OIL AND GAS CLIMATE INITIATIVE

OGCI TRANSPORTATION WORKSTREAM

ECONOMICALLY VIABLE AND SUSTAINABLE BIOMASS FOR MARINE FUEL USE

FEBRUARY 2023

OGCI and Transport

The Oil and Gas Climate Initiative (OGCI) aims to accelerate the industry response to climate change and scale up practical solutions in accordance with the goals of the Paris Agreement. We work from the principle that decarbonizing energy systems is a complex task that demands the collective efforts of the oil and gas industry, our customers and other stakeholders. In that spirit, we leverage the combined strength of our member companies and collaborate broadly with others to lower the carbon impact of our own operations, reduce the carbon intensity of products and implement complementary solutions that cross industry boundaries.

Our objective is to develop a portfolio of solutions for the short, medium *and* long term, that can decarbonize the various modes of transport. OGCI's initial focus is on challenging areas such as long-haul commercial vehicles, deep-sea marine vessels and international aviation, where short-term gains may be realized by blending renewable fuel components into established distribution networks. Our joint efforts are designed to harness the capability of industry partners, complement actions carried out by our members both individually and collectively and leverage the Climate Investments fund to spur innovative solutions.

Executive Summary

Maritime shipping has declared long-term ambitions for decarbonization in alignment with the goals set by the Paris Agreement. To help meet this goal, the industry has been evaluating technologies and solutions ranging from relatively simple efficiency measures to large scale adoption of carbon-free fuels.

One solution is to substantially increase the use of bio-fuels derived from several biomass feedstocks. The potential for bio-fuels to play a role in the marine sector comes down to 'availability'; a general term encompassing the annual global inventory of bio-feedstocks, the definition of sustainability for those feedstocks, their economic recoverability, compatibility with conversion processes and competition for a limited resource by other industrial and transportation sectors.

To understand the potential for bio-fuels to decarbonize the international shipping fleet, the OGCI launched a study to assess the question of availability and estimate the overall annual volumes suitable for marine fuel use through 2050. Having first estimated the total volume of biomass available for use, the team screened for sustainability and conversion process suitability before identifying competitive industries that may prioritize certain feedstocks. Finally, the feedstocks were evaluated for economic recovery and sector competitive pressures once converted into a useable fuel.

The screening process showed that without greater biomass mobilization, feedstock availability for marine biofuel may be constrained by 2050. A lack of legislative support for biofuel use in the marine sector means that significant volumes of biomass for marine fuel use are unlikely to manifest, funneled instead for use in the road and aviation sectors. However, the study also showed that with greater legislative backing and production mobilization, there is more than enough biomass available for marine

fuel use, even when accounting for sector competition. This demonstrates the importance of support in providing sufficient feedstock for all segments of transportation.

Perhaps the most critical takeaway from the study is the complexity of biomass availability and the large number of factors and assumptions which determine it, as seen in the significant variation between the three cases. While biomass is likely to be available for use as a marine fuel and can play a role in the decarbonization of the maritime industry, the broad range of availability demonstrates that it may be best viewed as only part of a portfolio of decarbonization options.

International Maritime Ambition

Maritime shipping, like other industrial sectors, has declared long-term ambitions for decarbonization in alignment with the goals set by the Paris Agreement. The International Maritime Organization (IMO), the UN body that oversees international shipping rules and regulations, has set an ambition for the global fleet to reduce greenhouse gas emissions in 2050 by 50% compared to the baseline year of 2008 (International Maritime Organization, 2018). Considering the potential for growth in international shipping, this could lead to a higher percentage reduction needed on a per-ship basis by 2050.

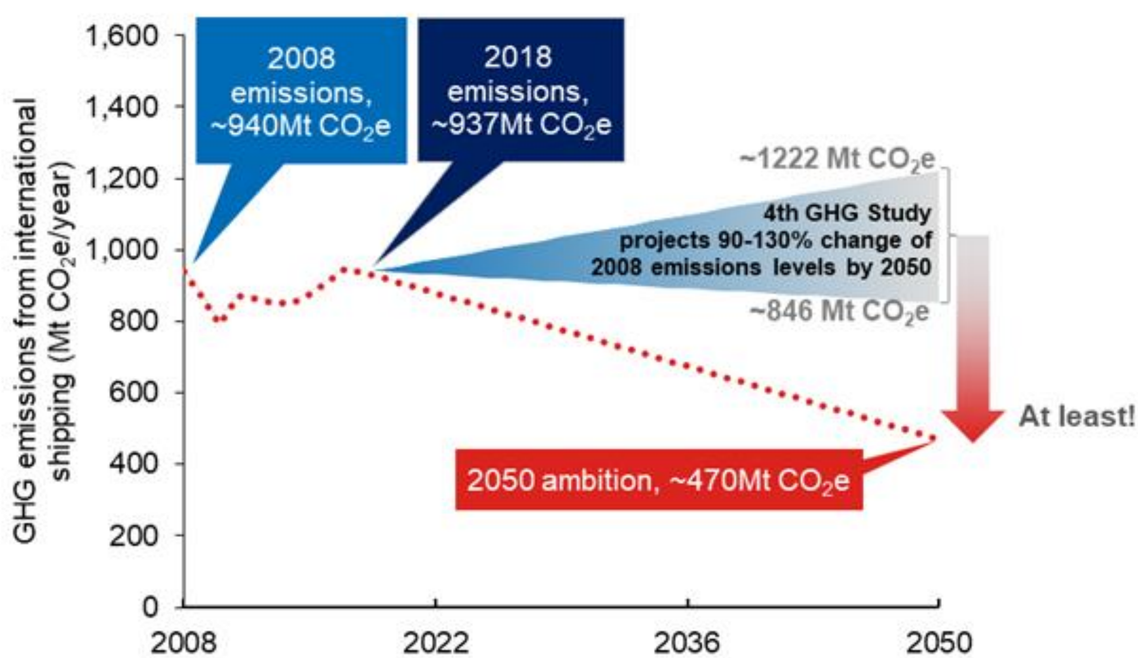

Figure 1: Global GHG emissions from international shipping with projections to 2050. The IMO ambition of a 50% reduction compared to 2008 could translate to a higher requirement on an average per-ship basis. (Ricardo Energy and Environment, 2022)

