TRANSPORT

N° 3 The transition from fossil-fuelled to electric engines is overtaken by growing demand for transport

- Since the Paris Agreement, global CO_2 emissions from transport have been rising, except in the OECD countries, where it is slightly contracting. Demand for mobility is growing in the Global South, while efforts to reduce demand are still in their early days.
- The success of electric car sales in Europe and China has not yet dented the hegemony of oil, which has been eroded by biofuels only in a handful of countries (Norway, Sweden, Brazil...).
- Carmakers, whose sales have been falling for the past five years, have resolutely embarked on their transition, but the "SUVization" of the market is wiping out efficiency gains made possible by electrification.
- The mitigation roadmaps for international air and sea transport promote alternative fuels which remain marginal and do not address the growth in demand.
- The supply and demand for high-speed rail is expanding, particularly in China. Europe is gradually rehabilitating night trains and short-distance rail, while India has electrified its lines on a massive scale.

KEY FIGURES

Demand for mobility and emissions still rising in the transport sector

- **+6%** CO_2 emissions related to transport from 2015 (6.39 $GtCO_2$) to 2022 (6.78 $GtCO_2$) (Enerdata, 2023).
- **Road: +6.1%** from 2015 (5.75 $GtCO_2$) to 2022 (6.14 $GtCO_2$), with a slight drop observed in the OECD (-1.5%) and a strong increase elsewhere (+14.9%) (*ibid.*).
- **Rail: +4.2%** from 2015 (91.37 $MtCO_2$) to 2022 (95.24 $MtCO_2$) (*ibid.*).
- **Air: -9.1%** from 2015 (882.81 $MtCO_2$) to 2022 (789 $MtCO_2$) (*ibid.*).
- **Sea: +6.5%** from 2015 (663 $MtCO_2$) to 2022 (734 $MtCO_2$). +150% CH_4 from 2012 to 2018 (UNCTAD, 2022).
- **Road: +7%** energy consumption from 2015 and 2022 (Enerdata).
- **Rail: 4,100 billion passenger-kilometres** in 2019: record unequalled since the pandemic (UIC, 2023).
- **Air: 94.2%** of air traffic had picked up since the pandemic by June 2023. -8% air freight in 2022, dropping below its 2019 level (IATA, 2023).
- **Sea: +14%** transport of containerized cargo, +11.7% bulk cargo (UNCTAD, 2022).

Dependence on oil not yet contested

- **95% of road transport runs on petroleum** vs. 4.7% on biofuels and 0.3% on electricity (Enerdata).
- **42% of new vehicle sales are SUVs**, of which 84% have internal combustion engines (IEA, 2023).
- **98.2%** of ships in operation and 73.8% of ships on order run on conventional fuels (DNV, 2023).

Transition signals

- **23 countries and 17 sub-national jurisdictions** plan to phase out combustion vehicles (REN21, 2023).
- **14% of new vehicles sold were electric** in 2022, *i.e.* 20x more than in 2015. But EVs still only make up 2.1% of the global automobile fleet (IEA, 2023).
- **115 gCO_2/km average emissions for car manufacturers in Europe**, compared to 131 g/km in 2020 (12%) – the biggest drop observed since records began in 2010 (ICCT, 2022).

FURTHER READING

TRENDS

- Recycling Lithium-ion batteries, the new frontier in the electrification of mobility (2021)
- Metals, the precious fuel for the automotive market in the race to electrification (2022)

CASE STUDIES

ZIMBABWE • Mobility for Africa. Promoting access to sustainable electric mobility in rural areas to empower women (2022)

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COLOMBIA • Sustainable urban mobility, rural accessibility and interurban connectivity (2021)

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TRENDS
TRANSPORTS

The energy transition in the transport sector is struggling to keep up with the growing mobility demand

ANTOINE GILLOD • Director of the Global Observatory of Climate Action, Climate Chance

Responsible for one-fifth of global emissions, transport was hit hard by the immobility imposed by lockdowns during the Covid-19 pandemic. Since then, passenger and freight transportation has gradually got back to normal, rekindling demand, with certain trends accelerating the transition. In Europe and in China, sales of electric automobiles are driven by a mix of public infrastructure investments, purchase subsidies, and regulations on internal combustion engines. Nevertheless, low-carbon technologies for local and international mobility remain marginal in the global energy system. Strategies to bring down demand and shorten value chains still rarely feature on the agenda.

Strongly impacted by the pandemic, global transport emissions are on the rise again

Global CO_2 emissions from fossil fuel combustion in transport rose by 6% from 2015 (6.39 $GtCO_2$) to 2022 (6.78 $GtCO_2$). This figure covers emissions from road transport (6,214 $MtCO_2$ in 2022, +6.2% compared to 2015), rail (95 $MtCO_2$, +4.2%), domestic flights (363 $MtCO_2$, +1.6%) and domestic shipping (180 $MtCO_2$, +10.7%) (**FIGURE 1**). The growth of emissions in each of these sectors plummeted in 2020 during the pandemic. Only road transport has since returned to and exceeded its pre-pandemic emissions level.[a] About 58% of emissions from transport are related to passenger transportation activities, and 42% to freight.[1]

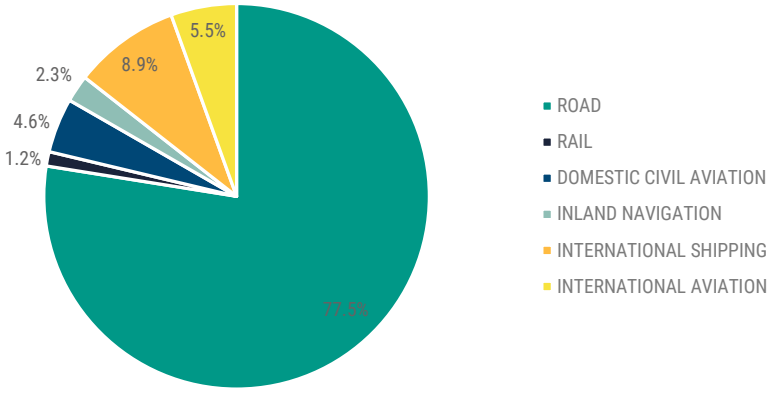
International air and maritme transport are subject to specific measures. Emissions from international shipping broke their upward trend in 2019 (-2.2% in one year), slumped further in 2020 following the major upheaval in trade (-8.5%), then recovered in 2022 (734 $MtCO_2$) surpassing the 2018 peak (708 $MtCO_2$). Emissions from international aviation rose the fastest from 2015 (525 $MtCO_2$) to 2019 (619 $MtCO_2$, +18%), but also shrank the most during the pandemic (-52.2%). Although emissions finally started to pick up again as air traffic increased, in 2022 they remained well below pre-pandemic levels (420.6 $MtCO_2$).

a Unless indicated otherwise, all data in this document come from the Enerdata "Global CO_2 and Energy" database.

