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IMPACT ASSESSMENT

Accompanying the

Proposal for a Regulation of the European Parliament and of the Council

on the use of renewable and low-carbon fuels in maritime transport

{COM(2021) 562 final} - {SEC(2021) 562 final} - {SWD(2021) 636 final}

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Glossary

Term or acronym	*Meaning or definition*
AFID	Alternative Fuels Infrastructure Directive (2014/94/EU)
CAPEX	Capital expenditure
CO_2	Carbon dioxide
CH_4	Methane
CTP	Climate Target Plan, COM(2020) 562 final
Drop-in fuels	Fuel options that are functionally equivalent to the fossil fuels currently in use and fully compatible with the distribution infrastructure and the on-board machinery / engines
EEA	European Economic Area
EEDI	Energy Efficiency Design Index
EGD	European Green Deal
EMSA	European Maritime Safety Agency
EPF	European Ports Forum
ESSF	European Sustainable Shipping Forum
GHG	Greenhouse gases
HFO	Heavy fuel oil
IMO	International Maritime Organization
Ktoe	Kilo-tonnes of oil equivalent
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MDO	Marine diesel oil
MGO	Marine gas oil
MBM	Market-based measure
MARPOL	International Convention for the Prevention of Pollution from Ships
Methane slip	Release of methane in the atmosphere while using gaseous fuels due, for instance, to the possible incomplete combustion of the fuel
MOVE	Directorate Directorate-General for Mobility and Transport
MRV	Monitoring Reporting and Verification (in the meaning of Regulation (EU) 2015/757 as amended)
N_2O	Nitrous oxide (greenhouse gas)
Nm	Nautical mile

NOx	Nitrogen Oxides (air pollutant emissions to air)
NMVOCs	Non-methane volatile organic compounds (air pollutant emissions to air)
OPC	Open public consultation
OPEX	Operating expenditure
OPS	On-shore power supply
PM	Particulate matter (air pollutant emissions to air)
PO	Policy option
PSC	Port State Control
RED II	Renewable Energy Directive (Directive (EU) 2018/2001)
RFNBO	Renewable fuels of non-biological origin
RLF	Renewable and low-carbon fuels
R&I	Research and Innovation
SO	Specific objective
SOx	Sulphur Oxides (air pollutant emissions to air)
STCW	International Convention on Standards on Training, Certification and Watchkeeping for Seafarers
Sulphur Directive	Codified Directive (EU) 2016/802 regulating the sulphur content in marine fuels (adopted in 2012 and codified in 2016)
Tank-to-wake	Method for calculating emissions that takes into account the greenhouse gas impact of combustion of a specific source of energy
TC	Targeted consultation
TEN-T	Trans-European Network of Transport
TRL	Technology readiness level
Well-to-wake	Method for calculating emissions that takes into account the greenhouse gas impact of energy production, transport, distribution ("upstream emissions") and use on-board, including during combustion

1. INTRODUCTION: POLITICAL AND LEGAL CONTEXT

1.1 Overall political context

This Impact Assessment accompanies a legislative proposal – hereby 'FuelEU Maritime' – aimed at increasing the demand of renewable and low-carbon fuels (RLF) in the maritime transport sector. These include liquid biofuels, e-liquids, decarbonised gas (including bio-LNG and e-gas), decarbonised hydrogen, decarbonised hydrogen-derived fuels (including methanol, and ammonia) and electricity[1].

By contributing to around 75% of EU external trade volumes and 31% of EU internal trade volumes, maritime transport is an essential component of Europe's transport system and plays a critical role for the European economy. Every year, around 400 million passengers embark or disembark in EU ports, including around 14 million on cruise ships, and fulfil an important role in safeguarding the connectivity of islands and peripheral maritime regions with the rest of the internal market[2].

While maritime transport constitutes arguably the most energy efficient way of moving large quantities of cargo[3], it nevertheless has a noticeable impact on the environment, notably in terms of air pollution[4], emissions of GHG[5] and marine pollution. In 2018, CO_2 emissions from international shipping in the EU27 were still around 36% above 1990 levels, despite their 18% reduction between 2008 and 2018[6]. This is driven by the growth in transport activity not sufficiently compensated by corresponding improvements in energy efficiency, and exacerbated by slow implementation of emission reduction measures and heavy reliance on fossil fuels.

The European Green Deal (EGD) Communication[7] of December 2019 emphasised the need to accelerate the transition to a climate-neutral economy and a toxic-free environment, also by shifting to sustainable and smart mobility. The EU is committed to implement the Paris Agreement, which calls for reaching carbon neutrality in the second half of this century, and has adopted a long-term vision to become carbon neutral by 2050. Furthermore, the European Commission has proposed to translate the political commitment into a legal obligation as part of the Climate Law[8], which also integrates the target of reducing GHG emissions by at least 55% below 1990 levels by 2030. On 11 December

[1] Annex 5 provides greater information on the current maritime fuel mix and an overview of available alternative fuels for maritime transport and their maturity
[2] EU Transport in figures, the statistical pocketbook 2020, https://ec.europa.eu/transport/media/media-corner/publications_en
[3] https://www.cedelft.eu/publicatie/stream_freight_transport_2016/1855, TRT
[4] In particular, emissions of sulphur oxides (SOx), nitrous oxides (NOx) and their derivative (e.g. ozone) as well as primary and secondary particulate matter (PM)
[5] Notably emissions of carbon dioxide (CO_2). When relevant, other non-CO_2 greenhouse gases will also be considered in this report, in particular methane (CH_4) and nitrous oxide (N_2O).
[6] EEA, https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer
[7] COM(2019) 640 final
[8] COM(2020) 80 final and COM(2020) 563 final

2020, the European Council endorsed the binding EU target of a net domestic reduction of at least 55% in GHG emissions by 2030 compared to 1990[9].

The 2030 Climate Target Plan (CTP)[10] adopted in September 2020 sets out in more detail the steps towards climate-neutrality by 2050. The Commission has already indicated in the EGD and 2030 CTP that it will propose to deploy various complementary policy instruments ('basket of measures') to ensure that maritime transport fairly contributes to the increased EU climate effort, along with the measures agreed at global level within the International Maritime Organization (IMO). The interaction between these policy instruments in described in details in Section 1.2.

The Commission strategy for sustainable and smart mobility[11] defines a framework of EU measures for the transport sector in line with the political ambitions of the EGD and of the 2030 CTP, and in synergy with zero pollution efforts[12]. This strategy sets the course of action for each mode of transport to decrease its carbon footprint in line with the objective of cutting GHG emissions by at least 55% by 2030 and reaching EU climate neutrality by 2050. It also sets a number of milestones for the transport sector, drawing on the common analytical work underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy, while considering deploying a broad mix of policy instruments, including carbon pricing and a moderate increase in the energy and transport sectoral regulatory policy ambition. Furthermore, the strategy acknowledges the severe effects that the COVID-19 pandemic has had on the entire transport sector including maritime. The public support mobilized to help the economy recover should create a leap forward to a sustainable and smarter future by accelerating the decarbonisation and modernisation of maritime transport, reducing its negative impact on the environment while safeguarding safety and competitiveness.

As part of the 'Fit for 55 package', the Commission aims at proposing a package of initiatives (e.g. the revision of the EU Emissions Trading System, an amendment to the Renewable Energy Directive, the revision of the Energy Tax Directive, the revision of the Directive on deployment of alternative fuels infrastructure, etc.) that together with the 'ReFuelEU Aviation' and 'FuelEU Maritime' initiatives, will deliver on the increased ambition to cut economy-wide GHG emissions by at least 55% by 2030.

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[9] Source: https://www.consilium.europa.eu/media/47296/1011-12-20-euco-conclusions-en.pdf
[10] COM(2020) 562 final
[11] COM(2020) 789 final
[12] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12588-EU-Action-Plan-Towards-a-Zero-Pollution-Ambition-for-air-water-and-soil

1.2 Interaction between policy tools to address maritime CO_2 emissions: the 'basket of measures'

The interaction and expected contribution of the basket of measures to the overall carbon neutrality objective has been assessed in details as part of the CTP impact assessment, which involved contributions from all relevant initiatives to reach the 55% increased ambition and, ultimately, the carbon neutrality target by 2050. All the policy scenarios of the Climate Target Plan impact assessment include a combination of a pricing mechanism in maritime as well as a fuel-specific measures to ensure minimum uptake and deployment of renewable and low carbon fuels.

The unsatisfactory progress in the reduction of emissions from shipping can be explained by insufficient incentives for operators to cut emissions and by the lack of mature, affordable, and globally utilisable technological alternatives to fossil fuels in the sector. A number of market failures – including negative externalities; interdependencies between supply, distribution and demand of fuels; split incentives; lack of information on future regulatory requirements; long life span of assets (vessels and bunkering infrastructure); and insufficient access to finance – partly cause and reinforce these problems.

A basket of measures is considered necessary to address these various and distinct market failures hindering the deployment of mitigation actions in the sector. Beside the FuelEU Maritime initiative that aims at increasing the demand of RLF a proposal to extend the European emissions trading system (ETS)[13] to maritime and a proposal to review the Energy Taxation Directive (ETD)[14] are part of the 'Fit for 55' package. These two initiatives should ensure that the price of transport reflects the impact it has on the environment, health and energy security.

In addition, the basket of measures includes the review of several other directives, including the Alternative Fuels Infrastructure Directive (AFID)[15] and the Renewable Energy Directive (RED II)[16], part of the 'Fit for 55' package. Next to these revised legislations, the Commission will address the need for additional research and innovation (R&I) activities, in particular through the co-programmed Zero Emissions Waterborne Transport partnership proposed by the Waterborne Technology Platform under Horizon Europe[17]. It will also revise the Guidelines on State aid for environmental protection and

[13] Directive 2003/87/EC
[14] Council Directive 2003/96/EC
[15] Directive 2014/94/EU – the Directive is currently being evaluated with a view to a possible revision: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12251-Low-emission-vehicles-improving-the-EU-s-refuelling-recharging-infrastructure
[16] Directive (EU) 2018/2001– the revision process for this Directive has already been launched: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12553-Revision-of-the-Renewable-Energy-Directive-EU-2018-2001
[17] https://www.waterborne.eu/

energy[18] in line with the policy objectives of the EGD, which should allow adequate funding of the sector's green transformation (including for deployment of on-shore charging infrastructures), while avoiding any distortion of competition.

Looking more specifically at proposed actions, there is currently no mechanism, neither at the IMO level nor in the EU, to correct for the presence of negative externalities in the sector. This prevents operators from taking into account, in their operational and investment choices, the social cost of their activity in terms of climate change and air pollution. The economic literature indicates pricing mechanisms as the instruments of choice to 'internalise' external costs. The main examples would be a tax fixed at the level of the external cost, or a 'cap and trade' instrument, such as the EU emission trading system (ETS), that sets a limit to the overall emissions and lets the market determine their appropriate price. Both are described as 'market-based measures' (MBMs).

The Commission proposes to give an increasing role to ETS because it has proven to be an effective tool in reducing GHG emissions. The implementation of carbon pricing policies in the maritime transport sector is subject to another comprehensive impact assessment presented in the framework of the 'Fit for 55' package. In general, emissions trading can achieve GHG emissions reductions cost- effectively and provides a correct price signal that influences decisions of operators, investors and consumers.

However, carbon pricing does not address all barriers to the deployment of low and zero emissions solutions. Additional policy actions are necessary to ensure that other obstacles to investments in clean energy technologies and infrastructure are removed, thereby reducing abatement costs and complementing the action of the ETS. This is particularly relevant to support mitigation measures – such as the use of RLF in the maritime transport sector – that have a high potential to reduce emissions in the future but which, presently, face high abatement costs as well as specific market barriers.

Achieving significant reductions in CO_2 emissions of international maritime transport by 2050, would require using both less energy (increasing energy efficiency) and a cleaner type of energy (using RLF). While a carbon price is likely to further drive energy efficiency improvements and narrow the price gap between conventional and low-emission technologies, its ability to support the deployment of RLF technologies in the maritime sector would strongly depend on its actual price level, which is unlikely to reach sufficient levels for this purpose in the short to medium term. These aspects are further examined and presented in greater detail in Section 5.3.1.

Similarly, legislation dealing with fuel *supply* (RED II) and *infrastructure* (AFID) has not had a significant impact on the uptake of RLF in the maritime sector and needs to be

[18] Communication from the Commission (2014/C 200/01), *Guidelines on State aid for environmental protection and energy 2014-2020;* the open public consultation runs between 12/11/2020 – 07/01/2021

complemented by measures that are capable of creating a *demand* for RLF. In addition, the review of the RED II is not be able to address the high risk of fuel bunkering outside the EU for the shipping sector. Further considerations on this issue are presented in Section 5.3.3.

This impact assessment report looks specifically at how to address the specific market barriers preventing the deployment of RLF in the maritime transport sector, in the context of the overall approach to maritime transport sustainability.

Summing up, the proposed approach is to deploy various complementary policy instruments ('basket of measures') to address various and distinct market failures. In this context, the impact assessment accompanying the EU's 2030 CTP has looked at the interaction between measures focusing on fuels obligations and carbon pricing[19].

1.3 EU approach to alternative fuels in maritime transport

The importance of developing and introducing alternative and cleaner fuels in maritime transport is present in several policy documents adopted by the Commission in recent years, such as the European Strategy for Low-Emission Mobility of 2016[20]; the Commission Communication of 2013 on integrating maritime transport emissions in EU's GHG reduction policies[21]; and the 2016 Implementation report of the EU Maritime Transport Strategy[22].

The June 2020 Council Conclusions on *"EU Waterborne Transport Sector – Future outlook: Towards a carbon-neutral, zero accidents, automated and competitive EU Waterborne Transport Sector"*[23] also stress the need to support the development of alternative fuels for use in all segments of waterborne transport. The document presents a vision for green and carbon-neutral ports and coastal areas that includes the use of liquefied natural gas (LNG) as a transitional fuel and the provision of onshore power supply and alternative fuels. The Council Conclusions also emphasize the need to ensure sufficient financial support through Horizon Europe.

There is currently no regulatory framework in the EU specifically addressing the use of RLF in maritime transport. However, the EU acquis already contains a number of legal requirements related to this initiative, notably:

- The AFID establishes requirements for the deployment of an appropriate number of LNG bunkering points in the ports of the TEN-T Core Network by 31 December 2025 and those of the TEN-T Comprehensive Network by 31 December 2030. The Directive

[19] SWD(2020) 176 final
[20] COM(2016)501 final
[21] COM(2013) 479 final
[22] SWD(2016) 326 final
[23] https://www.consilium.europa.eu/media/44311/st08648-en20.pdf

provides also for the installation of shore-side electricity supply as a priority in ports of the TEN-T Core Network, and in other ports, by 31 December 2025, unless there is no demand and the costs are disproportionate to the benefits, including environmental benefits.

- The RED II establishes an obligation on fuel suppliers to ensure a minimum mandatory share of 14% of renewable energy within the final consumption of energy in the transport sector by 2030. Although this provision targets mainly the fuels used in road and rail transport, the renewable fuels supplied to the maritime sector (except those produced from food and feed crops) may also be considered for compliance, and would count 1.2 times their energy content.
- The Monitoring, Reporting and Verification Regulation (MRV)[24] establishes the system to monitor and report CO_2 emissions from ships above 5000 gross tonnes sailing to or from ports of the EEA. It contains methods for calculating CO_2 emissions which rely on applying CO_2 emission factors to data on fuel consumption[25]. The MRV already contains default values for emission factors of fuels other than the traditional liquid marine fuels[26] (such as Liquefied Petroleum Gas, LNG, methanol and ethanol) and it provides that *"appropriate emission factors shall be applied for biofuels, alternative non-fossil fuels and other fuels for which no default values are specified"*.
- The Sulphur Directive[27] sets the maximum sulphur content for the fuels used by ships in Europe to protect the health of coastal citizens and their environment from the impacts of SOx emissions. It also encourages compliance beyond EU legislation through the use of alternative fuels and on-shore power supply (OPS) for ships at berth as alternative emission abatement methods. Furthermore, it allows the use of mixtures of heavy fuel oil (HFO) and boil-off liquefied natural gas to comply with the stricter sulphur requirement at berth or in SOx-Emission Control Area (SECA) or the use of biofuels and their mixture with HFO.

On 8 July 2020, the Commission also adopted a new dedicated Strategy on hydrogen in Europe[28], in parallel with the Strategy on energy system integration[29]. These strategies bring together different strands of action, from R&I over production and infrastructure to the international dimension. For waterborne transport, the importance of hydrogen is highlighted as a stepping stone to the production of derived fuels such as methanol or ammonia and synthetic "drop-in" fuels, which can be used with existing technology and infrastructure. The importance of biofuels is also recognised in particular for "hard-to-decarbonise" sectors, such as aviation and maritime transport.

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[24] Regulation (EU) 2015/757

[25] Annex I of the Regulation expresses the method for calculating CO_2 emissions as the product of the amount of fuel used multiplied by the appropriate emission factor corresponding to the type of fuel used.

[26] Currently, 97% of the fuel reported under MRV is constituted of HFO, MGO or MDO.

[27] Directive (EU) 2016/802

[28] COM(2020) 301 final

[29] COM(2020) 299 final

The 2030 CTP, adopted in September 2020[30], mentions that *"Both the aviation and maritime sectors will need to scale up efforts to improve the efficiency of aircraft, ships and their operations and to increase the use of sustainably produced renewable and low-carbon fuels. This will be assessed in greater detail in the context of the ReFuelEU Aviation and FuelEU Maritime initiatives that aim to increase the production and the uptake of sustainable alternative fuels for these sectors. The necessary technology development and deployment has to happen already by 2030 to prepare for much more rapid change thereafter."*

1.4 International context

Given the strong international nature of maritime transport, the sector is also subject to international rules and conventions adopted by the IMO. The IMO is the specialised United Nations' agency acting as the global standard-setting authority for the safety, security and environmental performance of international shipping[31].

The main set of international rules on the environmental performance of ships is contained in the International Convention for the Prevention of Pollution from Ships (MARPOL)[32]. While MARPOL does not contain explicit mandatory requirements on the use of alternative fuels from ships, it sets a series of rules[33] regarding emissions to air, which may provide an incentive for the use of alternative energy sources.

The IMO has adopted in 2011 the Energy Efficiency Design Index (EEDI), which sets mandatory energy efficiency standards for all new built ships, and in 2018 the Initial Strategy on the reduction of GHG emissions from ships[34]. Discussions are ongoing on the implementation of the 2018 IMO's Initial Strategy on the reduction of GHG emissions from ships, starting with energy efficiency standards to set minimum improvement thresholds both in terms of technical and operational carbon intensity of existing ships.[35]

The strategy recognises that the *"global introduction of alternative fuels and/or energy sources for international shipping will be integral to achieve the overall ambition"*. Within

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[30] COM(2020) 562 final

[31] http://www.imo.org/EN/Pages/Default.aspx - All EU Member States are also IMO members.

[32] The convention covers the prevention of pollution of the marine environment by ships from operational or accidental causes and contains a series of annexes addressing pollution from oil, noxious liquid substances in bulk, packaged harmful substances, sewage from ships, garbage from ships and the prevention of air pollution from ships. http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx

[33] This is the case for Regulations 13 and 14 of MARPOL Annex VI respectively on NOx, SOx and PM.

[34] The full text of the Initial IMO Strategy can be found in the IMO submission to the Talanoa dialogue: https://unfccc.int/sites/default/files/resource/250_IMO%20submission_Talanoa%20Dialogue_April%202018.pdf The IMO initial strategy envisages in particular to reduce CO_2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008. It also expects to peak GHG emissions from international shipping as soon as possible and to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008 whilst pursuing efforts towards phasing them out on a pathway of CO_2 emissions reduction consistent with the Paris Agreement temperature goals. The strategy will be subject to a revision in 2023.

[35] https://www.imo.org/en/MediaCentre/PressBriefings/Pages/42-MEPC-short-term-measure.aspx

the list of identified candidate short-term measures (meant to enter into force before 2023), the IMO includes the promotion of uptake of alternative low-carbon and zero-carbon fuels and the provision of shore-side electricity. It also calls for the development of robust lifecycle GHG/carbon intensity guidelines for all types of fuels, to prepare a programme for effective uptake of alternative low-carbon and zero-carbon fuels. The discussion on the uptake of alternative fuels as well as on market-based measures (MBM) is expected to start at IMO in the course of 2021, also based on the EU proposal on fuel lifecycle guidelines based on sustainability and GHG emissions saving criteria [36].

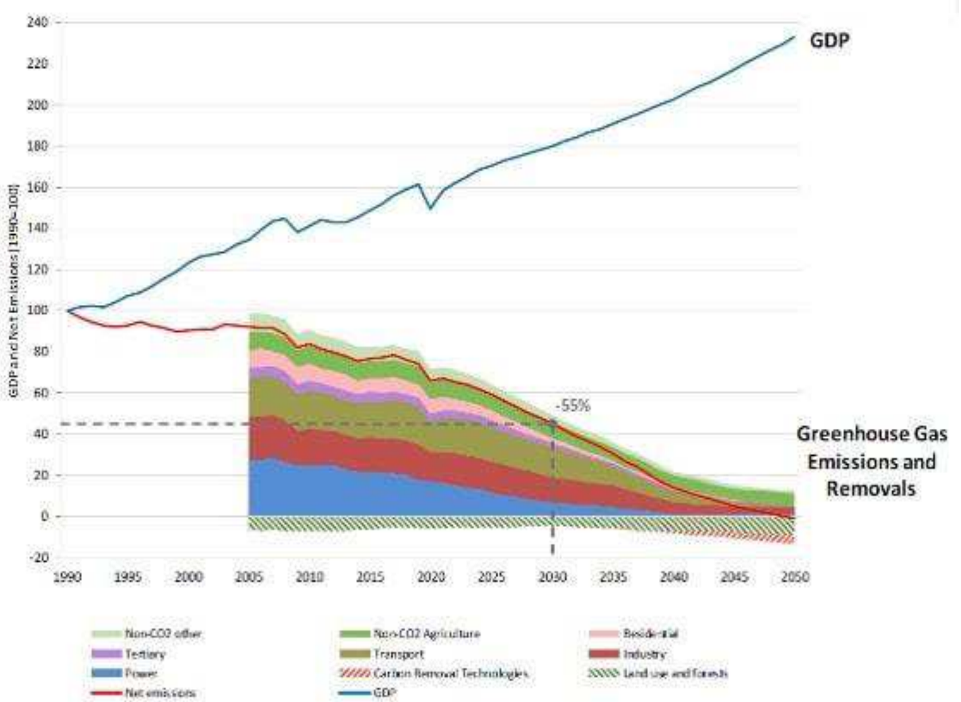
The International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code)[37] also entered into force on 1 January 2017, along with new training requirements for seafarers working on those ships. These rules contain mandatory provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using low-flashpoint fuels, focusing initially on LNG.

1.5 Trajectories for renewable and low carbon fuels

The European Green Deal has set the key objective to deliver a 90% reduction in transport-related greenhouse gas emissions by 2050, drawing on the in-depth analysis underpinning the 2050 long-term strategy[38]. The common scenarios underpinning the Impact Assessment accompanying the 2030 Climate Target Plan[39] and the Staff Working Document accompanying the Sustainable and Smart Mobility Strategy confirmed that for achieving climate neutrality by 2050 transport emissions (including intra-EU aviation and intra-EU maritime) would need to decrease by 95-96% by 2050 relative to 2015 (94-96% relative to 1990). When considering all intra-EU and extra-EU maritime transport, the emissions reductions are projected at around 91-92% relative to 2015 (89-90% relative to 1990). The lower emissions reductions in transport relative to other sectors like for example power generation is in recognition of the fact that emissions in some transport modes, in particular aviation and maritime, are more difficult to abate. The EU's pathway towards climate neutrality, covering all sectors of the economy, is provided in Figure 1.

[36] EU submission to the 7th meeting of the Intersessional Meeting of the Working Group on Reduction of GHG emissions from ships from the IMO (ISWG-GHG 7/5/9), which suggests methodological elements on how to develop fuel lifecycle guidelines based on sustainability and GHG emissions saving criteria to incentivize the uptake of alternative fuels at global level.
[37] http://www.imo.org/en/OurWork/Safety/SafetyTopics/Pages/IGF-Code.aspx
[38] COM (2018) 773
[39] SWD/2020/176 final

Figure 1: The EU's pathway to sustained economic prosperity and climate neutrality, 1990-2050



Source: COM(2020) 562 final. Commission Communication "Stepping up Europe's 2030 climate ambition Investing in a climate-neutral future for the benefit our people

Among the transport modes, road and rail transport would need to be almost fully decarbonised by 2050. Lower emissions reductions are projected in aviation and maritime, due to the more limited technological options available for these sectors. Nevertheless, air transport sector would need to achieve emissions reductions of at least 52-59% by 2050 relative to 2015 (equivalent to 14-25% reduction relative to 1990) and international maritime of at least 84-86% (equivalent to 80-82% emissions reductions relative to 1990).

The common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy, looked at a range of pathways/scenarios to explore the delivery of the increased ambition of cutting the economy-wide GHG emissions by at least 55% by 2030 and achieving climate neutrality by 2050. These pathways/scenarios were constructed around a set of specific policies for all sectors of the economy that either focus on carbon pricing or focus on regulatory measures, or combine the two types of instruments. For the maritime transport, the same policy instruments (including 'FuelEU Maritime' initiative) were included in all scenario configurations.

The staff working document accompanying the Sustainable and Smart Mobility Strategy describes the trajectories for renewable and low carbon fuels in more detail[40], drawing on the common economic analysis underpinning the 2030 Climate Target Plan and the

[40] Source: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020SC0331

Sustainable and Smart Mobility Strategy. These trajectories are derived in a way that enables kick starting the scale-up of renewable and low carbon fuels in the maritime sector from 2025 onwards and their large scale deployment by 2050, while ensuring the consistency with the required overall GHG emissions reductions by 2030 and 2050, preserving the competitiveness of the sector, promoting innovation, and ensuring feedstock availability for renewable and low carbon fuels in all energy and transport sectors in the transition towards a climate neutral economy. The pathways/scenarios delivering a reduction in the EU GHG emissions by at least 55% by 2030 and climate neutrality by 2050 show that renewable and low carbon fuels should represent 6 to 9% of the energy used in the international maritime sector in 2030 and 86 to 88% by 2050[41,42].

When considering a pathway/scenario that strengthens and further expands the carbon pricing to the road transport and buildings sectors, be it via EU ETS or other carbon pricing instruments, in combination with low intensification of transport policies and no intensification of energy efficiency and renewables policies, the analysis shows that renewable and low carbon fuels should represent at least 6% of the energy used in the international maritime sector in 2030 and 86% by 2050.

When considering a pathway/scenario that assumes high increase of the ambition of energy efficiency, renewables and transport policies, while keeping the EU ETS scope unchanged, renewable and low carbon fuels should represent close to 9% of the energy used in the international maritime sector in 2030 and 88% by 2050.

Finally, the pathway/scenario focusing on a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy shows that renewable and low carbon fuels should represent 7.5% of the energy used in the international maritime sector in 2030 and 86% by 2050.

All the pathways described above are consistent with the increased ambition of cutting the economy-wide GHG emissions by at least 55% by 2030 and achieving climate neutrality by 2050. They all deliver a 90% reduction in transport emissions by 2050, in line with the European Green Deal Communication and the Sustainable and Smart Mobility Strategy, and 80-82% emissions reductions in the international shipping sector by 2050 relative to 1990 (equivalent to 88-89% emissions reductions relative to 2008)[43]. In addition, the impact assessment underpinning the 2030 Climate Target Plan[44] noted particular benefits in deploying a broad mix of policy instruments, including carbon pricing and increased energy and transport sectoral regulatory policy ambition, and clearly suggested that there is

[41] If the scope of EU greenhouse gas emissions target would be additionally extended to all aviation and maritime emissions, the renewable and low carbon fuels would represent 13.5% of the energy used in the international maritime sector and 88% by 2050.
[42] The shares of renewable and low carbon fuels presented in this section do not account for the contribution of on-shore supply.
[43] The choice of 2008 as a base year for the emissions reduction projections in maritime transport is made to allow consistency with the IMO objectives that are all expressed in relation to 2008.
[44] Source: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020SC0176

no single policy instrument being capable of achieving all the objectives considered in the assessment alone.

This impact assessment takes as starting point the pathway for renewable and low carbon fuels that represent 7.5% of the energy used in the international maritime sector by 2030 and 86% by 2050 in the scenario focusing on a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy, while additionally considering the contribution of the on-shore power supply**.** It ensures consistency with the 2030 Climate Target Plan and with the other initiatives of the 'Fit for 55' package by delivering the necessary contribution in terms of emissions reductions to the increased ambition of cutting the economy-wide GHG emissions by at least 55% by 2030 and achieving climate neutrality by 2050. The impact assessment focuses on the specific design of the policy option that would best allow to reach this contribution. A qualitative assessment of the implications of lower/higher trajectory for the renewable and low carbon fuels is however provided in Sections 5.4 and 6.1.2**.**

An update of the pathway/scenario focusing on a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy for the purpose of the 'Fit for 55' package, while also reflecting the COVID-19 pandemics, the National Energy and Climate Plans and refining the policy design of the initiatives, confirms that maritime transport effectively contributes to the EU climate goals while considering the central trajectory for the renewable and low carbon fuels.

2. PROBLEM DEFINITION

2.1 What is the problem?

Currently, the fuel mix in the maritime sector relies entirely on fossil fuels. The vast majority of the 44 million tonnes of fuel consumed and reported by ships within MRV in 2018 concerned liquid fossil fuels. The use of LNG was only 3% of the total amount of fuel consumed (mostly by LNG and gas carriers) and other alternatives, in particular renewable fuels, were negligible[45]. According to the fourth IMO GHG study, 98.4% of all engines used in the fleet in 2018 were conventional fuel oil engines and 0.52% were LNG engines (including dual-fuel engines)[46].

The ship traffic monitored under the MRV accounted for more than 138 million tonnes of CO_2 emissions in 2018[47]. This represents around 11% of all EU transport CO_2 emissions

[45] European Commission, SWD(2020) 82 final, *Report from the Commission 2019 Annual Report on CO2 Emissions from Maritime Transport* https://ec.europa.eu/clima/sites/clima/files/transport/shipping/docs/swd_2020_82_en.pdf

[46] The remaining percent is constituted of methanol engines, gas and steam turbines, sails, batteries and non-propelled vessels.

[47] The MRV Regulation covers CO_2 emissions produced by ships above 5000 gross tonnage carrying out voyages from or to a port in the EEA, when transporting goods or passengers for commercial purposes.

and 3-4% of total EU CO_2 emissions[48]. EU international shipping CO_2 emissions are projected to grow by over 30% between 2015 and 2050 under current trends and policies, also considering the impacts of the COVID-19 pandemic[49,50]. Since emissions had fallen between 2008 and 2015, this implies a stabilisation of CO_2 emissions by 2050 relative to 2008 levels. This development is however not in line with the climate neutrality objective.

Emissions occurring when the ships were at berth (anchored or navigating in EEA ports) amounted to around 6% of the total CO_2 emissions as reported under the MRV. In addition, emissions of sulphur oxides (SOx), nitrogen oxides (NOx), and particulate matter (PM) significantly contributed to air pollution in coastal areas and port cities, where ship engines are still being used to produce the necessary power during the port visit[51]. There are hotspot areas in Europe where the contribution of shipping to air pollutant emissions can be up to 80% for NO_x and SO_2 and up to 25% for primary $PM_{2.5}$[52]. While the situation is improving with the use of cleaner fuels resulting from the introduction of the Sulphur Directive and the establishment of ECAs[53] in Northern Europe, as confirmed by the 2018 Commission report on the implementation of the Sulphur Directive[54], air quality remains an important area of concern for port cities. This is also clearly recognised by the industry; in the past five years, air quality ranked first among the top 10 environmental priorities of the port sector as illustrated in the environmental report from the European Sea Ports Organisation (ESPO)[55]. While the use of on-shore power supply (OPS) for ships at berth would allow removing these emissions, its uptake has so far remained negligible[56].

The almost exclusive reliance on fossil fuels constitutes an important risk to the sector's ability to contribute effectively to the carbon neutrality objectives in the long term. As explained in Section 1.5, RLF should provide 6-9% of the international maritime transport fuel mix in 2030 and 86-88% by 2050 to contribute to the EU economy-wide GHG emissions reduction targets[57]. This, in combination with carbon pricing and other

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[48] By limiting the monitoring requirements to large ships, above 5000 gross tonnage, the MRV Regulation covers around 90% of all CO_2 emissions, whilst only including ca 55% of all ships calling into EEA ports.

[49] Annex 4 provides the assumptions and results for developments under current trends and policies (i.e. the baseline scenario).

[50] In comparison, emissions from international shipping at global level are expected to continue growing to around 90-130% of 2008 emissions by 2050 for a range of plausible long-term economic and energy scenarios (IMO, Fourth Greenhouse Gas Study, 2020). These projections however do not take into account the impacts of the COVID-19 pandemics.

[51] See EEA, 2017, 'Aviation and shipping — impacts on Europe's environment', European Environment Agency Report No 22/2017, in particular section 4.2.: https://www.eea.europa.eu/publications/term-report-2017

[52] EEA, 2013, The impact of international shipping on European air quality and climate forcing, Technical Report No 4/2013, European Environment Agency, https://www.eea.europa.eu/publications/the-impact-of-international-shipping

[53] https://www.iiasa.ac.at/web/home/research/researchPrograms/air/Shipping_emissions_reductions_main.pdf

[54] COM(2018) 188 final

[55] https://www.espo.be/media/Environmental%20Report-WEB-FINAL.pdf

[56] For more details see chapter 2.2.4

[57] Drawing on the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy, the scenario assessing a combination of carbon pricing and regulatory measures (so-called MIX) projects a share of 7.5% for 2030 and 86% by 2050.

operational and technical measures would allow the sector to reduce its CO_2 emissions by 22% by 2030 and 88-89% by 2050 compared to 2008 levels (equivalent to 80-82% reduction relative to 1990)[58]. In the same vein, the IMO estimates that about 64% of the total amount of CO_2 reduction in 2050 would result from the use of alternative fuels[59].

In addition, the slow uptake of RLF in the maritime sector is an issue to be addressed in the short term because the adoption of new fuels in the sector takes time. LNG provides a good illustration of the time necessary for adoption of new fuels in the sector; while LNG was primarily used already as fuel in Norway in 2000, it took 13 years for it to spread outside Norway[60]. Still today, LNG powered ships represent a minor fraction of the fleet, despite the competitive fuel price and the attractiveness of this option to meet the existing requirements on SOx and NOx emissions[61].

In the open public consultation (OPC), 95% (129/136) of the respondents confirmed that it is 'very relevant' or 'relevant' to promote the uptake of sustainable alternative fuels and diversify the fuel mix of maritime transport to accelerate the decarbonisation of shipping. Without action at EU level, 59% (19/32) of the respondents to the targeted consultation (TC) think that by 2030, the use of RLF will remain the same as today for ships in navigation. For ships at berth, the share of TC respondents is 44% (14/32).[62]

The main problems that this initiative will address therefore concern: **(1) the low uptake of RLF by ships calling EU ports** and **(2) and the low uptake of zero-pollution fuels by ships at berth in EU ports**.

Although closely resembling, and sharing most of the problem drivers, these are assessed as distinct problems because of two important aspects that differentiate them. The first relates to the consequence of the (non)use of RLF: while the climate effect does not change with respect to the place of emission, the impact of air pollution is considerably higher for ships at berth. This might justify a different and more ambitious policy in terms of type and use of RLF in ports. Indeed, fuels that perform well in terms of both GHG and local pollutants (NOx or PM), such as electricity or hydrogen, are much preferable for use at berth than fuels that perform well on GHG but less so on local pollutants, as is the case of, for example, advanced biofuels and e-fuels. The second aspect relates to the availability of additional technologies for use in ports, where energy can be drawn from shore and use of

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[58] The choice of 2008 as a base year for the emissions reduction projections in maritime transport is made to allow consistency with the IMO objectives that are all expressed in relation to 2008.

[59] IMO, Fourth Greenhouse Gas Study, 2020. The study was submitted to the Marine Environment Protection Committee (MEPC) in July 2020, as document MEPC 75/7/15 - the study can be downloaded via the IMODOCS website (registration required).

[60] DNV GL (2019), Comparison of Alternative Marine Fuels, Study commissioned by SEA-LNG: https://sea-lng.org/wp-content/uploads/2020/04/Alternative-Marine-Fuels-Study_final_report_25.09.19.pdf

[61] Note, however, that use of gas from fossil sources will not be sufficient to meet the EU climate objectives.

[62] For ships in navigation, while 28 % think RLF use will increase moderately. For ships at berth, that figure is 41 %. Looking towards 2050, the majority of TC respondents expects the RLF share to increase either moderately or significantly both for ships in navigation (69 %) and at berth (72 %).

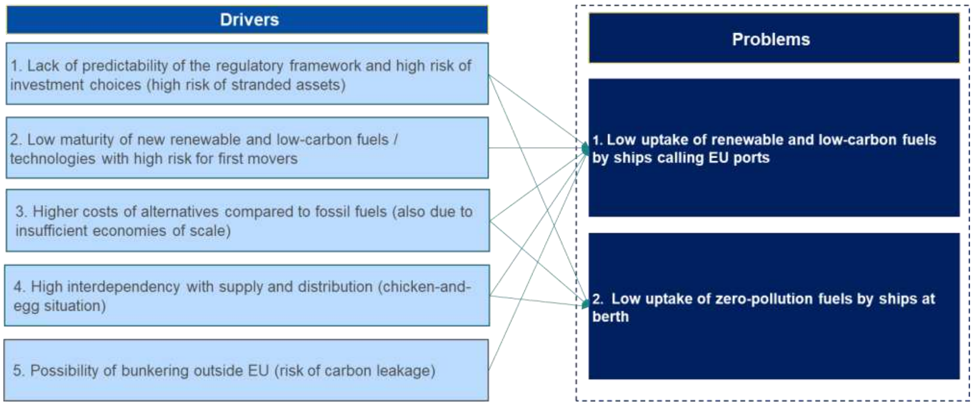
fuels with low energy density is less problematic. Also this aspect might justify a different approach for ships at berth.

These two problems need to be addressed because they hamper the sector's ability to effectively decarbonise in the long term, while also reducing the air pollution emissions in the ports. Ensuring a higher penetration of RLF, along with energy efficiency improvements is critical to bring maritime transport in line with the European ambition of climate-neutrality by 2050 and reduce air pollution from ships in ports and coastal cities.

2.2 What are the problem drivers?

Several drivers underpin these problems and result from significant technological, market or regulatory barriers. They consist in the lack of predictability of the regulatory environment and the resulting high risk for investments; the uncertainty over alternative technologies and the risk for first movers; the higher costs of low-carbon technologies in the absence of significant levels of production; the interdependency between demand, supply and distribution aspects; and sector specific issues related to the possibility of bunkering outside the EU. These issues are summarised in Figure 2:

Figure 2: Problem tree



2.2.1 *Lack of predictability of the regulatory framework and high risk of investment choices (high risk of stranded assets)*

Ships are costly and long-lived assets; in accordance with data from UNCTAD, the average age of the world merchant fleet in 2019 was around 21 years[63], even though differences can be observed across different market segments. The age distribution of ships monitored in 2018 under the MRV system indicate that that the age of vessels operating in Europe is usually lower than the global average as ships are either relocated or sold on the second-hand market. Given this, it is important for ship-owners to anticipate the framework conditions that could impact the economic value of the investment and lead to

[63] UNCTAD (2019), Review of maritime transport 2019, https://unctad.org/en/PublicationsLibrary/rmt2019_en.pdf

assets being stranded. This applies both to the operating life of the vessels and to their potential value on the second-hand market.

Assets would be stranded when they lose economic value well ahead of their anticipated useful life[64]. The main risk factors resulting in ships becoming stranded assets can be associated with ship specifications no longer meeting needs of demand or regulatory requirements (e.g. possible introduction of new standards). In this context, a predictable regulatory environment is very important for investment decisions. Climate policy can reinforce the risk of stranded assets. This is mainly related to evolving standards, such as the increased level of energy efficiency that cannot be sustained by older equipment.

The importance of this driver was also confirmed by the public consultation. After the higher price of RLF, the high risk of investment in vessels technology and port infrastructure was the second most important barrier identified by the respondents. In addition, 61.5% (83/136) of the respondents indicated that the lack of predictability of the regulatory framework was either an important or the most important barrier to the deployment of RLF in maritime transport.

In the absence of clear-cut technological choices (see Section 2.2.2) and of a defined regulatory path setting clear provisions for the decarbonisation of the future fuel mix, it is difficult for operators to build a business case and make long-term investment decisions. Given the potential investment risks, a wait-and-see approach is likely to prevail and defer deployment of new technologies and hence of RLF.

2.2.2 *Low maturity of new renewable and low-carbon fuels/technologies with high risk for first movers*

The uncertainty caused by the unpredictable regulatory environment is compounded by the absence of a clear substitute to fossil fuels. No technological solution has yet emerged as a preferred choice among various alternatives. Most of the alternative technologies are at a low level of maturity[65] and the market has not yet started a process of deployment and selection. The difficulty for the market to converge on the choice of alternative technologies is also due to the operating conditions of the sector, which reflect the specific needs and constraints of market operators. The maritime sector is not uniform and important differences can be observed between market segments.

A first differentiation can be made between short-sea and deep-sea shipping. In the EU, short-sea shipping is defined usually as maritime transport between ports situated in geographical Europe, as well as on the Mediterranean and Black seas[66]. This type of traffic typically consists of relatively short routes with frequent port calls and can include fixed-

[64] Smith et al. 2015, Stranded Assets and the Shipping Industry, https://www.researchgate.net/publication/321348262
[65] In terms of maturity of emission reduction options, the fourth IMO GHG study categorises all fuel options with a relatively low rate (evolving maturity, sometimes with some unit available).
[66] COM (1999) 317 final

schedule routes. In comparison, deep-sea shipping is mainly characterised by vessels covering long routes, without necessarily a regular schedule (with the exception of liners). In practical terms, this differentiation affects the operators' needs in terms of quantity of fuel carried, energy density (energy per unit volume) and global availability of fuels.

On shorter distances and in ports, lower energy density is sufficient, already opening additional decarbonisation and zero-pollution pathways (e.g. hydrogen and electrification). However, currently, these solutions remain limited to experimental vessels and very specific market segments (e.g. short-distance ferries) with relatively low power requirements and the possibility to bunker or recharge frequently.

An additional element concerns the compatibility of the new fuel options with the existing machinery (no or minor needs to retrofit the ship) and infrastructure. The performance of the different fuel options in terms of air pollutant reduction can also be considered, even though these emissions (e.g. NOx or PM) may be addressed by technical means such as engine management and exhaust gas treatment. This is particularly relevant for the second problem (low uptake of zero pollution fuels by ships at berth), which as mentioned in Section 2.1 is important in these areas.

Biofuels, biomethane and drop-in e-fuels are compatible with the existing assets and infrastructure (liquid or gaseous) and can therefore be deployed immediately in existing oil- or LNG-fuelled vessels. However, the supply of this type of fuels to the maritime sector is very limited and their GHG reduction potential depends on whether they can be produced and used sustainably at scale (availability of feedstocks, etc.). LNG is a technologically mature solution that substantially contributes to air pollution reduction, but its contribution towards GHG reduction can be limited, particularly taking into account methane slip, and depends on the engine technology[67]. Other RLF may be deployable within existing vessels as a retrofit, but these options are at an early stage of development. Regarding OPS, the technology can be considered to be at a mature stage. Based on information by the European Alternative Fuels Observatory (EAFO)[68], ports in Europe have started the first steps in using these installations as of the 1990's, and an increased trend in their installation is recorded since 2010. Ports now have experience with such installations for different vessel types.

The feedback received from the consultation activities in preparation of this initiative confirmed that market actors expect using a variety of fuels still in 2050 with no dominant source of energy. The respondents of the targeted consultation survey indicated also their

[67] LNG does not contain sulphur, which results in (almost) no SOx emissions (95% to 100% reduction compared to HFO) and almost no PM-emissions (90-100% compared to HFO). NOx emissions reductions depend on the type of engine used but vary between 40% and 80% compared to HFO. In addition, because LNG has a higher hydrogen-to-carbon ratio in comparison to conventional fuels, the specific CO_2 emissions are lower by around 25% compared to HFO. The overall GHG impact depend on methane slip control but it can be reduced to 0% benefits compared to HFO. EMSA (2018) *Guidance on LNG Bunkering to Port Authorities and Administrations*,

[68] https://www.eafo.eu/

expectation on fuels most likely to be used in 2030 and 2050, both during navigation and at berth. Concerning 2030, biofuels are perceived as most promising for use in navigation, followed by batteries. Looking at 2050, the expectations are different: the categories ‘other decarbonised hydrogen-derived fuels (including ammonia)’ and ‘Decarbonized hydrogen (including fuel cells)’ received the highest scores. For emissions at berth, the alternative fuel option that stands out in being promising both for 2030 and 2050 is OPS[69].

The ‘wait and see’ attitude of market operators can therefore be explained with the uncertainty on both the right timing of investments – also in connection with regulatory requirements (see also 2.2.1) – and on the choice of technologies; all in a context of long-lived and costly assets (vessels) and different needs in different business segments.

2.2.3 Higher costs of alternatives compared to fossil fuels (also due to insufficient economies of scale)

In response to the public consultation carried out in the context of this initiative 47.8% of the respondents (65/136) indicated the higher price of RLF as a very relevant barrier to their uptake, which made this barrier score the highest. This problem driver is particularly critical as the costs of fuel is the single most important item determining the voyage costs of a ship, accounting for 47% of the total[70].

The cost of RLF is generally higher than that of fossil fuels. Increasing the production volumes can be expected to reduce production cost due to learning effects and economies of scales, but the lack of current profitability and of significant volumes of expected demand forms a major barrier to investment.

While existing literature confirms the price gap between RLF and conventional fuels, it also shows that the production cost ranges of biofuels and e-fuels are larger than those of fossil fuels. To some extent, this is caused by the fact that production systems for biofuels and e-fuels are newer and subject of uncertainties and on-going research. 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 wide ranges also relate to the uncertainty about renewable electricity costs, which are linked to electricity market price developments and which form a major part of the production costs of e-fuels. This is a similar challenge for the uptake of OPS. The energy price at the grid (including taxes) must be comparable to the bunkering price of the conventional fuel for the OPS to be economically attractive for use on a vessel. The price gap is an element that stakeholders like the European Sea Ports Organisation (ESPO), are considering as reducing the demand for OPS[71].

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[69] See Stakeholder consultation report

[70] Stopford (2009) – Maritime Economics, Third Edition, published by Routledge, Oxon.

[71] https://www.espo.be/media/ESPO%20Green%20Deal%20position%20paper%20Green%20Deal-FINAL_4.pdf

These prices are expected to fall as technology matures. In this respect, the EU Hydrogen Strategy already notes that costs for renewable hydrogen are going down quickly. For instance, the costs for electrolysers, which are necessary for the production of renewable hydrogen, have already been reduced by 60% in the last ten years, and are expected to halve in 2030 compared to today with economies of scale. In regions where renewable electricity is cheap and available, electrolysers may be able to compete with fossil-based hydrogen already in 2030. On the other hand, in the medium to long term the competition for biomass feedstocks with other energy and transport sectors in the transition towards a climate neutral economy is expected to push the feedstock prices upwards. This is fully taken into account in the analysis and further explained in Section 5.4.

The fragmentation of the sector and the high level of customisation of vessels represent a barrier to reach critical mass for the deployment of new technologies, unless a significant number of operators takes action. The lack of sufficient production levels contribute to the higher cost of RLF compared to conventional fossil fuels, which remains a barrier to their uptake[72]. MBMs, such as ETS or ETD, may help bridging the gap, but the price difference is likely to remain too high until the production of sustainable fuels and technologies achieves sufficient economies of scale. A price of emission allowances of at least €200/tCO_2 would be necessary to make RLF economically interesting, which is unlikely in the short- or medium-term.

2.2.4 High interdependency with supply and distribution (chicken-and-egg situation)

The introduction of new fuels does not only require the development of appropriate vessel technologies (see 2.2.2) or the willingness of users to adopt a new source of energy; it also necessitates sufficient availability of fuels in terms of production (type and quantity of fuel produced), supply and distribution through an adequate bunkering infrastructure. The global nature of the maritime business means that many vessels need to be able to operate and refuel across the world. Therefore, an alternative technology to fossil fuels would require the availability of sufficient production of the energy carrier, vessels capable of using it, and an infrastructure for its distribution in ports around the world.

Although the situation differs depending on the technology, in all cases there is a strong need for coordination between supply and demand. Investments in production are not made, and economies of scale are not reached, without enough demand; conversely, there is not enough demand without a reasonable priced supply ('chicken-and-egg' situation). This is a clear case of interdependency of business decisions by market actors on the side of demand (ship operators and ship owners) and supply (fuel production, supply and infrastructure). At present, the EU regulatory framework focusses on the supply, infrastructure and distribution of fuels, but puts no obligations on their use.

[72] The Port of Rotterdam reports that 0.5% - 2% of fuels sold were biofuels or a biofuel mixture in 2019 (approximatley100 kilotons of fuel supplied).

AFID establishes rules on the deployment of alternative fuels infrastructure for transport, including provisions for equipment of ports on the Trans-European Transport Network (TEN-T) for the supply of LNG and OPS[73]. While the Directive was expected to create sufficient conditions for the use of alternative fuels, the very low demand for alternative fuels or connections to the electric grid while at berth gave grounds to ports to delay investments in the relevant infrastructure. AFID is due to be reviewed[74].

Indeed, data compiled by the European Alternative Fuels Observatory (EAFO)[75] show that the deployment of OPS has been slower than initially expected – in December 2020, 41 maritime and inland waterway EU ports had at least one berth equipped with OPS. However, depending on the location within the port and the power provided at each OPS, only specific vessels can be supplied with power while at berth. For example, an OPS located at a container terminal can only supply container vessels but not passenger vessels. Concentrating the regulatory approach solely on the provision of infrastructure may therefore not be sufficient to break the "chicken-and-egg" situation.

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. 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[76]. Note that, even though the use of LNG required an upfront investment (in particular in vessels' technologies and the development of the bunkering infrastructure), LNG was cheaper than HFO per unit of energy, throughout the 2010-2020 period in all years except 2016 (DNVGL (2020), Alternative Fuels Insight[77]) and significantly cheaper than marine gas oil (MGO)[78] for the entire period.

Besides the provision of adequate distribution infrastructure, there is an additional interdependency with the production of fuels. Alternative fuels are not put in production

[73] The Directive lists LNG and OPS as the two mature alternative fuels for waterborne transport. It foresees the provision of sufficient LNG bunkering capacity in all TEN-T Core ports by the end of 2025. While a similar approach in principle applies to OPS, the provisions may not apply if there is no demand and the costs are disproportionate to the benefits, including environmental benefits.

[74] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/2111-Evaluation-of-the-Alternative-Fuels-Infrastructure-Directive
https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12251-Revision-of-Alternative-Fuels-Infrastructure-Directive

[75] https://www.eafo.eu/

[76] This means that during this period, there were no dedicated bunkering facilities for ships and LNG bunkering was done via trucks, which is a rather sub-optimal solution for the maritime sector given the fuel quantities required.

[77] https://www.dnvgl.com/services/alternative-fuels-insight-128171

[78] The use of MGO is the principal compliance option for meeting the 0.10% sulphur requirements in SOx Emissions Control Areas (applicable as of 2015 in Europe in the Channel, the North Sea and the Baltic Sea). Next to LNG, the other alternative would be the use of HFO with exhaust gas cleaning system (SOx scrubbers), which also require investment in the ship engine.

unless there is a demand, or at least market prospects; but without guaranteed availability of fuels, operators do not invest in alternative fuel vessels and do not generate demand.

The RED II supports the supply of RLF for the land (road and rail) transport sectors and indirectly for the aviation and maritime transport sector, via the use of multipliers. The Directive must be transposed by the Member States into national legislation by 30 June 2021. Its impact on the use of RLF in maritime remains still uncertain at this stage. The revision of the REDII Directive is also part of the 'Fit for 55' package. This should provide further incentives for the supply of RLF to the maritime transport sector.

2.2.5 Possibility of bunkering outside EU (risk of carbon leakage)

Being an international sector by nature, maritime transport is highly prone to carbon leakage. If rules were to apply to fuels *sold* in Europe without obligations for their use, it would be possible for many vessels active in both deep sea and short sea trades to bunker fuel outside the EU. Due to their large tank capacities, most ships are able to undertake long voyages on a single bunkering. Estimations made in the framework of the support study for this impact assessment (Ecorys / CE Delft, forthcoming) indicate that bulk carriers can sail more than 30,000 nautical miles (nm) on average on full tanks, containerships up to 50,000 nm and tankers between 10,000 nm and 30,000 nm on average. To put this into perspective, a transatlantic journey from Europe would cover around 6,000-7,000 nm and a journey to South-East Asia around 10,000 nm.

A number of important bunkering hubs are located in the EU, in particular the ports of Rotterdam, Antwerp and Algeciras, which rank among the world's ten largest ports for bunkering (in terms of volume)[79]. Overall, in 2017, European countries (including the UK) supplied a little less than 20% of the international maritime bunker fuels[80]. The study carried out in 2011 in support for the impact assessment of a proposal to address maritime transport GHG emissions[81], notes that the possible introduction of taxes on fuel supplied is likely to be circumvented by bunkering outside the scheme (either in ports outside the EU, or by using offshore bunkering facilities). Addressing only the EU supply of RLF would, in principle, not be sufficient to provide the expected results in terms of higher penetration of these fuels in the maritime fuel mix.

The possibility of bunkering outside the EU also calls for requirements that do not distort the level playing field between fuel distributors and producers within and outside the EU.

[79] https://maritimefairtrade.org/top-ten-bunkering-ports/
[80] Eurostat and IEA data
[81] https://ec.europa.eu/clima/sites/clima/files/transport/shipping/docs/ghg_maritime_report_en.pdf

2.3 How will the problem evolve?

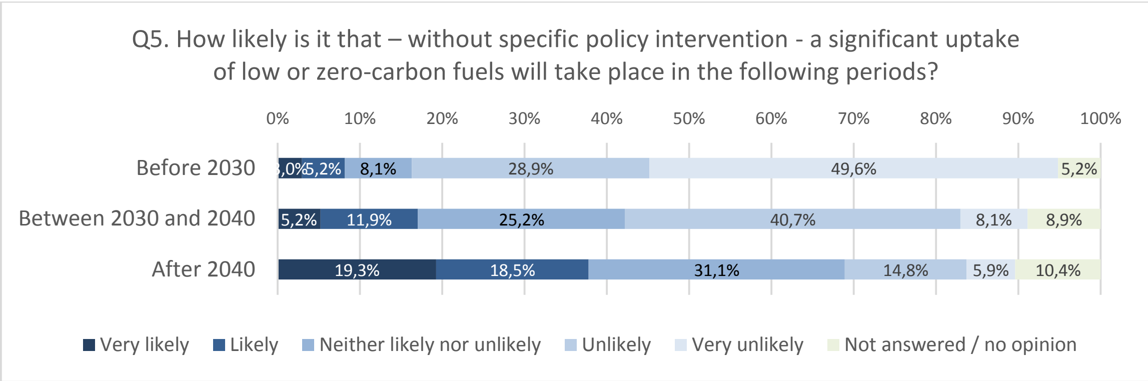
It is unlikely that the situation will evolve towards a significantly greater penetration of RLF in shipping without further policy intervention. The uptake is likely to remain anecdotal, driven by pioneers in the sector. The baseline scenario, showing developments under current trends and policies[82], projects a limited uptake of biofuels in international maritime by 2050 (0.1% in 2030 and 1.3% in 2050). Electricity use at berth is also projected to remain limited at around 0.1% of the total fuel mix by 2050. No other type of RLF is foreseen to enter the international maritime fuel mix by 2050 without further intervention. As a result, tank to wake CO_2 emissions are projected to increase by 14% by 2030 and by over 30% by 2050 relative to 2015. By 2050 this would imply a stabilisation of CO_2 emissions to their 2008 levels, which is however not in line with the climate neutrality objectives. Well to wake GHG emissions would grow slightly faster at 15% during 2015-2030 and over 35% for 2015-2050.[83] The increase in emissions is driven by the sustained growth projected for transport activity (20% during 2015-2030 and 50% for 2015-2050), even when accounting for the impact of the COVID-19 pandemic, and despite the projected significant improvements in energy efficiency. More details on the baseline scenario are provided in Annex 4.

It is also worth noting that the existing provisions of EU legislation (in particular the Sulphur Directive or the AFID), which could have encouraged the uptake of alternative fuels, in particular LNG and OPS, have not produced yet any significant uptake of new sources of energy in maritime transport. However, by 2050 LNG is projected to represent around 19% of the international maritime fuel mix, mainly as a result of more stringent requirements on air pollution control (in particular SOx and NOx emissions)[84]. Even though the GHG benefits of fossil LNG remain modest (in particular due to possible methane slip) and insufficient to meet EU GHG reduction targets; this fuel provides a good solution to air pollution issues, allowing reductions in SOx and NOx emissions and, as a result, it represented an attractive compliance option to the Sulphur Directive and MARPOL Annex VI. In the longer term, LNG can pave the way to the use of bio-LNG or e-gas, which would also offer climate-related benefits.

The feedback received in the context of the public consultation confirms that, without policy intervention, the uptake of RLF in maritime transport is unlikely to happen to a significant extent before 2040.

Figure 3 Feedback from the public consultation on the likely uptake of RLF without specific policy intervention

[82] More details on the baseline scenario are provided in Annex 4.
[83] Well to wake emissions also take into account the CH_4 and N_2O from methane slippage.
[84] More details on the baseline scenario are provided in Annex 4.



Breaking this deadlock would require some external development, such as a significant technological breakthrough on the side of research and development (including lowering the cost and upscaling maturing technology solutions), a strong push from public authorities towards the use of certain technologies, or the imposition of performance requirements that would force operators to choose low carbon technologies and kick-start a process of transition. Whereas a breakthrough in research providing a superior technology that the market would spontaneously adopt cannot be excluded, there is no certainty of this happening in time to reduce maritime emissions by the desired amount by 2050. To reduce maritime emissions in a timely fashion, additional policy intervention is required, as also indicated by respondents to the public consultation[85].

As explained in Sections 1.5 and 2.1, maritime transport should reduce its CO_2 emissions by at least 22% by 2030 and 88-89% by 2050 compared to 2008, to be in line with the EU climate objectives. Existing literature suggests that with current technologies, at best, a vessel can improve the energy efficiency of its operations by roughly further 20 to 30% compared to current levels[86]. Moreover, individual energy savings are likely to be partially offset by an increase in the volume of maritime activity. As a result, a large part of the emission savings would need to also be achieved via use of RLF already within the next couple of decades. It is therefore clear that a specific approach dedicated to the uptake of RLF is essential for the sector to effectively contribute to the post-2030 climate targets. As explained in Section 1.5, RLF should provide 6-9% of the international maritime transport fuel mix in 2030 and 86-88% by 2050. The scenario assessing a combination of carbon

[85] More than 87% of the respondents in the OPC focusing on the demand-side. When asked about possible intervention, 76% of the respondents consider it very relevant or relevant to set a clear regulatory pathway for decarbonising the current marine fuel mix

[86] Further improvements in energy efficiency depend on the different types and combinations of energy saving technologies available for the different ship types and their use in operation. For example, shipyards estimate on average further EEDI improvements at 0-5%, wind assisted propulsion at 5-10% (albeit it is voyage dependent and is suitable primarily for bulk carriers and tankers), air lubrication at ca 5% (but not suitable for larger tankers and bulk carriers). Fouling control and speed reduction can bring additional savings, as well as waste heat recovery which has however limited performance at reduced speeds and is only suitable for certain ships with sufficient electrical load to absorb the power generated. These are estimates for individual ships, but considering a fleet level perspective – these percentages need to be adjusted to account for the fact that not all ships are compatible with these interventions. Source: ABS et al (forthcoming), "Decarbonisation of Shipping: Technical Study on the future of the Ship Energy Efficiency Design Index".

pricing and medium intensification of regulatory measures underpinning the impact assessment accompanying the 2030 Climate Target Plan and the staff working document accompanying the Sustainable and Smart Mobility Strategy projects a share of 7.5% for 2030 and 86% by 2050.

