Waterborne Transportation Roadmap

November 2024

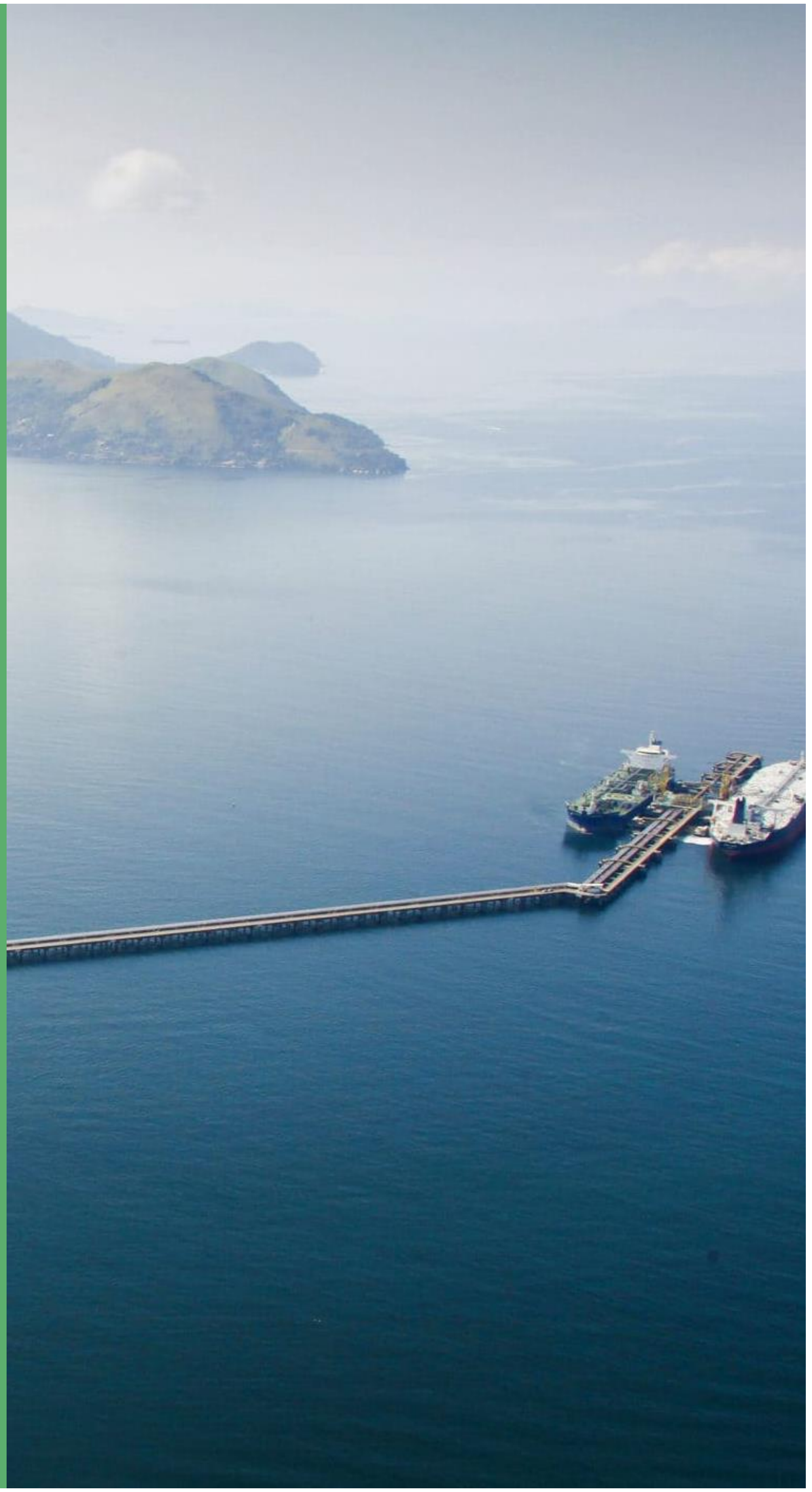
MINISTÉRIO DE MINAS E ENERGIA

GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO

Public Values

The Waterborne Transportation Roadmap document addresses strategic issues for the sustainable and efficient development of this vital sector for the global economy. Maritime transport is responsible for approximately 90% of international trade, and a document that outlines an action plan for the future of the industry can have a broad impact across various spheres of society.

The information provided enhances sector predictability, reinforces national energy security, guides decisions for various stakeholders including governments, businesses, and civil society, and serves as a foundation for creating public policies.



Disclaimers

This publication contains projections about future events that reflect the perspective of the Energy Research Office (EPE). These projections involve a wide range of known and unknown risks and uncertainties, and therefore the data, analyses, and any information in this document do not guarantee future achievements or outcomes.

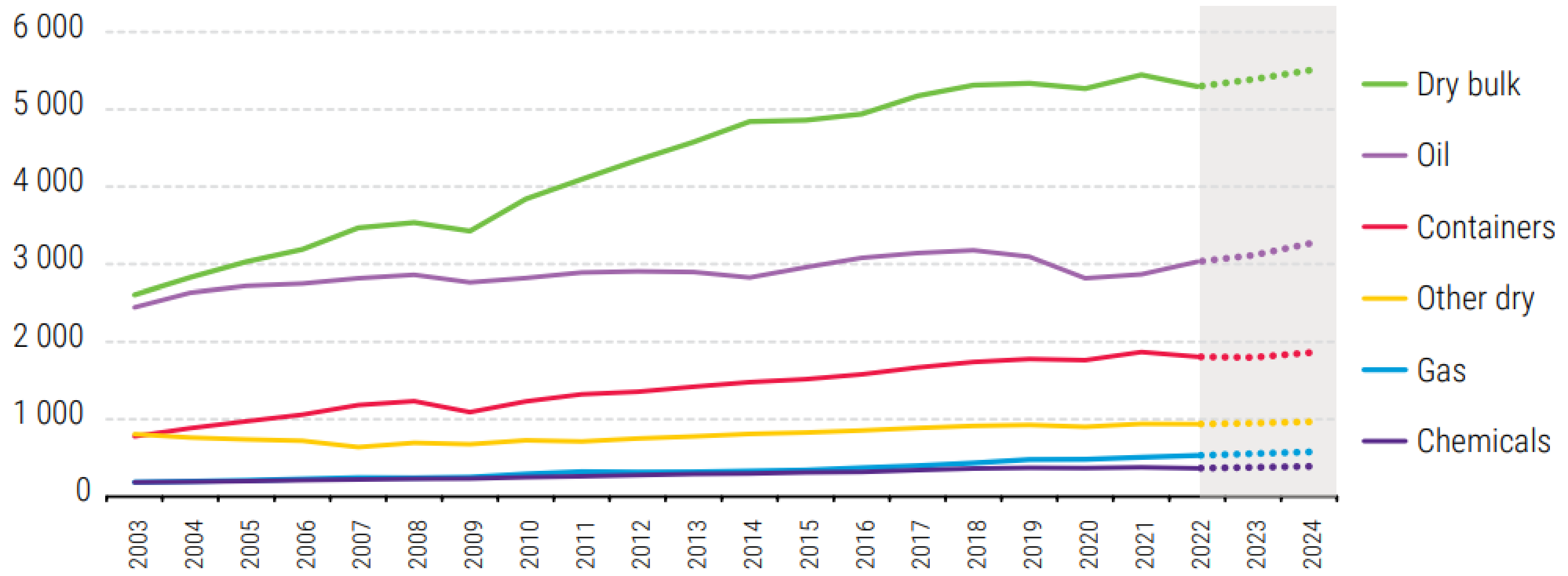
This document is informative, as a preliminary study, and is intended to support planning of the national energy sector. Decisions regarding policy formulation, strategic direction, investment decisions, or business strategies depend on other public and private institutions.

EPE is not liable for any actions or decisions made by individuals or entities based on the information contained in this document.

