UBA Forum
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Heavy Freight. Big Challenge. One goal.

Environmentally sustainable freight transport: international, national, local

German Environment Agency

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German Environment Agency
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
buergerservice@uba.de
Internet: www.umweltbundesamt.de/en

Authors:
Martyn Douglas, Juliane Bopst, Wolfram Calvet, Miriam Dross, Katrin Dziekan, Katharina Koppe, Martin Lambrecht, Martin Lange, Juliane Schicketanz, Frank Wetzel

and
Percy Appel, Anna Chanin, Christian Fabris, Andrea Fechter, Kilian Frey, Detlef Gebauer, Michael Golde, Detlef Grimski, David Hartmann, Olaf Hölzer-Schopohl, Helge Jahn, Andrea Kolodziej, Christine Kornher, Anja Leskovar, Benjamin Lünenbürger, Thomas Myck, Elke Örtl, Maximilian Pagel, Carola Pahl, Ulrike Pirntke, Katja Purr, Inke Schauser, Ulrike von Schlippenbach, Martin Schmied, Dana Shilton, Annett Steindorf, Doris Tharan, Julia Treichel, Christoph Töpfer, René Weinandy, Jan Weiß

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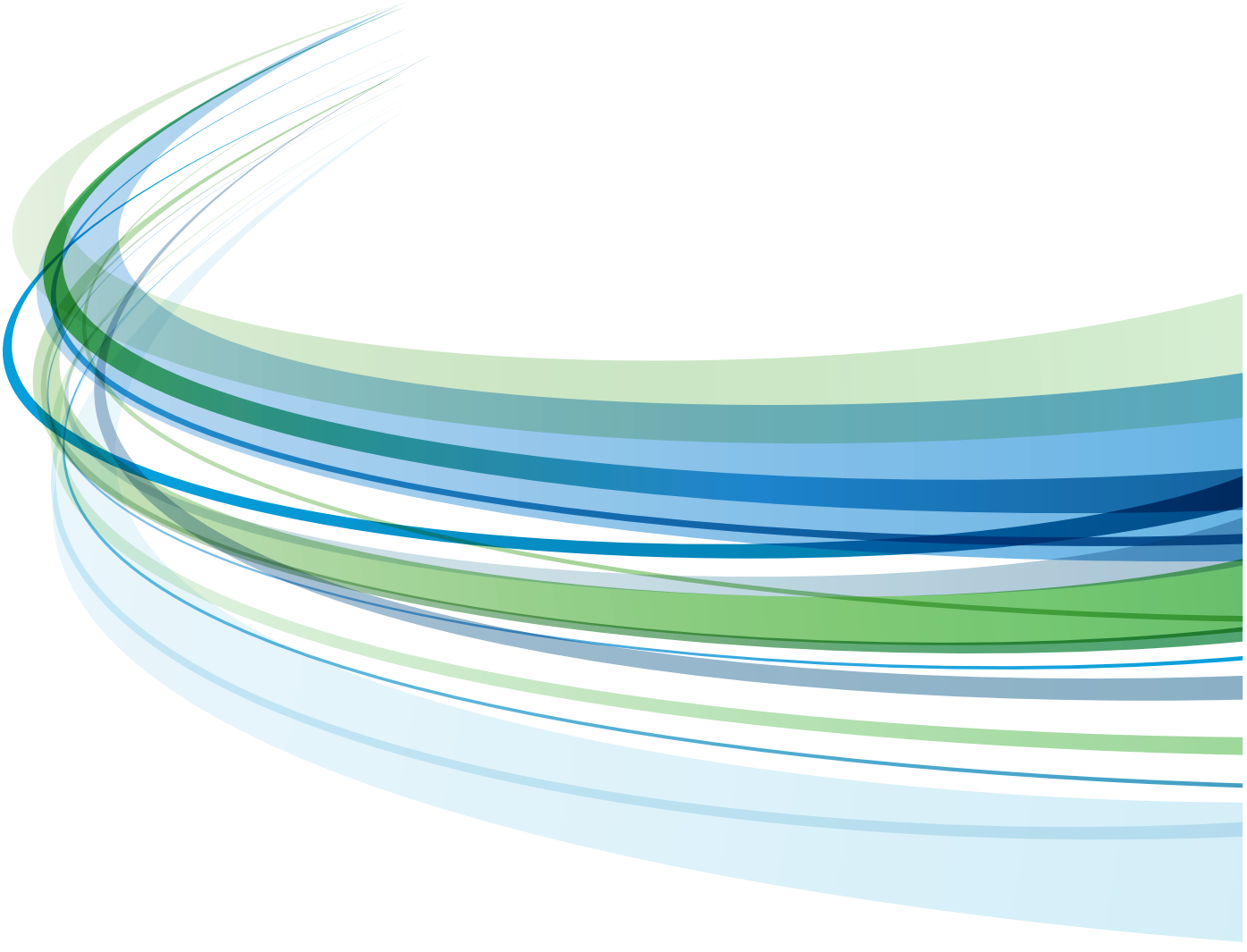
Heavy Loads.
Big Challenge.
One goal.

UBA Forum 2024

Environmentally sustainable freight transport

climate-neutral, resilient, low-emission, affordable, intergenerationally just



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Introduction: re-navigate quickly!

1

Introduction: re-navigate quickly!

Freight transport keeps the world running. If goods were not packed, loaded, transported, reloaded, distributed, sorted and delivered every single second of the day, the plug would be pulled on the global economy. Factories would no longer be able to produce, construction sites would come to a standstill, waste would no longer be collected, and shelves would remain empty.

The years with the coronavirus 2020 to 2022 have shown how heavily society and economic systems around the world are dependent on goods transport. However, COVID-19 is over, logistics is booming, and supply chains are once again firmly established. So – keep going with business as usual?

No question. Like other sectors of the economy, freight transport must answer climate and environmental protection challenges. And quickly: the current German Climate Protection Act stipulates a reduction in greenhouse gas emissions for the entire transport sector to 85 Mt CO_2 equivalent by 2030. Germany aims to be greenhouse gas neutral by 2045. In 2023, the transport sector missed its reduction targets for the third time in a row. Its greenhouse gas emissions amounted to 146 Mt and were therefore 13 Mt too high.

Freight transport must significantly reduce its emissions – internationally, nationally and in urban areas. It's not a simple task. The demand for logistics services is growing worldwide. Reductions in emissions, for example through more efficient lorry engines, optimised ship propulsion systems and improved aircraft turbines, are quickly being overcompensated. As a result, technical progress is not having any sufficient impact on emissions.

What's often forgotten is this: freight transport is currently a variable that is largely derived from economic activities. The better the economic situation, the higher the demand for goods and their transport. However, the link between economic growth and ever more transport is not a natural constant. Mileage and emissions can be reduced if transports are better planned, coordinated and organised or distances are shortened.

In order to achieve environmental and climate protection targets, the entire sector must re-navigate: with electric drives instead of diesel engines, with post-fossil fuels, by firmly shifting goods from road to rail and with the help of comprehensive digitalisation. That is a transformation task that all players can only accomplish together.

This specialist brochure from the German Environment Agency (UBA) shows how freight transport can be steered in a greenhouse gas-neutral, resilient, low-emission, affordable and intergenerationally just direction in the future. Herein UBA outlines a vision for environmentally sustainable transport and proposes measures and instruments that can point **international transport** by sea and air, **national transport** by road, rail and inland waterway and **urban logistics** in the right direction.

Far-reaching changes in transport systems take time and the status quo is characterised by a high degree of perseverance. Many of the measures and instruments proposed in this specialist brochure will therefore only have an impact in the medium and long term. This makes it all the more important to act now without further delay. After all, environmentally sustainable freight transport would not only be greenhouse gas-neutral and clean. Strengthening alternatives to road transport, moving away from fossil dependence and openness to digital solutions at all levels can also ensure that the freight transport system becomes more resilient to political, economic and ecological crises.

A burden on health, environment and climate


2

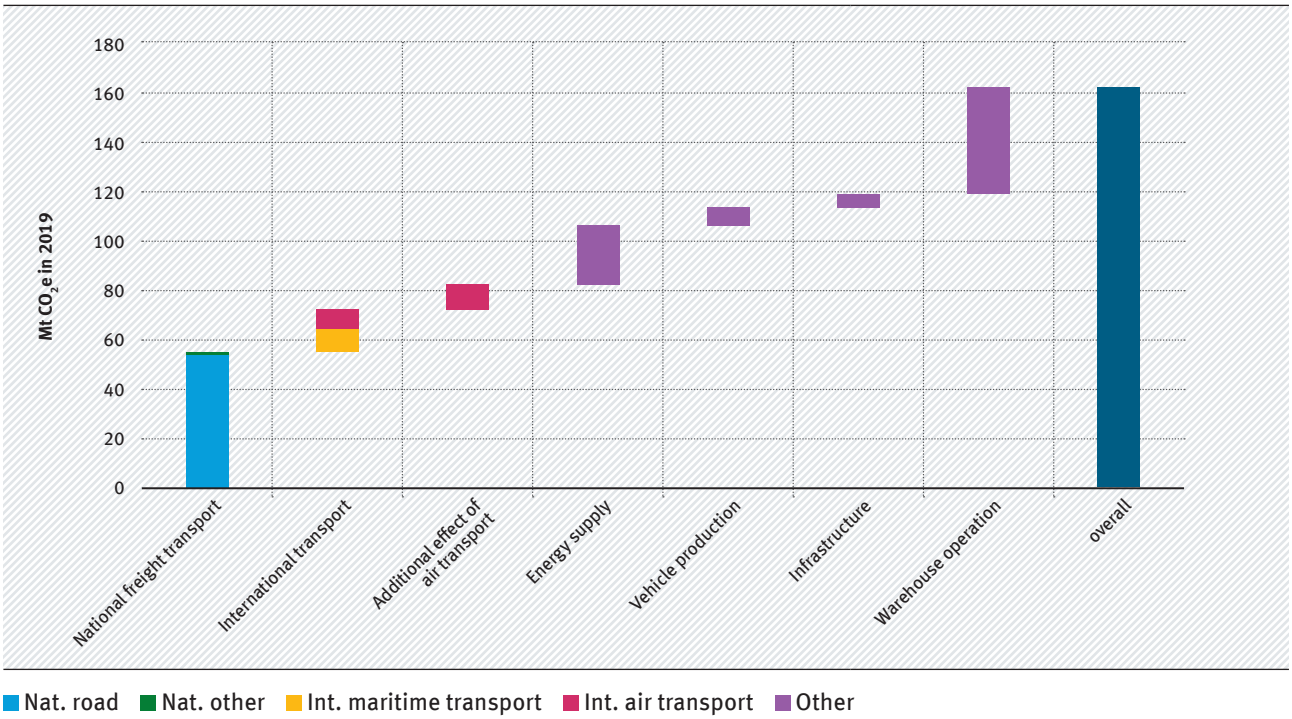
A burden on health, environment and climate

Freight transport is a burden on people, environment and climate. It generates greenhouse gases, air pollutants and noise and consumes a lot of land. Freight transport is also not yet on course towards environmental compatibility and greenhouse gas neutrality. In areas with heavy traffic, the World Health Organization's recommended limits for particulate matter and nitrogen dioxide are significantly exceeded. But above all: if the energy transition in transport does not become a reality faster than it has so far, freight transport will not reach its climate protection goal.

Greenhouse gas emissions. How many greenhouse gas emissions are caused by freight transport depends on how you look at it. As the years 2020 to 2023 were strongly characterised by the effects of the coronavirus pandemic and wars, many of the figures in this specialist brochure refer to 2019 – the last year in which global business-as-usual was still possible.

Figure 1

GHG emissions from German freight transport in 2019, in consideration of other climate impacts outside of transport



Freight transport in the transport sector according to TREMOD 6.43, only direct emissions (TTW) of fossil fuels and according to the energy balance principle; international transport: Biemann et al. 2024a, energy supply: source TREMOD 6.43 and Biemann et al. 2024a; vehicle production and infrastructure, warehouse operation (only concerns warehouses in Germany): Opitz et al. 2024.

Source: German Environment Agency, own illustration according to Opitz et al. 2024

In 2019, freight transport in Germany emitted 55 Mt CO_2e (carbon dioxide equivalents).[1] This is roughly equivalent to the emissions of the entire agricultural sector and over 7 % of Germany's total greenhouse gas emissions. If you include international transport, where half of the emissions from the entire route are added in accordance with the "halfway principle", and also the so-called non-CO_2 effects of air transport (e. g. by soot particles and condensation trails), the total increases to over 80 Mt CO_2e.

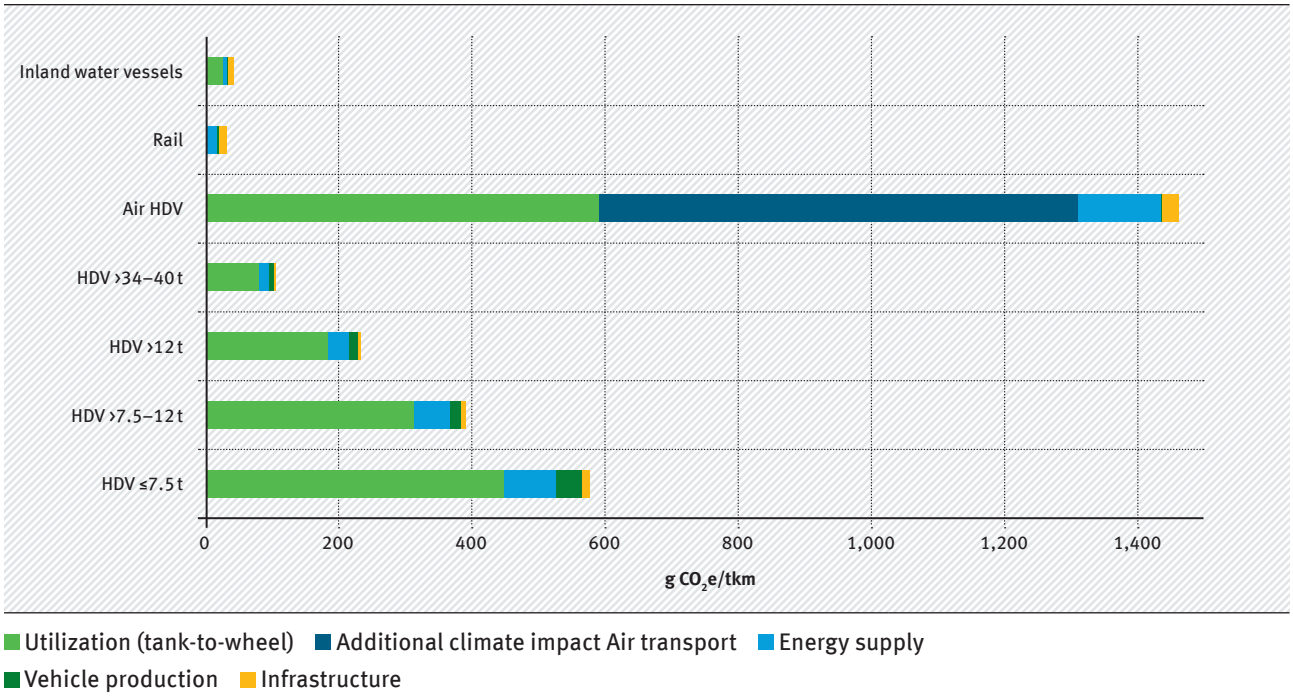
The figure even doubles to around 160 Mt CO_2e when emissions for electricity, heat, warehouse operations and infrastructure construction caused by freight transport are considered (see Figure 1). These include, for example, the construction and maintenance of roads and railways, electricity for and the heating of warehouses, the production of vehicles and fuels such as diesel or kerosene. In comparison, total greenhouse gas emissions in Germany in 2019 were 797 Mt CO_2e.

The German Climate Protection Act (KSG) only covers the national part of freight transport in the transport sector.

This is dominated by lorry transport, as a result of which the majority of emissions also result from road freight transport – it accounts for 98 % of greenhouse gases from freight transport in Germany (see Figure 1). International transport causes an additional 27 Mt CO_2e, i. e. half as many emissions as national freight transport. Air transport accounts for two thirds of these emissions, even though it only handles around 0.1 % of the freight volume in Germany.
If the non-CO_2 effects of air transport are included, the climate-damaging emissions per tonne-kilometre (tkm) from air freight are 200 times higher than those of maritime transport.[2] International maritime transport therefore has a better carbon footprint. Its freight volume in 2019 was as high as around 8.2 % of the national volume and it emitted 9.6 Mt CO_2e. Most greenhouse gases from international transport are produced on routes to and from Asia, followed by connections to North and South America.

Figure 2

Greenhouse gas potential of freight transport per tonne-kilometre



Data as of 2017. Air = international air freight, HDV = heavy duty vehicle
Sea-going vessels were not analysed in the study.

Source: Opitz et al. 2024

1 Opitz et al. 2024: Environmental and climate protection in logistics - potentials of environmentally oriented logistics concepts to reduce emissions from freight transport (PULK).

2 Biemann et al. 2024a: Local, national and international environmentally sustainable freight transport - Data report on the transformation dialogue and UBA Forum mobil und nachhaltig.

Tab. 1

Estimation of GHG emissions for vehicle production and transport infrastructure in German freight transport for 2019

Vehicle category	Transport performance in billion tkm	Infrastructure in Mt CO_2e	Vehicles in Mt CO_2e
Motor vehicles	498.5[1)]	3.2	6.9
Aeroplane	12.2[2)]	0.3	0.01
Railway	133.6	1.6	0.3
Inland water vessel	50.9	0.4	0.1
Total	**695.2[1), 2)]**	**5.5**	**7.3**

1 Additional mileage of 53.7 billion vehicle kilometres for light commercial vehicles.
2 Air freight incl. international flights.
Seagoing vessels were not analysed in the study.

Source: Opitz et al. 2024, calculation using emission factors for 2017 from (Al- lekotte et al. 2020) and driving and transport performance from TREMDO 6.43. Values rounded

It's not only the transports themselves that are harmful to the climate. The production and distribution of the necessary fuels and the manufacturing of vehicles, inland waterway vessels, freight trains and aeroplanes consume energy and therefore generate large amounts of greenhouse gas emissions (see Figure 2). Added to this are the construction and expansion of transport infrastructure, without which transport would not be possible. A significant proportion of emissions is caused by the operation of buildings of all kind, which a logistics chain requires (see Figure 1). Table 1 compares the different means of transport in regards to the level of emissions for infrastructure and vehicle production.

Air pollutants. Road freight transport in Germany emitted around 107,000 t of nitrogen oxides in 2022.[3] Nitrogen oxides can cause respiratory diseases and are a particular danger to children, people with an impaired health and the elderly. Nitrogen oxides negatively impact humans especially in busy and also densely populated cities and urban centres. Only a relatively small proportion of particulate matter emissions are released into the air via exhaust fumes from freight transport. More significant are abrasions from tyres, brakes and road surfaces. In 2022, the amount of particulate matter with a particle diameter of less than 10 micrometres (known as PM10) from all road transport was around 25,000 t.

In comparison, transport by rail is relatively clean. Emissions of nitrogen oxides in 2022 amounted to just under 8,000 t, and 9,000 t for PM10. Nitrogen oxides in rail freight transport mainly derive from the combustion of diesel fuel, e. g. from shunting operations. As with road freight transport, particulate matter emissions are primarily a result of mechanical abrasion, i. e. in the case of rails, brakes and overhead lines.

Inland waterway transport is a somewhat minor source of air pollutants in Germany. In 2022, exhaust emissions from inland water vessels in freight transport amounted to around 20,000 t of nitrogen oxides and 800 t of PM10. However, if these values are applied to transport performance, which is only around a tenth that of road transport, inland water-

3 For direct pollutant emissions, current data from the national reporting of pollutants is available for 2022. In the area of pollutant emissions, fleet renewal has a greater reducing effect compared to greenhouse gas emissions, making up-to-date information particularly important.

Tab. 2

Pollutant emissions per transport performance of German freight transport for the year 2022 (incl. energy provision and energy conversion).

Means of transport	Nitrogen oxides in g/tkm	Particles excl. abrasion in g/km
Lorry	0.198	0.010
Freight railways	0.032	0.001
Inland water vessel	0.415	0.011

Source: German Environment Agency 2024 / TREMOD 6.51

way vessels have – unlike with greenhouse gas emissions – no advantage in terms of air pollutants. This can be explained by the fact that the diesel engines of inland water vessels often only have outdated exhaust gas aftertreatment systems. In sections of waterways close to cities, however, it is not the emissions from ships that dominate, but those from neighbouring road traffic. Table 2 clearly shows the advantage of rail transport in terms of air pollutants.

The picture is quite different for international maritime transport. Here, the total quantities of air pollutants are comparable to those from road freight transport. International freight transport by ship in 2019[4] – based on the half-route principle[5] – emitted over 177,000 t of nitrogen oxides and over 12,000 t of PM10. A specific problem in maritime transport are sulphur dioxides from the combustion of fuels for which high sulphur contents are permitted. In Germany, diesel fuel for lorries, trains and inland water vessels may contain a maximum of 0.001 % sulphur. For fuels used in maritime shipping, a global limit of 0.5 % has been in existence since 2020, which is 500 times higher. In so-called Sulphur Emission Control Areas (SECAs) such as the North and Baltic Seas, a sulphur limit of 0.1 % is permitted. Additionally, even in SECAs the use of heavy fuel oils with more than 0.1 % sulphur is permitted if the ship has an Exhaust Gas Cleaning System, also called Scrubber, on board. Running a Scrubber usually results in discharges of polluted wastewater.

Air freight transport emitted around 39,000 t of nitrogen oxides and 320 t of PM10 in 2019. In relation to its low transport performance, these values are quite high. In particular, the relevant share of ultra-fine particles with a diameter of less than 100 nanometres gives rise to health hazards in the vicinity of airports, as these tiny particles can penetrate deep into the lungs and cause respiratory illnesses. Within a one-kilometre radius around an airport, air traffic can account for up to 25 % of exposure to ultrafine particles.

4 For air and sea transport, data as at 2019 is used due to different evaluation methods.

5 In the case of maritime transport, the following geographical scope is often used: half of the emissions for all outbound and inbound transport or from imports and exports are taken into account.

Noise pollution. Transport generates noise. Many people in Germany feel disturbed or annoyed by noise and their health is jeopardised. A survey in 2020[6] revealed that 76 % felt disturbed by road traffic noise, with one fifth feeling extremely disturbed. Only 24 % tend to accept road noise or live in areas with little traffic. Aeroplanes and trains also cause noise problems. 43 % of respondents felt disturbed by air traffic and around one in three by rail traffic (see Figure 3).

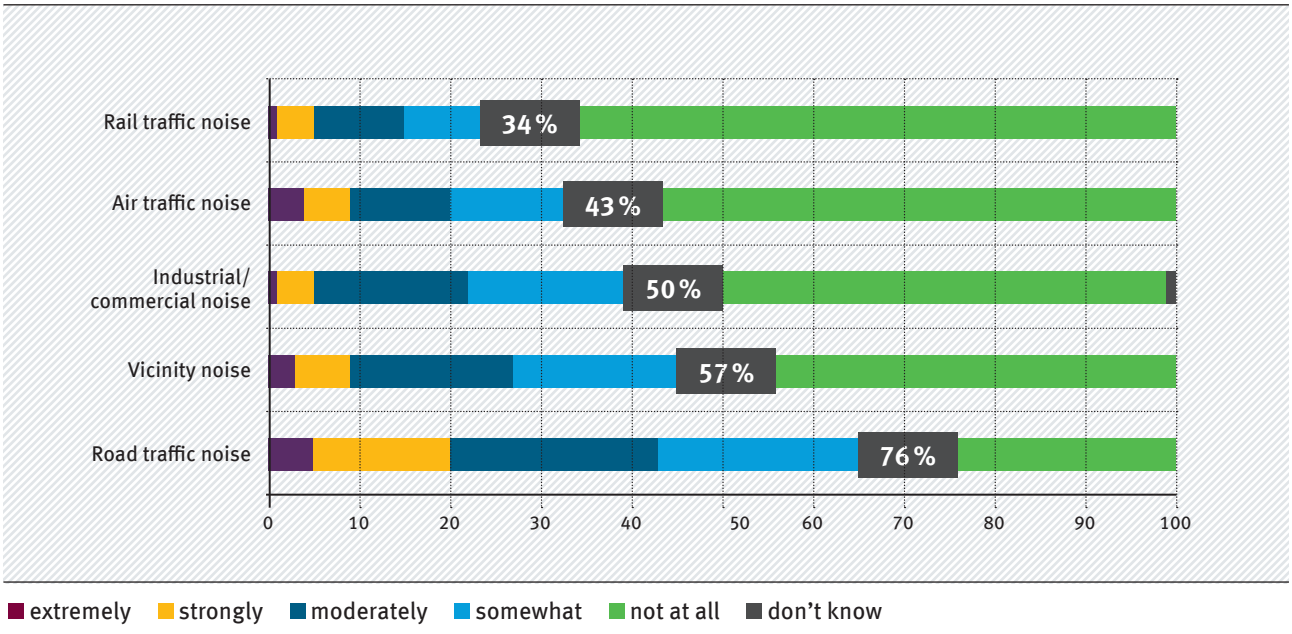
Noise mapping as part of the EU Environmental Noise Directive and UBA calculations for the year 2022 also revealed that large parts of the population are exposed to traffic noise. Around 16 out of 25.5 million people in the areas covered by noise mapping are exposed to road traffic noise with average levels of at least 55 decibels(A)[7] throughout the day alone. At these average levels, psychological and social well-being is increasingly likely to be impaired. More than ten million people are also exposed to nightly noise levels of at least 50 dB(A), of these every second person is exposed to significantly higher levels. According to the WHO, healthy sleep is no longer possible above 50 dB(A).

Figure 3

How disturbing is the traffic noise?

Question: Thinking back over the last 12 months around these environs, how much have you personally been disturbed or annoyed by the noise from the following things?

(Figures in per cent, deviations from 100 per cent due to rounding)



Source: Belz et al. 2022

6 Belz et al. 2022: Environmental awareness in Germany 2020.

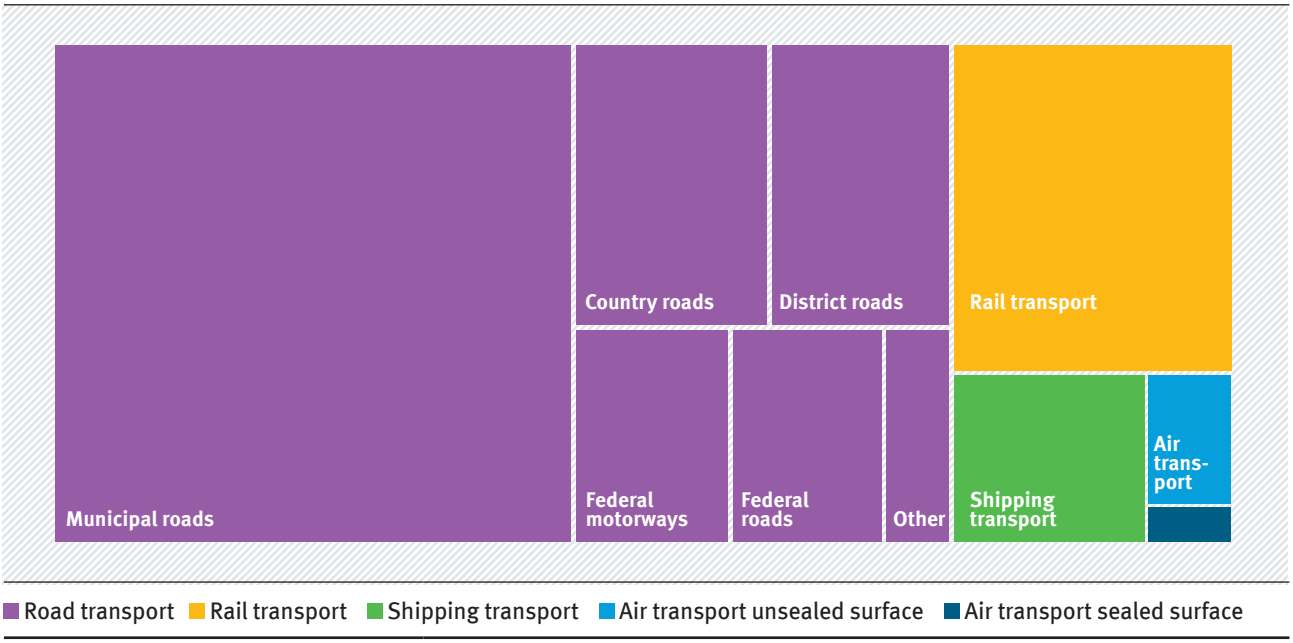
7 The unit of sound pressure level is decibel. The frequency constant A adjusts a physically measured sound pressure level to the sensitivity of the human ear. This is why decibel(A) or dB(A) for short is used in literature.

