MODULE 1 | 1.1

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Transforming Transport and Mobility to Achieve the Targets of the Paris Agreement and the Sustainable Development Goals

SLOCAT Partnership on Sustainable, Low Carbon Transport

Transport, Climate and Sustainability Global Status Report - 3rd edition

Key findings

Context and key challenges

- A just transition to equitable, healthy, green, and resilient transport and mobility systems is central to socio-economic prosperity for people and the planet. To achieve this, systemic transformations in transport and mobility – linked to wider socio-economic transformations – are needed.
- The past couple of years have changed the world. Most transport and mobility systems globally have become more vulnerable to systemic shocks, disproportionately affecting people living in vulnerable situations.
- The COVID-19 pandemic and other recent events have led to a greater understanding that decarbonised, resilient, and sustainable transport and mobility systems are an essential service that can increase the social return on investment, reduce the impacts of shocks and speed recovery.

Emission trends

- In November 2022, atmospheric concentrations of carbon dioxide (CO_2) reached their highest monthly mean ever recorded, at 417.8 parts per million. Estimates for the year indicate that CO_2 emissions hit a record high. Global fossil CO_2 emissions exceeded 37.6 gigatonnes in 2019, dropped to 35.6 gigatonnes in 2020, then rose to 37.5 gigatonnes in 2021.
- The Russian Federation's invasion of Ukraine, which began in February 2022, has had significant, long-lasting impacts on the climate, in addition to its wide-ranging humanitarian, social and economic impacts.
- During 2010-2019, the transport sector had the fastest growth in CO_2 emissions among combustion sectors globally, rising 2% annually on average and 18% overall. In 2020, due mainly to the impacts of the COVID-19 pandemic, transport CO_2 emissions fell 13%, dropping to 2012 levels. However, emissions nearly completely recovered in 2021 and likely resumed their upward trend in 2022.
- In 2021, high-income countries were responsible for 50.7% of transport CO_2 emissions, while low-income countries contributed less than 1%. Per capita transport CO_2 emissions have doubled in middle-income countries since 1980, while barely changing in low-income countries.
- During 2010-2021, Asia experienced the highest growth in transport CO_2 emissions among regions, at 36%, followed closely by Africa at 34%. In 2021, transport emissions continued to fall in Europe, North America and Oceania, due to the pandemic, but grew in Latin America and the Caribbean.
- In 2019, freight's share of transport emissions increased to 42%, while passenger transport's share fell to 58%. Road transport (passenger and freight) contributed 77% of global transport CO_2 emissions in 2019.
- Aviation (domestic and international) is responsible for around 4% of the human-induced climate change to date, despite contributing only 2.4% of annual global CO_2 emissions.
- In 2020, CO_2 emissions from international aviation fell 45%, returning to 1999 levels. They then increased 15% in 2021 but were still 37% below 2019 levels. An estimated 1% of the world's population is responsible for more than half of all CO_2 emissions from passenger air travel.
- International shipping produces more transport CO_2 emissions than the regions of Africa and Oceania combined. In 2020, CO_2 emissions from international shipping fell only 2.6%, and they recovered by 2021 to exceed pre-pandemic levels.

