distinct policy objectives which address these drivers.

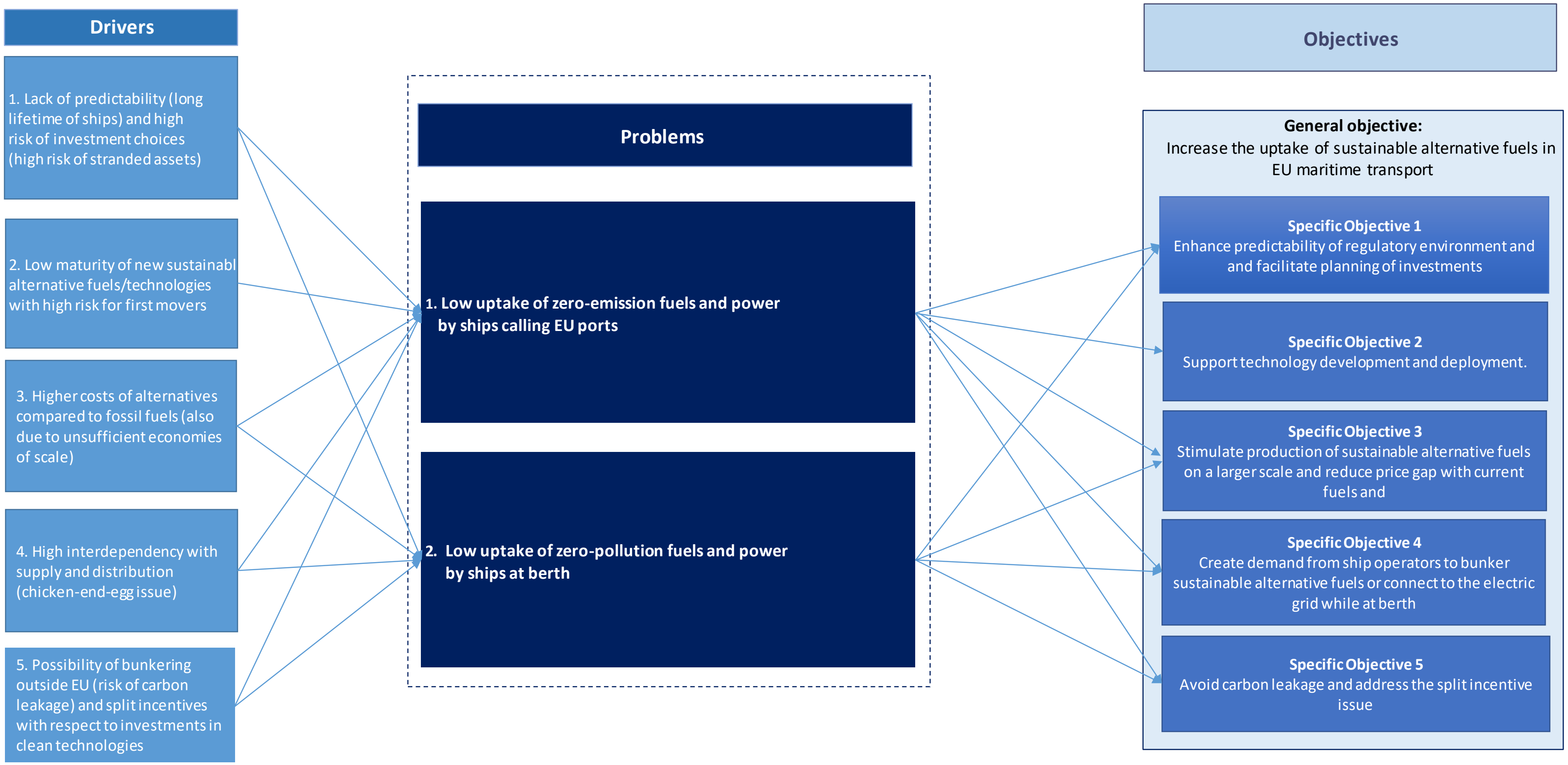

Figure 1 Logical chain between problems, objectives and policy measures.

Source: CE Delft / Ecorys.

2 ANALYSIS OF SURVEY RESULTS

The problem tree from Figure 1 provides a description of the problems for which the FuelEU Maritime initiative seeks to find a solution. However, it could be the case that parts of the problem are perceived differently by the stakeholders. Therefore, in this section it is analysed whether the survey responses are in line with the problem tree. More precisely, the following three questions are answered in this subsection:

1. Are the problems as described in the problem tree recognized by stakeholders and if so, to which extent?
2. Are the problem drivers as described in the problem tree recognized by stakeholders and if so, to which extent?
3. Which options for policy measures are supported by stakeholders?

2.1 Problems

This Section discusses whether the stakeholders agree with the problem definition from Figure 1. This analysis is first presented based on the quantitative results of the OPC and TC surveys. Afterwards, the more qualitative results of the stakeholder interviews and position papers are discussed.

Survey results

First of all, the question should be answered whether the respondents agree that significant greenhouse gas emissions from the maritime sector are a problem. This is related to the OPC question 'In your view, how relevant is the uptake of sustainable alternative fuels and diversifying the fuel mix of maritime transport in order to accelerate the decarbonisation of shipping?'. As can be seen in Figure 2, a large majority of open public consultation respondents thinks that this is very relevant. It can therefore be concluded that emissions of greenhouse gasses from the maritime sector are seen as a problem by the stakeholders.

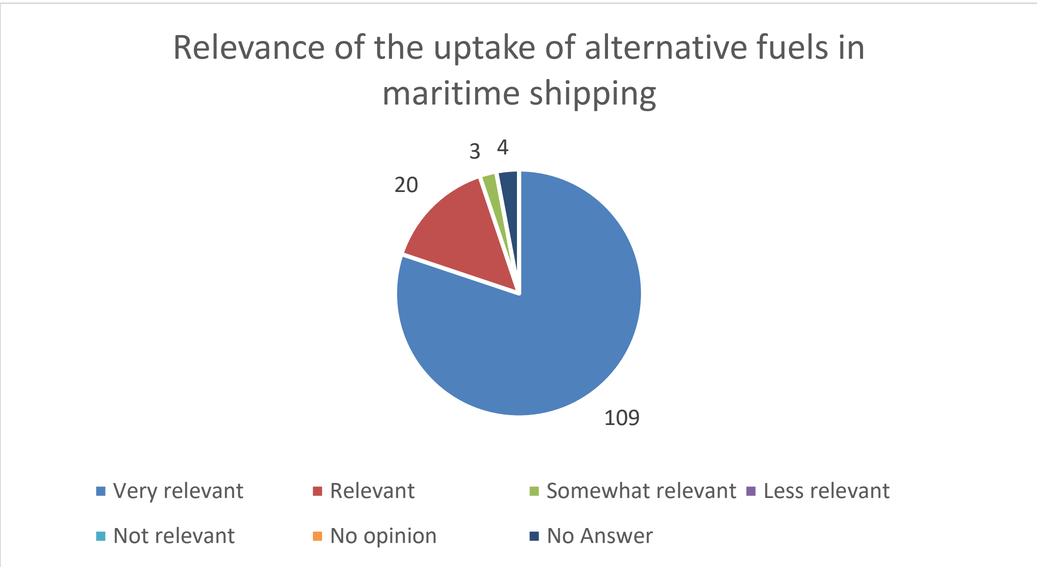

Figure 2 Relevance of the uptake of alternative fuels in maritime shipping (OPC).

The second part of the first problem states that greenhouse gas emissions from the maritime shipping are rising. In OPC questionnaire, it was not explicitly asked whether the respondents think that the greenhouse gas emissions from the maritime sector are rising.

However, in the literature it is expected that there will be an increase in maritime shipping in the coming decades (e.g. IMO 2020). The OPC survey responses shown in Figure 3 and Figure 4 show that a significant uptake of low carbon fuels in the near future is not expected by the respondents who answered to the OPC and the TC. The TC asked in more detail about the timeline for the uptake of sustainable alternative fuels. The answers, presented in Figure 4 Relevance of demand side policy (TC).

, indicate that many stakeholders expect the use of sustainable alternative fuels to increase after 2030.

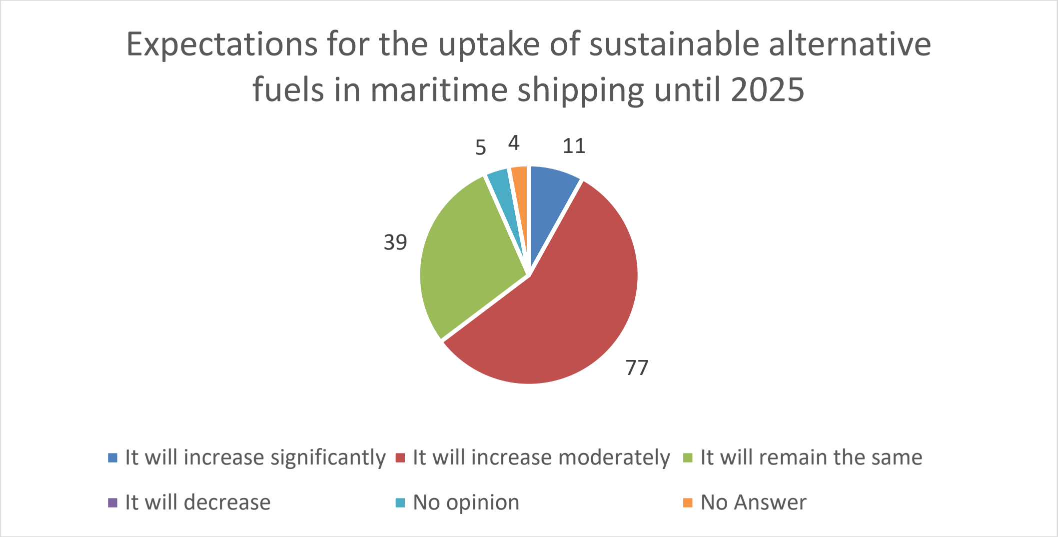

Figure 3 Expectations for the uptake of sustainable fuels in maritime shipping until 2025 (OPC).

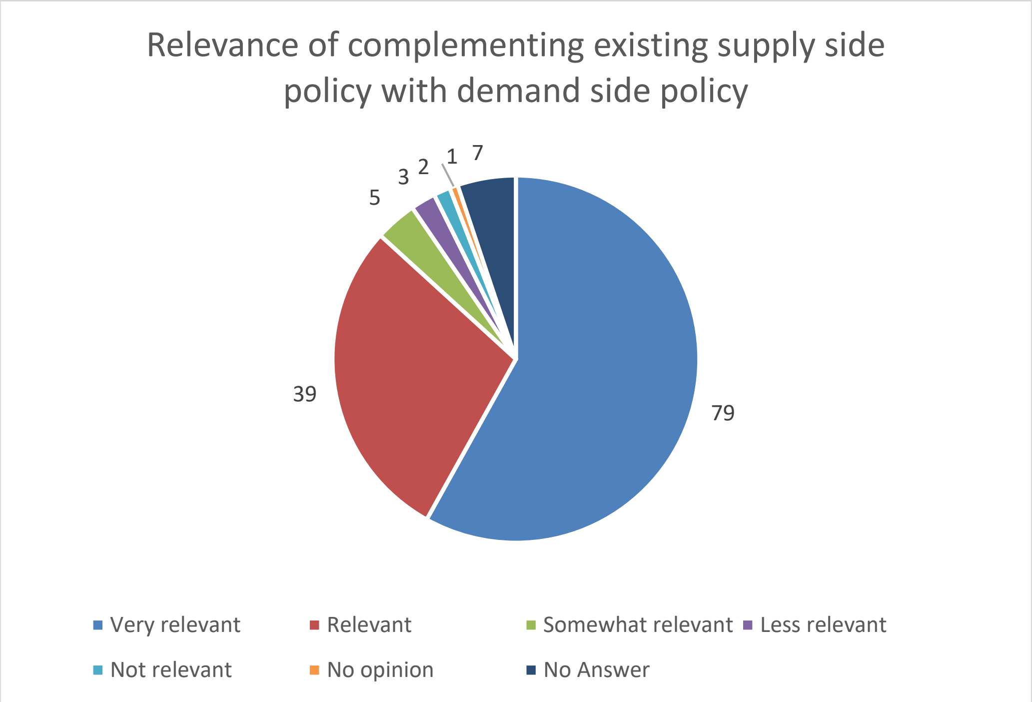

Figure 4 Relevance of demand side policy (TC).

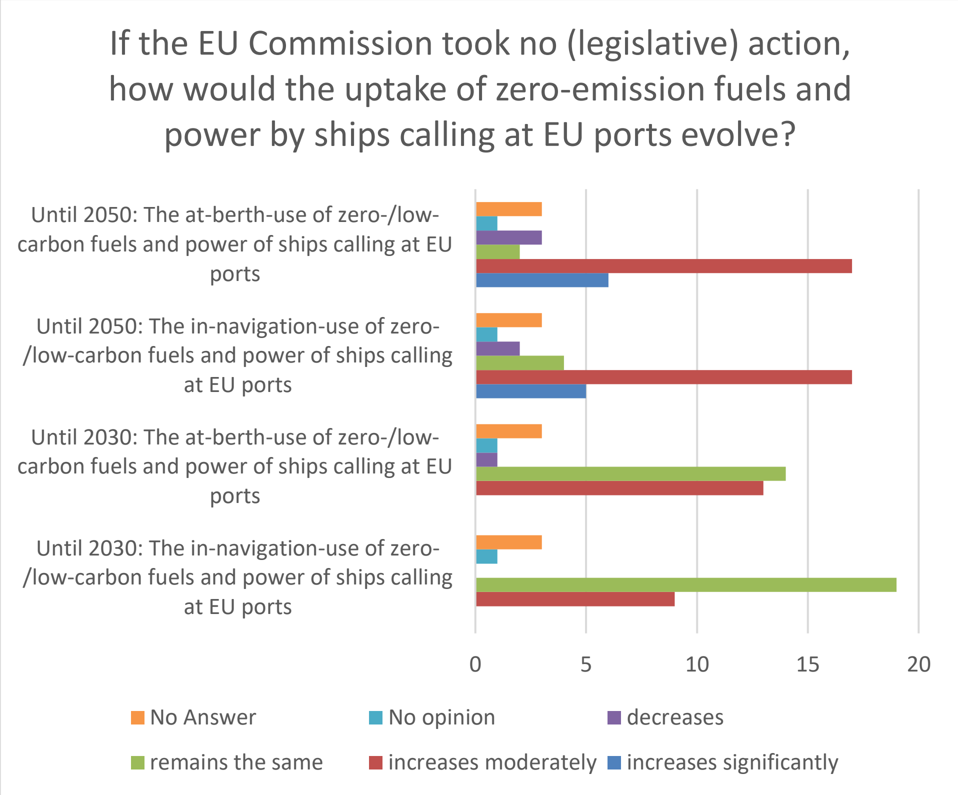

Figure 5 Projections for the uptake of low-carbon fuels (TC).

The second problem as defined in the problem tree concerns emissions of greenhouse gases and air pollutants from ships at berth. In the previous discussion, it was already established that greenhouse gas emissions from the maritime sector are indeed seen as a problem by the respondents. Based on the survey results shown in Figure 6, it can be concluded that, even though the emissions at berth are relatively small, these emissions are seen as relevant by the respondents. This conclusion is supported by the results of the targeted consultation, as shown in Figure 7. Also, based on Figure 8, it can be concluded that there is a wide recognition that besides greenhouse gases as well air pollutant emissions should be taken into account.

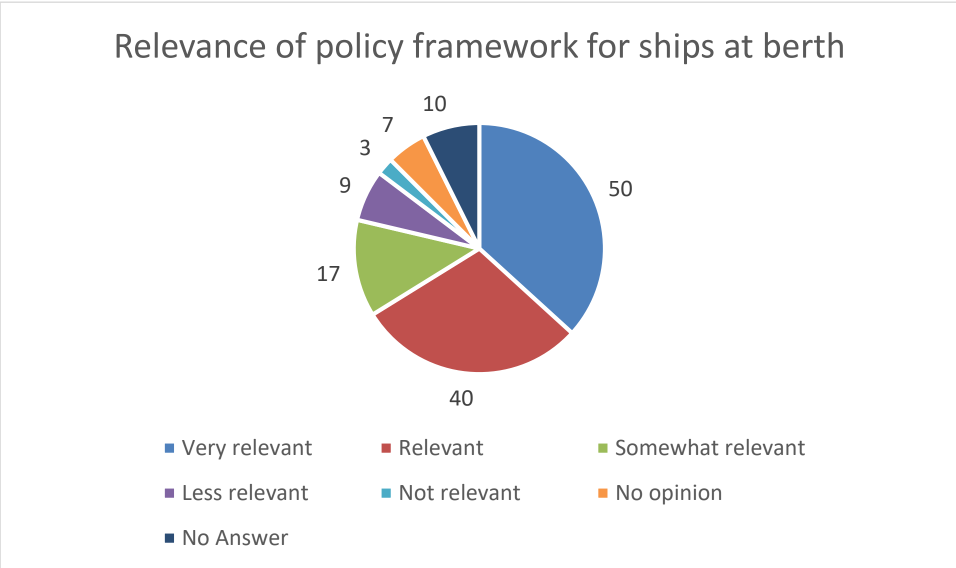

Figure 6 Relevance of a policy framework for ships at berth (OPC).

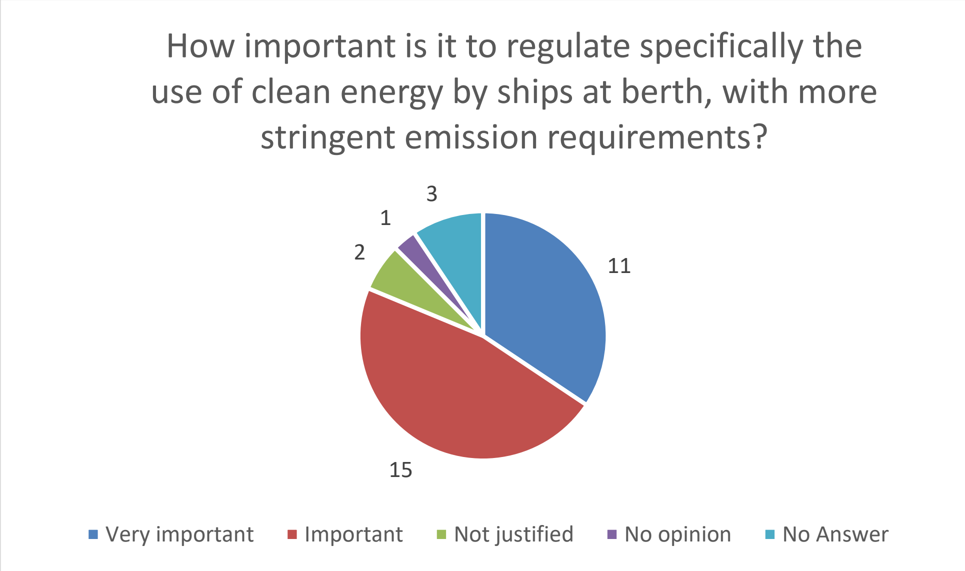

Figure 7 Importance of policy for ships at berth (TC).

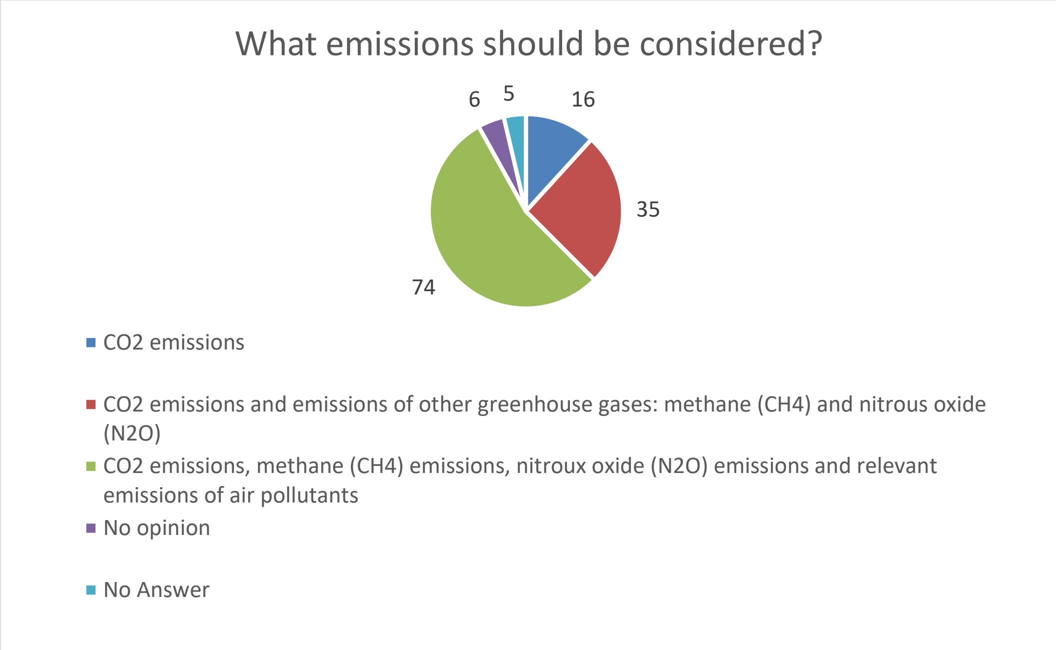

Figure 8 What emissions should be measured? (OPC).

It can be concluded that the problem, as defined in Figure 1, is recognized widely among the stakeholders.

Interviews, position papers and ESSF Roundtable

Based on the interviews, position papers and ESSF Roundtable discussion, it can be concluded that all stakeholder groups recognize the problems as defined in the problem tree and welcome the aim of the FuelEU Maritime initiative. Also, based on the stakeholders who did comment on this, there seems to be a consensus that both air pollutant emissions at berth and greenhouse gas emissions during navigation and at berth are problems that need to be addressed.

2.2 Problem drivers

In this Section, the stakeholder consultation results are analysed with respect to the problem drivers. First, the quantitative results from the OPC and TC surveys are discussed. Afterwards, the more qualitative results of the stakeholder interviews and position papers are discussed.

Survey results

In the targeted consultation survey, the respondents were asked to rank the problem drivers by relevance. The responses, which are shown in Figure 9, show that all five problem drivers are regarded as relevant. However, there still are large differences between scores. The higher costs of alternative fuels compared to fossil fuels was perceived as the most relevant barrier, with the lack of predictability and high risk of investment choices on the second place. The least relevant of these five barriers was the risk of bunkering outside of the EU.

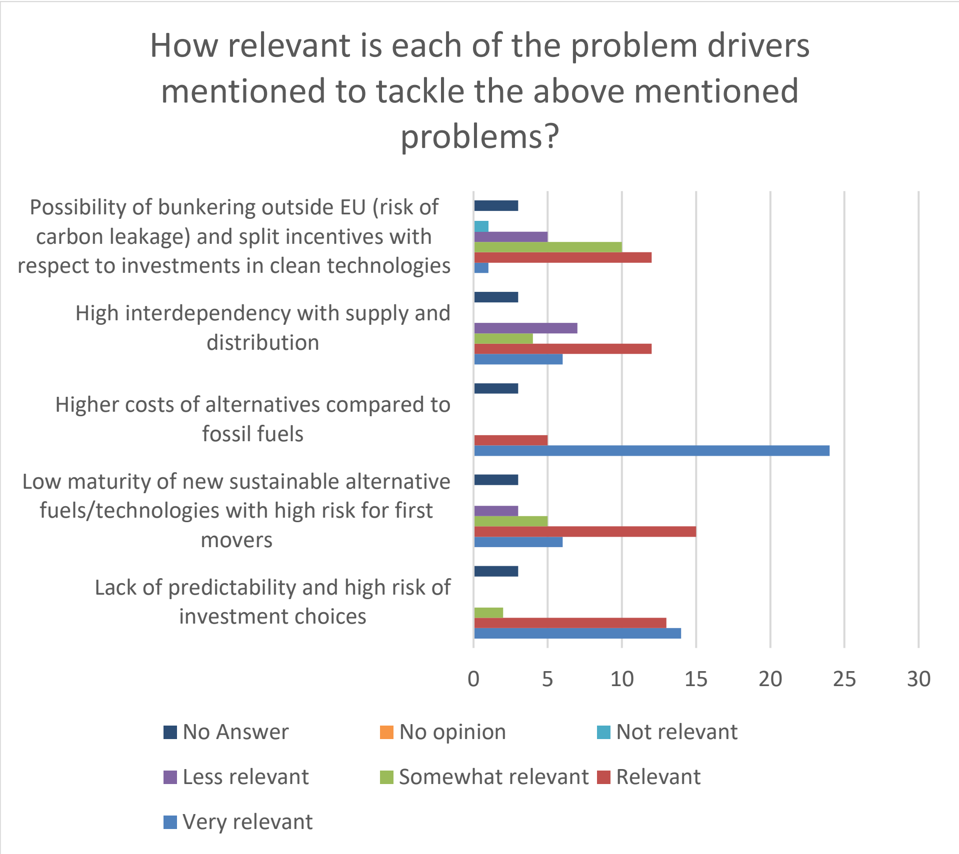

Figure 9 Relevance of problem drivers (TC).

The problem drivers as stated in Figure 1 do not exactly correspond to the problem drivers as defined in the open public consultation survey. Therefore, before answering this question it needs to be determined how to compare the two. Below, an overview is made of how the problem drivers from Figure 1 (the numbered items) are related to the problem drivers of the survey (the listed items with lower case letters):

1. Lack of predictability and high risk of investment choices:
    a. Lack of predictability of the regulatory framework;
    b. High risk of investment in vessels technology and port infrastructure;
2. Low maturity of new sustainable alternative fuels/technologies with high risk of first movers:

    a. Lack of mature technologies (e.g. on ships and on shore);

3. Higher costs of alternative fuels compared to fossil fuels:
    a. Higher price of sustainable alternative fuels;
4. High interdependency with supply and distribution:
    a. Insufficient supply (fuel production and infrastructure) of sustainable alternative fuels or on-shore power supply;
    b. Insufficient demand for sustainable alternative fuels or on-shore power supply;
5. Possibility of bunkering outside of the EU:
    a. Bunkering (i.e. fuel supply) of ships outside the EU;
    b. Presence of split incentives in the sector (i.e. situations where the benefits of an investment do not entirely accrue to the investor. Example: a ship owner that is not also the ship manager may have less incentive to invest in green technologies);
    c. Lack of communication between actors and lack of transparency on the environmental performance, including of the fuel performance[178].

When looking at the results in Figure 10, it can be seen that none of the mentioned barriers are regarded irrelevant (the lowest average score of the options is 2,9/5). However, there are noteworthy differences between how relevant the barriers are regarded. The barriers which score highest in relevance are 'higher price of sustainable alternative fuels' and 'high risk of investment in vessels technology and port infrastructure'. The lowest scoring measure is 'Lack of communication between actors and lack of transparency on the environmental performance, including of the fuel performance'.

[178] This can be seen as a cause for the split incentives in the sector.

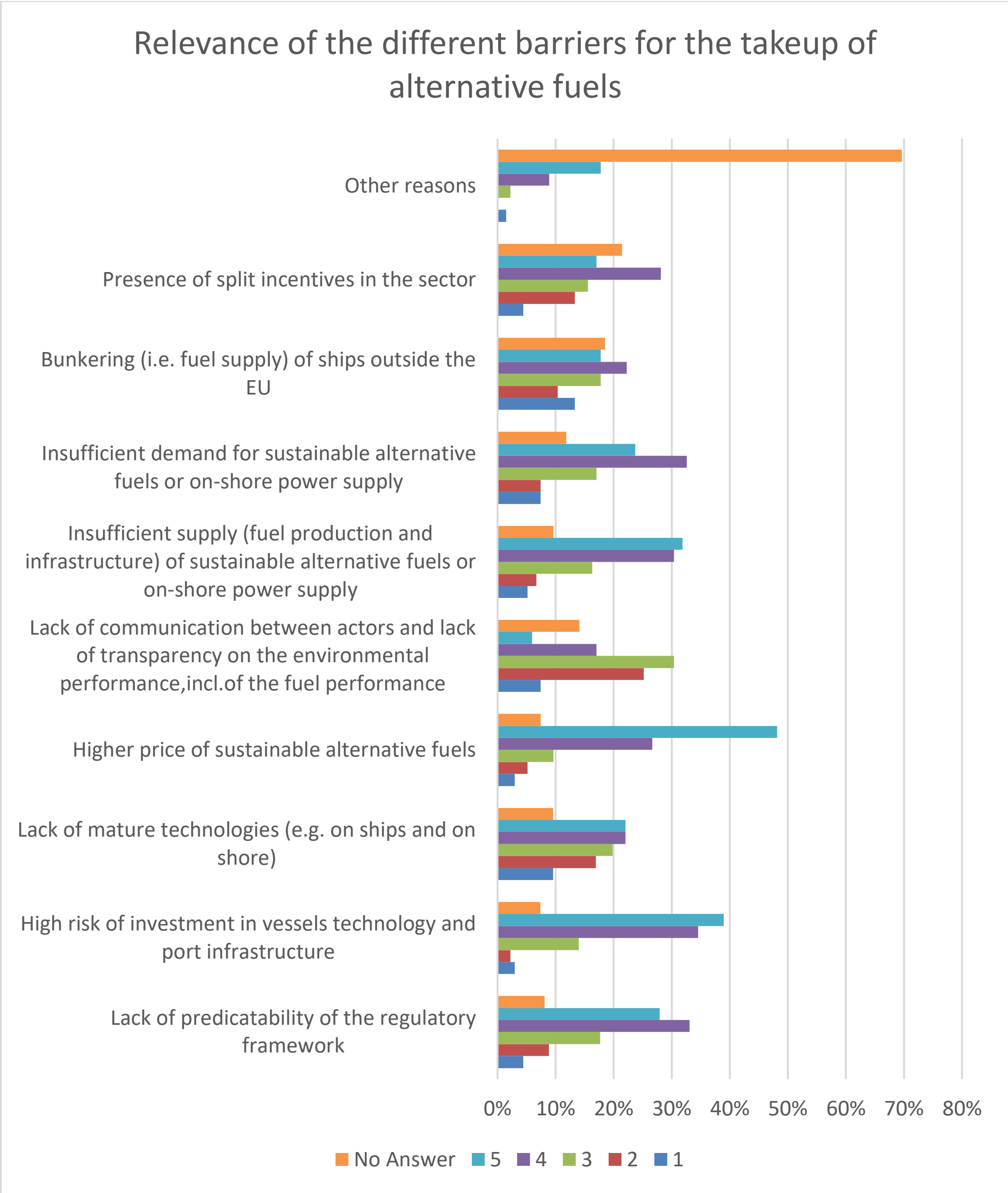

Figure 10 Barriers to the uptake of sustainable alternative fuels in maritime transport (OPC).

Apart from the options in the survey, there was also the possibility to add alternatives not in this list. Thirty percent of the respondents chose to submit another option. The options which were mentioned most often, and are considered different than the barriers already included, are shown in Table 1.

Table 1 other suggestions for barriers to the uptake of low carbon fuels in maritime shipping (OPC).

Suggestion	Number of times mentioned
lack of regulation	8
lack of standards	5
lack of economic incentives	3
level playing field issues	2

Suggestion	Number of times mentioned
insufficient knowledge of stakeholders	1
lack of financing	1
insufficient incentives from consumers	1
competition for biofuels	1
fear of access of periphery	1

In the stakeholder interviews, the interviewees were asked about the problem drivers. All drivers included in the problem tree were mentioned in at least one interview, which indicates that these drivers are indeed of importance. The driver which was mentioned most often, and which was most important according to the interviewees, was the higher cost of low-carbon fuels. Some other potential drivers were mentioned as well. First of all, the limited availability was mentioned as a barrier to the uptake of specifically biofuels. Other barriers that were mentioned are a lack of standards and regulations, specifically for low flashpoint fuels, and a low acceptance or trust that the use of alternative fuels is safe.

Do the different stakeholder groups agree on the problem drivers?

In the previous discussion, the results of all respondents together were analysed. However, different stakeholder groups might disagree about the relative importance of the different problem drivers. In this Paragraph, these potential differences are analysed, based on the open public consultation and stakeholder interview results. In this analysis, only stakeholder groups with 10 or more responses are included. This gives the following list of stakeholders that is included in the following analysis:

1. National public authorities (transport ministries, agencies);
2. Ship owning and ship management;
3. Short sea shipping;
4. Ports management and administrations;
5. Port terminal operator or other port services provider;
6. Inland waterways sector;
7. Shipbuilding and marine equipment manufacturers;
8. Academia, research and innovation;
9. Energy producers and fuel supply (including alternative / sustainable fuel sources);
10. Interest organisations representing societal interests, particularly on environmental and social topics.

Looking at Table 2, it seems that there is a reasonable agreement between stakeholders about what the most important problem drivers are. ‘Lack of predictability of the regulatory framework’ and ‘higher fuel prices’ are recognized as important issues by all stakeholders. On the other end of the spectrum, none of the stakeholder groups gave ‘lack of communication transparency’ or ‘the risk of bunkering outside of the EU’ a high score compared to the other options. However, even though there is some agreement, there also are point on which stakeholder groups disagree. First of all, the ‘lack of mature technology’ is regarded a very important issue by ‘national public authorities’, ‘ship owners and management’ and ‘short sea shipping’, whereas it is considered relatively unimportant by the ‘inland waterways sector’, ‘shipbuilding and marine equipment manufacturers’, ‘energy producers and fuel suppliers’ and ‘interest organisations’. Another barrier which the stakeholder groups rate differently is the ‘insufficient demand of sustainable alternative fuels or OPS’: for this category, ‘inland shipping’ and port ‘management and administration’ give the single highest score, whereas for example ‘short sea shipping’, ‘interest organizations’ and ‘academia, research and innovation’ give relatively low scores.

Table 2 Comparison of the scores on relevance of barriers per stakeholder group (OPC).

	number of contributions	Lack of predicatability of the regulatory framework	High risk of investment	Lack of mature technologies	Higher fuel prices	Lack of communication transparency	Insufficient supply of sustainable alternative fuels or OPS	Insufficient demand for sustainable alternative fuels or OPS	Bunkering of ships outside the EU	Split incentives
National public authorities	15	4,1	4,2	4,0	4,4	3,2	4,4	4,3	3,6	3,8
Ship owning and ship management	40	3,4	4,2	4,1	4,3	3,1	4,3	3,2	2,8	3,5
Short sea shipping	25	3,3	4,2	3,8	3,9	3,0	3,7	3,0	2,9	3,4
Ports management and administrations	13	3,5	4,2	3,5	3,8	3,3	3,5	4,3	3,3	3,8
Port terminal operator or other port services provider	13	3,4	4,0	3,5	4,0	3,2	3,5	3,5	3,2	3,4
Inland waterways sector	11	3,0	3,8	3,0	3,6	3,3	3,9	4,1	3,0	3,5
Shipbuilding and marine equipment manufacturers	10	4,0	4,1	2,7	4,0	2,5	3,6	3,2	3,6	3,3
Academia, research and innovation	12	3,7	4,1	3,7	4,2	3,1	3,8	3,5	2,8	3,5
Energy producers and fuel supply	37	4,0	4,2	2,8	4,3	2,6	3,6	3,9	3,4	3,5
Interest organisations	14	3,9	3,5	2,9	4,2	3,1	3,1	3,4	3,3	3,9

When comparing which barriers should be addressed with priority by the EU according to different stakeholder groups, as shown in Table 3, some different barriers come to the foreground. Both ‘higher fuel prices’ and ‘high risk of investment still score high’, but ‘lack of predictability for the regulatory framework’ now also is rated highly by most stakeholders. An interesting difference between groups is that lack of mature technologies is regarded an important barrier by many stakeholders, especially by ‘academia, research and innovation’, whereas ‘shipbuilding and marine equipment manufacturers’ and ‘energy producers and fuel suppliers’ rate this barrier lowly. Another interesting observation is that stakeholder groups which seem to give ‘insufficient demand’ a high rating tend to give ‘insufficient supply’ a lower rating, and vice versa.

