

BIOFUELS IN SHIPPING





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1. Executive summary

The use of biofuels in shipping is picking up. As the industry prepares to meet regulations requiring decarbonization, biofuels – in the form of methane, methanol or fuel oils – have been touted as a convenient way for shipping to achieve these goals. Since CO₂ emitted from biofuels during combustion is regarded as potentially carbon-neutral as biomass is able to absorb CO₂ during growth, certain biofuels are regarded as sustainable. Biofuels can, therefore, play a significant role in the maritime industry's decarbonization efforts and will reduce shipping's impact on climate change.

Biofuels can be used as drop-in fuels, mixing with similar fossil versions of the fuels. This is an attractive option to shipowners as it provides them with a flexible way of achieving carbon reductions without having to make large capital investments.

The work presented in this white paper sheds light on the potential role of biofuels to enable decarbonization of shipping. An overview of the current status with respect to uptake and regulations for shipping is given, and we provide practical advice on preparations needed before using biofuels onboard a vessel. In addition, we estimate the total potential production of sustainable biofuels given constraints

on biomass and compare this to the current and planned production capacity from our database covering more than 5 000 existing and planned biofuel production projects.

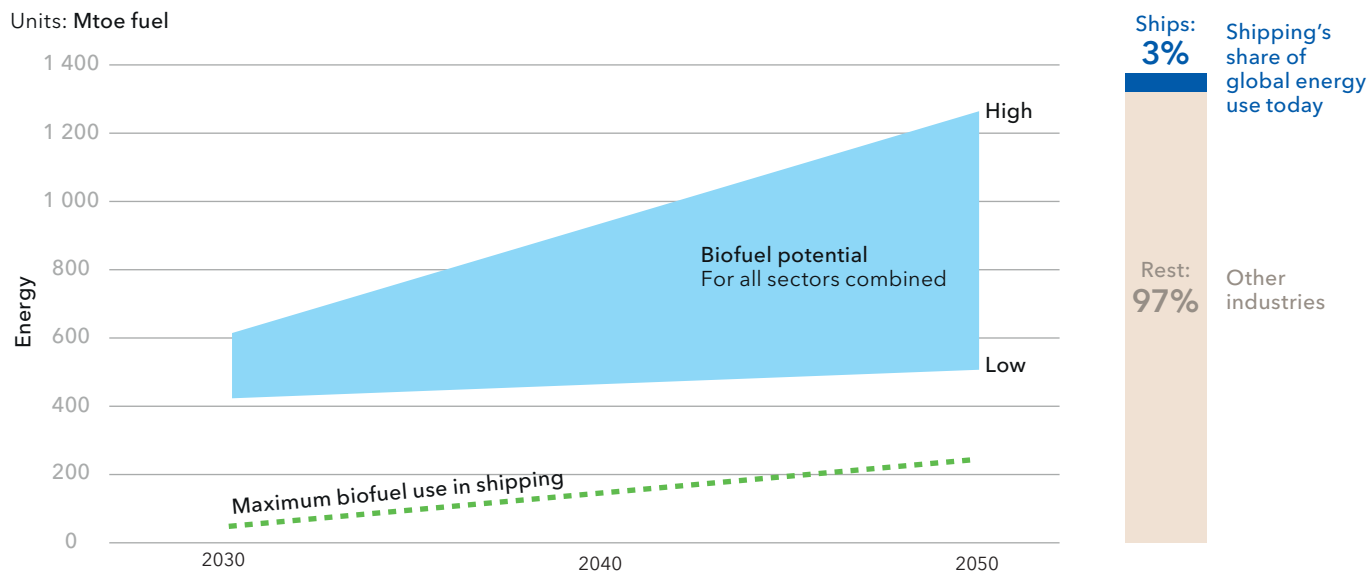
Current global production capacity of sustainable biofuels is around 11 million tonnes of oil equivalent (Mtoe) per year and our database indicates that this could grow to 23 Mtoe per year by 2026. Using stringent sustainability criteria, we estimate a sustainable and economical potential supply of biofuels of 500 – 1 300 Mtoe per year by 2050. Therefore, a major build-up of sustainable biofuel production capacity is needed before the full biofuel potential is reached. If shipping was to decarbonize fully by 2050 primarily using biofuels, 250 Mtoe of sustainable biofuels would be needed annually (see Figure 1-1).

Based on the results presented in this white paper, we believe it is likely that biofuels can and will play a significant role in decarbonizing shipping. However, in the short-term, there are limitations on production capacity of advanced biofuels that may limit the supply to shipping. In the longer-term, shipping will have to compete with other sectors for use of biofuels to achieve decarbonization. As a result, biofuels are unlikely to be the only solution to shipping's goal of transitioning to zero GHG emissions in the future.

FIGURE 1-1

Potential of global supply for sustainable biofuel compared to maximum simulated demand from shipping 2030 – 2050 (left), and shipping's share of global energy use today (right).

Units: Mtoe fuel



2. Introduction

As the maritime industry prepares to meet decarbonization regulations, demand for biofuels is increasing. Biofuels – in the form of methane, methanol or fuel oils – have been touted as a convenient way for shipping to decarbonize, as they can be used as drop-in fuels, mixing with similar fossil versions of the fuels. At the same time, questions have been raised on two important aspects that can have serious implications on how much biofuels can contribute to the decarbonization of shipping:

1. Are biofuels sustainable?

2. Can sufficient volumes of sustainable biofuels be produced?

The work presented in this white paper is an attempt to answer these questions and provide guidance to ship owners and other stakeholders on other important matters related to biofuels. The report is structured as follows:

- First, we present a status overview for use of biofuels in shipping today and relevant regulations
- Second, we outline the total potential biofuel supply in the future, as well as the planned current and future sustainable biofuel production capacity. The potential biofuel supply estimate only factors in biomass considered sustainable under the EU renewable energy directive (RED II), mostly only allowing for the use of waste biomass as feedstock. To assess the biofuel production capacity, we draw on our compiled database of existing and planned biofuel production projects.
- Finally, we compare the potential supply of biofuels in the future with demand from shipping, noting that shipping will not be the only sector with a demand for biofuels.



3. Biofuels in shipping

Biofuels are seen as a promising path to decarbonize a given ship, due to both their relative ease of implementation technically and their availability today. The other potential carbon-neutral fuels under consideration are electrofuels or blue fuels made from fossil energy with carbon capture (see Figure 3-1), in addition to nuclear propulsion and onboard carbon capture. In this chapter we give an overview of the use of biofuels in shipping today, what a shipowner should consider before using biofuels, and the regulatory landscape for biofuels.

