FuelEU Maritime: T&E analysis and recommendations

How to drive the uptake of sustainable fuels in European shipping

TRANSPORT & ENVIRONMENT

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Author: Delphine Gozillon
Modelling: Valentin Simon
Expert group: Faïg Abbasov, Carlos Calvo Ambel, Thomas Earl, Laura Buffet, Geert Decock, Maik Marahrens
Editeur responsable: William Todts, Executive Director

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Further information

Delphine Gozillon
Sustainable Shipping Officer
Transport & Environment
delphine.gozillon@transportenvironment.org
Mobile: +32(0)478 10 00 88
www.transportenvironment.org | @transenv | fb: Transport & Environment

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Executive summary

In July 2021, the European Commission proposed the first-ever legislative initiative requiring ships to progressively switch to alternative marine fuels. Out of the four proposals addressing shipping in the EU's so-called Fit-for-55 Package, the FuelEU Maritime, if fixed, has the highest potential to put the sector on track to decarbonisation by 2050. The proposed regulation has a unique design: a goal-based GHG intensity target that increases in stringency over time, requiring ship operators to reduce the carbon footprint of the energy used onboard ships. It is expressed in Well-to-Wake (WTW) CO_2-equivalent emissions to account for all the life-cycle GHG emissions (CO_2, CH_4 and N_2O) of the different fuels and relevant engine technologies.

However, T&E had warned that the simple goal-based (i.e. technology neutral) target envisioned in the draft proposal[1] would likely result in the acceleration of fossil natural gas uptake as the cheapest alternative fuel eligible until 2040, as well as biofuels from dubious origin. The present report provides an update of the T&E analysis following the publication of the final Commission proposal (see Section 1). It confirms the earlier conclusion that the Commission proposal bears high risks of fossil gas lock-in, with liquified natural gas (LNG) to be given a strong push in the market at the expense of more sustainable alternative fuels. The current proposal jeopardises the transition towards zero-emission shipping. In particular, green e-fuels would struggle to find their way to the shipping sector in the absence of dedicated requirements and incentives to support their uptake. In addition, sustainability safeguards and the general enforcement framework of the proposed regulation needs to be strengthened, too. Should the FuelEU proposal be adopted as it stands now, it would directly undermine the objective of the EU Climate Law to achieve climate neutrality by 2050, as well as the objective of the EU Smart and Sustainable Mobility Strategy to deploy ocean-going zero-emission vessels by 2030 and the EU Hydrogen Strategy aiming to deploy hydrogen-based solutions in the maritime sector.

Thus, many aspects of the proposal need considerable revision by the EU co-legislators to avoid shipping following a climate and environmental disaster scenario in the coming decades (see policy recommendations Section 2). As a priority, we recommend policy-makers introduce dedicated quotas and incentives to boost demand for sustainable e-fuels:

- Set a minimum share of 6% e-fuels/RFNBO use on ship operators under FuelEU Maritime and equivalent mandate on fuels suppliers under REDIII or FuelEU Maritime.
- Bridge the cost-competitiveness gap with other alternative fuels via the introduction of a multiplier of 5 for e-fuels/RFNBO and exclusive benefits from the compliance pooling system

In parallel, advancing the GHG targets by 5 years compared to the Commission proposal is important to engage a fuel switch right from the start.

[1] See T&E analysis of the draft FuelEU Maritime proposal (June 2021) [1]

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1. Why the FuelEU proposal is unfit for a climate-neutral Europe - T&E analysis

1.1. Overview of key issues

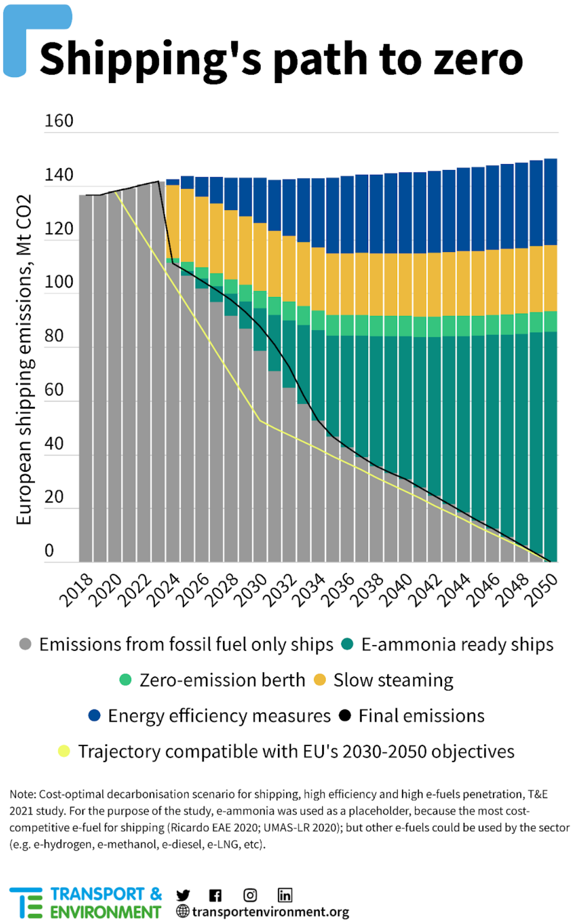

Figure 1: Cost-optimal shipping decarbonisation scenario by 2050, T&E roadmap study (2021)

Today, the maritime sector relies almost entirely on fossil fuels and shipping emissions are growing rapidly. In this context, the EU has set an objective of cutting Union-wide emissions by -55% by 2030 below 1990 levels and fully decarbonising the economy by mid-century. To contribute its fair share to achieving the -55% emissions reduction objective, shipping would have to cut 90 $MtCO_2$/year emissions in this decade, down from 140 $MtCO_2$/year today. The scale of the effort is huge: **if energy efficiency can deliver up to one third emissions cuts, full decarbonisation by 2050 will require kick-starting the uptake of sustainable fuels already in this decade** (Fig. 1).[2] Green hydrogen-based fuels (also known as “e-fuels” or “RFNBOs”[3]), notably e-hydrogen and e-ammonia produced from renewable electrolysis, offer a sustainable and scalable pathway for the sector to decarbonise. But as nascent technologies, they’re more expensive and require investments in new vessel technology and port infrastructure. Hence, e-fuels require dedicated policy support.

However, the technical design and the overall ambition of the FuelEU Maritime regulation makes it unfit to promote sustainable and scalable renewable fuels. This is because ships will be allowed to use not only expensive RFNBOs, but also supposedly lower-carbon cheap fossil fuels, such as LNG in order to comply with the emissions reduction targets. This is inconsistent with the objectives of the EU Green Deal, as well as with the other fuel initiatives of the Fit-for-55 package targeting renewable fuels only (i.e. the review of the Renewable Energy Directive and the ReFuelEU Aviation initiative).

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[2] See T&E’s 2021 shipping decarbonisation roadmap study. [2]

[3] RFNBOs = Renewable Fuels of Biological Origin, as defined by the forthcoming EU delegated act to the revised Renewable Energy Directive (EU) 2018/2001. RFNBOs are typically produced from renewable hydrogen. Relevant RFNBOs for shipping include e-hydrogen, e-ammonia, e-methanol, e-diesel, e-LNG.

Moreover, the fuel GHG intensity targets[4] proposed by the Commission are off-track with the Paris Agreement and EU's own climate goals. The European Climate Law requires all emissions regulated in the EU, including shipping, to be reduced to net zero by 2050 at the latest. EU Member States and the Commission have also expressed at the International Maritime Organisation (IMO) their full support to in-sector decarbonisation of shipping by 2050. In this regard, 75% GHG intensity reduction under FuelEU Maritime is incompatible with both domestic and international pledges that the EU has made.

1.2. The FuelEU Maritime proposal: a potential climate disaster for shipping

1.2.1. Fuel GHG target trajectory

The FuelEU Maritime proposal aims for limited ambition in the first 15 years of its application, i.e. until 2039, as can be seen in Fig. 2. The proposed targets only require ships to reduce their energy GHG intensity by 2% until 2029, 6% until 2034 and 13% only until 2039. In addition, the proposal does not even take into account the current market trends for the uptake of LNG in a business as usual scenario (BaU) and implicitly counts the contribution of shore side electricity (SSE, also known as onshore power supply, OPS) use at berth to the achievement of the overall GHG intensity improvements. For example, the combined effect of LNG natural market uptake and the implementation of the SSE mandate for passenger ships and containerships will already achieve 0.9% reduction by 2025, about half of the proposed -2% target. By 2030, BaU LNG and the SSE mandate will already achieve 2.9% reduction, also half of the -6% 2030-2034 target.[5] **This means that, at best, ships would need to use only half as much alternative fuels than what the headline targets suggest. Also, the -13% target for 2035-2039 means that ships would have to reduce their GHG intensity by 87%[6] (i.e. switch the remaining 87% of energy to sustainable alternatives) in the ensuing 10 years if shipping is to fully decarbonise by 2050.** This would be an unrealistic decarbonisation trajectory for any sector and result in higher cumulative emissions than is permissible under the remaining carbon budgets. This clearly shows that the ambition of the FuelEU Maritime Regulation is currently not in line with Paris Agreement's temperature goals and the targets must be revised upward especially for the initial years of the regulation's implementation.

[4] In percentage reduction compared to the average well-to-wake (WtW) GHG intensity of the fleet in 2020, in gCO_2e/MJ

[5] More information on the methodology followed to derive these results can be found in Appendix A.

[6] Compared to 2020 baseline

FuelEU Maritime will achieve negligible GHG reduction until 2040

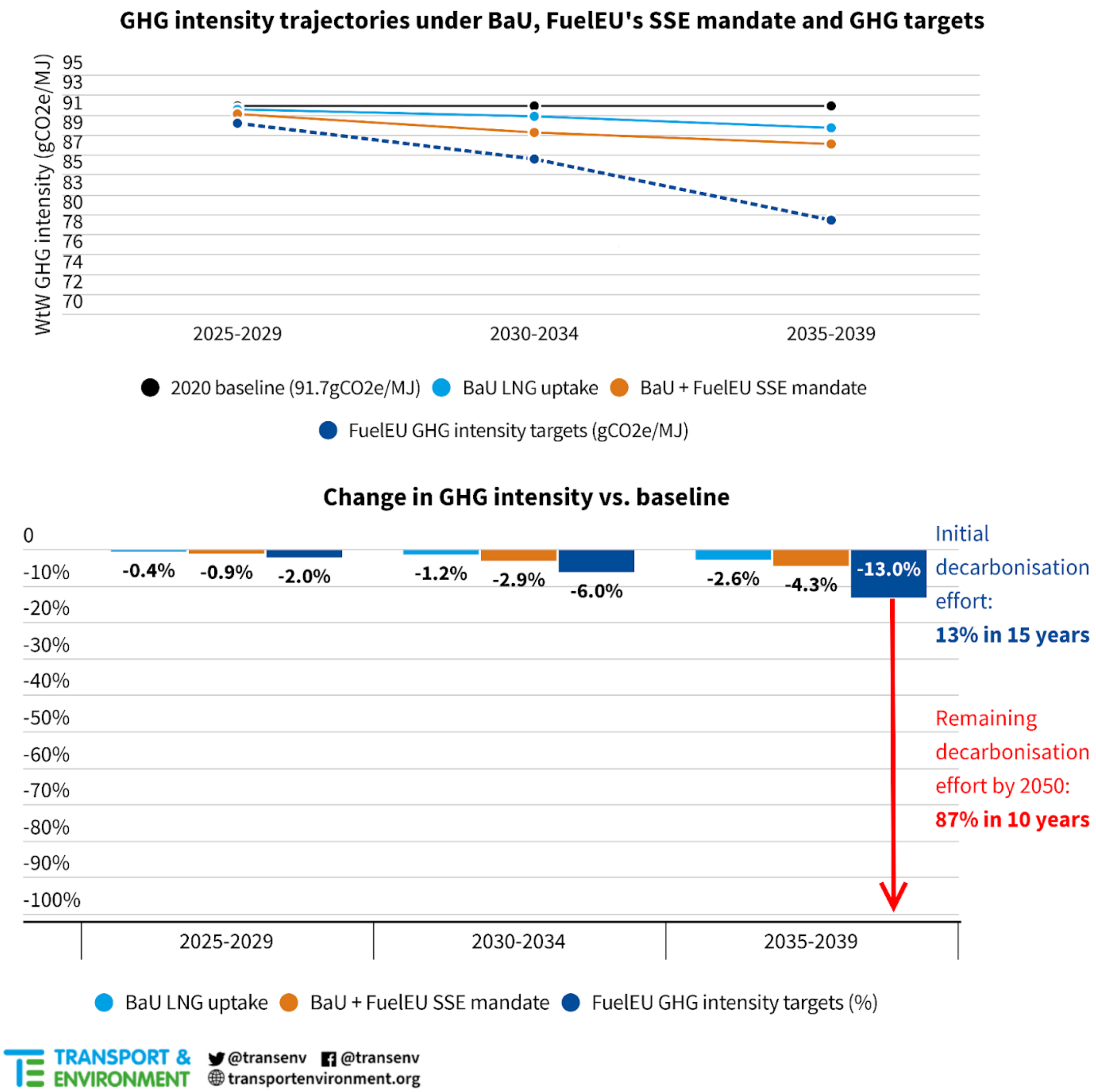

Figure 2: Evolution of the GHG intensity of the fleet under a BaU scenario with SSE mandate and GHG reductions targeted under FuelEU proposal

1.2.2. Scope of the Regulation

In addition, the geographical scope chosen by the European Commission is likely to limit the environmental effectiveness of the proposed Regulation, as it applies to the fuels used by ships during voyages within the EU and only half of the inbound and outbound voyages to/from the EU ports. This represents a drop in emissions coverage by almost one-third (28% or 42Mt CO_2) of the total 146 MtCO_2 emitted by EU-related shipping in 2019.[7] Worse, a limited scope is likely to ease the effort for the biggest shipping companies that are more predominantly engaged in extra-EU international voyages, whereas the contribution of these companies to decarbonisation efforts via large investments in zero-emission fuels and technologies is essential to upscale production and drive costs down. Consequently, there is a risk that smaller and less wealthy EU coastal shipping companies would carry a disproportionately larger share of costs of decarbonising EU shipping.

Another shortcoming of the FuelEU Maritime is that it applies to large ships only. This would exempt significant amounts of emissions: 19.7 Mt CO_2 were emitted in 2020 from vessels under 5,000 GT, including 17.2 Mt from vessels between 400 and 5000 GT. Moreover, by exempting smaller ships, FuelEU Maritime forgoes the opportunity to drive immediate technological transition in substantial parts of the European coastal fleet which have lower energy needs and thus are easier to decarbonise[8].

1.2.3. Projected EU shipping fuel mix as a result of the Commission proposal

An updated assessment of the impact of the Commission's FuelEU proposal on the EU shipping's fuel mix is shown in . The main conclusion of T&E's original analysis of the draft leaked proposal published in June still largely holds true [1]. The adoption of a goal-based target with no safeguards against unsustainable alternative fuels would be a true climate and environmental disaster. This analysis shows that fossil LNG could reach 23% of the total energy used in EU-related shipping by 2030.[9]

With this policy paving the way for fossil LNG for decades to come, the European Commission seems to be turning a blind eye to the World Bank's latest report on the use of LNG as a marine fuel [5], as well as the latest IEA report showing the ephemeral role for LNG in shipping's decarbonisation [6]. The World Bank report explicitly called on regulators to avoid any policy support to LNG in the maritime sector, including as a, so-called, transitional fuel, due to the risk of stranded assets it creates. Many other studies show that LNG has very marginal GHG benefits over existing marine fuels and depending on the ship engine, LNG can have a worse climate impact than the fuel it is supposed to replace [7].

[7] Full scope of the MRV Regulation (EU) 2015/757, i.e. 100% of incoming voyages to EU ports, voyages within between EU ports and outgoing voyages from EU ports. NB: EU 2019 MRV data still included the UK shipping emissions; total EU27 emissions will be different. [3]
[8] See T&E 2022 study" Climate Impacts of Exemptions to EU's Shipping Proposals". [4]
[9] This figure is higher than in our analysis of the draft proposal [1] because we had estimated the share of LNG used in the current (2020) fleet to be 1.2% of total energy, based on Rotterdam's bunker sales data. For this updated analysis, an in-depth look at 2020 MRV data showed that the share of LNG is close to 6%. More information on the methodology followed can be found in Appendix A.

