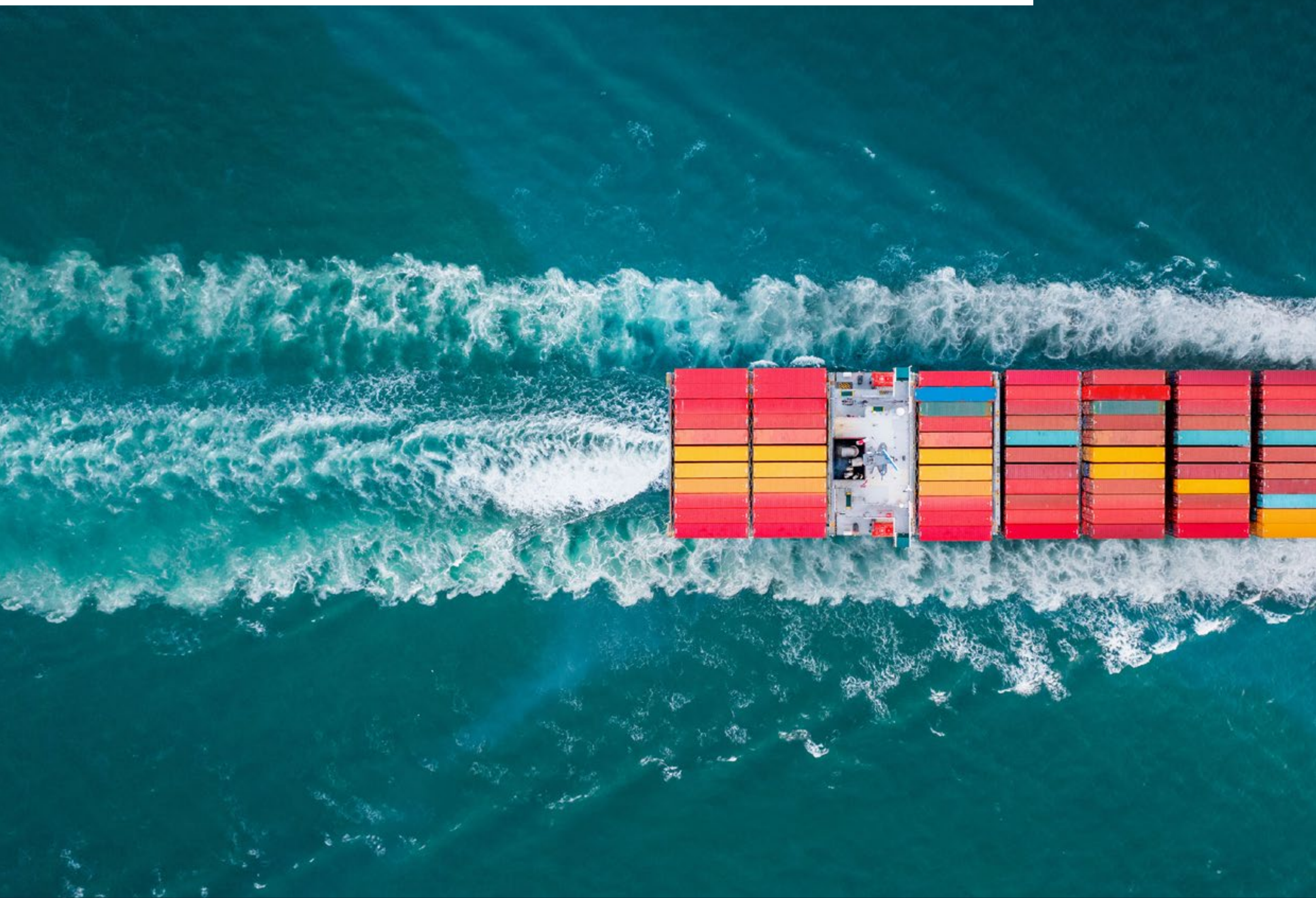
Evaluating Marine Fuels Based on a Well-to-Wake Approach for a Successful Transition to Net Zero

Life Cycle Assessment of eMethanol



Liquid Wind
eMPowering our Future

White Paper - Evaluating Marine Fuels

Well-to-Wake

White Paper

1 Introduction

Global regulatory control of atmospheric pollution from the maritime or shipping industry is becoming increasingly stringent, with further measures expected to be imposed in the coming years. In general, this paper welcomes the increased regulation of shipping emissions, particularly those relating to greenhouse gases, as part of efforts to mitigate the future effects of global climate change. However, we encourage shipping companies, policy makers and users of shipping and transportation services to use a 'well-to-wake' approach when evaluating emissions from the shipping industry. This means understanding emissions and other impacts associated with the production, storage and distribution of fuels, as well as emissions generated on board ocean-going vessels. Using a well-to-wake approach brings many benefits, but most importantly it ensures that the intended greenhouse gas reduction benefits from fuels are actually achieved. While greenhouse gas emissions are important and are currently the focus, further criteria should be investigated, e.g. as discussed by the Sustainable Shipping Initiative (SSI)[1].

2 Regulation Review: Current Regulation on GHG Emissions

2.1 Calculation, Developments and Outlook

Environmental regulations for the shipping industry address atmospheric pollution, water pollution and noise pollution, which are mainly regulated through the 6 Annexes of the MARPOL 73/78. The most notable atmospheric pollutants from shipping are currently sulphur dioxide (SOx), nitrogen oxide (NOx), particulates and carbon dioxide.