3.1 Biofuel use in shipping today

Use of biofuels within the transportation sector has historically been limited to the use of biofuel blends for road-transportation. Recently, however, use within the shipping sector has accelerated significantly from a very low

level – mostly demonstrations and pilots – to a total of 930 000 tonnes of blended biofuel being reported bunkered in Singapore and Rotterdam in 2022, see Figure 3-2, and (Ricardo & DNV, 2023).

Accounting for the fact that biofuels are typically being used in blends, often consisting of 30% biofuel, we can translate this into approximately 280 000 tonnes of pure biofuel. This is equivalent to about 0.1% of current maritime energy consumption of about 280 Mtoe per year.

A significant number of biofuel trials onboard ships have been carried out over the past few decades. An overview of historical biofuel research, trialling, and pilot projects related to shipping, can for example be found in (EMSA, 2022); (IEA, 2017); (ECOFYS, 2012).

FIGURE 3-1

Potential carbon-neutral fuels considered for ship propulsion.

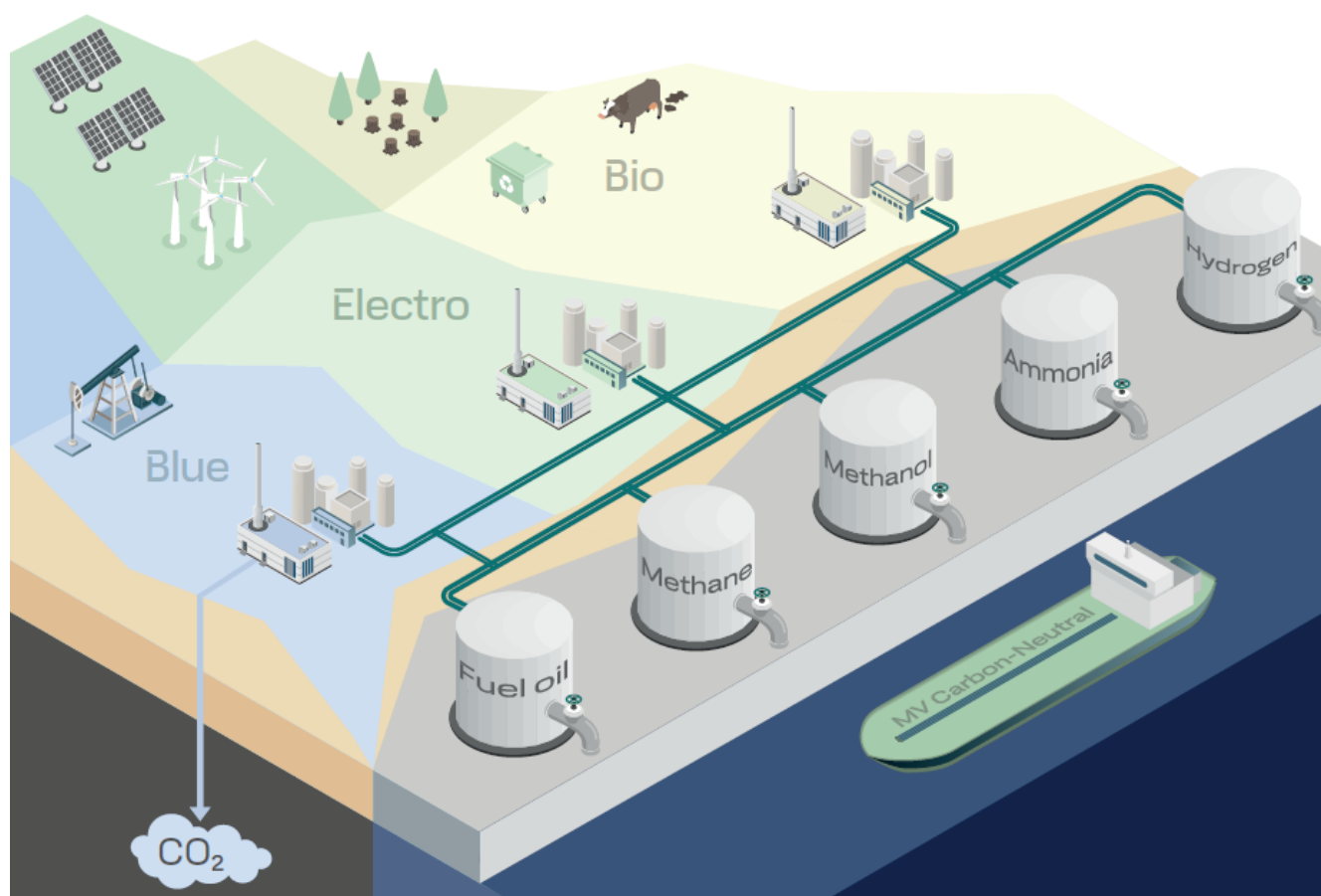
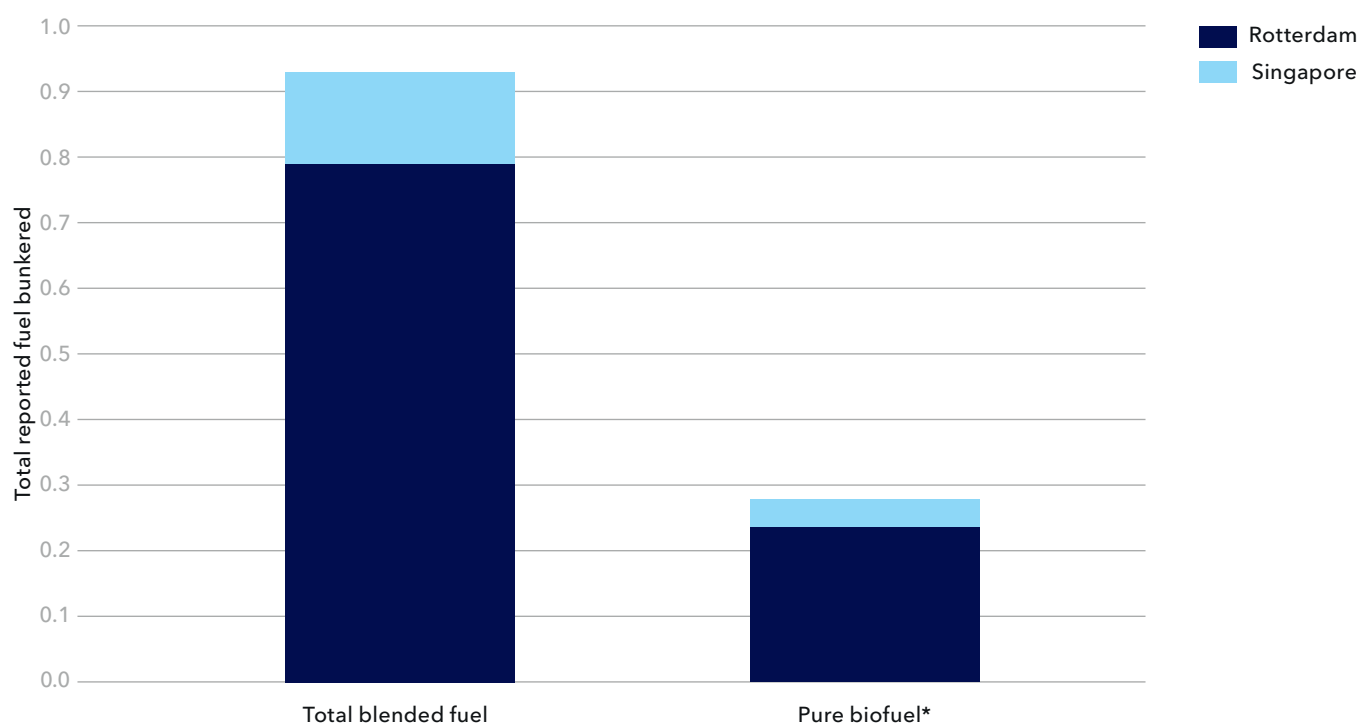