Achieving 2050 emission reduction targets in maritime transport is highly unlikely, as shown by the Baseline scenario projections, if the production of sustainable fuels, the testing and certification for maritime use, the deployment of the necessary infrastructure in ports, and the renewal of the fleet do not start as soon as possible, particularly in the case of technologies that require dedicated infrastructure, retrofit solutions as well as new vessels and engine design. RLF that can be blended with the fossil fuels currently in use (drop-in fuels) can be deployed much more rapidly, but even in their case production needs to be scaled up and production costs reduced.

These considerations suggest that a scenario in which a new dominant technology replaces rapidly the current one is not very likely[87]. The most probable scenario is that various technologies, possibly used in different segments of the market, will coexist for a prolonged period of time. This tends to indicate that the process of decarbonisation of the energy used in the sector must start promptly and develop in parallel with the improvements in energy efficiency.

In addition, it is important to stress that increasing the penetration of alternative fuels in maritime transport is a long and complicated process, requiring cooperation and coordination among different market actors. Availability of technology (including the technical means to use it), sufficient supply of fuels (in terms of production and bunkering/charging infrastructure) as well as sufficient conditions to sustain the use of the technology by market operators is critical. Without a regulatory framework providing a clearly identified pathway for decarbonising the maritime fuel mix and for the necessary technology developments, the uptake of new fuels is likely to remain marginal and the costs for their introduction will solely fall upon first movers (even though these may not receive any competitive advantage as a result[88]).

The review of the Renewable Energy Directive is expected to drive scaling up the production of renewable and low carbon fuels in the EU. However, as explained in section 2.2.4, and given the possibility of ships to bunker internationally and carry long journeys on a single bunkering, any requirements relying solely on supply may be easily circumvented in the context of maritime and would not ensure their uptake in the sector.

[87] The maritime sector has already gone in the past through two transitions: from wind to steam, and from steam to oil. Even if in those cases the 'next' technologies were clearly identified, both transitions took around 50 years to complete.

[88] This is also due to the fact that the use of alternative fuels is likely to be seen as an additional cost item as opposed to the introduction of fuel saving / efficiency technologies, where first movers would in principle be able to lower their fuel-related voyage costs. This would, in turn, allow them to either increase profit margins or be able to offer more competitive prices as a clear first mover advantage.

On the other hand, the current initiative complements the review of the Renewable Energy Directive by securing the demand for these fuels in the maritime sector and thus reinforcing the delivery of renewable energy in the transport sector. In this regard, it should be highlighted that this initiative intends to fully match the definitions and sustainability criteria of the Renewable Energy Directive. In fact, in the absence of RLF supply in the EU, maritime would rely exclusively on imports or bunkering such fuels in third countries. Further insights in related policy instruments governing the supply and infrastructure of RLF are provided in Section 5.3.1.

The revision of the Energy Taxation Directive revisits the tax exemptions for conventional fossil fuels used in shipping. This will however not be able to address problem drivers 1, 2, 4 and 5 of the present initiative. Finally, as explained above, for the EU ETS to make RLF economically interesting for the maritime sector, a price of CO_2 emission allowances of at least €200 would be necessary. By comparison, the impact assessment[89] accompanying the 2030 Climate Target Plan projected carbon prices for the ETS sector (including the maritime sector) in the range of 32 to 65 €/tCO2, to cut the economy-wide GHG emissions by at least 55% by 2030. The EU ETS is therefore unlikely, by itself, to drive RLF uptake in the medium-term. More details are provided in Section 5.3.3.

3. WHY SHOULD THE EU ACT?

3.1 Legal basis

The legal basis giving the EU the right to act is Article 100(2) of the Treaty on the Functioning of the European Union. In accordance with Article 4(2) of the Treaty, shared competence between the EU and the Member applies in the area of transport.

3.2 Subsidiarity: Necessity of EU action

Maritime transport is an international sector by nature. In Europe, approximately 75% of the voyages reported under the MRV are within the EEA (and could therefore be a proxy for intra-EU traffic) and only around 9% of the traffic is estimated to be domestic voyages (between ports within the same Member State). The cross-border dimension of the sector is therefore essential and calls for coordinated action at European level.

Without action at EU level, the risk is the establishment of a patchwork of regional or national requirements across Members States, which would trigger the development of technical solutions that may not necessarily be compatible with each other. Several Member States are already developing national maritime strategies that include specific approaches to ship emissions and in particular the uptake of alternative fuels[90]. As the

[89] SWD(2020) 176 final.
[90] This includes national plans being developed by the Netherlands, Sweden and Italy (in the form of their ‘Guidelines for Energy and Environmental Planning Documents of the Port System Authorities (DEASP)’. Non-EU Member States like

problem drivers identified in Section 2.2 do not fundamentally differ from one Member State to another, and given the cross-border dimension of sector's activities, these issues can be best addressed at EU level. EU action can also inspire and pave the way for the development of future measures to accelerate the uptake of alternative fuels at global level[91].

Previous EU action on GHG issues has already stimulated a corresponding response from the IMO, notably by the adoption of the EU Regulation on Monitoring, Reporting and Verification of GHG emissions from ships that led shortly afterwards to IMO adopting a similar mandatory global GHG Data Collection System. A coordinated approach by EU Member States to developments in GHG emission reduction at IMO has more recently ensured that mandatory operational energy efficiency measures are included within IMO's short term actions to reduce GHG. Projecting a common viewpoint from a considerable group of IMO member states within the IMO fora means that the EU can have a significant impact on the direction and outcome of IMO discussions.

3.3 Subsidiarity: Added value of EU action

The implementation of this initiative at European level is necessary to achieve the economies of scale in the uptake of RLF in maritime transport as well as avoiding carbon leakage, and ensuring level playing field between operators calling in EU ports and between the EU ports themselves. To give an example, obligations established at national level on the use of RLF could divert traffic to competing ports of other MSs and distort competition. Accordingly, harmonisation at EU level is necessary to ensure a level playing field for all actors of the maritime cluster (in particular, operators, ports and fuel suppliers).

4. OBJECTIVES: WHAT IS TO BE ACHIEVED?

4.1 General objectives

This initiative aims at increasing the uptake of RLF in EU maritime transport with a view to reducing emissions from the sector, both in navigation and at berth and thereby contribute to achieving EU and international climate objectives. Ensuring a more diverse fuel mix and higher penetration of RLF is critical to ensure the sector's contribution to the European ambition of climate-neutrality by 2050. At the same time, a differentiated approach to the use of RLF in navigation and in ports is important to account for different implications on air pollution (more relevant for ships in ports) and different availability of technologies (more options for ships in ports).

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the UK and Norway have also established their own plans. It is important to mention them in this respect as their objectives may affect short-sea shipping traffic to and from the EU.

[91] Currently listed in the Initial IMO Strategy on reduction of GHG emissions from ships among candidate mid-term measures, i.e. measures to be agreed by the IMO between 2023 and 2030.

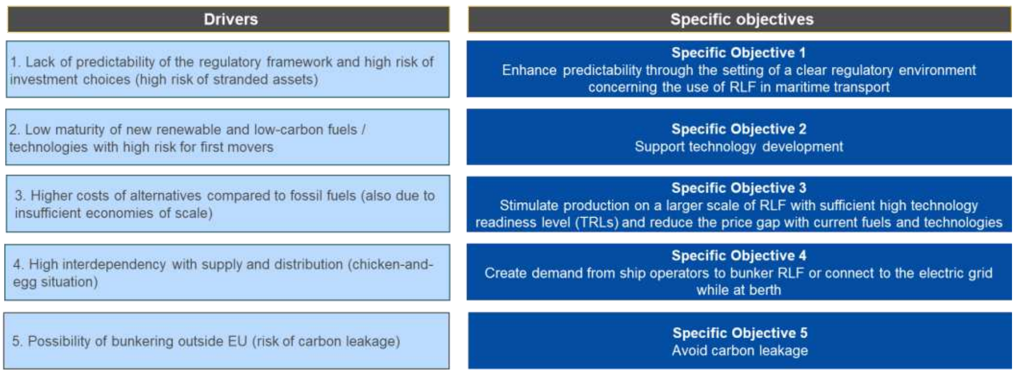
The initiative aims at setting a harmonised regulatory framework in the EU with a view to increase the share of RLF in the fuel mix of international maritime transport, including: liquid biofuels, e-liquids, decarbonised gas (including bio-LNG and e-gas), decarbonised hydrogen, decarbonised hydrogen-derived fuels (including methanol, and ammonia) and electricity. The present intervention is focused on demand-side aspects (the *use* of fuels, in this case RLF) and will complement the existing EU regulatory framework related to supply and infrastructure. It will also provide synergies with pollution reduction initiatives.

4.2 Specific objectives

This initiative is designed to effectively address the existing barriers that hamper the further deployment of RLF.

The specific objectives (SOs) and their correspondence with the problem drivers are presented in Figure 4:

Figure 4 Correspondence between the specific objectives and the problem drivers



The initiative will contribute to the achievement of the general objective by pursuing the following SOs:

- **Enhance predictability through the setting of a clear regulatory environment concerning the use of RLF in maritime transport.** The establishment of clear and mandatory targets for decarbonising the marine fuel mix to be used on-board will provide certainty on future obligations, facilitate planning of investments, and counteract a 'wait-and-see' attitude of operators. Setting a clear pathway for decarbonising the marine fuel mix, with progressively more stringent requirements, will also help understanding which technologies are more 'future proof' than others.
- **Stimulate technology development.** Establishing minimum levels of demand for RLF in the maritime sector is expected to stimulate the process of their selection and deployment, as well as of gradual technological improvement of yet immature solutions. It is expected to speed-up the deployment of more performant propulsion systems (energy converters) that can be used with specific fuels (e.g. fuel cells to be used with hydrogen and hydrogen-based fuels). It would also ensure that the development and deployment costs are spread more evenly across the sector and not only on first movers, who may not gain any competitive advantage in return. It is also

important that the chosen intervention, while encouraging a more rapid deployment of the more mature options (e.g. drop-in fuels) in the medium-term, does not prevent additional progress on the most environmentally sound, but yet immature, technologies that are needed in the longer term.

- **Stimulate production on a larger scale of RLF with sufficient high technology readiness level (TRLs) and reduce the price gap with current fuels and technologies.** By triggering demand of RLF by maritime operators, this initiative would create the conditions for higher volumes of production and attainment of economies of scale. This could contribute towards reducing the existing price gap with respect to conventional fuels.
- **Create demand from ship operators to bunker RLF or connect to the electric grid while at berth.** At the moment, the EU legislative framework is solely focussed on fuel supply and provision of infrastructure. However, in the absence of sufficient and predictable levels of demand, investments in production and infrastructure remain unprofitable and extremely limited in practice (as explained in Section 2.2.4). In order to address this interdependency issue, this initiative should complement measures taken on the supply and distribution side with a corresponding demand-side intervention (i.e. the use of fuels).
- **Avoid carbon leakage**. This initiative should help avoiding the carbon leakage that would derive from bunkering fuels outside the EU. This would be achieved by setting specific performance requirements on the fuel used by ships, regardless of where the fuel is acquired. The intervention should also be designed with a view to avoid any possible distortion of competition and regulatory advantage derived from ships belonging to different jurisdictions.

These objectives are consistent with the objectives of other Commission initiatives currently being pursued as part of the overall basket of measures to address GHG emissions from maritime transport, in line with the renewed EU climate ambition.

5. WHAT ARE THE AVAILABLE POLICY OPTIONS?

5.1 What is the baseline from which options are assessed?

The baseline scenario reflects developments under current trends and adopted policies as described in Section 2, and without further EU-level intervention. It builds on the baseline scenario underpinning the impact assessment accompanying the 2030 Climate Target Plan and the staff working document accompanying the Sustainable and Smart Mobility Strategy[92], but it additionally considers the impacts of the COVID-19 pandemic and the National Energy and Climate Plans. In this scenario, the penetration of RLF would continue to remain extremely limited (1.4% of the fuel mix by 2050, of which 1.3%

[92] SWD(2020) 331 final.

biofuels and 0.1% electricity use at berth). No other type of RLF is foreseen to enter the international maritime fuel mix by 2050 without further intervention. A series of independent, and potentially diverging, company-based approaches would characterise the development and deployment of alternative fuel solutions. While ship operators are currently making different assumptions on the type of energy to be used in their market segment in the future, the uptake of RLF in the baseline scenario is expected to principally concentrate on the most mature and currently available option for maritime transport, which is biofuels. In this scenario, LNG uptake will continue growing, as the result of the application of more stringent requirements on air pollution control in the maritime sector (in particular SOx and NOx emissions). LNG is projected to represent 19% of the fuel mix by 2050 without further EU-level intervention.

This is explained by the maturity of the technology, the gradual availability of infrastructure and considerations on fuel supply (bearing also in mind the limited competition for feedstock for LNG compared to other potential fuel options). The lack of sector-wide coordination and harmonised approach at EU level regarding the type and emission footprint of fuels, the limited geographical scope of application as well as the timeframe for their deployment is likely to lead to sub-optimal results and overall insufficient penetration on RLF to meet the EU climate objectives set out in the EGD and the 2030 CTP.

Tank to wake CO_2 emissions from international shipping are projected to increase by 14% by 2030 and by over 30% by 2050 relative to 2015. By 2050 this would imply a stabilisation of CO_2 emissions to their 2008 levels, which is however not in line with the climate neutrality objectives. Well to wake GHG emissions would grow slightly faster at 15% during 2015-2030 and over 35% for 2015-2050.[93] The increase in emissions is driven by the sustained growth projected for transport activity, even when accounting for the impact of the COVID-19 pandemic, and despite the projected significant improvements in energy efficiency. More details on the baseline scenario are provided in Annex 4.

The baseline scenario does not include the other ‘Fit for 55’ initiatives. This ensures a consistent approach with the impact assessments accompanying the other ‘Fit for 55’ initiatives. However, a qualitative assessment of their possible impact on how the problem will evolve is provided in Section 2.3.

In addition, as explained in Section 1.5, the trajectory of the RLF uptake from 2025 to 2050 in the policy options is based on the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy, while considering a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy. This ensures a consistent approach for delivering the EU climate ambition by 2030 and 2050, while at the same time identifying the impacts

[93] Well to wake emissions also take into account the CH_4 and N_2O from methane slippage.

of the design of the policy option that would best allow to reach this contribution. A qualitative assessment of the implications of lower/higher trajectory for the renewable and low carbon fuels is however provided in Section 5.4**.**

5.2 Description of the policy options

5.2.1 Possible policy measures and preliminary screening of options

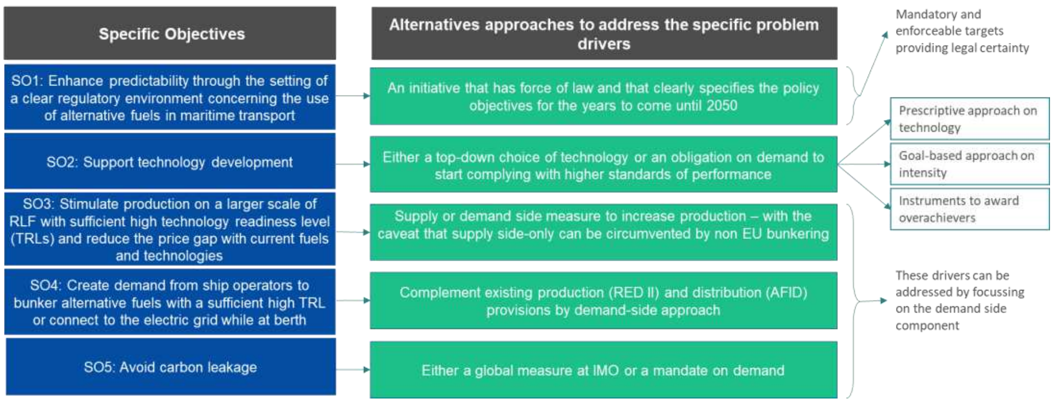
As a first step, a comprehensive list of possible policy measures was established after extensive consultations with stakeholders, expert meetings, independent research and the Commission's own analysis. This initial list is presented in Annex 6. This list was subsequently screened based on the likely effectiveness, efficiency and proportionality of the proposed measures in relation to the given objectives, as well as their legal, political and technical feasibility.

As a result of this analysis, several measures were not retained in the main policy options, although, in some cases, their important role as complementary measures, supporting the climate objective for the maritime transport sector, is fully recognised. The non-retained options are discussed in greater detail in Section 5.3.

5.2.2 Identification of the general policy approach and the choice of main policy options

The screening of the initial list of possible policy measures was accompanied by a reflection on what type of approaches would be needed to address each of the SOs identified in Section 4. The list of suitable approaches related to each of the SOs is presented in Figure 5:

Figure 5 General policy approaches to address the problem drivers



Following this analysis, it appears that all policy approaches potentially capable of fulfilling the given objectives would need to share two principal characteristics:

- They should provide certainty on the future short to long-term policy targets for the carbon intensity of the energy used by ships. Such targets should preferably be mandatory and enforceable, thus providing legal certainty.

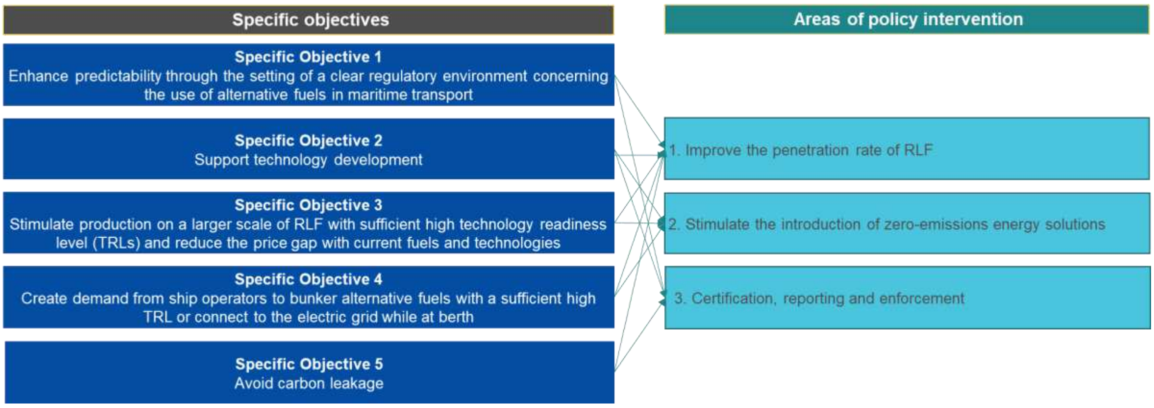
- They should address the demand side component, by incentivising or prescribing minimum performance requirements of the marine energy mix. This is necessary for complementing existing supply-side measures and solving the interdependency issue, as well as for avoiding carbon leakage.

Policy approaches could, however, differ on the way that the required level of performance is achieved. This could either be done by prescribing the use of certain technologies/fuels or by setting certain goals that operators could meet with technologies/fuels of their choice. As a result, this aspect was considered to be the main factor differentiating the suitable policy options (POs) to be analysed for this initiative.

In the next step, the retained policy measures were classified according to their approach and characteristics in relation to three areas of policy intervention: i) improve the penetration rate of RLF, ii) stimulate the introduction of zero-emissions energy solutions, and iii) certification, reporting and enforcement.

The correspondence between the SOs and the areas of policy intervention are illustrated in Figure 6:

Figure 6 Correspondence between the specific objectives and the identified areas of policy interventions



As explained in Section 5.2.1, the full list of identified policy measures is presented in Table 69 in Annex 6. It clearly indicates if these measures have been retained or are considered as flanking measures or complementary measures. Only retained measures have been included in policy options and were subject to a thorough analysis.

The correspondence between the specific policy objectives, the retained policy measures grouped in accordance with the three areas of policy intervention and links to the different POs is shown in Table 1.

Table 1 Overview of specific policy objectives, measures and links to policy options

Retained policy measure	**Driver / Specific objective**	**Policy options**		
		PO1	**PO2**	**PO3**

Field of policy intervention 1: Improve the penetration rate of RLF					
1	Establish minimum share (in volume terms) of selected RLF for ships in navigation calling EU ports (blending mandate)	SO1, SO2, SO3, SO4, SO5	✓	-	-
2	Set maximum targets on the GHG intensity (meaning the GHG emissions per unit of energy) of the energy used by vessels (the fuel / energy emissions per MJ).	SO1, SO2, SO3, SO4, SO5	-	✓	✓
3	Mandate the use of OPS (or equally performant alternatives e.g. batteries, zero-pollution energy sources like hydrogen) for the most polluting ships in ports	SO1, SO2, SO3, SO4	✓	✓	✓
4	Provide guidance to facilitate uptake of technology, including on the deployment of the necessary supply infrastucture	SO2, SO3, SO4	✓	✓	✓
Field of policy intervention 2: Stimulate the introduction of zero-emissions energy solutions					
5	Adopt additional incentives to stimulate the introduction of zero-emission energy solutions, avoid fuel technology lock-in and reward over-achievers	SO2, SO3, SO4	-	-	✓
6	Increase awareness raising, exchange of experience, encouragement and promotion of industry-led programmes in support of the uptake of alternative fuels	SO2, SO3, SO4	✓	✓	✓
Field of policy intervention 3: Certification, reporting and enforcement					
7	Establish an EU-wide methodology to certify the well-to-wake performance of fuels, reflecting all relevant GHG emissions and define the related documents to certify compliance	SO1, SO2, SO5	✓	✓	✓
8	Establish requirements for certification and acceptance of bunkering supplied in third countries	SO5	✓	✓	✓
9	Establish a set of rules to follow for monitoring, reporting and verification of consumption of alternative fuels in the context of the EU MRV	SO1, SO5	✓	✓	✓
10	Establish Port State Control procedures for the use of RLF (including upskilling and training of PSC officers)	SO1, SO5	✓	✓	✓

The three policy options can be summarised as follows:

- In PO1, demand obligations would be identified by the regulator and defined in terms of share of RLF in the total maritime fuel mix to be used from 2025 onwards;
- In PO2, maritime operators would be required to achieve a certain goal in terms of carbon intensity of the energy used from 2025 onwards, but would retain freedom on the choice of fuels (and technologies);
- PO3, represents a mixed approach whereby obligations would remain 'goal-based' from 2025 onwards, but a system of incentives would be put in place to favour adoption of certain technologies identified by the regulator.

These differences would apply only to ships in navigation, while the three options would share the same approach for ships at berth. The reasoning for selecting a single approach for the ships at berth is based on a number of considerations.

First of all, there is a strong case for advocating, in ports, the use of fuels that have minimal emissions of *both* GHG and local pollutants (zero emission fuels). Use of zero emission fuels generates considerably higher health benefits for ships at berth than for ships at sea.

This 'double dividend' on climate and health justifies not only a preference for zero emission fuels, but also a higher level of ambition in terms of emission abatement for ships at berth. Indeed, other things equal, the same reduction in the use of fossil fuels will produce greater benefits when occurring in ports than in navigation. For this reason, and considering that the cost of abating emission is not higher in ports, it makes sense to set a target of zero emissions for ships at berth.

In addition, there is a strong convergence on the promotion and use of OPS for ships at berth. OPS is a technology that allows for zero emissions of both GHG and air pollutants. It is a tried and tested solution, in application for more than two decades, mandated in certain parts of the world (e.g. the state of California) and increasingly deployed in other (e.g. China). In the EU, the Sulphur Directive encourages the use of OPS and the AFID requires deployment of OPS when demand conditions justify it.

In view of these considerations, the proposed intervention at berth focussed primarily on the use of OPS, but it does not exclude other zero GHG and air pollutants technologies, like batteries or hydrogen, which can be available in the medium to long term. As a result, maritime operators keep the possibility to use alternative zero-emission solution and the policy approach remains technology neutral. With regard to possible variations of the option in terms of timing or scope, it should be noted that:

a) Timing: the use of OPS is highly dependent on the deployment of the required infrastructure (currently still immature), the proposed intervention at berth would start from 2030 onwards and first focus on the most polluting ships in ports.
b) Scope: The most polluting ship categories have been identified on the basis of MRV data from 2018, and consists of containerships, passenger ships and ro-pax ships. These three ship categories represent roughly 40% of the emissions at berth, have among the highest levels of emissions per ship in port and belong to the first movers in the use of OPS. It also ensures alignment with the decisions regarding vessels in navigation.

In conclusion, with respect to use of fuels at berth, the proposed approach of requiring use of OPS, or equivalent solution, by the main emitters, did not apper to have a credible alternative which would retain the same level of ambition while remaining technically possible. Each of the policy options is presented in more details below.

Policy Option 1 : Prescriptive approach on the choice of technologies
Improve the penetration rate of RLF
In PO1, improvement of the penetration rate is expected to be delivered by requiring shares

of specific RLF to be used in navigation (x% of the fuel used by ships during the journeys in scope). The type of fuels and the corresponding shares would be established *ex-ante* in line with technology maturity and GHG saving potential. The minimum share would increase over time. The types of fuels included in this option would be regularly extended once more advanced options become mature.

The indicative trajectory is provided in the table below. As explained in Section 1.5, this trajectory has been derived in a way that enables kick starting the scale-up of renewable and low carbon fuels in the maritime sector from 2025 onwards and their large scale deployment by 2050, while ensuring the consistency with the required overall GHG emissions reductions by 2030 and 2050, preserving the competitiveness of the sector, promoting innovation, and ensuring feedstock availability for renewable and low carbon fuels in all energy and transport sectors in the transition towards a climate neutral economy.

Shares in the fuel mix (%)	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Total RLF shares	2.9%	7.4%	15.6%	30.0%	68.8%	85.9%
Biofuels and bio-LNG	2.9%	7.2%	12.5%	22.8%	46.4%	53.3%
Renewable fuels of non-biological origin	0.0%	0.2%	2.8%	6.8%	21.7%	31.5%
Electricity	0.0%	0.1%	0.2%	0.4%	0.7%	1.1%

The category renewable fuels of non-biological origin, in the meaning of Article 2(63) of the Renewable Energy Directive, covers here e-liquids, e-gas, hydrogen and other hydrogen-derived fuels like ammonia and methanol.

At berth, the use of OPS will be mandated from 2030 onwards for the most polluting ships in ports, which have been identified on the basis of MRV data from 2018, i.e. containerships, passenger ships and ro-pax ships,[94] unless they can prove the use of equally performant alternative (e.g. batteries). The shares of electricity use at berth due to the OPS requirements comes in addition to the trajectory illustrated above and is a result of the assessment presented in Section 6.1.1. A phased-in implementation could gradually extend the requirements to the entire fleet (subject to a review clause and an impact assessment in the future).

The Commission, assisted by EMSA, will continue to support Member States in exchanging best practices in line with international developments and the latest technological / scientific knowledge, and to facilitate the uptake of technology, including the deployment of the necessary supply infrastucture. These could take place in the framework of the expert groups from the Commission such as the European Sustainable Shipping Forum (ESSF) or the European Ports Forum (EPF). In the past, EMSA has already delivered LNG bunkering guidance[95] and is currently working on developping OPS guidelines to facilitate the deployment of on-shore power connection in European

[94] These three ship categories represent roughly 40% of the emissions at berth, have among the highest levels of emissions per ship in port and belong to the first movers in the use of OPS.
[95] EMSA (2018) *Guidance on LNG Bunkering to Port Authorities and Administrations*

Ports. The main purpose here is to facilitate planning and / or the development of local rules for the safe use / handling of fuels.

Stimulate the introduction of zero-emissions energy solutions

As specific technological choices are prescribed under this option and considering technological progress over time, there is a risk that the choice made in year x may not be an optimal solution in year z. For this reason, the list of selected fuels would be updated on a regular basis and reflect the technology developments. The Commission will continue to foster awareness raising, exchange of experience, innovation, encouragement and promotion of industry-led programmes in support of the uptake of RLF.

Certification, reporting and enforcement

In order to document compliance with the regulatory obligations, an EU-wide methodology to establish the GHG emissions performance / sustainability of fuels for maritime transport would be based on the RED II Directive and EU MRV Regulation, both of which would be cross-referenced in this initiative. As regards the latter, it is also proposed to include the non-CO_2 emissions and alternative sources of power[96]. Requirements for the certification of fuel suppliers (including in third countries) and documentation to report performance would be necessary and as above it would be also based on RED II requirements[97]. In this PO, the performance of fuel is established *ex-ante* and demonstrating sufficient blending levels would be necessary to prove compliance. Compliance needs to be documented 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.

Policy Option 2 : Goal-based approach on technologies

Improve the penetration rate of RLF

In PO2, improvement of the penetration rate of RLF is expected to be delivered by a goal-based approach requiring fuels used in navigation and at berth to meet maximum GHG intensity targets. A maximum limit on the GHG content of energy used by ships in navigation (e.g. CO_2eq/MJ) is identified to deliver comparable GHG emissions reductions on the well to wake basis as in PO1. This target will be made more stringent over time,

[96] Theoretically, a new governance could be designed for the purpose of this initiative only, with reporting requirements different or separate from the existing EU MRV Regulation. This option has been discarded at an early stage of the analysis as disproportionate and unnecessary, also in view of the fact that one of the main objectives of the EU MRV Regulation is to provide a framework for the implementation of EU climate policies. Similarly for REDII, where any divergence from the definition and certification of RLF may create inconsistencies between EU regulatory provisions – at the moment or in the future. This applies to all PO.

[97] The European Commission recognises a number of voluntary schemes that demonstrate compliance with the sustainability criteria for biofuels (at the moment). Schemes may adopt their verification procedures but must notify changes that might be relevant to the Commission, such as changes in auditing procedures. Examples of approved certification schemes under RED II can be found at: https://ec.europa.eu/energy/topics/renewable-energy/biofuels/voluntary-schemes_en#approved-voluntary-schemes

which would require operators to shift to increase the overall share of RLF in their fuel mix (including thorugh the inclusion of more innovative solutions such as hydroen-based fuels of electricity). The reduction in the well to wake GHG intensity relative to the base period (2015)[98] is provided in the table below.

Well to wake GHG intensity reduction (in %)	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Resulting from the use of RLF	-2%	-7%	-14%	-26%	-59%	-74%

Concerning emissions at berth, the approach is the same as for PO1.

Stimulate the introduction of zero-emissions energy solutions

As no technology choice is made in this PO, the risk of technology lock-in is reduced as the market operators are likely to maximise the use of existing and developing infrastructure and on-board equipment to meet the targets. They also may decide to comply with more performant and advanced technology (i.e. battery, fuel cell), in terms of GHG reductions, than fuel blends. The target could also be set in a way that reflects the uptake of energy sources such as wind propulsion. Also, since all fuels consumed onboard are accounted to meet the same target, ship operators may decide to comply by averaging very performant technology for ancillary power (e.g. renewable hydrogen) with more conventional fuels used for propulsion. The Commission will continue to foster awareness raising, exchange of experience, innovation, encouragement and promotion of industry-led programmes in support of the uptake of alternative fuel, similarly to what is described for PO1.

Certification, reporting and enforcement

In order to document compliance with the regulatory obligations, an EU-wide methodology to establish the performance / sustainability of fuels for maritime transport be based on the RED II Directive and EU MRV Regulation, both of which would be cross-referenced in this initiative. As regards the latter, it is also proposed to include the non-CO_2 emissions and alternative sources of power. Requirements for the certification of fuel suppliers (incl. in third countries) and documentation to report performance would be necessary and as above it would be also based on RED II requirements. In PO2, 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. Similarly to PO1, 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 PSC procedures.

Policy Option 3 : Goal-based approach on technology and reward mechanisms for overachievers

[98] For 2015 the average GHG intensity of marine fuels on well to wake basis is estimated at 87 gCO2eq/MJ. The emissions factors used are provided in Annex 4.

Improve the penetration rate of RLF

In PO3, improvement of the penetration rate of RLF is expected to be delivered by a goal-based approach requiring fuels used in navigation and at berth to meet maximum GHG intensity targets. A maximum limit on the GHG content of energy used by ships (e.g. CO2eq/MJ) is identified in the same manner as for PO2 to deliver GHG emissions reductions that are comparable on a well-to-wake basis across all three policy options.

The reduction in the well to wake GHG intensity relative to the base period (2015)[99] is provided in the table below. This table does not account for the "multipliers for zero-emission options", explained below, in order to show the true reduction in the well to wake GHG intensity of fuels.

Well to wake GHG intensity reduction (in %)	2025	2030	2035	2040	2045	2050
Resulting from the use of RLF	-2%	-7%	-14%	-26%	-60%	-75%

Concerning emissions at berth, the approach is the same as for PO1 and PO2.

Stimulate the introduction of zero-emissions energy solutions

The requirements in this option are similar to PO2 as they are based on a goal-based approach. However, this PO also integrates specific additional measures to foster over-achievement and encourage the development of more advanced, zero-emissions technologies. Two aspects will be assessed as part of the mechanism to foster over-achivements. These concern specifically higher weight attributed to zero-emission solutions when establishing the ship's performance in achieving the yearly target ("multipliers for zero-emission options") as well as the possibility to not only average compliance on a yearly basis (as in PO2) but also pool compliance with other ships / operators via a mechanism for *voluntary* transfer and compensation of balances. This mechanism does not represent an additional regulatory obligation, but it offers operators more flexibility and an additional means of compliance with the requirements, allowing them to optimise the investments at the ship level. In practice, it will allow operators using more performant technologies to exchange "excess compliance points" with less perfomant ships / operators, provided that the minimum targets are met on average. A specific module will be added to the existing MRV system to track compliance and, where necessary trace the transfer of balance. Balances would be generated automatically and there would be no need for a system of auctioning or attribution. Also, as the mechanism remains voluntary, the transfer of balance will not be subject to specific conditions but be governed by private-law agreements between the concerned operators. In practice, most of the transfers are likely to take place within the same firm or group (representing de facto a solution to pool compliance at company level), but will not be limited to it and would offert the possibiltiy to also provide transfers between different companies. Alternatively, a possible link with upcoming revision of the ETS to reward overachievers could be also envisaged

[99] For 2015 the average GHG intensity of marine fuels on well to wake basis is estimated at 87 gCO2eq/MJ. The emissions factors used are provided in Annex 4.

(e.g. through the provision of additional free allowances) but it is not expected to signifcantly affect the likely impacts of the instrument. The Commission will continue to foster awareness raising, exchange of experience, innovation, encouragement and promotion of industry-led programmes in support of the uptake of alternative fuels, similarly to what is described for PO1 and PO2.

Certification, reporting and enforcement

In order to document compliance with the regulatory obligations, an EU-wide methodology to establish the performance / sustainability of fuels for maritime transport be based on the RED II Directive and EU MRV Regulation, both of which would be cross-referenced in this initiative. As regards the latter, it is also proposed to include the non-CO_2 emissions and alternative sources of power. Requirements for the certification of fuel suppliers (incl. in third countries) and documentation to report performance would be necessary and as above it would be also based on RED II requirements. In PO3, the performance of the fuel is not established on-board but needs to be documented on annual basis for the total energy generated on-board. A specific mechanism to account for possible pooled compliance and transfer of balances needs to be established. 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 PSC procedures.

5.2.3 Specific aspects of policy design

Concerning the more specific characteristics of the proposed policy intervention, the following aspects have also been considered and assessed in the same way for all POs.

Targets (volumes or GHG intensity) are set and gradually increase over time to deliver higher RLF penetration rates (and the related emissions reductions until 2050). All POs are designed to deliver similar GHG emission reductions pathways. Targets are specified up to 2050 to provide operators and investors with sufficient clarity and predictability. The analysis made in support of this impact assessment also include increased shares of electricity covering the growing uptake of OPS by ships at berth; this was not available at the time of the work on the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy.

The GHG performance of fuels is assessed on a well-to-wake basis, taking into account the impacts of production, transport, distribution and use on board. This is to incentivise technologies and production pathways that provide real benefits compared to the existing conventional fuels. This approach is also supported by the open public consultation (OPC) results.[100] The emission factors reflect the characteristics of the different fuels and are provided in Annex 4.

With regards to the type of emissions, the proposed intervention is not limited to CO_2, but also include other GHG emissions such as CH_4 and N_2O emissions. Even though the volume of these emissions is lower than CO_2 only, their global warming potential is stronger, in particular in the short term. Including these emissions is particularly relevant as they may be fuel-dependent, which is for instance the case of CH_4 which can be released as a slippage when using gaseous fuel. This option provides hence a more comprehensive approach to GHG emissions. 81% of the OPC respondents were in favour of at least this scope[101]. Limiting the approach to CO_2, would overlook significant GHG emissions that can be generated by fuels with CO_2 savings potential, thereby creating a distortion between different technologies and potentially reducing overall GHG savings.

In terms of addressees, the regulated entity should be a company with obligations put on each ship arriving and departing from EU ports. As for the MRV Regulation, the scope is limited to vessels beyond 5,000 gross tonnes. Even though these ships represents only ca 55% of all ships calling EEA ports, in accordance with MRV data, they are responsible for 90% of the CO_2 emissions from the maritime sector. As it is also the case for the MRV Regulation, small emitters (ships below 5,000 gross tonnes) have been excluded for proportionality reasons, because although they represent about 45 % of the fleet, they only account for 10% of the total emissions. According to estimates provided by EMSA, this picture is very similar when considering air pollution. Vessels above 5,000 gross tonnes account for 94.5% of the maritime SOx emissions produced by ships calling EEA ports, 89.5% of the NO_2 emissions and 57.9% of the $PM_{2.5}$ emissions. The approach followed by this initiative focusses therefore on the highest emitters in order to strike the best balance between the environmental objectives while limiting the potential regulatory and administrative burden to the smallest operators. As in the scope of EU MRV, warships, fishing vessels, ships not propelled by mechanical means, and inland vessels are not covered by the proposed intervention. The scope of MRV was decided on the basis of a proportionality analysis, which concluded that the measures would be disproportionate for these ship types[102]. Regarding warships, there is no legal basis for the Union to regulate them under the TFEU. Indeed, this initiative concerns sea transport as explained in the legal basis in Section 3.1, which leaves out fishing vessels and inland vessels.

The ships that have been excluded from the scope of this initiative may still benefit from supply-side intervention through the RED as revised and from a higher availability of

[100] In the open public consultation, 56% of the respondents (76/136) were in favour of measuring environmental performance on a well-to-wake basis.

[101] 55% (75/136) of the OPC respondents indicated that the measurement should take into account both GHG (including CH_4 and N_2O) and air quality emissions. 26% (35/136) indicated that it should take into account just GHG. 12% (16/136) thought it should only focus on CO_2.

[102] See the 2013 IA for the EU MRV proposal (SWD(2013) 236) and the 2019 IA for the revised MRV proposal (SWD(2019) 11).

renewable and low-carbon fuels in ports following the revision of AFID. Small ships such as tug boats and dredger vessels might not engage in extra-EU voyages and thus be less prone to carbon leakage.

Some possible variants allowing pooled compliance, through voluntary transfer and compensation of balances, have been tested as part of the assessment of PO3 as they could offer additional flexibility to the industry. For the retained design of PO3, the pooled compliance is organised among different ships rather than companies, which proved to be the only solution that does not penalise small and medium size companies with a limited number of ships. The respondents to the targeted consultation did not express a clear preference for an entity that should be regulated by the policy measure[103].

Concerning the geographical scope, the options have been assessed on a similar scope to MRV, which covers voyages from the last port of call to an EU port of call and from an EU port to their next port of call[104]. This approach is expected to avoid distortion of competition among market actors, maximise the impacts and reap the full potential of the reporting requirements put in place by the EU MRV Regulation. A similar geographical scope has been used for this measure in the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy. On the other hand, a more limited geographical scope could be easier to accept by third-country operators, but would have considerably lower impact. The OPC respondents did not clearly express a preference with regard to a particular geographical scope[105].

The monitoring, reporting and verification requirements of this initiative are based on the EU MRV Regulation, under which all ships calling at EEA ports, irrespective of their flag (i.e. all flags), are obliged to report their fuel consumption to the Commission (via THETIS-MRV database) and to the EU flag States. It applies in a non-discriminatory way to all ships and requires third party verification in order to ensure the accuracy of the data submitted. It uses a specific verification system similar (though simplified) to the one applied in the EU Emissions Trading System (ETS), based on internationally agreed ISO standards and EU specific verification rules. As Commission Communication of 2013 on integrating maritime transport emissions in EU's GHG reduction policies[106], the EU MRV Regulation was put in place to provide (among others) for robust and reliable data on GHG emissions from shipping activities as a prerequisite for any further policy action and the

[103] The targeted consultation shows that 24% of the respondents chose the option 'each individual ship' (8/32), while 'company fleet' received support by 18% of the respondents (6/32). In addition, 50% did not indicate a preference by choosing the option 'no answer' (16/32).
[104] Alternative approaches are discussed in Annex 6.
[105] The open public consultation indicates that there is no agreement among the respondents concerning the right geographical scope. The option 'ships calling at ports of the EU' received 30% of the responses (41/136), whilst 24% would prefer a scope taking into account 'ships sailing in the territorial waters and Exclusive Economic Zones of the EU Member States' (33/136). Only the proposal "ships bunkering in EU ports" received a very low rate of support, with 2% of responses (3/136).
[106] COM(2013) 479 final

development and implementation of effective EU measures. Additional elements that would need to be included in the EU MRV system are assessed in this impact assessment.

In addition to EU MRV monitoring, reporting and verification obligations, this initiative will include more rigorous compliance and enforcement provisions. Recognizing that compliance will impose additional fuel costs on ship operators, effective enforcement is important to avoid distortion of competition and regulatory loopholes. It is therefore necessary to add specific provisions for demonstrating compliance with this initiative, while building on existing processes to minimize administrative burden. Shipping companies will need to document to their third party verifier that they have been compliant with the RLF requirements coming from this initiative. Upon fulfilment of the reporting obligations, the third party verifier will then issue a Document of Compliance to the ship that can be checked in subsequent PSC inspections. Appropriate and proportional sanctions that reflect fuel cost-savings of non-compliance are important for maintaining the level playing field in the sector.

5.2.4 Additional elements of policy intervention

In addition to the measures resulting directly from the proposed policy intervention and those included in the 'basket of measures' to address ship emissions, a number of 'flanking measures' would also help addressing the problems identified. The intensification of the work at international level (IMO) on the development of lifecycle GHG/carbon intensity guidelines for all types of fuels paves the way for future measures. Steering financial support towards the development and deployment of RLF is also relevant. This applies in particular to R&I, where the preparation of the co-programmed 'Zero Emissions Waterborne Transport' partnership under Horizon Europe is expected to play an important role of support. Public funding from Member States and the EU budget could also support the uptake of RLF through deployment of the necessary infrastructure, support to investments, etc.

5.3 Options discarded at an early stage or identified as complementary measures

As already mentioned, the process of selection of policy options started with the analysis of the wider set of possible policy measures that is listed in Annex 6.

In the following sections, further details are provided on those, non-retained, measures that deserve more attention, either because they are part of the 'basket of measures' for GHG emissions reduction and are subject of another impact assessment (ETS, ETD, RED II and AFID) or because they have been specifically proposed by stakeholders in the context of the consultations activities (energy efficiency standards). In the former case, the analysis also explores interaction and complementarities between different instruments.

5.3.1 *Carbon pricing measures (ETS and ETD) and impact on the penetration rate for RLF*

As part of the 'Fit for 55' package, the Commission proposes the extension of the ETS to the maritime sector[107], therefore introducing carbon pricing also for maritime operators. While ETS can also be described as a demand side measure, its scope is wider than the proposed intervention under this initiative, as it addresses overall emissions and is not targeted specifically at fuels.

For any given level of activity, there are two categories of possible intervention to reduce ship emissions: either measures that increase energy efficiency (resulting from either design / technical options or operational choices) or greater uptake of cleaner fuels and alternative sources of energy[108]. The ETS is designed to reduce emissions in the most cost-effective way, triggering first the cheapest abatement measures and only later the more expensive options. There is ample scientific literature[109] demonstrating that in most cases, options like voyage execution, routing, speed reduction, reduction in auxiliary power, optimised propellers have all lower marginal abatement costs than the switch to alternative fuels or the use of on-shore power supply while at berth. The ETS is therefore expected to affect initially energy demand, without *necessarily* influencing also the type of energy used.

The analysis carried out in the fourth IMO Greenhouse Gas Study confirms that the use of alternatives fuels in maritime have a comparatively higher abatement costs than other options[110]. Out of the 16 technology groups identified by the study, the use of alternative fuels ranks as the second or third most expensive technology depending on whether the focus is on the alternative fuels containing carbon (above 250 USD/t-CO_2) or zero-carbon fuels (above 410 USD/t-CO_2). The difference is explained in this case by the expected higher fuel price resulting from synthesis process. Based on the fuel price projections used in the context of this impact assessment, consistent with those used in the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy, for the EU ETS to make RLF economically interesting for the maritime sector, a price of CO_2 emission allowances of at least €200 would be necessary.

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[107] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12660-Updating-the-EU-Emissions-Trading-System

[108] This is well documented in existing literature, such as Bouman et.al.(2017), which assesses the potential of different options, gathered in six main groups: hull design, power and propulsion, economies of scale, speed, weather routing and scheduling, fuels and alternative energy sources. - Bouman et.al.(2017), State-of-the-art technologies, measures, and potential for reducing greenhouse gas emissions from shipping –a review, Transportation Research Part D 52, 408-421

[109] Relevant studies which have modelled a series of technical and operational measures in Marginal Abatement Costs Curves (MACC) for each vessel category:
CE DELFT 2011, *Analysis of GHG Marginal Abatement Cost Curves,* https://www.cedelft.eu/publicatie/analysis_of_ghg_marginal_abatement_cost_curves/1155
DNV 2010, *Pathway to low carbon shipping, abatement potential towards 2030*
TNO 2015, "*GHG emission reduction potential of EU-related maritime transport and on its impacts*", study funded by DG CLIMA and available at: https://ec.europa.eu/clima/sites/clima/files/transport/shipping/docs/report_ghg_reduction_potential_en.pdf

[110] IMO (2020), Fourth IMO GHG Study

By comparison, the impact assessment[111] accompanying the 2030 Climate Target Plan projects carbon prices for the ETS sector (including the maritime sector) in the range of 32 to 65 €/tCO2, to cut the economy-wide GHG emissions by at least 55% by 2030. The EU ETS is therefore unlikely, by itself, to drive RLF uptake in the medium-term.

As a result, while carbon pricing would promote a reduction of CO_2 emissions in all sectors where it applies, it is likely that interventions in the maritime sector would concentrate initially only on energy efficiency improvements, without determining any significant modification of the fuel mix. This is a problem because, in addition to the cost elements, the introduction of the new fuels is also hampered by the complexities and the long lead times required by the extra coordination of fuel supply and distribution (including the deployment of the specific infrastructure when necessary). Whereas most energy efficiency measures can be implemented by individual operators – via operational measures, retrofitting or technical specifications of new vessels – the uptake of alternative fuels is more complex and typically outside the control of the single operator.

The simplest case is the use of drop-in low and zero-carbon sustainable fuels, as these can virtually be used in current machinery on-board and taking advantage of the existing infrastructure. However, this requires sufficient levels of production and availability in ports that would have to be triggered by predictable demand. Other technologies like hydrogen or ammonia are even more complex, as they would in principle require dedicated infrastructure for distribution, safety certification, and new bunkering protocols, in addition to technical adaptation of vessels and sufficient production from renewable sources.

Accordingly, the marginal abatement cost curve in the maritime sector is not likely to be smooth and allow a gradual uptake of abatement options in line with the evolution of the carbon price. On the contrary, the risk is that once the energy efficiency options have been exploited, the uptake of fuel technologies would require considerable time, before reaching sufficient levels, had it not been prepared in advance. For this reason, while ETS has other advantages such as facilitating emission reductions in a cost-effective manner across sectors, it has been identified as a desirable complementary measure, but not one sufficient to address all the problems identified in this impact assessment, focused on the insufficient penetration of RLF in the maritime fuel mix. A dedicated policy intervention, such as the one proposed under FuelEU Maritime is expected to establish the necessary conditions for lead markets to start emerging as rapidly as possible and to support the deployment of new fuel technologies to deliver on the post-2030 climate objectives.

On the other hand, the present initiative does not weaken the case for the inclusion of maritime transport in the ETS. Carbon pricing will render profitable certain measures and investments in energy efficiency which are not targeted by fuel mandates and will also contribute to reducing the price gap between fossil fuels and RLF. More importantly, the

[111] SWD(2020) 176 final.

ETS ensures that all the sectors comprised in the system respect, as a whole, the total cap on emissions. This means that any departure of individual sectors from the intended sectoral emission abatement target – which could result from a variety of factors, including unrealised expectations on the level of economic activity or the effectiveness of policy measures – will find automatic compensation via adjustments of the carbon price. In other words, independently on the level of emission reductions that can be attributed to the ETS or to other interventions, ETS has an important role in ensuring overall consistency and climate integrity of the policy framework. Last but not least, ETS revenues could also be used in support of a higher penetration of RLF by using available budget from the Innovation Fund to bring to the market innovative industrial solutions to decarbonise the EU and support its transition to climate neutrality.

Besides ETS, energy taxation can also have an impact on the relative price of RLF and influence the demand for fuels. The review of the ETD will result in an increased cost of conventional fuels, but as in the case of ETS, the price increase would have to be substantial in order to render profitable the use of RLF. To give an example, a tax rate of at least 550 EUR/1000 litres for diesel, coupled with a tax exemption for RLF, would be needed to make the latter fuels competitive. The ETD has also the additional problem that ships can easily circumvent its provisions by bunkering outside the EU, especially if high tax rates are put in place to bridge the price gap. In any event, the ETD remains a taxation instrument whose primary goal is revenue collection; while it can have incentive effects for RLF, it cannot be fine-tuned to the exclusive needs of RLF promotion in the maritime sector.

5.3.2 A standard for carbon intensity of maritime operations (limit for CO2 emissions per tonne-nautical mile)

In response to the public consultation, some stakeholders have argued in favour of setting a standard for the carbon intensity of maritime operations.

In line with the MRV Regulation, the CO_2 emissions of the ships (and hence the carbon intensity of operations if this figure is made relative to distance / tonnes of cargo carried) is the product of the amount of fuel consumed multiplied by the emission factor of the given fuel. The first term of this equation relates to the amount of energy used while the second focuses on the carbon intensity of the energy.

In other words, maritime operators would have to reduce their emissions per unit of ‘transport work’ (e.g. expressed in CO_2 per tonne-nautical-mile) and could do so by improving their energy efficiency (first term), by using energy with lower carbon content (second term), or via a combination of the two (both terms).

Similarly to the case of carbon pricing, this approach is expected to have only a very limited impact on the uptake of RLF in the short term as the market actors would first favour solutions with lower marginal abatement costs and less complexities in terms of introduction (no coordination of actors, etc.). As in the case of carbon pricing (e.g. ETS), this instrument could be considered as a solution to other market failures, but not to the problems highlighted in this impact assessment, in terms of the insufficient penetration of RLF in the maritime fuel mix and the need to prepare their uptake in advance.

Building on this policy option, a possible alternative would be to establish sub-targets for each term of the equation. In this case, establishing a carbon intensity limit for the energy used is actually comparable to the PO2 and PO3 described in Section 5.2.1. While improving energy efficiency of maritime transport will be an essential instrument to decarbonise the sector, their impact on RLF uptake is expected to be more modest. For this reason, the introduction of additional targets on energy efficiency have not been assessed in greater details in the context of this initiative.

5.3.3 Revision of other relevant legal instruments (AFID and RED II)

One aspect that has been also considered is whether the problem drivers identified in this report could be addressed via the revision of AFID and the RED II (cf. Section 1.2).

Both are directives addressed at Members States, to promote, in the case of AFID, the provision of infrastructure for use of alternative fuels, and, in the case of RED II (for the part related to the transport sector), to set obligations on fuel suppliers to ensure a certain share of renewable energy in final consumption. By not addressing demand, these tools would not solve the carbon leakage issue. For example, even if obligations on suppliers resulted in RLF (or otherwise-defined complaint fuels) being the only fuels available in EU ports, vessels would retain the possibility to bunker conventional fuels outside the EU. In addition, RED II and AFID do not guarantee a level of demand that would justify investments in supply and distribution. This is also the reason why they did not succeed so far in promoting RLF in maritime.

One possibility would have been to modify the current approach in RED II and AFID and include an aspect of 'maritime demand' into those instruments. However, addressing vessels operators in RED II and AFID would have been quite complex from a legal drafting perspective because of the different addressees and the need to include a lot of specific provisions for maritime transport in horizontal instruments that cover the entire transport sector (and beyond for RED II). In both cases, the inclusion of provisions addressed to maritime operators would not have been in line with the general approach of these instruments, would have create unnecessary complexity, and would have run against the Commission's better regulation principles. Moreover, the two directives could be implemented differently by the various Member States, which could be problematic for a sector with a strong international connotation as maritime.

The conclusion that the revision of RED II and AFID is capable, on its own, to address all the problems identified in this report should not overshadow the important role of these instruments in ensuring the overall goal of promoting use of RLF, also in the maritime sector. Very important complementarities exist between demand, supply and distribution of RLF, and if one of these three components is not adequately developed, the overall goal of promoting use of RLF would be compromised. Indeed, the lack of sufficient demand can be held responsible for the extremely limited impact that RED II and AFID have had in the maritime sector until now. A proposal that targets demand can make the difference, since it is more likely that market players on the supply-side accommodate developments in demand, rather than demand be created by the supply of (more expensive) RLF. Nevertheless, the revised RED II and AFID is necessary to correct any market failures that exist on the side of RLF supply and distribution.

5.4 Feasibility of alternative pathways for the uptake of RLF

As explained in Section 1.5, the trajectory for the uptake of RLF in PO1 has been based on the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy while considering a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy. It has been derived in a way that enables kick starting the scale-up of RLF in the international maritime sector from 2025 onwards and their large scale deployment by 2050, while ensuring the consistency with the required overall GHG emissions reductions by 2030 and 2050, preserving the competitiveness of the sector, promoting innovation, and ensuring feedstock availability for renewable and low carbon fuels in all energy and transport sectors in the transition towards a climate neutral economy. An update of the pathway/scenario focusing on a combination of carbon pricing and medium intensification of regulatory measures in all sectors of the economy for the purpose of the 'Fit for 55' package, while also reflecting the COVID-19 pandemics, the National Energy and Climate Plans and refining the policy design of the initiatives, confirms that international maritime sector effectively contributes to the EU climate goals while considering the RLF trajectory in PO1. As further explained in Section 5.2.1, PO2 and PO3 have defined in such way to ensure comparable well to wake GHG emissions reductions as PO1. This approach preserves the consistency with the EU climate objectives for 2030 and 2050 in all policy options.

As regards the possible impact of fuel mandates on the ETS system, the analysis above suggests that abating emissions via use of clean energy comes at a higher cost than the ETS carbon price. The implication is that in the presence of fuel mandates the maritime sector would reduce its emissions – and thus its demand for ETS allowances – to a greater extent than otherwise. As explained in Section 1.5, the economic assessment taken as reference for the definition of the policy options in this report simulates the joint operation of a fuel mandate and ETS. If the fuel mandate is removed (or set at a lower level of ambition), the result in the short and medium term would be an upward shift in the overall demand for allowances, a correspondingly higher carbon price, and a shift in emission cuts from the maritime sector to other ETS sectors. In the longer term, the postponement in the deployment and adoption of RLF technologies would lead to higher abatement costs and a higher carbon price imposed on the economy. This is explained in more detail below.

A somewhat lower RLF uptake by 2030 would be possible, but the lower RLF uptake is expected to push the price of the EU ETS allowances upwards. In this case, the impacts on emissions reductions in the maritime sector by 2030 would be more limited, while somewhat higher emissions reductions would take place in other sectors. At the same time, with a lower RLF uptake by 2030, the build-up of RLF capacities could be delayed, due to path dependency effects, diverting them (i.e. advanced biofuels, e-fuels) towards the road transport sector, where more promising options (like for example large scale electrification) are available. Post-2030, a steeper trajectory for the reduction in the maritime transport emissions would be needed to contribute towards EU climate neutral economy by 2050. This would require a steep build-up of RLF production capacities, starting from a low base and under a limited time horizon, which may not be feasible. It may require substantially higher effort when approaching 2050. The latter could result in steep reductions in maritime transport activity, with negative consequences on jobs in the sector, connectivity, as well as growth of businesses and regions.

A somewhat higher RLF uptake by 2030 would also be possible. The higher RLF uptake is expected to push to some extent the price of the EU ETS allowances downwards and to require less emissions reduction efforts in other sectors. Yet, a higher RLF by 2030 would lead to a higher increase in the freight rates than in the central trajectory, with impacts on growth of businesses and regions, while more options for emissions reduction would be available in other sectors at lower costs. At the same time, some advanced biofuels would still be required in the road transport sector by 2030 considering that the electrification of the sector takes time due to the gradual replacement of the vehicle fleet. The higher RLF uptake may intensify the competition for biomass feedstock with other transport and energy sectors, pushing the feedstock prices further up. Post-2030, continuing the central RLF uptake trajectory would ensure the required contribution towards the climate neutrality by 2050.

Overall, as explained in Section 1.5, a range of 6 to 9% for the share of RLF in the international maritime fuel mix is feasible by 2030, while keeping in mind the considerations above. The possibilities of lower or higher RLF uptake post-2030 are more limited while ensuring the consistency with the required overall GHG emissions reductions by 2050, preserving the competitiveness of the sector, promoting innovation, and ensuring feedstock availability for renewable and low carbon fuels in all energy and transport sectors in the transition towards a climate neutral economy. This assessment takes into account the current knowledge related to the possible evolution of technology costs and feedstock costs. If higher decrease in these costs would materialise in the future, higher RLF could be possible post-2030. On the other hand, lower uptake post-2030 may require substantially higher effort when approaching 2050, with the associated risks explained above.

6. WHAT ARE THE IMPACTS OF THE POLICY OPTIONS?

This section summarizes the main expected economic, social and environmental impacts of each PO.[112] This analysis does not only focus on the impacts expected for the ship operators but also consider them for the maritime cluster at large, including ports (particularly given the need for potential specific infrastructure deployment), technology providers and shipbuilders as well as fuel suppliers.

In terms of time horizon, the assessment has been undertaken for the 2025-2050 period (in five-year steps). The measures that are part of the POs are assumed to be implemented from 2025 onwards. This long term perspective is particularly important as the penetration of RLF requires a long period for building RLF production and distribution capacity.

The analysis presented in this section covers the EU27 scope. Costs and benefits are expressed as present value using a 4% discount rate. While the results presented in this section concern the impacts of the POs over the 2025-2050 period, it is important to remind that the costs and benefits will be spread out over time due to the *gradual* strengthening of the regulatory targets. More details on the modelling exercise, including the possible limitations and uncertainties, are provided in Annex 4.

6.1 Economic impacts

Different aspects have been analysed to determine the economic impacts of each of the POs. These concern: the impacts on ship operators, the impacts on RLF prices, feedstocks and renewable electricity needs, the regulatory costs for economic actors, the costs related to enforcement, the impacts on ports to provide the necessary infrastructure, the impact on the EU maritime cluster and the impact on third countries.

6.1.1 Impacts on ship operators

Impacts on the fuel mix used by ship operators: The direct impact of the assessed POs will be the increased share of RLF in the overall maritime energy mix. Table 2 presents the evolution of this share for each of the PO and the baseline for two specific target years: 2030 and 2050. It also presents a breakdown by type of RLF uptake corresponding to each PO.

Table 2 Share of renewable and low carbon fuels in maritime energy use in navigation and at berth

Share of renewable and low carbon fuels in maritime energy use (in %)	Baseline		PO1		PO2		PO3	
	2030	2050	2030	2050	2030	2050	2030	2050
Total	0.3%	1.4%	8.6%	86.9%	8.6%	89.5%	8.6%	88.8%

[112] The analysis in this section is based on modelling performed by E3Modelling with the PRIMES-TREMOVE transport model and by TRT with the TRUST model, on the Ecorys et al (forthcoming) Assessment of impacts from accelerating the uptake of sustainable alternative fuels in maritime transport, and on the analysis of stakeholders' feedback. References to the sources of specific information and explanations of assumptions underlying various cost and benefits results are further presented in Annex 4.