Land consumption. When it comes to land consumption, intentions and reality lie far apart. The German Sustainability Strategy of 2021 stipulates that land consumption in Germany should be reduced – to an average of less than 30 hectares per day by 2030. In its sustainability strategy, the German government is aiming for a circular land economy by 2050. This means that in line with the EU's 2030 soil strategy, all in all no more new land should be used for settlement and transport purposes. Germany is a long way from achieving this: the four-year average for the years 2019 to 2022 still amounted to 52 hectares per day. The entire transport sector currently takes up almost 6,000 square kilometres of land which corresponds to around 1.5 % of Germany's land area, with road transport being by far the largest land user (see Fig. 4).[6]

Freight transport needs space not only for roads and railways, but also for ports, terminals and multimodal hubs, for warehouses, depots and administrative buildings. Measures and instruments that reduce freight transport represent a clear benefit for health protection and air pollution control. Last but not least, they spare the valuable resource, soil. A resource that is very limited in Germany and that must fulfil many uses at the same time: soils are indispensable for climate protection, as carbon and water reservoirs, for food production and for nature conservation. Where roads and other transport routes cross habitats or isolate populations they can disturb important functions and, for example, lead to a deterioration of flora and fauna.

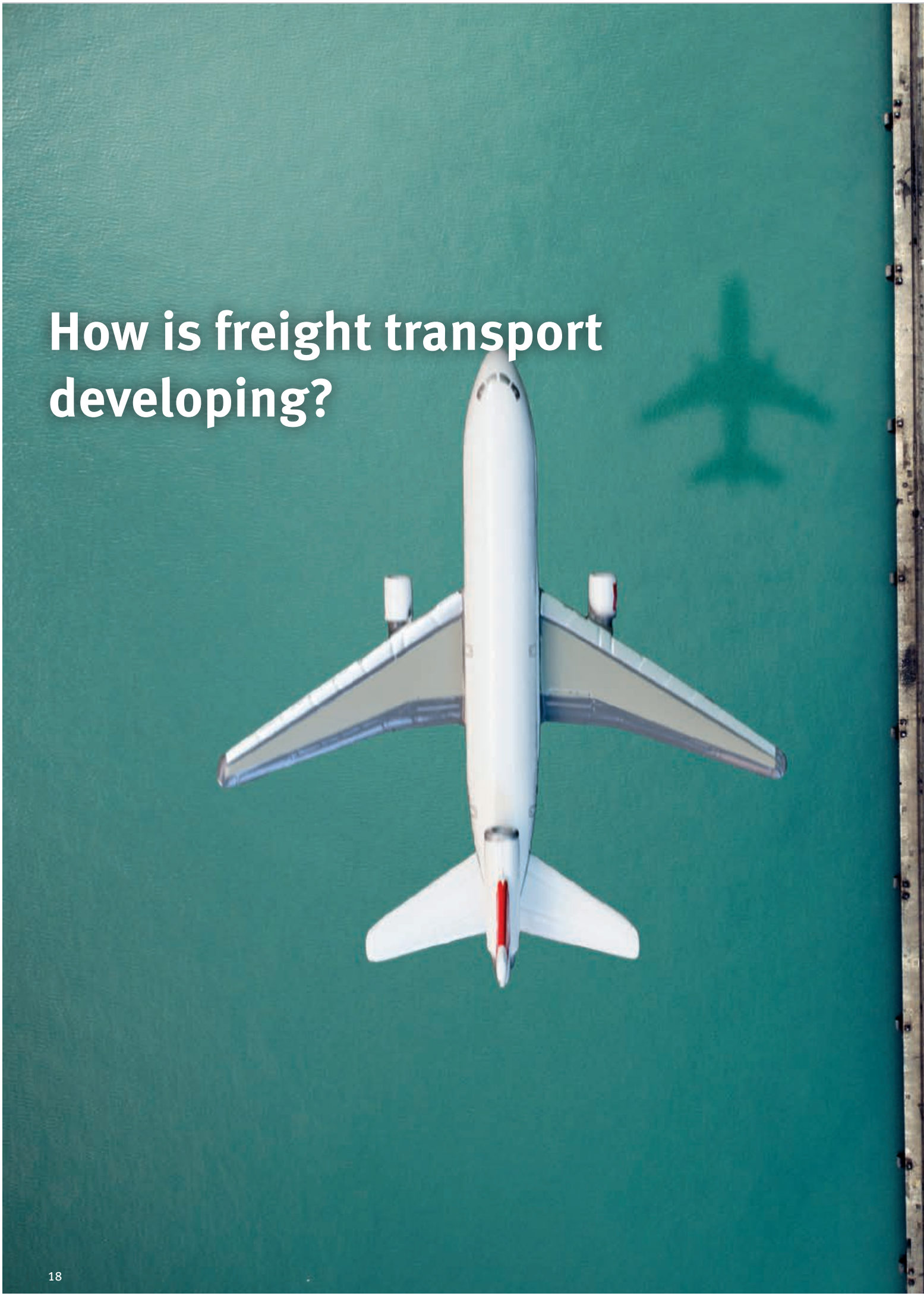
Figure 4

Land consumption by type of transport



Source: German Environment Agency, own illustration with data from Biemann et al. 2024a

How is freight transport developing?



3

Where is freight transport headed?

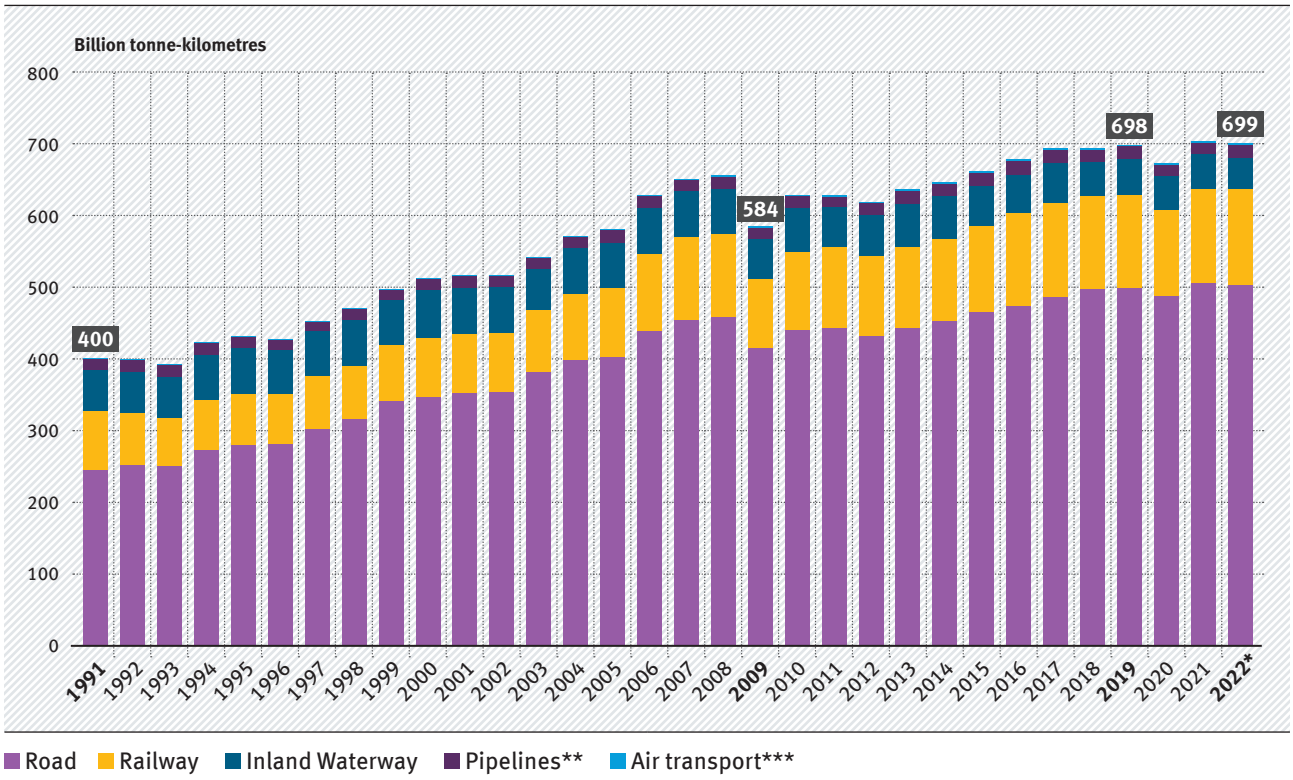
To date, both transport as a whole and freight transport in particular have been on the rise, which has led to an increase in transport-related climate and environmental stresses. In terms of energy consumption, freight transport accounts for around 40 % of total transport in Germany. In the past, it grew significantly faster than passenger transport. As globalisation progressed and economic output grew, transport distances became longer and the number of transport routes increased; freight transport performance continued to rise. Price-adjusted gross domestic product and domestic freight transport have each risen by almost 20 % since 2005, which illustrates their close link. Despite efficiency measures, energy consumption in freight transport has also increased by around 20 % since 2005.[8]

Looking back over the last 30 years (see Figure 5), freight transport performance in Germany increased by around 75 % between 1991 and 2022, from 400 to 699 billion tonne-kilometres. Growth in passenger transport was significantly lower at 22 %. Road freight transport recorded an increase of around 105 % and rail freight transport an increase of just under 61 %.

The bulk of freight transport in Germany is carried out on the road. The share of the more environmentally compatible modes of transport, rail and inland waterways, has fallen from a combined 34.5 % in 1991 to 25.3 % in 2022. Rail freight transport was only able to partially compensate for the decline to a share of 6.3 % in inland waterway transport. Over the last 20 years, rail freight transport has grown slightly faster than overall freight transport, with rail share rising from just under 16 % to 19 %.

Figure 5

Freight transport performance by mode of transport in Germany



* partly preliminary data
** from 1996 only crude oil
*** Freight and airmail, excluding handling

Source: German Environment Agency 2023, data from Transport in Figures of the BMDV

8 UBA 2024: Data and calculation model Transport Emission Model "TREMOD", Version 6.51.

In March 2023, the Federal Ministry for Digital and Transport (BMDV) presented a new transport forecast: the **"Moving Long-Term Transport Forecast"**.[9] It extends to the year 2051 and attempts to forecast the development of freight transport over the next almost 30 years. Compared to older forecasts, it takes an increased population, changes due to the accelerated energy transition and high energy costs as a result of the war in Ukraine into account. However, it does not incorporate further-reaching measures such as transport avoidance or modal shift in order to safely achieve the climate targets in transport or in accordance with the EU's Effort Sharing Regulation.

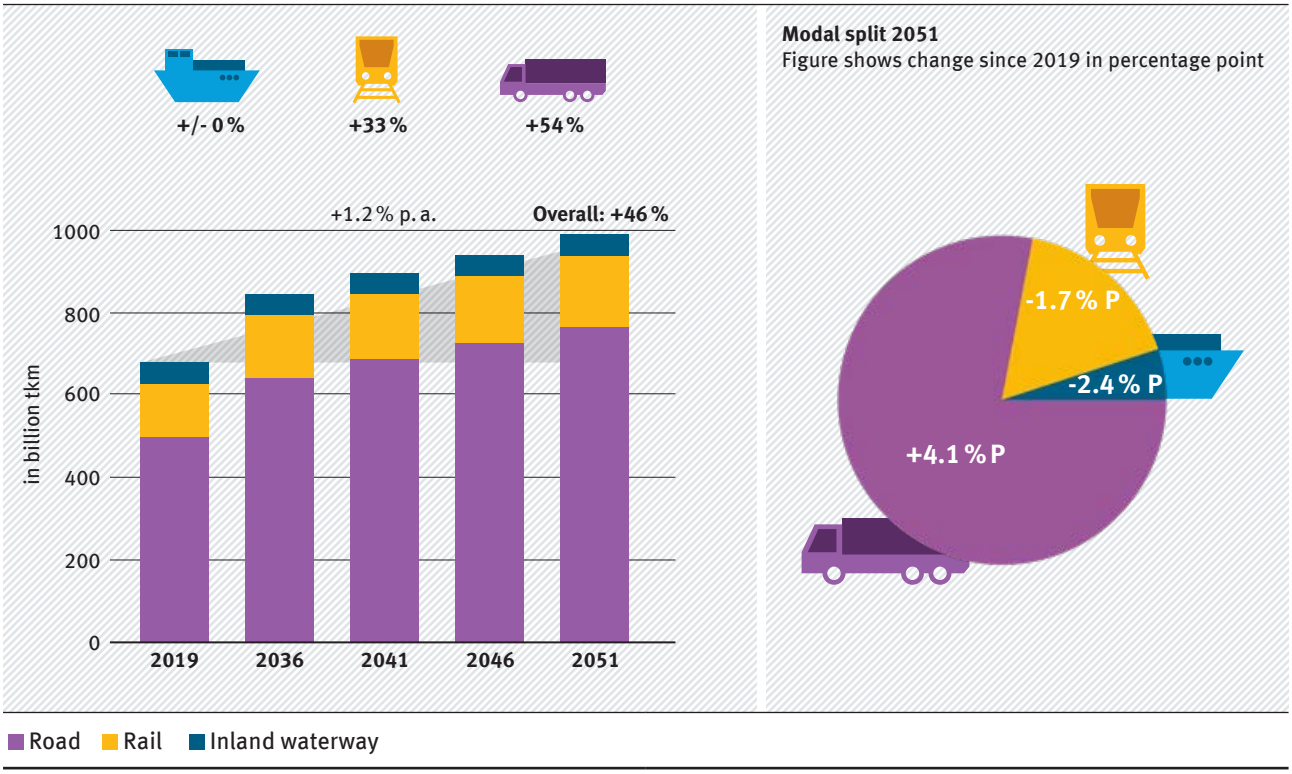
According to this forecast, freight transport will continue to grow strongly in line with the assumptions made (see Figure 6). Transport performance will increase by 1.2 % per year in the period from 2019 to 2051 and thus by 46 % in total until 2051. The volume of freight transport will be slightly lower at just under 30 %, although transport distance will continue to grow.

Between 2010 and 2019, freight transport was growing by 1.3 % per year. Accordingly, a similarly high growth rate can be expected in freight transport if no further measures are taken to induce an ecopolitical transition in this area.

According to the forecast, road transport will record the highest growth of 54 %. As a result of the above-average growth on the road, modal split is favouring road freight transport while rail and inland waterway transport are losing importance. Transport performance in rail freight transport is forecast to grow by 33 %, primarily due to the strong increase in intermodal transport (rail/lorry). The moving long-term transport forecast also assumes that the transport volume (in tonnes) in inland waterway transport will decrease by 10 % by 2051 (compared to 2019). As the transport distances will increase, the transport performance will nevertheless remain the same.

Figure 6

Change in freight transport performance according to the "Moving Long-Term Transport Forecast"



Source: Own representation according to BMDV 2023

9 BMDV 2023: Moving long-term transport forecast 2021–2022, results report on the 2022 forecast "Foreseeable route".

Further growth of freight transport by road would put pressure on existing transport systems. In this context, various stakeholders criticise the fact that planned further expansion of road transport will perpetuate its continued growth and that the need for changes in freight transport to protect the climate will not be sufficiently respected, if the focus for infrastructure projects is not placed on rail transport.

Change in freight transport: the Goods-Structure Effect. The main reason for the sharp increase in road transport lies in the restructuring of freight transport as a result of a changing economic structure.

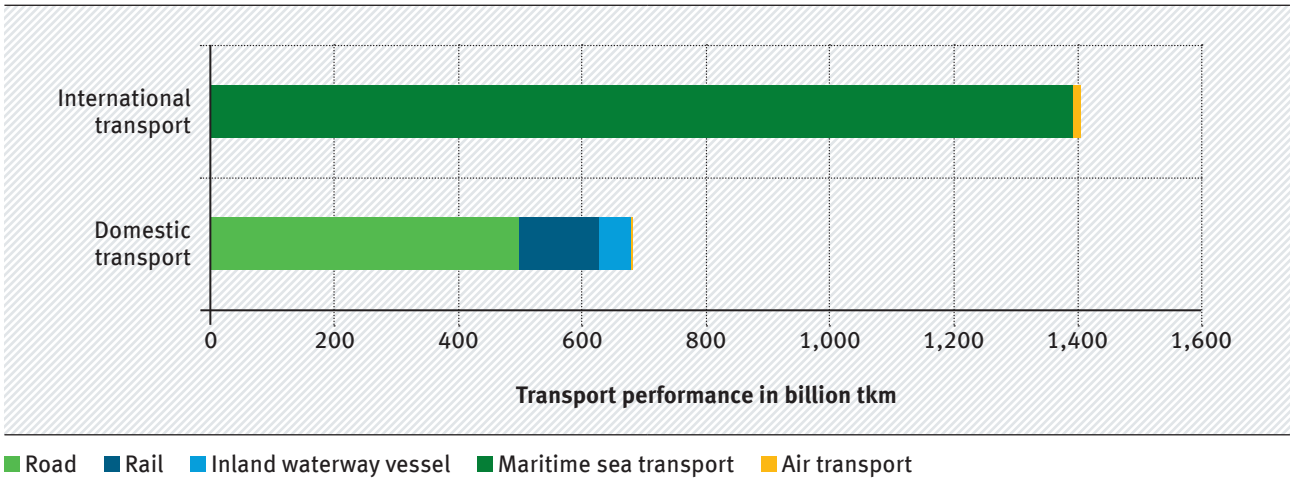
The Freight Structure Effect means a decrease in the average weight of transports and an increase in demand for the transport of smaller, individualised goods of relatively high value. Primarily due to rising energy costs, phasing out coal and replacement of oil for heating and mobility with renewable electricity, fewer bulk and energy goods will be transported in the future. This comes at the expense of the market shares of rail and inland waterway transport.

According to the Moving Long-Term Transport Forecast, the volume of bulk goods will drop to 24 % in 2051 compared to the volume in 2019. For collective consignments and general cargo as well as mail items, which are preferably sent via lorry, a strong growth is forecasted. Accordingly, the volume of mail and parcels will increase by 200 %, that of collective consignments by 91 % and the "machinery and equipment" group will also grow strongly by 64 %.

In 2019, the transport performance of international transport to and from Germany was around twice as high as that on German territory (see Figure 7). Maritime shipping accounts for the majority of this freight transport performance. In contrast, air transport only has a very small share. The Freight Structure Effect also shifts the shares between the modes of transport internationally, and thus has an impact on air and sea transport. Transport volume in maritime transport through exports increases from 425 billion tonne-kilometres (tkm, 2019) to 441 billion tkm (2050), while import transport performance will fall from 968 billion tkm (2019) to 781 billion tkm in 2050.[10] In air freight, inbound and outbound transport volume will result in different effects. Air freight transport performance amounted to 12.2 billion tkm in 2019 and will increase by 44 % to around 17.6 billion tkm by 2050.[11] In 2019, two thirds of transport performance was carried out by cargo plane, while the remaining 37 % was handled as so-called belly freight in large passenger aircraft.[10]

Figure 7

Transport performance of international transport compared to domestic transport for 2019



* Air transport up to the first (stopover) landing, sea transport 50 % of the sum of import and export up to the country of origin/destination

Source: Own illustration according to Biemann et al. 2024a

10 Biemann et al. 2024a

11 UBA 2024. according to "trend scenario".

Effects of high energy prices. The impact of the Freight Structure Effect will be significantly amplified by future energy prices remaining at high levels. In the Moving Long-Term Transport Forecast, it's assumed that real energy prices, beyond fuel prices, will stabilise at a high level in the period up to 2051. This initially has a direct impact on user costs in freight transport. High energy prices cause economic changes outside the transport market, but also on the transport market as a whole. In particular industrial energy- and resource-intensive production would in part be relocated abroad, in line with the Moving Long-Term Transport Forecast and its elements. As a result, rail freight and inland waterway transport in particular would lose transport volumes, partly due to the coal phase-out in Germany. High energy prices are accelerating the energy transition in transport, as energy efficiency is playing a greater role. Due to electromobility in passenger and freight transport the need for fuels will decline. Foreseeably higher prices for greenhouse gas-neutral fuels in the form of e-fuels or PtX fuels (power-to-X, power-to-gas or power-to-liquid) could accelerate this decline faster than the forecast predicts.

Reviewing the forecast. Regular updating of forecasts is important for structuring environmentally compatible freight transport. Economic fluctuations are indirectly included in transport forecasts when past developments are extrapolated. However, global crises with an impact on world trade – and therefore on freight transport – cannot be foreseen.

The Federal Ministry of Transport's Moving Long-Term Transport Forecast contains over 130 assumptions and comprehensive analyses of the structural data, which have been broken down to below district level in terms of spatial distribution. Its assumptions also seize on demographic and economic structural breaks (e. g. energy costs, migration). It contains every political instrument adopted to date and shows how things could develop if no further instruments – for example to achieve the environmental and climate protection targets – are adopted or targets are changed. The forecast can serve as a basis or starting point for scenarios in which the impact of additional, urgently needed climate protection measures in transport is calculated. However, BMDV has not yet done this. UBA's vision for environmentally sustainable freight transport presented in this brochure as well as the proposed measures could form a basis for the development of a transformation scenario.

Despite the high number of assumptions and the risk of distortion, the Moving Long-Term Transport Forecast provides an overview of a possible future transport development, minus a focus on the achievement of environmental, climate protection and sustainability goals, and is used in the brochure as a starting point for the discussion of further measures and instruments.

The BMDV's forecast shows that the environmentally compatible modes of transport, rail and inland waterway, are under considerable pressure. They must be supported by comprehensive infrastructural, operational and market-related measures in order to continue to make a key contribution to environmental and climate protection. At the same time, however, measures must also be discussed which, by consolidating freight flows, shortening transport distances and avoiding transports, dampen growth in freight transport overall without having negative consequences for economic development.

Vision for environmentally sustainable freight transport


4

Vision for environmentally sustainable freight transport

Transport is the only sector in Germany in which greenhouse gas emissions remain as high as ever. As a rapidly growing area of transport, freight transport causes considerable environmental pollution – primarily through emissions of carbon dioxide, particulate matter and nitrogen oxides as well as noise emissions.

What characterises environmentally sustainable freight transport? Which goals must be achieved? Which decisions need to be made on the way there? UBA has developed a vision of environmentally sustainable freight transport. It incorporates existing environmental and transport policy goals in Germany and Europe and puts them into concrete terms. In 2045, freight transport is to be greenhouse gas-neutral, resilient, low-emission, affordable and intergenerationally just.

To realise the vision a large number of measures and instruments are required for international transport, transport within Germany, as well as urban logistics. Some of the measures and instruments are simpler to achieve, others more difficult to be made a reality. The vision is directed at the political and economic system in Germany, but also addresses measures and instruments that need to be implemented at European or even international level.

This vision is not unattainable. To start by thinking about the goal and thus looking to the future makes it possible to set the necessary course in the present. With the right economic framework conditions and ambitious targets, a great deal can be achieved. Successful implementation of the measures and instruments will make freight transport more sustainable.

Strategies and goals: the framework must fit

Status quo: In climate protection, too much emphasis is placed on technical solutions, while avoidance and sufficiency are neglected. Germany is swimming along rather than forging ahead.

Our vision for 2045: The strategic focus in freight transport is on avoiding transport, shifting to more environmentally sound alternatives and progressing environmental and climate protection in logistics. At the same time, the energy transition in transport has been successfully implemented.

Germany is an environmental and climate protection pioneer in freight transport and is driving the socio-ecological transformation within the European Union (EU). The transformation in freight transport is making a significant contribution toward achieving German and European climate protection targets. This means that by the middle of the century the entire supply chains of domestic companies will be organised in a greenhouse gas-neutral way, even outside of Germany.

Transport and resource consumption are reduced by expanding local production depths and the regional circular economy. Products are durable and repairable. Sustainable consumption and sufficiency support resource-conserving economic activity and avoid transport. Furthermore, digital solutions are increasingly bundling transports and optimising the efficiency of freight transport.

In addition, freight transport – in line with the polluters-pays-principle – bears the costs for infrastructure use and for the consequential damages to the environment and climate. Environmentally harmful subsidies have been eliminated. The construction of necessary infrastructure for the transport transition is financially secured.

International sea and air transport: trimming ships for efficiency, avoiding flights

Status quo: Maritime transport is indispensable regarding long-distance and low-cost transport but has so far largely used fuels which are harmful to the environment and climate. Air freight is growing rapidly, which is an increasing burden on the climate.

Our vision for 2045: Maritime transport is energy-efficient, greenhouse gas-neutral and low in pollutants and causes as little damage as possible to oceans and inland waters. To achieve this, only greenhouse gas-neutral fuels will be used by 2045 at the latest. In addition, comprehensive efficiency measures have been implemented on ships and within their propulsion systems, thus reducing fuel consumption. Integration into the EU Emissions Trading Scheme (EU ETS 1) and a supplementary economic instrument that is effective internationally beyond the EU will ensure a reduction in greenhouse gas emissions in maritime transport well before 2045.

Air freight is largely greenhouse gas neutral. By 2045 at the latest, it will only be carried out using greenhouse gas-neutral fuels. In addition, the climate-damaging non-CO_2 effects typical of aviation will be minimised. At the same time, freight transport by plane is playing an increasingly minor role in logistics. Digital solutions in warehousing, for example, are contributing to this. In addition, local alternatives are increasingly being developed for critical goods that were previously transported by air. The air close to airports is cleaner and noise pollution is reduced.

National freight transport: moving goods by rail, converting drives

Status quo: Lorries are transporting more and more goods by road. The low importance of rail and inland waterway transport is thwarting successes in climate protection. Diesel lorries emit too many greenhouse gases, cause high levels of noise pollution and emit large quantities of air pollutants, from which some demographic groups suffer disproportionately.

Our vision for 2045: reight transport is shifted from road to rail and waterways wherever possible. On all important national and European freight corridors, there is fair competition on equal footing between rail and road transport modes. Thanks to its high reliability, low costs, high service quality and good availability, rail freight transport is an attractive alternative to lorries even on shorter routes. The German rail network is largely electrified, and rail freight transport is done completely greenhouse gas-neutral on all routes. It will be low-noise well before 2045, thus contributing to the health and quality of life of the population.

Inland waterway transport is resilient to low water and reliable with shallow-draft, fully automated and battery-powered vessels. It is environmentally sound and competitive to other means of transport.

Automated and greenhouse gas-neutral freight nodes provide easy access to rail freight transport and transport by waterway.

The federal highway network in Germany is in good condition and transport infrastructure is adapted to climate change. Expansion and new construction of federal roads and motorways are the exception. Locations with particularly high freight volumes are linked with each other in an environmentally sustainable manner and across all modes of transport by means of a “Central Places Concept” for freight transport, thus avoiding traffic congestion. Transport routes and logistics locations are developed in a space-saving manner and with as little land fragmentation as possible.

Road-bound freight transport is completely greenhouse gas-neutral thanks to the energy transition in transport. It’s run predominantly electric, or supplemented with greenhouse gas-neutral fuels. It is low-noise and low-emission. From 2038 on no more fossil fuel-powered lorries will be newly registered. There is targeted funding available for the transition from combustion engines to electric lorries until their use for the operators is economical viable. In addition, a sufficient number of standardised megawatt charging systems are available for electric trucks throughout the EU.

Urban logistics: allowing cities to breathe again

Status quo: Cities and urban centres are suffocating in traffic, with freight transport making a significant contribution. Conflicts over the use of limited urban space are increasing.

Our vision for 2045: Urban logistics is low-noise, low-emission and greenhouse gas-neutral.
The "last mile" is handled in an environmentally and city-compatible manner. Conflicts with residents are avoided. Alternative transport concepts with cargo bikes and micro-depots have been implemented. Only electric vehicles and cargo bikes are used in city centres. Where reasonable, low-noise and energy-efficient drones may also be used.

Advances in digitalisation enable the efficient bundling of goods and transport flows. The logging of goods is standardised, which simplifies consolidations in freight centres. Cross-company solutions for parcel stations, parcel boxes and micro-depots are easily and quickly accessible and are available for alternative address delivery. To this end, logistics requirements are incorporated at an early stage in urban land-use planning in order to secure space for logistics.

