Fuelling clean mobility with bio-LNG

Market developments and policy implications of using bio-LNG in transport

EBA European Biogas Association

GIE

NGVA Europe

SEA-LNG

About the authors

The EBA is the voice of renewable gas in Europe. Founded in February 2009, the association is committed to the active promotion of the deployment of sustainable biogas and biomethane production and use throughout the continent. EBA counts today on a well established network of 41 national organisations and over 150 scientific institutes and companies from Europe and beyond.

GIE is the association of the gas infrastructure operators of Europe active in transmission, underground storage, and LNG terminals. It represents around 70 member companies from 26 countries. GIE members work and innovate to become the backbone of the new innovative energy system, allowing European citizens to benefit from a secure, efficient, and sustainable energy supply.

The Natural & bio Gas Vehicle Association (NGVA Europe) is the European association that promotes the use of natural and renewable gas as a transport fuel. Founded in 2008, its 114 members from 27+4 countries include companies and national associations from across the entire gas and vehicle manufacturing chain.

SEA-LNG is a multi-sector industry coalition established to demonstrate LNG'S benefits as a viable marine fuel. This organisation fully believes in the benefits of LNG and have been working diligently to bring about a positive and pragmatic change – driving the widespread adoption of LNG as a leading marine fuel and helping to reduce emissions for the shipping industry.

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Content

Executive summary

The objective of this paper is to highlight the environmental advantages of the use of bio-LNG in the heavy duty (HD) transport and the maritime sector and its importance as the most readily available solution for the sectors' decarbonisation. Additionally, it is crucial to underline the role bio-LNG will play in the future and the regulatory framework needed to support this sustainable fuel's development. Current information regarding the existing bio-LNG/LNG market, the bio-LNG/LNG potential, needs of the sector, and political recommendations are herewith presented and summarised below.

1. General recommendations

Technology-neutral approach based on life-cycle assessments (LCA).

2. Alternative Fuels Infrastructure Regulation (AFIR)

- Alignment with existing legal framework, notably RED and FuelEU Maritime.
- Proportionality principle between the fleet size and the power output of the infrastructure expanded to all energies.
- Development of the LNG (and CNG) refuelling station network across the EU.

3. CO2 emission performance standards for new heavy-duty vehicles

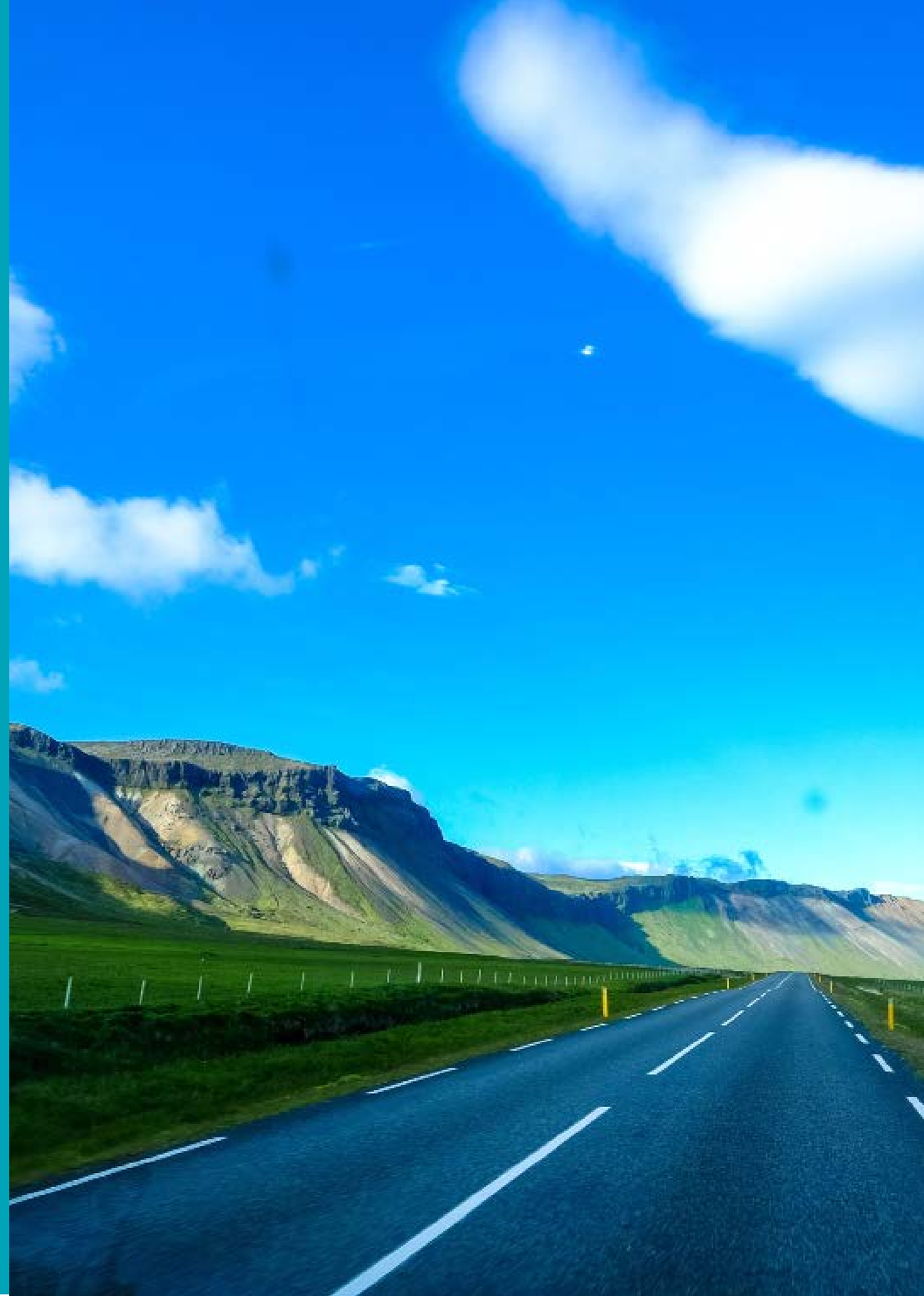
Well-to-wheel approach to measure GHG emissions from trucks.