FIGURE 3-2

Reported bunkering of biofuels in 2022 in Rotterdam and Singapore. Based on news articles by Reuters¹ and Tradewinds². We assume that 1 tonne fuel = 1 toe.

Units: Mtoe



*assuming a weighted average blend consisting of 30% biofuel

3.2 Practical considerations of biofuel use

A key reason why biofuels are seen as an attractive decarbonization pathway for vessels, is their ability to be used onboard existing vessels without modifications (i.e., drop-in capability). This holds largely true for bio-methanol and bio-LNG if the correct equipment onboard is installed, since they have practically the same properties as their fossil-based counterparts. For biodiesels³ and bioliquids⁴ used to replace fuel oils and distillates, on the other hand, drop-in capability depends on factors such as what feedstock the biofuel is based on, the production process, and the storage time. It is therefore important to evaluate each fuel type on a case-by-case basis to make sure that the fuel specification⁵ and quality is compatible with the

intended applications onboard the vessel. Otherwise, there is a risk of damage to equipment and loss of power onboard the vessel.

Due to the lack of long-lasting trials, there is a shortage of experience with regards to biodiesels and bioliquids and their compatibility with existing onboard machinery. The most widely used liquid biofuels in shipping are FAME (Fatty Acid Methyl Esters) and HVO (Hydrotreated Vegetable Oil). Both of these have their own characteristics which should be considered by users. For example, the oxidative stability of FAME is low, leading to degradation of the fuel during long-term storage. HVO, on the other hand, has high oxidation stability, and can be stored for long periods.

1) <https://www.reuters.com/business/energy/singapore-2022-bunker-fuel-sales-dip-43-yy-479-mln-tonnes-2023-01-13/>

2) https://www.tradewindsnews.com/ports/rotterdam-aims-for-regular-methanol-bunkering-by-the-summer/2-1-1395133?utm_source=email_campaign&utm_medium=email&utm_campaign=2023-01-30&utm_term=tradewinds&utm_content=daily

3) A general term referring to refined liquid fuels of biological origin (FAME, HVO, etc.)

4) A general term which refers to unrefined liquid fuels of biological origin (biocrudes, bio-oils, vegetable oils etc.).

5) See, e.g., [ISO 8217:2017 - Petroleum products – Fuels \(class F\) – Specifications of marine fuels](#)

In the future, other biofuel types may emerge, and more specific guidelines will evolve and be established as more tests are conducted. Before transitioning towards the use of biodiesels and bioliquids onboard vessels built to run on fuel oils, it is important to investigate some key parameters and areas onboard the vessel, see Figure 3-3.

To reduce the risk of damage to equipment onboard the vessel, we recommend the actions and steps given in Figure 3-4 before a transition to biofuels.

FIGURE 3-3

Key parameters worth investigating when considering a transition to biodiesels and bioliquids.