International Maritime Transportation

Maritime trade and GHG emissions

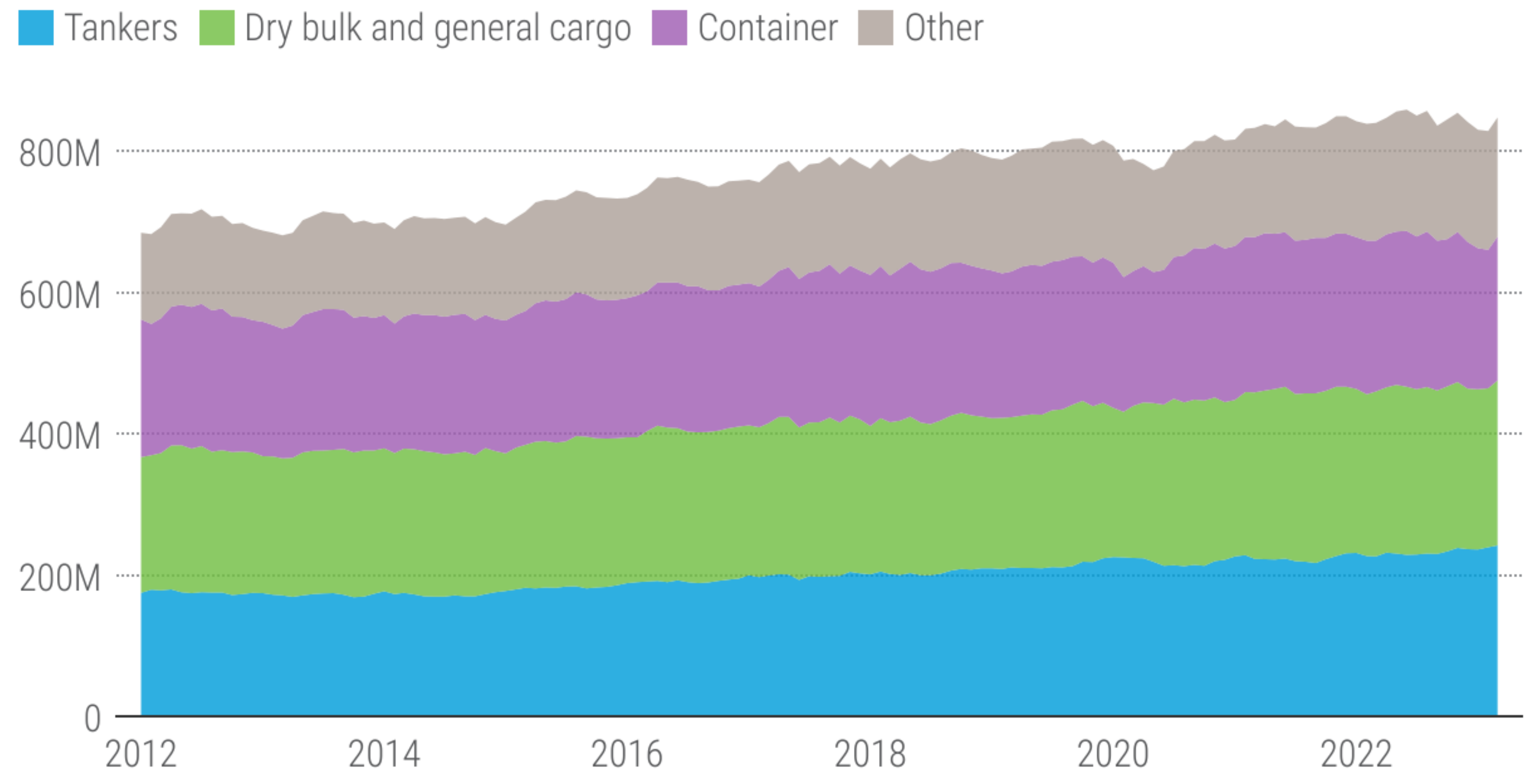
International maritime trade, 2003–2024 (Million tons loaded)



Source: [Unctad]

Note: 2023 and 2024 are forecast. “Dry bulk” includes major bulks (iron ore, coal and grain) and minor bulks (metals, minerals, agribulks and softs); “Oil” encompasses crude oil and refined oil products; “Other dry” is an estimation of all other dry trade that is not included in major/minor bulks, for instance, cars and other vehicles, roro and project cargoes, as well as reefer cargoes that don’t go in containers and breakbulk cargoes that are not in the minor bulk category; “gas” includes LPG, LNG and ammonia.

Carbon Dioxide emissions by main vessel types, tons, 2012-2023



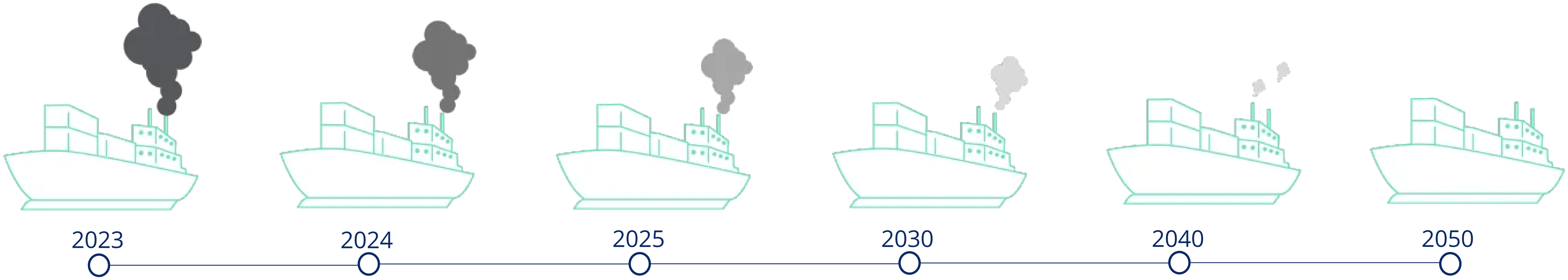
Note: The group “other” includes vehicles and roll-on/roll-off ships, passenger ships, offshore ships and service and miscellaneous ships.

Source: UNCTAD based on data provided by Marine Benchmark, June 2023.

Maritime transport plays a crucial role in the economy, accounting for approximately 90% of world trade.

International shipping is responsible for 3% of GHG emissions and essential for world trade.

Extensive regulation is increasing the pressure to decarbonize



IMO Short Term
EEXI and CII are IMO directives requiring significant energy efficiency improvements in the existing fleet.

EU ETS
Shipping to be included in the EU ETS carbon trading system.

Fuel EU Maritime
EU Regulation to limit the yearly average GHG intensity of energy used on-board a ship sailing from and/or to EU Ports.

Firm Reduction Targets
EU: 40% reduction in carbon emissions relative to 2018 levels.

IMO: Reduction in total GHG emissions by at least 20%, striving for 30%, compared to 2008 levels.

Indicative Checkpoint
The IMO: Reduction in total GHG emissions by at least 70%, striving for 80%, compared to 2008 levels.

Zero Emissions
EU targets zero emissions by 2050 while the IMO aims to reach net-zero GHG emissions (considering different national circumstances.

Source:Clarksons

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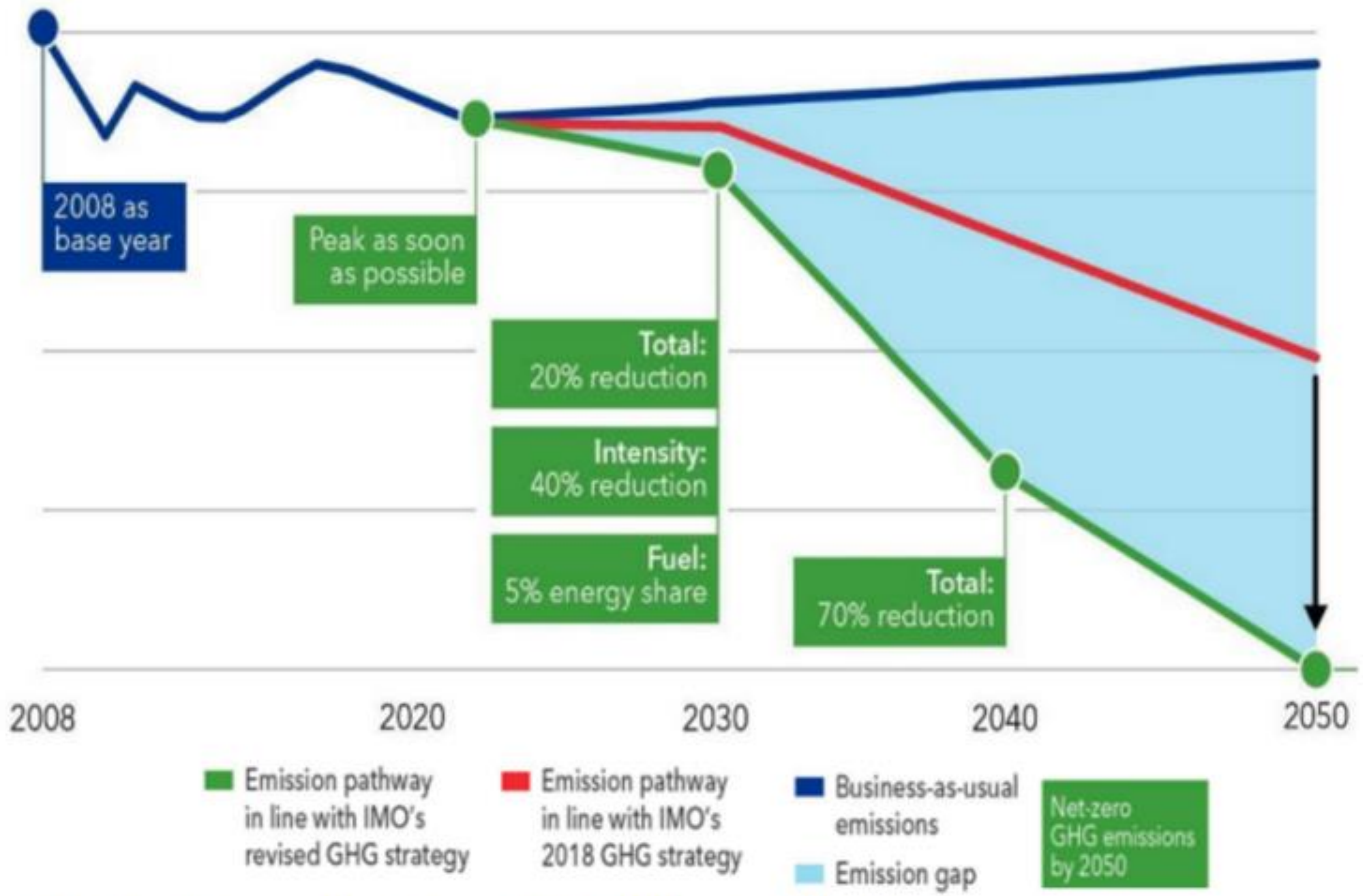
The revised International Maritime Organization (IMO) GHG Strategy