4. FuelEU Maritime

Well-to-wake performance of maritime fuels using default or actual certified emission factors.

5. Renewable Energy Directive Recast

- Clear terms for a Guarantees of Origin (GoOs) system.
- Definition of "non-food cellulosic material" including cover/sequential crops.
- Increase share of advanced biofuels to a minimum of 4% by 2030.



Introduction

The European Green Deal aims to reduce 55% of the greenhouse gas (GHG) emissions of the European Union by 2030. This directive would turn Europe into the first climate neutral continent. A swift decarbonisation of the EU economy is needed to reach that goal. This will require a deep transformation of our energy system to accommodate increasing shares of renewable and low-carbon energy sources, such as biomethane or hydrogen. This process will encompass all sectors of our economy, including transport, which is responsible for nearly a quarter of Europe's GHG emissions.

Today, most of our vehicles run on fossil fuels. Among the different solutions for cutting GHG emissions in the transport sector, the EU seems to rely heavily on the deployment of (renewable) electricity.

As the power sector continues to develop, not only available recharging points across Europe, but also enough electricity production, will be required to supply all the fleet demand. This last aspect could be the most limiting, as the current energy consumption of Europe extends to 10,800 terawatt hours (TWh), while the production is only 2,780 TWh. In the transport sector alone, energy consumption reaches 3,555 TWh. Even if we look at the future electricity production predicted in the various scenarios, by 2050 Europe will produce approximately 4,500 TWh. These data demonstrate that an electrification of all sectors might be challenging, and other alternatives must be additionally supported. Still, some sectors such as the maritime fleet are a long way from being electrified.

Ninety-four per cent of the total electric vehicle fleet in the EU are passenger cars. The decarbonisation of long-distance trucks and shipping will require renewable and low-emissions liquid fuels such as liquified biomethane (bio-LNG). Bio-LNG can make an impact today and decarbonise the heavy duty and shipping sectors, at the time it represents a long-term energy alternative. It is carbon-neutral and even carbon negative, depending on the feedstock used during the biomethane production. As biomethane is indistinguishable from natural gas, the existing gas infrastructure can be used without huge investments. In Europe, for instance, an extensive network of compressed natural gas (CNG) and liquified natural gas (LNG) filling stations as well as several operational LNG-fuelled vessels are already in place, where bio-LNG is being delivered either directly to customer or via a guarantee of origin (GO).

The sector continues to grow at high-speed with more than 78 bio-LNG plants confirmed to be ready by 2024. Bio-LNG is an available solution today and will continue playing an important role during the coming decades and after 2050, cutting CO2 emissions for heavy-duty trucks and shipping.

Heavy-duty road transport

Over the coming years, multiple solutions will be needed to cover different market needs and transport scenarios. Electric trucks might find applications in some use cases up to 500 km, but other alternatives will be needed in the long term to cover long-haulage transport needs. Heavy-duty road transport is technically hard to electrify because it requires powerful engines able to cover long distances while carrying a heavy payload. This demands specific and highly efficient powertrains supported by an adequate amount of onboard energy.

To operate a 40-ton truck for over 1,000 km, an electric truck would require a 6.4 tonne battery with today's best technology, while the same distance can be covered with approximately 280 kg (620 litres) of (bio)-LNG.

Heavy-duty vehicles running on (bio)-LNG have been part of Europe's fleet of vehicles for several years and they can also run on bio-LNG. The (bio)-LNG sector in Europe has made substantial financial investing in the construction of stations, liquefaction plants and in the purchase of long-haul trucks, and demand is growing across Europe.

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The main European truck manufacturers (IVECO, Scania and Volvo) have fully integrated CNG, as well as LNG trucks running on bio-LNG in their long-term commercial catalogue. Additionally, an increasing number of European freight operators, shipping companies, vehicle manufacturers, as well as companies like Amazon are today making the switch to LNG vehicles, backed by investments by European companies into biomethane liquefaction plants.