Share of renewable and low carbon fuels in maritime energy use (in %)	Baseline		PO1		PO2		PO3	
	2030	2050	2030	2050	2030	2050	2030	2050
biofuels	0.1%	1.3%	6.0%	39.0%	6.2%	47.8%	6.1%	42.4%
bio-LNG	0.0%	0.0%	1.2%	14.2%	1.2%	16.8%	1.2%	15.4%
e-liquids	0.0%	0.0%	0.2%	16.3%	0.0%	13.4%	0.1%	15.8%
e-gas	0.0%	0.0%	0.0%	6.5%	0.0%	4.9%	0.0%	5.6%
hydrogen	0.0%	0.0%	0.0%	7.9%	0.0%	4.8%	0.0%	7.2%
ammonia	0.0%	0.0%	0.0%	0.5%	0.0%	0.2%	0.0%	0.4%
methanol	0.0%	0.0%	0.0%	0.3%	0.0%	0.1%	0.0%	0.2%
electricity	0.1%	0.1%	1.3%	2.1%	1.2%	1.4%	1.2%	1.9%
of which at berth	0.1%	0.1%	1.2%	1.0%	1.2%	1.0%	1.2%	1.0%

Source: PRIMES-Maritime, E3Modelling; Note: hydrogen in this table covers both hydrogen used in fuel cell vessels and direct use of hydrogen.

These results indicate a number of important elements to take into account. The increased penetration of RLF in the maritime fuel mix will be gradual, with relatively modest shares by 2030 (i.e. around 3% of the fuel mix in 2025 and 8.6% in 2030 in all POs) and then an acceleration of the uptake by 2040 to reach around 87-89% of the total fuel mix by 2050. The overall shares of RLF in the fuel mix in Table 2 also take into account the analysis of the OPS requirements at berth, which was not available at the time of the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy. Electricity used at berth is projected to represent 94-99% of the overall electricity used in the maritime sector in 2030 (94% in PO1, 99% in PO2 and 96% in PO3) and 46-75% in 2050 (46% in PO1, 75% in PO2 and 53% in PO3).

While the overall penetration rate is comparable in all three POs, due to the fact that by design they achieve similar reductions in the GHG emissions on well to wake basis, the type of RLF deployed diverge between them, in particular as time progresses and more technologies mature.

The share of biofuels, which represent today the most cost-effective way to reduce the GHG intensity of the fuels, is the highest in PO2 (48% of the fuel mix by 2050), which remains fully goal-based with no incentive for overachievers. Bio-LNG uptake in the fuel mix also shows the largest share in PO2. In lack of any specific mandate (like in PO1) or a mechanism to reward the use of the most advanced technologies (like in PO3), PO2 therefore focusses mainly on the currently cheapest and most readily available technical solution.

PO1 results in higher shares of hydrogen-based fuels (e-fuels, hydrogen, ammonia and methanol) as well as electricity, due to constraints on the use of biofuels by design of the policy option and incentives for renewable fuels of non-biological origin (RFNBOs)[113]. This reflects the regulator's preference for hydrogen based fuels and for a wider

[113] RFNBOs follow the definition of the Renewables Energy Directive.

availability of technological solutions and pathways to decarbonisation, which would alleviate pressure on feedstocks for advanced biofuels.

PO3 is also based on a goal-based approach like PO2, but the share of hydrogen-based fuels and electricity is projected to be closer to that in PO1 as a result of the incentives given to over-achievers. Hydrogen-based fuels and electricity are projected to deliver 31% and 34% of the fuel mix in PO3 and PO1, respectively.[114]

Costs for ship operators: The additional fuel costs relative to the baseline are the largest cost item resulting from the proposed intervention. The fuel choice resulting from each of the POs is also an important driver of the overall costs of the measure. PO2 shows the lowest additional capital and fuel costs relative to the baseline. This results directly from the highest share of drop-in fuels in the overall energy mix, and in particular biofuels. The use of these fuels does not require significant capital investment on the ships and is currently the cheapest available fuel alternative.

PO3 and PO1 have higher additional costs relative to the baseline than PO2 as the share of hydrogen-based fuels (e-fuels, hydrogen and ammonia) and electricity increases. This concerns also the capital costs as specific propulsion systems (fuel cells and electric vessels), which are not compatible with current engines, are expected to be used in greater proportion.

Bearing in mind that the RLF penetration takes place gradually over time, fuel costs are projected to increase by 2.9-3.2% in 2030 relative to the baseline and total costs by 2.6-2.8%. The highest increase in the fuel and total costs would take place in PO1 and the lowest in PO2, with PO3 falling between the two.

PO2 has also slightly higher additional capital costs for equipping vessels with OPS (€2.6bn expressed as present value over 2021-2050, relative to the baseline) than PO1 and PO3 (€2.5bn). That is due to the larger share of conventional engine ships in PO2[115], which provides fewer alternatives to the use of OPS in ports.

Finally, all POs also show a slight decline in operation costs (around 1% compared to the baseline), resulting from lower maintenance and crew costs driven by lower transport

[114] The electricity to produce synthetic fuels (i.e. e-ammonia, e-methanol, synthetic diesel, synthetic fuel oil and e-gas) is projected to be the highest in PO1 (almost 2 TWh in 2030 and 246 TWh in 2050). This would represent around 0.1% of renewable electricity generation in 2030 and 4.7% by 2050. In PO3 the electricity to produce synthetic fuels is projected at around 0.6 TWh in 2030 and 2030 by 2050 (i.e. less than 0.1% of renewable electricity generation in 2030 and 4.4% in 2050). PO2 shows the lowest share of synthetic fuels in the energy mix and thus the lowest electricity needs to produce them (0.1 TWh in 2030 and 198 TWh in 2050). The electricity is primarily used to produce synthetic diesel blends and clean gas. More details are provided in Annex 4.

[115] CAPEX related to OPS have been estimated by assuming OPS equipment installation on vessels powered by internal combustion engines (as opposed to electric ships or fuel cells) from the three ship types concerned by the OPS requirements. In terms of cost estimates, the valuation has been done using the high estimates from GloMEEP (https://glomeep.imo.org/technology/shore-power/) taking into consideration the vessel size distribution on each of the ship types as observed in MRV reporting.

activity relative to the baseline. The costs in Table 3 are presented as present value over the 2021-2050 time horizon.

Table 3 Total costs for ship operators compared to the baseline (present value over 2021-2050 horizon)

Costs for ship operators - present value for 2021-2050 compared to Baseline (bil. €'2015)	Baseline (bil. €'2015)	PO1	PO2	PO3
Capital costs	428	26.9	22.9	25.8
of which for OPS on vessels	0.8	2.5	2.6	2.5
Fuel costs	561	69.1	59.1	63.9
Operation costs	232	-2.4	-2.2	-2.3
Total costs	**1,221.1**	**93.6**	**79.8**	**87.3**

Source: PRIMES-Maritime, E3Modelling

Impacts on transport activity: While maritime transport activity would continue growing over the period until 2050 in all POs, a slight decrease of 2.7% for freight and 4% for passenger traffic compared to the baseline is projected as a result of the policy intervention. In freight transport, the highest impact is projected on short-sea shipping, as this segment is expected to operate mostly in voyages covered by the proposed intervention. The situation is similar and reinforced for passenger transport, where higher uptake of electric and fuel ships is projected to result in somewhat higher costs.

Table 4 Changes in the maritime transport activity

Transport activity (% change to Baseline)	Baseline (levels)		PO1		PO2		PO3	
	2030	2050	2030	2050	2030	2050	2030	2050
Total freight sea shipping (Gtkm)	17,075	21,354	-1.0%	-2.7%	-1.0%	-2.7%	-1.0%	-2.7%
Short sea shipping	3,080	3,817	-1.1%	-3.2%	-1.1%	-3.2%	-1.1%	-3.2%
Deep sea shipping	13,995	17,537	-0.9%	-2.7%	-0.9%	-2.7%	-0.9%	-2.7%
Passenger Shipping Activity (Gpkm)	2,426	3,016	-1.1%	-4.0%	-1.1%	-4.0%	-1.1%	-4.0%

Source: PRIMES-Maritime, E3Modelling

The baseline scenario and the policy options take into account the reduction in the long-distance shipping of fossil fuel volumes driven by the carbon policies and National Energy and Climate Plans. On the other hand, some increase in the transport of renewable and low carbon fuels from EU producing countries to the other EU countries is projected to moderate this decrease to some extent in the policy options.

6.1.2 Impacts on RLF prices, feedstock and renewable electricity needs for e-fuels

Impacts on RLF prices: The assessment assumes the implementation of measures by various actors that enables the uptake of advanced technologies at scale, not only for the maritime sector. This is particularly relevant for advanced biofuel production routes that are not yet commercially available. Novel routes relate mainly to advanced biodiesel produced from Gasification and Fischer-Tropsch synthesis, biofuel oil produced from Hydrothermal Upgrading, and biomethane from Catalytic Gasification of biomass. These biomass conversion technologies are capital intensive, yet empirical observations suggest that learning effects due to scaling of production are possible. The demand for advanced biofuels and bio-LNG (Annex IX Part A of REDII)[116] leads to additional production capacity in the EU. In the context of the transition towards a climate neutral economy by 2050, the demand for advanced biofuels comes from all transport sectors (and other sectors of the energy system) reducing production costs through economies of scale and learning-by-doing.

In the short-term, the demand for advanced biodiesel comes primarily from road transport and that of bio-LNG from other sectors of the energy system. The demand of bio heavy fuel oil comes mainly from maritime. As such, in the short-term, the demand for RLF in the maritime sector contributes primarily to the cost reduction of bio heavy fuel oil. Beyond 2030, due to the significant increase in the uptake of electric vehicles in road transport, maritime becomes a key sector that drives the production of advanced biodiesel and bio-LNG and further reduces the costs of scalable components of these technologies through an increase in cumulative production capacity and technological learning. A counterbalancing effect would however come into play from the increase in feedstock costs driven by the demand for biomass feedstock from other sectors. These insights are based on the modelling of bioenergy demand in the context of the EU climate ambition for 2030 and 2050, which means that significant quantities of bioenergy are needed by other transport modes (including aviation) and energy sectors. Hence, the biomass system is pushed towards more expensive feedstocks, outweighing to some extent the benefits from scaling the production that may be brought from the increase in the advanced biofuels demand in the maritime sector. In the PRIMES biomass model, which is used for the purpose of this assessment, the reduction in the costs of scalable components of these technologies and the impacts due to higher feedstock demand are both taken into account.

Annex IX Part B biofuels are mainly represented by the FAME and the HVO production route that use used cooking oil as feedstock. These are mature technologies/pathways commercially available today that have benefited from cost reductions due to the increase in the demand for biodiesel used in road transport. On the other hand, the production technologies for advanced biofuels are not yet available at scale, and require investments in first-of-a-kind plants. Their scale-up would benefit from learning effects and result in lower costs. Another reason that leads to cost differences between Annex IX Part B and advanced biofuels (Annex IX Part A) is that the latter require substantially more quantities of biomass feedstock input compared to Part B biofuels produced from used cooking oil. This leads to overall higher feedstock costs of advanced biofuels compared to Part B. Food and feed crop-based biofuels are out of scope of the policy options.

Similarly to advanced biofuel routes, the demand for hydrogen and hydrogen-based fuels (e-fuels, ammonia and methanol) from maritime but also from other transport sectors drives an increase in hydrogen demand and eventually leads to large-scale deployment of

[116] Annex IX Part A and Part B biofuels follow the definition of the Renewables Energy Directive.

hydrogen generation technologies. The modelling considers learning-by-doing effects, reducing the costs of electrolysers, which is a critical cost component.

The evolution of the RLF prices used in the modelling supporting the assessment of the policy options is consistent with those used for the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy and is provided in Annex 4. The price of biofuels (weighted average price of bio heavy oil and biodiesel) used in international maritime remains relatively stable between 2030 and 2050, due to the competition for biomass feedstock with other energy and transport sectors and despite the reduction in the costs of scalable components as explained above. However, the ratio between the biofuels price and the price of liquid fossil fuel used in maritime products goes down over time, to 2.1 in 2030 and 1.5 by 2050. Similarly, the ratio between the e-liquids prices and liquid fossil fuel prices goes down from 3.6 in 2030 to 1.9 by 2050.

Types of biofuels and feedstock: Biofuels and bio-LNG consumption, together, is projected to increase almost by a factor of 10 between 2030 and 2050, from around 3 Mtoe in 2030 up to 32 Mtoe in 2050. The highest supply is projected in PO2 (close to 32 Mtoe) and the lowest in PO1 (around 26 Mtoe) with PO3 falling in between (28 Mtoe). In their vast majority, Annex IX Part A (advanced biofuels and bio-LNG)[117] would be supplied to the maritime sector (more than three-quarters of supply to the maritime sector in 2030 and 90% in 2050, similarly across policy options). Annex IX Part B biofuels would cover the remainder of the biofuel demand. Biofuels imports for the maritime sector are projected to account for around 1.5% in 2030 to 4% in 2050 of the total biofuel demand in the sector. These would be biodiesel imports that are assumed to be exclusively Part B biofuels. More details are provided in Annex 4.

By 2030, the vast majority of the feedstock used is projected to originate from forestry and from biomass waste flows, whether agricultural residues, wood waste or manure. By 2050, energy crops and notably dedicated energy crops (annual lignocellulosic crops) provide more than one-third of the feedstock required to produce Part A biofuels. Substantial growth is also projected in agricultural residues used for biofuels production in international maritime that increase by more than a factor of 10 between 2030 and 2050.

Table 5 Biomass feedstock consumption by type (in Mtonnes)

Feedstock consumption	PO1		PO2		PO3	
Mtonnes	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
Part A						
Perennial crops	0.0	6.3	0.0	7.7	0.0	6.9
Annual crops	0.3	33.6	0.3	40.8	0.3	36.4
Forestry products	3.1	14.4	3.2	18.4	3.1	15.9
Forestry residues	1.4	11.7	1.5	14.7	1.5	12.8

[117] Annex IX Part A and Part B biofuels follow the definition of the Renewables Energy Directive.

Feedstock consumption	PO1		PO2		PO3	
Mtonnes	2030	2050	2030	2050	2030	2050
Wood waste	1.8	6.7	1.8	8.0	1.8	7.2
Agricultural residues	1.5	15.4	1.5	18.6	1.5	16.8
Manure	1.2	2.8	1.2	3.3	1.2	3.0
Part B						
Non-agricultural oils	0.80	1.4	0.83	1.8	0.82	1.6

Source: PRIMES Biomass model, E3Modelling

Model projections show that EU has sufficient biomass available domestically to produce biofuels and bio-LNG for EU international maritime sector. By 2030, there is sufficient supply of waste lipids (non-agricultural oils, such as used cooking oil), as the demand from international maritime requires about 20% of the feedstock available in the EU. The remaining feedstock is consumed in other transport sectors such as road transport and aviation. By 2050, the need for waste lipids to produce Part B biofuels for international maritime increases, and as a result the sector requires higher shares of the available feedstock. Part A biofuels from lignocellulosic feedstock consume 6 to 20% of the available feedstock potential in the EU by 2050, depending on the type of feedstock and policy option. Manure used for bio-LNG for international maritime increases from around 2% in 2030 to 5-6% in 2050.

Table 6 Used potential for the EU maritime sector as % of domestic potential in EU27

Used potential	POA		POB		POC	
(% of domestic potential in the EU27)	2030	2050	2030	2050	2030	2050
Part A						
Perennial crops	0.2%	10.9%	0.2%	13.3%	0.2%	11.8%
Annual crops	0.2%	10.6%	0.2%	12.8%	0.2%	11.4%
Forestry products	2.8%	15.4%	2.9%	19.7%	2.9%	16.9%
Forestry residues	2.3%	15.9%	2.4%	20.0%	2.3%	17.4%
Wood waste	1.7%	6.4%	1.8%	7.7%	1.8%	6.9%
Agricultural residues	1.4%	16.1%	1.5%	19.4%	1.5%	17.5%
Manure	2.4%	5.3%	2.4%	6.4%	2.4%	5.8%
Part B						
Non-agricultural oils	20.6%	27.4%	21.3%	34.4%	21.1%	29.9%

Source: PRIMES Biomass model, E3Modelling

In the production of biofuels, biomass feedstock comprises most of the energy demand to produce bioenergy commodities. In addition, bioenergy production requires energy inputs in several steps in the production process, from biomass cultivation or collection, to transport, and conversion of biomass to bioenergy. Based on insights from PRIMES Biomass, the production of all bioenergy commodities projected in the context of the transition towards a climate neutral economy, requires about 36 Mtoe of electricity, liquid fuels and gas in 2050. This corresponds to less than 3% of the overall energy supply (of electricity, liquid fuel and gas) for the same year. The contribution of international maritime fuels, is significantly lower than that, with estimates ranging between 0.3% and

0.35% of the overall energy supply for the POs. The energy use in the production of biofuels is also reflected in the well to tank emissions in all POs.

Renewable electricity needs for e-fuels: The electricity to produce e-fuels is projected to be the highest in PO1 (almost 2 TWh in 2030 and 246 TWh in 2050). This would represent around 0.1% of renewable electricity generation in 2030 and 4.7% by 2050. In PO3 the electricity to produce e-fuels is projected at around 0.6 TWh in 2030 and 230 by 2050 (i.e. less than 0.1% of renewable electricity generation in 2030 and 4.4% in 2050). PO2 shows the lowest share of e-fuels in the energy mix and thus the lowest electricity needs to produce them (0.1 TWh in 2030 and 198 TWh in 2050). The electricity is primarily used to produce synthetic diesel blends and e-gas.

Table 7 Electricity consumption for producing e-fuels for the maritime sector (in TWh and %)

Electricity consumption for synthetic fuels (TWh and %)	PO1		PO2		PO3	
	2030	2050	2030	2050	2030	2050
Electricity consumption, TWh	1.8	246	0.1	198	0.6	230
Share of gross electricity generation, %	0.0%	2.0%	0.0%	1.6%	0.0%	1.9%
Share of renewable electricity generation, %	0.1%	4.7%	0.0%	3.8%	0.0%	4.4%

Source: PRIMES model, E3Modelling

Uncertainties underlying the analysis: This assessment takes into account the current knowledge related to the possible evolution of technology costs and feedstock costs. If higher decrease in the costs of e-fuels would take place than assumed in this assessment, their uptake could be higher especially in PO2 and PO3 due to their increased competitiveness relative to biofuels and bio-LNG. This consideration also applies to alternative propulsion systems like fuel cells and electric vessels). This is because PO2 and PO3 provides flexibility in terms of choice of the fuel mix. On the other hand, if the availability of biofuels and bio-LNG for the maritime sector would be lower, due to higher demand by other sectors, a higher share of e-fuels would be needed to compensate for achieving the mandates in PO2 and PO3. In case the technology costs and feedstock costs would be higher than assumed in this assessment, this may results in higher fuel costs and subsequently freight rates.

6.1.3 Regulatory and administrative costs related to businesses

Regulatory and administrative costs have been looked at for three main stakeholder categories that are mostly affected by the regulatory obligations resulting from the POs: ship owners and operators, bunker suppliers and ports.

The administrative costs for ship owners and operators will primarily consist of monitoring, verification and reporting, determined by additional requirements compared to the existing EU MRV Regulation. In essence, the EU MRV Regulation already provides for an extensive monitoring of individual ships' CO_2 emissions (fuel consumption and other parameters, such as distance travelled, time at sea and cargo carried on a per voyage basis), which are gathered annually into an emissions report submitted to an accredited

MRV shipping verifier and reported, through THETIS-MRV, to the Commission and to the States in which those ships are registered (the so-called ‘flag States’).

This initiative can therefore rely to a large extent on the already existing reporting requirements in the EU MRV Regulation. However, given that more emissions and energy sources will be included, additional information will need to be monitored, reported and verified. The following assessment is based on conservative assumptions.

Administrative costs for ship owners are estimated on the fact that each vessels will have to comply with the following information obligations:

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 builds on the EU MRV Monitoring plan and includes additional emissions as well as energy sources. The same conservative assumptions have been used as in the EU MRV Impact Assessment[118] for the preparation of the entire Monitoring plan (i.e. 40 hours per ship over the period of 10 years).
2. *Annual energy report:* The annual energy report is the calculation of the annual energy consumption of the vessel, broken down to different energy sources/types of fuel and to navigation and berth. This report builds on the EU MRV Emission report, but is more extensive as well-to-tank, non-CO_2 emissions and OPS/electricity consumption are included as well. The targeted survey asked about the corresponding administrative cost. 8 out of 9 respondents indicated that for ship owners, the reporting time would increase by two hours at most, per voyage. However, it could not be verified to what extent the reply already included the existing requirements of EU MRV Regulation (i.e. part of the baseline) or whether only additional elements were included. It can be assumed that specific information on the use of OPS is already included in such reporting (as they would, at least partly, replace the fuel use currently reported at berth), based on information supplied by the electricity supplier (i.e. electricity bills). Similarly for the use of THETIS-MRV system: ship owners and operators are already using it and thus, it will only incur incremental familiarisation cost.
3. *Proof of compliance:* Each ship has to carry a document of compliance and cooperate during PSC inspections. The first requirement will not impose any additional administrative costs, as the document is supplied by the verifier, and thus only has to be carried on board. The only action during PSC is to retrieve the document of compliance and show it to the inspector. The additional administrative costs of this will be a maximum of 15 minutes per inspected ship.
4. The administrative costs incurred by operators will also cover the training needs to ensure the safe switch to RLF on-board ships. Furthermore it is assumed that training

[118] 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

for alternative fuels will become standard in training programs for new seafarers in 2035. This means that only the ships which switch to RLF before 2035 would need to invest in additional training.

Administrative cost for bunker suppliers will primarily consist of certification of fuel and upstream emissions/sustainability criteria. The certification requirements will build on existing provisions and sustainability criteria in the RED II. Fuel producers already have experience with certification of biofuels under RED. When a new (bio)fuel needs to be certified, for instance under the International Sustainability & Carbon Certification Scheme (ISCC), the entire supply chain has to be certified[119]. Certification schemes mostly have one-time registration fees that vary between €50 and €500, so these are one-off costs. 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. It has not been possible to estimate how many certification schemes would be established or what the exact impact of certifying upstream emissions would be (several fuel producers have been interviewed, but none were able to make an estimate of the effort needed for certification). However, based on the illustrative costs listed above, it can be assumed that the overall certification costs will not have significant impact on the price of alternative fuels.

Administrative costs for ports are more modest and relate to the publication of guidelines and the revision of ports regulations to cover the safe handling, bunkering and use of RLF. It is expected that around one third of EU ports will be affected by a significant increase in new safety guidelines.

Table 8 presents an overview of these costs for the entire period 2021-2050, expressed as present value. More details on the assumptions used for calculating the costs are provided in Annex 4.

Table 8 Total costs relative to the baseline, expressed as present value for the period 2021-2050

Administrative costs - present value for 2021-2050 compared to Baseline (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**
Set up guidelines in ports	1.8	1.8	1.8

Source: Ecorys / CE Delft forthcoming, and own calculations

[119] This means that either all suppliers and other stakeholders need to cooperate in the certification, or are already ISCC certified themselves.

6.1.4 Enforcement costs

Similarly to the EU MRV, third-party verifiers will verify the documents supplied by operators to check compliance. As the information requirements are based on the ones used for the EU MRV Regulation (including in terms of timing and expected IT system), it is reasonable to expect that the same entity will be tasked by the ship owners to verify compliance with both regulations. The new tasks for the verifiers will be to verify the additional elements contained in the annual energy compliance plan and the annual energy report, to establish compliance with the required RLF use.

During the targeted consultation, the verifiers assumed that several hours are needed for the necessary verification per single ship on an annual basis and indicated in an interview that if the EU has a regulatory requirement that needs to be verified, the verifiers will step up to meet the challenge.

As the reporting and verification system is similar in all options, the additional costs relative to the baseline are the same in all options. They are based on the conservative assumption that 5 hours would be need to verify the additional elements in both the annual energy report as well as the energy compliance plan.[120] Ensuring that a ship has met its obligations before issuing a Document of Compliance is an important element of the intervention to ensure that non-compliance do not get a competitive advantage from fuel costs savings.

On the side of the public administrations, a PSC officer will have to determine whether the Document of Compliance is on board (similar assumption as above is made of 15 minutes per inspection, which is the upper bound based on a conservative assumption that each vessel under EU MRV Regulation is inspected every year). At the same time, it is proposed to allow for the use of electronic certificates, which can remove the need for a physical check in its entirety.

Furthermore, additional one-off cost for adapting the EU MRV IT system (THETIS-MRV) should be foreseen for the EU budget to accommodate the additional information as well as additional functionalities related to the RLF obligations. In addition, a new module in THETIS-EU should support PSC officers as well as EU flag state inspectors in their work. Based on the cost of THETIS-MRV[121] and experience with existing THETIS-EU modules supporting various pieces of EU legislation, such IT-developments costs are estimated at €300,000. 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.

[120] According to the IA on the revision of the EU MRV Regulation, p. 51 (overview of administrative burden), verification costs turned out to be significantly lower than estimated in the 2013 EU MRV impact assessment: https://ec.europa.eu/clima/sites/clima/files/transport/shipping/docs/swd_2019_10_en.pdf

[121] Source: EMSA 2020

Table 9 summarises all enforcement costs relative to the baseline for the period 2021-2050, expressed as present value. More details on the assumptions used for calculating the costs are provided in Annex 4.

Table 9 Summary of the enforcement costs for the period 2021-2050

Administrative costs - present value for 2021-2050 compared to Baseline (million €'2015)	PO1	PO2	PO3
Total enforcement costs	**83.3**	**83.3**	**83.5**
Verify annual emissions report	41.0	41.0	41.0
Approve annual compliance plan	41.0	41.0	41.0
Additional time during audits/inspections	1.0	1.0	1.0
Adaptation to the IT system	0.3	0.3	0.5

Source: Ecorys / CE Delft forthcoming, EMSA 2020, and own calculations

6.1.5 *Impact on ports to provide the necessary infrastructure*

The uptake of alternative maritime fuels in maritime transport will require several actions from ports. The impact of the proposed intervention will depend on the type of technical solutions adopted. Indeed, drop-in fuels can, to a very large extent, rely on existing fuel oil infrastructure (for liquid drop-in fuels) or LNG bunkering (for the gaseous fuels). Fuels like methanol, hydrogen and ammonia would require various degrees of adaptation / modification of the bunkering facilities or even new infrastructure. The provision of OPS also requires the installation of appropriate connection points at berth, port level substation(s) and high-voltage electricity supply infrastructure.

The investments required by ports are likely to be distributed over time in all POs in such a way that they would first target the installation of OPS infrastructure (required as of 2030 in all POs for certain ship types) and then gradually accompany the deployment of hydrogen, ammonia and methanol. While the provision of OPS is covered by AFID, the current uptake of this solution remains very limited in European ports. However, on this particular point the three POs will not differentiate as the requirements at berth are defined in the same manner for all options. Overall, it can be expected that PO1 will lead to the highest levels of ports investments given the higher penetration of non-drop-in RLF in the overall energy mix. It will be followed respectively by PO3 and PO2.

The level of ports investments are likely not to be uniform across all ports but to depend largely on the size of the port, the type of traffic that it usually accommodates and to a lesser extent the port layout and the need for connection to the grid[122]. In other words, the infrastructure needs of a large transhipment port are likely to be different from those of a port of a smaller size mostly used for passengers or those of a cruise ship terminal. It is also worth noting that the bunkering offer can be an element of competition among ports. As for the likelihood to invest in RLF bunkering infrastructure, it can be assumed that the largest 25 freight ports will invest in multiple types of alternative fuels due to willingness

[122] https://sustainableworldports.org/ops/costs/investments/

and financial possibilities to invest. It is also expected that the largest passenger ports will invest to facilitate cruise and ferry traffic.

Another aspect adding to complexity concerns the fact that the costs of infrastructure investment are highly port specific and depend on a series of local conditions (e.g. the port layout mentioned above). Identifying an average or typical investment cost for a given infrastructure is therefore not possible. Instead, an indicative range of the required investments has been identified based on a review of past investments projects and case studies of RLF investment by ports. However, the size of the identified range is significant. Investments in a hydrogen infrastructure are valued between €35 million to more than €100 million[123]. The cost of onshore power supply installation varies between €1 and €25 million (dependent on the size and complexity)[124].

Based on the above, and considering the high range of installation costs for hydrogen and power demand estimations by EMSA for the OPS, the total investments in alternative fuels infrastructure over the period 2025-2050 would be €9.9bn (€2.5bn for hydrogen infrastructure and €7.4bn for OPS). This is equivalent to additional capital costs relative to the baseline estimated at €5.7bn, expressed as present value over 2021-2050 horizon. This figure is based on the assumption that the installation of the infrastructure in the EU will focus on the 25 large ports for hydrogen and the TEN-T core and comprehensive ports for OPS. This estimate is considered to be indicative of the scale of investments that will be needed, considering the challenges linked to the number and complexity of the factors impacting these types of investments. This cost is the same for all POs.

6.1.6 Impact on innovation

All POs are expected to have a positive impact on innovation as they will foster the deployment of more advanced technologies (including to improve energy efficiency) and fuel solutions. Compared to the use of drop-in fuels in conventional internal combustion engines, the deployment of fuel cells and electric propulsion represent arguably the solutions requiring the highest innovation efforts, in particular with a view to scale them for use in longer distances and, potentially, deep-sea shipping. Table 10 presents, as a proxy, an indication of the penetration of fuel cell-powered ships and electric ships in the overall vessel stock for all POs by 2030 and 2050 (compared to the baseline).

[123] Source: North Sea Port (2020), https://en.northseaport.com/volth2-signs-cooperation-agreement-with-north-sea-port-for-the-development-of-a-green-hydrogen-plant. In the absence of proper reference points for the development of infrastructure of hydrogen as marine fuel, this investment bandwidth is estimated on the basis of costs for the deployment of hydrogen plants in ports.

[124] Based on the analysis of project submitted for funding through INEA and referenced with literature, source: Greencruiseport (2018) http://www.greencruiseport.eu/files/public/download/studies/Opportunities%20and%20Limitations%20for%20Connecting%20Cruise%20Vessels%20to%20Shore%20Power_04.01.2018_Bergen.pdf

Table 10 Stock of fuel cell and electric ships (difference to the baseline and share of the stock)

Fuel cell and electric ship vessels	**PO1**		**PO2**		**PO3**	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**
Stock - difference to the Baseline						
fuel cell ships	0	3,523	0	2,446	0	3,372
electric ships	46	1,251	7	380	26	969
Share of the total stock (in %)						
fuel cell ships	0.0%	19.7%	0.0%	13.7%	0.0%	18.9%
electric ships	0.3%	7.0%	0.1%	2.1%	0.2%	5.4%

Source: PRIMES-Maritime, E3Modelling

While all options have a noticeable positive impact on the deployment of these technologies (and hence on the effective innovation potential to support their deployment), PO1 results in the highest share of fuel cell-powered ships (19.7%) and electric ships (7.0%) by 2050, followed by PO3 (18.9% and 5.4% respectively) and PO2 (13.7% and 2.1% respectively). It is interesting to notice that the gap between PO1 and PO3 is much lower than with PO2. This is expected to be the result of the application of the mechanism for overachievers within the PO3. We can also observe that the innovation push is mainly unlocked after 2030. This is likely to result from the combined effect of tightening the GHG limits and the achievement of a sufficient TRL.

Other aspects that have not been quantified by the modelling activities concern the further development of internal combustion engines, to be able to operate more frequently as “dual-fuel” engines or to use emerging fuels (such as ammonia) as well as the necessary air pollution abatement-measures to further reduce ship emissions. In addition, the development and deployment of energy efficiency measures, including the use of wind assistance, is expected to increase as a means to mitigate the fuel costs increase induced by the proposed intervention.

As also highlighted in Section 6.2.1, all POs under consideration are also expected to have a positive impact on employment levels in R&I related to the provision of marine RLF. This is also explained by the increased share of hydrogen, hydrogen-based fuels and e-fuels.

6.1.7 Impact on the competitiveness of other parts of the EU maritime cluster

The expected impact on ship operators has already been presented in Section 6.1.1 and on ports in Section 6.1.5. This section focuses on the possible changes to the competitiveness of a wider set of actors composing the EU maritime cluster, namely the international competitiveness of the shipping industry, shipbuilding industry, the marine equipment industry, the fuel suppliers and bunkering facilities. The impact on competitiveness is based a qualitative assessment following consultations and stakeholders interviews.

Table 11 Expected impacts on competitiveness of the EU maritime cluster

Stakeholder category	**PO1**	**PO2**	**PO3**
Shipping industry	Small positive	No change	Small positive
Shipbuilding industry	Small positive	No change	Small positive

Stakeholder category	PO1	PO2	PO3
Marine equipment industry	Small positive	No change	Small positive
Fuel suppliers	Small positive	No change	Small positive
Bunker facilities	No change	Negative	Negative

In practice, a small positive improvement of the competitive position of the shipping industry, the shipbuilding industry, the marine equipment industry and the fuel suppliers is expected to be seen in line with the acceleration of the RLF uptake and in particular a higher demand for the most advanced solutions (zero or near-zero propulsion). This is mainly resulting from the already strong competitive position of the EU industry in the delivery of specialised vessels / solutions. For the bunker facilities the accelerated uptake of RLF has negative consequences in particular with higher shares of non-drop-in fuels which will require dedicated infrastructure.

6.1.8 Impact on third countries

Three main aspects can be relevant when considering the impact that a measure incentivising the uptake of RLF can have on third countries. These concern: impact on fuel production and distribution, impact on shipbuilding, and impact of trades with third countries. However, these impacts are not easily quantifiable. As a result, this section will focus on identifying the most relevant aspects and trends.

Concerning **fuel production and distribution**, all policy measures will incentivize the production of RLF, which will have to be made available to the sector. Given the global nature of maritime transport, there is an interest in the widest possible distribution and availability of RLF. In order to prevent fuel shortage, all POs have been modelled so that they could be sustained by production in EU countries. However, bunkering of RLF is also allowed in third countries that comply with the certification requirements. While the production of conventional bunker fuels was mainly focussed in Asia, followed by Europe and the Middle-East[125], the production of RLF does not necessarily have to emerge in countries that currently produce conventional fossil bunker fuels. Since different feedstock and input factors are required, this could open possibilities for new market actors to emerge. Countries with favourable conditions for the production of renewable electricity could be attractive production locations for e-fuels[126]. In addition, the largest bunkering hubs outside Europe such as Singapore, Fujairah, Hong Kong, Busan, and Panama could also be impacted and may start offering higher quantities of RLF to their customers.

As mentioned in Section 6.1.7, the **impact on shipbuilding** will vary among the POs in line with the increased uptake of more advanced and innovative solutions. However, even in the case of drop-in fuels the proposed intervention could have an effect on increasing the demand for energy-efficient new-built vessels (as a way to mitigate the expect fuel cost increase) and boost the deployment of advanced energy efficiency solutions for the

[125] https://www.cedelft.eu/publicatie/assessment_of_fuel_oil_availability/1858

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

existing fleet. The most important shipbuilding nations outside Europe are China, Japan and the Republic of Korea.

The increase in fuel cost induced by the three POs may also have an impact on **trade with third countries**. This would depend on the type of cost increases for ship operators. Table 12 provides an indication for each PO compared to the baseline.

Table 12 Percentage of costs increase for ship operators compared to the baseline in 2030 and 2050

Costs for ship operators (% change compared to Baseline)	Baseline (bil. €'2015)		PO1		PO2		PO3	
	2030	2050	2030	2050	2030	2050	2030	2050
Capital costs	22.6	36.0	4.1%	13.3%	3.8%	11.3%	3.9%	13.0%
Fuel costs	32.0	50.6	3.2%	26.7%	2.9%	28.1%	3.0%	27.2%
Operation costs	13.3	16.8	-0.3%	-2.6%	-0.3%	-2.4%	-0.3%	-2.5%
Total costs	67.8	103.3	2.8%	17.3%	2.6%	17.3%	2.7%	17.4%

Source: PRIMES-Maritime, E3Modelling

In effect, the fuel costs increase for 2030 vary between 2.9% and 3.2% and between 26.7% and 28.1% in 2050. The impact on the total cost of operators remains around 17% by 2050 in all POs. The cost increase compared to the baseline remains limited in the first years of the policy intervention to gradually increase over time. The impact of the POs on EU trade with third countries is therefore likely to remain limited. Section 6.2.2 looks in greater details at the potential impact of the POs on freight rates.

6.2 Social impacts

The social impacts have been analysed through three main aspects: the impact on jobs in the different parts of the EU maritime sector, the impact on freight rates (as a proxy for costs related to maritime transport services) as well as the issue of connectivity of remote islands and peripheral maritime regions, and last but not least the health benefits.

6.2.1 Impact on jobs in the different parts of the EU maritime cluster

Two types of impacts can be distinguished on jobs: the direct impact on employment, measured in number of jobs, reflecting potential job creation / losses, and the indirect impact, related to changes of skills and knowledge of employees. These impacts are expected to differ depending on the technology choices that will be made for compliance. Differences among the POs will therefore result from the variation in the expected penetration levels of the different fuels in each option. Table 13 presents an overview of the impact on employment per technology.

Table 13 Assumed impacts per technology on employment levels

Stakeholder 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 increase depending on size / type / efficiency of facility	Possible increase depending on size / type / efficiency of facility	Possible increase depending on size / type / automation level / efficiency of facility

Stakeholder category	Biofuels	Electro-liquids	Hydrogen	OPS
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 / CE Delft forthcoming

While direct impacts on any of the options may be limited in certain cases (e.g. manning levels on-board vessels), the training needs arising from the growing penetration of alternative fuels is a common factor for all the POs and for all segments of the EU maritime sector. The need to upgrade skills will result in potentially significant investments in training and certification of seafarers (see also Section 6.1.3. for the assessment of training costs), as these are not included in current training and education programmes nor required by existing regulations (e.g. STCW Convention). However, this evolution is also a potential benefit, as it is likely to increase the competitiveness of European employees in the global market, and improve the image of the sector and inspire more people (young people as well as women) to opt for a maritime career.

Table 14 presents the overview of the qualitative assessment of the expected employment impact of the POs.

Table 14 Expected impacts of the policy options on employment

Stakeholder category	PO1	PO2	PO3
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 & repair	Medium positive	Small positive	Medium positive
Research and development	High positive	High positive	High positive

Source: Ecorys / CE Delft forthcoming Note: All impacts are presented against today's situation.

In practice, the employment impact is expected 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, the job 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 in all options.

6.2.2 Impact on freight rates and connectivity of remote islands and peripheral regions

The impact on freight rates of the proposed intervention could be used as a determinant of the potential impact on final consumer prices, bearing in mind that maritime transport is an essential vector of EU trade (75% of all EU external trade in volume and 31% of EU internal trade). By extension the impact on freight rates will be used as an indicator of the potential impact of the measure on the connectivity of remote islands and peripheral regions. However, it is difficult to directly relate freight rates to consumer prices. Historical data showed a decline of the cost of maritime transport in the transport of certain commodities, while over the same period freight rates were not following the same trend.

Drawing conclusions on the impacts of fuel prices on freight rates is also complex, due to the diversity of the maritime sector. The proportion of fuel costs in the operating costs differ indeed from one market segment to another. For instance, while bunker costs may account for around 35% of the freight rate of a small tanker, this proportion is much higher (53%) for container/bulk vessels. The type of traffic can also influence the importance of fuel price fluctuation. Generally, the share of bunker cost is lower for deep sea shipping, compared to short sea shipping. This results in important differences on the impact of fuel prices on freight rates among different sectors. While the general freight index oil shows a strong correlation with the price of marine diesel, freight rates in the dry bulk sector (Baltic Dry Index) are decoupled from bunker prices and mainly influenced by the demand and supply of raw materials, fleet composition and demand and supply of ships.

Nevertheless, based on the existing literature[127] on the relation between fuel prices and freight rates, the impacts on the freight rates have been estimated for 2030 and 2050 and are provided in Table 15. Drawing on the modelling exercise performed with PRIMES-Maritime model, the increase in the price 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. This is relevant in all POs, because 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.

Table 15 Possible impacts of the projected 'diesel blend' price increase on freight rates

Segment	Freight rate elasticity	2030	2050
General	0.018-0.36	0.1%-2.5%	0.8%-15.1%
Containers	0.11-0.36	0.8%-2.5%	4.6%-15.1%
Dry bulk	0.28	2.0%	11.8%

Source: own calculations based on Ecorys (forthcoming) and PRIMES-Maritime

As the impact of the proposed intervention remains limited on freight rates, and given the low share of transport costs on final consumer prices, the intervention is not expected to lead to any significant on commodity, product and raw material prices.

6.2.3 Public health

All POs are estimated to have a positive impact on public health due to the decrease in air pollution. For instance, by 2050, in all POs NOx and PM10 emissions associated to

[127] UNCTAD (2010). Oil Prices and Maritime Freight Rates: An Empirical Investigation., OECD (2008) Clarifying Trade Costs in Maritime Transport, Hummels(2007) Transportation costs and international trade in the second era of globalization, Mirza and Zitouna (2009) Oil prices, geography and endogenous regionalism – all within the range provided.

maritime transport are projected to decrease by 24-27% relative to the baseline (with small differences among POs as shown in Section 6.3). These decreases are driven by the reduction in transport activity relative to the baseline, the uptake of zero-emission vessels and the uptake of on-shore supply. The POs would results in €9.4 to 10.3bn savings in the external costs of air pollution relative to the baseline[128], expressed as present value over the 2021-2050 period.

Table 16 External costs savings on air pollution

External costs - present value for 2021-2050 compared to Baseline (bil. €'2015)	Baseline (bil. €'2015)	PO1	PO2	PO3
External costs of air pollution	124	-10.3	-9.4	-10.0

Source: PRIMES-Maritime

Savings happening as the result of the use of cleaner energy sources at berth, in particular OPS, are particularly important as they would contribute reducing the air pollution pressure on ports and port cities.

6.3 Environmental impacts

The environmental impacts have been assessed in terms of fossil fuel savings and GHG emissions reductions, as well as impacts on air quality. An analysis of the risk of carbon leakage and the possible traffic diversion resulting from the proposed intervention is also provided in this section.

6.3.1 Fossil fuels savings

All POs achieve significant fossil fuel savings relative to the baseline, estimated to be around 13% by 2030 and 89 to 91% by 2050. The share is slightly higher for passenger ships and short sea shipping than for deep-sea shipping. This is in line with previous conclusions concerning the frequency of the journeys within the scope of the proposal. Oil products and fossil LNG are gradually replaced over time with renewable and low-carbon liquid and gaseous fuels. This also reduces the EU fossil fuel dependency.

Table 17 Fossil fuel savings in the policy options relative to the baseline

Fossil fuel use in maritime (% change to Baseline)	Baseline (ktoe)		PO1		PO2		PO3	
	2030	2050	2030	2050	2030	2050	2030	2050
Total shipping	**45,793**	**55,675**	**-13.2%**	**-88.6%**	**-13.1%**	**-90.7%**	**-13.1%**	**-90.2%**
oil products	43,597	45,135	-12.3%	-88.9%	-12.2%	-91.7%	-12.2%	-91.0%
LNG	2,196	10,540	-30.1%	-87.1%	-30.1%	-86.2%	-30.1%	-86.9%

Source: PRIMES-Maritime, E3Modelling

6.3.2 Impacts on GHG emissions and air quality

Impacts on GHG emissions: As the policy intervention requires to improve the GHG performance of the energy used on-board of the ship the GHG emissions are also expected to be reduced, both as a result of the use of RLF and the slight changes in the transport

[128] To monetise the costs, the CE Delft (2019) Handbook on the external costs of transport, has been used.

activity as described in Section 6.1.1. Table 18 presents the evolution of maritime GHG emission both on tank-to-wake (consumption) and well-to-wake (including upstream emissions related to fuel production, transport, etc.) basis. On a well-to-wake approach, the highest savings are shown in PO3, followed by PO1 and PO2. The levels of CH_4 emissions are increasing by 2050 relative to the baseline, as a result of a larger uptake of decarbonised gaseous fuels; this outcome is due to the fact that no significant progress on methane slip control is assumed in the POs. However, this increase is lower in PO1 and PO3, which generally see a higher penetration of hydrogen-based fuels (e-fuels, hydrogen, methanol and ammonia) as well as electricity.

Table 18 Evolution of GHG emissions from maritime transport on a tank-to-wake and well-to-wake basis

Maritime transport GHG emissions (% change to Baseline)	**Baseline (kt CO_2-eq)**		**PO1**		**PO2**		**PO3**	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
Tank to wake GHG emissions	**144,474**	**169,166**	**-12.9%**	**-88.4%**	**-12.8%**	**-90.6%**	**-12.9%**	**-90.1%**
CO_2 emissions	144,363	168,708	-12.9%	-88.6%	-12.8%	-90.9%	-12.9%	-90.4%
CH_4 from slippage	96	440	-6.2%	7.5%	-6.2%	14.9%	-6.2%	9.5%
N_2O from slippage	16	18	-6.3%	-23.3%	-6.2%	-19.9%	-6.2%	-22.7%
Well to wake GHG emissions	**166,662**	**199,015**	**-11.1%**	**-77.3%**	**-11.0%**	**-76.8%**	**-11.1%**	**-78.0%**

Source: PRIMES-Maritime, E3Modelling

In terms of tank-to-wake, CO_2 emissions from international maritime are projected to be 81% to 84% lower relative to 1990 in the POs. This is consistent with the climate neutrality objective for 2050 as explained in Section 1.5.

All POs result in significant reductions in the GHG emissions intensity of fuels relative to the baseline, as shown in Table 19, estimated at around 6% on well to wake basis for 2030 and 73-74% for 2050. Relative to the current period this is equivalent to 7% reduction by 2030 and 74-75% by 2050.[129]

Table 19 Evolution of GHG intensity of fuels from maritime transport on a tank-to-wake and well-to-wake basis

Maritime transport GHG intensity of fuels (% change to Baseline)	**Baseline (gCO2eq/MJ)**		**PO1**		**PO2**		**PO3**	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
Tank to wake GHG intensity	75	72	-8%	-86%	-8%	-89%	-8%	-89%
Well to wake GHG intensity	87	84	-6%	-73%	-6%	-73%	-6%	-74%

Source: PRIMES-Maritime, E3Modelling

Impacts on air pollutant emissions: The analysis of impacts on air pollutants covers impacts on nitrogen oxide (NOx), carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), sulphur oxide (SOx) emissions and PM_{10}. Air pollution emissions are reduced in all POs relative to the baseline, including air pollution at berth, with the

[129] The GHG intensity of fuels shown here are based on the actual GHG emissions and energy use, without accounting for multipliers in PO3 to provide incentives for the zero-emission technologies. These incentives are discussed in Annex 4.

widening of the use of OPS (or equivalent technologies) by the most polluting fleet. The highest reduction are expected in NOx, SOx and PM_{10}, which in all POs reach 23%-27% reduction in 2050 as compared to the baseline. The reduction in levels of air pollutants will be higher for passenger ships than for freight ships (34%-39% for NOx, SOx and PM), however this is also due to slightly higher decrease of passenger traffic activity compared to the baseline as a result of the policy intervention. The impact of the reduction through the use of OPS (or equivalent) is not homogenously distributed and will be localised, depending on the volume and type of traffic for each port. Thus port-cities and the adjacent areas are those with a direct benefit.

Table 20 Evolution of air pollutant emissions from maritime transport

Air pollution emissions (% change to Baseline)	Baseline (kt)		PO1		PO2		PO3	
	2030	2050	2030	2050	2030	2050	2030	2050
Total shipping								
NOx	1,574	1,664	-6%	-27%	-6%	-24%	-6%	-27%
CO	164	236	-6%	-16%	-6%	-11%	-6%	-15%
NMVOC	62	74	-6%	-22%	-6%	-19%	-6%	-22%
PM10	74	64	-6%	-27%	-6%	-24%	-6%	-27%
SOx	302	249	-6%	-27%	-5%	-23%	-6%	-26%

Source: PRIMES-Maritime, E3Modelling

Impacts on external costs: Based on the GHG emissions and the reduction in the air pollutant emissions presented above, Table 21 presents the savings in external costs of air pollution and climate change relative to the baseline[130], expressed as present value over the 2021-2050 period. These have been monetised using the Handbook on the external costs of transport. As already explained in Section 6.2.3, the initiative would result in a reduction of external costs of air pollution of €9.4 to 10.3bn relative to the baseline. The reduction in external costs of GHG emissions is projected to be more significant at €135.9 to 138.6bn relative to the baseline over the 2021-2050 period, expressed as present value.

Table 21 Changes in external costs of air pollution and climate change relative to the baseline, expressed as present value over the 2021-2050 period

External costs - present value for 2021-2050 compared to Baseline (bil. €'2015)	Baseline (bil. €'2015)	PO1	PO2	PO3
External costs of air pollution	124	-10.3	-9.4	-10.0
External costs of GHG emissions	363	-135.9	-138.5	-138.6
Total external costs	487	-146.2	-148.0	-148.6

Source: PRIMES-Maritime, E3Modelling

6.3.3 *Carbon leakage*

In the absence of any fuel requirement imposed on maritime operators, ship would continue use of conventional fuels. In the event that conventional fuels were not available in the EU, ships would bunker them in non-EU ports during one of their regular calls. In

[130] CE Delft (2019) Handbook on the external costs of transport.

other words, without obligations on demand, carbon leakage would occur without any need for ships to modify their normal activity.

If obligations are imposed on ships for the use of (some proportion of) RLF for voyages within the scope of the mandates, ships would have an interest in reducing the length of those voyages. In this case, carbon leakage could still occur, but would require ships to re-route and alter their normal course of business.

The potential for ships re-routing to reduce the amount of traffic that falls in scope of the initiative has been analysed for 2030 by comparing the situation without re-routing (i.e. direct link from port A to port B, where port A is a non-EU/EEA port and port B is an EU/EEA port) with a situation including an intermediate stop to a non-EU/EEA port (port C), closer (or the closest) to the EU/EEA port (port B). The analysis, performed with the TRUST model by TRT, takes into account the cost types according to different ship types along different routes, as illustrated in Annex 4, as well as the increase in the fuel blend cost projected as a result of the initiative. The analysis has been performed for PO1 and PO3 and three categories of ships: container ships, dry bulk ships and liquid bulk ships.

For container ships, the analysis shows that, for the vast majority of routes, total travel cost increases in case of an intermediate stop to a non-EU/EEA port. In PO1 although fuel costs in case of a route diversion (i.e. with an intermediate stop to a non-EU/EEA port) are projected to be reduced by 1-6% relative to the Baseline in 2030 (i.e. €26,000 to €242,000 depending on the route and ship type), travel time costs would increase by 4-13% (i.e. €13,300 to €102,000) and costs at ports would go up by 50% (i.e. €47,500 to €137,000 depending on the ship type). These results suggest that the risk of leakage resulting from container ships' route diversion to reduce the amount of traffic that falls in the scope of the initiative is low, due to the increase in the travel time costs and costs at ports that outweighs the reduction in the fuel costs.[131] For PO3, the analysis shows similar results as PO1, with fuel costs projected to reduce by 1-6% (i.e. €26,000 to €238,600), while travel times costs and costs at ports would increase at the same rate as in PO1. This, for example, results in an increase of total travel costs ranging from about €17,000 for a 21,000 TEU ship travelling from Shanghai to North Europe (Antwerp, Rotterdam, Hamburg) and performing an intermediate stop in Egypt (Port Said) to near €201,000 if the intermediate stop is performed in Turkey (Mersin). Similar considerations apply to dry bulk ships and liquid bulk ships, as illustrated in Annex 4, showing that the risk of re-routing to reduce the amount of traffic that falls in scope of the initiative is low.

[131] It is worth considering that container ships usually perform several stops along the route to load/unload cargo and therefore the whole journey from the origin port to the destination port would not fall under the scope of the initiative. Container ships might find convenience in relocating one of the stops to the closest non-EU/EEA port (rather than performing an additional stop). Such a case, however, would limit the leakage only to the final leg of the trip with limited impacts on the overall effectiveness of the initiative.

7. HOW DO THE OPTIONS COMPARE?

7.1 Effectiveness

The effectiveness of the options is examined against the policy objectives identified in Sections 4.1 and 4.2. However, as already indicated in Section 5.2.1, the three POs have been designed to address the key specific objectives *"by design"* and to mostly differ on their approach to technology developments (SO2).

As the type of intervention in all retained POs is of a regulatory nature, they are all expected to produce the same results with regards to SO1 (predictability of the regulatory environment). While it could be argued that a prescriptive approach (PO1) provides the highest possible degree of predictability, the design of the goal-based approaches presented (PO2 and PO3) are expected to perform equally well in this respect. This is due to the fact that the proposed regulation will clearly identify the performance level to be met as well as indicate how this performance will be measured. Given the long lifetime of vessels (and the fuel's distribution infrastructure), it is important that the framework sets a clear pathway and targets towards 2050 to provide a clear signal to allow the market to develop and mature.

SO3 (stimulation of production and price gap), SO4 (demand signal) and SO5 (carbon leakage) are equally addressed by all POs through the focus of the proposed intervention on demand-side requirements. This approach is designed to complement the already existing regulatory framework (in particular RED II and AFID). By boosting demand for certain quantities of RLF, all POs are expected to address the interdependency issue, which has been identified as an obstacle to the development of mature ecosystem for marine RLF.

Concerning the issue of price gap (SO3), all POs are expected to be equally effective in tackling it. In PO1, the regulator would give precise indications on the types of fuel to be used, which would minimise uncertainty for both demand and supply. This would result in a more rapid achievement of critical mass and quicker reduction of the price gap. However, PO1 is also the option that is more rigid and less easily adaptable to changing circumstances. Whenever technological advances or unexpected market developments require it, the regulator would need to modify the mandates and this would require time and difficult negotiations to account for past investments.

PO2 leaves total flexibility to the operators to decide on the most appropriate RLF options to meet the specified targets. It would therefore draw operators to the most cost-effective technologies for their individual situation, and those better reflecting their strategic planning. As this selection process matures, it is expected that the market will reduce the number of technologies further and reach on a longer term a more optimal result than in PO1. However, PO2 is also the scenario in which a greater convergence towards fewer technologies – those initially cheaper – is likely to develop and, therefore, its ability to reduce the price gap for some of the less mature technologies might be lower.

PO3 would combine the flexibility of the goal-based approach in PO2, with the advantages of the wider availability of technologies of PO1 that results from the incentive schemes, and would appear to be at least as effective as the other two options in reducing the price gap of RLF.

All POs will perform equally well in limiting the risk of carbon leakage (SO5). This is the result of the intervention's focus on the demand for fuels. Indeed, given the large autonomy of ships and the ability to bunker outside the EU, any regulatory approach based solely on EU supply can easily be circumvented in the maritime sector. In the same manner, possible remaining risks of carbon leakage (as presented in 6.3.2) will affect all POs equally.

Given the nature of the main market barrier addressed by the initiative, all POs will have a positive effect on the development of new RLF technology for the maritime sector (SO2). However, their effectiveness in doing so, and in particular in allowing the introduction of new technologies (hence reducing the risk of technology lock-in), differ. While the share of RLF in the overall maritime fuel mix is the highest in PO2, it mainly results from a larger uptake of bio-fuels compared to other technologies considered (notably e-fuels, hydrogen and ammonia). This is explained by the fact that economic actors will react to the goal-based target by preferring the cheapest and most technologically mature way of achieving the goal. As PO1 implies a technology choice, it allows to better steer the type of technologies used, and hence, if selected, also to accelerate the development of new solutions.

In the projections made in support of this initiative, PO1 is the one delivering the highest usage share of hydrogen-based fuels (e-fuels, hydrogen and ammonia) and electricity. This will however depend on the ability of the regulator to foresee and reflect the technology developments well into the future.

While in practice, PO3 is based on the same principles as PO2, it also includes a specific mechanism to reward overachievement, which not only provides flexibility to the economic actors, but also boosts the uptake of the most advanced technology, via a built-in multiplier for the use of zero-emission solutions. This is also reflected in the impacts of the POs on innovation (see 6.1.6). In summary, when it comes to technology development, PO1 and PO3 are performing better than PO2 as they are less prone to technology lock-in and are also stimulating the uptake of more advanced technology solutions (electricity or hydrogen-based fuels). In comparison to PO2, PO3 delivers ca. 5 percentage points more in fuel cell ships and 3 percentage points in electric ships. While the capacity of PO3 to foster technology development results directly from the design of the policy option itself (through the mechanism for overachievers), the capacity of PO1 depends on the agility of the regulator to reflect the technical progresses.

Table 19 summarises the analysis of impact of the three POs in terms of their effectiveness to address the SOs.

Table 22 Comparison of impact of policy options in terms of the specific objectives (relative to the baseline)

Specific objectives / compared to baseline	PO1	PO2	PO3
SO1: Enhance predictability through the setting of a clear regulatory environment concerning the use of alternative fuels in maritime transport	+++	+++	+++
SO2: Stimulate technology development	++	+	++
SO3: Stimulate production on a larger scale of RLF with sufficient high technology readiness level (TRLs) and reduce the price gap with current fuels and technologies	++	++	++
SO4: Create demand from ship operators to bunker alternative fuels with a sufficient high TRL or connect to the electric grid while at berth.	+++	+++	+++
SO5: Avoid carbon leakage	+++	+++	+++

7.2 Efficiency

The combined measures under the three POs have economic, social and environmental impacts. The net benefits for all three options is positive, with the highest net benefits shown by PO2 (€61.9bn) and PO3 (€55.0bn).

Table 23 Costs and benefits of the policy options relative to the baseline over the full scope of the policy intervention (2021-2050), expressed as present value

Costs and benefits - present value for 2021-2050 compared to Baseline (bil. €'2015)	**PO1**	**PO2**	**PO3**
Costs			
Capital costs	32.6	28.6	31.5
of which for OPS on vessels	2.5	2.6	2.5
of which for ports	5.7	5.7	5.7
Fuel costs	69.1	59.1	63.9
Operation costs	-2.4	-2.2	-2.3
Administrative costs of ship owners	0.4	0.4	0.4
Administrative costs for port authorities	0.0	0.0	0.0
Enforcement costs	0.1	0.1	0.1
Total costs	**99.8**	**86.0**	**93.6**
Benefits			
External costs savings of air pollution	10.3	9.4	10.0
External costs savings of GHG emissions	135.9	138.5	138.6
Total benefits	**146.2**	**147.9**	**148.6**
Net benefits	**46.4**	**61.9**	**55.0**

Source: PRIMES-TREMOVE, E3Modelling and Ecorys / CE Delft forthcoming

It is important to keep in mind that these calculations are made on the basis of current knowledge related to the possible evolution of technology costs and feedstock costs. As explained in section 6.1.2, the costs may turn out to be somewhat different if the evolution of the technology costs and feedstock costs proves to be different.

Benefits are very similar across the three POs as they have been designed to provide comparable emissions reductions over time, in line with the objectives of the CTP. As a result, the impact on capital costs and fuel costs are the most important cost elements where the three POs differ. As explained in Section 6.1.1, these differences result from the variation in the fuel mix among the three POs. PO2 remains the least expensive option as it does not contain any additional "constraint" for the operators than meeting the GHG intensity target. Operators are assumed to make a rationale decision and focus on the cheapest and most readily available options, i.e. biofuels. In both PO1 and PO3, the introduction of specific mandates for more advanced fuels (PO1) or the mechanism for overachievers (PO3) result in a more diverse fuel mix and a higher penetration of the electricity and hydrogen-based fuels, that are more expensive but potentially more performant technology solutions.

Because it relies on a technology choice by the regulator, PO1 would be the most sensitive to possible mistakes in identifying the potential of certain technologies. Having to respect the legal requirements on the fuel mix, market operators would not have the possibility to quickly adapt their fuel choices to economic and technological developments, but would have to wait for modifications in the regulatory framework to take into account any change in the optimal adjustment path.

On the contrary, PO2 leaves full freedom to operators to meet the goal with fuels and technologies of their choice. This is likely to translate in operators always opting for the least cost solution, but also, possibly, taking lower risk in experimenting with other technologies. This could make the fuel mix more prone to technology lock-in and vulnerable to price fluctuations, as the amount of fuel alternatives would be more limited than in the other scenarios.

PO3 would provide operators with an equal degree of flexibility as PO2, but would offer additional incentives to invest in more advanced solutions. As a result, a broader range of technologies is likely to be tested in PO3 – and potentially rolled out if successful – than in the other two options. For this reason, PO3 is expected to best meet the objectives of the proposed intervention.

In conclusion, PO3 would be the most robust policy option to unexpected developments and possible wrong predictions on the side of both maritime operators and the regulator. It would offer significant net benefits with respect to PO1 not only on the basis of current projections, but also in possible alternative scenarios. PO3 would also be better suited than PO2 in preparing the sector for different technological developments.

For this reason, PO3 appears at least as efficient as PO2 in meeting the objectives despite slightly lower net benefits quantified on the basis of current projections. These considerations are also well reflected in the stakeholders' views (see Section 7.5).