To help meet this goal, the shipping industry has been evaluating a number of technologies and solutions ranging from relatively simple efficiency measures to large scale adoption of carbon-free fuels like ammonia. Included among these solutions is a substantial increase in the use of bio-fuels which can be derived from a number of different biomass feedstocks. These bio-fuels come in a variety of forms, but the most compatible products are blendable with the two dominant fuel types used in the industry today: heavy fuel oil (HFO) and marine diesel oil (MDO). HFO is a high density, high viscosity fuel originally derived from the residual components of a refinery's distillation column. MDO, however, is a lower density, lower viscosity fuel more similar to diesel fuel and other middle distillate products. As a result, bio-fuels more compatible with MDO are likely to see competitive demand from the aviation and on-road markets where these types of products are widely used. Ultimately, the role that bio-fuels can play in the marine sector comes down to a question of availability. And "availability" may depend upon the annual global inventory of bio-feedstocks, the definition of sustainability for those feedstocks, their economic recoverability, compatibility with conversion processes and competition for a limited resource by other industrial and transportation sectors.

To gain more insight into the potential role for bio-fuels in decarbonizing the international shipping fleet, the OGCI launched a study to assess the question of availability and estimate the overall annual volumes suitable for marine fuel use through 2050. The study used a staged screening methodology to perform the assessment and started with an estimate of the total volume of biomass available for use. This total volume was then screened for sustainability and conversion process suitability before identifying competitive industries that may prioritize certain feedstocks. Finally, the feedstocks were evaluated for economical recovery and sector competitive pressures once converted into a useable fuel.

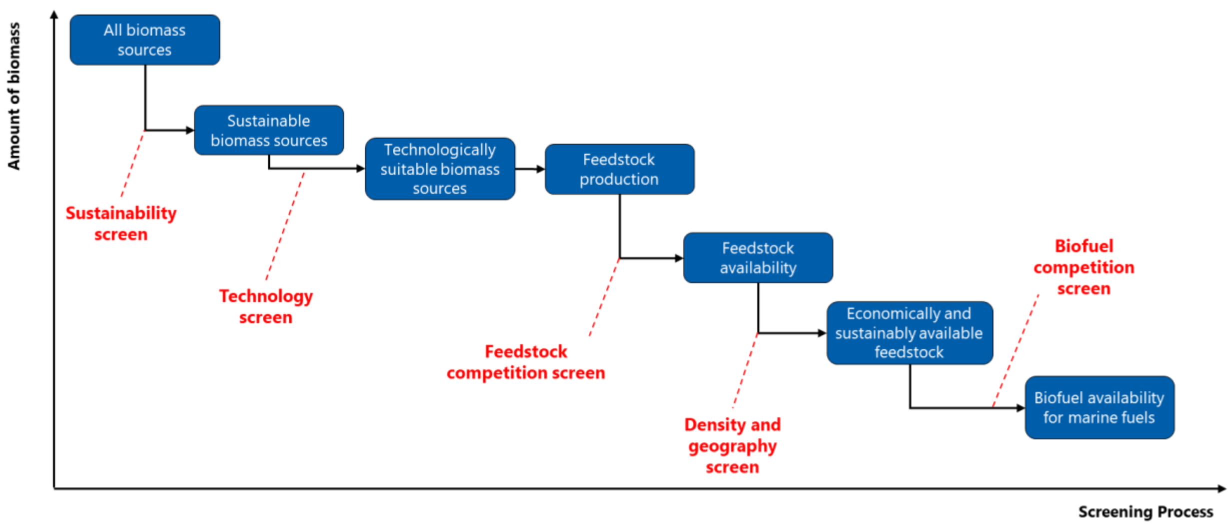

Figure 2: Methodology for assessing the availability of bio-fuels for marine fuel use.

Sustainability

The definition of biomass is generally agreed to be "organic material of recent biological origin", but this refers to a wide range of potential sources. To help organize them, they can be broadly split into Forest, Agriculture and Biowaste categories. There are a number of products within each of these categories and their degree of "sustainability" depends in large part on how that term is defined and the processes used to recover or produce the relevant feedstock. It was important for this study to arrive at a definition of sustainability that would be widely accepted and reflect recent and future trends so that a credible estimate of biomass could be constructed. Consequently, an extensive review of existing sustainability definitions and schemes proposed by regulatory agencies and academic and non-governmental organizations was conducted. This resulted in a consolidated list of the most common and important environmental, social and economic indicators of a feedstock's sustainability (Table 1). In addition to defining the sustainability criteria, the table also offers an assessment of the impact of that indicator on overall biomass availability. For instance, the Soil Quality metric demands that the soil not suffer degradation through the removal of the biomass grown there. Depending upon the specific feedstock, best practices may require that certain elements of the crop be left on the field and plowed into the soil. Consequently, the full mass of the crop is no longer available for conversion into biofuels and the overall availability must be adjusted accordingly. The impact of these indicators on the most common categories of biomass sources are shown in Table 2. Of note are the complete removal of both high quality stemwood and food crops from the biomass inventory. Forestry and field residues and dedicated energy crops can be sustainable if grown and harvested under the right conditions and according to best practices. This screening step eliminates a substantial amount of biomass that is available for conversion into energy products, but it is reflective of the trends emerging in how sustainability is defined and applied to a number of feedstocks. Notably absent from the list is the category of fats, oils and greases (FOG) which are heavily used today to produce road and aviation biofuels. FOG were omitted from this study because shifting them from existing high demand fuel markets was not considered economically viable.

Table 1: Environmental, social and economic indicators used to define sustainability in this study.