Table 3 Comparison on priority for addressing of barriers on EU level per stakeholder group (OPC)[179].

	number of contributions	Lack of predicatability of the regulatory framework	High risk of investment	Lack of mature technologies	Higher fuel prices	Lack of communication transparency	Insufficient supply of sustainable alternative fuels or	Insufficient demand for sustainable alternative fuels or	Bunkering of ships outside the EU	Split incentives
National public authorities	15	9,0	8,0	6,6	6,9	5,1	6,9	7,6	3,8	3,7
Ship owning and ship management	40	7,1	7,9	8,0	7,7	5,3	6,8	4,7	4,1	4,9
Short sea shipping	25	6,6	7,7	7,9	7,5	5,8	6,7	5,3	3,8	5,4
Ports management and administrations	13	6,9	7,9	7,3	7,4	5,3	6,6	7,2	5,9	5,8
Port terminal operator or other port services provider	13	6,8	7,6	7,1	7,4	4,5	6,5	5,6	5,3	5,0
Inland waterways sector	11	7,7	6,2	6,8	7,2	3,9	6,0	6,4	4,2	5,9
Shipbuilding and marine equipment manufacturers	10	8,3	7,0	5,3	7,2	4,2	7,8	6,3	4,1	5,4
Academia, research and innovation	12	6,7	6,9	8,9	7,4	4,7	7,5	6,3	4,6	3,9
Energy producers and fuel supply	37	7,7	7,2	5,3	7,4	3,4	6,2	7,2	4,5	4,2
Interest organisations	14	7,7	6,0	7,3	7,3	5,2	6,0	7,3	5,4	5,6

It can be concluded that, even though there are some differences, there is a reasonable overall agreement between stakeholders both with respect to the relevance of barriers and with respect to what barriers the EU should prioritize through legislation.

Interviews, position papers and ESSF Roundtable

The barriers which were mentioned most often are related to the costs of adopting alternative fuels; both the higher fuel prices compared to the conventional bunker fuels and the high investment costs were often mentioned.

Another issue which was pointed out in multiple position papers and interviews was the lack of predictability and high risk for investors. Because it is still unclear what technologies will become dominant globally, the risk of stranded assets currently is too high for many investors, which slows down the developments towards cleaner ships. In three position papers, regulatory unpredictability was stated specifically as an important barrier that needs to be addressed. Other barriers which were mentioned multiple times were the low maturity and limited availability of sustainable alternative fuels. Also, the lack of bunkering infrastructure was addressed by multiple stakeholders.

Other barriers that were mentioned are the global nature of the industry, long lifetime of vessels, safety issues, lack of standards, lack of guidelines for low flash-point fuels and the risk of ships bunkering outside the EU.

These findings are in line with the quantitative survey results as presented above. Both consultation results suggest that the different stakeholders agree that high fuel- and investment costs together with uncertainty for the investors are the most important barriers.

[179] Unlike the other questions, this one has a 1 to 10 scale for the answers.

2.3 Potential policy measures

In this Section, the stakeholder consultation results are analysed with respect to the potential policy measures. First, the quantitative results from the OPC and TC surveys are discussed. Afterwards, the more qualitative results of the stakeholder interviews and position papers are discussed.

Survey results

It can be seen from Figure 11 that, according to the open public consultation respondents, all of the proposed policy measures are regarded to be of importance at least to some extent. The ones which have the highest relevance score are ‘accelerate research and innovation enabling the use of sustainable alternative fuels and power (demonstration and deployment)’, ‘set a clear regulatory pathway for decarbonising the current marine fuel mix’. ‘increase public funding and incentivise private investment to overcome the high investment risk in vessels powered by sustainable alternative fuels or propulsion systems’ and ‘increase public funding and financial support to overcome the high investment risk in sustainable alternative fuel supply or on-shore power supply infrastructure’. In Table 4, the alternative suggestions that were mentioned are shown.

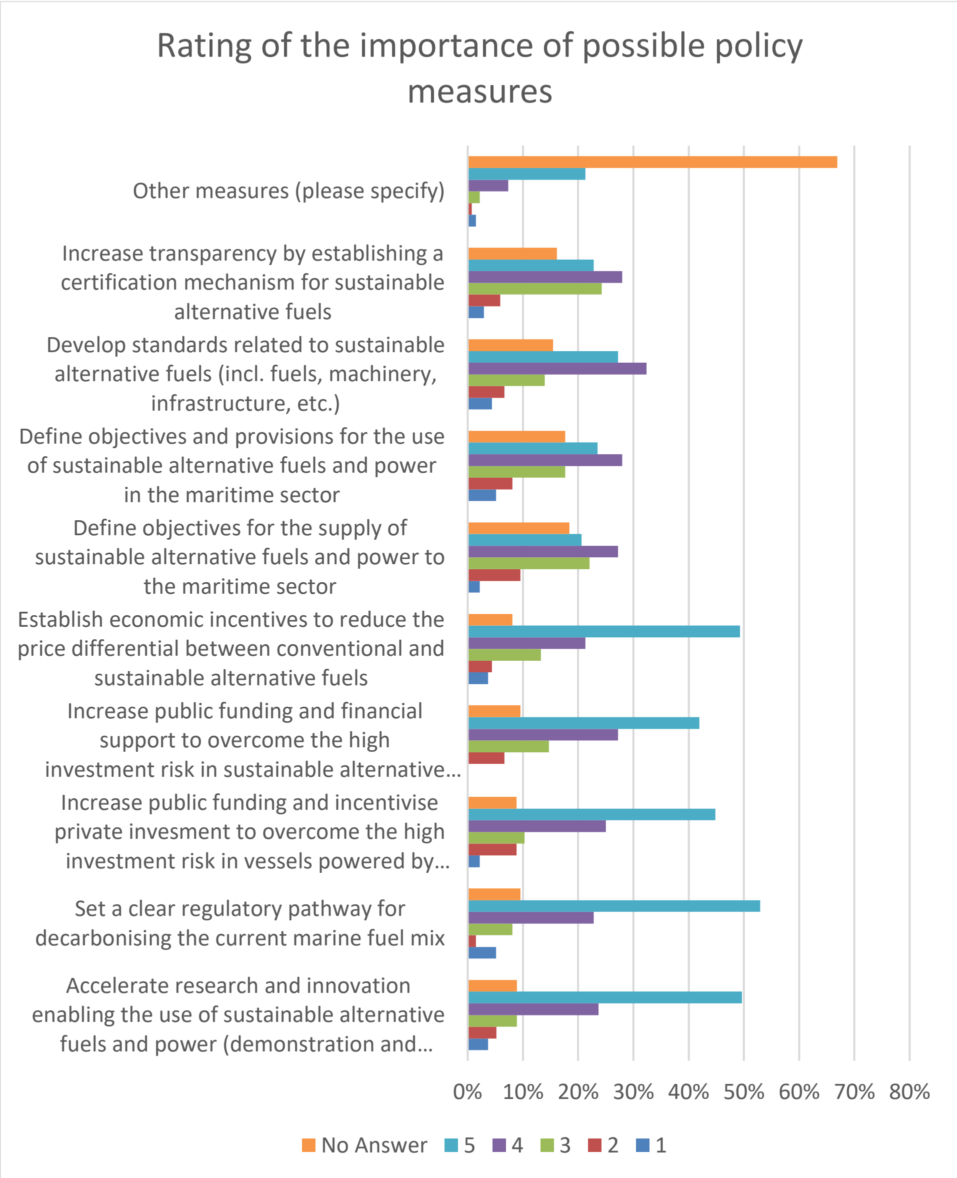

Figure 11 Rating of possible policy options by importance (OPC).

Table 4 other suggestions for policy measures.

Suggestion	Number of times mentioned
make policy through IMO	6
goal based/technology neutral policy	3
maximum % fossil use	2
promote uptake in short sea	1
promote LNG as bridging fuel	1
create production capacity	1
contract for difference (supply side)	1
coordinated policy with all transport sectors	1
carbon ECA	1

In the targeted questionnaire, respondents were asked about the importance of a list of policy objectives. These results are shown in Figure 12. It is clear that all of the seven proposed policy objectives are considered relevant, with ‘providing more certainty on the climate and environmental requirements for ships in operation’ the most important policy objective. The next question asked was what support measures would be most helpful and effective. As can be seen in Figure 13, the respondents to the targeted consultation were most positive about support measures related to funding for R&I, CEF funding for specific projects on the deployment of infrastructure and technological developments and standardization aspects.

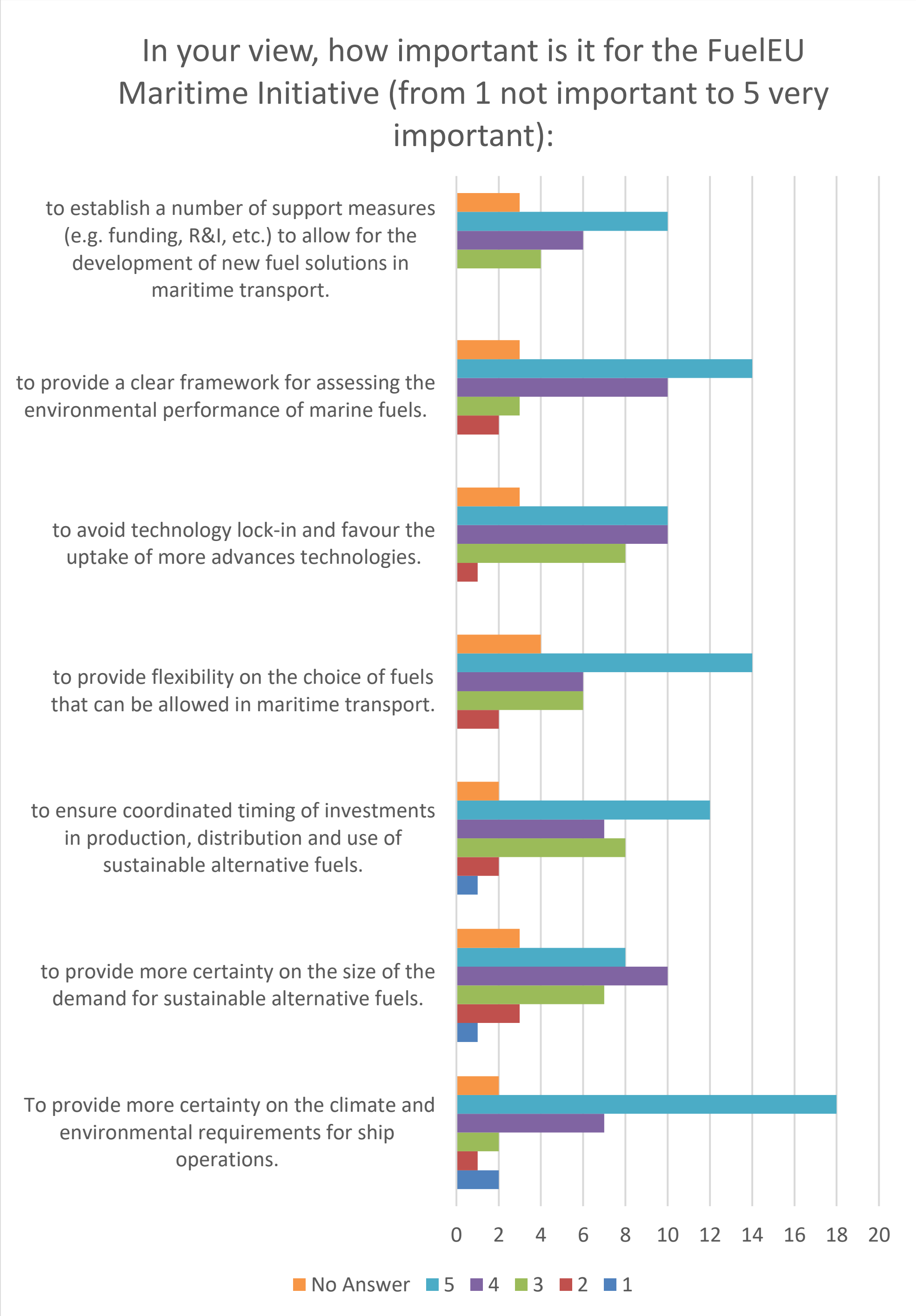

Figure 12 Importance of the FuelEU Maritime Initiative (TC).

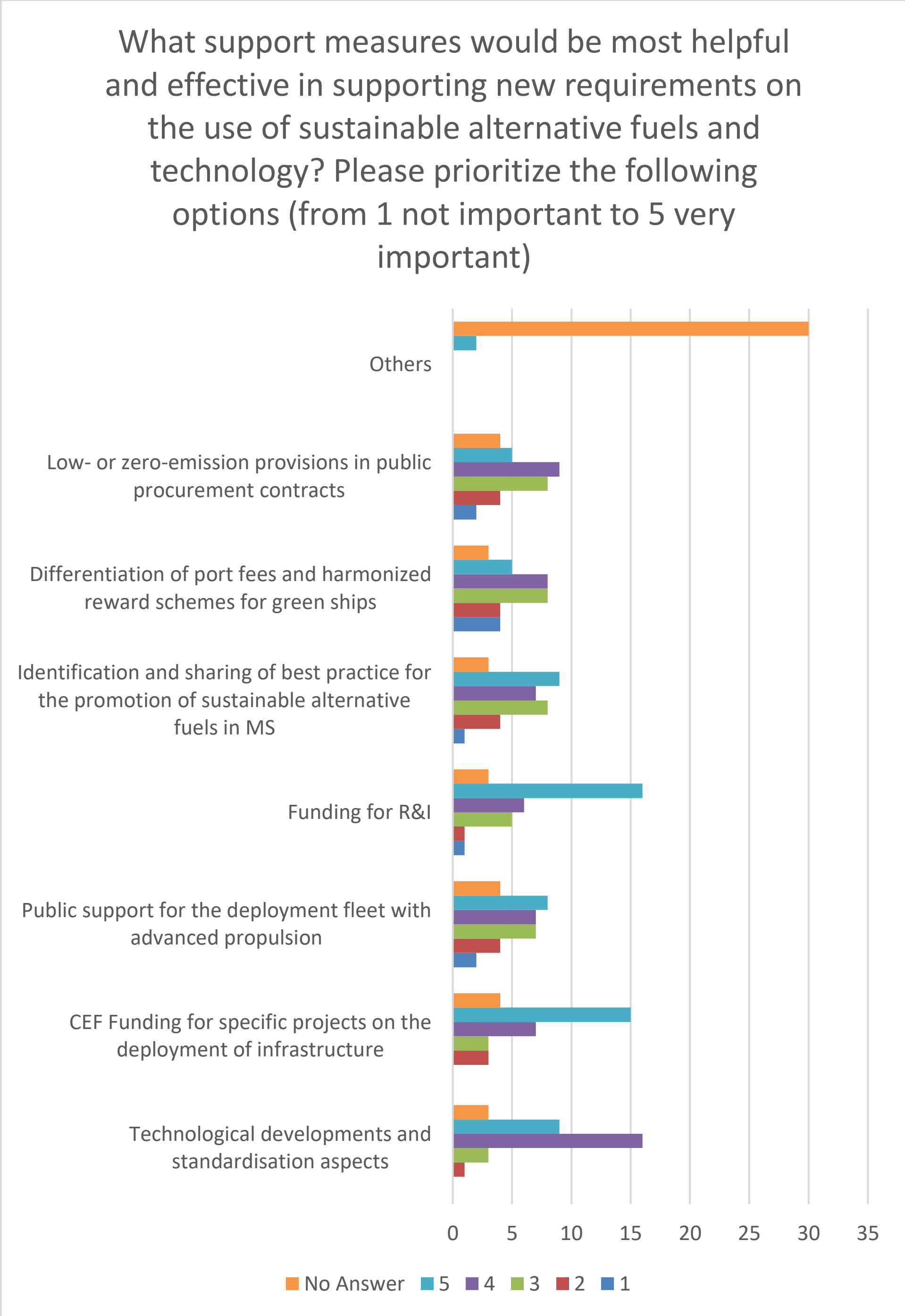

Figure 13 Usefulness of support measures (TC).

Furthermore, as can be seen in Figure 14, the open public consultation respondents voiced a strong preference for goal based measures for ships during navigation. For ships at berth, the largest share of respondents as well opts for a goal based approach. However, there was a relatively large share of respondents who opted for the prescriptive approach as well.

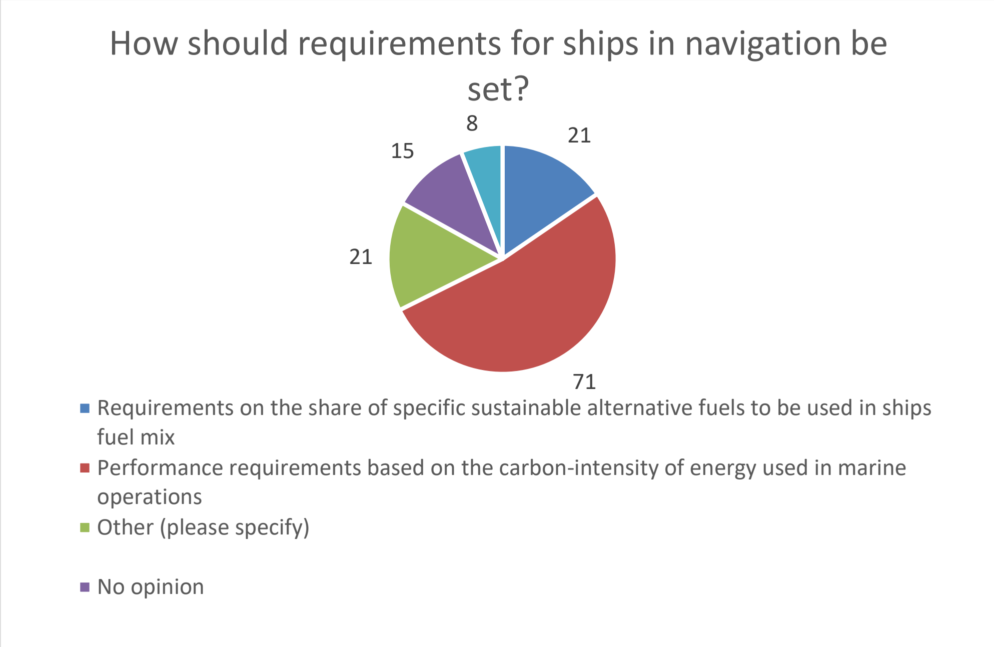

Figure 14 How should requirements for ships in navigation be set? (OPC)

A next policy choice to discuss is whether these requirements should apply to all ship types. A majority of respondents to the open public consultation indicated, as can be seen in Figure 15, that this is the case. On the other hand, there is no agreement on the right scope for the measures: both the options 'ships calling at ports of the EU' and 'ships sailing in the territorial waters and Exclusive Economic Zones of the EU Member States' got approximately an equal amount of votes. In addition to this, it was suggested in an interview that the right approach would be to start with policy for ships which regularly visit the same ports, since in those cases it is easier for the ships and ports to adapt.

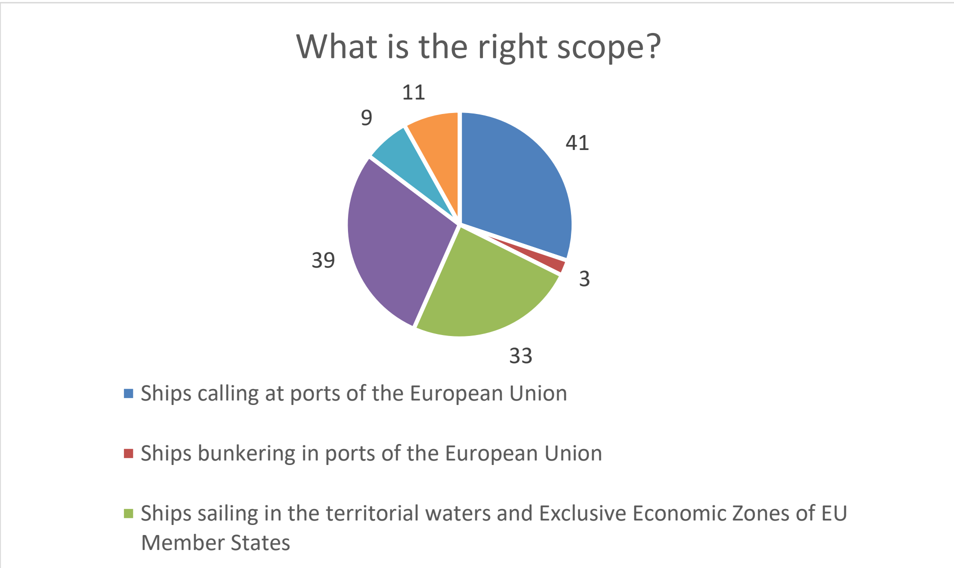

Figure 15 Scope of measures (OPC).

Table 5 other suggestions for policy for ships in navigation

Suggestion	Number of times mentioned
A combination of the three options	12

worldwide (through IMO)	11
aligned with IMO	6
Goal based	4
flag neutral	2

Another aspect of the potential policy that should be discussed is whether the policy applies on the company fleet level or on the individual ship. Based on Figure 16, the targeted consultation respondents are not clearly in favour of one of these options; both got approximately an equal amount of votes and half of the respondents did not answer the question.

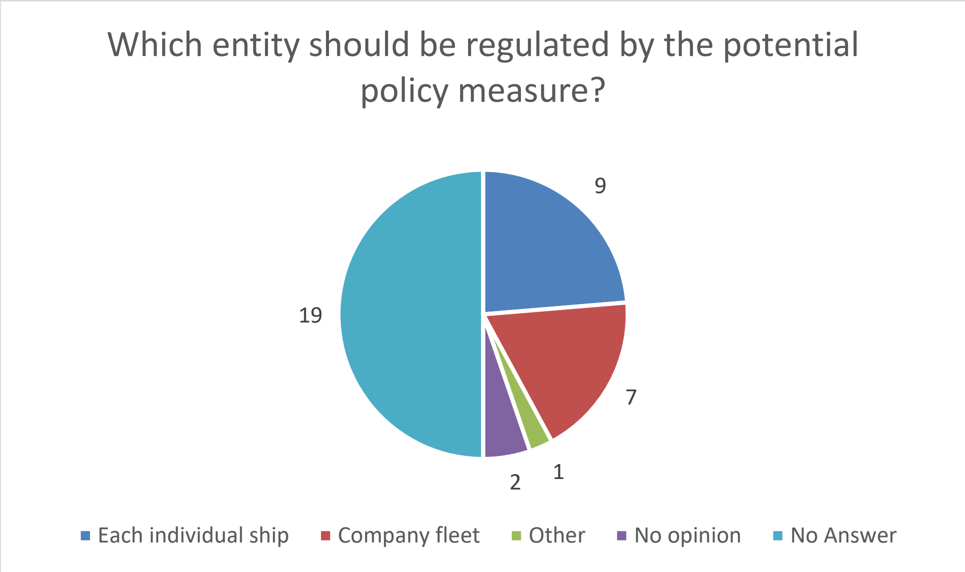

Figure 16 Which entity should be regulated by the potential policy measures? (TC)

There is relatively good agreement about how emissions should be included in the policy framework. Most respondents prefer a “well-to-wake” approach, as indicated in Figure 17. It is also preferred by a majority of stakeholders, as shown in Figure 18, that this takes into account both greenhouse gas- and air pollutant emissions.

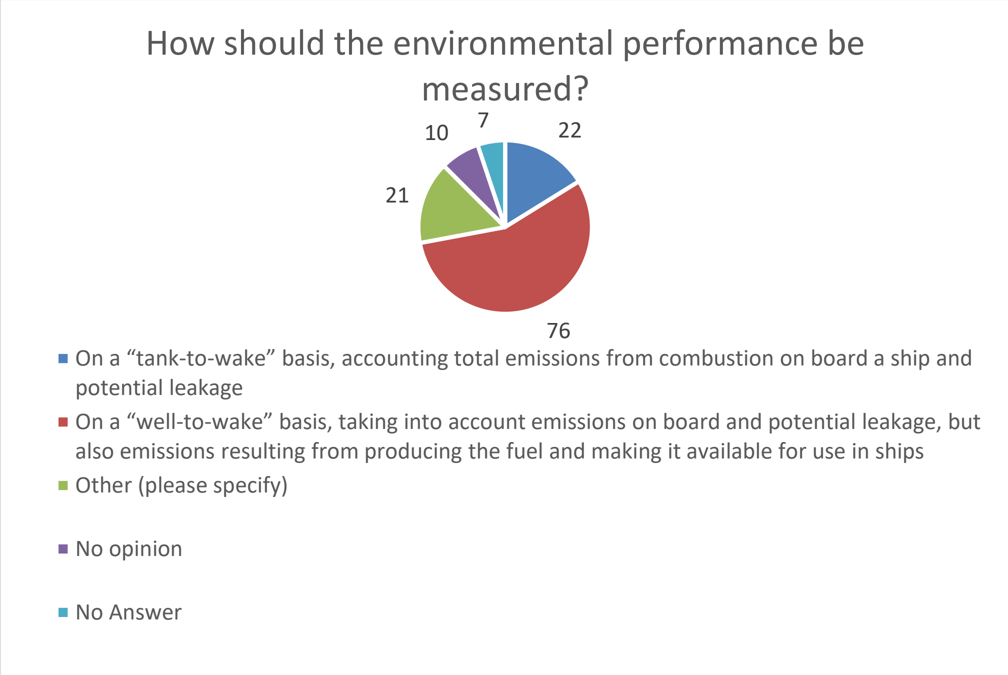

Figure 17 How should the environmental performance be measured? (OPC)

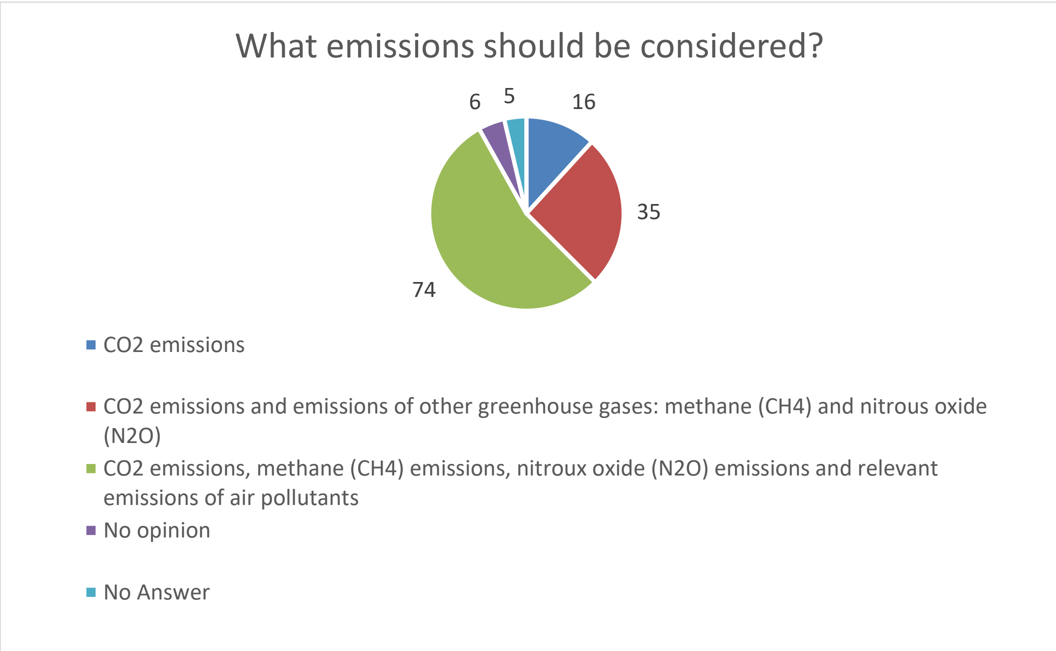

Figure 18 What emissions should be measured? (OPC)

A last point of discussion is the relevance of a policy framework for ships at berth. As is clear from.

Figure 19, most open public consultation respondents think it is important that emissions at berth are also in the scope of a policy framework. This is supported by the results of the targeted consultation, as is shown in Figure 20. However, as is shown in Figure 21, there is less agreement about how such requirements should apply. Both the option to make the policy apply to all ships at berth and the option to prioritize the highest emitters gained a substantial amount of votes. However, also the category 'other' was chosen often. In Table 6 the other suggestions are shown. Most of these are not policies but rather criteria that policies should meet.

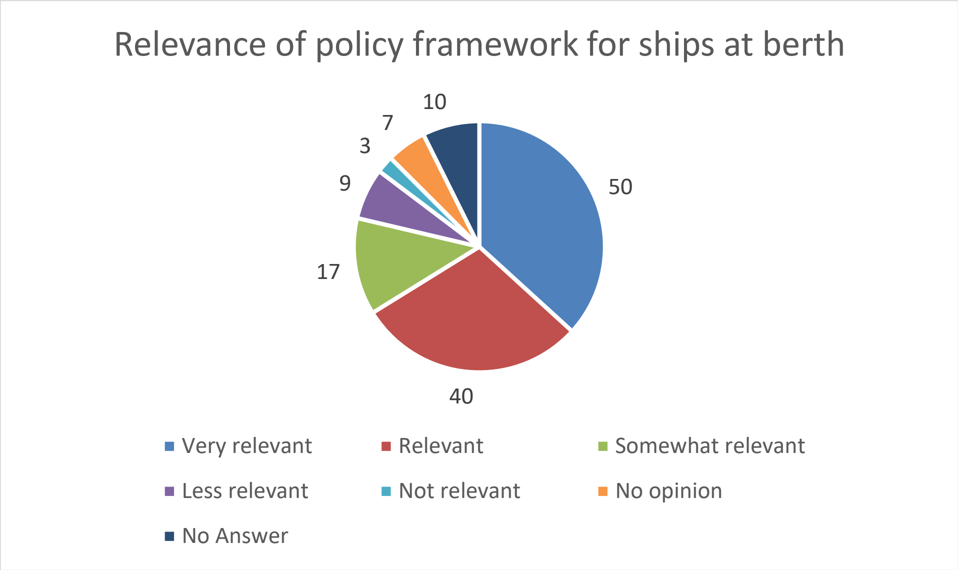

Figure 19 Relevance of a policy framework for ships at berth. (OPC)

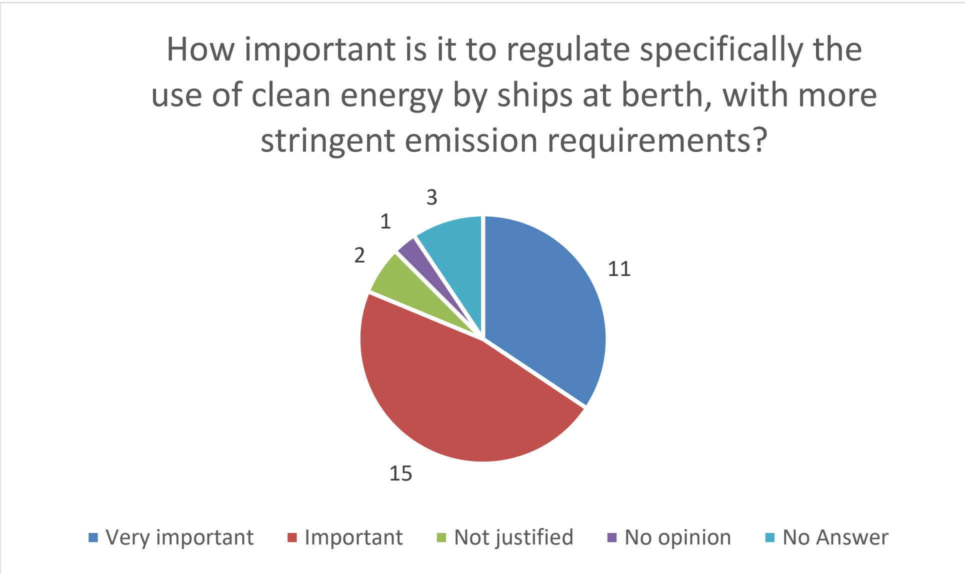

Figure 20 Importance of policy for ships at berth. (TC)

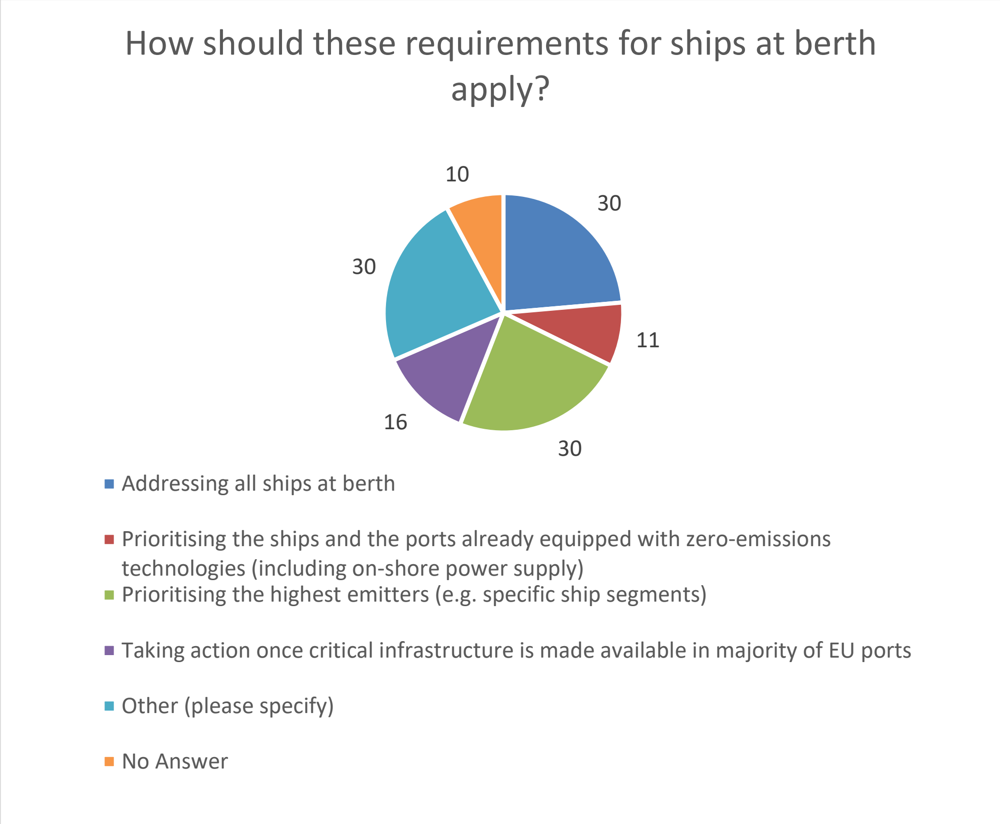

Figure 21 How should these requirements for ships at berth apply? (OPC)

Table 6 other suggestions for policy for ships at berth

Suggestion	Number of times mentioned
combination of options	6
Cost Benefit Analysis determining for OPS	4
technology neutral	4
no OPS requirements for ships using other alternative fuels	2
only do OPS if it is sustainable	1
reducing port costs for alternative fuel ships	1
RoRo, container and cruise vessels first	1

What type of policy instrument is preferred by the different stakeholder groups?

In this section, a comparison between different stakeholder groups is made with respect to policy instruments. First of all, for the following policy measures the stakeholders were asked to give a rating of importance:

1. Accelerate research and innovation enabling the use of sustainable alternative fuels and power (demonstration and deployment);
2. Set a clear regulatory pathway for decarbonising the current marine fuel mix;
3. Increase public funding and incentivise private investment to overcome the high investment risk in vessels powered by sustainable alternative fuels or propulsion systems;
4. Increase public funding and financial support to overcome the high investment risk in sustainable alternative fuel supply or on-shore power supply infrastructure;
5. Establish economic incentives to reduce the price differential between conventional and sustainable alternative fuels;

6. Define objectives for the supply of sustainable alternative fuels and power to the maritime sector;
7. Define objectives and provisions for the use of sustainable alternative fuels and power in the maritime sector;
8. Develop standards related to sustainable alternative fuels (incl. fuels, machinery, infrastructure, etc.);
9. Increase transparency by establishing a certification mechanism for sustainable alternative fuels;
10. Other measures (please specify).

The resulting scores for each measure per stakeholder group are shown in Table 7. First of all, there is no policy that clearly is rated highest by all stakeholder groups. Rather, the options to 'accelerate research and innovation', 'set clear regulatory pathway', increase public funding and incentivise investment for alternative fuels or propulsion' and increase public funding and financial support to alternative fuel supply/OPS infrastructure all score relatively well. As can be seen, there are some differences between those four policy options for the different stakeholder groups. The groups that think it is most important to 'set a clear regulatory pathway' tend to rate the other three options lower and vice versa.