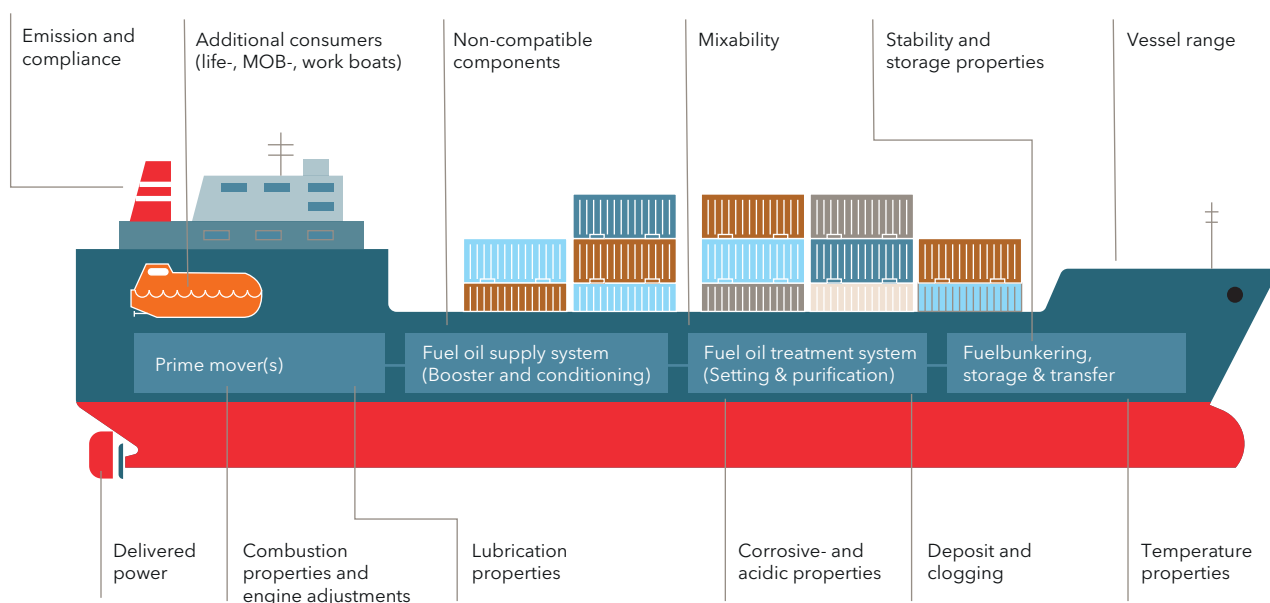
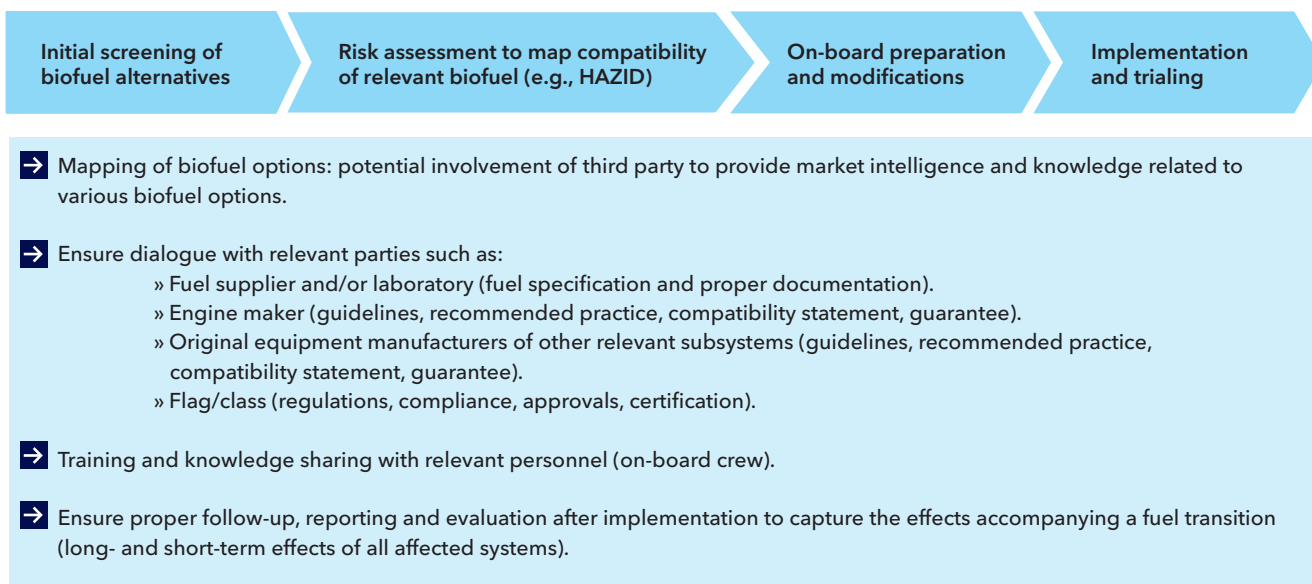


FIGURE 3-4

Technical aspects of a biofuel transition process and relevant items recommended to consider for a ship owner.



3.3 Regulatory status

Because biofuels have a relatively short track-record as fuel for ships, the maritime regulatory framework for biofuels is still under development. Two key areas of current regulations relate to emissions of NO_x and GHG⁶ and biofuels' regulatory status within these areas is described in Table 3-1.

In addition to the below, it is important to note that the status of biofuels under DCS & CII is to be considered at MEPC 80, in July. IMO is also in the process of developing Lifecycle Assessment (LCA) guidelines for all marine fuels, including biofuels. The first version of this is expected to be ready at MEPC 80.

6) Greenhouse gases, e.g., CO₂

TABLE 3-1

Regulatory status of biofuels with respect to GHG and NO_x regulations.

GHG	EEXI/EEDI	No effect. The EEXI and EEDI is a design requirement using the carbon content of the standard reference fuel used in the test report of the NO _x Technical File.
	DCS & CII	Reduction of CII if accepted by flag. Use of biofuels is currently not covered explicitly by DCS or CII guidelines. Therefore, a non-standard approach needs to be taken in determining tank-to-wake emissions, subject to acceptance from the vessel's flag administration.
	EU MRV & EU ETS	Reduction of the annually reported CO₂ emissions. If biofuel is certified to meet the EU RED's sustainability and GHG emission saving criteria, CO ₂ emissions shall be taken as zero.
	FuelEU Maritime	WtW GHG emissions reduced. If biofuel is certified to meet the EU RED's sustainability and GHG emission saving criteria, well-to-wake GHG emission values for the specific biofuel is to be used. Non-sustainable biofuels and biofuels based on food and feed-based crop are considered equivalent to fossil fuels.
NO_x	Fuels with biofuel content <30%	No NO_x testing or assessment required. Not necessary to prove that the NO _x limits are not breached when using fuels with a biofuel content of less than 30%.
	Fuels with biofuel content >30%	In case no changes to NO_x critical components are needed, use is permitted. If it is confirmed by the engine manufacturer that the engine can run on the fuel, and no settings or NO _x -critical components need to be changed outside those given in the approved NO _x Technical File, then biofuel use is permitted.