Pollution and emissions from shipping are regulated at various levels around the world. These range from domestic laws relevant to specific countries and their waters, regional regulations from bodies such as the European Union, and international regulations which are set by the International Maritime Organization (IMO) but regulated by national administrations.

Individual countries may choose to set their own emissions regulations for ships operating in their 'coastal' waters, typically defined as being within 12 nautical miles of their coast. Given the global nature of international shipping and of climate change itself, individual countries' regulations are not discussed in depth in this paper.

[1] https://www.sustainableshipping.org/wp-content/uploads/2021/09/Defining-sustainability-criteria-for-marine-fuels.pdf

At a regional level, groups of countries may collectively impose shared regulations on shipping emissions. Two examples of these are the four existing emissions control areas for sulphur dioxide emissions (the Baltic, the North Sea, North America, and the Caribbean), and the European Union (EU). In the case of the EU, there are no existing laws in place for greenhouse gas (GHG) emissions from shipping. However, under the EU's 'Fit for 55' package and the related FuelEU Maritime Initiative, the EU parliament has approved draft legislation which would include shipping emissions in the EUs emissions trading scheme (ETS) from 2023. This legislation, which was open for stakeholder feedback until 8th November 2021, will include all emissions from ships calling at an EU port for voyages within the EU, as well as 50% of the emissions from voyages starting or ending outside of the EU. As of yet, we are awaiting concrete feedback on any revisions to be implemented. Some studies estimate that it could cover around two thirds of maritime emissions globally[2]. The inclusion of shipping in the ETS is intended to bring the sector in line with the EU's wider ambition to reduce emissions by 55% by 2030 as compared to 1990 levels.

Internationally, the International Maritime Organization (IMO) is a specialised agency of the United Nations (UN) responsible for setting a global regulatory framework for shipping. As a UN agency, its emissions control activities are focused on the UN's sustainable development goals for 2030 goals and require negotiation with its 174 member nations in order to set regulations. The IMO's current GHG goal is to reduce carbon intensity, as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, as compared to 2008 levels.

In this global context, the EU and IMO's GHG regulations are two of the most internationally-relevant for shipping. They have the greatest potential for wide scale impact, and therefore form the main focus area of our discussion.

2.2 Current Reporting

As a general rule, robust GHG emissions regulatory frameworks will include the following elements:

- Monitoring, reporting and verifying emissions
- Target setting
- Incentive & compliance mechanisms
- Resourcing research and development into emissions reduction technologies

Presently, both the EU and IMO are focused on embedding the monitoring, reporting and verification processes. This means that when regulation comes into force, a clear baseline of emissions has been established, and robust systems for data collection are already in place.

Although it is yet to be confirmed, the EU is expected to assess emissions from shipping within the ETS on the basis of total quantity of fuel used by ship operators. In turn, the carbon intensity of fuel used is anticipated to be calculated in accordance with its revised Renewable Energy Directive (RED II). RED II provides a set of criteria for assessing the overall carbon intensity of various types of fuels, and sets thresholds of carbon emissions which fuels such as biofuels and alternative fuels must meet in order to be considered 'renewable'. For example, biofuels for transport must represent a minimum 65% reduction in GHG emissions versus fossil fuel equivalents in order to qualify. Renewable fuels of non-biological origin, such as renewable methanol, must meet a threshold of 70%.

[2] https://www.offshore-energy.biz/eu-revises-ets-to-include-shipping-sector/

The IMO's approach is different, calculating emissions on the basis of "carbon intensity". In this context, carbon intensity refers to CO_2 emissions per transport work, and therefore links carbon emissions to the amount of cargo transported and the distance sailed for a specific ship. In order to embed the practise of measuring carbon intensity, in 2021 the IMO adopted amendments to MARPOL Annex VI, introducing a requirement for all vessels over 5,000 gross tonnes to report an Energy Efficiency Existing Ship Index (EEXI) value and establish a carbon intensity indicator (CII) value by 1st November 2022.

In the context of measuring emissions in order to set targets, it is important to understand the full life cycle emissions of carbon dioxide, and other pollutants, when producing fuels, so that the overall goal of reducing total GHG emissions can be achieved without simply shifting emissions from one part of the fuel supply chain to another, and without creating other undesirable externalities. We discuss this topic in much greater depth in the remainder of this paper.

With the proposal of the FuelEU Maritime, the EU will assess fuels based on their lifetime carbon emissions, whereas the IMO currently only considers GHG emissions from shipping on an 'operational' basis. This means that for the IMO, carbon dioxide emissions are only assessed on the basis of what is emitted from combustion of fuel on board the ship, ignoring any carbon emissions or sequestration that has taken place in the production and transportation of the fuel itself.

2.3 Outlook

Global regulatory control of atmospheric pollution from the maritime sector is becoming increasingly stringent, with further evolution of the regulations in the coming years.

Historically, the regulatory landscape for pollution from shipping has moved slowly. The inclusion of emissions from shipping in the EU ETS has been discussed since before its inception in 2005. At the international level, IMO regulations to limit sulphur emissions from ships in 2020 took nearly 12 years to implement after a draft agreement was reached.