Table 7 Average rating of policy instruments per stakeholder group. (OPC)

	number of contributions	Accelerate research and innovation	Set a clear regulatory pathway	Increase public funding and incentivise investment for alternative fuels or propulsion	Increase public funding and financial support to alternative fuel supply/OPS infrastructure	Establish economic incentives to reduce the price differential	Define objectives for the supply of sustainable alternative fuels and power to the maritime sector	Define objectives and provisions for the use of sustainable alternative fuels and power	Develop standards related to sustainable alternative fuels	Increase transparency by establishing a certification mechanism
National public authorities	15	4,8	4,2	4,5	4,3	4,3	3,8	3,8	4,1	4,0
Ship owning and ship management	40	4,5	3,9	4,4	4,4	4,0	3,7	3,1	3,6	3,7
Short sea shipping	25	4,3	4,0	4,4	4,3	4,0	4,0	3,4	3,6	3,7
Ports management and administrations	13	4,1	4,7	4,0	4,2	4,7	3,5	4,1	4,5	3,8
Port terminal operator or other port services	13	4,2	4,4	4,1	4,3	4,5	4,2	4,0	4,0	3,7
Inland waterways sector	11	4,0	4,9	4,1	3,6	4,1	4,1	3,9	4,5	3,8
Shipbuilding and marine equipment manufacturers	10	4,3	4,5	4,3	3,8	4,0	3,4	3,3	3,4	3,4
Academia, research and innovation	12	4,5	4,6	4,3	4,3	4,3	3,8	3,7	4,5	4,1
Energy producers and fuel supply	37	3,8	4,6	3,9	3,9	4,4	3,8	4,1	3,8	3,7
Interest organisations	14	3,7	4,5	3,6	3,7	4,1	4,0	4,0	4,4	4,0

A second point of comparison between stakeholders is whether a goal based or prescriptive policy is preferred. For ships in navigation all stakeholder groups agree that a 'performance based requirement based on carbon intensity' is preferable as can be seen in Table 8. However, during the interviews and the roundtable it became clear that there are diverging views on what this performance based requirement should be. Stakeholders in ship owning and ship management as well as interest organisations preferred a goal-based approach at the ship level, i.e. a requirement for the operational performance of a ship. Most other stakeholder groups argued for a performance-based requirement of the fuel, i.e. a standard for the embedded GHG emissions in the fuel per unit of energy.

Table 8 How should requirements for the use of sustainable alternative fuels and power be set for ships in navigation? (OPC)

	number of contributions	Performance requirements based on carbon-intensity	Requirements on the share of alternative fuels	Other	No opinion
National public authorities	13	69%	0%	23%	8%
Ship owning and ship management	37	65%	14%	11%	11%
Short sea shipping	24	63%	13%	17%	8%
Ports management and administrations	13	38%	15%	23%	23%
Port terminal operator or other port services	13	38%	15%	15%	31%
Inland waterways sector	8	50%	0%	25%	25%
Shipbuilding and marine equipment manufacturers	10	80%	20%	0%	0%
Academia, research and innovation	12	50%	17%	33%	0%
Energy producers and fuel supply	37	49%	22%	24%	5%
Interest organisations	13	31%	15%	31%	23%

For ships at berth, as can be seen in Table 9, most stakeholder groups also prefer a performance based approach. However, ‘academia, research and innovation’ slightly prefers ‘requirements on the share of sustainable alternative fuels’ and ‘port management and administration’ as well as ‘port terminal operator or other port service provider’ is indifferent between the two choices.

Table 9 How should requirements for the use of sustainable alternative fuels and power be set for ships at berth? (OPC)

	number of contributions	Performance requirements based on the	Requirements on the share of sustainable	Other	No opinion
National public authorities	13	54%	23%	15%	8%
Ship owning and ship management	36	53%	25%	14%	8%
Short sea shipping	23	52%	13%	26%	9%
Ports management and administrations	13	31%	31%	23%	15%
Port terminal operator or other port services	13	31%	31%	31%	8%
Inland waterways sector	7	43%	0%	29%	29%
Shipbuilding and marine equipment manufacturers	9	67%	33%	0%	0%
Academia, research and innovation	12	33%	42%	25%	0%
Energy producers and fuel supply	34	50%	21%	21%	9%
Interest organisations	13	23%	23%	15%	38%

A third question is whether the regulations should apply to all ship types. As can be seen in Table 18, all stake holder groups agree that the requirements should apply to all ship types.

However, concerning the right scope of the measures, there is remarkable disagreement between the stakeholder groups. First of all, it is important to note that a policy that applies to ships bunkering in the EU is extremely unpopular. A scope of 'ships calling ports in the European Union' is popular with 'port management and administrations', port terminal operator or other port service provider and 'academia, research and innovation'. On the other hand, a scope of 'ships sailing in the territorial waters and Exclusive Economic Zones of the EU' is popular with the 'inland waterways sector' and 'interest organizations'.

Concerning the scope of emissions, all stakeholder groups agree that the policy should be calculated on a "well-to-wake" basis, as can be seen in Table 10. There also is, as can be seen in Table 11, agreement between groups of stakeholders about what emissions should be considered: both greenhouse gas (CO_2 and other) and air polluting emissions should be included in the policy framework.

A last topic to discuss in this Section is the relevance of including emissions at berth. As can be seen in Table 12, all stakeholder groups agree that it is relevant to include emissions at berth. However, there is no agreement about how these requirements should apply. Some stakeholder groups prefer that this policy addresses all ships at berth, whereas other stakeholder groups prefer to take action once the relevant infrastructure is in place at all major EU ports or to Prioritize the highest emitters. Also, many respondents chose the option 'other', indicating that there may be alternative options to the four mentioned in the question.

Table 10 How should emissions be calculated? (OPC)

		On a "tank-to-wake" basis	On a "well-to-wake" basis	Other	No opinion
National public authorities	12	33%	67%	0%	0%
Ship owning and ship management	27	44%	56%	0%	0%
Short sea shipping	18	22%	78%	0%	0%
Ports management and administrations	9	11%	89%	0%	0%
Port terminal operator or other port services	9	33%	67%	0%	0%
Inland waterways sector	6	17%	83%	0%	0%
Shipbuilding and marine equipment manufacturers	10	10%	90%	0%	0%
Academia, research and innovation	11	9%	91%	0%	0%
Energy producers and fuel supply	27	7%	93%	0%	0%
Interest organisations	9	11%	89%	0%	0%

Table 11 What emissions should be included? (OPC)

		CO2 emissions	CO2 emissions and emissions of other greenhouse gases	Greenhouse gas- and air quality emissions	No opinion
National public authorities	14	21%	7%	71%	0%
Ship owning and ship management	37	27%	32%	38%	3%
Short sea shipping	24	21%	29%	46%	4%
Ports management and administrations	13	23%	15%	62%	0%
Port terminal operator or other port services	13	23%	31%	46%	0%
Inland waterways sector	9	0%	11%	78%	11%
Shipbuilding and marine equipment manufacturers	10	20%	10%	70%	0%
Academia, research and innovation	12	0%	17%	83%	0%
Energy producers and fuel supply	37	5%	43%	51%	0%
Interest organisations	14	0%	14%	86%	0%

Table 12 How relevant is it to establish a regulatory framework specifically addressing emissions produced by ships at berth? (OPC)

		Very relevant	Relevant	Somewhat relevant	Less relevant	Not relevant	No opinion
National public authorities	14	43%	29%	21%	7%	0%	0%
Ship owning and ship management	36	31%	25%	22%	11%	8%	3%
Short sea shipping	24	29%	29%	17%	8%	13%	4%
Ports management and administrations	13	38%	38%	15%	8%	0%	0%
Port terminal operator or other port services	13	31%	31%	15%	15%	0%	8%
Inland waterways sector	9	22%	67%	0%	0%	0%	11%
Shipbuilding and marine equipment manufacturers	9	33%	44%	22%	0%	0%	0%
Academia, research and innovation	12	58%	33%	0%	0%	0%	8%
Energy producers and fuel supply	35	40%	34%	11%	6%	0%	9%
Interest organisations	14	71%	21%	0%	0%	0%	7%

Interviews, position papers and Roundtable

The interviews and the contributions made at the Roundtable confirmed the findings from the OPC and the TC. First of all, there was a clear signal from the stakeholders that the policy framework should be clear, consistent and predictable. Also, it was stressed that the policy should be in line with existing frameworks such as the Alternative Fuels Infrastructure Directive and the Energy Taxation Directive. A suggestion which was often heard in relation to the Energy Taxation Directive was that all sustainable marine fuels and power should be exempted from taxation to increase the competitiveness. Another point voiced by the stakeholders which is related to this is that there is a need for harmonization of policy, standards and rules within the EU.

In the interviews, all stakeholder groups have expressed a preference for goal-based over prescriptive policy. Another, closely related, requirement for the policy which was voiced by most stakeholders is technology neutrality. In two interviews as well as a position paper, it was argued explicitly that prescriptive measures for a certain technology would be suboptimal, because of the high risk of stranded assets. However, there is less consensus about the form which such a goal based approach should take. On the one hand, four interviewees and one position paper indicated that they are proponents of the inclusion of carbon taxation, either through the inclusion of the maritime sector in the EU ETS or through establishing a new emissions trading scheme. An alternative option which was advocated for in the position papers and interviews is an emission cap for ships. In either case, as pointed out by several stakeholders, there should be some flexibility for the market to ensure that the efforts for decarbonization can be done where this is most efficient.

Another point about which there is agreement between the stakeholders is that more research and funding is necessary to speed up the developments. One interviewee suggested that this could be funded with the revenues from a carbon tax system.

There also is agreement between stakeholders is that emission should be measured on a well-to-wake basis. However, one stakeholder argued that although all emissions should be considered, the shipping sector should only be responsible for the exhaust emissions. Also, the need for a certification system was pointed out by four interviewees and two position papers. This is necessary to ensure the sustainability of alternative fuels on the market.

There is some divergence of preferences between stakeholders concerning the timing of action. Seven stakeholders explicitly indicated during the interviews that taking action now is preferable, be it with a sensible transition period. However, two interviewees indicated that it is better to wait with taking action in order to establish a global policy through the IMO. All stakeholder groups agree that the IMO is an important organization which should be closely involved in any EU policy. However, one interviewee as well as five position papers argued that it is necessary that policy is established through the IMO whereas three interviewees argued that EU policy could work as a trigger for the rest of the world to follow.

Concerning different fuel types, there are a few interesting observations which are worth mentioning. First of all, there seems to be agreement amongst stakeholders that for the long term research and development is needed in a range possible marine fuels such as hydrogen, ammonia and methanol. However, it is also worth pointing out that three interviewees as well as seven position papers argued that LNG should be stimulated as a transitionary fuel. Especially during the ESSF Roundtable discussion there were also voices heard which argued that, due to the limited potential for decarbonization, investments in LNG do not contribute to the long term goals. Also, five interviewees as well as four position papers argued explicitly for the role of biofuels. However, all stakeholders agree that first generation biofuels, which compete with agriculture, should be excluded.

Concerning policy for ships at berth, there seems to be an agreement that this is relevant and necessary for achieving the decarbonization objectives. Also, most stakeholders agree that there will be an important role for OPS in reaching the targets. However, mandating the use of OPS in ports is a very unpopular policy option. During the interviews, all ports that we spoke with stressed that mandating OPS is not a good policy option because the viability varies greatly per port. Even ports who already invested in OPS infrastructure were against such a policy. A goal based policy at berth would therefore have more support from the stakeholders.

Other concerns that were voiced by the stakeholders are that the policy should be flag neutral, preserve the level playing field, prevent carbon leakage, preserve the competitiveness of the EU maritime sector and incentivize rather than punish first movers. Also, it was stressed by three interviewees and four position papers that ensuring the safety of new technologies through standards is important.

3 Public Consultation Results

In this chapter, the full results to the public consultation survey are presented.

3.1 General characteristics of respondents

There were in total 136 responses to the Public Open Consultation. Of the respondents, 30% (41 out of 136 contributions) responded anonymously. We have not identified identical responses suggesting a coordinated response. Except for questions here respondents were asked to rank answers or supply additional comments, the non-response did not exceed 16 (12%). In the pie charts, the numbers indicate the number of responses per answer.

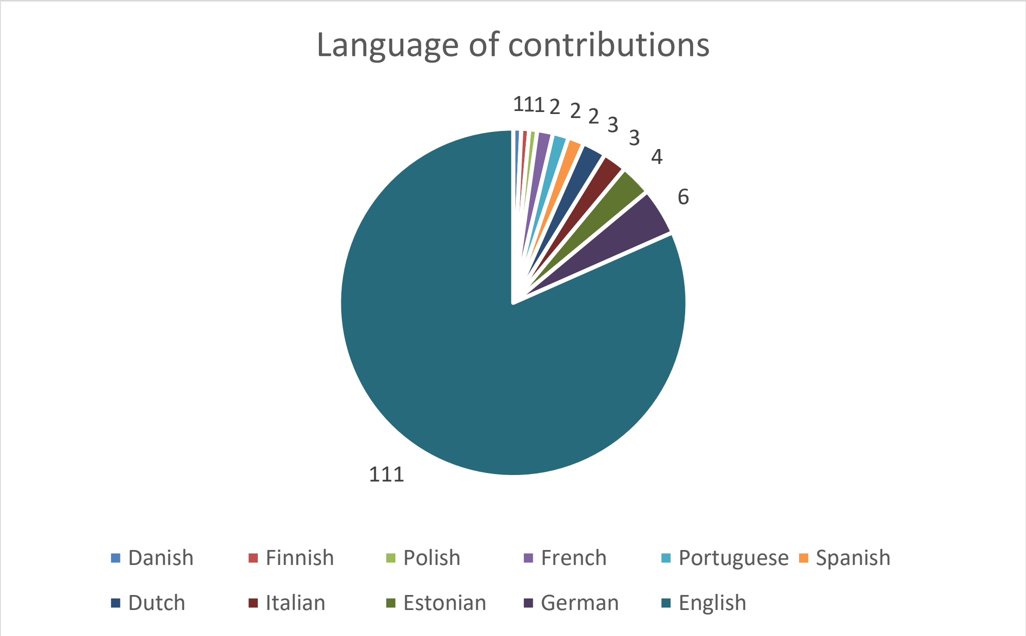

Figure 22 Language of contributions

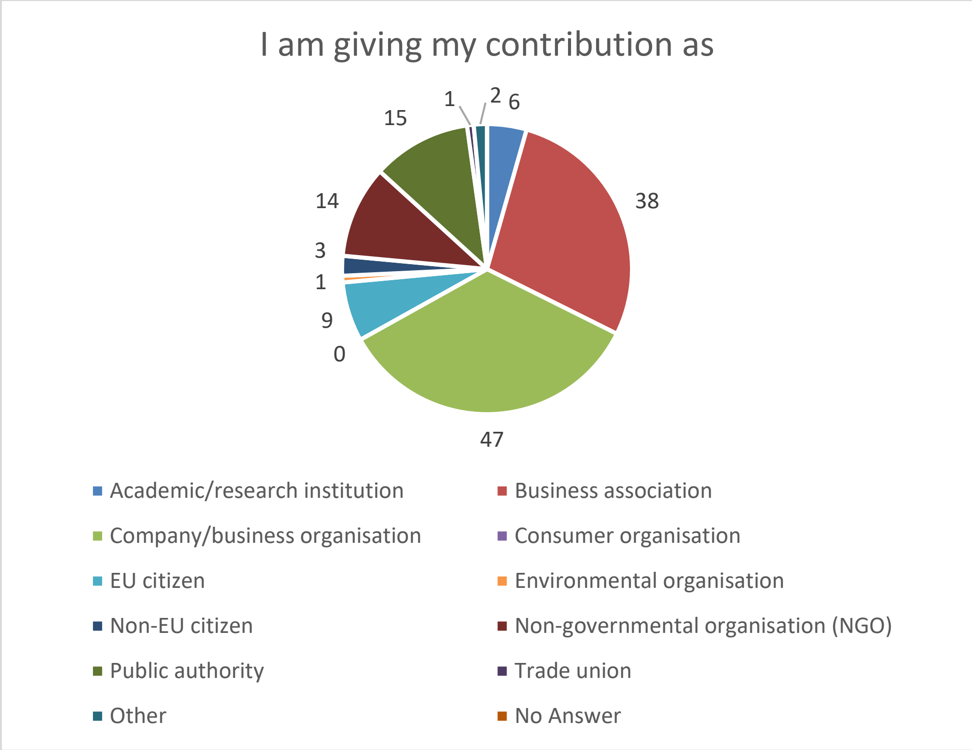

Figure 23 Contributors per type

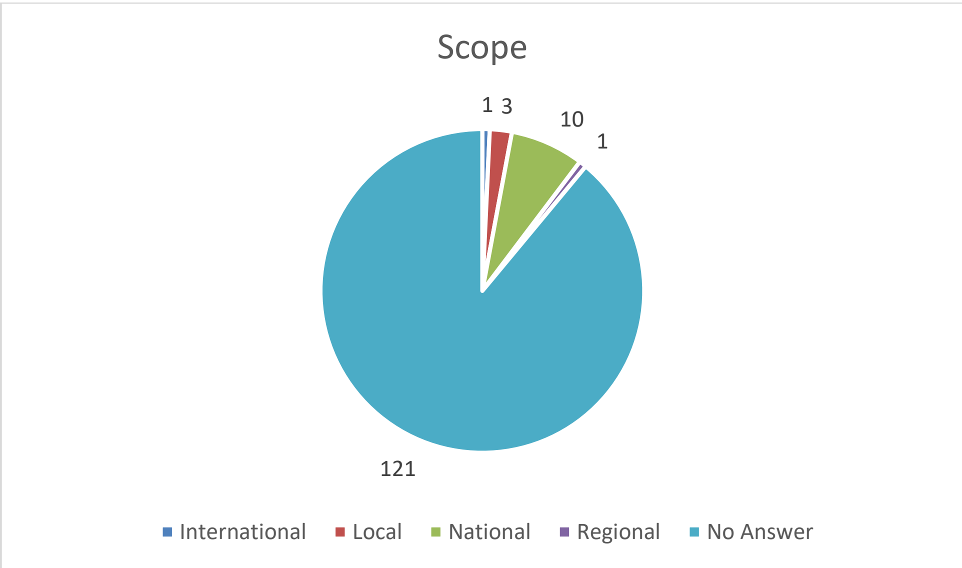

Figure 24 Scope of contributions

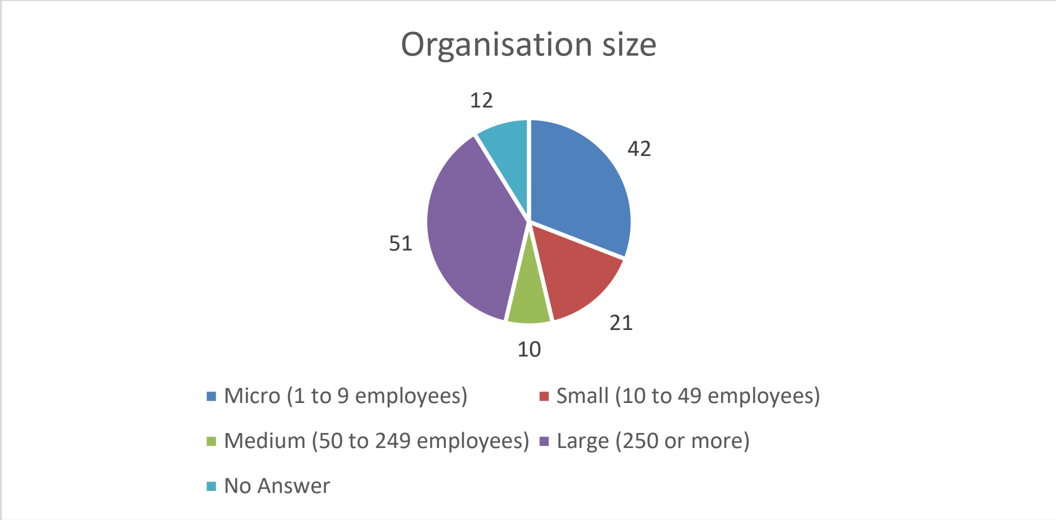

Figure 25 Contributor organization sizes

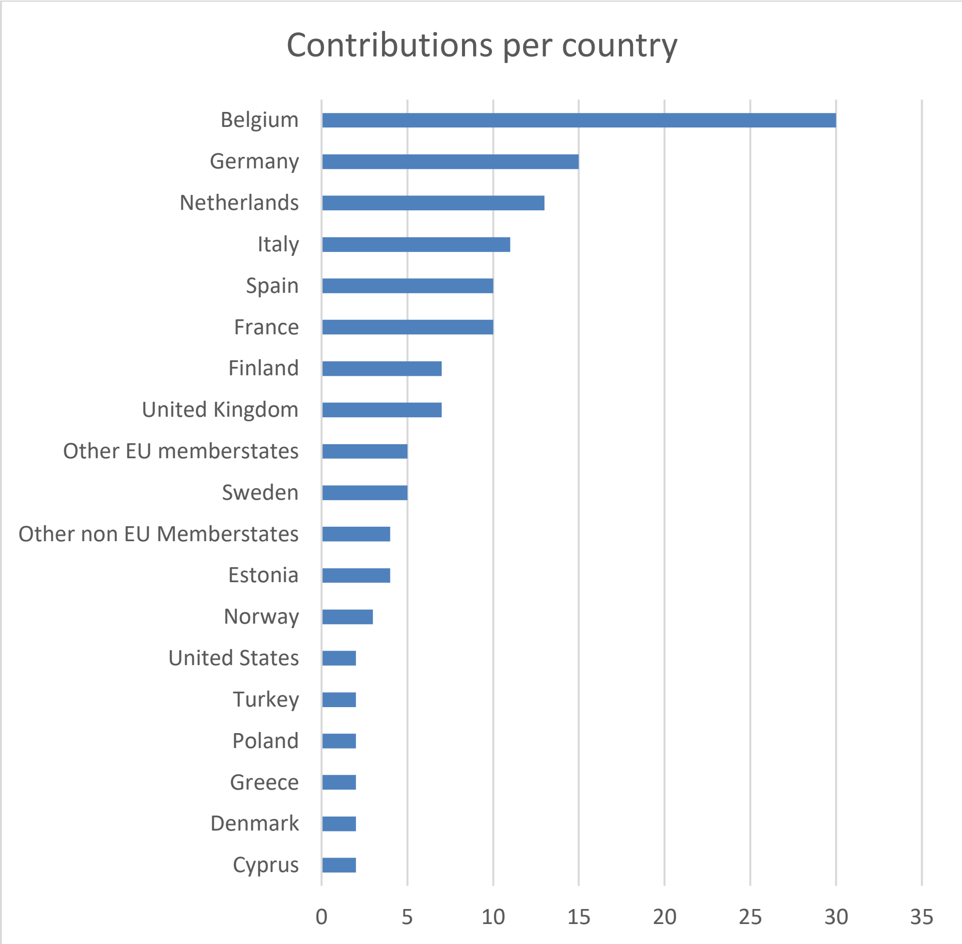

Figure 26 Number of contributions per country

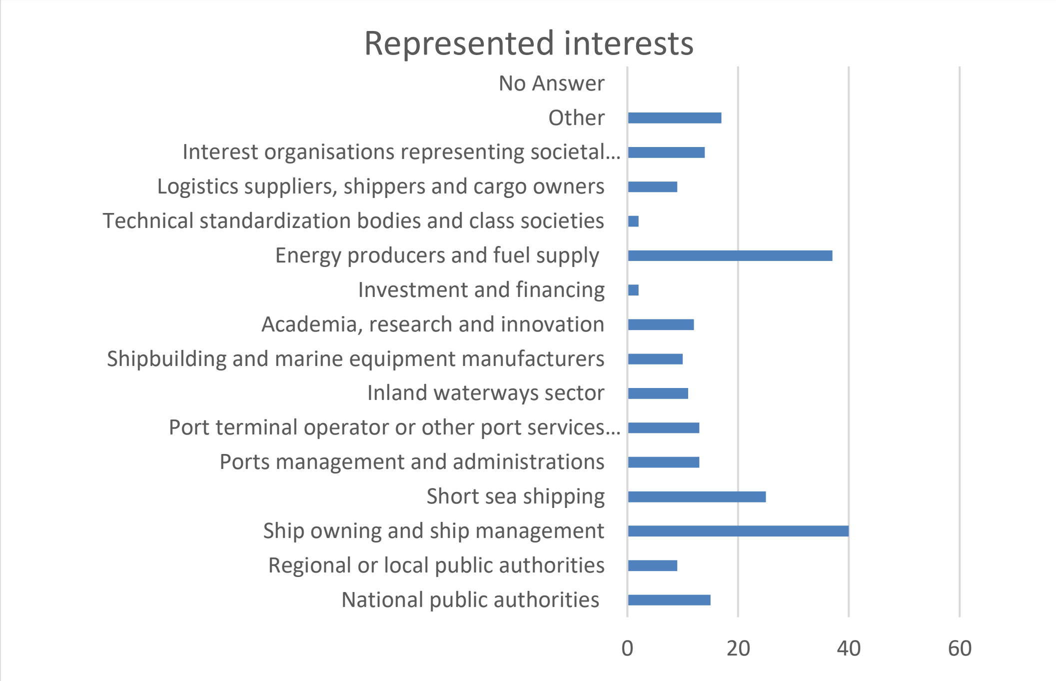

Figure 27 Represented interests

3.2 General assessment and policy context

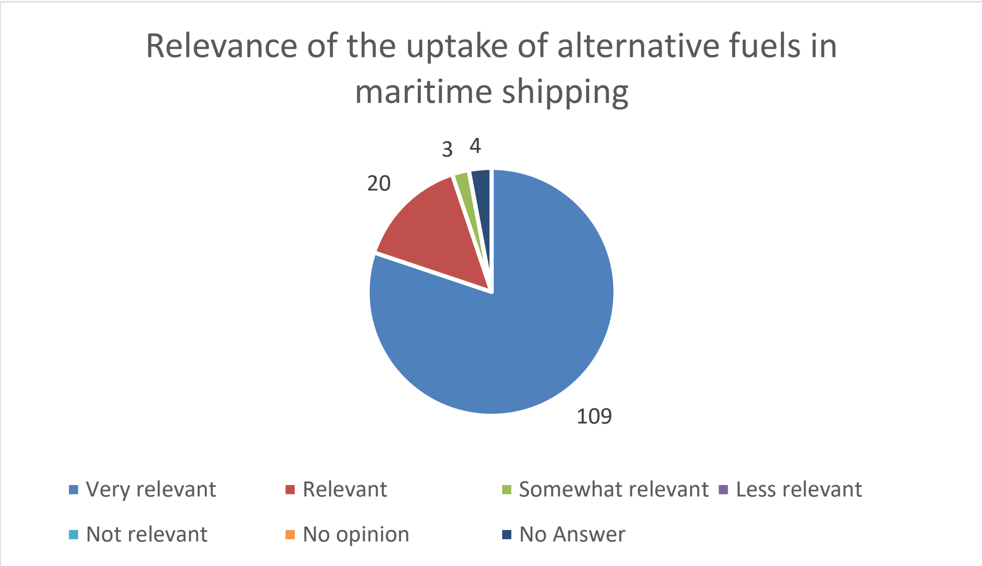

Figure 28 Relevance of the uptake of alternative fuels in maritime shipping.

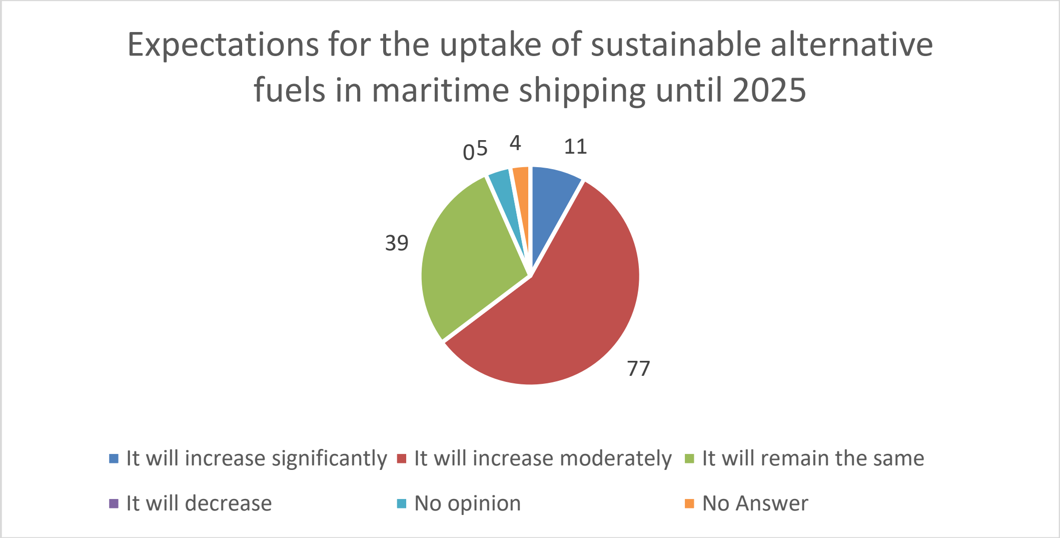

Figure 29 Expectations for the uptake of sustainable fuels in maritime shipping until 2025.

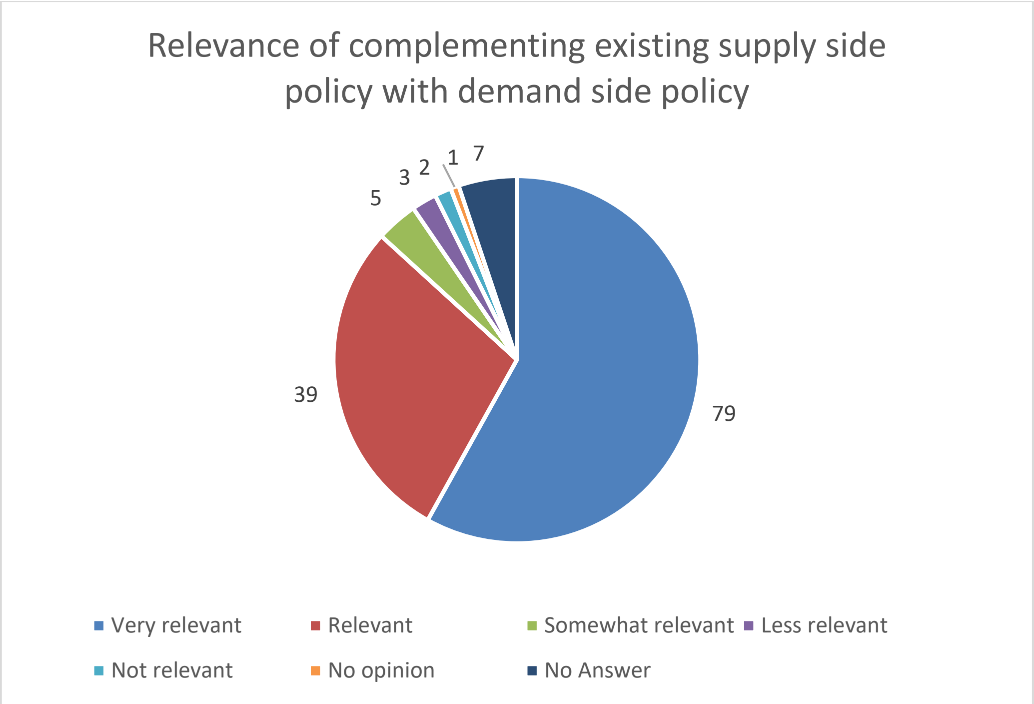

Figure 30 Relevance of demand side policy.

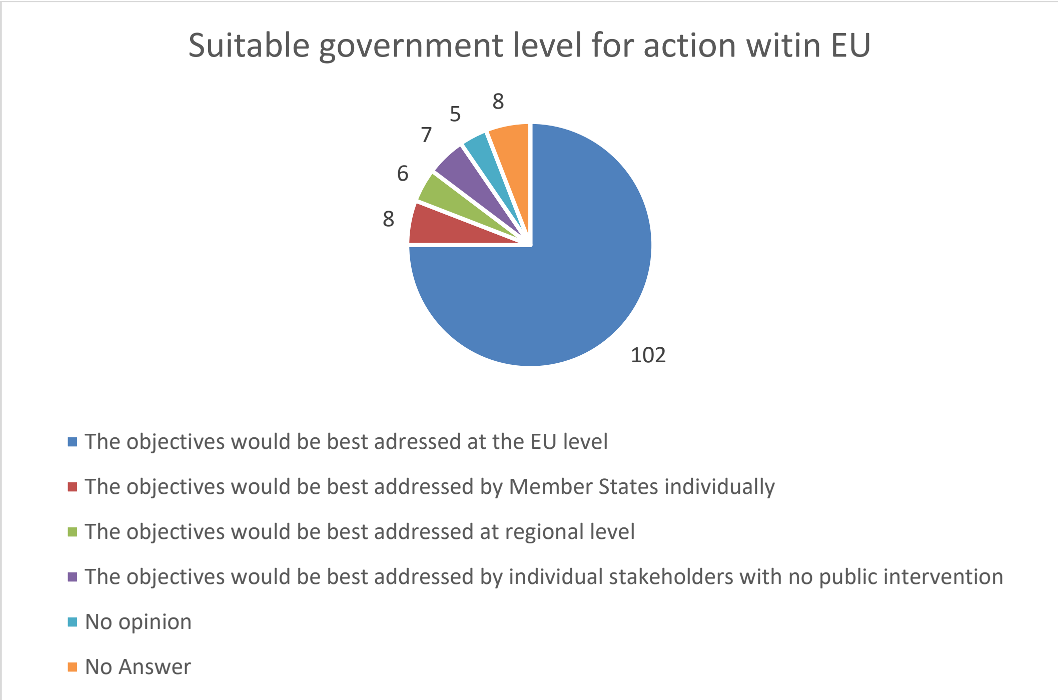

Figure 31 Suitable government level for action within EU

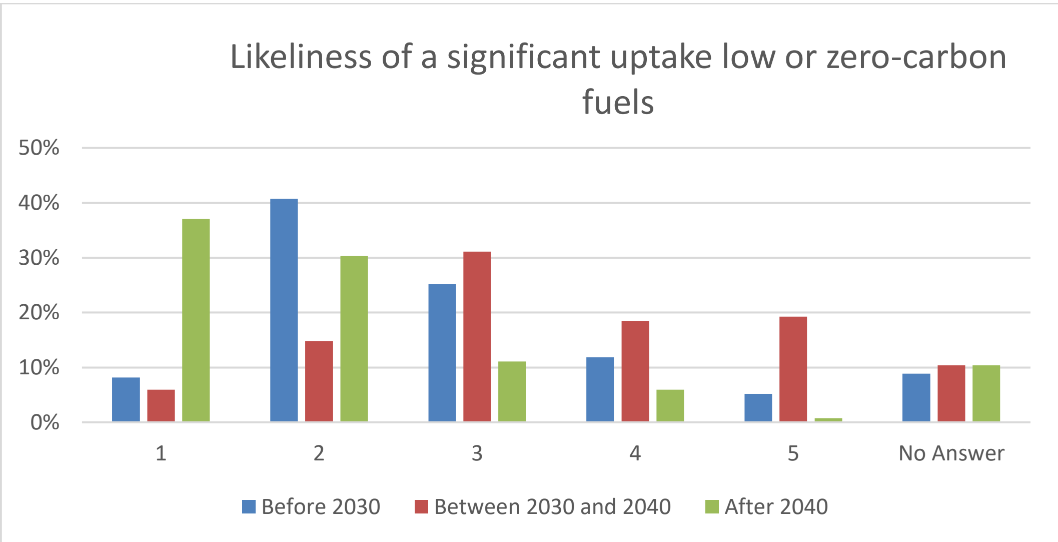

Figure 32 Likeliness of a significant uptake of low of zero-carbon fuels.

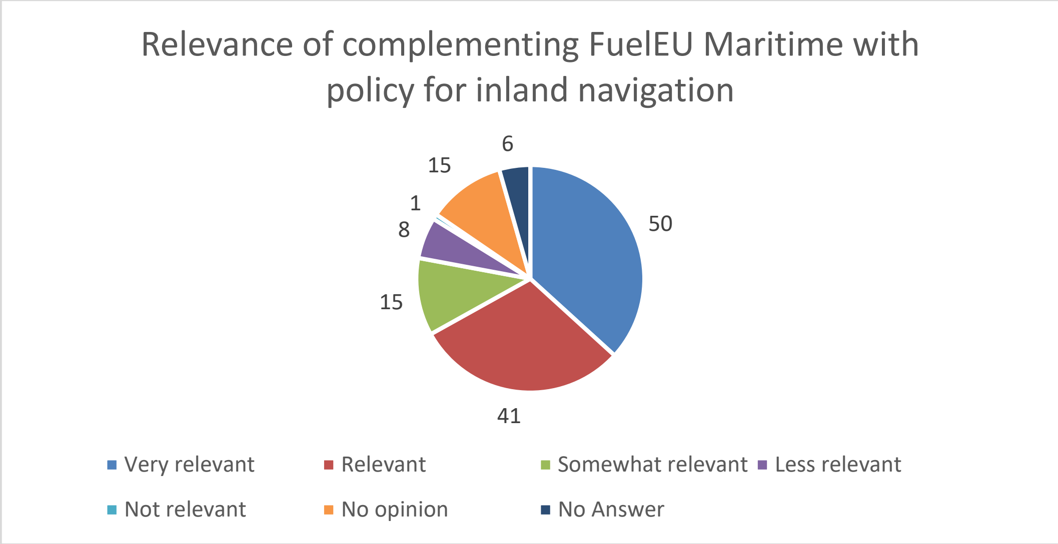

Figure 33 Relevance of complementing the FuelEU Maritime initiative with policies focussed on inland navigation.