Indicator	Criteria	Impact on Availability
Lifecycle GHG Emissions	Biofuels achieve >70% reduction in WtW GHG emissions relative to baseline fuel	Any biomass feedstocks not achieving this reduction are omitted
Soil Quality	Soil quality maintained or improved or adverse soil degradation reversed	Soil best practices translate to leaving certain agricultural and forestry residues in place, reducing recoverable mass
Air Quality	Air pollution minimized or eliminated along full supply chain	Feedstocks with evidence of producing polluting gases throughout life cycle are omitted
Biodiversity	Biomass cannot be taken from areas of nationally recognized high biodiversity, critical ecosystems, protected areas or where conservation efforts or endangered species are present.	Significant areas of biomass omitted
Land Use Change	Biomass production must not lead to negative land use change	Feedstocks with high indirect land use change or produced on previously cultivated or primary forest land are omitted
Carbon Stock	Biomass cannot be taken from land with high carbon stock	Peatlands and wetlands are unavailable and forest growth must outpace harvest levels to avoid deforestation
Food Security	Operations ensure the human right to adequate food	Biomass cannot replace arable crops and feedstocks associated with increased food prices are omitted
Legality	Applicable international, national and local regulations must be observed	Biomass from countries out of compliance omitted
Social Rights	Human rights, labor rights, land use rights and social equity must be met	Biomass from countries not meeting these requirements omitted
Economic & Financial Viability	Biomass must be produced and traded with economic and financial viability	Feedstocks produced in an uneconomically sustainable way are omitted
Infrastructure & Accessibility	Biomass must be accessible through relevant infrastructure	Inaccessible biomass omitted

Table 2: Results of the sustainability screening step where biomass sources are assessed using the defined sustainability criteria in Table 1.

Source	Feedstock	Impact on Availability

Forest Biomass	High quality stemwood		Carbon stock, land use change and deforestation disqualify stemwood for expanded energy use
	Forestry residues (fellings & thinnings)		Roots, stumps and leaves must be left behind, but branches, bark and discarded stemwood qualify
	Wood processing residues		By-products with no associated negative consequences
Agricultural Biomass	Food and feed crops		Land use change and food security disqualify these crops
	Field residues		Significant portion must be left behind for soil quality, but amount depends on species, location, etc.
	Processing residues		Highly sustainable waste products that are typically burned on site
	Dedicated energy crops		Only qualify if grown on marginal land and do not interrupt food supply
Biowastes	Manure, MSW, sewage sludge, etc.		All biowastes are assumed sustainable since they would otherwise be disposed of

Suitability for Conversion

Because biomass feedstocks vary in composition, density and form, the practicality of converting them into products useable by the marine industry may act as a further screen on availability. Thermochemical processes, including hydrothermal liquefaction (HTL), fast pyrolysis (FP) and gasification plus Fischer-Tropsch, are well-suited to converting the primarily lignocellulosic residues and waste streams identified as most sustainable in the previous section. These processes, although not yet proven at commercial scale, can produce distillate fuels, residual fuels and blending components compatible with marine fuels. Of particular interest are the processes that can readily convert biomass into a fuel blendable with heavy fuel oil as these may offer a more cost-effective and competitive pathway to introduce biomass into the marine sector.

The study developed three key metrics when assessing the suitability of feedstocks to be converted through these thermochemical processes:

1. Feedstock Quality: is the quality of the feedstock such that it can be physically transported and processed effectively? Does feedstock composition affect quality and yield and are there thresholds for impurities or chemical properties that disqualify a feedstock?
2. Fuel Quality: Does the resulting fuel meet existing fuel specifications and if not, what amount of blending or upgrading is necessary for compatibility?
3. Economics: What effect does the cost of the feedstock have on overall production costs?

Although an environmental metric is applicable, only feedstocks that successfully passed the sustainability screening are considered in this step.

All of the feedstocks meeting the sustainability criteria proved suitable for harvesting, transporting, handling, storage and pre-processing (e.g. drying, grinding or slurry formation), although the cost of performing any of these steps varied depending upon the feedstock. The chemical composition, moisture content and impurity levels of these feedstocks differed, but if one proved unsuitable for a particular thermochemical process, another process was capable of handling it. Further, if a specific feedstock suffered from low quality in a particular metric, it could be blended with another feedstock to address the shortcoming. Consequently, the Feedstock Quality metric did not uncover any sustainable biomass sources that were not suitable for conversion into marine fuel products.

Marine fuels are broadly categorized into residual fuels primarily used by large, slow-speed 2-stroke engines typically used in large ocean-going vessels, and distillate fuels more commonly used in medium speed 4-stroke engines installed on smaller shorter-route and inland waterway vessels or as auxiliary power sources on large vessels. FP bio-oils and HTL biocrudes are similar to residual fuel oils, although they tend to suffer from higher corrosivity and instability due to higher oxygen content. Of the two, HTL biocrudes generally have higher energy density and stability with lower oxygen content which makes them more desirable as direct or blended fuels. In both cases, however, processing and upgrading is necessary to develop them into fuels comparable to on-road diesel or aviation kerosene, adding to the cost of production. Marine gas oils, despite incorporating middle distillates, have lower quality requirements than aviation kerosene or on-road diesel which means that the bio-oils and biocrudes require less upgrading. As a result, there may be a competitive advantage in using these thermochemical processes for the production of marine fuels, although further research is necessary to determine the extent of upgrading required. Blending may offer another cost-competitive route as the greenhouse gas emissions savings can still be significant without the need for upgrading. Ultimately, the lower quality requirements of marine fuels allows for a wide variety of feedstocks and thermochemical processing, and so these metrics did not result in the disqualification of any sustainable biomass candidate.

Ultimately, the energy content and yield of a particular feedstock proved to be a more useful measure of that feedstock's suitability for conversion into a marine focused bio-fuel. Although all feedstocks passed this screening step, the achievable yields for each feedstock require more research, especially for commercial scale thermochemical processing facilities. Of more immediate relevance was the feedstock costs (in $/GJ) and conversion economics which provided a more informative picture of the most suitable feedstocks for thermochemical conversion. Feedstock costs are variable, but they can be generally categorized by how they are harvested, collected and processed. Biomass residues that are spread across a field or throughout a cut forest generally have the highest costs since they must be collected and transported to a processing site. Collected residues are densely generated in central processing sites and so have lower collection, handling and transportation costs. Dedicated energy crops, because they are grown for purpose, come with relatively high costs associated with them, especially compared to by-product feedstocks. Finally, waste biomass typically has the lowest cost since it must normally be disposed of. Figure 3 shows estimated relative costs for a number of feedstocks, but it is important to recognize that these costs will vary by geographic region and do not reflect local market dynamics.