Transport emissions in a business-as-usual scenario

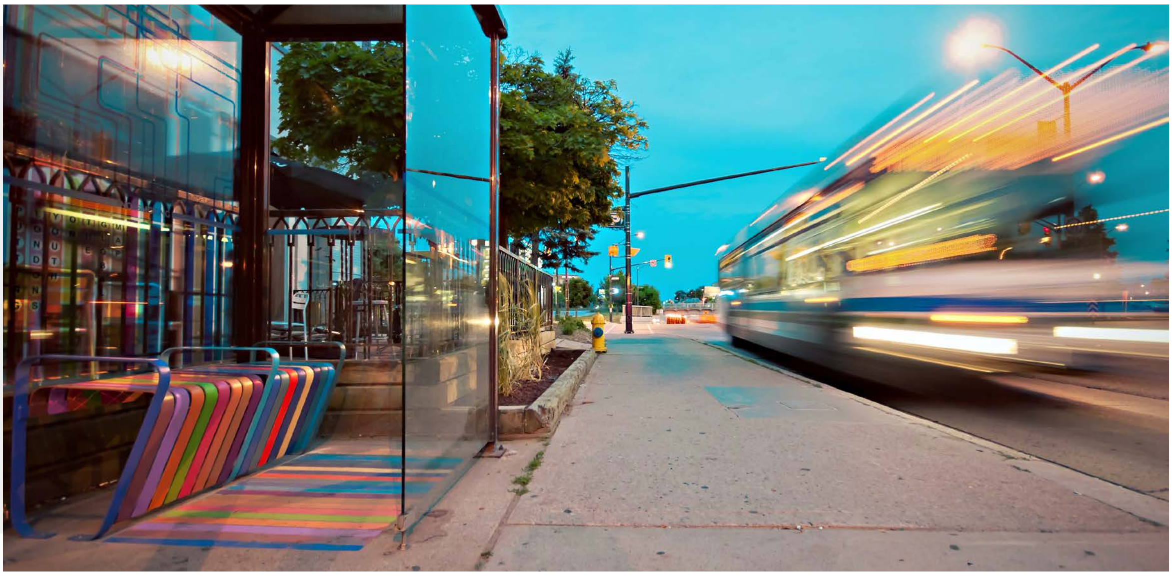
- Under business as usual, global transport activity is projected to nearly double by 2050, rising 1.8 times for passenger transport and 2.0 times for freight transport compared to 2019 levels. Without more ambitious policies, transport CO_2 emissions could grow 16-50% by 2050.
- Although countries have made progress in developing long-term visions for addressing climate change in transport, current policies and measures (focused heavily on electrification) are insufficient to put the sector on a decarbonisation pathway in line with the Paris Agreement goal of keeping global temperature rise below 1.5 degrees Celsius (°C).
- Climate action in the transport sector is still deeply insufficient, and countries' Nationally Determined Contributions (NDCs) under the Paris Agreement that feature transport lack the necessary ambition. Even if the current NDC targets for mitigating transport emissions are met, emissions in the sector will still grow.

Pathways for decarbonising transport

- Total economy-wide greenhouse gas emissions need to peak before 2025 to limit global warming to 1.5°C (with no or limited overshoot).
- Achieving low carbon transport pathways that limit global warming to 1.5°C will require a 59% reduction in transport-related CO_2 emissions by 2050, compared to 2020 levels.
- The maximum increase in passenger transport activity should be 50%, and in freight activity should be 20%, over the 2020-2050 period. Overall, the carbon intensity of the energy used in transport and of the fuels consumed needs to be halved by 2050.
- Fossil fuel dependence in road transport needs to decline drastically, from 95% in 2020 to 10% by 2050, with electricity becoming the dominant fuel in transport by the early 2040s.
- In addition to the transition of technologies ("Improve" measures), behavioural changes ("Avoid" and "Shift" measures) are needed to support transport decarbonisation, as emission reductions will not be achieved without critical transitions in transport modes. A 2021 study found that while "Improve" measures can contribute half of the required emission reductions in transport, "Avoid" and "Shift" actions are needed to meet the other half.
- Different regions need to contribute differently to the reduction of transport CO_2 emissions, with stronger reductions required in high-income countries than in low- and middle-income countries.

Transforming transport and mobility systems for more sustainable societies

- Achieving equitable, healthy, green, and resilient transport and mobility systems has both explicit and implicit implications for the success of the United Nations' 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs).
- Since the 2015 adoption of the landmark 2030 Agenda and the Paris Agreement, rising inequalities coupled with the COVID-19 pandemic and geopolitical conflicts have led to significant setbacks in the accomplishment of these agendas and their transport-related targets.
- In a world of interconnected challenges, the opportunity lies in finding solutions for systemic transformation that cut across transport, sustainability and climate action. Applying "Avoid-Shift-Improve" measures across passenger and freight transport through integrated, inter-modal and multi-dimensional approaches remains critical to deliver such cross-cutting solutions.
- Global fossil fuel subsidies have continued to rise, whereas strong financial support is lacking for sustainable, low carbon transport and mobility options. A fundamental reform of transport economics is urgently needed to deliver the necessary just transformations at the speed and scale required to achieve the targets of the Paris Agreement and the SDGs.