3.3 Barriers to the uptake of sustainable alternative fuels in maritime transport

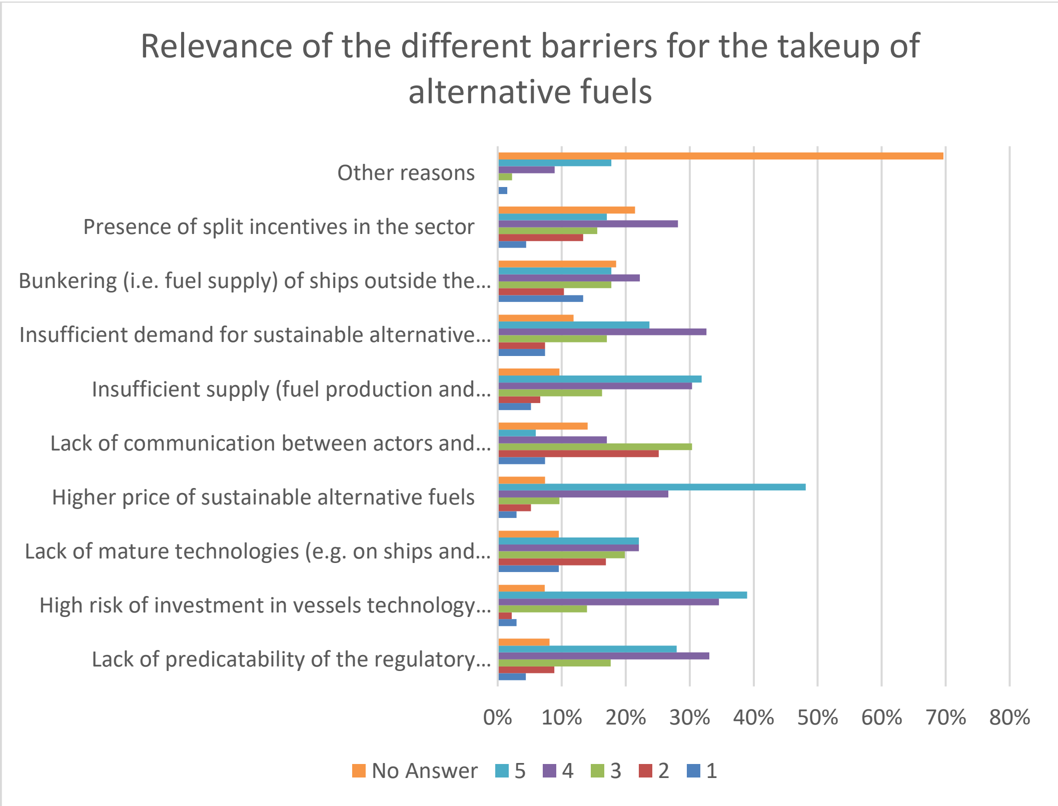

Figure 34 Barriers to the uptake of sustainable alternative fuels in maritime transport.

Table 13 Comparison of the scores on relevance of barriers per stakeholder group.

	number of contributions	Lack of predicatability of the regulatory framework	High risk of investment	Lack of mature technologies	Higher fuel prices	Lack of communication transparency	Insufficient supply of sustainable alternative fuels or OPS	Insufficient demand for sustainable alternative fuels or OPS	Bunkering of ships outside the EU	Split incentives
National public authorities	15	4,1	4,2	4,0	4,4	3,2	4,4	4,3	3,6	3,8
Ship owning and ship management	40	3,4	4,2	4,1	4,3	3,1	4,3	3,2	2,8	3,5
Short sea shipping	25	3,3	4,2	3,8	3,9	3,0	3,7	3,0	2,9	3,4
Ports management and administrations	13	3,5	4,2	3,5	3,8	3,3	3,5	4,3	3,3	3,8
Port terminal operator or other port services provider	13	3,4	4,0	3,5	4,0	3,2	3,5	3,5	3,2	3,4
Inland waterways sector	11	3,0	3,8	3,0	3,6	3,3	3,9	4,1	3,0	3,5
Shipbuilding and marine equipment manufacturers	10	4,0	4,1	2,7	4,0	2,5	3,6	3,2	3,6	3,3
Academia, research and innovation	12	3,7	4,1	3,7	4,2	3,1	3,8	3,5	2,8	3,5
Energy producers and fuel supply	37	4,0	4,2	2,8	4,3	2,6	3,6	3,9	3,4	3,5
Interest organisations	14	3,9	3,5	2,9	4,2	3,1	3,1	3,4	3,3	3,9

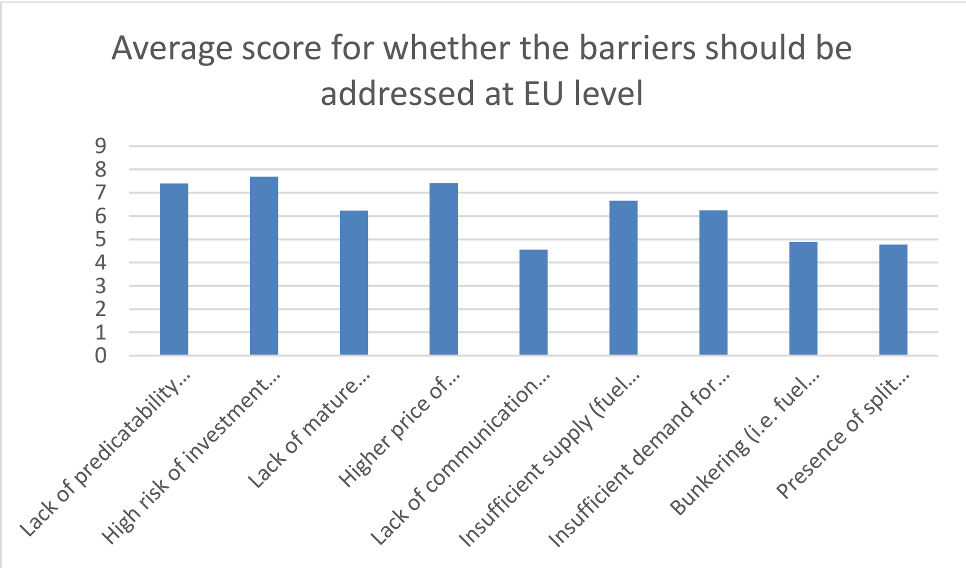

Figure 35 Which of these barriers should be addressed as a matter of priority at the EU level?

Table 14 Comparison on priority for addressing of barriers on EU level per stakeholder group (scale 1/10).

	number of contributions	Lack of predicatability of the regulatory framework	High risk of investment	Lack of mature technologies	Higher fuel prices	Lack of communication transparency	Insufficient supply of sustainable alternative fuels or	Insufficient demand for sustainable alternative fuels or	Bunkering of ships outside the EU	Split incentives
National public authorities	15	9,0	8,0	6,6	6,9	5,1	6,9	7,6	3,8	3,7
Ship owning and ship management	40	7,1	7,9	8,0	7,7	5,3	6,8	4,7	4,1	4,9
Short sea shipping	25	6,6	7,7	7,9	7,5	5,8	6,7	5,3	3,8	5,4
Ports management and administrations	13	6,9	7,9	7,3	7,4	5,3	6,6	7,2	5,9	5,8
Port terminal operator or other port services provider	13	6,8	7,6	7,1	7,4	4,5	6,5	5,6	5,3	5,0
Inland waterways sector	11	7,7	6,2	6,8	7,2	3,9	6,0	6,4	4,2	5,9
Shipbuilding and marine equipment manufacturers	10	8,3	7,0	5,3	7,2	4,2	7,8	6,3	4,1	5,4
Academia, research and innovation	12	6,7	6,9	8,9	7,4	4,7	7,5	6,3	4,6	3,9
Energy producers and fuel supply	37	7,7	7,2	5,3	7,4	3,4	6,2	7,2	4,5	4,2
Interest organisations	14	7,7	6,0	7,3	7,3	5,2	6,0	7,3	5,4	5,6

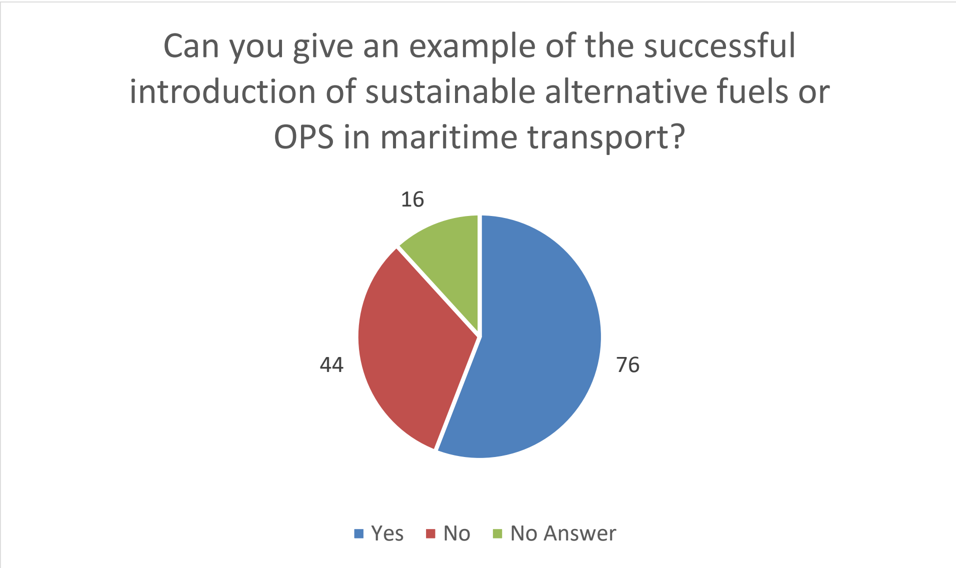

Figure 36 Examples of the successful introduction of sustainable alternative fuels or OPS in maritime transport.

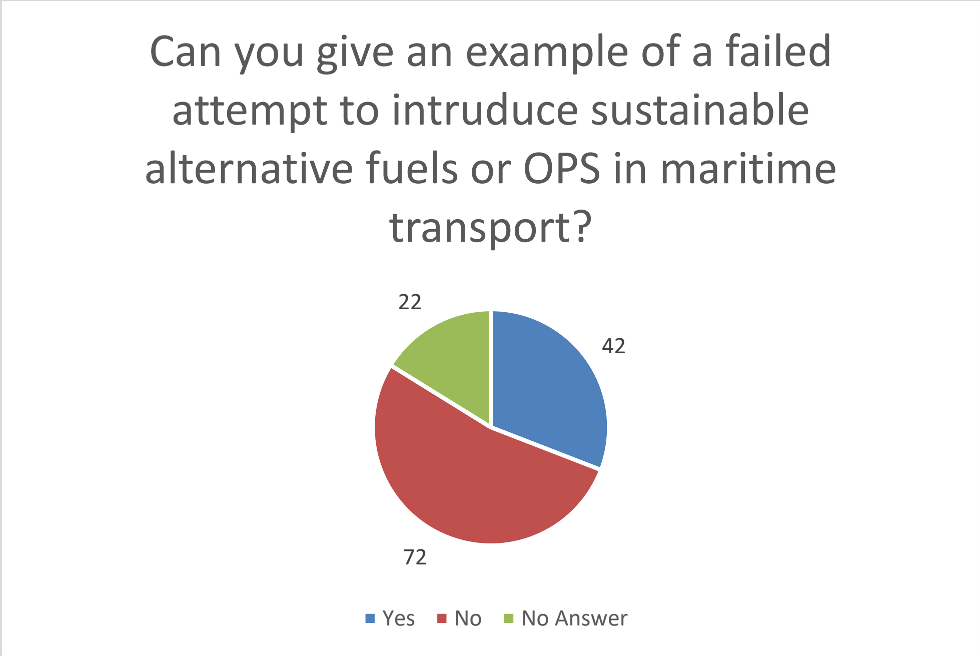

Figure 37 Examples of failed attempts to introduce sustainable alternative fuels or OPS in maritime transport.

3.4 Policy options

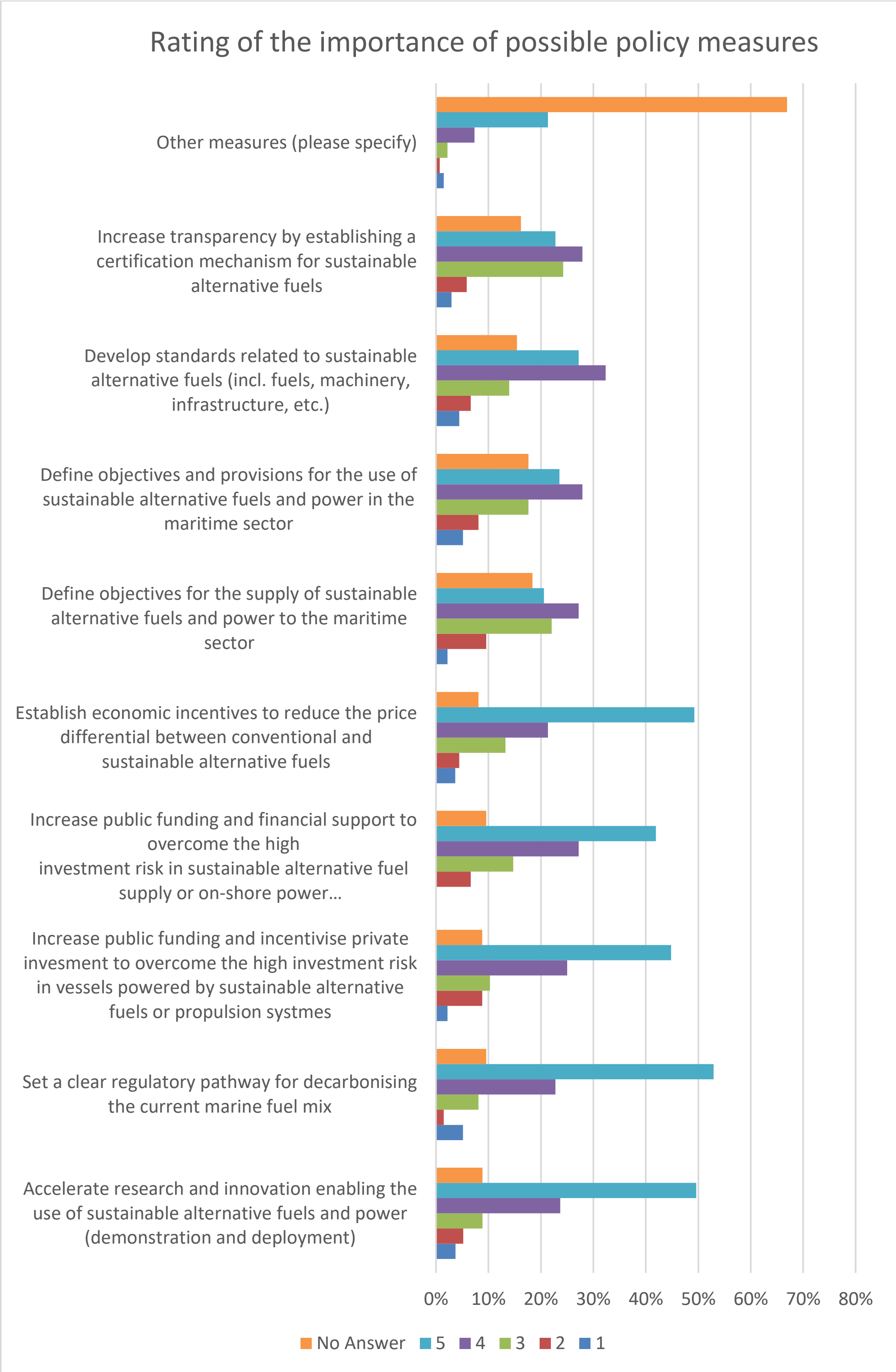

Figure 38 Rating of possible policy options by importance.

Table 15 Average rating of policy instruments per stakeholder group.

	number of contributions	Accelerate research and innovation	Set a clear regulatory pathway	Increase public funding and incentivise investment for alternative fuels or propulsion	Increase public funding and financial support to alternative fuel supply/OPS infrastructure	Establish economic incentives to reduce the price differential	Define objectives for the supply of sustainable alternative fuels and power to the maritime sector	Define objectives and provisions for the use of sustainable alternative fuels and power	Develop standards related to sustainable alternative fuels	Increase transparency by establishing a certification mechanism
National public authorities	15	4,8	4,2	4,5	4,3	4,3	3,8	3,8	4,1	4,0
Ship owning and ship management	40	4,5	3,9	4,4	4,4	4,0	3,7	3,1	3,6	3,7
Short sea shipping	25	4,3	4,0	4,4	4,3	4,0	4,0	3,4	3,6	3,7
Ports management and administrations	13	4,1	4,7	4,0	4,2	4,7	3,5	4,1	4,5	3,8
Port terminal operator or other port services	13	4,2	4,4	4,1	4,3	4,5	4,2	4,0	4,0	3,7
Inland waterways sector	11	4,0	4,9	4,1	3,6	4,1	4,1	3,9	4,5	3,8
Shipbuilding and marine equipment manufacturers	10	4,3	4,5	4,3	3,8	4,0	3,4	3,3	3,4	3,4
Academia, research and innovation	12	4,5	4,6	4,3	4,3	4,3	3,8	3,7	4,5	4,1
Energy producers and fuel supply	37	3,8	4,6	3,9	3,9	4,4	3,8	4,1	3,8	3,7
Interest organisations	14	3,7	4,5	3,6	3,7	4,1	4,0	4,0	4,4	4,0

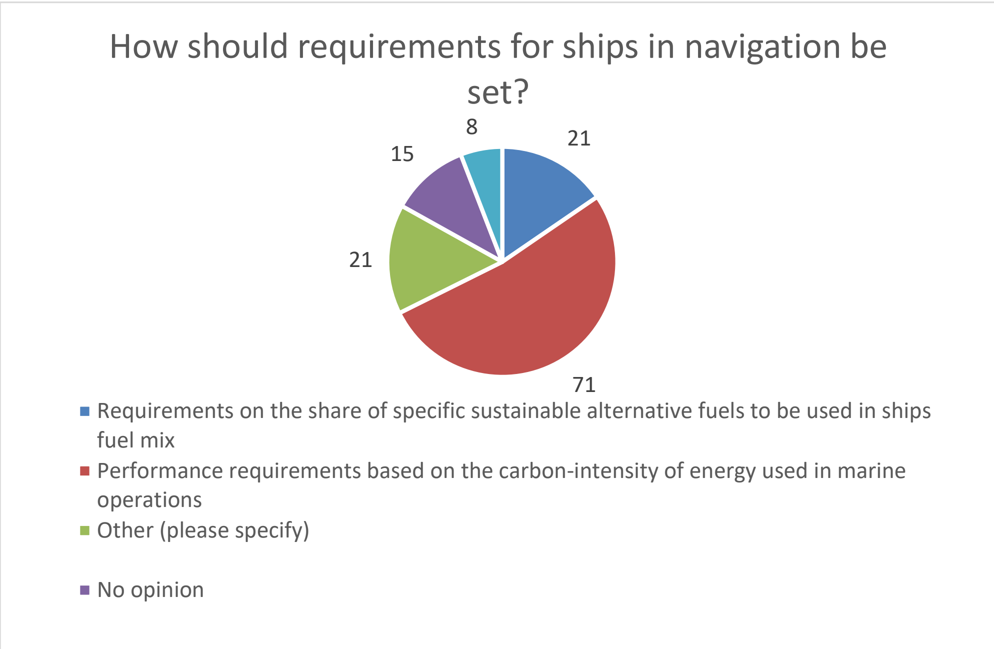

Figure 39 How should requirements for ships in navigation be set?

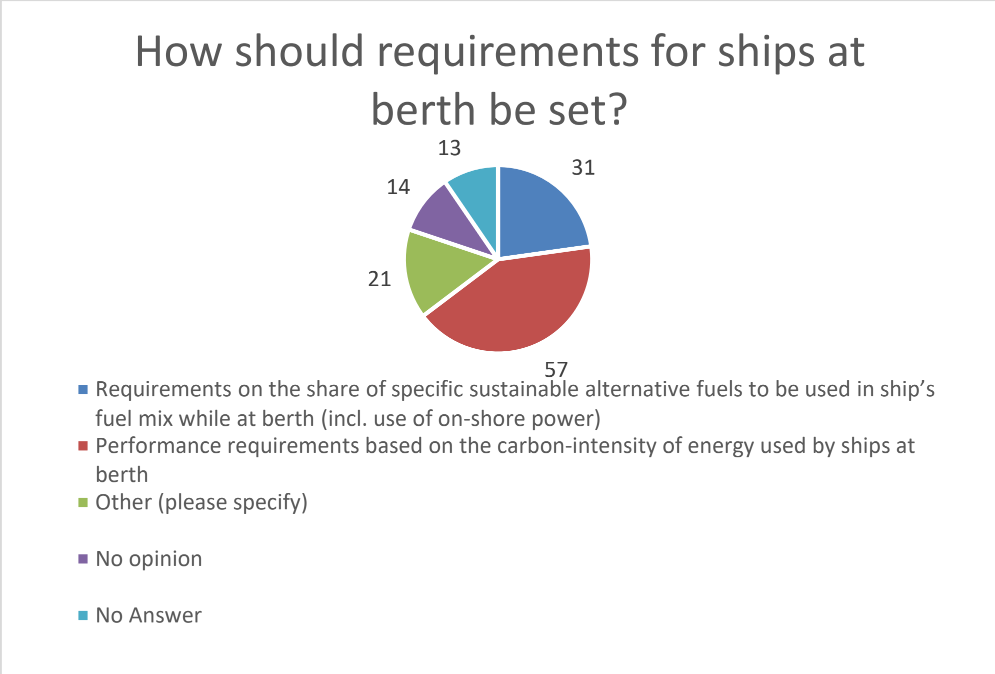

Figure 40 How should requirements for ships at berth be set?

Table 16 How should requirements for the use of sustainable alternative fuels and power be set for ships in navigation?

	number of contributions	Performance requirements based on carbon-intensity	Requirements on the share of alternative fuels	Other	No opinion
National public authorities	13	69%	0%	23%	8%
Ship owning and ship management	37	65%	14%	11%	11%
Short sea shipping	24	63%	13%	17%	8%
Ports management and administrations	13	38%	15%	23%	23%
Port terminal operator or other port services	13	38%	15%	15%	31%
Inland waterways sector	8	50%	0%	25%	25%
Shipbuilding and marine equipment manufacturers	10	80%	20%	0%	0%
Academia, research and innovation	12	50%	17%	33%	0%
Energy producers and fuel supply	37	49%	22%	24%	5%
Interest organisations	13	31%	15%	31%	23%

Table 17 How should requirements for the use of sustainable alternative fuels and power be set for ships at berth?

	number of contributions	Performance requirements based on the	Requirements on the share of sustainable	Other	No opinion
National public authorities	13	54%	23%	15%	8%
Ship owning and ship management	36	53%	25%	14%	8%
Short sea shipping	23	52%	13%	26%	9%
Ports management and administrations	13	31%	31%	23%	15%
Port terminal operator or other port services	13	31%	31%	31%	8%
Inland waterways sector	7	43%	0%	29%	29%
Shipbuilding and marine equipment manufacturers	9	67%	33%	0%	0%
Academia, research and innovation	12	33%	42%	25%	0%
Energy producers and fuel supply	34	50%	21%	21%	9%
Interest organisations	13	23%	23%	15%	38%

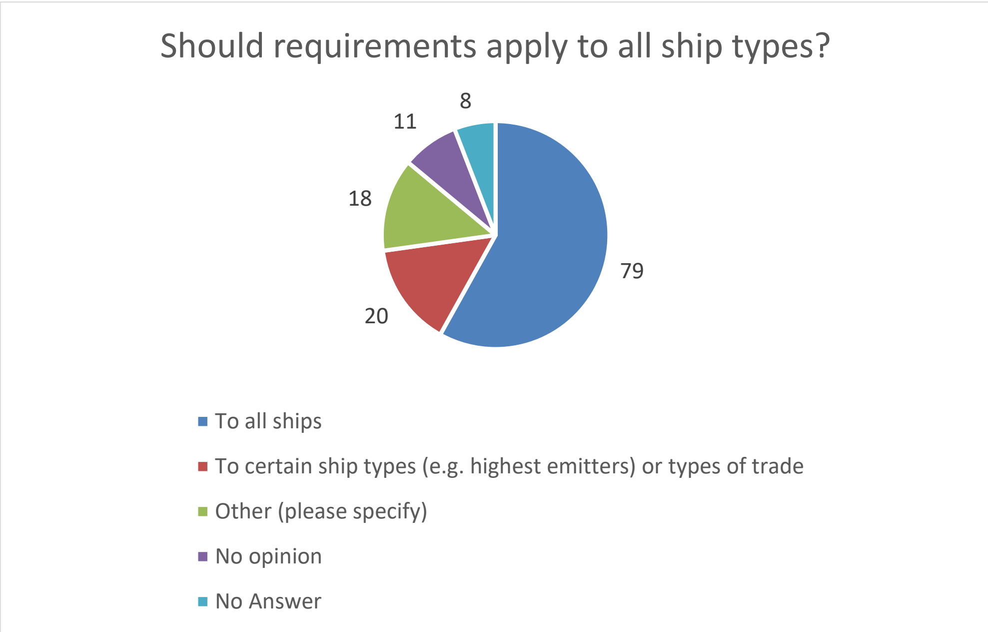

Figure 41 Should requirements apply to all ship types?

Table 18 To whom should these requirements apply?

	number of contributions	To all ships	To certain ship types	Other	No opinion
National public authorities	13	69%	8%	23%	0%
Ship owning and ship management	38	61%	16%	13%	11%
Short sea shipping	24	46%	29%	13%	13%
Ports management and administrations	13	69%	23%	0%	8%
Port terminal operator or other port services	12	58%	17%	17%	8%
Inland waterways sector	9	56%	22%	11%	11%
Shipbuilding and marine equipment manufacturers	9	78%	22%	0%	0%
Academia, research and innovation	12	83%	17%	0%	0%
Energy producers and fuel supply	37	51%	16%	22%	11%
Interest organisations	13	77%	15%	8%	0%

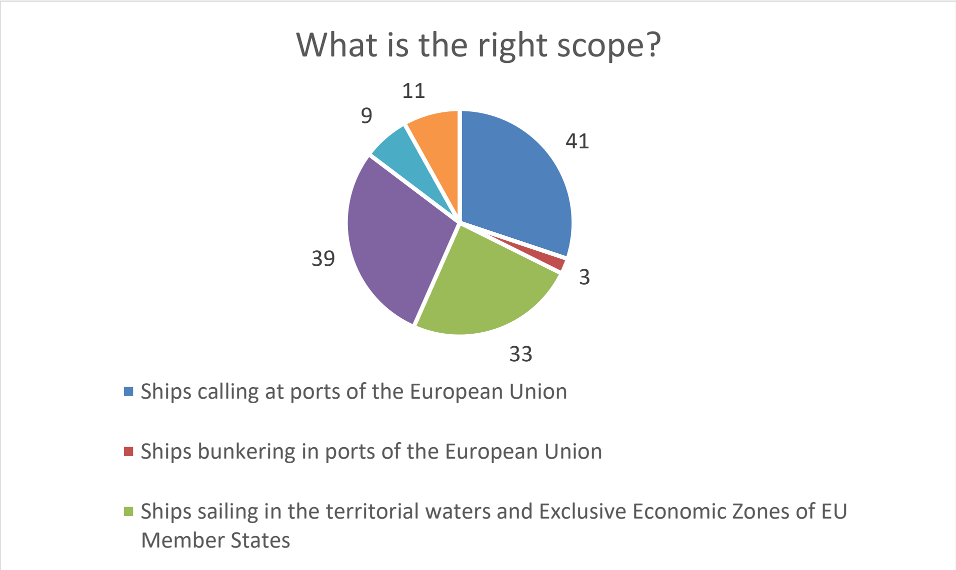

Figure 42 Scope of measures.

Table 19 What would be an appropriate scope of these measures?

		Ships calling at ports of the European Union	Ships bunkering in ports of the European Union	Ships sailing in the territorial waters and Exclusive Economic Zones of EU	Other	No opinion
National public authorities	13	38%	0%	15%	38%	8%
Ship owning and ship management	37	32%	0%	30%	32%	5%
Short sea shipping	24	29%	0%	29%	38%	4%
Ports management and administrations	13	46%	0%	38%	15%	0%
Port terminal operator or other port services	13	38%	0%	23%	38%	0%
Inland waterways sector	9	0%	0%	67%	11%	22%
Shipbuilding and marine equipment manufacturers	9	22%	0%	33%	22%	22%
Academia, research and innovation	12	58%	0%	33%	8%	0%
Energy producers and fuel supply	35	29%	6%	26%	34%	6%
Interest organisations	12	25%	0%	67%	8%	0%

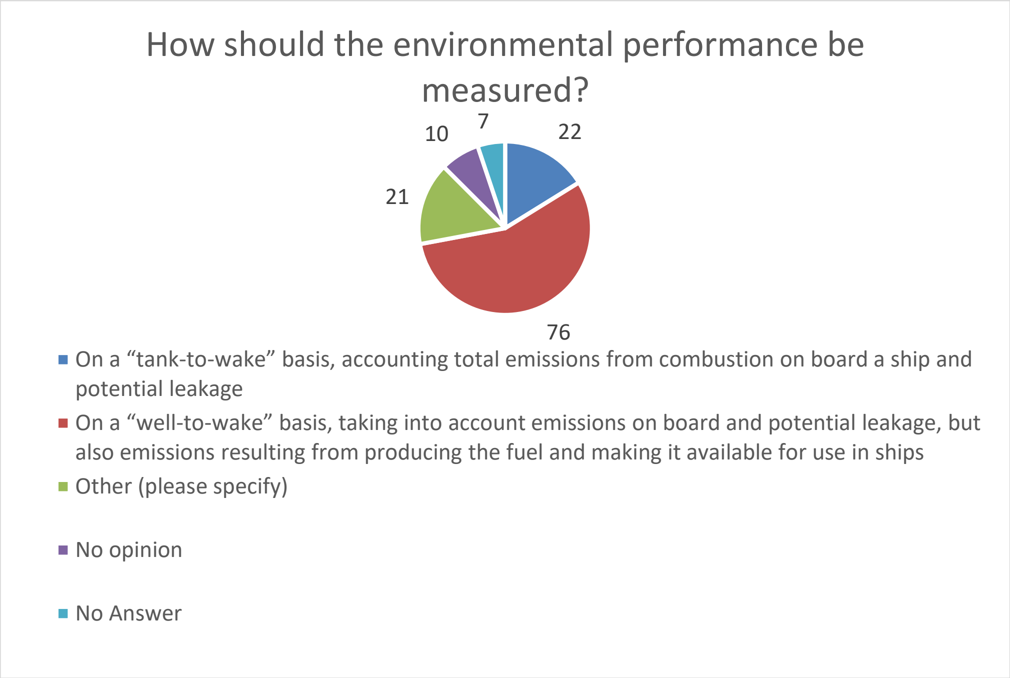

Figure 43 How should the environmental performance be measured?

Table 20 How should emissions be calculated?

		On a "tank-to-wake" basis	On a "well-to-wake" basis	Other	No opinion
National public authorities	12	33%	67%	0%	0%
Ship owning and ship management	27	44%	56%	0%	0%
Short sea shipping	18	22%	78%	0%	0%
Ports management and administrations	9	11%	89%	0%	0%
Port terminal operator or other port services	9	33%	67%	0%	0%
Inland waterways sector	6	17%	83%	0%	0%
Shipbuilding and marine equipment manufacturers	10	10%	90%	0%	0%
Academia, research and innovation	11	9%	91%	0%	0%
Energy producers and fuel supply	27	7%	93%	0%	0%
Interest organisations	9	11%	89%	0%	0%

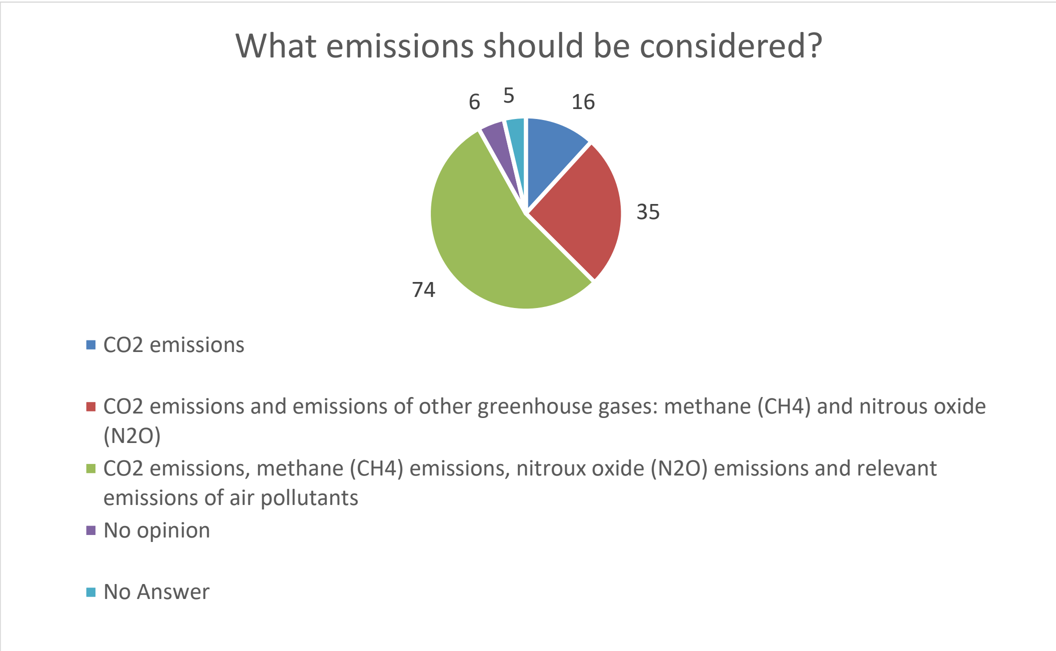

Figure 44 What emissions should be measured?

Table 21 What emissions should be included?

		CO2 emissions	CO2 emissions and emissions of other greenhouse gases	Greenhouse gas- and air quality emissions	No opinion
National public authorities	14	21%	7%	71%	0%
Ship owning and ship management	37	27%	32%	38%	3%
Short sea shipping	24	21%	29%	46%	4%
Ports management and administrations	13	23%	15%	62%	0%
Port terminal operator or other port services	13	23%	31%	46%	0%
Inland waterways sector	9	0%	11%	78%	11%
Shipbuilding and marine equipment manufacturers	10	20%	10%	70%	0%
Academia, research and innovation	12	0%	17%	83%	0%
Energy producers and fuel supply	37	5%	43%	51%	0%
Interest organisations	14	0%	14%	86%	0%

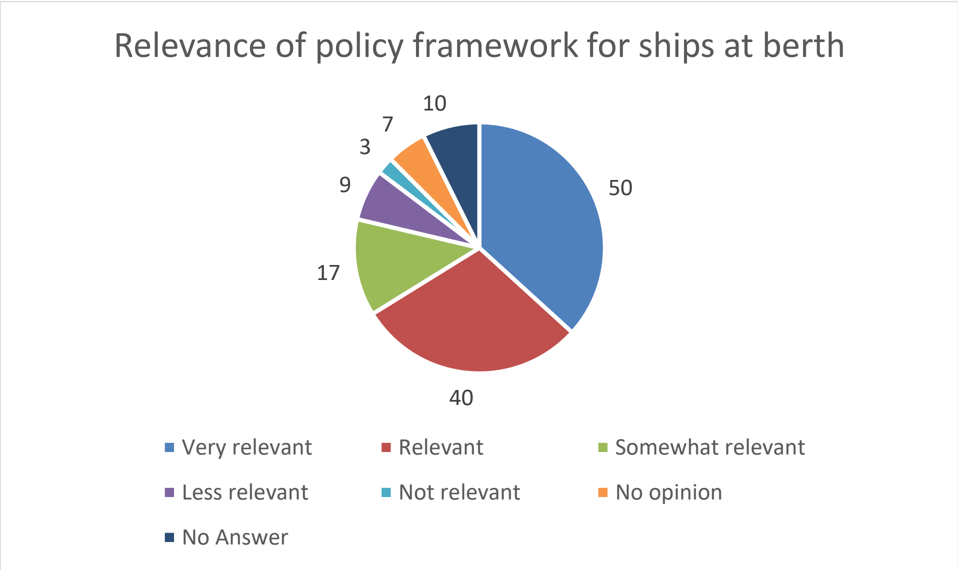

Figure 45 Relevance of a policy framework for ships at berth.

Table 22 How relevant is it to establish a regulatory framework specifically addressing emissions produced by ships at berth?