Yet, the European Commission keeps promoting this fuel, not only in FuelEU Maritime but also in the Alternative Fuels Infrastructure Regulation proposal (AFIR), where it sets a binding mandate on ports to install LNG refuelling infrastructure by 2025. Also, while the Commission ostensibly defends the "technology neutral'' principle under the FuelEU Maritime, it explicitly backs LNG under AFIR. Furthermore, the EU ETS Maritime proposal could also potentially promote fossil LNG vessels too, since the MRV reporting system on which the ETS is based currently covers only CO_2. If CH_4 is not included in the MRV as part of the ongoing review, the ETS would literally give about a 20%[10] carbon pricing discount to fossil LNG vessels, which could lead to substantial amounts over the compliance year. For example, LNG ship "Clean Planet" reporting ~37,000 tonnes CO_2 under MRV ETS scope (50:50)[11] actually emits ~48,000 tCO_2e when accounting for CH_4. Under a €80/tCO_2 ETS price (i.e. ETS price at the time of writing [8], it would only pay about €3.1mln instead of €3.9mln in ETS costs every year.

Considering the EU's international climate commitments, including the recently initiated Global Methane Pledge at COP26 to slash global methane emissions, the promotion of high-methane emissive LNG by EU domestic regulation in shipping is not only incoherent, but also directly threatens the achievement of the Paris Agreement's temperature goals.

[10] The TtW emission factor of LNG used in the MRV is 2.75 gCO_2/g fuel, which is equivalent to 56.0gCO_2/MJ. Using FuelEU's formula, the TtW emission factor of LP 4-stroke LNG engines with 1% pilot MDO is 56.3 gCO_2/MJ without accounting for CH_4 (and N_2O), and the real TtW factor is 72.1 gCO_2e/MJ when accounting for CH_4 (and N_2O), which corresponds to 3.54 gCO_2/g fuel. Calculations performed using a GWP_{CH4} of 29.8.

[11] IMO: 9637507, year 2020.

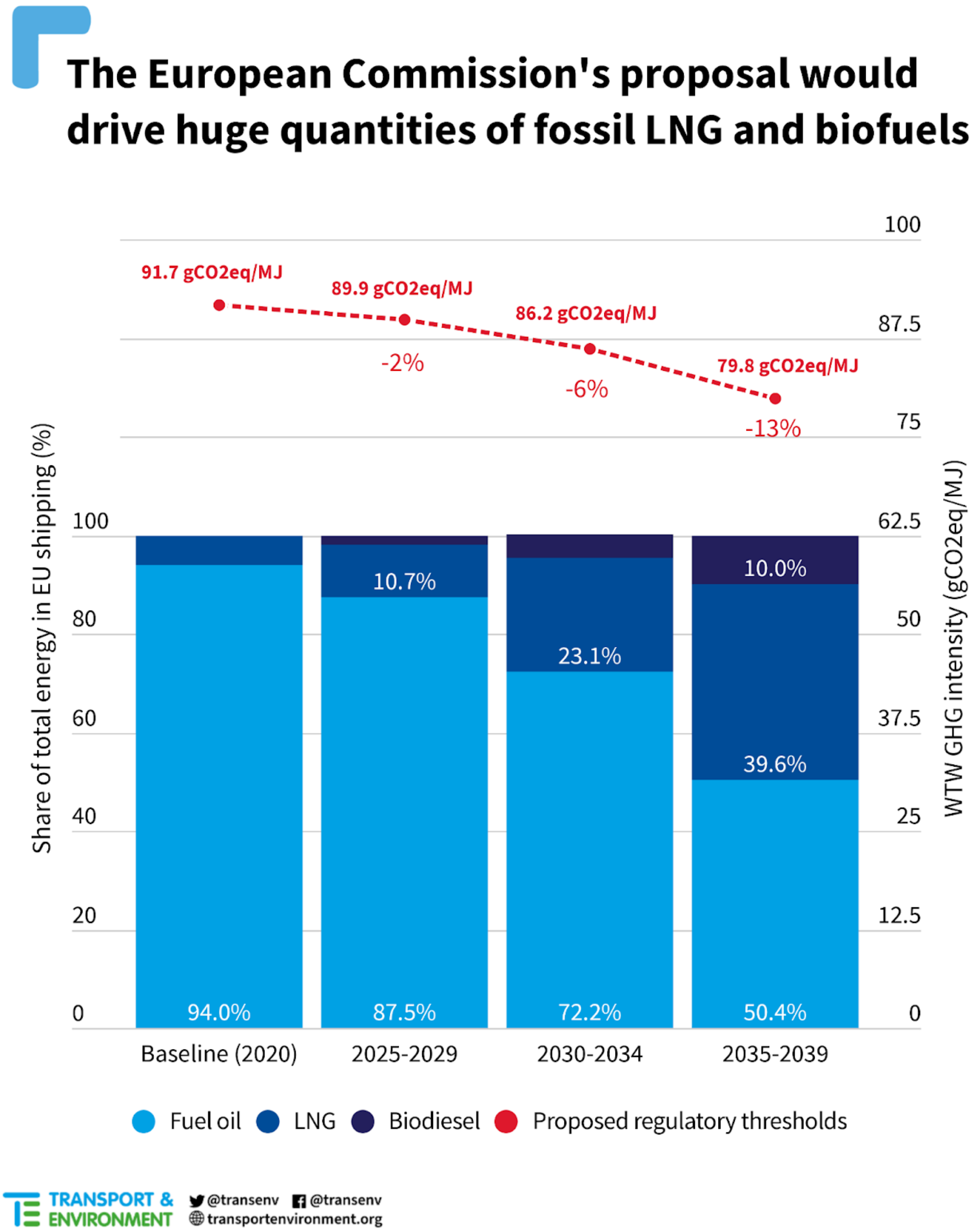

Figure 3: Disaster scenario: Projection of EU shipping fuel mix complying with the FuelEU proposal

T&E modelling assumes that rational ship operators will choose the cheapest alternative fuel as long as its GHG intensity is compliant with the regulatory targets.[12] Due to its competitive price advantage, any GHG intensity thresholds set below the 2020 baseline but still allowing fossil LNG to comply for a significant number of years will likely result in the acceleration of dual-fuel LNG propulsion uptake by new vessels (see Appendix A). Although the LNG engine type with the highest methane slip (dual fuel

[12] Based on the given targets, related fuel costs (see appendix A), EU-related fleet composition and its future evolution, T&E projected the evolution of EU shipping's fuels demand (figure 2). As fuel costs account for most operating costs of a shipping company, they are likely to be the most important parameter in compliance behaviours with FuelEU Maritime.

low-pressure 4-stroke - Otto cycle) will likely cease to comply with the goal-based target from 2025, the use of fossil LNG via other engine types would remain compliant for up to two decades. Specifically, under the proposed targets, dual fuel 2-stroke low-pressure engines (Otto cycle) with medium methane slippage would be compliant at least until 2034, and 2-stroke high pressure dual-fuel engines (diesel cycle) remaining compliant until 2039.

These ships could also bank and use over-compliance credits from the initial years when fossil LNG was over-compliant, or buy credits from other compliant ships via the pooling mechanism (see Section 2.2.1). Under current targets, this would lead to continuous use of fully fossil LNG-powered ships well into the 2040s, with no need to even blend in bio-LNG. The graph below shows how an LNG ship could make use of the potential loophole in Article 17 of the Regulation to bank all compliance surplus until 2039, and then use the past surplus to extend its compliance lifetime until as far as 2046[13] (Fig. 4).

Not to mention that, ships using LNG engines could connect to onshore power supply or install wind-assist technology[14] and thus further extend their compliance for a few more years. Either way, if the law is adopted in its current form, this would give a blank cheque to the continued use of fossil LNG well beyond what could be reasonably considered a transitional period.

[13] This assumes a constant consumption and total year-on-year GHG intensity per energy unit of LNG, using only fossil LNG in the same engine from 2025 to 2050.

[14] Ships that derive energy from wind get a bonus, in the form of a reward factor applied to the total GHG intensity of fuel used (Annex II).

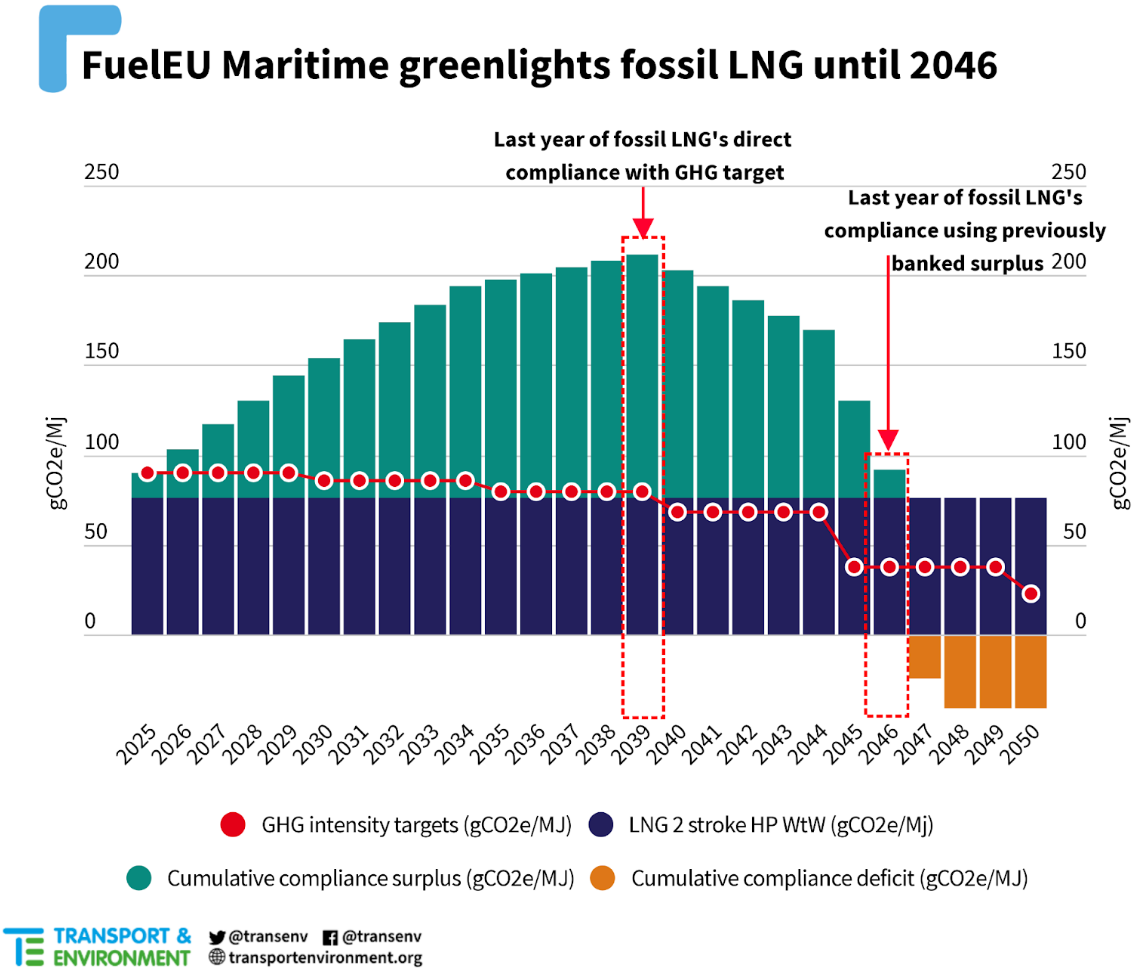

Figure 4: Cumulated compliance balance of fossil LNG use in 2 stroke HP engine, with unlimited use of banked compliance surplus over time

However, the analysis also concludes that EU-related shipping as a whole would not be able to comply with the current draft targets at fleet level even if two-thirds of new ships switch to fossil natural gas. This would require the uptake of additional alternative fuels by the rest of the fleet. As bioLNG (biomethane) is projected to remain expensive and scarce, we consider that blending drop-in biofuels in existing fuel oil ships would be a preferred option by the operators. According to the literature review (see appendix A - methodology), the next cheapest fuel available on the market is biodiesel produced from waste, such as used cooking oil (UCO).

Although relatively lower volumes are expected to be driven by the implementation of the FuelEU proposal compared to T&E previous analysis[15], the uptake of biodiesel in shipping would still be very high compared to potential supply (Fig. 5):

- If all current EU production of UCO (1.3Mt in 2019) were diverted to shipping, it would still fall short to cover ship operators' needs by 2030 (1.8 Mt)[16];
- Due to the EU's limited domestic production potential of waste-based biofuels, additional shipping demand would further increase already disproportionately high imports. In addition, this would deprive other sectors from waste biofuels supply, for example, from its current use in road transport or future needs in aviation where even fewer sustainable fuel options exist than in shipping. The imports needed to satisfy total EU demand are estimated at 6.4 Mt, which is far beyond the level estimated by existing studies[17]
- Beyond the ethical issue of importing huge quantities of biofuel feedstocks from third countries that need them for their own decarbonisation, it also means that crop-based biodiesel could sneak its way into the supply chain. Although in theory the use of food and feed-based biofuels such as palm oil or rapeseed oil does not allow compliance with the FuelEU targets (article 9), already today, avoiding fraud along the UCO supply chain proves difficult to ensure in a context of increasing imports for road transport.[18] Similarly, Member States recently asked for additional supervision of the biofuels supply chains.[19] Since ships sail internationally, they can easily refuel outside of the EU. Therefore, the risk of fraud on the sustainability credentials of biofuels would be even greater in shipping than what is experienced today in road transport, and extremely difficult for the regulator to control.

[15] A few changes have been made to the final Commission proposal compared to the draft [9]. For example, the Well-to-Wake values of biodiesel from used cooking oil have been corrected in the annex (less GHG intensive than crop-based biodiesel) and the geographical scope has been reduced from full to semi-full scope of MRV voyages, which reduce the amount of emissions to be abated and thus biodiesel expected demand in the present analysis (1.8 Mt in 2030 instead of 5.1Mt).

[16] However, should all container ships and passenger ships plug-in at berth by 2030 as required under article 5 of the proposal, the GHG intensity reduction achieved by these ships would drive down the sector's demand for biodiesel to 1Mt or 2.7% of the shipping fuel mix (under current GHG target of -6%).

[17] CE Delft 2020 study concludes that 3.1-3.3Mt of UCO could be supplied to Europe by 2030. [10] This is based on an increase of the EU+UK production up to 1.7Mt (from 1.3Mt today, due to improvements in collection schemes), and maintaining the same imports levels as today (1.5Mt). While the import potential might be higher, the risk of displacement effects due to competing uses (for example, producing countries using the UCO domestically) sets a limit on the increase in imports. See T&E Briefing "Used Cooking oil demand likely to double, and EU can't fully ensure sustainability", graph p.6 [11]

[18] Current RED II allows fuel suppliers to report lower WTW emissions for biofuels than the RED default values, provided these biofuels meet sustainability criteria and other limits imposed in the RED and the new values are approved by certification schemes. However, the EU Court of Auditors has warned that voluntary schemes under current RED II legislation cannot guarantee that all the UCO imported into Europe is actually "used" [12]

[19] Joint statement on improving supervision for the use of renewable energy in the Renewable Energy Directive [13].

