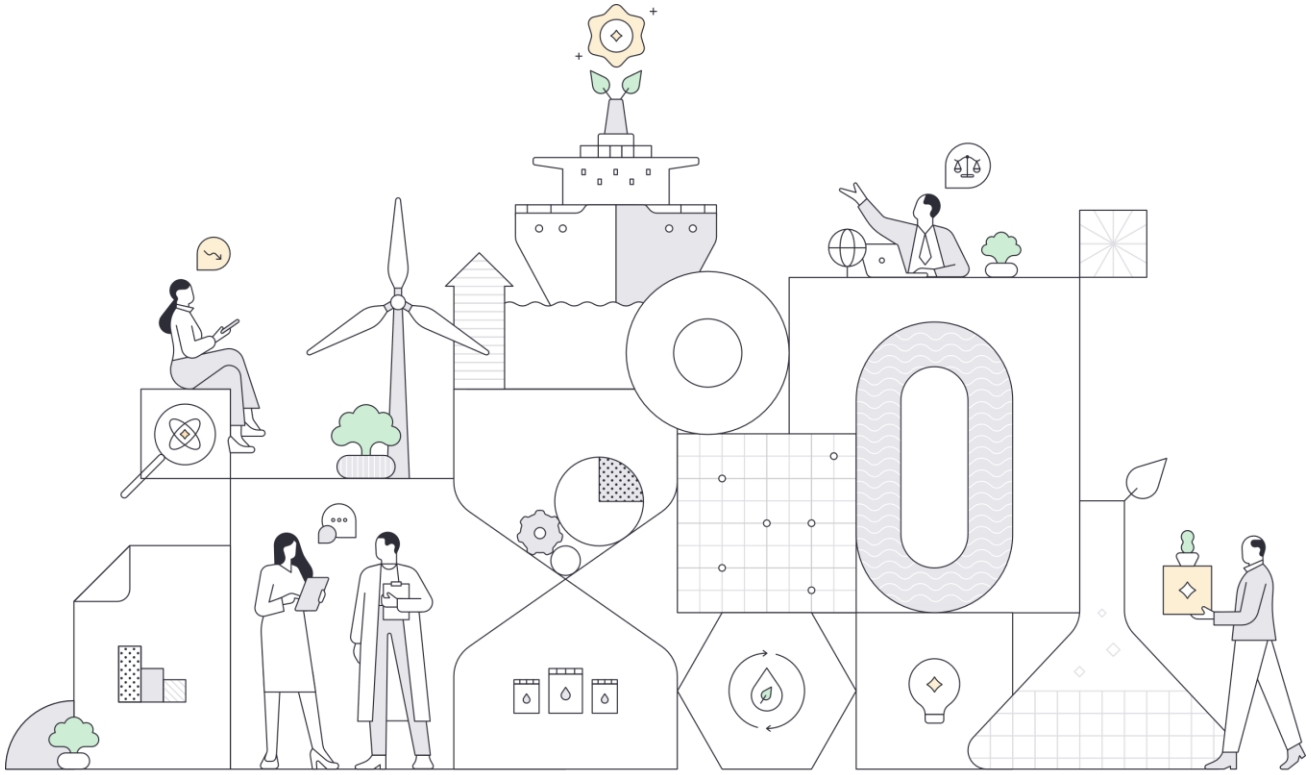
We show the world it is possible

What can the industry learn and adopt from regional regulations?

Deep-diving on two EU regulatory proposals for the maritime industry



Disclaimer:
Political agreement on changes to the EU Emissions Trading System (EU ETS) and the Social Climate Fund, including bringing shipping into the EU ETS was reached on 18 December 2022. The proposed legislation will now be submitted for formal approval. No legal text has yet been presented to the public.
All analysis in this report is based on previous proposals on the EU ETS. Updates may be required when details of the new proposal are published

Modelling methodology and data assumption

- This paper analyzes the impact of EU regulatory proposals – FuelEU Maritime and EU-ETS – on future fuel costs and emissions
  - The proposal suggests 100% coverage of CO_2 emissions coming from intra-EU trade and 50% coverage of CO_2 emissions coming from extra-EU trades. For simplicity, the main focus of this study is an analysis of the maximum possible impact from the proposal, assuming that all fuel usage is fully covered by the proposal such as the intra-EU trade setup
  - Basis the boundaries of regions, regulatory EU impact will have a weaker global effect if the rest of the world chooses not to follow the same proposal as the EU. A sensitivity analysis based on sailing patterns – where some emissions will be subject to EU regulations, and some will be not - has therefore also been included to the analysis
- For the analyses, the Center has considered five fuel groups: fossil fuels (LSFO and LNG), ammonia, methanol, methane and bio-oils
  - Each group in turn contains different types of fuels, distinguished depending on the feedstock and fuel production processes used
- All analysis is based on data and outlooks available from publicly available sources or provided as industry-specific input from our Partners and Mission Ambassadors[1]
  - The acquisition of new ships, capital expenditures and other operating costs are not included in the analysis. However, fuel represents ~20-35% of total annual costs for a shipowner, and is therefore an important component for a shipowner in defining the need for newbuilds or re-purposing of existing vessels to run on alternative fuels
  - Fuel costs are expressed as global levelized cost forecasts. Regional subsidized fuel costs are not included. The estimated costs of fuels are based on methods, data and assumptions of high quality but they are still uncertain
- Regulatory proposals reference scenario
  - EU-ETS: supply and demand of allowances will determine the price on the allowances traded. In this analysis we start by analyzing the effects of the 2021/2022 trading average of ~70USD/tCO_2, but alternative scenarios are considered
  - FuelEU Maritime: the regulatory proposal argue for using a reference value corresponding to the average GHG intensity in 2020. Calculations will be carried out at a later stage of the legislative procedure. In this analysis we use the Low-Sulfur Fuel Oil (LSFO) at ~ 96 gCO_2-eq/MJ as baseline, but alternative scenarios are also tested[2]
  - Discussions are currently underway as to whether shipowners or operators should bear the costs of the proposed regulation. However, our analysis is independent of such a decision as we focus the analysis on the regulations' direct mark-up on fuel costs (USD/GJ) across fuel types
- The Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping is an independent research organization whose mission is to decarbonize the maritime industry by 2050

1: At the Center, we take cross sectoral collaboration to the next level. Partners to the Center take an active role in identifying, demonstrating and maturing viable operational zero carbon solutions and their transition pathways. As of today, we are engaging with 23 Strategic Partners, 10 Knowledge Partners and 19 Mission Ambassadors
2: Default emission coefficients of EU regulation RED II have also been tested. Results do not alter any of the conclusions made in this analysis

Key takeaways

- Even the combined effect of ETS (at current levels) and FuelEU Maritime will not take us to full decarbonization by 2050, and the emissions reductions will be slow to kick in
- In their current wording the two initiatives could lock in LNG/Methane as the dominant fuel – which may become very expensive for the end-consumer in the long run
- Dual-fueled ships are attractive investment options already today as these ships can change fuel according to compliance levels needed, fuel availability and operating cost
- However, dual-fueled vessels may be encouraged to occasionally breach FuelEU and pay a penalty if always picking the cheapest fuel available. Many dual-fuel strategies that qualify from a compliance perspective also prove to be sub-optimal emission reduction strategies compared to what is technically possible
- An ETS well-to-wake approach could lead to significant additional emissions reductions by accelerating alternative fuel uptake
- Changing the baseline from LFSO to LNG will accelerate the emissions reductions significantly
- Alternatively, the intensity reduction targets can be brought forward or steepened

The world can learn and adopt from regional decarbonization proposals

A global carbon price can effectively reduce emissions...

- A carbon price is a proven economic instrument widely used
- There are two options to consider viz; Emissions Trading Scheme (ETS) and carbon levy
- Choice from the options depend on political, administrative and/or economic preferences
- The carbon price mechanism stimulates scaling up of new innovations by the polluter-pays principle, i.e., by bridging the cost gap between fuels by penalizing the ones causing most environmental damage

...however, implementing it in a short time frame is challenging!