7.3 Coherence

In general, there are no specific issues regarding internal coherence, inconsistencies or gaps among the POs, which were designed to ensure that all drivers are addressed. This is ensured by the general policy approach described in Section 5.2.15.2.1.

All options are coherent with the key EU policy objectives, in particular the environmental objective of the Union to become a climate neutral economy by 2050 and other elements presented as part of the ‘Fit for 55’ package. The POs build upon the directions outlined in the EGD, as regards ramping-up the production and deployment of sustainable alternative transport fuels, accelerating the deployment of zero-and low-emission vehicles and vessels, and regulating access of the most polluting ships to EU ports as well as obliging docked ships to use shore-side electricity.

As explained in Section 1.5, the level of ambition proposed in this initiative is fully coherent with the common economic assessment underpinning the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy and is also consistent with the conclusions drawn in the 2050 Long Term Strategy (Clean Planet for All). The objective of the proposed intervention is based on the recognition of the major potential of RLF in decarbonising maritime transport and the need to significantly improve their penetration in the maritime fuel mix, for the sector to appropriately contribute to the EU climate objectives.

In this context, the proposed POs are designed as an integral part of the overall “basket of measures” to address maritime emissions (see Section 1.2). More precisely, the proposed intervention is expected to specifically address the technology barrier related to RLF uptake and, by doing so, make available a wider and cheaper range of abatement options. As a result, a cap-and-trade mechanism, such as the ETS, would be able to achieve its target – other things equal – at a lower price of carbon and lower cost for society. Conversely, carbon pricing would narrow the price gap between fossil fuels and RLF and support progress on alternative fuels technologies. Even though, in all analysed POs, the penetration rate of RLF is expected to become significant only after 2035 (reaching around 30% of the overall fuel mix in 2040), rapid policy intervention is necessary to address the long lead times related to RLF deployment and to reflect the long-lived nature of the vessels and, generally, the fuel infrastructure. As regards the coherence with other EU policies on RLF, all POs have been designed to complement the existing framework (in particular RED II concerning fuel supply and AFID concerning the deployment of the distribution infrastructure) and fill a specific gap concerning the lack of demand-side push on the uptake of marine RLF. Sustainability and eligibility criteria of RLF and the corresponding certification requirements will be based on the RED II provisions. While coherence and consistency with AFID is guaranteed with all POs, PO1 may facilitate the identification of the need to deploy new infrastructure for a given technology (as the number of technology options is limited and a technology choice is made ex-ante) through AFID. However, in all options, the highest share of RLF is expected to be compatible with existing infrastructure.

The proposed POs are also fully consistent with the EU MRV framework and have been designed to build as much as possible on the existing monitoring, reporting and verification requirements and systems in order to facilitate compliance by operators as well as compliance checks by the public authorities.

7.4 Proportionality and subsidiarity

None of the options goes beyond what is necessary to achieve the objectives. The proposed intervention ensures the minimum uptake of RLF in the maritime sector necessary for delivering the EU climate ambition. To do so, the initiative addresses the technology barriers currently hampering the deployment of RLF in the maritime sector, which is an essential component of the overall approach to shipping emissions. The proposed measures are designed to boost the uptake of RLF in the EU, which is unlikely to be realised by the sector without a specific regulatory push (as seen from the limited uptake and existing plans and also confirmed by answers in the OPC as referenced in Section 2.1). The POs are all expected to provide a stable and predictable regulatory framework, which would unlock and stimulate investments to develop the necessary fuel ecosystem (predictable level of demand, increase production and distribution of marine RLF, etc.).

The options are designed not to impose any disproportionate impacts on the shipping operators, notably by setting targets that imply a gradual introduction of RLF in the maritime fuel mix, which is increased over time (from around 3% in 2025 to more than 85% in 2050). This approach is expected to provide sufficient time for the market to adjust: for operators to plan the shift towards higher levels of RLFs and for the suppliers to ramp-up production and provide appropriate levels of RLF to meet upcoming demand. In this context, it is important to note that while the initiative will not require that the RLF are bunkered in the EU (for the reasons of carbon leakage explained above), the target levels have been set in such a way that they can be answered, if necessary, by sufficient level of such fuels produced in the EU. Also, concerning the particular case of emissions at berth, the specific requirements for the use of OPS (or equally performant alternative such as batteries) are foreseen to be phased-in with a sufficient lead-time and first mandated to only the most polluting ships in ports, i.e. containerships, passenger ships and ro-pax ships, to avoid imposing disproportionate impacts to the entire fleet and the ports.

The long time horizon included in each PO (up to 2050) is also an important element allowing proportionality for the sector. Given the long lead times related to RLF deployment as well as the long-lived nature of the concerned assets (vessels and infrastructure), this long time perspective is an important aspect of the proposed intervention. It is also critical to provide the highest degree of predictability to all market operators, and hence facilitate planning and investments.

In terms of technology developments, PO2 and PO3 are expected to provide more flexibility for operators to comply compared with PO1, as it allows them to make their own technology choice to meet the given standard. By introducing a mechanism on over-achievement, PO3 also provides a greater incentives for the best performers. Given the diversity of the maritime sector, an ex-ante technology choice as in PO1 may create suboptimal situations, in which the type of selected fuels are not the most economically or environmentally efficient choice for specific operators.

Overall, emissions reductions produced by each PO significantly outweigh the costs of the measure imposed on the sector. They also guarantee that the sector adequately contributes to the overall CO_2 emissions targets set for the entire European economy.

Given then international nature of maritime transport, the proposed intervention at EU level is also expected to deliver the highest benefits compared to regional or national requirements, which would trigger the development of technical solutions that may not necessarily be compatible among each other. EU action is also justified by the fact that the nature and scope of the identified problems is the same across all EU Member States. In the absence of specific provisions on RLF at global level (IMO), this initiative is also expected to provide substantial input to such debate, expected to start in the second half of 2021.

7.5 Stakeholder's views on the options

87% (118/136) of the OPC respondents finds it either relevant or very relevant to complement existing supply-side policy with demand-side policy to promote the uptake of RLF in maritime transport. Only 2 % (3/136) find it less relevant or not relevant at all.

Similarly to the feedback received on the inception impact assessment, respondents to the OPC voiced a clear preference for goal-based approach to regulate ships during navigation (53% (71/136))[132]. All stakeholder groups preferred a goal-based approach. However, during the interviews and the roundtable revealed diverging views on what this goal-based requirement should be. Stakeholders in ship owning and ship management and NGOs preferred a broader approach including also energy efficiency criteria, i.e. the amount of fuel or energy used per transport work irrespective of its GHG footprint. Most other stakeholder groups argued for a goal-based requirement of the fuel only.

For ships at berth, most stakeholder groups also prefer a goal-based approach. Even though the situation is more balanced with the prescriptive approach concerning the regulation of ships at berth, the goal-based approach is also the one which received the largest share of support (42% (57/136))[133]. However, academia, R&I stakeholders slightly prefer 'requirements on the share of sustainable alternative fuels'. Representatives of port management and administration as well as port terminal operators or other port service providers are indifferent between the two.

Another closely related requirement for the policy voiced by most stakeholders is technology neutrality. Multiple stakeholders, including NGOs and technology suppliers

[132] 15 % prefer a prescriptive approach for ships in navigation and 25 % choose 'other', 'no opinion' or 'no answer'.
[133] 23 % prefer a prescriptive approach for ships in navigation and 35 % choose 'other', 'no opinion' or 'no answer'.

explicitly indicated that prescriptive measures for a certain technology would be suboptimal, because of the high risk of technology lock-in and stranded assets.

On this aspect of the stakeholders' views vis-à-vis the overall policy approach, PO2 and PO3 would both be superior to PO1. The PO3 mechanism to reward overachievement addresses better the flexibility needs of the economic actors while boosting the uptake of the most advanced technology and, consequently reducing the risk of technology lock-in. Annex 2 provides further information on the stakeholder consultation.

7.6 Summary on the comparison of options

All POs are comparable in meeting the effectiveness criteria, even though PO2 is less suitable for tackling the need of technology development. Also while PO1 may be effective on this issue, it will require the regulatory framework to be sufficiently flexible to reflect technology development in the list of selected technology options. Concerning effectiveness, PO3 ranks first followed by PO1 and then PO2.

As regards efficiency, all POs are also producing very similar results. Both PO2 and PO3 are providing greater flexibility to the operators to choose technology to meet the given target. However, in the lack of any mechanism to incentivise the uptake of more advanced technology options, PO2 is expected to foster first the most cost-efficient options and hence deliver the best cost-benefit ratio. Indeed, as all POs have been designed to provide comparable emissions reductions over time, in line with the objectives of the CTP, the diversity of the fuel mix is what will influence most the overall cost of the initiative. As PO2 focusses mainly on the cheapest solutions (64.6% of the fuel mix is delivered by biofuels in liquid or gaseous form), it is the one delivering the best cost-benefit ratio. This is however done "at the expense" of a greater stimulation of most advanced technologies (SO2) and a more divers fuel mix. In terms of cost-benefit ration, PO2 is followed by PO3 and then PO1.

In terms of coherence, all options are perfectly coherent with the overall policy objectives of the Green Deal and with the other measures developed to address ship emission. The consistency with infrastructure policy (in particular AFID) may be facilitated by PO1 as it implies a clear technology choice, which allows to better plan the resulting infrastructure needs. However, PO2 and PO3 remain highly performant, considering that, as indicated in Section 6.1.1, around three quarters of the RLF expected to be deployed under these POs may not require specific infrastructure (bio- and e-fuels, bio- and e-gas can be considered as drop-in fuels in this respect).

The proportionality is also guaranteed in all POs. The prescriptive approach implied by PO1 may not be the most optimal, and turns to be also the most costly one. Both PO2 and PO3 provides the highest degree of flexibility for the sector to make the most appropriate choices to comply with the proposed targets and therefore perform similarly in terms of proportionality. The introduction of the mechanism for over-achievers in PO3 requires slightly higher administrative costs for the public authorities, but this is considered justified in terms of the incentives it provides on the uptake of most advanced technologies (hence addressing SO2). While the use of this mechanism may come with a limited additional burden for the operators, it remains a *voluntary* scheme and its use is likely to be subject on an individual assessment by the concerned operators.

Table 24 summarises the performance of the three POs on each assessment criteria compared to the baseline. It also provides an overview of the stakeholder preferences.

Table 24 Comparison of the policy options

Assessment criteria / compared to baseline	PO1	PO2	PO3
Effectiveness	+++	++	+++
Efficiency	++	+++	+++
Coherence	+++	++	++
Proportionality	++	+++	+++
Stakeholder preferences	+	++	+++

8. PREFERRED OPTION

Based on the combined analysis of cost-benefit ratio, acceptance by stakeholders and expected effectiveness and proportionality, the preferred option is therefore **policy option 3** (goal-based approach with reward mechanisms for overachievers).

This option strikes the best balance between the achieved objectives and the overall implementation costs. It provides net benefits amounting to €55.0bn over the 2021-2050 period (expressed as present value). Through the goal-based approach, this PO also answers the needs for flexibility, which have been stressed by stakeholders during the consultation activities (in particular operators and ports). An important aspect where PO3 is also superior compared to the two other approaches concerns the introduction of a mechanism for rewarding over-compliance through the use of the most advanced – zero-emission – technologies. In doing so, this PO also reduces the risk of technology lock-in and ensures several technology options can be used by operators as soon as they become mature and contribute to meeting the defined targets. This choice of this PO as the preferred one is thus determined by the need to create lead markets for zero-emission technologies, which will be necessary to deliver on the post-2030 climate objectives. This mechanism however implies additional administrative costs, which are considered justifiable compared to the benefits it provides, in particular in fulfilling the objective of stimulating technology developments.

As regards the type of legal instrument which would implement the preferred policy option, a Regulation appears to be the most appropriate choice.

Annex 3 contains a more detailed description of the regulatory measures envisaged, as well as an indication of how implementation could take place in practice, based on already existing practices set out in the EU MRV system as well as the applicable PSC procedures.

9. HOW WILL ACTUAL IMPACTS BE MONITORED AND EVALUATED?

The Commission will follow the progress, the impacts and results of this initiative through a set of regular monitoring tools as well as dedicated evaluations.

Indication on the RLF penetration in the maritime fuel mix will be the main criterion to evaluate the impacts of the proposed initiative. The evaluation arrangements of the impacts of this initiative, as well as the identification of the operational objectives and monitoring plan have been developed for the preferred option, PO3. A set of operational objectives were derived from the general and specific objectives of the initiative, which reflect the nature and type of measures adopted. The monitoring should start immediately after the entry into force of the Regulation.

One of the most important elements of the monitoring framework will be the data collected through the EU MRV that ships calling EU ports need to fulfil, in which they indicate the quantities and types of fuel consumed during the journeys covered by the Regulation. This will allow to have an annual indication of the penetration rate of RLF in the maritime transport fuel mix, which is one of the main indicators of progress. In this respect, it is worth noting that the MRV requirements also concern ships at berth. As a result, data collected through the EU MRV will allow providing an accurate picture of the use of RLF in the maritime sector not only while in navigation (addressing problem 1) but also at berth (problem 2). In addition, data on alternative fuel infrastructure collected under the framework of the AFID would also allow to identify what impacts this initiative will have on the deployment of port infrastructure, in particular on-shore power connection points.

In this context, additional information will be collected on the use of electricity on the ship side and the first review of the Regulation will also include assessment on possible extension of the requirements at berth to additional ship types.

The Commission will also initiate an evaluation to verify whether the objectives of the initiative have been reached, based on the data collected through EU MRV, the evolution of the distribution infrastructure as well as a series of targeted surveys. This should also provide an indication on the impact of the initiative on production levels of marine RLF as well as the cost evolution of these fuels. Interactions with other policies aimed at decarbonisation of the maritime sector will also form an important element of such an assessment to ensure continued consistency and complementarity between initiatives. If necessary, the evaluation will inform future decision-making processes to ensure necessary adjustments for reaching the set objectives, while also taking into account developments of other policy initiatives.

The list of operational objectives, indicators and data sources is presented in Annex 7 (Table 70). Some of these monitoring arrangements will be established more in detail only after thorough discussion with Member States and key stakeholders.

Annex 1: Procedural information

1. LEAD DG, DECIDE PLANNING/CWP REFERENCES

The lead DG is Directorate General for Mobility and Transport (MOVE), Unit D1: Maritime Transport and Logistics

DECIDE reference number: PLAN/2020/6945

The development of this initiative was announced under item 8 in Annex I to the Adjusted Commission Work Programme 2020[134]. The Inception Impact Assessment was published on 27 March 2020[135].

2. ORGANISATION AND TIMING

The Inter Service Steering Group (ISSG) for the Impact Assessment was set up in February 2020 and includes the following DGs and Services: SG, LS, CLIMA, ENV, ENER, RTD, GROW, MARE, COMP, TAXUD as well as EMSA (European Maritime Safety Agency).

The ISSG approved the Inception Impact Assessment and discussed the main milestones in the process, in particular the consultation strategy and main stakeholder consultation activities, the task specifications to launch the contract for the external IA support study, the key deliverables from the support study, and the draft impact assessment report before submission to the Regulatory Scrutiny Board. In total, 5 meetings of the ISSG were organised to discuss this impact assessment, including virtual meetings, resulting from the COVID-19 crisis. These meetings took place on 24 February 2020, 30 April 2020, 1 July 2020, 1 October 2020 and 14 December 2020. Further consultations with the ISSG were carried out by e-mails. When necessary bilateral discussions were also organised with the most concerned services.

3. CONSULTATION OF THE RSB

The Regulatory Scrutiny Board received the draft version of the impact assessment report on 18 December 2020. The Board meeting took place on 20 January 2021, following which it gave a negative opinion on the report. The Board also made several recommendations which were addressed in the revised impact assessment report as follows:

Table 25 Modification of the IA report in response to RSB recommendations

RSB recommendations	Modification of the IA report

[134] https://ec.europa.eu/info/sites/info/files/cwp-2020-adjusted-annexes_en.pdf
[135] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12312-FuelEU-Maritime-

Main considerations	
(1) The report is unclear about how it has established the fuel specific targets and pathways for the maritime sector, and what the key assumptions and uncertainties are. It does not show how, and under what conditions, they are compatible with the overall EU 2030/2050 climate targets. The report does not analyse the implications and feasibility of alternative targets and pathways.	A new Section 1.5 has been added to the report, to explain the trajectory for the RLF uptake. It also explains the compatibility with the overall EU 2030/2050 climate targets. In addition, Section 5.4 includes a qualitative assessment of the implications and feasibility of alternative trajectories for RLF uptake.
(2) The report is not sufficiently clear on how it ensures coherence with the other 'Fit for 55' initiatives. It does not explain how it takes into account the uncertainty on the future content of the most directly related climate initiatives.	A new Section 1.2 has been added based on elements provided in the previous Annex 7 (deleted now to avoid duplication). The new Section 1.5 also adds clearer explanation on the trajectories for RLF as assessed in the context of the analytical work underpinning the Climate Target Plan and the Smart and Sustainable Mobility Strategy. This, in conjunction with Section 5.3, explains how the different elements of the "basket of measures" for maritime transport are complementing to each other.
(3) The report does not explain convincingly why the present initiative cannot be integrated into existing instruments that are part of the 'Fit for 55' package.	As per consideration (2) above
(4) The report is not always clear on the content of the options and how they will function. It does not sufficiently explain the functioning of the reward mechanisms for overachievers and its possible interaction with the Emission Trading System. The report does not show clearly why it prefers the option with the reward mechanisms for overachievers.	Details have been added in Section 5.2.2 on the description of each of the policy options including elements related to certification. Concerning the scheme for over-achievers, additional elements have been introduced in the detailed description of PO3. Details on reporting and enforcement have been added to Section 5.2.3, which outlines aspects of policy design that all options have in common. While some elements from Annex 6 have been brought to the main text in chapter 5 to facilitate the reading and understand the design of the policy options, the long list of policy measures identified in the early stages of the analysis has been kept to the Annex in order to still limit the size of the document. Concerning the choice of the preferred policy option, clarifications have been brought to chapter 7 (in particular Sections 7.1, 7.2 and 7.6).
Adjustment requirements	

(1) The report should explain how the fuel-specific targets (or parameters) for maritime transport were chosen. It should make clear how the proposed pathways towards these targets align with the GHG reduction targets of the Climate Law, and how they follow or differ from the Climate Target Plan modelling scenarios. The report should explain the assumptions behind the maritime fuel targets, and under what conditions they are compatible with targets for the other transport sectors.	The new Section 1.5 adds explanations on the trajectories for RLF as assessed in the context of the analytical work underpinning the Climate Target Plan and the Smart and Sustainable Mobility Strategy and consequently how the fuel-specific targets for this initiative have been established. Specific indication have consequently be added in the description of the policy options under Section 5.2.2.
(2) The report should justify why it does not include any alternative maritime fuel targets and pathways. Do the costs of alternative pathways disqualify them as unfeasible? It should present at least a qualitative check on the feasibility and implications of deviating from the set target, including for the overall 'Fit for 55' package.	The new Section 1.5 adds explanation on the trajectories for RLF as assessed in the context of the analytical work underpinning the Climate Target Plan and the Smart and Sustainable Mobility Strategy. A new Section 5.4 has also been added to discuss the feasibility of alternative pathways for marine RLF uptake.
(3) The report should better explain how the initiative is coherent with the most directly related other 'Fit for 55' initiatives (in particular the Renewable Energy Directive, the Emissions Trading System (ETS) and the Energy Taxation Directive). Would this initiative make some of the others superfluous for the maritime sector? As the baseline does not include the envisaged changes of the other 'Fit for 55' initiatives, the report should explain why it does not include alternative policy scenarios in the options, to reflect the uncertainty on the future content of these other initiatives.	A new Section 1.2 has been added based on elements provided in the previous Annex 7 (deleted now to avoid duplication). The new Section 1.5 also adds clearer explanation on the trajectories for RLF as assessed in the context of the analytical work underpinning the Climate Target Plan and the Smart and Sustainable Mobility Strategy. This, in conjunction with Section 5.3, explains how the different elements of the "basket of measures" for maritime transport are complementing to each other. Section 5.1 (What is the baseline from which options are assessed?) clarifies that the other 'Fit for 55' initiatives are not part of the baseline. It further explains how coherence is ensured.
(4) The report should explain why this initiative cannot be (partly) covered by the other 'Fit for 55' initiatives. For example, could the voluntary transfer of balances and a possible reward scheme for overachievers not be integrated in the ETS?	A new Section 1.2 has been added based on elements provided in the previous Annex 7 (deleted now to avoid duplication). The new Section 1.5 also adds clearer explanation on the trajectories for RLF as assessed in the context of the analytical work underpinning the Climate Target Plan and the Smart and Sustainable Mobility Strategy. In addition, elements from the former Annex 6 have been moved to the main text and extended under Section 5.3 to explain how other measures included in the 'Fit for 55' package would not sufficiently address the objectives of this initiative. Concerning the voluntary transfer of balances, more information has been included in the description of PO3 in

	Section 5.2.2.
(5) The report should clarify the connection between the problems concerning greenhouse gases and local air pollution. It should properly reflect the latter throughout the intervention logic (i.e. also in the options and impact analysis).	Clarifications have been added in Section 2.1 and further in chapter 5. In both cases, the problem definition focuses on the *uptake of specific fuels*. However, the introduction of a specific problem at berth recognises the fact that, when ships are in ports, effects on air quality impose an additional constraint on the techncial solution to be chosen, being cognisant to the fact that not all RLF will have equal performance in terms of reduction of air pollutants.
(6) The report should provide more detail on how far scaling up of RLF demand will contribute to reducing costs and prices. It should provide more detail about the sources of greater feedstock supply and competing demands. It should explain better the cost differences between standard and advanced biofuels. The report should also acknowledge the high-energy demand for producing biofuels. The impact assessment should be explicit about how coherence will be ensured with the EU's overall renewable energy policy (e.g. for competition for feedstock, or accounting of total renewable targets), and how the risk for overlapping regulation is avoided.	A new Section 6.1.2 has been added to provide an overview of the impact on RLF prices, feedstocks and renewable electricity needs for e-fuels. This provide greater details in particular on the sources of feedstocks that have been assumed in this analysis. It also discusses the energy needs for producing biofuels. Concerning coherence with the overall renewable energy policy, these points are also covered by Sections 1.5 and 5.4. In addition to this, clarification on the risk of overlaps is provided in Sections 1.2 and 5.3, which describe also how the different elements of the "basket of measures" (and hence other initiatives of the "Fit for 55" package) are complementing each other.
(7) The report should further specify the content of the options and how they would function. In particular, it should specify the target values and technology shares, and explain better certification, reporting and enforcement under the different options. It should also specify how the scheme for overachievers would function. It should explain how the proposed options are cost-effective.	Details have been added in Section 5.2.2 on the description of each of the policy options including elements related to certification. Concerning the scheme for over-achievers, additional elements have been introduced in the detailed description of PO3. Details on reporting and enforcement have been added to Section 5.2.3, which outlines aspects of policy design that all options have in common. While some elements from Annex 6 have been brought to the main text in chapter 5 to facilitate the reading and understand the design of the policy options, the long list of policy measures identified in the early stages of the analysis has been kept to the Annex in order to still limit the size of the document.
(8) The report should elaborate the assessment and comparison of options. It should justify better why the option with the reward mechanisms for overachievers is the preferred option, given that the net benefits of the option without these mechanisms are estimated to be higher. It should explain why the preferred option does not lead to a higher GHG emission	As presented in Section 6.3.2, the preferred option, PO3 is actually the one delivering the highest degree of GHG emissions reductions from maritime transport on a well-to-wake basis. Further clarifications have been added so Sections 7.1, 7.2 and 7.6, in particular on the effectiveness of the three assessed policy options in tackling the specific objectives of this initiative. It also clarifies that the main difference in terms of costs between the options result from the fuel costs associated with the different energy mix delivered. While PO2 remains the least expensive option as

reduction than the option without rewards for overachievers.	it does not contain any additional "constraint" for the operators than meeting the GHG intensity target (hence allowing them to select the cheapest compliance option), it does not address the SO2 (technology development) as good the other options.
(9) The impact assessment should discuss the importance of the sectors and activities that are excluded from the scope of the options. It should analyse the effect of these exemptions on the realisation of the targets.	Further clarifications have been added in Section 5.2.3 to explain why it is proposed to replicate the MRV approach in terms of types and size of ships covered by the initiative. This approach strikes a balance between environmental effectiveness and the administrative burden. Broadening the scope to ships above 400 GT (which is the minimum size applicable in international conventions) would bring minimal benefits in terms of emission reductions but would significantly increase the number of regulated entities. The approach currently proposed allows to address the highest emitters in terms of GHG and air pollutants while limiting the number of regulated ships.

The Board issued a second, positive opinion on 3 March 2021, including some further recommendations. These have been addressed in **this final version of the Impact Assessment report** as detailed in the table below.

Table 26 Modification of the IA report in response to RSB recommendations

RSB recommendations	Modification of the IA report
Main considerations	
(1) The report does not sufficiently stress the importance of getting maritime renewable fuel technologies ready in time to reach the post-2030 climate target.	An explicit reference to the need for increase uptake of RLF in order to reach the post-2030 climate targets has been added in section 2.3. Furthermore, section 5.3.1 explains the need for the legislative instrument to establish the necessary conditions for lead markets to start emerging as rapidly as possible and to support the deployment of new fuel technologies to deliver on the post-2030 climate objectives
(2) The report is not clear enough about the uncertainties underlying the impact assessment.	An explicit reference to uncertainties has been added in the introduction of section 6 that points out to the methodology described in Annex 4. Additional paragraphs highlighting the uncertainties have been added in sections 6.1.2 and 7.2.
Adjustment requirements	
(1) The report should briefly explain why the transport sector should reduce its CO_2 emissions only by 90% by 2050. It should similarly clarify how this margin has been distributed across the transport sectors.	Details have been added in Section 1.5.2.2 on the implications of meeting th European Green Deal objectives for the transport sector in general and for the maritime transport in particular.

(2) The report discusses the relation between the demand-side measures in the maritime sector and the cost-efficient emissions trading system, and compares the cost-efficiency and cost-effectiveness of the options. However, the report and executive summary should highlight more prominently that the choice for the preferred option is determined by the need to create lead markets for new fuel technologies to deliver on the post-2030 climate objectives. It should better explain how the monitoring and evaluation arrangements will help ensure complementarity between the various policy initiatives over time.	A specific reference has been added to section 5.3.1 on the need for the legislative instrument to establish the necessary conditions for lead markets to start emerging as rapidly as possible and to support the deployment of new fuel technologies to deliver on the post-2030 climate objectives.
(3) The report should be more transparent about uncertainities underlying the analysis. In particular, it should discuss uncertainties in the costs of renewable fuels and the demand by other sectors, and their possible effects on the greening and competitiveness of the maritime sector. It could also be more nuanced on the expected effects of the preferred option's scheme for over-achievers on stimulating new technologies, by better aligning the text with the presented scenario outcomes.	An explicit reference to uncertainties has been added in the introduction of section 6 that points out to the methodology described in Annex 4. Additional paragraphs highlighting the uncertainties have been added in sections 6.1.2 and 7.2. Concerning the expected impact of the preferred option (mechanism to reward over-achievers) on stimulating new technologies, figures have been added to section 7.1.
(4) The report should better justify why it excludes smaller ships and certain categories of ships (e.g. fishing vessels) from the scope of the intiative, as this would significantly limit the reduction of particulate matter emissions. The report should also consider to what extent exempted ships could be affected by the supply measures of the (to be revised) Renewable Energy Directive, as their smaller size limits their bunkering capacity.	Further clarifications have been added in Section 5.2.3 on the size of ships considered under the initiative and possible links with specific measures on supply.

4. EVIDENCE, SOURCES AND QUALITY

The impact assessment is based on research/analyses done by the Commission with support of EMSA. The Commission also contracted an external, independent consultant (Ecorys and CE Delft) to support this impact assessment. The external support study will be published alongside this report.

Qualitative and quantitative data supporting this impact assessment has been collected from Member States, shipping owners and operators, ports, fuel and technology producers, academia and non-governmental organisations.

Modelling of the policy options in a consistent way with the scenarios prepared in support of the Climate Target Plan has been performed by E3Modelling with the PRIMES model, including its PRIMES-TREMOVE and PRIMES-Maritime modules. Specific analysis on the risk of carbon leakage in the introduction of extra-EU journeys in the scope of the policy options has been carried out by TRT with the TRUST model.

This report also draws on the activities of two Commission's expert groups, namely the European Ports Forum[136] (EPF) and the European Sustainable Shipping Forum[137] (ESSF), in particular its sub-group on Sustainable Alternative Power for Shipping.

[136] https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=3542
[137] https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=2869

Annex 2: Stakeholder consultation

1. INTRODUCTION

This annex provides a summary of the outcome of the consultation activities, which have been carried out for the FuelEU Maritime initiative (including in the context of the external support study). It provides a basic analysis of the range of stakeholder groups that were engaged in those activities and a summary of the main issues that they raised.

The objectives of the consultation activities were to:

- Collect stakeholder views on draft policy measures and policy options (POs) discussed in this impact assessment;
- Gather evidence on expected costs and benefits of draft policy measures; and
- Help in identifying gaps in the intervention logic or areas requiring further attention.

The main consultation activities included:

- An open public consultation (OPC), organised by the Commission, running from 2 July 2020 to 10 September 2020;
- A targeted stakeholders consultation (TC) organised by the consultant responsible for the impact assessment support study, running from 18 August 2020 to 18 September 2020 and directed at experts from the European Sustainable Shipping Forum (ESSF). The consultant also conducted a series of interviews with stakeholders, including industry representatives and national authorities, between 10 July 2020 and 1 December 2020;
- A stakeholders roundtable, organised by the Commission on 18 September 2020 with members of European Sustainable Shipping Forum[138] (ESSF) and the European Ports Forum[139] (EPF);
- Regular expert group meetings.

The information collected from stakeholders was key in allowing the Commission to refine the design of the POs as well as to assess their economic, social and environmental impacts, compare them and determine which PO is likely to maximize the benefits/costs ratio for the society.

[138] https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=2869

[139] https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=3542

2. Feedback on the Inception Impact Assessment

The Commission received 81 replies to the Inception Impact Assessment (IIA)[140] during the public feedback period (27 March - 24 April 2020).

Most of the feedback was submitted by companies and business associations (54/81), including beyond the "traditional" maritime stakeholders and also covering expertise on fuel supply and distribution. NGOs, academia and citizens also responded directly to the IIA publication. Several public authorities provided feedback to the IIA (DE, SP, SE, City of Stockholm).

In general, the initiative as presented in the inception impact assessment received positive reactions. Some representatives of the sector stressed the importance to pursuing activities at global (IMO) level as well as the need to develop a series of support measures (including financial support) for boosting the uptake of alternative fuels in maritime transport. There was no clear preference emerging concerning the fuels and technologies that would ultimately provide the best pathway to reduce emissions. Concerning the regulatory approach, the majority of respondents was in favour of goal-based measures over prescriptive measures.

3. Methodology

Expert Group Meetings

As part of its consultation strategy, the Commission held several expert group meetings to gather specialised input. On these occasions, the Commission presented the FuelEU Maritime initiative and gathered stakeholders' opinions on the proposal and the POs.

On 2 March 2020, the Commission consulted a targeted group of stakeholders in the sub-group Sustainable Alternative Power for Shipping (SAPS) in the context of the ESSF. The meeting was attended by approximately 60 participants. On this occasion, several stakeholders such as individual independent experts, associations, third country authorities and Member States representatives participated (BE, DE, DK, ES, FI, FR, HR, IE, LT, NL, PT and SE). They welcomed the initiative and many participants confirmed their availability to support the work by sharing their knowledge.

On 4 March 2020, the Commission consulted the EPF Plenary. The meeting gathered ports associations and representatives from Member States (BE, DK, EL, ES, FR, LV, MT, IE, PL and RO). The 38 participants stressed that clarity and certainty about the fuels of the future is crucial for first movers and investors. The importance of port call optimization

[140] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12312-FuelEU-Maritime/feedback?p_id=7658088

was also mentioned as important, which, besides the maritime sector, requires cooperation between all port stakeholders.

On 17 June 2020, another ESSF SAPS sub-group meeting was held with individual independent experts, associations, third country authorities and Member States representatives (BE, DE, DK, ES, FI, FR, HR, IE, LT, NL, PT and SE) making up approximately 80 participants. The meeting focused on discussions on the feedback from the IIA. The participants noted suggestions concerning predictability for first movers and investors, mandatory requirements with regards to the availability of OPS for the ports, highlighted that requirements should target different ship types and ship sizes, and expressed preferences for a goal-based approach where port incentive schemes decided by port managing bodies would be one way to support it.

On 18 September 2020, a joint ESSF and the EPF Roundtable took place with approximately 150 participants. The ESSF plenary, the ESSF SAPS sub-group, the EPF plenary and the EPF sub-group Sustainable Ports were invited. Present on this occasion were associations representing ports, ship owners and operators, equipment manufacturers, bunker suppliers, industry, trade unions, third country authorities, individual independent experts and Member States representatives (CY, FR, IE, IT, PL, PT and SE). Following information-sharing about the initiative and the preliminary outcome of the impact assessment, the Roundtable meeting was split into two panel sessions, covering both the role of FuelEU Maritime in the sector's decarbonisation strategy, and how to ramp-up sustainable alternative fuels through FuelEU Maritime. The participants stressed the importance of a stable regulatory framework with sufficient flexibility for a sector where there was no "one size fits all" and the need to act rapidly on a measure stimulating demand.

On 4 December 2020, the ESSF Plenary was informed about progress on the development of the FuelEU Maritime initiative. On 8 December 2020, the final ESSF SAPS sub-group meeting of the year was held with approximately 80 participants. In a poll about the updated policy options in which half the participants responded, the new PO 3 came out as the preferred approach with 53 % in favour (while 8 % expressed support for a prescriptive approach (PO1), 23 % for a goal-based approach (PO2)).

Open Public Consultation

The OPC was launched on 2 July 2020 and closed on 10 September 2020. Given the importance of the measure including in the recovery from the crisis, the OPC has been open for a period of 10 weeks instead of the standard 12 weeks.

The aim of the OPC was to gather views on the main elements of the impact assessment; problem definition and respective drivers, the issue of subsidiarity, the added value of an EU level intervention, and preliminary policy options and policy measures.

A total of 136 responses[141] were received, covering a variety of stakeholder groups. The responses came from ship owning and ship management (40), energy producers and fuel supply (37), short sea shipping (25), national public authorities (15), interest organizations (14), ports management and administrators (13), port terminal operator or other port services provider (13), academia research and innovation (12), inland waterways sector (11), shipbuilding and marine equipment manufacturers (10), regional or local public authorities (9), logistics suppliers, shippers and cargo owners (9), technical standardization bodies and class societies (2), investment and financing (2), and other (17).[142]

Responses were received from respondents residing or based in 14 EU Member States (BE, CY, DE, DK, EE, EL, ES, FI, FR, IT, NL, PL, SE and UK), as well as from Norway, Turkey and United States. Most responses were received by stakeholders in BE (30), followed by DE (15), NL (13), and IT (11).

Targeted Consultation

A targeted consultation (TC) survey was distributed to four Commission expert groups[143], and 32 responses were received.

The responses came from ports management and administrators (7), ship owning and ship management (7), shipbuilding and marine equipment manufacturers (6), and interest organisations (5), technical standardization bodies and class societies (3), port terminal operator or other port services provider (3), energy producers and fuel supply. (2), academia research and innovation (2), short sea shipping (2), regional or local public authorities (2), national public authorities (2) and other (3). No respondents represented logistics suppliers, shippers and cargo owners, investment and financing or the inland waterways sector.[144]

Stakeholder Interviews

A total of 18 interviews were conducted in the framework of the impact assessment support study, covering a wide range of stakeholder categories, namely equipment providers (2), fuel suppliers (3), shipping companies (3), port (4), Member State (1 - NL), shipper and cargo owner (3), port state control authority (1), and trade union (1).

[141] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12312-FuelEU-Maritime-/public-consultation

[142] Participants were asked to indicate which interests they represented. They could select one or more options as appropriate, so the results add up to more than the 136 total replies to the OPC.

[143] The groups were the two ESSF sub-groups on Sustainable Alternative Power for Shipping and Ship Energy Efficiency, as well as the European Ports Forum and the ART Fuels forum.

[144] Participants were asked to indicate which interests they represented. They could select one or more options as appropriate, so the results add up to more than 32 total replies to the TC.

4. ANALYSIS OF RESULTS OF THE STAKEHOLDER CONSULTATION

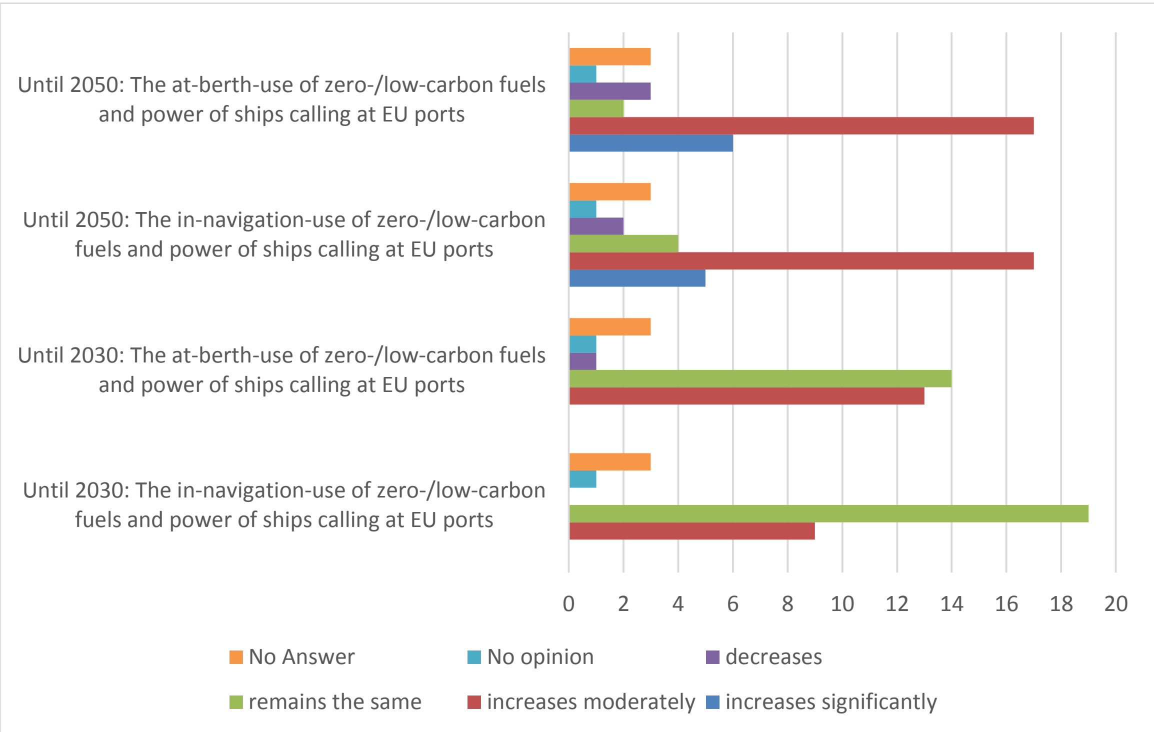
The remainder of the report presents the main findings from the analysis of stakeholder contributions to the consultation process. They are presented in the following sections and structured around the main elements of the intervention logic (problems, drivers, objectives) as well as the key aspects of policy design.

Problems

80% of the OPC respondents confirmed that it is 'very relevant' to promote the uptake of sustainable alternative fuels and diversify the fuel mix of maritime transport to accelerate the decarbonisation of shipping[145]. In addition, a majority of the OPC respondents also support a policy framework for ships at berth: 37% indicated that this is 'very relevant' and 30% indicated 'relevant'. This conclusion is supported by the TC results: 34% of the TC respondents indicated that a policy for ships at berth is 'very important', and 47% indicated that this policy scope is 'important'.

The results from the TC also confirmed that without policy intervention, the expected levels of RLF use in maritime transport will only increase moderately, if at all, by 2030 and 2050.

Figure 7 Projections for the uptake of low-carbon fuels (TC) without policy intervention.



[145] 15 % answered "relevant", 2 % "somewhat relevant", and 3 % did not provide an answer to this question.

When adding the qualitative results from the stakeholder interviews, position papers submitted alongside the replies to the OPC, and the joint ESSF and EPF Roundtable discussions, the conclusion is that there is consensus among all stakeholder groups on the problems as identified by the initiative. They also support the underlying objective of the FuelEU Maritime initiative to promote the uptake of RLF in the maritime fuel mix.

In addition, the OPC responses indicate consensus about going beyond addressing only CO_2 emissions from fuels used in navigation and at berth. In the OPC, only 16 out of the 136 participants considered that the approach should be based on CO_2 only. 35 respondents considered that other GHG should be addressed (in particular methane and nitrous oxides) and 74 respondents favoured an approach covering GHG emissions at large as well as air pollution. In the qualitative responses on how to weigh the relative advantages and assess possible trade-offs of fuels between GHG and air pollutants, no real consensus emerged. Some participants pointed out to the fact that certain air pollutants are to be regulated beyond a fuel-specific initiative, others that a focus on GHG is still most relevant for achieving the climate goals or that the balance between air pollution and climate change needs to be kept. A few participants pointed out to needs to undertake a valuation exercise of the external costs of different emissions.

Problem drivers

The TC results confirmed that all five drivers identified in the framework of the initiative are regarded as relevant. The most relevant barrier to tackle is considered to be ‘higher costs of alternative fuels compared to fossil fuels’. The least relevant of the five barriers is ‘the risk of bunkering outside of the EU’.

The OPC results imply that none of the mentioned barriers are regarded irrelevant (the lowest average score of the options is 2.9/5). The barriers that received the highest sore are ‘higher price of sustainable alternative fuels’ and ‘high risk of investment in vessels technology and port infrastructure’. The lowest scoring measure is the ‘lack of communication between actors and lack of transparency on the environmental performance, including of the fuel performance’.

The barriers which were mentioned most often during the stakeholder interviews, the joint ESSF and EPF Roundtable meeting and in positions papers 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’. Another issue which was pointed out in multiple position papers and interviews was the ‘lack of predictability and high risk for investors’.

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.

Figure 8 OPC feedback on the importance of the different barriers preventing the uptake of RLF

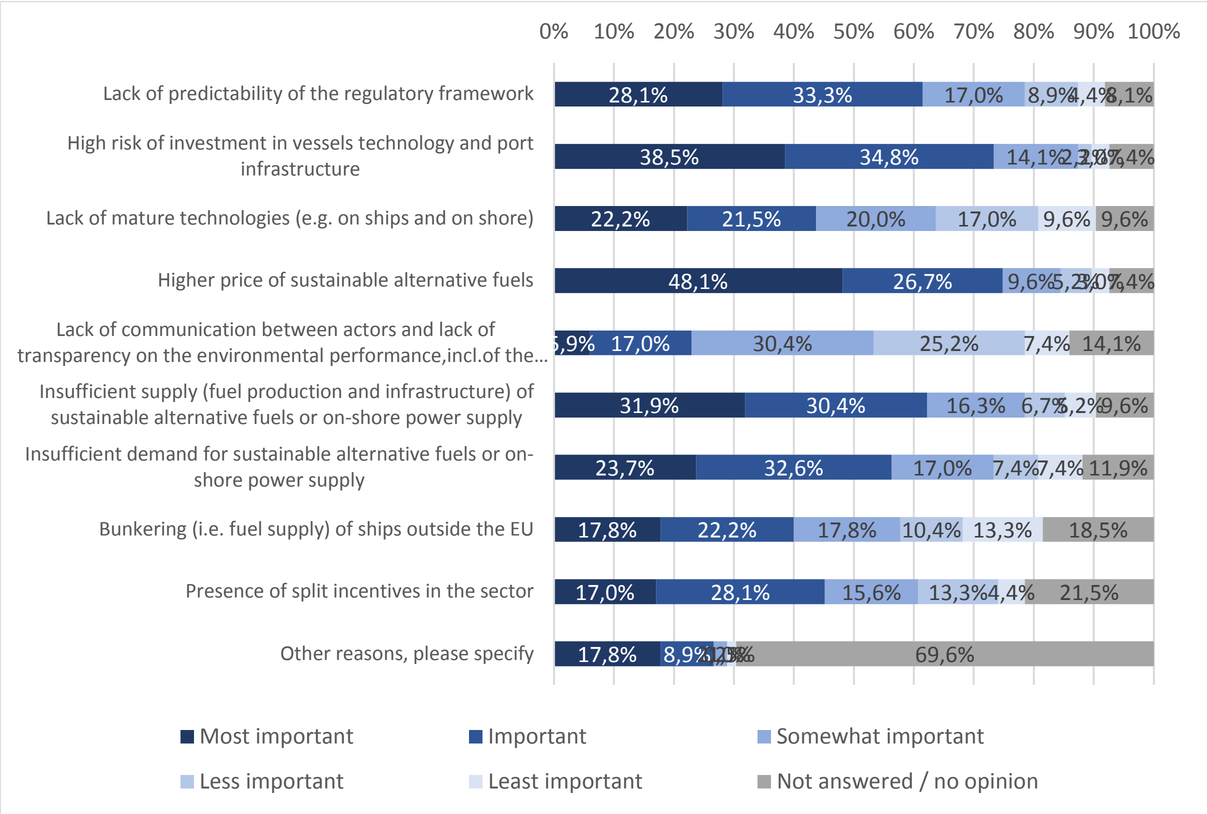


Table 27 Comparison of the scores on relevance of barriers per stakeholder group (OPC)[146]

	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	Insuficient 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

[146] Participants were able to indicate one or more interests appropriate. One participant may belong to more than one stakeholder group and thus, the number of total contributions does not add up to 136 (the total number of OPC contributions).

Even though there is some agreement, the quantitative results show that there are points on which the stakeholder groups disagree. The 'lack of mature technology' is generally regarded as an important barrier by national public authorities, ship owners and management and short sea shipping, while the same barrier is considered relatively unimportant by the inland waterways sector, shipbuilding and marine equipment manufacturers, energy producers and fuel suppliers and interest organisations.

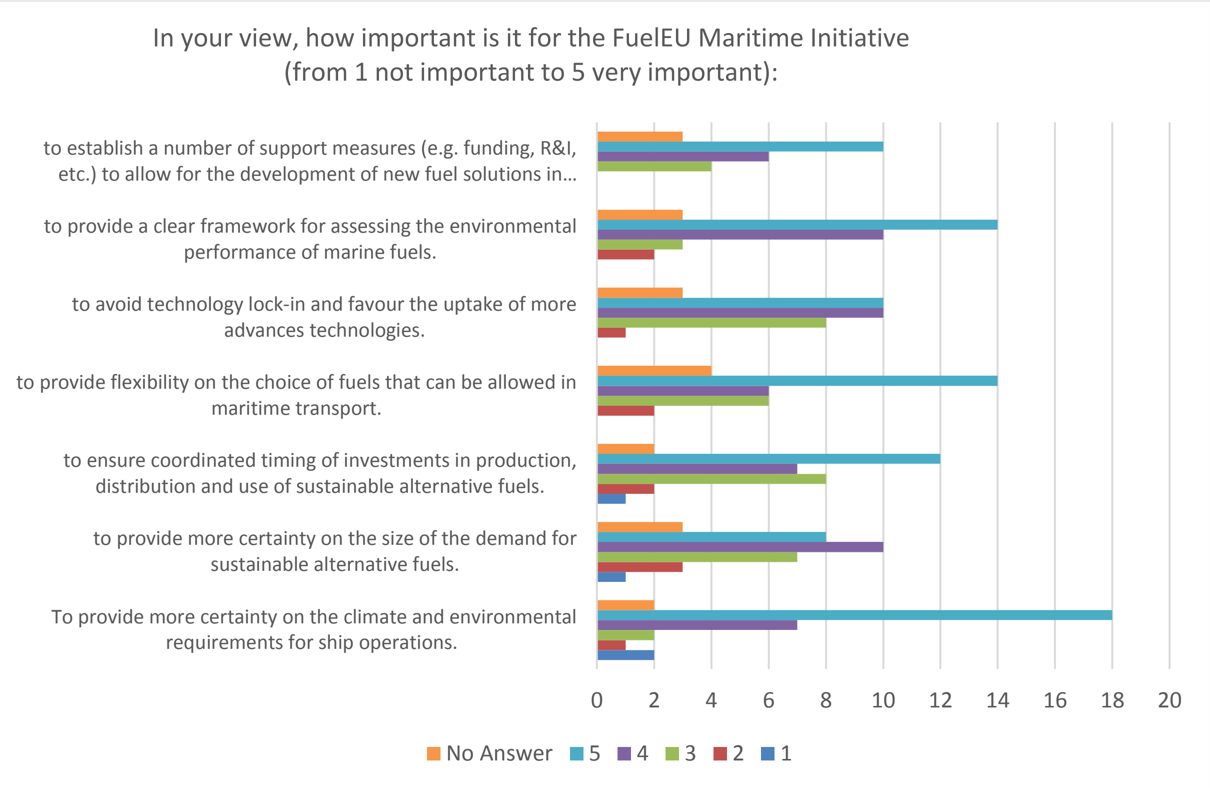
Another barrier that receive divergent rating is the 'insufficient demand of sustainable alternative fuels or OPS'. For this category, inland shipping and port management and administration give this barrier the highest score, whereas short sea shipping, interest organizations and academia, research and innovation give the same barrier a relatively low score.

When comparing the barriers that should be addressed with priority by the EU according to different stakeholder groups, 'higher fuel prices', 'high risk of investment' and 'lack of predictability for the regulatory framework', are rated highly by most stakeholders.

Policy objectives

In the targeted questionnaire, respondents were asked about the importance of a list of policy objectives.

Figure 9 Importance of the FuelEU Maritime Initiative (TC).



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' being the most important policy objective.

Goal-based approach or prescriptive policy

In the public consultation, participants were consulted on their preference for either setting requirements on the share of specific sustainable alternative fuels to be used in ship's fuel mix while at berth (including use of onshore power) i.e. a prescriptive approach or setting performance requirements based on the carbon-intensity of energy used in marine operations i.e. a goal-based approach.

For ships in navigation, 52 % of respondents preferred a goal-based approach, while 15 % preferred a prescriptive approach. 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.

For ships at berth, the preference for a prescriptive approach was slightly bigger than for ships in navigation with support from 23 % of the participants, while 42 % indicated a preference for a goal-based approach.

The results from the qualitative consultations show that all stakeholder groups 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. Multiple stakeholders explicitly indicated that prescriptive measures for a certain technology would be suboptimal, because of the high risk of technology lock in and stranded assets. However, there is less consensus about the form which such a goal-based approach should take.

On the one hand, there are proponents of the inclusion of carbon pricing, 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 decarbonisation can be done where this is most efficient. This suggests either a system in which carbon permits can be traded, or a fleet based approach.

Potential policy measures

According to the OPC results, all of the policy measures envisaged are regarded to be of importance at least to some extent. Of the participants who rated the options, the policy measures receiving the highest scores (i.e. scores above 4.00/5) were:

- Set a clear regulatory pathway for decarbonising the current marine fuel mix (average score: 4.29/5, 123 responses)
- Accelerate research and innovation enabling the use of sustainable alternative fuels and power (average score: 4.21/5, 123 responses)
- Establish economic incentives to reduce the price differential between conventional and sustainable fuels (average score: 4.18/5, 125 responses)
- Increase public funding and financial support to overcome the high investment risk in sustainable alternative fuel supply or OPS infrastructure (average score: 4.15/5, 123 responses)
- Increase public funding and incentivise private investment to overcome the high investment risk in vessels powered by sustainable alternative fuels or propulsion systems (average score: 4.11/5, 124 responses)

Several respondents added their own suggestions for measures, the most noteworthy being to pursue a policy within the IMO (6 responses).

Being asked specifically about support measures, the TC respondents are most positive about funding for R&I (average score: 4.21/5, 32 responses), CEF funding for specific projects on the deployment of infrastructure (average score: 4.21/5, 32 responses) and technological developments and standardization aspects (average score: 4.29/5, 32 responses). All other options[147] scored well below (3.70 or less). These results are also in line with what was communicated by different stakeholders during the interviews.

Ship types and scope

58 % to the OPC respondents indicated that the requirements should apply to all ship types, while 15 % thought they should apply to certain ship types only e.g. the highest emitters.

At the same time, there is no agreement on the right geographical 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 with 30 % and 24 % respectively. It is noteworthy that a negligible 2 % thought that the scope should be ships bunkering in ports of the European Union, so this option is extremely unpopular.

[147] The other options were low- or zero-emission provisions in public procurement contracts; differentiation of port fees and harmonized reward schemes for green ships; identification and sharing of best practice for the promotion of sustainable alternative fuels in MS; and public support for the deployment of fleet with advanced propulsion.

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.

Measuring environmental performance

There is relatively good agreement about how emissions should be included in the policy framework. 56 % of OPC respondents prefer a “well-to-wake” approach. It is furthermore preferred by 54 % of stakeholders that this takes both greenhouse-gas and air quality emissions into account.

During the stakeholder interviews, the joint ESSF and EPF Roundtable and in the position papers, there is also agreement between stakeholders on the fact that emissions should be measured on a well-to-wake basis. In the feedback to the IIA, 13 out of the 81 participants also mentioned their preference for a well-to-wake approach. However, one stakeholder argued that although all emissions should be considered, the shipping sector should only be responsible for the exhaust emissions i.e. the tank-to-wake emissions. Multiple stakeholders also pointed out the need for a certification system for sustainable alternative fuels as necessary to ensure the sustainability of alternative fuels on the market.

All stakeholder groups thus generally agree that the emissions under this policy should be calculated on a “well-to-wake” basis.

Policy framework for ships at berth

Most of the OPC respondents think that it is either very relevant (37 %) or relevant (29 %) that emissions at berth are included in the scope of a policy framework. This is supported by the TC results. However, there is less agreement about how such requirements should apply. Both the option to make the policy apply to all ships at berth (22 %) and the option to prioritize the highest emitters (30 %) gained a substantial amount of votes. 12 % indicated that action should only be taken once critical infrastructure is made available in majority of EU ports, while 8 % preferred prioritising the ships and the ports already equipped with zero-emissions technologies (including OPS).

During the interviews, the joint ESSF and EPF roundtable and in the position papers there seems to be an agreement that OPS requirements for ships at berth is relevant and necessary for achieving the decarbonisation 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 option. All the interviewed ports stressed that mandating OPS is not a good option because the viability varies greatly from port to 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.

5. CONCLUSION

The objectives of the consultation activities have been largely achieved: all relevant stakeholders groups have been consulted and most provided their views on current barriers hindering the uptake of sustainable alternative fuels and the policy measures under consideration. Where available, respondents also provided additional quantitative and qualitative information.

The consultations showed that there is consensus among all stakeholder groups on the problems as identified by the initiative. They also support the underlying objective to promote the uptake of RLF in the maritime fuel mix.

The consultations confirmed that all five drivers identified in the framework of the initiative are regarded as relevant. The results suggest that the different stakeholders agree that high fuel and investment costs together with uncertainty for investors are the most important barriers. In terms of policy objectives, 'providing more certainty on the climate and environmental requirements for ships in operation' appears to be the most important policy objective in view of stakeholders. All stakeholder groups also expressed a preference for goal-based over prescriptive policy, which also concurs with another requirement for the policy voiced by most stakeholders, the technology neutrality. As regards the policy measures, setting a clear regulatory pathway for decarbonising the current marine fuel received the highest scores from the stakeholders. On geographical scope, there was no obvious preference on the right geographical scope for the measures. In terms of measuring environmental performance and how emissions should be included in the policy framework, majority of stakeholders prefers a "well-to-wake" approach as that it takes into account not only emissions from the combustion of fuel on board the ship, but also upstream emissions from production, transport, and distribution of fuels. As regards ships at berth, OPS requirements are found to be relevant and necessary for achieving the decarbonisation objectives by most stakeholders. The information collected corresponded in general to the objectives and expectations of the consultation activities defined for each stakeholder. The results have helped shape the assessment of impacts and the choice of policy options and policy measures.

Annex 3: Who is affected and how?

1. Practical implications of the initiative

1.1. Outlook of the preferred option implementation

The FuelEU Maritime initiative aims at increasing the uptake of RLF in EU maritime transport with a view to reducing emissions from the sector in navigation and at berth. Ensuring a more diverse fuel mix and a higher penetration of RLF is critical to ensure the sector's contribution to the European ambition of climate-neutrality by 2050. Reducing emissions from ships at berth is also particularly important to control air pollution in ports and port cities.

The preferred policy option identified in the context of the impact assessment, policy option 3, is defined as a goal-based approach with a mechanism to reward overachievers. It envisages a compliance and enforcement regime, based on reporting and verification of GHG intensity of on-board energy usage (metric expressed in CO_2e/kWh). It will rely, to the extent possible, on the reporting requirements already included in the EU MRV scheme as well as the corresponding IT tool, THETIS-MRV. However, the amount of data required for checking compliance with this initiative will be different as it will cover additional energy sources (not currently covered in EU MRV, such as electric propulsion) as well as additional emissions (well-to-tank emission factors and non-CO_2 emissions such as CH_4 and N_2O). The regulation will apply equally to all ships above 5000 gross tonnes, regardless of the flag they are flying, during the voyages involving EU ports: intra-EU, extra-EU inbound and outbound.

1.2. Implications on market operators and public authorities

Ship operators are the stakeholder category mostly impacted by the proposed intervention as they are in practice the regulated entities. They will have to comply with the maximum GHG intensity limits for the energy used on board which will be set by the regulation and are expected to apply as of 2025 and be gradually strengthen in 5-year intervals. Compliance will be determined for the voyages involving EU ports: intra-EU, extra-EU inbound and outbound. Compliance will not be checked on voyage-per-voyage basis but on an annual basis, allowing ship operators to average results between the regulated voyages. They will also have the possibility to acquire excess compliance points generated by other ships or roll-over negative points for the next reporting period. Should that prove not possible, operators will have to pay a compensation amount to acquire their document of compliance.

As the approach under the preferred policy options will be goal-based, market operators will enjoy full flexibility as regard the type of RLF they wish to use to meet the regulatory targets. They would also be free to bunker the compliance fuels outside the EU provided that its GHG performance can be certified in accordance with the applicable criteria. The compliance costs will therefore result in a gradual increase of fuel costs as well as an increase in capital costs (resulting from the deployment of new, innovative, propulsion systems) compared to the baseline. The compliance costs are distributed over time and are expected to gradually increase in line with the further penetration of RLF in the fuel mix. This has also as consequence that the compliance costs are more limited in the early phases of the intervention; the overall costs increase for ship operators are estimated to be around 2.7% by 2030 and up to 17.4% by 2050 in PO3.

Ports will be indirectly impacted by the proposed regulatory requirements as they will have to ensure access to bunkering infrastructure for marine RLF. However, policy intervention under FuelEU Maritime will not directly require ports to install specific infrastructure (such requirements are set by the EU Alternative Fuel Infrastructure Directive, which also is currently being reviewed). It is also worth noting here that the bunkering offer can be an element of competition among ports. In practice, most of the investments for ports are likely to result in the provision of OPS connection for ships at berth, focussing initially on container ships, passenger ships and ro-pax vessels, as well as, in the longer-term, the provision of specific infrastructure dedicated to hydrogen or ammonia. In order to guarantee the safe handling of fuels and bunkering operations, ports are expected to develop relevant provisions into their port rules and port bye-laws, accounting for the different dimensions of alternative fuels/OPS deployment. This will be a role of the port authorities in close cooperation with port administrations. Whilst doing so, port authorities are expected to follow existing regulations and best-practice guidance, at EU or international level. Considering the existence of such instruments, and the fact that mainly port authorities will develop national level regulatory framework, the administrative cost is not expected to impact significantly on the ports/port administrations/port operators.

In terms of **administrative requirements**, compliance will be demonstrated by operators through the submissions of additional information obligations in parallel to the ones already existing for the EU MRV. These concern in particular:

- *Annual energy compliance plan*: Each vessel will have to prepare an annual compliance plan, which describes which fuels and technologies the ship is planning to use. This plan builds on the EU MRV Monitoring plan.
- *Annual energy report*: The annual energy report is the calculation of the annual GHG performance of the vessel’s energy production. It should be broken down to different energy sources/types of fuel. In practice this report builds upon the EU MRV Emission report (incl. type of fuel, fuel consumption figures) and adds specific emission factors covering all regulated emissions on a well-to-wake basis.
- *OPS consumption:* As part of the annual energy report, all ships have to register the exact amount of electricity consumed while at berth (i.e. replacing the fuel used at

berth currently reported under EU MRV), or demonstrate the use of of equally performant alternative (e.g. batteries, hydrogen etc.). This will impact mainly the containerships, passenger ships and ro-pax vessels, who will be subject to specific OPS requirements at berth.