		Very relevant	Relevant	Somewhat relevant	Less relevant	Not relevant	No opinion
National public authorities	14	43%	29%	21%	7%	0%	0%
Ship owning and ship management	36	31%	25%	22%	11%	8%	3%
Short sea shipping	24	29%	29%	17%	8%	13%	4%
Ports management and administrations	13	38%	38%	15%	8%	0%	0%
Port terminal operator or other port services	13	31%	31%	15%	15%	0%	8%
Inland waterways sector	9	22%	67%	0%	0%	0%	11%
Shipbuilding and marine equipment manufacturers	9	33%	44%	22%	0%	0%	0%
Academia, research and innovation	12	58%	33%	0%	0%	0%	8%
Energy producers and fuel supply	35	40%	34%	11%	6%	0%	9%
Interest organisations	14	71%	21%	0%	0%	0%	7%

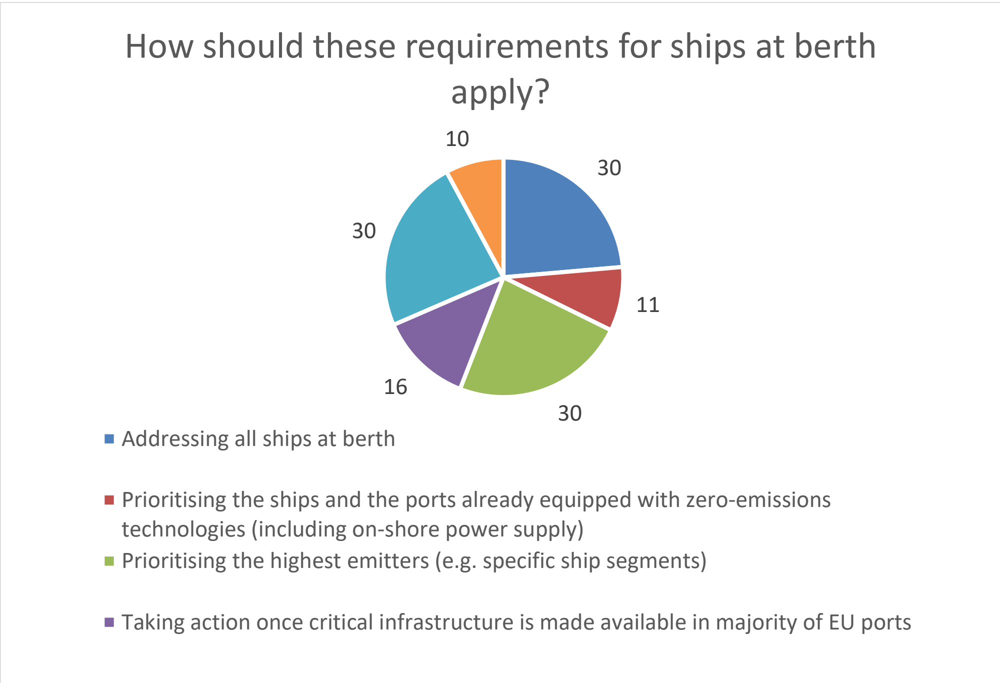

Figure 46 How should these requirements for ships at berth apply?

Table 23 Do you have any views on how these requirements for ships at berth should apply?

		Addressing all ships at berth	Prioritising the ships and the ports already equipped with zero-emissions	Prioritising the highest emitters	Taking action once infrastructure is available in majority of EU ports	Other	No opinion	
National public authorities	13	23%	0%	15%	8%	46%	8%	1,0
Ship owning and ship management	36	17%	19%	19%	25%	19%	0%	1,0
Short sea shipping	24	8%	13%	25%	25%	25%	4%	1,0
Ports management and administrations	13	23%	8%	15%	15%	31%	8%	1,0
Port terminal operator or other port services	13	8%	0%	15%	31%	38%	8%	1,0
Inland waterways sector	9	22%	11%	44%	0%	0%	22%	1,0
Shipbuilding and marine equipment manufacturers	9	33%	11%	22%	22%	11%	0%	1,0
Academia, research and innovation	12	50%	25%	8%	8%	0%	8%	1,0
Energy producers and fuel supply	35	17%	9%	31%	3%	26%	14%	1,0
Interest organisations	14	50%	14%	14%	7%	0%	14%	1,0

4 TARGETED CONSULTATION RESULTS

In this Chapter, the quantitative survey results of the targeted consultation are presented.

4.1 General characteristics of respondents

There were 32 survey responses to the targeted consultation questionnaire.

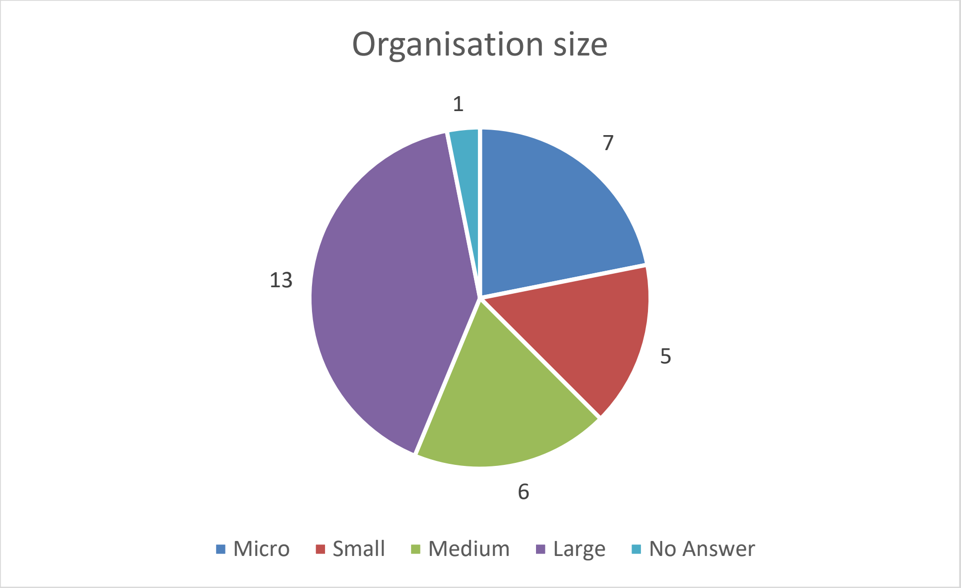

Figure 47 Organization size.

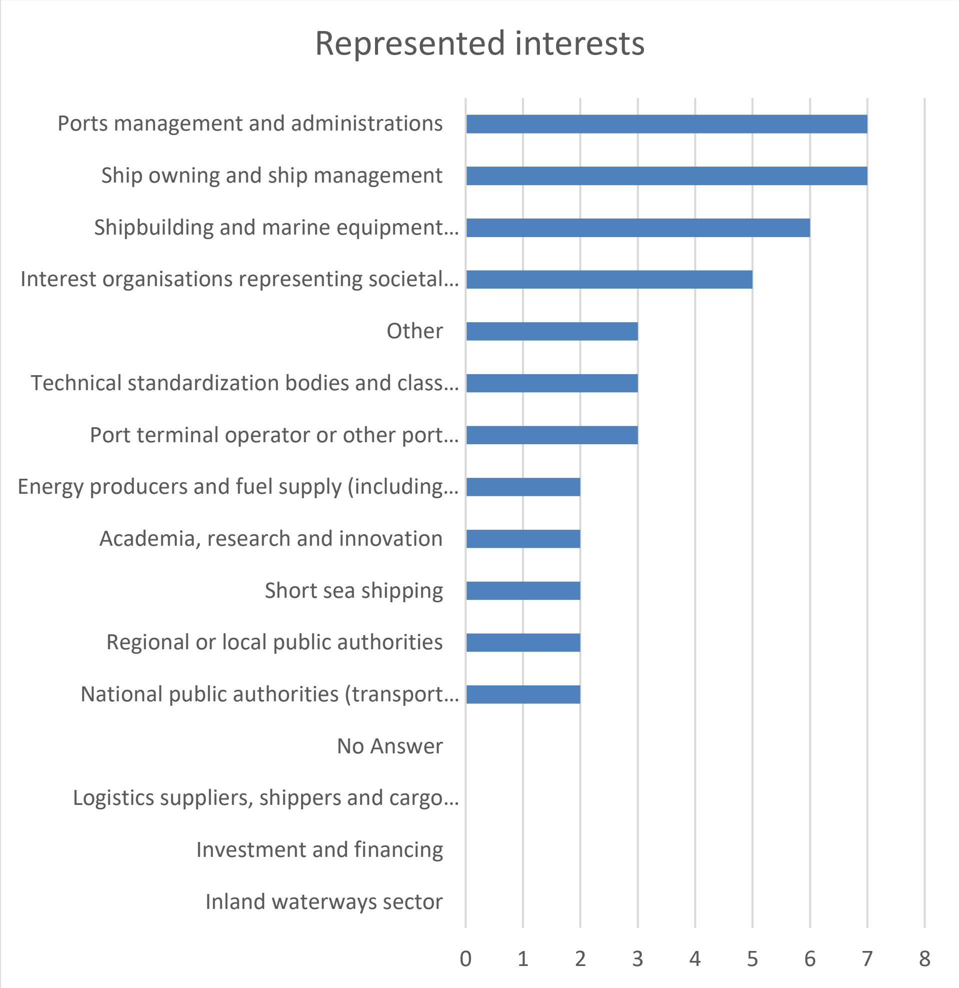

Figure 48 Represented interests.

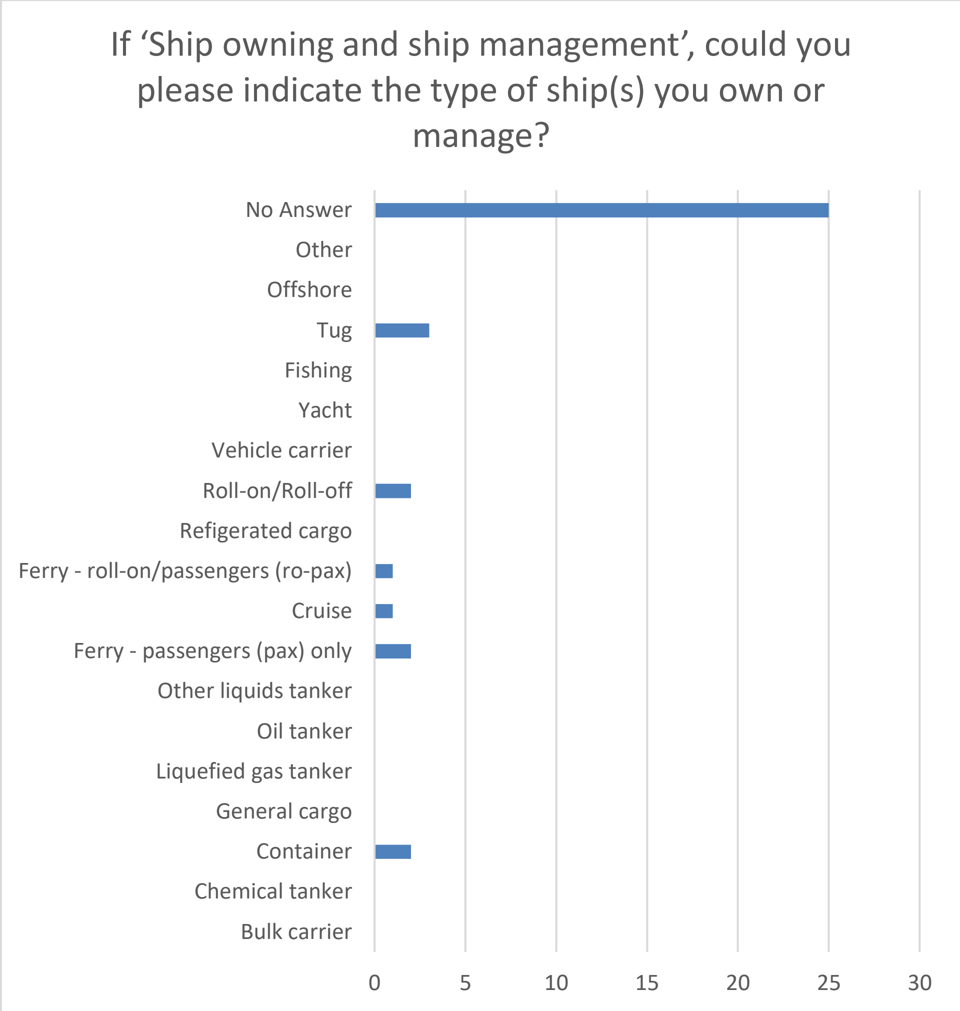

Figure 49 Types of ships owned or managed.

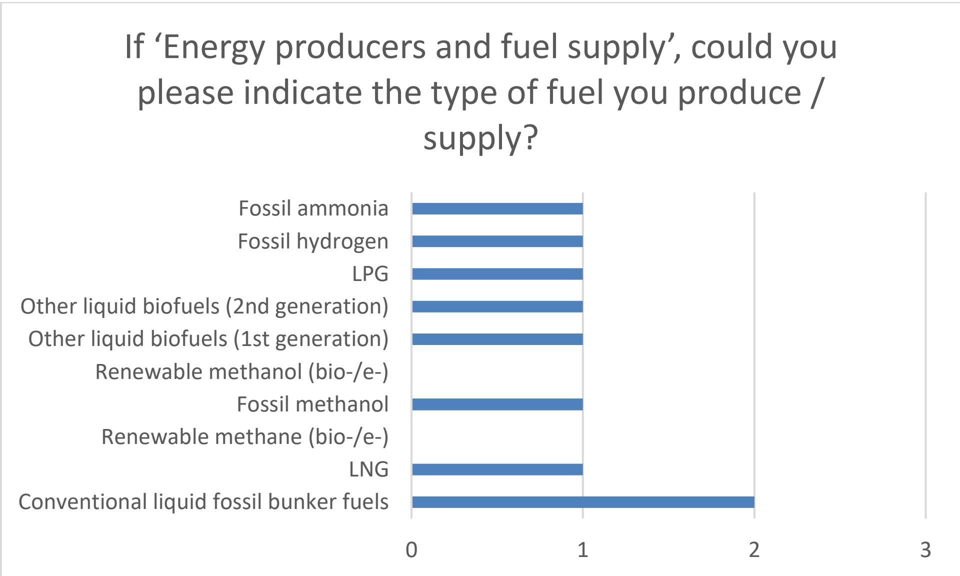

Figure 50 Type of fuel produced or supplied.

4.2 Problems, drivers and specific objectives

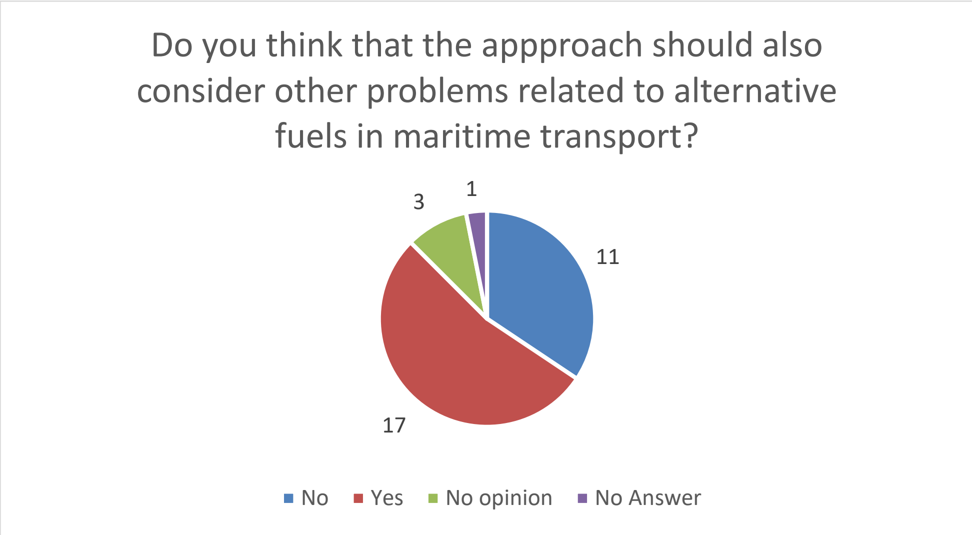

Figure 51 should the initiative consider other problems?

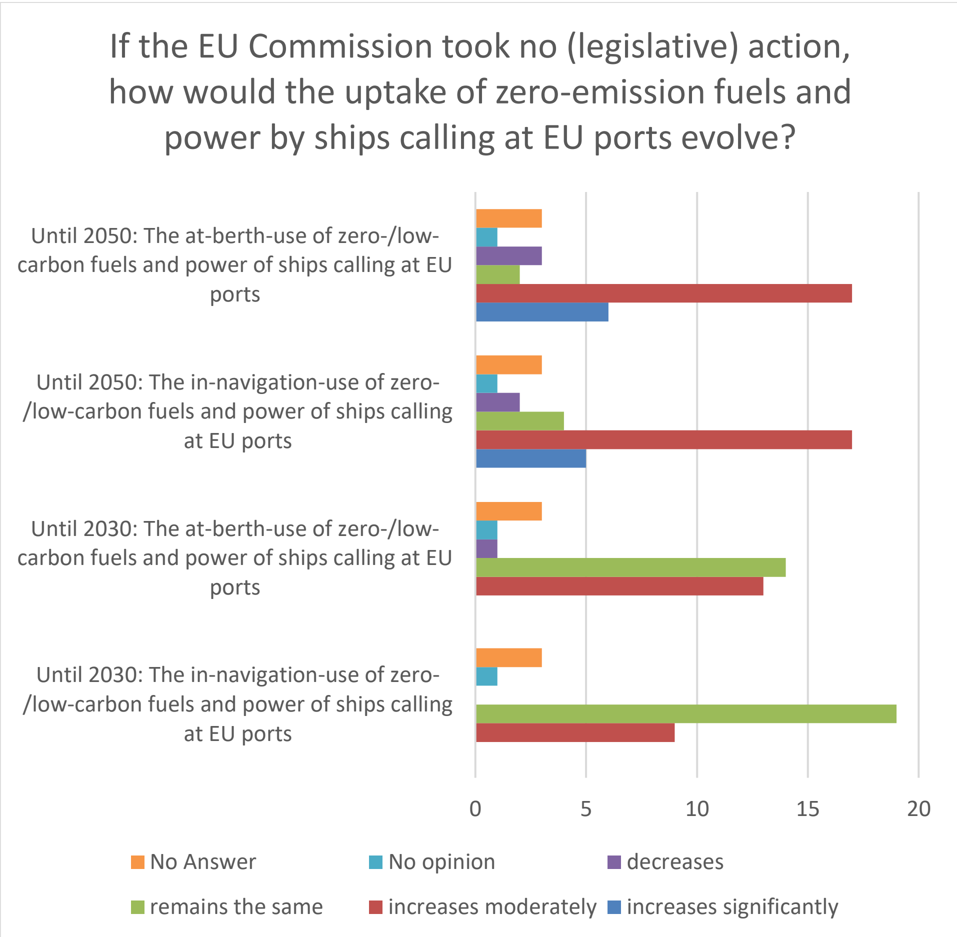

Figure 52 Projections for the uptake of low-carbon fuels.

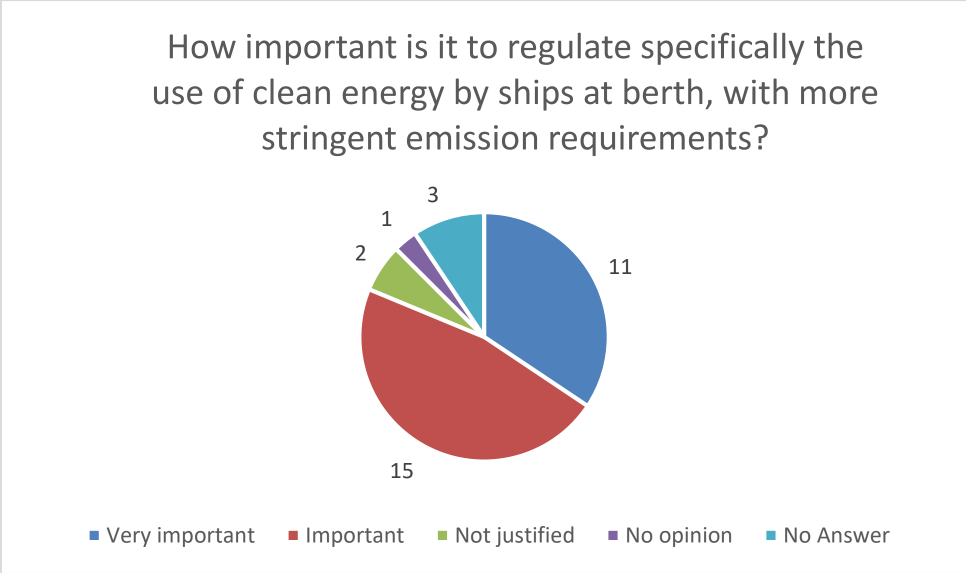

Figure 53 Importance of policy for ships at berth.

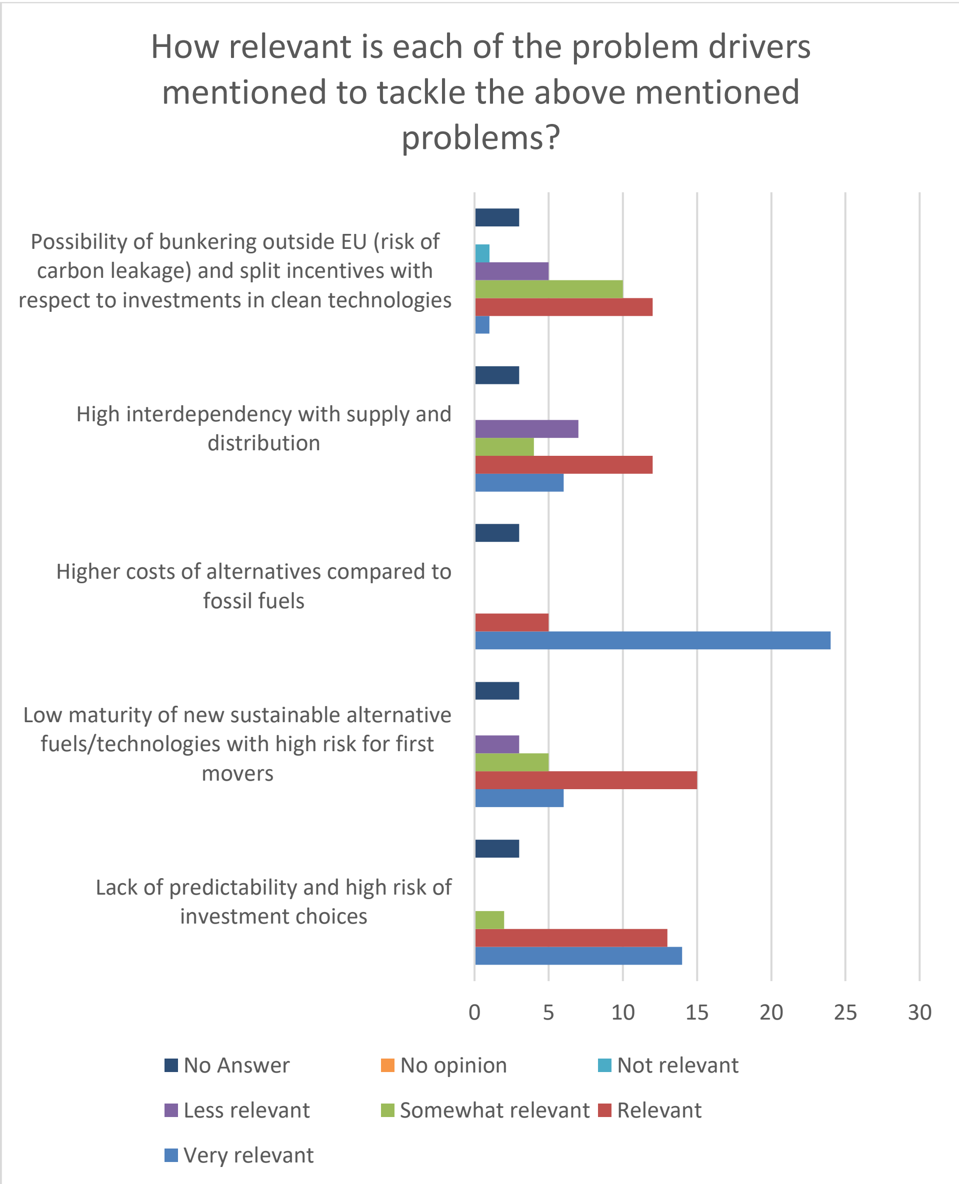

Figure 54 Relevance of problem drivers.

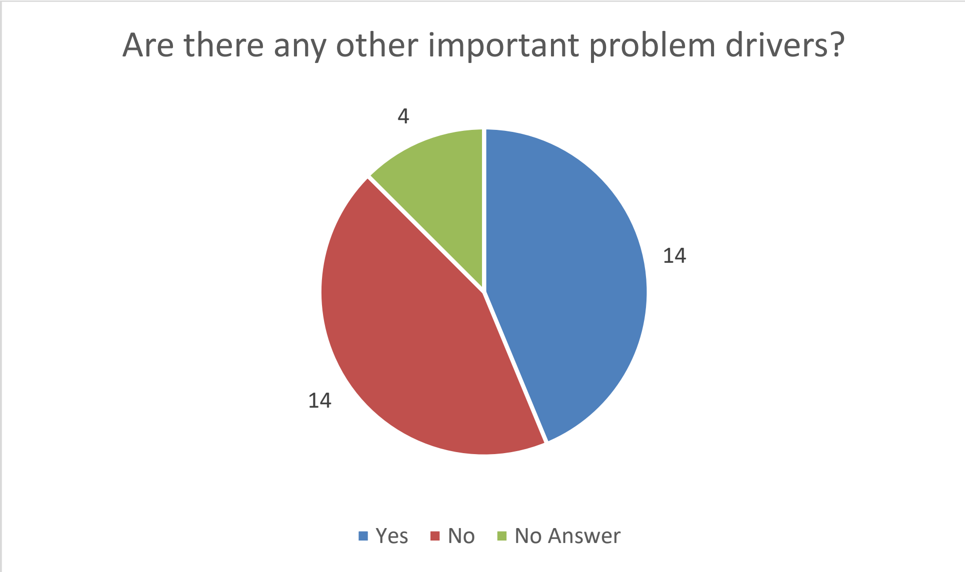

Figure 55 Other relevant problem drivers.

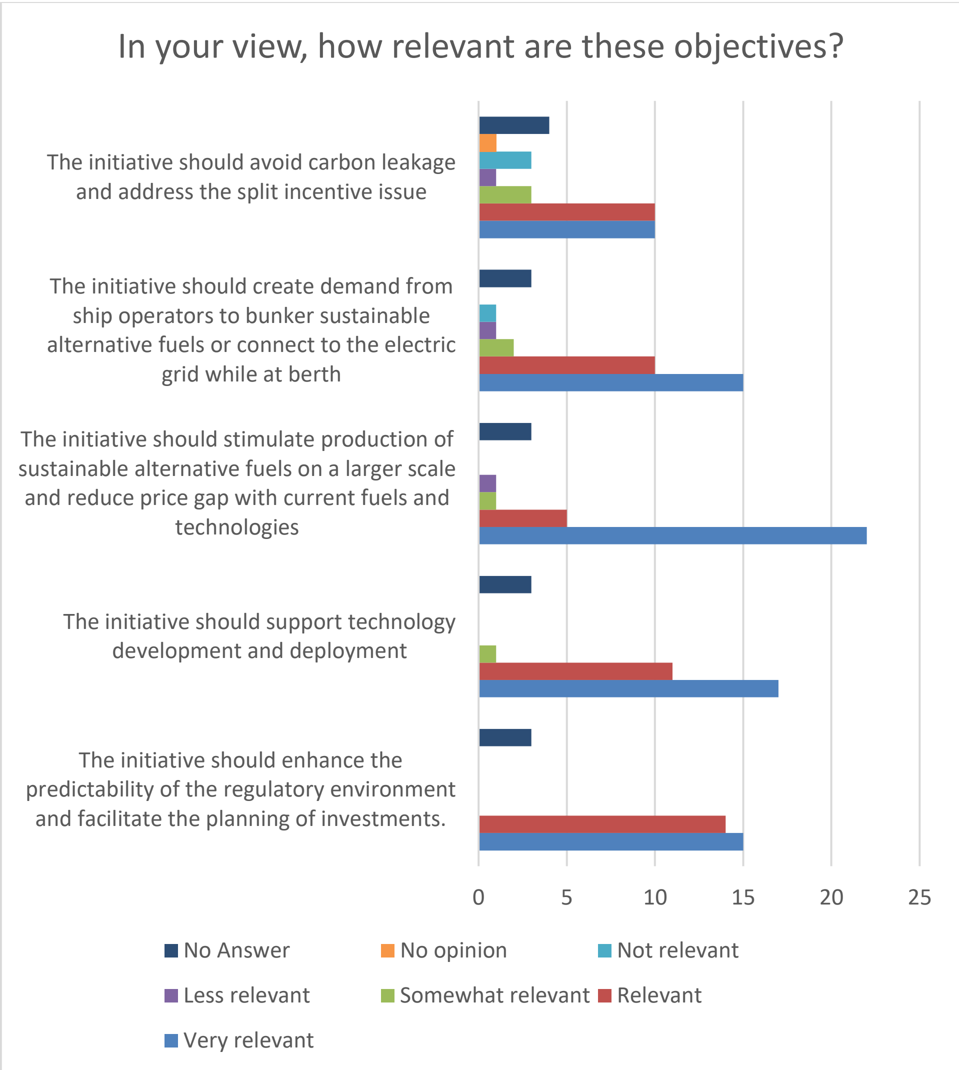

Figure 56 Relevance of objectives.

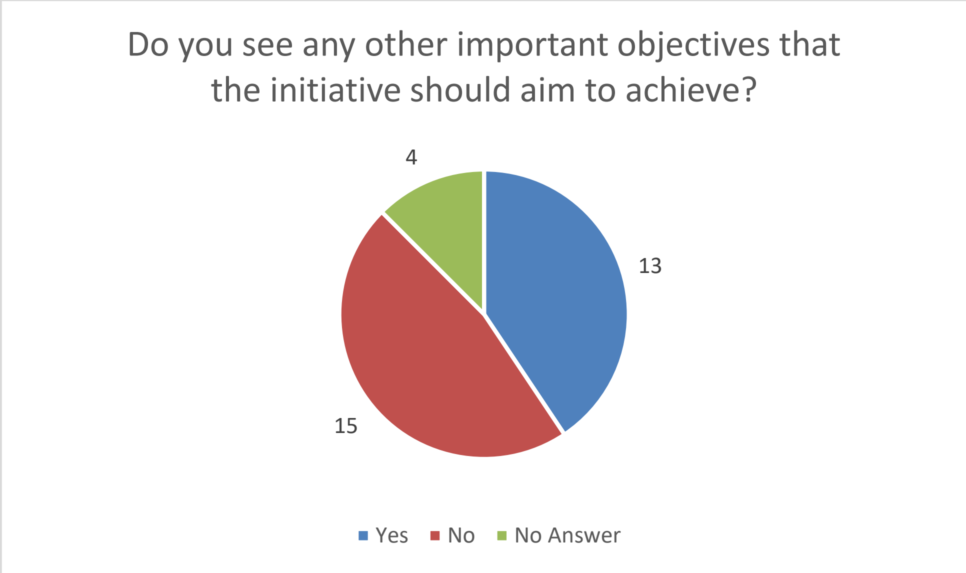

Figure 57 Other important objectives.

4.3 Assessment of sustainable low- or zero carbon fuels and technologies

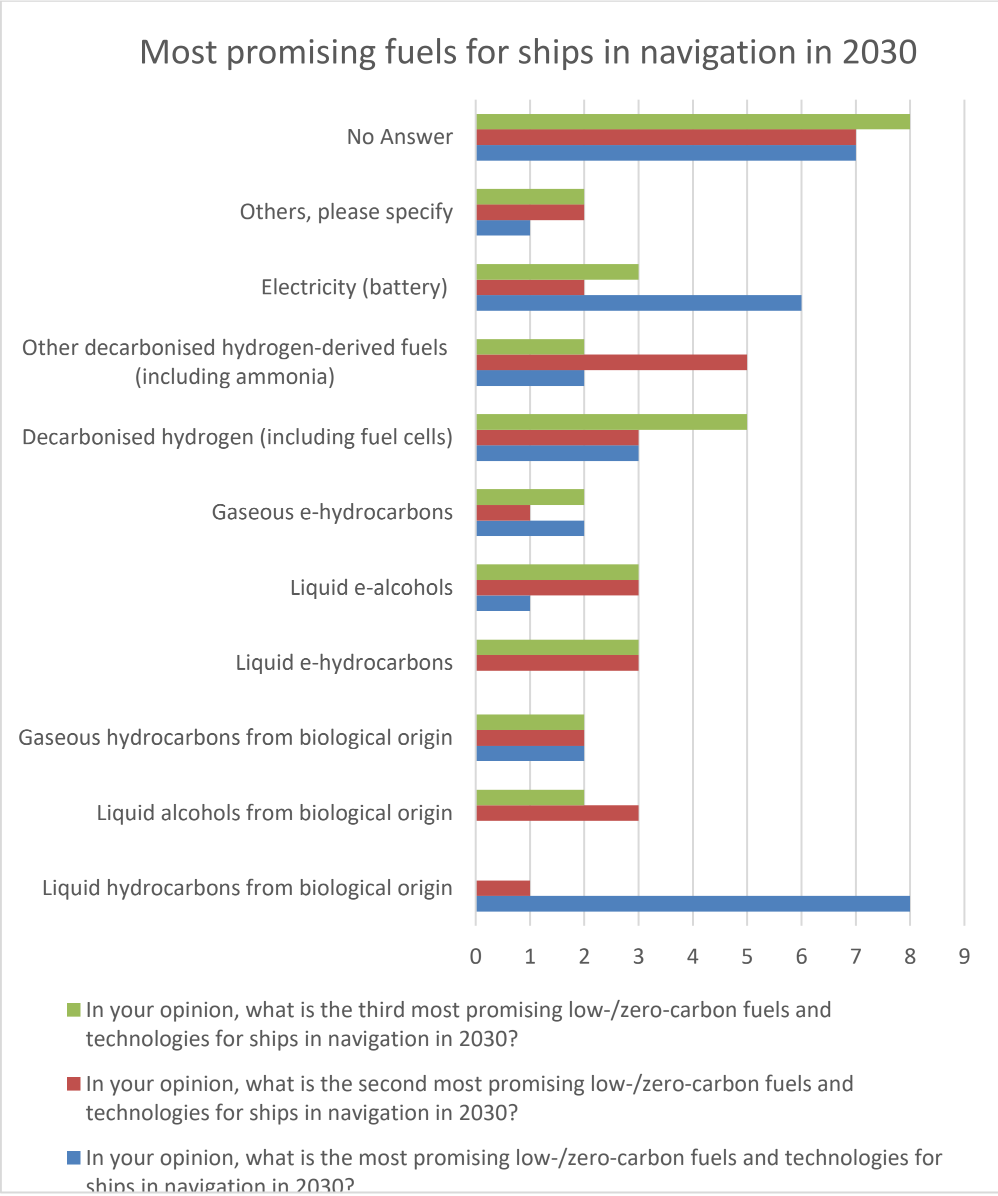

Figure 58 Most promising fuel types for ships in navigation in 2030.