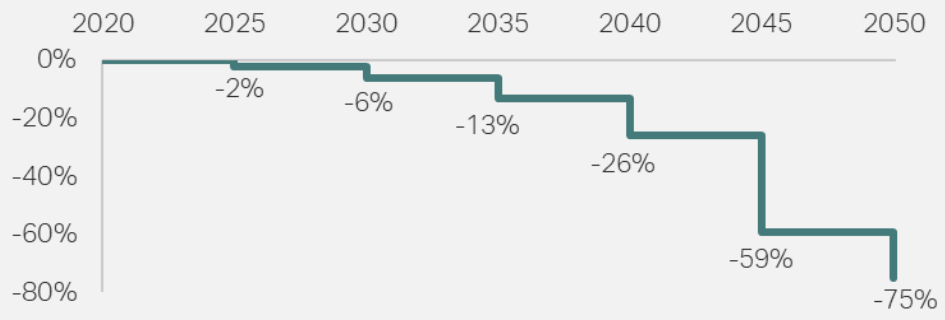
- Reaching a political consensus and global agreement on the needed carbon price tag or stringent cap on emissions is challenging
- Such negotiations are underway at IMO level, but no decisions have yet been taken
- Countries are unequally responsible for the climate crisis and have unequal possibilities to address it
  - While all countries have a common responsibility to reduce emissions, a global carbon price needs to carefully consider the circumstances of various countries by allowing for a just and equitable transition

Alternatively, the world can learn and adopt from regional proposals

- There is increased regulatory interest in finding regional solutions while awaiting a global one
- Regional carbon prices, performance and emissions standards are measures considered
- In July 2021, EU launched "Fit for 55", in reference to the 55% reduction target on CO_2 emission by 2030
- Many "Fit for 55" proposals affect shipping: a prime example is the draft measures to extend EU-ETS and reduce emissions from vessels
  - Fuel EU maritime: mandating emissions intensity of fuels
  - EU-ETS: a cap-and-trade system for maritime emissions in EU
- Further analysis on the proposals may act as blue-prints for other nations and regions to follow

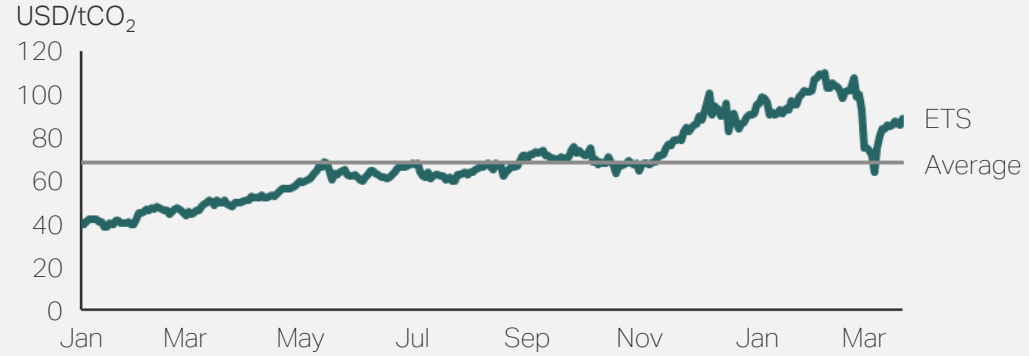
EU proposals are targeted to propel decarbonization efforts, but differ significantly in their emissions coverage

FuelEU Maritime - *sets emission intensity reduction targets*



- *General:* Mandates demand requirements for fuels with a decreasing GHG intensity content over time, grams of CO_2 equivalent per MJ
- *Emissions:* **WTW, GHG emissions** (recalculated to CO_2-equivalents)[1]
- *Scope:* All ships ≥5,000 GT visiting a port in EU and transporting cargo or passengers for commercial purposes. Capturing all intra-EU voyages emissions, and 50% of emissions from extra-EU voyages
- *Baseline:* Using a reference value corresponding to the 2020 average GHG intensity
- *Cost:* A "pay-to-comply" mechanism – set at 2,400 EUR/tHFOe (~800 USD/tCO_2)- can be paid when breaching the limit. Only the the part breached is subject to the penalty. This option gives firms the option not to comply with the GHG intensity targets against simple payment of a penalty

EU-ETS - *caps emissions and forms a tradeable market*

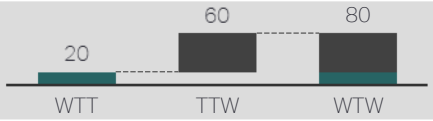
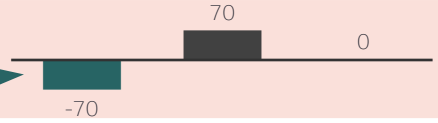
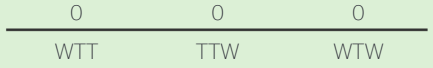


- *General:* Defines a maximum amount of allowable emissions. For each ton of CO_2 one emission allowance is issued, auctioned, and traded among the emitters on secondary markets during a trading period
- *Emissions:* **TTW, CO_2 emissions**[2]
- *Scope:* Same as FuelEU
- *Baseline:* Maritime emissions tradable allowances will be added to the EU-ETS trading scheme. All allowances are made available by auction with a scheduled linear reduction of ~4% tradeable allowances yearly
- *Cost:* Supply and demand of allowances will determine the trading price

1: WTW = well to wake. This approach includes emissions related to every stage, from its production until it is used to fuel a vessel
2: TTW = tank to wake. **This approach takes into account the emissions** that result from burning or using a fuel once it is already in the tank. Currently, ETS is proposed to only account for CO_2-emissions, not CO_2eq-emissions. In NavigaTE and in this analysis, only CO_2eq-emissions are considered.
Note: Discussions are currently underway as to whether shipowners or operators should bear the costs of the proposed regulation and if fleet pooling mechanisms should be allowed. Decisions on ownership will not affect the conclusions in this report as we focus on the bills' direct impact on fuel costs (USD/GJ) . The possibility of pooling, on the other hand, could influence decisions and optimization of each shipowner's individual fleet and is therefore assessed in this document.

EU-ETS and FuelEU Maritime have different baselines in terms of tracking emissions

Mapping the entire fuel value chain shows the difference in well-to-tank vs tank-to-wake

LNG	WTT: 20 $kgCO_2eq/GJ$ TTW: 60 $kgCO_2eq/GJ$	WTW: 80 $kgCO_2eq/GJ$	
e-Methanol	WTT: -70 $kgCO_2eq/GJ$ TTW: 70 $kgCO_2eq/GJ$	WTW: 0 $kgCO_2eq/GJ$	CO_2 captured and stored in the fuel[1] 
e-Ammonia	WTT: 0 $kgCO_2eq/GJ$ TTW: 0 $kgCO_2eq/GJ$	WTW: 0 $kgCO_2eq/GJ$	

1: CO_2 captured using biogenic CO_2 or direct air capture (DAC) 2: For simplicity, EU-ETS is modelled using CO_2-equivalents. If only considering CO_2 emissions, no incentives to bring down e.g., methane or nitrous oxide slips are present. In terms of emissions, methane is ~35 more potent than CO_2 on a 100-year timeline.
2: e-methanol has a negative CO_2 footprint when produced (-70 $kgCO_2eq/GJ$) while LNG is positive (20). An ETS system that does not compensate for this removal (either to fuel producers by compensation, or to fuel consumers by WTW calculations) erroneously encourages more production of fossil fuels

The baseline for emissions tracking differs greatly:

EU-ETS is proposed only to cover CO_2 emissions[2] on a tank-to-wake (TTW). To exemplify the impact of this, we zoom in on on three fuels in this example – a fossil LNG, electro-methanol and electro-ammonia with the following emissions intensities (emissions per energy):

- LNG: 60 $kgCO_2eq/GJ$
- e-Methanol: 70 $kgCO_2eq/GJ$
- e-Ammonia: 0 $kgCO_2eq/GJ$

On TTW basis, all types of ammonia, including versions produced from fossil feedstocks, will have 0 emissions. And an alternative fuel like e-methanol would be judged even higher emissions than LNG.

To fully incorporate all emissions from fuel production until it is used on a vessel, it is advised to construct an ETS system to cover a well-to-wake perspective or to include a credit scheme of CO_2 removals by compensating energy and fuel companies for the CO_2 they remove when producing the fuel.[2]

Opposed to the EU-ETS, FuelEU Maritime is proposed to cover all greenhouse gas (GHG) emissions such as carbon dioxide, methane, and nitrous oxide emissions on a well-to-wake (WTW) basis. Using this, the three fuels will have the following emissions intensity (emissions per energy):

- LNG: 80 $kgCO_2eq/GJ$
- e-Methanol: 0 $kgCO_2eq/GJ$
- e-Ammonia: 0 $kgCO_2eq/GJ$

Impact and regulatory scope will differ depending on the sailing routes chosen

Illustrative example

For ships, the cost of fuels will be dependent on their carbon emissions contents, as well as how much of their sailed distance will be subject to the proposed EU regulation

A shipowner or operator that sails only intra-EU (from an EU port to another EU port) will be the most affected by the proposal as both EU ETS and FuelEU will be added to 100% of the fuel consumed onboard