Minimum Indicative Checkpoints in IMO GHG Strategy



Total: well-to-wake GHG emissions; **Intensity**: CO_2 emitted per transport work;
Fuel: uptake of zero or near-zero GHG technologies, fuels and/or energy sources

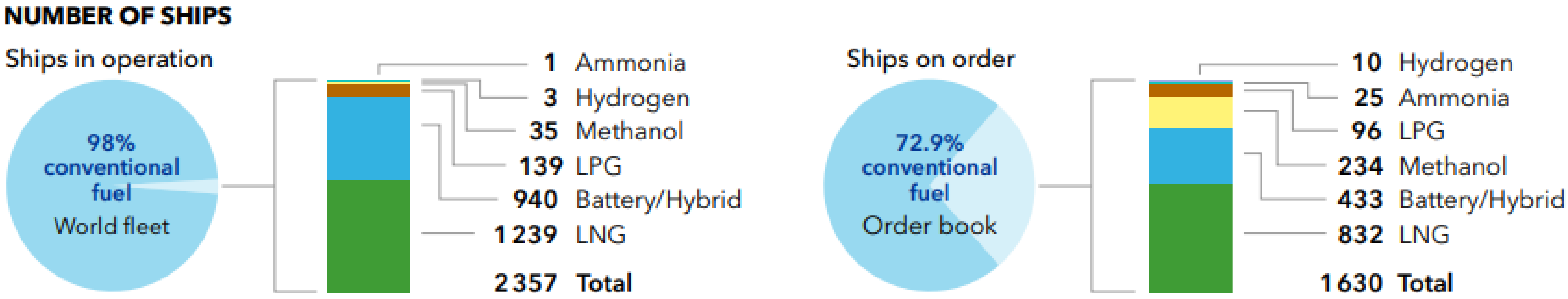
Fonte: *LLoyd's Register*

In July 2023, IMO Member States adopted the 2023 IMO Strategy on Reduction of GHG Emissions from Ships, with enhanced targets to tackle harmful emissions.

The revised IMO GHG Strategy includes an enhanced common ambition to reach net-zero GHG emissions from international shipping by or around 2050, a commitment to ensure an uptake of alternative zero and near-zero GHG fuels by 2030, with indicative check-points for international shipping to reach net-zero GHG emissions for 2030 (by at least 20%, striving for 30%) and 2040 (by at least 70%, striving for 80%).

Alternative fuel uptake in the world fleet in number of ships (upper)

Status in June 2024



Source: IHSMaukit e DNV

- The companies have already started orders for new vessels seeking to meet IMO targets.
- LNG is still the main choice, and it is also possible to use it in the "dual-fuel" mode with bunker. There is also an increase in the use of methanol, also in the dual-fuel mode.
- Currently, most orders of LNG-powered ship are of LNG carriers (use of a transition fuel), especially due to increased investments in LNG export capacity around the globe.

Alternatives for decarbonization

Solutions that contribute to the decarbonization of maritime transport

GHG reduction potentials

LOGISTICS AND DIGITALIZATION	HYDRODYNAMICS	MACHINERY	ENERGY	AFTER-TREATMENT
Speed reduction Vessel utilization Vessel size Alternative routes	Hull coating Hull-form optimization Air lubrication Cleaning	Machinery efficiency improvements Waste-heat recovery Engine de-rating Battery hybridization Fuel cells	LNG, LPG Biofuels Electrification Methanol Ammonia Hydrogen Wind power Nuclear	Carbon capture and storage
>20%	5%-15%	5%-20%	0%-100%	0%-90%

Reducing GHG emissions potential (%)