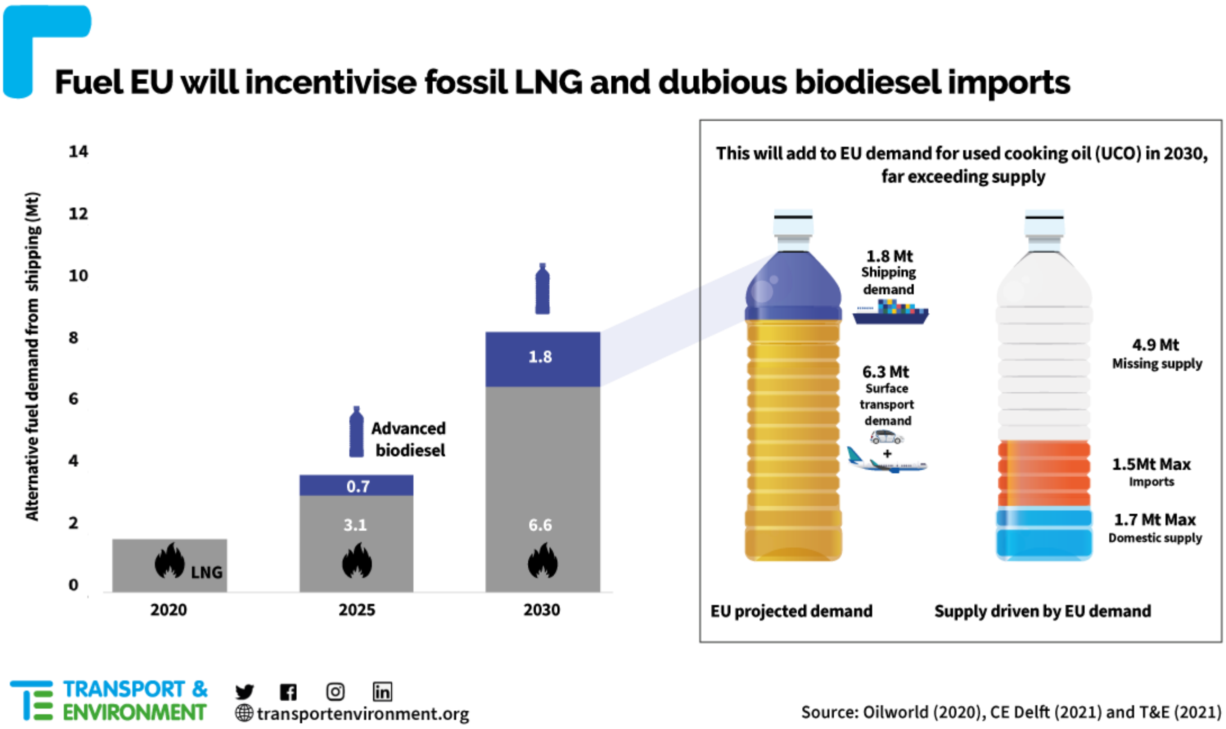

Figure 5: LNG and biodiesel demand in shipping resulting from FuelEU proposal (right); comparison of EU 2030 UCO demand from transport and UCO supply potential[20]

Consequently, there seems to be no rational business case for shipping players to invest in truly sustainable fuels, i.e. RFNBOs, if compliance can be achieved with much cheaper fuels despite their limited GHG savings or unsustainably-sourced supply. Thus, no uptake of green e-fuels is foreseen in the EU shipping's fuel mix modelled by T&E under the current FuelEU proposal. This is mainly due to the absence of any dedicated sub-target or economic incentive to use more expensive e-fuels (see Section 2.2), and reinforced by the existence of a "pay-to-comply" mechanism (Article 20) as demonstrated in the below (Fig. 6).

[20] However, should all container ships and passenger ships plug-in at berth by 2030 as required by current article 5, the GHG intensity reduction achieved by these ships would drive down the sector's demand for biodiesel to 1Mt (under current GHG target).

Looming over the uptake of RFNBOs: the "pay-to-comply" mechanism

Under Article 20 (3) of the FuelEU proposal, companies can be exempted from compliance with the GHG intensity targets against simple payment of a penalty. Assuming the access to biofuels remains limited, this would further disincentivise ship operators from pursuing new innovative solutions as it might be cheaper for shipowners to pay annual fees - especially in the non-liner market - than making actual investments in zero-emission vessels. In addition, our calculation shows that the current penalty level proposed is far too low to justify any investment in RFNBOs in this decade. As shown in , the cost of using e-ammonia[21] to comply with the 2025-2029 target of -2% GHG intensity will be higher than paying the penalty instead. As an example, for a big container ship (>20,000 TEU), it would cost €30,000 more per year to comply with e-ammonia compared to using the pay-to-comply mechanism. Not to mention the increased capital expenditure required to transition to ammonia-based propulsion technology. Hence T&E recommends the pay-to-comply mechanism to be removed from the Regulation, and the penalty level to be raised from €2400/t to at least €3000/t (see Section 2.3.2).

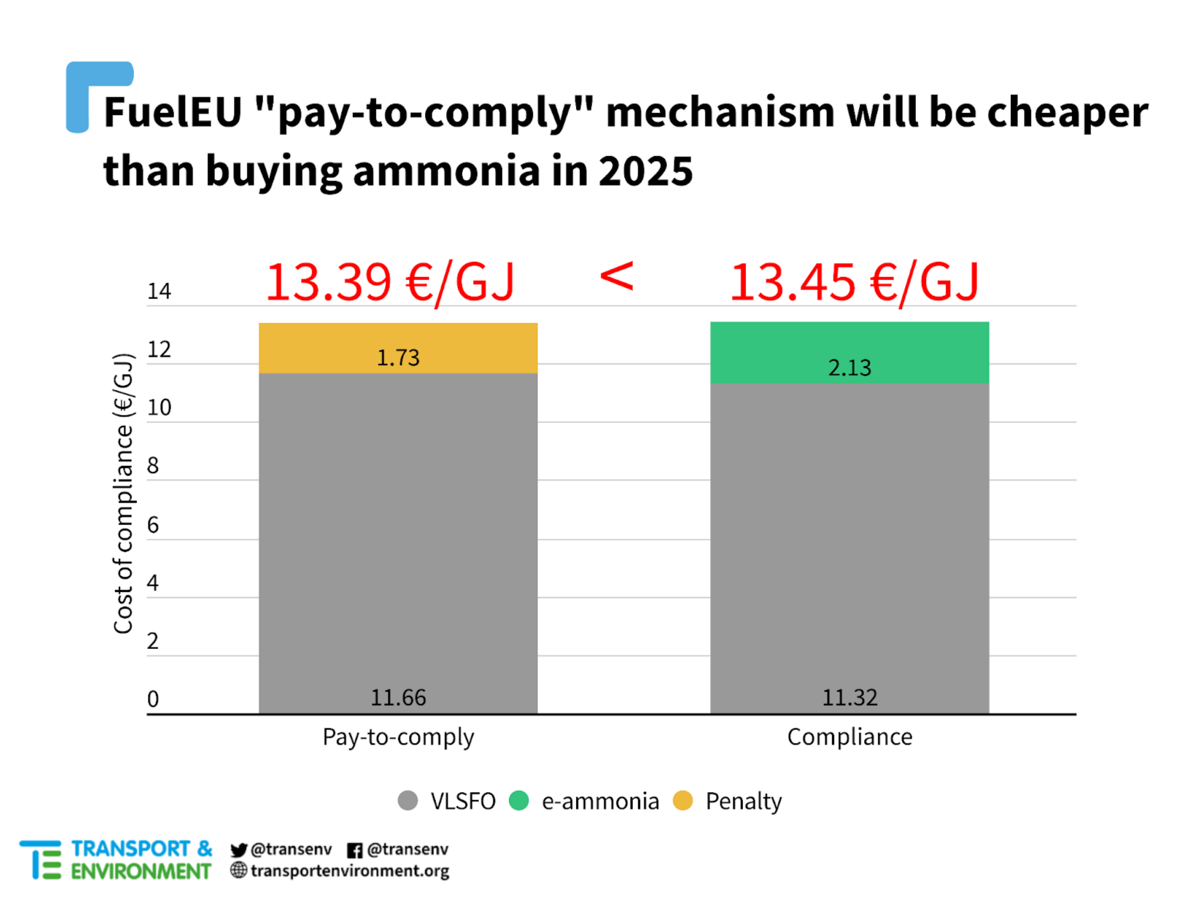

Figure 6: Comparison of compliance costs for operators paying the penalty and operators using e-ammonia to comply with the GHG target

[21] Ammonia is predicted to be the cheapest RFNBO for shipping [14].

2. How to fix it? T&E policy recommendations

To avoid shipping following an unsustainable technological transition pathway, as described in Section 1, the Commission proposal needs to be significantly improved while respecting the design of the proposed Regulation. T&E has the following recommendations to that end.

2.1. Limit the uptake of fossil LNG

A major problem with the FuelEU Maritime proposal is the dangerous push it will give to fossil LNG, with high risks of lock-in threatening the achievement of EU climate targets. In order to limit the potential uptake of LNG in the shipping fuel mix, we recommend as priority to increase the stringency of the GHG target and to adopt a 20-year global-warming potential accounting of methane emissions.
First, the FuelEU Maritime GHG targets must be strengthened, for several reasons:

- To deliver effective emissions reductions beyond business as usual (see Section 1.1.);
- It is also a matter of setting the compass to zero-emission shipping by 2050, in line with the Paris Agreement, the EU Climate Law and the EU call on the IMO to target zero by 2050 for international shipping;
- Increasing the ambition of the FuelEU GHG target would reduce the eligibility timeline of fossil LNG. If GHG intensity targets were advanced by 5 years, LNG would become non-compliant as of 2035, compared to 2040 in the current proposal. Beyond that date, LNG vessels would either have to switch to biomethane or e-LNG or purchase compliance credits from other vessels. Therefore, as such this would denote a ban on fossil natural gas as a fuel as opposed to a ban on LNG dual-fuel technology.

T&E's earlier analysis had warned that a more stringent target in FuelEU could drive unsustainable amounts of biofuels in shipping if introduced with no safeguards [1]. The risk still exists but appears more limited than previously assessed (see Section 1.2.) because of the BaU improvements in the fleet as well as the implicit counting of SSE in the FuelEU fuel/energy GHG intensity targets.
Hence, we recommend strengthening the targets by advancing them by 5 years and defining 2050 as the sunset clause for the last use of GHG-emitting fuels by ships, as shown in Table 1 below. These advanced targets would have the advantage to engage the sector in a fuel switch from the entry into force of the first target, while setting a progressive and realistic trajectory for European shipping to fully decarbonise by 2050. Overall, adopting T&E recommended targets would increase emission savings by 478 $MtCO_2$ over the period 2025-2050 (Fig. 7).

<table>
<tr><th>Target year</th><th>BaU reductions</th><th>BaU reduction + effect of OPS mandate</th><th>Commission proposal</th><th>T&E recommendation</th></tr>
<tr><td>2020 (baseline)</td><td colspan="4">91.7 gCO_2e/MJ</td></tr>
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2025	-0.4% (91.4 gCO_2e/MJ)	-0.9% (90.9 gCO_2e/MJ)	-2% (89.9 CO_2e/MJ)	**-6% (86.2 gCO_2e/MJ)**
2030	-1.2% (90.6 gCO_2e/MJ)	-2.9% (89.0 gCO_2e/MJ)	-6% 86.2 gCO_2e/MJ)	**-13% (79.8 gCO_2e/MJ)**
2035	-2.6% (89.4 gCO_2e/MJ)	-4.3% (87.8 gCO_2e/MJ)	-13% (79.8 gCO_2e/MJ)	**-26% (67.9 gCO_2e/MJ)**
2040	-4.2% (87.9 gCO_2e/MJ)	-5.8% (86.4 gCO_2e/MJ)	-26% (67.9 gCO_2e/MJ)	**-59% (37.6 gCO_2e/MJ)**
2045	-5.4% (86.9 gCO_2e/MJ)	-6.9% (85.4 gCO_2e/MJ)	-59% (37.6 gCO_2e/MJ)	**-75% (22.9 gCO_2e/MJ)**
2050	-5.8% (86.5 gCO_2e/MJ)	-7.3% (85.0 gCO_2e/MJ)	-75% (22.9 gCO_2e/MJ)	**-100% (0 gCO_2e/MJ)**

Table 1: T&E recommendation for revising FuelEU GHG target levels

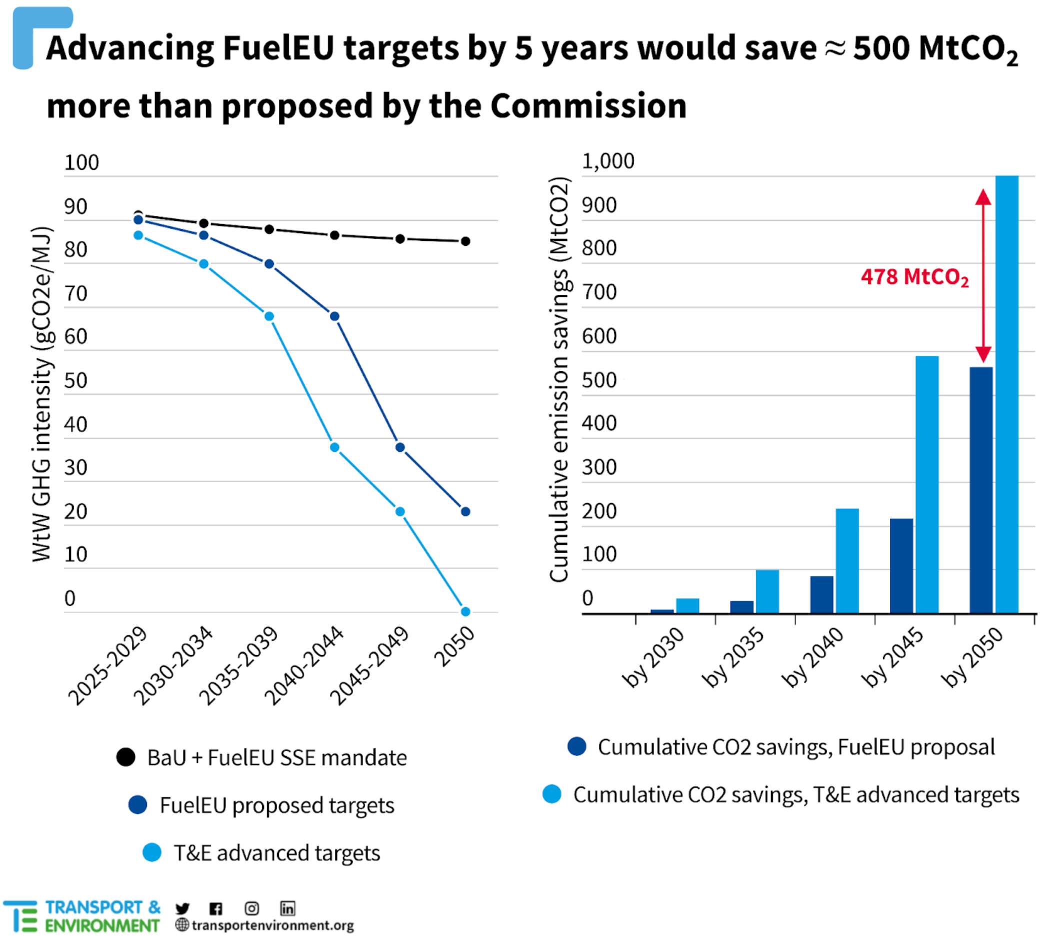


Figure 7: GHG intensity targets proposed in FuelEU and recommended by T&E, and resulting emission savings compared to BaU with only the FuelEU SSE mandate

Any strengthening of the target must, however, be coupled with appropriate incentives for the deployment of e-fuels (see section 2.2.) in order to avoid a surge in (unsustainable) biofuel demand. Policy-makers may also choose to slightly adapt the level of the 2045 target to avoid requiring a steeper effort between 2045 and 2050 than between 2040 and 2045. For example, a target of -80% (18.4gCO_2e/MJ) in 2045 would correspond to a linear improvement between 2040 and 2050.