There are, however, several factors in place today which could support faster implementation of regulation. First, shipping now falls within the context of clearly defined wider policy targets, such as the EU's 'Fit for 55' and the IMO's SDGs and 2030 targets. Second, there is increasing global alignment in the acceptance of the science surrounding climate change forecasts as published by the IPCC and other independent organisations. Third, platforms for multilateral agreements such as the EU, the UN Framework Convention Climate Change Conferences (COP), and the IMO's MEPC are increasingly mature and propelled by greater public expectation for policymakers to find solutions. Fourth, technological solutions to reduce GHG emissions are constantly reaching greater levels of commercial and technical readiness. And lastly, there is growing understanding of some of the more complex aspects of assessing GHG emissions, including life cycle analysis and 'well to wake' emissions assessment.

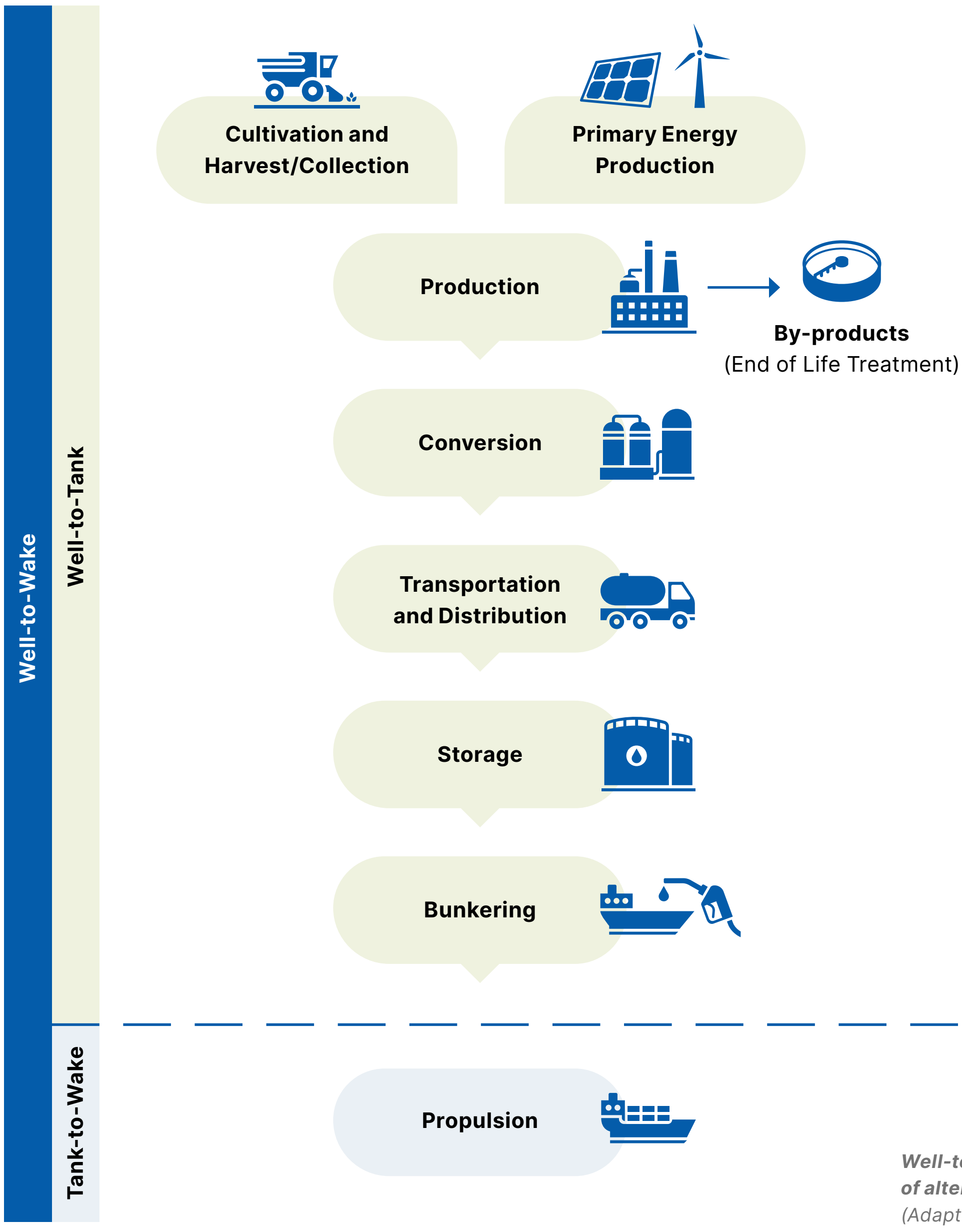
For example, the Methanol Institute put forward a position paper in October 2021[3] supporting the adoption of a well-to-wake approach in measuring emissions from maritime transport under FuelEU maritime. This is also supported through the criteria in the proposal by the SSI[4].

[3] https://www.methanol.org/wp-content/uploads/2021/10/FUELEU-MARITIME-ETS-PAPER.pdf
[4] https://www.sustainableshipping.org/wp-content/uploads/2021/09/Defining-sustainability-criteria-for-marine-fuels.pdf

3 Why Upstream (Well-to-Tank) Emission Matter in Assessing Marine Fuels

3.1 What is Well-to-Wake?

The performance of marine fuels can be calculated by accounting for all material and energy inputs and outputs in the production and supply chain. The fuel can be produced from multiple feedstocks which each present a different environmental profile. The following diagram gives an overview of how well-to-wake emissions analysis might be approached.