Instruments and measures

The three spatial references of freight transport:

International transport by sea and air

National transport by road, rail and waterway

Urban logistics

International freight transport

MARITIME TRANSPORT

- Set minimum quotas for low greenhouse gas intensity fuels
- Establish shore power
- Further development of economic instruments und Emission Trading Scheme (EU-ETS 1)
- Sharpen efficiency requirements regarding existing and new building ships
- Monitor methane and nitrous oxide emissions
- Introduce fuel certification
- Establish green corridors
- Reduce environmentally harmful emissions, protect ecosystems

AIR TRANSPORT

- Exit fossil kerosene before 2045
- Reduce subsidies
- Internalise external costs
- Strengthen alternatives in rail transport
- Prohibit regular night flight in urban areas from 2050
- Develop airports for night flights before 2050

Urban Logistics

- Collect data regularly
- Update study on motor vehicle traffic in Germany 2010
- Introduce transport planning for commercial transport in municipalities
- Introduce competence centres for urban logistics
- Appoint municipal logistics officers
- Fund automation, digitalisation and circular approaches
- Support bundling of deliveries through logistics hubs
- Support the bundling of tours
- Set industry standards for a sustainable last mile
- Establish mandatory allocation of parcel boxes in new buildings
- Fund low-noise logistics
- Establish smart charging and delivery zones
- Improve transport infrastructure for the last mile
- Establish cycling path and protected lanes
- Amend StVZO and VwV-StVO
- Set up priority routes for lorries
- Create low or zero-emission zones

National freight transport

ROAD

- Maintain the steering effect of the HGV toll
- Further develop CO_2 pricing via EU ETS 2
- Further develop energy and electricity tax
- Maintain GHG quota
- Subsidise the purchase of new e-trucks
- Tighten fleet target values for new lorries
- Expand charging infrastructure

TRANSPORT NETWORKS

- Develop a cross-modal corridor concept
- Develop a comprehensive financing model
- Establish a transport infrastructure organisation
- Adapt assessment methodology in the Federal Transport Infrastructure Plan
- Involve stakeholders comprehensively

Overview of the measures

Priority measures are highlighted.

RAIL TRANSPORT

- Safeguard rail network financing in the long term
- Increase rail capacities
- Strengthen single wagon load
- Promote and optimise intermodal transport
- Improve and simplify goods handling
- Simplify the railway siding funding programme
- Reduce charges for rail infrastructure use
- Automate and accelerate train composition
- Expand electrification of the rail network
- Promote alternative drives

LOGISTICS

- Establish the Blue Angel certificate for data centres
- Use durable and recyclable digital technologies
- Using telematics to save fuel
- Promote freight exchanges and crowd logistics
- Establish sales models for passing on the cost of returns
- Standardise automated handling
- Support the preparation of greenhouse gas balances
- Reduce resource usage in product and production design
- Promote ecological sustainability in companies
- Develop procurement concepts with low transport intensity
- Make greater use of additive manufacturing processes
- Strengthen the sustainable use of buildings
- Use automated storage concepts and conveyor technology
- Optimise the choice of means of transport (synchromodality)

INLAND WATERWAY SHIPPING

- Improve the hydromorphological condition of waterways
- Develop shallow-draft, automated, emission-free ships
- Digitise water level data/forecasts
- Reduce subsidies and finance fleet renewal
- Continue funding programmes for the modernisation of inland waterway vessels and emissionfree drives

5 International transport by sea and air

The international transport of goods by sea and air faces enormous challenges when it comes to reducing emissions and minimising environmental impact. First of all, tankers, container ships and cargo aircraft can seldomly be electrified directly. They are usually too heavy and too large for this. Secondly, alternative and climate-compatible fuels that can be used to power marine and jet engines are not yet available in the required quantities. Their production is initially being trialled in a few facilities, however, those processes are a long way from being adapted on an industrial scale. Finally, innovative approaches such as wind-assisted propulsion systems for sea-going vessels are being developed but have not yet established themselves on the market.

Major challenges also await elsewhere: long freight transport operations require open routes across oceans, seas and through canals. That world, though, is increasingly becoming closed off. Sea routes such as those in the Gulf of Aden are suddenly no longer safe due to conflicts such as the current one in the Middle East. Additionally, climate change is having an impact. Decreasing rainfall in the region around the Panama Canal, for example, is leading to low water levels and thwarting the movement of large freighters.

Still: maritime freight transport is in some respects better than its reputation. It is significantly more energy-efficient and climate-compatible than transport by road and air. Between 2012 and 2018, global greenhouse gas emissions fell by 11 % in relation to transport performance, particularly due to ever larger ships.[12] Sea freight transport only consumes around 20 % of the energy used for transport, while accounting for 70 % of total freight transport performance handled.[13] It could do even more. On shorter sea routes within Europe, goods could be shifted from rail and road to ships. To date, there has yet to be a corresponding national strategy to utilise this potential.

When goods need to be transported quickly, reliably and, above all, on time, they are usually transported by air. Although international air freight enables fast transport around the globe, the bottom line is that it has a high environmental impact. Air transport is by far the most climate-damaging form of freight transport.

Maritime transport and air freight transport are regulated internationally. Both sectors are primarily governed by special UN organisations, the International Maritime Organisation (IMO) and the International Civil Aviation Organisation (ICAO). Decisions made by these organisations have a major global leverage effect. At the same time, however, numerous states and players must agree on goals, measures and obligations to actually initiate change.

12 IMO 2020: Fourth IMO GHG Study.

13 Lindstad et al. 2022: Decarbonising bulk shipping combining ship design and alternative power. ITF 2023: ITF Transport Outlook 2023.

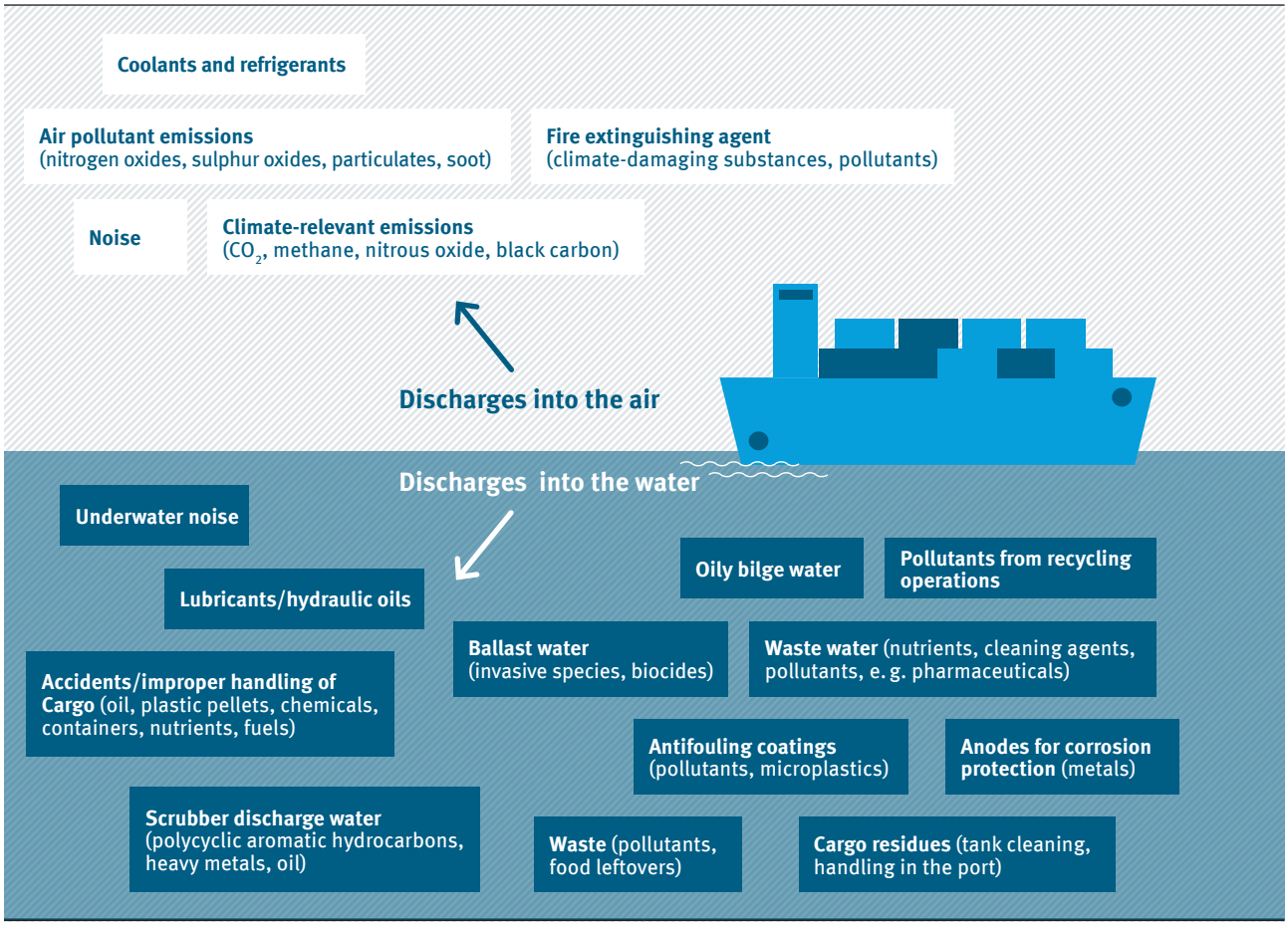
Freight on the high seas

International maritime transport is a giant in freight transport. By 2050, global maritime transport performance could almost double from its current level. Around 55,000 merchant ships handle around 70 % of global freight transport performance. Across the EU, maritime shipping accounts for 80 % of total exports and imports in terms of volume and around 50 % in terms of value.[14] Correspondingly, the energy demand of international maritime transport is massive: in 2022, it was around 9.0 exajoules, which corresponds to emissions of 690 Mt CO_2e and accounts for around 1 % of global greenhouse gas emissions.[15]

To reduce greenhouse gas emissions, IMO tightened its climate protection target in July 2023. Emissions from international shipping are to reach net zero by or around 2050. This is linked to a package of measures including a fuel standard and an emissions pricing mechanism. The measures are to be concretised by autumn 2026 and adopted by the IMO Marine Environment Protection Committee.

Figure 8

Environmental impacts of maritime shipping – possible substance inputs through ship operation



Source: German Environment Agency, own illustration

14 ICS o. J.: Shipping and world trade: driving prosperity.

15 Campbell et al. 2023: Study on the readiness and availability of low- and zero-carbon technology and marine fuels.

Negative environmental impacts from ship transport are manifold (see Figure 8). Shipping accidents and incidents present a major threat to marine ecosystems and their marine life. However, emissions from regular operations can also be harmful, especially for sensitive areas such as the Arctic and Antarctic or the Wadden Sea. These areas therefore need special protection, which can be designated by the IMO. Climate change is also opening up new routes through polar regions where accidents would have catastrophic consequences. The "Polar Code" of 2017 is the first collection of binding legal provisions and recommendations for ships operating in polar waters, which should be expanded to include further requirements, e. g. on wastewater discharges and underwater noise.[16]

International regulations are important, but often not particularly ambitious. It can therefore make sense to introduce guidelines at regional[17] or European level. Although, from a global perspective they achieve lower reductions than worldwide agreements, they can act as a concrete first step in accelerating global action or ensure important regional reductions. In 2023, the EU adopted measures as part of the Fit for 55 package to decarbonise the maritime transport sector. These include the Fuel EU Maritime Regulation and the expansion of the existing European Emissions Trading Scheme (EU ETS 1) to the maritime sector.

With its National Port Strategy, Germany is looking to develop seaports and inland ports into resilient, sustainable hubs for the energy transition and hubs for a modal shift. For this to succeed, it is not only necessary to implement infrastructure measures within ports. It is also particularly important to improve the interlocking of various modes regarding hinterland transport by rail and ship. The port strategy can help accelerate the transformation of freight transport.

Climate protection measures in maritime transport

Technical efficiency measures. Cargo ships have an operation life span of 25 to 40 years. Technical measures are therefore particularly useful if they can also be implemented on older ships through retrofitting.

Quite simple measures can make a big difference. Targeted slow steaming significantly reduces fuel consumption. As a rule of thumb, a 10 % reduction in speed reduces energy consumption by 19 % per unit of distance travelled.[18] Shipping companies also save money, as fuel costs account for 30 to 60 % of total operating costs.[19] In order to optimise this efficiency potential it can make sense to retrofit ships by replacing the propeller and bulbous bow or adapting the engine.[20]

On the high seas wind as a fuel comes at no extra cost. Wind-assisted propulsion system such as kites, rotors or modern sail systems can help save fuel and therefore reduce emissions. For large bulk carriers and tankers travelling at lower speeds, savings are considerable and can amount to up to 18 %. However, there is still a lack of mature technical solutions for utilising wind on container ships. Operational savings are possible by increasing the load factor and optimising trim, e. g. by repositioning the cargo in the ship. Weather-adapted route selection and just-in-time deliveries can also help to achieve savings.

It's estimated that if all technical and operational options are realised, around 30 % of global CO_2 emissions from shipping could be abated by 2030 compared to a business-as-usual scenario.[21]

16 IMO 2017: International Code for Ships Operating in Polar Waters (Polar Code).

17 In this context, regional means a spatial reference to the waters of several countries, as in the Baltic Sea or North Sea.

18 Faber et al. 2017: Regulation speed: a short-term measure to reduce maritime GHG emissions.

19 DG MARE 2023: Blue Invest supports '13 Mari' innovation for fuel efficiency.

20 Faber et al. 2012: Regulated Slow Steaming in Maritime Transport.

21 Faber et al. 2023: Shipping GHG emissions 2030.

New fuels for maritime transport. One key to decarbonising maritime transport is the switch to fuels from renewable energy. In maritime transport several options can be considered. Synthetically produced diesel or methane can be blended with fossil fuels, which requires relatively little adaptation of ships and infrastructure. In addition, methanol and ammonia are being tested as new fuels and are considered promising candidates. Among electricity-based fuels these are cheaper to produce and burn more cleanly than the heavy fuel oil and marine diesel currently in use. However, ammonia and methanol exhibit significantly lower energy densities than conventional marine fuels. Moreover, the combustion of ammonia produces nitrous oxide which is particularly harmful to the climate. Ammonia is also toxic, corrosive and hazardous to water – in the event of an accident, the ecological damage to the oceans would be extensive. Compared to heavy fuel oil or ammonia, shipping accidents involving methanol would result in environmental impacts far less severe.

A lot of discussion about hydrogen and electric drives is currently taking place, however they will probably only be used for shorter distances – on ferries, for example. The reason is that their volumetric energy density is too low for efficient and economical transport around the globe.

Utilising shore power. The direct use of electricity while a ship lies at berth is a sensible and practicable way of avoiding local pollutant emissions and reducing greenhouse gases. It's estimated that on a global level shore power could replace up to 5 % of ship fuel consumption by 2050.[21]

Alternative fuels for global maritime transport – where might they come from?

According to a study by Ricardo Energy & Environment and DNV[22], if all planned production facilities were to go into operation by 2030 then 2.5 exajoules of synthetic fuels with different carbon footprints (biogenic, RFNBO and fossil fuels with CO_2 capture as well as fuels from nuclear energy, so-called "low-carbon fuels") could be produced worldwide. A multiple thereof would be required; for maritime transport alone, for 2030 and 2045, respectively, a global energy demand of 4.1 exajoules resp. 10.7 exajoules can be assumed.

The member states of the IMO are pursuing different approaches in regards to providing the large quantities of fuel required or reducing fuel requirements. Fuels that are produced with the help of renewable ("green") hydrogen, so-called "Renewable Fuels of Non-Biological Origin" (RFNBO), are considered promising. In addition, biofuels from cultivated biomass continue to receive support, as do low-carbon fuels. Relatively new methods for capturing the CO_2 produced on board during fuel combustion are also seen as an option by IMO.

Internationally binding fuel standards for maritime transport to reduce greenhouse gas emissions could provide security of investment through quotas, and initiate projects for the purpose of large-scale industrial production along the entire production chain of alternative fuels, including renewable electricity generation. However, the different interests of the IMO states pose a challenge to the targeted support of the RFNBOs required for GHG neutrality. In addition, reliable certification mechanisms are needed to verify the greenhouse gas intensity of the respective fuel.

22 Campbell et al. 2023.

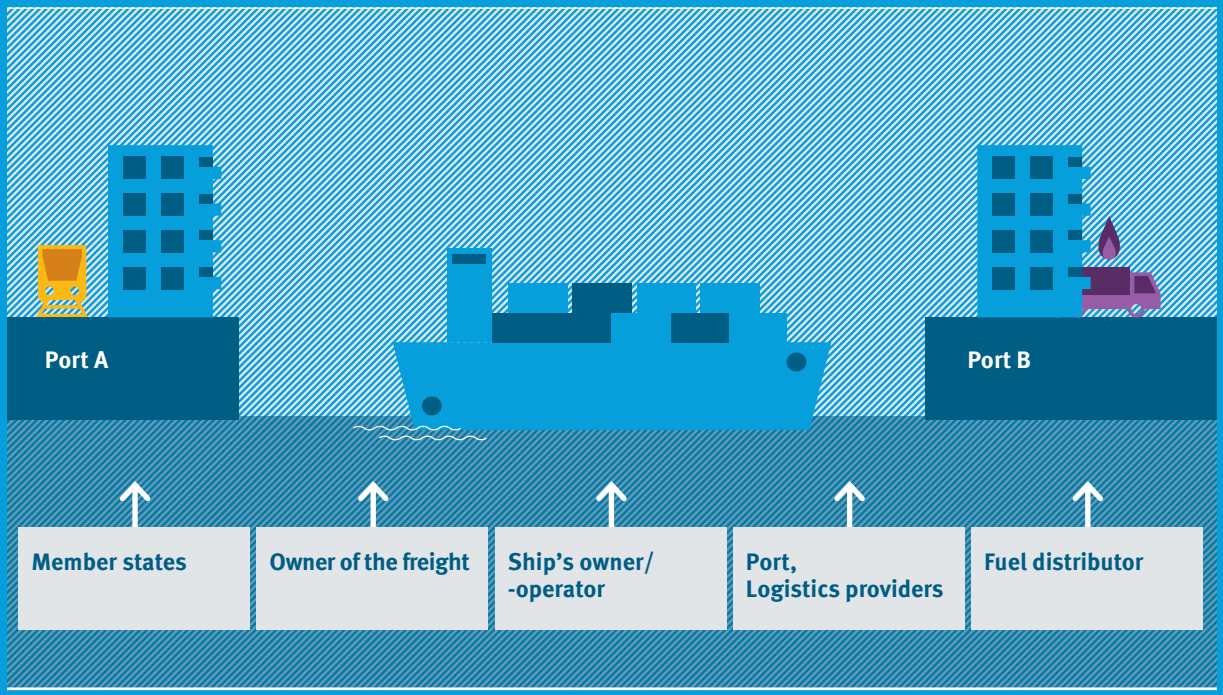
Emission-free freight: Green Shipping Corridors

Trade routes between important hubs, on which emission-free solutions for ships, ports and fuel are demonstrated and promoted ("Green Shipping Corridors"), represent an important key element for the market ramp-up of alternative fuels. The concept was adopted by 24 countries, including Germany, at the 2021 UN Climate Change Conference and aims to realise at least six green corridors by 2025.

A first step has been taken within the EU: In many European ports, among other things, shore power supply must be established by 2030. Germany should invest expressly in infrastructure providing renewable energy sources – both on-shore electricity and alternative fuels – in its ports.

Figure 9

Possible initiators and partners for the realisation of the "Green Corridors"



Source: German Environment Agency, own illustration

Climate protection instruments in maritime transport

The EU focuses on low-carbon and renewable fuels. The FuelEU Maritime (EU) 2023/1805 Regulation, which was adopted in 2023, aims to reduce the greenhouse gas intensity of fuels by 80 % by 2050 and boost the use of renewable and low-carbon fuels. In addition, FuelEU Maritime stipulates the use of shore power or zero-emission technologies at many European inland and seaports: from 2030, cargo and passenger ships with a gross tonnage (GT)23[23] of over 5,000 and moored at the quayside for more than two hours must be connected to shore power. This limit of 5,000 GT covers around 55 % of ships travelling between EU ports. A second important set of rules is the Alternative Fuels Infrastructure Regulation of 2023 (AFIR for short, Regulation (EU) 2023/1805). It sets binding requirements for the construction of corresponding shore power infrastructure and LNG bunkering stations.

Vessels in EU Emissions Trading System. A lot can be controlled via costs and prices. This also applies to freight transport. As part of a "policy mix", economic instruments could increase operational costs for environmentally harmful activities and thus trigger efficiency measures or a transition to alternative fuels. In principle, it is favourable and important to fully price external climate and environmental costs into maritime transport.

In 2023, the EU adopted a comprehensive reform of the existing European Emissions Trading Scheme (EU ETS 1, Directive (EU) 2023/959), thereby taking on a pioneering role internationally. From 2024, cargo and passenger ships bigger than 5,000 GT on routes within the European Economic Area are included in the EU ETS 1. Operators must buy certificates covering 40 % of CO_2 emissions of their transports. This share increases to 70 % by 2025 and to 100 % by 2026. A full auction (and no free allocation) of emission allowances is planned for maritime transport. At present, it's still unclear to what extent the price signal from emissions trading will lead to reductions in emissions in maritime transport itself – or whether the prescribed reductions will take place in other areas of the EU ETS. In general, reforming of the EU-ETS 1 is a clear and urgently needed step towards an ambitious climate protection regime for maritime transport: citing, in particular, the broad scope of application, which includes routes within the European Economic Area and also incorporates routes to and from Europe with 50 % of the emissions, the complete auctioning of certificates and the inclusion

Doings and dealings through the EU ETS 1

The existing European Emissions Trading Scheme (EU ETS 1) has been the EU's central climate protection instrument since 2005. The cap set by the EU/government is a political decision on how many tonnes of CO_2 equivalent may be emitted in total. An ambitious cap ensures that emission allowances for CO_2 become scarce and that a high price for the certificates is generated on the market (trade). High prices in turn create incentives to invest in climate protection measures.

Ever since the most recent reform of the EU ETS, member states have been mandated to use all of their revenue from auctioning of emission allowances for climate protection measures. Before the reform, this number was 50 %. In Germany, national proceeds from auctions since 2012 have been channeled in full into the German government's Climate and Transformation Fund (KTF) to support and promote climate protection projects and measures.

In addition, the European Innovation Fund, which is also fed by auctioning revenues, will be increased and expanded to include maritime transport through the use of specific tenders, among other things. A total of 20 million certificates are earmarked within the innovation fund by 2030 to support investments in the decarbonisation of the maritime sector. Assuming a CO_2 price of € 80 per certificate[24] the certificates would then have a not inconsiderable value of € 1.6 billion.

23 The gross tonnage is a measure of the volume of a ship and therefore depends on the size of the ship.

24 As of May 2024, at around € 70.

of the strong greenhouse gases methane and nitrous oxide from 2026. The effects of this inclusion in the EU ETS 1 must be examined in the course of implementation. On this basis, UBA will derive recommendations for readjusting the EU ETS 1 or supplementary instruments.

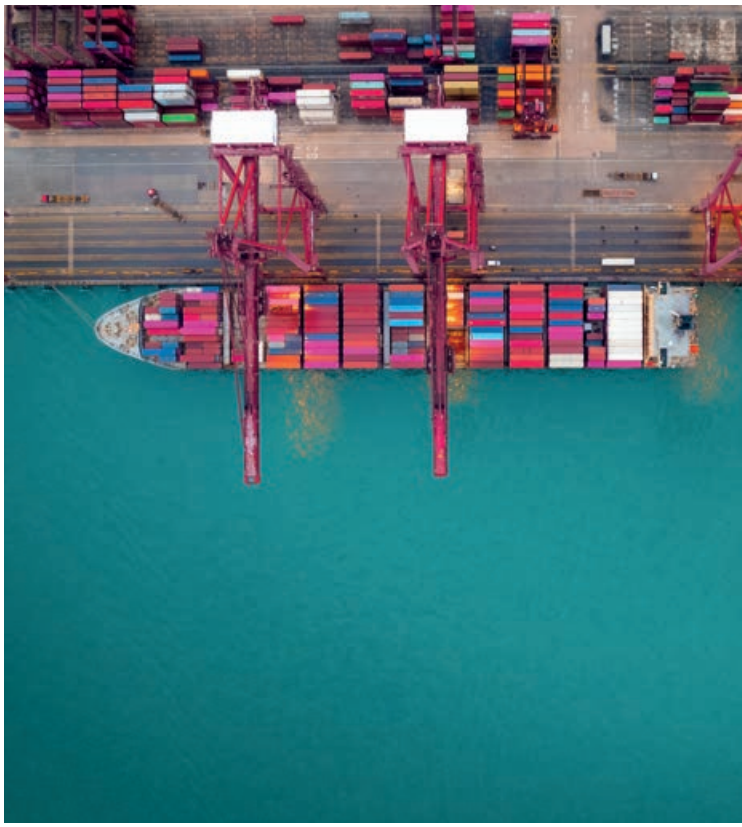
Both instruments – the European Emissions Trading Scheme and the FuelEU Maritime Regulation – are essential for decarbonising the maritime sector. While CO_2 pricing in emissions trading provides technology-neutral incentives for more climate protection in maritime transport on a broad scale, the regulation's fuel specifications serve as a safeguard. They strengthen innovative fuels, their development and market launch. The EU ETS 1 also supports sustainable biofuels, as no certificates are required for their combustion. Similar crediting is necessary for electricity-based fuels. Which of the two instruments will ultimately have a greater impact is difficult to predict and depends on the design of the instruments and the development of CO_2 prices.

LNG, the critical interim solution. The switch from fossil fuels to fuels with low greenhouse gas intensity takes time. In the medium term, many players will use liquefied natural gas (LNG) for ship propulsion. In terms of energy output per mega joule of fuel, LNG releases around 20 % less CO_2 emissions than marine diesel. However, methane emissions during extraction, transport, liquefaction and storage of LNG are problematic. In addition, it escapes during combustion, this so called "methane slip" increases significantly at lower engine load ranges.[25] It's important that continuous monitoring is carried out when using LNG to identify and prevent leaks. Investing in LNG as a possible interim fuel solution with its essential production capacities and energy supply infrastructures should therefore be examined with an especially critical eye.

25 Methane is a powerful greenhouse gas and is even more harmful to the climate in the short term, e. g. 20 years instead of 100 years.

Quotas for e-fuels. Fuels with low greenhouse gas intensity include biofuels, as long as the source materials are not crops but waste or residues. RFNBOs are not made from biomass but have great potential, they are produced with the help of regeneratively produced ("green") hydrogen, for example e-methanol or e-ammonia. Both European and national hydrogen strategies are pushing for this approach. Rapid expansion of renewable energies is therefore also of great importance for maritime transport.

However, to really speed up this process, higher minimum quotas for RFNBOs would be needed in the FuelEU Maritime Regulation, and even more ambitious reduction targets from 2030 onwards. Synthetic fuels are seen as the key to environmentally sustainable freight transport. Germany and Europe should support and develop initiatives and cooperation projects with other countries and regions, accelerate the market ramp-up of RFNBOs and ensure that they are produced sustainably. Creating formative and anticipatory policy in hydrogen production will ensure the EU itself can become an important player. Geopolitically, Europe should gain more independence through additional green hydrogen production plants of its own.[26]



More efficiency at international level. The International Maritime Organisation (IMO) has already established a series of binding instruments to improve energy efficiency. They apply to existing and new build ships and aim to ensure that ships are more energy efficient both through design and their mode of operation. Unfortunately, the requirements are not very ambitious. For example, the Energy Efficiency Existing Ship Index (EEXI), which has been in force since 2023 and relates exclusively to the technical design of a ship, is estimated to reduce just 1 % of emissions by 2030.[27] To achieve ambitious climate protection goals, international efficiency requirements must be significantly tightened.

International Emissions Trading System. International emissions trading would be a cost-efficient climate protection instrument with a high degree of reliability, as only as many certificates would be placed on the market as the defined emissions budget allows. At a global level, IMO has adopted a revised greenhouse gas strategy and aims to achieve net zero emissions by or around 2050. However, it's unlikely that IMO will introduce a global emissions trading regime. The proposal for a levy per tonne of greenhouse gases emitted has more support. It is crucial that international targets do not thwart the objectives of the EU ETS 1 for maritime transport and do not restrict its scope or effectiveness. If, for example, a global but less effective economic instrument were to come into force, it must be avoided that transport between the EU and third countries is only covered by this instrument but no longer by EU ETS 1.