The following actions result from the above mentioned additional information requirements:

- Prepare and submit annual energy compliance plan (for the next year);
- Prepare and submit annual energy report, including the OPS consumption (for the previous year);
- Transfer excess or negative compliance points or pay compensation amount if needed;
- Carry document of compliance with the regulatory requirements;
- Cooperate during audits/inspections.

Similarly to the verification cycle established for the MRV Regulation, compliance checks will have to be made by an accredited verifier, which will issue, on that basis, a document of compliance. In terms of compliance cycle, ships will have up to 6 months following the reported year to receive their document of compliance. Within the deadlines specified in the EU MRV Regulation, they will have to submit all relevant information to the verifier (e.g. proof of fuel consumption during the regulated journeys, type of fuel used, fuel certificates, etc.) so that it can check performance against the target.

Indirectly, **marine equipment providers** will be able to further strengthen their strong competitive 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 is expected be a stimulus for research and development in such technologies.

Fuel suppliers will also be indirect impacted by the regulatory requirements as they will have to certify marine RLF reflecting upstream emissions and sustainability criteria. The certification requirements will build on existing provisions and sustainability criteria in the RED, as well as the existing certification scheme such as the International Sustainability & Carbon Certification (ISCC) Scheme[148]. As bunkering may not be limited to the EU, it is difficult to assess to which degree EU fuel suppliers will be impacted. However, based on existing literature and already existing comparable systems, these are anticipated not to have significant impact on the price of RLF and illustrative cost estimates have been provided in Section 6.1.2.

[148] https://www.iscc-system.org/process/overview/

The impact of **national administrations** is expected to remain very limited. As the system is building on the existing MRV one, it is also expected to rely on the existing IT tool, THETIS-MRV, which should be enhanced to handle the new information / data streams. This will be done at EU-level. Most of the compliance check will in practice be done by third-party verifiers which will be audited / controlled on a regular basis. The document of compliance will be registered electronically and the system will allow a rapid identification of non-compliant ships. The need for additional Port State Control inspections is therefore considered limited.

2. SUMMARY OF COSTS AND BENEFITS

Table 28 Overview of benefits

I. Overview of Benefits (total for all provisions) – Preferred Option – PO3 (relative to the baseline, expressed as present value over 2021-2050)		
Description	***Amount***	***Comments***
Direct benefits		
Reduction of external costs related to air pollution relative to the baseline (i.e. present value over 2021-2050)	EUR 10.0 billion	Direct benefit to society at large. It is the effect of the reduction of air pollution from ships resulting from the use of cleaner fuels and propulsion solutions. For instance, NOx and PM10 emissions associated to maritime transport are projected to decrease by 27% by 2050 relative to the baseline. These also include savings related to air pollution resulting from the use of OPS (or equally performant alternative) by the most polluting ships at berth (container ships, passenger ships and ro-pax vessels).
Reduction of external costs related to GHG emissions relative to the baseline (i.e. present value over 2021-2050)	EUR 138.6 billion	Direct benefit to society at large. These savings result directly from the gradual decrease of the GHG intensity of fuels used on-board as well as to a modest reduction in the transport activity (-2.7% by 2050 compared to the baseline).
Increased use of innovative fuels and propulsion technologies		Significant increase of innovative propulsion in the fleet reaching 18.9% of fuel cell-powered vessels and 5.4% of electric propulsion by 2050 (compared to no penetration of these technologies in the baseline).
Indirect benefits		
Reduced operation costs for ship operators relative to the baseline (i.e. present value over 2021-2050)	EUR 2.3 billion	The main beneficiary group will be the ship operators. The reduction in operation costs result from lower maintenance and crew costs. Some of this reduction will also be partly driven by lower transport activity relative to the baseline.

Table 29 Overview of costs

II. Overview of costs – Preferred option – PO3 (relative to the baseline, expressed as present value over 2021-2050)							
		Citizens/Consumers		Businesses		Administrations	
		One-off	Recurrent	One-off	Recurrent	One-off	Recurrent
Compliance costs resulting	Direct costs (relative to		Impact on consumer prices		EUR 89.7 billion for ship operators		

from the introduction of the GHG intensity targets of on-board energy usage	the baseline in present value over 2021-2050)		expected to be limited (as freight rates increase remain contained)		covering capital costs (EUR 25.8bn) and fuel costs (EUR 63.9bn)		
	Indirect costs (relative to the baseline in present value over 2021-2050)				EUR 5.7 billion for ports to provide the necessary infrastructure (OPS and hydrogen-related)		
Administrative and enforcement costs	Direct costs (relative to the baseline in present value over 2021-2050)				EUR 439.7 million resulting from additional information obligations, cooperation during audits and inspections and crew training. EUR 82 million for verification and approval	EUR 0.5 million to adapt the IT system for reporting and compliance checks (EU budget)	EUR 1 million for additional time during audits/inspecti ons
	Indirect costs (relative to the baseline in present value over 2021-2050)				EUR 1.8 million resulting from the establishment of guidelines by ports to guarantee safe handling of RLF. Fuel certification costs could not be quantified but based on existing literature and similar systems are expected not to have significant impact on the price of RLF		

Annex 4: Analytical methods

1. Description of the modelling tools used

The main models used for developing the baseline scenario for this initiative are the PRIMES and PRIMES-TREMOVE models (including their PRIMES-Maritime module). These models have a successful record of use in the Commission's energy, transport and climate policy assessments. In particular, they have been used for the impact assessment accompanying the 2030 Climate Target Plan[149], the Staff Working Document accompanying the Sustainable and Smart Mobility Strategy, the Commission's proposal for a Long Term Strategy[150] as well as for the 2020 and 2030 EU's climate and energy policy framework. In addition, the POLES-JRC[151] model has been used for the world energy price projections and the GEM-E3 model[152] for the macro-economic developments by sector of activity, used in the baseline scenario.

Modelling of the policy options, in a consistent way with the scenarios prepared in support of the impact assessment accompanying the 2030 Climate Target Plan and the Staff Working Document accompanying the Sustainable and Smart Mobility Strategy, has been performed by E3Modelling with the PRIMES-Maritime transport module of PRIMES and PRIMES-TREMOVE. Specific analysis on the risk of carbon leakage in the introduction of extra-EU journeys in the scope of the policy options has been carried out by TRT with the TRUST model. The administrative costs for businesses and the costs for authorities draw on the impact assessment support study.[153]

- **The entire energy** (energy demand, supply, prices and investments to the future) and **transport systems**, and **all GHG emissions and removals** from the EU economy
- **Time horizon:** 1990 to 2070 (5-year time steps)
- **Geography:** individually all EU Member States
- **Impacts:** on the energy system (PRIMES and its satellite model on biomass), transport (PRIMES-TREMOVE and PRIMES-Maritime).

The modelling suite has been continuously updated over the past decade. Updates include the addition of a new buildings module in PRIMES, improved representation of the electricity sector, more granular representation of hydrogen (including cross-border

149 SWD/2020/176 final
150 https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf
151 The POLES-JRC model provides the global energy and climate policy context and is operated by the JRC. Source: https://ec.europa.eu/jrc/en/poles.
152 Source: https://e3modelling.com/
153 Ecorys and CE Delft (forthcoming), Assessment of impacts from accelerating the uptake of sustainable alternative fuels in maritime transport.

trade154) and other innovative fuels, improved representation of the maritime transport sector, as well updated interlinkages of the models to improve land use and non-CO2 modelling. Most recently a major update was done of the policy assumptions, technology costs and macro-economic assumptions.

PRIMES model

The PRIMES model (Price-Induced Market Equilibrium System)[155] is a large scale applied energy system model that provides detailed projections of energy demand, supply, prices and investment to the future, covering the entire energy system including emissions. The distinctive feature of PRIMES is the combination of behavioural modelling (following a micro-economic foundation) with engineering aspects, covering all energy sectors and markets. The model has a detailed representation of policy instruments related to energy markets and climate, including market drivers, standards, and targets by sector or overall. It simulates the EU Emissions Trading System in its current form. It handles multiple policy objectives, such as GHG emissions reductions, energy efficiency, and renewable energy targets, and provides pan-European simulation of internal markets for electricity and gas.

PRIMES offers the possibility of handling market distortions, barriers to rational decisions, behaviours and market coordination issues and it has full accounting of costs (CAPEX and OPEX) and investment on infrastructure needs. The model covers the horizon up to 2070 in 5-year interval periods and includes all Member States of the EU individually, as well as neighbouring and candidate countries. PRIMES is designed to analyse complex interactions within the energy system in a multiple agent – multiple markets framework.

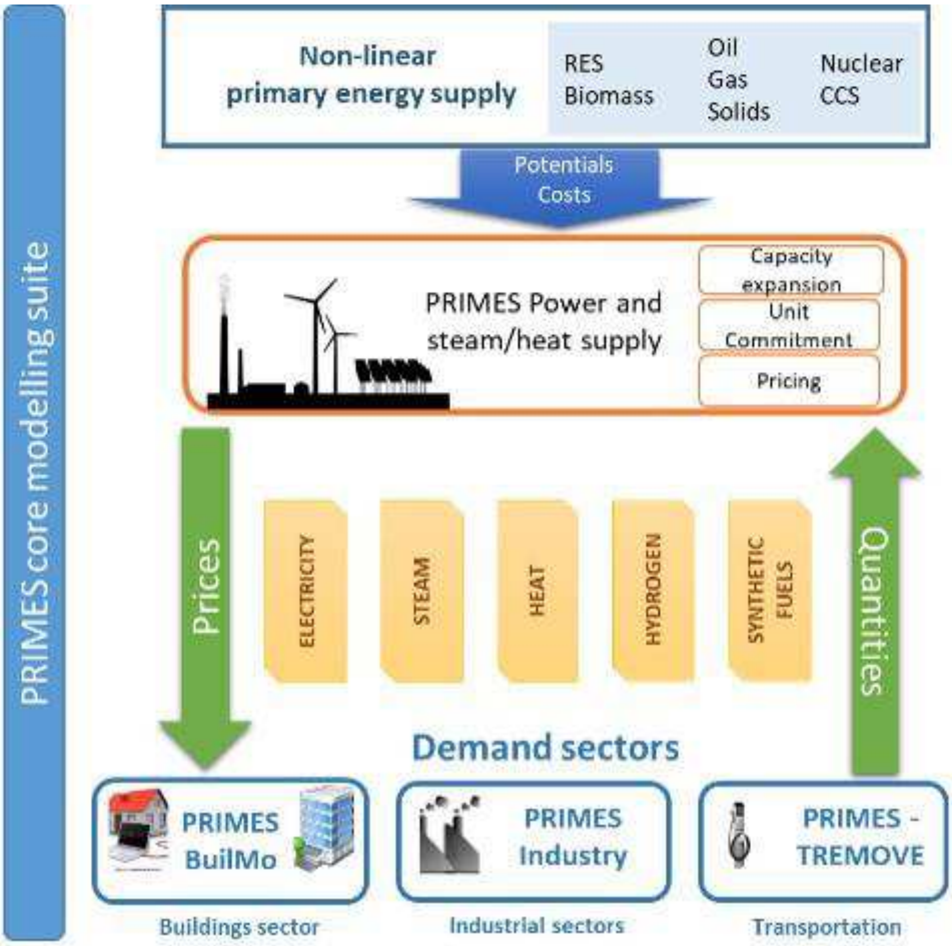
Decisions by agents are formulated based on microeconomic foundation (utility maximization, cost minimization and market equilibrium) embedding engineering constraints and explicit representation of technologies and vintages; optionally perfect or imperfect foresight for the modelling of investment in all sectors.

PRIMES allows simulating long-term transformations/transitions and includes non-linear formulation of potentials by type (resources, sites, acceptability etc.) and technology learning. Figure 10 shows a schematic representation of the PRIMES model.

[154] While cross-border trade is possible, the assumption is that there are no imports from outside EU as the opposite would require global modelling of hydrogen trade.

[155] More information and model documentation: https://e3modelling.com/modelling-tools/primes/

Figure 10: Schematic representation of the PRIMES model



It includes a detailed numerical model on biomass supply, namely PRIMES-Biomass, which simulates the economics of supply of biomass and waste for energy purposes through a network of current and future processes. The model transforms biomass (or waste) feedstock, thus primary feedstock or residues, into bio-energy commodities which undergo further transformation in the energy system e.g. as input into power plants, heating boilers or fuels for transportation. The model calculates the inputs in terms of primary feedstock of biomass and waste to satisfy a given demand for bio-energy commodities and provides quantification of the required production capacity (for plants transforming feedstock into bioenergy commodities). Furthermore, all the costs resulting from the production of bioenergy commodities and the resulting prices are quantified. The PRIMES-Biomass model is a key link of communication between the energy system projections obtained by the core PRIMES energy system model and the projections on agriculture, forestry and non-CO_2 emissions provided by other modelling tools (CAPRI, GLOBIOM/G4M, GAINS).

PRIMES is a private model maintained by E3Modelling[156], originally developed in the context of a series of research programmes co-financed by the European Commission. The model has been successfully peer-reviewed, most recently in 2011[157]; team members regularly participate in international conferences and publish in scientific peer-reviewed journals.

Sources for data inputs

A summary of database sources, in the current version of PRIMES, is provided below:

- Eurostat and EEA: Energy Balance sheets, Energy prices (complemented by other sources, such IEA), macroeconomic and sectoral activity data (PRIMES sectors correspond to NACE 3-digit classification), population data and projections, physical activity data (complemented by other sources), CHP surveys, CO_2 emission factors (sectoral and reference approaches) and EU ETS registry for allocating emissions between ETS and non ETS
- Technology databases: ODYSSEE-MURE[158], ICARUS, Eco-design, VGB (power technology costs), TECHPOL – supply sector technologies, NEMS model database[159], IPPC BAT Technologies[160]
- Power Plant Inventory: ESAP SA and PLATTS
- RES capacities, potential and availability: JRC ENSPRESO[161], JRC EMHIRES[162], RES ninja[163], ECN, DLR and Observer, IRENA
- Network infrastructure: ENTSOE, GIE, other operators
- Other databases: District heating surveys (e.g. from COGEN), buildings and houses statistics and surveys (various sources, including ENTRANZE project[164], INSPIRE archive, BPIE[165]), JRC-IDEES[166], update to the EU Building stock Observatory[167]

PRIMES-TREMOVE model

The PRIMES-TREMOVE transport model projects the evolution of demand for passengers and freight transport, by transport mode, and transport vehicle/technology, following a formulation based on microeconomic foundation of decisions of multiple actors. Operation, investment and emission costs, various policy measures, utility factors and

156 E3Modelling (https://e3modelling.com/) is a private consulting, established as a spin-off inheriting staff, knowledge and software-modelling innovation of the laboratory E3MLab from the National Technical University of Athens (NTUA).
157 SEC(2011)1569 : https://ec.europa.eu/energy/sites/ener/files/documents/sec_2011_1569_2.pdf
158 https://www.odyssee-mure.eu/
159 Source: https://www.eia.gov/outlooks/aeo/info_nems_archive.php
160 Source: https://eippcb.jrc.ec.europa.eu/reference/
161 Source: https://data.jrc.ec.europa.eu/collection/id-00138
162 Source: https://data.jrc.ec.europa.eu/dataset/jrc-emhires-wind-generation-time-series
163 Source: https://www.renewables.ninja/
164 Source: https://www.entranze.eu/
165 Source: http://bpie.eu/
166 Source: https://ec.europa.eu/jrc/en/potencia/jrc-idees
167 Source: https://ec.europa.eu/energy/en/eubuildings

congestion are among the drivers that influence the projections of the model. The projections of activity, equipment (fleet), usage of equipment, energy consumption and emissions (and other externalities) constitute the set of model outputs.

The PRIMES-TREMOVE transport model can therefore provide the quantitative analysis for the transport sector in the EU, candidate and neighbouring countries covering activity, equipment, energy and emissions. The model accounts for each country separately which means that the detailed long-term outlooks are available both for each country and in aggregate forms (e.g. EU level).

In the transport field, PRIMES-TREMOVE is suitable for modelling *soft measures* (e.g. eco-driving, labelling); *economic measures* (e.g. subsidies and taxes on fuels, vehicles, emissions; ETS for transport when linked with PRIMES; pricing of congestion and other externalities such as air pollution, accidents and noise; measures supporting R&D); *regulatory measures* (e.g. CO_2 emission performance standards for new light duty and heavy duty vehicles; EURO standards on road transport vehicles; technology standards for non-road transport technologies, deployment of Intelligent Transport Systems) and *infrastructure policies for alternative fuels* (e.g. deployment of refuelling/recharging infrastructure for electricity, hydrogen, LNG, CNG). Used as a module that contributes to the PRIMES model energy system model, PRIMES-TREMOVE can show how policies and trends in the field of transport contribute to economy-wide trends in energy use and emissions. Using data disaggregated per Member State, the model can show differentiated trends across Member States.

The PRIMES-TREMOVE has been developed and is maintained by E3Modelling, based on, but extending features of, the open source TREMOVE model developed by the TREMOVE[168] modelling community. Part of the model (e.g. the utility nested tree) was built following the TREMOVE model.[169] Other parts, like the component on fuel consumption and emissions, follow the COPERT model.

PRIMES-Maritime model

The maritime transport model is a specific sub-module of the PRIMES and PRIMES-TREMOVE models and aiming to enhance the representation of the maritime sector within the energy-economy-environment modelling nexus. The model, which can run in stand-

[168] Source: https://www.tmleuven.be/en/navigation/TREMOVE

[169] Several model enhancements were made compared to the standard TREMOVE model, as for example: for the number of vintages (allowing representation of the choice of second-hand cars); for the technology categories which include vehicle types using electricity from the grid and fuel cells. The model also incorporates additional fuel types, such as biofuels (when they differ from standard fossil fuel technologies), LPG, LNG, hydrogen and e-fuels. In addition, representation of infrastructure for refuelling and recharging are among the model refinements, influencing fuel choices. A major model enhancement concerns the inclusion of heterogeneity in the distance of stylised trips; the model considers that the trip distances follow a distribution function with different distances and frequencies. The inclusion of heterogeneity was found to be of significant influence in the choice of vehicle-fuels especially for vehicles-fuels with range limitations.

alone and/ or linked mode with PRIMES and PRIMES-TREMOVE, produces long-term energy and emission projections, until 2070, separately for each EU Member-State.

The coverage of the model includes the European intra-EU maritime sector as well as the extra-EU maritime shipping. The model covers both freight and passenger international maritime. PRIMES-Maritime focuses only on the EU Member State, therefore trade activity between non-EU countries is outside the scope of the model. The model considers the transactions (bilateral trade by product type) of the EU-Member States with non-EU countries and aggregates these countries in regions. Several types and sizes of vessels are considered.

PRIMES-Maritime features a modular approach based on the demand and the supply modules. The demand module projects maritime activity for each EU Member State by type of cargo and by corresponding partner. Econometric functions correlate demand for maritime transport services with economic indicators considered as demand drivers, including GDP, trade of energy commodities (oil, coal, LNG), trade of non-energy commodities, international fuel prices, etc. The supply module simulates a representative operator controlling the EU fleet, who offers the requested maritime transport services. The operator of the fleet decides the allocation of the vessels activity to the various markets (representing the different EU MS) where different regulatory regimes may apply (e.g. environmental zones). The fleet of vessels disaggregated into several categories is specific to cargo types. PRIMES-Maritime utilises a stock-flow relationship to simulate the evolution of the fleet of vessels throughout the projection period and the purchasing of new vessels.

PRIMES-Maritime solves a virtual market equilibrium problem, where demand and supply interact dynamically in each consecutive time period, influenced by a variety of exogenous policy variables, notably fuel standards, pricing signals (e.g. ETS), environmental and efficiency/operational regulations and others. The PRIMES-Maritime model projects energy consumption by fuel type and purpose as well as CO_2, methane and N_2O and other pollutant emissions. The model includes projections of costs, such as capital, fuel, operation costs, projections of investment expenditures in new vessels and negative externalities from air pollution.

The model serves to quantify policy scenarios supporting the transition towards carbon neutrality. It considers the handling of a variety of fuels such as fossil fuels, biofuels (bioheavy[170], biodiesel, bio-LNG), synthetic fuels (synthetic diesel, fuel oil and gas, e-ammonia and e-methanol) produced from renewable electricity, hydrogen produced from renewable electricity (for direct use and for use in fuel cell vessels) and electricity for electric vessels. Well-To-Wake emissions are calculated thanks to the linkage with the PRIMES energy systems model which derives ways of producing such fuels. The model

[170] Bioheavy refers to bio heavy fuel oil.

also allows to explore synergies with Onshore Power Supply systems. Environmental regulation, fuel blending mandates, GHG emission reduction targets, pricing signals and policies increasing the availability of fuel supply and supporting the alternative fuel infrastructure are identified as drivers, along fuel costs, for the penetration of new fuels. As the model is dynamic and handles vessel vintages, capital turnover is explicit in the model influencing the pace of fuel and vessel substitution.

Data inputs

The main data sources for inputs to the PRIMES-Maritime model, such as for activity and energy consumption, comes from EUROSTAT database and from the Statistical Pocketbook "EU transport in figures[171]. Other data comes from different sources such as research projects (e.g. TRACCS project) and reports. PRIMES-Maritime being part of the overall PRIMES and PRIMES-TREMOVE transport model is calibrated to the EUROSTAT energy balances and transport activity; hence the associated CO_2 emissions are assumed to derive from the combustion of these fuel quantities. The model has been adapted to reflect allocation of CO_2 emissions into intra-EU, extra-EU and berth, in line with data from the MRV database.[172] For air pollutants, the model draws on the EEA database.

In the context of this exercise, the PRIMES-Maritime model is calibrated to 2005, 2010 and 2015 historical data.

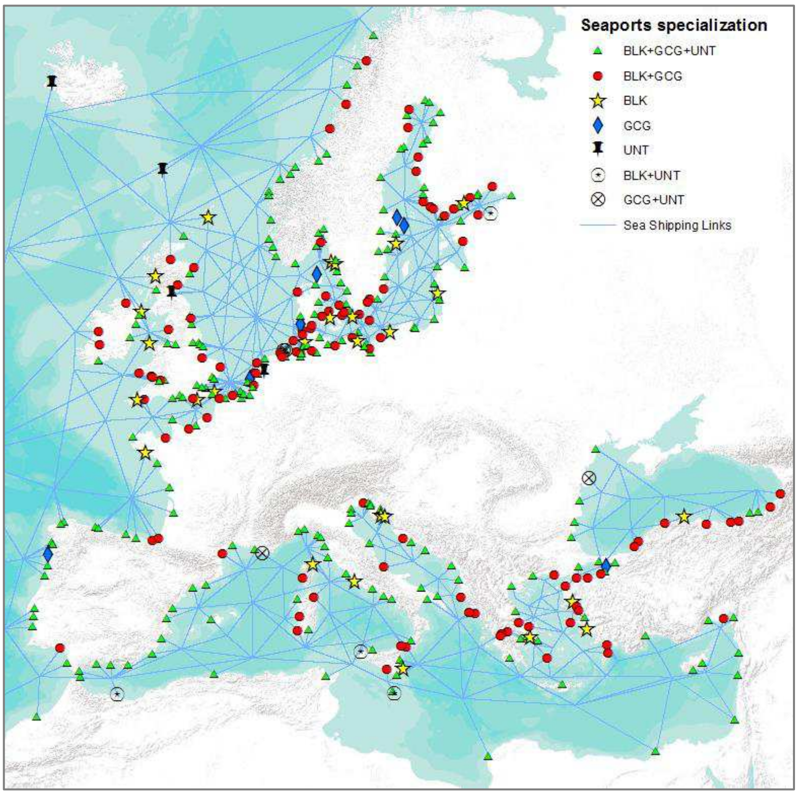
TRUST maritime network model

Maritime transport supply: TRUST maritime network includes the main ports throughout Europe, including all ports belonging to the TEN-T core network. Notional maritime links provide sea routes to link ports and allows the model to compute travel distances of maritime connections. Using these links each port is at least in principle linked to each other.

Maritime ports are classified into three categories: bulk (BLK) ports, container (UNT) ports and general cargo (GCG) ports. Most of the ports belong to more than one category but some ports have only one or two specialisations. These ports can host only demand for those freight segments (e.g. if one port is classified only as a bulk port, routes for general cargo and container demand cannot go through that port).

171 Source: https://ec.europa.eu/transport/facts-fundings/statistics_en
172 https://mrv.emsa.europa.eu/#public/eumrv

Figure 11: Seaports and sea routes in the TRUST maritime network model



The ship mode has to be accessed through feeder modes (road, rail or inland waterway according to existing infrastructures). As a consequence, rail and road networks are also used in the TRUST maritime model as well as inland waterways because trains, barges and trucks are used as feeder modes to connect internal zones with ports and allow the definition of full path between origin and final destination of freight. Connections between ports and inland networks are also part of the network.

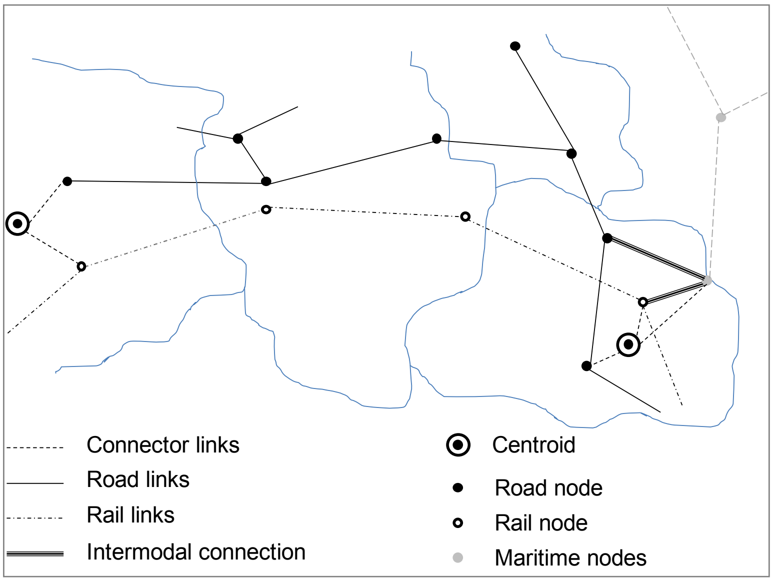
Maritime transport demand: maritime demand consists of Origin-Destination matrices segmented according to the three freight categories of bulk, container and general cargo. Matrices are in terms of thousand tonnes per year. Each segment of demand has its autonomous matrix that is assigned independently to the network.

TRUST maritime network model is a private model developed and maintained by TRT[173]. It is part of the TRUST transport network model for the assignment of Origin-Destination matrices at the NUTS3 level for passenger and freight demand for the whole Europe and neighbouring countries.[174]

173 Source : http://www.trt.it/wp/wp-content/uploads/2016/09/TRUST-model-detailed-description-1.pdf

174 TRUST model, in connection with ASTRA, has been used for several impact assessment support studies commissioned by EC (e.g. Support Study for the Impact Assessment accompanying the revision of the Eurovignette Directive (1999/62/EC), Study on the deployment of C-ITS in Europe) and other studies (e.g. The impact of TEN-T

Figure 12: Intermodal connection at ports in the TRUST maritime network model



Data inputs

The main data sources for inputs to the TRUST model are the EUROSTAT database and the Statistical Pocketbook "EU transport in figures[175], TENtec Information system[176] and ETISplus database.

2. BASELINE SCENARIO

Main assumptions of the Baseline scenario

The baseline scenario used in this impact assessment builds on the baseline scenario underpinning the impact assessment accompanying the 2030 Climate Target Plan and the staff working document accompanying the Sustainable and Smart Mobility Strategy, but it additionally considers the impacts of the COVID-19 pandemic and the National Energy and Climate Plans.

Economic assumptions: The modelling work is based on socio-economic assumptions describing the expected evolution of the European society. Long-term projections on population dynamics and economic activity form part of the input to the energy and transport model and are used to estimate transport activity and energy demand in transport. Population projections from Eurostat[177] are used to estimate the evolution of the European population that is projected to change very little in total number in the coming decades.

completion on growth, jobs and the environment, Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities).

175 Source: https://ec.europa.eu/transport/facts-fundings/statistics_en

176 https://ec.europa.eu/transport/themes/infrastructure-ten-t-connecting-europe/tentec-information-system_en

177 Source: https://ec.europa.eu/eurostat/web/population-demography-migration-projections/population-projections-data

Macro-economic projections draw on DG ECFIN.[178] In particular, the Commission's Spring Economic Forecast 2020 projected that the EU economy would contract by 7.4% in 2020 and pick up in 2021 with growth of 6.1%. By 2030, real GDP in 2030 could be approximately 2.3% lower compared to the pre-COVID estimates, based on the Autumn Forecast 2019.

Energy prices assumptions: The COVID pandemics has had a major impact on international fuel prices. As a large part of the world went into lockdown, fossil fuel prices collapsed with crude oil spot prices halved compared to last year levels. The oil price is projected to gradually recover over time, reaching 80USD/bbl in 2030 and 118USD/bbl in 2050. It is however projected to remain below the projected pre-COVID-19 pandemic levels.[179] Figure 13 shows the fuel prices projections used in the baseline scenario.

Figure 13: International fuel prices assumptions

in USD'15 per boe	**'15**	**'30**	**'40**	**'50**
Oil	52.3	80.1	97.4	117.9
Gas (NCV)	43.7	40.9	52.6	57.8
in €'15 per boe	**'15**	**'30**	**'40**	**'50**
Oil	47.2	72.2	87.8	106.3
Gas (NCV)	38.7	36.2	46.6	51.2

Source: Derived from JRC, POLES-JRC model, Global Energy and Climate Outlook (GECO)

Technology assumptions: Modelling scenarios on the evolution of the energy and transport system is highly dependent on the assumptions on the development of technologies - both in terms of performance and costs. For the purpose of the impact assessments related to the "Climate Target Plan" and the "Fit for 55" policy package, these assumptions have been updated based on a rigorous literature review carried out by external consultants in collaboration with the JRC.

Continuing the approach adopted in the long-term strategy in 2018, the Commission consulted technology assumption with stakeholders in 2019. In particular, the technology database of the main model suite (PRIMES, PRIMES-TREMOVE, GAINS, GLOBIOM, and CAPRI) benefited from a dedicated consultation workshop held on 11th November

[178] The long-term evolution of economic activity was estimated from three sources: DG ECFIN's short term economic forecast, updated t+10 projections up to 2029 and the 2018 Aging Report projections elaborated by the European Commission. For the short-term (2020-2021), the projections are based on growth forecast by the Directorate General for Economic and Financial Affairs (Spring 2020 Economic Forecast). Projections up to 2029 use the associated t+10 work from DG ECFIN, which is based on projections of potential output growth and a closure of output gap in the medium term. The long-term per capita GDP growth projections of the 2018 Ageing Report are used for the period 2030-2050, available at: https://ec.europa.eu/info/publications/economy-finance/2018-ageing-report-economic-and-budgetary-projections-eu-member-states-2016-2070_en

[179] Communication from the Commission 'Stepping up Europe's 2030 climate ambition - Investing in a climate-neutral future for the benefit of our people', COM(2020) 562 final.

2019. EU Member States representatives had also the opportunity to comment on the costs elements during a workshop held on 25th November 2019. The updated technology assumptions are published together with the EU Reference Scenario 2020.

Policies included in the Baseline scenario

The Baseline scenario projects developments under the current EU and national policy framework. It embeds in particular the EU legislation in place to reach the 2030 climate target of at least 40% compared to 1990, as well as national contributions to reaching the EU 2030 energy targets on Energy efficiency and Renewables under the Governance of the Energy Union. It thus gives a detailed picture of where the EU economy and energy system in particular would stand in terms of GHG emission if the policy framework were not updated to enable reaching the revised 2030 climate target to at least -55% compared to 1990 proposed under the Climate Target Plan[180].

In addition to the headline targets, some of the policies included in the baseline scenario are:

- For maritime shipping, in addition to emissions being monitored under the Regulation on Monitoring, Reporting and Verification of Maritime Emissions[181], the Baseline scenario reflects the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) adopted by the International Maritime Organisation, as well as the Sulphur Directive.
- The EU Emissions Trading System[182] (EU ETS) covers 45% of EU GHG emissions, notably from industry, the power sector and aviation. Emissions for the sectors under the system are capped to reduce by 43% by 2030 compared to 2005. The baseline scenario additionally assumes that the Market Stability Reserve (MSR) will ensure that the ETS contributes to the achievement of the overall target cost-effectively. MSR functioning is set to be reviewed[183] in 2021 and every five years after to ensure its aim of tackling structural supply-demand imbalances.
- Aviation emissions are also covered by the EU ETS. The EU, however, decided in 2014 to limit the scope of the EU ETS to flights within the EEA until 2016 to support the development of a global measure by the International Civil Aviation Organization (ICAO).[184] In light of the adoption of a Resolution by the 2016 ICAO Assembly on the global measure, the EU has decided to maintain the geographic scope of the EU ETS limited to intra-EEA flights from 2017 until the end of 2023.[185] The EU ETS for aviation is subject to a new review in the light of the international developments related

[180] COM/2020/562 final
[181] Regulation (EU) 2015/757
[182] Directive 2003/87/EC
[183] Decision (EU) 2015/1814
[184] Regulation (EU) 421/2014
[185] Regulation (EU) 2017/2392

to the operationalisation of CORSIA. This review considers how to implement the global measure in Union law through a revision of the EU ETS legislation. In the absence of a new amendment, the EU ETS would revert back to its original full scope from 2024.

- For aviation, in addition to implementation of the EU Emission Trading Scheme, the Baseline reflects the Union-wide air transport performance targets for the key performance area of environment, Clean Sky, Single European Sky and SESAR, and aircraft CO_2 emissions standards, as part of the so-called "basket of measures" that aim to reduce emissions from the sector.
- The revised Renewable Energy Directive[186] entered into force in 2018. It establishes a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a possible upwards revision by 2023.
- The Fuel Quality Directive[187] requires a reduction of the GHG intensity of transport fuels by a minimum of 6% to be achieved by 2020.
- CO_2 emission standards for new cars and vans[188] and for new trucks[189] have been defined, and will contribute towards reducing emissions from the road transport sector. Besides the post-2020 CO_2 standards for new light duty and heavy duty vehicles, the Clean Vehicles Directive and the Directive on the deployment of alternative fuels infrastructure contribute to the roll-out of recharging infrastructure. Furthermore, the uptake of sustainable alternative fuels is supported by the Renewables Energy Directive and Fuel Quality Directive. Improvements in transport system efficiency (by making the most of digital technologies and smart pricing and further encouraging multi-modal integration and shifts towards more sustainable transport modes) are facilitated by e.g. the TEN-T Regulation supported by CEF funding, the fourth Railway Package, the Directive on Intelligent Transport Systems, the European Rail Traffic Management System European deployment plan, the Regulation establishing a framework for the provision of port services, and others. The Baseline also accounts for other initiatives addressing air pollution from inland waterways vessels, as well as road safety, and thus reducing the external costs of transport.
- The Effort Sharing Regulation[190] (ESR) sets binding annual reduction targets for member states, with an aim to reduce emissions by 30% compared to 2005 by 2030. The ESR targets are set according to national wealth and cost-effectiveness. The ESR allows for flexibilities such as transfers between member states.

In addition, these policies will continue pushing further GHG emissions reduction, and increasing energy savings and renewable energies deployment after 2030, either because

[186] Directive 2018/2001/EU
[187] Directive 2009/30/EC
[188] Regulations (EU) 2019/631
[189] Regulation (EU) 2019/1242
[190] Regulation (EU) 2018/842

they do not have a "sunset clause" (notably ETS, and since recently, Article 7 in revised EED), or because of the technological learning and cost reductions that they are expected to induce. Moreover, most actions in the energy and transport system have long-term impacts. The baseline captures these dynamics, but it needs to be emphasised that no intensification of policies post-2030 was assumed and no target for GHG emissions reduction in 2050 was set concerning climate neutrality.

The Baseline scenario considers existing national policies and those reflected in the National Energy and Climate Plans.

The Baseline scenario models the policies already adopted, but not the target of net-zero emissions by 2050. As a result, there are no additional policies introduced driving decarbonisation after 2030. However, climate and energy policies are not rolled back after 2030 and several of the measures in place today continue to deliver emissions reduction in the long term.

Main results of the Baseline scenario

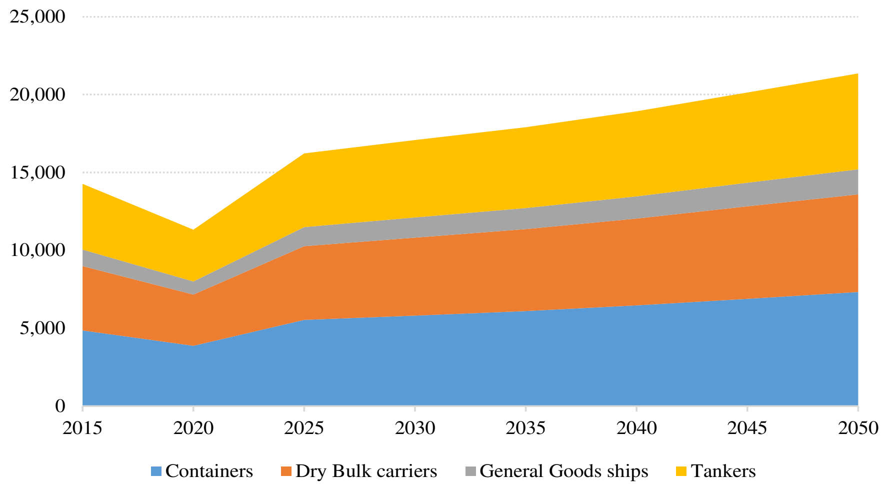
EU freight transport activity for inland modes is projected to grow at a rate of 1.2% per year on average between 2015 and 2050, despite the significant impact of the COVID-19 pandemic. Growth rates per mode of transport would however be different. The highest growth is projected in the rail freight transport, driven by the assumed completion of the TEN-T core network by 2030 and of the comprehensive network by 2050, supported by the CEF, Cohesion Fund and ERDF funding. Road freight transport would grow by 1.2% per year followed by inland navigation transport that is projected to grow by around 0.9% per year.

The COVID-19 pandemic had a major impact on global shipping, affecting all its segments from passenger ships to container ships and oil tankers. About 30% of all goods in the EU are transported by ships. *International maritime transport activity* (intra and extra-EU) is projected to be 21% lower in 2020 relative to 2015. From 2021 onwards however it is projected to start recovering and grow strongly by 2025 and beyond (i.e. 20% growth for 2015-2030 and 50% for 2015-2050), due to the rising demand for primary resources and container shipping. Passsenger shipping activity (i.e. passenger cruise and Ro-Pax) has been affected more strongly than the freight shipping due to the travel restrictions linked to the COVID-19 pandemic. Its activity is projected to be around 40% lower in 2020 relative to 2015 but to strongly recover from 2021 onwards. *Passenger shipping activity* is projected to grow by 24% during 2015-2030 and by 54% for 2015-2050 despite the significant impact of the COVID-19 pandemic on the sector.

The baseline scenario projects a limited uptake of biofuels in international maritime by 2050 (0.1% in 2030 and 1.3% in 2050). No other type of renewable and low carbon fuels is foreseen to enter the international maritime fuel mix by 2050 without further EU level intervention. Only a very small uptake of electricity (0.1% of the fuel mix) is projected by 2030 and 2050 due to the on-shore power supply at berth.

The existing provisions of EU legislation (in particular the Sulphur Directive or the AFID), which could have encouraged the uptake of alternative fuels, in particular LNG, have not produced yet any significant uptake of new sources of energy in maritime transport. However, by 2050 LNG is projected to represent around 19% of the international maritime fuel mix, mainly as a result of more stringent requirements on air pollution control (in particular SOx and NOx emissions). Even though the GHG benefits of LNG remain modest (in particular due to possible methane slip) the technology provides a good solution to air pollution issues, allowing reductions in SOx and NOx emissions and, as a result, it represented an attractive compliance option to the Sulphur Directive. In the longer term, LNG can pave the way to the use of bio-LNG or e-gas, which would also offer climate-related benefits. In the Baseline scenario, the LNG-fuelled fleet is projected to be around 5,100 by 2050.

Figure 14 Projected evolution of EU27 international maritime transport activity in the Baseline scenario



Source: PRIMES-Maritime model, E3Modelling

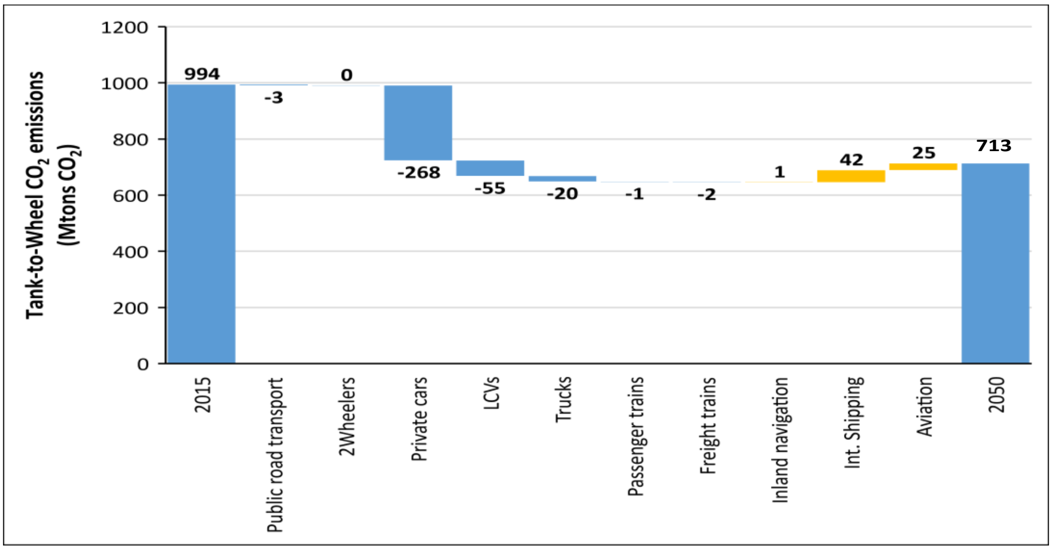
Tank-to-wake GHG emissions from international shipping (including CH4 and N2O emissions from slippage) are projected to increase by 14% by 2030 and by 34% by 2050 relative to 2015. This is driven by the sustained growth projected for transport activity, even when accounting for the impact of the COVID-19 pandemic, and despite the significant improvements in energy efficiency taking place over time. On a well-to-wake basis, this is equivalent to 15% increase during 2015-2030 and 38% for 2015-2050.

Total transport Tank-to-Wheel CO_2 emissions (including international shipping) are projected to decrease from approximately 994 Mtons in 2015 to about 888 Mtons in 2030 and 713 Mtons in 2050, or by 11% and 28%, respectively. The reduction in CO_2 emissions is primarily achieved in road transport due to the roll-out of efficient internal combustion engine vehicles and the uptake of electric vehicles, especially in the period after 2030, but also due to the shift to rail. Specifically, the emissions of road transport are projected to decrease from 732 Mtons in 2015, to 588 Mtons in 2030 (or 20% compared to 2015) and to 386 Mtons in 2050 (or 47% compared to 2015). Emissions from rail transport also decrease, by 3 Mtons in 2050 (or 65% compared 2015). The reduction in these segments compensates for the increase of CO_2 emissions in aviation, which from 120 Mtons in 2015, increases to 140 Mtons in 2030 (by 17%) and 144 Mtons in 2050 (by 21%), and international shipping that increases its emissions by around 42 Mtons between 2015 and 2050.

Well-to-Wheel (WTW) emissions (including those from international maritime) are projected to follow a similar declining trend. In the Baseline scenario they decrease from 1,118 Mtons CO_{2eq} in 2015, to 1,019 Mtons CO_{2eq} in 2030 and 838 Mtons CO_{2eq} in 2050.

The Baseline scenario results are closely aligned to those of the EU Reference scenario 2020.

Figure 15 Reduction of Tank-to-Wheel CO2 emissions by transport segment in the EU27 between 2015 and 2050 in the Baseline scenario



Source: PRIMES model, E3Modelling

3. METHODOLOGICAL APPROACH FOR MODELLING POLICY OPTIONS

In Policy Option 1 the shares of renewable and low carbon fuels ‘in navigation’ by 2030 and 2050 have been set in a consistent way with the analysis underpinning the MIX scenario of the 2030 Climate Target Plan and the Sustainable and Smart Mobility Strategy. This ensures consistency with the available fuel production capacity in the EU and reflects the expected levels of demand from other energy and transport sectors. It ensures that the feedstock for the production of biofuels and bio-LNG is sufficient for satisfying the demand from all sectors, including the maritime sector, by 2030 and 2050. It also ensures that sufficient production capacities are in place for ensuring the demand for e-fuels.

The evolution of the overall share of renewable and low carbon fuels additionally takes into account the analysis of the on shore power requirements at berth, which was not available at the time of the modelling exercise performed for the impact assessment underpinning the 2030 Climate Target Plan. Electricity used at berth is projected to represent around 1.2% of the total energy mix in 2030 and 1% by 2050 in all policy options, driven by the requirements for on-shore power supply at berth.

Policy Options 2 and 3 have been designed to achieve comparable well-to-wake GHG emissions reductions over time with Policy Option 1, to allow the comparability of costs and benefits. GHG performance of fuels/technologies is assessed on a well-to-wake basis, and is not limited to CO_2, but also includes other GHG such as CH_4 and N_2O emissions. In addition, the well-to-tank emission factors take into account the context of the analysis underpinning the 2030 Climate Target Plan, where the power generation sector is set to achieve decarbonisation by 2050. The fuel mix in Policy Options 2 and 3 have been derived to achieve comparable emissions reductions with those in Policy Option 1. This also ensures consistency with the analysis underpinning the 2030 Climate Target Plan.

In addition, in Policy Option 3 when establishing the ships performance in achieving the yearly target, higher weight is attributed to zero-emission technologies. More specifically, GHG intensity of fuels is derived as the ratio between the GHG emissions and the energy use by type of fuel:

$$GHGIT = \frac{\sum_x GHGI_x \cdot kWh_x}{\sum_x kWh_x \cdot M_x}$$

where:

GHIGIT stands for the maximum limit on the GHG content of energy used by ships;

‘x’ means the fuel and energy types falling within the scope of this initiative;

‘kWh_x’ means the total energy use of fuel ‘x’ expressed in kWh;

‘$GHGi_x$’ is the GHG intensity of fuel or energy ‘x’ expressed in gCO_{2eq}/kWh;

‘M_x’ represents the adjustment factor attributed to zero-emission technologies that should stimulate the introduction of zero-emissions energy solutions.

In the modelling, the adjustment factor is derived in such a way that it increases the competitiveness of zero-emission technologies (i.e. e-fuels, hydrogen, electricity used in electric vessels) relative to that of advanced biofuels, when deciding in an endogenous way the contribution of the various technologies/fuels for achieving the GHG intensity targets in PO3. The cost competitiveness is measured in €/tCO_2 mitigated (the numerator reflects the additional cost of each pathway relative to the fossil fuel counterpart and the denominator the respective CO_2 mitigated). In particular for hydrogen and electricity, the cost competitiveness numerator also includes the additional capital costs related to the hydrogen fuel cell and electric vessels compared to the internal combustion engine ones. Modelling results show that an adjustment factor of 1.5 would be needed for the uptake of synthetic liquids (in the 2030-2040 time horizon), while in the case of electric and fuel cell vessels, adjustment factors in the order of 3-4 are necessary. It should however be noted that these adjustment factors would also depend on the actual evolution of the costs of zero-emission technologies over time (RLF costs and capital costs). In addition, other measures like the ETS for the maritime sector may also have an impact on the cost competitiveness of the zero-emission technologies.

In terms of time horizon, the assessment has been undertaken for the 2025-2050 period (in five-year steps). The measures that are part of all policy options are assumed to start being implemented from 2025 onwards.

The price projections of the renewable and low carbon fuels are fully embedded in the 2030 Climate Target Plan policy context, where the EU economy is moving towards carbon neutrality by 2050. This leads to strong competition for biomass feedstock with other energy and transport sectors. Feedstock and renewable electricity are considered to be sourced predominantly in the EU, in order to support the reduction in energy dependence. The projected prices of the renewable and low carbon fuels used in the international maritime sector for the purpose of this analysis are provided in Table 30.

Table 30 Projected prices of the renewable and low carbon fuels used in the international maritime sector

Fuel prices (€/toe)	**2030**	**2050**
liquid fossil fuels	627	861
LNG	608	715
biofuels	1301	1252
bio-LNG	868	978
e-liquids	2285	1658
e-gas	2220	1238
electricity	1698	1665
liquid hydrogen		1467
ammonia		1467

Source: PRIMES model, E3Modelling

The price of biofuels used in international maritime remains relatively stable between 2030 and 2050. Biofuels comprise of bioheavy and biodiesel and the price is weighted based on the relative shares of the biofuel quantities.[191]

This assessment takes into account the current knowledge related to the possible evolution of technology costs and feedstock costs. If higher decrease in the costs of e-fuels would take place than assumed in this assessment, their uptake could be higher especially in PO2 and PO3 due to their increased competitiveness relative to biofuels and bio-LNG. This is

191 With respect to costs, the production costs of biofuels used in international maritime are lower compared to biofuel production costs used in other transport modes like aviation (by about 35% in 2030 and 25% in 2050, respectively). One explanation lies within the technology portfolio, that for international maritime biofuels is broader than that of biokerosene, which includes only ASTM certified technologies. For international maritime, technologies such as hydrothermal liquefaction and upgrading are deployed which display lower production costs than, for instance, the Alcohol-to-Jet route. Secondly, fungible biodiesel and bioheavy are also used by sectors other than maritime, and therefore technologies are deployed driven by a broader demand than that of international maritime. The model exploits the learning-by-doing effects driven by the combined fuel deployment across all sectors, the benefits of which are indicated by lower capital and fixed costs, compared to the biokerosene routes.

because PO2 and PO3 provides flexibility in terms of choice of the fuel mix. On the other hand, if the availability of biofuels and bio-LNG for the maritime sector would be lower, due to higher demand by other sectors, a higher share of e-fuels would be needed to compensate for achieving the mandates in PO2 and PO3. In case the technology costs and feedstock costs would be higher than assumed in this assessment, this may results in higher fuel costs and subsequently freight rates.

In modelling, the assumption was made that the RFNBOs only can fulfil the maritime e-fuels and hydrogen obligations in 2030 and afterwards, which is in line with the Renewable Energy Directive currently in force. Low-carbon electricity for production of e-fuels could be considered in line with Energy System Integration Strategy. This may have impacts on some modelling results.

The well-to-wake emission factors used in this impact assessment are provided in Table 31.

Table 31 Well-to-wake emission factors for fossil fuels and biofuels used in the analysis

Well-to-wake emission factors (gCO2eq/MJ)	**2030**	**2050**
Fossil fuels		
Diesel	88.4	88.4
Fuel oil	86.1	86.1
Natural gas	75.1	75.1
Biofuels		
Biodiesel	26.3	26.3
Bioheavy	26.3	26.3
Biomethane	9.6	9.1

Source: PRIMES model, E3Modelling

4. IMPACT ON BIOMASS FEEDSTOCK AND RENEWABLE ELECTRICITY NEEDS

Biofuels supplied to international maritime include biodiesel and bio-HFO. Bio-LNG is also included. Biofuels and bio-LNG are further classified into Annex IX Part A and Part B, depending to the type of feedstock used for their production in line with the definitions of Directive (EU) 2018/2001 Annex IX. Synthetic liquids refer to e-ammonia, e-methanol, synthetic diesel, synthetic fuel oil and clean gas.

The volume and share of deployed biofuel and bio-LNG production pathways draw on the MIX scenario projections context of the PRIMES Biomass supply model, underpinning the analysis accompanying the 2030 Climate Target Plan. Results are presented for EU27, for 2030 and 2050.

Biofuels and bio-LNG consumption

Biofuels and bio-LNG consumption, together, is projected to increase almost by a factor of 10 between 2030 and 2050, from around 3 Mtoe in 2030 up to 32 Mtoe in 2050. The highest supply is projected in PO2 (close to 32 Mtoe) and the lowest in PO1 (around 26 Mtoe) with PO3 falling in between (28 Mtoe). In their vast majority, Annex IX Part A (advanced biofuels and bio-LNG) would be supplied to the maritime sector (more than three-quarters of supply to the maritime sector in 2030 and 90% in 2050, similarly across policy options). Annex IX Part B biofuels would cover the remainder of the biofuel demand. Notably, biofuels imports for the maritime sector are projected to account for around 1.5% in 2030 to 4% in 2050 of the total biofuel demand in the sector. These would be biodiesel imports that are assumed to be exclusively Part B biofuels. This can be regarded as a conservative assumption as Part A biofuels may also be imported instead.

Table 32 Share of biofuels and bio-LNG consumption by type of feedstock (Annex IX Part A and Part B)

Biofuels and bio-LNG consumption share (%)	**PO1**		**PO2**		**PO3**	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**
Part A	77%	90%	76%	90%	77%	90%
Part B	23%	10%	24%	10%	23%	10%
imports (as part of total)	1.5%	3.8%	1.5%	3.7%	1.5%	3.8%

Source: PRIMES Biomass model, E3Modelling

Biomass feedstock consumption

Annex IX Part A type of feedstock (i.e. mainly lignocellulosic biomass) would represent more than 90% of feedstock used for maritime biofuel and bio-LNG production in EU27 by 2030, and almost 99% by 2050, whilst the remainder would be Part B types of feedstock (mainly waste lipids such as used cooking oils). These shares do not consider the feedstock used outside the EU to produce the imported quantities of biofuels. It should also be noted that the conversion efficiency of Part B feedstock to Part B biofuels is higher than that of Part A feedstock to Part A biofuels and bio-LNG, thereby explaining the lower share of Part A biofuels in terms of final product (i.e. 90% in 2050) when compared to their share in terms of feedstock (i.e. 98.5% in 2050).

Table 33 Biomass feedstock consumption by type of feedstock (Annex IX Part A and Part B)

Feedstock consumption share %	**PO1**		**PO2**		**PO3**	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**
Part A	92.1%	98.5%	92.0%	98.4%	92.0%	98.4%
Part B	7.9%	1.5%	8.0%	1.6%	8.0%	1.6%

Source: PRIMES Biomass model, E3Modelling

By 2030, the vast majority of the feedstock used is projected to originate from forestry and from biomass waste flows, whether agricultural residues, wood waste or manure. By 2050, energy crops and notably dedicated energy crops (annual lignocellulosic crops) provide more than one-third of the feedstock required to produce Part A biofuels. Substantial growth is also projected in agricultural residues used for biofuels production in international maritime that increase by more than a factor of 10 between 2030 and 2050.

Table 34 Biomass feedstock consumption by type (in Mtonnes)

Feedstock consumption	**PO1**		**PO2**		**PO3**	
Mtonnes	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
Part A						

Perennial crops	0.0	6.3	0.0	7.7	0.0	6.9
Annual crops	0.3	33.6	0.3	40.8	0.3	36.4
Forestry products	3.1	14.4	3.2	18.4	3.1	15.9
Forestry residues	1.4	11.7	1.5	14.7	1.5	12.8
Wood waste	1.8	6.7	1.8	8.0	1.8	7.2
Agricultural residues	1.5	15.4	1.5	18.6	1.5	16.8
Manure	1.2	2.8	1.2	3.3	1.2	3.0
Part B						
Non-agricultural oils	0.80	1.4	0.83	1.8	0.82	1.6

Source: PRIMES Biomass model, E3Modelling

Model projections show that EU has sufficient biomass available domestically to produce biofuels and bio-LNG for EU international maritime sector. By 2030, there is sufficient supply of waste lipids (non-agricultural oils, such as used cooking oil), as the demand from international maritime requires about 20% of the feedstock available in the EU. The remaining feedstock is consumed in other transport sectors such as road transport and aviation. By 2050, the need for waste lipids to produce Part B biofuels for international maritime increases, and as a result the sector requires higher shares of the available feedstock. Part A biofuels from lignocellulosic feedstock consume 6 to 20% of the available feedstock potential in the EU by 2050, depending on the type of feedstock and policy option. Manure used for bio-LNG for international maritime increases from around 2% in 2030 to 5-6% in 2050.

Table 35 Used potential for the EU maritime sector as % of domestic potential in EU27

Used potential	**POA**		**POB**		**POC**	
(% of domestic potential in the EU27)	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
Part A						
Perennial crops	0.2%	10.9%	0.2%	13.3%	0.2%	11.8%
Annual crops	0.2%	10.6%	0.2%	12.8%	0.2%	11.4%
Forestry products	2.8%	15.4%	2.9%	19.7%	2.9%	16.9%
Forestry residues	2.3%	15.9%	2.4%	20.0%	2.3%	17.4%
Wood waste	1.7%	6.4%	1.8%	7.7%	1.8%	6.9%
Agricultural residues	1.4%	16.1%	1.5%	19.4%	1.5%	17.5%
Manure	2.4%	5.3%	2.4%	6.4%	2.4%	5.8%
Part B						
Non-agricultural oils	20.6%	27.4%	21.3%	34.4%	21.1%	29.9%

Source: PRIMES Biomass model, E3Modelling

E-fuels

E-fuels include e-ammonia, e-methanol, synthetic diesel, synthetic fuel oil and e-gas. The electricity to produce e-fuels is projected to be the highest in PO1 (almost 2 TWh in 2030 and 246 TWh in 2050). This would represent around 0.1% of renewable electricity generation in 2030 and 4.7% by 2050. In PO3 the electricity to produce e-fuels is projected at around 0.6 TWh in 2030 and 230 by 2050 (i.e. less than 0.1% of renewable electricity generation in 2030 and 4.4% in 2050). PO2 shows the lowest share of e-fuels in the energy mix and thus the lowest electricity needs to produce them (0.1 TWh in 2030 and 198 TWh in 2050). The electricity is primarily used to produce synthetic diesel blends and e-gas.

Table 36 Electricity consumption for producing e-fuels for the maritime sector (in TWh and %)

Electricity consumption for synthetic fuels (TWh and %)	PO1		PO2		PO3	
	2030	2050	2030	2050	2030	2050
Electricity consumption, TWh	1.8	246	0.1	198	0.59	230
Share of gross electricity generation, %	0.0%	2.0%	0.0%	1.6%	0.0%	1.9%
Share of renewable electricity generation, %	0.1%	4.7%	0.0%	3.8%	0.0%	4.4%

Source: PRIMES model, E3Modelling

5. METHODOLOGICAL APPROACH FOR REGULATORY AND ADMINISTRATIVE COSTS RELATED TO BUSINESSES, AND FOR ENFORCEMENT COSTS

Regulatory and administrative costs

Administrative costs for ship-owners are estimated based on the fact that each vessel would have to comply with the following information obligations:

- *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 builds on the EU MRV Monitoring plan and includes additional emissions as well as energy sources. To model the worst-case scenario, same assumptions could be used as in the EU MRV Impact Assessment[192] for the preparation of the entire Monitoring plan (i.e. 40 hours per ship). This will lead to total annual administrative costs of around €18.9 million (40 hours * 12,114 ships * €39.1 labour costs per hour). Based on the experience with the implementation of EU MRV Regulation, it is likely that such cost would be the highest in the first year and significantly decrease afterwards.

  Annual energy report: The annual energy report is the calculation of the annual energy consumption of the vessel, broken down to different energy sources/types of fuel and to navigation and at berth. This report builds on the EU MRV Emission report, but is more extensive as well-to-tank, non-CO_2 emissions and OPS/electricity consumption are included as well. The question on the corresponding administrative cost has been asked in the targeted survey, where 8 out of 9 respondents indicated that for ship owners, the reporting time would increase by two hours at most, per voyage. However, it could not be verified to what extent such reply may already include the existing requirements of EU MRV Regulation (i.e. part of the baseline) or whether only additional elements are included.

  It can be therefore assumed that specific information on the use of OPS is already included in such reporting (as they would, at least partly, replace the fuel use currently

[192] 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

reported at berth), based on information supplied by the electricity supplier (i.e. electricity bills). This is similar for the use of THETIS-MRV system, which the ship owners and operators are already using and the adaptation of which will necessitate incremental familiarisation cost (however it is not expected that a new account would need to be created by the system users for the purpose of this initiative).