4. Biofuel production and potential

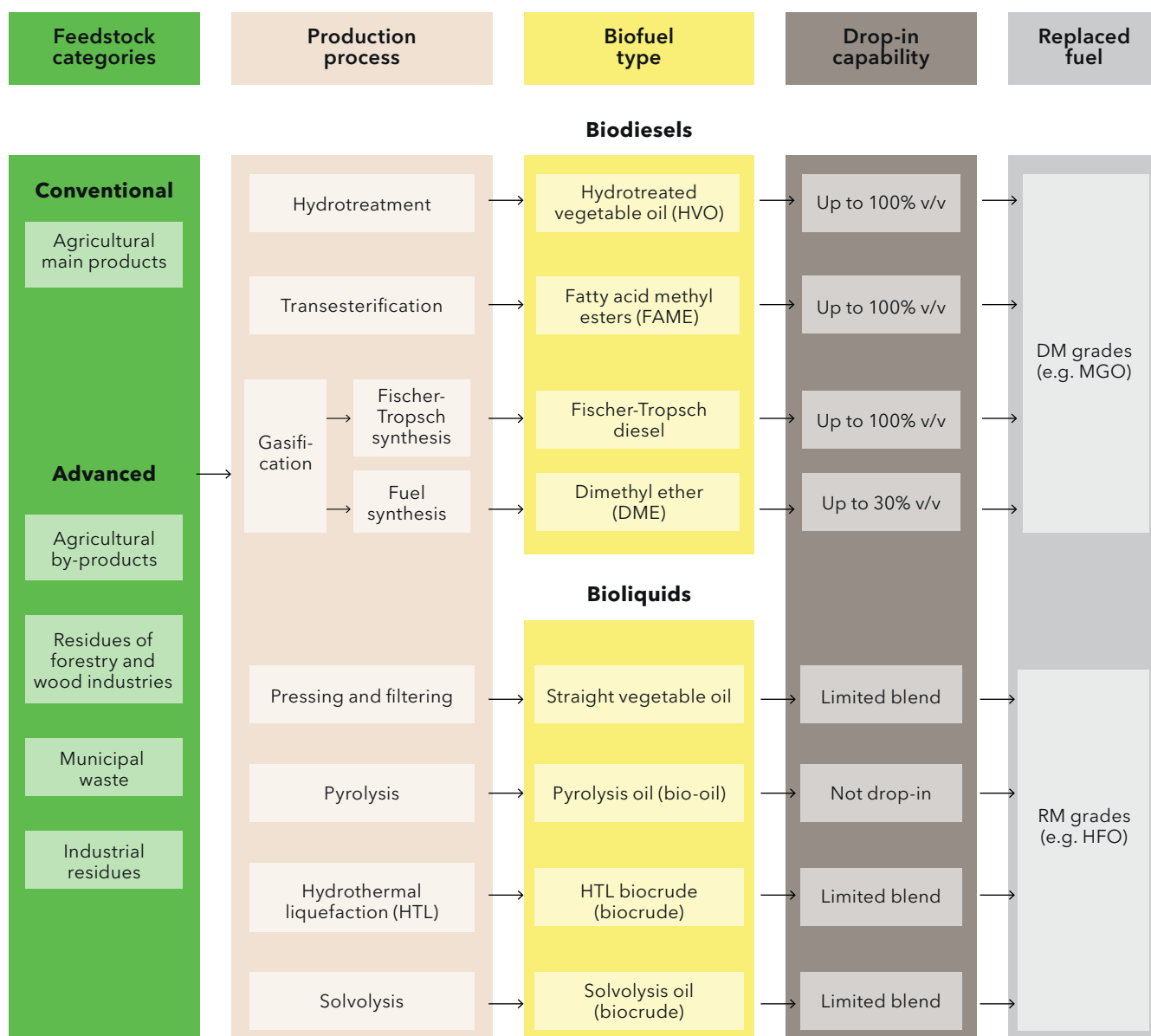
Biofuels are made by converting organic matter (also known as biomass) into a fuel product. While CO₂ is emitted when combusting most biofuels, this is negated by the fact that biomass absorbs CO₂ from the atmosphere during growth, giving biofuels the potential to be carbon-neutral.

Biofuels can be made in several different ways from many different feedstocks, and the resulting biofuels have dif-

fering qualities that have impacts on their capability to be used as drop-in fuels, see Figure 4-1. The different feedstocks used have implications for the sustainability of the biofuels. In addition – as we explore in this chapter – there are limits to the availability of sustainable and economical feedstocks for biofuel production. Biomass sources from agricultural main products are usually referred to as conventional, while those from non-food or non-feed sources are termed advanced.

FIGURE 4-1

Production of biofuels from several feedstocks using different process, resulting in different types of liquid biofuels with differing qualities.



4.1 Biofuel potential

Due to physical constraints on the amount of suitable feedstock for biofuels, such as amounts of municipal waste and used cooking oil, there is an upper limit on the volume of biofuels that can be produced. We refer to this upper limit as the biofuel potential.

To estimate the sustainable and economical biofuel potential we use a stepwise approach:

1. First, the theoretical biomass potential was assessed by using data on, e.g., agricultural production and waste production.

2. The sustainable and economical potential was then estimated by the use of:

- a. technical restrictions (e.g., urban waste collection rates)
- b. limitations from sustainability criteria (e.g., RED II Sustainability criteria, only considering advanced biomass sources)
- c. economic boundary conditions (e.g., non-consideration of fractions profitable in other markets).

Our methodology for estimating sustainable and economical biofuel potential is based on a thorough review and alignment with existing studies in this area (see, e.g., (S2Biom, 2017) and (Brosowski, 2016)). A high and low potential estimate was made by varying sustainability criteria and economic considerations for sourcing biomass for biofuel production.

FIGURE 4-2

Approach for estimation of sustainable and economic biomass potential, from theoretical potential to sustainable and economic potential.