Achievable ranges with different propulsion technologies

Figure 1: Achievable ranges with different propulsion technologies: BEV (Battery Electric Vehicles), FCEV (Fuel Cell Electric Vehicles), RNG (Renewable Natural Gas) and diesel.

Environmental advantages

Figure 2 shows the total well-to-wheel (WTW) and manufacturing emissions for trucks. Conventional diesel trucks, LNG trucks, and fuel cell electric vehicles (FCEV) running on grey hydrogen all have similar overall emissions. Gas mobility using a mix of LNG and bio-LNG has half the total emissions of diesel and FCEV running on grey hydrogen. When using 100% bio-LNG, and particularly when it is produced from liquid manure, the GHG emissions balance can even be negative. This means that the truck is not increasing the emissions but, instead, reducing them. In terms of air quality, bio-LNG can also improve air quality by decreasing NOx emissions up to 65% compared to diesel-powered vehicles[1].

Low risk strategy

In contrast to the passenger car sector, purchase decisions for heavy-duty trucks are very much dependent on economics rather than emotions. When looking at carbon abatement costs relative to diesel, existing data prove that LNG is even more competitive than fuel cell powered trucks running on green hydrogen. FCEV trucks are a promising decarbonisation option in the medium-to-long term, but there is significant uncertainty around availability and cost of the vehicles, and the fuel supply in the time horizon to 2030[2]. LNG and bio-LNG mobility offer near term decarbonisation at a low cost of carbon abatement.

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1 "Studio delle emissioni di gas serra e di biossido di azoto in atmosfera dal comparto dei trasporti con alimentazione a gasolio, a metano e a biometano liquefatto". March 2021. Authors: Patrizio Tratzi, Marco Torre, Valerio Paolini, Francesco Petracchini.
2 Frontier Economics – CO2 Emission abatement costs of gas mobility and other road transport options – Report for NGVA Europe; April 2021

Truck emissions per ton km in 2030

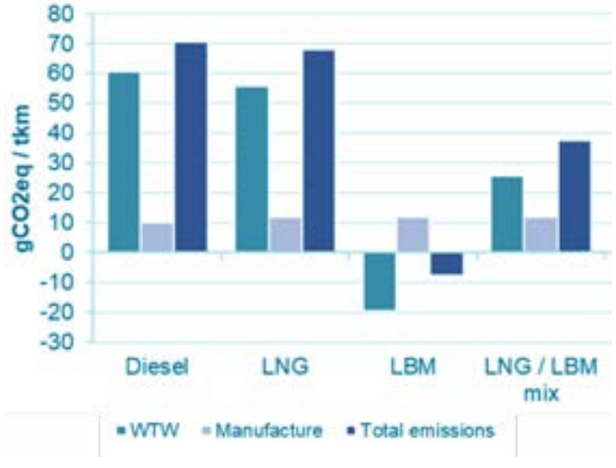

Figure 2: Frontier Economics based on JEC WtW v5 for WTW emissions and Ricardo (2020) for manufacturing emissions. Fuels considered: diesel, Liquified Natural Gas (LNG), Liquified Biomethane (LBM).

Market uptake

It is not surprising to see that LNG-fuelled trucks are fast developing in European markets. In 2020, over 15,000 LNG vehicles were driving on European roads, and fleet development is happening at a fast pace, as shown by Figure 3. With annual sales reaching 5,000 new registrations in 2020 (France, Germany, Italy and Poland drive the market), the European LNG truck market is becoming increasingly dynamic, with continuously rising sales and an ever-expanding range of models. By 2030, NGVA Europe expects that 280,000 LNG trucks will be on the roads, representing at least 25% of the EU market share for trucks.

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EU fleet of LNG trucks

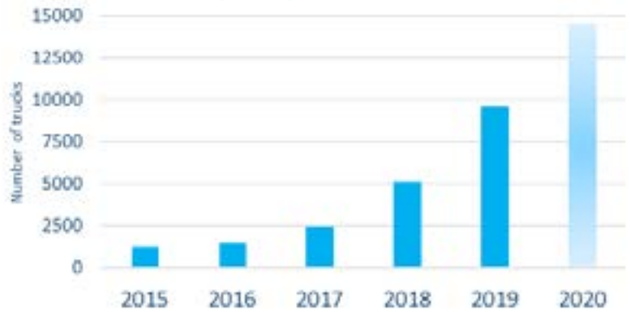

Figure 3: Evolution of LNG vehicles fleet in Europe according to NGVA Europe statistics.

Maritime sector

Decarbonisation of the maritime sector is likely to require a basket of different fuels and propulsion systems. LNG offers immediate local emissions improvements and GHG reductions, enabling the shipping industry to start this journey now with a transition to carbon neutrality through the use of bio-LNG and subsequently renewable synthetic LNG (e-LNG, or liquefied e-methane) as it becomes available in larger volumes. Additionally, bio-LNG can be used as a drop-in fuel in existing LNG engines with little or no modification and transported, stored and bunkered in ports using existing LNG infrastructure.