To model the worst case cost-scenario, and assuming that indeed the reported 2 hours would be truly additional, the total annual administrative costs in the policy options relative to the baseline are derived by multiplying the addition time spent for the annual energy report (i.e. 2 hours) by the number of voyages per year and by the labour costs per hour. This amount is also comparable with the preparation of the EU MRV Emission report, as estimated in the EU MRV Impact assessment (i.e. 40 hours per ship). The assumptions used for estimating the annual costs are provided in Table 37. The evolution of the total number of voyages per year for each policy option is linked to the evolution of transport activity, drawing on the PRIMES model results.

- *Proof of compliance:* Each ship has to carry a document of compliance and cooperate during Port State Control inspections. The first requirement will not impose any additional administrative costs, as the document is supplied by the Recognized Organisation, and thus only has to be stored. As regards cooperation during Port State Control Inspections, the only action needed is to retrieve the document of compliance and show it to the inspector. The additional administrative costs of this will be a maximum of 15 minutes per inspected ship. Assuming that each ship that falls under the scope of the initiative will be inspected every year, the maximum amount of annual administrative costs are approximately €75,000 per year (which is the upper bound based on a conservative assumption that each vessel currently under EU MRV Regulation is inspected every year). The assumptions used for estimating the annual costs are provided in Table 37.

- The administrative costs incurred by operators will also cover the *training needs* to ensure the safe switch to RLF on-board ships. Furthermore it is assumed that training for renewable and low carbon fuels will become standard in training programs for new seafarers in 2035. This means that only the ships which switch to RLF before 2035 would need to invest in additional training. The costs would be spread over the period 2025-2035 and are calculated assuming 3 days of training of 8 hours each. Their evolution over time is linked to the share of RLF in each policy option. The assumptions used for estimating the annual costs are provided in Table 37.

Administrative cost for bunker suppliers will primarily consist of certification of fuel and upstream emissions/sustainability criteria. The certification requirements will build on existing provisions and sustainability criteria in the Renewable Energy Directive (RED). Fuel producers already have experience with certification of biofuels under RED. When a new (bio)fuel needs to be certified, for instance under the International Sustainability &

Carbon Certification (ISCC) Scheme, the entire supply chain has to be certified. This means that either all supplier and other stakeholders need to cooperate in the certification, or are already ISCC certified themselves. Certification schemes mostly have one-time registration fees that vary between €50 and €500, so these are one-off costs. 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. It has not been possible to estimate how many certification schemes would be established or what the exact impact of certifying upstream emissions would be (several fuel producers have been interviewed, but none were able to make an estimate of the effort needed for certification). However, based on the illustrative costs listed above, it can be assumed that the overall certification costs will not have significant impact on the price of alternative fuels.

Administrative costs for ports are much more modest and related to the publication of guidelines and the revision of ports regulations to cover the safe handling, bunkering and use of RLF. It is also expected that not all ports will be affected by a significant increase in new safety guidelines. In the analysis, 34% of the EU ports were assumed affected by the policy intervention. The new guidelines would have to be established for six fuel categories (e.g. bio-LNG, e-liquids, e-gas, hydrogen, ammonia and methanol) in the 160 medium and large sized ports (470 ports x 34%) in Europe. The total annual administrative costs would be spread over 25 years and be derived by multiplying the number of additional hours by the labour costs per hour and the number of ports affected. The assumptions used for estimating the annual costs are provided in Table 37.

Enforcement costs

As the reporting and verification system is similar in all options, the annual verification costs are similar for all policy options. They are calculated by assuming in a conservative way that 5 additional hours would be needed to verify the additional elements in both the annual energy report as well as the energy compliance plan relative to the baseline.[193] The additional number of hours are multiplied with the labour costs and the number of vessels subject to the initiative. The assumptions used for estimating the annual costs are provided in Table 37. The evolution of the total number of ships for each policy option is linked to the evolution of the stock of vessels, drawing on the PRIMES-TREMOVE model results.

On the side of the public administrations, a Port State Control Officer will have to determine whether the Document of Compliance is on board (similar assumption as above is made of 15 minutes per inspection and the cost of €75,000 on an annual basis, which is the upper bound based on a conservative assumption that each vessel currently under EU

[193] According to the IA on the revision of the EU MRV Regulation, p. 51 (overview of administrative burden), verification costs turned out to be significantly lower than estimated in the 2013 EU MRV impact assessment: https://ec.europa.eu/clima/sites/clima/files/transport/shipping/docs/swd_2019_10_en.pdf

MRV Regulation is inspected every year). At the same time, it is proposed to allow for the use of electronic certificates, which can remove the need for a physical check in its entirety.

Furthermore, additional one-off cost for adapting the EU MRV IT system (THETIS-MRV) should be foreseen for the EU budget to accommodate the additional information as well as additional functionalities related to the RLF obligations. In addition, a new module in THETIS-EU should support port state control officers as well as EU flag state inspectors in their work. Based on the cost of THETIS-MRV[194] and experience with existing THETIS-EU modules support various pieces of EU legislation, such IT-developments cost are estimated at €300,000. For PO3, an additional tool would need to be developed to support the tool to trace, and when necessary balance over- or under-compliance. This tool is estimated to cost €200,000.

Table 37 summarises the input used for quantifying the regulatory, administrative and enforcement costs.

Table 37 Input assumptions for quantifying the regulatory, administrative and enforcement costs

Information obligation	**Administrative action**	**Frequency (per year)**	**Time (hours)**	**Tariff (per hour)**	**Number of entities**	**Entities affected per policy option**
		(1)	(2)	(3)	(4)	(5)
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[195]	39.1[196]	Vessels under EU MRV Regulation: 12,114 (in 2019); linked to the evolution of the stock of vessels in the policy options	PO1, PO2, PO3: 100%
Annual energy report	Collecting additional information (per voyage)	1	2	24.5	Number of voyages under EU MRV Regulation: 317,900 (in 2019); linked	PO1, PO2, PO3: 100%

[194] Source: EMSA 2020

[195] 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

[196] Eurostat (LC_LCI_LEV) Labour costs index EU27, Professional, scientific and technical activities (M)

Information obligation	Administrative action	Frequency (per year)	Time (hours)	Tariff (per hour)	Number of entities	Entities affected per policy option
					to the evolution of transport activity over time in the policy options	
Proof of compliance	Cooperate during PSC inspection	1	0.25	24.5[197]	Vessels under EU MRV Regulation: 12,114 (in 2019)[198]	PO1, PO2, PO3: 100%[199]
Safety procedures	Crew training	4.5[200] (to spread costs over 10 years)	24[201]	24.5 (wages) + 50 (fee)	Vessels under EU MRV Regulation: 12,114 (in 2019); linked to the evolution of the stock of vessels in the policy options	PO1, PO2, PO3: linked to the uptake of RLF in each option
Administrative costs for port authorities						
Guidelines in ports	Set up guidelines in ports	0.18[202] (to spread costs over 25 years)	160	28.1	Number of ports in the EU: 470[203]	PO1, PO2, PO3: 34%[204]
Enforcement costs						

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

198 Upper bound based on a conservative assumption that each vessel currently under EU MRV Regulation is inspected every year.

199 Assuming that each vessels under EU MRV Regulation is inspected every year

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

201 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)

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

203 470 European ports have registered throughput statistics, see section 5.2.4 (impact on ports)

204 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

Information obligation	Administrative action	Frequency (per year)	Time (hours)	Tariff (per hour)	Number of entities	Entities affected per policy option
Annual energy compliance plan	Approve annual energy compliance plan	1	5	39.1[205]	Vessels under EU MRV Regulation: 12,114 (in 2019); linked to the evolution of the stock of vessels in the policy options	PO1, PO2, PO3: 100%
Annual energy report	Verify annual energy report	1	5	39.1	Vessels under EU MRV Regulation: 12,114 (in 2019); linked to the evolution of the stock of vessles in the policy options	PO1, PO2, PO3: 100%
Proof of compliance	Additional time during audits/inspections	1	0.25	39.1	Vessels under EU MRV Regulation: 12,114 (in 2019) [206]	PO1, PO2, PO3: *Unknown* % of vessels inspected that fall under scope of EU-MRV regulation

6. METHODOLOGICAL APPROACH FOR PORT INVESTMENTS

The estimated investment costs on hydrogen and OPS installations should be taken as indicative of the scale of investments expected by ports under the conditions of the policy options. The large variations in energy demands by maritime vessels (type, size) as well as the geographical and operational conditions of the ports (port layout, existence of sufficient energy link to the grid, etc) limit the level of accuracy. The underlying assumptions are coherent with real life examples and thus have value in providing a general estimate.

[205] Eurostat (LC_LCI_LEV) Labour costs index EU27, Professional, scientific and technical activities (M)
[206] Upper bound based on a conservative assumption that each vessel currently under EU MRV Regulation is inspected every year.

Hydrogen installations

The estimation is based on the range of identified investments between €35 million to more than €100 million[207]. Given the size of the investments needed, it is assumed that only the 25 largest cargo ports will undertake such investments. The highest range is used in the estimation.

OPS installations

The estimation is based on calculations by EMSA on the average power demand needs at berth. SafeSeaNet data on number of individual ships at ports have been used, and a multiplying factor has been used to calculate the effective power average and peak demand per ship at berth based on existing literature[208]. The demand has been calculated for ports in the TEN-T network, with at least one vessel above 5000 GT at berth in 2019. Even though traffic volumes are expected to increase in the following years, the number of port calls is assumed to remain relatively stable, as vessel capacity is expected to increase. This is in line with the considerations of the estimates for the European Maritime Single Window environment[209]. The energy investment needed is estimated at: 262MW for container, 2084MW for ro-pax and 3297MW for cruise vessels.

The architecture of OPS installations is characterized by a variety of port-specific elements that dictate the final figure for capital cost. The specific port spatial layout, number of berths to be provided with shore power connections, individual terminal characteristics, power demand, ship types calling the port, frequency conversion and cable management system options are amongst the most relevant drivers for OPS configuration and, therefore, affecting directly investment cost. Indicative values are used for the cost of investing in OPS infrastructure per each type of vessel (€1.0m/MW for containerships, €1.2m/MW for ro-pax and €1.5m/MW for cruise vessels), using publicly available studies[210].

Baseline estimation

With regard to the baseline investments, EAFO[211] , provides an overview of the OPS installations in Europe. According to this information, maritime ports in the EU have installed more than 90MW of power capacity for container, ro-pax and cruise vessels since 2000. The introduced capacity varies per year, between zero and approximately 18MW.

[207] Source: North Sea Port (2020), https://en.northseaport.com/volth2-signs-cooperation-agreement-with-north-sea-port-for-the-development-of-a-green-hydrogen-plant. In the absence of proper reference points for the development of infrastructure of hydrogen as marine fuel, this investment bandwidth is estimated on the basis of costs for the deployment of hydrogen plants in ports.

[208] Shore Power Technology Assessment at U.S. Ports, 2017; Energy analysis and costs estimation of an On-shore Power Supply system in the Port of Gävle, 2019

[209] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018SC0181&from=EN

[210] For example: Rotterdam: https://sustainableworldports.org/wp-content/uploads/Port-of-Rotterdam-Onshore-power-supply-let-stay-connected-2010.pdf , North and Baltic ports: http://www.greencruiseport.eu/files/public/download/studies/Opportunities%20and%20Limitations%20for%20Connecting%20Cruise%20Vessels%20to%20Shore%20Power_04.01.2018_Bergen.pdf , Malta: https://electromobility.gov.mt/en/Documents/PORT-PVEV%20Feasibility%20Study.pdf , Hamburg: https://www.hamburg.de/contentblob/3613158/9dbe23fb1cbaf9bcaac9969d7550f4a1/data/landstrom-untersuchung-2012.pdf

[211] https://www.eafo.eu/shipping-transport/port-infrastructure/ops/data

There is also a steady increase with some 20MW being installed between 2006 and 2010, 30MW between 2011 and 2015 and 39MW between 2016 and 2020. Given the above, it can be expected that EU ports will continue to bring OPS capacity in service in the following years. In the absence of other indications, it is assumed that 10MW of OPS power capacity will be introduced each year until between 2025 and 2050. Baseline investment costs are estimated at €0.3 bn.

7. Methodological approach and results of the risk of carbon leakage analysis

The potential for ships re-routing to reduce the amount of traffic that falls in scope of the initiative is analysed by comparing the situation without re-routing in 2030 (i.e. direct link from port A to port B, where port A is non-EU/EEA port and Port B is a EU/EEA port) with the situation including an intermediate stop to a non-EU/EEA port (port C) closer (or the closest) to the EU/EEA port (port B). The analysis takes into account the costs by ship type along different routes. The analysis has been performed with the TRUST model by TRT for PO1 and PO3 (PO2 was assumed to likely react similarly to PO2 as their design is similar).

Cost types

The analysis considers the costs incurred by ships from the origin port (port A) to the destination port (port B). In case of a direct route (no leakage case) between port A and port B these costs include:

- Costs at port A: the costs for the ports' call (i.e. port dues, pilotage, towage, mooring, other costs) and the cost of operation time at port.
- Fuel costs from port A to port B: in this case the whole navigation shall be performed with the mix of RLFs required, having a higher cost than the conventional maritime fuels.
- Other navigation costs from port A to port B: these are the costs for the operation of the ship covered by the ships' time charter rates[212].
- Costs at port B: these costs include the costs for the ports' call (i.e. port dues, pilotage, towage, mooring, other costs) the cost of waiting time to access the port and the cost of operation time at port.

In case of an intermediate stop (leakage case) the costs include:

- Costs at port A: these costs are the same as in the case of a direct route.
- Fuel costs from port A to port C: This leg of the trip is assumed to be performed with conventional maritime fuels as it falls outside the scope of the policy measure (leg between two non-EU/EEA ports).

[212] Time Charter Rates cover ship operating costs such as crewing, lubricants, planned maintenance, insurance and general administration expenses.

- Other navigation costs from port A to port C: these costs are the same as in the case of a direct route.
- Costs at port C: These costs include the costs for the ports' call (i.e. port dues, pilotage, towage, mooring, other costs) the cost of waiting time to access the port and the cost of operation time at port.
- Fuel costs from port C to port B: This leg of the trip is assumed to be performed with RLFs as it falls within the scope of the policy measure.
- Other navigation costs from port C to port B: these costs are the same as in the case of a direct route.
- Costs at port B: these costs are the same as in the case of a direct route.

Ship types

The analysis covers three freight ship types of the most relevant ship categories operating in the scope of the initiative:

- Bulk carriers which represent respectively 32% of all ships and 37% of the total fleet deadweight falling into the scope of the initiative.
- Container ships representing 15% of all ships and 18% of the total fleet deadweight.
- Oil tankers representing 15% of all ships and 18% of the total fleet deadweight.

Route types

The analysis covers different routes and potential intermediate stops for the above mentioned different ship types[213]. These are presented in Table 38, Table 39, and Table 40.

Table 38: Routes and ship types considered for container ships

Origin region	**Origin port**	**Destination region**	**Destination port**	**Ship size [TEU]**	**Port of intermediate stop**
China	Shanghai	North Europe	Antwerp Rotterdam Hamburg	14,000 21,000	Port Said (Egypt) Mersin (Turkey) Tangier (Morocco) Felixstowe (UK)
China	Shanghai	Mediterranean	Genoa Marseille Barcelona	14,000	Port Said (Egypt) Mersin (Turkey)
US East coast	New York Savannah	North Europe	Antwerp Rotterdam Hamburg	12,000	Felixstowe (UK)
US East coast	New York Savannah	Mediterranean	Genoa Marseille Barcelona	8,000	Tangier (Morocco)
South America	Santos	North Europe	Antwerp Rotterdam Hamburg	4,000	Felixstowe (UK)
South America	Santos	Mediterranean	Genoa	4,500	Tangier (Morocco)

[213] The routes were selected among those more likely providing an advantage of leakage. With respect to EU ports and concerned maritime areas this is deemed significant in the Mediterranean area for ships sailing through Suez Canal and through the Gibraltar straits, and in the Northern Europe for ships arriving for the Atlantic Ocean. Routes in other areas have not been considered: for example, routes calling at Baltic ports are normally stopping earlier in other EU ports and the relative advantage gained by introducing a stop in an extra EU port such as a Russian port would bring a very limited advantage.

Origin region	Origin port	Destination region	Destination port	Ship size [TEU]	Port of intermediate stop
			Marseille Barcelona		
US West Coast	Long Beach	North Europe	Antwerp Rotterdam Hamburg	4,000	Felixstowe (UK)
US West Coast	Long Beach	Mediterranean	Genoa Marseille Barcelona	4,500	Tangier (Morocco)

Source: TRUST model, TRT

Table 39: Routes and ship types considered for dry bulk ships

Origin region	Origin port	Destination region	Destination port	Ship size [DWT] - Goods	Port of intermediate stop
US East coast	New Orleans	North Europe	Antwerp Rotterdam Hamburg	65,000-grain 35,000-grain	Grimsby (UK)
US East coast	New Orleans	Mediterranean	Marseille Livorno Naples	35,000-grain 28,000-grain	Oran (Algeria)
US East coast	New Orleans	Mediterranean	Taranto	70,000-coal	Oran (Algeria)
South America	Santos	North Europe	Antwerp Rotterdam Hamburg	65,000-grain 35,000-grain	Grimsby (UK)
South America	Santos	Mediterranean	Marseille Livorno Naples	35,000-grain 28,000-grain	Oran (Algeria)
South America	Tubarao	North Europe	Rotterdam Hamburg	200,000-iron ore 300,000-iron ore	Grimsby (UK)
South America	Ponta Da Madeira	North Europe	Rotterdam Hamburg	165,000-coal	Grimsby (UK)
South America	Ponta Da Madeira	Mediterranean	Taranto	200,000-iron ore	Oran (Algeria)

Source: TRUST model, TRT

Table 40: Routes and ship types considered for liquid bulk ships

Origin region	Origin port	Destination region	Destination port	Ship size [DWT] - Goods	Port of intermediate stop
US Gulf	Corpus Christi	North Europe	Antwerp Rotterdam	70,000-dirty products-crude oil 130,000-dirty products	Milford Haven (UK)
West Africa	Lagos	North Europe	Antwerp Rotterdam	135,000-dirty products	Jorf-Lasfar (Morocco) Medway (UK)
Arabian Gulf	Ju'aymah	North Europe	Antwerp Rotterdam	90,000-clean products	Alexandria (Egypt) Milford Haven (UK)
North Africa	Arzew	North Europe	Antwerp Rotterdam	80,000	Medway (UK)
US Gulf	Corpus Christi	Mediterranean	Augusta Cartagena Agioi Theodoroi	70,000-dirty products-crude oil 130,000-dirty products	Jorf-Lasfar (Morocco)
West Africa	Lagos	Mediterranean	Savona Cartagena Leixoes	130,000-dirty products	Jorf-Lasfar (Morocco)

Origin region	Origin port	Destination region	Destination port	Ship size [DWT] - Goods	Port of intermediate stop
Arabian Gulf	Ju'aymah	Mediterranean	Savona Cartagena Leixoes	90,000-clean products	Alexandria (Egypt)

Source: TRUST model, TRT

Underlying assumptions

The approach described above implies the following underlying assumptions:

- The analysis considers 'ship' costs and not 'cargo' costs (i.e. cargo handling costs are not considered);
- The analysis considers (i) the existing costs for ports and charter rates, which are assumed to be kept constant over time in real terms, and (ii) assumptions on maritime gas oil fuel costs for 2030 for both conventional and blended fuel as estimated by PRIMES model.
- Consistently with PRIMES projections, fuel efficiency is the same in the case of blended maritime gas oil and conventional maritime gas oil.
- The 'value of time' for ports' operation and waiting times is derived from ships' time charter rate.
- Ports' costs used in the analysis are average values of the TRUST model and are not representative of specific cases (i.e. port / ship size / cargo).
- In case of re-routing to reduce the amount of traffic that falls in scope of the initiative, the cargo continues to be carried on the same vessel (and not distributed to smaller vessels at intermediate port) and the port of destination is preserved (i.e. the cargo is not delivered to multiple EU/EEA ports instead).

Speed: The following speeds have been considered for the different ship types: containers - 14 knots; dry bulkers and tankers - 11 knots. These speeds are in line with those indicated in the 2019 Annual Report on CO_2 Emissions from Maritime Transport[214] for the above mentioned ship types.

Time at ports: Given the lack of specific information at individual ports, the following average values of the TRUST model are considered: waiting time (time to access the port) at intermediate and destination ports is 10 hours; operation time (time to load/unload cargo) at all ports is 24 hours.

Fuel consumption: Table 41 lists the fuel consumption factors, expressed in tonnes of fuel per day used in the TRUST model.

Table 41: Fuel consumption factors by speed and ship type

Ship type	Ship size	Speed [knots]	Fuel consumption [Tonnes/day]
Container	21,000 TEU	14	126
	18,000 TEU	14	112
	14,000 TEU	14	94
	12,000 TEU	14	76
	8,000 TEU	14	49

[214] SWD(2020) 82 final

Ship type	Ship size	Speed [knots]	Fuel consumption [Tonnes/day]
	4,500 TEU	14	31
	4,000 TEU	14	31
Dry bulker	28,000 DWT	11	12
	35,000 DWT	11	16
	65,000 DWT	11	23
	70,000 DWT	11	23
	165,000 DWT	11	31
	200,000 DWT	11	32
	300,000 DWT	11	38
Liquid bulker	70,000 DWT	11	24
	80,000 DWT	11	24
	90,000 DWT	11	25
	130,000 DWT	11	30
	135,000 DWT	11	30

Source: TRUST model, TRT

Fuel cost: the cost in 2030 of conventional MGO is assumed at €906 per tonne in both PO1 and PO3. This is an average of the costs estimated by PRIMES at country level for EU27 Member States and United Kingdom. Consistently with PRIMES projections, the cost of blended MGO in PO1 is assumed at € 971 per tonne (i.e. 7.2% higher than the cost of conventional MGO) in 2030. In PO3 the cost for blended MGO in 2030 is € 970 per tonne (i.e. 7.1% higher than the cost of conventional MGO).[215]

Time charter rates: TRUST values for Time Charter Rates (expressed in $/day) are based on data provided by Drewry's publication 'Shipping Insight' (December 2019). Interpolation on published data was performed to fill in data gaps for missing ship sizes. Time Charter Rates cover ship operating costs such as crewing, lubricants, planned maintenance, insurance and general administration expenses. These values are used to compute other navigation costs and the cost of time at ports (waiting and operation).

Table 42: Time charter rates by ship type

Ship type	Ship size	Time charter rates [€/day]
Container	21,000 TEU	39,000
	18,000 TEU	34,000
	14,000 TEU	28,000
	12,000 TEU	25,000
	8,000 TEU	20,000
	4,500 TEU	13,800
	4,000 TEU	8,700
Dry bulker	28,000 DWT	7,055
	35,000 DWT	7,400
	65,000 DWT	9,430
	70,000 DWT	9,650
	165,000 DWT	14,260
	200,000 DWT	15,960
	300,000 DWT	20,815
Liquid bulker	70,000 DWT	13,600
	80,000 DWT	15,300
	90,000 DWT	18,020
	130,000 DWT	24,650
	135,000 DWT	25,500

215 It is worth to consider that the price of maritime fuel is quite variable over time and fluctuations of prices over one year might be higher than the estimated increase in fuel cost due to the analysed policy options.

Source: TRUST model, TRT

Costs at ports: The costs incurred by ships at ports (i.e. port dues, pilotage, towage, mooring, other costs) depend on the type and size of the ship and on the type of cargo. These costs are highly variable from case to case as they may be dependent on commercial agreements between the port terminals / port authorities and the ship owners / shippers. Given its commercial sensitivity, this kind of information is hardly disclosed by maritime operators and very little evidence on these costs exist in literature.

As part of this analysis an attempt to collect specific information on the costs of some non-EU/EEA ports was performed. A dedicated questionnaire covering different cost types by type of ship was sent to all ports' authorities/operators considered in this analysis. Unfortunately, the survey response rate was extremely low and very little evidence was collected.

Ports' costs used for the calculations (expressed in € per DWT) are therefore not representative of the specific case (i.e. port / ship size / cargo), but are the average values of the TRUST model estimated by TRT on the basis of in-house data.

Table 43: Cost at ports by ship type

Ship type	Ship size	Cost of ship at ports [€/DWT]
Container	21,000 TEU (198,500 DWT)	0.720
	18,000 TEU (185,200 DWT)	0.730
	14,000 TEU (165,500DWT)	0.740
	12,000 TEU (153,500 DWT)	0.748
	8,000 TEU (105,450 DWT)	0.953
	4,500 TEU (60,900 DWT)	0.962
	4,000 TEU (49,200 DWT)	0.964
Dry bulker	28,000 DWT	0.956
	35,000 DWT	0.869
	65,000 DWT	0.882
	70,000 DWT	0.847
	165,000 DWT	0.608
	200,000 DWT	0.612
	300,000 DWT	0.542
Liquid bulker	70,000 DWT	0.876
	80,000 DWT	0.876
	90,000 DWT	0.779
	130,000 DWT	0.719
	135,000 DWT	0.719

Source: TRUST model, TRT

Results for PO1

Analysis for container ship routes

In case of an intermediate stop to a non-EU/EEA port, total travel time increases in the range of 4% to 13% relative to the Baseline in 2030 depending on the routes (i.e. 34 to 63 additional hours relative to the direct route). The lowest relative increases of about 4% apply to the routes from South East Asia (Shanghai) to North Europe (Antwerp, Rotterdam, Hamburg) with an intermediate stop in Egypt (Port Said) (equivalent to 34 hours), Morocco (Tangier) (equivalent to 35 hours) and United Kingdom (Felixstowe) (equivalent to 37 hours). The highest relative increase of 13% occurs for the route from

North America (New York) to North Europe (Antwerp and Rotterdam) with an intermediate stop in United Kingdom (Felixstowe) (equivalent respectively to 39 and 38 hours). The highest absolute increase of 63 hours applies to the route from Shanghai to North Europe (Antwerp, Rotterdam, Hamburg) and to the Mediterranean port of Barcelona with an intermediate stop in Turkey (Mersin). It corresponds to an increase of 8% in total travel time relative to the Baseline.

Increases in sailing time are relatively small and in the range of 0% to 5% relative to the Baseline in 2030, as intermediate ports are conveniently located along the routes and require small detours to be reached, while time at ports increases by 59% due to the additional stop[216].

The analysis of costs shows that for the vast majority of the routes total travel costs increase in the case of an intermediate stop to a non-EU/EEA port. The cost increase ranges from 0.3% for a 21,000 TEU ship travelling from Shanghai to North Europe (Antwerp, Rotterdam, Hamburg) and stopping in Egypt (Port Said) to 9.9% for a 8,000 TEU ship travelling from New York to Barcelona and stopping in Morocco (Tangier). More specifically, for a 21,000 TEU ship travelling from Shanghai to North Europe (Antwerp, Rotterdam, Hamburg), the additional total travel cost ranges from about €14,500 in case of an intermediate stop in Egypt (Port Said) to near € 199,000 in the case of an intermediate stop in Turkey (Mersin).

Total travel costs slightly decrease only for few routes due to the lower fuel costs, as shown in Table 44. This decrease is in the range of 0.1% to 0.8%, depending on the ship type, for the routes from Shanghai to Northern Europe (Antwerp, Rotterdam, Hamburg) with an intermediate stop in Morocco (Tangier) and in United Kingdom (Felixstowe).

Table 44: Container routes with decreasing total travel costs in PO1 relative to the Baseline (% change of travel costs components)

Ship size TEU	Origin Port	Destination Port	Intermediate Port	Fuel cost [%]	Time cost [%]	Ports cost [%]	TOTAL [%]
14,000	Shanghai	Antwerp	Tangier (Morocco)	-5.8%	4.3%	50%	-0.1%
14,000	Shanghai	Rotterdam	Tangier (Morocco)	-5.8%	4.3%	50%	-0.1%
14,000	Shanghai	Hamburg	Tangier (Morocco)	-5.7%	4.2%	50%	-0.1%
14,000	Shanghai	Antwerp	Felixstowe (UK)	-6.1%	4.8%	50%	-0.2%
14,000	Shanghai	Rotterdam	Felixstowe (UK)	-6.2%	4.7%	50%	-0.3%
14,000	Shanghai	Hamburg	Felixstowe (UK)	-6.2%	4.4%	50%	-0.4%
21,000	Shanghai	Antwerp	Tangier (Morocco)	-5.8%	4.3%	50%	-0.5%
21,000	Shanghai	Rotterdam	Tangier (Morocco)	-5.8%	4.3%	50%	-0.5%
21,000	Shanghai	Hamburg	Tangier (Morocco)	-5.7%	4.2%	50%	-0.5%
21,000	Shanghai	Antwerp	Felixstowe (UK)	-6.1%	4.8%	50%	-0.6%
21,000	Shanghai	Rotterdam	Felixstowe (UK)	-6.2%	4.7%	50%	-0.7%
21,000	Shanghai	Hamburg	Felixstowe (UK)	-6.2%	4.4%	50%	-0.8%

Source: TRUST model, TRT

In such cases the total cost saving ranges from a minimum of about € 5,300 for a 14,000 TEU ship stopping in Tangier to a maximum of near € 45,900 for a 21,000 TEU ship stopping in Felixstowe.

[216] Waiting time (time to access the port) at intermediate and destination ports is assumed at 10 hours; operation time (time to load/unload cargo) at all ports is assumed at 24 hours.

Table 45: Container routes with decreasing total travel costs in PO1 relative to the Baseline (change in travel costs components)

Ship size TEU	Origin Port	Destination Port	Intermediate Port	Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]
14,000	Shanghai	Antwerp	Tangier (Morocco)	-166,526	40,417	120,827	-5,282
14,000	Shanghai	Rotterdam	Tangier (Morocco)	-166,526	40,417	120,827	-5,282
14,000	Shanghai	Hamburg	Tangier (Morocco)	-166,526	40,417	120,827	-5,282
14,000	Shanghai	Antwerp	Felixstowe (UK)	-173,975	45,250	120,827	-7,898
14,000	Shanghai	Rotterdam	Felixstowe (UK)	-178,058	44,000	120,827	-13,230
14,000	Shanghai	Hamburg	Felixstowe (UK)	-181,868	42,833	120,827	-18,208
21,000	Shanghai	Antwerp	Tangier (Morocco)	-222,034	56,295	136,955	-28,785
21,000	Shanghai	Rotterdam	Tangier (Morocco)	-222,034	56,295	136,955	-28,785
21,000	Shanghai	Hamburg	Tangier (Morocco)	-222,034	56,295	136,955	-28,785
21,000	Shanghai	Antwerp	Felixstowe (UK)	-231,967	63,027	136,955	-31,985
21,000	Shanghai	Rotterdam	Felixstowe (UK)	-237,410	61,286	136,955	-39,170
21,000	Shanghai	Hamburg	Felixstowe (UK)	-242,491	59,661	136,955	-45,876

Source: TRUST model, TRT

For all the other analysed combinations for ships departing from Shanghai (18 out of 54 total routes analysed) and directed (i) to Northern Europe (Antwerp, Rotterdam, Hamburg) or (ii) to the Mediterranean region (Genova, Marseille, Barcelona) and performing an intermediate stop in Egypt (Port Said) or in Turkey (Mersin), no reduction in total travel costs occurs.

Table 46: Other container routes departing from Shanghai (% change of travel costs components in PO1 relative to the Baseline)

Ship size TEU	Origin Port	Destination Port	Intermediate Port	Fuel cost [%]	Time cost [%]	Ports cost [%]	TOTAL [%]
14,000	Shanghai	Antwerp	Port Said (Egypt)	-4.7%	4.2%	50%	0.7%
14,000	Shanghai	Rotterdam	Port Said (Egypt)	-4.7%	4.2%	50%	0.7%
14,000	Shanghai	Hamburg	Port Said (Egypt)	-4.5%	4.1%	50%	0.7%
14,000	Shanghai	Antwerp	Mersin (Turkey)	-1.1%	7.7%	50%	4.0%
14,000	Shanghai	Rotterdam	Mersin (Turkey)	-1.1%	7.8%	50%	4.0%
14,000	Shanghai	Hamburg	Mersin (Turkey)	-1.0%	7.6%	50%	4.0%
21,000	Shanghai	Antwerp	Port Said (Egypt)	-4.7%	4.2%	50%	0.3%
21,000	Shanghai	Rotterdam	Port Said (Egypt)	-4.7%	4.2%	50%	0.3%
21,000	Shanghai	Hamburg	Port Said (Egypt)	-4.5%	4.1%	50%	0.3%
21,000	Shanghai	Antwerp	Mersin (Turkey)	-1.1%	7.7%	50%	3.7%
21,000	Shanghai	Rotterdam	Mersin (Turkey)	-1.1%	7.8%	50%	3.7%
21,000	Shanghai	Hamburg	Mersin (Turkey)	-1.0%	7.6%	50%	3.6%
14,000	Shanghai	Genova	Port Said (Egypt)	-5.6%	5.0%	50%	0.8%
14,000	Shanghai	Marseille	Port Said (Egypt)	-5.6%	5.0%	50%	0.8%
14,000	Shanghai	Barcelona	Port Said (Egypt)	-5.5%	4.9%	50%	0.8%
14,000	Shanghai	Genova	Mersin (Turkey)	-1.4%	9.1%	50%	4.7%
14,000	Shanghai	Marseille	Mersin (Turkey)	-1.4%	9.0%	50%	4.6%
14,000	Shanghai	Barcelona	Mersin (Turkey)	-1.3%	9.1%	50%	4.7%

Source: TRUST model, TRT

More specifically, in such cases total travel costs increase from a minimum of about € 14,500 for a 21,000 TEU ship directed to Northern Europe and stopping in Egypt (Port Said) to a maximum of near € 199,000 for a 21,000 TEU ship directed as well to Northern Europe but stopping in Turkey (Mersin).

Table 47: Other container routes departing from Shanghai (change of travel costs components in PO1 relative to the Baseline)

Ship size TEU	Origin Port	Destination Port	Intermediate Port	Fuel cost	Time cost	Ports cost	TOTAL
14,000	Shanghai	Antwerp	Port Said (Egypt)	-133,294	39,667	120,827	27,200
14,000	Shanghai	Rotterdam	Port Said (Egypt)	-133,294	39,667	120,827	27,200
14,000	Shanghai	Hamburg	Port Said (Egypt)	-133,294	39,667	120,827	27,200
14,000	Shanghai	Antwerp	Mersin (Turkey)	-30,130	73,250	120,827	163,947
14,000	Shanghai	Rotterdam	Mersin (Turkey)	-30,130	73,250	120,827	163,947
14,000	Shanghai	Hamburg	Mersin (Turkey)	-30,130	73,250	120,827	163,947
21,000	Shanghai	Antwerp	Port Said (Egypt)	-177,726	55,250	136,955	14,479
21,000	Shanghai	Rotterdam	Port Said (Egypt)	-177,726	55,250	136,955	14,479
21,000	Shanghai	Hamburg	Port Said (Egypt)	-177,726	55,250	136,955	14,479
21,000	Shanghai	Antwerp	Mersin (Turkey)	-40,174	102,027	136,955	198,808
21,000	Shanghai	Rotterdam	Mersin (Turkey)	-40,174	102,027	136,955	198,808
21,000	Shanghai	Hamburg	Mersin (Turkey)	-40,174	102,027	136,955	198,808
14,000	Shanghai	Genova	Port Said (Egypt)	-133,294	39,667	120,827	27,200
14,000	Shanghai	Marseille	Port Said (Egypt)	-133,294	39,667	120,827	27,200
14,000	Shanghai	Barcelona	Port Said (Egypt)	-133,294	39,667	120,827	27,200
14,000	Shanghai	Genova	Mersin (Turkey)	-34,213	72,000	120,827	158,614
14,000	Shanghai	Marseille	Mersin (Turkey)	-34,213	72,000	120,827	158,614
14,000	Shanghai	Barcelona	Mersin (Turkey)	-30,130	73,250	120,827	163,947

Source: TRUST model, TRT

It should however be noted that these calculations do not consider increases in ports costs and in charter rates over time. These costs are kept constant in real terms (in 2020 prices); this implies that an increase in these costs by 2030 may reduce or even offset the estimated costs savings. Table 48 shows for each route the percentage increase in charter rates that would offset the cost savings. Similarly, Table 49 shows for each route the percentage increase in port costs that would offset the cost savings[217].

Table 48: Percentage increase in charter rates that would offset the cost savings in PO1

Ship size TEU	Origin Port	Destination Port	Intermediate Port	Charter rates increase [%]
14,000	Shanghai	Antwerp	Tangier (Morocco)	13%
14,000	Shanghai	Rotterdam	Tangier (Morocco)	13%
14,000	Shanghai	Hamburg	Tangier (Morocco)	13%
14,000	Shanghai	Antwerp	Felixstowe (UK)	18%
14,000	Shanghai	Rotterdam	Felixstowe (UK)	30%
14,000	Shanghai	Hamburg	Felixstowe (UK)	43%
21,000	Shanghai	Antwerp	Tangier (Morocco)	51%
21,000	Shanghai	Rotterdam	Tangier (Morocco)	51%
21,000	Shanghai	Hamburg	Tangier (Morocco)	51%
21,000	Shanghai	Antwerp	Felixstowe (UK)	51%
21,000	Shanghai	Rotterdam	Felixstowe (UK)	64%

[217] The tables provide the increase in only one cost component, but increases in both components are more likely to occur. Their different combinations however generate countless possibilities for cost increases that would offset the costs savings. As an example, a combined increase of 20% in charter rates and of 25% in ports' costs would offset costs savings of all routes. A similar result is achieved with a combined increase of 31% in charter rates and of 20% in port costs.

Ship size TEU	Origin Port	Destination Port	Intermediate Port	Charter rates increase [%]
21,000	Shanghai	Hamburg	Felixstowe (UK)	77%

Source: TRUST model, TRT

Table 49: Percentage increase in port costs that would offset the cost savings in PO1

Ship size TEU	Origin Port	Destination Port	Intermediate Port	Port costs increase [%]
14,000	Shanghai	Antwerp	Tangier (Morocco)	5%
14,000	Shanghai	Rotterdam	Tangier (Morocco)	5%
14,000	Shanghai	Hamburg	Tangier (Morocco)	5%
14,000	Shanghai	Antwerp	Felixstowe (UK)	7%
14,000	Shanghai	Rotterdam	Felixstowe (UK)	11%
14,000	Shanghai	Hamburg	Felixstowe (UK)	15%
21,000	Shanghai	Antwerp	Tangier (Morocco)	21%
21,000	Shanghai	Rotterdam	Tangier (Morocco)	21%
21,000	Shanghai	Hamburg	Tangier (Morocco)	21%
21,000	Shanghai	Antwerp	Felixstowe (UK)	24%
21,000	Shanghai	Rotterdam	Felixstowe (UK)	29%
21,000	Shanghai	Hamburg	Felixstowe (UK)	34%

Source: TRUST model, TRT

The analysis of the different cost components shows that, for the vast majority of the routes, total travel costs increase in the case of an intermediate stop to a non-EU/EEA port. Indeed, although fuel costs in the case of route diversion (i.e. with an intermediate stop to a non-EU/EEA port) are expected to reduce in the range of 1% to 6% (i.e. €26,000 to €242,000 depending on the route and the ship type) in 2030 relative to the Baseline, travel time costs are expected to increase in the range of 4% to 13% (i.e. €13,300 to €102,000) and costs at ports are expected to increase by 50% (i.e. €47,500 to €137,000 according to the ship type). These results suggest that the risk of leakage resulting from containers ships' route diversion to reduce the amount of traffic that falls in scope of the requirements is low.

Furthermore, it is worth to consider that container ships usually perform several stops along the route to load/unload cargo and therefore the whole journey from the Origin port to the Destination port would not fall under the scope of the regulation. It might be the case that container ships find a convenience in relocating one of the stops to the closest non-EU/EEA port (rather than performing an additional stop). In such a case however, the leakage would be limited only to the final leg of the trip with limited impacts on the overall effectiveness of the initiative.

Analysis for dry bulker routes

In case of an additional stop performed to a non-EU/EEA port, total travel time (navigation and time at ports) of dry bulkers for all considered routes is expected to increase in the range of 6% to 13% relative to the Baseline in 2030 (i.e. 36 to 62 additional hours relative to the direct route). The lowest relative increase of near 6% occurs on the routes from North America (New Orleans) to the Mediterranean ports of Italy (Naples and Taranto) with an intermediate stop in Algeria (Oran). The highest relative increase of 13% occurs on the route from South America (Ponta Da Madeira) to North Europe (Rotterdam) with an intermediate stop in United Kingdom (Grimsby).

Similarly to the routes for container ships, the increase in sailing time is relatively limited (up to 6%) due to the strategic position of intermediate ports. The increase of time at ports is estimated at 59%.

For all considered routes total travel costs are expected to go up by 5% to 14% (i.e. €25,000 to €202,000 depending on the route and the ship type) in case of an additional stop performed to a non-EU/EEA port.

More specifically, the analysis of the different cost components shows that although fuel costs in the case of an intermediate stop are expected to reduce by up to 5% (i.e. €2,700 to €33,500), travel time costs are expected to increase in the range of 6% to 13% (i.e. € 11,000 to € 50,000) and costs at ports are expected to increase by 50% (i.e. €27,000 to €163,000). On the basis of this analysis it can be concluded that the risk of leakage resulting from dry bulkers' route diversion to reduce the amount of traffic that falls in scope of the requirements is very low.

Analysis for tankers routes

The increase of total travel time (navigation and time at ports) of tankers for all considered routes in case of an additional stop performed to a non-EU/EEA port is in the range of 6% to 20% (i.e. 35 to 61 additional hours depending on the route). More specifically, the increase in sailing time ranges between 0% and 5% and the increase of time at ports is around 59%.

The lowest relative increase of near 6% occurs on the routes from the Arabian Gulf (Ju'aymah) to the Northern Europe ports (Antwerp and Rotterdam) with an intermediate stop in Egypt (Alexandria). The highest relative increase of 20% occurs on the route from North Africa (Arzew) to North Europe (Antwerp and Rotterdam) with an intermediate stop in United Kingdom (Medway).

For all considered routes total travel costs are expected to increase in case of an additional stop performed to a non-EU/EEA. This increase is estimated in the range of 7% to 23% (i.e. €71,000 to €133,000) depending on the route and the ship type. The analysis of the different cost components shows that, although fuel costs are expected to reduce in the case of an intermediate stop to a non-EU/EEA ports by up to 6% (i.e. €1,900 to €21,600), travel time costs are expected to increase in the range of 6% to 20% (i.e. €26,000 and €50,000) and costs at ports are expected to increase by 50% (i.e. €61,000 to €97,000). On the basis of this analysis it can be concluded that the risk of leakage resulting from tankers' route diversion to reduce the amount of traffic that falls in scope of the initiative is very low.

Results for PO3

Analysis for container ship routes

Table 56 and Source: *TRUST model, TRT*

Table 57 provide the comparison of travel times and related components for the analysed container ships along the different routes in two cases (a direct route from the origin non-EU/EEA port to the destination EU/EEA port and a route with a stop to an intermediate non-EU/EEA port). Due to the additional stop, total travel time increases in the range of 4% to 13% depending on the routes[218].

As far as travel costs are concerned, it is to be noted that the increase in the costs of blended MGO relative to conventional MGO in PO3 is relatively similar to the increase in PO1. Therefore, there are small differences between the results of PO1 and PO3. The analysis of travel costs reported in Table 58 shows that, also in this case for the vast majority of analysed routes total travel costs increase in the case of an intermediate stop to a non-EU/EEA port and that the increase ranges from 0.3% for a 21,000 TEU ship travelling from Shanghai to North Europe (Antwerp, Rotterdam, Hamburg) and stopping in Egypt (Port Said) to 10% for a 8000 TEU ship travelling from New York to Barcelona and stopping in Morocco (Tangier).

The increase in total travel costs ranges from €17,000 for a 21,000 TEU ship travelling from Shanghai to North Europe (Antwerp, Rotterdam, Hamburg) and performing an intermediate stop in Egypt (Port Said) to near €201,000 if the intermediate stop is performed in Turkey (Mersin).

In PO3 total travel costs slightly decrease only for few routes, similarly to PO1. More specifically a decrease is observed for 12 out of 54 total analysed combinations of routes and ship types (i.e. 22% of analysed combinations). This decrease, in the range of 0.1% to 0.8% depending on the ship type, occurs only for the routes departing from Shanghai and directed to Northern Europe (Antwerp, Rotterdam, Hamburg) with an intermediate stop in Morocco (Tangier) and in United Kingdom (Felixstowe).

Table 50: Container routes with decreasing total travel costs in PO3 relative to the Baseline (% change of travel costs components)

Ship size TEU	Origin Port	Destination Port	Intermediate Port	Fuel cost [%]	Time cost [%]	Ports cost [%]	TOTAL [%]
14,000	Shanghai	Antwerp	Tangier (Morocco)	-5.7%	4.3%	50%	-0.1%
14,000	Shanghai	Rotterdam	Tangier (Morocco)	-5.7%	4.3%	50%	-0.1%
14,000	Shanghai	Hamburg	Tangier (Morocco)	-5.6%	4.2%	50%	-0.1%
14,000	Shanghai	Antwerp	Felixstowe (UK)	-6.0%	4.8%	50%	-0.1%
14,000	Shanghai	Rotterdam	Felixstowe (UK)	-6.1%	4.7%	50%	-0.3%
14,000	Shanghai	Hamburg	Felixstowe (UK)	-6.1%	4.4%	50%	-0.4%
21,000	Shanghai	Antwerp	Tangier (Morocco)	-5.7%	4.3%	50%	-0.5%
21,000	Shanghai	Rotterdam	Tangier (Morocco)	-5.7%	4.3%	50%	-0.5%
21,000	Shanghai	Hamburg	Tangier (Morocco)	-5.6%	4.2%	50%	-0.5%
21,000	Shanghai	Antwerp	Felixstowe (UK)	-6.0%	4.8%	50%	-0.5%
21,000	Shanghai	Rotterdam	Felixstowe (UK)	-6.1%	4.7%	50%	-0.7%
21,000	Shanghai	Hamburg	Felixstowe (UK)	-6.1%	4.4%	50%	-0.8%

Source: TRUST model, TRT

In such cases the total cost saving ranges from €2,700 for a 14,000 TEU ship stopping in Tangier to near €42,000 for a 21,000 TEU ship stopping in Felixstowe (see Table 51).

[218] As no changes apply to the underlying assumptions on navigation speed, time spent at ports and on analysed routes, time changes observed in PO1 apply also to PO3.

Table 51: Container routes with decreasing total travel costs in PO3 relative to the Baseline (change of travel costs components)

Ship size TEU	Origin Port	Destination Port	Intermediate Port	Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]
14,000	Shanghai	Antwerp	Tangier (Morocco)	-163,957	40,417	120,827	-2,713
14,000	Shanghai	Rotterdam	Tangier (Morocco)	-163,957	40,417	120,827	-2,713
14,000	Shanghai	Hamburg	Tangier (Morocco)	-163,957	40,417	120,827	-2,713
14,000	Shanghai	Antwerp	Felixstowe (UK)	-171,069	45,250	120,827	-4,992
14,000	Shanghai	Rotterdam	Felixstowe (UK)	-175,148	44,000	120,827	-10,320
14,000	Shanghai	Hamburg	Felixstowe (UK)	-178,955	42,833	120,827	-15,294
21,000	Shanghai	Antwerp	Tangier (Morocco)	-218,610	56,295	136,955	-25,360
21,000	Shanghai	Rotterdam	Tangier (Morocco)	-218,610	56,295	136,955	-25,360
21,000	Shanghai	Hamburg	Tangier (Morocco)	-218,610	56,295	136,955	-25,360
21,000	Shanghai	Antwerp	Felixstowe (UK)	-228,092	63,027	136,955	-28,111
21,000	Shanghai	Rotterdam	Felixstowe (UK)	-233,531	61,286	136,955	-35,290
21,000	Shanghai	Hamburg	Felixstowe (UK)	-238,606	59,661	136,955	-41,991

Source: TRUST model, TRT

For all the other analysed combinations for ships departing from Shanghai (18 out of 54 total routes analysed) and directed (i) to Northern Europe (Antwerp, Rotterdam, Hamburg) or (ii) to the Mediterranean region (Genova, Marseille, Barcelona) and performing an intermediate stop in Egypt (Port Said) or in Turkey (Mersin), no reduction in total travel costs occurs (see Table 52).

Table 52: Other container routes departing from Shanghai (% change of travel costs components in PO3 relative to the Baseline)

Ship size TEU	Origin Port	Destination Port	Intermediate Port	Fuel cost [%]	Time cost [%]	Ports cost [%]	TOTAL [%]
14,000	Shanghai	Antwerp	Port Said (Egypt)	**-4.6%**	**4.2%**	**50%**	**0.7%**
14,000	Shanghai	Rotterdam	Port Said (Egypt)	**-4.6%**	**4.2%**	**50%**	**0.7%**
14,000	Shanghai	Hamburg	Port Said (Egypt)	**-4.5%**	**4.1%**	**50%**	**0.7%**
14,000	Shanghai	Antwerp	Mersin (Turkey)	**-1.0%**	**7.7%**	**50%**	**4.1%**
14,000	Shanghai	Rotterdam	Mersin (Turkey)	**-1.0%**	**7.8%**	**50%**	**4.1%**
14,000	Shanghai	Hamburg	Mersin (Turkey)	**-1.0%**	**7.6%**	**50%**	**4.0%**
21,000	Shanghai	Antwerp	Port Said (Egypt)	**-4.6%**	**4.2%**	**50%**	**0.3%**
21,000	Shanghai	Rotterdam	Port Said (Egypt)	**-4.6%**	**4.2%**	**50%**	**0.3%**
21,000	Shanghai	Hamburg	Port Said (Egypt)	**-4.5%**	**4.1%**	**50%**	**0.3%**
21,000	Shanghai	Antwerp	Mersin (Turkey)	**-1.0%**	**7.7%**	**50%**	**3.7%**
21,000	Shanghai	Rotterdam	Mersin (Turkey)	**-1.0%**	**7.8%**	**50%**	**3.7%**
21,000	Shanghai	Hamburg	Mersin (Turkey)	**-1.0%**	**7.6%**	**50%**	**3.6%**
14,000	Shanghai	Genova	Port Said (Egypt)	**-5.6%**	**5.0%**	**50%**	**0.9%**
14,000	Shanghai	Marseille	Port Said (Egypt)	**-5.5%**	**5.0%**	**50%**	**0.9%**
14,000	Shanghai	Barcelona	Port Said (Egypt)	**-5.5%**	**4.9%**	**50%**	**0.8%**
14,000	Shanghai	Genova	Mersin (Turkey)	**-1.4%**	**9.1%**	**50%**	**4.7%**
14,000	Shanghai	Marseille	Mersin (Turkey)	**-1.4%**	**9.0%**	**50%**	**4.7%**
14,000	Shanghai	Barcelona	Mersin (Turkey)	**-1.2%**	**9.1%**	**50%**	**4.8%**

Source: TRUST model, TRT

More specifically, in such cases total travel costs increase from around €17,200 for a 21,000 TEU ship directed to Northern Europe and stopping in Egypt (Port Said) to near

€201,500 for a 21,000 TEU ship directed as well to Northern Europe but stopping in Turkey (Mersin) (see Table 53).

Table 53: Other container routes departing from Shanghai (change of travel costs components in PO3 relative to the Baseline)

Ship size TEU	Origin Port	Destination Port	Intermediate Port	Fuel cost	Time cost	Ports cost	TOTAL
14,000	Shanghai	Antwerp	Port Said (Egypt)	-131,266	39,667	120,827	29,228
14,000	Shanghai	Rotterdam	Port Said (Egypt)	-131,266	39,667	120,827	29,228
14,000	Shanghai	Hamburg	Port Said (Egypt)	-131,266	39,667	120,827	29,228
14,000	Shanghai	Antwerp	Mersin (Turkey)	-28,116	73,250	120,827	165,962
14,000	Shanghai	Rotterdam	Mersin (Turkey)	-28,116	73,250	120,827	165,962
14,000	Shanghai	Hamburg	Mersin (Turkey)	-28,116	73,250	120,827	165,962
21,000	Shanghai	Antwerp	Port Said (Egypt)	-175,022	55,250	136,955	17,183
21,000	Shanghai	Rotterdam	Port Said (Egypt)	-175,022	55,250	136,955	17,183
21,000	Shanghai	Hamburg	Port Said (Egypt)	-175,022	55,250	136,955	17,183
21,000	Shanghai	Antwerp	Mersin (Turkey)	-37,488	102,027	136,955	201,494
21,000	Shanghai	Rotterdam	Mersin (Turkey)	-37,488	102,027	136,955	201,494
21,000	Shanghai	Hamburg	Mersin (Turkey)	-37,488	102,027	136,955	201,494
14,000	Shanghai	Genova	Port Said (Egypt)	-131,266	39,667	120,827	29,228
14,000	Shanghai	Marseille	Port Said (Egypt)	-131,266	39,667	120,827	29,228
14,000	Shanghai	Barcelona	Port Said (Egypt)	-131,266	39,667	120,827	29,228
14,000	Shanghai	Genova	Mersin (Turkey)	-32,194	72,000	120,827	160,633
14,000	Shanghai	Marseille	Mersin (Turkey)	-32,194	72,000	120,827	160,633
14,000	Shanghai	Barcelona	Mersin (Turkey)	-28,116	73,250	120,827	165,962

Source: TRUST model, TRT

As in PO1, it should be noted that these calculations do not consider increases in ports costs and in charter rates over time. These costs are kept constant in real terms (in 2020 prices). This implies that an increase in these costs by 2030 may reduce or even offset the estimated costs saving. Table 54 shows for each route the percentage increase in charter rates that would offset the cost savings. Similarly, Table 55 shows for each route the percentage increase in port costs that would offset the cost savings[219].

[219] As already mentioned for PO1, tables provide the increase in only one cost component, but increases in both components are more likely to occur. Their different combinations however generate countless possibilities for cost increases that would neutralise the costs savings. As an example, a combined increase of 18% in charter rates and of 23% in ports' costs would neutralise costs savings of all routes. A similar result is achieved with a combined increase of 29% in charter rates and of 18% in port costs.

Table 54: Percentage increase in charter rates that would offset the cost savings in PO3

Ship size TEU	Origin Port	Destination Port	Intermediate Port	Charter rates increase [%]
14,000	Shanghai	Antwerp	Tangier (Morocco)	7%
14,000	Shanghai	Rotterdam	Tangier (Morocco)	7%
14,000	Shanghai	Hamburg	Tangier (Morocco)	7%
14,000	Shanghai	Antwerp	Felixstowe (UK)	11%
14,000	Shanghai	Rotterdam	Felixstowe (UK)	24%
14,000	Shanghai	Hamburg	Felixstowe (UK)	36%
21,000	Shanghai	Antwerp	Tangier (Morocco)	45%
21,000	Shanghai	Rotterdam	Tangier (Morocco)	45%
21,000	Shanghai	Hamburg	Tangier (Morocco)	45%
21,000	Shanghai	Antwerp	Felixstowe (UK)	45%
21,000	Shanghai	Rotterdam	Felixstowe (UK)	58%
21,000	Shanghai	Hamburg	Felixstowe (UK)	70%

Source: TRUST model, TRT

Table 55: Percentage increase in port costs that would offset the cost savings in PO3

Ship size TEU	Origin Port	Destination Port	Intermediate Port	Port costs increase [%]
14,000	Shanghai	Antwerp	Tangier (Morocco)	3%
14,000	Shanghai	Rotterdam	Tangier (Morocco)	3%
14,000	Shanghai	Hamburg	Tangier (Morocco)	3%
14,000	Shanghai	Antwerp	Felixstowe (UK)	4%
14,000	Shanghai	Rotterdam	Felixstowe (UK)	9%
14,000	Shanghai	Hamburg	Felixstowe (UK)	13%
21,000	Shanghai	Antwerp	Tangier (Morocco)	19%
21,000	Shanghai	Rotterdam	Tangier (Morocco)	19%
21,000	Shanghai	Hamburg	Tangier (Morocco)	19%
21,000	Shanghai	Antwerp	Felixstowe (UK)	21%
21,000	Shanghai	Rotterdam	Felixstowe (UK)	26%
21,000	Shanghai	Hamburg	Felixstowe (UK)	31%

Source: TRUST model, TRT

The analysis of the different cost components reported in Table 59 shows that although fuel costs in the case of an intermediate stop to a non-EU/EEA port are expected to reduce in the range of 1% to 6% (i.e. €26,000 to €238,600 depending on the route and the ship type), travel time costs are projected to increase in the range of 4% to 13% (i.e. €13,300 to €102,000) and costs at ports are expected to increase by 50% (i.e. € 47,500 to €137,000 according to the ship type). As already mentioned above, this results in an increase of total travel costs ranging from about €17,000 for a 21,000 TEU ship travelling from Shanghai to North Europe (Antwerp, Rotterdam, Hamburg) and performing an intermediate stop in Egypt (Port Said) to near €201,000 if the intermediate stop is performed in Turkey (Mersin).

These results suggest that also in PO3 the risk of leakage resulting from containers ships route diversion to reduce the amount of traffic that falls in scope of the initiative is low.

Analysis for dry bulker routes

Table 60 and Table 61 provide the analysis of travel time changes and related components for the analysed dry bulker ships along the direct route and the route with a stop to an intermediate non-EU/EEA port). In case of an additional stop, total travel time (navigation and time at ports) of dry bulkers is expected to increase in the range of 6% to 13%.

Looking at the costs reported in Source: *TRUST model, TRT*

Table 62, it can be seen that for all considered routes total travel costs are expected to increase in case of an additional stop. This increase is estimated in the range of 5% to 14%. The lowest relative increase of 5% occurs on the routes from North America (New Orleans) to the Mediterranean ports (Marseille, Livorno and Naples) with an intermediate stop in Algeria (Oran). The highest relative increase of 14% occurs on the route from South America (Ponta Da Madeira, Tubarao) to North Europe (Rotterdam) with an intermediate stop in United Kingdom (Grimsby). Overall, total travel costs increase in the range of €25,000 to €202,000 depending on the route and the ship type.

The analysis of the different cost components reported in Table 63 shows that although fuel costs in the case of an intermediate stop to a non-EU/EEA ports are expected to reduce by up to 5% (i.e. the overall reduction ranges between €2,200 and €32,600), travel time costs would increase in the range of 6% to 13% (i.e. €11,000 to €50,000) and costs at ports are projected to increase by 50% (i.e. €27,000 to €163,000).

Similarly to PO1, also for PO3 it can be concluded that the risk of leakage resulting from dry bulkers' route diversion to reduce the amount of traffic that falls in scope of the initiative is very low.

Analysis for tankers routes

In case of an additional stop performed to a non-EU/EEA port, total travel time (navigation and time at ports) of tankers for all considered routes is expected to grow in the range of 6% to 20% (see Table 64). The same applies to total travel costs (Table 66) that are expected to increase for all considered routes. Depending on the route and the ship type, this increase is estimated in the range of 7% to 23% (i.e. €71,000 to €133,000). The lowest relative increase of 7% occurs on the routes from the Arabian Gulf (Ju'aymah) to the Northern Europe ports (Antwerp, Rotterdam) with an intermediate stop in Egypt (Alexandria). The highest relative increase of 23% occurs on the route from North Africa (Arzew) to North Europe (Antwerp and Rotterdam) with an intermediate stop in United Kingdom (Medway).

Looking at the different cost components (Table 67) it can be seen that although fuel costs are expected to reduce in the case of an intermediate stop by up to 5% (i.e. €1,800 to €21,200), travel time costs are projected to increase in the range of 6% to 20% (i.e. €26,000 to €50,000) and costs at ports would increase by 50% (i.e. €61,000 to €97,000).

On the basis of this analysis it can be concluded that also for PO3 the risk of leakage resulting from tankers route diversion to reduce the amount of traffic that falls in scope of the requirements is very low.

The detailed results for PO3 for all ship types are provided in the tables below.