26 Lünenbürger et al. 2023: Ambitious climate protection: pitfalls and conditions for success.

27 Comer and Carvalho 2023: IMO's newly revised GHG strategy: what it means for shipping and the Paris Agreement.

Levy as an alternative. In addition to international emissions trading, a global, standardised CO_2 or GHG levy could also be considered as an economic instrument. This is the direction taken by the proposal for a GHG levy at IMO level described above. Depending on how it is structured, a GHG levy could increase the prices of fuels and thus incentivise savings. However, the climate impact of such a levy would be unpredictable as it would not limit total greenhouse gas emissions. In order to achieve the climate targets, the level of the levy would have to be constantly adjusted over the years.

Overview of measures and instruments in maritime transport

Measures and instruments	Who decides?	Who is responsible for the implementation?
Fuel standards Reduction of greenhouse gas intensity or minimum quota for fuels with low greenhouse gas intensity, tightening FuelEU Maritime standards for EU and introduction of similar instrument at IMO level	EU, IMO	Shipping companies, fuel distributors
Shore power Development of on-shore- and shipside infrastructure and mandatory utilisation (AFIR), development of common standards at IMO level	EU, EU member states, IMO	Ports, shipping companies
Economic instruments Review integration of maritime transport into the EU ETS 1; initiate further developments if necessary; Introduce an international economic instrument at IMO level by 2030 without jeopardising EU instruments	EU, IMO	Shipping companies
Efficiency requirements Tightening of international indices for existing ships new build ships to utilise existing technical and operational potentials	IMO	Shipping companies, shipbuilding
Monitoring methane and nitrous oxide emissions in combination with a fuel standard	EU/IMO member states	Shipping companies, engine manufacturers
Fuel certification Introduction to ensure complete, tamper-proof recording of greenhouse gas intensity, plus a sustainability certificate	IMO, EU, certification systems	Certifiers, interfaces, accreditation bodies
Establish Green Corridors as pioneering routes Six corridors planned to be built by 2025 with shore power and alternative fuels	Member states	Ports, fuel distributors, ship operators
Other environmental protection measures and instruments Reduce emissions into air and water, expand protection of sensitive ecosystems	IMO, EU, regional bodies (e. g. for North Sea, Baltic Sea, Arctic, Antarctic)	Shipping companies, logistics sector

Source: German Environment Agency (2024)

International air freight

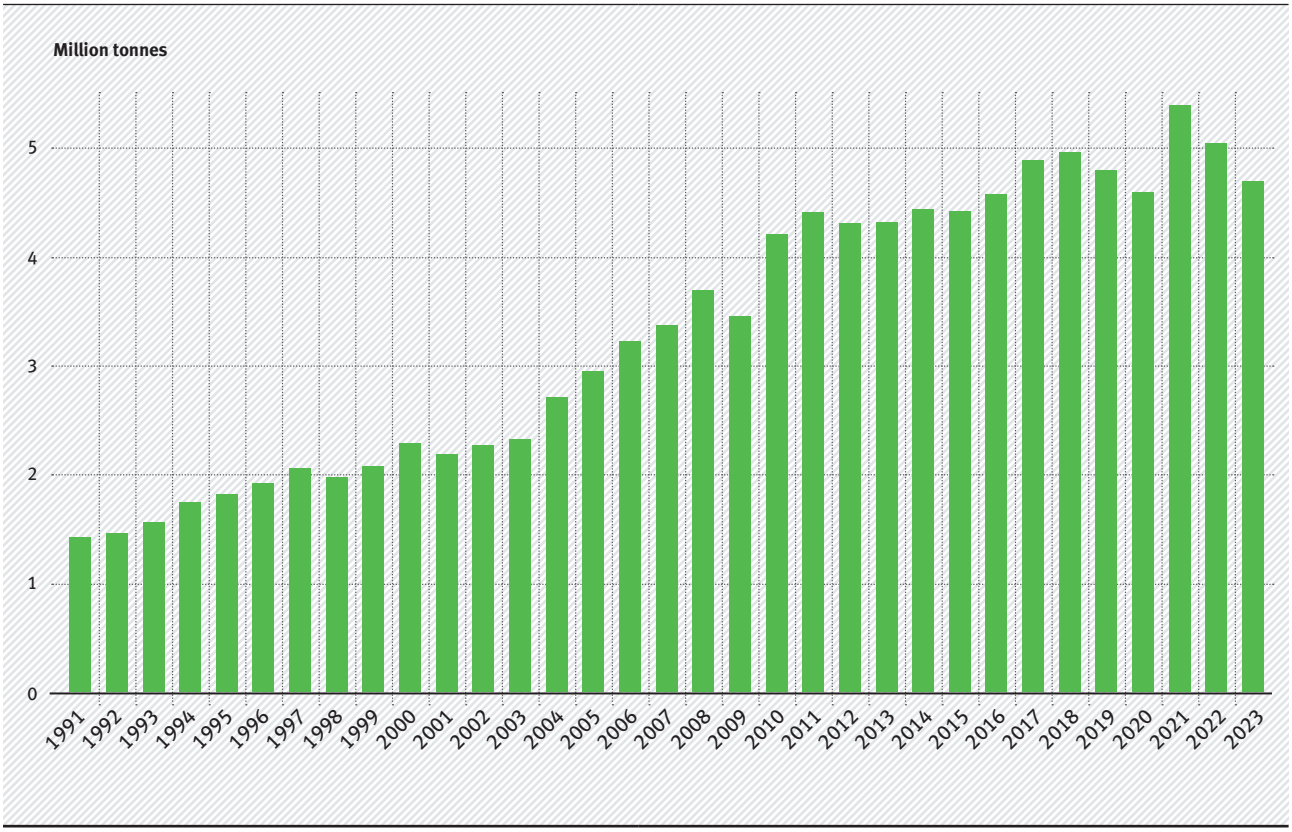
Aeroplanes transport significantly fewer goods than sea transport, for example, but often transport high-value products, such as machine parts or all sorts of electronics. The average value of goods handled by air freight in Germany in 2022 was €152,807 per tonne, compared to €6,525 per tonne by lorry and only €2,090 per tonne by rail.28 Planes are also faster on long routes and are therefore used for urgent transport. Perishable goods such as fresh food or flowers are often dependent on air freight, if they are offered on far-off markets.

Trade air freight volume between Germany and countries outside the EU increased by 54 % between 2000 and 2022. The most important countries of origin and destination are China, the USA, India, Japan and South Korea. They accounted for around 64 % of tonnage in 2022.[28] Air freight volume has generally grown strongly in recent decades (see Figure 10). At the beginning of the COVID-19 pandemic, the volume of freight transport handled in Germany collapsed, only to rise sharply again in 2021. The industry predicts annual global growth in air freight to be 4 % in the period up to 2041 – driven primarily by the Asian markets.[29]

Figure 10

Development of air freight volume to and from Germany

Loading and unloading (starting in 2008, incl. airmail)



Source: German Environment Agency, own representation according to ADV monthly statistics

28 BDL 2023: Importance of air freight for Germany as an industrial location - Analysis of the goods structure and development of the air freight market in Germany.

29 Boeing 2022: World Air Cargo Forecast 2022-2041.

The more flying is done, the greater the climate impact of air transport. It's unique characteristic is that the climate impact of an aeroplane is not mainly caused by CO_2 emissions from the combustion of fuel. The so-called non-CO_2 effects are at least as important.[30] This term summarises very different substances and effects, e. g. the effect of contrails and soot particles, aerosols and nitrogen oxides. In terms of tonne-kilometres, transporting goods by air is around 200 times more harmful to the climate than by sea. Even when taking into account the shorter transport distance due to more direct routes when transporting goods by air compared to sea, air freight remains significantly more harmful to the climate.

Generally speaking, measures and instruments that make overall air transport more climate and environmentally sustainable also have an effect on air freight. In addition, passenger transport and freight transport often cannot be separated clearly. Freight is often loaded in the belly of passenger aircraft, known as belly freight (see text box).

In its publications "Where are we going?" and "Umweltschonender Luftverkehr: lokal – national – international"[32], the German Environment Agency addressed air transport and proposed extensive and detailed measures and instruments, most of which are still valid today (see Figure 11). For this reason, despite its importance in freight transport, air freight is dealt with more briefly in this brochure than maritime transport.

Figure 11

UBA publications on environmentally sustainable air transport

Source: German Environment Agency, own representation

Belly freight: combined transport in the air

If goods are not transported in a cargo plane but as additional cargo in a passenger plane, they are referred to as belly freight. In the pre-Corona year 2019, almost half the global air freight transport performance was moved as belly freight.[31] High aircraft utilisation is positive in general because it reduces the specific emissions per transport unit. On the other hand, combined transport by air can induce additional traffic: the sale of additional cargo contributes significantly to the profitability of passenger flights, meaning that air freight makes passenger flights on certain routes possible in the first place. Conversely, strong growth in passenger flights also increases the capacity for additional cargo.

It's difficult to say whether belly freight makes air freight transport more environmentally and climate-sustainable. In general, emissions must be properly and proportionately allocated to passengers and freight. However, current methods for calculating greenhouse gas emissions and allocating them according to the ISO 14083 standard and the RP 1678 recommendation of the International Air Transport Association mean that belly freight transport systematically performs worse than dedicated cargo flights.

30 Dahlmann et al. 2023: Climate impact of aviation.

31 IATA 2023: IATA's Chart of the Week "Uneven recovery trends in air cargo traffic and capacity".

32 UBA 2019: Where are we going? und Bopst et al. 2019: Umweltschonender Luftverkehr: lokal – national – international.

Climate and environmental protection measures in air freight transport

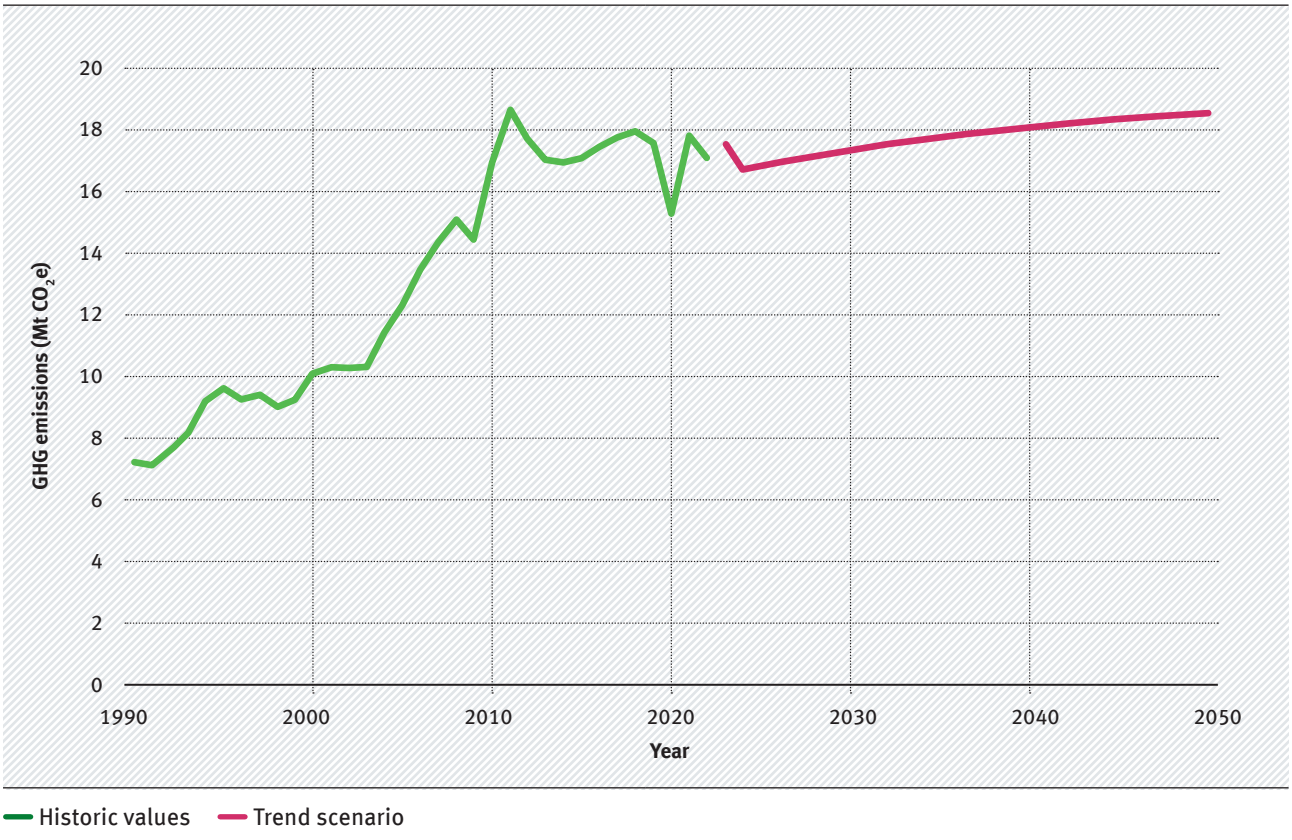
Get the ball rolling on alternative fuels. Air transport and air freight must become largely greenhouse gas-neutral in the coming decades but are not on track to achieve this as of yet (see Figure 12). Above all, this means switching to sustainable alternative fuels (Sustainable Aviation Fuel, SAF for short).[33] As SAF will be more expensive than fossil fuels for the foreseeable future, specific instruments are needed. A blending quota that increases continuously over the years, as the EU decided in 2023 with the ReFuelEU Aviation Regulation (EU) 2023/2405, is a suitable instrument. Such a quota can support the development of production capacities for SAF in general, but also for renewably generated electricity required for the production of PtL-kerosene. Alternative fuels can also reduce non-CO_2 effects because, for example, they contain fewer aromatics from which soot forms during combustion.

Optimise flight routes. The non-CO_2 effects of air transport must be significantly reduced. They are harmful to the climate to at least the same extent as any CO_2 emissions emitted. Optimised flight routes that avoid air spaces in which the non-CO_2 effects are particularly strong, such as cold and humid air masses, can help to reduce these effects. This can lead to additional costs due to higher fuel consumption or longer flight times. Economic incentives are therefore needed to ensure that less climate-damaging routes are actually flown.[34]

Reassigning air freight. One approach to avoiding air freight is to strengthen alternatives. Aside from shipping, certain routes may favour rail or lorry, with ship-aeroplane combinations also to be considered. Alternatives to air freight must be fostered, but also advertised and made more visible. In some cases, air transport takes place without corresponding alternatives being examined.

Figure 12

Annual GHG emissions (incl. additional climate impact at high altitudes) of air freight transport departing Germany up to 2022 and in the trend scenario until 2050 (TREMOD)



Source: German Environment Agency, own illustration according to Biemann et al. 2024a

33 SAFs as sustainable fuels for aviation are both biofuels and e-fuels/PtL-fuels.

34 Bopst et al. 2019.

Reduce noise. One issue regarding air transport are the many night-time cargo flights, which take place especially at Cologne/Bonn and Leipzig/Halle airports. In the interest of preventive health protection, no regular flight operations should therefore take place at airports close to urban centres between 10 p. m. and 6 a. m. The same requirements should also be valid in neighbouring EU countries in order to avoid shifting flight operations to foreign airports. Unavoidable night flight operations could – in compliance with the World Health Organisation (WHO) target value of 40 dB(A) at night – be concentrated at a single or at few airports in Germany in areas that are as sparsely populated as possible. The selection of possible airport locations with night flight operations should be decided on the basis of integrated, ecologically orientated airport planning by the federal government or the EU. Of course, this cannot be realised in the short term – but it should aspired to by 2050 at the latest to discontinue regular flight operations between 10 p. m. and 6 a. m. at airports close to urban areas providing that all infrastructural requirements will have been met by then.

Climate protection instruments in air freight transport

Promote e-fuels. The ReFuelEU Aviation Regulation ((EU) 2023/2405) adopted in 2023 as part of the Fit for 55 package regulates the ramp-up of sustainable aviation fuels (SAF) within the EU. The regulation provides for a minimum share of 70 % SAF by 2050, of which at least 35 % is kerosene generated from renewable electricity (so-called e-fuels or PtL – power to liquid kerosene). In addition, "advanced" biofuels obtained from waste or residues for which, however, availability is limited, also contribute to the quota. For reach greenhouse gas neutrality completely replacing fossil kerosene with PtL by 2045 is necessary. To avoid cargo flights switching to routes outside the scope of the regulation, use can be made of the welcome International Civil Aviation Organisation (ICAO)'s aim toward net-zero CO_2 emissions by 2050.

Creating honest pricing. In freight transport, pricing often determines the choice of the mode of transport. Hence, prices are needed which reflect all environmental and social costs and allow for a genuine comparison between modes of transport. For example, if air transport was no longer exempt from energy tax, kerosene would be taxed at 65.45 cents per litre.[35] In global aviation, the internalisation of external environmental costs requires worldwide solutions or intergovernmental agreements, which means lengthy negotiations. A proposal by the EU Commission to reform the Energy Tax Directive envisages a kerosene tax on intra-European flights. It's currently unclear whether the member states will be able to agree to this. Alternatively, broadening the air passenger tax is an option. It currently only applies to passenger aeroplanes. The legislator would have to introduce a corresponding extension for the freight sector. External environmental costs that arise in the proximity to airports due to aircraft noise and poorer air quality are also to be levied as emission-based take-off and landing fees and used to eliminate or avoid environmental pollution.

35 Burger and Bretschneider 2021: Environmentally harmful subsidies in Germany

Sharpen emissions trading for aviation. The mandatory purchase of certificates increases pricing in air transport and makes climate protection investments more economical. Within the European Emissions Trading Scheme (EU ETS 1), in which aviation has been included since 2012, regulations for aviation were tightened in 2023.[36] Free allocations of emission allowances will be restricted and completely abolished by 2026. In addition, monitoring and reporting obligations on non-CO_2 effects are envisaged for the future – an aspect that UBA has campaigned for in recent years.

The international CO_2 offsetting mechanism (Carbon Offsetting and Reduction Scheme for International Aviation, CORSIA for short), launched in 2021, also requires airlines to compensate for emissions. Under CORSIA, the so-called baseline was lowered, and the calculations of offsetting obligations changed as a result. Instead of the average CO_2 emissions for 2019 and 2020, 85 % of the emissions from 2019 now serve as the baseline. This means a tightening of 15 %, and the coronavirus year 2020, deemed unsuitable as a baseline, has been removed from the calculation. The CORSIA targets can be reviewed every three years; there will probably be a further revision in EU ETS 1 in 2028. It would by then be important to adequately include non-CO_2 effects in the EU ETS 1 with a fee obligation to minimise these climate effects. Despite the tightening, both instruments are currently not ambitious enough and are not compatible with the goals of the Paris Climate Agreement.

Overview of measures and instruments in the air freight sector

Measures and instruments	Who decides?	Who is responsible for the implementation?
Use of sustainable aviation fuels (SAF) Ambitious blending quota over time and complete phase-out of fossil kerosene from 2045	EU, federal government	Airlines, fuel suppliers
Subsidy reduction EU-wide kerosene tax, alternatively extension of air passenger tax to freight, no state aid	EU, federal government	EU member states
Internalisation of external environmental costs Strengthen EU ETS 1 and CORSIA, include non-CO_2 effects, increase emission-based landing fees	EU, ICAO	EU member states
Strengthening the alternatives Expansion of the railway in long-distance freight transport	EU, federal government	EU member states
Ban on regular flight operations from 10 p. m. to 6 a. m. at airports close to cities to protect against noise by 2050	Federal government	Federal states, airports
Relocation of night flights at airports in sparsely populated areas by 2050	Federal government	Airlines, freight forwarders

Source: German Environment Agency (2024)

36 Directive (EU) 2023/958.

6 National freight transport

A look at the statistics shows that lorry transport dominates freight transport in Germany. Lorries transport over 86 % of all goods and account for 73 % of freight transport performance.[37] The reasons for this are obvious. There are roads everywhere, transport by lorry is very flexible and in principle reaches every recipient directly, and is often cheaper than the alternatives.

The downside: road freight transport is responsible for 98 % of all greenhouse gas emissions of total freight transport in Germany and emits large quantities of air pollutants. Vehicles, logistics and value chains must therefore become more efficient, lower-emission and more climate-compatible. Electric trucks with batteries or fuel cells, post-fossil synthetic fuels, shifting goods to rail or waterways, and optimised logistics concepts – there are certainly more environmentally sustainable approaches.

But all this takes time and needs the right framework. A decisive role hereby is assigned to the electrification of road freight transport. However, this will only succeed if sufficient renewable electricity is available, the charging infrastructure is closely tied, and new e-trucks are affordable for logistics companies. If roads are to be unburdened and goods shifted to rail or waterways, a digitalised and automated infrastructure for handling must be in place to ensure seamless and fast loading.

37 BMDV 2023.

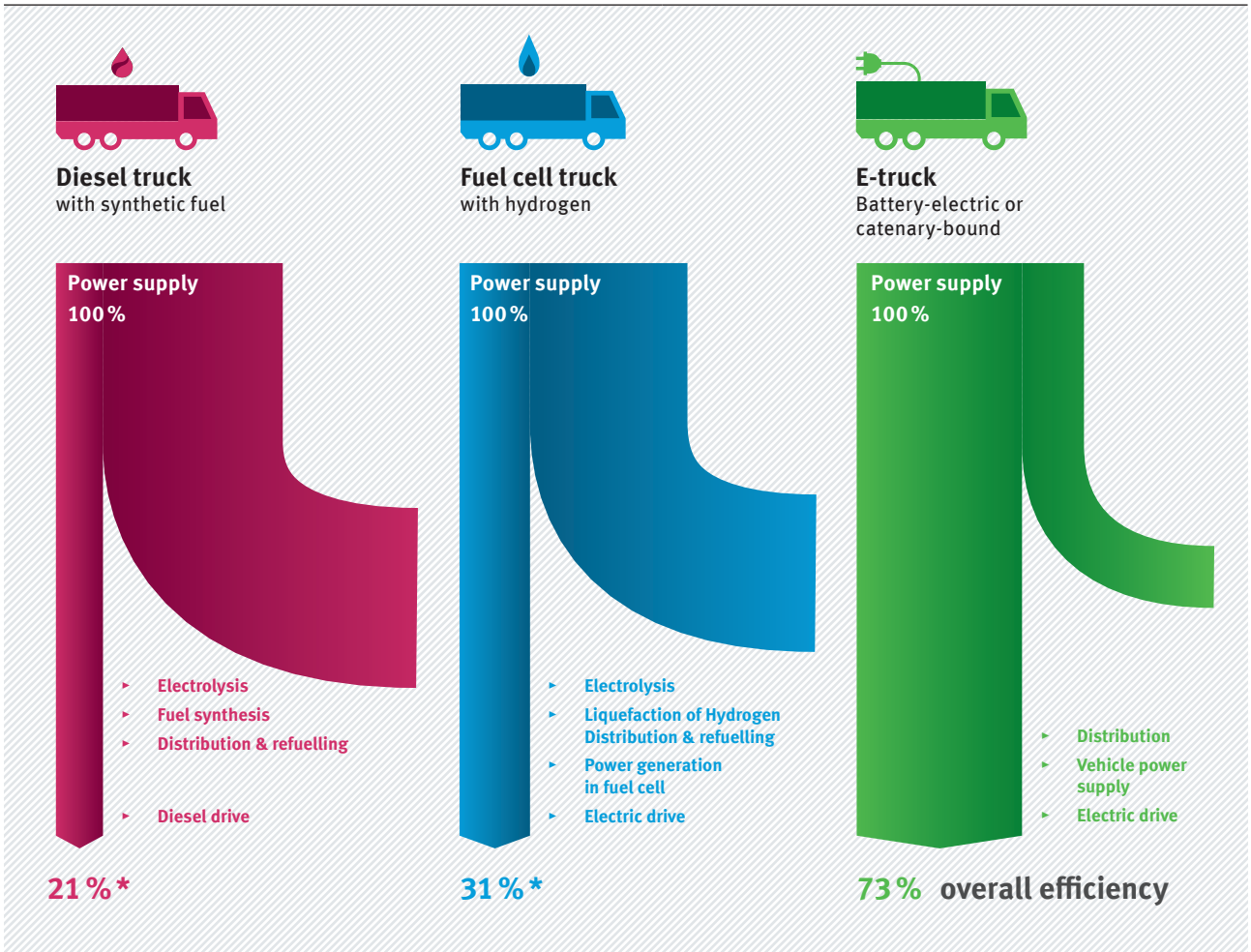
Accelerate the transition to alternative drives on the road

Between 1990 and 2022, greenhouse gas emissions from light and heavy commercial vehicles (LCV and HCV) rose from 33 Mt to 51 Mt CO_2e. The share of road freight transport in the total emissions of the transport sector thus climbed from 21 % to 34 %. This share is expected to remain similarly high in the coming years. This means that there is great potential for reducing greenhouse gas emissions in freight transport on the road. At the beginning of 2024, the EU voted in favour of significantly more ambitious CO_2 fleet limits for all heavy commercial vehicles. The prescribed upper emissions limits will continue to be reduced incrementally over the coming years. From 2040 onwards, an average CO_2 reduction of 90 % must be achieved for new registrations.

Alternative drives. A key component is the transition from diesel engines to low-emission or zero-emission drives and post-fossil fuels. The basic principle is that electric motors are significantly more efficient than combustion engines, as they convert electrical energy directly into kinetic energy. Trucks that charge electricity via an overhead line (so-called O-BEV) are slightly more efficient than a normal, battery-powered electric truck, as their traction battery is smaller and lighter. Fuel cell-powered vehicles occupy an intermediate position because cold combustion of hydrogen is associated with higher energy losses than direct use of electricity in battery-powered e-trucks (see Figure 13).

Figure 13

Efficiency comparison of different truck drivetrains options based on electricity utilisation



* When tapping efficiency potential in electrolysis, fuel synthesis and fuel cells

Source: German Environment Agency, own illustration according to Öko-Institut 2020

It's a fact that only a few electric and fuel cell trucks are currently on the road and no relevant quantities of synthetic fuels have yet been produced. This makes it difficult to estimate future greenhouse gas emissions from road transport.

Figure 14 shows the greenhouse gas potential of articulated lorries ("artics") with alternative or conventional drive systems for the 2020 and 2030 model years, based on a so-called life cycle analysis, i. e. a complete analysis of transports by artic, including the extraction and provision of fuel all the way to its conversion into kinetic energy in the vehicle, as well as vehicle production, maintenance and disposal. A typical diesel artic put into operation in 2020 therefore has a global warming potential of around 970 g CO_2e/km. Natural gas-based alternatives only have a small advantage regarding climate impact or are even slightly more harmful to the climate compared to diesel. For lorries built after 2030, there are slight improvements for conventional drives due to an increase in efficiency. The O-BEV and battery electric lorry (Batterie electric Vehicle; BEV) have by far the lowest climate impact.[38]

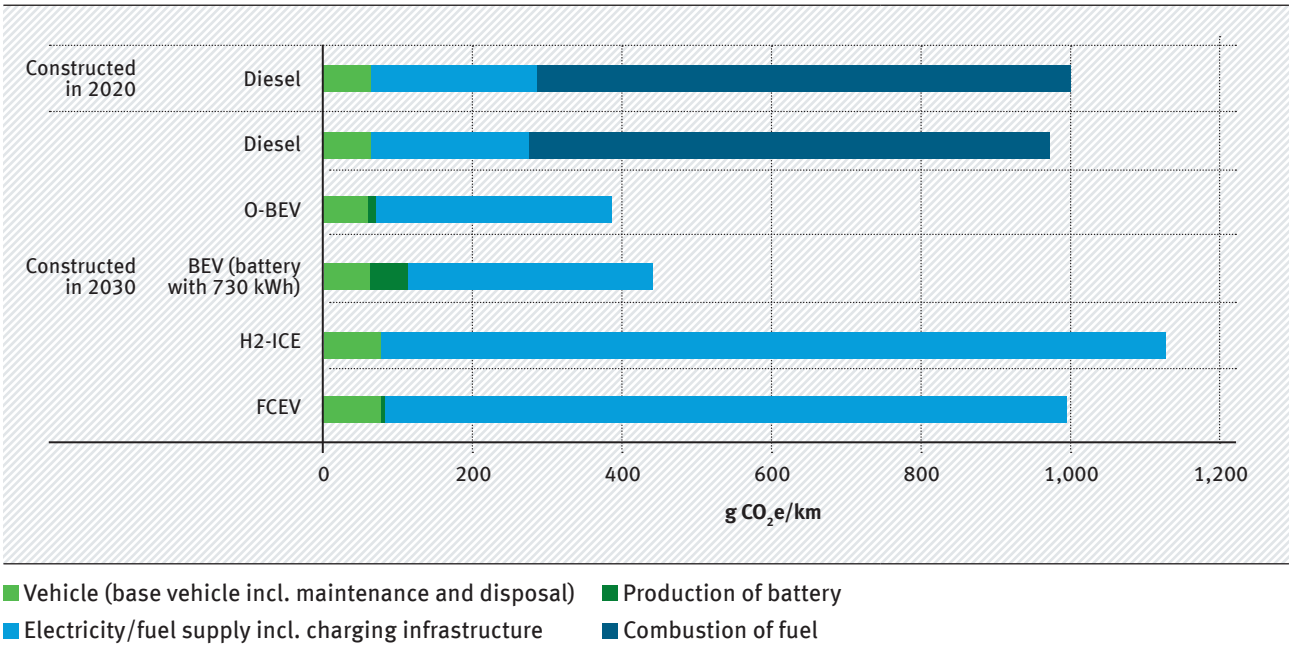
Vehicles with a fuel cell (FCEV) or hydrogen internal combustion engine (H2 ICE), which will be on German roads from 2030, have no advantages over diesel artics. Essentially, this is because they will still be travelling with "grey" hydrogen which is produced by steam reforming of fossil natural gas.