Environmental advantages

The use of LNG in the maritime sector can reduce GHG emissions by up to 23%[1] compared with current oil-based marine fuels on a full life-cycle ie Well-to-Wake basis, including methane emissions.

Methane slip in marine engines is attracting a lot of attention in relation in the debate about the GHG benefits of LNG as a marine fuel. Slip is often misleadingly characterised as an irremediable design flaw, which is not correct. LNG-fuelled engines were originally developed in the 1990s to address local emissions, i.e. NOx and SOx. GHG emissions were not an area of focus at the time. Since then, levels of methane slip, where applicable, have been reduced by a factor of four. By 2030 engine manufacturers forecast that all LNG-fuelled engine technologies will have minimal levels or no methane slip[2].

Compared with fossil LNG, bio-LNG - used initially as a drop in fuel - can have a major impact on GHG emissions. With a typically-sourced bio-LNG drop-in fuel, a blend of 20% bio-LNG can reduce GHG emissions by up to 18% on a tank-to-wake basis; for 100% bio-LNG the reduction is of the order of 93% in the combustion cycle[3], with even further reductions possible on a well-to-wake basis depending on the origin of the bio-LNG. For example, if bio-LNG is produced from domestic and agricultural waste it has the potential for negative emissions.

The air quality benefits resulting from the use of LNG as a marine fuel are well known and accepted. Vessels using fossil fuel LNG emit virtually no SOx while dramatically limiting emissions of NOx. LNG also virtually eliminates particulate matter, including black carbon or soot, which while not yet regulated, is a growing environmental concern.

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1 *https://sea-lng.org/reports/independent-study-confirms-lng-reduces-shipping-ghg-emissions-by-up-to-23/*
2 *https://sea-lng.org/reports/independent-study-confirms-lng-reduces-shipping-ghg-emissions-by-up-to-23/*
3 *https://sea-lng.org/reports/life-cycle-ghg-emissions-study-on-the-use-of-lng-as-marine-fuel/*

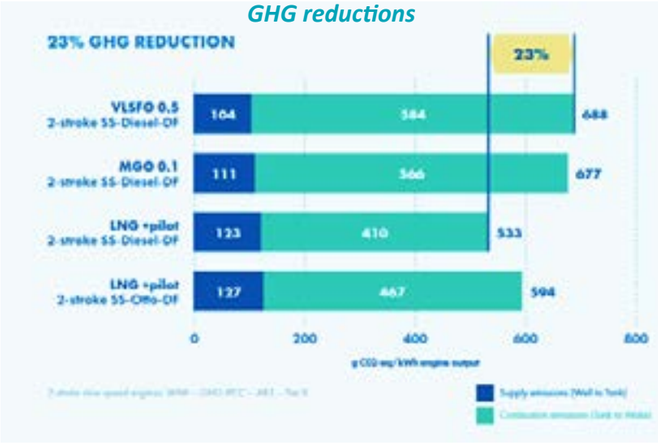

Figure 4: Sphera study, https://sea-lng.org/news-views

Low risk strategy

The use of LNG as a marine fuel is growing due to increasing recognition of its commercial and operational viability. A recent study commissioned by SEA-LNG from CE Delft concludes that bio-LNG is likely to be commercially competitive relative to other low- and zero-carbon fuels such as green hydrogen and ammonia[1]. It has the clear commercial advantage over these fuels that it can be transported and bunkered using existing LNG infrastructure.

Currently, the only commercial alternative to the LNG pathway, including bio-LNG and renewable synthetic LNG, is fuel-oil powered ships that will last at least 25 years. Whereas an LNG-powered ship, with its large cryogenic tank and dual fuel engine can adapt to a wide variety of solutions[2], this is much less the case for a fuel-oil powered ship. Investing in LNG ships opens options for the future, whereas waiting ten more years for eventual new technologies will not only delay the transition, it will make the next 30 years harder for owners of oil-powered vessels threatened with obsolescence.

Market uptake

There are currently 251 LNG-fuelled vessels in operation with approximately 403 on order worldwide. Take up of LNG as a marine fuel has accelerated rapidly over the last 12-18 months with LNG-fuelled vessels in 2021 accounting for more than 30% of the gross tonnage of the new build order book[3], and with a further acceleration anticipated in the first three-quarters of 2022.

Bio-LNG is likely to be commercially competitive relative to other low- and zero-carbon fuels such as green hydrogen and ammonia. It has the clear commercial advantage over these fuels that it can be transported and bunkered using existing LNG infrastructure.

1 https://sea-lng.org/reports/availability-and-costs-of-liquefied-bio-and-synthetic-methane-the-maritime-shipping-perspective/
2 For instance, ammonia requires a corrosive resistant, cryogenic tank four times the size of a fuel oil tank for the same energy.
3 https://www.tradewindsnews.com/technology/green-technology-uptake-ramping-up-across-fleet-says-clarksons-research/2-1-1146316

LNG as a marine fuel for both LNG-fuelled vessels and LNG carriers amounts to some 3% of global marine fuel and demand is growing rapidly in line with new tonnage. This growing demand is supported by infrastructure developments. LNG bunkering is currently available in 56 European ports and under development and planned in 40 more. LNG bunker vessels are key to delivering the volumes and flexibility needed to the maritime sector. There are 21 LNG bunker vessels in operation in Europe with a further 17 planned or under discussion.