Well-to-Wake Lifecycle of alternative fuels
(Adapted from SSI)*

* https://www.sustainableshipping.org/wp-content/uploads/2021/09/Defining-sustainability-criteria-for-marine-fuels.pdf

3.2 Upstream Emissions and Considerations of Fossil Fuel Production

For marine fuel oils or natural gas based methanol, upstream emissions mainly occur during the extraction, processing, transportation and refining steps, which are energy intensive. For LNG, GHG emissions occur, similarly to marine oils, during the **extraction** and **processing** but also during the **energy intensive liquefication process** and **pressured storage**. These upstream emissions can vary depending on their gas sources.

The majority (~80%) of emissions by a fossil based marine fuel happen downstream, during the tank-to-wake phase when the fuel is used. This is because of the high carbon intensity of combustion of these fuels. Until now, for simplicity's sake these GHG emissions have not been included in their respective carbon intensity factor due to their relatively small upstream emission size.

With the introduction of alternative fuels and increased focus on GHG emissions, these upstream emissions have become a more important factor. Especially in the case of LNG, considered a cleaner alternative or a transition fuel by the EU taxonomy draft amendments, will be subjected to a well-to-wake scope. This avoids burden shifting to other countries, sectors or industries and achieves an accurate comparison to other alternative fuels and identifies holistic carbon reduction options. LCA enables the incentivisation of cleaner production efforts by fossil fuel producers. With a tank-to-wake approach, only fixed combustion emissions are considered, there is no room for differentiation through more sustainable or efficient practices in the upstream production.

Through the well-to-wake approach, fossil fuels will be able to benefit from those practices and ranges of emission intensities, which even for fossil fuels unlocks possibilities for product development. Another route to lower those emissions is the implementation of carbon capture and storage (CCS) in the production process.

3.3 Upstream Emissions and Considerations of Bio-based Fuel

Biofuels, such as bio-methanol, can be liquid or gaseous in form and are able to reduce emissions by 60-95%. As biogenic CO_2 combustion emissions are usually not considered or reported, biofuels are considered carbon neutral when applying a tank-to-wake approach. Considering the various pathways, feedstocks (e.g. 1st or 2nd generation), location and production facility, there can be significant differences in upstream emission and direct or indirect environmental impacts. A well-to-wake approach is able to capture these differences and incentivise sustainable biomass usage and production by including specific emission calculations. Differences may occur due to the usage of ILUC-risk[5] biomass, efficiencies of harvesting and processing or transport distances of the feedstock and the final biofuel. A well-to-wake approach enables the comparison of different biofuel pathways and supports the ability to make educated decisions on choosing a sustainable alternative.

[5] Indirect Land Use Change (ILUC): "High ILUC-risk fuels are fuels that are produced from food and feed crops that have a significant global expansion into land with high carbon stock such as forests, wetlands and peatlands. This expansion releases a considerable amount of GHG emissions and therefore negates emission savings from the use of biofuels instead of fossil fuels, which justifies their limitation to count towards the renewable energy target."

3.4 Upstream Emissions and Considerations of eFuels

Another green fuel production pathway is eFuels, under which eMethanol falls, which are hydrogen derivatives. Main feedstocks are electricity, water and captured carbon dioxide or nitrogen, if applicable. Therefore, the sustainability (including GHG emissions) of these fuels mainly depends on the source of the electricity and CO_2 for the carbon capture. Besides the importance of the source of feedstocks, the efficiency of the facility is a determining factor, meaning how well the sources are used and how much fuel can be produced per unit input. Lastly, the distance and means of transport impact the GHG reduction potential of the eFuels.

4 Case Study: Life Cycle Assessment of Liquid Wind's FlagshipONE eMethanol Production Facility

To meet the growing demand for carbon neutral fuel and the need to reduce CO_2 emissions, Liquid Wind is developing standard commercial-scale renewable eMethanol facilities. Each facility generates 50,000 tonnes of eMethanol annually, through upcycling 70,000 tonnes of biogenic CO_2. Liquid Wind's first facility, FlagshipONE will be built in the north of Sweden in the city of Örnsköldsvik, capturing CO_2 emissions from a biomass CHP that sources forest residues like bark and sawdust. Liquid Wind has gathered an expert consortium of industry players in their respective fields to efficiently establish eMethanol production facilities.

FlagshipONE is sourcing the electricity from renewable energy sources, like wind and solar. The carbon dioxide to be processed will be captured from biogenic point sources, such as biomass heat and power plants. To quantify the environmental benefit, Liquid Wind has performed an internal life-cycle analysis (LCA) to determine the life-cycle emissions of the eMethanol to be produced at FlagshipONE, considering all stages of the eMethanol life cycle and identifying the GHG reduction potential compared to conventional fuels.

FlagshipONE Visualisation

About LCA

LCA is a commonly used and accepted method to assess environmental impacts of products and processes. It is used by the scientific community and governmental stakeholders like the European Union, as noted in their own handbook on LCA in the European context. Due to its holistic view of a product's emissions, including all production steps, burden-shifting can be avoided, which makes it a valuable tool to evaluate alternative fuels on a well-to-wake basis.