Source: DNV

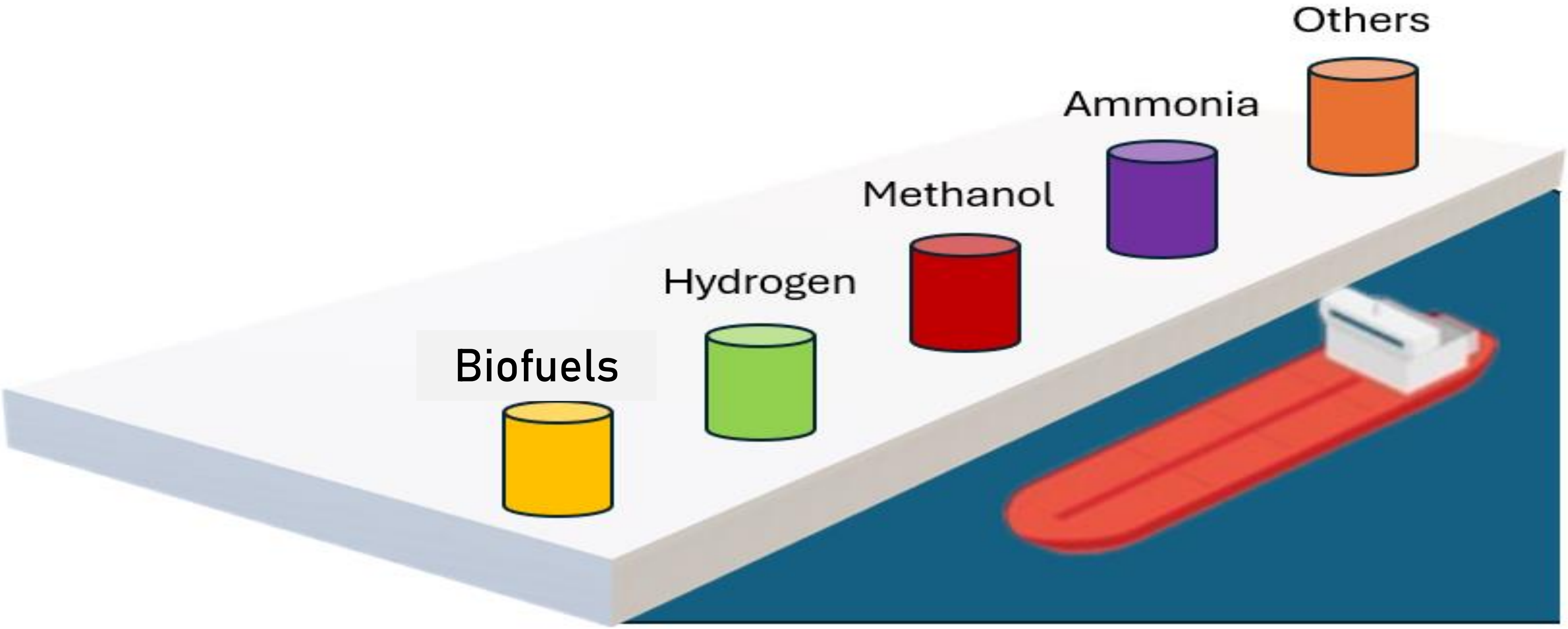
Readiness level of shipping fuels

Applicability
- Compatibility with current fleet
- Existing logistics

Regional and global availability
- Feedstocks
- Existing infrastructure

Local sustainability
- Impacts on biodiversity and water bodies

Global sustainability
- GHG emissions



Technical/economic maturity level
- Fuel production and utilization technologies

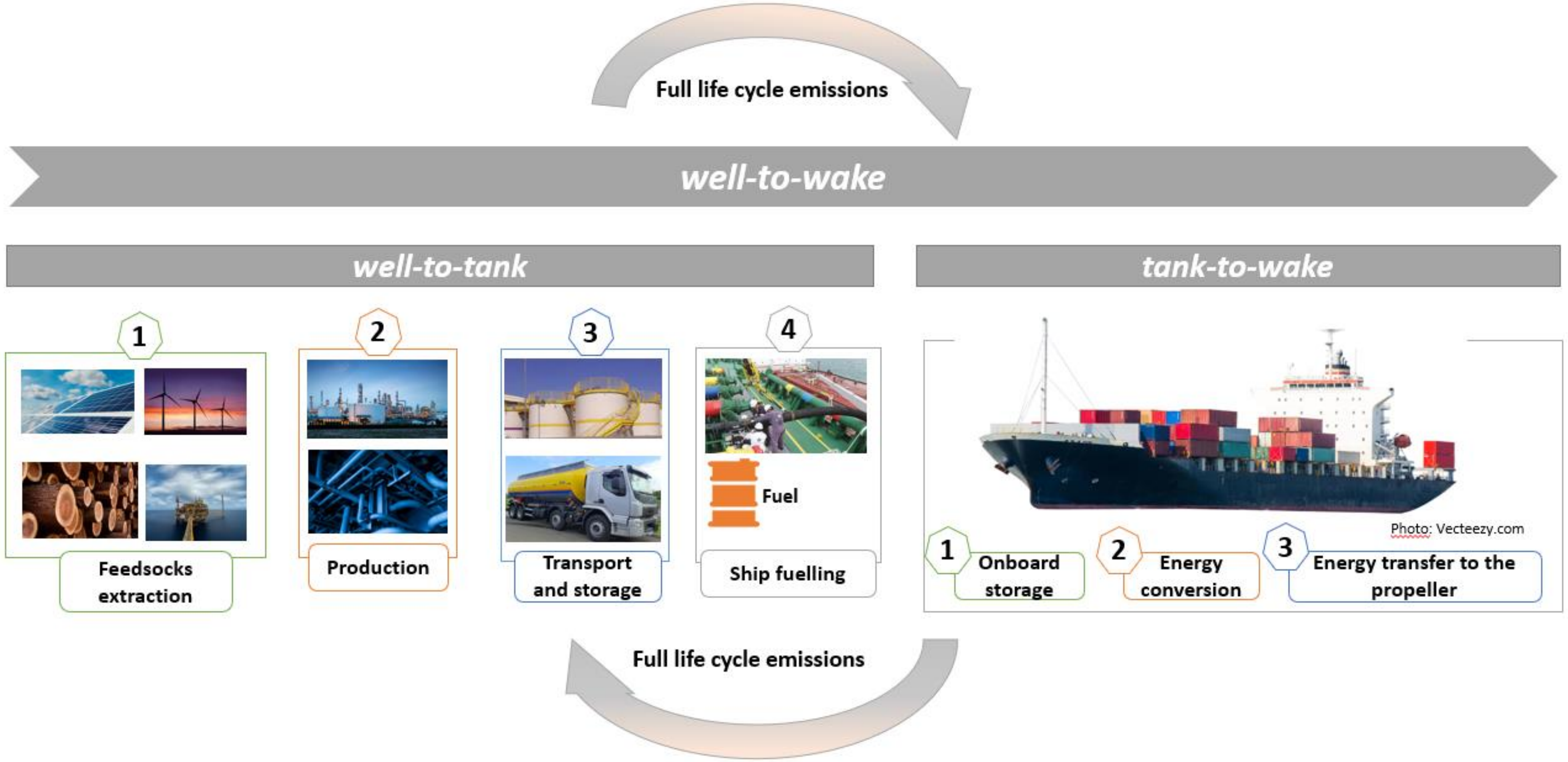
Volumetric energy density
- Additional tank space and loss of range

Economic
- Production, supply, and infrastructure costs

Security
- Regulation, toxicity, storage, handling, and operation

Standardization
- Fuel certification and specification

Full Life cycle emissions



A well-to-wake approach is essential to calculate life cycle GHG emissions of marine fuels.

Understanding the steps and challenges of emissions monitoring, as well as the stakeholders in your maritime scenario. The onboard combustion engine may be used for small or large GHG emissions, or the appropriate production process (for example) may have a high environmental impact.

Challenges

Short term

- High number of global vessels in operation, with slow renewal rates.
- Potential fuels (H2, ammonia, and methanol) still face challenges relative to safety, low energy density, and low TRL (Technology Readiness Levels).
- Prevalence of Diesel Cycle Combustion Engines in the Current Marine Fleet.
- Regulatory agreement between countries.

Medium and Long term

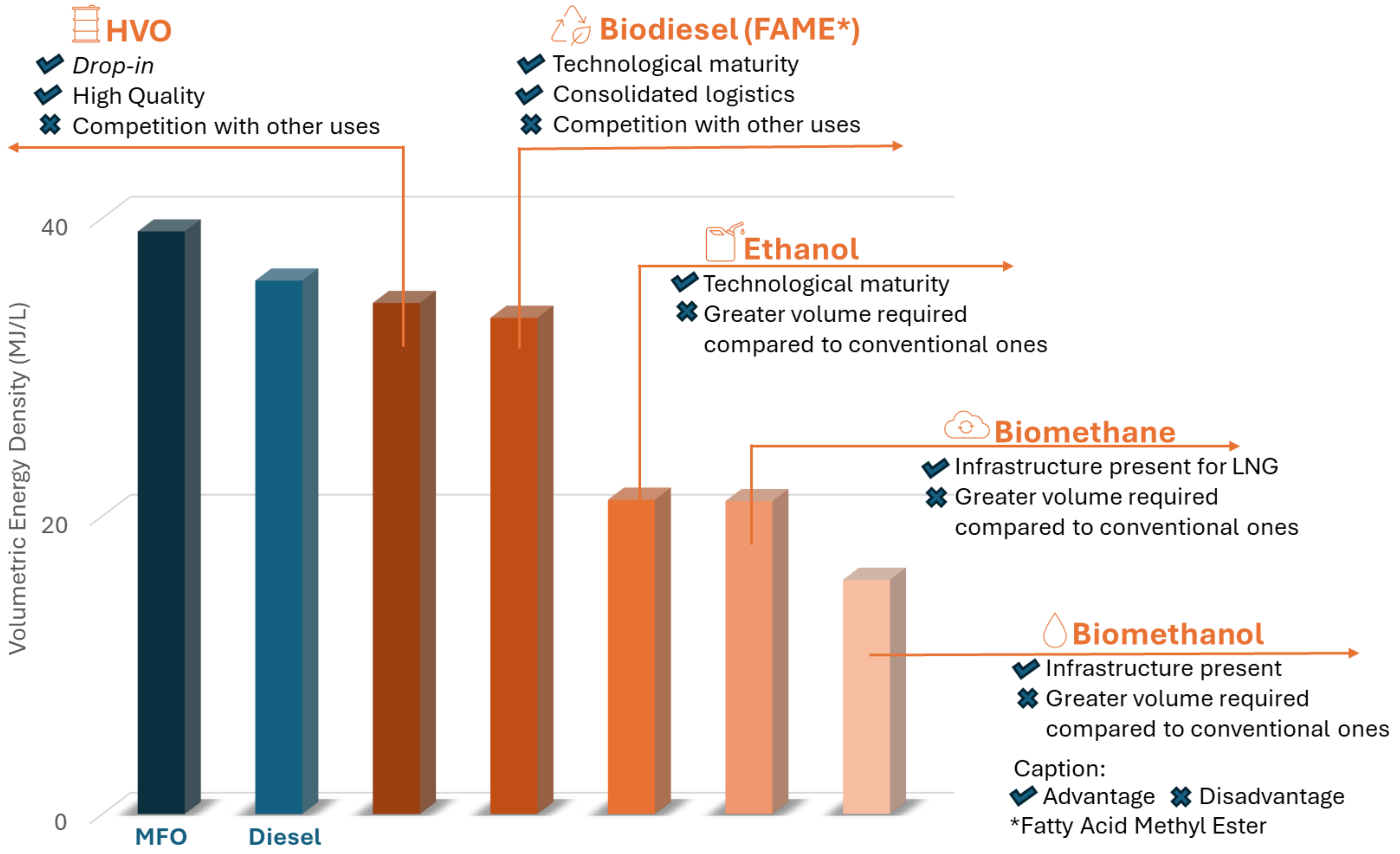
- High demand for alternative fuels, for supply of the maritime sector and other sectors.
- Availability of raw materials.
- Difficulty in achieving neutral or negative emissions with H2, ammonia and methanol, considering the LCA (Life Cycle Assessment) of each fuel.
- Investments in storage and supply infrastructure.