Overview

A just transition to equitable, healthy, green, and resilient transport and mobility systems is central to socio-economic prosperity for people and the planet. In addition to reducing greenhouse gas emissions from transport, such a transition will yield social, environmental and economic "multiplier effects" that go well beyond the scale of the necessary financial investment. This is why the transformation of transport and mobility systems has both explicit and implicit implications for the success of the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs), as well as of the Paris Agreement on climate change.

To achieve this, systemic transformations in transport and mobility – linked to wider socio-economic transformations – are needed. The reality is that most of the world's population does not have access to affordable, sustainable transport. Human-caused greenhouse gas emissions continue to rise, including from transport. Although the transport sector experienced the largest decline in emissions among combustion sectors in 2020, transport emissions recovered almost completely in 2021.[1] Without a structural transformation and more ambitious policies, transport emissions could increase 16-50% by 2050.[2]

The past couple of years have changed the world. Most transport and mobility systems globally have become more vulnerable to systemic shocks, disproportionately affecting people living in vulnerable situations. The COVID-19 pandemic has amplified longstanding, unresolved, and interconnected challenges and inequalities, and has greatly impacted emerging and low-income economies. The Russian Federation's invasion of Ukraine has made even more apparent the multi-pronged consequences of humanity's addiction to fossil fuels.

Wide-ranging challenges have put the already-elusive progress towards the SDGs and the Paris Agreement at increased risk. Such challenges include: fast-growing inequalities within and among countries; rocketing prices for energy and essential goods; crises around raw materials, semiconductors and global supply chains; escalating extreme weather events; low levels of climate financing for low- and middle-income countries despite pledges; and the threat of sovereign default in many of these countries.

The Intergovernmental Panel on Climate Change (IPCC) has revealed an important gap between countries' pledged emission reductions for 2030 (outlined in their Nationally Determined Contributions, or NDCs, submitted to the United Nations in 2021) and the models for the emission reduction pathways that are needed to keep global temperature rise within 2 degrees Celsius (°C).[3] Modelled pathways to 2030 that are consistent with the NDCs submitted as of November 2021 were estimated to result in median global warming of 2.8°C by 2100.[4]

Although countries have made progress in developing long-term climate visions, current transport policies and measures are insufficient to put transport on a decarbonisation pathway in line with the Paris Agreement's goal of keeping global warming within 1.5°C. According to the International Energy Agency (IEA), electric vehicles are the only transport-related area on track with scenarios for net zero greenhouse gas emissions. Although reducing fossil fuel dependence in transport is key, electrification of transport – even if powered with renewable energy – will not be enough. A shift to more energy-efficient transport modes, complemented with behavioural changes, is mandatory.

Moreover, the substantial threat that natural hazards pose to transport systems around the world is only expected to increase due to climate change. The cascading impacts of disruptions in other sectors, as well as macroeconomic and geopolitical shocks or societal events, also can disrupt transport networks, leading to monetary costs that far exceed the damage to physical assets alone. This reinforces the need for greater adaptation and resilience of transport systems, and for holistic notions of socio-economic resilience through transport. (*See Section 1.2 Transport Adaptation and Resilience.*)

Yet, the magnitude of the challenges should not obscure the opportunities that lie ahead. Transport systems have always created prospects for socio-economic development. Humanity's inexorable desire to explore, connect, exchange and learn requires the use of transport. **The pandemic and other recent events have led to a greater understanding that decarbonised, resilient, and sustainable transport and mobility systems are an essential service that can increase the social return on investment, reduce the impacts of shocks and speed recovery.** As countries have experienced, shifting to active modes of transport can deliver a host of resilience, social and environmental benefits. Pressures on the energy supply have reinvigorated discussions about energy efficiency and independence, as well as interest in reforming energy policies to transform transport.