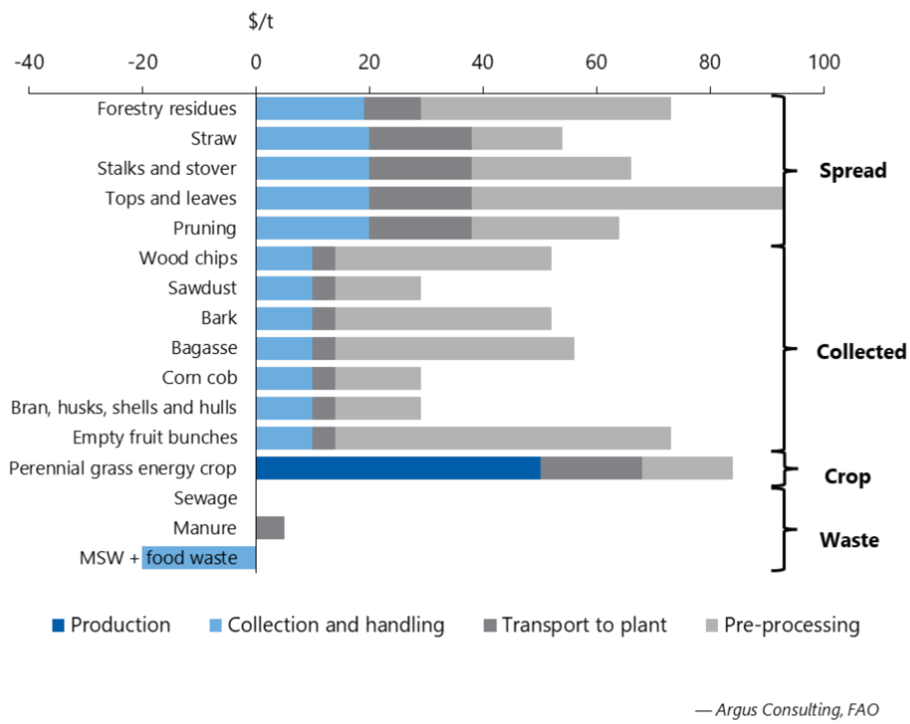

Figure 3: Relative feedstock costs categorized by harvesting and collection technique.

The thermochemical processes considered in the study allow for a wide variety of feedstocks and none were identified as unsuitable for conversion into marine fuels. The quality of the fuels is expected to be sufficient to meet existing marine fuel standards, but the extent of upgrading necessary to meet those standards was not assessed. This is an important consideration because further processing adds cost and this will have an impact on the ability of the marine market to compete for middle distillate compatible fuels against demands stemming from the on-road and aviation markets. The use of bio-oil and biocrude as direct blending components with HFO offers an interesting opportunity, since the low processing requirements translate to associated low costs, but more research is needed to explore blending limits and technical requirements.

Availability for Biofuel Conversion

With a number of feedstocks identified as both sustainable, as defined by this study, and suitable for thermochemical conversion, the next step was to determine global availability and then identify how much of that biomass would ultimately be available for conversion into biofuels for the transportation sector. The rationale for the reductions includes the application of best practices to meet sustainability requirements, infrastructural limitations on waste recovery in urban areas, and competing uses where some feedstocks contribute to products of higher economic, environmental or social value than conversion to energy. From a geographical point of view, two additional criteria were evaluated: the regional density of biomass, which determines how economically the feedstock can be collected in a central processing facility, and the ability of a region to meet either the sustainability criteria or reasonably deliver feedstocks. For example, a landlocked country far from the coast is unlikely to contribute feedstocks to a marine fuel focused processing facility.

Figure 4 illustrates the total global biomass available for the sustainable (defined as fully and partially) feedstocks identified in Table 2. All feedstock volumes are expected to grow through 2050 with agricultural biomass representing the single largest source that scales with population and food demand. Forestry-based mass, although increasing, is not expected to rise as significantly as the agricultural and waste-based streams. However, not all biomass indicated in the chart can be sustainably removed or feasibly collected and this results in the estimated available mass shown in Figure 5. In order to maintain soil health in agricultural fields, best practice is to leave some residue behind to recycle nutrients and so a sustainable removal rate of 40% was assumed. Similarly, forests also benefit from leaving some residue in place and so the assumption was made that roots, stumps and leaves would be left in place while branches and non-merchantable stemwood could be sustainably removed. For biowastes, not all urban areas have sufficient sewage treatment facilities for the production of sludge and so collection rates were adjusted accordingly. Once these adjustments were made, the overall volume of biomass available dropped from 4750 Mtoe to 2050 Mtoe in the year 2050.

When determining how much biomass will be available for marine fuel conversion, it is important to recognize the principles of cascading value which is intended to optimize the economic value of a product and minimize its environmental impact through re-use and recycle. In the cascading principle, disposal of a product is deemed the lowest value use with conversion into energy only one step above it. As a consequence, non-energy demand for biomass was assumed to take priority and availability was reduced accordingly. However, future demand from the nascent bio-based chemicals industry was not accounted for due to uncertainties in expected volumes. More difficult to estimate was the use of biomass for non-transport energy conversion such as heat and power production. For this study, demand from this sector was forecast using an average of the two IEA energy scenarios, SDS and STEPS.

The impact of these competing uses was a dramatic drop in biomass availability to 461 Mtoe in 2050, observable in Figure 6 (note order of magnitude reduction in y-axis scale).