Container ship routes – detailed results for PO3

Table 56: Container ship routes - Travel times

Ship size TEU	Origin Region	Origin Port	Destination Region	Destination Port	Total travel time direct route			Intermediate Port	Total travel time intermediate stop			Diff. Travel time	
					Days	Hours	Total [h]		Days	Hours	Total [h]	[h]	[%]
14,000	South East Asia	Shanghai	North Europe	Antwerp	33	18	810	Port Said (Egypt)	35	4	844	34	4%
14,000	South East Asia	Shanghai	North Europe	Rotterdam	33	18	810	Port Said (Egypt)	35	4	844	34	4%
14,000	South East Asia	Shanghai	North Europe	Hamburg	34	12	828	Port Said (Egypt)	35	22	862	34	4%
14,000	South East Asia	Shanghai	North Europe	Antwerp	33	18	810	Mersin (Turkey)	36	9	873	63	8%
14,000	South East Asia	Shanghai	North Europe	Rotterdam	33	18	810	Mersin (Turkey)	36	9	873	63	8%
14,000	South East Asia	Shanghai	North Europe	Hamburg	34	12	828	Mersin (Turkey)	37	3	891	63	8%
14,000	South East Asia	Shanghai	North Europe	Antwerp	33	18	810	Tangier (Morocco)	35	5	845	35	4%
14,000	South East Asia	Shanghai	North Europe	Rotterdam	33	18	810	Tangier (Morocco)	35	4	844	35	4%
14,000	South East Asia	Shanghai	North Europe	Hamburg	34	12	828	Tangier (Morocco)	35	23	863	35	4%
14,000	South East Asia	Shanghai	North Europe	Antwerp	33	18	810	Felixstowe (UK)	35	9	849	39	5%
14,000	South East Asia	Shanghai	North Europe	Rotterdam	33	18	810	Felixstowe (UK)	35	8	848	38	5%
14,000	South East Asia	Shanghai	North Europe	Hamburg	34	12	828	Felixstowe (UK)	36	1	865	37	4%
21,000	South East Asia	Shanghai	North Europe	Antwerp	33	18	810	Port Said (Egypt)	35	4	844	34	4%
21,000	South East Asia	Shanghai	North Europe	Rotterdam	33	18	810	Port Said (Egypt)	35	4	844	34	4%
21,000	South East Asia	Shanghai	North Europe	Hamburg	34	12	828	Port Said (Egypt)	35	22	862	34	4%
21,000	South East Asia	Shanghai	North Europe	Antwerp	33	18	810	Mersin (Turkey)	36	9	873	63	8%
21,000	South East Asia	Shanghai	North Europe	Rotterdam	33	18	810	Mersin (Turkey)	36	9	873	63	8%
21,000	South East Asia	Shanghai	North Europe	Hamburg	34	12	828	Mersin (Turkey)	37	3	891	63	8%
21,000	South East Asia	Shanghai	North Europe	Antwerp	33	18	810	Tangier (Morocco)	35	5	845	35	4%
21,000	South East Asia	Shanghai	North Europe	Rotterdam	33	18	810	Tangier (Morocco)	35	4	844	35	4%
21,000	South East Asia	Shanghai	North Europe	Hamburg	34	12	828	Tangier (Morocco)	35	23	863	35	4%
21,000	South East Asia	Shanghai	North Europe	Antwerp	33	18	810	Felixstowe (UK)	35	9	849	39	5%
21,000	South East Asia	Shanghai	North Europe	Rotterdam	33	18	810	Felixstowe (UK)	35	8	848	38	5%
21,000	South East Asia	Shanghai	North Europe	Hamburg	34	12	828	Felixstowe (UK)	36	1	865	37	4%
14,000	South East Asia	Shanghai	Mediterranean	Genova	28	5	677	Port Said (Egypt)	29	15	711	34	5%
14,000	South East Asia	Shanghai	Mediterranean	Marseille	28	12	684	Port Said (Egypt)	29	22	718	34	5%
14,000	South East Asia	Shanghai	Mediterranean	Barcelona	28	17	689	Port Said (Egypt)	30	3	723	34	5%

Ship size TEU	Origin Region	Origin Port	Destination Region	Destination Port	Total travel time direct route			Intermediate Port	Total travel time intermediate stop			Diff. Travel time	
					Days	Hours	Total [h]		Days	Hours	Total [h]	[h]	[%]
14,000	South East Asia	Shanghai	Mediterranean	Genova	28	5	677	Mersin (Turkey)	30	19	739	62	9%
14,000	South East Asia	Shanghai	Mediterranean	Marseille	28	12	684	Mersin (Turkey)	31	2	746	62	9%
14,000	South East Asia	Shanghai	Mediterranean	Barcelona	28	17	689	Mersin (Turkey)	31	8	752	63	9%
12,000	North America	New York	North Europe	Antwerp	12	12	300	Felixstowe (UK)	14	3	339	39	13%
12,000	North America	New York	North Europe	Rotterdam	12	12	300	Felixstowe (UK)	14	1	337	38	13%
12,000	North America	New York	North Europe	Hamburg	13	5	317	Felixstowe (UK)	14	18	354	38	12%
12,000	North America	Savannah	North Europe	Antwerp	14	4	340	Felixstowe (UK)	15	18	378	39	11%
12,000	North America	Savannah	North Europe	Rotterdam	14	3	339	Felixstowe (UK)	15	17	377	38	11%
12,000	North America	Savannah	North Europe	Hamburg	14	17	353	Felixstowe (UK)	16	10	394	41	12%
8,000	North America	New York	Mediterranean	Genova	14	12	348	Tangier (Morocco)	15	22	382	34	10%
8,000	North America	New York	Mediterranean	Marseille	14	0	336	Tangier (Morocco)	15	11	371	34	10%
8,000	North America	New York	Mediterranean	Barcelona	13	12	324	Tangier (Morocco)	14	22	358	34	11%
8,000	North America	Savannah	Mediterranean	Genova	15	22	382	Tangier (Morocco)	17	8	416	34	9%
8,000	North America	Savannah	Mediterranean	Marseille	15	10	370	Tangier (Morocco)	16	21	405	34	9%
8,000	North America	Savannah	Mediterranean	Barcelona	14	22	358	Tangier (Morocco)	16	8	392	34	10%
4,500	South America	Santos	Mediterranean	Genova	17	23	431	Tangier (Morocco)	19	9	466	34	8%
4,500	South America	Santos	Mediterranean	Marseille	17	12	420	Tangier (Morocco)	18	22	454	34	8%
4,500	South America	Santos	Mediterranean	Barcelona	16	23	407	Tangier (Morocco)	18	10	442	34	8%
4,500	North America	Long Beach	Mediterranean	Genova	26	14	638	Tangier (Morocco)	28	1	673	34	5%
4,500	North America	Long Beach	Mediterranean	Marseille	26	3	627	Tangier (Morocco)	27	13	661	34	5%
4,500	North America	Long Beach	Mediterranean	Barcelona	25	15	615	Tangier (Morocco)	27	1	649	34	6%
4,000	South America	Santos	North Europe	Antwerp	18	14	446	Felixstowe (UK)	20	5	485	39	9%
4,000	South America	Santos	North Europe	Rotterdam	18	14	446	Felixstowe (UK)	20	4	484	38	8%
4,000	South America	Santos	North Europe	Hamburg	19	8	464	Felixstowe (UK)	20	21	501	37	8%
4,000	North America	Long Beach	North Europe	Antwerp	25	12	612	Felixstowe (UK)	27	3	651	39	6%
4,000	North America	Long Beach	North Europe	Rotterdam	25	12	612	Felixstowe (UK)	27	1	649	38	6%
4,000	North America	Long Beach	North Europe	Hamburg	26	6	630	Felixstowe (UK)	27	19	667	37	6%

Source: TRUST model, TRT

Table 57: Container ship routes – Time comparison of the route with an intermediate stop relative to the direct route (% change in travel time components)

Ship size TEU	Origin Port	Destination Port	Total travel time direct route			Intermediate Port	Total travel time intermediate stop			Sailing time [%]	Time at ports [%]	Total [%]
			Sailing time [h]	Time at ports [h]	Total [h]		Sailing time [h]	Time at ports [h]	Total [h]			
14,000	Shanghai	Antwerp	752	58	810	Port Said (Egypt)	752	92	844	0%	59%	4%
14,000	Shanghai	Rotterdam	752	58	810	Port Said (Egypt)	752	92	844	0%	59%	4%
14,000	Shanghai	Hamburg	770	58	828	Port Said (Egypt)	770	92	862	0%	59%	4%
14,000	Shanghai	Antwerp	752	58	810	Mersin (Turkey)	781	92	873	4%	59%	8%
14,000	Shanghai	Rotterdam	752	58	810	Mersin (Turkey)	781	92	873	4%	59%	8%
14,000	Shanghai	Hamburg	770	58	828	Mersin (Turkey)	799	92	891	4%	59%	8%
14,000	Shanghai	Antwerp	752	58	810	Tangier (Morocco)	753	92	845	0%	59%	4%
14,000	Shanghai	Rotterdam	752	58	810	Tangier (Morocco)	752	92	844	0%	59%	4%
14,000	Shanghai	Hamburg	770	58	828	Tangier (Morocco)	771	92	863	0%	59%	4%
14,000	Shanghai	Antwerp	752	58	810	Felixstowe (UK)	757	92	849	1%	59%	5%
14,000	Shanghai	Rotterdam	752	58	810	Felixstowe (UK)	756	92	848	0%	59%	5%
14,000	Shanghai	Hamburg	770	58	828	Felixstowe (UK)	773	92	865	0%	59%	4%
21,000	Shanghai	Antwerp	752	58	810	Port Said (Egypt)	752	92	844	0%	59%	4%
21,000	Shanghai	Rotterdam	752	58	810	Port Said (Egypt)	752	92	844	0%	59%	4%
21,000	Shanghai	Hamburg	770	58	828	Port Said (Egypt)	770	92	862	0%	59%	4%
21,000	Shanghai	Antwerp	752	58	810	Mersin (Turkey)	781	92	873	4%	59%	8%
21,000	Shanghai	Rotterdam	752	58	810	Mersin (Turkey)	781	92	873	4%	59%	8%
21,000	Shanghai	Hamburg	770	58	828	Mersin (Turkey)	799	92	891	4%	59%	8%
21,000	Shanghai	Antwerp	752	58	810	Tangier (Morocco)	753	92	845	0%	59%	4%
21,000	Shanghai	Rotterdam	752	58	810	Tangier (Morocco)	752	92	844	0%	59%	4%
21,000	Shanghai	Hamburg	770	58	828	Tangier (Morocco)	771	92	863	0%	59%	4%
21,000	Shanghai	Antwerp	752	58	810	Felixstowe (UK)	757	92	849	1%	59%	5%
21,000	Shanghai	Rotterdam	752	58	810	Felixstowe (UK)	756	92	848	0%	59%	5%
21,000	Shanghai	Hamburg	770	58	828	Felixstowe (UK)	773	92	865	0%	59%	4%
14,000	Shanghai	Genova	619	58	677	Port Said (Egypt)	619	92	711	0%	59%	5%
14,000	Shanghai	Marseille	626	58	684	Port Said (Egypt)	626	92	718	0%	59%	5%
14,000	Shanghai	Barcelona	631	58	689	Port Said (Egypt)	631	92	723	0%	59%	5%
14,000	Shanghai	Genova	619	58	677	Mersin (Turkey)	647	92	739	4%	59%	9%
14,000	Shanghai	Marseille	626	58	684	Mersin (Turkey)	654	92	746	4%	59%	9%
14,000	Shanghai	Barcelona	631	58	689	Mersin (Turkey)	660	92	752	5%	59%	9%

Ship size TEU	Origin Port	Destination Port	Total travel time direct route			Intermediate Port	Total travel time intermediate stop			Sailing time [%]	Time at ports [%]	Total [%]
			Sailing time [h]	Time at ports [h]	Total [h]		Sailing time [h]	Time at ports [h]	Total [h]			
12,000	New York	Antwerp	242	58	300	Felixstowe (UK)	247	92	339	2%	59%	13%
12,000	New York	Rotterdam	242	58	300	Felixstowe (UK)	245	92	337	2%	59%	13%
12,000	New York	Hamburg	259	58	317	Felixstowe (UK)	262	92	354	1%	59%	12%
12,000	Savannah	Antwerp	282	58	340	Felixstowe (UK)	286	92	378	2%	59%	11%
12,000	Savannah	Rotterdam	281	58	339	Felixstowe (UK)	285	92	377	1%	59%	11%
12,000	Savannah	Hamburg	295	58	353	Felixstowe (UK)	302	92	394	2%	59%	12%
8,000	New York	Genova	290	58	348	Tangier (Morocco)	290	92	382	0%	59%	10%
8,000	New York	Marseille	278	58	336	Tangier (Morocco)	279	92	371	0%	59%	10%
8,000	New York	Barcelona	266	58	324	Tangier (Morocco)	266	92	358	0%	59%	11%
8,000	Savannah	Genova	324	58	382	Tangier (Morocco)	324	92	416	0%	59%	9%
8,000	Savannah	Marseille	312	58	370	Tangier (Morocco)	313	92	405	0%	59%	9%
8,000	Savannah	Barcelona	300	58	358	Tangier (Morocco)	300	92	392	0%	59%	10%
4,500	Santos	Genova	373	58	431	Tangier (Morocco)	374	92	466	0%	59%	8%
4,500	Santos	Marseille	362	58	420	Tangier (Morocco)	362	92	454	0%	59%	8%
4,500	Santos	Barcelona	349	58	407	Tangier (Morocco)	350	92	442	0%	59%	8%
4,500	Long Beach	Genova	580	58	638	Tangier (Morocco)	581	92	673	0%	59%	5%
4,500	Long Beach	Marseille	569	58	627	Tangier (Morocco)	569	92	661	0%	59%	5%
4,500	Long Beach	Barcelona	557	58	615	Tangier (Morocco)	557	92	649	0%	59%	6%
4,000	Santos	Antwerp	388	58	446	Felixstowe (UK)	393	92	485	1%	59%	9%
4,000	Santos	Rotterdam	388	58	446	Felixstowe (UK)	392	92	484	1%	59%	8%
4,000	Santos	Hamburg	406	58	464	Felixstowe (UK)	409	92	501	1%	59%	8%
4,000	Long Beach	Antwerp	554	58	612	Felixstowe (UK)	559	92	651	1%	59%	6%
4,000	Long Beach	Rotterdam	554	58	612	Felixstowe (UK)	557	92	649	1%	59%	6%
4,000	Long Beach	Hamburg	572	58	630	Felixstowe (UK)	575	92	667	0%	59%	6%

Source: TRUST model, TRT

Table 58: Container ship routes - Travel costs

Ship size TEU	Origin Port	Destination Port	Total travel cost direct route				Intermediate Port	Total travel cost intermediate stop				Diff. Travel cost [%]
			Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]		Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]	

Ship size TEU	Origin Port	Destination Port	Total travel cost direct route				Intermediate Port	Total travel cost intermediate stop				Diff. Travel cost [%]
			Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]		Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]	
14,000	Shanghai	Antwerp	2,863,144	945,167	241,655	4,049,966	Port Said (Egypt)	2,731,878	984,833	362,482	4,079,194	**0.7%**
14,000	Shanghai	Rotterdam	2,861,785	944,750	241,655	4,048,189	Port Said (Egypt)	2,730,518	984,417	362,482	4,077,417	**0.7%**
14,000	Shanghai	Hamburg	2,930,576	965,833	241,655	4,138,064	Port Said (Egypt)	2,799,310	1,005,500	362,482	4,167,292	**0.7%**
14,000	Shanghai	Antwerp	2,863,144	945,167	241,655	4,049,966	Mersin (Turkey)	2,835,028	1,018,417	362,482	4,215,927	**4.1%**
14,000	Shanghai	Rotterdam	2,861,785	944,750	241,655	4,048,189	Mersin (Turkey)	2,833,669	1,018,000	362,482	4,214,151	**4.1%**
14,000	Shanghai	Hamburg	2,930,576	965,833	241,655	4,138,064	Mersin (Turkey)	2,902,461	1,039,083	362,482	4,304,026	**4.0%**
14,000	Shanghai	Antwerp	2,863,144	945,167	241,655	4,049,966	Tangier (Morocco)	2,699,187	985,583	362,482	4,047,252	**-0.1%**
14,000	Shanghai	Rotterdam	2,861,785	944,750	241,655	4,048,189	Tangier (Morocco)	2,697,827	985,167	362,482	4,045,476	**-0.1%**
14,000	Shanghai	Hamburg	2,930,576	965,833	241,655	4,138,064	Tangier (Morocco)	2,766,619	1,006,250	362,482	4,135,351	**-0.1%**
14,000	Shanghai	Antwerp	2,863,144	945,167	241,655	4,049,966	Felixstowe (UK)	2,692,075	990,417	362,482	4,044,974	**-0.1%**
14,000	Shanghai	Rotterdam	2,861,785	944,750	241,655	4,048,189	Felixstowe (UK)	2,686,637	988,750	362,482	4,037,869	**-0.3%**
14,000	Shanghai	Hamburg	2,930,576	965,833	241,655	4,138,064	Felixstowe (UK)	2,751,622	1,008,667	362,482	4,122,771	**-0.4%**
21,000	Shanghai	Antwerp	3,817,526	1,316,482	273,909	5,407,917	Port Said (Egypt)	3,642,504	1,371,732	410,864	5,425,100	**0.3%**
21,000	Shanghai	Rotterdam	3,815,713	1,315,902	273,909	5,405,524	Port Said (Egypt)	3,640,691	1,371,152	410,864	5,422,707	**0.3%**
21,000	Shanghai	Hamburg	3,907,435	1,345,268	273,909	5,526,612	Port Said (Egypt)	3,732,413	1,400,518	410,864	5,543,795	**0.3%**
21,000	Shanghai	Antwerp	3,817,526	1,316,482	273,909	5,407,917	Mersin (Turkey)	3,780,038	1,418,509	410,864	5,609,411	**3.7%**
21,000	Shanghai	Rotterdam	3,815,713	1,315,902	273,909	5,405,524	Mersin (Turkey)	3,778,225	1,417,929	410,864	5,607,018	**3.7%**
21,000	Shanghai	Hamburg	3,907,435	1,345,268	273,909	5,526,612	Mersin (Turkey)	3,869,947	1,447,295	410,864	5,728,106	**3.6%**
21,000	Shanghai	Antwerp	3,817,526	1,316,482	273,909	5,407,917	Tangier (Morocco)	3,598,916	1,372,777	410,864	5,382,557	**-0.5%**
21,000	Shanghai	Rotterdam	3,815,713	1,315,902	273,909	5,405,524	Tangier (Morocco)	3,597,103	1,372,196	410,864	5,380,163	**-0.5%**
21,000	Shanghai	Hamburg	3,907,435	1,345,268	273,909	5,526,612	Tangier (Morocco)	3,688,825	1,401,563	410,864	5,501,252	**-0.5%**
21,000	Shanghai	Antwerp	3,817,526	1,316,482	273,909	5,407,917	Felixstowe (UK)	3,589,433	1,379,509	410,864	5,379,806	**-0.5%**
21,000	Shanghai	Rotterdam	3,815,713	1,315,902	273,909	5,405,524	Felixstowe (UK)	3,582,182	1,377,188	410,864	5,370,234	**-0.7%**
21,000	Shanghai	Hamburg	3,907,435	1,345,268	273,909	5,526,612	Felixstowe (UK)	3,668,829	1,404,929	410,864	5,484,621	**-0.8%**
14,000	Shanghai	Genova	2,357,404	790,167	241,655	3,389,225	Port Said (Egypt)	2,226,137	829,833	362,482	3,418,453	**0.9%**
14,000	Shanghai	Marseille	2,382,691	797,917	241,655	3,422,262	Port Said (Egypt)	2,251,424	837,583	362,482	3,451,490	**0.9%**
14,000	Shanghai	Barcelona	2,403,355	804,250	241,655	3,449,260	Port Said (Egypt)	2,272,089	843,917	362,482	3,478,488	**0.8%**
14,000	Shanghai	Genova	2,357,404	790,167	241,655	3,389,225	Mersin (Turkey)	2,325,209	862,167	362,482	3,549,858	**4.7%**
14,000	Shanghai	Marseille	2,382,691	797,917	241,655	3,422,262	Mersin (Turkey)	2,350,496	869,917	362,482	3,582,895	**4.7%**
14,000	Shanghai	Barcelona	2,403,355	804,250	241,655	3,449,260	Mersin (Turkey)	2,375,240	877,500	362,482	3,615,222	**4.8%**
12,000	New York	Antwerp	745,741	312,500	229,553	1,287,793	Felixstowe (UK)	711,922	352,902	344,329	1,409,152	**9.4%**

Ship size TEU	Origin Port	Destination Port	Total travel cost direct route				Intermediate Port	Total travel cost intermediate stop				Diff. Travel cost [%]
			Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]		Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]	
12,000	New York	Rotterdam	744,640	312,128	229,553	1,286,321	Felixstowe (UK)	707,520	351,414	344,329	1,403,262	**9.1%**
12,000	New York	Hamburg	796,807	329,762	229,553	1,356,121	Felixstowe (UK)	760,126	369,196	344,329	1,473,652	**8.7%**
12,000	Savannah	Antwerp	867,683	353,720	229,553	1,450,956	Felixstowe (UK)	825,745	394,122	344,329	1,564,196	**7.8%**
12,000	Savannah	Rotterdam	866,582	353,348	229,553	1,449,483	Felixstowe (UK)	821,343	392,634	344,329	1,558,306	**7.5%**
12,000	Savannah	Hamburg	908,404	367,485	229,553	1,505,441	Felixstowe (UK)	873,950	410,417	344,329	1,628,695	**8.2%**
8,000	New York	Genova	577,251	289,583	200,971	1,067,805	Tangier (Morocco)	547,742	318,214	301,456	1,167,413	**9.3%**
8,000	New York	Marseille	554,890	280,238	200,971	1,036,099	Tangier (Morocco)	525,381	308,869	301,456	1,135,707	**9.6%**
8,000	New York	Barcelona	529,966	269,821	200,971	1,000,758	Tangier (Morocco)	500,457	298,452	301,456	1,100,366	**10.0%**
8,000	Savannah	Genova	645,331	318,036	200,971	1,164,337	Tangier (Morocco)	611,289	346,667	301,456	1,259,412	**8.2%**
8,000	Savannah	Marseille	622,970	308,690	200,971	1,132,631	Tangier (Morocco)	588,928	337,321	301,456	1,227,706	**8.4%**
8,000	Savannah	Barcelona	598,045	298,274	200,971	1,097,290	Tangier (Morocco)	564,004	326,905	301,456	1,192,365	**8.7%**
4,500	Santos	Genova	473,475	247,907	117,399	838,781	Tangier (Morocco)	447,630	267,663	176,098	891,391	**6.3%**
4,500	Santos	Marseille	459,245	241,459	117,399	818,103	Tangier (Morocco)	433,400	261,214	176,098	870,713	**6.4%**
4,500	Santos	Barcelona	443,384	234,271	117,399	795,054	Tangier (Morocco)	417,539	254,027	176,098	847,664	**6.6%**
4,500	Long Beach	Genova	736,224	366,973	117,399	1,220,596	Tangier (Morocco)	692,886	386,729	176,098	1,255,713	**2.9%**
4,500	Long Beach	Marseille	721,995	360,525	117,399	1,199,918	Tangier (Morocco)	678,656	380,280	176,098	1,235,035	**2.9%**
4,500	Long Beach	Barcelona	706,133	353,338	117,399	1,176,870	Tangier (Morocco)	662,795	373,093	176,098	1,211,986	**3.0%**
4,000	Santos	Antwerp	492,599	161,753	94,893	749,244	Felixstowe (UK)	466,321	175,813	142,339	784,472	**4.7%**
4,000	Santos	Rotterdam	492,145	161,623	94,893	748,661	Felixstowe (UK)	464,508	175,295	142,339	782,142	**4.5%**
4,000	Santos	Hamburg	515,076	168,174	94,893	778,143	Felixstowe (UK)	486,170	181,483	142,339	809,992	**4.1%**
4,000	Long Beach	Antwerp	703,052	221,876	94,893	1,019,820	Felixstowe (UK)	662,762	235,936	142,339	1,041,037	**2.1%**
4,000	Long Beach	Rotterdam	702,599	221,746	94,893	1,019,238	Felixstowe (UK)	660,949	235,418	142,339	1,038,706	**1.9%**
4,000	Long Beach	Hamburg	725,529	228,297	94,893	1,048,719	Felixstowe (UK)	682,611	241,606	142,339	1,066,556	**1.7%**

Source: TRUST model, TRT

Table 59: Containers routes – Costs comparison of the route with an intermediate stop relative to the direct route (% change in travel costs components)

Ship size TEU	Origin Region	Origin Port	Destination Region	Destination Port	Intermediate Port	Fuel cost [%]	Time cost [%]	Ports cost [%]	TOTAL [%]
14,000	South East Asia	Shanghai	North Europe	Antwerp	Port Said (Egypt)	-4.6%	4.2%	50%	0.7%
14,000	South East Asia	Shanghai	North Europe	Rotterdam	Port Said (Egypt)	-4.6%	4.2%	50%	0.7%

Ship size TEU	Origin Region	Origin Port	Destination Region	Destination Port	Intermediate Port	Fuel cost [%]	Time cost [%]	Ports cost [%]	TOTAL [%]
14,000	South East Asia	Shanghai	North Europe	Hamburg	Port Said (Egypt)	-4.5%	4.1%	50%	0.7%
14,000	South East Asia	Shanghai	North Europe	Antwerp	Mersin (Turkey)	-1.0%	7.7%	50%	4.1%
14,000	South East Asia	Shanghai	North Europe	Rotterdam	Mersin (Turkey)	-1.0%	7.8%	50%	4.1%
14,000	South East Asia	Shanghai	North Europe	Hamburg	Mersin (Turkey)	-1.0%	7.6%	50%	4.0%
14,000	South East Asia	Shanghai	North Europe	Antwerp	Tangier (Morocco)	-5.7%	4.3%	50%	-0.1%
14,000	South East Asia	Shanghai	North Europe	Rotterdam	Tangier (Morocco)	-5.7%	4.3%	50%	-0.1%
14,000	South East Asia	Shanghai	North Europe	Hamburg	Tangier (Morocco)	-5.6%	4.2%	50%	-0.1%
14,000	South East Asia	Shanghai	North Europe	Antwerp	Felixstowe (UK)	-6.0%	4.8%	50%	-0.1%
14,000	South East Asia	Shanghai	North Europe	Rotterdam	Felixstowe (UK)	-6.1%	4.7%	50%	-0.3%
14,000	South East Asia	Shanghai	North Europe	Hamburg	Felixstowe (UK)	-6.1%	4.4%	50%	-0.4%
21,000	South East Asia	Shanghai	North Europe	Antwerp	Port Said (Egypt)	-4.6%	4.2%	50%	0.3%
21,000	South East Asia	Shanghai	North Europe	Rotterdam	Port Said (Egypt)	-4.6%	4.2%	50%	0.3%
21,000	South East Asia	Shanghai	North Europe	Hamburg	Port Said (Egypt)	-4.5%	4.1%	50%	0.3%
21,000	South East Asia	Shanghai	North Europe	Antwerp	Mersin (Turkey)	-1.0%	7.7%	50%	3.7%
21,000	South East Asia	Shanghai	North Europe	Rotterdam	Mersin (Turkey)	-1.0%	7.8%	50%	3.7%
21,000	South East Asia	Shanghai	North Europe	Hamburg	Mersin (Turkey)	-1.0%	7.6%	50%	3.6%
21,000	South East Asia	Shanghai	North Europe	Antwerp	Tangier (Morocco)	-5.7%	4.3%	50%	-0.5%
21,000	South East Asia	Shanghai	North Europe	Rotterdam	Tangier (Morocco)	-5.7%	4.3%	50%	-0.5%
21,000	South East Asia	Shanghai	North Europe	Hamburg	Tangier (Morocco)	-5.6%	4.2%	50%	-0.5%
21,000	South East Asia	Shanghai	North Europe	Antwerp	Felixstowe (UK)	-6.0%	4.8%	50%	-0.5%
21,000	South East Asia	Shanghai	North Europe	Rotterdam	Felixstowe (UK)	-6.1%	4.7%	50%	-0.7%
21,000	South East Asia	Shanghai	North Europe	Hamburg	Felixstowe (UK)	-6.1%	4.4%	50%	-0.8%
14,000	South East Asia	Shanghai	Mediterranean	Genova	Port Said (Egypt)	-5.6%	5.0%	50%	0.9%
14,000	South East Asia	Shanghai	Mediterranean	Marseille	Port Said (Egypt)	-5.5%	5.0%	50%	0.9%
14,000	South East Asia	Shanghai	Mediterranean	Barcelona	Port Said (Egypt)	-5.5%	4.9%	50%	0.8%
14,000	South East Asia	Shanghai	Mediterranean	Genova	Mersin (Turkey)	-1.4%	9.1%	50%	4.7%
14,000	South East Asia	Shanghai	Mediterranean	Marseille	Mersin (Turkey)	-1.4%	9.0%	50%	4.7%
14,000	South East Asia	Shanghai	Mediterranean	Barcelona	Mersin (Turkey)	-1.2%	9.1%	50%	4.8%
12,000	North America	New York	North Europe	Antwerp	Felixstowe (UK)	-4.5%	12.9%	50%	9.4%
12,000	North America	New York	North Europe	Rotterdam	Felixstowe (UK)	-5.0%	12.6%	50%	9.1%
12,000	North America	New York	North Europe	Hamburg	Felixstowe (UK)	-4.6%	12.0%	50%	8.7%
12,000	North America	Savannah	North Europe	Antwerp	Felixstowe (UK)	-4.8%	11.4%	50%	7.8%

Ship size TEU	Origin Region	Origin Port	Destination Region	Destination Port	Intermediate Port	Fuel cost [%]	Time cost [%]	Ports cost [%]	TOTAL [%]
12,000	North America	Savannah	North Europe	Rotterdam	Felixstowe (UK)	-5.2%	11.1%	50%	7.5%
12,000	North America	Savannah	North Europe	Hamburg	Felixstowe (UK)	-3.8%	11.7%	50%	8.2%
8,000	North America	New York	Mediterranean	Genova	Tangier (Morocco)	-5.1%	9.9%	50%	9.3%
8,000	North America	New York	Mediterranean	Marseille	Tangier (Morocco)	-5.3%	10.2%	50%	9.6%
8,000	North America	New York	Mediterranean	Barcelona	Tangier (Morocco)	-5.6%	10.6%	50%	10.0%
8,000	North America	Savannah	Mediterranean	Genova	Tangier (Morocco)	-5.3%	9.0%	50%	8.2%
8,000	North America	Savannah	Mediterranean	Marseille	Tangier (Morocco)	-5.5%	9.3%	50%	8.4%
8,000	North America	Savannah	Mediterranean	Barcelona	Tangier (Morocco)	-5.7%	9.6%	50%	8.7%
4,500	South America	Santos	Mediterranean	Genova	Tangier (Morocco)	-5.5%	8.0%	50%	6.3%
4,500	South America	Santos	Mediterranean	Marseille	Tangier (Morocco)	-5.6%	8.2%	50%	6.4%
4,500	South America	Santos	Mediterranean	Barcelona	Tangier (Morocco)	-5.8%	8.4%	50%	6.6%
4,500	North America	Long Beach	Mediterranean	Genova	Tangier (Morocco)	-5.9%	5.4%	50%	2.9%
4,500	North America	Long Beach	Mediterranean	Marseille	Tangier (Morocco)	-6.0%	5.5%	50%	2.9%
4,500	North America	Long Beach	Mediterranean	Barcelona	Tangier (Morocco)	-6.1%	5.6%	50%	3.0%
4,000	South America	Santos	North Europe	Antwerp	Felixstowe (UK)	-5.3%	8.7%	50%	4.7%
4,000	South America	Santos	North Europe	Rotterdam	Felixstowe (UK)	-5.6%	8.5%	50%	4.5%
4,000	South America	Santos	North Europe	Hamburg	Felixstowe (UK)	-5.6%	7.9%	50%	4.1%
4,000	North America	Long Beach	North Europe	Antwerp	Felixstowe (UK)	-5.7%	6.3%	50%	2.1%
4,000	North America	Long Beach	North Europe	Rotterdam	Felixstowe (UK)	-5.9%	6.2%	50%	1.9%
4,000	North America	Long Beach	North Europe	Hamburg	Felixstowe (UK)	-5.9%	5.8%	50%	1.7%

Source: TRUST model, TRT

Dry bulker ships routes – detailed results for PO3

Table 60: Dry bulkers routes - Travel times

Ship size [DWT]-Goods	Origin Region	Origin Port	Destination Region	Destination Port	Total travel time direct route			Intermediate Port	Total travel time intermediate stop			Diff. Travel time	
					Days	Hours	Total [h]		Days	Hours	Total [h]	[h]	[%]
65,000-grain	North America	New Orleans	North Europe	Antwerp	20	20	500	Grimsby (UK)	23	6	558	58	12%
65,000-grain	North America	New Orleans	North Europe	Rotterdam	20	19	499	Grimsby (UK)	23	1	553	54	11%
65,000-grain	North America	New Orleans	North Europe	Hamburg	21	14	518	Grimsby (UK)	23	17	569	50	10%

Ship size [DWT]- Goods	Origin Region	Origin Port	Destination Region	Destination Port	Total travel time direct route			Intermediate Port	Total travel time intermediate stop			Diff. Travel time	
					Days	Hours	Total [h]		Days	Hours	Total [h]	[h]	[%]
65,000-grain	South America	Santos	North Europe	Antwerp	23	0	552	Grimsby (UK)	25	14	614	62	11%
65,000-grain	South America	Santos	North Europe	Rotterdam	22	24	552	Grimsby (UK)	25	9	609	57	10%
65,000-grain	South America	Santos	North Europe	Hamburg	23	23	575	Grimsby (UK)	26	1	625	50	9%
35,000-grain	North America	New Orleans	North Europe	Antwerp	20	20	500	Grimsby (UK)	23	6	558	58	12%
35,000-grain	North America	New Orleans	North Europe	Rotterdam	20	19	499	Grimsby (UK)	23	1	553	54	11%
35,000-grain	North America	New Orleans	North Europe	Hamburg	21	14	518	Grimsby (UK)	23	17	569	50	10%
35,000-grain	South America	Santos	North Europe	Antwerp	23	0	552	Grimsby (UK)	25	14	614	62	11%
35,000-grain	South America	Santos	North Europe	Rotterdam	22	24	552	Grimsby (UK)	25	9	609	57	10%
35,000-grain	South America	Santos	North Europe	Hamburg	23	23	575	Grimsby (UK)	26	1	625	50	9%
35,000-grain	North America	New Orleans	Mediterranean	Marseille	22	8	536	Oran (Algeria)	24	1	577	41	8%
35,000-grain	North America	New Orleans	Mediterranean	Livorno	22	24	552	Oran (Algeria)	24	16	592	40	7%
35,000-grain	South America	Santos	Mediterranean	Marseille	21	15	519	Oran (Algeria)	23	8	560	41	8%
35,000-grain	South America	Santos	Mediterranean	Livorno	22	6	534	Oran (Algeria)	23	22	574	40	7%
28,000-grain	North America	New Orleans	Mediterranean	Marseille	22	8	536	Oran (Algeria)	24	1	577	41	8%
28,000-grain	North America	New Orleans	Mediterranean	Livorno	22	24	552	Oran (Algeria)	24	16	592	40	7%
28,000-grain	North America	New Orleans	Mediterranean	Naples	23	10	562	Oran (Algeria)	24	23	599	37	6%
28,000-grain	South America	Santos	Mediterranean	Marseille	21	15	519	Oran (Algeria)	23	8	560	41	8%
28,000-grain	South America	Santos	Mediterranean	Livorno	22	6	534	Oran (Algeria)	23	22	574	40	7%
28,000-grain	South America	Santos	Mediterranean	Naples	22	17	545	Oran (Algeria)	24	5	581	37	7%
200,000-iron ore	South America	Tubarao	North Europe	Rotterdam	21	6	510	Grimsby (UK)	23	16	568	57	11%
200,000-iron ore	South America	Tubarao	North Europe	Hamburg	22	5	533	Grimsby (UK)	24	7	583	50	9%
300,000-iron ore	South America	Tubarao	North Europe	Rotterdam	21	6	510	Grimsby (UK)	23	16	568	57	11%
300,000-iron ore	South America	Tubarao	North Europe	Hamburg	22	5	533	Grimsby (UK)	24	7	583	50	9%
165,000-coal	South Africa	Durban	North Europe	Rotterdam	28	17	689	Grimsby (UK)	31	3	747	57	8%
165,000-coal	South Africa	Durban	North Europe	Hamburg	29	16	712	Grimsby (UK)	31	19	763	50	7%
70,000-coal	North America	New Orleans	Mediterranean	Taranto	24	10	586	Oran (Algeria)	25	22	622	36	6%
165,000-coal	South America	Buenaventura	North Europe	Rotterdam	22	2	530	Grimsby (UK)	24	12	588	57	11%
165,000-coal	South America	Buenaventura	North Europe	Hamburg	23	1	553	Grimsby (UK)	25	3	603	50	9%
165,000-coal	South America	Ponta Da Madeira	North Europe	Rotterdam	17	23	431	Grimsby (UK)	20	9	489	57	13%
165,000-coal	South America	Ponta Da Madeira	North Europe	Hamburg	18	22	454	Grimsby (UK)	21	1	505	50	11%
200,000-iron ore	South America	Tubarao	Mediterranean	Taranto	21	23	527	Oran (Algeria)	23	11	563	36	7%

Source: TRUST model, TRT

Table 61: Dry bulkers routes – Time comparison of the route with an intermediate stop relative to the direct route (% change in travel time components)

Ship size [DWT]-Goods	Origin Port	Destination Port	Total travel time direct route			Intermediate Port	Total travel time intermediate stop			Sailing time [%]	Time at ports [%]	Total [%]
			Sailing time [h]	Time at ports [h]	Total [h]		Sailing time [h]	Time at ports [h]	Total [h]			
65,000-grain	New Orleans	Antwerp	442	58	500	Grimsby (UK)	466	92	558	6%	59%	12%
65,000-grain	New Orleans	Rotterdam	441	58	499	Grimsby (UK)	461	92	553	4%	59%	11%
65,000-grain	New Orleans	Hamburg	460	58	518	Grimsby (UK)	477	92	569	4%	59%	10%
65,000-grain	Santos	Antwerp	494	58	552	Grimsby (UK)	522	92	614	6%	59%	11%
65,000-grain	Santos	Rotterdam	494	58	552	Grimsby (UK)	517	92	609	5%	59%	10%
65,000-grain	Santos	Hamburg	517	58	575	Grimsby (UK)	533	92	625	3%	59%	9%
35,000-grain	New Orleans	Antwerp	442	58	500	Grimsby (UK)	466	92	558	6%	59%	12%
35,000-grain	New Orleans	Rotterdam	441	58	499	Grimsby (UK)	461	92	553	4%	59%	11%
35,000-grain	New Orleans	Hamburg	460	58	518	Grimsby (UK)	477	92	569	4%	59%	10%
35,000-grain	Santos	Antwerp	494	58	552	Grimsby (UK)	522	92	614	6%	59%	11%
35,000-grain	Santos	Rotterdam	494	58	552	Grimsby (UK)	517	92	609	5%	59%	10%
35,000-grain	Santos	Hamburg	517	58	575	Grimsby (UK)	533	92	625	3%	59%	9%
35,000-grain	New Orleans	Marseille	478	58	536	Oran (Algeria)	485	92	577	2%	59%	8%
35,000-grain	New Orleans	Livorno	494	58	552	Oran (Algeria)	500	92	592	1%	59%	7%
35,000-grain	Santos	Marseille	461	58	519	Oran (Algeria)	468	92	560	2%	59%	8%
35,000-grain	Santos	Livorno	476	58	534	Oran (Algeria)	482	92	574	1%	59%	7%
28,000-grain	New Orleans	Marseille	478	58	536	Oran (Algeria)	485	92	577	2%	59%	8%
28,000-grain	New Orleans	Livorno	494	58	552	Oran (Algeria)	500	92	592	1%	59%	7%
28,000-grain	New Orleans	Naples	504	58	562	Oran (Algeria)	507	92	599	1%	59%	6%
28,000-grain	Santos	Marseille	461	58	519	Oran (Algeria)	468	92	560	2%	59%	8%
28,000-grain	Santos	Livorno	476	58	534	Oran (Algeria)	482	92	574	1%	59%	7%
28,000-grain	Santos	Naples	487	58	545	Oran (Algeria)	489	92	581	1%	59%	7%
200,000-iron ore	Tubarao	Rotterdam	452	58	510	Grimsby (UK)	476	92	568	5%	59%	11%
200,000-iron ore	Tubarao	Hamburg	475	58	533	Grimsby (UK)	491	92	583	3%	59%	9%
300,000-iron ore	Tubarao	Rotterdam	452	58	510	Grimsby (UK)	476	92	568	5%	59%	11%
300,000-iron ore	Tubarao	Hamburg	475	58	533	Grimsby (UK)	491	92	583	3%	59%	9%
165,000-coal	Durban	Rotterdam	631	58	689	Grimsby (UK)	655	92	747	4%	59%	8%
165,000-coal	Durban	Hamburg	654	58	712	Grimsby (UK)	671	92	763	2%	59%	7%
70,000-coal	New Orleans	Taranto	528	58	586	Oran (Algeria)	530	92	622	0%	59%	6%

Ship size [DWT]-Goods	Origin Port	Destination Port	Total travel time direct route			Intermediate Port	Total travel time intermediate stop			Sailing time [%]	Time at ports [%]	Total [%]
			Sailing time [h]	Time at ports [h]	Total [h]		Sailing time [h]	Time at ports [h]	Total [h]			
165,000-coal	Buenaventura	Rotterdam	472	58	530	Grimsby (UK)	496	92	588	5%	59%	11%
165,000-coal	Buenaventura	Hamburg	495	58	553	Grimsby (UK)	511	92	603	3%	59%	9%
165,000-coal	Ponta Da Madeira	Rotterdam	373	58	431	Grimsby (UK)	397	92	489	6%	59%	13%
165,000-coal	Ponta Da Madeira	Hamburg	396	58	454	Grimsby (UK)	413	92	505	4%	59%	11%
200,000-iron ore	Tubarao	Taranto	469	58	527	Oran (Algeria)	471	92	563	0%	59%	7%

Source: TRUST model, TRT

Table 62: Dry bulkers routes - Travel costs

Ship size [DWT]-Goods	Origin Port	Destination Port	Total travel cost direct route				Intermediate Port	Total travel cost intermediate stop				Diff. Travel cost [%]
			Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]		Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]	
65,000-grain	New Orleans	Antwerp	415,020	196,351	116,099	727,470	Grimsby (UK)	410,290	219,319	174,148	803,757	**10%**
65,000-grain	New Orleans	Rotterdam	414,593	196,173	116,099	726,864	Grimsby (UK)	405,336	217,247	174,148	796,731	**10%**
65,000-grain	New Orleans	Hamburg	432,529	203,674	116,099	752,302	Grimsby (UK)	420,198	223,462	174,148	817,808	**9%**
65,000-grain	Santos	Antwerp	464,218	216,926	116,099	797,242	Grimsby (UK)	459,561	241,394	174,148	875,102	**10%**
65,000-grain	Santos	Rotterdam	463,791	216,747	116,099	796,636	Grimsby (UK)	454,607	239,322	174,148	868,077	**9%**
65,000-grain	Santos	Hamburg	485,400	225,784	116,099	827,283	Grimsby (UK)	469,469	245,537	174,148	889,154	**7%**
35,000-grain	New Orleans	Antwerp	292,189	154,083	61,436	507,707	Grimsby (UK)	288,859	172,106	92,154	553,119	**9%**
35,000-grain	New Orleans	Rotterdam	291,888	153,942	61,436	507,266	Grimsby (UK)	285,371	170,480	92,154	548,005	**8%**
35,000-grain	New Orleans	Hamburg	304,516	159,829	61,436	525,781	Grimsby (UK)	295,835	175,358	92,154	563,346	**7%**
35,000-grain	Santos	Antwerp	326,826	170,228	61,436	558,490	Grimsby (UK)	323,547	189,429	92,154	605,130	**8%**
35,000-grain	Santos	Rotterdam	326,525	170,088	61,436	558,049	Grimsby (UK)	320,060	187,803	92,154	600,016	**8%**
35,000-grain	Santos	Hamburg	341,739	177,180	61,436	580,354	Grimsby (UK)	330,523	192,680	92,154	615,357	**6%**
35,000-grain	New Orleans	Marseille	316,302	165,323	61,436	543,061	Oran (Algeria)	301,815	178,020	92,154	571,990	**5%**
35,000-grain	New Orleans	Livorno	326,706	170,172	61,436	558,313	Oran (Algeria)	311,437	182,505	92,154	586,096	**5%**
35,000-grain	Santos	Marseille	304,697	159,913	61,436	526,045	Oran (Algeria)	290,982	172,611	92,154	555,747	**6%**
35,000-grain	Santos	Livorno	315,100	164,762	61,436	541,298	Oran (Algeria)	300,604	177,095	92,154	569,853	**5%**
28,000-grain	New Orleans	Marseille	227,626	157,615	53,700	438,941	Oran (Algeria)	217,201	169,721	80,550	467,471	**6%**
28,000-grain	New Orleans	Livorno	235,113	162,238	53,700	451,051	Oran (Algeria)	224,125	173,997	80,550	478,671	**6%**

Ship size [DWT]- Goods	Origin Port	Destination Port	Total travel cost direct route				Intermediate Port	Total travel cost intermediate stop				Diff. Travel cost [%]
			Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]		Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]	
28,000-grain	New Orleans	Naples	240,133	165,338	53,700	459,171	Oran (Algeria)	227,500	176,081	80,550	484,131	**5%**
28,000-grain	Santos	Marseille	219,274	152,457	53,700	425,432	Oran (Algeria)	209,405	164,563	80,550	454,518	**7%**
28,000-grain	Santos	Livorno	226,761	157,081	53,700	437,541	Oran (Algeria)	216,329	168,839	80,550	465,717	**6%**
28,000-grain	Santos	Naples	231,781	160,181	53,700	445,661	Oran (Algeria)	219,704	170,923	80,550	471,177	**6%**
200,000-iron ore	Tubarao	Rotterdam	590,347	339,271	244,599	1,174,217	Grimsby (UK)	581,189	377,478	366,898	1,325,566	**13%**
200,000-iron ore	Tubarao	Hamburg	620,375	354,566	244,599	1,219,540	Grimsby (UK)	601,841	387,997	366,898	1,356,736	**11%**
300,000-iron ore	Tubarao	Rotterdam	688,311	442,476	325,884	1,456,672	Grimsby (UK)	677,634	492,306	488,826	1,658,766	**14%**
300,000-iron ore	Tubarao	Hamburg	723,322	462,424	325,884	1,511,630	Grimsby (UK)	701,712	506,025	488,826	1,696,563	**12%**
165,000-coal	Durban	Rotterdam	788,789	409,543	199,705	1,398,037	Grimsby (UK)	765,125	443,680	299,558	1,508,364	**8%**
165,000-coal	Durban	Hamburg	817,528	423,209	199,705	1,440,442	Grimsby (UK)	784,890	453,079	299,558	1,537,527	**7%**
70,000-coal	New Orleans	Taranto	495,649	235,438	118,037	849,125	Oran (Algeria)	470,289	249,950	177,056	897,295	**6%**
165,000-coal	Buenaventura	Rotterdam	590,002	315,016	199,705	1,104,723	Grimsby (UK)	579,573	349,154	299,558	1,228,285	**11%**
165,000-coal	Buenaventura	Hamburg	618,741	328,682	199,705	1,147,128	Grimsby (UK)	599,338	358,553	299,558	1,257,448	**10%**
165,000-coal	Ponta Da Madeira	Rotterdam	466,640	256,356	199,705	922,701	Grimsby (UK)	464,424	290,493	299,558	1,054,476	**14%**
165,000-coal	Ponta Da Madeira	Hamburg	495,379	270,022	199,705	965,106	Grimsby (UK)	484,189	299,892	299,558	1,083,639	**12%**
200,000-iron ore	Tubarao	Taranto	611,711	350,153	244,599	1,206,463	Oran (Algeria)	581,600	374,153	366,898	1,322,651	**10%**

Source: TRUST model, TRT

Table 63: Dry bulkers routes – Costs comparison of the route with an intermediate stop relative to the direct route (% change in travel costs components)

Ship size [DWT]- Goods	Origin Region	Origin Port	Destination Region	Destination Port	Intermediate Port	Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]
65,000-grain	North America	New Orleans	North Europe	Antwerp	Grimsby (UK)	-1%	12%	50%	10%
65,000-grain	North America	New Orleans	North Europe	Rotterdam	Grimsby (UK)	-2%	11%	50%	10%
65,000-grain	North America	New Orleans	North Europe	Hamburg	Grimsby (UK)	-3%	10%	50%	9%
65,000-grain	South America	Santos	North Europe	Antwerp	Grimsby (UK)	-1%	11%	50%	10%
65,000-grain	South America	Santos	North Europe	Rotterdam	Grimsby (UK)	-2%	10%	50%	9%
65,000-grain	South America	Santos	North Europe	Hamburg	Grimsby (UK)	-3%	9%	50%	7%
35,000-grain	North America	New Orleans	North Europe	Antwerp	Grimsby (UK)	-1%	12%	50%	9%
35,000-grain	North America	New Orleans	North Europe	Rotterdam	Grimsby (UK)	-2%	11%	50%	8%
35,000-grain	North America	New Orleans	North Europe	Hamburg	Grimsby (UK)	-3%	10%	50%	7%

Ship size [DWT]- Goods	Origin Region	Origin Port	Destination Region	Destination Port	Intermediate Port	Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]
35,000-grain	South America	Santos	North Europe	Antwerp	Grimsby (UK)	-1%	11%	50%	8%
35,000-grain	South America	Santos	North Europe	Rotterdam	Grimsby (UK)	-2%	10%	50%	8%
35,000-grain	South America	Santos	North Europe	Hamburg	Grimsby (UK)	-3%	9%	50%	6%
35,000-grain	North America	New Orleans	Mediterranean	Marseille	Oran (Algeria)	-5%	8%	50%	5%
35,000-grain	North America	New Orleans	Mediterranean	Livorno	Oran (Algeria)	-5%	7%	50%	5%
35,000-grain	South America	Santos	Mediterranean	Marseille	Oran (Algeria)	-5%	8%	50%	6%
35,000-grain	South America	Santos	Mediterranean	Livorno	Oran (Algeria)	-5%	7%	50%	5%
28,000-grain	North America	New Orleans	Mediterranean	Marseille	Oran (Algeria)	-5%	8%	50%	6%
28,000-grain	North America	New Orleans	Mediterranean	Livorno	Oran (Algeria)	-5%	7%	50%	6%
28,000-grain	North America	New Orleans	Mediterranean	Naples	Oran (Algeria)	-5%	6%	50%	5%
28,000-grain	South America	Santos	Mediterranean	Marseille	Oran (Algeria)	-5%	8%	50%	7%
28,000-grain	South America	Santos	Mediterranean	Livorno	Oran (Algeria)	-5%	7%	50%	6%
28,000-grain	South America	Santos	Mediterranean	Naples	Oran (Algeria)	-5%	7%	50%	6%
200,000-iron ore	South America	Tubarao	North Europe	Rotterdam	Grimsby (UK)	-2%	11%	50%	13%
200,000-iron ore	South America	Tubarao	North Europe	Hamburg	Grimsby (UK)	-3%	9%	50%	11%
300,000-iron ore	South America	Tubarao	North Europe	Rotterdam	Grimsby (UK)	-2%	11%	50%	14%
300,000-iron ore	South America	Tubarao	North Europe	Hamburg	Grimsby (UK)	-3%	9%	50%	12%
165,000-coal	South Africa	Durban	North Europe	Rotterdam	Grimsby (UK)	-3%	8%	50%	8%
165,000-coal	South Africa	Durban	North Europe	Hamburg	Grimsby (UK)	-4%	7%	50%	7%
70,000-coal	North America	New Orleans	Mediterranean	Taranto	Oran (Algeria)	-5%	6%	50%	6%
165,000-coal	South America	Buenaventura	North Europe	Rotterdam	Grimsby (UK)	-2%	11%	50%	11%
165,000-coal	South America	Buenaventura	North Europe	Hamburg	Grimsby (UK)	-3%	9%	50%	10%
165,000-coal	South America	Ponta Da Madeira	North Europe	Rotterdam	Grimsby (UK)	0%	13%	50%	14%
165,000-coal	South America	Ponta Da Madeira	North Europe	Hamburg	Grimsby (UK)	-2%	11%	50%	12%
200,000-iron ore	South America	Tubarao	Mediterranean	Taranto	Oran (Algeria)	-5%	7%	50%	10%

Source: TRUST model, TRT

Liquid bulker ships routes – detailed results for PO3

Table 64: Tankers routes - Travel times

Ship size [DWT]-Goods	Origin Region	Origin Port	Destination Region	Destination Port	Total travel time			Intermediate Port	Total travel time			Diff. Travel time	
					Days	Hours	Total [h]		Days	Hours	Total [h]	[h]	[%]

Ship size [DWT]-Goods	Origin Region	Origin Port	Destination Region	Destination Port	Total travel time			Intermediate Port	Total travel time			Diff. Travel time	
					Days	Hours	Total [h]		Days	Hours	Total [h]	[h]	[%]
70,000-dirty	US Gulf	Corpus Christi	North Europe	Antwerp	21	13	517	Milford Haven (UK)	23	13	565	48	9%
70,000-dirty	US Gulf	Corpus Christi	North Europe	Rotterdam	21	13	517	Milford Haven (UK)	23	13	565	48	9%
130,000-dirty	US Gulf	Corpus Christi	North Europe	Antwerp	21	13	517	Milford Haven (UK)	23	13	565	48	9%
130,000-dirty	US Gulf	Corpus Christi	North Europe	Rotterdam	21	13	517	Milford Haven (UK)	23	13	565	48	9%
135,000-dirty	West Africa	Lagos	North Europe	Antwerp	18	4	436	Jorf-Lasfar (Morocco)	19	23	479	43	10%
135,000-dirty	West Africa	Lagos	North Europe	Rotterdam	18	3	435	Jorf-Lasfar (Morocco)	19	22	478	43	10%
135,000-dirty	West Africa	Lagos	North Europe	Antwerp	18	6	438	Medway (UK)	19	23	479	42	9%
135,000-dirty	West Africa	Lagos	North Europe	Rotterdam	18	5	437	Medway (UK)	19	22	478	41	9%
90,000-clean	Arabian Gulf	Ju'aymah	North Europe	Antwerp	27	2	650	Alexandria (Egypt)	28	16	688	38	6%
90,000-clean	Arabian Gulf	Ju'aymah	North Europe	Rotterdam	27	2	650	Alexandria (Egypt)	28	16	688	38	6%
90,000-clean	Arabian Gulf	Ju'aymah	North Europe	Antwerp	26	22	646	Milford Haven (UK)	29	11	707	61	9%
90,000-clean	Arabian Gulf	Ju'aymah	North Europe	Rotterdam	26	22	646	Milford Haven (UK)	29	11	707	61	9%
80,000	North Africa	Arzew	North Europe	Antwerp	8	14	206	Medway (UK)	10	7	247	42	20%
80,000	North Africa	Arzew	North Europe	Rotterdam	8	13	205	Medway (UK)	10	6	246	41	20%
70,000-dirty	US Gulf	Corpus Christi	Mediterranean	Augusta	24	13	589	Jorf-Lasfar (Morocco)	26	11	635	46	8%
70,000-dirty	US Gulf	Corpus Christi	Mediterranean	Cartagena	21	12	516	Jorf-Lasfar (Morocco)	23	10	562	46	9%
70,000-dirty	US Gulf	Corpus Christi	Mediterranean	Agioi Theodoroi	26	6	630	Jorf-Lasfar (Morocco)	28	4	676	46	7%
130,000-dirty	US Gulf	Corpus Christi	Mediterranean	Augusta	24	13	589	Jorf-Lasfar (Morocco)	26	11	635	46	8%
130,000-dirty	US Gulf	Corpus Christi	Mediterranean	Cartagena	21	12	516	Jorf-Lasfar (Morocco)	23	10	562	46	9%
130,000-dirty	US Gulf	Corpus Christi	Mediterranean	Agioi Theodoroi	26	6	630	Jorf-Lasfar (Morocco)	28	4	676	46	7%
130,000-dirty	West Africa	Lagos	Mediterranean	Savona	17	6	414	Jorf-Lasfar (Morocco)	18	16	448	35	8%
130,000-dirty	West Africa	Lagos	Mediterranean	Cartagena	14	23	359	Jorf-Lasfar (Morocco)	16	10	394	35	10%
130,000-dirty	West Africa	Lagos	Mediterranean	Leixoes	14	18	354	Jorf-Lasfar (Morocco)	16	12	396	42	12%
90,000-clean	Arabian Gulf	Ju'aymah	Mediterranean	Augusta	18	0	432	Alexandria (Egypt)	19	15	471	38	9%
90,000-clean	Arabian Gulf	Ju'aymah	Mediterranean	Cartagena	20	22	502	Alexandria (Egypt)	22	12	540	38	8%
90,000-clean	Arabian Gulf	Ju'aymah	Mediterranean	Agioi Theodoroi	16	20	404	Alexandria (Egypt)	18	14	446	42	10%

Source: TRUST model, TRT

Table 65: Tankers routes – Time comparison of the route with an intermediate stop relative to the direct route (% change in travel time components)

Ship size [DWT]-Goods	Origin Port	Destination Port	Total travel time direct route	Intermediate Port	Total travel time intermediate stop	Sailing time	Time at ports	Total [%]

			Sailing time [h]	Time at ports [h]	Total [h]		Sailing time [h]	Time at ports [h]	Total [h]	[%]	[%]	
70,000-dirty	Corpus Christi	Antwerp	459	58	517	Milford Haven (UK)	473	92	565	3%	59%	9%
70,000-dirty	Corpus Christi	Rotterdam	459	58	517	Milford Haven (UK)	473	92	565	3%	59%	9%
130,000-dirty	Corpus Christi	Antwerp	459	58	517	Milford Haven (UK)	473	92	565	3%	59%	9%
130,000-dirty	Corpus Christi	Rotterdam	459	58	517	Milford Haven (UK)	473	92	565	3%	59%	9%
135,000-dirty	Lagos	Antwerp	378	58	436	Jorf-Lasfar (Morocco)	387	92	479	2%	59%	10%
135,000-dirty	Lagos	Rotterdam	377	58	435	Jorf-Lasfar (Morocco)	386	92	478	2%	59%	10%
135,000-dirty	Lagos	Antwerp	380	58	438	Medway (UK)	387	92	479	2%	59%	9%
135,000-dirty	Lagos	Rotterdam	379	58	437	Medway (UK)	386	92	478	2%	59%	9%
90,000-clean	Ju'aymah	Antwerp	592	58	650	Alexandria (Egypt)	596	92	688	1%	59%	6%
90,000-clean	Ju'aymah	Rotterdam	592	58	650	Alexandria (Egypt)	596	92	688	1%	59%	6%
90,000-clean	Ju'aymah	Antwerp	588	58	646	Milford Haven (UK)	615	92	707	5%	59%	9%
90,000-clean	Ju'aymah	Rotterdam	588	58	646	Milford Haven (UK)	615	92	707	5%	59%	9%
80,000	Arzew	Antwerp	148	58	206	Medway (UK)	155	92	247	5%	59%	20%
80,000	Arzew	Rotterdam	147	58	205	Medway (UK)	154	92	246	5%	59%	20%
70,000-dirty	Corpus Christi	Augusta	531	58	589	Jorf-Lasfar (Morocco)	543	92	635	2%	59%	8%
70,000-dirty	Corpus Christi	Cartagena	458	58	516	Jorf-Lasfar (Morocco)	470	92	562	3%	59%	9%
70,000-dirty	Corpus Christi	Agioi Theodoroi	572	58	630	Jorf-Lasfar (Morocco)	584	92	676	2%	59%	7%
130,000-dirty	Corpus Christi	Augusta	531	58	589	Jorf-Lasfar (Morocco)	543	92	635	2%	59%	8%
130,000-dirty	Corpus Christi	Cartagena	458	58	516	Jorf-Lasfar (Morocco)	470	92	562	3%	59%	9%
130,000-dirty	Corpus Christi	Agioi Theodoroi	572	58	630	Jorf-Lasfar (Morocco)	584	92	676	2%	59%	7%
130,000-dirty	Lagos	Savona	356	58	414	Jorf-Lasfar (Morocco)	356	92	448	0%	59%	8%
130,000-dirty	Lagos	Cartagena	301	58	359	Jorf-Lasfar (Morocco)	302	92	394	0%	59%	10%
130,000-dirty	Lagos	Leixoes	296	58	354	Jorf-Lasfar (Morocco)	304	92	396	3%	59%	12%
90,000-clean	Ju'aymah	Augusta	374	58	432	Alexandria (Egypt)	379	92	471	1%	59%	9%
90,000-clean	Ju'aymah	Cartagena	444	58	502	Alexandria (Egypt)	448	92	540	1%	59%	8%
90,000-clean	Ju'aymah	Agioi Theodoroi	346	58	404	Alexandria (Egypt)	354	92	446	2%	59%	10%