Alternatives to decarbonize waterborne transportation in Brazil

Challenges

- The Brazilian international trade profile, characterized by exports of commodities to distant markets, requires the use of alternative fuels with high energy density to optimize the cargo space on the ship and guarantee its autonomy.
- The age of the fleet, which is relatively young (around 15 years), indicates that it is necessary to prioritize technical and operational measures and the use of drop-in alternative fuels, given that they would not imply changes in the propulsion and supply system.
- Because the fleet is predominantly associated with the oil and gas industry, decarbonization of national water transportation will require the participation of that sector.
- The high number of supply ships means that special attention is given to this category, which operate only in short-distance transport and represent 37% of emissions in the EEZ.

Possible actions to decarbonize waterborne transportation in Brazil

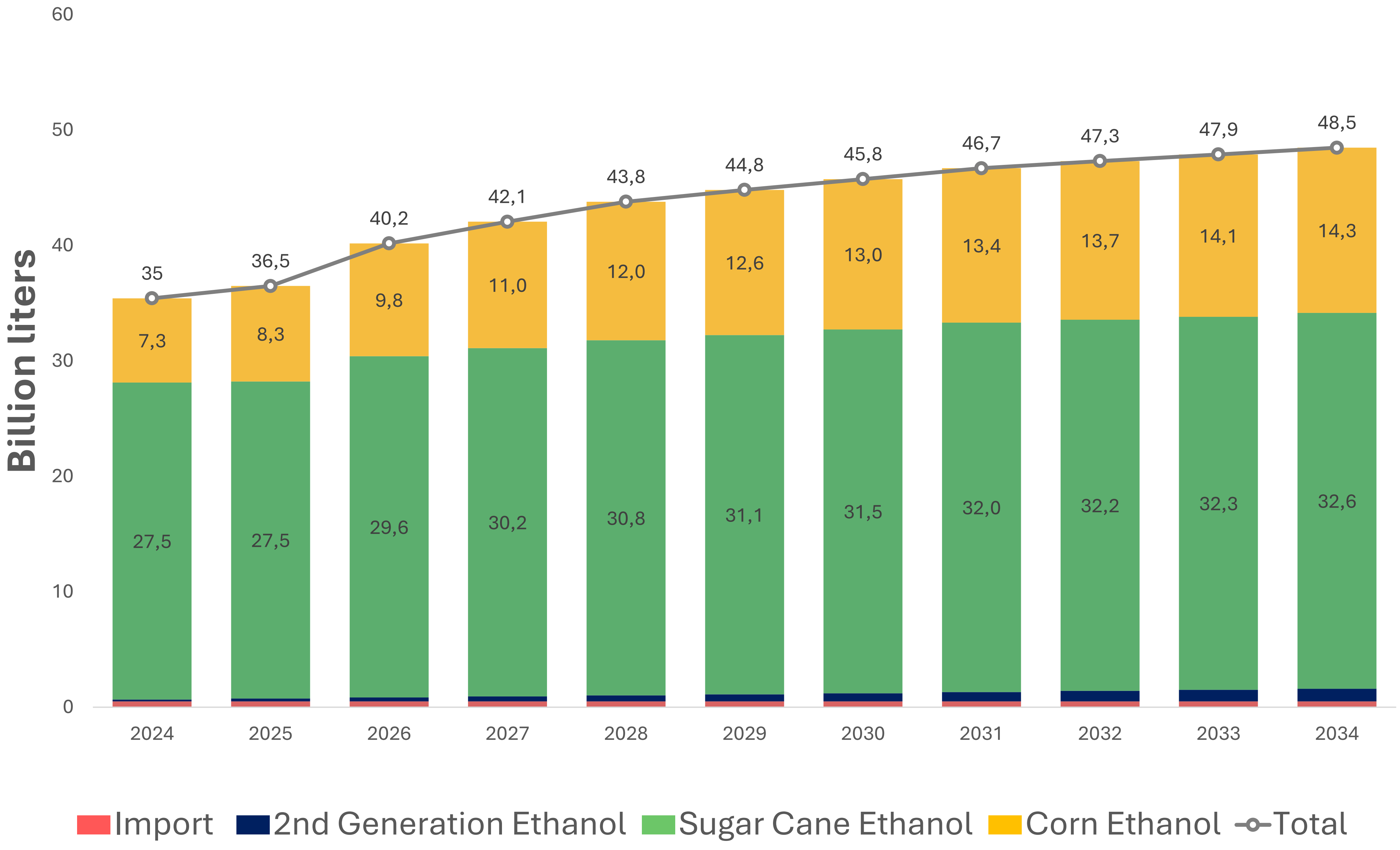


Biofuels can be an alternative to contribute to the reduction of GHG emissions in maritime transport:

- Have a lower carbon intensity than fossil fuels.
- Potential to meet the IMO target of adopting zero or near-zero emission technologies, fuels and/or energy sources, corresponding to at least 5% by 2030.

Possible actions to decarbonize waterborne transportation in Brazil

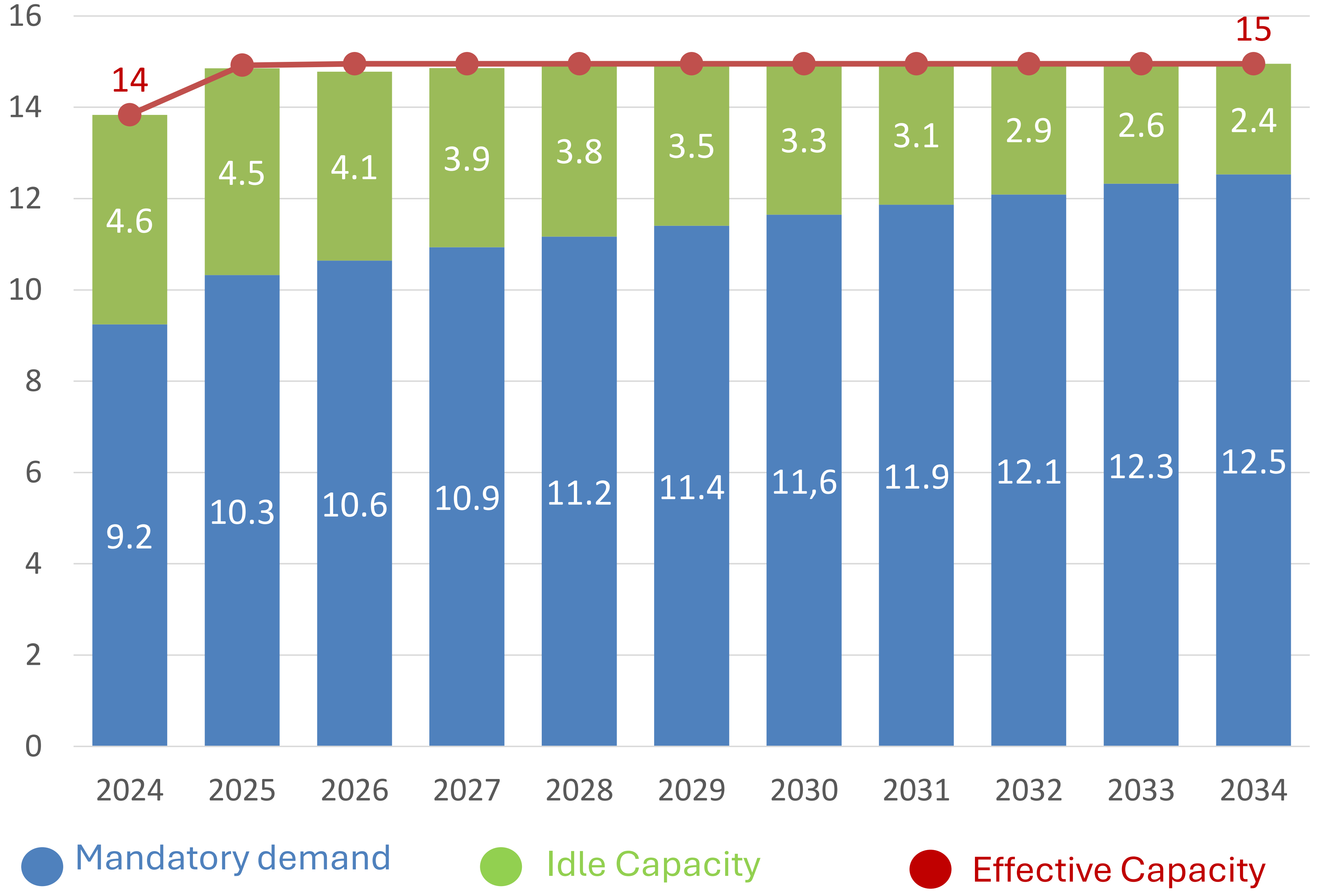
Ethanol supply (billion liters)