The current circumstances confront us with the urgent need for profound and systemic socio-economic transformations – many of which directly impact the ability to transform transport systems over the coming decade. However, policy responses to today's transport challenges remain insufficient and are too slow. In a world of interconnected challenges, the opportunity lies in finding solutions for systemic transformation that cut across transport, sustainability and climate action. Applying the "Avoid-Shift-Improve" framework through integrated, inter-modal multi-dimensional solutions across passenger and freight transport remains critical to deliver on such cross-cutting solutions.

As global subsidies for fossil fuels have continued to rise, there remains a lack of financial support for sustainable, low carbon transport. A fundamental reform of transport economics is urgent to deliver the needed transformation at the speed and scale required to achieve the goals of the Paris Agreement and the SDGs.

Emission trends

Economy-wide emissions

In the previous (2021) edition of this report, it was reported that atmospheric concentrations of carbon dioxide (CO_2) had reached their highest level in more than 800,000 years (as of March 2019).[5] Since then, **global CO_2 levels have continued to rise, and in November 2022 they reached their highest monthly mean ever recorded, at 417.8 parts per million.**[6] The world has exceeded 1.2°C of global warming since the start of the industrial era, with each decade registering higher temperatures than the preceding one.[7] So far, in every year of the 21st century, the global average temperature has been at least 0.5°C above the average of 1951-1980, with 2016 and 2020 surpassing 1.0°C above the average (see Figure 1).[8]

Human-caused greenhouse gas emissions have risen in every major sector since 2010.[9] Efficiency improvements (measured as the energy intensity of gross domestic product, and carbon intensity) have been outweighed by absolute increases in emissions in all sectors. Starting from a 2020 baseline, the remaining "carbon budget" to keep global temperature rise within 1.5°C (at a 66% likelihood) is 400 gigatonnes of CO_2.[10] This means that, as of 2023

FIGURE 1. Global temperature change, 1880-2020

Source: See endnote 8 for this section.