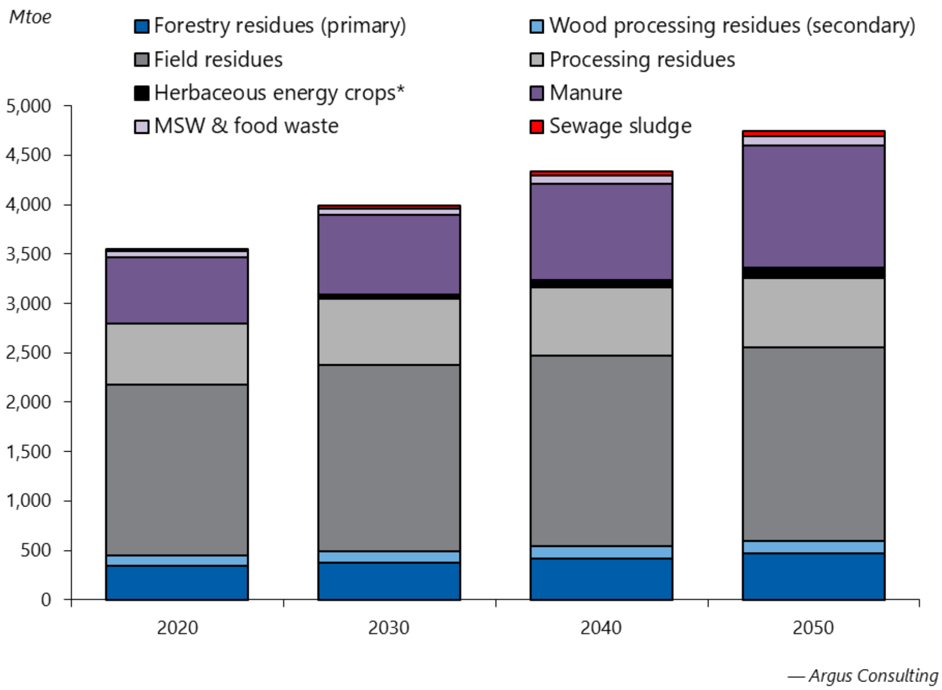

Figure 4: Total global biomass production of sustainable feedstocks, 2020-2050. (Energy crop values include only North America and Europe, where demand is expected to be significant, but excludes rest of world. ROW has significant potential, but only if direct local support emerges.)*

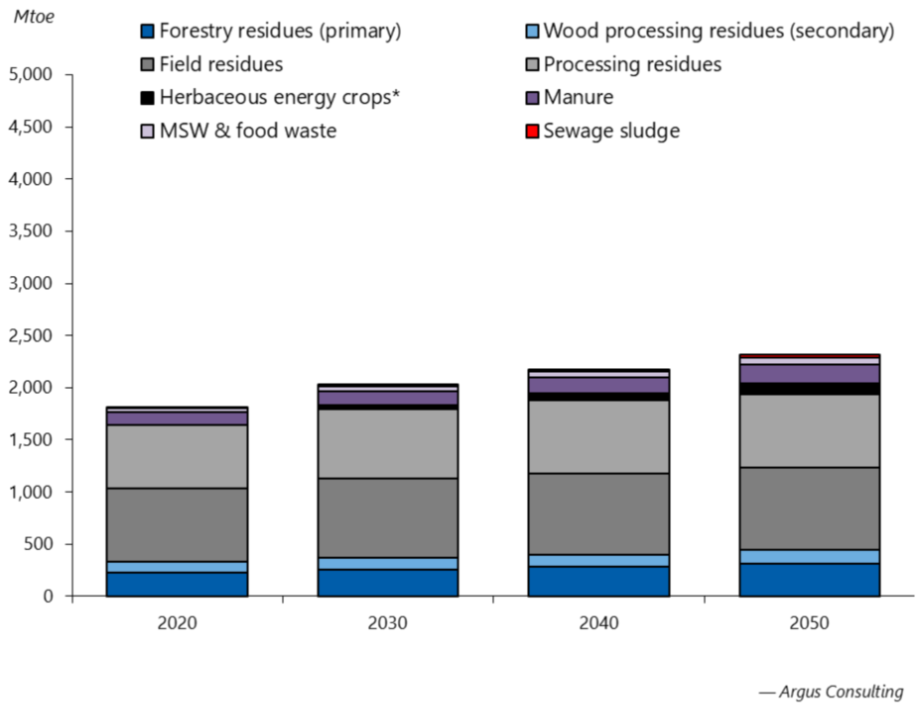

Figure 5: Estimated biomass availability after sustainability limits and biowaste collection restrictions are applied.

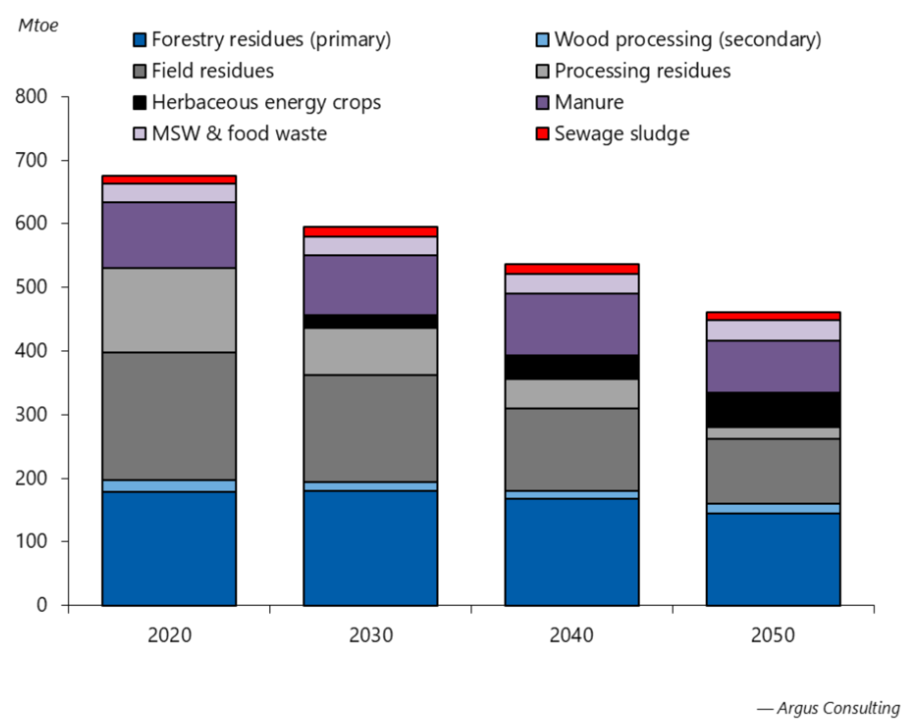

Figure 6: Global biomass availability after competing uses according to the cascading principle are removed.