- Widespread production and infrastructure in Brazil.
- Technology exists so ethanol can be used on cabotage vessels on the Brazilian coast
- Need for modernization/retrofit of dual fuel vessels/engines.
- Brazil has an enormous potential of producing more corn by increasing its 2nd and 3rd crops. Which can potentially add a lot more ethanol producing capacity with very limited land use emissions.

Possible actions to decarbonize waterborne transportation in Brazil

Biodiesel production (billion liters)



- No need for structural adaptations to engines and vessels.
- Widespread production and infrastructure in Brazil, with idle installed capacity, which can be used to achieve this goal in a more agile way in the short term.
- In the revision of the 8217/2024 standard, ISO presented the specifications for the use of 100% biodiesel for navigation, with use conditioned to MARPOL/IMO evaluations.
- ANP Authorization No. 402/2024 allowed, on a special basis, the commercialization by Petrobras of marine fuel oil (bunker) with up to 24% biodiesel (volume), subject to the established specifications.
- Companies have already used the B100 as a substitute for fossil diesel in Brazilian inland vessels.

Preliminary Studies - Trajectories for the decarbonization of Brazil´s Waterborne transportation

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Preliminary Long-Term Studies – Building Trajectories

Trajectory Base

Emissions reduction techniques

Trajectory 2

No fossil fuels in 2050

Trajectory 3

No fossil fuels in 2050, prioritizing methanol and ammonia

Trajectory 4

No fossil fuels in 2050, prioritizing biofuels

4a

+ best agricultural practices combined with BECCS

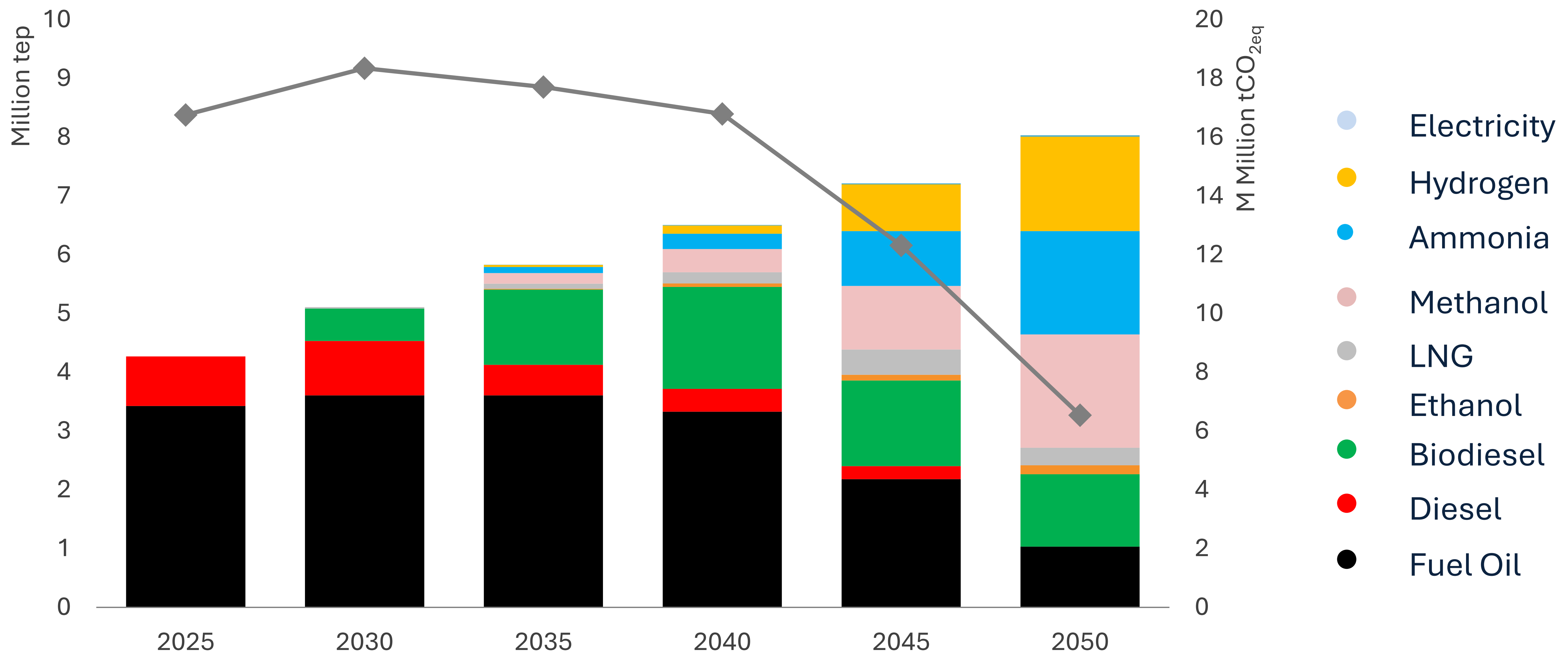
Note: Energy efficiency gains (22%) in all trajectories (2025-2050)

Trajectories resume

Trajectory	Fuels use	Inland navigation	Cabotage	International maritime transport	GHG Emmisions reduction
Base	**Emissions reduction techniques**	gradual replacement of **marine diesel** by **biodiesel**, reaching **100%** by 2050	blending **biodiesel** in the **bunker fuel** starts in 2026, reaching 30% mix in 2038. New large vessels, delivered from 2034/2035, will use other fuels such as **ethanol, methanol, ammonia, and hydrogen**	use of **biodiesel** in short term. **GNL** in medium term. New large vessels, delivered from 2034/2035, will use other fuels such as **ethanol, methanol, ammonia, and hydrogen**	**61%**
2	**No fossil fuels in 2050**	gradual replacement of **marine diesel** by **biodiesel and ethanol**, reaching **90% and 10%** by 2050	blending **biodiesel** in the **bunker fuel** starts in 2026, reaching 30% mix in 2038. New large vessels, delivered from 2034/2035, will use other fuels such as **ethanol, methanol, ammonia, and hydrogen**	use of **biodiesel** in short term. **GNL** in medium term. New large vessels, delivered from 2034/2035, will use other fuels such as **ethanol, methanol, ammonia, and hydrogen**	**91%**
3	**No fossil fuels in 2050, prioritizing methanol and ammonia**	gradual replacement of **marine diesel** by **biodiesel and ethanol**, reaching **90% and 10%** by 2050	blending **biodiesel** in the **bunker fuel** starts in 2026, reaching 30% mix in 2038. New large vessels, delivered from 2034/2035, will use other fuels such as **ethanol, methanol and ammonia**	use of **biodiesel** in short term. **GNL** in medium term. New large vessels, delivered from 2034/2035, will use other fuels such as **ethanol, methanol, and ammonia**	**90%**
4	**No fossil fuels in 2050, prioritizing biofuels**	gradual replacement of **marine diesel and bunker fuel** by **biodiesel and ethanol**, reaching **80% and 20%** by 2050	gradual replacement of **marine diesel and bunker fuel** by **biodiesel and ethanol**, reaching 80% and 20% by 2050	**no fossil fuels**, using **biodiesel (30%),ammonia (22%), methanol (22%), ethanol (20%), and hydrogen (6%)** in 2050	**81%**
4a	***No fossil fuels in 2050, prioritizing biofuels + best agricultural practices combined with BECCS***	gradual replacement of marine **diesel and bunker fuel** by biodiesel and ethanol, **reaching 80% and 20%** by 2050	gradual replacement of **marine diesel and bunker fuel** by **biodiesel and ethanol**, reaching 80% and 20% by 2050	**no fossil fuels**, using **biodiesel (30%),ammonia (22%), methanol (22%), ethanol (20%), and hydrogen (6%)** in 2050	**102%**