4.1 Methodology and Assumptions

Liquid Wind has used Material Energy Flow Analysis (MEFA) to determine the carbon inventory of its production process, compliant with ISO 14041 and 14044 for LCA. The MEFA has a modular approach, which handles the complexity of the system by carrying out an input-output analysis for each production step, which are investigated individually. All direct and indirect material or energy flows for each module are captured and include the scope 1 and 2 emissions. This is handled the following way:

1. Flows of energy and material in and out of every module are analyzed and researched.
2. These flows are subjected to LCA analysis to determine their impact on the environment.
3. The research is integrated, resulting in a module where all the flows of energy and material in and out are defined, along with their environmental impacts.

This approach keeps the model **understandable**, **transparent** and **manageable**.

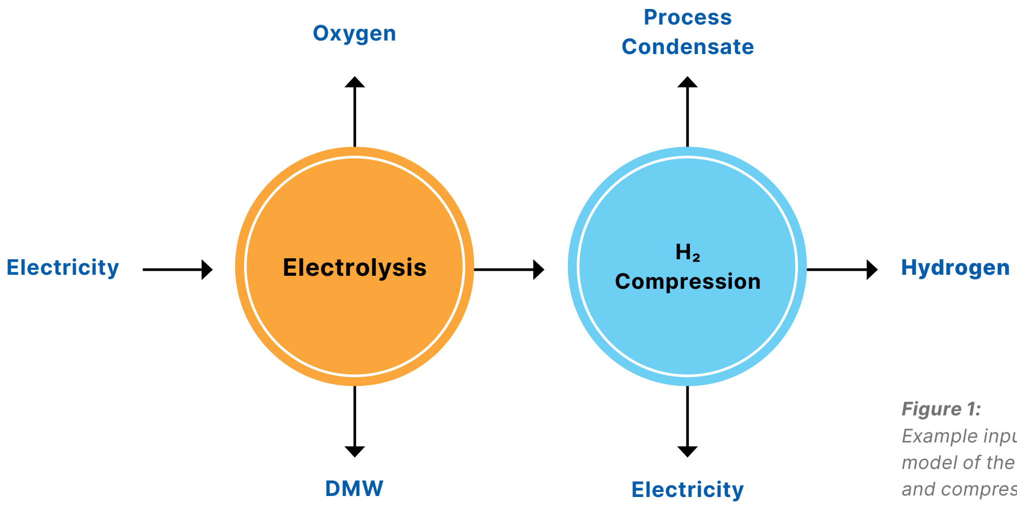


Figure 1:
Example input-output model of the electrolysis and compression process

Assumptions

For the basis of the evaluation, the following high-level assumptions were made:

- 100% wind-based electricity with a carbon intensity of 6.5 gCO_2eq/kwh.
- Steam production (100% biomass CHP based).
- Negative carbon credit for capturing of CO_2 (captured carbon results in negative emissions, compensating eMethanol emissions during combustion).
- Oxygen production is treated as a waste product (no emissions of the electrolysis process are assigned towards an oxygen product and therefore fully towards the eMethanol product).
- Heat recovered in the process and fed into the district heating network is credited with negative emissions due to an avoided burden, as the heat would have been otherwise produced by the biomass CHP.
- Embodied emissions of technology and construction are negligible (Typically not accounted for in comparable studies, due to a negligible contribution to life cycle emissions of fuel production facilities).

4.2 Greenhouse Gas Emissions Along the Production Pathway

On the one hand, a well-to-wake approach avoids burden shifting and includes upstream emissions that are otherwise ignored in decision making. On the other hand, it enables the integration of new necessary alternatives like eMethanol to reach maritime carbon emissions targets, as it includes the positive impacts of capturing carbon and using renewable electricity to produce these novel fuels. It also facilitates the comparison of different new alternative fuels. Figure 2 transparently shows the emissions during the lifecycle of the eMethanol production by Liquid Wind's FlagshipONE facility. For simplicity, the eMethanol production has been summarized as one module.