In addition to the tractor vehicle, lorry- and artic trailers also have an influence on the efficiency of the artic or lorry. The revised EU fleet targets for heavy commercial vehicles now for the first time stipulate efficiency measures for semi-trailers and trailers. Improved trailers, e. g. with less air resistance, can reduce diesel consumption and CO_2 emissions. In addition, the maximum permissible weights for zero-emission lorries and the authorisation of extra-long trucks in cross-border transport are being discussed.[39] It is unclear whether lorries with higher weights may only be allowed to drive on certain routes, for example on particularly stable "eternal roads".

The generation and provision of the required energy have a major influence on overall efficiency. Electricity-based fuels (so-called e-fuels) are low emission but require a lot of energy for their production. In an efficiency analysis, they therefore cannot compete with

Figure 14

Global warming potential of articulated lorries for the 2020 and 2030 model years and subsequent typical use



Note: Values for average load (11 t payload) and service life of eight years with a total mileage of 900,000 km. O-BEV (battery-electric lorry with additional use of the overhead line), BEV (battery-electric lorry), H2-ICE (lorry with hydrogen combustion engine) and FCEV (fuel cell electric lorry)

Source: German Environment Agency, own representation according to Biemann et al. 2024c

38 Biemann et al. 2024c: Analysis of the environmental balance of motor vehicles with alternative drive systems or fuels on the way to greenhouse gas-neutral transport.

39 Amendment of Directive 69/53/EC as part of the EU's "Greening Freight Package".

the more direct conversion of electricity into kinetic energy. Electricity-based fuels in freight transport should primarily be used where direct use of renewable electricity in battery-electric drives is not possible. This applies, for example, to international maritime transport and air freight.

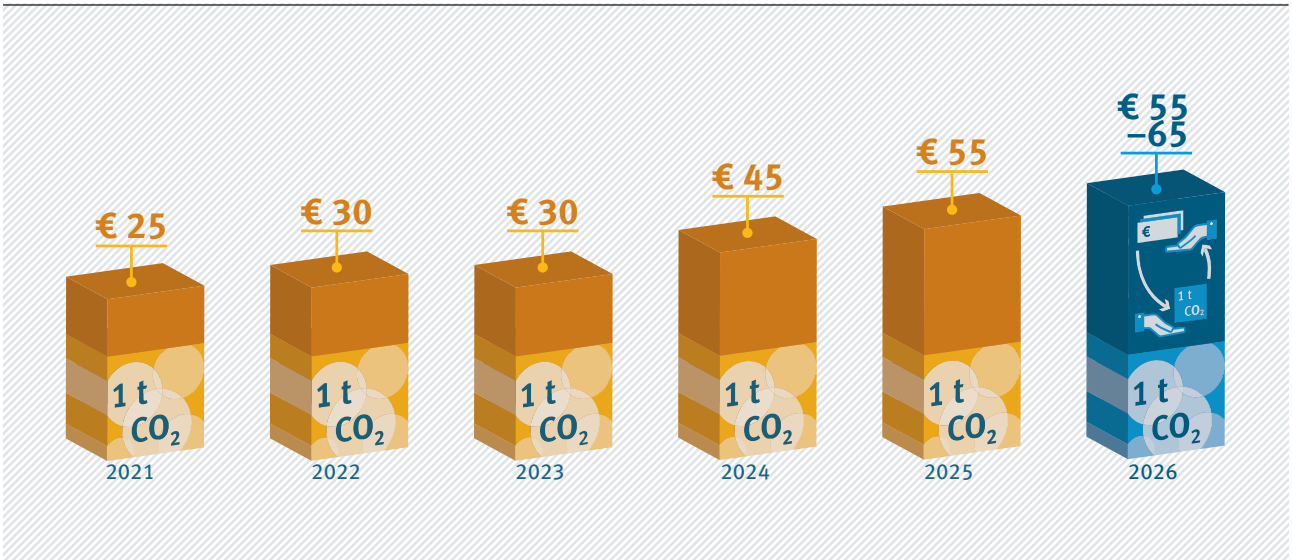
Barriers to the transition. Lorries with alternative drive systems are currently expensive to purchase and cannot be operated economically without government subsidies or other political measures. How quickly electrification in road-bound freight transport will succeed depends above all on the "total cost of ownership". This includes not only the purchase price of the lorry, but also energy costs, toll, repair costs and maintenance. They must be more favourable compared to conventional drive systems in order for logistics companies to make the transition. Despite a new toll with a CO_2 surcharge targeted subsidies for the purchase of new e-trucks or other instruments will therefore continue to be necessary to secure the market ramp-up in the coming years. Furthermore, day-to-day business must also run smoothly using novel drives, meaning the implementation of an energy transition in freight transport will not succeed without a closely tied charging infrastructure, sufficient hydrogen refuelling stations or a catenary network.

CO_2 surcharge as part of the toll. Starting December 2023, the lorry toll has included a CO_2 component of € 200/t CO_2. This surcharge initially only applies to conventionally powered lorries with a gross vehicle weight (GVW) of 7.5 t or more. From mid-2024, it will apply from a GVW of 3.5 t. Lorries that no longer emit any pollutant emissions will be completely exempt from the lorry toll until the end of 2025. This will make battery-powered lorries cheaper than diesel vehicles in ever-growing applications, and thus more economically attractive. Competitive competition to the detriment of the German logistics industry does not occur, as CO_2 pricing by means of the toll applies to all logistics companies, including foreign ones. In principle, it should be possible for freight haulers to pass the additional costs of the toll on to their customers. Currently, a relevant proportion of the CO_2 surcharge from the toll is used to strengthen the railways.

CO_2 pricing as a lever. The Fuel Emissions Trading Act (BEHG) and the national emissions trading scheme for fuels (nEHS) created as a result also make CO_2 emissions in freight transport more expensive. Since 2024, a CO_2 price of € 45 per tonne of CO_2 has been charged on diesel and petrol at the gas station (see Figure 15). There are plans to gradually increase the certificate price per tonne of CO_2 emitted to up to € 65 by 2026.

Figure 15

Development of the CO_2 price per tonne of CO_2 emitted under the Fuel Emissions Trading Act until 2026



Source: German Environment Agency 2024

From 2027, the nEHS is to be transferred to the new European Emissions Trading Scheme for Fuels (the so-called EU ETS 2), which will be adopted in 2023.

In contrast to the nEHS, the CO_2 prices in the EU ETS 2 will be shaped directly by the market at the start of the system. Market pricing is linked to a fixed emissions cap, which will be continuously reduced. In view of the ambitious cap and the low emission reductions in the building and transport sectors to date, CO_2 prices in the EU ETS 2 are likely to be significantly higher than the current level in the nEHS. A recent study commissioned by UBA shows that the rate of reduction must increase fivefold by 2030 compared to the status quo.[40] This will also increase the cost of fossil fuels, while alternative fuels will be advantaged. In order to avoid an abrupt price increase in 2027, UBA recommends raising the prices in national emissions trading per tonne of CO_2 emitted to €110 in 2025 and €130 in 2026. In terms of fair competition, the EU ETS 2 is noncritical for the German logistics industry, as not only will all freight haulers in Germany pay the same lorry toll on roads in Germany, as is already the case, but the EU ETS 2 price must also be paid at the same level throughout the EU.

In the future, the CO_2 component in the toll should be used as an instrument in conjunction with the EU ETS 2. If various economic instruments are applied regarding CO_2 pollution, as in this case the lorry toll and the EU ETS 2 (from 2027), the existing European legal framework for combined CO_2 pricing should be utilised to the fullest: the combined CO_2 price should therefore correspond to the CO_2 avoidance costs in the lorry sector, so that a switch to climate-neutral alternatives is secured until the climate targets are met. In order to secure this price level, a procedure must be developed to adequately harmonise EU ETS 2 and toll. The CO_2-based toll in conjunction with the EU ETS 2 can thus make an important climate policy contribution to the transformation of road freight transport and the achievement of national climate protection targets. To this end, it is also crucial that revenues from the EU ETS 2 and the CO_2 component of the toll are used proportionately to actively support this transformation process in terms of transport policy.

Further develop energy taxation. The energy tax for diesel should be gradually raised to the level of the energy tax for petrol (based on energy content), which would reduce the tax privileges for diesel. Temporary exemptions for vehicles subject to the toll should be examined. In addition to adjustments to diesel taxation, reforming the energy and electricity tax is also needed. This tax should serve to protect the climate as well as the environment. In addition to a structure of national tax rates and EU minimum tax rates geared towards this, indexation of the tax rates for energy and electricity should also be introduced so that they at least keep pace with general price trends.

GHG quota in a supporting role. The greenhouse gas reduction quota (GHG quota) which has been in force since 2015 as part of the EU Renewable Energy Directive, also makes e-trucks more financially attractive. As electric drives have far lower greenhouse gas emissions than diesel lorries, those obliged to meet the quota[41] can now also meet their quota via e-trucks.

Are alternative fuels a necessary bridging technology?

Paraffinic fuels from waste and residual materials (HVO), biomethane or natural gas are already being used today to reduce climate-damaging emissions from heavy commercial vehicles and thus achieve corresponding corporate goals or fulfil legal requirements. It's a fact that, unlike e-fuels, alternative fuels from waste and residual materials can already be purchased, but apart from natural gas, which has a low GHG reduction potential, their availability will remain limited. In addition, HVO and biomethane are only as climate-compatible as the raw materials used to produce them. Increased use of these fuels in transport in Germany will only lead to more fossil fuels being used in the countries of origin instead of using the alternatives in situ.

40 Graichen and Ludig 2024: Supply and demand in the ETS 2.

41 Quota obligated parties are the distributors of petrol and diesel fuels for road transport.

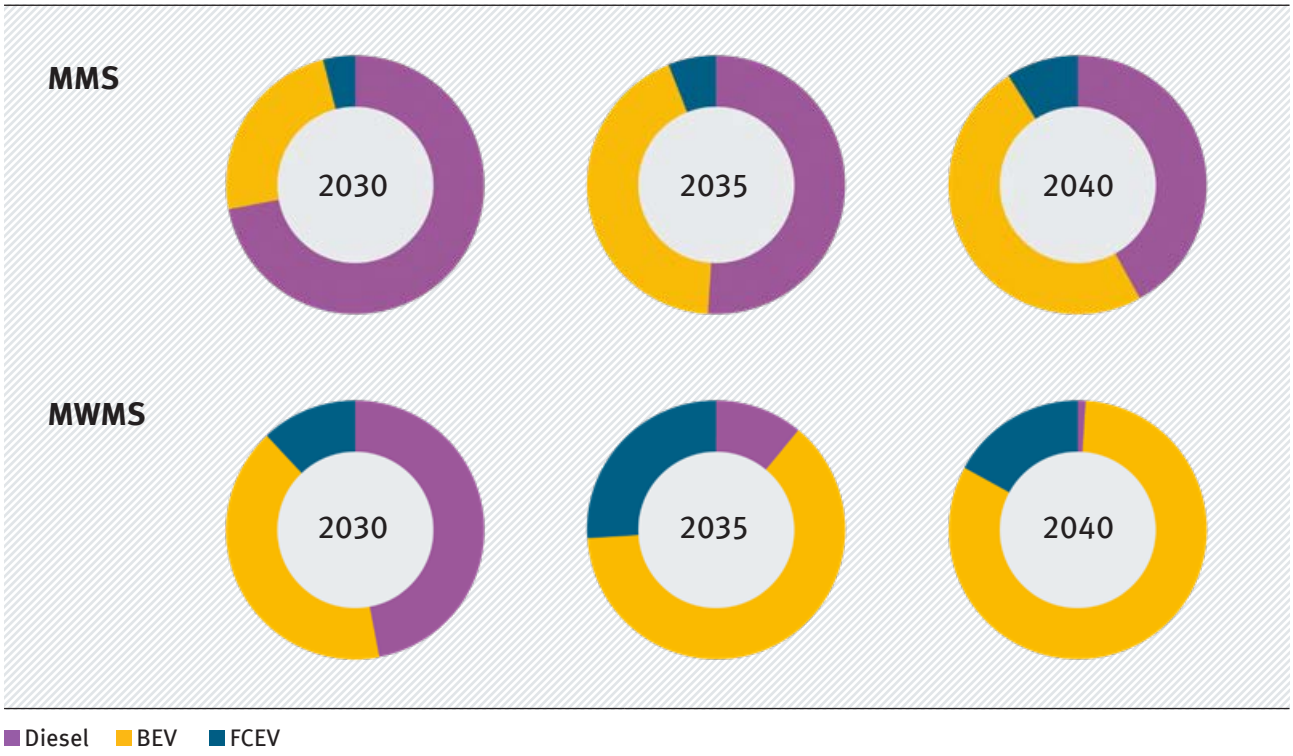
Ambitions for new lorries. The tightening of CO_2 fleet targets in the EU will make the construction of lorries with alternative drive systems more lucrative for manufacturers as well. The average CO_2 emissions of new lorries from 2030 on must be 45 % lower than in 2019, 65 % lower from 2035 onwards and 90 % lower starting in 2040. These targets are a step in the right direction, but even more ambitious targets and a ban on combustion engines in road freight transport would have brought us closer to climate protection targets. The Euro 7 emissions standards adopted in accordance with Regulation (EU) 2024/1257 will, in addition to nitrogen oxide, also regulate tyre and brake wear on heavy commercial vehicles. It will come into effect in 2028 at the earliest.

Gaps in the charging network. No electrification without charging points! Measures to promote e-drives are ineffective if there are large gaps in the charging network. Charging points must be available nationwide providing optimum access and sufficient numbers to make electromobility attractive for the logistics industry. The national charging infrastructure control centre coordinates planning and expansion throughout Germany. At EU level, minimum requirements for charging and refuelling infrastructure have been defined by the Alternative Fuels Infrastructure Regulation (AFIR). It calls for charging stations for heavy commercial vehicles to be installed every 100 km and hydrogen filling stations every 200 km on the motorway network from 2025. Full coverage of the roads within the trans-European transport network (TEN-T) is planned by 2030.

The expansion and development of the charging infrastructure is a major endeavour. Numerous charging stations and hydrogen refuelling stations need to be installed. In addition, the electricity grids will have to be adapted because demand for electricity will increase enormously as a result of the transition to new drives. The biggest foreseeable obstacle is the long lead times for planning and implementing energy connections in the medium-voltage grid, especially next to motorways. The power connection for warehouses and depots will also often have to be expanded so that many e-trucks can be charged at the same time. The Charging Infrastructure Masterplan II, which the German government adopted in 2022, sets out key steps to accelerate the expansion.

Figure 16

Distribution of new registrations of HCVs by drive system



Note: MMS and MWMS describe scenarios with different measures (see text).

Source: German Environment Agency, own illustration based on Harthan and Förster et al. 2023

Electricity costs must be kept as low as possible through suitable market structures or a suitable energy market design. It is also advisable to consider the option of a catenary system along the main corridors of the German motorway network in order to be able to counteract possible stationary charging infrastructure bottlenecks in the future.

Measures can be effective. Figure 16 shows the results of a study commissioned by UBA, the Federal Government's Projection Report for 2023.[42] There are two scenarios for the development of new registrations of heavy commercial vehicles: one, if politicians only implement the measures already adopted (MMS), the other, MWMS, if measures were to be implemented that are close to being decided on. In the more ambitious MWMS, all-electric trucks could already have a 41 % share of new registrations by 2030 – mainly thanks to the stricter toll, which had not yet been concluded at the time the study was published. By 2040, diesel lorries would have virtually disappeared from the list of new registrations.

In the road freight transport domain, many instruments have been adopted in recent years that will take effect well before 2030. Changes to adopted instruments and any additional instruments that may be necessary to achieve the climate targets should take appropriate account of the needs of stakeholders within the transformation, and support changes in terms of transport transition or energy transition in freight transport. Post-2030, the question of the most climate-compatible fuels in road freight transport and discussions about renewing the existing fleet will take centre stage. The instrumental framework for the next steps in the energy transition must therefore be developed at an early stage.

Overview of measures and instruments for drive technologies and charging infrastructure

Measures and instruments	Who decides?	Who is responsible for the implementation?
Lorry toll (Eurovignette Directive) Ensuring the toll continues to have a steering effect in the future	EU	Federal government
CO_2 pricing via nEHS/EU-ETS 2 Ambitious further development of the EU ETS 2 from 2027 and increase of the prices in the nETS from 2025; develop procedure for adequate coordination of EU ETS 2 and tolls	Federal government, EU	Federal government
Further develop energy and electricity tax Uniform taxation of diesel and petrol; further reforms to energy and electricity tax with a view to climate and environmental protection	Federal government, EU	Federal government
GHG quota Maintain the current level of crediting for e-trucks and specifically co-finance charging infrastructure via the GHG quota	Federal government	Federal government, energy industry, automotive industry
Subsidies for purchasing new e-trucks Support for additional costs in transition phase; consider benefits during utilisation phase	Federal government	Federal government
CO_2 fleet targets for new lorries Use planned reviews for tightening: 2030 (-50 %), 2035 (-70 %) and phase-out of fossil-fuel combustion engines between 2035 and 2038	EU	Automotive industry
Funding for charging infrastructure Forward-looking expansion, closing gaps, ensuring availability, taking depot charging stations into account and strengthening grid connections	Federal government	Federal government, federal states, energy industry, automotive industry

Source: German Environment Agency (2024)

42 Harthan and Förster et al. 2023: Projection report 2023 for Germany.

Transport infrastructure: making sure that goods are in the right place

Climate protection in transport will not succeed without shifting goods to more environmentally sustainable modes of transport. However, transport performance by rail in 2022 was only 133 billion tonne-kilometres, which corresponds to a market share of 19 %. This share is roughly the same as in 2019 (see Figure 17). Rail freight transport is therefore growing only slowly, while road transport performance is growing much faster. The market share of inland waterway transport actually decreased and stood at 6.3 % in 2022 (2005: 11.1 %).

That means that for the future design of transport networks, alternatives to road freight transport must be developed, promoted, strengthened and advertised. This creates greater competitiveness between modes of transport and the development of rivalries that bring more environmentally sound options into play.

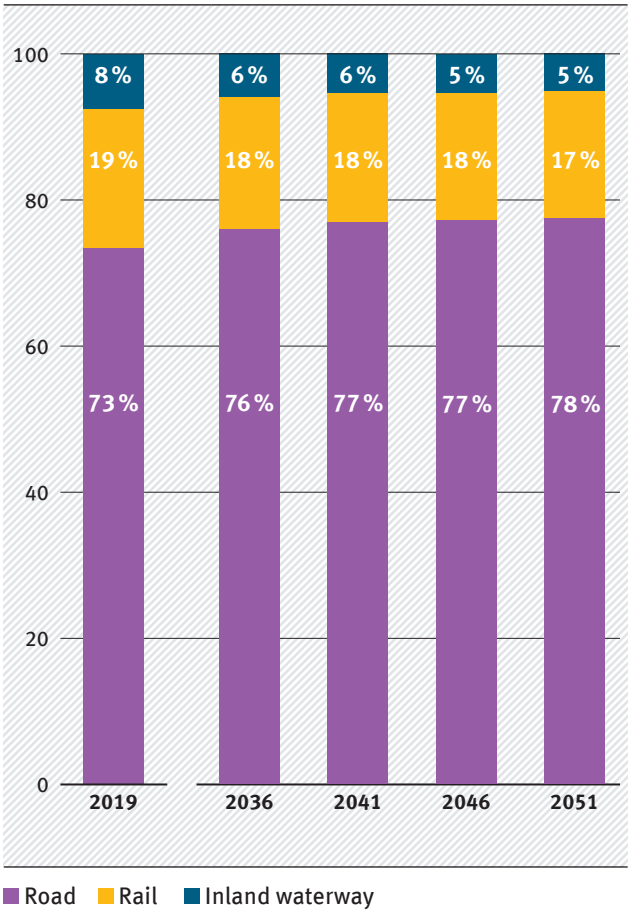
Shifting transport to rail promises far greater energy efficiency, as trains already show a much higher degree of electrification than lorries (currently 97 % of transport performance). A direct modal shift is currently only possible on 20 % of the transport relations within the federal long-distance network. On these routes, however, around 43 % of the volume (in terms of tonnage) is handled by rail and inland waterway vessel. This makes it clear that rail and inland waterway vessels are alternatives to be taken seriously – provided the transport network permits a modal shift. Rail and waterway are currently only without competition for 7 % of the volume transported exclusively by rail and waterway.[43]

Development of a shifting infrastructure. Shifting goods requires infrastructure – roads and railways, but also terminals, ports and storage areas. Spatial planning instruments such as the so-called Central Places Concept are needed to plan and connect these. It categorises cities into different classes, according to their importance for the surrounding area.

Figure 17

Modal split by volume and mode of transport

in %*



*Percentage figures rounded

Source: German Environment Agency, own illustration based on Moving Long-Term Transport Forecast (BMDV 2023)

This categorisation could also be applied to important transport routes between central locations, via which the population is supplied with goods, jobs and services throughout the area.

The concept is only of limited suitability for freight transport because logistics centres, reloading points and transport volume hot spots are rarely located in the centre of large cities, but mostly in neighbouring municipalities with lower centrality.

43 Blechschmidt, Kotzagiorgis, Jödden et al. 2022: Options for action for an ecological design of the choice of means of transport in freight transport.

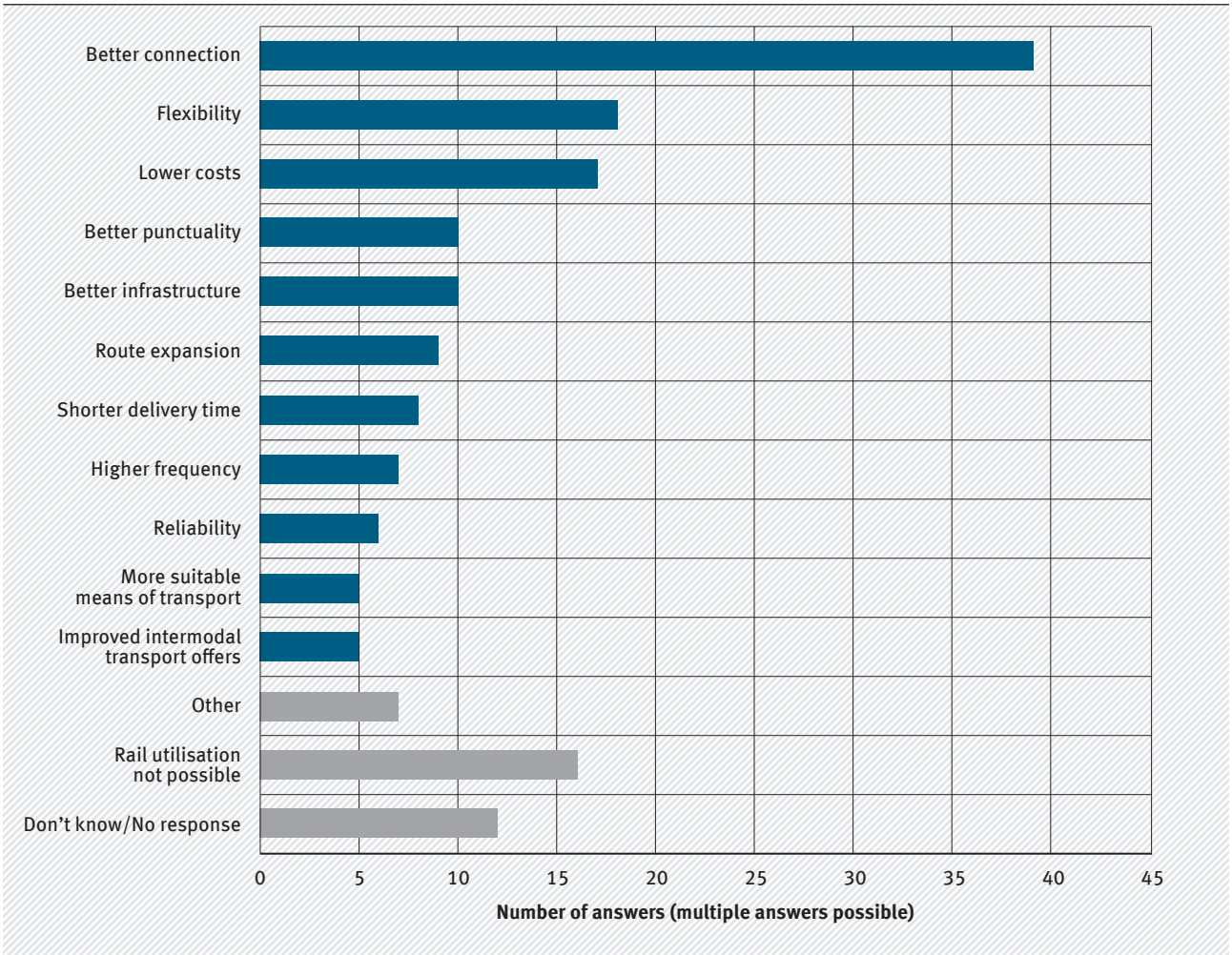
Based on the BMDV's structural data forecast for 2040, however, a similar concept can be developed for central locations and corresponding freight transport corridors. At the heart of this are indicators such as a particularly high volume of goods, an above-average number of employees in the logistics sector, long transport distances and high shares of multimodal transshipment. This concept can be used to determine transport duration or reliability of all modes of transport in the corridors (so-called levels of service quality). If the quality of rail or waterway services is worse than that of road freight transport, the alternatives can be specifically promoted, expanded, modernised and improved.

A transition in transport also requires a corresponding demand for alternatives. A 2022 study on courses of action for an ecological design of the choice of means in long-distance freight transport shows[43] that costs are only the third most important factor from the perspective of the shipping industry (see Fig. 18). The decisive factors for the choice of transport mode are often arguments that are congruent with the systemic advantages of the lorry, i. e. its good connections thanks to the dense road network and its high flexibility. One way to create such a system advantage for rail transport would be to develop commercial areas across municipalities (regionally consolidated commercial area development). This would create a local "base load" for rail transport.[44]

Figure 18

From road to rail: what is important for the shipping industry?

How would the transport offerings or transport services on the rail have to be developed so that you would consider transporting by rail in the future? A total of 169 answers.



Source: Blechschmidt, Kotzagiorgis, Jödden et al. 2022.

44 Veres-Homm et al. 2019: Regionally consolidated commercial spacial development (RekonGent).

Financing a modal shift infrastructure. Without sufficient funds, there can be no maintenance of infrastructure and no expansions or new constructions for a modal shift. There are several financing options, e. g. funds provided through user costs for all modes of transport, public funds and income from external environmental costs. They could be managed by a (newly created) infrastructure organisation, whose task would be to reliably finance infrastructure projects and carry out an assessment across all modes of transport.[45]

Table 3 shows the concept of such an organisation, which rests on three pillars:
cross-modal assessment and supervision, user financing based on the polluter-pays principle and the internalisation of external environmental costs, as is already the case with the lorry toll, for example. A valuable aspect of this approach is that, for the first time, both a cross-modal assessment of infrastructure projects and reliable financing are being considered.