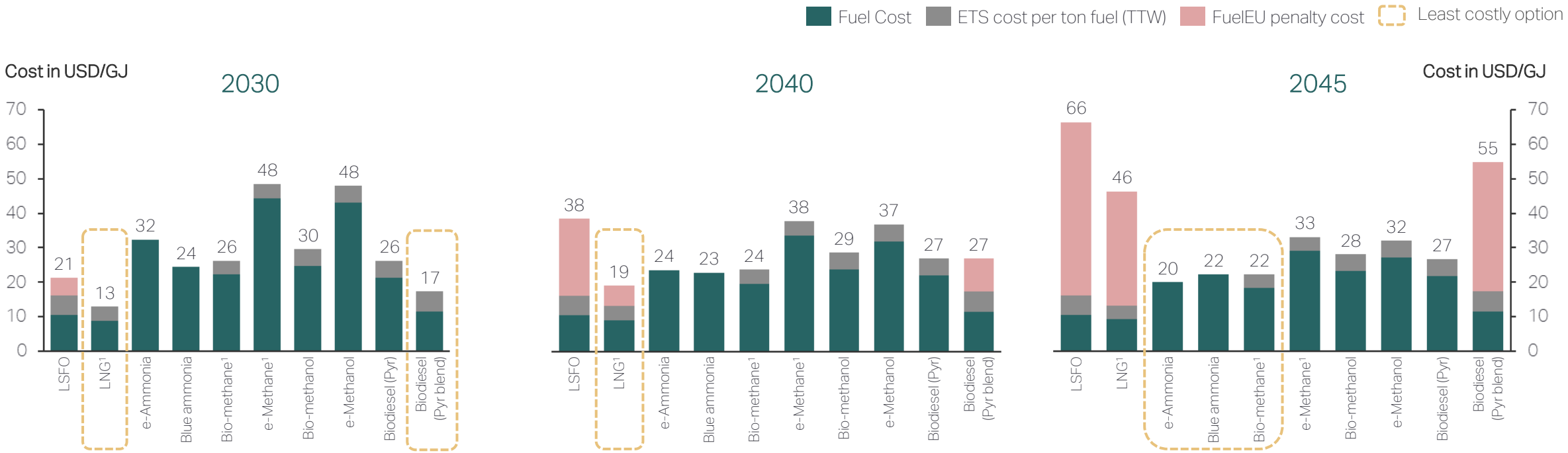
The more of the journey that takes place outside of EU borders, the lower becomes the regulatory impact on ship's average fuel costs. Current proposal suggests that 50% of the fuel consumption on extra-EU voyages (departing and incoming between an EU port and a port outside the EU) should be subject to EU regulation. Distances sailed outside of EU-regulated areas will thus be subject to other global/regional/national regulation

In the illustrative example a ship sailing from Tokyo in Japan to Rotterdam in Europe would be subject to EU regulation according to the following logic:

- Le Havre (EU) - Rotterdam (EU):100% of the fuel consumption will be subject to EU regulation
- Le Havre (EU) – Colombo (first leg and stop outside EU): 50% of the fuel consumption will be subject to EU regulation
- Colombo – Tokyo: no impact from EU regulation

If the ship instead schedules a port call to Agadir (Morocco) as first leg and stop outside EU, the 50% impact from EU regulation will be applied to the distance Agadir-Le Havre. A shorter fraction of the Tokyo-Rotterdam journey, including less fuel consumption, would then be in scope for the proposed EU regulation

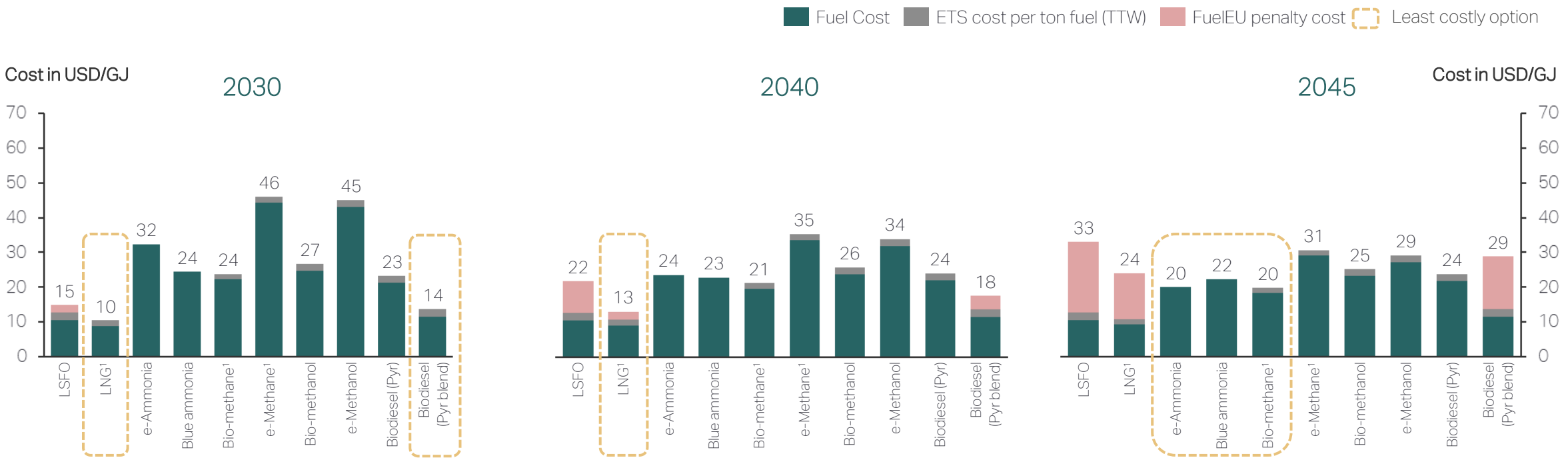
Assuming full regulatory impact, such as on intra-EU voyages, it is only in 2045 that alternative fuels emerge as competitive fuel options



- The proposed emission intensity reduction pathway results in only neglectable penalty cost on fossil fuels for many years
  - By 2030, the intensity reduction of -6% compared to today's baseline, will only impact low sulfur fuel oil (LSFO).
  - It takes until ~2045 until LNG will be affected by the emission intensity factor, but it depends on methane slip assumptions.[1]
- ETS will impact on all carbon containing fuels, including biofuels and some electro-fuels. However, as ETS only considers CO2 tank-to-wake (TTW) emissions the effect will not be big enough to allow this measure to effectively promote green fuels.[2]
- Combined regulations will not close the forecasted cost gap between carbon and alternative fuels until 2045

Note: fuel costs are expressed as global levelized cost forecasts. Regional subzidised fuel costs are not included.
1: The emission intensity of LNG is roughly 20% lower compared to LSFO but depends on methane slip, so an effect from FuelEU will only come when the emission intensity target is stricter than that. Methane slip between 0-5% can be seen depending on engine type. For this analysis, a methane slip of 4% is assumed initially in 2020 going towards 0% in 2050. When considering well-to-wake emissions, upstream methane slip is also included as part of well-to-tank emissions.
2: See page 8 for more information on the difference between TTW and WTW emissions on fuels.

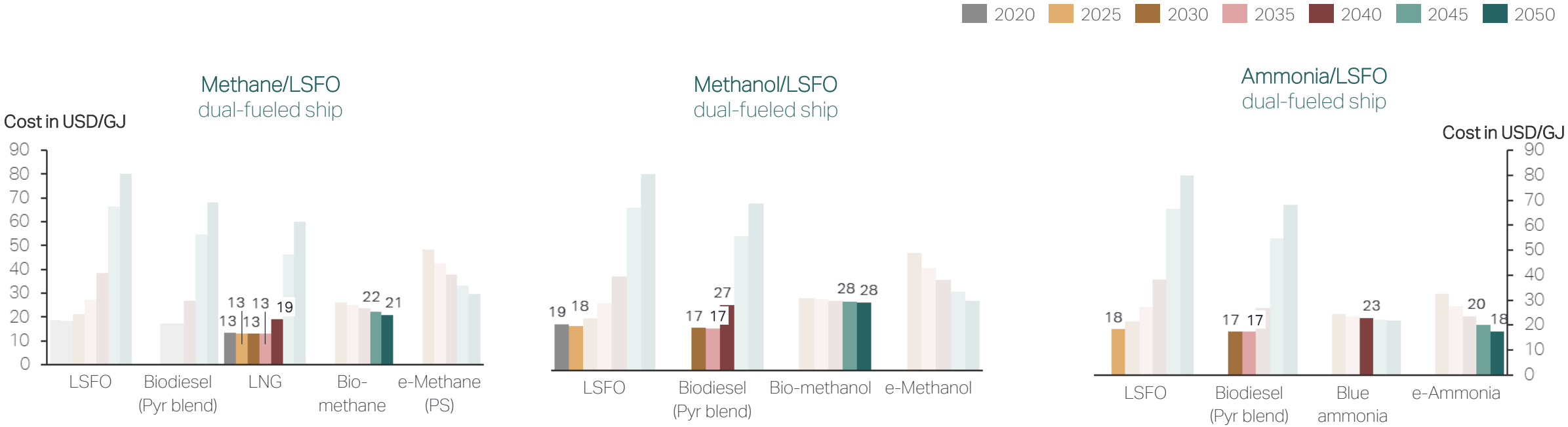
Effects are dampened and could risk delaying the transition if ships only are subject to ETS and FuelEU on part of their routes