Note: Energy efficiency gains (22%) in all trajectories (2025-2050)

Baseline Trajectory

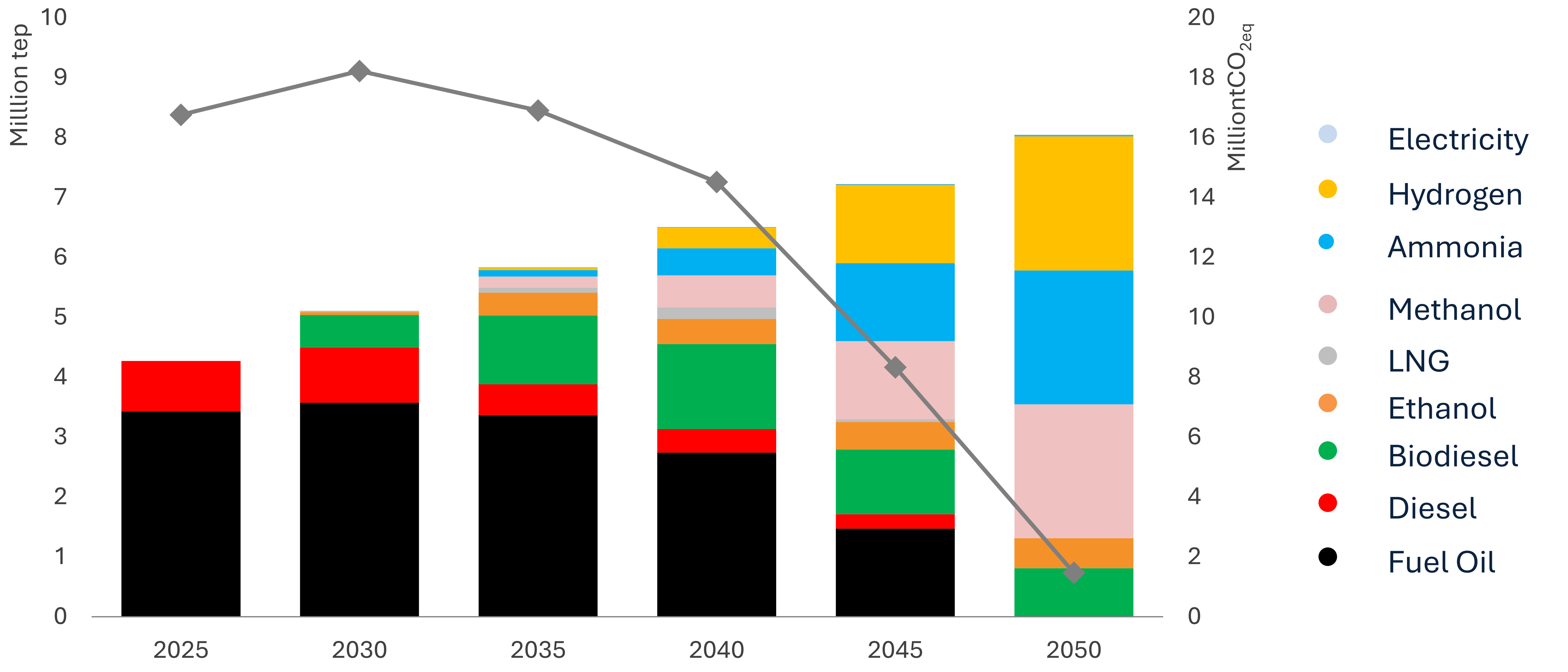


Growth energy demand: 88%

GHG emissions reduction: 61%

- Emissions reduction techniques
- Inland navigation: gradual replacement of marine diesel by biodiesel, reaching 100% by 2050.
- Hibridization and electrification: ferries and passengers transportation
- Cabotage: blending biodiesel in the bunker fuel starts in 2026, reaching 30% mix in 2038. New large vessels, delivered from 2034/2035, will use other fuels such as ethanol, methanol, ammonia, and hydrogen
- International maritime transport: use of biodiesel in short term. GNL in medium term. New large vessels, delivered from 2034/2035, will use other fuels such as ethanol, methanol, ammonia, and hydrogen.

Trajectory 2

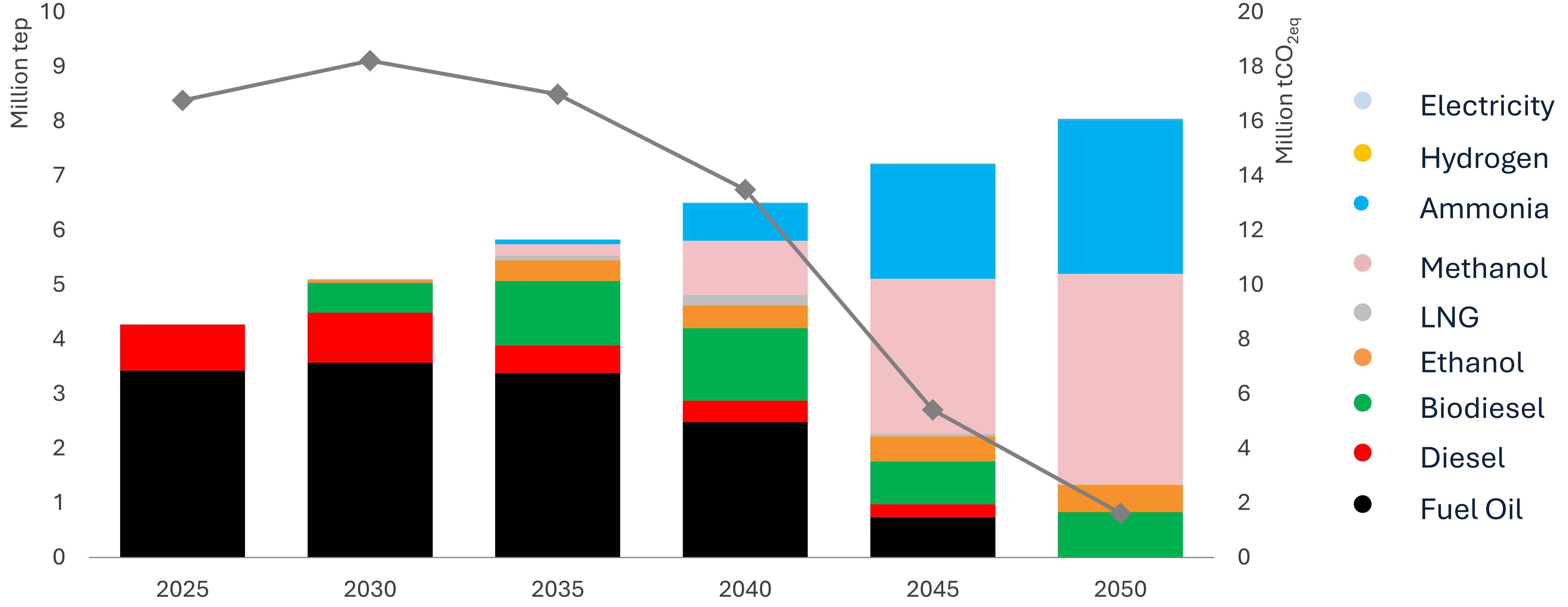


Growth energy demand: 88%

GHG emissions reduction: 91%

- No fossil fuels in 2050
- Inland navigation: gradual replacement of marine diesel by biodiesel and ethanol, reaching 90% and 10% by 2050
- Hibridization and electrification: ferries and passengers transportation
- Cabotage: blending biodiesel in the bunker fuel starts in 2026, reaching 30% mix in 2038. New large vessels, delivered from 2034/2035, will use other fuels such as ethanol, methanol, ammonia, and hydrogen
- International maritime transport: use of biodiesel in short term. GNL in medium term. New large vessels, delivered from 2034/2035, will use other fuels such as ethanol, methanol, ammonia, and hydrogen