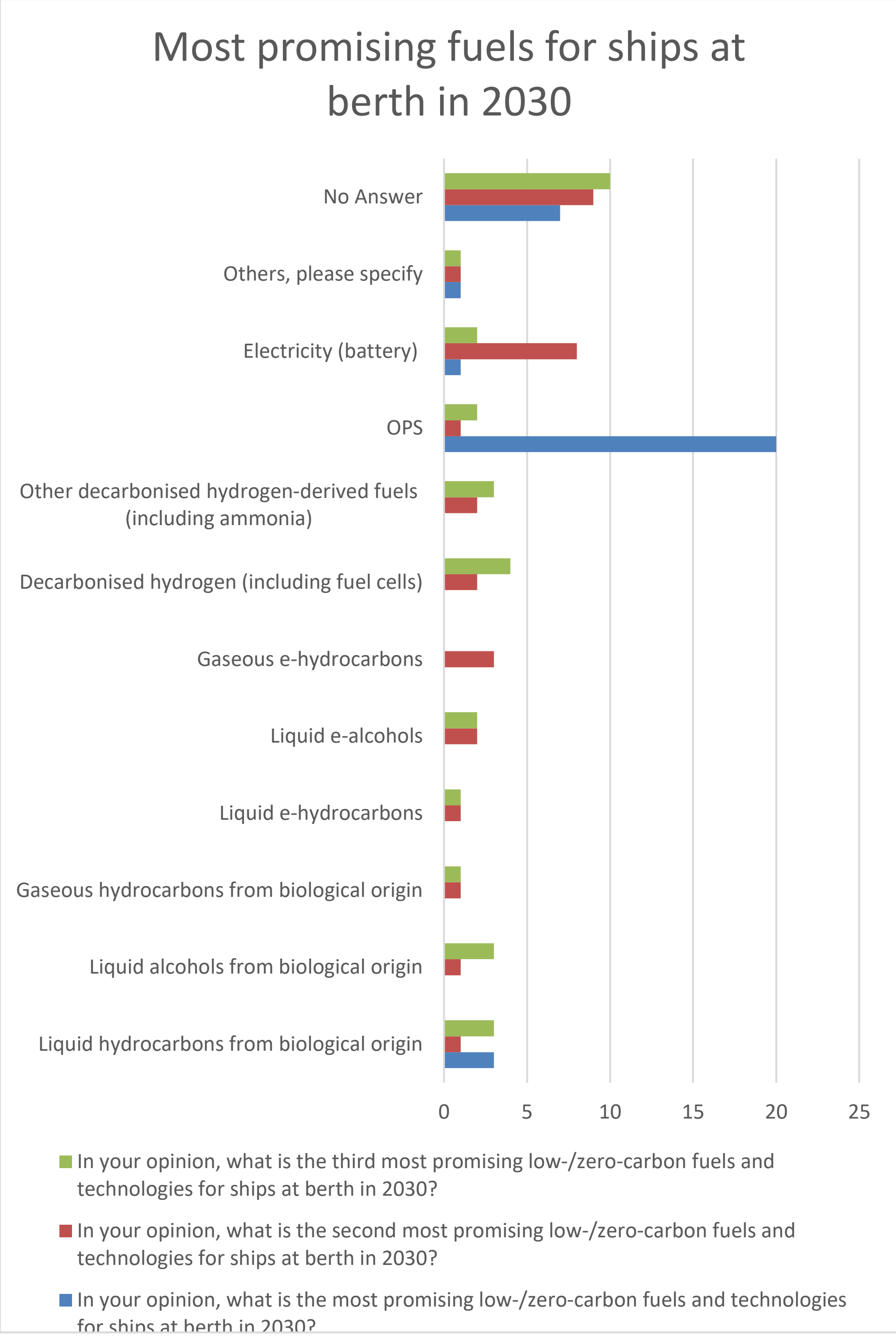

Figure 59 Most promising fuel types for ships at berth in 2030.

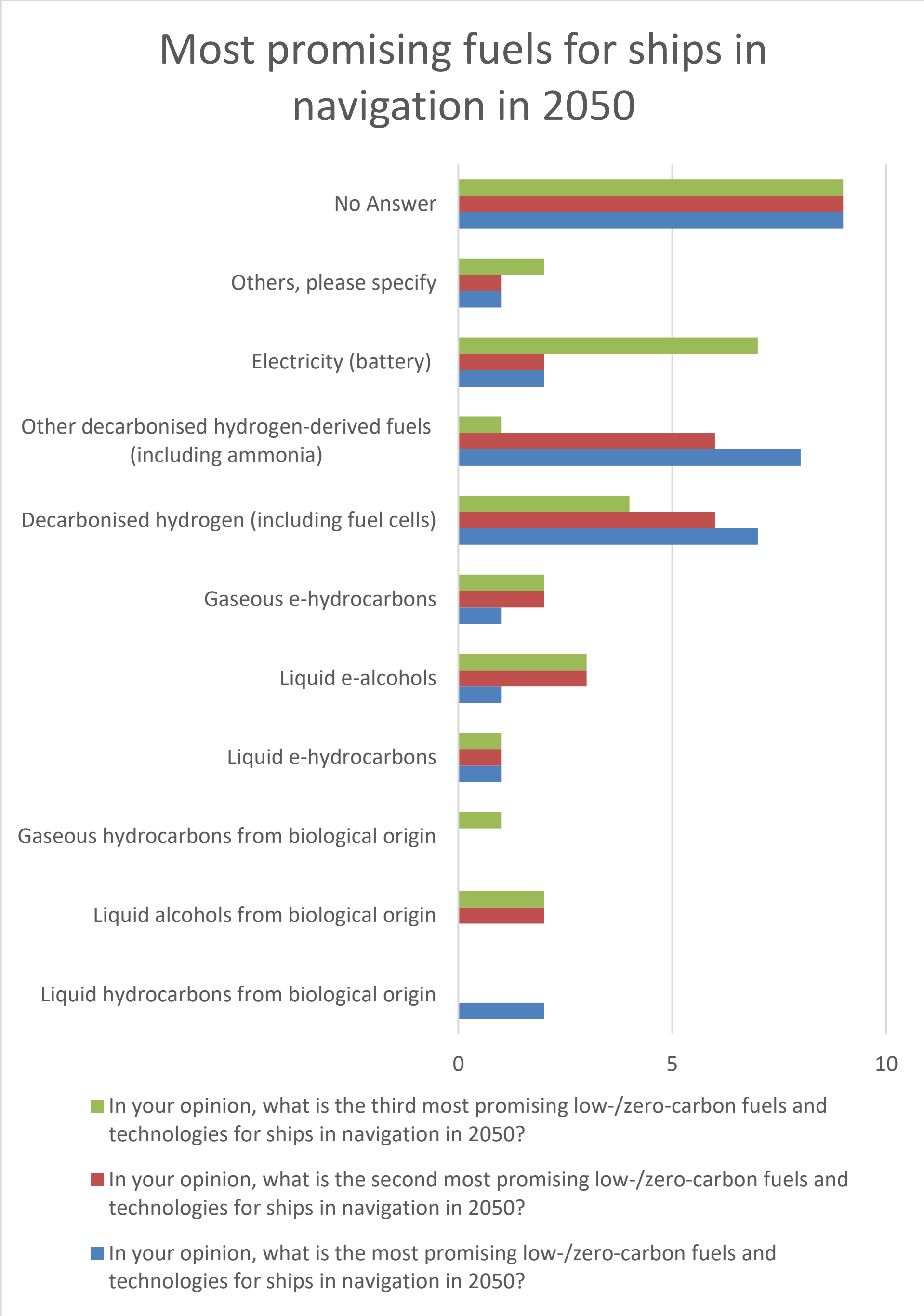

Figure 60 Most promising fuel types for ships in navigation in 2050.

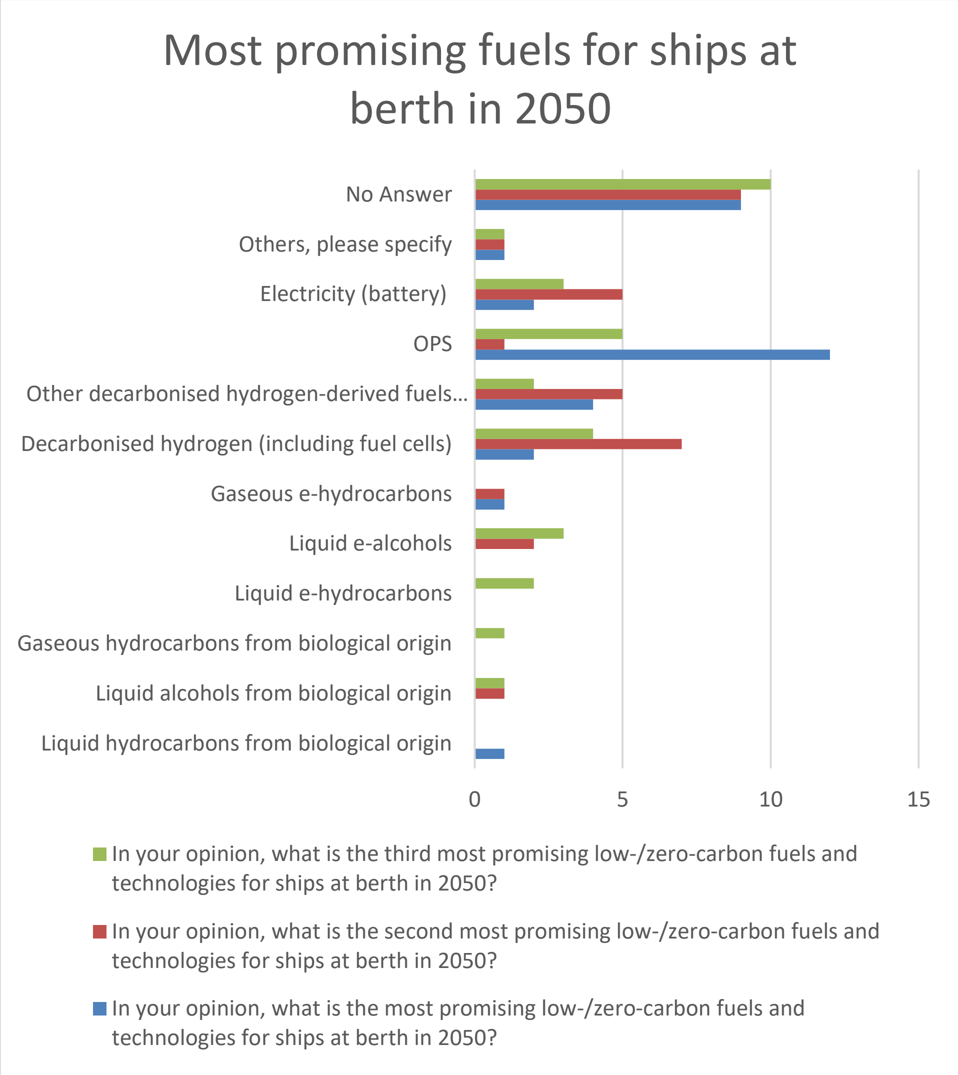

Figure 61 Most promising fuel types for ships at berth in 2050.

4.4 Experience with sustainable alternative fuels and power for maritime transport

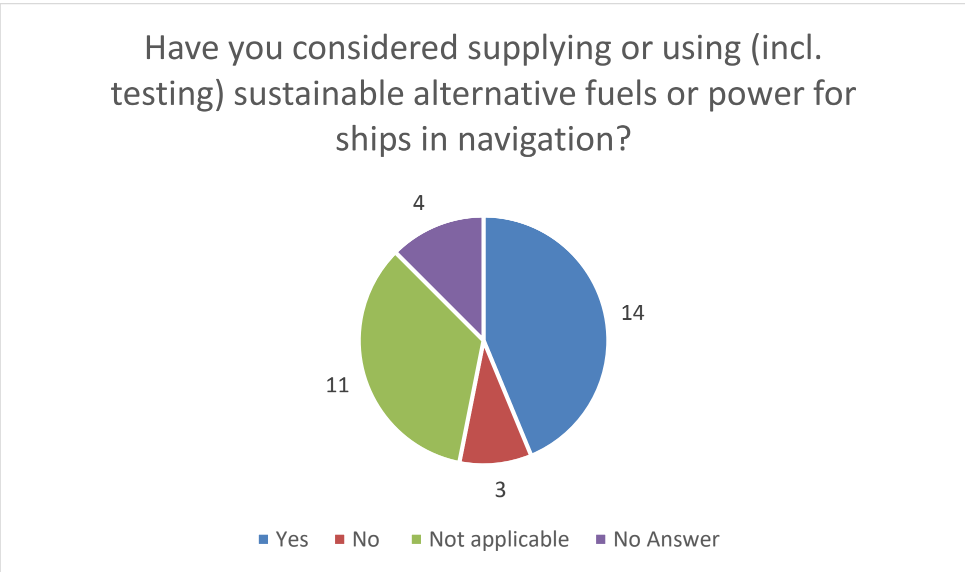

Figure 62 Tests with supplying alternative fuels.

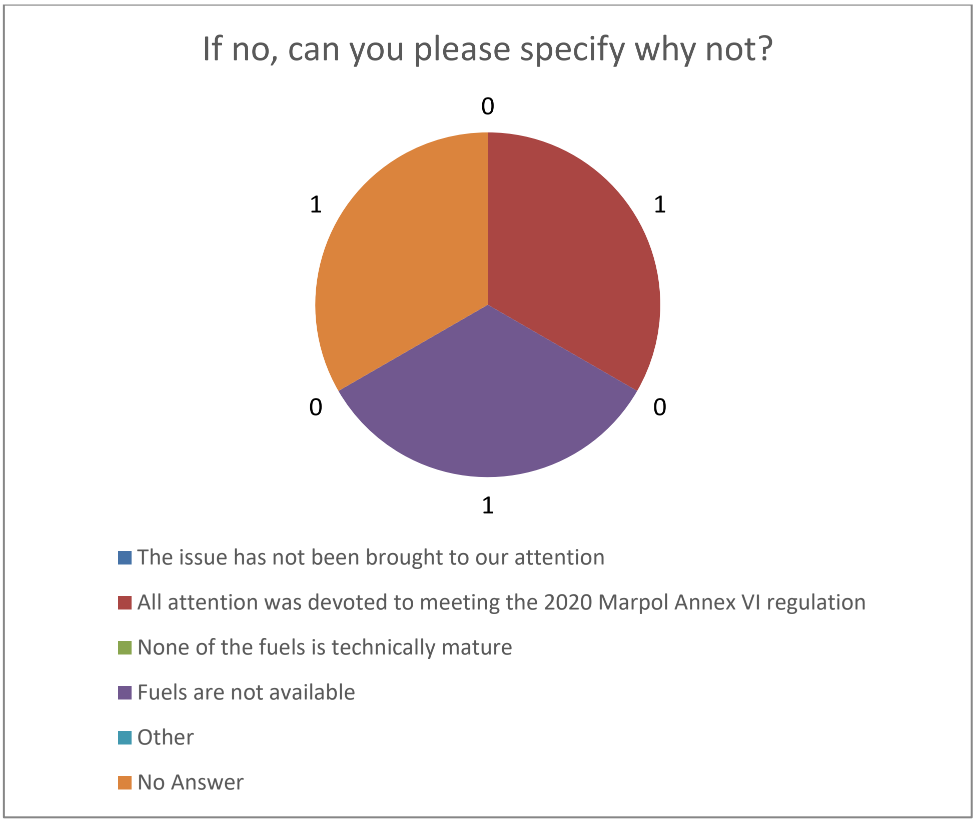

Figure 63 Reasons why stakeholders did not test with alternative fuels.

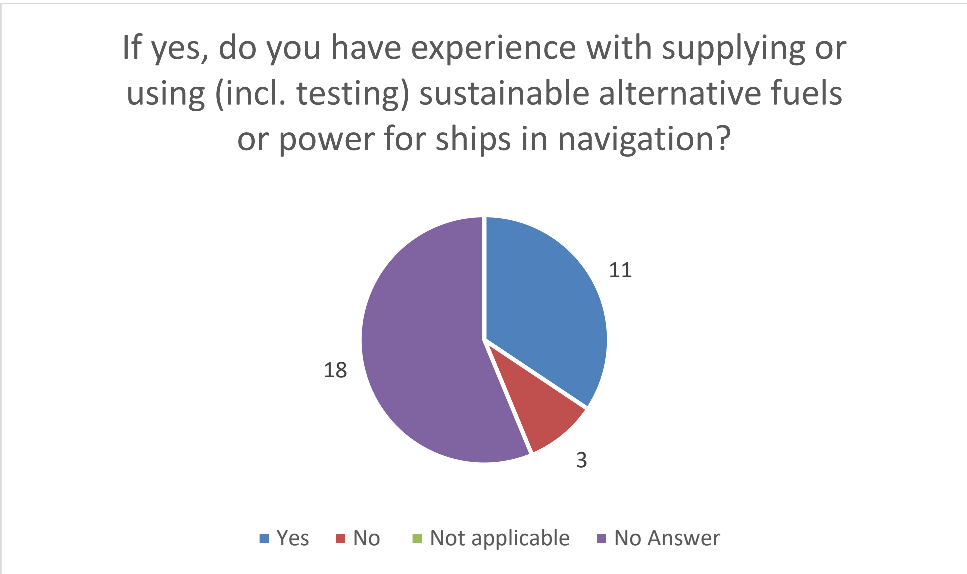

Figure 64 Experience with alternative fuels in navigation.

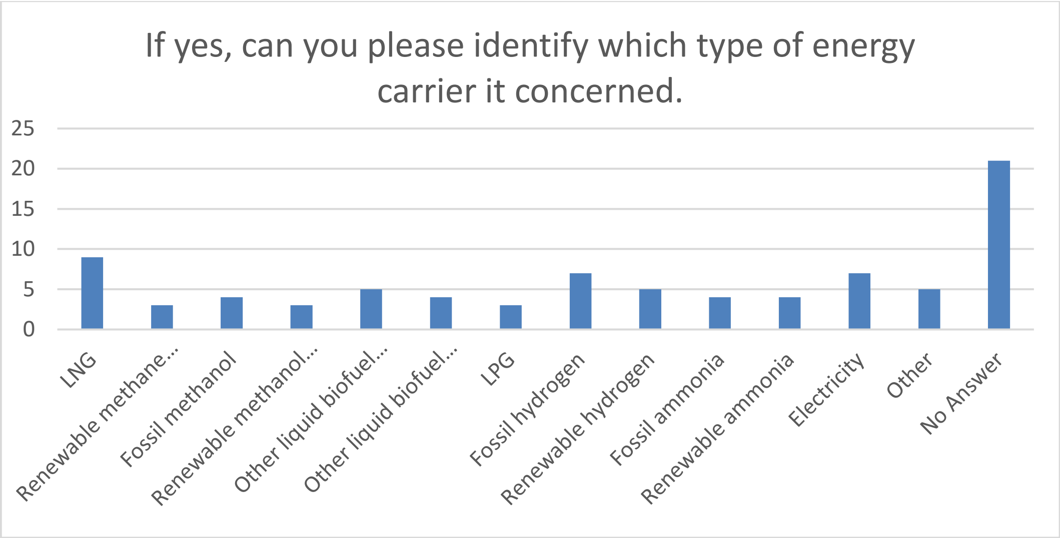

Figure 65 Energy carriers of the low carbon fuel tests.

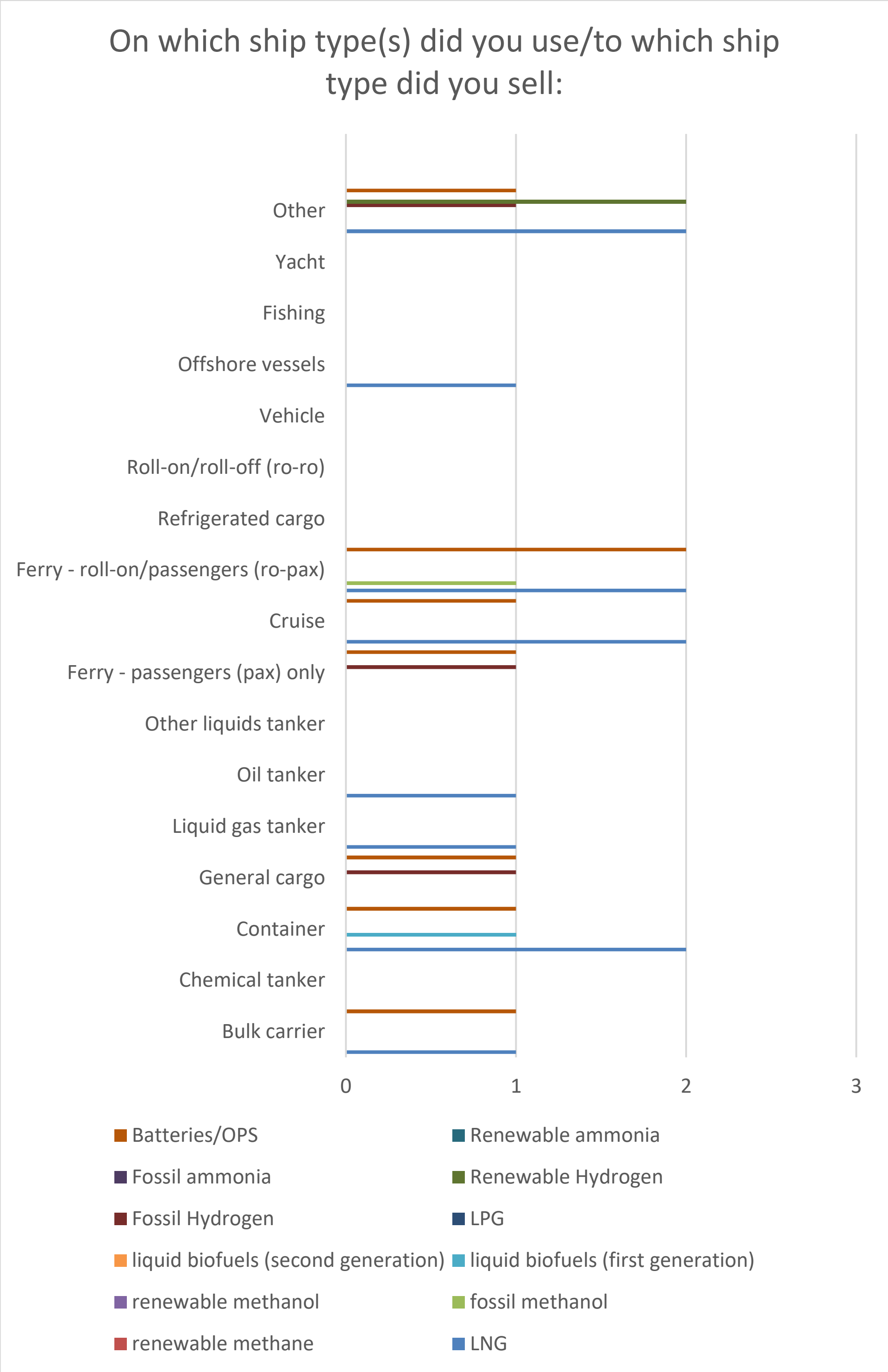

Figure 66 What alternative fuels were used on what vessel types?

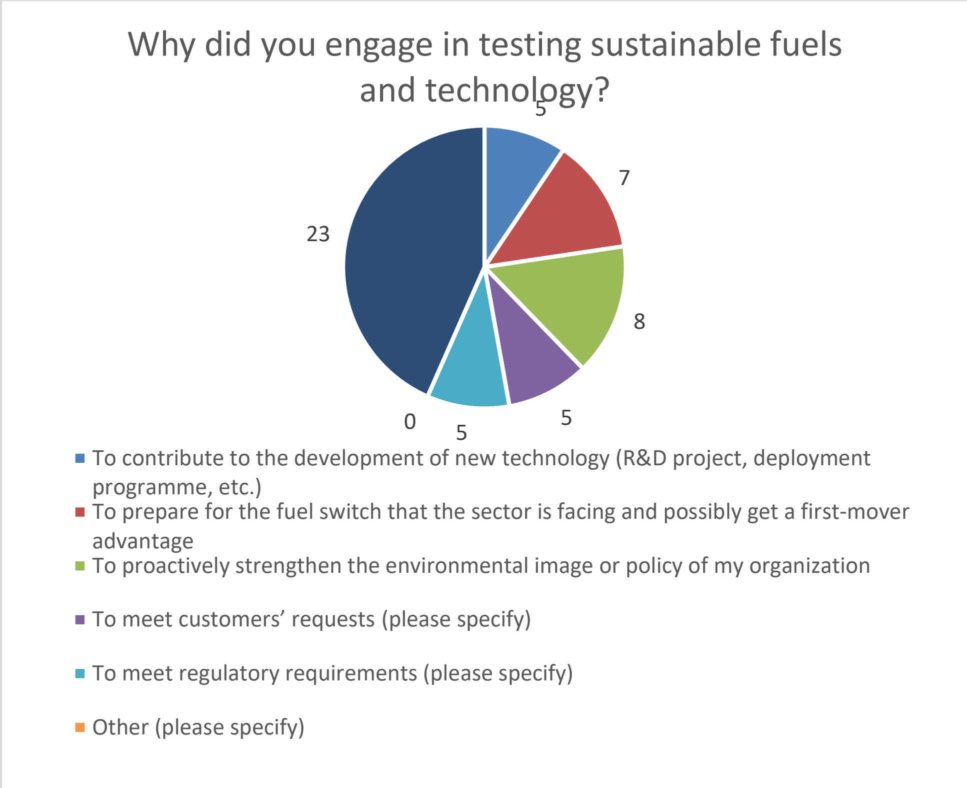

Figure 67 Testing of alternative fuels.

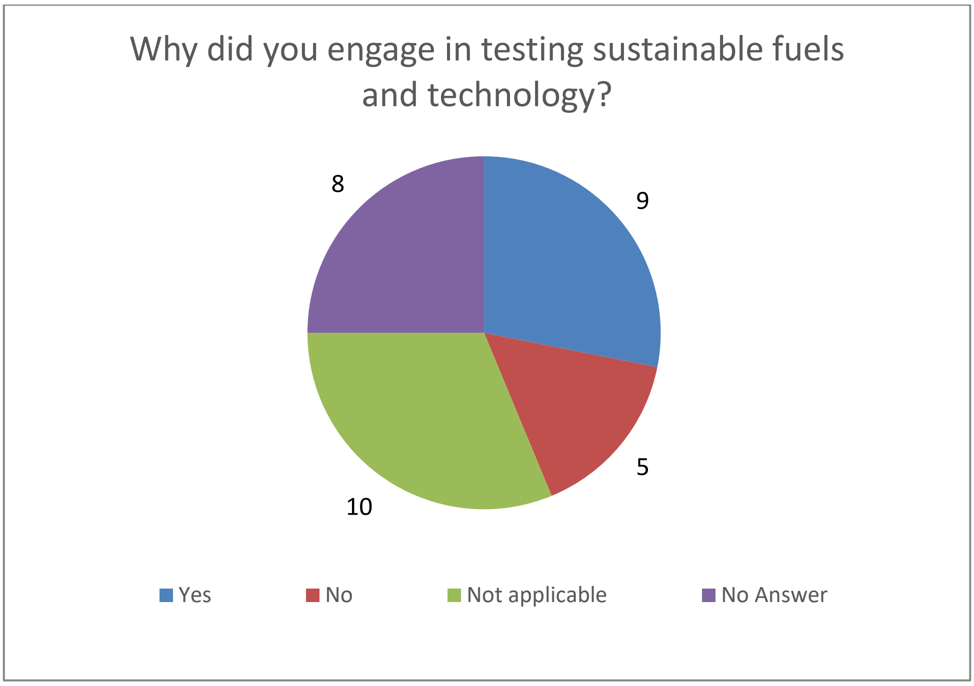

Figure 68 Reasons for testing alternative fuels.

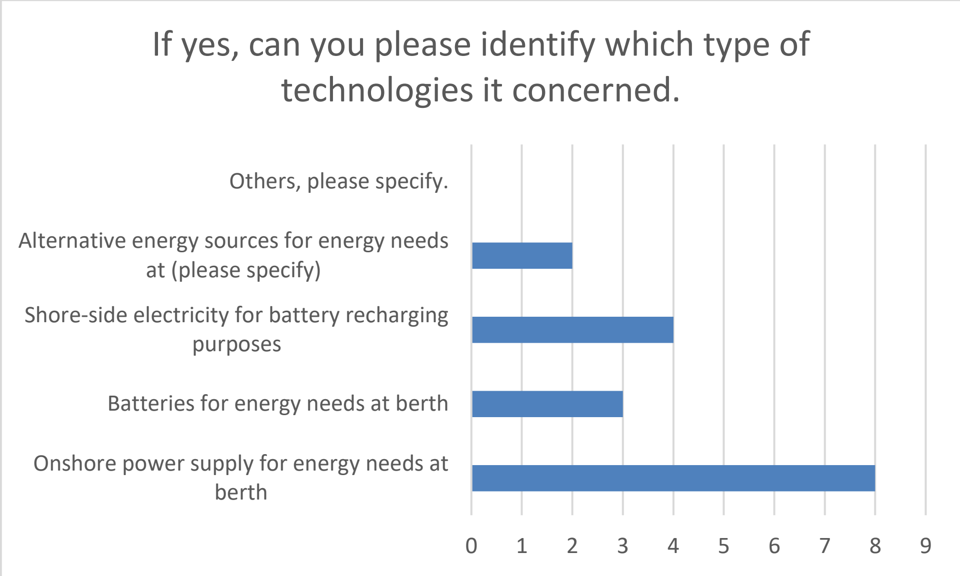

Figure 69 Technology which was tested.

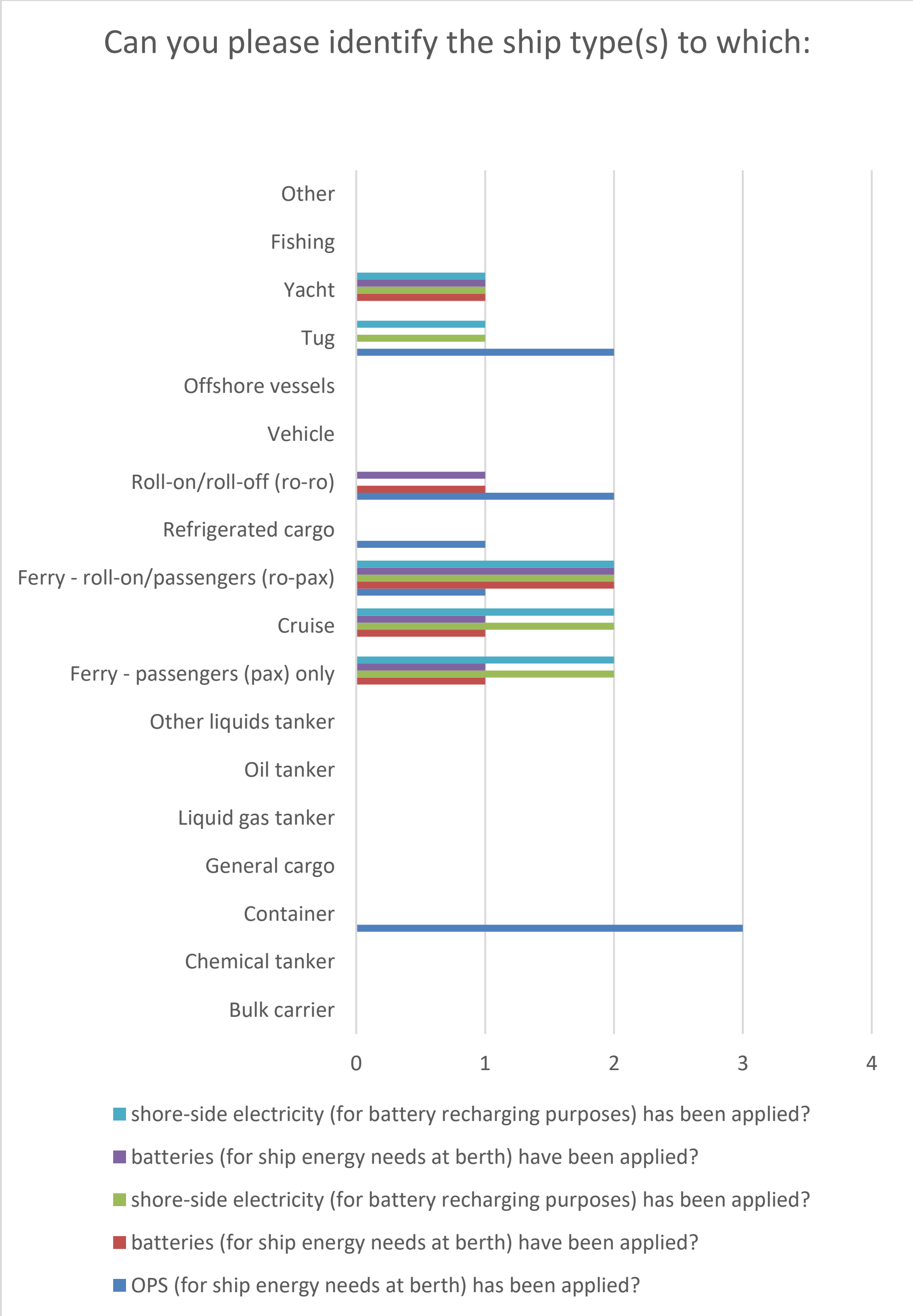

Figure 70 Ship types to which the alternative fuel technologies have been applied.

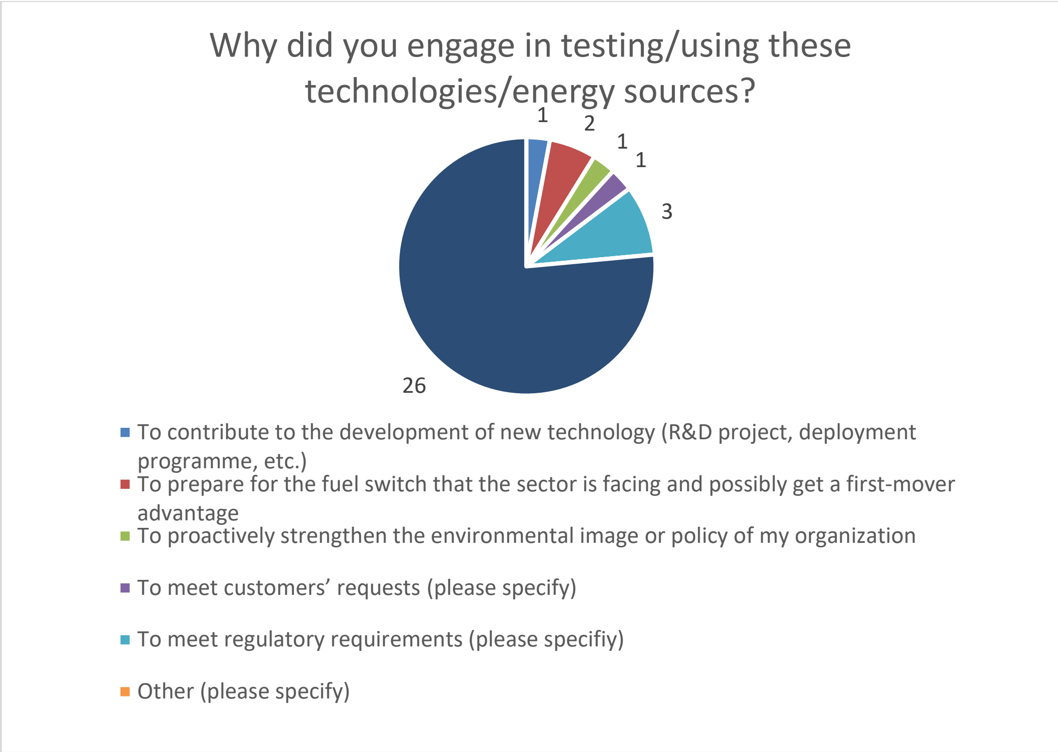

Figure 71 Reasons for testing these alternative energy sources.

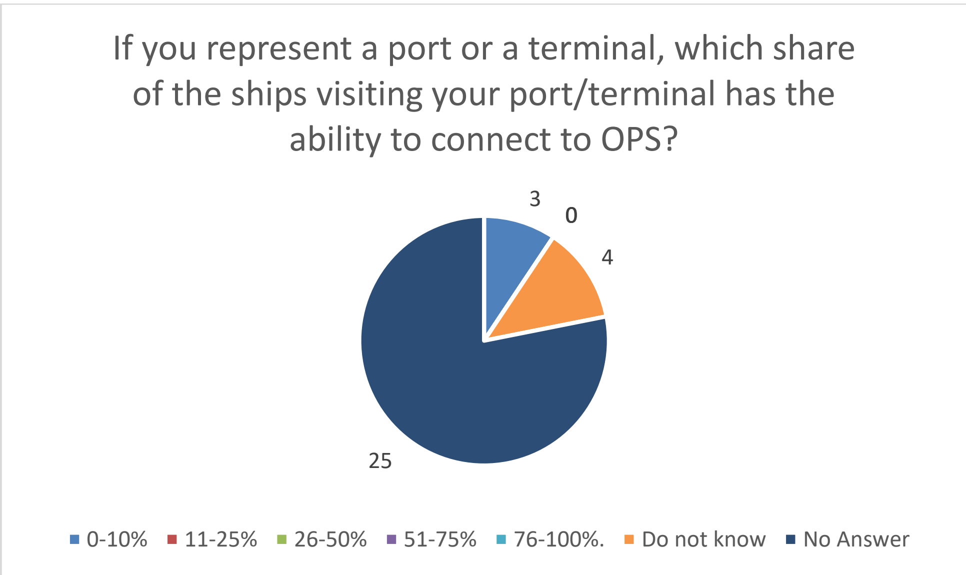

Figure 72 Ship-side compatibility of OPS.

