INSIGHT BRIEFING SERIES

New fuels: Total cost of operation

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The Getting to Zero Coalition is committed to accelerating shipping decarbonization by getting commercially viable deep sea zero emission vessels powered by zero emission fuels into operation by 2030 to put shipping on a path for full decarbonization by 2050. To unpack the different fuels and technologies options that could support the transition to zero emission fuels, the workstream on Fuels & Technologies has hosted a series of webinars, gathering perspectives from experts across the maritime value chain - shipowners, operators, charterers, financial institutions, classification societies, and NGOs. The insight briefing paper series aims to reach a broader audience and build a common understanding of the fuels, engines, and storage technologies that will enable the decarbonization transition.

The Insight Brief is based on analysis by Global Maritime Forum for the Getting to Zero Coalition, a partnership between the Global Maritime Forum and the World Economic Forum, made possible with funding from Mission Possible Partnership.

Date of the webinar: October 2020

Watch the webinar here.

Panelists:

- Alexandra Ebbinghaus, General Manager Decarbonisation, Shell Marine, Shell
- Dr Tristan Smith, Co-founder, University Maritime Advisory Services
- Ludovic Laffineur, Policy Manager, Maritime, Aviation and Ports, Hydrogen Europe
- Tore Longva, Consultant, DNV GL

Moderator: Randall Krantz, Senior Project Advisor on Shipping Decarbonization, Global Maritime Forum/Getting to Zero Coalition

Executive Summary

Synopsis: Currently, a range of different models and comparisons are used to project costs of scalable zero emission fuels (SZEF) for shipping. These projections are conditional to the assumptions used and the level of understanding of science, technology, and the economic landscape. Different factors across the fuel lifecycle might influence the modelling exercise and result in broad ranges of projected costs. This webinar and paper aim to bring insights on the Total Cost of Ownership (TCO) in order to support decision making.

Key takeaways:

> Modelling is the first step for a business case. It is a tool to foster decision making on the transition strategy, raise funds, and support pilots that contribute to scaled solutions.

> As renewable energy costs are decreasing, zero emissions fuel competitiveness will improve over time due to decreasing production costs. Meanwhile, research shows an expected increase for the TCO for Heavy Fuel Oil (HFO) and Low Sulfur Fuel Oil (LFSO).[1]

> Policy and regulation will play a major role in overcoming high costs of SZEF, while 87% of the estimated USD 1.4-1.9 trillion investment needed for future shipping fuels will be onshore.[2]

1 Lloyds Register and University Maritime Advisory Services, LR and UMAS. (2020). Techno-economic assessment of zero-carbon fuels.

2 Krantz, Søgaard and Dr Smith, RK, KS and TS. (2020), The scale of investment needed to decarbonize international shipping. Insight Brief.

> The input, outputs, assumptions, and sensitivity analysis when modelling aim at reducing uncertainties to identify key drivers and make tests.

Detailed Summary

About the total cost of ownership

The total cost of ownership (TCO) is the purchase price of an asset plus the costs associated with its operation, use, and disposal over its lifetime. In addition to the short-term capital expenditure (CAPEX), when choosing among alternatives in a purchasing decision, buyers should also consider its long-term costs including the operational expenditure (OPEX). The asset with the lower total cost of ownership generally has greater value in the long run (IEA, 2019)[3]. Different factors influence investment decisions. While TCO is a primary factor, it does not include technology readiness, risk assessment, or policy landscape.

1. The techno economic model

A techno economic model is a simplified description of reality, designed to yield hypotheses about economic behaviour that can be tested. An important feature of an economic model is that it is necessarily subjective in design because assumptions used as inputs cannot be 100% certain and there is no absolute objective measure for most assumptions. As mentioned by Alexandra Ebbinghaus, General Manager Decarbonisation at Shell Marine “do not mix studies as underlying assumptions will be different”.

a. The inputs for a model

When evaluating the impact of a study it is important to have in mind what the model is about and as demonstrated by the panel, to capture the interaction of different parameters - key assumptions, sensitivity analysis, and key drivers.