Secondly, it is essential to improve the accounting of methane emissions in the FuelEU Maritime Annex II in order to adequately capture the near term global warming impact of LNG. The current proposal uses a 100-year global warming potential (GWP100) of methane, which tends to underestimate the climate warming impact of methane. The warming considered over a 20-year time horizon (GWP20) tends to overestimate the warming impact of methane. Recent work in this area indicates that the most appropriate metric to capture this is the (GWP*)[15, 16]. GWP* considers the rate of change of emissions, as well as the historical cumulative emissions. However the concept remains quite new and values are yet to be defined for implementation in legislation, particularly when it is for individual sectors of the economy. The IPCC 6th Assessment report leaves the choice of metric to policy-makers, depending on regulatory needs[22]. For the purpose of the FuelEU Maritime, T&E recommends adopting the GWP20, instead of a GWP100. It is important for several reasons:

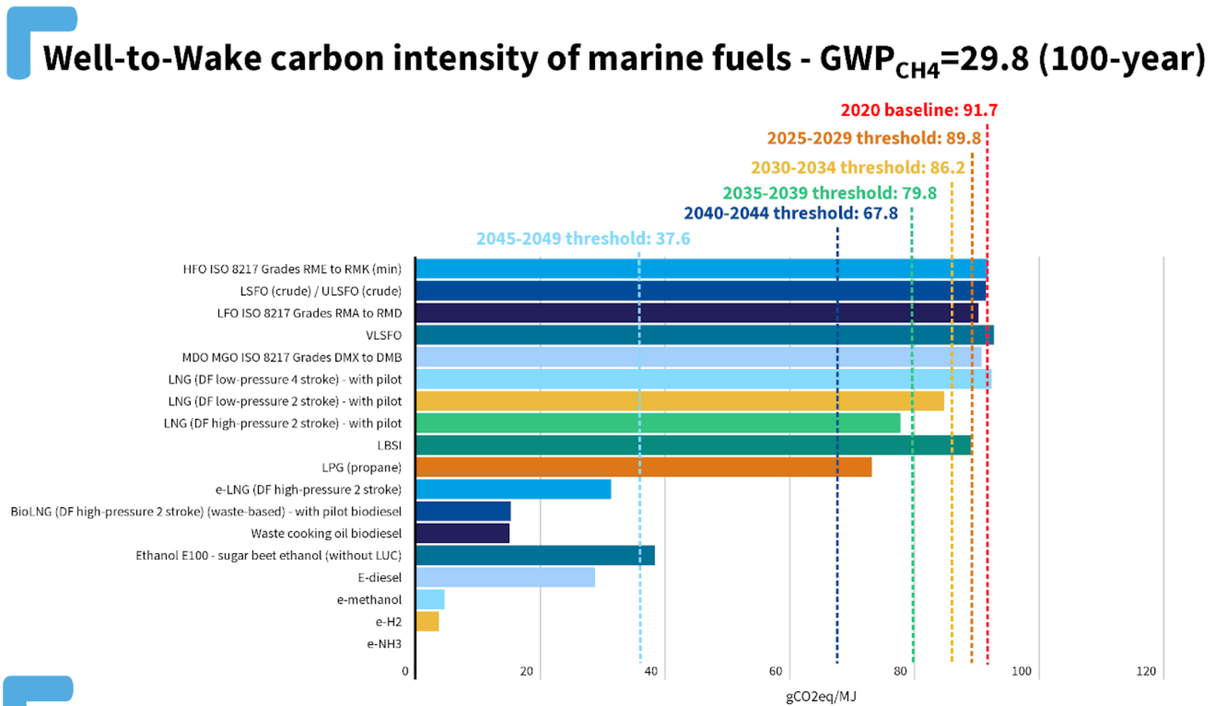
- While it is positive that the Commission proposal accounts for all GHG emissions, including CH_4, the text ignores the short-term climate forcing effects of methane. According to the latest IPCC report, methane is 82.5 times more potent GHG than CO_2 over 20 years (GWP20), compared to 29.8 times over 100 years[23].
- As decarbonisation efforts must take place in the next 28 years remaining until 2050, the use of GWP100 is inappropriate for the purpose of the FuelEU Maritime Regulation.
- Moreover, the adoption of the GWP 20 value in the FuelEU Maritime regulation would reduce the attractiveness of fossil LNG despite its relatively (pre-COVID) cheap prices compared to other alternative fuels.
- Adopting the GWP20 for methane should not come at the expense of real CO_2 reductions. Hence this recommendation should ideally go hand-in-hand with advancing the targets (as per Table 1) and the inclusion of sub-targets for sustainable, scalable, renewable fuels of non-biological origin (RFNBOs) as detailed in Section 2.2.

As illustrated in Fig. 8, this would increase the weight of methane slips and leaks in the WTW GHG intensity of LNG, and consequently render fossil LNG combustion in 4-stroke and 2-stroke low-pressure Otto cycle engines ineligible from 2025 onwards. In addition, the advanced GHG target shortens the

[22] See p.1739 of the IPCC's 6th Assessment Report (full report [17]): "*Following AR5, this report does not recommend an emission metric because the appropriateness of the choice depends on the purposes for which gases or forcing agents are being compared. Emission metrics can facilitate the comparison of effects of emissions in support of policy goals. They do not define policy goals or targets but can support the evaluation and implementation of choices within multi-component policies (e.g., they can help prioritise which emissions to abate). The choice of metric will depend on which aspects of climate change are most important to a particular application or stakeholder and over which time horizons. Different international and national climate policy goals may lead to different conclusions about what is the most suitable emission metric (Myhre et al., 2013b)*"
[23] See table 7.15 p.204 of the IPCC's 6th Assessment Report (full report [17]).

lifetime of fossil LNG use even by the best engines (Diesel cycle) by 5 years. Consequently only the best-in-class LNG engine would remain compliant with FuelEU until 2034, instead of 2039 as it is in the current text.

The combined effect of advanced targets by 5 years and the use of 20 year GWP for methane (i.e. 82.5) can limit the uptake of LNG, thereby reducing risks of technology lock-in and leaving room for other alternative fuels to penetrate the market.



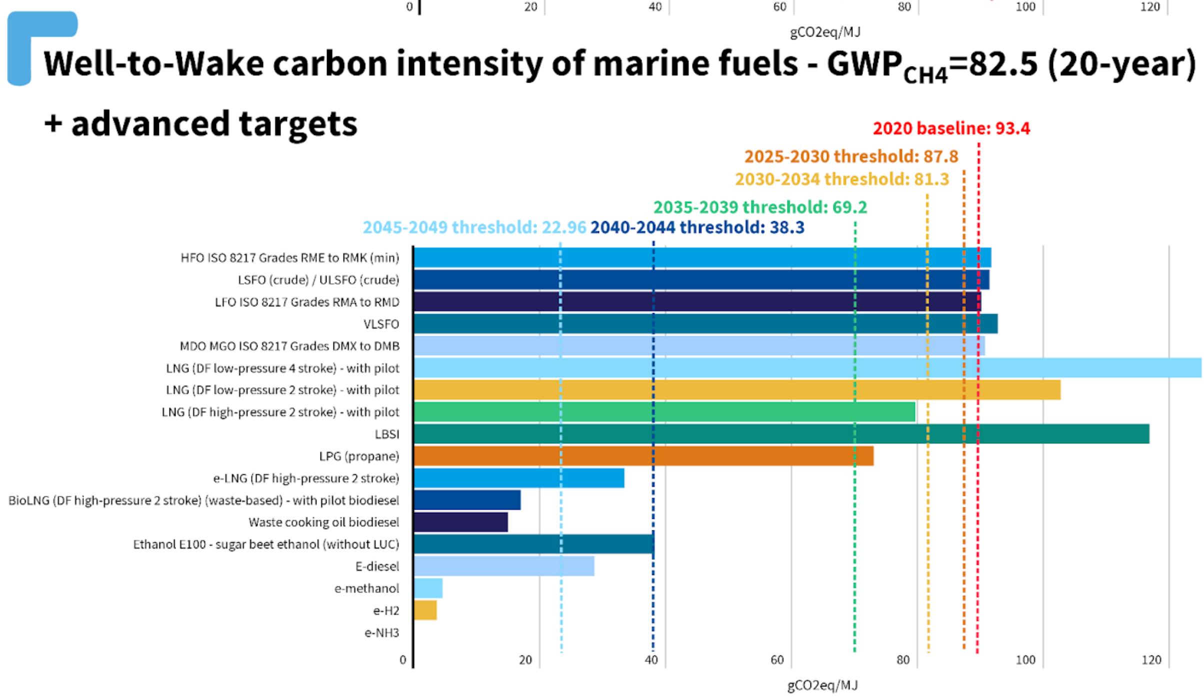


Figure 8: Comparison of WTW GHG intensity of different fuels under different GWP time horizons for methane and FuelEU GHG targets (as proposed or advanced by 5 years)

2.2. Boost demand for sustainable fuels with dedicated incentives

Despite the objective of the FuelEU Maritime initiative to drive the uptake of sustainable alternative marine fuels, a fully technology-neutral approach will fail to address market barriers standing in the way of deploying sustainable and scalable alternative fuels, such as e-fuels/RFNBOs, which are crucially needed to achieve shipping's decarbonisation by 2050. This is because under the current proposal, sustainable e-fuels would be treated on an equal basis with fossil gas and unsustainable and/or unscalable biofuels. Although green ammonia appears to be the most competitive e-fuel for deep-sea shipping, and in spite of future cost reductions, it is still about 4 times more expensive today than conventional fuels. Considering that fuel use accounts for most of shipping operating costs, the main barrier to the uptake of e-fuels is their price - in addition to availability in the immediate future. Without tailor-made incentives as part of the FuelEU Maritime Regulation, green e-fuels will not be cost-competitive against fossil gas and biofuels and are unlikely to be adopted by the industry, thus putting at risk the achievement of EU climate goals by 2050.

2.2.1. Ensure the predictability of supply and demand with dedicated goal-based e-fuels/RFNBO sub-targets

An e-fuel mandate is the most straightforward way to ensure demand for sustainable fuels in shipping and provide business predictability to the fuel suppliers. This approach was taken in the ReFuelEU Aviation proposal to kick-start by 2030 the deployment and use of e-kerosene by planes taking off from European airports. Similarly, we strongly recommend introducing a minimum share of green e-fuels/RFNBOs in the total energy demand used onboard ships covered by the FuelEU Maritime Regulation.

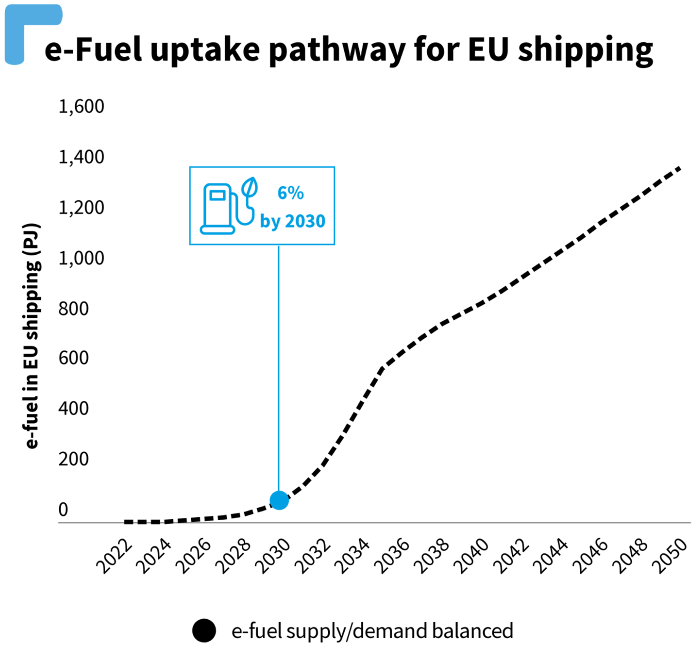
In practice, this mandate would apply in parallel with the GHG intensity targets and be met by ships thanks to the use of the pooling system at the fleet level. Based on T&E's shipping decarbonisation study[24], we recommend a mandate of 6% of the energy demand used by ships by 2030. Under the proposed geographical scope of the FuelEU Maritime (a.ka. a semi-full scope MRV), 6% of shipping's 2030 energy demand would be equivalent to about 85PJ of e-fuels (Fig. 9). The proposed sub-target should be goal-based if the co-legislators decide to remain consistent with the technology-neutral logic of the proposed legislation. This means that ships would be able to comply with the sub-targets by using a suite of sustainable e-fuels/RFNBOs, including e-H2, or green hydrogen-based fuels such as e-ammonia (e-NH_3), e-methane (e-CH_4), e-methanol (e-MeOH), as well as e-diesel[25]. Some of these fuels are drop-in and can be directly used in existing vessels with no or minor retrofits.

[24] T&E study estimated that about 4.6 Mt of green e-ammonia, or 85 PJ, could be deployed in shipping by 2030 [2].

[25] The use of e-fuels produced from hydrogen and CO_2 such as e-methanol, e-LNG and e-diesel should only be considered sustainable when carbon is sourced using direct air capture technology (DAC). See T&E answer to the GHG accounting of RFNBOs relevant to the upcoming RFNBO delegated act [19].

However, the suggested 6% sub-target can also be met even if the EU shipping exclusively relies on e-ammonia (which requires purpose built-vessels) and deploys ammonia-dual-fuel vessels under normal fleet renewal process up to 2030. Should the e-fuels/RFNBOs mandate in shipping be supplied entirely by green ammonia (85 PJ), it would require:

- About 14.6 GW additional renewable electricity capacity; this compares to 14.7 GW of new wind capacity installed in Europe in 2020 alone and 220 GW total wind capacity installed in Europe by the end of 2020;[26]
- About 7.5 GW electrolyser, or a little more than 20% of the EU goal for domestic green hydrogen production in 2030 (40 GW[27]).



Note: T&E analysis which uses e-ammonia as a "placeholder" for calculations. This does not prejudge other e-fuels uptake by ships. Analysis assumes no regulatory-driven energy efficiency gains by the sector until 2050 and full shore-side electricity use by all vessels at berth. Energy density of e-ammonia: 18.6Mj/kg. **Source**: Decarbonising European Shipping Technological, operational, and legislative roadmap, T&E, 2021.

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Figure 9: E-fuel uptake pathway for European shipping 2025-2050 (PJ)

Finally, a mandate on ships to use e-fuels under FuelEU Maritime should be complemented with a mandate on fuel suppliers/refineries to supply those fuels in European ports, to ensure sufficient quantities are distributed to the shipping sector. This can be achieved either via a dedicated shipping e-fuel/RFNBO sub-target under the Renewable Energy Directive (RED) or introducing a parallel supply mandate under the proposed FuelEU Maritime Regulation.

Option 1: A parallel e-fuels/RFNBO *supply* sub-target under RED III

As part of the Fit-for-55 package the European Commission has proposed under RED III a dedicated 2.6% e-fuels/RFNBO target on transport fuel suppliers, which technically covers the maritime sector, too. The draft RED III could be revised during co-decision to have a dedicated shipping supply target. Should this

[26] See WindEurope 2020 statistics [20]. NB: Forecasts for 2030 are 323 GW cumulative wind turbines capacity and 563 GW of solar capacity [21]; [22].

[27] See the Commission's 2020 Hydrogen Strategy for Europe [23].

approach be taken, the shipping sub-target under RED should be set at 0.8% in order to match the 85 PJ demand quota under FuelEU Maritime (Fig. 10).

Option 2: A parallel e-fuels/RFNBO *supply* sub-target on fuel suppliers/refineries directly under the FuelEU Maritime Regulation

A second approach to guaranteeing necessary volumes of sustainable e-fuels/RFNBOs for shipping, a dedicated supply target could be introduced directly into the FuelEU Maritime without replacing the use quotas on ships as explained above. This would mirror the approach taken by the European Commission under the ReFuel Aviation proposal and solve the chicken and egg problem under a single instrument.

Either way, there are three main reasons for having a dedicated supply sub-target for shipping e-fuels/RFNBOs:

1. Switching to expensive and technically challenging e-fuels requires policy certainty both on the supply and demand side. The proposed FuelEU Maritime regulation will only drive *demand* for alternative fuels in shipping. An RFNBO sub-target for shipping in the RED III or FuelEU Maritime would ensure that the ship operators wanting to comply with their obligations under FuelEU (Maritime) with e-fuels can be assured that fuel suppliers will *supply* a minimum level of RFNBOs at European ports.
2. Introducing the RFNBO sub-target for shipping would ensure that the supply of RFNBOs by fuel suppliers to bunkering infrastructure in EU ports matches the demand for alternative fuels from ships calling in EU ports, mutually reinforcing each other.
3. The RFNBO subtarget for shipping addresses the potential competition for RFNBOs between the road and shipping sectors. The road fuels market is much bigger than the maritime market (i.e. ~260Mt vs. 33 Mt) and gasoline and diesel for road transport fuels are more expensive (largely due to high fuel taxes). Hence, blending a low level of expensive RFNBOs in the larger pool of higher-priced road fuels could be an interesting compliance option for fuel suppliers instead of supplying e-fuels to shipping.