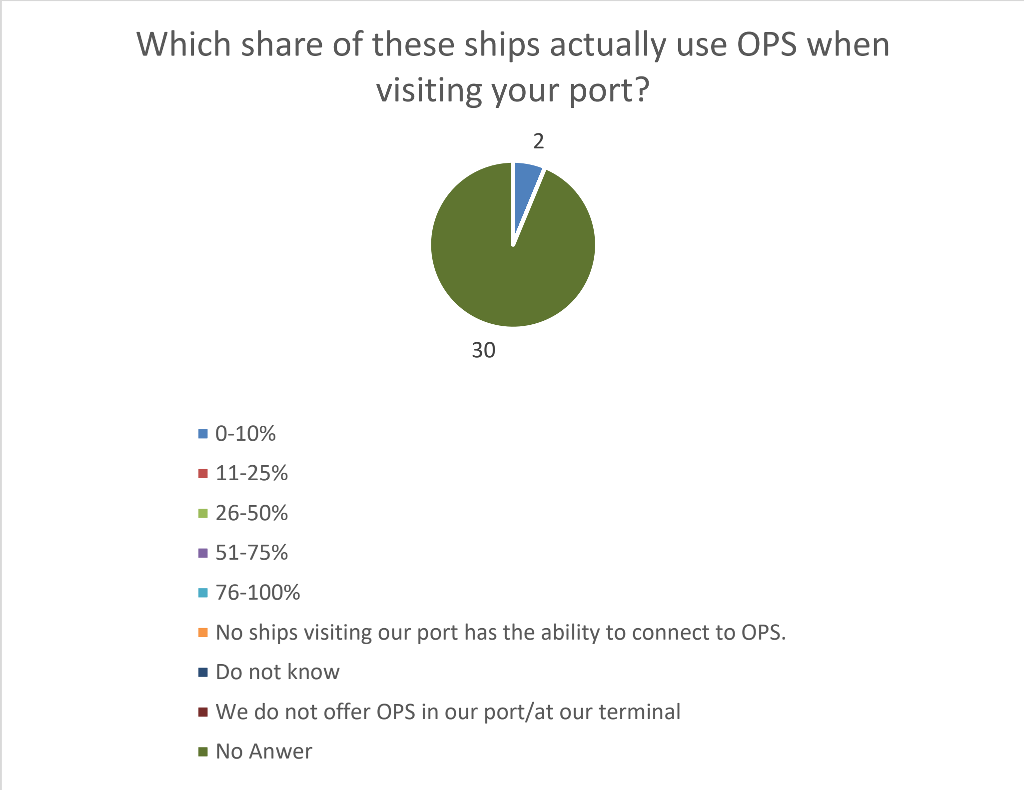

Figure 73 Usage of OPS in ports.

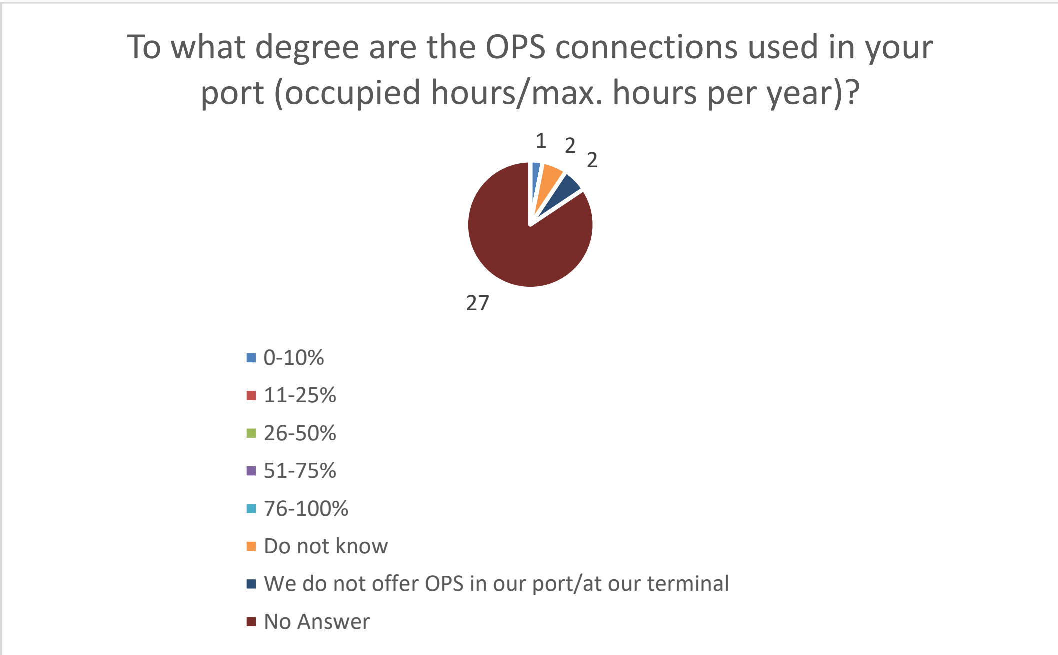

Figure 74 Usage per year of OPS facilities.

4.5 Possible policy options and measures

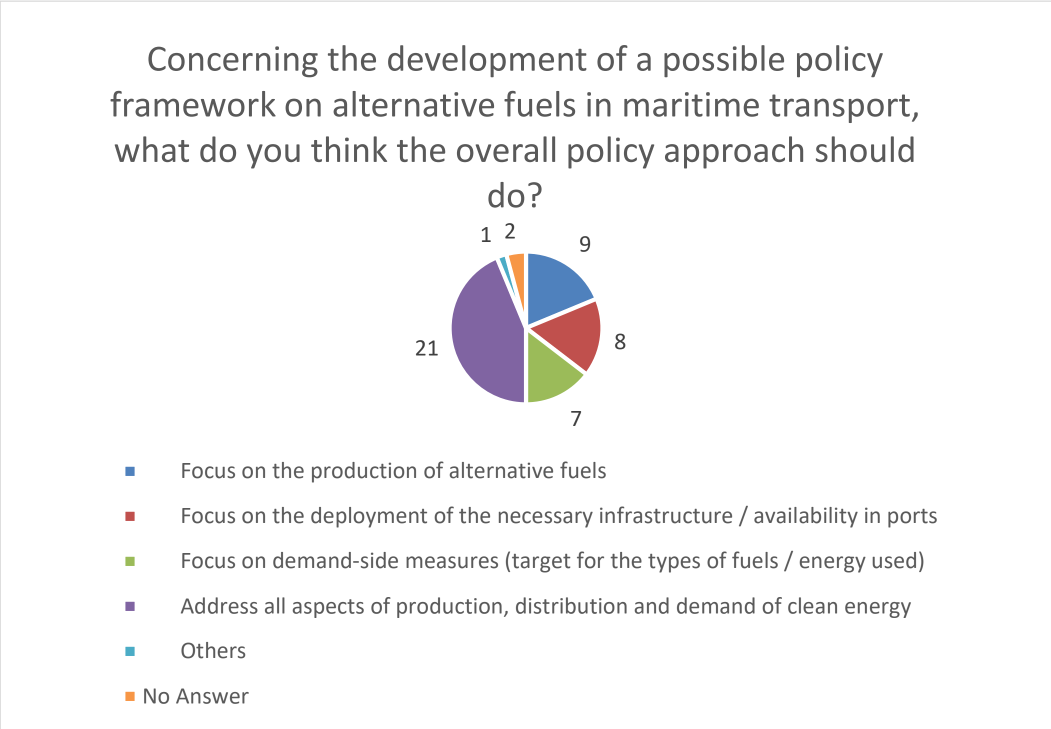

Figure 75 Aim of a policy approach.

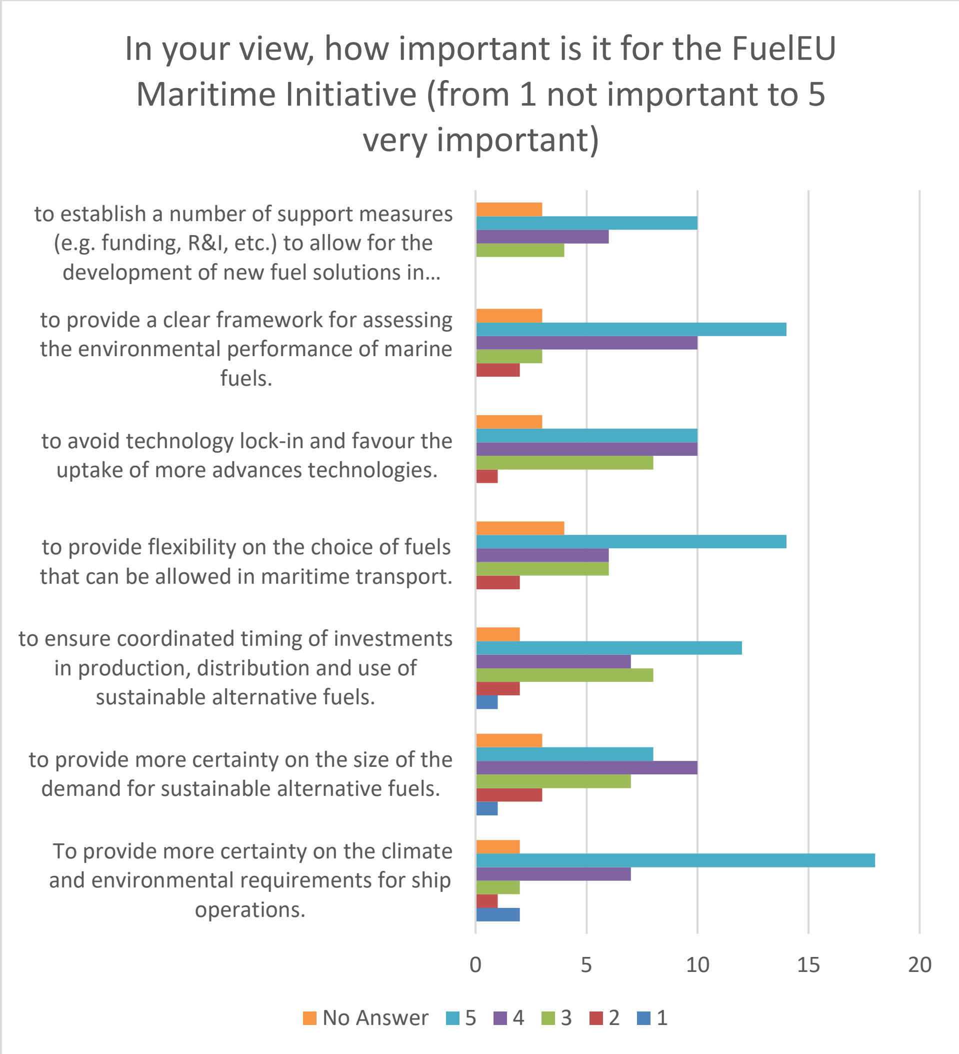

Figure 76 Importance of the FuelEU Maritime Initiative.

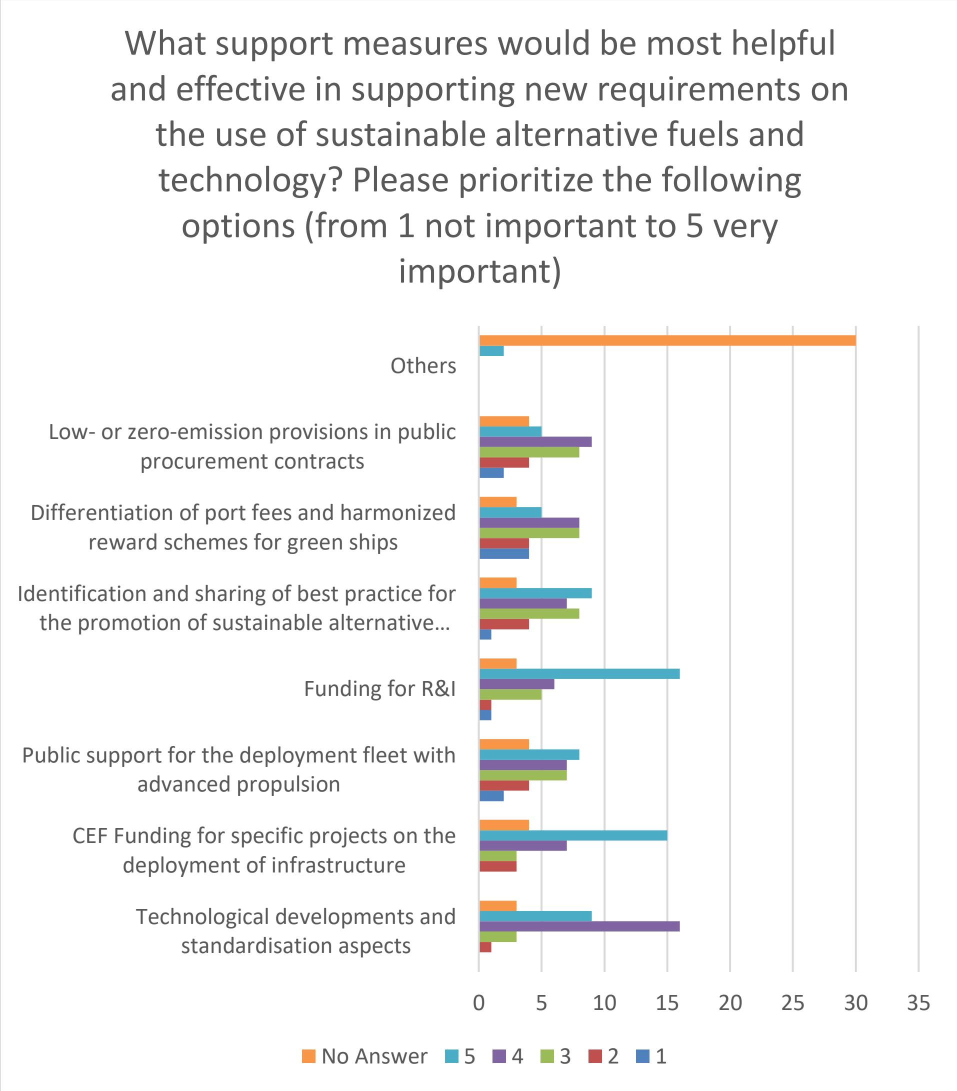

Figure 77 Usefulness of support measures.

4.6 Compliance and enforcement

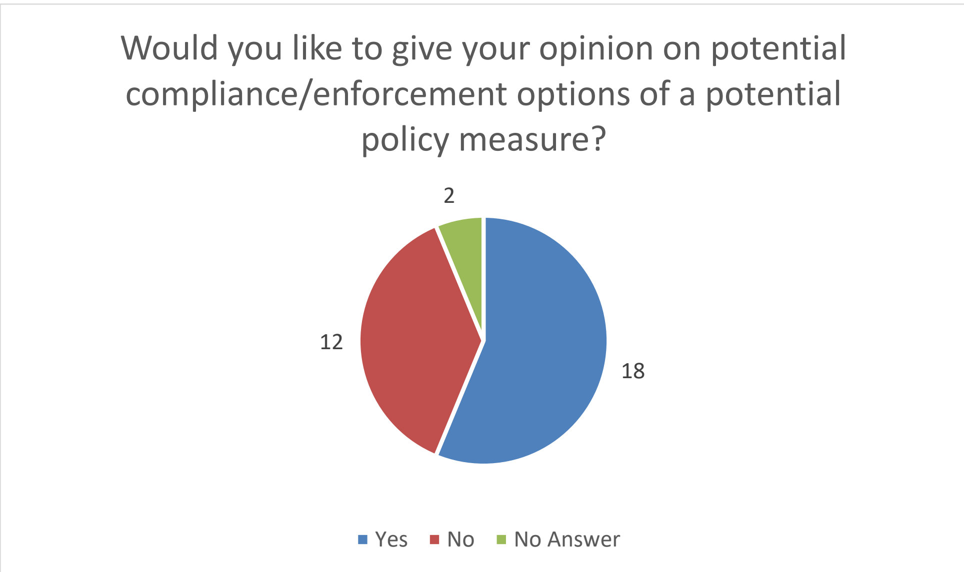

Figure 78 Opinion on compliance or enforcement of potential policy measures.

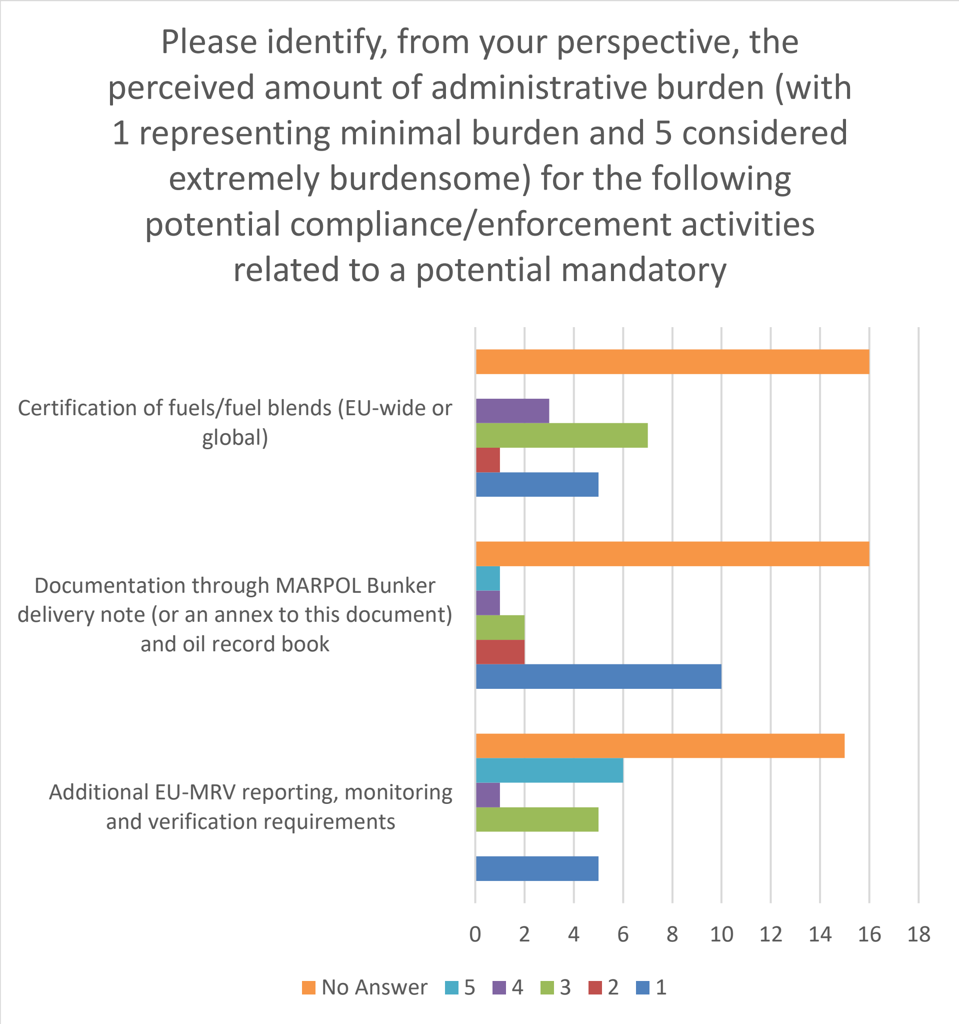

Figure 79 Administrative burden of potential compliance/enforcement activities.

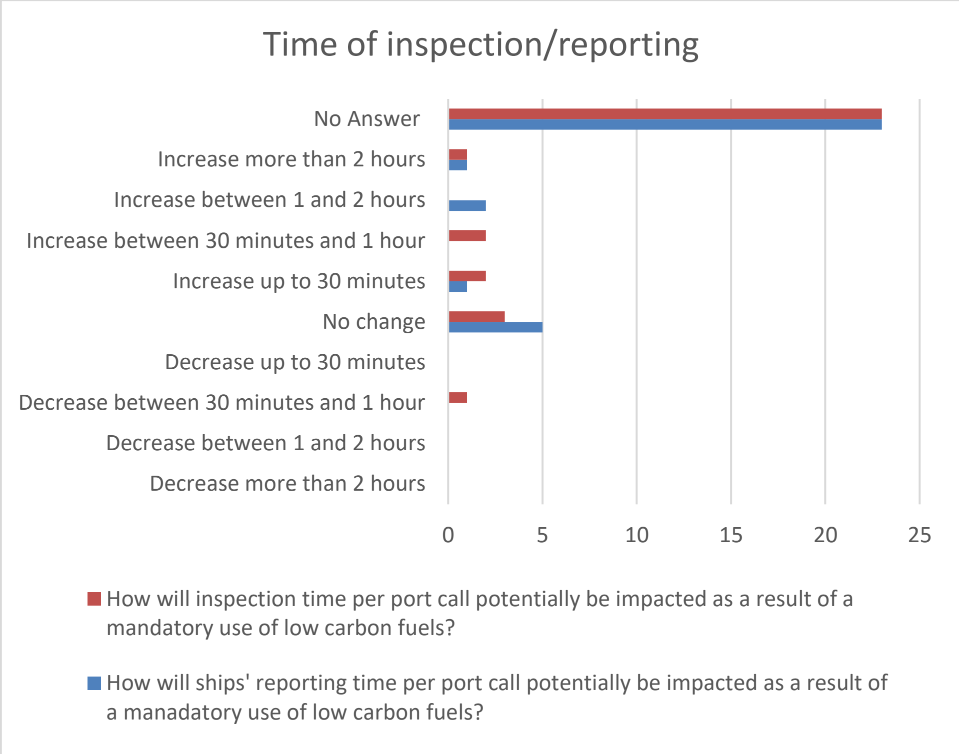

Figure 80 Time of inspection and reporting.

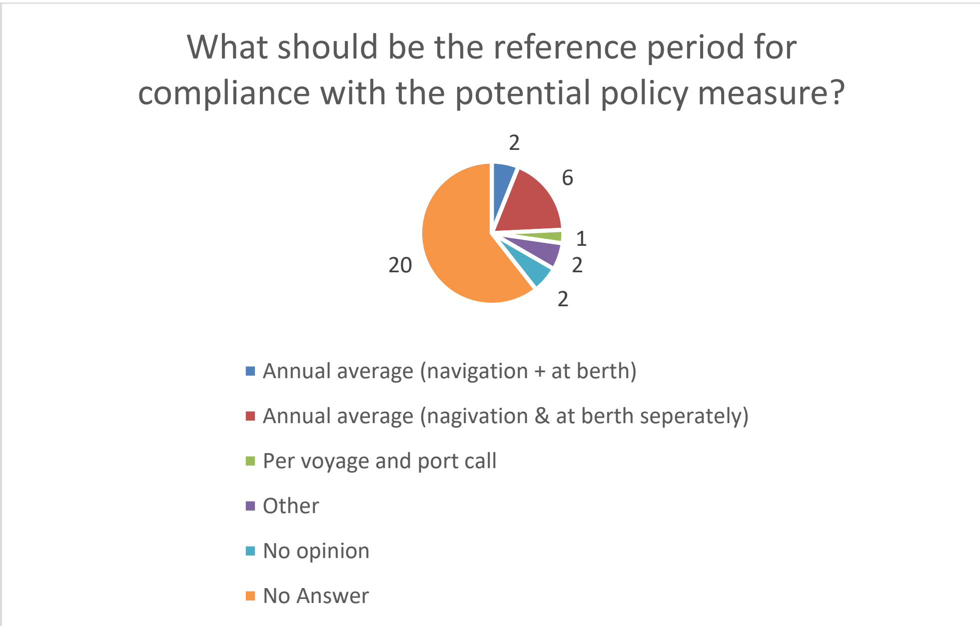

Figure 81 Reference period for compliance with the policy measure.

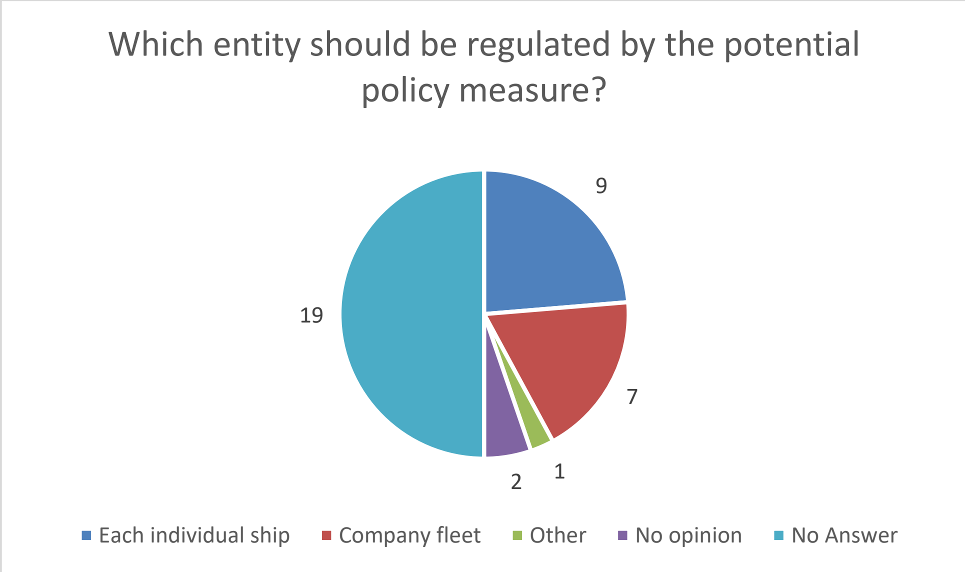

Figure 82 Which entity should be regulated by the potential policy measures?

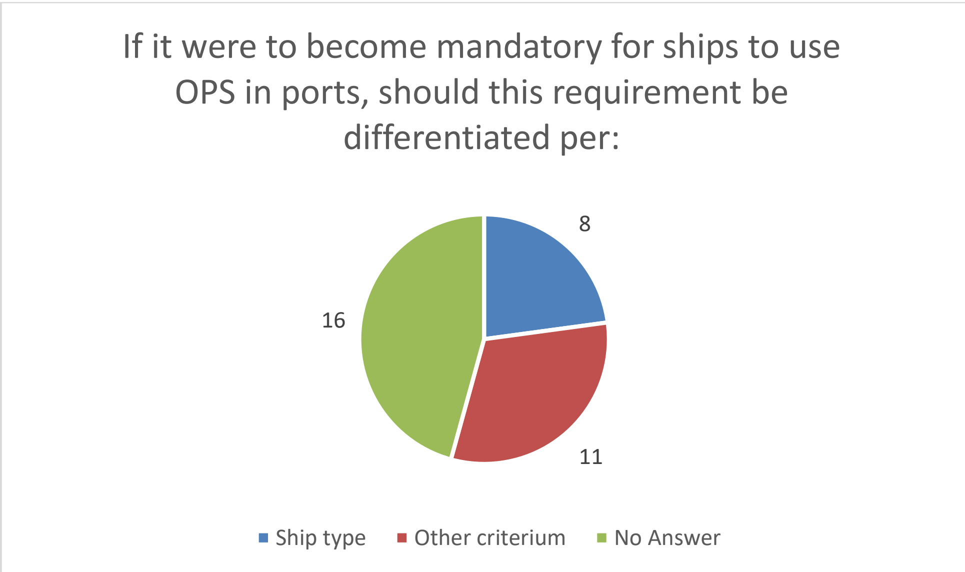

Figure 83 Differentiation of policy for emissions at berth.

4.7 Social and economic impacts

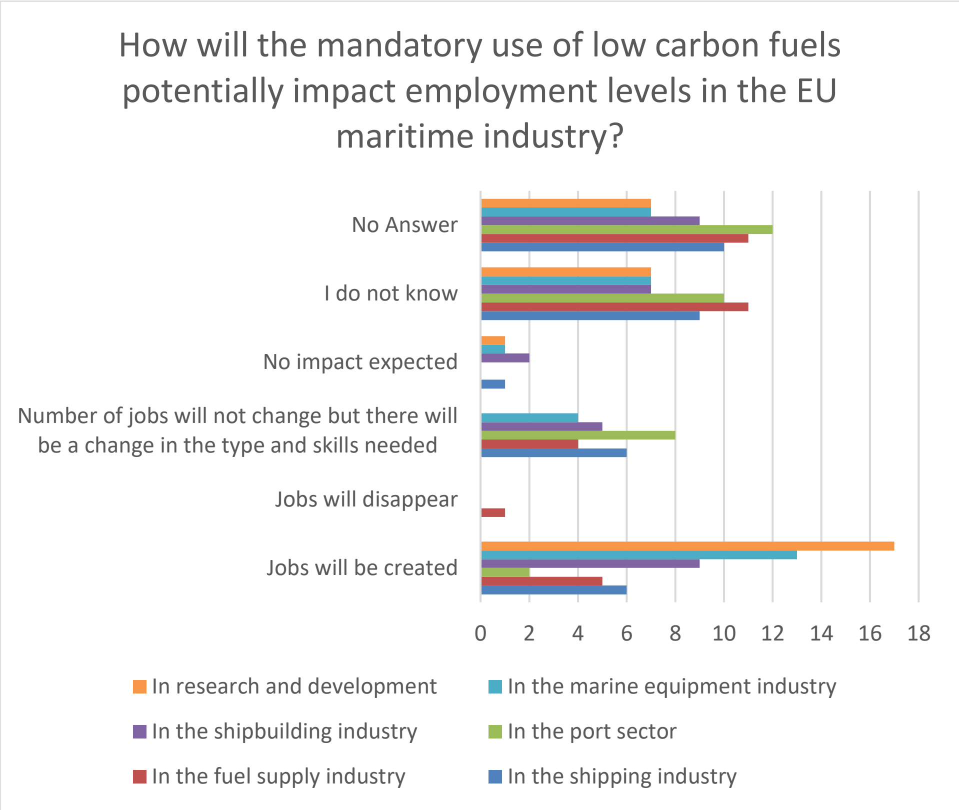

Figure 84 Effects on employment.

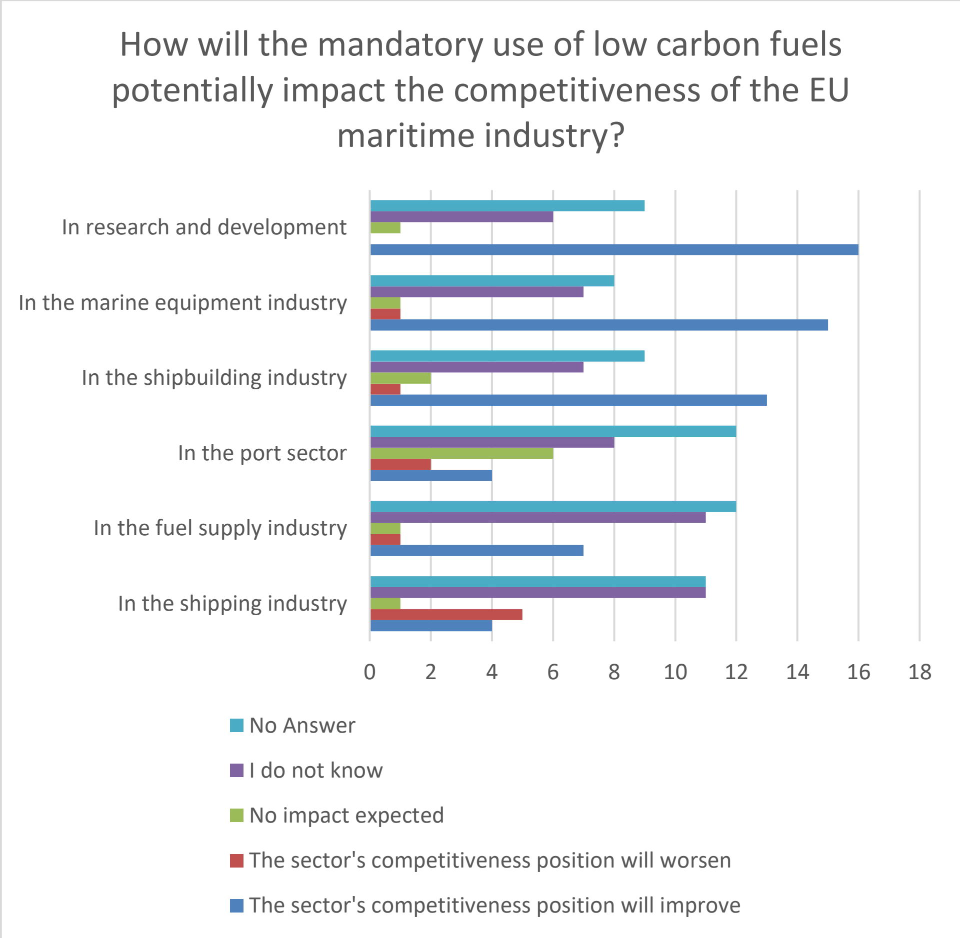

Figure 85 Effects on competitiveness.

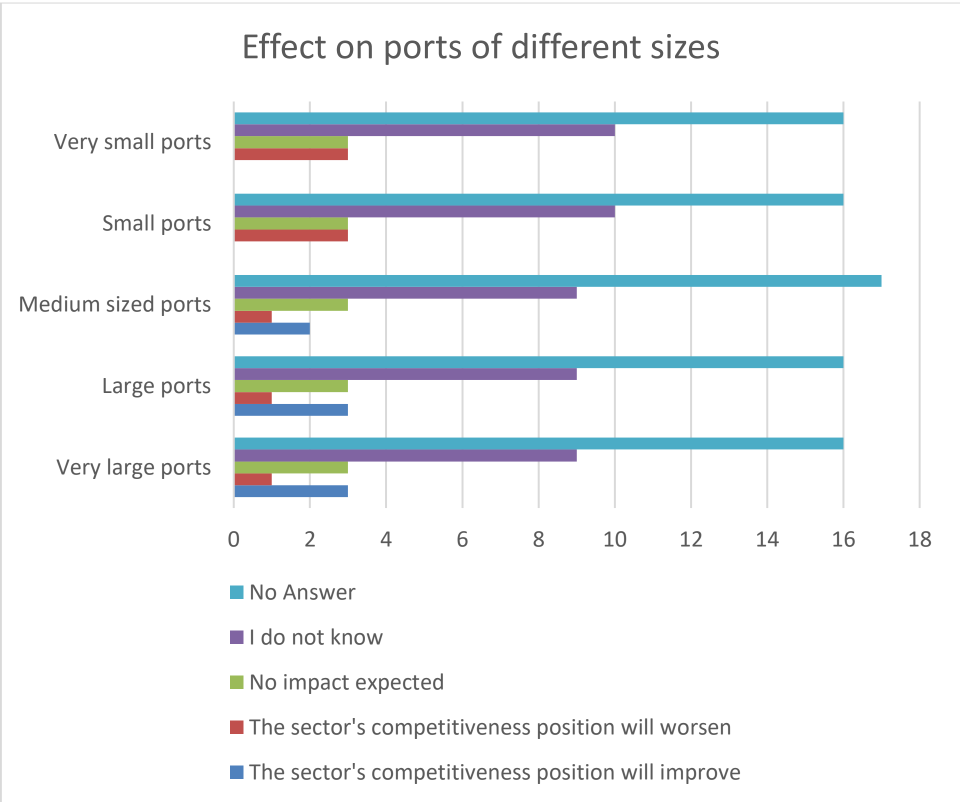

Figure 86 Effects on ports of different sizes.

4.8 Rewards and incentives for first movers and overachievers

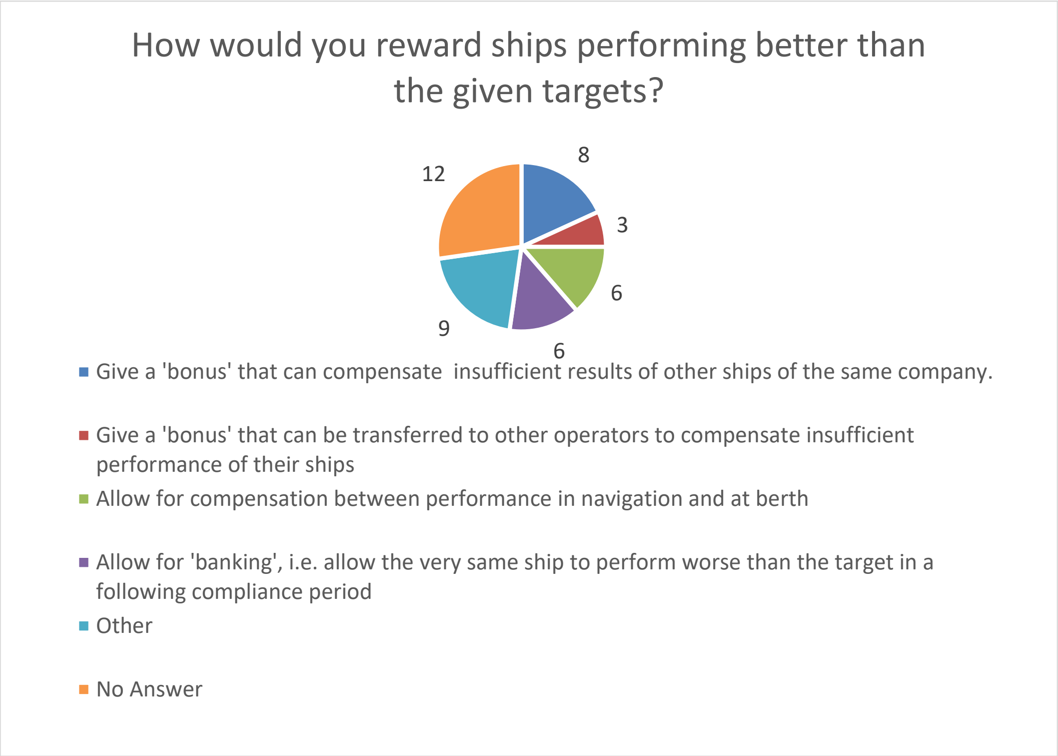

Figure 87 How should overachievers be rewarded?