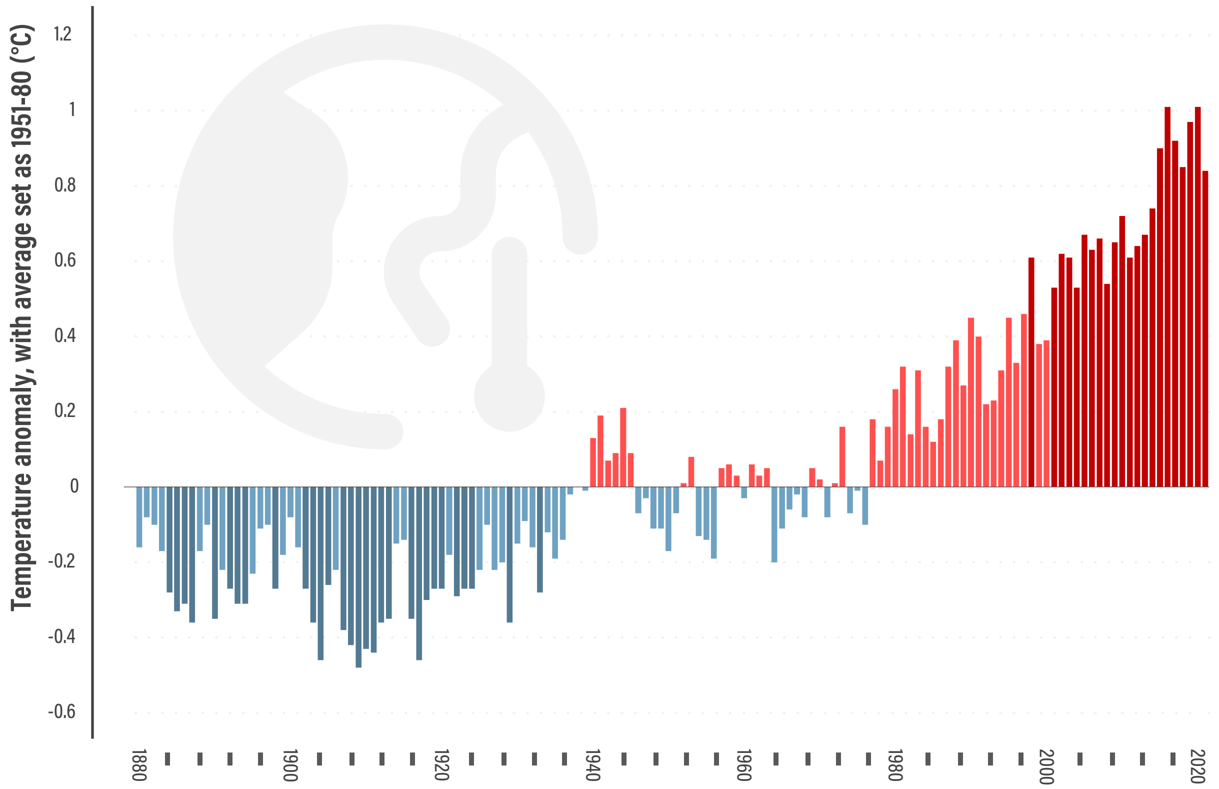
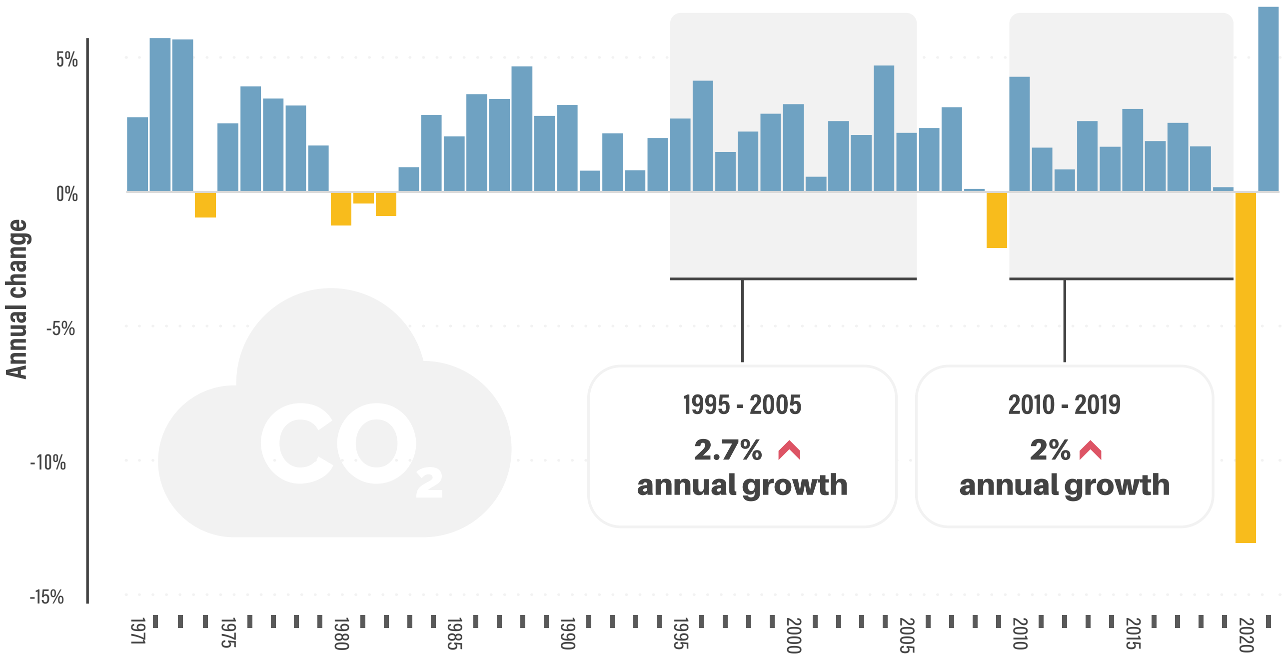


FIGURE 2. Annual change in transport CO_2 emissions (including international aviation and shipping), 1971-2021

Source: See endnote 21 for this section.