If introduced under **the RED, the RFNBO sub-target for shipping should be 0.8% of all the transport fuels sold in the EU in order to match the 85 PJ demand quota as described above. If introduced under FuelEU Maritime directly, then demand and supply quotas for e-fuels should be identical.** As demonstrated by Fig. 10, this subtarget would match the RFNBO volumes mandated under FuelEU by 2030, i.e. 85 PJ or 6% of EU-related shipping demand.

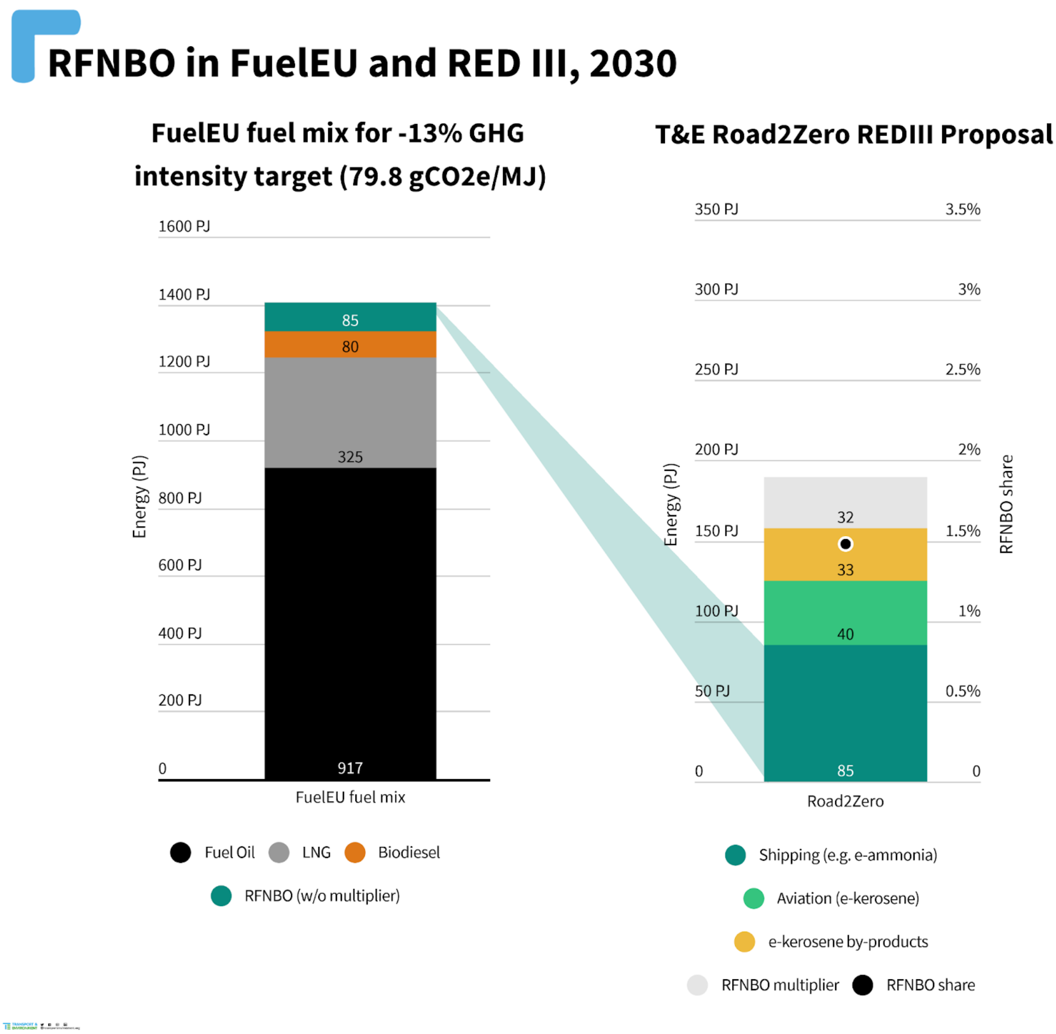


Figure 10: T&E proposal of RFNBO mandates matching supply and demand in shipping under FuelEU Maritime and RED III proposals

2.2.2. Boost the cost-competitiveness of e-fuels with a multiplier of 5 and exclusive pooling

The introduction of multipliers on e-fuels can help improve their competitiveness vis-à-vis other alternative fuels. Based on T&E's calculations, to comply with the current 2030 FuelEU regulatory target of -6%, green ammonia can become more cost-effective than waste-based biofuels if a multiplier of 4 is applied. Since the analysis is limited to fuel costs only and does not take into account additional CAPEX for ammonia-powered vessels and bunkering infrastructure costs, a multiplier of 5 could be a safer option to account for non-fuel costs.

Fig. 11 below illustrates schematically how the use of multipliers can boost e-fuels' attractiveness, taking the example of green ammonia (or e-ammonia). With a multiplier of 5, the amount of e-ammonia necessary to comply at a fleet level (assuming non-compliant fuel oil ships pool with compliant e-ammonia ships) is roughly[28] divided by 5 (top part of Fig. 11). The total cost of compliance will be reduced since fewer amounts of expensive e-ammonia would be used (bottom part of Fig. 11).

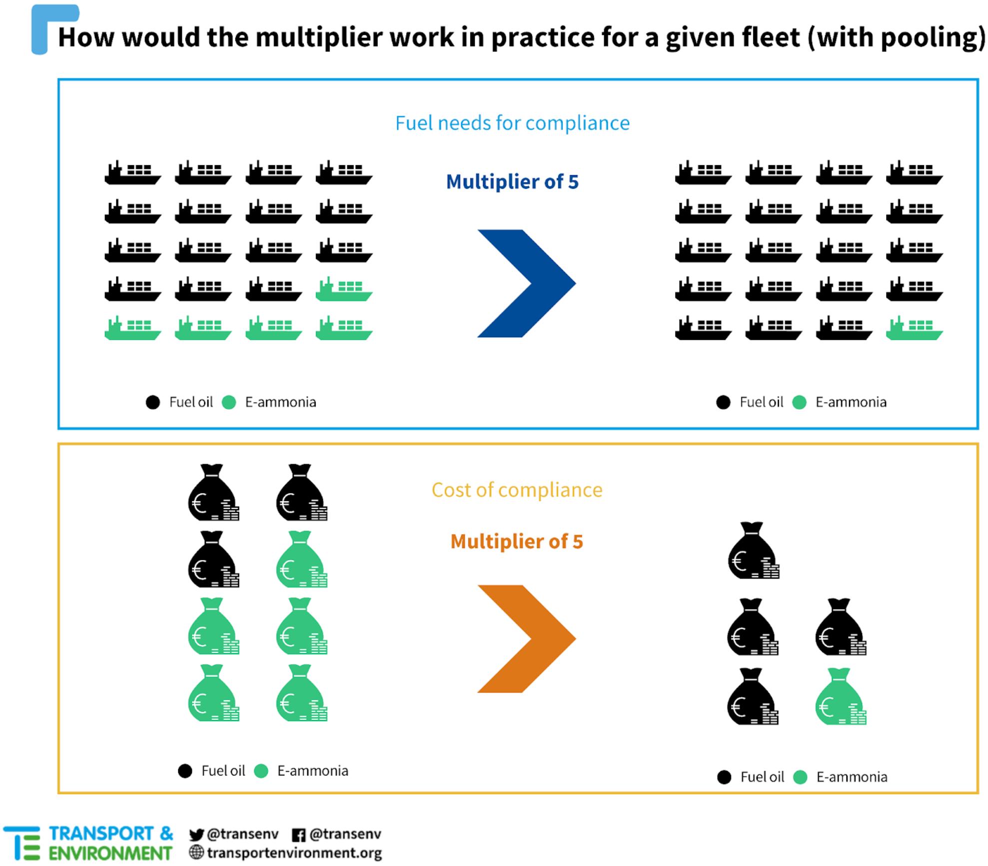


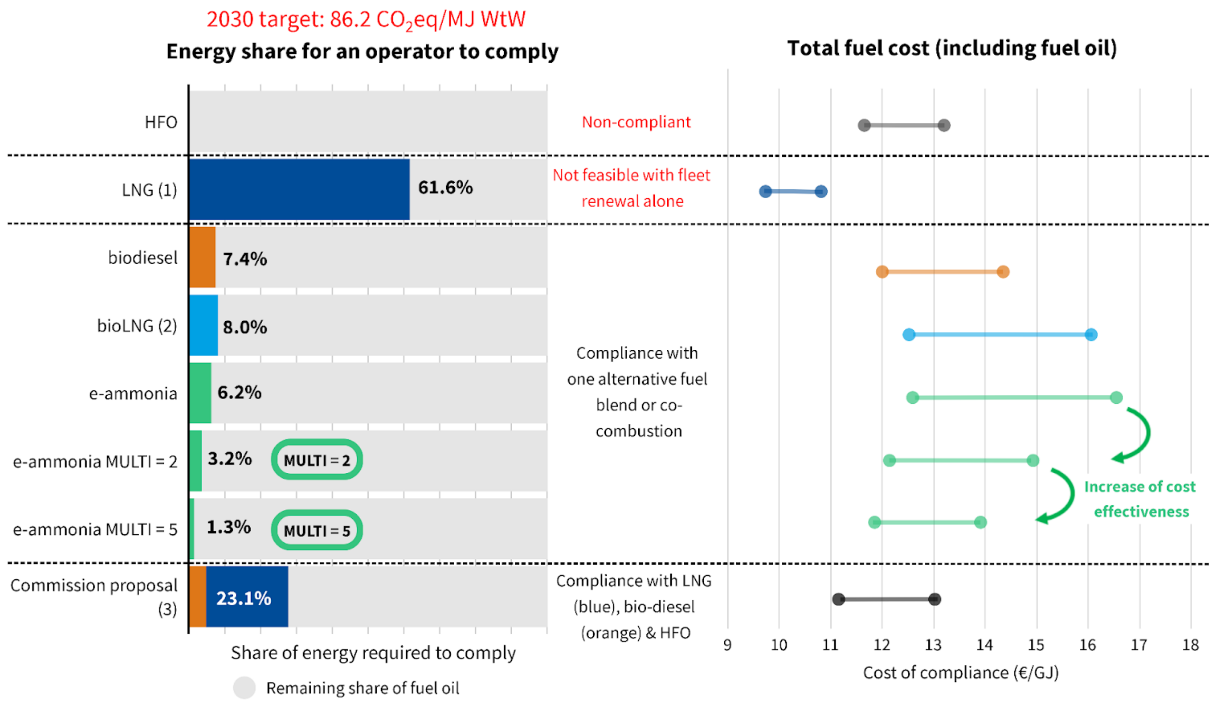
Figure 11: Effect of a multiplier on volumes of RFNBOs required to comply and the resulting cost

Fig. 12 shows the real numbers from our hypothetical case modelling. With a multiplier of 5, a share of 1.3% of ammonia in the total shipping energy demand would be sufficient to comply with the 2030 target[29], whereas 6.2% would normally be required without the multiplier. Thanks to the discount on the volume because of a multiplier of 5, the cost of using e-ammonia to comply with the 2030 target becomes much cheaper (right part of Fig. 12).

The use of a multiplier has even been recommended by the Commission's impact assessment to boost the uptake of zero-emission technologies, but unfortunately did not find its way in the final proposal. As such, it can be easily reintroduced in the proposal via a simple amendment to the GHG target formula in Annex I.

[28] Because the multiplier would be added at the denominator of the FuelEU fuel GHG intensity formula, the amount of ammonia needed with a multiplier of 5 would not be divided by exactly 5.
[29] Numbers refer to the energy share required for operators to comply at fleet level, assuming that ships will pool together for compliance with the GHG target.

Compliance costs - multipliers can boost cost-effectiveness of e-fuels for operators in 2030



Note: This graph shows how multipliers can incentivize e-fuels by boosting their cost effectiveness for compliance per operator. This simplistic approach only includes fuel costs - carbon mark-up is excluded. Price range based on the difference between conservative and optimistic cost assumptions. See Table 1 for sources.
(1) Fossil LNG, engine technology mix (see figure 2) with an average WtW of 82.63 gCO2e/MJ. We calculate the maximum share from LNG could be 23.1% from a fleet turn-over model.
(2) Bio-LNG from biowaste, engine technology mix (see figure 2) with an average WtW of 20.70 gCO2e/MJ.
(3) LNG technology mix and biofuel from Climate Disaster Scenario (resulting from Commission proposal).

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Figure 12: Impact of using multipliers on e-fuels' compliance costs

T&E modelling shows that smaller multipliers than 5 would not be sufficient to make e-fuels cost-competitive. It is also important to note that higher multipliers might still not change the cost-competitiveness balance between e-ammonia and fossil LNG (right part of Fig. 12), which requires additional policy tools.

Parallel to a multiplier of 5, excluding LNG from the benefits of the pooling system would further boost the cost-competitiveness of green e-fuels/RFNBOs. The FuelEU proposal includes a pooling mechanism, which is a flexibility granted to shipping companies to comply with the regulatory thresholds at the fleet level rather than at a ship level. Theoretically, this could help companies to deploy fully zero-emission vessels as opposed to marginally improving the GHG intensity of existing ships via biofuel blending. This is positive. However, the proposed system is flawed:

- There is no time limitation to banking compliance for the future. This means that ships using fossil LNG with 2-stroke high-pressure engines would be able to accumulate excess credits and use them to comply even after the compliance end date for fossil LNG, i.e. 2039. Under current targets, this would lead to continuous use of fully fossil LNG-powered ships until 2046, with no need to even blend bio-LNG (see Section 1.2.).
- Ships using fossil LNG with 2-stroke engines would be able to sell their excess credits until 2030-2040 (i.e. as long as their WtW GHG intensity over-complies with the FuelEU target), which would further boost their already advantageous price-competitiveness and further widen the gap with truly sustainable fuels.

To further boost their cost-competitiveness, we recommend limiting the possibility of banking and pooling compliance surplus to e-fuels/RFNBOs only (Fig. 13). This would allow progressive companies to immediately deploy zero life-cycle e-fuels and lend/sell their surplus credits to other vessels/companies. This would encourage market operators to start equipping their fleet increasingly with engines running on e-fuels from the entry into force of the Regulation in 2025.

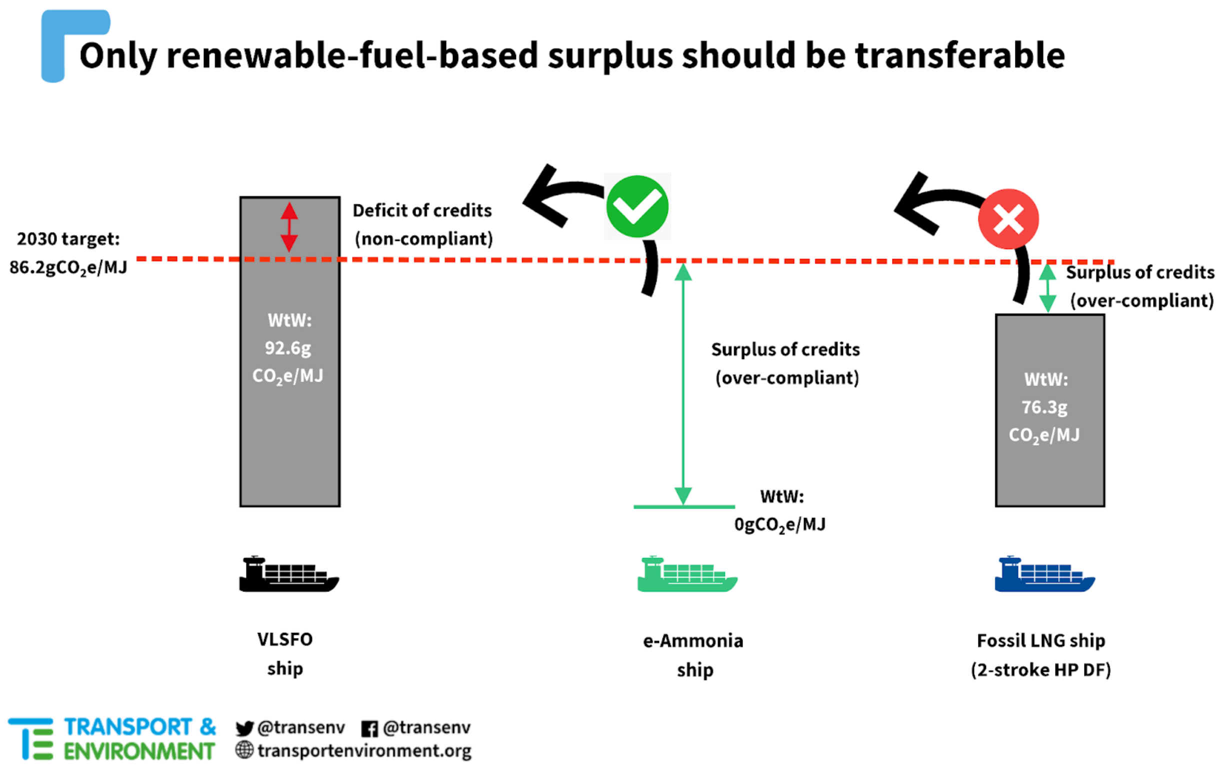

Figure 13: Example of surplus credit exchange limited to ships using RFNBOs (T&E recommendation)

Last but not least, the stricter the fuel GHG intensity targets, the more cost-effective e-fuels with multipliers become. This explains why under stricter targets (see Table 1), T&E's recommendations, i.e. a multiplier of 5 and exclusive pooling benefits for e-fuels, would make overall compliance cheaper than in the EC's proposal (shown on the part of Fig. 14).