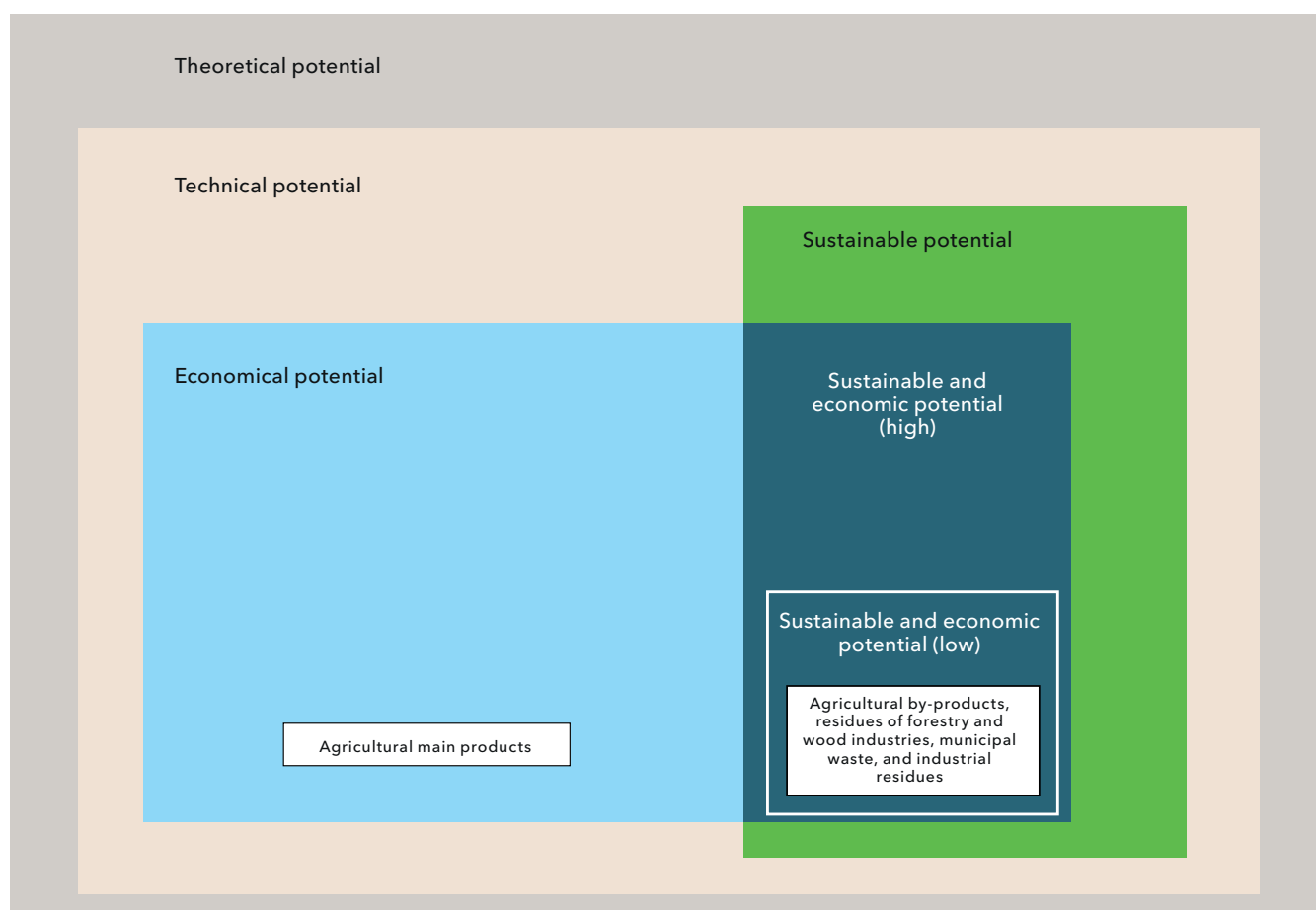
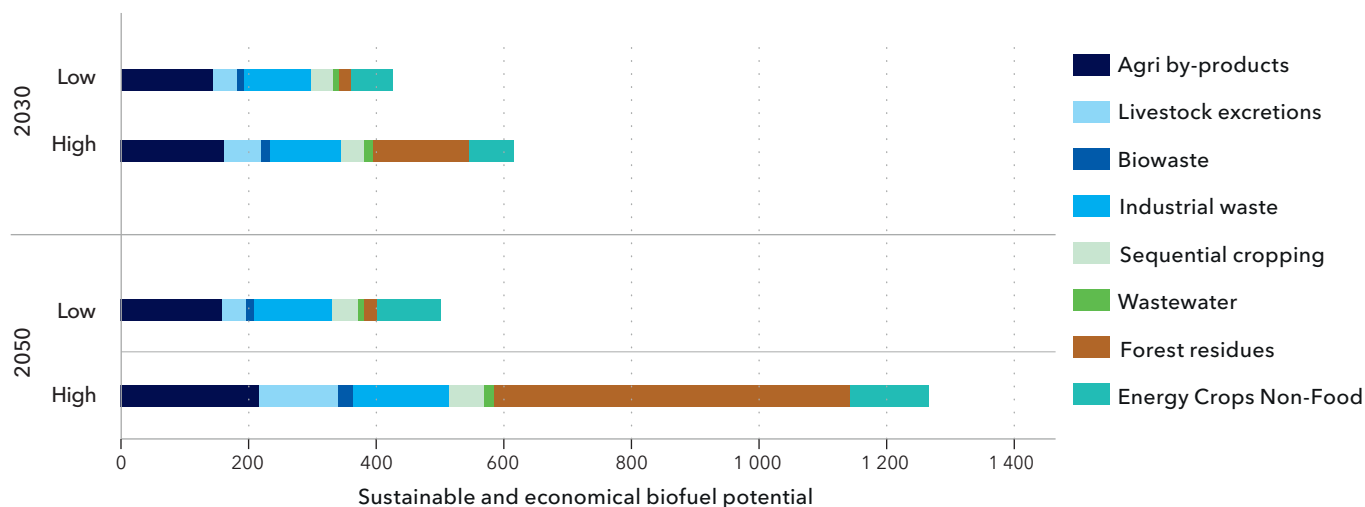


FIGURE 4-3

Sustainable and economical biofuel potential by feedstock category in 2030 and 2050.

Units: Mtoe



As a result of this analysis, we estimate the potential for each of the biomass categories (see Figure 4-3).

We estimate that the global sustainable and economical biofuel potential lies between 400 – 600 Mtoe per year in 2030, after converting biomass to biofuel assuming a 50% conversion efficiency. This could grow to 500 – 1 300 Mtoe per year in 2050 (Figure 4-3). These estimated potentials

are lower than what can be found in many other studies (see, e.g., (IRENA, 2022) and (IEA, 2021)). A key reason for this is that we apply strict sustainability measures in line with the EU's Renewable Energy Directive II (RED II). This directive sets out criteria for sustainable biomass production, including the protection of high-carbon stock forests and the avoidance of negative environmental impacts.



4.2 Present and planned production of biofuels

We have assessed the current and future global biofuel production capacity by developing a database containing in-operation plants and planned biofuel production projects worldwide. The database was created by compiling a range of different public sources and datasets (e.g., (IEA Bioenergy, 2022)) and allows us to estimate the current and future production capacity for biofuels. Currently, the database has information collected on up to 5 000 biofuel production facilities. This represents one of the most comprehensive biofuel production databases to our knowledge. Figure 4-4 shows the location of those projects (in operation or planned) identified to use advanced biomass sources as primary feedstock.

Figure 4-5 shows the cumulative biofuel production capacity in our database, broken down into main feedstock-type. We see that today, biofuel production is dominated by agricultural main products – food or feed crops grown with the primary purpose to produce biofuels – with some production of biofuels via residual sources. However, looking towards 2026, we see that a significant number of projects involving production from advanced biomass sources are expected to come on-stream. In particular, we see residues of forestry and wood industries emerging as a significant feedstock for advanced biofuel production.