The *assumptions* are based on facts, but they go a step further in making statements about those facts—interpreting them, analysing them, explaining them, evaluating them. They can be optimistic, pessimistic or conservative. Examples for a shipping TCO model include:

- Fuel availability based on feedstock and geography
- Feedstock specificity as sources of energy production (renewable electricity, CCS, etc.)
- Technology and cost efficiency
- The cost of managing safety for different fuels machinery

3 IEA. (2019) Current and future total cost of ownership of fuel/powertrain alternatives in a bulk carrier ship.

The *sensitivity analysis* is a method to determine the robustness of an assessment by examining the extent to which results are affected by changes in methods, models, values of unmeasured variables, or assumptions”. In the pathway of decarbonization, this includes:

- Regulation/ambition and policies
- Fuel prices
- Seaborne trade demand

The *key drivers* input to the model aimed at reducing uncertainty which will decrease with the development of a key drivers portfolio:

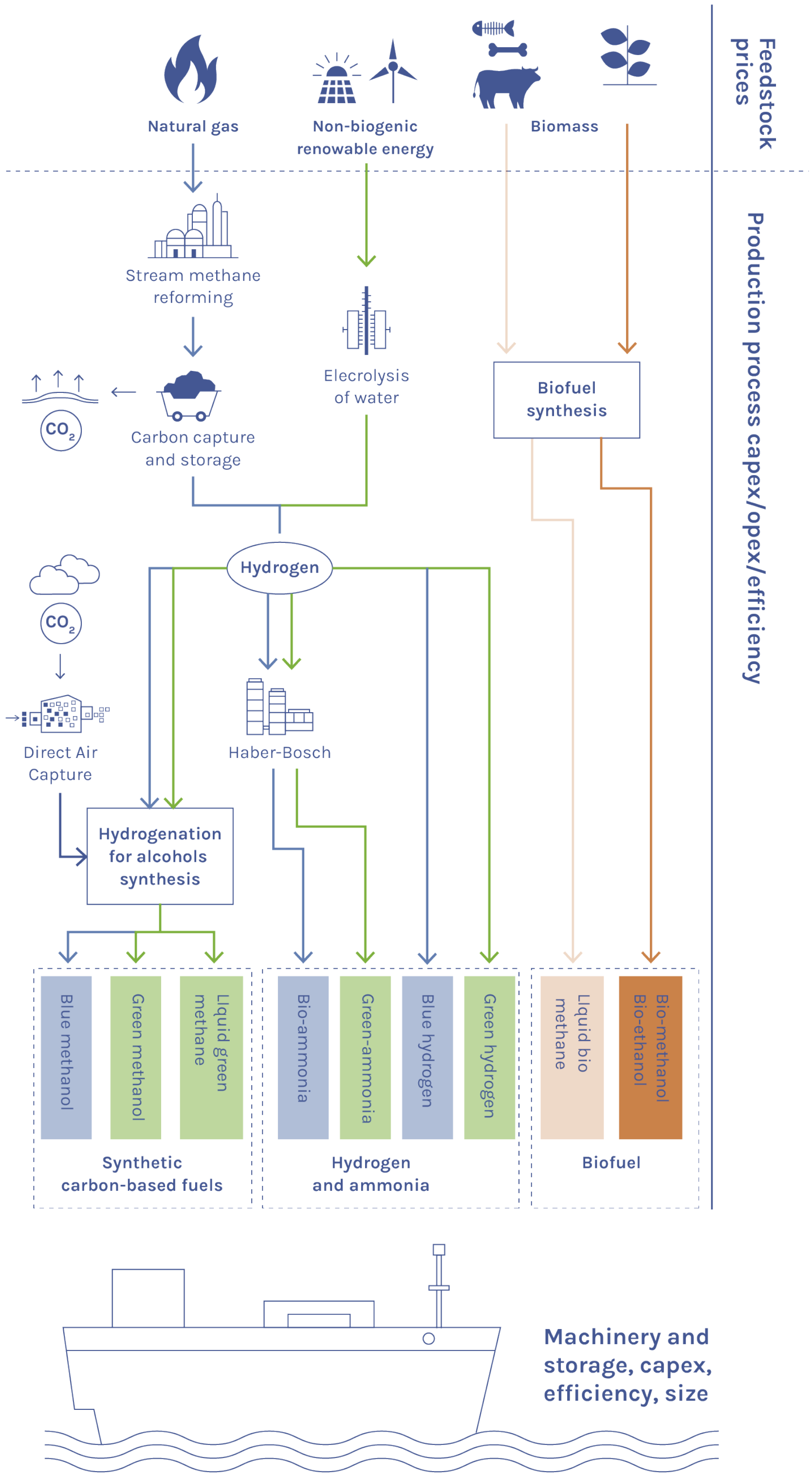
- Technology and technology cost and efficiency assumptions and evolution over time
- Regulations for carbon price and technical operational
- Fuel applicability and cost on different ship
- The criteria regarding different emissions and slip (NOx, N2O, methane)
- Input prices, energy systems of the transition pathway
    - Infrastructure leverage
    - Production scale / cost reduction leverage
    - Competition for constrained supply