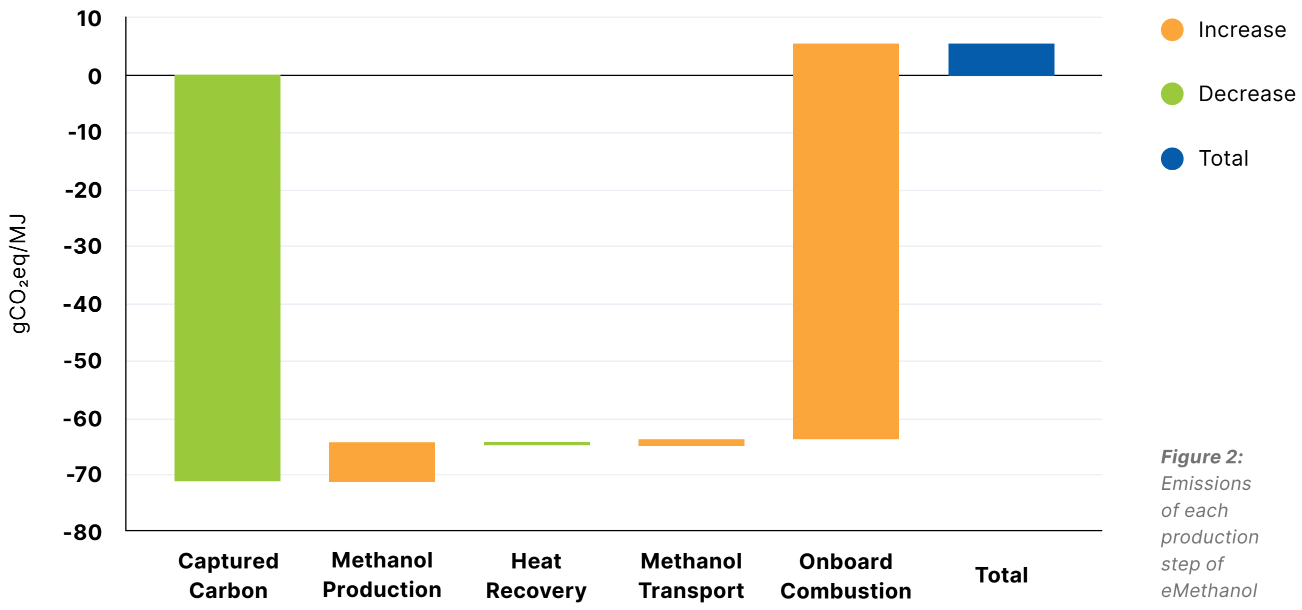


Figure 2: Emissions of each production step of eMethanol

The waterfall diagram shows how the captured carbon almost completely offsets the emissions that occur during the production, transport and onboard combustion, leaving only around 5 gCO_2eq/MJ fuel. The main contributor is the carbon intensity of the electricity source, which is in this case additional[6] wind power. Therefore, Liquid Wind is not relying on grid power, which can have a range of carbon intensity from country to country. With FlagshipONE's prime location in north Sweden, which has a very high renewable energy penetration and one of the lowest grid carbon intensities of Europe, life-cycle emission would still be sufficiently low if its production were to fall back on average grid electricity. As all hydrogen-derived fuels depend on electricity, which is the main contributor to their GHG emissions, other synthetic fuels will have similar carbon footprints when the electricity is based on wind-energy.

4.3 LCA Results as a Methanol Product and Use as Marine Fuel

The well-to-gate emissions of FlagshipONE eMethanol, meaning the life-cycle emission when leaving the eMethanol production facility, is around -1.3 kg CO_2eq per kg of eMethanol produced. About -1.4kg of CO_2 is from capturing the carbon and is credited as negative emissions. The emissions during the methanol production are relatively small, leaving the previously mentioned total negative emissions of about -1.3 $kgCO_2eq$ (see figure 3). eMethanol acts as a carbon sink until combusted, at which point the previously captured CO_2 is re-emitted to the atmosphere. Alternatively, it can be used as a clean alternative in the chemical sector or other sectors.

eMethanol Product:
$kgCO_2eq/kg$ methanol

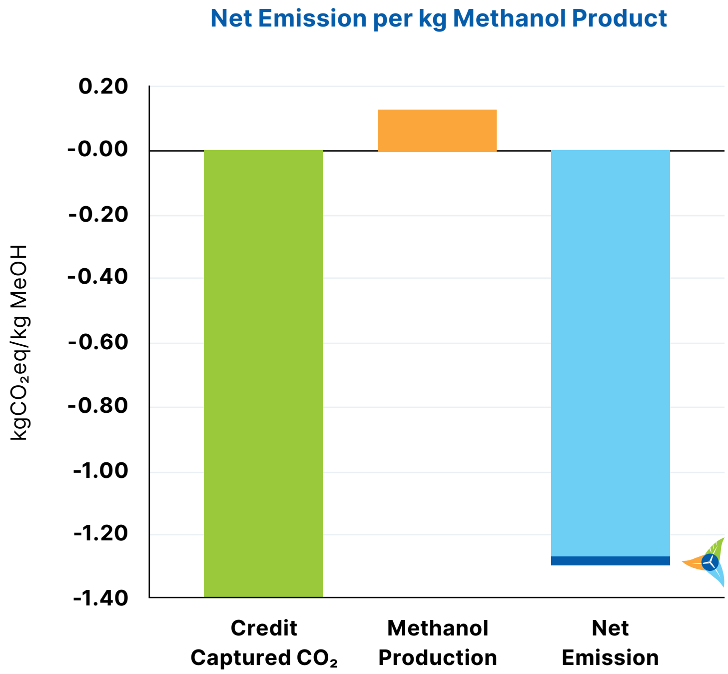


Figure 3: Well-to-Gate/Tank Analysis of eMethanol Produced by FlagshipONE

[6] Additionality in this context means that Liquid Wind is contracting electricity from a wind farm with a commissioning date close to the commissioning date of FlagshipONE for its whole energy demand and therefore is adding to the deployment of renewable energy.

When the scope is expanded to include the "use phase", well-to-wake, the emissions of transport and combustion are considered. The captured CO_2 is re-emitted, which results in a net positive climate change potential of about 5 gCO_2eq/MJ. Considering the life cycle emissions, fossil-based fuels emit around 85-90 gCO_2eq/MJ, which results in a reduction of about 94% when replaced with **wind-based** eMethanol. In figure 4, the well-to-wake emissions of eMethanol are compared to further marine fuel alternatives based on data provided in (Brynolf, 2014)[7]. In reality different fuels, depending on their production process, will have different ranges in carbon intensity. It is not surprising that fuel producers are working on lowering their respective fuel carbon footprint, as a result of this recognition.