- The current ETS and FuelEU applies to all of the energy used at EU ports, on voyages between EU ports, and 50% of the energy used on voyages between EU ports and third countries. In such a setup, the impact of EU ETS and FuelEU on average fuel costs will decrease the more of the distance sailed is extra-EU
- In the assessed example we calculate the regulatory impact based on a representative journey split between 30% intra-EU, 20% extra-EU and 50% is subject to no regulation.[1]
- Regulatory effects will be dampened on deep-water ships as these often only will be subject to ETS and FuelEU on part of their routes. However, even though effects are dampened, the conclusion holds that it takes until ~2045 until the costs of using fossil become big enough to trigger alternatives fuel usage.
- Subsequent analysis will focus on analysing the maximum cost and decarbonisation effects that can arise via ETS and FuelEU. This means that we make a simplification and assume that all fuels will be fully used and included with the current proposal as if they are intra-EU regulated

1: In this example we assume that journeys outside of EU (i.e. distances not labelled as intra-EU or extra-EU) are not subject to any other carbon pricing scheme. It should be noted that such an assumption can change and that additional costs could emerge other national/regional/global carbon pricing schemes also take effect.

Dual-fueled vessels could allow shipowners the flexibility to adopt alternative fuel options while remaining regulatory compliant



- Today's LNG vessels can also sail on other types of methane without any conversion costs
- The cheapest available operating option will be to switch to bio-methane when FuelEU and ETS effects on LNG becomes too large
- e-Methane remains too costly based on current fuel cost outlooks

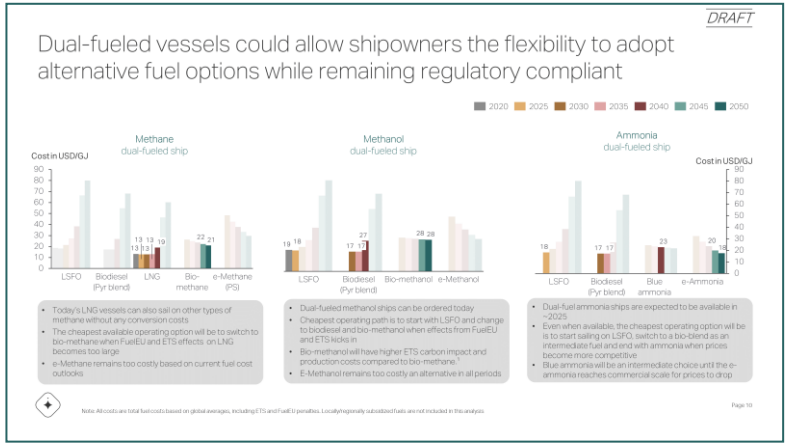
- Dual-fueled methanol ships can be ordered today
- Cheapest operating path is to start with LSFO and change to biodiesel and bio-methanol when effects from FuelEU and ETS kicks in
- Bio-methanol will have higher ETS carbon impact and production costs compared to bio-methane.[1]
- E-Methanol remains too costly an alternative in all periods

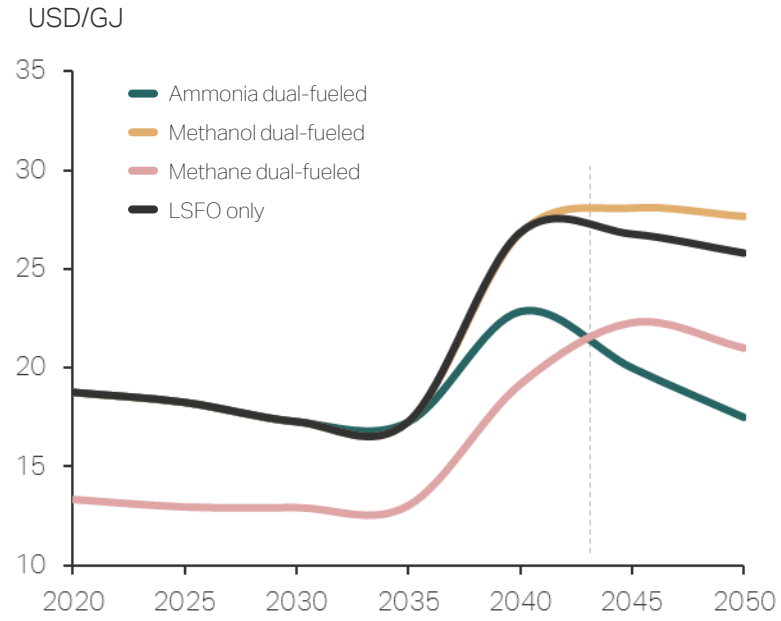
- Dual-fuel ammonia ships are expected to be available in ~2025-2030
- Even when available, the cheapest operating option will be is to start sailing on LSFO, switch to a bio-blend as an intermediate fuel and end with ammonia when prices become more competitive
- Blue ammonia will be an intermediate choice until the e-Ammonia reaches commercial scale and prices

Note: All costs are total fuel costs based on global averages, including ETS and FuelEU penalties. Locally/regionally subsidized fuels are not included in this analysis

Low fossil fuel cost projections make shipowners increasingly turn to LNG to curb air pollution…

Comparing the costs of the various dual-fuel pathways with a full fossil alternative





Current fuel cost projections point to dual-fuel LNG/Methane will be the least costly fuel option until ~2045, also when including ETS and FuelEU costs

Given the historically low and relatively stable price of LNG fuel, 2021 became a banner year for ordering dual-fuel LNG vessels. The commercial incentives for LNG as a future marine fuel also looks strong if turning to more recent industry data. About one third of the current orderbook of tonnage is set to use LNG and the infrastructure network is expanding to +200 operational LNG bunkering ports by 2024 (Clarksons, March 2022)

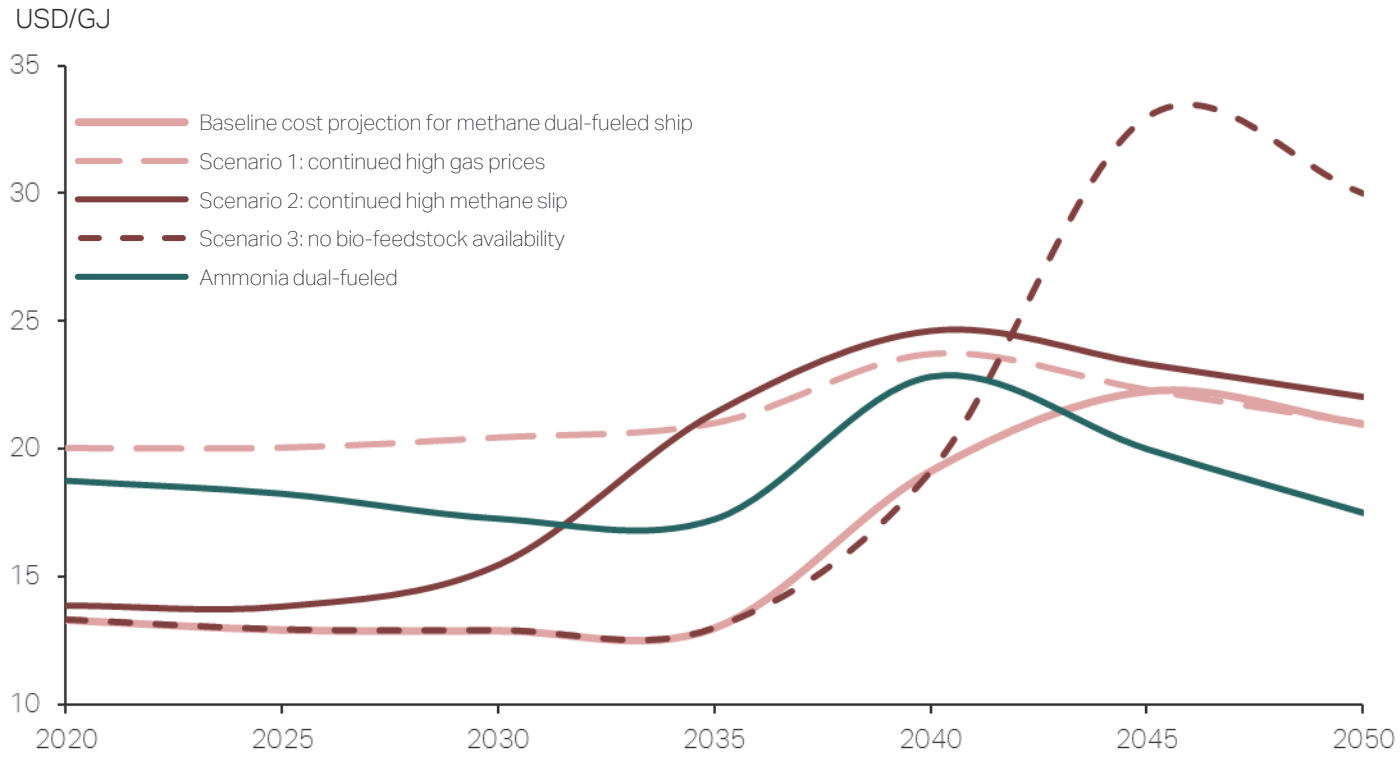
Data consequently tells us that while LNG is still categorically a fossil fuel failing to fully decarbonize the sector (also if later changed to bio-methane) many industry players may simply compare future fuel cost projections to the existing alternatives and chose the least costly, yet compliant, option[1]