Alexandra Ebbinghaus mentioned that the first liquid hydrogen carrier trial made by Shell has generated data to provide input to the comparative tool modelling tool developed by Shell.

Along the supply chain, different costs must be considered [exhibit 1]. The feedstock price will be the first variable. During the production process, it is relevant to take into consideration the cost of renewable electricity depending on the cost of the energy transition. Then comes the price of fuel, transportation, and storage. Onboard, machinery, storage and power for retrofit or new build vessels require CAPEX investments, to which running and operational costs must be added. Finally, the capacity of the vessel to carry cargo depending on its size, the propulsion and the distances between bunkering is also a factor.

Exhibit 1: *Total cost of operation framework*

Source: *UMAS (2020)*



b. *Beyond the framework of the total cost of ownership*

Depending on the framework considered, the analyses outcomes can vary based on the upstream criterias considered as inputs. The framework of the lifecycle analysis paired with a Well-to-Wheel (WtW) approach could help to frame the emissions and the cost related. For instance, it depends if photovoltaic development is included in the feedstock price of energy production. It also depends if the cost for transport is taken into consideration. In addition, the risk factor, political landscape, and technology readiness is not considered in the TCO and could be addressed with a set of tools for risk analysis and a transition strategy.

As a guideline, lifecycle analysis (LCA) approach aims to reduce some of the uncertainties, as explored more deeply in another webinar and accompanying paper. The LCA framework to reduce greenhouse gases emissions can be determined on Well-to-Wheel (WtW) approach.[4] LCA allows to replace the colours with an actual value on the greenhouse gases (GHG) emissions. The WtW approach encompasses the whole emission process of a fuel from its extraction to its combustion.

A set of risk tools can be complementary to a model, in particular to help users identify possible consequences of various choices to be made and their likelihood. For example:

- A Risk Register will capture qualitative and quantitative elements that are not projected to be part of the Model, acknowledging the "known unknowns" and the problems that need to be solved for the outputs of the model to be true.
- A Risk Assessment tool will be used to provide input to an overall assessment inclusive of both risk and modelling analysis, and will be an output in its own right, as it is one of the decision making tools that investors (and other actors) can use when making technology choices.

A transition strategy[5] can help to make better informed decisions taking into account different prices, economic realities, and scenarios. Those scenarios can be directly influenced by the political incentives deployed for certain fuels and the development of new technologies that could be scaled and influenced directly the TCO.