The available biomass remaining after competing uses from non-transport sectors are accounted for represents an ideal case that does not reflect geographic or political circumstances. To better refine the estimates of biomass, a screening was performed based on geographic limitations for supply lines and compliance with sustainability criteria and then additionally to account for variations in bio-density, a measure of how economically viable it will be to recover feedstocks from some regions. The geographic screening began with a relatively simple identification of those landlocked countries where biomass is unlikely to be converted into fuel for marine use. Mongolia, Bhutan and Chad are examples of countries that met this criterion. Of greater consequence was the assessment of countries for compliance with sustainability metrics that are expected to govern the biofuel markets where demand is greatest. For example, deforestation was defined as a reduction in forest area at a rate of change greater than 0.05% per year, and countries where this was prevalent had their biomass contributions removed from the pool of availability. Similar metrics of sustainability were applied to agricultural products. Figure 7 shows the resulting map of the world after this screening was applied. Of particular note is Africa which currently does not meet the sustainability criteria as defined. However, this assessment reflects a snapshot in time and should not be interpreted to mean that these countries cannot be reclassified in the future.

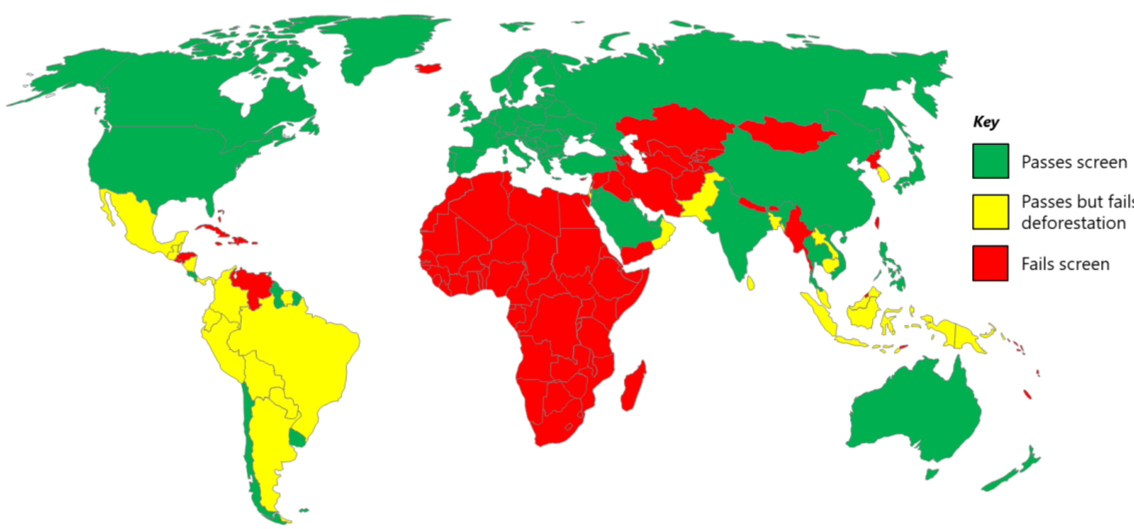

Figure 7: Geographic screening for sustainably managed biomass resources.

More difficult to assess is the economically accessible amount of biomass in each country. Production and collection costs were shown to be modest compared to the higher cost of transportation, which meant that the economic availability of feedstocks was limited by transport distances. Theoretically, a biofuel plant can be built anywhere there are sufficient volumes of feedstock within an approximately 50km radius, so a density screen that applies a mass concentration metric in tonnes/km^2 can provide guidance on areas of low, medium and high density. Some feedstocks can be blended together for delivery to the hypothetical fuel plant and two categories were identified: 1) lignocellulosic sources such as wood and agricultural residues and 2) biowastes such as manure, MSW and sewage sludge. A key limitation of the available dataset was that biomass data was only available at the national level, but density should be assessed on a sub-national basis. Australia provided an excellent example of this, since its area is quite large, but the vast majority of this land is unsuitable for biomass production. Since this would lead to a very low density assessment, the density calculation was adjusted to account only for the agricultural or forested area of a country. Limitations to this approach still existed, but it provided a higher degree of accuracy than the alternative and supplied a strong directional indicator for economic availability. Figure 8 shows the results of the screening where the density rating translates to 80% biomass availability for high density, 65% for medium density and 50% for low density.

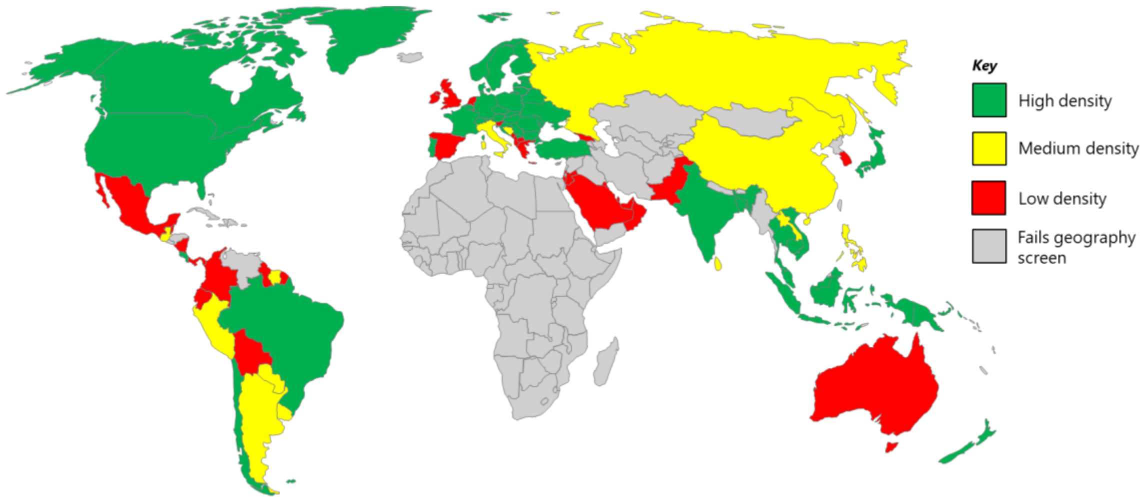

Figure 8: Global results for the biomass density screening.