The use of cost incentives for e-fuels allows a certain uptake by 2030, albeit modest. Where the original Commission proposal makes any market penetration of e-fuels unlikely by 2030, the combination of a multiplier and exclusive pooling benefits could drive in roughly 1% of e-fuels by 2030 under current targets; if targets were advanced by 5 years, e-fuels could reach about 2.5% of the EU shipping fuel mix. However, this assumes ship operators make use of the incentives to invest in e-fuels and that sufficient quantities are delivered to the shipping sector. To ensure sufficient uptake by 2030 and reach zero-emission shipping by 2050, the most effective tool remains e-fuels/RFNBOs sub-targets on ship operators and fuel suppliers, as recommended above (see section 2.2.1). The multiplier and limited pooling system may be combined with dedicated targets/quotas for the use of e-fuels to reduce compliance costs. If this combined option is chosen, the multiplier should only apply to e-fuel/RFNBO volumes above the sub-target, otherwise the physical amount of e-fuels used would be much lower than what the subtarget intends.

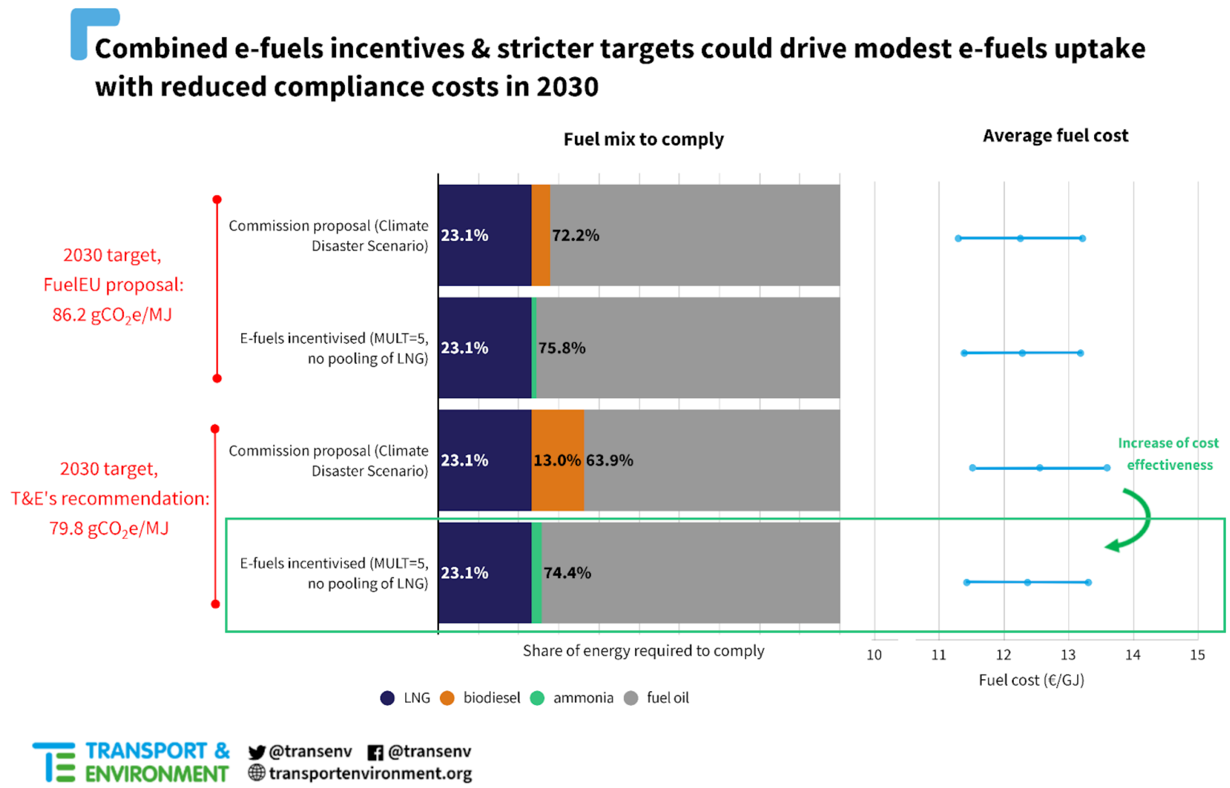

Figure 14: Comparison of compliance cost between the Commission's proposal and T&E's recommendation of advanced target, multiplier and limited pooling

2.2.3. Raise the ambition of the zero-emission berth mandate

T&E's 2021 shipping decarbonisation study[30] calculated that total MRV fleet CO_2 emissions could be reduced by roughly 6% if all ships were plugged at berth. Under the semi-full scope of the FuelEU proposal, this would represent 9% of the covered emissions. Even though the shore-side electricity (SSE), a.k.a. onshore power supply technology (OPS) has existed for over 20 years now, only a small number of ships use it at the moment in Europe. This results in underused and costly SSE infrastructure in EU ports. The very fact that the European Commission proposed to break this chicken and egg problem by introducing a mandate on ships in the FuelEU Maritime is a success as it promises to finally create a business case for ports to deploy the appropriate infrastructure. It is also positive that the mandate at Article 5 has been designed as a zero-emission berth standard instead of a simple obligation to plug in at berth, leaving the possibility for zero-emission ships to use battery-electric or hydrogen fuel cell technologies at berth instead of using electricity from the grid (Annex III).

However, the current mandate has some room for improvement, both in relation to the proposed timeline and the type of ships that are covered. The Commission proposal gives a decade-long lead time before the OPS mandate kicks in. This will give an easy ride to the most energy-consuming ship types at berth, especially that the use of SSE is counted towards the fuel GHG intensity target in FuelEU Maritime. As such, one-third of all ships could already comply with the current 2030 (-6%) target by simply plugging at berth.[31] For example, 100% of cruise ships can comply if they all plug in at berth, i.e. with no need to switch to alternative fuels until 2035. If cruise ships pooled compliance units between themselves, they would even over-comply with the 2030 target (-7.4%) and be able to bank the remainder for the following years.

Moreover, the scope of the current SSE mandate is limited to passenger and container ships only. This leaves out 57% of EU emissions at berth, i.e. 5 Mt of CO_2 and 3 kt of sulphur oxide (SO_x) per year, equivalent to the SO_x emissions of the entire EU passenger car fleet (250 million cars).[32]

To foster the rapid deployment of onshore power supply and cut GHG emissions and air pollution, T&E recommends that the FuelEU zero emission berth mandate applies to all passenger ships starting from 2025, and be followed by containerships, tankers and refrigerated-bulk carriers from 2030. Finally, all remaining ships should be covered by 2035 (Fig. 15). The same adjustments to the timeline and type of ships covered should be applied to ports (AFIR article 9), to ensure sufficient

[30] See p.41-42, Section 5.6. Zero-emission berth mandate of T&E 2021 shipping decarbonisation study [2].

[31] 65% of cruise ships, 34% of Ro-pax ships and 13% of containers would comply with the 2030 (-6%) target by simply plugging at berth.

[32] Sulphur oxide emissions are responsible for air pollution, together with nitrogen oxide (NOx) and particulate matter (PM). A total of 3kt SOx emissions was calculated for the ship types other than passenger ships and containerships, assuming they comply with the 0.1% limit on SOx content applicable to most European seas (Baltic Sea, North Sea, and recently the Mediterranean Sea are Emission Control Areas under IMO's MARPOL Annex VI [24]. This corresponds to roughly 250 million passenger cars, based on T&E's SOx car comparator (see T&E's 2019 cruise ships study [25]). This compares to the 242.7 million passenger cars on EU roads reported by ACEA in 2019 [26].

deployment of shore-side electricity infrastructure for ships to meet the zero-emission berth requirements.[33]

This timeline is both realistic and environmentally effective, because all ship types can technically use ship-to-shore options, and literature shows all ship types benefit from onshore power supply in terms of GHG savings and air quality gains.[34] Moreover, the direct use of electricity at berth is expected to become more cost-effective than generating electricity from fuels onboard, taking into account both infrastructure and electricity costs.[35] And as the use of SSE is implicitly counted towards the achievement of the GHG fuel intensity target (see Section 1.2), SSE will likely be a no-regret measure for all ship types.

[33] See T&E's Briefing on the review of the Alternative Fuels Infrastructure Regulation [27].
[34] See table 4 in Stolz et al. 2021 [28]
[35] See p.28, Section 3.4. Costs and energy demand of T&E's shipping decarbonisation study: "The total installed power required is calculated to be 2480 MW in 2030 (in the high energy efficiency and fuels only scenarios), and 2780 MW in 2050. With these assumptions and a constant HFO price of €326/t, we calculate zero-emission berths to have a negative marginal abatement cost in 2050, i.e. sparing more fuel cost than the required infrastructure and electricity costs." [2]

Timeline for the introduction of zero-emission mandate for ships at berth, T&E 2021

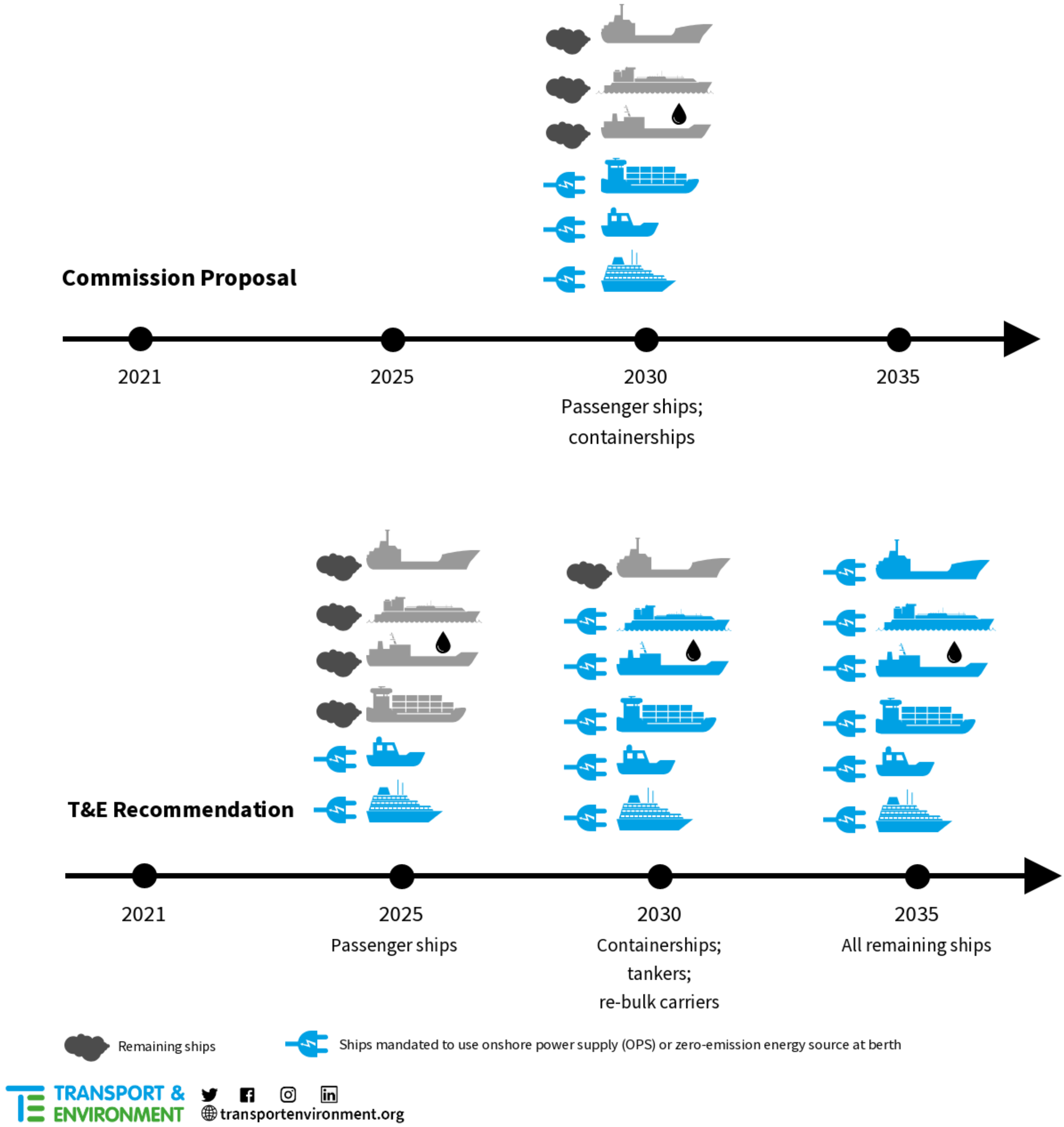

Figure 15: Commission proposal and T&E recommendation of timelines for the introduction of onshore power supply (OPS) at berth, differentiated by ship type

2.2.4. Extend the scope of the FuelEU Maritime to smaller ships and cover all EU-related shipping

If the EU aims to decarbonise all its transport emissions, there is no reason why half the energy consumed on EU-related voyages be exempted from GHG intensity reductions. The draft version of the Commission proposal did consider a full MRV scope for the application of the FuelEU Maritime regulation [9]. With a global low-GHG fuel standard upcoming in IMO negotiations, EU policy-makers should seize the opportunity to set high the level of ambition by deciding on an open-scope of FuelEU Maritime.

Besides, the size limit of 5000 GT envisaged by the FuelEU Maritime, but also ETS and AFIR proposals is unjustified. This could create a two-tier market in shipping, with more and more vessels built under 5000 GT. And there is no clear legislative precedent to justify the 5000 GT threshold: although the EU MRV applies to ships above 5000 GT, for example, the IMO's Marpol Annex VI regulation on ships' energy efficiency (EEDI) applies to ships above 400 GT. In the case of EU-related shipping, lowering the size limit to 400GT would help addressing the bulk of exempted emissions - 17.2Mt CO_2 (see Section 1.2.2.). To further reduce administrative burden on vessels that do not operate much each year, policy-makers could consider a carbon threshold whereby vessels above 400 GT are only obliged to comply with the FuelEU Maritime if they report more than 1,000 tCO_2 in the previous year's MRV [4].

Therefore, similarly as for the EU ETS proposal, T&E recommends applying the Regulation to 100% of the energy used in EU-related voyages, i.e. full scope of the EU MRV Regulation, and to extend the FuelEU scope to ships above 400 GT.