The expected outcome from the current regulatory proposals illuminates the mismatch and misunderstanding that today exists between regulatory time horizons and time frames often used in corporate strategies and business models. For example, FuelEU seems to rely heavily on signal values for major future changes happening in 15-20 years from now. But for companies that think that even 10 years is a long planning horizon, such signals become toothless.[2] Basis the current proposals, it is only in ~2045 that alternative fuels emerge as competitive fuel options to LNG and/or bio-methane

1: The graphs do not consider any differences on the vessel side. For example, a methane vessel is more expensive than the other vessels to purchase, but that difference is not big enough to trump the large differences in fuel costs
2: Shipowners not only believe that today's high prices will come down but also see it as "the best return on investment over a conservative 10-year horizon" when comparing to other low-sulfur options like scrubbers (see maritime-executive.com).

...but lurking risks to cost forecasts may significantly alter any such business case

Cost effects of three key risk scenarios

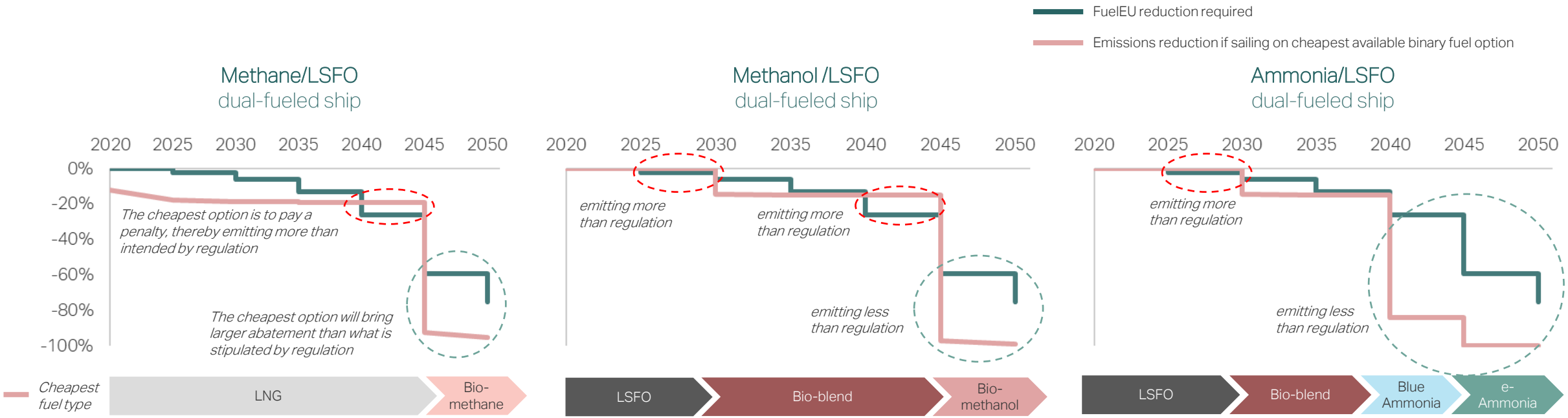


Note: This analysis only investigate the sensitivities for the methane/LNG-vessels. A similar sensitivity analysis can be done for the dual-fueled ammonia and methanol vessels.

But what at first glance may look like an optimal strategy based on future cost projections, could quickly turn into a suboptimal outcome because:

- *Today's high natural gas prices may stay at high levels:* natural gas prices as of April 20222 trade between 2-10 times higher than 2021 averages. In scenario 1, gas prices will not fall back to historic levels. The updated scenario is based on a global average forward curve three times higher than the forward curve used in the baseline scenario (2021)
- *Methane emissions may be a lot higher than projected:* Methane emissions from LNG-fuelled ships are not yet well documented and projects such as ICCT/FUMES have been launched to quantify total fugitive methane emissions onboard ships. Current forecasts rely on low slippage assumptions and any opposing evidence will FuelEU penalty effects and cost outlook. Scenario 2 assumes a constant methane slip of 4% instead of the initial assumed decline down to 0% by 2050
- *Scarce and uncertain availability of sustainable biomass required to produce bio-methane pushes prices upwards:* Cross sectoral competition for bio-methane may be high. Many hard-to-abate industries are set to compete for the same sustainable – and constrained - biomass resources. The more and faster shipowners and industries choosing the LNG/methane strategy, the quicker we run into a situation where demand outgrows supply, pushing prices upwards. Scenario 3, assumes no bio-feedstock availability for the maritime sector. Hence, only availability of LNG and e-Methane

Dual-fueled vessels may be encouraged to occasionally breach FuelEU and pay a penalty if always picking the cheapest fuel available



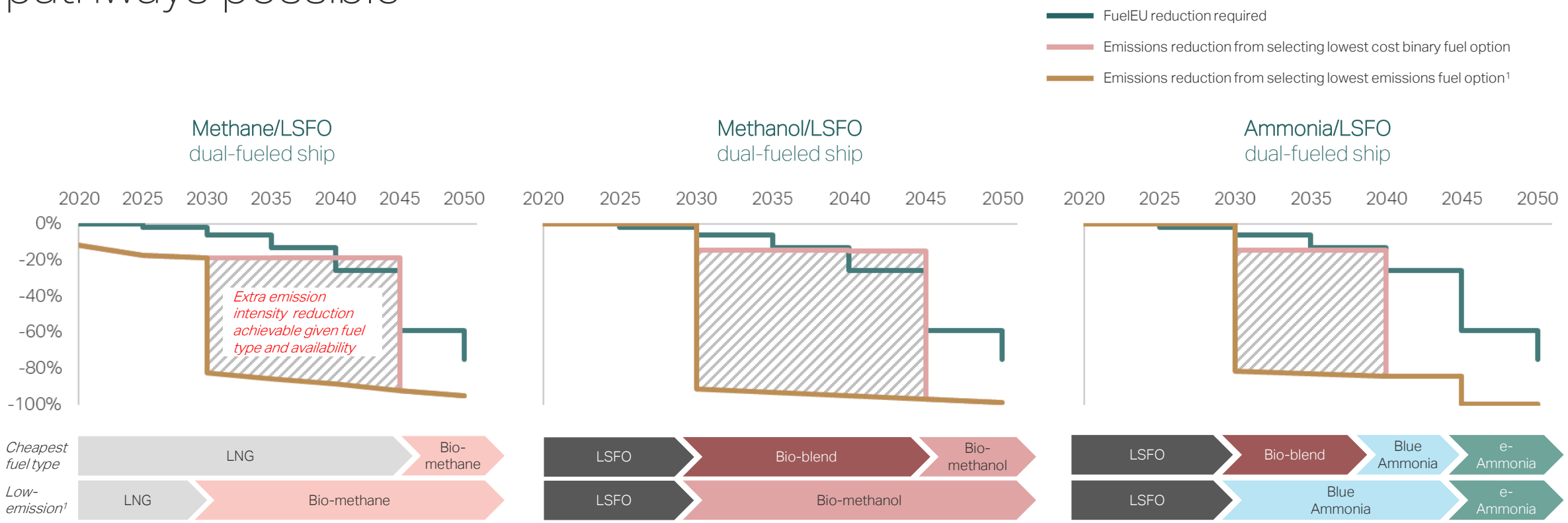
- Based on today's assumptions on methane slip, an LNG ship will be compliant with the FuelEU until the late 2030s
- In the in the early 2040s the least costly binary fuel option will be to use "pay-to-comply" principle on LNG rather than switching to a costlier (but less emitting) fuel option
- The choice of paying the penalty would result in an emissions breach compared to FuelEU

- The "pay-to-comply" possibility will be attractive dual-fueled methanol ships in two periods:
  - To continue to run on LSFO during this decade
  - To continue to run on biodiesel in the late 30s/early 40s, when the cost difference to bio-methanol is still too large even with ETS and FuelEU penalty effects included