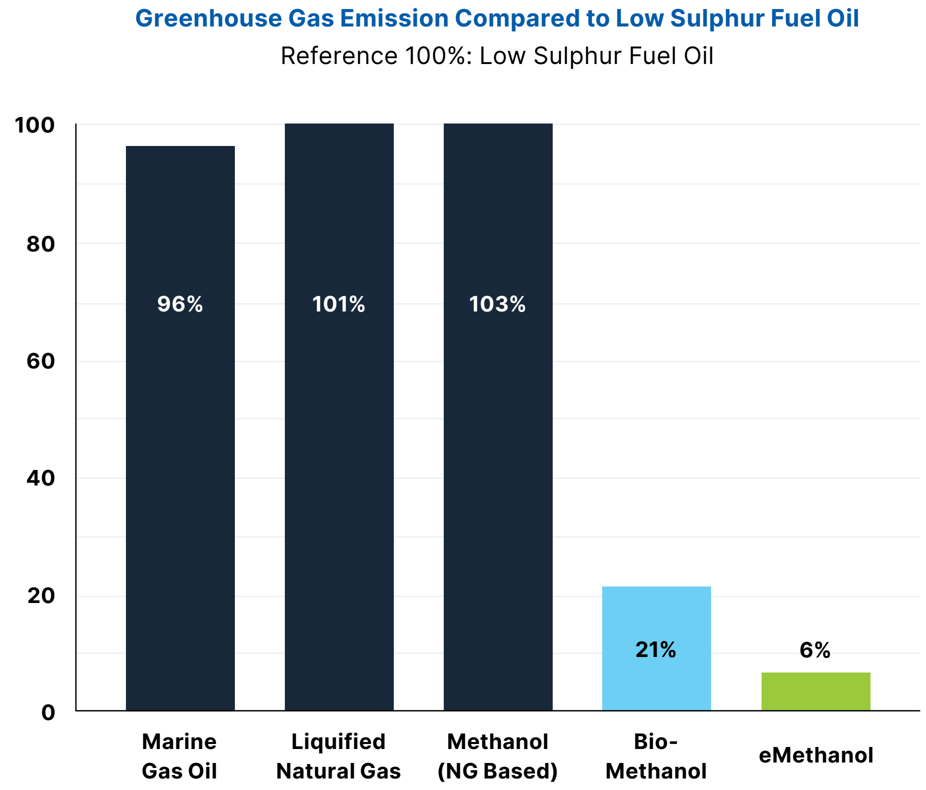


Figure 4: *Greenhouse Gas of Marine Fuels Compared to Low Sulphur Oil*

[7] S. Brynolf, "Environmental assessment of present and future marine fuels," Department of Shipping and Marine Technology, Chalmers University of Technology, Gothenburg, 2014.

5 Overview of Current Verification and Certification for RFNBO

Using sustainable fuel serves many purposes, such as being compliant with current and future regulation, reaching corporate reduction goals for sustainability reporting and offering sustainable transport to customers. To ensure that the used fuel is sustainable and stakeholders can trust reported data, certification and verification is inevitable and will gain increasing significance with the introduction of well-to-wake emissions and a variety of different emission values.

Currently, in the case of biofuels, certification is usually carried out by third party verification parties like International Sustainability & Carbon Certification (ISCC) or the Roundtable of Sustainable Biomaterials (RSB). For eFuels, including eMethanol, a similar practice can be expected, at least in the short-term. The European Commission has announced the introduction of its own certification scheme. Thanks to the high data quality in the eFuel production, compared to a more complex biofuel supply chain, another possible future is a blockchain-based system that enables transparency, trust and avoids risks like double counting of emissions.

6 Evaluating Alternative Fuels – Key Considerations

Greenhouse gas emission reduction of the maritime sector is and will be the main driver for the introduction of alternative fuels. Therefore, well-to-wake GHG emissions of these fuels are of great importance when evaluating different options. But just a low carbon footprint does not make a widely accepted and scalable marine fuel. In order to be able to scale the de-fossilisation of the maritime industry rapidly, low carbon fuels need to be available, cost efficient, safe and ideally possible to gradually phase in, to enable the start of the energy transition as soon as possible. In the following, key considerations for choosing an alternative fuel will be discussed.

6.1 Global Distribution and Availability of the Fuel

When deciding on an alternative fuel and consequently the infrastructure and machinery for it, a high availability of that fuel is required to ensure sufficient quantities, flexibility of routes and minimize the risk of a stranded assets. To start GHG reductions as soon as possible, green fuels with a high technology readiness level can be expected to enter the market in significant quantities first. Availability on the major ports is a prerequisite for a successful adoption of new fuels. For example, methanol, one of the most traded chemicals in the world, is already available at more than 100 ports globally. The ability to use fuel oils or methanol in dual fuel engines de-risks the investments of new built ships. The switch to methanol can be done easily, and green methanol can be blended with grey methanol when available, to meet future emission reduction regulation and cost efficiently phase into low emission fuels.

6.2 Fuel Handling

Switching to new alternative fuels requires, to varying extents, changes in infrastructure and safety measures to deal with the different characteristics, which may slow down adoption and increase cost. There are significant differences in handling liquid fuels, that have similar properties to traditional marine fuel under ambient conditions, and gaseous fuels, which may require to be stored in pressurized or cooled tanks for storage or transportation. Another important aspect is the experience and safety of handling such fuels, including toxicity for human but also marine ecosystems. High toxicity fuels require additional safety measures to avoid accidents or large environmental impacts in the cases of spillages.