2.3. Improve enforcement of the Regulation

2.3.1. Apply strict rules on the origin of eligible fuels

FuelEU Maritime needs clear safeguards against unsustainable fuels that could be driven in the short-medium term as a result of the technology-neutral GHG target (see section 1.2.). While it is positive that food and feed-based biofuels are excluded from the Regulation (article 9), it needs to be complemented with stringent safeguards to make sure FuelEU does not repeat the mistakes of the Renewable Energy Directive.[36] For example, indirect land use emissions are not accounted for in RED GHG saving criteria, and some feedstocks that are not considered 'advanced' biofuels can still be counted towards the overall RED transport target. This is problematic as these feedstocks are not residues but by-products [30] and already have important existing uses (e.g. palm fatty acid distillates - PFAD, animal fats category III, molasses) [31]. Another issue is that of intermediate crops [32] and energy crops (e.g. lignocellulosic material): if their use was to be scaled up as suggested by the FuelEU Maritime's impact

[36] T&E's 2021 analysis of Oil World data found that 10 years of EU's failed biofuels policy has wiped out forests the size of the Netherlands, and resulted in up to 3 times more CO2 emissions than the fossil diesel it replaced in road transport [29].

assessment, it would require large swatches of land otherwise used for growing food or feed by the agricultural sector. Even soy grown in rotation with corn, as it is a common practice in Brazil, could be classified as intermediate crop [33] and hence qualify as feedstock under the FuelEU Maritime.

Therefore, T&E recommends that in parallel with higher GHG targets and e-fuels specific incentives, the FuelEU Maritime Regulation should also:

- **Explicitly exclude the use of all first generation biofuels from the scope of compliant fuels, and not only food and feed-based biofuels.** This can be done by simply extending the list of feedstocks considered to have the same emissions factors as the least favourable fossil fuel pathway in Article 9, to the following feedstocks: intermediate crops, energy crops, and by-products already used in other sectors such as PFAD, animal fats cat III, and molasses. FuelEU Maritime should at least align on the standard proposed in the ReFuelEU Aviation initiative, which limits the use of biofuels to Annex IX of the RED (i.e. no intermediate crops and PFAD). In parallel, the RED II's list of advanced biofuels at Annex IX should be revised to exclude unsustainable feedstocks, and the definition of food and feed crops should be extended to cover all crop biofuels [31].
- **Apply minimum RED II GHG saving criteria to all eligible fuels, as defined in Article 29 of the RED.**[37] This would effectively create a two-step approach and filter out fuels that could claim for emissions saving under the goal-based approach. For example, if an alternative fuel delivers e.g. only 10% emissions reduction compared to baseline fuel, the fuel GHG intensity reduction would not be accounted for if the ship partially or fully switches to that fuel. It would be treated as using baseline fossil fuel and using a baseline life-cycle carbon factor.
- **Improve certification schemes of biofuels and RFNBOs under the RED III review.** This is essential to addressing the needs of shipping operators to comply with FuelEU and reduce the risk of frauds by fuel suppliers, which is especially high in shipping as fuel bunkering often takes place in third-countries. In particular, the possibility for companies to use voluntary schemes to divert from Well-to-Wake default values was already flagged by the EU Court of Auditors as ineffective to guarantee the origin of used cooking oil.[38] If allowed for shipping as suggested by recital 27 of the FuelEU proposal, voluntary schemes could lead to widespread frauds on the origin of biofuels used by ships, especially when bunkered outside of the EU.

2.3.2. Prevent risks of non-compliance with appropriate safeguards

In addition to fuel eligibility issues, the FuelEU Maritime's enforcement framework must be improved to ensure the environmental effectiveness of the proposal.

Firstly, the EU legislator should mandate a strict EU-wide system of high penalties for non-compliance:

[37] The RED lays down minimum GHG saving criteria for transport fuels to be accounted as renewable. Current article 29 requires at least 65% GHG savings compared to the fossil fuel equivalent; this should be strengthened to 70% GHG savings in the ongoing RED III review [31].

[38] Current RED II allows fuel suppliers to report lower WTW emissions for biofuels than the RED default values, provided these biofuels meet sustainability criteria and other limits imposed in the RED and the new values are approved by certification schemes. However, the EU Court of Auditors has warned that voluntary schemes under current RED II legislation cannot guarantee that all the UCO imported into Europe is actually "used". [12]

- **Remove the "pay to comply" mechanism at article 20 paragraph 3 of FuelEU**, or at least limit it to a short phase-in period. Although the revenues from the penalties could be reinvested back in the sector, the existence of a pay to comply is counter-productive, as in certain cases it could be easier for shipowners to pay annual fees and pass on the costs to the final consumers/charterers rather than making actual investments in zero-emission vessels. It is also unnecessary: flexibility to comply with the GHG target is already provided by the pooling mechanism; and a much larger source of green shipping funding could come from EU ETS revenues, especially if they are allocated to shipping operators investing in zero-emission ships via carbon contracts for difference (CCfDs).
- **Raise the level of the penalty from to 2400 to 3000 EUR per ton of non-compliant fuel** equivalent to VLSFO (very low-sulfur fuel oil). This level is based on the price gap between green e-fuels and conventional fuels to make non-compliance prohibitive for ship operators

Secondly, it will be important to ensure robust enforcement of the Regulation. In the current text, third-party verifiers are entrusted with very large enforcement powers. This concerns notably the certification of non-compliance and determining corresponding penalties. Considering that there is a competitive customer and service-provider relationship between verifiers and shipowners, this could give rise to conflict of interests in enforcement. **To avoid this, significant enforcement powers should be transferred to Member States, for example by allocating the competence on penalties to national administering authorities of shipping companies** (as defined in article 3gd of the EU ETS Maritime proposal).

Last but not least, it will be important to ensure transparency of ships' compliance data to allow monitoring of progress, in a similar way as the annual MRV data publication.

3. Conclusion

The FuelEU Maritime initiative has the potential to put EU shipping on track to decarbonisation. To improve the Commission proposal, we recommend Members of the European Parliament and EU governments to take the following steps, summarised in the below (Table 2).

T&E analysis of the Commission proposal	T&E recommendation
1) Boost demand for sustainable e-fuels with dedicated quotas and incentives	
If compliance can be achieved with much cheaper fuels despite their limited GHG savings or unsustainably-sourced supply, no uptake of sustainable and scalable fuels can	• Mandate a minimum 6% e-fuels/RFNBO sub-target on ships under FuelEU Maritime and equivalent mandate on fuels suppliers under REDIII or FuelEU Maritime. This would kick-start

be realistically foreseen.	the supply chain in this decade and make full decarbonisation of shipping within reach by 2050.
Sustainable e-fuels are several times more expensive than conventional marine fuels; they need dedicated support to become cost-competitive	• Introduce cost incentives to use e-fuels, with a multiplier of 5 for e-fuels/RFNBOs. If introduced in combination with a sub-target on ships, the multiplier should apply to volumes above it; • Limit banking and pooling of compliance surplus to e-fuels only. This could be effective to bridge the cost-competitiveness gap with other alternative fuels.
2) Limit regulatory-driven uptake of fossil LNG	
FuelEU Maritime promotes fossil LNG ships for decades: fully fossil LNG ships with 2 stroke high pressure engines comply with the GHG target until 2039, and could extend their compliance until as far as 2046 by making use of compliance surplus banking.	To limit the eligibility of fully fossil LNG ships to 2034: • Advance the GHG target by 5 years compared to the proposed trajectory by the Commission; • Exclude fossil LNG from banking compliance surplus.
As decarbonisation efforts must take place in the next 28 years remaining until 2050, the use of the 100-year Global Warming Potential for methane (29.8) is inappropriate for the purpose of the FuelEU Maritime Regulation.	• Use GWP20 value for methane (i.e. 82.5 times more potent than CO_2) to fully account for the short-term climate forcing impacts of LNG. This limits the eligibility of fossil LNG to low-methane-slipping engines only (i.e. 2 stroke high-pressure).
3) Raise the overall ambition level of the Regulation	
The FuelEU Maritime proposal aims for limited ambition in the first 15 years of its application, and does not even aim at zero-emission by 2050. Until 2039, ships would need to use only half as much alternative fuels than what the headline targets suggest, leaving 87% of the effort to full decarbonisation in the ensuing 10 years.	• Advance the GHG target by 5 years. This will increase emission savings by 650Mt CO_2 over the period 2025-2050, compared to the Commission proposal.
The current zero-emission at berth mandate is limited to passenger and container ships, which leaves out 57% of EU emissions at berth.	• Accelerate the deployment of the zero-emission berth mandate, starting from 2025 for passenger ships, 2030 for containerships, tankers and refrigerated bulk carriers, and all remaining ship types by 2035 latest.

Current 50/50 geographical scope on voyages from and to third countries represents a drop in emissions coverage by almost one-third (28% or 42Mt CO_2) of the total 146 MtCO_2 emitted by EU-related shipping in 2019. Further, the size limit of 5000 GT exempts 19.7 Mt of emissions.	• Extend the geographical scope to cover 100% of EU-related shipping; • Apply the Regulation to all ships above 400 GT.
4) Improve enforcement of the Regulation	
FuelEU excludes food and feed-based crop biofuels, which is positive and should be defended; however all crop-based biofuels are problematic feedstocks; and the Regulation allows the use of fuels not compliant with RED II criteria.	• Exclude all crop-based biofuels from the Regulation; • Apply RED II's GHG saving criteria to all eligible fuels • Improve RED certification schemes
Article 20 (3) exempts companies from compliance with the GHG targets against simple payment of a penalty, which might be cheaper for shipowners than making actual investments in zero-emission vessels.	• Removing the pay to comply mechanism (or time-limit it) to prevent risks of non-compliance; • Raise the penalty level to 3000 EUR/ton to make costs of non-compliance prohibitive compared to investments in green e-fuels.

Table 2: Summary of T&E analysis results and related policy recommendations

4. Appendices

4.1. Appendix A - methodology

4.1.1. Estimation of the current and future share of LNG in the MRV fleet

We performed an in-depth analysis of 2020 MRV emissions report data [34] to estimate the amount of energy coming from LNG in the EU-related fleet. Fuel consumption and emissions of ships allow us to calculate emission factors (gCO_2/gfuel) and deduce the type of fuel(s) used by ships. It is then possible to estimate the share of LNG burned in the fleet in 2020, which is about 6%.

Future EU fleet emissions were calculated with a stock model based on MRV emissions and on the transport work growth predicted in the Fourth IMO GHG study (SSP2_RCP2.6_G scenario) [35]. In the business-as-usual scenario, the uptake of LNG ships is based on IHS order book until 2023 and later stays at 2023 levels (i.e. 39% of all new ships). In the FuelEU Maritime proposal scenario, the uptake of LNG ships is based on IHS order book until 2023 and rises up to 72% in 2025, which represents the current share of energy consumption by marine 2-stroke engines.[39] This assumption reflects the technical constraint of certain types of ships that are not able to be powered by 2-stroke engines, but can no longer comply with fossil LNG only in 4-stroke engines from the entry into force of FuelEU Regulation GHG intensity thresholds in 2025.

Shares of different LNG engine technologies are based on IHS order books (for the global fleet) until 2023 and assumed constant from 2024 onwards. From 2025, as a result of the entry into force of the first GHG target which rules out 4-stroke engines, LNG ship sales are considered to be half low-pressure 2-stroke (Otto cycle), half high-pressure 2-stroke (Diesel cycle). From 2030, all LNG ship sales are considered to be high-pressure 2-stroke, assuming anticipated decisions of shipowners ahead of the entry into force of the 2035 threshold which rules out fossil LNG use with other types of engines than high-pressure. Table 3 and Table 4 show the estimated market share of LNG ships and their share in the global fleet (in energy terms), differentiated by type of LNG engine.

Table 5 shows estimated volumes of LNG that would be driven in the shipping market as a result of the FuelEU Maritime proposal, compared to the business as usual LNG market share evolution. Volumes are derived from market share scenarios in tables 3 and 4, applied to two possible geographical scopes: 50/50 inclusion of international voyages (as proposed by the Commission) and full MRV scope.

	2020	2025	2030	2035	2040	2045	2050
LNG market share	6.5%	39.0%	39.0%	39.0%	39.0%	39.0%	39.0%
Share of LP 4-Stroke engines in new LNG ships sold	5%	0%	0%	0%	0%	0%	0%
Share of LP 2-Stroke engines in new LNG ships sold	70%	50%	0%	0%	0%	0%	0%
Share of HP 2-Stroke engines in new LNG ships sold	25%	50%	100%	100%	100%	100%	100%
Share of LNG ships in the fleet	6.0%	9.4%	16.1%	25.0%	35.3%	42.3%	44.8%
Share of LP 4-Stroke in LNG fleet	79.0%	49.9%	29.2%	18.7%	13.1%	10.8%	10.0%
Share of LP 2-Stroke in LNG fleet	7.7%	29.5%	33.1%	21.3%	14.9%	12.3%	11.3%
Share of HP 2-Stroke in LNG fleet	13.3%	20.6%	37.7%	60.0%	72.0%	76.9%	78.7%

Table 3: Energy shares of LNG ships in the BaU scenario

[39] See Table 6.5. in Sphera 2021 study [36].

	2020	2025	2030	2035	2040	2045	2050
LNG market share	6.5%	72.0%	72.0%	72.0%	72.0%	72.0%	72.0%
Share of LP 4-Stroke in new LNG ships sold	5%	0%	0%	0%	0%	0%	0%
Share of LP 2-Stroke in new LNG ships sold	70%	50%	0%	0%	0%	0%	0%
Share of HP 2-Stroke in new LNG ships sold	25%	50%	100%	100%	100%	100%	100%
Share of LNG ships in the fleet	6.0%	10.7%	23.1%	39.6%	58.5%	71.5%	76.4%
Share of LP 4-Stroke in LNG fleet	79.0%	43.9%	20.5%	11.9%	7.9%	6.4%	5.9%
Share of LP 2-Stroke in LNG fleet	7.7%	32.8%	35.7%	20.8%	13.9%	11.2%	10.3%
Share of HP 2-Stroke in LNG fleet	13.3%	23.2%	43.8%	67.3%	78.2%	82.4%	83.8%

Table 4: Energy shares of LNG ships in the FuelEU proposal scenario

	Geographical scope	2020*	2025	2030	2035	2040
BaU scenario	Semi-full scope (50/50 of international voyages)	1.7	2.7	4.6	7.2	10.3
	Full scope	2.3	3.8	6.5	10.1	14.4
FuelEU proposal scenario	Semi-full scope (50/50 of international voyages)	1.7	3.1	6.6	11.4	17.0
	Full scope	2.3	4.3	9.3	15.9	23.8

Table 5: Volumes of LNG in the BaU and FuelEU proposal scenarios, in semi-full or full scope (Mt)

*For 2020 the estimation does not account for the decrease in maritime traffic due to the COVID pandemic, as T&E fleet turnover model was built before 2020 MRV data was available.

4.1.2. Fuel prices used for the analysis

We selected reference publications which provided estimation of fuel prices **for 2030**, as this was a key date in our analysis.

Fuel name	Range	fuel price (€/t)	Fuel price (€/GJ)	Source
Fuel Oil	**min**	478	11.7	CE DELFT (p68), range 15-17 USD/MMBtu
Fuel Oil	**max**	542	13.2	
bio-diesel	**min**	549	19.7	ICCT, HVO from waste vegetable oil, range 0.024-0.039 USD/MJ
bio-diesel	**max**	1190	32.0	
ammonia	**min**	501	26.9	Ash, N., Davies, A., & Newton, C. (2020). Renewable electricity requirements to decarbonise transport in Europe with electric vehicles, hydrogen and electrofuels
ammonia	**max**	1251	67.2	UMAS-LR, Techno-economic assessment of zero-carbon fuels. Upper bound 82$/GJ
LNG	**min**	420	8.5	CE DELFT (p70) 2030 range 11-12 USD/MMbtu
LNG	**max**	458	9.3	
Bio-LNG	**min**	1127	22.5	CE DELFT (p70) 2030 range 29-63 USD/MMbtu
Bio-LNG	**max**	2448	49.0	

Table 6: Fuel prices used in the analysis

Fuel prices were used in the analysis in combination with the fuel GHG intensity targets envisaged by the FuelEU Maritime proposal, as the basis for the projected EU shipping fuel mix (Section 1.2). The trajectory of mandated carbon intensity improvements until 2050 in percentage was translated in absolute terms (gCO_2e/MJ), as shown in . In the absence of a 2020 fuel GHG intensity baseline in the Regulation proposal, the baseline of 91.7 gCO_2e/MJ was calculated based on port of Rotterdam bunker sales in 2020[40], with the share of LNG corrected to 6% (as estimated from the 2020 MRV emissions report data[41]) at the expense of VLSFO .