Bio-LNG is available commercially in north-west Europe, now. Suppliers are quoting prices for delivery of bio-LNG bunkers in Rotterdam, the biggest marine fuel bunkering hub in Europe, and in several North Sea and Baltic Sea ports. In November 2020, TotalEnergies completed the world's largest LNG bunkering operation to date in Rotterdam, supplying 17,300 cubic metres of LNG to French shipping group CMA CGM's ultra-large container vessel, Jacques Saadé, 13% of which was bio-LNG. In the Baltic Sea, bunkering of bio-LNG blends for ferries, tankers and dry bulk carriers is now a regular occurrence.

DNV, in its 2020 Maritime Energy Transformation Outlook, estimates that bio-LNG demand from shipping could reach 7 billion cubic metres (biomethane equivalent) (bcm), or 74 TWh, in 2040 rising to just over 70 bcm, or 745 TWh, by 2050[1]. Pro-rating for the European bunker demand, the corresponding numbers are 1.3 bcm (14 TWh) in 2040 and 13 bcm (138 TWh) by 2050.

The FuelEU Maritime Impact Assessment for the preferred policy option estimates that bio-LNG demand could represent about 1.2% of total marine fuel demand in 2030, growing to 16.8% by 2050[2]. This corresponds to 0.6 bcm (6 TWh) of biomethane demand, in the form of bio-LNG, in 2030 and 9.7 bcm (101 TWh) in 2050.

1 https://eto.dnv.com/2020/Maritime/
2 https://ec.europa.eu/info/sites/default/files/fueleu_maritime_-_green_european_maritime_space.pdf

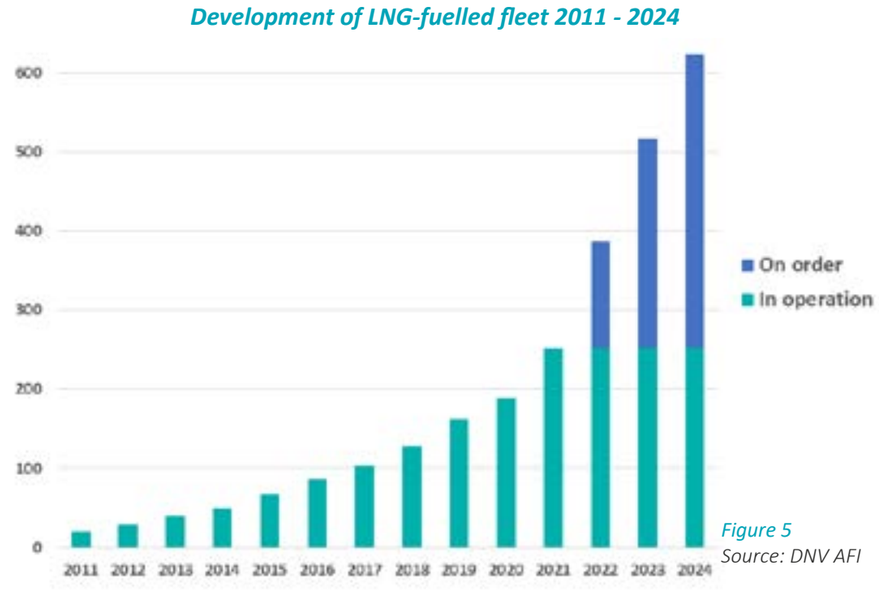

Figure 5
Source: DNV AFI

Infrastructure

The European gas infrastructure is already available to cope with total EU biomethane or bio-LNG production, both from a transport or storage perspective. Earlier this year, Europe's rapidly growing gas refuelling network reached 4,109 CNG, and 497 LNG stations[1]. However, this infrastructure should be further developed to ensure the deployment of full bio-LNG, which is the only available fuel alternative today ensuring the decarbonisation of the heavy-duty transport modes.

The production of LNG has gained importance over the years. Truck loading in LNG large-scale terminals, for instance, has increased by 12% per year over the last four years. In numbers, this totals almost 80,000 LNG tanker truck loading operations in 2020. In the maritime sector, LNG small-scale ship loadings in LNG large-scale terminals increased to more than 150 operations in 2020. This reflects an increase of almost 50% compared to the year before. Such developments have a significant impact on the environment, because LNG lowers the carbon footprint compared to the use of fuel oil and diesel and consequently improves air quality and health.

The LNG infrastructure is able to accommodate carbon-neutral gases like bio-LNG and future renewable synthetic LNG with no or only minor modifications, also saving infrastructure costs for society. Moreover, the CNG/LNG refuelling infrastructure will be able to manage drop-in carbon-neutral LNG fuels and, after some retrofitting, other fuels such as hydrogen, methanol or ammonia. Therefore, investing in LNG infrastructure is a low-risk, long term investment that opens more decarbonisation pathways, but closes none.