FIGURE 1

BREAKDOWN OF GLOBAL CO_2 EMISSIONS FROM FUEL COMBUSTION IN THE TRANSPORT SECTOR, 2022

Source: Climate Chance, based on data from Enerdata



The transport sector has not really broken its dependence on fossil fuels. Petroleum still made up 93.1% of final energy consumption for transport in 2022, compared to 94.3% in 2015. At the same time, the electrification of transport is moving slowly: electricity accounted for only 1.2% of the final energy consumption of transport in 2022, compared to 0.91% in 2015. Over this period, energy demand for transport increased by 1.3%, despite a significant fall in 2020 during the confinements (-13.78%). Demand is particularly strong in India (+4.9%) and China (+3.39%), and generally stronger outside the OECD (+2.44%) than in the OECD (+0.48%). However, scattered signals show that new models are gradually being put in place, with support from non-state actors.

Electrification of the automobile fleet, driven by public policies, has not dented petroleum's domination

Slight drop in emissions from road transport in the OECD

Global emissions from the road transport sector, which represent 77.5% of total transport emissions, rose 6.1% from 2015 (5.75 $GtCO_2$) to 2022 (6.14 $GtCO_2$). Developing and developed countries are following crossed trajectories, with a slight drop in emissions in OECD countries (-1.5%), continuing an erratic trend that began in 2008, and a clear increase in non-OECD countries (+14.9%), over half of it concentrated in the BRICS.

Biofuel breakthrough restricted to a handful of countries

Global final energy consumption by road transport, which has grown 7% since 2015, was still made up of 95% fossil fuels (petrol, diesel, LPG and gas) in 2022. In comparison, the share of biofuels (ethanol and biodiesel) was only 4.7% and, despite the strong growth of electric vehicles, the electrification of road vehicles remains marginal (0.3%). The division of this balance has remained almost unchanged since the Paris Agreement (**FIGURE 2**). The efficiency gains made from 2005 to 2016 (+1.8% per year) slowed down from 2016 to 2017 (-0.7%) and remain far from the 2030 goals set by the Global Fuel Economy Initiative (-3.7% per year from 2017 to 2030).[2]

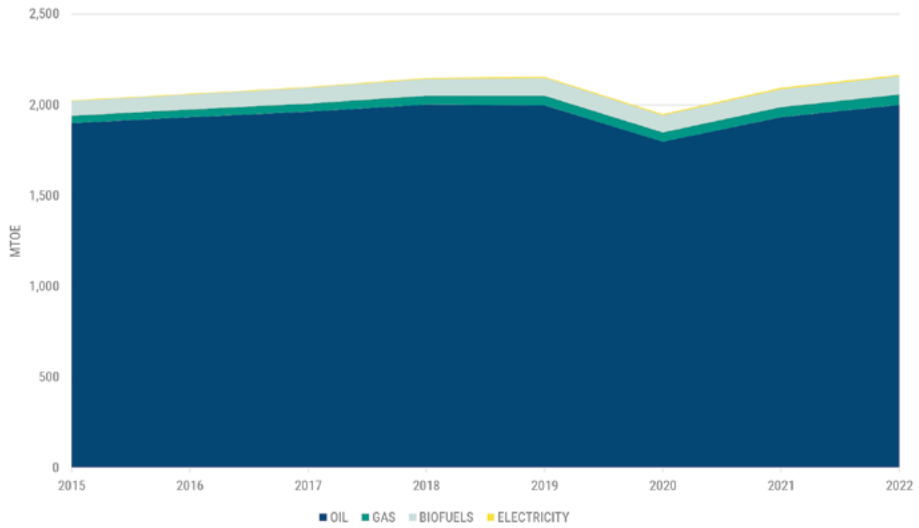
In the few countries that have succeeded in reducing their petroleum share, it has been to the benefit of biofuels. The final consumption of biofuels in road transport increased by one quarter from 2015 (80 Mtoe) to 2022 (101.3 Mtoe). These fuels are made up of 60% bioethanol (+10.3%) – manufactured through the fermentation of sugar from starch and sugar crops – and 40% biodiesel (+63%) – obtained from vegetable oils or animal fat. In Sweden, the share of petroleum used for transportation dropped from 83.3% to 68.6% thanks to a policy that saw the percentage of biofuels double (26.6% in 2022) over the period.[3] Brazilian transportation also has one of the lowest petroleum dependencies in the world (75.3%), thanks to the 22.3% share of biofuels, mainly in the form of ethanol.[4] In Indonesia, generous programmes subsidizing palm-oil-based biofuel took the share of biomass in transport's final energy consumption from 1.16% in 2015 to 14% in 2022. In Norway, the share of petroleum in the final energy

consumption of transport fell from 93.6% in 2015 to 85.9% in 2022, thanks to a combined target to increase electrification and develop biofuels.[5] Other European countries have substantially developed biofuels since 2015, like Albania (15.6% in 2021) and Belgium (9.8%).

FIGURE 2

GLOBAL FINAL ENERGY CONSUMPTION OF ROAD TRANSPORT, 2015-2022

Source: Climate Chance, based on data from Enerdata



In 2022, 56 countries and 30 sub-national jurisdictions had a mandate and targets to incorporate biofuels; the number amounted to 65 in 2021, before some countries suspended their targets due to food price inflation.[6] The reason is that biofuels involve a change in land use that competes with agricultural production for food.[7] In Europe, the agricultural surface area devoted to biofuel could be used to feed 120 million people and absorb twice as much CO_2 if it were returned to its natural state, according to Transport & Environment.[8]

Generally, **the transition to biofuel or electric engines in some countries is not automatically accompanied by a fall in road transport emissions** (FIGURE 3). This is a sign that the growing demand for transport is wiping out some of the gains made by changes in engine technology.

Automobile market split between electrification and "SUVization"

Although a clear shift is not yet visible in emissions figures, recent years have seen a clear rising trend in sales of new electric vehicles on the main markets. From almost zero at the time of the Paris Agreement, **the final electricity consumption of road transport remains very marginal on a global scale (0.3%). However, demand has shot up in most industrial economies**: +240% in the OECD, +729% in the European Union, +172% in the United States, and +56% in China. In Norway, electricity demand from transport multiplied by sixteen from 2015 to 2022, and currently represents 5% of the national consumption of road transport.