2. The different models

a. *Convergence of studies*

Current models issued by Lloyds Register (LR) and UMAS, International Energy Agency (IEA) and Det Norske Veritas (DNV) showcase the competitiveness and viability of different fuel options. These have as drivers input costs, assumptions and market pricing. For example, models can use cost information on the expected supply of sustainable biofuels, or take into account expected pricing driven by market demand, e.g. the cost of production could increase over the course of time due to biofuel supply constraints.

The three models converge in different areas. To start off, those three techno economic models show an increase of the total cost of operation for Heavy Fuel Oil (HFO) and Low Sulfur Fuel Oil (LFSO). In addition, they show that ammonia is likely dominant in terms of cost in the long run, while further understanding of emissions (NOx and N2O) and safety are needed. All three techno economic models demonstrate a need for a large volume of zero hydrogen feedstock to meet the carbon zero emission target for the shipping industry.

Finally, as mentioned by Dr Tristan Smith from UMAS, it is important not to mix and match conclusions from different models or studies, as underlying inputs and assumptions can be different.

4 Gmobility (2019). Well-to-Wheel – How to better understand it.

5 Getting to Zero Coalition. (2021). A Strategy for the Transition to Zero-Emission Shipping.

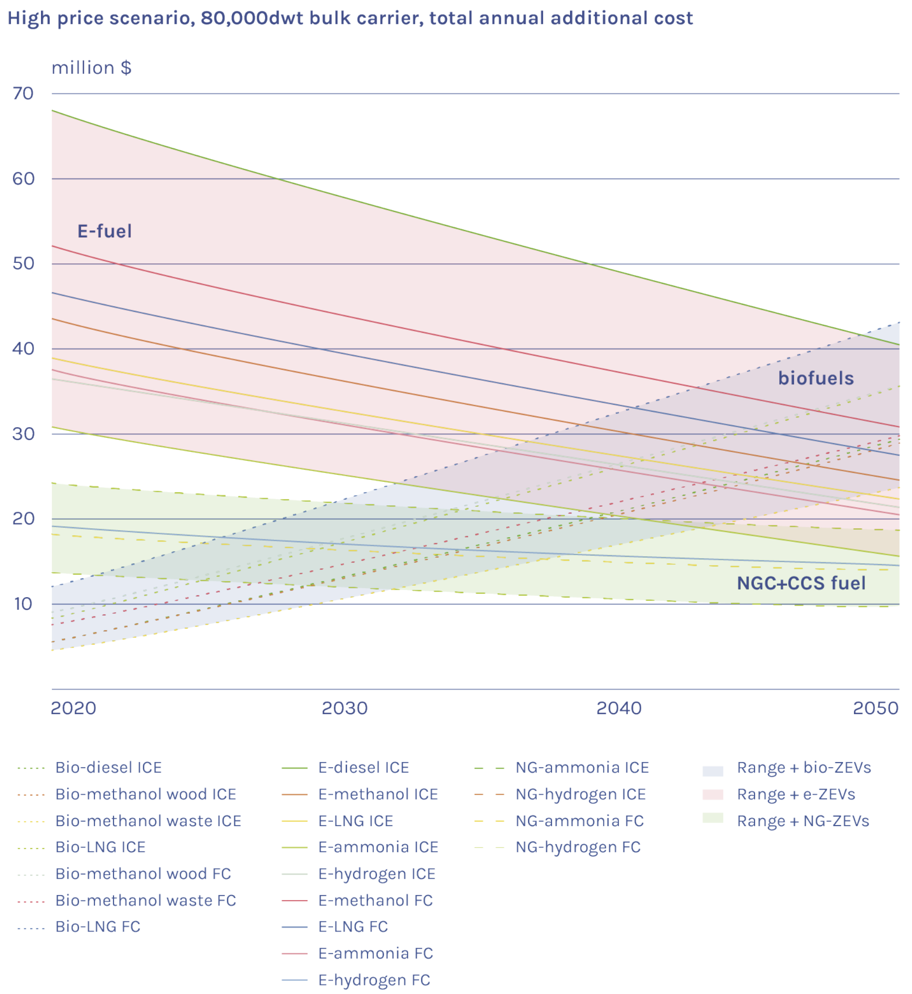
b. Key uncertainties and differences of studies