The application of the step-by-step screening process was meant to estimate the amount of biomass available for conversion into marine fuels with an emphasis on conversion routes that produce HFO blendable products. Figure 9 shows this progression for biomass available in 2020 which results in nearly an order of magnitude reduction. However, this is still a considerable volume of biomass and its conversion could play a significant role in decarbonizing the maritime sector. Uncertainty present in the assumptions applied during the screening steps also plays a role in the estimate and so a sensitivity analysis was performed to better understand the potential variability in the final result.

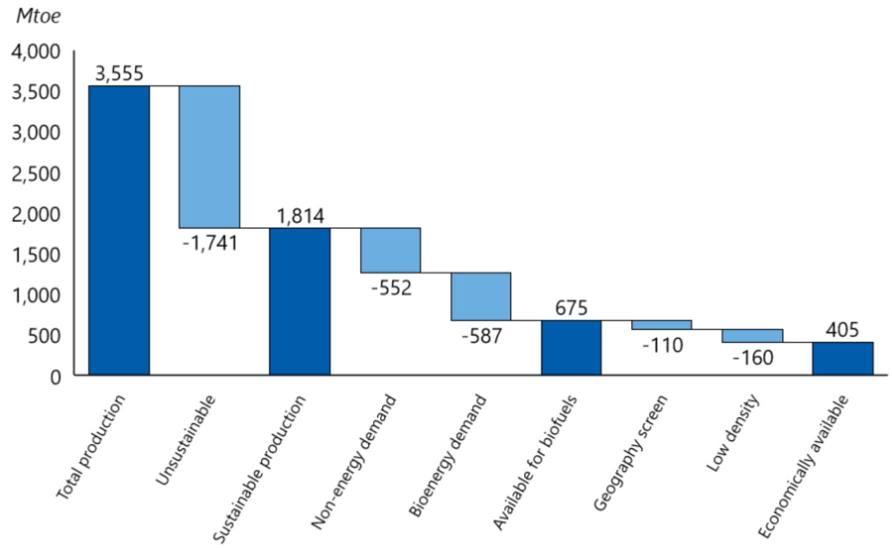

Figure 9: Economically viable biomass available for conversion into marine fuels in 2020 after screening process applied.

But the maritime sector is not alone in defining its ambition for large scale reductions in carbon emissions. Both the aviation and on-road sectors are expected to increase their demand for bio-based fuels and the same feedstocks can be used for this purpose. The final step in assessing the amount of biomass available for marine use was estimating competitive pressure from the aviation and on-road markets.

Transportation Sector Competition

As noted in the Sustainability section, FOG feedstocks were not considered in the study because they are already heavily relied upon for the production of biofuels demanded by the on-road and aviation sectors. This demand is driven by existing mandates legislated by governing authorities in the European Union, United States and elsewhere (European Parliament and the Council of the European Union, 2018; Environmental Protection Agency, 2021). As the volume of these mandates increases over time, the supply of FOG will become exhausted and suppliers will seek additional feedstocks to meet the demand, creating heightened competition for the feedstocks identified as suitable and economically viable for marine fuel use. Although the on-road sector is currently the dominant user of bio-fuels, total road fuel demand is expected to be eroded by electric vehicles, reducing the blending pool. Meanwhile, efforts to decarbonize the aviation sector through the use of sustainable aviation fuels indicate that this will be the primary demand driver in the future. Although hydrogen and battery powered aircraft are under development for small aircraft on short routes, long-haul flights will need low carbon liquid fuels derived from biomass or synthetic processes, and the lack of alternative decarbonization options will drive growth in demand from the aviation sector for these fuels.

Additionally, current maritime decarbonization efforts are driven by carbon reductions targets, rather than mandates to use specific fuels, such as waste feedstocks as in aviation or road. This allows for a broader choice of alternative fuels which can be used to decarbonize the maritime sector and increases the likelihood that the road and aviation sectors will be able to outcompete the marine sector for waste-based biofuels.

However, the marine sector has a competitive advantage relative to road and aviation, as it can utilize less processed fuels leading to reduced production costs. The extent of upgrading required for these marine fuels needs to be fully assessed to realize the marine sector's competitiveness in this regard.

To account for variations in future biomass supply, three scenarios were assessed to provide insight into the range of possibilities for the marine sector. In addition to the base case, a high and low scenario, which were based on the IEA's STEPS and SDS scenarios, were evaluated. The low scenario represents a low biomass mobilization scenario with strict sustainability limits, no increase in biowaste collection, and limited energy crop production. The high scenario is more optimistic on biomass availability, with lower sustainability limits and greater biomass mobilization.

In each scenario biomass availability for use in transportation falls between 2020 and 2050, but the total amount available remains significant. The drop in availability of sustainable biomass for biofuel production stems from greater competition for feedstock, especially from non-transport bioenergy uses such as heat and power generation. The significant variability, as seen in Figure 10, highlights the complexity of biomass production and the wide range of factors and assumptions regarding production.

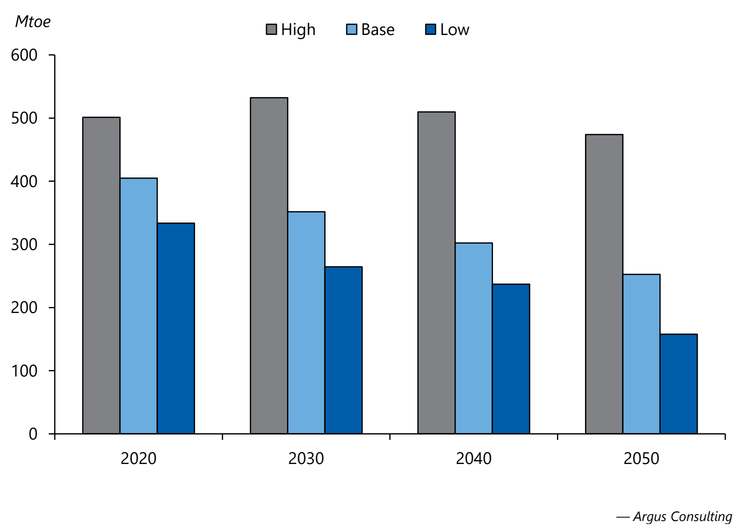

Figure 10: Availability of sustainable and economic biomass for total biofuel production by scenario, 2020-50

To determine the availability of biofuels for marine use, demand from road and aviation would need to be assessed. Biomass upgraded via thermochemical conversion technologies can be used to produce transportation fuels suitable for all segments of transportation, and the study reviewed legislative support, alternative fuel options, and technology and production costs to determine the allocation between transportation sectors.