The market for electric light-duty vehicles is rocketing. Ten million electric cars were sold in 2022: a record. **Sales have shot up 55% since 2021, and multiplied by twenty since 2015. Electric cars account for 14% of sales of new vehicles, compared to 4% in 2020, and 0.6% in 2015.** Battery electric vehicles (BEVs) are responsible for 70% of growth, ahead of plug-in hybrid electric vehicles (PHEVs). China, responsible for 60% of global sales, is by far the biggest world market, followed by Europe and the United States. Electric vehicles represent 29% of sales in China, and as much as 88% in Norway.[9]

Sales of electric buses and lorries are much lower, and mostly concentrated in China, which also controls most of production. According to IEA figures, 66,000 electric buses and 52,000 trucks were sold in 2022, respectively 80% and 85% of them in China. Sales of electric buses and lorries have not really taken off since 2015, but the market has become more geographically diverse. In India, two-wheelers are undergoing an "electric revolution": sales of electric two-wheel vehicles went from 0.2% to 6% of the mar-

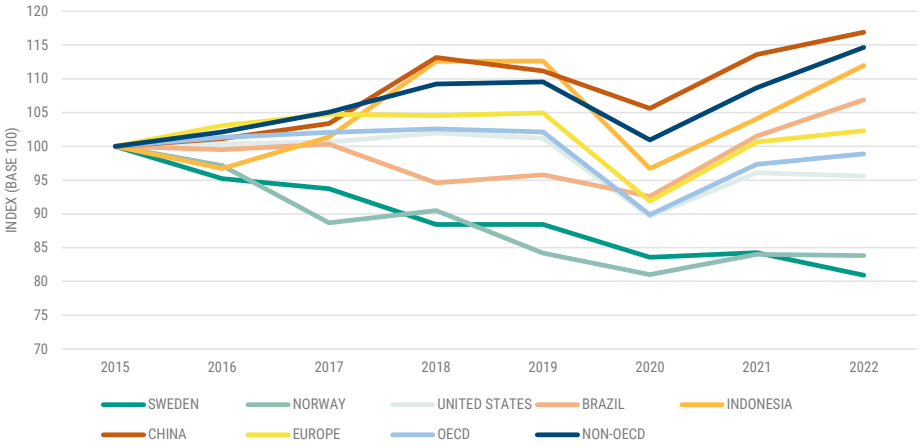
ket from 2020 to 2023, and the Indian government is aiming at 80% by 2030.[10]

The share of electric light-duty vehicles is all the more significant given that global sales of new vehicles have been decreasing for several years. Following a post-lockdown pickup in 2021, sales of new vehicles in the world resumed the downward trend that began following the peak observed in 2017: 81,628,533 vehicles were sold in 2022, which is -1.4% in a year, and -15% compared to 2017 (**FIGURE 4**).[11] This trend can partly be put down to manufacturers' difficulties getting hold of spare and electronic parts during the semi-conductor shortage and lockdowns. Nevertheless, this trend is not visible in manufacturers' financial results, where the drop in volume is compensated by the growth of a very profitable market: sales of SUVs (sport utility vehicles).

FIGURE 3

ROAD TRANSPORT CO_2 EMISSIONS EVOLUTION INDICES FOR SELECTED COUNTRIES AND ECONOMIC ZONES, 2015-2022

Source: Climate Chance, based on data from Enerdata



SUVs, which are heavier and consume more fuel than average, totalled 46% of sales of new vehicles in 2022, compared to 27.4% in 2015. Currently, more than three out of ten vehicles operating in the world are SUVs. These more expensive cars generate more profitable financial margins for manufacturers.[12] Yet on average, an SUV consumes 20% more fuel than a standard-size vehicle, and according to the International Energy Agency, the 330 million SUVs on the roads generate 1 $GtCO_2$/year, which is 2.6% of global emissions. This "SUVization" of the market also includes electric vehicles: currently, more than one electric vehicle in two sold in the world is an SUV, with some models heavier than 4,000 kg, way above the average weight of new vehicles in France (1,240 kg),[13] and even in the USA (1,857 kg).[14] In fact, the average efficiency of vehicles, even electric ones, tends to decrease as the size of the vehicles increases, reports the IPCC.[15]

Planned phase-out of combustion-engine vehicles sees manufacturers adjust their strategies

The penetration of electric vehicles is mainly boosted by a legislative and political impetus to phase out combustion vehicles. To date, 39 countries, 60 local and regional governments, and 13 carmakers have signed the COP26 Declaration on accelerating the transition to 100% zero-emission cars and vans by 2040. **In late 2022, REN21 listed 23 countries and 17 sub-national jurisdictions that had totally banned vehicles with internal combustion engines.** The European Union has prohibited the sale of vehicles running on petrol and diesel by 2035, while the United Kingdom has set a target of 2030. In Norway, where electric vehicles total nearly 90% of new sales, it will be illegal to drive a combustion-engine vehicle starting from 2025. In the United States, some cities prohibit the construction of new petrol stations.[16]

In urban areas, attempts to improve air quality also contribute to a modal shift towards soft mobilities and the exclusion of combustion vehicles from cities and towns. In 2022, 320 low emission zones (LEZs) existed in Europe, compared to 228 in 2019 (+40%).[17] These urban zones either restrict or prohibit access for vehicles that do not respect certain emissions standards, with the aim of improving urban air quality. However, they can increase the risk of social exclusion for inhabitants that are the most dependent on combustion engine vehicles.