Trajectory 3

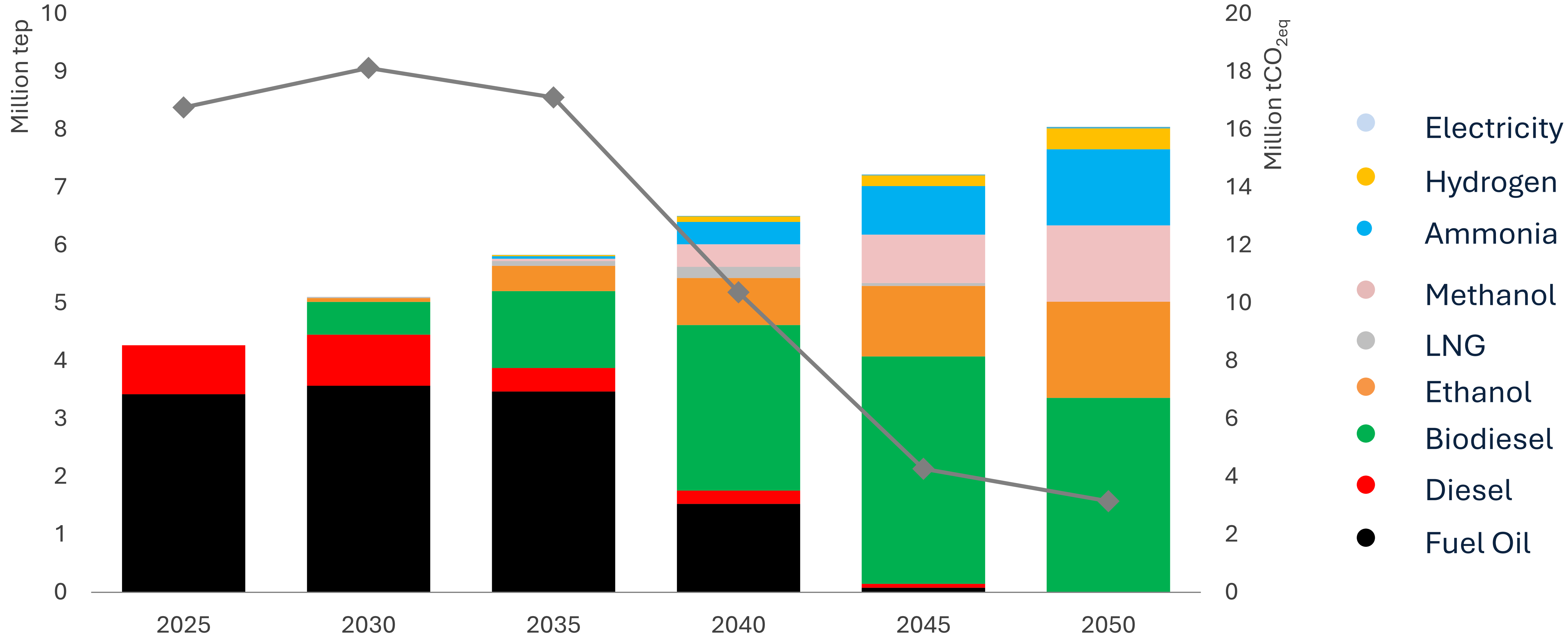


Growth energy demand: 88%

GHG emissions reduction: 90%

- No fossil fuels in 2050, prioritizing methanol and ammonia
- Inland navigation: gradual replacement of marine diesel by biodiesel and ethanol, reaching 90% and 10% by 2050.
- Hibridization and electrification: ferries and passengers transportation
- Cabotage: blending biodiesel in the bunker fuel starts in 2026, reaching 30% mix in 2038. New large vessels, delivered from 2034/2035, will use other fuels such as ethanol and methanol
- International maritime transport: use of biodiesel in short term. GNL in medium term. New large vessels, delivered from 2034/2035, will use other fuels such as ethanol, methanol, and ammonia

Trajectory 4

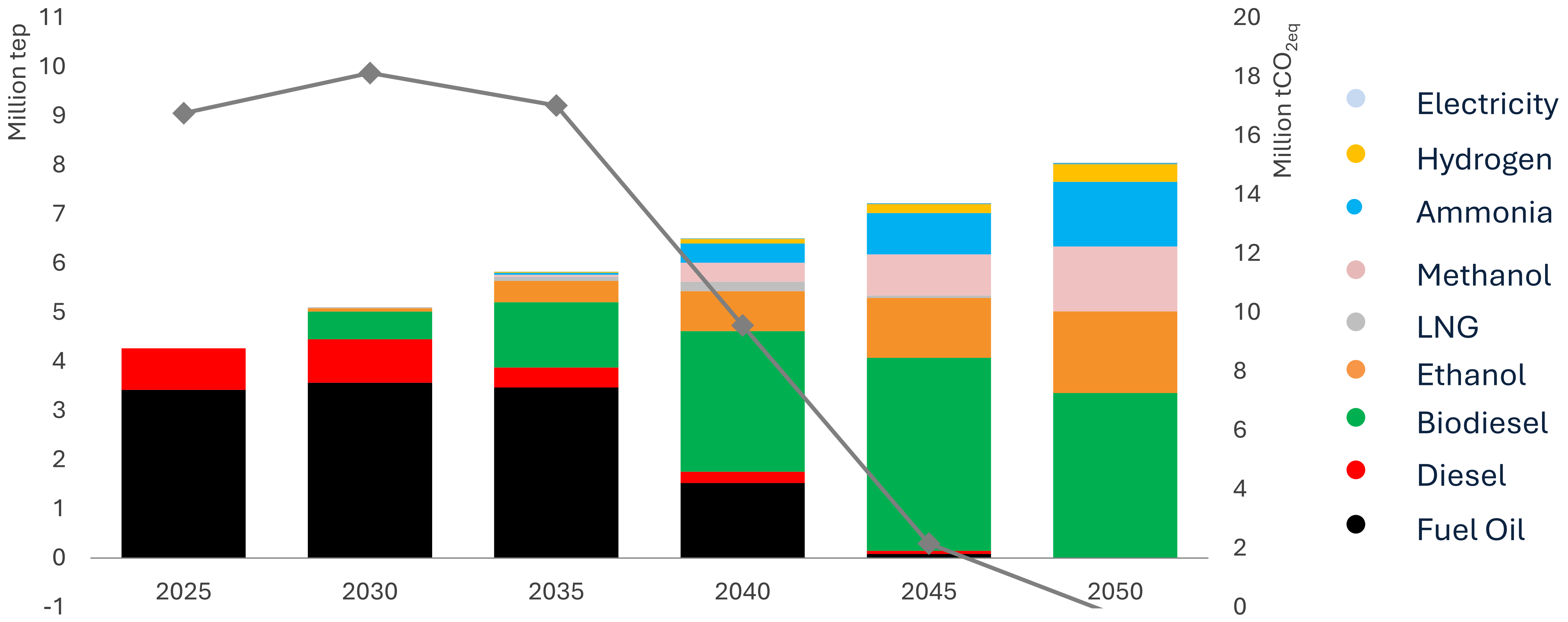


Growth energy demand: 88%

GHG emissions reduction: 81%

- No fossil fuels in 2050, prioritizing biofuels
- Inland navigation: gradual replacement of marine diesel and bunker fuel by biodiesel and ethanol, reaching 80% and 20% by 2050
- Hibridization and electrification: ferries and passengers transportation
- Cabotage: gradual replacement of marine diesel and bunker fuel by biodiesel and ethanol, reaching 80% and 20% by 2050
- International maritime transport: no fossil fuels, using biodiesel (30%),ammonia (22%), methanol (22%), ethanol (20%), and hydrogen (6%) in 2050

Trajectory 4a (best agricultural practices combined with BECCS)



Growth energy demand: 88%

GHG emissions reduction: 102%

- Trajectory 4 + best agricultural practices combined with BECCS
- Inland navigation: gradual replacement of marine diesel and bunker fuel by biodiesel and ethanol, reaching 80% and 20% by 2050
- Hibridization and electrification: ferries and passengers transportation
- Cabotage: gradual replacement of marine diesel and bunker fuel by biodiesel and ethanol, reaching 80% and 20% by 2050
- International maritime transport: no fossil fuels, using biodiesel (30%),ammonia (22%), methanol (22%), ethanol (20%), and hydrogen (6%) in 2050

Final Remarks

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Final Remarks

- For a decarbonized maritime sector, the penetration of alternative fuels, including biofuels, hydrogen, ammonia and electricity, will need to evolve despite the various uncertainties.
- Technological neutrality and diversity of options must be principles.
- It is worth noting that Brazil is in a prominent position in terms of biotechnology and bioenergy, with a biofuel industry installed in the country, which is competitive and can contribute to the decarbonization of the sector as a supplier of biofuels.
- The potential for using traditional biofuels and biomass to produce advanced biofuels to decarbonize the maritime sector should be the focus of discussions in Brazil at international forums.
- Advanced practices in the biofuel supply chain allow Brazil to reach negative GHG emissions.

Technical Sheet (november, 2024)

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