The Federal Transport Infrastructure Plan and the expansion laws derived from it, decide on the transport infrastructure, its financing and expansion, and the weighting of road, rail and inland waterway projects. Their contents essentially determine the development of transport and transport emissions, environmental

Tab. 3

Components of an infrastructure company

1. Cross-modal assessment & supervision	2. User financing based on the polluter-pays principle	3. Internalisation of external environmental costs
Introduction of a nationwide transport infrastructure company	Establishment of budget-related infrastructure funds	Establishment of an additional environment and climate fund alongside the budget-related infrastructure funds
Consolidation of the expansion laws into a joint Federal Transport Infrastructure Expansion Act	Introduction of a distance-based car toll	Charging external environmental costs in the car toll
Parliamentary control & ministerial supervision of expansion laws	Expansion of the lorry toll & revision of user financing for rail and waterways	Management of the CO_2 surcharge for the lorry toll
Examination of alternatives along spatial corridors	Promotion of public-private partnerships (PPP) for new builds and extensions	Charging of external environmental costs in the train path pricing process

Source: German Environment Agency, own representation according to Bernecker et al. 2021

45 Bernecker et al. 2021: Overall concept for an environmentally oriented organisation and institutionalisation of cross-modal infrastructure financing in Germany (GUIDE).

impacts and land consumption. It therefore goes without saying that when the Federal Transport Infrastructure Plan is redrafted and further developed, targets for environmental and climate protection must be established much more firmly than before, e. g. by respecting the so-called ecosystem services of different landscapes in the benefit-cost analysis. The Federal Transport Infrastructure Plan could then provide a crucial framework for Germany to achieve its climate targets in the transport sector.

An environmentally sustainable modal shift can only succeed if any expansion of the infrastructure – especially of the railways – is supported by society. Transparent public participation helps to continuously inform those affected directly plus interested parties throughout the process and to increase the acceptance of construction measures. This also applies to the so-called Strategic Environmental Assessment (SEA) at an early stage of the process, as it sets the course for a project because important decisions often have to be finalised ahead of any concrete planning stages.

Climate change has an impact. Infrastructure is susceptible to the effects climate change on a daily basis, with weather events adding various levels of difficulties depending on the mode of transport. Flooding, washouts and landslides block and destroy roads and railway tracks. Drought and heat lead to embankment fires and tarmac damage. Storms and falling trees obstruct rail transport. Inland waterways are affected by heavy rainfall and flooding, but also by drought combined with low water. Seaports and shipping lanes are affected by rising sea levels.

Expansion measures on federal waterways must not exacerbate these problems. In order to increase resilience of infrastructure to climate change, alternative rail transport routes are necessary so that freight flows can be shifted to other routes flexibly and at short notice.

Overview of measures and instruments for shaping transport networks

Measures and instruments	Who decides?	Who is responsible for the implementation?
Development of a corridor concept for freight transport as part of federal transport infrastructure planning up to 2030 Improvement of the conditions for a direct modal shift to sustainable modes of transport (also cross-border)	Federal government	Federal government, federal states, DB InfraGO, water and shipping authorities
Development of a cross-modal financing model Developing funding solutions that are fed, for example, by user costs and environmental costs	Federal government	Federal government
Establishment of a transport infrastructure company for the strategic and operational development of a modal shift infrastructure Implementation of the cross-modal assessment and financing of infrastructure projects	Federal government	Federal government
Adaptation of the assessment methodology in the Federal Transport Infrastructure Plan to better integrate environmental and nature conservation objectives Consideration of ecosystem services in the benefit-cost analysis, examination of land-saving project alternatives	Federal government	Federal government
Establishment of comprehensive stakeholder participation in infrastructure projects Comprehensive public participation, e. g. as part of the SEA	Federal government	Federal government

Source: German Environment Agency (2024)

Shift goods to rail! Potentials and obstacles

Freight transport by rail contributes greatly to a transport transition. With a modal split share of around 20 %, rail already plays an important role in the transport sector in Germany today. The German government's goal is to increase this share to 25 % by 2030.

Rail is environmentally sustainable: on average, infrastructure, vehicles, energy supply and use generate around four times less greenhouse gases than the averaged lorry (see Figure 19). Rail will have to play an even greater role in the future for environmentally compatible and energy-efficient freight transport. This is due to the physical concept of the wheel-rail system (steel on steel), exhibiting a significantly lower rolling resistance, such that the system has a major energy advantage over road transport (rubber on asphalt).

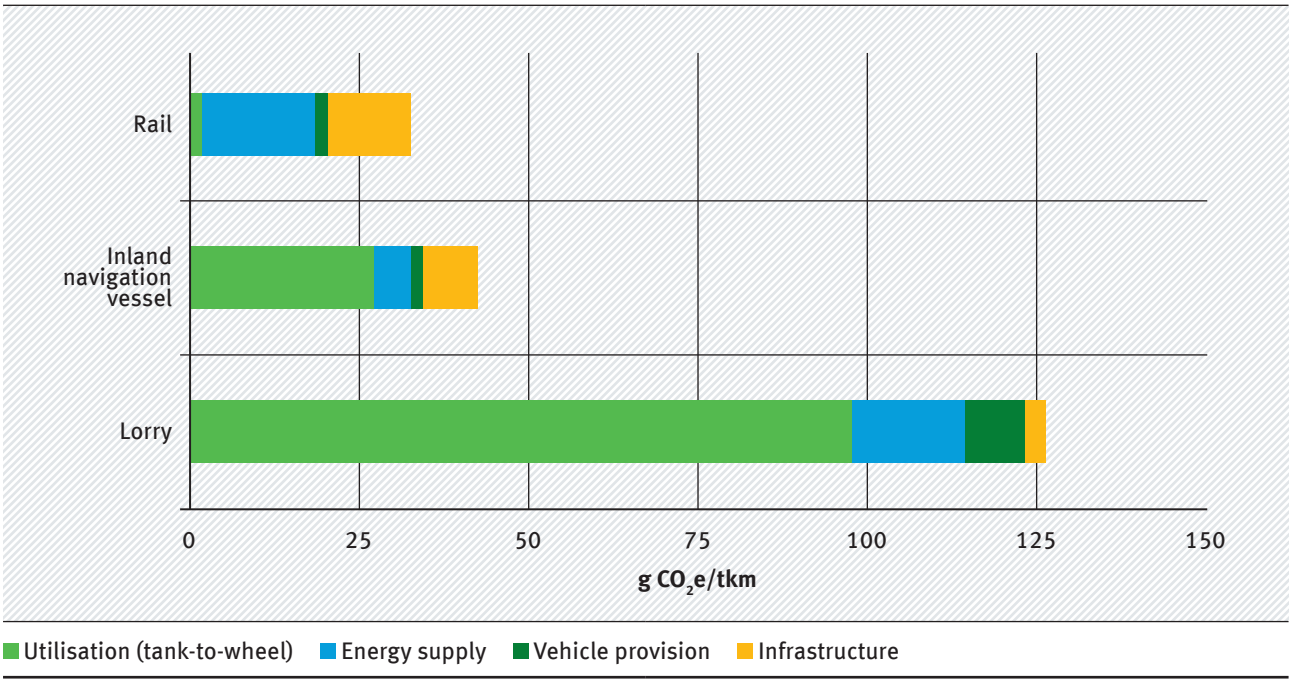
Of course, rail also has an environmental impact. Freight railways in particular must continue to reduce their noise emissions so that the necessary shift of more goods to rail is accepted by the public. To keep noise emissions within limits several approaches are necessary: noise protection at the source, e. g. through the mandatory introduction of noise-reducing bogies which have a significant reduction effect on curve noise; noise protection measures along existing lines; and, last but not least, when planning for new lines, take noise protection into account at an early planning stage.

Better resources, better speed, better strategy.
Over the last few decades, the rail network in Germany has experienced a loss of substance ("running for wear and tear"). Without a sufficiently large and efficient rail network, reliability and acceptance by the shipping industry will be adversely affected. In other words: only if rail is prioritised more strongly in transport policy can it realise its potential and bring freight transport closer to the goals of environmental and climate protection.

Securing long-term financing for the rail network beyond individual fiscal years and legislative periods is central to sustainable upgrading. Above all, an efficient use of financial resources is important.

Figure 19

Climate impact of long-distance freight transport



Data 2017; lorry – medium lorry

Source: German Environment Agency, own representation according to Allekotte et al. 2020

Such an efficient use would be, for example, optimising operations management, with network operators aligning the planning of train paths more closely with demand. Freight transport would also benefit from this.[46]

The rail industry has worked together with transport policymakers in the "Rail Acceleration Commission" to develop proposals on how the German rail network which is being used close to capacity limit could be upgraded by 2027.[47] At the end of 2022, the commission presented 70 specific recommendations for five fields of action. These include streamlined approval procedures for new lines, longer passing loops and the electrification of infrastructure. The commission also proposes a "Modern Rail Act" to accelerate digitalisation and electrification. According to the commission, financing of railways, with its current numerous programmes and budget titles, must be simplified and made clearer.

The equal treatment of all modes of transport through the creation of fair framework conditions is central to the success of the rail freight companies. This includes the internalisation of external environmental and climate costs across all modes of transport. Rail freight transport must, if nothing else, find the right responses to change: rail-related bulk goods such as coal are becoming less important, while urgent and rather small-scale goods are gaining enormously in importance in logistics.

Intermodal transport/single wagonload transport. Intermodal transport is the growth engine in rail freight transport. It ensures access all over the country, a high degree of flexibility and is therefore predestined for shifting goods to rail in long-distance transport. To realise its potential, new terminals, automated loading technology and seamless logistics chains are needed. The federal government should examine the extent to which an expansion of funding for loading points and a mandatory assessment of the viability of a rail siding could be beneficial for transport-intensive industrial estates.

To gain new market segments, single-wagonload transport, which also brings smaller quantities of goods directly to customers across the country, must become significantly more reliable and flexible. This can only be achieved with the help of modern digital and automated systems. The level of service in handling must be increased through digital and automated solutions – e. g. by extending operating hours, automated handling, introducing the use of digital automatic coupling (DAC), automated brake tests and digitally supported train formation.

The "last mile" – i. e. the direct connection of a customer to a railtrack – is also essential for freight railways in regard to their profitability. To this end, the application process for the federal government's sought-after track access subsidy programme should be simplified. In addition, a permanent halving of track access charges through federal funding beyond 2024 would make sense.[46]

46 Lambrecht et al. 2022: Recommendations for a new railway policy.

47 BMDV 2022a: Rail Acceleration Commission - Final Report.

Digitalisation in railway transport. Rail freight transport has great potential for digital technology. One major step is the switch to digital railway control centres and the European Train Control System, or ETCS for short. Standardisation enables infrastructure to be used throughout Europe, can increase the performance of rail networks and reduce operating costs. In Germany, several lines have been equipped with ETCS since 2015. To prepare the existing rail infrastructure for increasing freight volumes as quickly as possible, it's important to examine more favourable and simpler alternatives to ETCS for a higher signal block density. This involves dividing signalled sections of a line into smaller segments, which enables a denser train sequence.

As part of cross-border standardisation, care must be taken to ensure that noise protection is guaranteed. Moreover, preventive noise control and noise remediation should be standardised within Germany. Noise prevention is regulated in the 16th Ordinance of the Federal Emission Control Act and applies to new construction and significant changes to railway lines, thus constituting a legal claim. Noise remediation, on the other hand, is a voluntary federal programme for existing railway lines. At present, the level of protection provided by preventive noise control is up to 7 dB(A) higher than that provided by noise remediation, which cannot be justified in terms of effective protection of humans from noise.

Digitised systems such as digital automatic coupling (DAC) enable fully automated shunting operations. This leads to shorter dwell times in marshalling yards and transshipment hubs and increases the competitiveness of rail freight companies. To that effect the federal government and the EU should promote the introduction of DAC so that it will be in use comprehensively by 2030. Cargo handling costs can also be significantly reduced – by up to 50 % – through automation and digitalisation,[48] which also increases the competitiveness of the railways.

Alternative drives for the non-electrified network. Today, 97 % of rail freight transport performance is already electrically operated, but only 63 % of the rail network is electrified via overhead lines. According to the coalition agreement of the federal government, this share is to rise to 75 % by 2030.

The construction of an overhead line is not economically viable on every route. Alternative drives are the better option here, whereby the choice depends on factors such as the mission profile, costs, as well as availability of fuels. Hybrid drives combine an internal combustion engine with an electric drive. They go by different names – hybrid locomotive, last-mile locomotive, dual-mode locomotive – and represent different technical principles. Hybrid locomotives run on electricity from a battery. If more power is required, a diesel engine runs alongside which also serves as a power generator for recharging the battery. Last-mile locomotives and dual-mode locomotives use electricity from a catenary; if this wire is missing on a section of track, they apply their diesel engine. The (partial) use of electricity reduces diesel consumption and emissions for all hybrid drives.

One promising technology is the use of fuel cell drives. They possess high energy efficiency, significant cruising range and short refuelling times. However, if they are to be environmentally sustainable, fuel cells require "green" hydrogen, which must be generated using wind or solar power. The large-scale production of green hydrogen is still being developed on a global scale and also costly. In the long term, the use of fuel cells in rail transport must not lead to disuse of existing overhead lines or a reduction in the rate of electrification within the rail network.

48 Blechschmidt, Kotzagiorgis, Jödden et al. 2022.

Overview of measures and instruments in the rail freight system

Measures and instruments	Who decides?	Who is responsible for the implementation?
Securing long-term financing of the rail network Establishment of a multi-year infrastructure fund	Federal government	Federal government
Rapid realisation of capacity-enhancing measures Implementation of the proposals of the "Rail Acceleration Commission" of the BMDV by 2027	Federal government	Federal government
Increasing the reliability and flexibility of single-wagon transport Improved service level through digital and automated solutions	Rail sector	Rail sector
Stronger promotion of intermodal transport Provision of additional loading points (funding programme), optimisation of loading technology and the organisation of logistics chains; automation and standardisation	Federal government, rail sector	Federal government, rail sector
Improvement and simplification of freight handling Expansion of support for loading points, obligation for nonpartisan provision of shunting operations, mandatory assessment of a siding	Federal government	Federal government
Making the siding promotion programme more attractive Simplification of the application process	Federal government	Federal government
Reduction in charges for the use of train paths Increasing intermodal competitiveness by permanently promoting a track access charge	Federal government	Federal government
Simplification and acceleration of train formation Promotion of the comprehensive introduction of digital automatic coupling	EU, Federal government	EU, Federal government
Increasing the share of electric traction Electrify more railway lines; target of 75 % overhead line share of the overall network by 2030	Federal government	Federal government
Promotion of alternative drives Hybrid locomotives and fuel cell drives with green hydrogen	Federal government	Federal government

Source: German Environment Agency (2024)

Digital logistics

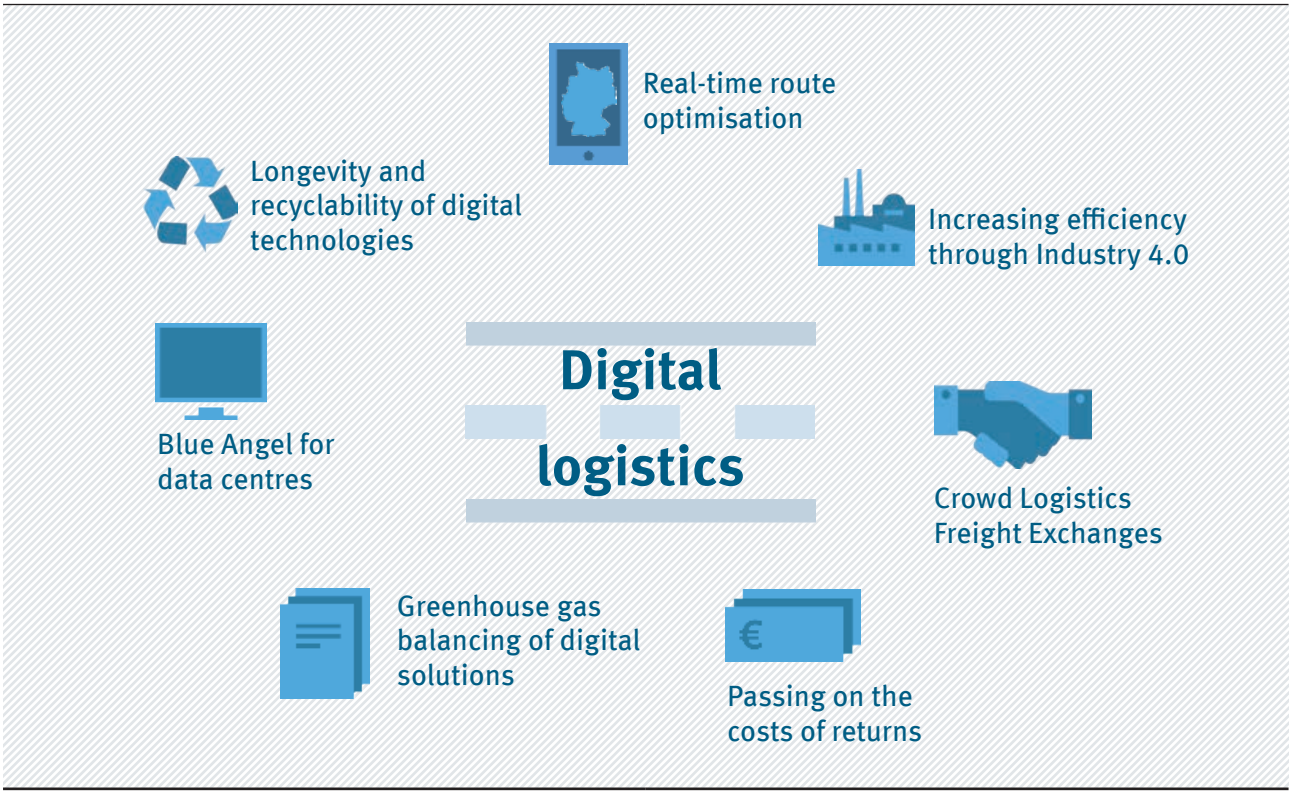
It goes without saying that many processes in freight transport have already been digitalised. This applies, for example, to route and loading management or production and procurement logistics, but also to retail and to distribution logistics. Automation processes are directly and indirectly changing freight transport. They save fuel if, for example, the optimum route is always calculated digitally, they speed up production processes, they can forecast the flow of goods and track them in real time. Cross-linked and increasingly automated e-vehicles can also lead to savings on the difficult and expensive "last mile". Figure 20 shows the various task areas of digital logistics.

Online commerce is changing freight transport. Global digital cross-linkage has been the foundation of online commerce, where place of production and delivery route are virtually irrelevant to customers. Transporting millions of goods halfway around the world, even if they are only worth a few euros, has become part of everyday life.

Shopping via click has now given rise to business models, platforms and portals that offer customers customised and compartmentalised transport. Often this even happens free of charge. Although online shopping eliminates the need to travel to the city centre, it also increases traffic due to the delivery of goods. Ordinarily 80 % of all online orders are delivered to the home and approx. 11 % of all goods ordered online are returned.[49] Alternative delivery locations to vendor-inclusive parcel stations as well as distribution models for chargeable returns could counteract this.

Figure 20

Fields of activity in digital logistics



Source: German Environment Agency 2024

49 Opitz et al. 2024.

Industry 4.0 is helping logistics to get on track. Industry 4.0 is a term from industrial production – a concept that digitally connects people, machines, processes and products. However, Industry 4.0. is also a driver for fast, transparent and precise flows of goods: algorithms calculate ideal delivery routes, machines report independently when they require new materials. The interlinking of computer systems improves the analysis of real-time data, which in turn supports vehicle tracking and fleet management. Machine learning and artificial intelligence (AI) make it possible to predict and plan the flow of goods in conjunction with improved transport and warehouse management. Access to precise information regarding your products and processes enables you to manage material flows better and make processes more efficient and energy-saving – in a best-case scenario, you can also reduce emissions.

On the other hand, data centres are true energy guzzlers. They should therefore be operated in accordance with the standards of the "Blue Angel" ecolabel for data centres (DE-UZ 228), a standard that has been in place since 2011. The ecolabel can be awarded to data centres whose technical facilities are operated in a particularly energy-, climate- and resource-efficient manner and whose operators implement long-term strategies for greater energy and resource efficiency. Such strategies would also include the use of components and systems with greater durability, improved reparability and good material recyclability (in accordance with the "European Ecodesign Directive" 2009/125/EC).

Industry-wide cooperation in logistics can help share technologies by developing and introducing uniform standards for freight transport. One example of this is the "Rail Freight Data Hub". This data platform for rail freight transport which was developed as part of a research project and is supported by the Association of German Transport Companies, intends to increase service quality, speed up processes and minimise the error rate.[50] The aim is to create an industry solution open to all companies that is also supported by them.

Moving in automated fashion. As of today, freight transport vehicles are already equipped with sensors and communication technologies which collect and process information about the condition of the vehicle, its fuel consumption and transport performance. Thus intelligent route planning and fuel-efficient driving are being supported. Installing digital equipment on motorways can reduce greenhouse gas emissions by easing traffic flow. In combination with driver assistance systems and intelligent transport systems, it's estimated that there is potential to save 0.4 to 1.5 Mt CO_2 per year.[50]

However, digital solutions in freight transport can also lead to additional greenhouse gas emissions. The consumption of raw materials and energy caused by data collection and processing is considerable. The use of digital instruments requires a complex life cycle analysis of these technologies and applications. Automation not least has an impact on logistics networks: automated driving and automated goods handling can promote direct transport using smaller vehicles as well as reduce batch sizes. As a result, road transport volume continues to increase while vehicle utilisation decreases.

50 Website: https://www.infra-dialog.de/

Algorithms as co-drivers. What drivers appreciate is crucial to the success of logistics: real-time route optimisation through the use of special algorithms. It determines the current traffic situation and shortens journeys, resulting in lower fuel consumption and fewer emissions. Digitally planned bundling of shipments – for example with the help of so-called freight exchanges – can avoid empty running and improve vehicle utilisation. The idea behind "crowd logistics" is to shift transport to private individuals who are paid to transfer goods directly from the place of dispatch to their destination. Collaborative routing actively and evenly distributes vehicles across the road network, which avoids congestion and improves traffic flow.

No optimising at all costs. With all digital optimisation measures it is important that a trade-off between potential savings and (surplus) energy consumption is avoided – in other words, that at the end of the day, logistics processes run more efficiently, but emissions of greenhouse gases or air pollutants are not reduced.

Overview of measures and instruments for the digitalisation of logistics

Measures and instruments	Who decides?	Who is responsible for the implementation?
Propagation of the Blue Angel certificate for data centres Establishment of high efficiency standards for energy requirements	EU	Data centre operators, manufacturers
Specifications regarding longevity and recyclability of digital technologies in use Increasing product durability and strengthening the circular economy (Ecodesign Product Regulation)	EU	Manufacturer in the Industry 4.0
Use of intelligent telematics for fuel-saving routing and mode of operation Utilisation of real-time traffic data to reduce network load from total traffic volume	EU, federal government	Vehicle manufacturers, freight delivery companies
Promotion of freight exchanges and crowd logistics Development and support of platforms that enable consolidated goods flow outside of long-distance transport, among other things	EU	Freight delivery companies
Development of sales models for passing on the costs of returns Minimising transport from online retail	EU, federal government	Online commerce
Specifications and standards for automated handling Support the digitalisation and automation of goods handling through uniform standards	EU	Investors and terminal operators, vehicle manufacturers

Source: German Environment Agency (2024)

Sustainable logistics concepts

Environmentally orientated logistics concepts advance the transport and energy transition. Assumption: The entire logistics chain is low-emission, energy-saving, cost-efficient and finally, customer-oriented. The development of environmentally sound logistics depends on many factors, e. g. value chain, the size of the companies and the respective industry. It is therefore difficult to develop a "standard concept" which addresses environmental and climate protection issues for all conceivable applications. However, there are building blocks in existence for a foundation that constitutes sustainable logistics.

Calculation of greenhouse gas emissions: In order for logistics companies to contribute to climate protection, it's essential to calculate greenhouse gas emissions, for example in accordance with ISO standard 14083:2023-03. According to the EU initiative "CountEmissions EU", the application of ISO 14083 shall become mandatory for companies to calculate their greenhouse gas emissions. UBA supports the standard's application with a guideline aimed at the shipping industry and hauliers. This would offer support regarding the application of the above ISO standard in-house, shows sample calculations and explains specifications for standard values for emission factors.[51] From 2025 onwards, large logistics companies will also have to publicly account for their direct and indirect greenhouse gas emissions in their annual reports. This will happen in accordance with new EU requirements for corporate sustainability reporting.[52]

Dematerialisation: Transporting bulk goods will decrease considerably in the future, while significantly smaller, lighter and higher-quality goods will be consigned and shipped around the world. This "structural effect of goods" brings certain aspects into focus: as lighter and higher-value goods are usually transported by lorry it's important, for example, to condense the quantity of goods using intelligent packaging systems to ensure high vehicle capacity utilisation. A strategy that supports resource-saving production methods and a circular economy is also necessary. By doing this, transports can be avoided. This is being discussed in the development of the National Circular Economy Strategy. The Ecodesign Directive (2009/125/EC) defines minimum requirements regarding product design for certain product groups. With guidelines for packaging, transport and distribution, it can play an important role in minimising and avoiding transport.

Environmental and sustainability management in logistics companies: Environmental and sustainability management enables logistics companies to systematically record their impact on both the environment and society, and define concepts with targets and measures to reduce this impact. The European Eco-Management and Audit Scheme (EMAS) has proven to be an effective and credible system for environmental management. It stands for improvements in negative environmental impacts and compliance with environmental legislation.[53] In addition, the introduction of an environmental management system will become mandatory for many companies in the future, e. g. if they operate plants in accordance with the Directive on Industrial Emissions or fall under the regulations of the energy efficiency act. Logistics companies can use the legal requirements for environmental management and sustainability reporting as an opportunity to develop sustainable logistics concepts and communicate them to investors, suppliers, customers and other interest groups.

Low-threshold approaches to environmental and sustainability management and reporting are also available for small and medium-sized companies. Nevertheless, the thematisation of sustainable solutions within companies is strongly dependent on firm size.[54] In forwarding companies, which are characterised by medium-sized enterprises, corresponding measures are implemented much less frequently, although forwarding companies recognise their GHG emissions more often.[54] The promotion of small transport companies could therefore be supported by clients (the shipping industry) or through an easy-access funding programme.

51 Biemann et al. 2024b: Greenhouse gas emissions in the transport sector – Guidance on ISO 14083.

52 Directive (EU) 2022/2464 on sustainability reporting by companies

53 See www.emas.de

54 Blechschmidt, Kotzagiorgis, Jödden et al. 2022.

Local sourcing: Those who buy regionally help reduce or avoid transport. Procurement concepts which place a particular focus on the geographical proximity of suppliers of raw materials or preliminary products can help specifically to reduce journeys and emissions. A regionally interlinked economy stabilises value chains, reduces dependence on global suppliers and avoids high-emission long-distance transport. Equally, production close to customers and sales markets makes long-distance transport unnecessary. Local authorities can support companies by developing intermunicipal commercial areas at logistical nodes.[55]

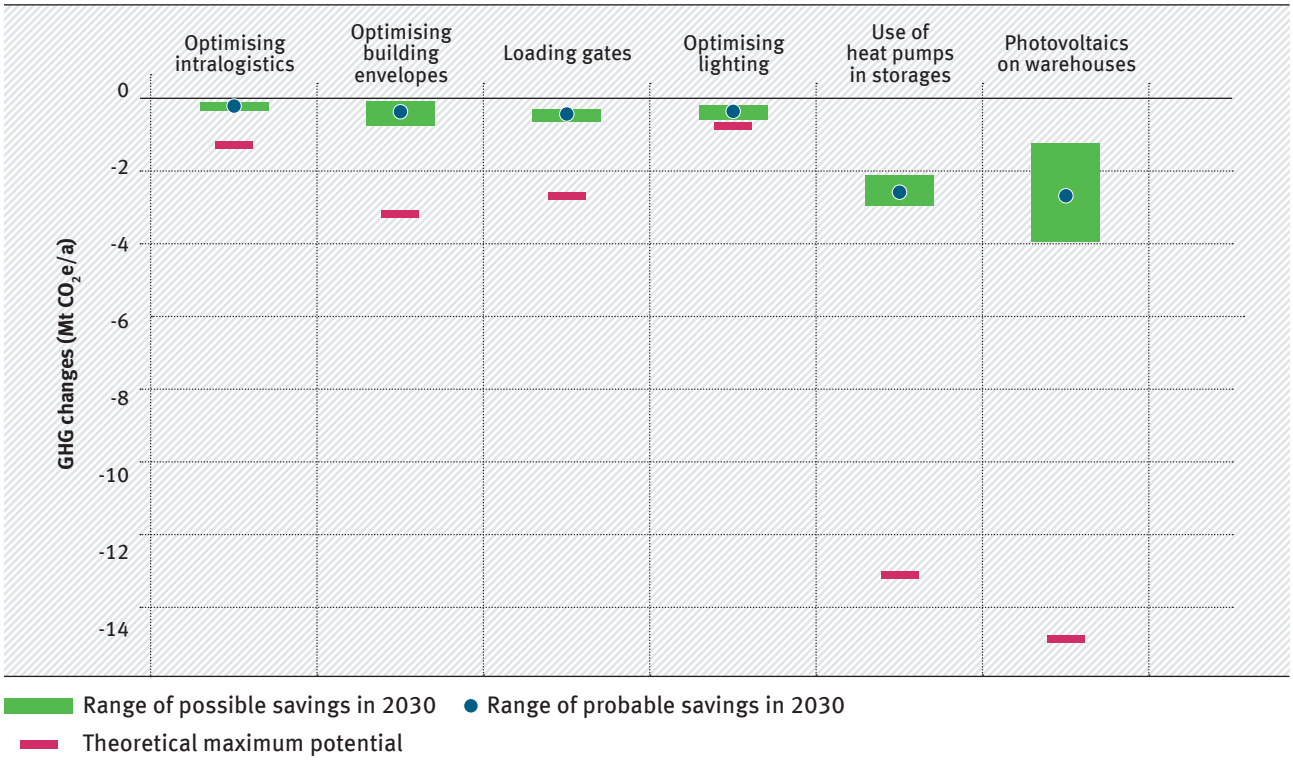
One building block for sustainable logistics concepts is the utilisation of symbioses between companies that are geographically not far apart. By utilising by-products from one company or industry, energy and natural resources can be saved and delivery journeys, e. g. for production equipment, can be reduced. A direct vicinity and the establishment of appropriate infrastructure (e. g. pipe connections) between the enterprises can reduce transport costs, energy consumption and emissions.