FIGURE 4

THE RECENT BREAKTHROUGH IN SALES OF ELECTRIC VEHICLES HAS NOT YET CHALLENGED THE HEGEMONY OF COMBUSTION-ENGINE VEHICLES

Source: Climate Chance, based on data from the International Energy Agency, 2023

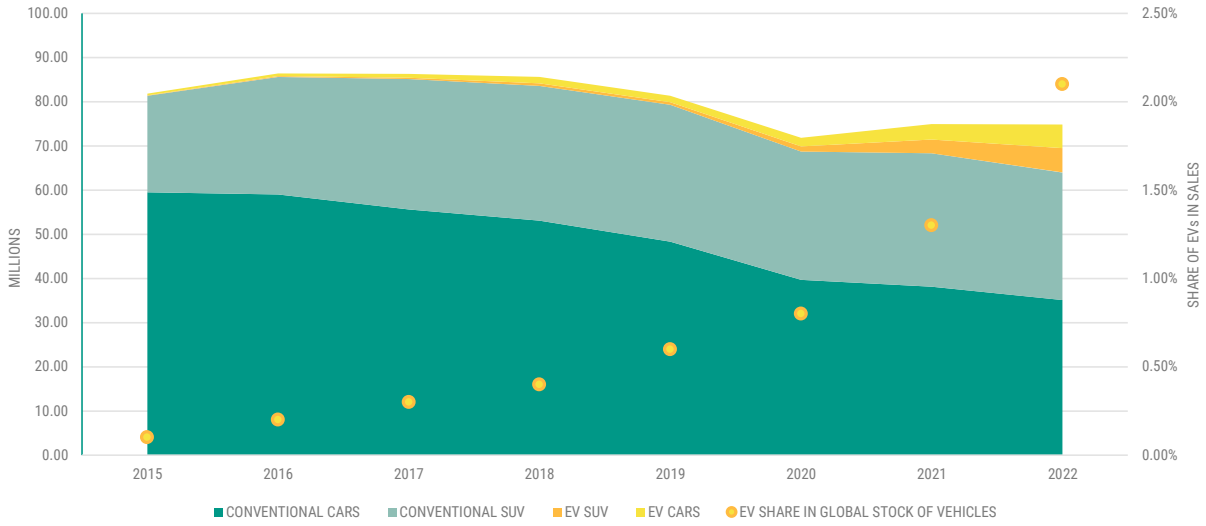
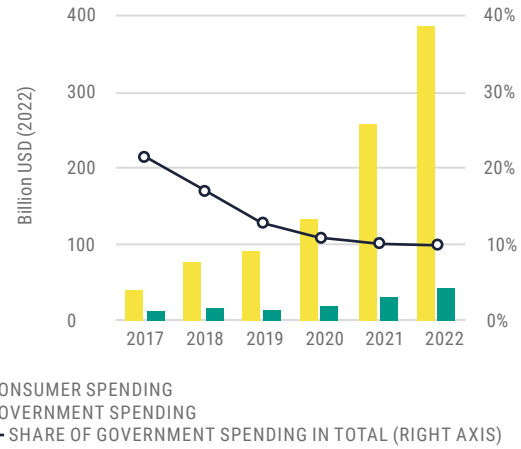


FIGURE 5

GLOBAL EXPENDITURES ON ELECTRIC VEHICLES, 2017-2022

Source: International Energy Agency, 2023



To encourage this transition, 90% of the market for sales of electric light-duty vehicles is covered by national incentive policies, taking the form of a bonus, purchase premium, or tax exemption. From 2017 to 2022, the ratio of public expenditure/private expenditure for electric vehicles went from 20% to 10% (**FIGURE 5**), proof of the lever effect of public expenditure, combined with the decreasing cost of batteries, which has been divided by three since 2015. Recycling of lithium-ion batteries, which takes a backseat in the regionalization strategies of industrial sectors, is gaining ground in North America: the province of Quebec, which strongly supports innovation and the emergence of a recycling channel, is a pioneer in this area.[18]

This legislative context, and growing competition from Chinese manufacturers, such as BYD, the world's leading EV manufacturer ahead of Tesla, obliges European carmakers to accelerate their transition. **In 2021, the average emissions of automobile manufacturers amounted to 115 g/km in Europe, compared to 131 g/km in 2020 (-12%) – the biggest drop observed since records began in 2010**. Eighty-four of the 88 manufacturers subject to EU regulation, taken individually or in groups authorized to align with legislation, reached or surpassed their targets, with variable margins: from 1 gCO_2/km for Renault-Nissan-Mitsubishi (109 g/km, against a target of 110) to 96 gCO_2/km for Tesla-Honda-Jaguar Land Rover, which obtained a result of 33 gCO_2/km against a target of 129.[19]

Chinese manufacturers were the first to stop building combustion engine vehicles: BYD has only sold electric vehicles since March 2022, while Chongqing Changan was the first to announce in 2017 that it would stop producing combustion vehicles by 2025. Jaguar-Land Rover, Mini and Rolls Royce, Lancia, Volkswagen and Mitsubishi have all announced that they will be totally converting to electric with different deadlines. Among the biggest carmakers, BMW anticipates 50% of EV sales in 2030, and Re-

nault 90%. Toyota, the biggest global automobile manufacturer and the pioneer of hybrid vehicles, was slow to move into BEVs but has set ambitious sales targets for 2025 to compete with Tesla and BYD.[20]

The pace of installing charging stations is crucial for the market's development. At the end of 2022, 2.7 million public charging points were installed in the world, including 900,000 set up in 2022 and 500,000 in 2021, with an average annual growth rate of 50% observed since 2015, according to the IEA. On the main markets, BEV sales are growing faster than charging stations; the EV-to-public charging station ratio is on a rising trend. The European Union, which in 2014, in its AFID (Alternative Fuel Infrastructure Directive), established the goal of one charging station for ten electric vehicles by 2020, has not met its target (13:1 in 2022). South Korea (2 vehicles for 1 station) and the Netherlands (4:1) boast the lowest ratios, while the figure is 8:1 in China, 24:1 in the United States, and 34:1 in Norway. However, the latter two countries feature high numbers of houses with a garage; the ratio is therefore higher than average and following an upward trend, due to a predominance of charging points in the home.

Slow electrification of company fleets

In 2022, EV100, Climate Group's initiative to electrify the automobile fleet, included 127 member companies, compared to 16 at its launch in 2017.[21] Members commit to converting their company fleet to electric and installing charging stations. The initiative now covers 102 markets in the world, and a total of 5.75 million electric vehicles promised by 2030, either in company fleets or leased.

The number of EVs deployed in 2022 in individual company fleets grew 49% in a year; 79,615 company cars were in service (two-thirds are BEVs, the rest are PHEVs), out of a total of 724,310 units according to commitments. EDF operates the biggest EV fleet (8,732 units) among EV100 members, and recorded the biggest growth, ahead of Swiss Post and Siemens. In addition, ten companies have committed to deploying 5 million leased EVs for their clients, of which 325,000 have already been put on the market (zero in 2017). The Netherlands company LeasePlan has already deployed almost 150,000 vehicles, ahead of Lloyds Banking Group and Lyft. The United Kingdom is by far the leading market in this segment. Other companies, such as Iberdrola and the Japanese electric power company TEPCO have equipped all of their numerous offices with charging stations. TESCO, which is a member of EV 100, recently reached the target it set in 2019 in partnership with Volkswagen and Pod Point to equip 600 stores with an electric charging station.[22]

The ride-hailing sector is moving more slowly towards electric. The key market players – Uber, Lyft, Didi Chuxing – and subnational governments like California, have made commitments to make 100% of their fleets electric by 2030. But the electrification of ride-hailing fleets in Europe, the USA and Canada is slower than the rest of the market, according to a study by the World Resource Institute (WRI).[23] Some cities are exceptions. In Amsterdam, where over 6.5% of Uber vehicles are electric, the installation of charging stations following user requests has led to a network covering the territory in line with drivers' needs. In London, where Uber works closely with the municipality, the firm maintains that almost 90% of new drivers operate a 100% electric vehicle. In India, Delhi has become the first state in the country to make electric vehicles mandatory for some new app-based taxis (especially two- and three-wheelers).[24]