The LNG infrastructure is able to accommodate carbon neutral gases like bio-LNG and future renewable synthetic LNG with no or only minor modifications, also saving infrastructure costs for society.

1 https://www.ngva.eu/stations-map/

More infrastructure needed in heavy-road transport

The amount of biomethane available and used in road transport is growing exponentially. By 2030, the biomethane share could rise to at least 40%, cutting GHG emissions by 55%. According to estimations made by NGVA Europe, achieving these targets would require at least 10,000 CNG stations and 1,000 LNG stations to fuel 13.2 million vehicles.

While developing fast, the gas refuelling station network remains concentrated in a few European states, and still insufficient to cover future demand. This network therefore needs to be developed much further in the medium to long term to support the uptake of rapidly increasing share of biomethane (either compressed as bio-CNG or liquified as bio-LNG) in road transport.

Building on the existing and expanding refuelling stations network it is crucial to enable the transition towards renewable fuels in transport and the decarbonisation of the sector. Infrastructure is, in this sense, the backbone of this transformation and an asset that should be carefully supported by the EU legislative framework.

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LNG stations across Europe

Figure 6: Map of LNG stations across Europe. Source: NGVA https://www.ngva.eu/stations-map/

Maritime sector: infrastructure already available

Europe is on track for technical leadership across the globe. The LNG infrastructure available today includes a wide range of services, from large-scale to small-scale ones (including LNG terminals, refuelling stations, reloading and transhipment). This can be seen by looking at the annual update of the GLE List of services and the New LNG Services Inventory[1],[2]. The demand keeps rising, especially since the infrastructure can also accommodate green molecules like bio-LNG and renewable synthetic LNG. In fact, infrastructure services support the uptake of bio-LNG and provide Europe with an opportunity it cannot afford to miss. Europe is in a leading position in this segment, providing a competitive advantage to European ports and shipping companies.

Being a viable solution for decarbonising road and maritime transport and for supplying energy to remote areas, LNG terminals have a major role to play, while also helping to deliver climate goals.

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1 https://www.gie.eu/transparency/databases/lng-new-services-inventory/
2 https://www.gie.eu/transparency/databases/lng-list-of-services/

Worldwide growth in LNG use and infrastructure

Figure 7: Worldwide growth in LNG use and infrastructure. Source: SEA-LNG https://sea-lng.org/wp-content/uploads/2022/01/LNG-2022_A-view-from-the-bridge_V937.pdf

Production

In the coming decades, bio-LNG has great capacity for expansion in Europe. Available bio-LNG production infrastructure is increasing year on year and will experience accelerated development between now and 2024.

According to the EBA Statistical Report 2021, 16 bio-LNG plants were active within Europe (as of August, 2021). While based on expansion announced to date, the number is expected to exponentially increase from 16 to nearly 80 bio-LNG plants by 2024 (Figure 8)[1].

1 https://www.europeanbiogas.eu/eba-statistical-report-2021/

Bio-LNG plants and production capacity in Europe

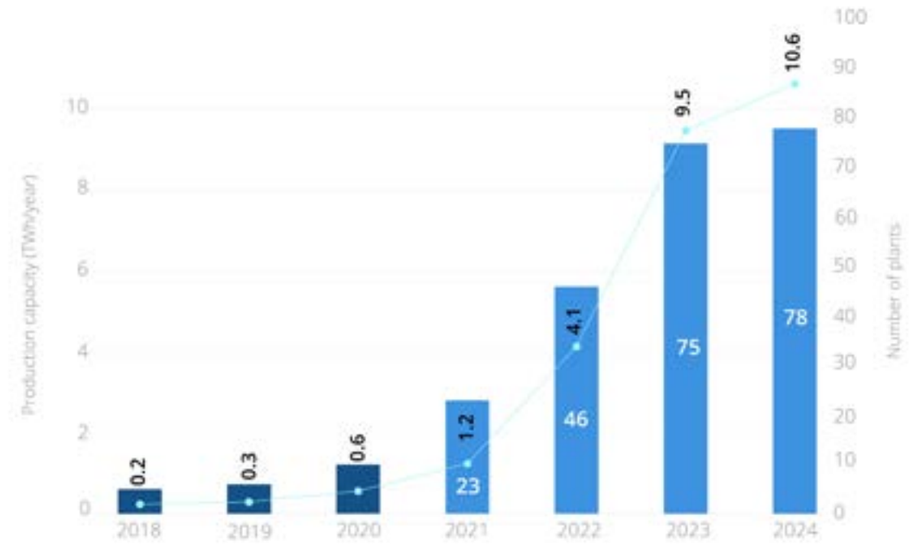


Figure 8: Current and future develoment of the number of bio-LNG plants and local bio-LNG production capacity in Europe (TWh/year) from 2018 t 2024.

The actual and upcoming bio-LNG plants will allow a production capacity of approximately 10.6 TWh per year by 2024.

This would allow for the equivalent of 25,000 LNG trucks to be fuelled year-round (Figure 9).