Although our database indicates that the global biofuel production capacity for advanced biofuels could grow from 11 Mtoe per year in 2023 to 23 Mtoe per year in 2026, much remains to be done in order to scale up production to significantly contribute to the decarbonization of shipping.

FIGURE 4-4

Map of existing production and planned projects for advanced biofuels in our database, by capacity shown as size of circle and location.

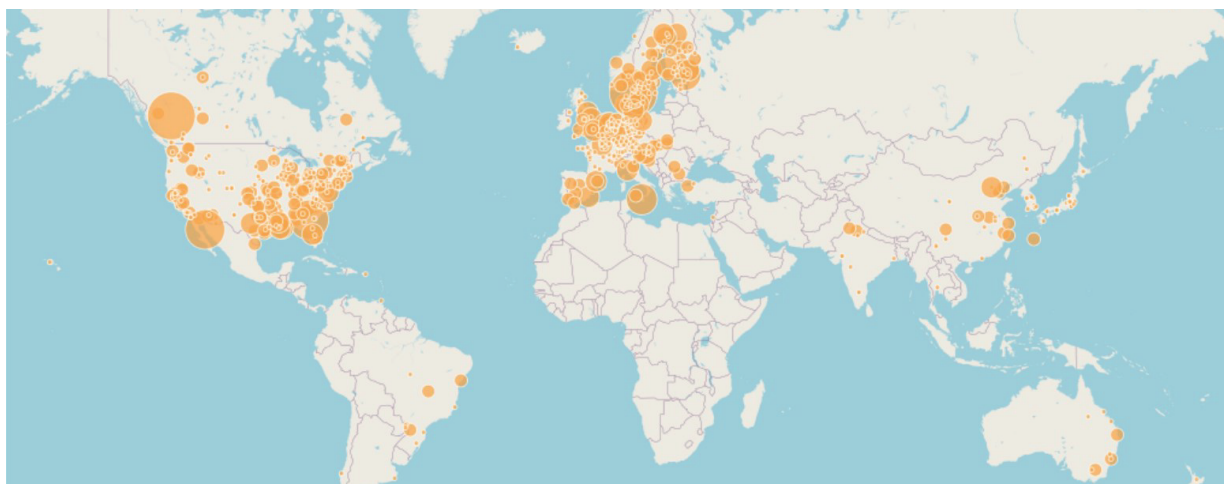
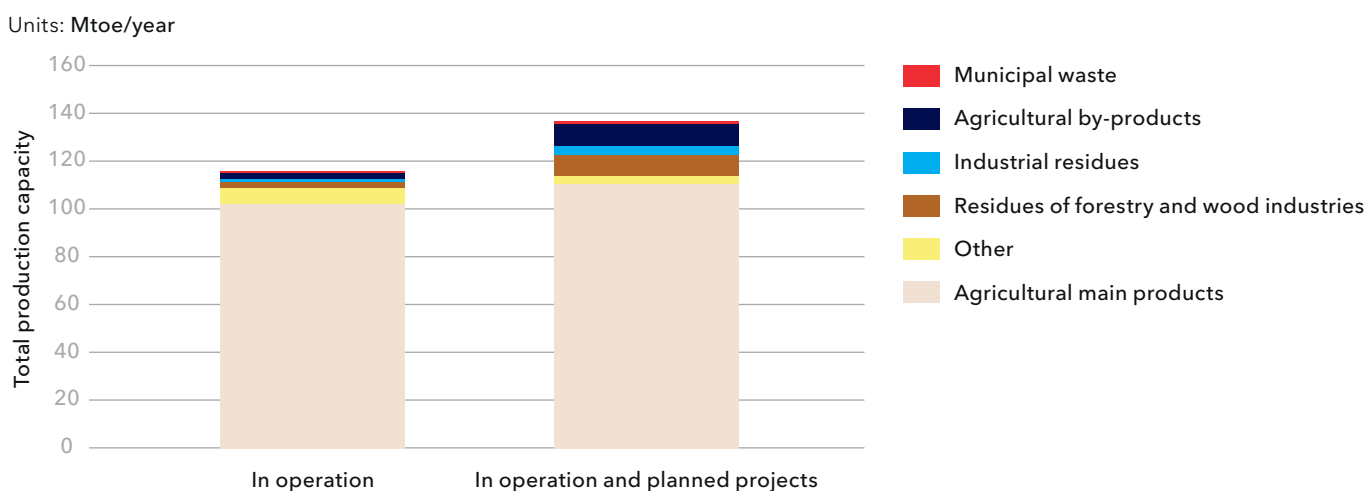


FIGURE 4-5

Existing and planned production capacity for biofuels in our database, divided by primary feedstock categories. Planned biofuel production projects in the database are expected to come on-stream in the time-period 2023-2026.



5. Competition for biofuel

Biofuels and biomass are attractive for sectors other than shipping, as they strive towards decarbonization. In Figure 5-1 we show to what extent biofuels and bioenergy are being used in different sectors today – not considering sustainability criteria – as total energy used (dark blue) and amount of bioenergy used (light blue)⁷. The biomass-up-take today is most significant within cooking, water & space heating, timber, pulp & paper, and road transport. For cooking, water & space heating (buildings), mostly traditional biomass sources are being applied today (e.g., fuel wood) (DNV, 2022a). Total energy demand today (including the non-energy sector) is equivalent to approximately 10 500 Mtoe per year, of which, marine transport makes up about 280 Mtoe per year (3%).

We estimate in Chapter 3.1 that the global sustainable and economical biofuel potential in 2030 lies between 400 – 600 Mtoe per year. This could grow to 500 – 1 300 Mtoe per year in 2050. Agricultural residues, industrial waste and non-food energy crops are the largest sustainable biomass-sources. In the long-term, improved waste management and collection of organic waste, further development of biomass sourcing (e.g. improved yields), increased land availability and improved management of forest and its residues have the potential to significantly increase biofuel production, reflected in the largest estimate.

The current fuel consumption of shipping is equivalent to about 280 Mtoe per year. In the scenario from DNV's Maritime Forecast to 2050 (DNV, 2022b) with the highest use of biofuels – where shipping decarbonizes by 2050 (accounting for moderate fleet growth) using a combination of logistics improvements, speed reduction, energy efficiency measures, shore power and biofuels – shipping needs about 250 Mtoe of sustainable biofuels annually by 2050. This would account for 20-50% of total potential supply in 2050. In Figure 5-2 we show the high and low estimates of potential for sustainable biofuels and the maximum simulated demand from shipping from 2030 to 2050.