In urban areas, bikes have shifted up a gear

Along with changes in fuel and improved energy efficiency, a modal shift to soft mobility is the main policy lever to reduce emissions from transport. Urban mobility in particular has undergone several major changes since 2015. Since Covid-19, the number of bike lanes in place in the world has risen considerably.[25] Forty-three of the biggest 94 cities in the European Union announced that they were setting up bike-friendly measures in reaction to the pandemic, according to the European Cyclists' Federation (ECF). Europe now boasts 458,934 km of cycling infrastructures in 37 countries. In the Netherlands, the length of the cycling network is the equivalent of 70% of the road network, compared to 31.4% in Belgium, 9.2% in Germany, and 3.2% in France.[26] **In mid-2022, 1,914 bike-sharing systems were active around the world, in 1,590 towns in 92 countries, of which 47% in Europe and 38% in Asia**. China is by far the country with the most bike-share systems in place, ahead of the United States, Italy, Germany, Poland and France.[27] Even in Cairo (Egypt), a metropolis of 22 million inhabitants and one of the most congested in the world, a bike-share system was set up in 2022 close to city subway stations.[28]

The market is growing very fast in Europe: **14.7 million bicycles were manufactured in the EU in 2022, which is 10% more than in 2021 and 29% more than the average from 2012 to 2022.**[29] With 14.7 million units sold, regular bicycle sales dropped by 9.1% in 2022 following a record year in 2021, while electric bicycles followed an opposite trend (+8.6%, 5.5 million units).[30] Underlying this trend, the ECF lists 300 tax incentives and purchase premium schemes established in Europe by national, regional or local authorities, a figure that has "increased significantly" since 2019.[31] Cycling is now an integral part of the

urban mobility policy in Bogota,[32] while in Jakarta, cycle lanes are devised to interconnect with the bus rapid transport network, with the result that four times more people can reach the city centre than the population within a 15-minute walk.[33]

Rail transport: in Asia and Europe, electrification of high-speed trains is on the right track

Rising emissions since 2015 do not give the whole rail picture

Global emissions from rail transport rose 4.2% from 2015 (91.37 $MtCO_2$) to 2022 (95.24 $MtCO_2$), with a peak in 2019 (103.25 $MtCO_2$) and a sharp drop in emissions in 2020 due to the pandemic (-16.7%). The train is one of the means of passenger transport that emits the least greenhouse gases (GHG): on average, its lifecycle carbon intensity is around 22.35 gCO_2e per passenger-kilometre, which is ten times less than for large cars and five times less than for planes.[34] Depending on the situation, the increase in emissions associated with rail can therefore translate into a positive global modal shift, and net emissions savings.

Despite a drop in passengers, rail infrastructure expansion is going full speed ahead

While passenger train travel grew to reach a new record in 2019 (over 4,100 billion passenger-kilometres), the volume of passengers transported dropped sharply by 34% from 2019 to 2020, due to the pandemic. Train passenger numbers then continued to drop in 2021 and 2022, with only half as many users as in 2019.[35, 36] Traffic picked up differently depending on the region and the country, as reported by the International Union of Railways (UIC).[37] In some countries in Europe – like France, Poland and Turkey – traffic has already exceeded its 2019 level, while recovery has been slower in Germany and Italy, and also in Asia, where passenger transport even dropped by 31% in China from 2021 to 2022, because of prolonged anti-Covid restrictions. The volume of rail freight, which was generally less impacted by the pandemic (-3.8%), surged back to its pre-level crisis, despite a drop in activity due to the war in Ukraine, especially in the Baltic countries.

Nevertheless, long-distance and urban rail infrastructures are burgeoning. In 2021, 58,839 km of high-speed lines were operating in twenty countries, compared to 38,828 km in 2015 (+51.5%). More than two-thirds (68%) of the global high-speed rail network is located in China (40,474 km), way ahead of Europe (11,990 km) and Japan (3,081 km). In relation to land area, South Korea has the highest density of high-speed railways, just ahead of Japan, Spain and Belgium. North America, where trains are used for freight but rarely to transport passengers, only counts 735 km of high-speed rails, with 274 km under construction. In Africa, the first and only high-speed railway was inaugurated in Morocco in 2018; the 186 km of tracks connect Tangiers with Kenitra. Other lines are planned, such as in Egypt.[38] Recent years have seen global railway growth driven by Chinese investments as part of the Belt and Road Initiative, and European investments through the Global Gateway initiative.[39]

Apart from high-speed trainlines, investments in rail transportation are more mixed. From 1995 to 2018, European countries devoted €1,500 billion to road infrastructures, compared to €930 billion for railways, according to Greenpeace. The road network in these 30 countries (EU27 + Norway, Switzerland and the United Kingdom) expanded by 60% over the period, while the rail network shrank by 6.5%. Since 1995, 13,700 km of passenger lines and 2,500 stations have closed. The only exceptions are Belgium, Austria and the United Kingdom, which invest more in rail than in roads.[40]

In late December 2021, the UITP listed 193 cities equipped with an underground railway system in the world, clocking up 17,221 km and over 58 million passengers transported in 2019 (before the pandemic). From 2014 to 2019, the number of passengers rose by 44% in Asia-Pacific, 21% in the Middle East/Africa, 16% in Latin America, 9% in Europe and 2% in North America. Covid-19 had a huge impact, bringing down subway usage by 34% in Tokyo, 42% in Beijing, 62% in New York and as much as 90% in Delhi in 2020.[41]

Electrification of rail transport steams ahead

From 2015 to 2019, final energy consumption (except electricity) of rail transport in the world rose by 14.6%, amounting to 60.01 Mtoe – a record, after thirty years of erratic evolution. Following the drop in 2020, consumption picked up in 2021, then decreased again in 2022 (55.07 Mtoe) to reach a level close to that of 1990 (55.92 Mtoe). The rail sector's energy mix comprises 36.8% petroleum, 34.7% diesel and 28.5% electricity. The use of coal has almost completely disappeared (0.02 Mtoe). However, trains cover about 9% of global passenger transport and 7% of global freight;[42] rail only represents 2.2% of energy demand from the transport sector, and 1.3% of its direct CO_2 emissions.