- The dual-fuel ammonia pathway will be the strategy most compliant to emission intensity reduction targets
  - The least costly fuel option will be to use the "pay-to-comply" mechanism on LSFO during this decade
  - The least costly options will thereafter be to always sail on fuel options that conform or is below proposed emission intensity targets

Note: this analysis is a simplification where we analyse binary choices of fuels and where only one type of fuel is used at a time. This is to show that there may be financial incentives to break the existing legislative proposals as the penalty costs imposed on the fuel are not particularly high. A mix of fuels can possibly be emphasized as a more realistic operational choice. Analysis of such scenarios are included in Appendix A1 together with the conclusion that regulatory compliance will be attained together with operational cost savings, but that some (and sometimes even significant) emission reduction potential will then be missed

The cheapest compliant option is distant from the emissions reduction pathways possible

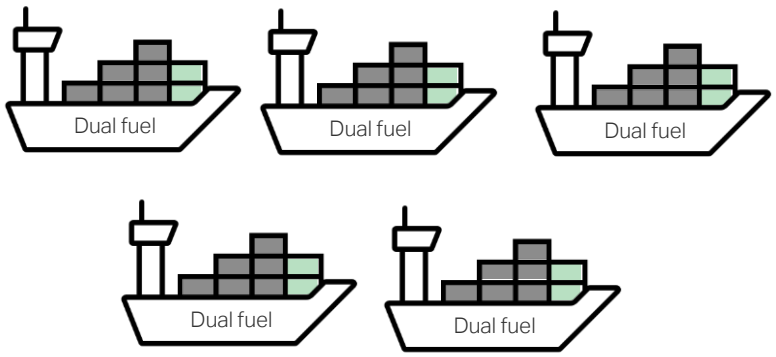


- If customers are willing to pay more for the alternative fuels available, much larger emission intensity reductions would be possible from all dual-fuel vessel
- Shipowners with clear abatement targets, and who also publish supplementary transparent emission reporting to allow for proper monitoring by e.g. customers and industry participants, will likely be more prone to switch early to alternative fuels
- But to change industry behavior, a further tightening of emission intensity targets is needed

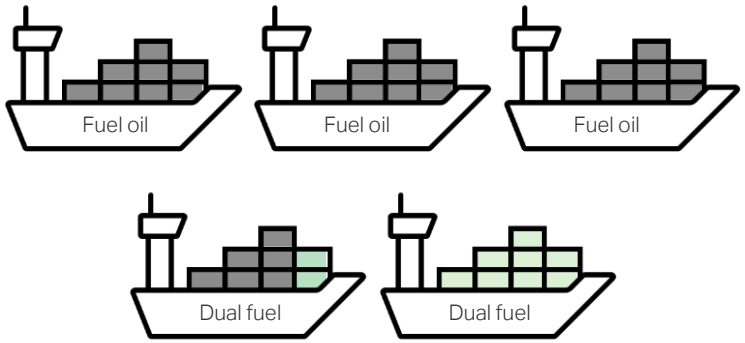
1: Achievable emissions reduction path = the most realistic path chosen if the operator decides not only to be cost driven but also by emission reduction possibilities. For the dual-fueled methanol ship, such a strategy would mean that the ship initially is sailed on LSFO, then switching to the more environmentally friendly bio-methanol even though it is a more expensive fuel type than the bio-blend option

Pooling may simplify the transition but should be limited in time

Option 1: Conforming with regulation on an individual ship basis



Option 2: Conforming with regulation by pooling



- Option 1 and option 2 show two alternative strategies where fleets' CO_2 emissions and emission intensity factor are equal (assuming they sail the same distance at the same speed)
- Pooling will facilitate swift regulatory compliance by allowing companies to keep large parts of their existing fleet unchanged and instead comply by retrofitting / replacing / extending fleets with the alternative vessels needed – making it an attractive short-term solution
- Pooling may also encourage long term usage of fossil fueled ships – highlighting the need to time-limit the option

Note: simplified illustration where the two options assume that ships are identical and sail the same distance

Pooling of ships may be allowed to fulfil the regulatory requirements. Such compliance may have varying societal impact and operational wiggle room opportunities.

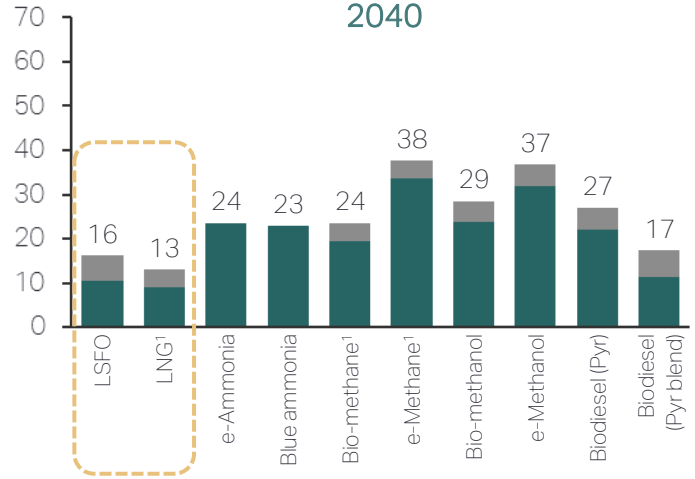
Comparing two strategies emitting the same number of emissions:

- Option 1: Compliance is needed to be attained for each vessel in isolation. Under this option, ships will quickly need to be retrofitted/replaced to be compliant and infrastructure development of alternative fuels needs to follow suit. However, basis the magnitude and life-cycle of fleet, such a proposal may not be feasible both in terms of costs, time and capacity
- Option 2: This provision allows for compliance with the intensity limit to be assessed for a group of vessels. As this would base compliance on the average vessel, it is argued by many to better incentivise investment by shipping companies in ships with the best available technology, putting more climate neutral ships on the seas. However, as owners/operators can stay compliant also with fossil fueled ships in their fleet beyond 2050, this may result in continued interest for fossil fuels (especially if the final target is set to 75% emission intensity reduction). A consequence may be that investments in alternative infrastructure are delayed

A pooling mechanism may accelerate the transition and could therefore be advisable to use for a limited period, preferably until this decade. If not limited in time, we risk still having a considerable share of fossil ships sailing our seas also in 2050

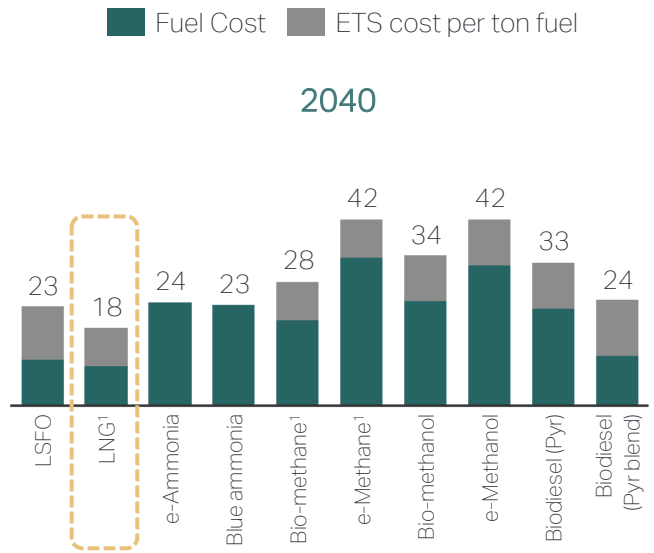
Altering ETS may not sufficiently trigger alternative fuel consumption

Base case
ETS is TTW, traded at 70USD/tCO_2



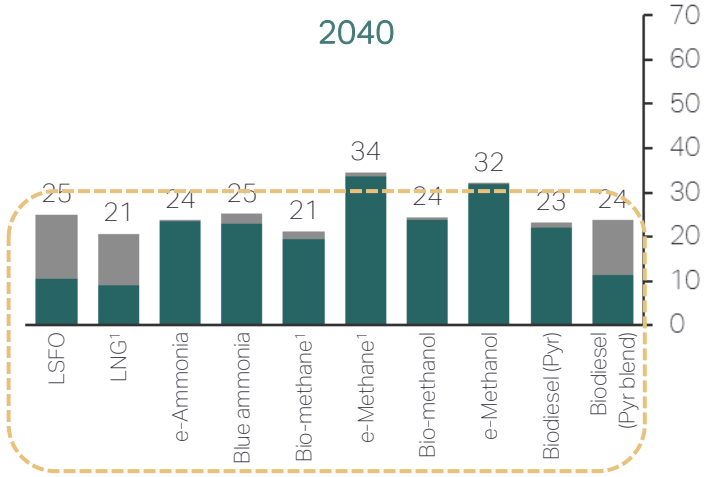
- EU-ETS carbon market incentivizes emission reductions via the polluter-pays principle. Emitters pay the costs they impose on others
- If ETSs will be traded at today's levels, those are not costly enough to cover the price difference to the fossil alternatives