(assuming current emission rates), only nine years remain until humanity "uses up" its carbon budget to keep warming within 1.5°C by the end of this century.[11]

Global fossil CO_2 emissions exceeded 37.6 gigatonnes in 2019, dropped by 2 gigatonnes to reach 35.6 gigatonnes in 2020, then rose to 37.5 gigatonnes in 2021.[12] **Estimates for 2022 indicate that global CO_2 emissions hit a record high.**[13] Emissions from oil outpaced those from coal and gas, driven by rising travel demand as the sector recovered from pandemic-related declines in 2020 and 2021.[14]

The Russian Federation's invasion of Ukraine, which began in February 2022, has had significant, long-lasting impacts on the climate, in addition to its wide-ranging humanitarian, social and economic impacts.[15] In just the first seven months of the invasion, related activities resulted in the release of an estimated 100 million tonnes of CO_2-equivalent emissions, or as much as the entire country of the Netherlands emitted in this period.[16] The emissions are attributed to the movement of refugees (1.4%), warfare (9.1%), fires (24.4%), reconstruction of civilian infrastructure (50%) and pipeline leakages (15%).[17]

Global transport emissions

The average annual growth in greenhouse gas emissions slowed during 2010-2019 in most sectors globally except for transport, which has remained heavily dependent on fossil fuels.[18] In 2010, oil and petroleum products accounted for 97.4% of the energy use in transport, a share that fell slightly to 95.9% in 2020.[19] Transport emissions have continued to grow in both absolute and percentage terms (their share in total emissions). The slow progress in reducing emissions in "hard-to-abate" sub-sectors – such as aviation, long-distance road freight and shipping – has made it difficult to translate efficiency gains into absolute emission reductions.

During 2010-2019, the transport sector had the fastest growth in CO_2 emissions among combustion sectors globally (excluding "other sectors"), rising 2% annually on average and 18% overall.[20] However, this was slower than the 2.7% annual average growth during 1995-2005 (see Figure 2).[21] CO_2 emissions from transport, including international aviation and shipping, reached 8.2 gigatonnes in 2019, or 22% of total fossil CO_2 emissions.[22]

FIGURE 3. Changes in CO_2 emissions by sector, 2010-2021

Source: See endnote 24 for this section.