Eighty-five percent of passenger rail transportation now operates on electricity, compared to 55% for freight, according to the IEA. Yet this overview disguises regional disparities. In the United States,

where trains are seldom used by passengers and more commonly for freight, less than 1% of the rail network is electrified.[43] In contrast, Asia has made great steps in electrification. India, which aims to make its entire network electric by the end of 2023, has already reached 90% electrification overall, and 100% in fourteen states.[44] In Europe, almost 60% of lines were electrified in 2021, with rates varying from 2.6% in the Republic of Ireland to 99.8% in Switzerland.[45] In any case, the final impact of electrification is highly dependent on the structure of the national electricity mix; for example, India still produces 72% of its electricity from coal (**CF. "ELECTRICITY" TRENDS**), and its very attractive passenger transport model is based on subsidies for transporting coal by rail.[46]

The electrification of trainlines is supported by a mix of national and/or regional investments, and a commitment from the key commercial and managing network operators. Deutsche Bahn (Germany) for example in 2021 announced that it was aiming to be climate-neutral by 2040, which is ten years earlier than its initial target. The company also aims to run its factories, offices and stations with 100% renewable energy by 2025. In 2021, it signed renewable energy purchase agreements with Statkraft and RWE.[47] To phase out the use of diesel for its "small lines" with low traffic, SNCF (France) is implementing a so-called "frugal electrification" strategy, based on developing battery-run trains on parts of the tracks that are difficult to electrify. A pilot project for the strategy has begun operating battery-powered trains on the Aix-Marseille section.[48] East Japan Railway, the biggest railway company in the country, has invested in solar energy since 2013, and in early 2021 announced new investments to reach its aim of "zero carbon" by 2050.[49]

In Germany, in summer 2022, the state of Lower Saxony launched the operation of fourteen *Coradia iLint* built by Alstom, the very first hydrogen-powered trains in the world,[50] while awaiting delivery of 27 more for the metropolitan region of Frankfurt Rhine-Main. Italy has also announced that it is earmarking €300 million of its post-Covid recovery funds to deploy hydrogen-powered trains to replace diesel trains in six regions.[51] Quebec is testing out a *Cordia iLint* on the Quebec-Charlevoix line, a first in the Americas.[52] Indian Railways is also setting its sights on hydrogen to electrify heritage lines.[53] However, one year after putting hydrogen trains into operation, the Lower Saxony rail company, LNVG, decided to opt for cheaper battery-electric and catenary-connected trains to phase out the remainder of its diesel lines.[54]

As well as action on power sources of trains, several governments have acted to boost demand for transport using trains. The return to night trains in Europe is part of this move. In February 2023, the European Commission announced a support programme for ten transboundary railway lines, three of them new night lines.[55] Starting from 2024, the private French operator Midnight Train hopes to connect Paris with a dozen European cities using upmarket night trains; the Belgian-Dutch cooperative European Sleeper is already running from Brussels and even links London to Berlin.[56] The Austrian company ÖBB, which operates the biggest night train fleet in Europe and covers 25 cities in fourteen countries, has ordered 33 new trains from Seimens worth €720 million.[57] Night trains, which are 28 times less polluting than aeroplane flights, have the potential to reduce emissions by 3% in Europe.[58]

Some countries have created fixed-price travel cards covering the entire transport network. In October 2021, following two years of negotiations between the government and regional authorities, Austria introduced the "KlimaTicket", which costs €3 per day (€1,095/year for an adult) and allows card holders to travel as much as they want on the country's transport system. 170,000 travel cards have been sold, and 85% of users state that they now travel by public transport instead of by car.[59] Germany has set up a similar initiative, with "D-Tickets" that allow travellers to take journeys on the entire urban and regional transport network for a cost of €49. The initiative was an immediate success, with 250,000 D-Tickets sold within three days of launching. This project follows the experiment of a 9-euro fixed-price ticket during the summer of 2022, which avoided an estimated 1.8 $MtCO_2$ of emissions.[60]

Air transport: decarbonization struggles to take off

After plummeting during the pandemic, emissions have gone sky high

Emissions from the entire international and domestic civil aviation sector in 2022 (789.2 $MtCO_2$) were 10.5% lower than in 2015 (882.5 $MtCO_2$). Yet the sector still represents over 10% of global emissions from transport. International aviation emissions grew the fastest from 2015 (525.9 $MtCO_2$) to 2019 (619.1 $MtCO_2$, +18.2%), and shrank the most during the during the 2020 pandemic (-52.2%). They then shot up again as air traffic took off, reaching 68% of their pre-pandemic levels in 2022 (420.6 $MtCO_2$),

according to data from Enerdata. Emissions from domestic civil aviation (362.88 $MtCO_2$), which were relatively less impacted by lockdowns (-31%), have also returned to near 2019 levels (85.5%), and have already overtaken the volumes emitted during the year of the Paris Agreement.

Air transport activity almost back up to 2019 levels

Airline passenger traffic was almost back to 80% of its pre-pandemic level by December 2022, and up to 94.2% in June 2023.[61] From 2000 to 2020, commercial flights grew by an annual average of 5%, pushing up CO_2 emissions by 2% a year. However, the Covid-19 pandemic brought the trend to an abrupt halt, with planes all over the world left sitting on the tarmac for months.[62] China's reopening to international flights accelerated the recovery of global traffic. International flights going to or from Europe alone account for a quarter of global traffic. Domestic flights, which represent 42% of aviation activity – almost half of it in the United States – already exceed by 5.9% the volume of activity recorded in 2019.

Air freight, which had surpassed its 2018 peak after an exceptional recovery in 2021 (+18.7%), ultimately ended the year on a downward trend (-8%), below its pre-pandemic level.[63] European transporters (22% of the market) are impacted by the war in Ukraine, while the Asia-Pacific region (32.4% of the market) is still suffering from the industrial aftermath of Covid-19 and new waves announced in China. Inflation and the high rate of the dollar have slowed down international trade.

In the run-up to CORSIA, alternatives to conventional engines take a backseat

Only domestic flights are covered by the Paris Agreement's scope of application. Nevertheless, in 2021, just 6% of nationally determined contributions (NDCs) mentioning transport made a reference to mitigating aviation emissions.[64] In order to "*achieve carbon neutral growth from 2020 and to reduce its carbon emissions by 50 per cent by 2050 compared to 2005 levels*"[b] since 2016 the international civil aviation sector has organized itself around CORSIA, a carbon offsetting and reduction scheme set up by the International Civil Aviation Organization (ICAO). In autumn 2022, the triennial ICAO general assembly agreed to set a net-zero target for the sector by 2050.[65]

But CORSIA has not really taken off yet. Initially, the programme planned total offsetting of emissions generated above the average emissions recorded in 2019-2020. Only flights between countries opting to take place in the pilot phase (2021-2023) were concerned: these totalled 107 at the end of 2022, out of 193 ICAO members, representing 76% of international activity. But the Covid-19 pandemic brought the programme to a halt before it had the chance to get started. In June 2020, the ICAO Council decided to reduce the programme's reference threshold to 2019 emissions only, instead of average emissions from the sector from 2019-2020.[66] This decision delayed the programme's kick-off date by three years: because emissions are still below 2019 levels, volunteer companies theoretically still have not had to offset any additional emissions since the start of the pilot phase. The programme will not become mandatory until 2027.