Printed instead of transported. Spare parts usually need to be transported from A to B particularly quickly and reliably. One alternative to conventional spare parts transport is 3D printing, which can be used to manufacture parts on site in a resource-saving manner. The exact impact of additive manufacturing processes on freight transport is still unclear. Although transport may be unnecessary, at the same time, 3D printing requires special raw materials which also must be supplied.

Sustainable building use: Logistics requires all sorts of buildings and properties. They consume space, building materials and energy. Demand-actuated temperature control, airlocks or sealed loading bays can significantly reduce the energy consumption of buildings. This also applies to intelligent lighting control and switching to LED lighting, which consumes up to 60 % less electricity.[56]

Figure 21

GHG reduction potential for logistics properties in Germany



GHG avoidance well-to-wheel (wtw)

Source: Opitz et al. 2024

55 Veres-Homm et al. 2020: Guideline: Regionally consolidated development of commercial areas.

56 Opitz et al. 2024

Renewable energies can also make a big difference. Applied to logistics properties, the installation of photovoltaic systems on the (mostly flat and large) roofs is particularly suitable. The Federal Ministry for Economic Affairs and Climate Action offers numerous funding opportunities for energy efficiency and the switch to renewable energies in non-residential buildings in its funding database (www.foerderdatenbank.de).

Figure 21 gives an overview of sustainable logistics measures. Both the installation of heat pumps and photovoltaic systems have considerable reduction potential.[56]

Automation and in-house logistics: Automated storage concepts and conveyor technology can help optimise the use of available space and reduce the size of heated areas. In non-automated areas, electric storage systems contribute to energy efficiency. In the future automated loading techniques could be of great importance if they allow transports to be shifted to a different time of day, provided that noise protection regulations can be complied with.

Synchromodality: Synchromodality is based on the idea of combining modes of transport in the transport chain in a flexible and optimised manner depending on the situation. No compulsory mode of transport is specified in advance, but instead a decision is made in real time as to which appears to be the most efficient, cheapest and most sustainable. This service provided by specialised companies strengthens rail and inland waterway transport, creates robust supply chains and can improve a company's greenhouse gas balance. If several shippers consolidate their transports via a service provider for synchromodal transport chains, capacity utilisation increases. Synchromodality, induces a shift to more environmentally sustainable modes of transport.

Overview of measures and instruments for sustainable logistics concepts

Measures and instruments	Who decides?	Wer setzt um?
GHG balancing/implementation of ISO 14083:2023-03 Support for preparing greenhouse gas balances in logistics companies	Companies	Companies
Minimal use of resources in product and production design Avoidance of transport through resource-saving production and value chains	Companies	Companies
Ecological sustainability in companies Funding for setting up and implementing eco-audits in smaller companies	Federal government, federal states	Companies
Procurement concepts with low transport intensity Regional procurement and disposal logistics	Companies	Companies
3D printing/additive manufacturing processes Easing burdens on spare parts logistics	Companies	Companies
Sustainable building utilisation of logistics properties Development of standards for the utilisation, use of heat pumps and PV on roofs of factory floors	Companies	Companies
Automated storage concepts and conveyor technology Support for efficient temperature control and automated loading of goods, e. g. onto rail	Companies	Companies
Synchromodality Real-time optimised choice of means of transport strengthens environmentally sustainable modes of transport	Companies	Companies

Quelle: Umweltbundesamt (2024)

Inland waterway transport faces new challenges

Inland waterway transport plays a niche role in freight transport in Germany. With a share of 6.3 % of total transport volume, it lags far behind road transport (72 %) and rail (19 %). The Rhine dominates as a waterway, with around 2,000 freight ships carrying around 88 % of transports (182.4 Mt) in 2022.[57] The volume of transport on German inland waterways has fallen slightly in recent years, mainly due to the Goods-Structureeffect.

Goods Structure Effect changes cargo. Inland vessels are traditionally used for heavy bulk goods. This tradition is changing: markets are shrinking as a result of the coal phase-out and the move away from other fossil fuels. The Goods-Structure-Effect means that more and more small and higher-value goods are being transported over long distances in a short amount of time, and the rather slow inland vessel has few trump cards to play here. However, the transport of containers, especially in the hinterland traffic of seaports, is a future opportunity for inland waterway transport.

Climate change slows down inland waterway vessels. Freight transport by inland waterway vessel faces major challenges. Of all modes of transport, inland waterway has the greatest need to adapt to climate change. Climate change brings hot summers with little precipitation and low water levels, which makes transportation by vessel difficult or even impossible. For this reason waterways are often deepened. However, intensifying the expansion of waterways can further exacerbate the negative consequences of climate change on the land's water budget. In addition, the expansion of waterways is contrary to the objectives of the European Water Framework Directive (WFD), which aims to achieve "good ecological status" for all waterways in the European Community by 2027. For example, transverse structures prevent the migration of fish in river systems. Since 2021, the Federal Water Management Administration has had the legal task of improving the hydromorphological status of federal waterways to such an extent that the objectives of the WFD can be achieved without restricting their use as waterways. At the same time, climate change is causing more heavy rainfall events, making efficient flood protection along waterways increasingly important. The federal Blue Belt Germany programme supports the renaturation of federal waterways and their floodplains and makes an important contribution to natural flood and climate protection.

57 Destatis 2024: Transport and traffic: Freight transport.

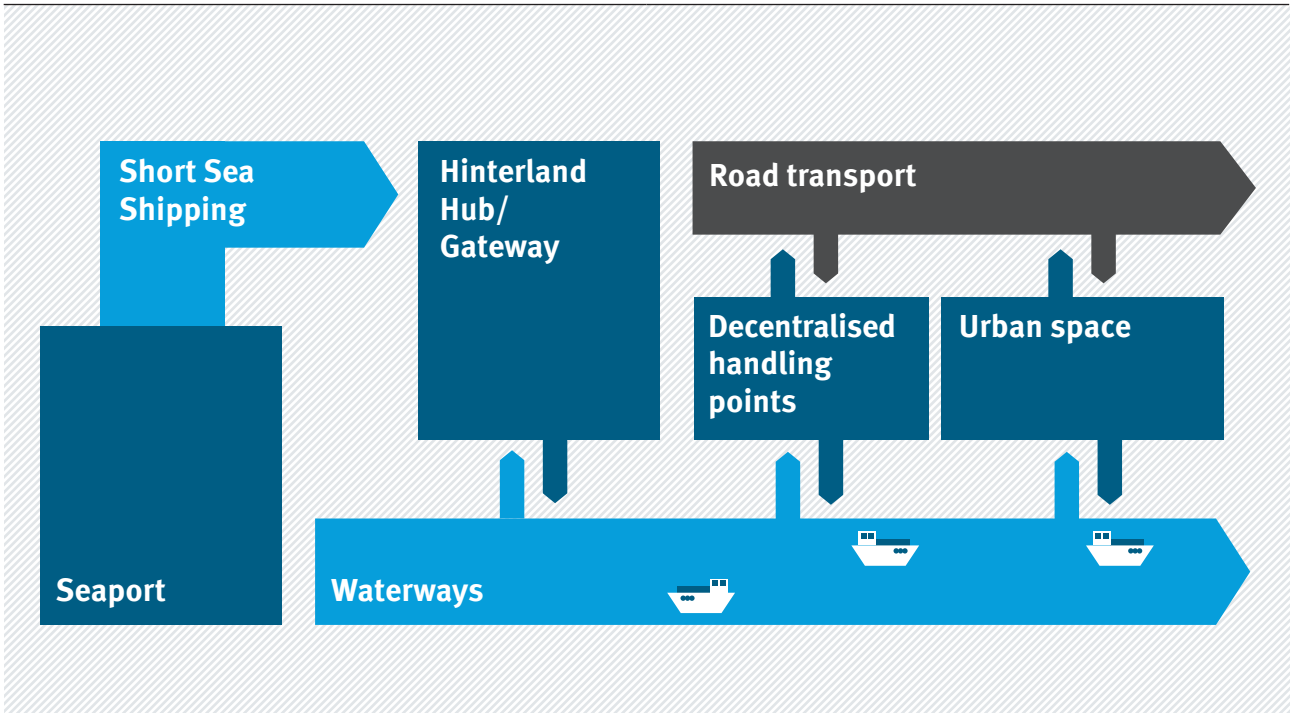
The need for shallow-draft barges, which can also in part operate at low water, will increase significantly. A corresponding demand, particularly in shipping on the Rhine, is already emerging.[58] Shallow-draft barges can also cushion uncertainties in supply chains and help guarantee the supply functions of inland waterway transport. Digital solutions on the waterways also help strengthen inland waterway transport in the face of low water events, e. g. through reliable forecasts of water levels.

Automation helps to adapt to the future. Inland waterway transport has to be modernised. Fully automated handling could increase market reach. Loading and unloading processes are much more efficient with the help of computer-controlled systems and robots that lift, transport and stow cargo independently, and at the same time helps reduce the need for skilled labour in inland waterway transport.

Several pilot projects are currently testing the extent to which this could contribute to a modal shift and – with the appropriate electrification of automated ship concepts – to an energy transition in freight transport. For example, within the "Port of the Future" in Duisburg, automated loading and unloading of container ships with driverless gantry cranes and straddle carriers is being tested; the "Smart Rhine Corridor", a digital corridor along the Rhine for automated inland waterway transport is being developed; and an autonomous system for loading and unloading bulk goods using robots and conveyor belts is being tested in the "Port of Magdeburg". In combination with automated handling, new ship concepts could also serve decentralised handling points to gain flexibility compared to lorries and open up new markets (see Figure 22). To take these steps, easy-access funding would have to be available to support structural change in inland waterway transport as early as possible.

Figure 22

Extended areas of application for shallow-draft, automated and battery-powered inland waterway vessels



Source: German Environment Agency 2024

58 BMDV 2022b: Study to examine funding for smaller and/or design-optimised inland waterway vessels. 58

Projects in the existing vessel fleet are supported within the framework of the funding guidelines for the modernisation of inland waterway vessels and the facilitation of emission-free and low-emission drives. The funding programme for the sustainable modernisation of inland waterway vessels is managed by the Federal Waterways and Shipping Agency. The core aim of the funding guidelines is to provide incentives for investments in zero-emission, low-emission and energy-efficient propulsion technologies and to promote the modernisation of inland waterway vessels.

Abolish subsidies. To level the playing field between modes of transport, marine diesel regardless of the climate benefits should gradually be taxed in the same way as diesel fuel, and its CO_2 emissions should therefore also be priced through national emissions trading (from 2027 through EU ETS 2). A minimum tax rate for marine diesel should be introduced at European level. If the tax concession is abolished it would make sense to use any additional tax revenue for the modernisation of inland waterway transport. The additional tax revenue could also be used for the further development and market launch of shallow-draft, automated and emission-free inland waterway vessels.[59]

Compared to lorries, inland waterway vessels are significantly more energy-efficient and produce fewer greenhouse gases per tonne-kilometre. For example, a ship with a load capacity of 1,000 t can transport as much as 40 lorries or an entire freight train, which makes a significant contribution to easing the burden on road and rail infrastructure. Battery-powered ships or hybrid systems of diesel and electric motors are expected to play an increasingly important role in the coming years. In the short and medium term, mainly diesel fuel will continue to be consumed, making it all the more important to modernise and retrofit the fleet with particulate filters and catalytic converters to reduce nitrogen oxide emissions to aid air pollution control.

Overview of measures and instruments for sustainable inland waterway transport

Measures and instruments	Who decides?	Who is responsible for the implementation?
Improving the hydromorphological status of waterways in accordance with the Water Framework Directive Avoiding the expansion of waterways, including through the Federal Transport Infrastructure Plan	Federal government, federal states	Federal government, federal states
Development of shallow-draft, automated and emission-free ships Modernisation can maintain markets and open new ones; provide easy-access funding	Companies	Companies
Digital equipment for waterways/forecasts of water levels Reliable traffic and water level data support automation and the stability of supply chains	Federal government, federal states	Federal government, federal states
Abolition of environmentally harmful subsidies and financing of fleet renewal Diesel taxation and CO_2 pricing can finance the switch to shallow-draft, automated and emission-free barges	Federal government	Companies/ vessel owner
Continuation of funding programmes to modernise inland waterway vessels and promote emission-free drives Faster modernisation of the fleet, retrofitting with particulate filters and SCR catalytic converters	Federal government	Shipping company, vessel owner

Source: German Environment Agency (2024)

59 Burger and Bretschneider 2021.

7 Urban logistics

Urban logistics: transports for local everyday life

No city or conurbation can function and survive without the daily transport of goods of all kind. Urban logistics is a basic requirement for an attractive living, working and supply environment. It encompasses far more than the courier and parcel delivery services that are visible everywhere. It also includes deliveries to catering and food retailers, industry, construction, trade and building management, as well as waste logistics and other services.

The term "urban logistics" – like the term "urban area" – is not clearly defined or delimitable, which has an impact on corresponding data and statistics. In metropolitan regions the spatial reference point for logistics should not only be the urban area, but the entire conurbation, as transitions between city and surrounding area are fluid when transporting goods.

Transport in densely populated areas does not run smoothly because urban space is scarce and expensive. This leads to congested roads, limited availability of loading zones, limited capacities for depots and warehouses and in general, to competition with other uses for the limited resource of space.

At the same time, urban logistics causes noise and pollutant emissions, congestion and accidents, and it's not always well received by residents. Urban transport is indispensable but also often unpopular.

The instruments for environmentally sound urban logistics must include regulatory, technical and cooperative measures to make transport in cities quieter, low-emission and greenhouse-gas neutral so conflicts of use can be resolved or do not arise in the first place.

Figure 24 (see page 75) shows the share of commercial traffic in total traffic of a city centre using the example of a large city. Commercial traffic accounts for around one third, with suppliers such as hauliers causing the largest share (14 %). Courier, express and parcel service providers (CEP), on the other hand, only account for around 5 % of commercial traffic.

A good plan is all that's needed

Urban logistics requires planning. For that purpose, local authorities need data on the current state of commercial transport, especially knowledge about the logistic processes of urban freight transport: data on route length, delivery area, number and type of vehicles, number of stops per route, number of customers served as well as route duration. The data should allow for cross-linking with traffic statistics, and monitoring.

Logistics data generally falls under the term "trade secret". As far as data made available to local authorities, this is done on a voluntary basis. At the same time, retailers and logistics companies have a huge interest in efficient processes. Local authorities should therefore include economic stakeholders in their planning. Nationwide statistics can also be a source of data for local authorities. The survey "Motor vehicle traffic in Germany" commissioned by the BMVD, for example, maps commercial traffic involving smaller lorries and cars. It should be updated regularly and in doing so collect more small-scale data on urban and regional delivery traffic. This data would be an important aid for local authorities and their transport development planning.

SUMP and SULP: how the EU envisions urban logistics. The European Commission has presented its own concept for the creation of integrated transport development plans under the name Sustainable Urban Mobility Plans (SUMP). Certain cities in the so-called Trans-European Transport Network – which aims to standardise transport systems across the EU to a certain extent – are to be obligated to draw up sustainable mobility plans. In Germany this includes 44 cities. The SUMP is based on a plan of measures that takes current and future mobility needs into account and should help improve quality of life in the city and surrounding areas. Urban transport planning will thus be aligned with EU guidelines via binding specifications for large cities. The SUMP shall be finalised by the end of 2027 and include measures for the integration of different transport modes, including sustainable and emission-free urban logistics.

For local freight transport, the Commission has drawn up Sustainable Urban Logistics Plans (SULP), which can be a key lever for reducing transport emissions from freight transport in conurbations. The task of the SULP is to provide local decision-makers with guidelines and procedures that help to control and steer urban logistics activities.

How it works: sustainable logistics at state level. The federal government cannot dictate transport development planning at municipal level. Therefore the federal states should obligate cities with a population of 100,000 or more to develop a SULP that includes administrative districts and metropolitan regions, and ensure funding for this task. Examples of urban commercial transport planning include the "Strategy for the last mile" in Hamburg or the "Integrated Economic Transport Concept" in Berlin. The aim of Berlin's concept is to reduce motorised road freight transport while at the same time keeping city centres functional and upgrading them. For example, it favours the use of waterways within the city, which can relieve the pressure on roads.

The urban freight transport concept addresses four target areas, each with appropriate indicators that help to document progress (see Figure 23).

The city of Hamburg, for example, with the help of an overall concept and clear targets wants to reduce CO_2 emissions from parcel delivery services by 40 % by 2030 and noticeably improve traffic flow.[60] Hamburg also has an "Environmental Fleet", a certification system for companies whose fleet share of emission-free vehicles is demonstrably at least 15 %. Among other things, the "Environmental Fleet" seal is associated with advantages in the utilisation of loading zones.

60 BS-Drs. 22/5939: Urban Logistics Hamburg - Strategy for the Last Mile.

Figure 23

Ambitious target system of an exemplary urban freight transport concept

Targeted field	Objective	Possible indicator	Targeted indicator development
Transport	Low mileage in urban freight transport	Vehicle kilometres per vehicle type (differentiated by road category according to RIN 2008 where applicable)	-10 % compared to actual by 2030 -20 % compared to actual by 2050
	Low number of commercial vehicle entries in central areas	Number of entries at the cordon (e. g. city centre ring road)	Level can only be determined relatively and depends on the starting conditions Example City of London: -15 % compared to actual by 2030
	High road safety	Fatalities/injuries in road accidents	Vision Zero by 2050
Environment	Compliance with all limit values for air pollutants	Indicators according to limit value testing carried out	Currently compliant
	Low noise pollution	Average level day/night	Compliance with limit values 16th BlmSchV for selected types of areas (residential areas, special zones) by 2030: Day: 59 dB(A), night: 49 dB(A) Compliance with limit values DIN 18005-1 for all area types until 2050
	Low greenhouse gas emissions	Total emissions within urban road network (excluding motorways)	-42 % compared to actual by 2030 -100 % compared to actual by 2050
Urban development	Minimal conflicts with pedestrian and cycle traffic	Illegal loading and unloading operations on pedestrian and cycle paths	Reduction of 50 % on selected main roads within one year
	Adequate road-space proportions	Distribution of space side area/roadway	Values according to RASt; e. g. ratio carriageway:side area 40:60
Efficiency of delivery traffic	High availability of loading zones	Number of loading zones by the roadside	Establishment of loading zones every 50 metres on main roads by 2025
	Minimal time lost on the way to the destination area	SAQ_N travelling speed index.*	Reaching level D in the HVZ in 2030
	Minimal disruptions to delivery activities in the target area	Lost time due to obstructions (parking, other delivery processes, etc.)	No data available yet
	Conveniently located handling areas for city logistics	Area size and -quality must meet the requirements	Comply with local requirements catalogues for urban logistics areas

*FGSV (2015), p. 233. The SAQ_N speed index relates the expected average car speed to the target average car speed, which results from the network function of the road section under consideration according to FGSV (2008), p. 23

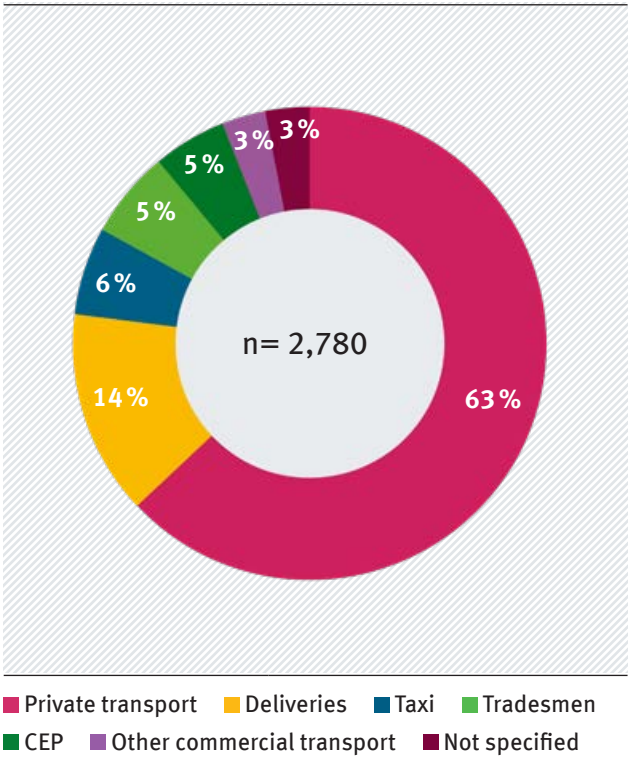
Source: German Environment Agency, own illustration based on Leerkamp et al. 2020

Competence centres for urban logistics at state level can support local authorities, ease the burden of transport planning and raise awareness for problems and solutions. North Rhine-Westphalia has "Guidelines for the planning of sustainable urban logistics", which promote digital and environmentally sustainable logistics approaches. The Centre for Sustainable Mobility Planning in the federal state of Hesse advises local authorities on transport planning and funding opportunities and serves as network and information platform.

Logistics is done by humans. Municipal logistics officers as contacts for local companies are a key success factor regarding greater sustainability. They promote innovation at the local level and organise the inter-municipal exchange of experience. As a neutral body, they can, for example, initiate cooperation, relieve the burden on other authorities and speed up planning procedures.

Figure 24

Share of commercial transport in total transport using the example of the state capital Wiesbaden



Source: German Environment Agency, own illustration based on Schäfer et al. 2019

Overview of measures and instruments data collection and transport planning

Measures and instruments	Who decides?	Who responsible for the implementation?
Data collection Regular collection, publication and monitoring of local (and possibly regional) data	Municipalities	Municipalities
Expand study on motor vehicle traffic in Germany Expansion of the study to focus on urban logistics, and regular updates	Federal government	Federal government
Transport planning for commercial transport in municipalities Obligation of major cities with over 100,000 inhabitants to draw up a Sustainable Urban Logistics Plan (SULP)	Federal states	Municipalities
Competence centres for urban logistics Establish guidelines, competence centres or central coordination offices at state level	Federal states	Federal states
Municipal representative for urban logistics Interface between business and administration for logistical matters	Municipalities	Municipalities

Source: German Environment Agency (2024)

Bundling material flows, consolidating delivery routes, connecting players

The technical capabilities and offerings for urban goods transports have changed enormously within a short period of time. In future, delivery robots, parcel drones or augmented reality glasses for rapid identification of individual shipments could be building blocks of a digital logistics world that no longer has much in common with the goods delivery of the past.

Innovative approaches in logistics. Innovative ideas are often initiated by non-corporate players. These include, for example, start-ups using AI platforms and electric vehicles that deliver goods for several companies in consolidated fashion using the most favourable distribution route or who drop off an ordered parcel in the recipient's parked car. Circular approaches that combine delivery, pick-up, repair and recycling will become increasingly important. The federal government, federal states and local authorities should utilise the great potential of digital systems, promote new approaches and – where necessary – adapt (legal) framework conditions.

Bundling as a strategy. Bundling is a kind of magic word in logistics. On the one hand, the bundling of capacities: cooperation in logistics can have enormous advantages, as space is used jointly, lorry utilisation is improved, empty runs are avoided and the costs of the "last mile" are reduced. All in all, transport flows can be concentrated and consolidated, which contributes to city-compatible solutions.

However, cooperation in logistics is not a sure-fire success. Experience from the 1990s has shown that often only unprofitable orders, but not profitable tours, are fed into a joint delivery system. There is a lot of competition on the last mile as well. In urban areas, many transports are also carried out by tradespeople, pharmacies or food markets. Cooperations also fail due to additional coordination efforts, different process times and demands in addition to legal requirements, for example regarding the cold chain or the transfer of liability. Nevertheless, approaches do exist to realise economically viable bundling of urban logistics, such as in the project "Transfer Roadmap for Urban Logistics (TUrLo)", which is being used to design logistics solutions for a cohesive industrial area on the outskirts of Berlin.

Hubs done well. Bundling is also the key to consolidating material flows in order to utilise the great potential for more efficiency and environmental compatibility. Different types of logistics hubs play a central role in the delivery of goods in urban areas (see Table 4). Hubs are collection and distribution points that act as turntables in the network of goods flows and are the main transshipment bases from the distribution centre to the recipient.

Large-scale logistics centres are usually located on the outskirts of conurbations, where there is sufficient space and a quick connection to the road network Municipalities and regions can apply (environmental) requirements to the establishment of companies at conveniently located sites. If logistics service providers want to use the space, they must then prove, for example, that they use environmentally sustainable vehicles and consolidate their transports. To avoid urban sprawl, commercial areas should be developed in a regionally unified manner. This also has the advantage that if several companies share one location a rail connection could be worthwhile (see also section "Transport infrastructure: making sure that goods are in the right place").

Multi-user micro-depots hold great promise regarding sustainable and effective urban logistics. Several service providers can deliver their consignments here using cargo bikes or small battery-powered vehicles. City car parks, for example, are suitable as attractive micro-depots – depending on their location and access height – especially if they allow extended access times. Such micro-depots have not yet become established, among other things because the amalgamation of non-corporate players is often subject to registration or authorisation, and parcel services and general cargo hauliers have different requirements in terms of location and design. An industry standard for micro-depots could contribute to better planning, cost transparency and faster implementation. Local authorities should hold discussions with potential users at an early stage and regulate conditions under which logistics service providers would participate in a micro-depot.

Tab. 4

Different types of logistics hubs and their function

Building/area	Location	Logistics process	Users
Parcel boxes	Public road space/ freely accessible private property	End-customer delivery (private)	Logistics companies and recipients
Parcel box at the house	Private property	End-customer delivery (private)	Logistics companies and recipients
Neighbourhood concierge service	Private property	End customer delivery (private) & handling for the last mile	Logistics companies and recipients
Delivery zone	Public road space	End customer delivery (commercial)	Logistics companies
Loading yard	Outside the public road space	End customer delivery (commercial)	Logistics companies
Micro-depot (mobile/ stationary, also called micro-hub)	Public road space/private property	Handling for the last mile	Logistics companies
City terminal	Private property (possibly in public ownership)	Close-to-downtown handling for urban supply	Logistics companies
Freight village	Private property (possibly in public ownership)	Handling for conurbation supply	Logistics companies

Source: Leerkamp et al. 2020, amended

The use of inner-city waterways is innovative, such as the integration of the western port in Berlin or the InnoWaTr 2.0 project, which has been testing an urban shuttle supply of retail stores in the Überseequartier of HafenCity Hamburg by barge since 2023. Shifting transport to another level – e. g. to underground tunnels or above-ground cable cars – has also been under discussion for some time but requires expensive systems. However, initial projects such as a transport tunnel for palletised goods (Smart City Loop) in Hamburg are in the works.