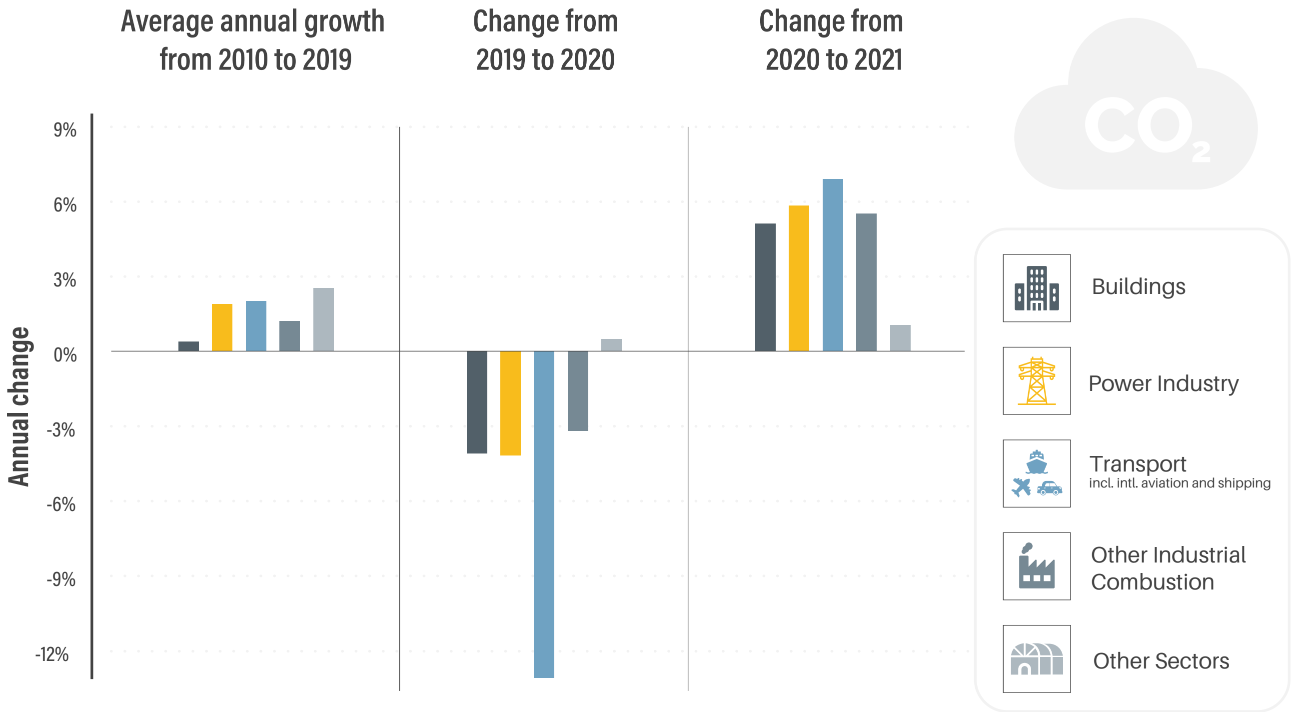
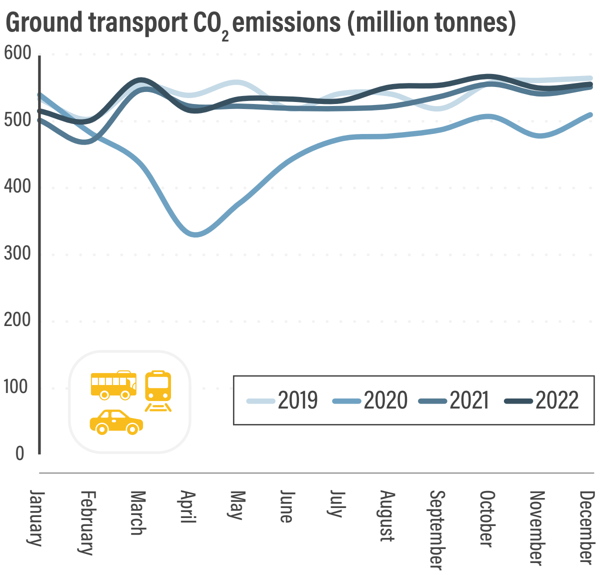


FIGURE 4. CO_2 emissions from ground transport and aviation, 2019-2022

Source: See endnote 25 for this section.