In Europe, several countries have recently set up regulatory and taxation levers to spur a drop in domestic aviation. Austria, for example, has banned domestic flights when the same journey can be made by train in under three hours, and in 2020 established a tax of €30 per passenger on flights of less than 350 km, except for transfer flights.[67] France has prohibited domestic flights when an alternative of under 2.5 hours is available, but the application decree features so many exemptions that only three lines are concerned.[68] Spain and Germany are planning similar measures.[69]

Despite being on the table since 2019, the EU has still not reached an agreement to bring to an end exemptions on carbon taxes.[70] According to Transport & Environment, these various tax exemptions cost the European Union over €34 billion in 2022, and 35 $MtCO_2$ of emissions savings.[71] In the absence of standardized taxation of fuel, several European countries have followed Austria's example and implemented a tax on flight tickets (France, Belgium, Germany, Italy, Norway, Sweden and the United Kingdom).

Policies aimed at encouraging biofuels as a substitute for kerosene are rare: in late 2021, three countries (Finland, Indonesia and Sweden) put forward biofuel targets for the aviation sector.[72] Aligned with the EU roadmap featuring in the "Fit for 55" regulation, France for example has required since 1 January

b As declared by the ICAO in the resolution adopted at its 39th session in October 2016 which launched the CORSIA programme.

2022 that planes refuelling on French territory must use at least 1% sustainable aviation fuel (SAF) (then 2% in 2025, 5% in 2030, and 50% in 2050). The EU agreed in June 2023 on a target of 2% SAF in 2025 and up to 70% in 2050, in the ReFuelEU regulation.[73] Since 2011, when KLM operated the first such flight, 516,453 commercial flights have been run on SAF (342,256 flights in 2021) but none have used 100% SAF to date. Only six airports are currently regularly supplied with biofuels.[74] Electrification of international civil aviation, although sometimes evoked, is still a long way off; the German airline Lufthansa estimates that converting its entire fleet to SAF and e-kerosene would consume half of Germany's electricity production.[75]

Maritime transport: the pickup in international trade dwarfs decarbonization efforts

Closely correlated to international trade, emissions from maritime transport are on the rise

In 2022, emissions from international maritime transport (734 $MtCO_2$) were 10.8% higher than in 2015 (663 $MtCO_2$), according to Enerdata figures.[76] Emissions had dipped slightly in 2019 (-2.2%) compared to 2018, due to a slowdown in international trade, before slumping in 2020 (-8.5 %). The progressive recovery of international maritime trade took emissions to a new record level in 2022. According to data from Enerdata, emissions from domestic transport (river, cabotage, ferries, etc.) rose by 12.3% from 2015 (162.5 $MtCO_2$) to 2022 (182.6 $MtCO_2$). The peak was reached in 2019 (184.03 $MtCO_2$) before the pandemic saw figures plummet in 2020 (-10.9%).

According to the fourth study on greenhouse gases (GHG) by the International Maritime Organization (IMO), carbon dioxide (CO_2) constituted 98% of GHG emissions from the sector. However, over the 2012-2018 period, the IMO observes a particularly steep increase (150%) in emissions of methane (CH_4), which has a global warming potential (GWP) 86 times that of CO_2 over 20 years.[77]

Slowdown in growth of international maritime trade

Strongly correlated to the state of the global economy, international maritime trade has seen a slowdown in recent years. After shrinking by 3.8% in 2020 due to the pandemic, international shipping increased by 3.2% in 2021. Already in 2019, the growth of volumes transported had seen its second consecutive year of slump, dropping from 2.7% in 2018 to 0.5% in 2019: figures way below the average recorded from 1970 to 2017 (+3% per year).[78] Global traffic of container ships, which is a key indicator of the state of international trade, followed the same downward trend, with the growth rate dropping from 6.7% in 2017 to 2% in 2019 according to UNCTAD annual reports.

Transportation of containerized cargo, which represents 43% of international maritime trade, has nevertheless remained the main driver of international commerce since 2015 (+14%, in volume), and has already exceeded pre-pandemic levels. Bulk commodity trade (iron ore, grain, coal, bauxite, phosphate, making up 30% of international maritime trade) rose by 11.7% from 2015 to 2021, back to 2019 levels. Lastly, after an increase from 2015 to 2018 (+9.2%), transport of petroleum and chemicals by tanker (27% of commerce), slowed down slightly from 2019 before plummeting in 2020 (-7.7%), and has still not returned to pre-pandemic levels. Among the hydrocarbons, liquified natural gas (LNG) continues to grow strongly (+5.6% from 2020 to 2021), while the traffic of petroleum products has gone down (-0.9%), remaining below pre-pandemic levels (-8.6%). The tonnage of the international fleet carried on growing from 2021 to 2022 (+3%), although the growth rate was its second lowest since 2005.

Decarbonization remains a distant technological and political goal

In April 2018, over one hundred states gathered at the IMO headquarters in London adopted a sectoral strategy to reduce emissions by 2050. This strategy was revised in July 2023, and now sets its sights on zero emissions by 2050 for companies in the sector, with intermediate targets to reduce emissions by 20-30% in 2030 and 70-80% in 2040. The agreement also establishes a minimum incorporation rate for low-carbon energy, fuels and technologies of 5% to 10% of the sector's energy mix by 2030.[79] In addition, since January 2020, the IMO 2020 regulation mandates a reduction in the sulphur content of heavy fuel oil (HFO) used in ships from 3.5% m/m (mass by mass) to 0.5% m/m for all ships circulating outside Emissions Control Areas (ECAs).

To deal with this dual requirement to reduce pollution and carbon levels, the sector has several potential levers, some of which are contradictory.[80] The carbon intensity of the international container ship fleet dropped from 21% between 2012 and 2022, while that of bulk commodities and goods transporters fell by 18%, according to UNCTAD statistics. Yet at the same time, gross emissions increased (**SEE ABOVE**), a sign that the general growth of the international trade fleet is wiping out increased efficiency.