Joint delivery processes would also require adjustments to parcel labels and the geocoding of address data. There are already service providers that consolidate consignments as neutral third parties. Co-operations between retailers, who do not have goods delivered to the shop but to the nearest city hub, are a good option. A service provider then takes over the consolidated delivery from the hub at the desired time.

The crux of the last mile. It's no secret that the last act of a transport – the "last mile" – is time-, labour- and cost-intensive for logistics service providers. The delivery costs for this final part amount to around 50 % of the total transport costs for smaller consignments.[61] Finding alternatives for this costly part of transport is urgent because the challenges on the last mile are enormous: the greater the increase in volume of parcels, the more difficult it becomes to deliver quickly and accurately within conurbations.

Solutions do exist. Direct deliveries to parcel stations or parcel shops increase the delivery rate, the stop factor is reduced, and the journey shortened. However, parcel stations have so far mostly only been operated and used by a single service provider. This results in space-intensive parallel structures of several service providers. It would make more sense to have parcel stations used by several companies. Whether they reduce emissions and traffic depends, among other things, on whether the recipient picks up the parcel on foot or by car.

Parcel boxes at apartment blocks and building complexes save the trip to the parcel shop. An obligation to provide parcel boxes in new buildings could be enshrined in the building regulations of the federal states. This would determine in advance – analogous to the parking space keys – whether parcel boxes must be included in the planning of a new building.

Shifting transports. To relieve road congestion, transport operations can be shifted to off-peak times or areas with less traffic. For transports in urban areas before 6 a. m. and after 6 p. m., journey times can be significantly reduced for the same distance. However, a study commissioned by UBA shows that the maximum theoretical potential for greenhouse gas reduction through night logistics in Germany is only less than 0.3 Mt COe[62] In addition, disruptive delivery traffic at night is unacceptable for residential areas. Delivery processes should therefore only be shifted to off-peak times in compliance with the existing noise limits of the Technical Instruction on Noise Abatement (TA Lärm). Against this background, all new developments that make logistics quieter are of great importance. Research projects on this should be promoted.

61 Stütz and Clausen 2022: Urban logistics. Metzler (2013): Last-mile logistics

62 Opitz et al. 2024.

Smart delivery zones. Illegally parking vehicles in cities often block designated delivery zones and, in turn, delivery vehicles double park or stop on cycle paths and pavements. This discourages people from getting on an environmentally sustainable bike or travelling by foot. Smart delivery zones promise a way out, such as developed in the SmaLa pilot project in Hamburg. The SmaLa app is a virtual booking system that registered parcel service providers, couriers and general cargo hauliers can use to reserve a delivery zone. Digital road signs show which delivery vehicles have booked a specific zone at what time and are therefore exempt from the absolute stopping restriction. The zones are equipped with in-ground sensors so that their utilisation can be monitored.

Overview of measures and instruments for the consolidation of goods and transport flows

Measures and instruments	Who decides?	Who is responsible for the implementation?
Promoting automation, digitalisation and circular approaches Review legal framework conditions, promote pilot projects and scale digital solutions	Federal government, federal states, municipalities	Federal government, federal states, municipalities
Supporting the bundling of deliveries through logistics hubs Provide space for urban-compatible logistics concepts	Federal states, municipalities	Federal states, municipalities
Bundling of tours Bundling delivery by service providers and cooperation in the retail sector	Companies	Companies
Establishment of industry standards Standardised micro-depots, parcel labels and transport containers	Federal government, federal states	Federal overnment, federal states, DIN
Building regulations of the federal states Make the installation of parcel stations mandatory or specify delivery alternatives when planning apartment blocks	Federal states	Municipalities
Promotion of low-noise logistics Test and support measures to minimise noise	Federal government, federal state, municipalities	Federal government, federal state, municipalities
Smart delivery zones linked to booking system and controls Promoting pilot projects	Municipalities	Municipalities, companies

Source: German Environment Agency (2024)

Environmentally sound vehicle concepts

Emissions reductions and greenhouse gas-neutral deliveries are an important topic in the logistics industry. Large logistics service providers in the general cargo and parcel sector have developed their own concepts and set themselves specific targets for reducing emissions.

Clean delivery with electric drives. Urban logistics is an ideal playing field for alternative drives. In cities and urban centres, delivery routes are relatively short, delivery points are close together and consignments are delivered by smaller vehicles. Battery-powered electric vehicles with a gross vehicle weight of up to 3.5 t are particularly suitable for delivery routes in cities. Downtimes for charging the batteries are uncritical and easy to plan, plus the daily mileage of the vehicles is low. Their efficiency is high in conjunction with the many start-stop processes, as the vehicle battery is constantly recharged through recuperation.

The first battery-powered production vehicles have also been available for heavy trucks with a gross vehicle weight of up to 26 t since 2022. Even if trends for electricity and fuel costs are difficult to predict experts assume that from 2030, electric trucks with a gross vehicle weight of up to 12 t will be able to transport goods in urban areas more cost-effectively than conventional diesel lorries.[63] Targeted subsidies for the purchase of battery-electric trucks for urban areas and additional funding programmes for the charging infrastructure can accelerate this development.

The charging infrastructure must be massively expanded for the comprehensive electrification of the vehicle fleet. Logistics sites with 50 to 100 vehicles lead to high load peaks if many vehicles are charging their batteries at the same time. Photovoltaic systems on logistics halls could reduce demand for electricity from the grid and batteries could serve as intermediate storage (see also the “sustainable logistics concepts” section).

Cargo to bike. Cargo bikes are a promising option for delivery services in cities. A significant proportion of courier, express and parcel deliveries could be shifted to cargo bikes. Within which radius deliveries can be handled economically with cargo bikes depends on various factors, such as stop density and topography of the delivery area. The delivery radius is estimated at a maximum of 2–3 km.[64]

63 Tol et al. 2022: Techno-economic uptake potential of zero emission trucks in Europe.

64 Stiehm et al. 2021: HANDBOOK: Micro-depots in inter-municipal networks. Part 2 From concept to implementation.

However, logistics by bike has several preconditions: first and foremost, logistics-compatible cargo bikes allowing payloads of 300 to 500 kg can be loaded at ground level even with small pallets, have weather-protected cabins and powerful engines. However, transport infrastructure must also be geared toward cargo bikes. Although the use of cycle paths in commercial transport promises short and direct routes, many cycle paths are too narrow or can only be used to a limited extent due to bollards. On shared pavement and cycle paths, cargo bikes may interfere with pedestrian traffic. More advisory cycle lanes on carriageways could facilitate transporting cargo on bicycles. This would require an amendment to road traffic law.

Choose better routes. Priority lorry routes or lorry routing systems lead to important spots such as ports, industrial areas or freight villages. They keep lorry traffic away from the city centre and especially from residential areas and reduce the environmental impact of noise and pollutants. Priority routes and lorry routing systems generally run along well-developed main roads and, in addition to shorter journey times, also guarantee compliance with clearance heights and permissible total weights on bridges.

Setting limits. Transport by vehicles with high pollutant emissions can be reduced in urban areas by banning vehicles from entering the city centre. The federal states can specifically reduce pollution of city centre areas with air pollutants such as nitrogen oxides or particulate matter by upgrading environmental zones into low- or zero-emission zones. This can be done as part of clean air plans. However, it is crucial in regards to legal certainty that generous transitional periods are set and that affected areas are initially limited to a core zone and then gradually expanded. In addition, alternative vehicles and delivery concepts must be available, otherwise Air Quality Plans won't work.

Overview of measures and instruments for the promotion of sustainable urban vehicle concepts

Measures and instruments	Who decides?	Who is responsible for the implementation?
Urban transport infrastructure Taking cargo bikes into account when planning and equipping urban transport infrastructure, removing barriers on cycle paths	Municipalities	Municipalities
Cycle lanes and hard shoulders Establish for cycle traffic on carriageways	Federal states, municipalities	Federal states, municipalities
Amendments to the StVZO and the VwV-StVO Coordinate regarding the increased use of logistics-compatible cargo bikes	Federal government	Federal government
Priority routes for lorries Leading to industrial areas, ports or freight centres to keep lorry traffic out of the city centre and residential areas	Municipalities	Municipalities
Low and zero-emission zones Federal State and local authorities create binding guidelines, and implement	Federal states, municipalities	Municipalities

Source: German Environment Agency (2024)

Environmentally sustainable freight transport: looking ahead


8

Environmentally sustainable freight transport: looking ahead

You have reached your destination! Anyone who has had an exhausting drive likes to hear these words from their navigation device. Sometimes the journey goes smoothly. More often there are problems along the way. You miss the correct exit, take a wrong turn, get stuck in a congestion, at a construction site or sometimes even in a full road closure.

It's a similar story for transport when it comes to climate protection. The objective – greenhouse gas neutrality by 2045 – is well-known thanks to the Climate Protection Act, as is the approximate route, and milestones are signposted. And yet little progress is being made: greenhouse gas emissions from the transport sector have been stagnating at a high level for years.

Freight transport has a particularly long journey ahead of it to reach the "goal of greenhouse gas neutrality". The volume of goods that need to be transported is expected to continue to grow in the future, as economic development generally means more transport. Customers' demands for swiftness and punctuality are high. Transport must be cheap so that product and raw material prices remain as low as possible. Booming online commerce is putting cities and urban centres under additional pressure due to ever more traffic even over short distances.

UBA is convinced that environmentally sustainable freight transport is feasible: internationally, nationally and also in urban areas. The necessary measures and instruments are listed and explained in this specialised brochure. The two main pillars on the way to more sustainable transport are **energy transition in freight transport** which includes comprehensive electrification and moving away from fossil fuels, and **transport transition**, i. e. the targeted strengthening of environmentally sustainable means of transport such as rail and inland waterway transport. Avoiding transport is also an essential part of the transport transition – e. g. by bundling material flows and capacities, through consistent use of digital technology, through regional consumption and sustainable procurement.

There are certainly first beginnings: the CO_2 component of the lorry toll introduced in 2023 is a big step in the right direction. Changes for aviation in the existing emissions trading scheme, the inclusion of maritime transport in this scheme and the creation of the European emissions trading scheme for fuels in the transport and building sectors send a clear price signal in favour of reducing emissions from fossil fuels and make low-emission alternatives economically viable. In addition, the auctioning of emission allowances generates considerable revenue at both the national and European level, which should be used proportionately to support the transformation process in freight transport in terms of transport policy.

Still a lot more needs to happen. The EU should place a clear focus on power-based fuels that are preferably used in air and sea transport to reduce emissions, set ambitious targets for CO_2 requirements for new lorries and move away from internal combustion engines more quickly. The EU can also specifically strengthen rail as an environmentally sustainable mode of transport, for example by harmonising cross-border transport. In air transport, a rapid reduction in subsidies, an EU-wide kerosene tax or an extension of the air passenger tax to freight transport would comprise effective contributions to climate protection. Many of these instruments are based on the idea of internalising, i. e. pricing in the external environmental costs caused by freight transport. This idea is not new, but it has lost none of its impact.

Clear directions are needed to change course. In other words, all of this requires suitable framework conditions. And these are still a long way from being created. Fossil-fuelled road freight transport is currently unrivalled in terms of cost, and the transport industry and customers are used to the flexibility and ubiquity of lorries. The transport transition in freight transport relies above all on a significant strengthening of rail and inland waterway transport and its infrastructure. Possible steps are shown, for example, by the proposals of the "Acceleration Commission for the railways": leaner approval procedures and a "Modern Rail Act" that speeds up digitalisation and

modernisation. Of all modes of transport, inland waterway transport has the greatest need to adapt to climate change. It needs modernisation from the keel up, for example, shallow-draft, automated and emission-free ships to secure existing markets and win new ones.

Many cities and urban centres are choking on traffic, and herein freight transport plays a significant role. In addition to the transport transition for motorised private transport, a **transition in urban logistics** is urgently needed. Major European cities are obliged to draw up a "Sustainable Urban Logistics Plan" by 2028 as part of their transport planning. Municipalities and federal state governments can already do a lot today: promote start-ups that provide new, environmentally sustainable transport ideas, integrate the potential of cargo bikes into transport planning, support the bundling of transports as well as cooperation in trade, test and scale digital instruments, plan logistics hubs and logistics centres in an integrated manner.

Freight transport always has a specific purpose. **It is triggered by people and made for people** – regardless of whether it's a giant freighter from China, a lorry from southern Spain or a local parcel delivery. Firstly, this means that there are a large number of players along the supply chain: players with very different interests, goals, price expectations and also with different levels of willingness to change and redirect things. They are all needed to make logistics systems and transport environmentally sustainable and climate-compatible.

Secondly, this means that Customers and consumers have some control over whether and how many goods need to be transported. If many people specifically buy regional and locally sourced products, quite a few long-distance transports become superfluous. If manufacturers and customers focus on longevity and ease of repair, there will be a reduction of the amount of new goods being transported.

Sustainability always includes the aspect of sufficiency, i. e. the question of the extent of consumption and production. Moderate consumption and durable, resource-saving products can limit the increasing demand for goods year after year, and are therefore a decisive strategy for achieving climate targets and respecting planetary boundaries.

Sufficiency does not mean painful sacrifice. Rather, it is the ability or the offer to be able to do what can satisfy one's own needs. To support sufficiency in consumption and production, financial incentives are therefore needed, e. g. for online retail returns, durable and repairable products and transparency in the ecological footprint. However, such offers only work if they are socially accepted and meet corresponding demand. Policy makers can create the right conditions for this, for example by promoting sustainable products and sustainable ordering options in online retail.

With the approaches shown here, politics, but also the economy and each individual person can contribute, so that environmentally sustainable freight transport does not remain a vision of the German Environment Agency, but largely becomes a reality.

Bibliography

Allekotte, M; Bergk, F; Biemann, K; Deregowski, C; Knörr, W; Althaus, H-J; Sutter, D; Bergmann, T (2020): Ökologische Bewertung von Verkehrsarten. On behalf of UBA. Texts 156/2020. Dessau-Roßlau. Retrieved from: https://www.umweltbundesamt.de/publikationen/oekologische-bewertung-von-verkehrsarten

BDL – Bundesverband der Deutschen Luftverkehrswirtschaft (2023): Bedeutung der Luftfracht für den Industriestandort Deutschland – Analyse der Warenstruktur und Entwicklung des Luftfrachtmarktes in Deutschland. Retrieved from: https://www.bdl.aero/wp-content/uploads/2023/09/230912_Studie-Luftfracht-digital.pdf

Belz, H; Follmer, R; Hölscher, J; Stieß, I; Sunderer, G; Birzle-Harder, B (2022): Umweltbewusstsein in Deutschland 2020. Im Auftrag des Bundesministeriums für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz und des UBA. Berlin/Dessau-Roßlau. Retrieved from: https://www.umweltbundesamt.de/publikationen/umweltbewusstsein-in-deutschland-2020

Bernecker, T; Bramme, M; Fichert, F; Burg, R; Röhling, W (2021): Gesamtkonzept für eine umweltorientierte Organisation und Institutionalisierung einer verkehrsträgerübergreifenden Infrastrukturfinanzierung in Deutschland (GUIDE). On behalf of UBA. Texts 153/2021. Dessau-Roßlau. Retrieved from: https://www.umweltbundesamt.de/publikationen/gesamtkonzept-fuer-eine-umweltorientierte

Biemann, K; Bolte, V; Fehrenbach, H; Heidt, C; Spathelf, F; Kirsch, D; Bernsmann, A; Gade, A; Horstmann, K (2024a): Lokaler, nationaler und internationaler umweltschonender Güterverkehr – Transformationsdialog und UBA Forum mobil und nachhaltig. On behalf of UBA. Dessau-Roßlau.

Biemann, K; Dobers, K; Jarmer, J-P; Knörr, W (2024b): Treibhausgasemissionen im Transportsektor – Leitfaden zur ISO 14083. On behalf of UBA. Dessau-Roßlau. Retrieved from: https://www.umweltbundesamt.de/publikationen/treibhausgasemissionen-im-transportsektor

Biemann, K; Helms, H; Münter, D; Liebich, A; Pelzeter, J; Kämper, C; Müller, J (2024c): Analyse der Umweltbilanz von Kraftfahrzeugen mit alternativen Antrieben oder Kraftstoffen auf dem Weg zu einem treibhausgasneutralen Verkehr. On behalf of UBA. Texts 13/2024. Retrieved from: https://www.umweltbundesamt.de/publikationen/analyse-der-umweltbilanz-von-kraftfahrzeugen.

Blechschmidt, J; Reher, J; Thaller, C; Liedtke, G; Kotzagiorgis, S; Jödden, C; Sauer, A; Führer, M (2022): Handlungsoptionen für eine ökologische Gestaltung der Transportmittelwahl im Güterfernverkehr. On behalf of UBA. Texts 50/2022. Dessau-Roßlau. https://www.umweltbundesamt.de/publikationen/handlungsoptionen-fuer-eine-oekologische-gestaltung

BMDV – Bundesministerium für Verkehr und digitale Infrastruktur (2022a): Beschleunigungskommission Schiene – Abschlussbericht; Berlin. BMDV (Ed.). Retrieved from: https://bmdv.bund.de/SharedDocs/DE/Anlage/K/abschlussbericht-beschleunigungskommission-schiene.pdf

BMDV – Bundesministerium für Verkehr und digitale Infrastruktur (2022b): Studie zur Prüfung einer Förderung für kleinere und/oder konstruktiv optimierte Binnenschiffe. BMDV (Ed.). Retrieved from: https://bmdv.bund.de/SharedDocs/DE/Anlage/WS/studie-kleine-binnenschifflange-fassung.pdf?__blob=publicationFile

BMDV – Bundesministerium für Verkehr und digitale Infrastruktur (2023): Gleitende Langfrist-Verkehrsprognose 2021–2022, Ergebnisbericht zur Prognose 2022 „Absehbarer Weg“. Intraplan Consult GmbH, TTS TRIMODE Transport Solutions GmbH, BMDV (Ed.). Retrieved from https://bmdv.bund.de/SharedDocs/DE/Anlage/K/prognose-berichtgleitende-langfrist-verkehrsprognose.pdf?__blob=publicationFile

Boeing (2022): World Air Cargo Forecast 2022–2041. Retrieved from: https://www.boeing.com/content/dam/boeing/boeingdotcom/market/assets/downloads/Boeing_World_Air_Cargo_Forecast_2022.pdf.

Bopst, J; Herbener, R; Hölzer-Schopohl, O; Lindmaier J; Myck, T; Weiß, J (2019): Umweltschonender Luftverkehr. German Environment Agency. Dessau-Roßlau. Retrieved from: https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-11-06_texte-130-2019_umweltschonender_luftverkehr_0.pdf

BS-Drs. – Bürgerschaftsdrucksache 22/5939 (05.10.2021): Urbane Logistik Hamburg – Strategie für die Letzte Meile. Mitteilung des Senats an die Bürgerschaft der Freien und Hansestadt Hamburg. Retrieved from: https://www.buergerschaft-hh.de/parldok/dokument/77388/

Burger, A und Bretschneider, W (2021): Umweltschädliche Subventionen in Deutschland. German Environment Agency. Dessau-Roßlau. Retrieved from: https://www.umweltbundesamt.de/publikationen/umweltschaedliche-subventionen-in-deutschland-0

Campbell, M; Eyton, E; MacLean, G; Pons, A; Scarbrough, T; Vasileiadis, N; Wan, J; Endresen, Ø; Helgesen, H; Longva, T; Nakstat, I S; Sekkesæter; Ø; Skåre, O G; Arntzen Slotvik, D A (2023): Study on the readiness and availability of low-and zero-carbon technology and marine fuels. DNV und Ricardo. Published in MEPC 80/INF.10. Retrieved from: https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/FFT%20Project/MEPC80-INF.10%20-%20Summary%20report%20on%20the%20study%20.PDF

Comer, B und Carvalho, F (2023): IMO’s newly revised GHG strategy: what it means for shipping and the Paris Agreement. BLOG. International Council for Clean Transportation. Retrieved from: https://theicct.org/aligning-the-imos-greenhouse-gas-fuel-standard-with-its-ghg-strategy-and-the-paris-agreement-jan24/

Dahlmann, K; Matthes, S; Plohr, M; Niklaß, M; Scheelhaase, J D; Wozny, F (2023): Klimawirkung des Luftverkehrs. On behalf of UBA. Dessau-Roßlau. Retrieved from: https://www.umweltbundesamt.de/publikationen/klimawirkung-des-luftverkehr-shttps://www.umweltbundesamt.de/publikationen/klimawirkung-des-luftverkehrs

DG MARE – Directorate-General for Maritime Affairs and Fisheries (2023): News Article. BlueInvest supports ‘13 Mari’ innovation for fuel efficiency. Retrieved from: https://oceans-and-fisheries.ec.europa.eu/news/blueinvest-supports-13-mari-innovation-fuel-efficiency-2023-08-18_en.

Destatis – Statistisches Bundesamt (2024): Transport und Verkehr: Güterverkehr. As of 03/2024. Retrieved from: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Transport-Verkehr/Gueterverkehr/_inhalt.html

Faber J; Nelissen, D; Hon, G; Wang, H; Tsimplis, M (2012): Regulated Slow Steaming in Maritime Transport. CE Delft and ICCT. Delft. Retrieved from: https://cedelft.eu/wp-content/uploads/sites/2/2021/04/CE_Delft_7442_Regulated_Slow_Steaming_Maritime_Transport_DEF.pdf

Faber, J; Huigen, T; Nelissen, D (2017): Regulation speed: a short-term measure to reduce maritime GHG emissions. CE Delft. Delft. Retrieved from: https://cedelft.eu/publications/regulating-speed-a-short-term-measure-to-reduce-maritime-ghg-emissions/

Faber J; van Seters, D; Scholten, P (2023): Shipping GHG emissions 2030. CE Delft. Delft. Retrieved from: https://cedelft.eu/wp-content/uploads/sites/2/2023/06/CE_Delft_230208_Shipping_GHG_emissions_2030_Def.pdf

Graichen, J und Ludig, S (2024): Supply and demand in the ETS 2. On behalf of UBA. Texts 09/2024. Retrieved from: https://www.umweltbundesamt.de/publikationen/supply-demand-in-the-ets-2

Harthan, R O und Förster, H; et al. (2023): Projektionsbericht 2023 für Deutschland. On behalf of UBA. Climate Change 39/2023. Retrieved from: https://www.umweltbundesamt.de/publikationen/projektionsbericht-2023-fuer-deutschland.

IATA – International Air Transport Association (2023): IATA's Chart of the Week: Uneven recovery trends in air cargo traffic and capacity. Retrieved from: https://www.iata.org/en/iata-repository/publications/economic-reports/uneven-recovery-trends-in-air-cargo-traffic-and-capacity/

ICS – International Chamber of Shipping (o. J.): Shipping and world trade: driving prosperity. As of 01.08.2023. Retrieved from: https://www.ics-shipping.org/shipping-fact/shipping-and-world-trade-driving-prosperity/

IMO – International Maritime Organization (2017): International Code for Ships Operating in Polar Waters (Polar Code). Retrieved from: https://www.imo.org/en/ourwork/safety/pages/polar-code.aspx

IMO – International Maritime Organization (2020): Fourth IMO GHG Study. London. Retrieved from: https://www.imo.org/en/OurWork/Environment/Pages/Fourth-IMO-Greenhouse-Gas-Study-2020.aspx

ITF – International Transport Forum (2023): ITF Transport Outlook 2023. Retrieved from: https://doi.org/10.1787/b6cc9ad5-en

Lambrecht, M; Berschin, F; Böttger, C; Hecht, M; Weigand, W; Holzhey, M; Petersen, T; Thalhofer, C (2022): Empfehlungen für eine neue Bahnpolitik; Dessau-Roßlau. https://www.umweltbundesamt.de/dokument/empfehlungen-fuer-eine-neue-bahnpolitik

Leerkamp, B; Thiemermann, A; Schlott, M; Holthaus, T; Aichinger, W; Wittenbrink, P (2020): Liefern ohne Lasten. On behalf of Agora Verkehrswende. Berlin. Retrieved from: https://www.agora-verkehrswende.de/fileadmin/Projekte/2019/Staedtischer-Gueterverkehr/Agora-Verkehrswende_Liefern-ohne-Lasten.pdf

Lindstad, E; Polić, D; Rialland, A; Sndaas, I; Stokke T (2022): Decarbonizing bulk shipping combining ship design and alternative power. Ocean Engineering 266 (2022) 112798. Retrieved from: https://doi.org/10.1016/j.oceaneng.2022.112798

Lünenbürger, B; Purr, K; Schultz, K (2023): Ambitionierter Klimaschutz: Fallstricke und Bedingungen des Gelingens. German Environment Agency. Dessau-Roßlau. Retrieved from: https://www.umweltbundesamt.de/publikationen/ambitionierter-klimaschutz-fallstricke-bedingungen

Metzler, U (2013): Letzte-Meile-Logistik. In: Clausen, U; Geiger, C (ED.), Verkehrs- und Transportlogistik. 2. Aufl. Springer-Verlag Berlin, Heidelberg. P. 287–288.

Opitz, M; Rosentritt, S; Schwemmer, M; Allekotte, M; Dünnebeil, F; Jöhrens, J; Kämper C; Brauer, C; Köhler, J; Bernsmann, A; Kirsch, D (2024, im Erscheinen): Umwelt- und Klimaschutz in der Logistik. On behalf of UBA. Dessau-Roßlau.

Schäfer, P; Bierwirth, B; Väth, J; Uhing, K (2019): Analyse des Wirtschaftsverkehrs in der Innenstadt der Landeshauptstadt Wiesbaden. Frankfurt/Main. Retrieved from: https://www.frankfurt-university.de/fileadmin/standard/Hochschule/Fachbereich_1/FFin/Neue_Mobilitaet/Veroeffentlichungen/2019/Analyse_des_Wirtschaftsverkehrs_in_der_Innenstadt_der_Landeshauptstadt_Wiesbaden.pdf

Stiehm, S; Wardenburg, S; Gade, A; Kirsch, D; Zelasny, D; Dragon, D (2021): HANDBUCH: Mikro-Depots im interkommunalen Verbund. Teil 2 Vom Konzept zur Umsetzung. On behalf of IHK Mittlerer Niederrhein. Retrieved from: https://mittlerer-niederrhein.ihk.de/de/media/pdf/verkehr/mikro-depots-handbuch-teil-2.pdf

Stütz, S und Clausen, U (2022): Urbane Logistik. In Trojahn, S; Dittrich, I; Frindik, R (Ed.) Grundlagen der Logistik. Theorie und Praxis logistischer Systeme. Edition 5. Huss-Verlag. P. 413–448.

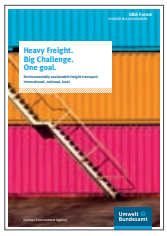
Tol, D; Frateur, T; Verbeek, M; Riemersma, I; Mulder, H (2022): Techno-economic uptake potential of zero-emission trucks in Europe. Agora Verkehrswende (Ed.). TNO. Retrieved from: https://www.agora-verkehrswende.de/fileadmin/Veranstaltungen/2022/Elektrische-Lkw/TNO_2022_R11862_Techno-economic_uptake_potential_of_zero-emission_trucks_in_Europe.pdf

UBA – Umweltbundesamt (2019): Wohin geht die Reise. Dessau-Roßlau. Retrieved from: https://www.umweltbundesamt.de/publikationen/wohin-geht-die-reise

UBA – Umweltbundesamt (2024): Daten und Rechenmodell Transport Emission Model „TREMOD", Version 6.51.

Veres-Homm, U; Wojtech, A; Richter, F; Becker, T; Lißner, S; Schmidt, W; Nehm, A; Grashoff, C (2019): Regional konsolidierte Gewerbeflächenentwicklung (RekonGent). Im Auftrag des Bundesministeriums für Umwelt, Naturschutz und nukleare Sicherheit. Erstellt im Rahmen des Aktionsprogramms Klimaschutz 2020. Texts 21/2019. Dessau-Roßlau. Retrieved from: https://www.umweltbundesamt.de/publikationen/regional-konsolidierte-gewerbeflaechenentwicklung

Veres-Homm, U; Cäsar, E; Nehm, A; Grashoff, C.; Richter, F; Becker, U; (2020): Regional konsolidierte Gewerbeflächenentwicklung. Leitfaden. Im Auftrag des Bundesministeriums für Umwelt, Naturschutz und nukleare Sicherheit. Erstellt im Rahmen des Aktionsprogramms Klimaschutz 2020. German Environment Agency (Ed.). Dessau-Roßlau. Retrieved from: https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/uba-fachbroschuere_regional-konsolidierte-entwicklung-gewerbeflaechen.pdf



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