Some divergences remain and underscore certain uncertainties across the three modelling approaches. Of course, the time frame for shipping decarbonization depends on the overall rate of decarbonization. As described by Tristan Smith, some divergences between studies about rates of decarbonization can be observed. For instance, the rates and milestones to achieve shipping decarbonization can diverge from the goals set by regulations to what climate science recommends to achieve such as the 1.5 degrees targeted by the Paris Agreement.

There is room for technology innovation regarding engines and auxiliary systems. The industry is facing a time of uncertainty regarding infrastructure and fuels availability and development. For those reasons it becomes imperative to take a high level view. This must go beyond the technologies (e.g. optionality of new builds and retrofitting for different fuels) to include speed reductions and operational changes at both a company and system level.

The techno-economic assessment of zero carbon fuels issued by LR and UMAS [exhibit 2] shows that natural gas and carbon capture storage (CCS) are cheaper than e-fuels but are not zero carbon. For hydrogen and e-LNG, the total cost remains 20-50% more expensive across sectors. Also, ammonia remains cheaper than synthetic hydrocarbons and its competitiveness improves with time.

Exhibit 2: *Techno-economic assessment of zero carbon fuels*
Source: *LR & UMAS (2020)*



3. Modelling methodology developed by UMAS with the Getting To Zero Coalition

By collecting input and iterative feedback from members of the Getting to Zero Coalition, UMAS is developing a techno economic modelling tool to enable better investment decision making. The first step was to gather internal data and run a literature review. In the second step, the work consisted of mapping the data confidence and potential gaps. The third step was to compile engagement deliverables. The prototype of this "interactive, open-access model" has been completed and is being further advanced in the MVP (minimum viable product) phase at the time of writing [exhibit 3].

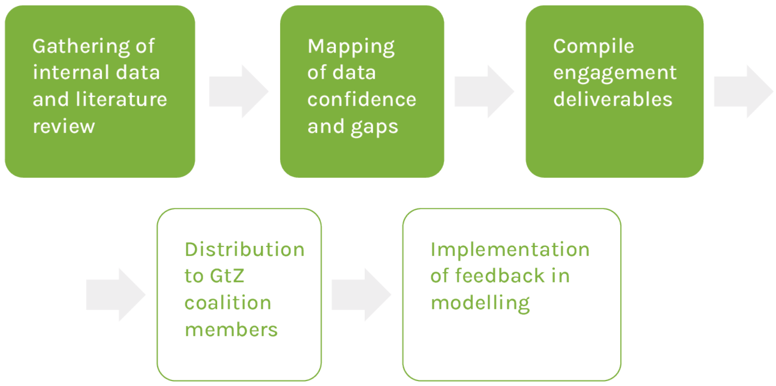


Exhibit 3: *Timeline and steps of engagement process - Technical assumption report*
Source: *UMAS (2021)*

Conclusion

In his concluding remarks, Ludovic Laffineur highlighted the importance of openness and transparency from data collection through to model use. In addition, the development process based on a feedback methodology presents an opportunity to identify the gaps, according to Tore Longva. He also noted that having different modellers is an opportunity to compare the different methodologies and create space for improvements. Also, for Dr Tristan Smith, While there are some aspects that will remain "known unknowns", such as the availability of sustainable biofuels in 20 years time, other opportunities to refine assumptions will emerge from trials and full-scale pilots.

Ultimately, across all the uncertainty, overlap and different information available, people can keep an open mind, according to Alexandra Ebinghaus.

This webinar has shown that different TCO models are currently available, and that both their commonalities as well as their differences can teach us. Ultimately, these unknowns and differences present an opportunity to refine the models.