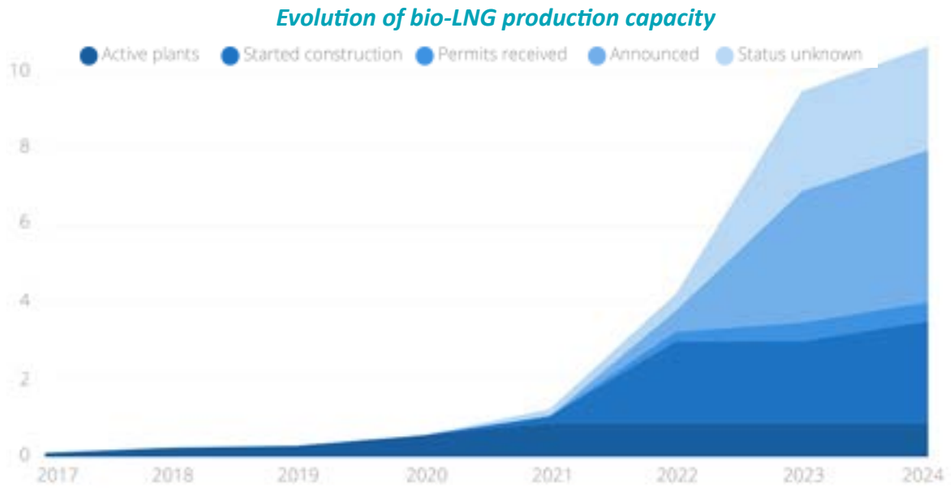


Figure 9: Current and future development of the bio-LNG production capacity (TWh/year)

EU countries leading the scale up of bio-LNG

Germany, Italy and the Netherlands are expected to be the leading producers of bio-LNG in the coming years. Germany has deployed over 100 LNG stations in four years and production takes place, or will take place, primarily in larger liquefaction plants using direct production of biomethane or purchasing it via GOs. Germany's largest biogas plant is now under construction and will have an annual production capacity of around 9,000 MT of bio-LNG from autumn 2022[1].

Italy gives significant financial support in the form of incentive schemes to stimulate the use of biomethane in transport and will propose new support measures in 2022.
Italy is currently home to four active bio-LNG plants, and a further 32 plants are at varying stages of development. The average bio-LNG production capacity for the active and projected plants in Italy amounts to 82 GWh/year. Almost all Italian bio-LNG production plants have a physical connection with a biogas upgrading unit.

The Netherlands also plans to boost bio-LNG production with the construction of seven new bio-LNG plants in the period 2021-2024, eventually reaching a production capacity of 1.5 TWh per year. The country supports the production of bio-LNG via the implementation of RED II.
Sweden opened Europe's first bio-LNG production plant in 2011. Here the state provides investment subsidies and offers a premium for sustainable biomethane production.

Refuelling infrastructure also receives investment support. Policymakers are equally dedicated to end user incentives, encouraging the purchase of vehicles running on sustainable gas for both light and heavy-duty transport.

The incentives are supported by a climate premium for trucks, a purchase bonus for cars and vans and strict environmental zones in cities that only allow the use of electric and gas driven vehicles. By applying long-term tax exemptions on biomethane, Swedish politicians ensure that vehicles are refuelled with renewable and sustainable biomethane, resulting in a world leading biomethane share of 95% of the fuel used in the transport sector.

Germany, Italy and the Netherlands are expected to be the leading producers of bio-LNG in the coming years.

1 Advanced biofuels from Germany's first integrated Bio-LNG plant – EnviTec Biogas AG (envitec-biogas.com)

Policy recommendations

General policy recommendations

- Regulation should be goal-based and technology-neutral creating a level playing field for all fuels and propulsion systems to enable the deployment of all possible solutions ensuring the decarbonisation of the transport sector in Europe.
- We strongly advocate for a technology-neutral approach based on life-cycle assessments (LCA). This ensures a holistic analysis of the carbon footprint of vehicles and GHG emissions, from well-to-tank and during the production and recycling phase of the vehicles.

Alternative Fuels Infrastructure Regulation (AFIR)

- We welcome the move from a Directive to a Regulation as this implies that the targets set will be binding and directly applicable in all EU member states.
- AFIR shall coherently support other pieces of the Fit-for-55 package. More concretely, there is a need for AFIR to closely align with the existing legal framework notably with the Renewable Energy Directive, which already defines the types of fuels that should be produced and used to decarbonise road transport. The coherence with FuelEU Maritime is also very relevant.
- The proposed proportionality principle between the fleet size and the power output of the infrastructure should not be limited to the electric recharging points and the principle should be expanded to all energies including hydrogen, CNG and LNG.
- There is a need to further develop the LNG (and CNG) refuelling station network across the EU, and to increase its density in the long term - at least until 2030.