5 Roundtable

The Roundtable was organised as a joint ESSF / EPF event, with the aim to wrap-up the consultation activities related to the FuelEU Maritime initiative. There were two sessions. The morning session comprised a presentation of the progress on the support study for the impact assessment by CE Delft; a presentation on pathways to alternative low- and zero carbon fuels by SINTEF Ocean; and a panel discussion with representatives from ECSA, ESPO, SEA Europe and Transport & Environment. The afternoon session comprised a presentation on the state of play with regards to alternative fuels and the policy options to support the uptake of renewable and low-carbon fuels and a panel on the promotion of fuels with representatives from Port of Barcelona, Maersk, Goodfuels, Waterborne Technology Platform.

Due to Covid-19, the Roundtable was organised as an online event. 280+ participants registered to the event and around 140 were connected at the same time in the morning and afternoon sessions. In addition to participants from DG MOVE (D and B), SG, CLIMA, ENER, ENV and RTD were represented and took part in the discussions. In order to encourage active participation of the attendees, several surveys were conducted.

ECSA, ESPO, SEA Europe and T&E participated in the first panel, focused on the importance of alternative fuels for reducing ship emissions. Panellists agreed with the need to act rapidly and stressed the need of cooperation between all actors (ports, users, technology providers and fuel suppliers). They mentioned the importance of providing a stable framework for encouraging investments and recalled the need for public support. Participants highlighted the role of IMO. ECSA and T&E in particular called for a wider approach covering carbon intensity of operations (which would allow to account for energy efficiency improvements) instead of a fuel-specific approach. The issue of technical development and the risk of technology lock-in was discussed, with strong calls from NGOs to focus on most advanced solutions rather than on bio-based drop-in fuels.

Some online polls were held during the discussion to collect opinions from the participants. The participants found that regulation, preferably at the IMO level, would be needed to reduce emissions from maritime transport by 90% by 2050. In response to a second question, 59% - 67% of the participants indicated that they considered that ammonia and hydrogen would be main components of the fuel mix. Around 40% saw a role for synthetic methane and synthetic fuels, 27% for methanol and ethanol and less than 20% for biofuels and fossil fuels, including LNG. When asked specifically, the participants were almost evenly split on the question of whether the maritime sector should use biofuels or whether those should be reserved for aviation and other hard-to-abate sectors.

64% of the participants in the poll found that the choice for a technology should be driven by environmental performance and 24% by price. Global availability and technology readiness were considered less important at 5%.

71% of the participants expected that clean fuels will have a knock-on effect on fuel efficiency.

70% of the participants found that policies should incentivise both demand for and supply of sustainable alternative fuels and 75% found that policies should take the diversity of the sector into account.

95% of the participants found that the incentive to increase demand for sustainable alternative fuels should be implemented as soon as possible, while 5% found it would be better to wait until 2030. Even then, 36% of the participants expected the transition to zero-carbon technologies to take 20 years; 37% 30 years and 19% expected the transition to take 40 years or more.

The presentation on the policy options discussed various ways to pool compliance. When asked, 41% of the participants favoured a baseline-and-credit trading system and 47% preferred voluntary pooling of compliance.

The second panel was focused on more concrete issues related to the deployment of alternatives fuels ‘on the ground’. It included representatives from the port of Barcelona, Maersk, the Waterborne Technology Platform and GoodFuels. Participants in the second panel stress the importance of funding, for R&I and to support first movers. They agreed that timeframes for technology uptake in maritime are very long and that, as a reason, a stable and predictable framework is necessary to stimulate investments. Maersk mentioned the importance to agree on an end-goal for emissions reductions and allow for a pathway / transition, which include all relevant fuels, incl. biofuels. In general, the preference for technology neutrality / goal-based approach was shared by all speakers. Maersk and Good Fuels insisted on the importance of demand-pull regulations.

6 INTERVIEWS

18 interviews have been conducted. For each stakeholder category, a specific questionnaire has been developed. The information and data gathered in the interviews has been taken into consideration in the drafting of the relevant sections of the report.

Table 24 List of interview partners.

Stakeholder category	Interview partner
Shipbuilding and marine equipment manufacturing	MAN
	Wärtsilä
Energy producers and fuel suppliers	Hydrogen Europe
	Goodfuels
	Methanol Institute
	CONCAWE
	FuelsEurope
	Shell
Ship owning and ship management	Hapag Lloyd, twice
	A.P. Moller - Maersk
	Fafalios Shipping SA
Port management and administration	Port of Rotterdam
	Port of Barcelona
	Port of Hamburg
	Port of Venice
National public authorities	Dutch Government
Logistics suppliers, shippers and cargo owner	Volkswagen Group
	Friesland Campina
	BICEPS Network
Port State Control	Inspectie Leefomgeving en Transport
Recognised orgnaisation	DNV-GL
	Lloyd’s Register
Interest organizations	European Transport Workers’ Association

7 ROUNDTABLE PARTICIPANTS

The roundtable was attended by representatives of the following organisations. The organisations are classified as follows, in line with the Commission Register of Expert Groups:

1. **Type A - individuals appointed in a personal capacity**, acting independently and expressing their own personal views.
2. **Type B - individuals appointed to represent a common interest** shared by stakeholder organisations in a particular policy area. They do not represent individual stakeholders, but a particular policy orientation common to different stakeholder organisations. They may be proposed by stakeholder organisations.
3. **Type C - organisations** in the broad sense of the word including companies, associations, NGOs, trade unions, universities, research institutes, law firms and consultancies.
4. **Type D - Member States' authorities**- national, regional or local.
5. **Type E - other public entities**, such as authorities from non-EU countries (including candidate countries), EU bodies, offices or agencies, and international organisations.

MEMBER STATE / ORGANISATION	TYPE (A-B-C-D-E)
ACCIARO MICHELE	A
ABS CORPORATE TECHNOLOGY	C
ASSARMATORI	C
ASSOCIATION OF GERMAN SEAPORT ASSOCIATIONS (ZDS)	C
ASSOCIATION OF SHIP BUILDING AND SEA TECHNOLOGIES	C
ASSONAVE	C
BALTIC PORT ORGANISATION (BPO)	C
BIMCO	C
BREMER INSTITUTE FOR PRODUCTION & LOGISTICS (BIBA)	C
CARNIVAL CORPORATION	C
CE DELFT	Ad hoc
CHAMBER OF COMMERCE AND INDUSTRY ANTWERP – VOKA	C
CLECAT	C
CLIA	C
CONCAWE	C
DANISH SHIPPING	C
DFDS A/S	C
DNV GL	C
ECTU - EUROPEAN SHIPPERS COUNCIL (ESC)	C
ENVIRONMENTAL DEFENSE FUND (EDF)	C
ESPO	C
ETF-EUROPE	C
EuDA	C
EUROMOT	C
EUROPEAN SHIPOWNER'S ASSOCIATION (ECSA)	C
EUROPEAN TUG ASSOCIATION	C
EUROSHORE	C
ESPO	C
FEPORT	C
GOODFUELS	Ad hoc
HAPAC LLOYD AG	C
HELLENIC COAST GUARD	C
HELLENIC NAVAL ACADEMY	C
HELLENIC SHORTSEA SHIPOWNERS ASSOCIATION	C
HYDROGEN EUROPE	C
IACS	C

INTERNATIONAL ASSOCIATION OF OIL &GAS PRODUCERS (IOGP)	C
INTERTANKO	C
MAERSK	C
MAN ENERGY SOLUTIONS	C
MARIN	C
MEDCRUISE	C
PORT OF ROTTERDAM	C
PORT OF BARCELONA	Ad hoc
ROYAL ASSOCIATION OF NETHERLANDS SHIPOWNERS	C
ROYAL BELGIAN SHIPOWNERS ASSOCIATION	C
SEA EUROPE	C
SEA/LNG	C
SHELL COMPANIES	C
SPC SPAIN	C
TRANSPORT & ENVIRONMENT	C
VALENCIA PORT FOUNDATION	C
VSM	C
WARTSILA	D
CYRPUS	D
DENMARK – Danish Maritime Authority	D
FINLAND – Finnish Ministry of Transport & Communication	D
FRANCE – Ministere du Development Durable	D
FRANCE – Permanent Representation	D
IRELAND – Irish Maritime Administration	D
ITALY – Ministry of Transport Infrastructure	D
LITHUANIA – Ministry of Transport and Communications	D
NETHERLANDS – Ministry of Infrastructure & Water Management	D
POLAND – Maritime University of SZCZECIN	D
PORTUGAL – DGRM – Direcao Geral de Recursos Naturais, Securanca e Servicos Maritimos	D
PORTUGAL – Administracao dos Portos de Sines e do Algrave S.A.	D
ROMANIA – Transport Supervision Directorate	D
ROMANIA – Romanian Naval Authority	D
SWEDEN – Swedish Transport Agency	D
SWEDEN – Swedish Ministry of Infrastucture – Division for Transport Market	D
Norwegian Maritime Authority	E

8 POSITION PAPERS

Below, a table with the organizations which presented a position paper to the OPC is presented.

Stakeholder category	organisation
energy producers and fuels suppliers	LSB
	Zeevaarttafel
	EDF
	Edison
	Liquid Wind
	Shell
	Hydrogen Europe
	GIE
	Eni
	Fuels Europe
inland waterways sector	European IWT Platform
interest organizations representing societal interests	Transport and Environment
	Surfrider Foundation Europe
logistics suppliers, shippers and cargo owners	CLECAT
national public authorities	IHK Nord
	French government
	Danish Maritime Authority
ports management and administrations	Rotterdam
	FEPORT
	ESPO
	Ports de France
ship owning and ship management	Spanish Shipowner Association
	ECSA
	CLIA
	World Shipping Council
shipbuilding and marine equipment manufacturers	Winterthur Gas & Diesel
	EUROMOT

ANNEX: TARGETED CONSULTATION QUESTIONNAIRE

Targeted survey questionnaire

☐ Introduction

The European Commission is currently undertaking an impact assessment in view of a possible initiative aiming to increase the use of sustainable alternative fuels in European shipping and ports (hereby referred to as ‘FuelEU Maritime’). More information about the initiative was published in the inception impact assessment published on 27 March. To support the impact assessment work, an external study is being carried out by Ecorys and CE Delft. The purpose of the support study is to validate the possible problems and the drivers underlying them and to assess the potential impacts of a number of possible policy measures/options[180] aiming to address the problems.

This questionnaire is part of the targeted consultation. Through this questionnaire, the European Commission invites all concerned stakeholders to express their views and provide relevant data or evidence for the assessment of impacts.

It complements the open public consultation, which is open from 2 July to 10 September 2020. Stakeholders who have already contributed to the public consultation or who plan to do so are therefore invited to share only information that has not already been/will not be provided while referring to specific previous submissions to the Commission they consider to be relevant.

1.1.1.2. Transparency and confidentiality

The contributions received from this questionnaire will not be published on the European Commission's website, but will be used for analytical purposes to assess the likely impacts of the measures, in qualitative and/or quantitative way, and have an overview of stakeholders' views on the possible measures considered.

All information and/or data provided to Ecorys will be shared with the European Commission and may be included in Ecorys's final report and the Commission's impact assessment, except where there are specific confidentiality considerations identified. Information/data which stakeholders consider as confidential will not be made publicly available or identifiable.

Please identify any data provided to us that you wish to remain confidential. Ecorys will be happy to discuss and agree confidentiality requirements where this would be necessary.

For any queries related to the questionnaire, please contact XXX

[180] While possible measures are designed to address a particular driver of a problem, the policy options are packages of measures designed to address the problem(s) as a whole.

☐ About you

Name

Answer box to open questions

First name

Answer box to open questions

Email

Answer box to open questions

Organisation name

Answer box to open questions

Organisation size

- ☐ Micro (1 to 9 employees)
- ☐ Small (10 to 49 employees)
- ☐ Medium (50 to 249 employees)
- ☐ Large (250 employees or more)

Transparency register number

Check if your organisation is on the transparency register. It's a voluntary database for organisations seeking to influence EU decision-making.

Answer box to open questions

1.1.1.3.Country of origin

Please add your country of origin, or that of your organisation.

Please specify which interests you (the organisation on behalf of which you respond). Please select one or more options as appropriate. represent

- ☐ National public authorities (transport ministries, agencies)
- ☐ Regional or local public authorities
- ☐ Ship owning and ship management
- ☐ Short sea shipping
- ☐ Shipper
- ☐ Ports management and administrations
- ☐ Port terminal operator or other port services provider
- ☐ Inland waterways sector
- ☐ Shipbuilding and marine equipment manufacturers
- ☐ Academia, research and innovation
- ☐ Investment and financing
- ☐ Energy producers and fuel supply (including alternative / sustainable fuel sources)
- ☐ Technical standardization bodies and class societies
- ☐ Logistics suppliers, shippers and cargo owners
- ☐ Interest organisations representing societal interests, particularly on environmental and social topics
- ☐ Other

If other, please specify:

Answer box to open questions

If you clicked the category 'Ship owning and ship management', could you please indicate the type of ship(s) you own or manage? Please select one or more options as appropriate

- ☐ Bulk carrier
- ☐ Chemical tanker
- ☐ Container
- ☐ General cargo
- ☐ Liquified gas tanker
- ☐ Oil tanker
- ☐ Other liquids tanker
- ☐ Ferry – passengers (pax) only
- ☐ Cruise
- ☐ Ferry – roll-on/passengers (ro-pax)
- ☐ Refrigerated cargo
- ☐ Roll-on/roll-off (ro-ro)
- ☐ Vehicle
- ☐ Yacht
- ☐ Miscellaneous – fishing
- ☐ Miscellaneous – other
- ☐ Service – tug
- ☐ Offshore
- ☐ Service – other (please specify)

If you clicked the category 'Energy producers and fuel supply', could you please indicate the type of fuel you produce / supply?). Please select one or more options as appropriate

- ☐ Fossil fuels
- ☐ LNG
- ☐ Biodiesel
- ☐ Methanol
- ☐ LPG
- ☐ Ammonia
- ☐ Hydrogen
- ☐ Electricity
- ☐ Other, please specify
- ☐ Not relevant

☐ Problems, drivers and specific objectives

Problem definition: The Commission services have provisionally defined the following problems which may need to be addressed through a policy initiative. The following problems have been identified:

- There is a low uptake of zero-emission fuels and power by ships calling EU ports
- There is a low uptake of zero-emission fuels and power by ships at berth

1. In your view, have problems been correctly identified?
   - Yes
   - No
   - I do not know

2. In your view, are there any other problems leading to a low uptake of zero-emission fuels and power?
   - Yes
   - No
   - I do not know

2b. If you have answered, yes, could you please indicate which problem(s) is/are missing and elaborate on them? Please explain your response, providing supporting information /examples where possible.

Answer box to open questions

3. In case the Commission would not take any (legislative action), how would the identified problems develop? The problem is most likely to….

Identified problem	… increase	… decrease	remain the	I do not

			same	know
Low uptake of zero-emission fuels and power by ships calling EU ports				
Low uptake of zero-emission fuels and power by ships at berth				
…				
…				

Problem drivers are the underlying causes of problems. The Commission services have provisionally defined the possible drivers listed below

- Lack of predictability (long lifetime of ships) and high risk of investment choices (high risk of stranded assets)
- Low maturity of new sustainable alternative fuels/technologies with high risk for first movers
- Higher costs of alternatives compared to fossil fuels (also due to unsufficient economies of scale)
- High interdependency with supply and distribution (chicken-end-egg issue)
- Possibility of bunkering outside EU (risk of carbon leakage) and split incentives with respect to investments in clean technologies

4. How relevant is each of the problem drivers mentioned to tackle the abovementioned problems?

	Strongly agree	Agree	Agree nor disagree	Disagree	Strongly disagree	I do not know
Lack of predictability and high risk of investment choices						
Low maturity of new sustainable alternative fuels/technologies with high risk for first movers						
Higher costs of alternatives compared to fossil fuels						
High interdependency with supply and distribution						
Possibility of bunkering outside EU (risk of carbon leakage) and split incentives with respect to investments in clean technologies						

4b. Can you provide examples to support your response?

	Examples
Lack of predictability and high risk of investment choices	
Low maturity of new sustainable alternative fuels/technologies with high risk for first movers	
Higher costs of alternatives compared to fossil fuels	
High interdependency with supply and distribution	
Possibility of bunkering outside EU (risk of carbon leakage) and split incentives with respect to investments in clean technologies	

What should be achieved: The Commission services have provisionally defined the possible objectives listed below

- The initiative should enhance the predictability of the regulatory environment and facilitate the planning of investments
- The initiative should support technology development and deployment
- The initiative should stimulate production of sustainable alternative fuels on a larger scale and reduce price gap with current fuels and technologies
- The initiative should create demand from ship operators to bunker sustainable alternative fuels or connect to the electric grid while at berth
- The initiative should avoid carbon leakage and address the split incentive issue

5. Should these objectives be considered:

	Strongly agree	Agree	Agree nor disagree	Disagree	Strongly disagree	I do not know
The initiative should enhance the predictability of the regulatory environment and facilitate the planning of investments						
The initiative should support technology development and deployment						
The initiative should stimulate production of sustainable alternative fuels on a larger scale and reduce price gap with current fuels and technologies						
The initiative should create demand from ship operators to bunker sustainable alternative fuels or connect to the electric grid while at berth						
The initiative should avoid carbon leakage and address the split incentive issue						

☐ Assessment of sustainable low- or zero carbon fuels and technologies

6. What are the most promising low- or zero carbon fuels and technologies? For each target year, please select up to three options.

	In 2030	In 2050
Liquid hydrocarbons from biological origin		
Liquid alcohols from biological origin		
Gaseous hydrocarbons from biological origin		
Liquid e-hydrocarbons		
Liquid e-alcohols		
Gaseous e-hydrocarbons		
Decarbonised hydrogen (including fuel cells)		
Other decarbonised hydrogen-derived fuels (including ammonia)		
Electricity (battery)		
OPS		
Others, please specify		

7. For the most promising option in 2030 and 2050, please identify the most important benefits.

Production of fuel/technology	☐ Technology readiness ☐ Scale of availability ☐ Other, please specify	☐ Technology readiness ☐ Scale of availability ☐ Other, please specify
Fuel price/OPS usage costs	☐ Costs compared to other zero/low carbon options ☐ Costs compared to conventional options	☐ Costs compared to other zero/low carbon options ☐ Costs compared to conventional options
Supply (infrastructure) of fuels/OPS	☐ Technology readiness ☐ Scale of availability ☐ Other, please specify	☐ Technology readiness ☐ Scale of availability ☐ Other, please specify
Required ship systems	☐ Technology readiness ☐ Scale of availability ☐ Costs compared to other zero/low carbon options ☐ Costs compared to conventional options ☐ Other, please specify If related to a specific ship type, please specify.	☐ Technology readiness ☐ Scale of availability ☐ Costs compared to other zero/low carbon options ☐ Costs compared to conventional options ☐ Other, please specify If related to a specific ship type, please specify.
Other challenges	Please specify	Please specify

8. For the most promising option in 2030 and 2050, please identify the most important challenges.

	2030	2050
Production of fuel/technology	☐ Technology readiness ☐ Scale of availability	☐ Technology readiness ☐ Scale of availability

	2030	2050
	☐ Other, please specify	☐ Other, please specify
Fuel price/OPS usage costs	☐ Costs compared to other zero/low carbon options ☐ Costs compared to conventional options	☐ Costs compared to other zero/low carbon options ☐ Costs compared to conventional options
Supply (infrastructure) of fuels/OPS	☐ Technology readiness ☐ Scale of availability ☐ Other, please specify	☐ Technology readiness ☐ Scale of availability ☐ Other, please specify
Required ship systems	☐ Technology readiness ☐ Scale of availability ☐ Costs compared to other zero/low carbon options ☐ Costs compared to conventional options ☐ Other, please specify If related to a specific ship type, please specify.	☐ Technology readiness ☐ Scale of availability ☐ Costs compared to other zero/low carbon options ☐ Costs compared to conventional options ☐ Other, please specify If related to a specific ship type, please specify.
Other challenges	Please specify	Please specify

9. Do you have any suggestions to overcome the identified challenges? If yes, please explain.

9a. Concerning the technical, design-related and operational challenges:

Answer box to open questions

9b. Concerning the economic and commercial challenges:

Answer box to open questions

9c. Concerning the environmental challenges:

Answer box to open questions

☐ Concrete experience with sustainable alternative fuels and technologies for maritime transport

Experience with ships in navigation

10. Have you considered supplying, deploying or using (incl. in test) sustainable alternative fuels for ships in navigation?
- ☐ Yes
- ☐ No
- ☐ Not applicable

10b. If no, can you specify why not

- ☐ The issue has not been brought to our attention
- ☐ All attention was devoted to meeting the 2020 Marpol Annex VI regulation
- ☐ None of the fuels is technically mature
- ☐ Fuels are not available

- ☐ Other (please specify)

10c. If yes, Do you have experience with supplying, deploying or using (incl. in test) sustainable alternative fuels for ships in navigation?

- ☐ Yes
- ☐ No
- ☐ Not applicable

➔ 10c.2 If **Yes**, can you please identify which type of fuels it concerned:

- ☐ LNG
- ☐ Biodiesel
- ☐ Methanol
- ☐ LPG
- ☐ Ammonia
- ☐ Hydrogen
- ☐ Electricity
- ☐ Other, please specify
- ☐ Not relevant

➔ 10c.3 On which ship type did you test this fuel?

Cargo-carrying transport ships:

- ☐ 1. Bulk carrier
- ☐ 2. Chemical tanker
- ☐ 3. Container
- ☐ 4. General cargo
- ☐ 5. Liquified gas tanker
- ☐ 6. Oil tanker
- ☐ 7. Other liquids tanker
- ☐ 8. Ferry – passengers (pax) only
- ☐ 9. Cruise
- ☐ 10. Ferry – roll-on/passengers (ro-pax)
- ☐ 11. Refrigerated cargo
- ☐ 12. Roll-on/roll-off (ro-ro)
- ☐ 13. Vehicle

Non-merchant ships

- ☐ 14. Yacht
- ☐ 15. miscellaneous – fishing

Non-seagoing merchant ships

- ☐ 16. miscellaneous – other

Work vessels:

- ☐ 17. Service – tug
- ☐ 18. Offshore
- ☐ 19. Service – other (please specify)

11. What were your main experiences with these fuels?

11a. Were these fuels used as the main source of energy / propulsion on the ship?

Answer box to open questions

11b. Were these fuels used in conjunction with other conventional fuels (blends, hybrid propulsion, etc.)? If yes to what percentage?

Answer box to open questions

11c. What were the main challenges and difficulties of each tested technology?

Answer box to open questions

11d. What were the main benefits of each tested technology?

Answer box to open questions

11e.Have you continued to supply or use these sustainable fuels in the longer term?

Answer box to open questions

12. Why did you engage in testing sustainable fuels and technology? Please select one or more options as appropriate
    - ☐ To contribute to the development of new technology (R&I project, deployment programme, etc.)
    - ☐ To prepare for the fuel switch that the sector is facing and possibly get a first-mover advantage
    - ☐ To proactively strengthen the environmental image or policy of my organization
    - ☐ To meet customers' requests (please specify)
    - ☐ To meet regulatory requirements (please specify)
    - ☐ Other (please specify)

To summarise, what were the most relevant takeaways of your experience with supplying, deploying or using (incl. in test) sustainable alternative fuels for ships in navigation?

13. If **No**, continue to next question.

<u>Experience with ships at berth</u>

14. Do you have experience with supplying, deploying or using (incl. in test) onshore power supply or other zero-emission technologies in port?

☐ Yes
☐ No
☐ Not applicable

15. If **Yes**, can you please identify which type of technologies it concerned:
    - ☐ Onshore power supply for energy needs at berth and port operations
    - ☐ Batteries for energy needs at berth and port operations
    - ☐ Alternative energy sources for energy needs at berth and port operations (please specify)
    - ☐ Shore-side electricity for battery recharging purposes
    - ☐ Others, please specify.

➔ Can you please identify the ship type(s) the technology/fuel has/have been applied to?

Cargo-carrying transport ships:

☐ 1. Bulk carrier
☐ 2. Chemical tanker
☐ 3. Container
☐ 4. General cargo
☐ 5. Liquified gas tanker
☐ 6. Oil tanker
☐ 7. Other liquids tanker
☐ 8. Ferry – passengers (pax) only
☐ 9. Cruise
☐ 10. Ferry – roll-on/passengers (ro-pax)
☐ 11. Refrigerated cargo
☐ 12. Roll-on/roll-off (ro-ro)
☐ 13. Vehicle

Non-merchant ships

☐ 14. Yacht
☐ 15. miscellaneous – fishing

Non-seagoing merchant ships

☐ 16. miscellaneous – other

Work vessels:

☐ 17. Service – tug
☐ 18. Offshore
☐ 19. Service – other (please specify)

16. What were your main experiences with these technologies?

16a. What were the main challenges and difficulties of each tested technology?

Answer box to open questions

16b. What were the main benefits of each tested technology?

Answer box to open questions

16c.Have you continued to supply or use these sustainable fuels in the longer term?

Answer box to open questions

17. Why did you engage in testing sustainable fuels and technology? Please select one or more options as appropriate
    - ☐ To contribute to the development of new technology (R&I project, deployment programme, etc.)
    - ☐ To prepare for the fuel switch that the sector is facing and possibly get a first-mover advantage
    - ☐ To proactively strengthen the environmental image or policy of my organization
    - ☐ To meet customers' requests (please specify)
    - ☐ To meet regulatory requirements (please specify)
    - ☐ Other (please specify)

18. To summarise, what were the most relevant takeaways of your experience with supplying, deploying or using (incl. in test) onshore power supply or other zero-emission technologies in port?

19. If you represent **port**, which share of the ships visiting your port has the ability to connect to OPS?
    - ☐ 0-10%
    - ☐ 11-25%
    - ☐ 26-50%
    - ☐ 51-75%
    - ☐ 76-100%.
    - ☐ Do not know

20. Which share of these ships uses OPS when visiting your port?
    - ☐ 0-10%
    - ☐ 11-25%

- ☐ 26-50%
- ☐ 51-75%
- ☐ 76-100%
- ☐ No ships visiting our port has the ability to connect to OPS.
- ☐ Do not know

21. To what degree are the OPS connections used in your port (occupied hours/max. hours per year)?
    - ☐ 0-10%
    - ☐ 11-25%
    - ☐ 26-50%
    - ☐ 51-75%
    - ☐ 76-100%
    - ☐ Do not know

22. If **No**, please continue to the next question.

☐ Possible policy options and policy measures for accelerating the uptake of sustainable alternative fuels and technologies for maritime transport

The Commission services have identified a number of policy measures that could achieve the defined objectives of the initiative. In the section below, we would like to understand what your views are on some possible measures for achieving each of the provisional objectives, as well as what are the impacts you estimate the implementation of such measures would have for your organisation.

23. Concerning the development of a possible policy framework on alternative fuels in maritime transport, what do you think the overall policy approach should do?

- ☐ Focus on the production of alternative fuels
- ☐ Focus on the deployment of the necessary infrastructure / availability in ports
- ☐ Focus on demand-side measures (target for the types of fuels / energy used)
- ☐ Address all aspects of production, distribution and demand of clean energy
- ☐ Others

23b. Additional comments:

Answer box to open questions

24. Emissions of ships at berth (at anchor in ports) represent around 6% of overall greenhouse gas emissions and constitute a significant source of air pollution. The use of shore-side electricity provides an alternative to the use of on-board ship generators. How important is to regulate specifically the use of clean energy by ships at berth, with more stringent requirements on emissions?
    - ☐ Very important
    - ☐ Important
    - ☐ Not justified
    - ☐ No opinion

25. The inception impact assessment for this initiative distinguishes between a goal-based (technologically neutral) approach and more specific requirements. The fundamental difference between the two approaches lies in the technology choice which is done / expected for meeting the given targets. Based on your experience could you list more of the advantages and disadvantages of these two approaches? Please specify between maritime shipping and ships at berth.

	Advantages	Disadvantages
In maritime shipping		
Prescriptive requirements (e.g. blending mandates)		
Goal-based approach (e.g. setting a limit on carbon intensity/CO_2 emissions of the energy/fuel used)		
At berth		
Prescriptive requirements (e.g. mandating the use of OPS at berth)		
Goal-based approach (e.g. setting a limit on carbon intensity/CO_2 emissions of the energy/fuel used)		

26. How would the above approaches regarding ***maritime shipping*** impact your company? Would it have positive impact, a negative impact, no impact? Please indicate which option applies and what the % change is likely to be.

	Prescriptive requirements (e.g. blending mandates)	Goal-based approach (e.g. setting a limit on carbon intensity/CO_2 emissions of the energy/fuel used)
Investment costs		
Operating cost		
Reporting time needed		
Inspection time needed		
Number of required employees		
Training needs to staff		
…		
…		

27. How would the above approaches regarding ***ships at berth*** impact your company? Would it have positive impact, a negative impact, no impact? Please indicate which option applies and what the % change is likely to be.

	Prescriptive requirements (e.g. blending mandates)	Goal-based approach (e.g. setting a limit on carbon intensity/CO_2 emissions of the energy/fuel used)
Investment costs		
Operating cost		
Reporting time needed		
Inspection time needed		
Number of required employees		
Training needs to staff		
…		
…		

28. In your view, how important is it for the FuelEU Maritime initiative to (from 1 not important to 5 very important):

	1	2	3	4	5

To provide more certainty on the climate and environmental requirements for ship operations					
To provide more certainty on the size of the demand for sustainable alternative fuels					
To ensure coordinated timing of investments in production, distribution and use of sustainable alternative fuels					
To provide flexibility on the choice of fuels that can be allowed in maritime transport					
To avoid technology lock-in and favour the uptake of more advances technologies					
To provide a clear framework for assessing the environmental performance of marine fuels					
To establish a number of support measures (e.g. funding, R&I, etc.) to allow for the development of new fuel solutions in maritime transport					
Others					

28b.Please provide your suggestions on the points above, which you consider particularly relevant:

Answer box to open questions

29. What support measures would be most helpful and effective in supporting new requirements on the use of sustainable alternative fuels and technology? Please prioritize the following options (from 1 not important to 5 very important)

	1	2	3	4	5
Technological developments and standardisation aspects					
CEF Funding for specific projects on the deployment of infrastructure					
Public support for the deployment fleet with advanced propulsion					
Funding for R&I					
Identification and sharing of best practice for promotion of SAF in MS					
Differentiation of port fees and harmonized reward schemes for green ships					
Low- or zero-emission provisions in public procurement contracts					
Others					

29b. Additional comments:

Answer box to open questions

☐ Compliance and enforcement

30. Please identify the perceived amount of administrative burden (with 1 representing minimal burden and 5 considered extremely burdensome) for the following enforcement activities.

	1	2	3	4	5
Reporting, monitoring and verification in THETIS-MRV					
Certification of fuels (EU-wide or global)					
Documentation through MARPOL Bunker delivery note (or an annex to this document) and oil record book					
Other, please specify other enforcement activities					

30b. Please elaborate

Answer box to open questions

31. Would it be possible to perform the requirements in a less burdensome way without compromising the safety performance? If so, please describe how.

Answer box to open questions

32. Can you describe specific benefits and challenges for each of the enforcement options listed above?

Answer box to open questions

33. What should be the reference period for compliance?

☐ Annual average

☐ The ship should always be compliant

☐ No opinion

33b. Please elaborate on your choice

Answer box to open questions

34. Which entity should be regulated?

☐ Each individual ship

☐ Company fleet

☐ No opinion

35b. Please elaborate on your choice

Answer box to open questions

35. If it were to become mandatory for ships to use OPS in ports, for which ship types should the requirement be introduced to first? Please prioritize the following ship types from 1 to 7.

Ship type	Ranking	Main reason?
Cargo-carrying transport ships		
Bulk carrier		
Chemical tanker		
Container		
General cargo		
Liquified gas tanker		
Oil tanker		
Other liquids tankers		
Ferry (passengers only)		
Cruise		

Ferry (roll on / passenger)		
Refrigerated cargo		
Roll-on / roll-off		
Non-merchant ships		
Yachts		
Miscellaneous - other		
Non-seagoing merchant ships		
Miscellaneous - other		
Work vessels		
Service – tug		
Offshore		
Service – other (please specify)		

1.1.1.4.*Question for shipping companies*

36. How will the reporting time with regard to fuels change for each port entry as a result of the mandatory use of low carbon fuels?

Change	Decrease more than 2 hours	Decrease between 1 and 2 hours	Decrease between 30 mins and 1 hour	Decrease up to 30 minutes	No change	Increase u to 30 mins	Increase between 30 mins and 1 hour	Increase between 1 and 2 hours	Increase more than 2 hours
Select as appropriate									

37. How will the activities to obtain a permit be impacted as a result of the mandatory use of low carbon fuels?

Change	Decrease more than 2 hours	Decrease between 1 and 2 hours	Decrease between 30 mins and 1 hour	Decrease up to 30 minutes	No change	Increase u to 30 mins	Increase between 30 mins and 1 hour	Increase between 1 and 2 hours	Increase more than 2 hours
Select as appropriate									

Question for Member State authorities

38. How will activities related to issuing a permit be impacted as a result of mandatory use of low carbon fuels?

Change	Decrease more than 2 hours	Decrease between 1 and 2 hours	Decrease between 30 mins and 1 hour	Decrease up to 30 minutes	No change	Increase u to 30 mins	Increase between 30 mins and 1 hour	Increase between 1 and 2 hours	Increase more than 2 hours
Select as appropriate									

39. How will inspection times be impacted as a result of the mandatory use of low carbond fuels?

Change	Decrease more than 2 hours	Decrease between 1 and 2 hours	Decrease between 30 mins and 1 hour	Decrease up to 30 minutes	No change	Increase u to 30 mins	Increase between 30 mins and 1 hour	Increase between 1 and 2 hours	Increase more than 2 hours
Select as appropriate									

39b. Why will inspection times change?

Answer box to open questions

☐ Social and economic impacts

40. Would additional training be needed for your staff in case the use of low carbond fuels becomes mandatory?

- Yes
- No
- I do not know

40b. If case yes:

- how much staff should be trained?
- how long would the training take (in number of days)?
- what would be the training costs?

41. How will the mandatory use of low carbon fuels impact employment levels in the EU maritime industry?

	Jobs will be created	Jobs will disappear	Number of jobs will not change but there will be a change in the type and skills needed	No impact expected	I do not know
In the shipping industry					
In the fuel supply industry					
In the bunker industry					
In the shipbuilding industry					
In the marine equipment industry					

In research and development					

42. How will the mandatory use of low carbon fuels impact the competitiveness of the EU maritime industry?

	The sector's competitiveness position will improve	The sector's competitiveness position will worsen	No impact expected	I do not know
In the shipping industry				
In the fuel supply industry				
In the bunker industry				
In the shipbuilding industry				
In the marine equipment industry				
In research and development				

42b. Can you please provide your arguments on how and why the competitiveness of the EU maritime industry would be impacted as a result of mandatory use of low carbond fuels?

43. How will the mandatory use of low carbond fuels impact the intra-EU competitive position of the following port types?

Classification

Very large ports	*more than 100 million tons on an annual basis*
Large ports	*between 75 – 100 million tons on an annual basis*
Medium sized ports	*between 50 –75 million tons on an annual basis*
Small ports	*between 20 – 50 million tons on an annual basis*
Very small ports	*less than 20 million tons on an annuals basis*

	The port's competitiveness position will improve	The port's competitiveness position will worsen	No impact expected	I do not know
Very large ports				
Large ports				
Medium sized ports				
Small ports				

Very small ports				

43b. Can you please provide your arguments on how and why the intra-EU competitive position of the ports (discussed above) would be impacted as a result of mandatory use of low carbon fuels? – open text box.

Answer box to open questions

44. How will the mandatory use of low carbon fuels impact the competitiveness of EU industry relying on maritime transport (but other than maritime industry)? Please specify sectors for which you anticipate a significant impact.

The sector's competitiveness can be expected to improve	The sector's competitiveness can be expected to worsen

☐ Rewards and incentives for first movers and overachievers

45. How would you reward results that are better than the given targets?
    a. Award of a 'bonus' that can compensate insufficient results of other ships of the same company

Answer box to open questions

    b. Award of a 'bonus' that can be transferred to other operators and compensate insufficient results of other ships

Answer box to open questions

    c. Compensation of performance in navigation and at berth

Answer box to open questions

    d. other, please specify

Answer box to open questions

☐ Final remarks

46. Do you have any other comments on aspects that the questions have not touched upon? Please specify.

Answer box to open questions

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