[40] See figure 5 in T&E Briefing on the draft FuelEU Maritime report [1]
[41] [37]

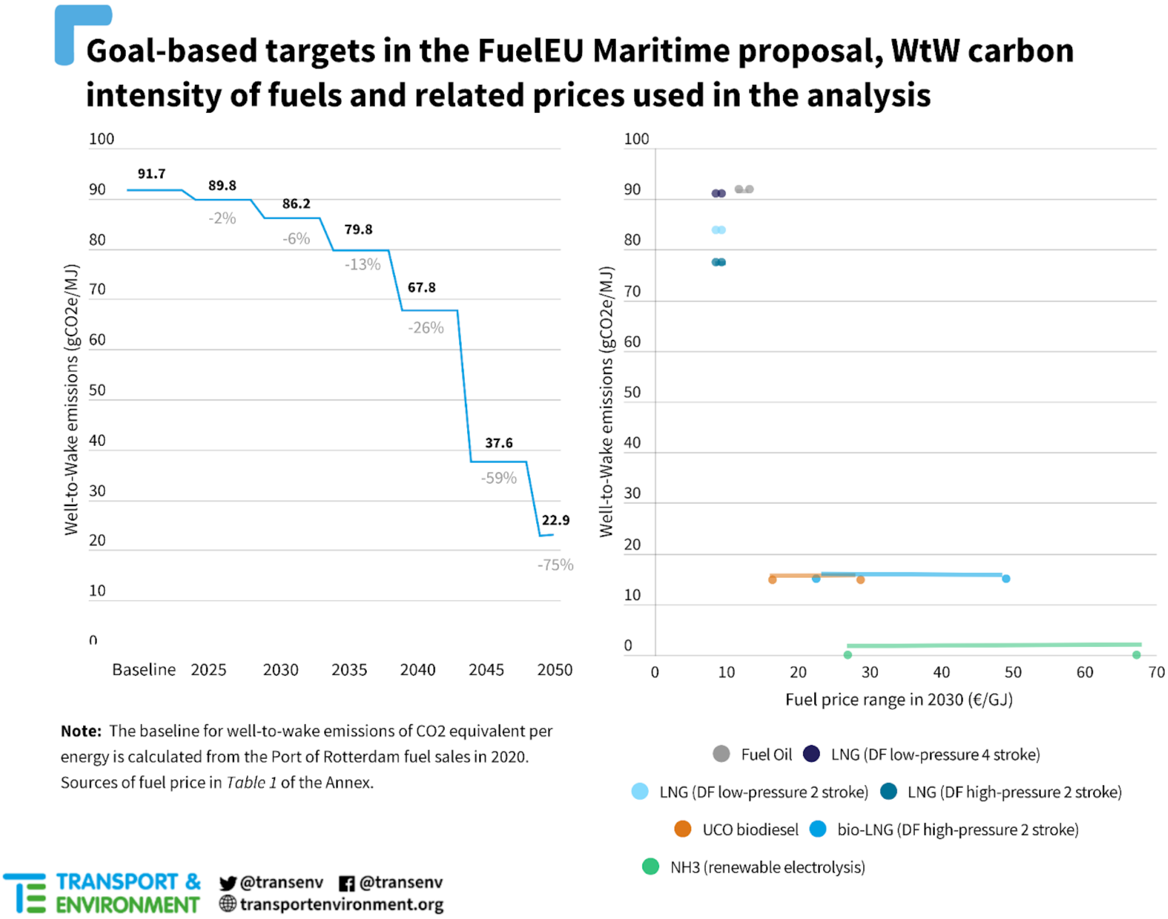

Figure 16: Goal-based target trajectory from 2025 to 2050 in FuelEU draft proposal (left); fuel carbon intensity of marine fuels with related price ranges (right)

4.2. Appendix B: Complementary findings

4.2.1. Recap graph: comparison of emissions between Commission proposal and T&E recommendations implemented

In we show the effect of T&E's recommendations on MRV fleet emissions and actual GHG intensity until 2034. As a reminder, these recommendations include advancing GHG intensity targets, an e-fuel subtarget (85PJ or 6% of fuel demand by 2030), exclusive pooling rights for e-fuels and a multiplier of 5 on e-fuels above the subtarget. We calculated that these recommendations would reduce EU shipping emissions by 10 $MtCO_2e$ in 2030 compared to business-as-usual, and 4 $MtCO_2e$ compared to the Commission's proposal. Most importantly, they would chart the path towards 2050 decarbonisation by fostering the development of e-fuels and limiting the attractiveness of unsustainable biofuels and fossil LNG.

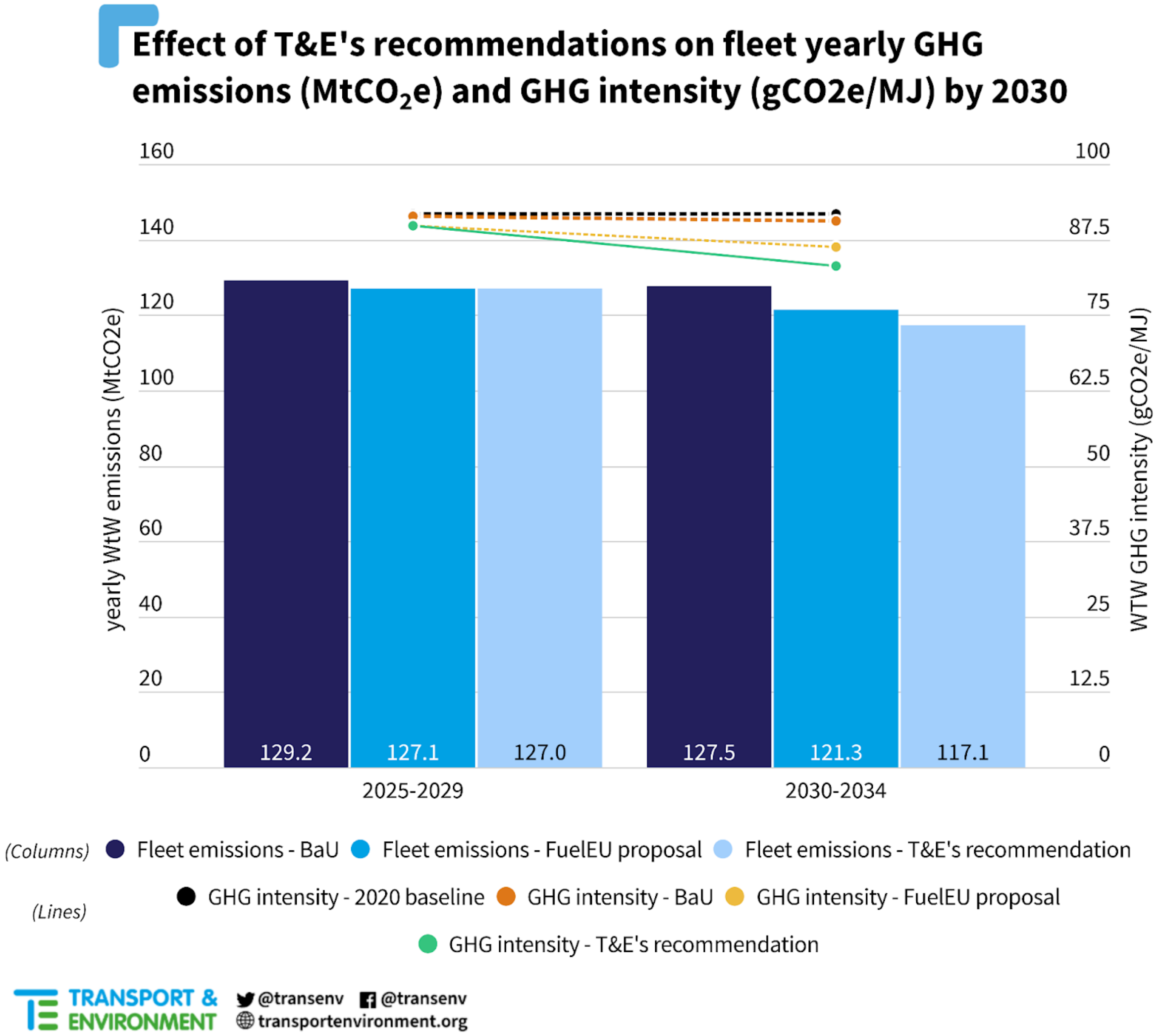

Figure 17: Effect of T&E's recommendations on fleet GHG emissions and GHG intensity

4.2.2. Closer look at errors and inconsistencies in the Commission's proposal and impact assessment

List of errors in FuelEU Annexes I and II

Annex I:

- C_{sf} values for CO_2, CH_4 and N_2O (i.e. emission factors by slipped fuel) are not defined. These values are needed to calculate accurate Tank-to-Wake GHG emissions of slipped fuel, as shown below. For CO_2 and N_2O, C_{sf} terms should either be removed or set to 0. For CH_4, C_{sf} is given in column 9 of Table 1 in Annex II of the proposal.

$C_{sf\,CO_2,j}, C_{sf\,CH_4,j}, C_{sf\,N_2O,j}$	TtW GHG emissions factors by slipped fuel towards combustion unit j [gGHG/gFuel]
$CO_{2eq,TtWslippage,j}$	TtW CO_2 equivalent emissions of slipped fuel i towards combustion unit j [gCO_2eq/gFuel] $CO_{2eq,TtW\,slippage,j} = \left(C_{sf\,CO_2,j} \times GWP_{CO_2} + C_{sf\,CH_4,j} \times GWP_{CH_4} + C_{sf\,N_2O,j} \times GWP_{N_2O}\right)_i$

Annex II:

- Bio-LNG is attributed the same C_f factor (TtW GHG emission factor by combusted fuel) as diesel for CH_4 and N_2O Tank-to-Wake emissions (respectively 0.00005 and 0.00018). However, as bio-LNG is used in LNG engines and not in diesel engines, these factors should be aligned with LNG (respectively 0 and 0.00011), as shown below:

Bio-LNG Main products / wastes / Feedstock mix	0,05	Ref. to Directive (EU) 2018/2001	LNG Otto (dual fuel medium speed)	2,755 MEPC245 (66), Regulation (EU) 2015/757	0,00005	0,00018	3,1
			LNG Otto (dual fuel slow speed)				1,7
			LNG Diesel (dual fuels)				0.2
			LBSI				N/A
LNG	0,0491	18,5	LNG Otto (dual fuel medium speed)	2,755 MEPC245 (66) Regulation (EU) 2015/757	0	0,00011	3,1
			LNG Otto (dual fuel slow speed)				1,7
			LNG Diesel (dual fuel slow speed)				0.2
			LBSI				N/A

- C_{slip} value for LNG, bio-LNG and e-LNG use in LBSI engines is missing (“N/A”). However existing literature indicates that methane slips also occur when using this type of engine. Based on the IMO’s 4th GHG Study data, LBSI methane slip can be estimated to 2,6%[42]. This value was used by default to calculate the WtW of LNG use in LBSI in this report (Fig. 8).

[42] See table 6, p.280 in IMO’s 4th GHG Study [35]

LNG	0,0491	18,5	LNG Otto (dual fuel medium speed)	2,755 MEPC245 (66) Regulation (EU) 2015/757	0	0,00011	3,1
			LNG Otto (dual fuel slow speed)				1,7
			LNG Diesel (dual fuel slow speed)				0.2
			LBSI				N/A

Annex V

- The compliance balance formula has the wrong unit, it should be expressed in gCO_{2eq} and not gCO_{2eq}/MJ;

Compliance balance [gCO_{2eq}/MJ] =	$(GHGIE_{target} - GHGIE_{actual})\ x\ [\sum_i^{n\ fuel} M_i \times LCV_i + \sum_i^{l} E_i\ ]$

- The compliance balance in the penalty formula has the wrong sign: it should be negative and not positive. Moreover the penalty formula is unclear on how the VLSFO conversion factor applies. We suggest replacing the formula with the following:

$$Penalty\ = (-\ compliance\ balance)\ /\ GHGIE_{actual}\ /\ (LCV_{VLSFO}\ *\ 1000)\ *\ 3000\ €/t$$

Where:

LCV_{VLSFO} = 41.0MJ/kg

Inconsistencies and gaps identified in the Commission's Impact Assessment (IA)

- Proposed targets in percentage reductions are based on a 2015 baseline of $87gCO_2e/MJ$ (p.40 of the IA), whereas article 4 mandates the targets compared to the 2020 baseline, which is not given. The availability of the baseline is however crucial to any analysis of the ambition of the targets and the effect on the uptake of alternative fuels. Hence, the T&E estimation of a 2020 baseline for the purpose of this study. The relatively higher baseline in 2020 (91.7gCO2eq/MJ) can be explained in part by the evolution of the shipping fuel mix following the entry into force in January 2020 of the IMO's global sulphur fuel standard, which led to a significant switch from heavy-fuel oil to lower-sulphur fuel oil; with VLSFO more GHG intensive than HFO due to further desulphurisation at refineries, the overall fuel GHG intensity of the fleet has risen.

- The IA says policy option 3 (i.e. goal-based target with a multiplier for e-fuels) is retained; but adjustment factors (a.k.a multipliers) proposed at p.124 have been omitted without any explanation from the text of the proposal.
- Fuel prices used by PRIMES and E3Modelling for the purpose of the impact assessment analysis (table 30) considerably differ from existing literature. In particular, the 2030 estimated price of fossil LNG in the Commission's IA is almost twice higher than CE DELFT's estimations, while the 2030 price of bio-LNG seems largely underestimated. As a result, there is only a small difference of price between fossil and bio-LNG in the Commission's estimation, switching from fossil to bio-LNG becomes very pricey for a ship operator, making biodiesel a potentially more attractive option. This has consequences on the modelling of alternative fuels uptake. The lack of transparency of the models used for the IA makes it difficult to understand how these prices are obtained.

Type of fuel	Fuel EU IA price 2030 (€/toe)	Price range 2030 used in T&E analysis (€/toe)	T&E sources (see appendix 4.2.)
Fuel oil	627	488 - 553	CE DELFT
Fossil LNG	608	358 - 390	CE DELFT
Bio-LNG	868	944 - 2050	CE DELFT
Biofuels	1301	687 - 1202	ICCT
E-ammonia	1467 (2050 - no estimation for 2030)	1128 - 2815	Ricardo and UMAS-LR

Table 6: Comparison between 2030 fuel prices used in Commission's IA and existing literature (€/toe)

- The Commission's impact assessment also concludes that in the long-term the majority of marine biofuels will be supplied by crop-based feedstock (table 5). This is contrary to the evolution of the biofuels economy towards waste-based feedstocks, and the very text of the proposal which excludes the use of food and feed-based biofuels at article 9.
- The Well-to-Wake GHG intensity value used in the IA for LNG, i.e. 75.1gCO_2/MJ (table 31), is inconsistent with the values obtained when using the formula and emission factors provided in Annexes I and II. Our calculated values range from 92.3 gCO_2e/MJ for LP 4-S engines to 76.3 for HP 2-S engines without pilot fuel, and from 92.2 to 77.6 gCO_2e/MJ with MGO as pilot fuel). This challenges the accuracy of results obtained in the IA.
- A bonus for the use of wind is proposed by the Commission in annex II of the Regulation. While it is commendable to encourage shipowners to install wind-assist technologies given their

potential to reduce GHG emissions from ships, no assessment has been performed of the effectiveness of such a tool.

In case substitute sources of energy are installed on board, a reward factor for substitute sources of energy can be applied. In case of wind power such reward factor is determined as follow:

Reward factor for substitute sources of energy- WIND (f_{wind})	$\frac{P_{Wind}}{P_{Tot}}$
0,99	0,1
0,97	0,2
0,95	$\geqslant$ 0,3

The ship GHG intensity index is then calculated by multiplying the result of Equation (1) by the reward factor.

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