For each feedstock availability scenario, biomass was converted to a biofuel product using a conversion efficiency of 60%, which translates to 25% in mass terms, typical of the gasification and Fischer-Tropsch pathway. The demand for waste-based biofuels (excluding demand for the FOG based biofuels which were not covered in this study) from the road and aviation sectors were taken away from the total availability to determine the amount of biofuel available for the marine sector.

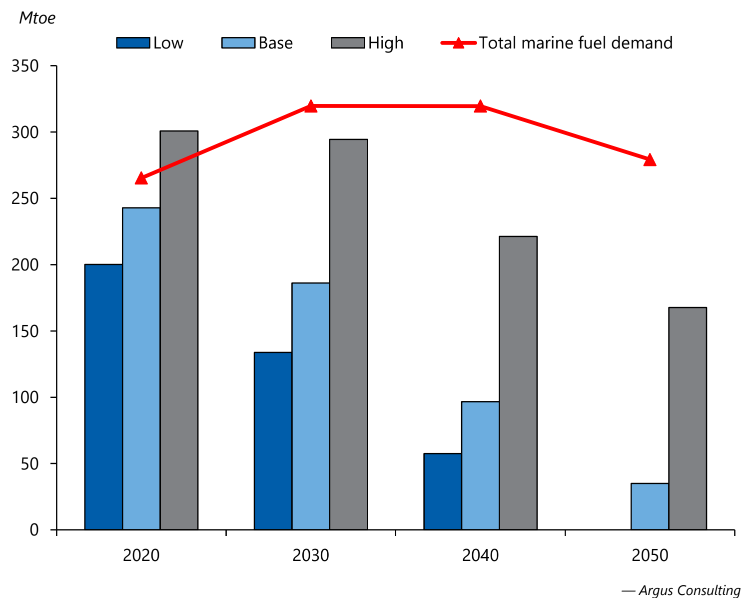

Figure 11: Marine sector biofuel availability prioritising road and aviation demand, 2020-50

In the base feedstock availability scenario, assuming the total demand for maritime fuels in 2050 is 280 Mtoe, enough biofuel to support 13% of global marine fuel demand is available.

In the high feedstock availability scenario, there is enough biofuel to support 60% of total maritime fuel demand by 2050 even when aviation and road outcompete the marine sector for feedstock. The high scenario's greater feedstock production, increased collection of biomass, and lower competition between sectors leads to much higher availability of biofuels for all transport uses. This scenario shows that when feedstock availability is not a limiting factor, as is currently the case, there is more than sufficient biomass supply for the marine market.

In the low feedstock availability scenario, biofuel availability is a limiting factor and if road and aviation outcompete marine, there will be no biomass left for marine use in 2050. This scenario shows that without increased biomass mobilization, biofuel competition may severely limit the amount accessible by the marine sector. However, this scenario is relatively unlikely as it assumes strict sustainability requirements, flat collection rates, and significant competition for both feedstock and biofuel product.

Conclusions

Without greater biomass mobilization, feedstock availability for marine biofuel may be constrained by 2050, as seen in both the base and low scenarios. A lack of legislative support for biofuel use in the marine sector means that significant volumes of biomass for marine fuel use are unlikely to manifest, funneled instead for use in the road and aviation sectors. However, it is important to note that feedstock availability is not limited in the short to medium term in either scenario, and bio-based marine fuel could provide a pathway for decarbonization over the next decade when other alternative fuels for marine use are expected to become available in greater volumes.

Yet, the results of the high scenario, in which there is more than enough biomass available for marine fuel use, show what is feasible with greater legislative backing and production mobilization, demonstrating the importance of support in providing sufficient feedstock for all segments of transportation. Governments could implement additional policies to bolster the supply chains of biomass and its use as a marine fuel.

In reviewing the study as a whole, it is important to recall that the parameters included a very conservative view on availability of biomass. Depending on the proliferation and support (or lack thereof) for biomass's use in heat and power production, the availability of biomass for marine use could increase. The study also did not consider technological advancements which could increase the available supply. Moreover, fuel production is not always binary and facilities produce a range of products which could include both aviation and marine fuel simultaneously.

Perhaps the most critical takeaway from the study is the complexity of biomass availability and the large number of factors and assumptions which determine it, as seen in the significant variation between the three cases. While biomass is likely to be available for use as a marine fuel and can play a role in the decarbonization of the maritime industry, the broad range of availability demonstrates that it may be best viewed as only part of a portfolio of decarbonization options.

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OIL AND GAS CLIMATE INITIATIVE

WHAT IS THE OIL AND GAS CLIMATE INITIATIVE?

The Oil and Gas Climate Initiative is a CEO-led organization bringing together 12 of the largest companies worldwide to lead the oil and gas industry's response to climate change. It aims to accelerate action towards a net zero emissions future consistent with the Paris Agreement. Together, OGCI member companies represent almost 30% of global oil and gas production.

OGCI members set up OGCI Climate Investments to create a US$1 billion-plus fund that invests in companies, technologies and projects that accelerate decarbonization within energy, industry, built environments and transportation. Combined, OGCI members have invested more than US$35 billion in low carbon solutions over the past five years.

OGCI members are Aramco, bp, Chevron, CNPC, Eni, Equinor, ExxonMobil, Occidental, Petrobras, Repsol, Shell and TotalEnergies.

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OUR MEMBER COMPANIES