Scenario 1: Increasing ETS costs
ETS is TTW, traded at 150USD/tCO_2



- Assuming that emission allowances would be traded at significantly higher prices (here modelled at 150 USD), it would still not be sufficient to fully close the cost gap on its own
- Supplementary "earmark and return" initiatives such as the proposed Innovation Funds and Carbon Contracts for Difference will thus be important features to the ETS to trigger additional emissions reductions[1]

Scenario 2: Emissions are WTW
ETS is WTW, traded at 150USD/tCO_2



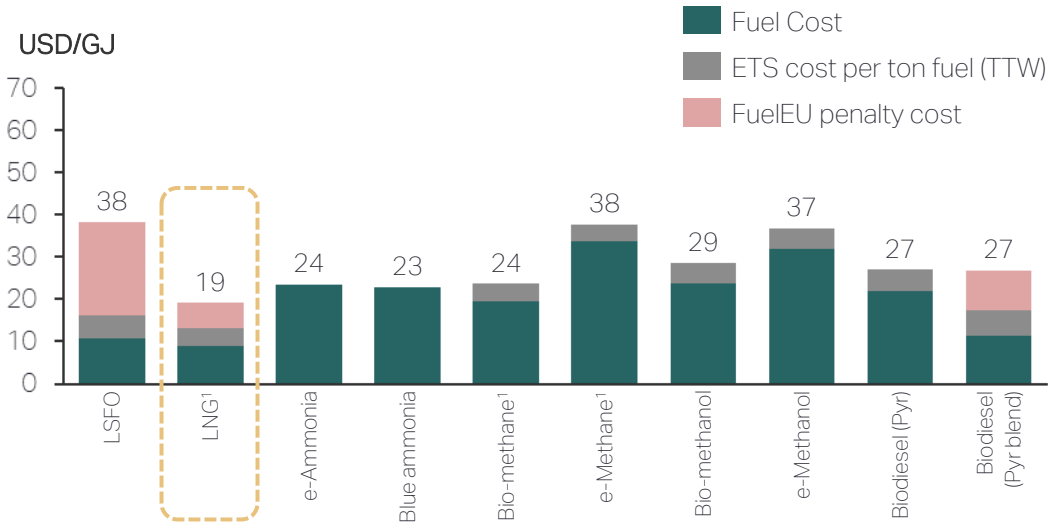
- The tank-to-wake emissions focus, penalizes carbon containing alternative fuels hard
- As these same alternative fuels have low emissions on a well-to-wake (WTW) perspective, the ETS effect will become very different
- Changing the scope to WTW would create a level playing field across fuels, making most of the fuels equally costly

Note: Fuel costs expressed as global levelized cost. Regional subzidised fuel costs are not included.
1: Innovation Funds and Carbon Contrancts for Difference are examples of initiatives under a "earmark and return" mechanism, as explained in ITS 2021 and referenced by the World bank's publication "Carbon Revenues from International Shipping: Enabling an Effective and Equitable Energy Transition"

An ambitious FuelEU baseline can push forward the change to alternative fuels

Base case: LSFO baseline

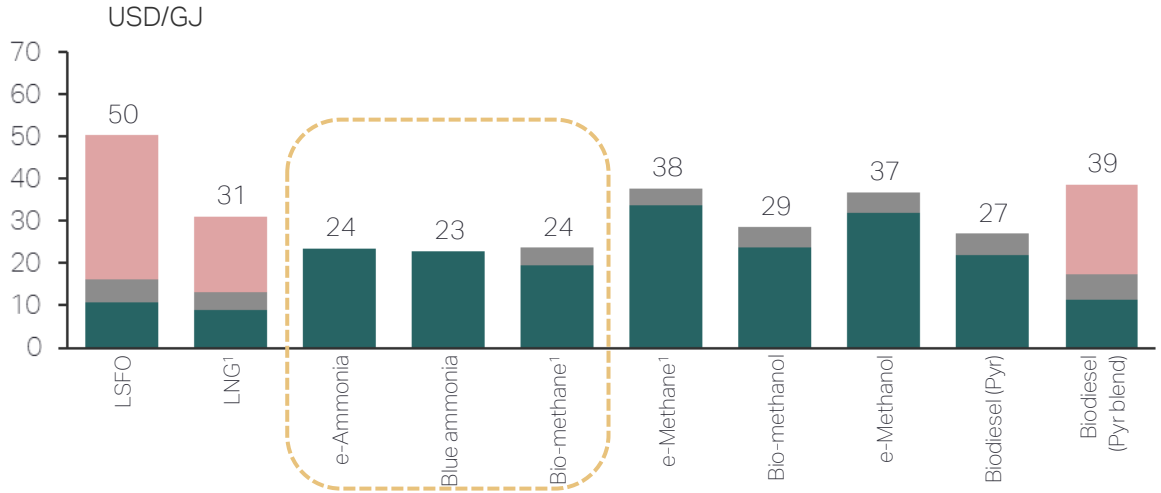
2040 cost outlook



- An LSFO baseline combined with a slow decline in the emission intensity during the first in 15 years may create a situation where continued investment in fossil fuels is encouraged, thereby postponing industry change until after 2040
- ETS trading schemes will not impose sufficient additional costs on the fossil fuels to compensate for the effect that FuelEU misses
- Large cost differences between fuels are expected to remain also when both regulations apply

Scenario: LNG baseline

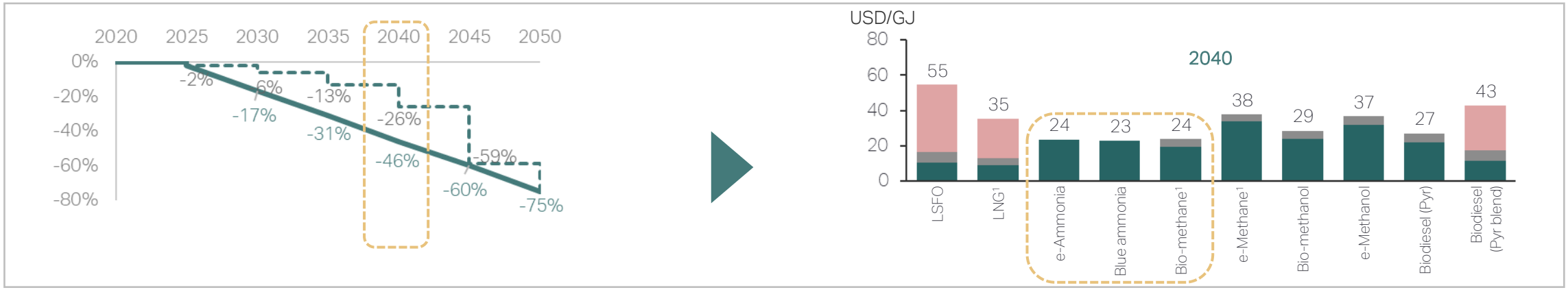
2040 cost outlook



- Changing baseline to LNG will push forward the competitiveness of alt. fuels by ~5 years
- Using a less emitting fuel as baseline may significantly change the speed of the transition, as well as the optimal fuel pathways:
  - Ammonia becomes the least costly option across all fuel types already by 2040
  - The switch to bio-methane will happen at approximately five years earlier than in the base case scenario, as LNG will no longer be the cheapest operational option

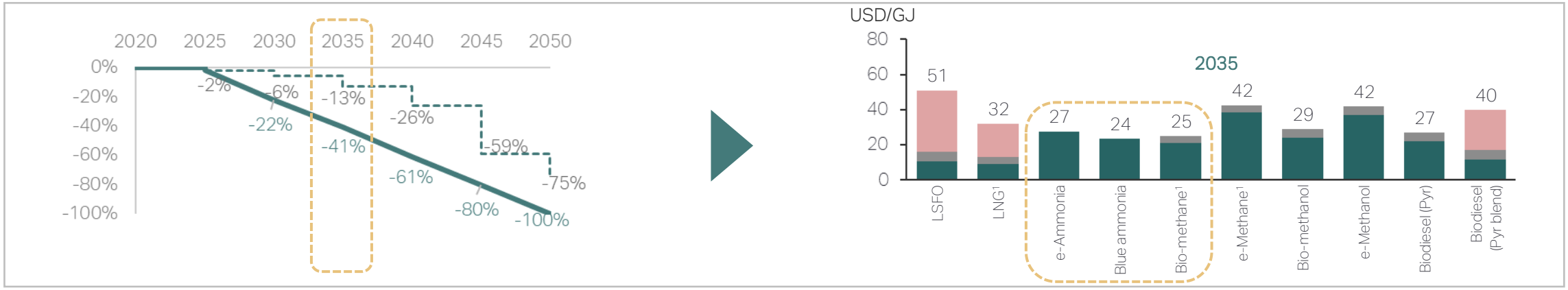
Replacing the staircase model to constant declines already from 2025 will speed up the transition

Introducing a linear decline to -75%...