6.3 Total Cost of Ownership (Fuel and Machinery)

Competitiveness requires cost efficient GHG emission reduction measures. Therefore, the total cost of ownership plays a major role when evaluating different fuel options. This does not just include the fuel price and its drivers, but also investments in new-built or retrofit machinery to be compatible with the fuel need to be considered. New-built ships that are low-carbon fuel ready require a premium compared to MGO or LSFO. In the case of a dual-fuel engine that is methanol ready, this premium is around 10-15% with costs expected to decrease with increased adoption. Though this increased cost can be justified with decreased risk of a stranded asset. When retrofitting an existing vessel, the cost is determined by the complexity of the upgrade as well as the ability of reusing parts and machinery that are already existing in the vessel, which may only require minor modification.

When it comes to price drivers for low-carbon fuels, especially green hydrogen-based fuel, the main cost components are very similar. Renewable electricity based hydrogen production, which is the base of synthetic fuels, is energy intensive, which makes the electricity cost the main contributor in the production cost of any hydrogen-based fuel. Additional cost depending on the fuel are CO_2 or nitrogen capturing and heat. Higher feedstock concentration (e.g. point sources) are able to lower production costs. After production, the distribution is a differentiator, as some are more complex or require energy during handling, storing, or transportation. This can be due to the use of cryogenic tanks. With the implementation of carbon prices and levies, different life cycle GHG emissions result in different reduction possibilities. As a result, a higher priced fuel with a lower footprint may have a lower total cost when carbon prices are included.

6.4 Regulation

Adopters of alternative fuels must consider current and potential future regulatory constraints affecting their operations. These may include methodologies for assessing fuel carbon intensity (such as well-to-wake), carbon taxes, handling and safety requirements, and restrictions on sulphur dioxide, particulate matters or other airborne pollutants. In section 2.3 of this paper, we have outlined some of the regulatory considerations for greenhouse gases in the EU and more globally under the IMO’s. Given the rapidly changing regulatory landscape, it is more important than ever to fully understand these potential regulatory impacts when assessing the adoption of new fuels.

7 Conclusion and Call to Action

In this paper we have highlighted that as well as the imperative to take action in the face of global climate change risks, global regulatory control of atmospheric pollution from the maritime or shipping industry is expected to become increasingly stringent. We have provided an overview and outlook of this changing landscape, and followed this with a discussion on the importance of well-to-wake analysis when assessing alternative fuels, including an illustrative example using Liquid Wind's eMethanol fuel as a basis. Finally, we have outlined several other key factors beyond well-to-wake emissions analysis that marine operators should consider when assessing alternative fuels.

In conclusion, we propose that the well-to-wake approach, in conjunction with an understanding of fuel distribution, handling, costs and regulation, provides ship owners with a practical and effective approach to assessing the risks of adopting new fuel types. The benefits of this approach are wide-ranging, and include the following:

- Control. Well-to-wake analysis ensures that the outcomes of greenhouse gas emissions reduction plans, as defined by their overall impact on reducing the effects of climate change, play out as originally intended.

- Reputational risk protection. The methodology acts as a risk control mechanism, giving visibility up and down supply chains and ensuring that shipping companies aren't accused of 'greenwashing' or other deceptive outcomes as they work to decarbonise their operations.

- Avoids burden shift. Well-to-wake addresses the problem of greenhouse gas emissions simply being moved 'upstream' or 'downstream' in the fuel supply chain.

- Accurate comparison and benchmarking. Consistent application of well-to-wake avoids the problem of comparing carbon reduction outcomes across different regimes or methodologies which account for fuel carbon intensities differently.

- Maximum regulatory compatibility. Well-to-wake analysis is the broadest possible framework for assessing the carbon intensity of fuels, giving it the widest possible applicability across different national or international regulatory regimes.

- Precise application of carbon levies. Well to wake ensures that carbon emissions associated with the use of various fuels are accounted for properly and in their entirety, enabling a more precise application of carbon levies, taxes or other incentive regimes.

- Pricing control. Well to wake gives ship operators maximum possible control over the pricing of low carbon fuels, by providing an accurate representation of the carbon intensity of each fuel, rather than a simplified picture which may bundle all low carbon fuels within a range of carbon emissions intensities into a single 'renewable' category.

- Increased choice. Taking a well-to-wake approach brings into scope a wider variety of potential low carbon fuels and feedstocks for the shipping industry to consider and use.

- Widens the scope for innovation and therefore cost reduction. The well to wake methodology opens up the scope of reducing fuel carbon intensity beyond the limited setting of how it is combusted on a ship, therefore opening up more possibilities for economically reducing carbon intensity (for example through fuel production processes or through sourcing alternative raw materials to create fuel).

- Avoids undesirable externalities. A thorough well-to-wake approach should consider other externalities from producing, transporting, storing and using the fuel, such as the emissions of other atmospheric pollutants, socially undesirable outcomes, or the unsustainable use of scarce resources.

We therefore propose that ship owners, and all other relevant stakeholders in the shipping and marine ecosystem, pursue the following:

- **Adopting a robust well-to-wake or life cycle analysis regarding GHG guidelines for all types of marine fuels (not only methanol).**

- **Integrate well-to-wake analysis into corporate risk assessments and procurement processes when assessing different fuel types.**

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