In terms of reducing carbon levels, some efforts focus on developing alternatives to the high-carbon fuels employed to power ships. In late 2022, 21 green shipping corridor initiatives were listed in the world, of which twelve are short-distance and seven are on the high seas. Nineteen of the corridors are run by non-state actors: ports (9), industries (4), and public-private partnerships (9); and the remainder by states (3).[81] The aim of these green shipping corridors is to develop low-carbon commercial shipping routes between major ports, by promoting the development of ships emitting low levels of CO_2, installing charging facilities, and creating an incentivizing legislative environment. To date, the targets set by these projects span from 2027 to 2030. For example, in January 2022, the ports of Los Angeles and Shanghai, joined in June by Long Beach Port, and in partnership with the global city network C40 Cities, A.P. Moller – Maersk, CMA CGM and other industrial and research players, announced the launch of a project to create the first green shipping corridor across the Pacific between China and the United States.[82]

Currently, according to figures from the risk management and assurance provider, DNV, 98.2% of ships operating in the world (93.5% in tonnage), and 73.8% of ships on order (48.7% in tonnage) use conventional fuel (**FIGURE 6**). Among the alternative operating fuels (6.5% in tonnage), liquified natural gas (LNG) largely dominates orders for long-distance ships (78% of tonnage on order and 91% of tonnage in operation), while the other options (batteries/hybrid, methanol, liquified petroleum gas) are more oriented towards short-distance ships.[83]

However, although LNG emits 25% less CO_2 than traditional ship fuels and contains almost no sulphur, it is responsible for the increase in CH_4 emissions observed by the IMO in recent years.[84] Methane leaks from ships running on LNG[85] could account for 0.2% to 3% of the combustion process.[86] In 100 years' time, provided more efficient technology is adopted, emissions savings thanks to LNG could reach 15% compared to marine gas oil (MGO); in twenty years, much closer to the urgent need for climate action, the use of LNG is likely to generate 4% more emissions.[87]

The use of ammonia as an alternative low-carbon shipping fuel comes up against the limitations of hydrogen production, of which it is a derivative. Since the energy density of ammonia is lower than that of petroleum, converting the entire international shipping fleet would mean tripling ammonia production to 440 million tonnes, requiring no less than 750 GW of renewable electricity.[88] Yet today, only 0.3% of the hydrogen produced in the world comes from renewable electricity (**CF. "INDUSTRY" TRENDS**). In February 2022, the Greek shipowner Avin International inaugurated Kriti Future, a "Suezmax" tanker announced as the first ship in the world running on ammonia. At the moment, the ship still operates using conventional fuel, but it is equipped with the necessary conversion technology.[89]

Methanol, which features in the strategies of the major shipping companies as a means to diversify their energy sources, has a high carbon content: almost all of the 98 million tonnes of methanol produced annually come from fossil energy (gas and coal). Only 0.2 million tonnes of "renewable" methanol are produced every year, mostly from biomass.[90] Here too, the production of "e-methanol" depends on the hydrogen market. A.P. Moller – Maersk, which has committed to only order low-carbon ships in the future, is expecting delivery of six methanol-powered ships in 2025,[91] and has signed a series of strategic partnerships with industrial companies (including Orsted, Proman and European Energy) to develop production of bio- and e-methanol.[92]

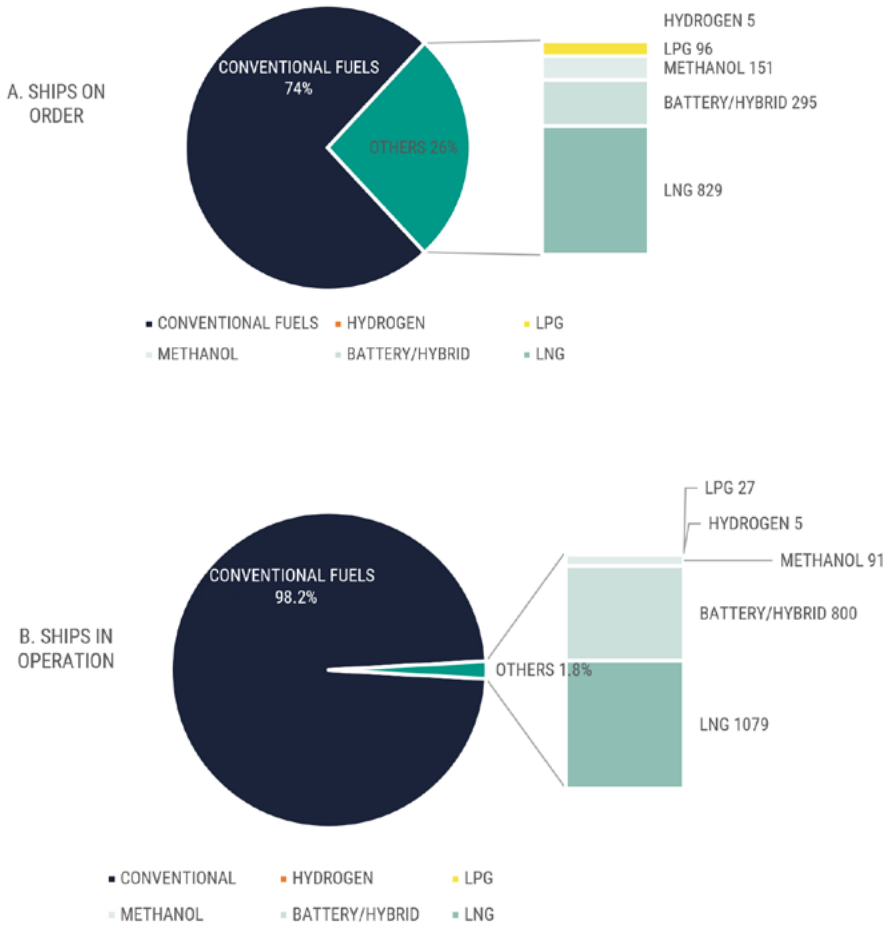
Currently, 800 ships operate with an electric battery or hybrid system, which only represents 0.26% of global tonnage, according to DNV. These are mostly short-distance ships. For example, in 2019 the Norwegian parliament voted to ban GHG emissions in the country's fjords, and since 2015, ferries and cruise liners must be equipped with zero- or low-emissions technology.[93] The Swedish company Stena Line, which already operates hybrid (diesel-electric) ferries, announced in September 2021 the launch of a 100% electric ferry... but not until 2030.[94] The *Yara Birkeland*, announced in 2017 as the first autonomous container ship powered by an electric battery, was baptized this year in Norway and is currently in a two-year testing phase to obtain certification.[95]

Reduced demand for transport and shorter value chains are not even on the table. Demand for transport of goods in tonne-kilometres is set to triple by 2050 if no action is taken.[96] This demand is the result of both more intense international trade (tonnes) and an organization of logistic trains that involves very long geographic distances (km). This reorganization involves a transition from a production-consumption system towards more circularity, proximity, and resilience to simplify and shorten value chains.[97] A recent UNCTAD study for example identified four key trajectories for logistics chains (reshoring, diversification, regionalization, and replication), three of which involve shorter, sometimes less fragmented chains.[98]

FIGURE 6

LIQUEFIED NATURAL GAS DOMINATES ALTERNATIVE FUELS FOR SHIPS IN OPERATION AND ON ORDER

Source: DNV, 2023



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