...will give similar results as if changing the baseline

Steepening the slope to reach zero carbon (-100%)...



...will push forward the green transition by another 5 years

1. Conclusions: Analyzing EU regulatory proposals

2. Analyses: Fuel EU Maritime and EU-ETS proposals

3. Recommendations to realize zero carbon shipping

The current proposals could potentially be more ambitious to drive the effort towards zero carbon shipping by 2050

1. Benchmarking ETS to WTW emissions could avoid penalizing carbon-based alternative fuels

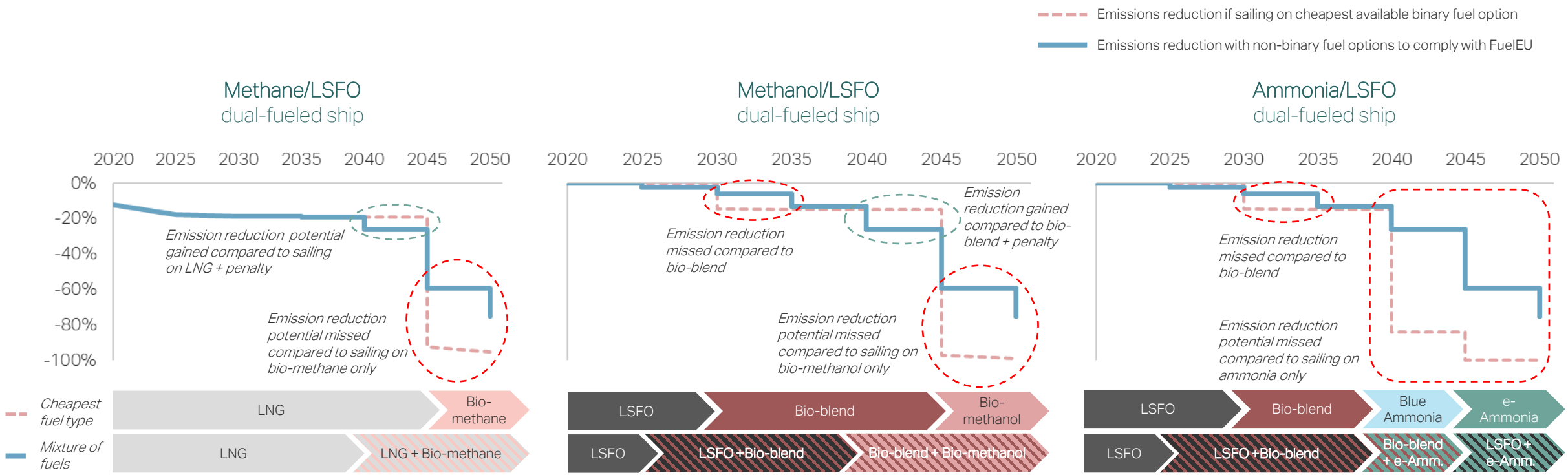
- Fuels' carbon contents differ greatly depending if we consider them as tank-to-wake (TTW) or well-to-wake (WTW)
- Some alternative fuels, such as biofuels and carbon containing electro-fuels have high tank-to-wake emissions and low well-to-wake emissions
- The current narrow scope on TTW and CO_2 emissions of ETS proposal will penalize such carbon containing fuels, even as their total emissions impact is much lower than any fossil alternative
- A change to WTW would change such disparity

2. Stricter mandates in FuelEU Maritime could prove more effective

- Stricter FuelEU Maritime mandates could enable the adoption of alternative fuels, thereby accelerating the transition
- Stricter mandates could be achieved by changing the curvature of the emissions intensity targets or by shifting the baseline from LSFO

Appendix

Sailing on a blend of fuels can provide both regulatory compliance and cost savings but some emission reduction potential is missed



- A ship operator on a dual fuel ship could save 5% in fuel costs until 2050 if choosing always to sail on a fuel mixture that contains exactly the part of (the more expensive) alternative fuel needed to comply with regulation and avoid paying penalty

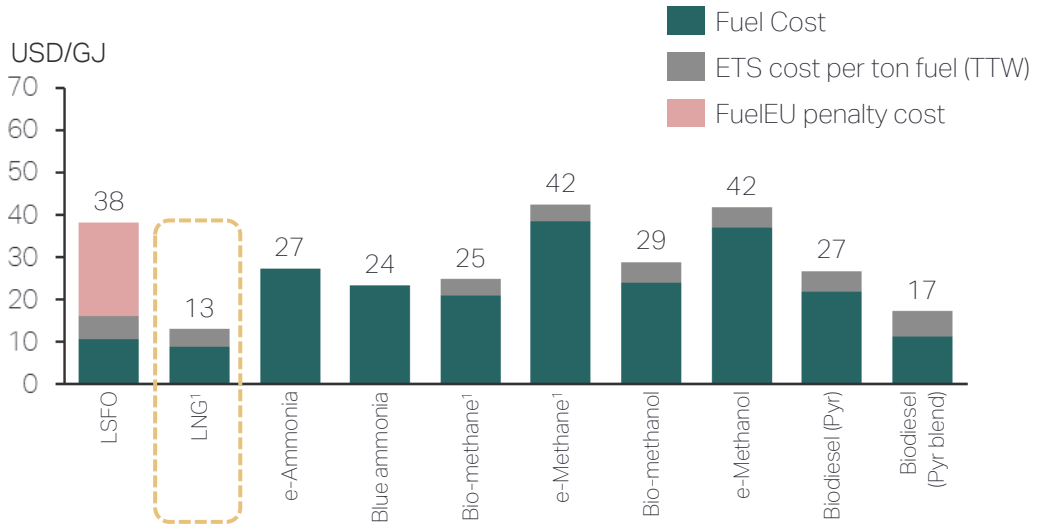
- Just like for methane, a dual-fueled methanol ship could save up to 10% in fuel costs until 2050 if using a mix of fuels needed to stay compliant
- Compared to the binary fuel option, such a strategy would miss a large possible abatement opportunity

- A dual-fueled ammonia ship could save up to 6% in fuel costs until 2050 if using a mix of fuels needed to stay compliant
- The cost savings would be in the range of methane and methanol, but the missed abatement opportunity would be significantly larger

Doubled FuelEU penalty costs may not lead to a faster transition

2035

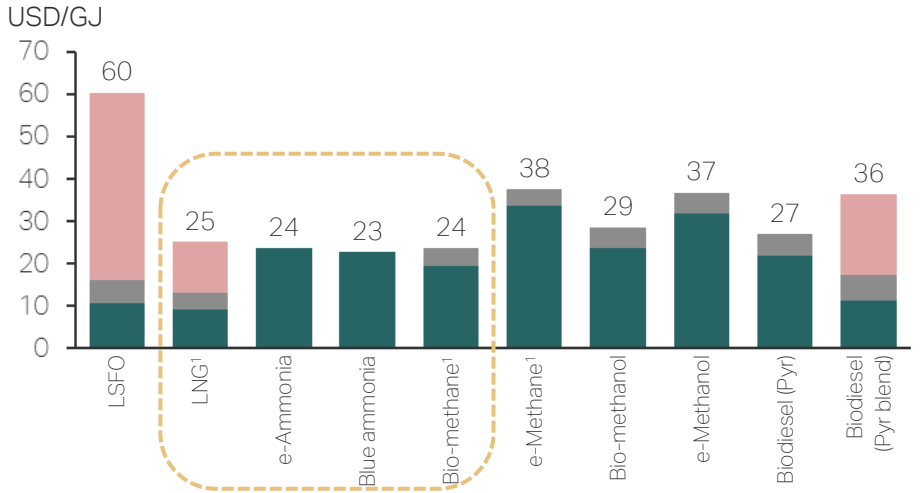
Doubling the penalty cost to 4800 USD/tHFOe (1600 USD/tCO_2)



- By 2035, the emission intensity of an LNG ship will be below the FuelEU target of -13%
- Hence, it is only ships running on LSFO that will be affected by a penalty cost increase

2040

Doubling the penalty cost to 4800 USD/tHFOe (1600 USD/tCO_2)



- By 2040, LNG will be a fuel affected by the FuelEU emission intensity target (-26%)
- However, the intensity difference is so small that even a doubled penalty level may not lead to an impact big enough to trigger behavioral changes and use of alternative fuel types
- A doubled penalty level would put this fossil fuel type at par with the cheapest alternative fuel options