CO2 emission performance standards for new heavy-duty vehicles

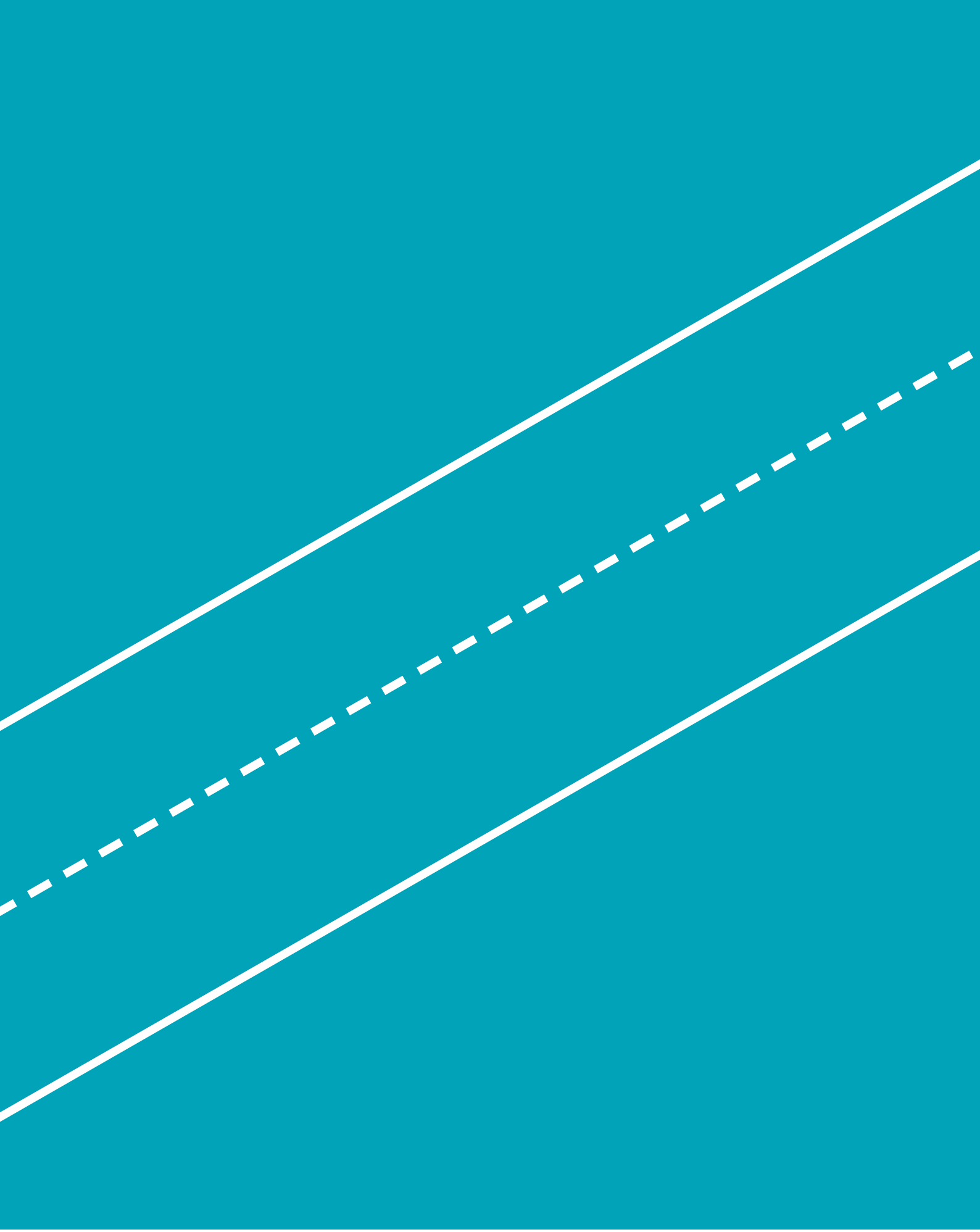
It is crucial that the updated CO2 regulation for heavy duty vehicles fully recognises the contribution of renewable fuels such as bio-LNG in cutting GHG emissions, complementing less mature technologies such as electric and hydrogen trucks. To do so, the regulation should move away from a pure tailpipe emissions approach by implementing a mechanism to introduce a well-to-wheel approach in measuring GHG emissions from trucks and to allow manufacturers to include bio-LNG trucks in their fleet's emission reduction targets.

FuelEU Maritime

The use of default only emission factors to calculate the emissions performance of fossil fuels versus default or actual and certified emission factors for renewable and low-carbon maritime fuels is likely to be unworkable. The well-to-wake performance of maritime fuels should be established using default or actual certified emission factors.

Renewable Energy Directive Recast

- It is essential that regulation is proposed in clear terms for a Guarantees of Origin (GoOs) system. This will result in certificates that could be traded separately from the physical gas molecules – across EU Member States - as soon as the renewable methane is either liquified or injected in a grid. GoOs would lower the complexity of supply chain logistics, be more environmentally efficient, and create a deeper, more liquid market in bio and synthetic methane and lower bio-LNG and also synthetic LNG costs to shipping and road.
- The definition of "non-food cellulosic material" should change to give more flexibility to the Member States to implement cover/sequential crops.
- Increase share of advanced biofuels to a minimum of 4% instead of 2.2% by 2030.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