Source: TRUST model, TRT

Table 66: Tankers routes - Travel costs

Ship size [DWT]-Goods	Origin Port	Destination Port	Total travel cost direct route	Intermediate Port	Total travel cost intermediate stop	Diff. Travel

			Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]		Fuel cost [€]	Time cost [€]	Ports cost [€]	TOTAL [€]	cost [%]
70,000-dirty	Corpus Christi	Antwerp	445,407	292,812	122,675	860,894	Milford Haven (UK)	431,932	320,167	184,013	936,111	9%
70,000-dirty	Corpus Christi	Rotterdam	445,407	292,812	122,675	860,894	Milford Haven (UK)	431,844	320,115	184,013	935,971	9%
130,000-dirty	Corpus Christi	Antwerp	548,590	530,722	186,815	1,266,127	Milford Haven (UK)	531,993	580,302	280,222	1,392,517	10%
130,000-dirty	Corpus Christi	Rotterdam	548,590	530,722	186,815	1,266,127	Milford Haven (UK)	531,884	580,209	280,222	1,392,315	10%
135,000-dirty	Lagos	Antwerp	451,505	462,767	194,000	1,108,272	Jorf-Lasfar (Morocco)	441,762	508,455	291,000	1,241,216	12%
135,000-dirty	Lagos	Rotterdam	451,396	462,670	194,000	1,108,067	Jorf-Lasfar (Morocco)	441,653	508,358	291,000	1,241,011	12%
135,000-dirty	Lagos	Antwerp	454,005	464,989	194,000	1,112,994	Medway (UK)	433,381	509,131	291,000	1,233,511	11%
135,000-dirty	Lagos	Rotterdam	453,462	464,506	194,000	1,111,968	Medway (UK)	432,294	508,165	291,000	1,231,458	11%
90,000-clean	Ju'aymah	Antwerp	594,492	488,383	140,200	1,223,075	Alexandria (Egypt)	577,776	516,642	210,300	1,304,718	7%
90,000-clean	Ju'aymah	Rotterdam	594,492	488,383	140,200	1,223,075	Alexandria (Egypt)	577,776	516,642	210,300	1,304,718	7%
90,000-clean	Ju'aymah	Antwerp	590,113	485,107	140,200	1,215,420	Milford Haven (UK)	579,465	530,907	210,300	1,320,673	9%
90,000-clean	Ju'aymah	Rotterdam	590,022	485,038	140,200	1,215,260	Milford Haven (UK)	579,374	530,839	210,300	1,320,513	9%
80,000	Arzew	Antwerp	145,637	131,035	140,200	416,872	Medway (UK)	143,867	157,520	210,300	511,687	23%
80,000	Arzew	Rotterdam	145,189	130,745	140,200	416,134	Medway (UK)	142,969	156,941	210,300	510,210	23%
70,000-dirty	Corpus Christi	Augusta	515,405	333,664	122,675	971,743	Jorf-Lasfar (Morocco)	499,382	359,627	184,013	1,043,021	7%
70,000-dirty	Corpus Christi	Cartagena	444,966	292,555	122,675	860,195	Jorf-Lasfar (Morocco)	428,855	318,467	184,013	931,334	8%
70,000-dirty	Corpus Christi	Agioi Theodoroi	555,832	357,258	122,675	1,035,765	Jorf-Lasfar (Morocco)	539,809	383,221	184,013	1,107,043	7%
130,000-dirty	Corpus Christi	Augusta	634,803	604,765	186,815	1,426,383	Jorf-Lasfar (Morocco)	615,068	651,824	280,222	1,547,115	8%
130,000-dirty	Corpus Christi	Cartagena	548,046	530,255	186,815	1,265,116	Jorf-Lasfar (Morocco)	528,203	577,221	280,222	1,385,646	10%
130,000-dirty	Corpus Christi	Agioi Theodoroi	684,596	647,529	186,815	1,518,940	Jorf-Lasfar (Morocco)	664,861	694,588	280,222	1,639,672	8%
130,000-dirty	Lagos	Savona	425,195	424,746	186,815	1,036,756	Jorf-Lasfar (Morocco)	405,450	460,320	280,222	1,145,992	11%
130,000-dirty	Lagos	Cartagena	360,508	369,190	186,815	916,513	Jorf-Lasfar (Morocco)	340,872	404,858	280,222	1,025,951	12%
130,000-dirty	Lagos	Leixoes	353,659	363,307	186,815	903,781	Jorf-Lasfar (Morocco)	342,502	406,258	280,222	1,028,983	14%
90,000-clean	Ju'aymah	Augusta	375,560	324,565	140,200	840,324	Alexandria (Egypt)	359,574	353,369	210,300	923,243	10%

Ship size [DWT]- Goods	Origin Port	Destination Port	Total travel cost direct route				Intermediate Port	Total travel cost intermediate stop				Diff. Travel
90,000-clean	Ju'aymah	Cartagena	445,892	377,191	140,200	963,283	Alexandria (Egypt)	429,632	405,791	210,300	1,045,723	9%
90,000-clean	Ju'aymah	Agioi Theodoroi	347,281	303,405	140,200	790,886	Alexandria (Egypt)	334,579	334,667	210,300	879,546	11%

Source: TRUST model, TRT

Table 67: Tankers routes – Costs comparison of the route with an intermediate stop relative to the direct route (% change in travel costs components)

Ship size [DWT]- Goods	Origin Region	Origin Port	Destination Region	Destination Port	Intermediate Port	Fuel cost [%]	Time cost [%]	Ports cost [%]	TOTAL [%]
70,000-dirty	US Gulf	Corpus Christi	North Europe	Antwerp	Milford Haven (UK)	-3%	9%	50%	9%
70,000-dirty	US Gulf	Corpus Christi	North Europe	Rotterdam	Milford Haven (UK)	-3%	9%	50%	9%
130,000-dirty	US Gulf	Corpus Christi	North Europe	Antwerp	Milford Haven (UK)	-3%	9%	50%	10%
130,000-dirty	US Gulf	Corpus Christi	North Europe	Rotterdam	Milford Haven (UK)	-3%	9%	50%	10%
135,000-dirty	West Africa	Lagos	North Europe	Antwerp	Jorf-Lasfar (Morocco)	-2%	10%	50%	12%
135,000-dirty	West Africa	Lagos	North Europe	Rotterdam	Jorf-Lasfar (Morocco)	-2%	10%	50%	12%
135,000-dirty	West Africa	Lagos	North Europe	Antwerp	Medway (UK)	-5%	9%	50%	11%
135,000-dirty	West Africa	Lagos	North Europe	Rotterdam	Medway (UK)	-5%	9%	50%	11%
90,000-clean	Arabian Gulf	Ju'aymah	North Europe	Antwerp	Alexandria (Egypt)	-3%	6%	50%	7%
90,000-clean	Arabian Gulf	Ju'aymah	North Europe	Rotterdam	Alexandria (Egypt)	-3%	6%	50%	7%
90,000-clean	Arabian Gulf	Ju'aymah	North Europe	Antwerp	Milford Haven (UK)	-2%	9%	50%	9%
90,000-clean	Arabian Gulf	Ju'aymah	North Europe	Rotterdam	Milford Haven (UK)	-2%	9%	50%	9%
80,000	North Africa	Arzew	North Europe	Antwerp	Medway (UK)	-1%	20%	50%	23%
80,000	North Africa	Arzew	North Europe	Rotterdam	Medway (UK)	-2%	20%	50%	23%
70,000-dirty	US Gulf	Corpus Christi	Mediterranean	Augusta	Jorf-Lasfar (Morocco)	-3%	8%	50%	7%
70,000-dirty	US Gulf	Corpus Christi	Mediterranean	Cartagena	Jorf-Lasfar (Morocco)	-4%	9%	50%	8%
70,000-dirty	US Gulf	Corpus Christi	Mediterranean	Agioi Theodoroi	Jorf-Lasfar (Morocco)	-3%	7%	50%	7%
130,000-dirty	US Gulf	Corpus Christi	Mediterranean	Augusta	Jorf-Lasfar (Morocco)	-3%	8%	50%	8%
130,000-dirty	US Gulf	Corpus Christi	Mediterranean	Cartagena	Jorf-Lasfar (Morocco)	-4%	9%	50%	10%
130,000-dirty	US Gulf	Corpus Christi	Mediterranean	Agioi Theodoroi	Jorf-Lasfar (Morocco)	-3%	7%	50%	8%
130,000-dirty	West Africa	Lagos	Mediterranean	Savona	Jorf-Lasfar (Morocco)	-5%	8%	50%	11%
130,000-dirty	West Africa	Lagos	Mediterranean	Cartagena	Jorf-Lasfar (Morocco)	-5%	10%	50%	12%
130,000-dirty	West Africa	Lagos	Mediterranean	Leixoes	Jorf-Lasfar (Morocco)	-3%	12%	50%	14%
90,000-clean	Arabian Gulf	Ju'aymah	Mediterranean	Augusta	Alexandria (Egypt)	-4%	9%	50%	10%

Ship size [DWT]- Goods	Origin Region	Origin Port	Destination Region	Destination Port	Intermediate Port	Fuel cost [%]	Time cost [%]	Ports cost [%]	TOTAL [%]
90,000-clean	Arabian Gulf	Ju'aymah	Mediterranean	Cartagena	Alexandria (Egypt)	-4%	8%	50%	9%
90,000-clean	Arabian Gulf	Ju'aymah	Mediterranean	Agioi Theodoroi	Alexandria (Egypt)	-4%	10%	50%	11%

Annex 5: Current maritime fuel mix and overview of available alternative fuels for maritime transport and their maturity

The purpose of this annex is to provide an overview of the current maritime fuel mix and to explore the range of technical possibilities to use alternative fuels in maritime transport. The content of this annex builds upon the support study carried out for this impact assessment (Ecorys / CE Delft forthcoming), a literature review carried out with the support of EMSA on ten different alternative fuels possibilities as well as the work carried out by the sub-group on Sustainable Alternative Power for Shipping (SAPS SUB-GROUP) of the European Sustainable Shipping Forum (ESSF)[220].

Current energy usage in maritime transport

Table 68 presents the fuel mix of the fleet as reported under the 2018 EU MRV reporting period. Data from the 2019 MRV reporting period were not yet verified at the time of finalising this report. However, preliminary estimates from the 2019 reporting show very similar shares to the ones observed in 2018.

Table 68 Share of various fuel types

Type of fuel	Share in fuel mix
Heavy fuel oil (HFO)	72.11%
Marine gas oil (MGO)	12.46%
Light fuel oil (LFO)	7.63%
Marine diesel oil (MDO)	4.02%
Liquefied natural gas (LNG)	3.17%
Other*	0.60%
Methanol	0.01%
Liquefied petroleum gas (LPG) - Butane	0.00%**
Total	**100.00%**

* This category covers other fuels with non-standard emission factors. In 2018, the average emission factor of the fuels reported under this category corresponded to 3.07 t-CO2 / t-fuel.
** While the percentage of LPG usage is at 0%, there was a very limited amount of LP volume used by the fleet in 2018. However, this is too small to be reflected in any percentage of fuel mix. Nevertheless, this category was added here to provide a complete picture of the fuel use within MRV in 2018.

Source: MRV Data 2018

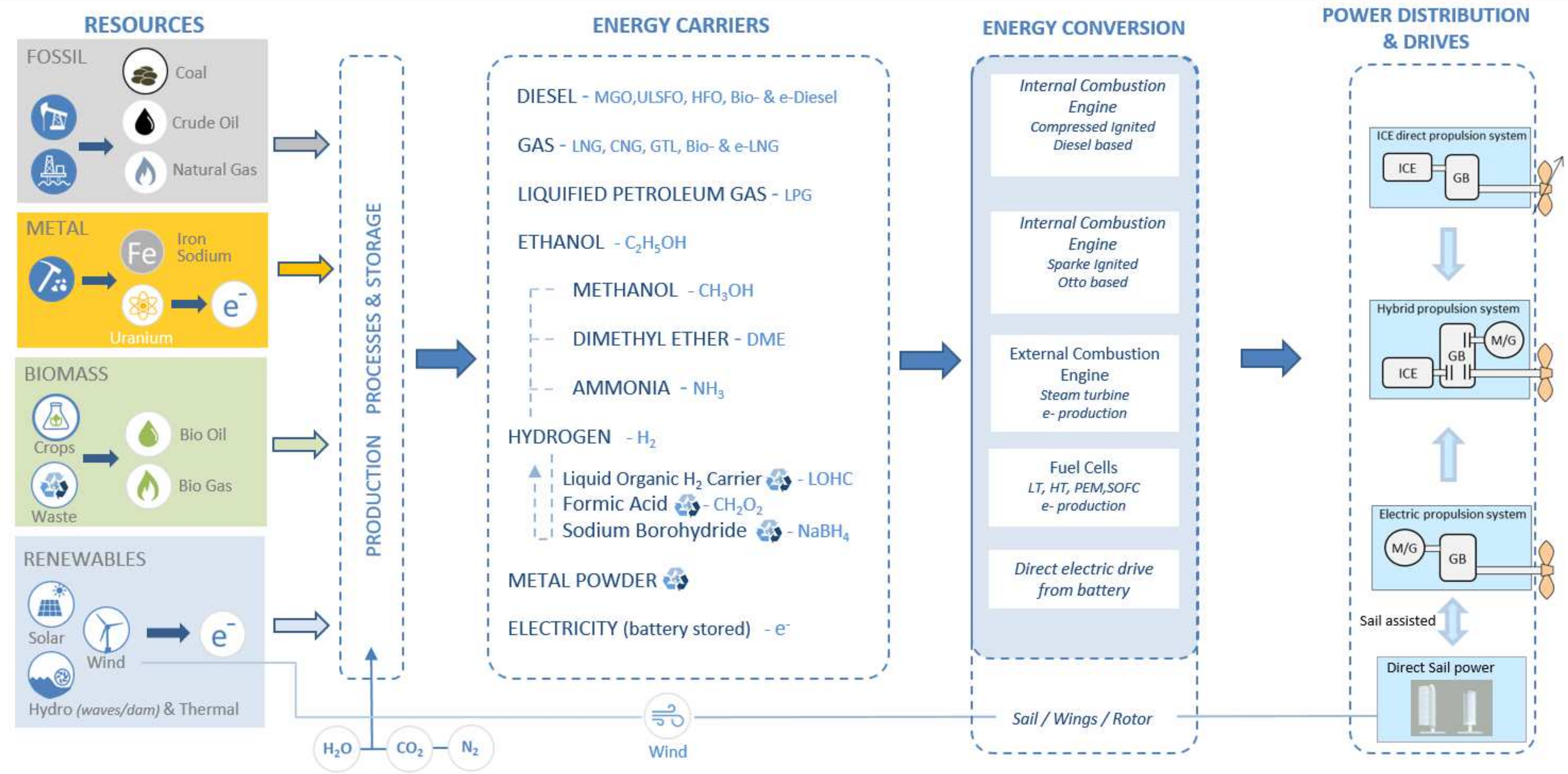
As already highlighted in Section 2 of this report, the current maritime fuel mix almost entirely relies on fossil fuels, with the vast majority of the fuel mix being concentrated on liquid fuel products such as HFO, MGO, light fuel oil and MDO. Gaseous fuels, in the form of LNG or liquefied petroleum gas are only a very small fraction of the energy mix.

[220] In particular, the work by the Maritime Research Institute Netherlands (MARIN) in work-stream 2 of this sub-group provides a summary of the existing scientific knowledge on the performance and potential of different alternative sustainable fuels, energy conversion technologies for shipping, including their environmental performance on a complete well-to-wake approach, complemented, where appropriate, with life cycle considerations.
The result of this work can be consulted under: https://sustainablepower.application.marin.nl/

Possible alternative fuel options

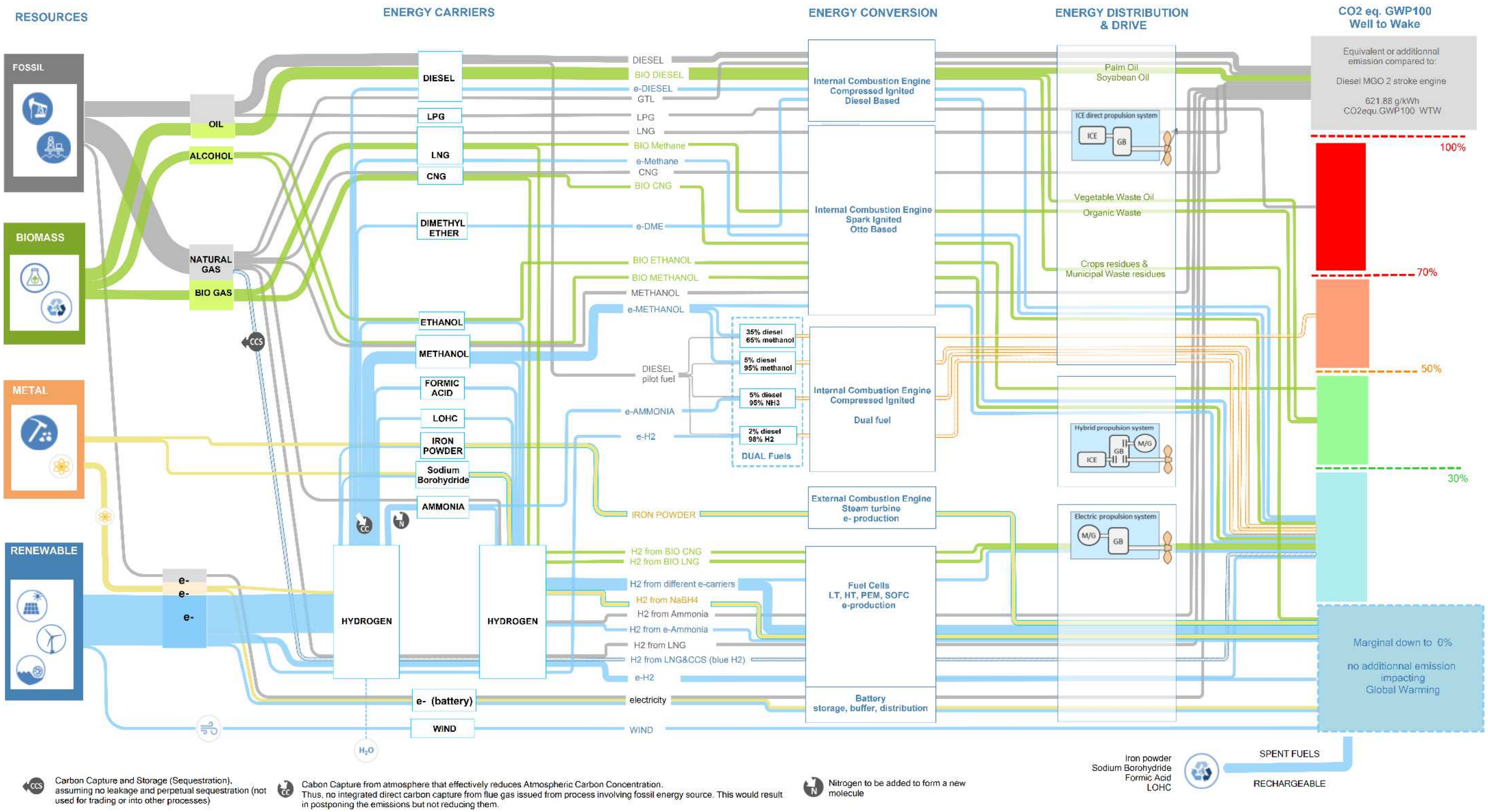
In order to analyse the performance and maturity of the different possible alternative fuels options available to the maritime sector (and be able to compare them), it is important to consider the different stages from initial resources to energy carriers (the fuel itself), energy conversion on board (type of "engines") and ship propulsion. These elements are summarised graphically in Figure 16. This simplified diagram presents only an overview of the main elements to be taken into account, but the database developed in the framework of the ESSF SAPS sub-group identified already 53 solutions (possibilities of combination) between these elements (resources, energy carriers and energy conversion), including the options relying on fossil resources. Figure 17 summarises a graphic presentation of the possible options (presented as Sankey-like diagram for the four categories of resources identified in Figure 16).

Figure 16 Simplified overview of the main components of the "energy diagram" for marine fuels



<u>Source:</u> MARIN (2020), ESSF SAPS SUB-GROUP.

Figure 17 Sankey diagram of the possible fuel combinations for the main resources categories



Source: MARIN (2020), ESSF SAPS SUB-GROUP.

Primary energy sources / resources:

The current maritime fuel mix relies almost entirely on fossil resources, either in the form of oil products or gaseous fuels. The main alternative fuels presented in this annex are options deriving from non-fossil origins. The three main alternative sources of energy which have been identified are biomass, metal or renewable energy. Given the relatively limited amount of options provided by metals, the analysis carried out in the context of the FuelEU Maritime initiative has mainly focussed on biomass and renewable energy / electricity, which have also been identified by the stakeholders as the most promising options.

- Biomass is expected to lead to three main fuel types (that can be used also in blends with fuels of other origin, including fossil): liquid biofuels (such as biodiesel), biogas (that can be used as bio-LNG or bio-CNG), and alcohol products (e.g. bio-ethanol).
- Renewable energy / electricity can be used directly for charging on-board batteries in vessels using fully electric propulsion systems or hybrid engines. Renewable energy can also serve the production of renewable hydrogen to directly power fuel cells (either carried as hydrogen or ammonia) or be blended for use in internal combustion engines. It can also be used for the production of synthetic liquid fuels (e-diesel), gas (e-LNG) or alcohols (e.g. e-methanol), which may also be blended with similar products of other origin, including fossil. Wind-assisted propulsion is today considered a means to reduce a ship's consumption of fossil energy. As efforts to reduce GHG emissions and climate change intensify, the commercial shipping world is looking at wind as an inexhaustible power source, at least in a supporting role, with renewed interest.

GHG saving potential, sustainability and availability of resources[221]

The consideration of the primary source of energy is important to determine the fuel's overall environmental performance. As a result, a well-to-wake approach is preferable to reflect the overall GHG performance of fuels/technologies as it takes into account the impacts of production, transport, distribution and use on-board. Such an approach is also more likely to incentivise technology options and production pathways that provide real benefits compared to the existing conventional fuels. As presented in Figure 17, an energy carrier like LNG can be produced from fossil origin, bio-origin or synthetically using renewable energy, similarly hydrogen can be produced from fossil energy or renewable electricity. All these different production pathways will have a significant impact on the fuel's performance. For instance, fossil LNG in a four stroke engine would have a GHG performance of 709.49 g-CO_2e/kWh, a biogas produced from organic waste of 248.39 g-CO_2e/kWh, and a synthetic gas from renewable sources a value of 75.19 g-CO_2e/kWh on a well-to-wake calculation (GWP100). There is a factor 9.5 difference between the worst case scenario and the best case for LNG. The variation between these values can be even greater, in particular when considering the

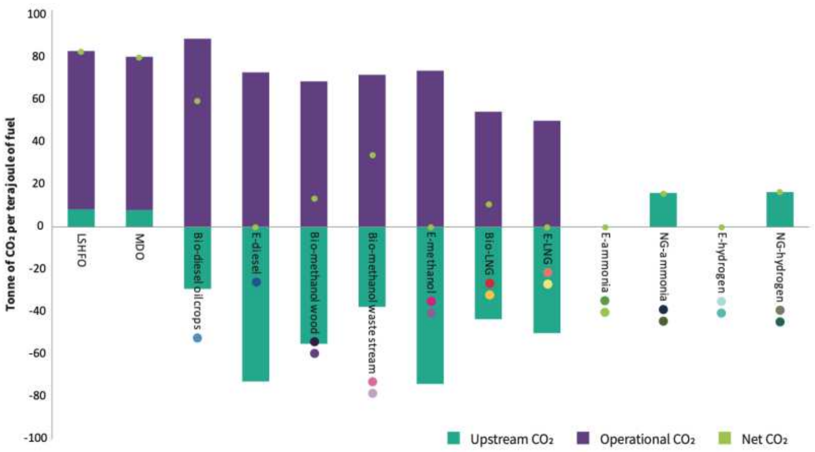
[221] Unless stated otherwise, all figures provided in this section on the GHG performance of difference energy carriers based on the initial energy source come from MARIN (2020) ESSF SAPS sub-group.

production of the same energy carriers from fossil or non-fossil resources: renewable ammonia use in fuel cells would have a value of 0 g-CO_2e/kWh while its equivalent produced from fossil resources (natural gas) would reach 2630.08 g-CO_2e/kWh on a well-to-wake basis (GWP100).

Similarly, even within the same group of resources, different production pathways are possible and would have ultimately an impact on the fuel's GHG saving potential and overall sustainability record. The most known example of this concerns the biofuels, which can be produced from different feedstocks. While a 100% biodiesel form waste (crop residues and municipal solid waste) can achieve substantial savings, the contribution of biofuels produced from food and feed crops is usually lower and uncertain due to the issue of indirect and use change. Biofuels produced from high ILUC-risk feedstock are unlikely to achieve any savings.[222]Given that the contribution of first generation of biofuels (food and feed-based ones) towards decarbonisation is limited , it is not foreseen that they would be eligible under this initiative.

From Figure 17 it is apparent that the number of truly zero-emission options is limited on a well-to-wake analysis. Additional incentives for these zero-emissions options are therefore needed to make sure that implementing WTW approach does not entrench HFO and MGO and paves the way for gradual transition to alternative fuels that are zero-emission on the well-to-wake perspective. Figure 18 presents the upstream, operational and net CO2 emissions for selected fuel options, including produced from different initial energy resource. The overall net CO2 impact hence depends not only on the operational (tank-to-wake) emissions but also on the upstream (well-to-tank) savings.

Figure 18 Upstream, operational and net CO2 emissions for selected fuel options



Source: LR/UMAS (2020) "Techno-economic assessment of zero-carbon fuels"

222 COM(2019) 142 final

In addition to the GHG saving potential, the availability of sufficient quantities of feedstocks is an important aspect to determine how a certain fuel option can be sustainably scaled-up and deployed in the future, ensuring sufficient production levels on the most appropriate and performant pathways.

Energy carriers and energy conversion

Different energy carriers (fuels) are presented in Figure 16 and Figure 17 and have already been presented compared to their potential primary energy source. There are however other criteria that can be used to group these in different categories and highlight specific attributes of the different fuel options or to limit the number of alternative fuel options based on certain technical characteristics or constraints that need to be met on the ship. In this context, it also worth considering the interaction with the energy conversion (engine) system on-board, which provides a set of conditions / constraints that need to be met by chose energy solution (compatibility of the engine and fuel storage system to a given technical option). Another determining aspect in the fuel choice concerns the operating conditions of the ship itself (constraints in terms of necessary range, available storage capacity, etc.).

Compatibility with the existing infrastructure and machinery

A first aspect concerns the compatibility of the fuel with the existing infrastructure and the existing machinery on-board. Drop-in fuels are defined as the fuel options that are functionally equivalent to the fossil fuels currently in use and fully compatible with the distribution infrastructure.

For maritime transport, the identified drop-in fuels will be bio-diesel or e-diesel, bio-gas or synthetic gas, bio-methanol or e-methanol.

One of the important advantages of drop-in fuels is to allow for lower capital costs on ramping-up of the fuel solution as the existing ship machinery is compatible with these fuels and because it does not require a dedicated infrastructure. As a result, the deployment can also be more rapid as the uptake of the option is not dependent on the deployment of a dedicated infrastructure nor on specific fleet characteristics, removing some of the interdependency issues that exist in developing new fuel solutions (chicken and egg). In addition, as these fuels are usually similar to the existing fossil options they are meant to replace, they can usually be safely blended allowing a gradual uptake of more sustainable energy options, while still providing some first GHG savings.

While drop-in fuels may be low or zero-carbon fuels on a well-to-wake perspective, when used either 100% or in very high blends, this is very dependent on the overall production pathway and the type of feedstock used. Furthermore, they have emissions on the tank-to-wake basis, as well as air pollution such as NOx and black carbon, which require additional attention and after-treatment. In comparison, hydrogen or ammonia eliminate such emissions if used in fuel cells as energy converters. When used in internal combustion engines, NOx emissions cannot be avoided and require after-treatment.

However, these fuels may not automatically be compatible with the existing infrastructure nor stored and used with existing vessels without specific adaptation of the equipment (on-board and/or on-shore). The type and complexity of the required modification depend on the current fuel system and the alternative carrier to be used. On board, they concern modification to the engine, the storage tanks and the piping system. Similar compatibility issues (or possible needs for modification) can be observed for the current distribution infrastructure (either HFO-MGO bunkering or LNG infrastructure).

These aspects related to the compatibility of the existing infrastructure and the fleet will undoubtedly affect the lead time for the uptake of the different fuel options.

In addition to this, the maturity of on-board energy conversion systems has also to be considered in looking at the different available pathways. The fleet currently consists almost entirely of internal combustion engines powered either by liquid of gaseous fuels. According to the fourth IMO greenhouse gas study, 98.4% of all engines used in the fleet in 2018 were oil engines and 0.52% were LNG engines (including dual-fuel engines). Figure 17 also indicates the possibility of using fuel cells, which is an attractive solution to reduce GHG emissions.

However, while already available at commercial scale, this technology have so far been demonstrated in small, low speed vessels with relatively low power needs (of up to a few hundred kW), the technology has not yet reached a sufficient level of maturity to be largely deployed on the entire fleet, in particular when involved in deep-sea traffic. Considering the typical power requirements of the fleet, the technology needs to be significantly scaled-up to become a mature alternative for maritime transport. As an example, the average main engine power installed on containerships range between 5 and 60 MW depending on the size of the ship and its cargo capacity. Considering the data provided by the fourth IMO greenhouse gas study, vessels above 5000 GT (corresponding to the MRV scope) are usually using multi-megawatt engines. There are several challenges associated with scaling-up fuel cells to the desired MW scale while simultaneously addressing durability, compatibility with maritime conditions (saline air, shock, rolling & vibration). These challenges are currently being addressed by different research and innovation projects, as well as by commercial demonstration projects. A similar situation can be depicted when it comes to the development and deployment of fully electric propulsion by batteries. Nevertheless, ongoing projects on fleet hybridisation have allowed the sector to gain more experience and knowledge with the use of large battery installation in support of maritime activities (propulsion or ancillary power).

The technology maturity of the different options, expressed in technology readiness levels (TRLs), is summarised in Figure 19.

Figure 19 TRL ranking for zero-emissions technologies

TRL	Bunkering			Storage onboard					Processing and conversion			Propulsion			
	Equipment	Procedures	Fuel quality standards	Structural tank	Membrane containment system	IMO type A tank	IMO type B tank	IMO type C tank	Venting system	Fuel supply system	Reformer	2-Stroke ICE	4-Stroke ICE	FC	Boiler
LSHFO ICE reference ship	9	9	9	9					9	9		9	9		9
Bio-diesel ICE	9	9	9	9					9	9		9	9		9
E-diesel ICE	9	9	9	9					9	9		9	9		9
Bio-methanol ICE	7	6	3	7					7	7		7	6		2
E-methanol ICE	7	6	3	7					7	7		7	6		2
Bio-methanol FC	7	6	3	7					7	7	3		6	7	2
E-methanol FC	7	6	3	7					7	7	3		6	7	2
Bio-LNG ICE	9	9	9		8		9	9	9	9		9	9		9
E-LNG ICE	9	9	9		8		9	9	9	9		9	9		9
Bio-LNG FC	9	9	9		8		9	9	9	9	4			7	
E-LNG FC	9	9	9		8		9	9	9	9	4			7	
E-ammonia ICE	7	2	2			7	7	7	3	7		3	2		2
NG-ammonia ICE	7	2	2			7	7	7	3	7		3	2		2
E-ammonia FC	7	2	2			7	7	7	3	7	2		2	7	2
NG-ammonia FC	7	2	2			7	7	7	3	7	2		2	7	2
E-hydrogen ICE	4	2	3				3	6	2	2		2	5		2
NG-hydrogen ICE	4	2	3				3	6	2	2		2	5		2
E-hydrogen FC	4	2	3				3	6	2	2			5	7	2
NG-hydrogen FC	4	2	3				3	6	2	2			5	7	2
Batteries	4	2	3				3	6	2	2			5	7	

Source: LR/UMAS (2020) "Techno-economic assessment of zero-carbon fuels"

Energy density

The maritime sector is characterised by high power needs, which, in turn, require fuels with high energy density. While short-sea shipping (defined as maritime transport between ports in the EU and ports situated in geographical Europe, on the Mediterranean and Black Seas) is characterised by relatively short routes with frequent port calls and can include a number of fixed-schedule routes, deep-sea traffic represents long distance journeys (trans-oceanic) without necessarily a fixed schedule. The fuel energy density is therefore an important aspect affecting the possibility of ships to safely carry out long distance journeys without compromising on the cargo carrying capacity (in volume or weight). Presently, bulk carriers can sail more than 30,000 nautical miles (nm) on average on full tanks, containerships up to 50,000 nm and tankers between 10,000 nm and 30,000 nm on average. To put this into perspective, a transatlantic journey from Europe would cover around 6,000-7,000 nm and a journey to South-East Asia around 10,000 nm.

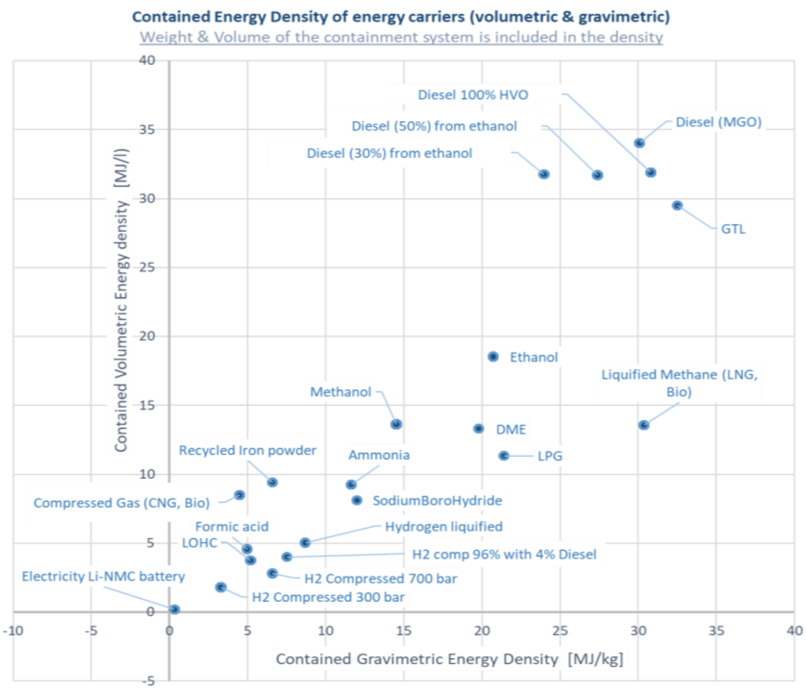
Among the possible alternative fuels, liquid biofuels and electrically synthesised hydrocarbons have the highest energy density followed by bio-gas. In practice, LNG has roughly 45 % lower volumetric energy density than diesel, while ammonia and hydrogen-based fuels have an even lower density. Both the volumetric and gravimetric density of the fuels have to be considered as they will impact potentially the range of a given ship or aspects related to vessel's design, including impacts on the cargo capacity (in volume or weight).

Indeed, the adoption of alternative fuels that require more volume and mass than HFO and MGO will inevitably lead to a reduction in deadweight and available volume for cargo. Alternatively, the lower energy density of alternative fuels may lead to potentially larger ships for similar deadweight capacities, impacting directly on resistance and power requirements.

When looking at energy densities for alternative fuel options for ships, in addition to the energy density characteristic to the energy carrier, it is necessary to also consider the impact of the weight and volume of containment system. This represents an important addition, in particular for options such as liquefied hydrogen, where the containment system may represent a decrease in the density of the energy carried by almost half, from 9.2 to 5MJ/l. An important focus to improve feasibility for such technology options will need to take into account the optimization of containment strategies, including materials technologies.

Figure 20 provides an overview of the possible alternative fuel options in terms of energy density (volumetric and gravimetric).

Figure 20 Overview of fuel options in terms of energy density



Source: MARIN (2020), ESSF SAPS SUB-GROUP.

Any fuel alternative moving from the current fuel (MDO) towards the bottom-left corner of the graph would result in further constraints and potential trade-off between fuel storage and cargo.

Safety and standardization aspects[223]

In addition to the inherent characteristics of the different fuel options, their production pathways and energy conversion technology, it is also considered important to highlight the relevance of safety and standardization as important enablers to ensure the deployment of safe and operable solution within a harmonized regulatory framework. The IGF Code, having entered into force on 1st January 2017, established a harmonized set of goals and functional requirements which are currently the regulatory backbone for the design, installation and operation of LNG fuelled ships. Work has continued to cover Ethyl/Methyl alcohols, with a set of Interim Guidelines approved at IMO, at MSC102. Fuel Cell installations, LPG and low flashpoint diesel fuels are currently the object of work within the IGF Code development agenda. Interim Guidelines appear to be the most flexible solution to develop harmonized goal-based requirements for specific technologies. They take however, on average, about 5 years to develop and this is a time pace which has to be taken into consideration in the context of any alternative fuel technology deployment.

As of today, in most of the cases, safety and technical requirements for alternative fuel and power installations, otherwise not covered in SOLAS/IGF, will be established by IMO MSC.1/Circ.1455 (*Guidelines for the approval of alternative and equivalents as provided for in various IMO instruments*). The use of this important IMO instrument, despite its relevance in a context of less mature technologies and innovative applications, is not preferred for continued application. Elements such as containment and fuel distribution, structural protection, detection or fire suppression technologies have to be designed in accordance to technology-specific requirements. Developing this at a pace which is coherent and consistent with the technology development and user needs is an important challenge to address at both IMO and standardization organizations such as ISO, IEEE or IEC.

Different Classification Societies have already important class rules and guidance covering design, installation and safety aspects for alternative fuels and power technologies. The challenge to have a harmonized framework is however best addressed at IMO where a consolidation of current experience can take place in the form of interim guidelines. These need to be sufficiently flexible to allow technology development whilst, at the same time, supported by robust goals and functional requirements.

[223] The present section is focused on the developing international framework for the safe use of alternative fuel technologies onboard ships, focused on the ongoing development of amendments and new sections to the IGF Code (http://www.imo.org/en/OurWork/Safety/SafetyTopics/Pages/IGF-Code.aspx)

Economic aspects affecting fuel choice

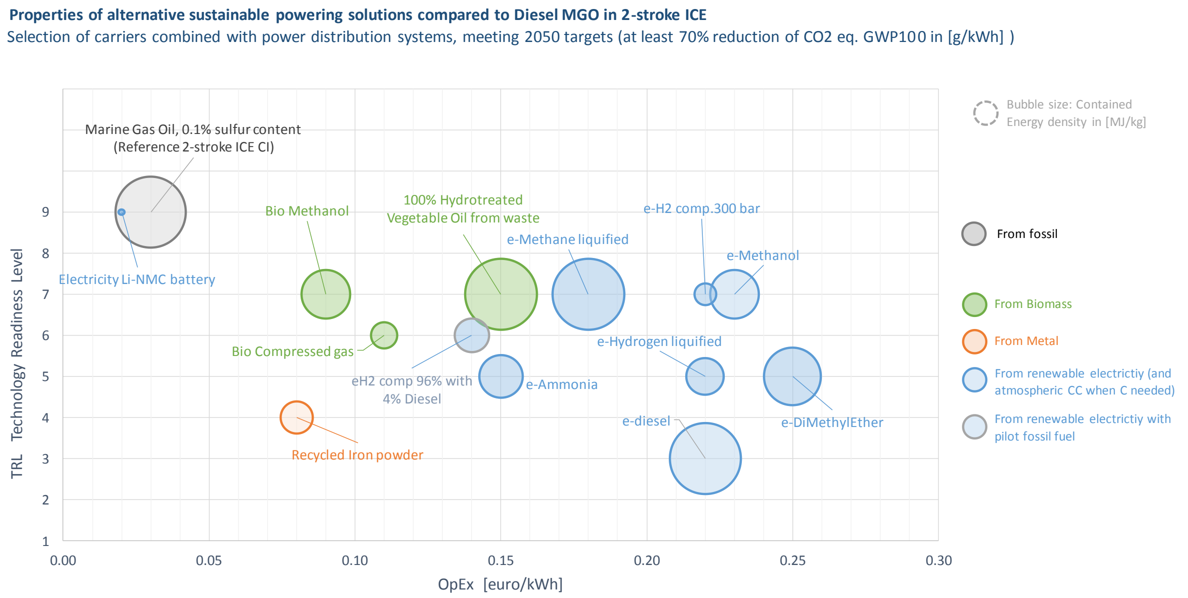
In addition to the technical aspects presented above, there are important economic elements, which will have the possible choice of alternative fuels.

Costs

An important reason behind 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 is confirmed by stakeholders' feedback received in the consultation activities on FuelEU maritime. For instance, in response to the public consultation, 48.1% of the respondents (65/136) indicated the higher price of RLF as one of the most important barrier to their uptake.

Figure 21 presents a comparison of the costs associated to the different fuels options per unit of energy (€/kWh).

Figure 21 Costs comparison of different alternative fuel options



Source: MARIN (2020), ESSF SAPS SUB-GROUP.

The production cost ranges of biofuels and e-fuels are larger than those of fossil fuels. To some extent, this is caused by the fact that production systems for biofuels and e-fuels are newer and subject of on-going research. 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 wide ranges also relate to the uncertainty about renewable electricity costs, which are linked to electricity market price developments and which form a major part of the production costs of e-fuels.

Production and fuel availability

When reviewing the initial energy resources to be used for fuel production, the availability of sufficient quantities of feedstocks is an important aspect to determine how a certain fuel option can be sustainably scaled-up and deployed in the future, ensuring sufficient production levels on the most appropriate and performant pathways.

Another important dimension for maritime transport concerns the wide availability of alternative options, not only in different European ports but also on a global scale. Indeed, a transition towards new sources of energy can only be sustained if these are deployed on a large scale allowing vessels engaged in international trade to cater for their fuel needs.

Possible evolutions and stakeholders' views

The study carried out by Ecorys and CE Delft in support of this impact assessment has provided an overview of different pilot projects and research and innovation initiatives carried out with respect to the use of alternative fuels in maritime transport.

The diversity of the sector in terms of ship type, age distribution, size, power required or operating conditions will result in different constraints determining the optimal fuel choice for a given economic actor. After reviewing existing literature and compiling the feedback received during the consultation activities on this initiative, it becomes apparent that a variety of different fuels with no dominant source of energy will be the most likely composition of the maritime fuel mix by 2050.

The respondents of the targeted consultation survey have indicated their expectations on what fuels are most likely to be used in 2030 and 2050, both during navigation and at berth. Concerning 2030, it can be concluded that biofuels are perceived as most promising for use in navigation, followed by batteries. Looking at 2050, the expectations focus rather 'other decarbonised hydrogen-derived fuels (including ammonia)' and 'Decarbonized hydrogen (including fuel cells)', which are the categories that received the highest scores. For emissions at berth, the alternative fuel option that stands out in being promising for 2030 is on-shore power supply (OPS). Looking at the survey results for 2050, OPS still is perceived as most promising compared to the alternatives.

Annex 6: Methodology followed for the definition of the policy options

This annex presents the comprehensive list of policy measures that was established for this initiative after extensive consultations with stakeholders, expert meetings, independent research and the Commission's own analysis.

This also includes policy measures that would not be focussed on addressing solely the technology barriers related to fuel uptake but could provide comparable level of CO_2 or GHG savings (including carbon pricing mechanisms or carbon intensity standards of ship operations). Their likely effectiveness in increasing the penetration of RLF was assessed qualitatively. Based on this initial screening, a number of policy measures were not considered apt to address all the SOs or were identified as complementary measures included in the "basket of measures".

Based on this assessment, the Commission also refined the general policy approach to narrow down the proposed intervention to a limited number of characteristics allowing to effectively address the problem drivers in a coherent manner.

Two principal characteristics were identified for the policy measure to fulfil the given objectives:

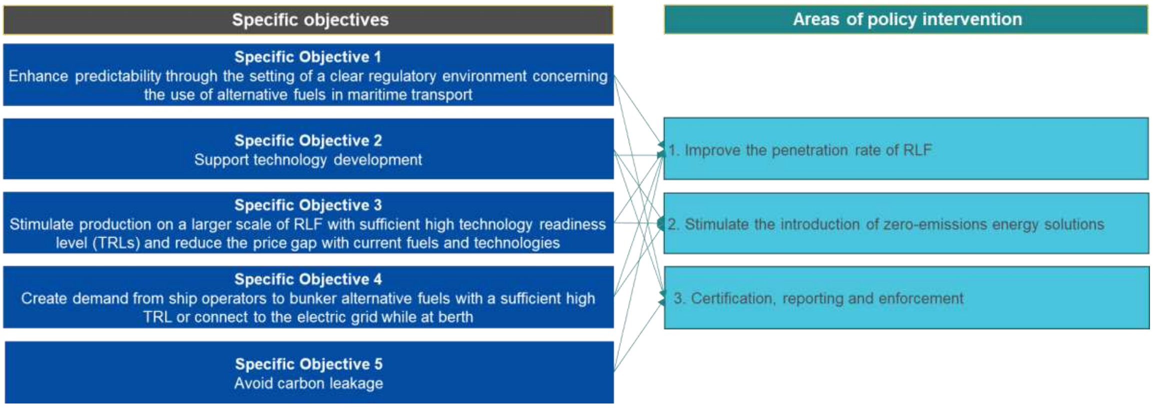
- They should provide certainty on the future short to long-term policy targets for the carbon intensity of the energy used by ships. Such targets should preferably be mandatory and enforceable, thus providing legal certainty.
- They should address the demand side component, by incentivising or prescribing minimum performance requirements of the marine energy mix. This is necessary for complementing existing supply-side measures and solving the interdependency issue, as well as for avoiding carbon leakage.

In the next step, the retained policy measures were classified according to their approach and characteristics in relation to three areas of policy intervention: i) improve the penetration rate of RLF, ii) stimulate the introduction of zero-emissions energy solutions, and iii) certification, reporting and enforcement.

The correspondence between the SOs and the areas of policy intervention are illustrated in

Figure 22:

Figure 22 Correspondence between the specific objectives and the identified areas of policy interventions



The full list of identified policy measures is presented in the Table 1Table 69. This table clearly indicates if these measures have been retained or are considered as flanking measures or complementary measures. Only retained measures have been included in policy options and were subject to a thorough analysis.

It indicates if the policy measure has been retained (R), dismissed (D) or is considered to be only a complementary measure (C) not assessed in the framework of this impact assessment. The table also highlights the flanking measures (F), which are not necessarily of regulatory nature nor resulting from this initiative but will contribute to meeting its objectives. To be noted that only retained measures (R) have been included in policy options and were subject to a thorough analysis.

Table 69 Full list of identified policy measures

Policy measure		Status[224]	Comments
Field of policy intervention 1: Improve the penetration rate of already mature sustainable alternative fuels			
1	Obligation to produce minimum quantities of marine RLF for EU fuel suppliers	C	While incentives on fuel suppliers, such as the ones introduced within RED II (multipliers for marine fuels) tend to provide positive results, they are currently limited to specific, contained, markets and subject to a system of incentives (remain voluntary). Changing this approach to mandatory target for minimum marine RLF production could provide a more structural trajectory. However, given the nature of the maritime sector and the possibility for ships to cover very large distances on a single bunkering, this measure could be easily circumvented by ships bunkering in third countries.
2	Obligation to distribute minimum level of distribution of marine RLF in all EU ports	C	The distribution of RLF through the appropriate infrastructure is an important condition for the success of the policy. However, the approach is not likely to be sufficient to result in a significant uptake of RLF. The possibility of ships to bunker in third countries reduces the effectiveness of such a measure. Even if RLF were the only marine fuel distributed in the EU, this could result in a limited uptake as ships could decide to bunker in third countires to avoid the costs related to RLF.
3	Prioritise at the IMO level discussions on the uptake of RLFs as a measure to implement the IMO GHG strategy	C	The uptake of RLF is clearly recognised as an important measure by the IMO. However, the discussion on the uptake of alternative fuels as well as market-based measures is expected to start at IMO only in the course of 2021, among others based on the EU proposal on fuel lifecycle guidelines based on sustainability and GHG emissions saving criteria. While international measures are necessary, it is important to also rapidly provide the sector with the definition of the long term trajectory for RLF uptake.
4	**Establish minimum share / volumes of selected RLF for ships in navigation calling EU ports (blending mandate)**	**R**	**Retained measure. As described in the report, the measure implies that a technology choice is made.**
5	**Set maximum targets on the GHG intensity (meaning the GHG emissions per unit of energy) of the energy used by vessels (the fuel / energy emission factor per kWh).**	**R**	**Retained measure. As described in the report, the measure implies a goal-based approach leaving the flexibility to the sector to identify the most appropriate compliance option.**

6	Set maximum targets on the GHG intensity of operations of a vessel (limit for GHG emissions per ton nautical mile)	C	This measure is expected to provide emissions reductions that could be comparable to the uptake of alternative fuels. It is expected that in response to the GHG emission limits, the sector will focus on achieving compliance by using options with the lowest marginal abatement costs. However, RLF have a comparatively higher marginal abatement costs to other measures such as energy efficiency. In conclusion while such a measure will allow emission reductions in sector, it is unlikely to sufficiently address the identified barrier on the low uptake of RLF. Setting a specific (sub-)target of RLF uptake within this context would be equal to measure 5 plus an additional element on energy efficiency that goes beyond the objectives of this intervention and is likely to to overalp with other initiatives within the 'basket of measures'.
7	**Mandate the use of on-shore power supply (or equally performant alternatives such as batteries or renewable hydrogen) for the most polluting ships in ports, gradually extending to the entire fleet over time**	**R**	**Retained measure. In this context OPS is considered as the main available compliance option (also allowing significant emissions reductions of air pollutants). Nevertheless, flexibility would be left to the sector to use equally performant alternative to OPS. In this case, specific criteria will be set to define what options can be considered equally performant.**
8	Increase the uptake of sustainable alternative fuels in the sector through a carbon price	C	Similarly to measure 6, this measure is complementary to the proposed inteverntion but is unlikely to sufficiently address the technology barrier related to fuels as operators are likely to respond to such an instrument by implementing solutions with the lowest marginal abatement costs.
9	Facilitate access to funding on low- and zero-emission vessels as well as advanced fuel distribution infrastructure	F	As presented in Section 6 of the report, the proposed intervention will lead to increased investment costs for the sector. Aside from private investments, which are expected to play a major role, public funding from Member States and the EU budget could be put to contribution to support the uptake of RLF through research funding, deployment of the necessary infrastructure, de-risking investments on vessels through financial instruments, etc.
10	Differentiation of port fees	C	The definition of port fees is a prerogative of port authorities / operators. Differentiating port fees to reward low- and zero-emission ships could be a complementary policy measure but it is unlikely to be sufficiently effective to break the chicken-and-egg situation, ensure an increasing demand for sustainable alternative fuels and remove the price differential, in particular or ships in navigation.
11	Introduce a preferential tax treatment for marine RLF	C	A preferential tax treatment for marine RLF could help reducing the price gap between conventional fuels and RLF. The Energy Taxation Directive currently provides for a mandatory exemption of marine bunker fuel. The ETD is currently being revised and could further strenghen the objectives of FuelEU maritime. It must be noted that, in the same vein as for measures 1 and 2, the risk of leakage through bunkering in third countries needs to be fully analysed.

12	**Provide guidance to facilitate testing and uptake of technology, including on the deployment of the necessary supply infrastructure**	**R**	**Retained measure. Similarly to guidance provided in the past on LNG bunkering or the one on OPS currently being developed by EMSA, such non-mandatory document can help accelerating the provision of the necessary infrastructure and ultimately boost the uptake of advanced technical solutions.**
Field of policy intervention 2: Stimulate the introduction of new low- and zero-emissions energy solutions			
13	Allow shipping companies to comply by fleet averaging	D	This measure would in principle increase the degree of flexibility offered to the industry by allowing companies to average compliance at fleet level instead of ship level. This measure could potentially favour the uptake of more advanced / performant solutions to compensate the non-compliance from other ships. However, by limiting the averaging to company fleet, the measure could also distort the level playing field in the sense that larger companies will benefit a much larger flexibility compared to smaller entities or single-ship operators.
14	**Allow ships to enter into pools with overachieving ships and comply on average within the pool by establishing a scheme of balancing for over- and under-compliance, in which excess compliance points can be exchanged between ships**	**R**	**Retained measure. This measure is very similar to measure 13 in its intention. It provides a system to reward the over-achievers and allow fleet-wide averaging. However, instead of limiting the averaging possibility to a single company, it allows through the establishment of a system to record excess compliance points to average compliance among a wider fleet, including from different companies, regardless of their size. Arrangements for transfer of the excess compliance points will be subject to private-law agreements between the concerned parties. This mechanism will mostly be used intra-company and only concern a modest number of transactions between companies. Those few transactions will not be capable of determining a transparent and uniform 'market' price. Also, the balances will not be purchasable by intermediaries. Since this mechanism is meant to provide additional flexibility rather than act as a primary means of compliance and is not expected to lead to the creation of a specific and significant market, it is not considered as a "market-based" measure.**
15	**Provide multipliers for zero-emission technologies**	**R**	**Retained measure. Multipliers (adjustment factors) for zero-emission technologies are designed to provide an additional incentive to reward over-achievers.**
16	Distinguish standards for the new fleet (compared to the existing ships)	D	The measure would in principle allow to establish stricter standards to the new fleet, taking into consideration the possibility for new ships to be equipped with new propulsion systems or designed specifically for more advanced fuel options (in particular when specific storage and piping is required). The effects of such a measure are very much dependent on fleet renewal. In addition, it may lead to an indirect effect that older fleet remains in operation (or is diverted to the regulated region) to avoid stricter standards. For these reasons, this measure was not retained as a policy measure for full assessment.

17	**Increase awareness raising, exchange of experience, encouragement and promotion of industry-led programmes in support of the uptake of alternative fuels**	**R**	**Retained measure that should continue in the long term. On the one hand, it can rely on exchanges on technical issues organised in the context of expert groups such as the ESSF of the EPF. On the other hand, standalone industry alliances could be established between operators, ports and fuel suppliers to foster the deployment of specific options or in the context of on-shore power supply.**
18	Issue recommendations on zero-emission technology requirements in public procurement of vessels	C	Public procurement can be an interesting tool to support the rapid deployment of advanced vessels technologies, including electric propulsion or fuel-cell systems. While this measure would be limited to the fleet of vessels subject to public procurement rules, this measure can be an interesting complementary measure to accelerate the deployment of the most advanced solutions.
19	Fund research and innovation activities in zero-emission technologies	F	Certain fuel solutions still need to mature to reach a sufficient techonology readiness level allowing market deployment (see Annex 5). Continuous focus on reseach and innovation is therefore critical for a successful RLF uptake. The preparation of the 'Zero Emissions Waterborne Transport' partnership under Horizon Europe, proposed by the Waterborne Technology Platform would therefore be an important flanking measure to support the uptake of advanced fuel solutions in maritime transport.
Field of policy intervention 3: Certification, reporting and enforcement			
20	**Establish an EU-wide methodology to certify the well-to-wake performance of fuels, reflecting all relevant GHG emissions and define the related documents to certify compliance**	**R**	**Retained measure. It is important that all fuels are subject to the same methodology to define their GHG performance. Since this initative is looking at emisisons on a well-to-wake basis (including emissions / savings from production, transport, etc.), the methodology should indicate all relevant steps to follow to establish and certify fuel performance and build on existing requiremens under REDII. It will also clarify what documents are necessary to demonstrate (and consequently check) compliance.**
21	**Establish requirements for certification and acceptance of bunker supplied in third countries**	**R**	**Retained measure. Given the international nature of maritime transport, it is important to recall that vessels can bunker fuels in non-EU countries; Specific rules should be set up to provide for GHG certification of fuels bunkered in third countries. This methodology shuld build upon existing practice such as the fuel import certification under REDII.**
22	Intensify the IMO work on the Fuel LCA guidelines and the promotion of the RLF uptake	F	The intensification of the work at international level (IMO) on the development of lifecycle GHG/carbon intensity guidelines for all types of fuels is an important element to provide global coherence to the shift towards RLF and to pave the way for future measures at global level.

23	**Establish a set of rules to follow for monitoring, reporting and verification of consumption of RLF in the context of the EU MRV**	**R**	**Retained measure. As the MRV reporting already relies on the reporting of fuel consumption and the type of fuel used, integrating the monitoring of RLF utpake in the framework of the EU MRV allows to greatly reduce the administrative burden for operators.**
24	**Establish Port State Control procedures and guidelines for the use of RLF (including upskilling and training of PSC officers), in view of enforcement**	**R**	**Retained measure. If necessary, specific Port State procedures and guidelines may need to be developed to enforce the RLF requirements.**
25	Intensify IMO work on the IGF Code development and associated Interim Guidelines for the safety use of alternative fuels	F	IGF Code, associated SOLAS amendments and interim guidelines on the use of alternative fuels and technologies are considered to be important pillars for the construction of increased certainty in the adoption of RLF. It is important to further intensify work pertaining shaping of the IGF Code revision and development agenda with a view to ensure adequate close alignment of the regulatory and standardization framework with the development and evolution of RLF-specific TRL. In parallel to the IGF work, consistently, ensure adequate confirmation of supporting international standards for the relevant technologies in consideration, always preferring ISO, IEC, IEEE or any similar relevant international-reaching standardization references.

Annex 7: Overview of the monitoring and evaluation framework

The detailed list of operational objectives, indicators and data sources is presented in Table 70. Some of these monitoring arrangements will be established more in detail only after thorough discussion with Member States and key stakeholders.

Table 70 Proposed monitoring and evaluation framework

General objective	Specific objectives	Operational objectives	Indicators	Data source
Increase the uptake of RLF in EU maritime transport with a view to reducing emissions from the sector in navigation and at berth.	Enhance predictability through the setting of a clear regulatory environment concerning the use of alternative fuels in maritime transport	• Provide clearly identified long-term targets (up to 2050) on the minimum use of RLF in maritime transport	• Regulatory framework established • Investment levels in RLF production and distribution • Penetration of RLF in the maritime fuel mix	• Evaluation (survey targeted at fuel suppliers) • EU MRV data
	Stimulate technology development	• Encourage R&I and the development of new, advanced, types of RLF for maritime transport	• Investment levels in RLF-related R&I in maritime transport • Share of e-fuels, hydrogen, ammonia and electricity in the maritime fuel mix	• Evaluation (survey targeted at ship-owners and technology providers) • EU MRV data
	Stimulate production on a larger scale of RLF with sufficient high technology readiness level (TRLs) and reduce the price gap with current fuels and technologies	• Significantly increase the volumes of RLF produced and distributed to the maritime sector • Enhance the competitiveness of RLF compared to conventional fossil fuels	• Production levels of marine RLF • RLF average prices and price differential with conventional fossil fuels • Number of RLF bunkering points in Europe • Penetration of RLF in the maritime fuel mix	• Evaluation (survey targeted at fuel suppliers) • Eurostat • National Policy Frameworks under AFID • EAFO data • EU MRV data
	Create demand from ship operators to bunker alternative fuels with a sufficient high TRL or connect to the electric grid while at berth.	• Provide a minimum level of RLF demand to sustain market developments • Increase the number of OPS connections by ships at berth, in particular for highest polluters	• Penetration of RLF in the maritime fuel mix • Number of ships and ports equipped with OPS • Percentage of port calls requiring OPS • Increased share of electricity in energy generation at berth	• Evaluation (survey targeted at ports and operators) • National Policy Frameworks under AFID • EAFO data • EU MRV data
	Avoid carbon leakage	• Limit regulatory avoidance through traffic diversion • Establish a common system of certification cover marine RLF (including production in third countries)	• Average distance of last journeys of vessel calling EU ports • Certification scheme established • Number of non-EU fuel suppliers certified	• EU MRV data • Evaluation (survey targeted at fuel suppliers)