Based on the results presented in this white paper, we believe it is likely that biofuels can and will play a significant role in decarbonizing shipping. However, in the short-term, there are limitations on production capacity of advanced biofuels that may limit the supply to shipping, and a large-scale building out of production capacity is needed. In the longer-term, depending on the extent to which other industries use bioenergy as a pathway to decarbonization, there could be limitations on the availability of sustainable biomass to produce marine biofuels.

As a result, biofuels are unlikely to be the only solution to shipping's goal of transitioning to zero GHG emissions in the future.

⁷) Note that depending on sector, the bioenergy demand refers to Mtoe biomass energy or Mtoe biofuel. There are conversion losses when producing biofuels from biomass, they are different for different feedstock and production processes, but roughly 2 Mtoe of biomass is needed to produce 1 Mtoe of biofuel. For example, within the buildings sector the bioenergy demand is largely supplied by biomass directly, while within transportation, it is supplied by biofuels.

FIGURE 5-1
Current global energy demand by sector (DNV, 2022a).

Units: Mtoe

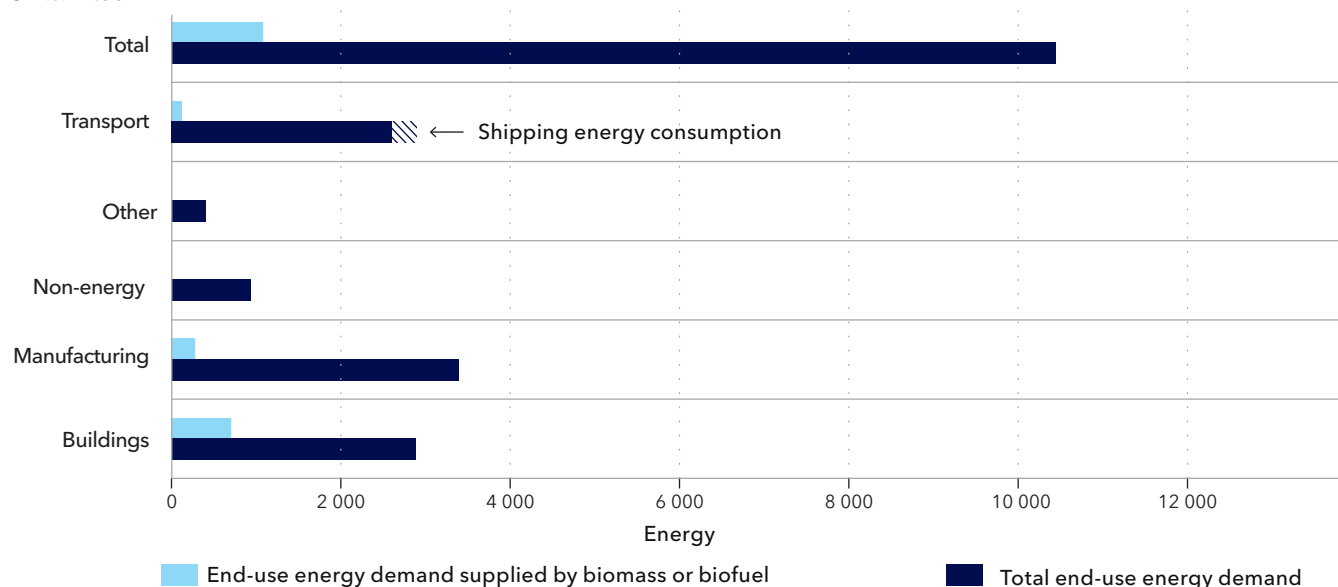
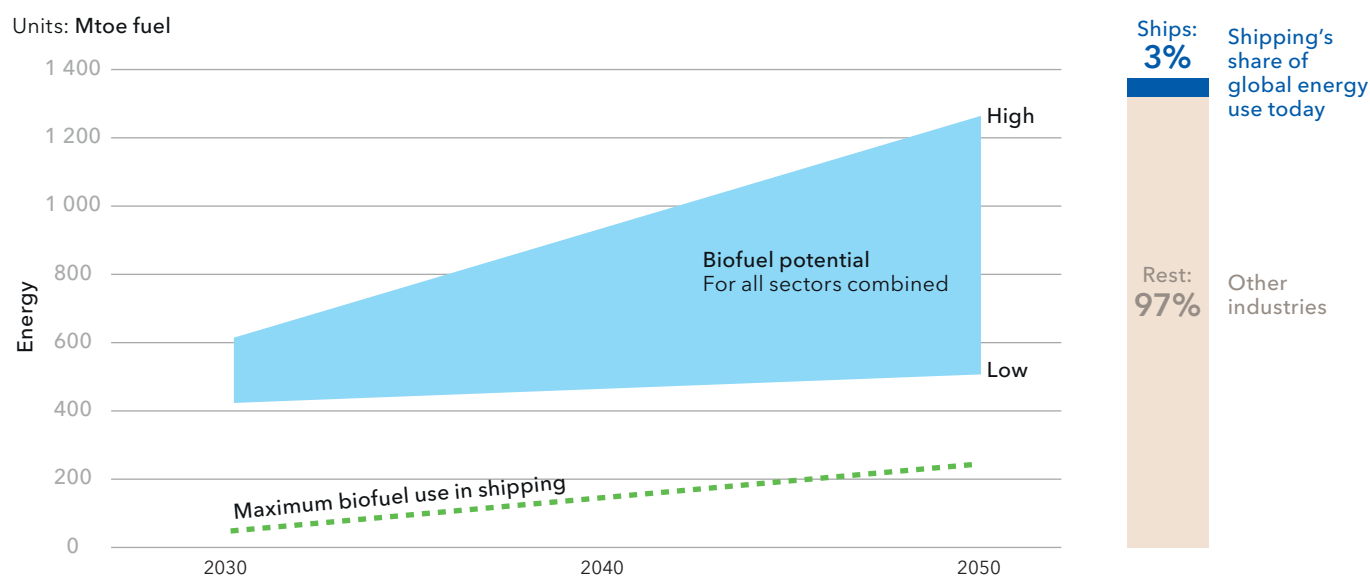


FIGURE 5-2

Potential of global supply for sustainable biofuel compared to maximum simulated demand from shipping 2030 - 2050 (left), and shipping's share of global energy use today (right).



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