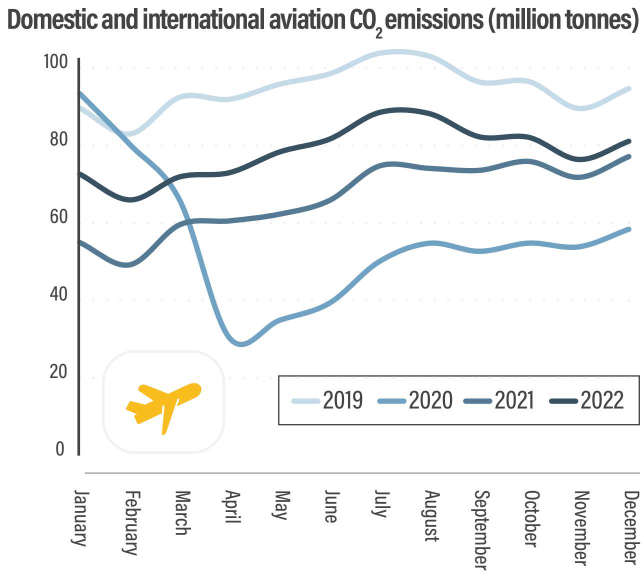
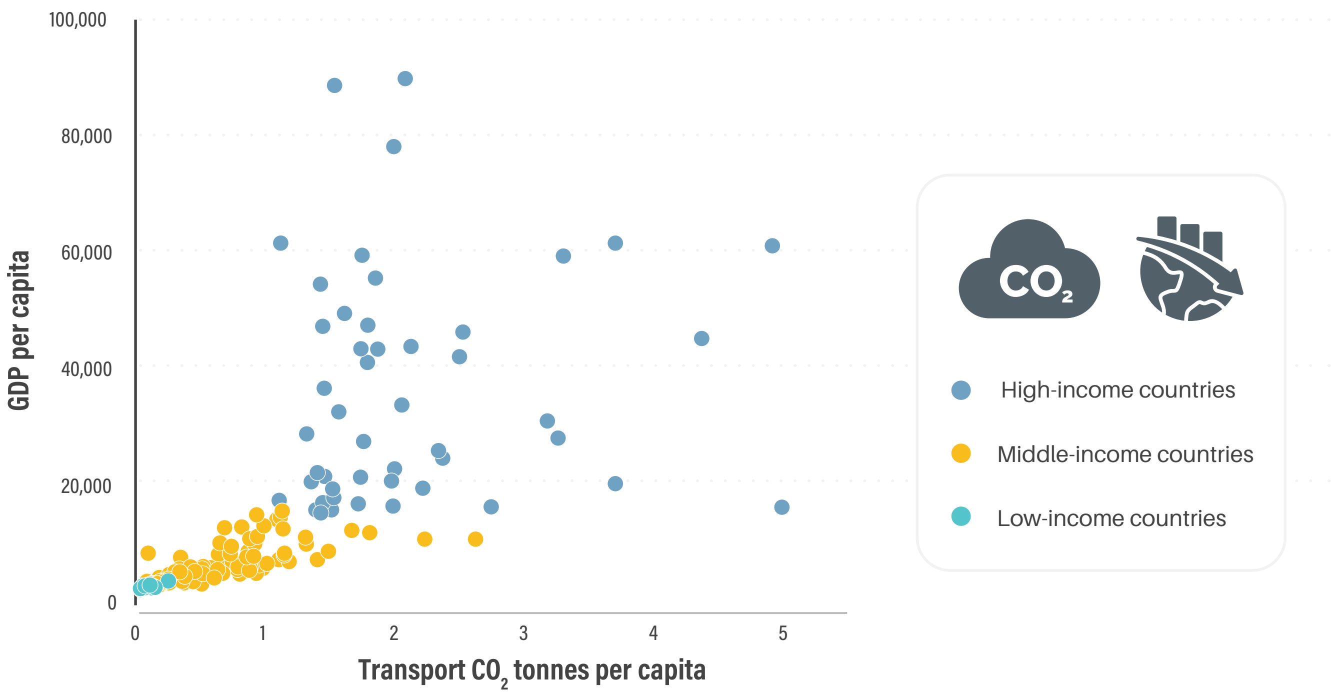


FIGURE 5. Per capita transport CO_2 emissions versus per capita gross domestic product, by country grouping, 2021

Source: See endnote 27 for this section.



In 2020, due mainly to the impacts of the COVID-19 pandemic, transport CO_2 emissions fell 13%, dropping to 2012 levels at 7.1 gigatonnes.[23] Transport experienced the greatest emission decline among combustion sectors, although it also showed the strongest rebound in 2021, to 7.6 gigatonnes of CO_2, or an average of 0.83 tonnes per capita (see Figure 3).[24] Early estimates for 2022 indicate that emissions from ground transport (road and rail) nearly recovered to pre-pandemic CO_2 levels, whereas aviation emissions (domestic and international) were still 20% below 2019 levels (see Figure 4).[25] **Overall, transport emissions nearly completely recovered in 2021 and likely resumed their upward trend in 2022.**[26]

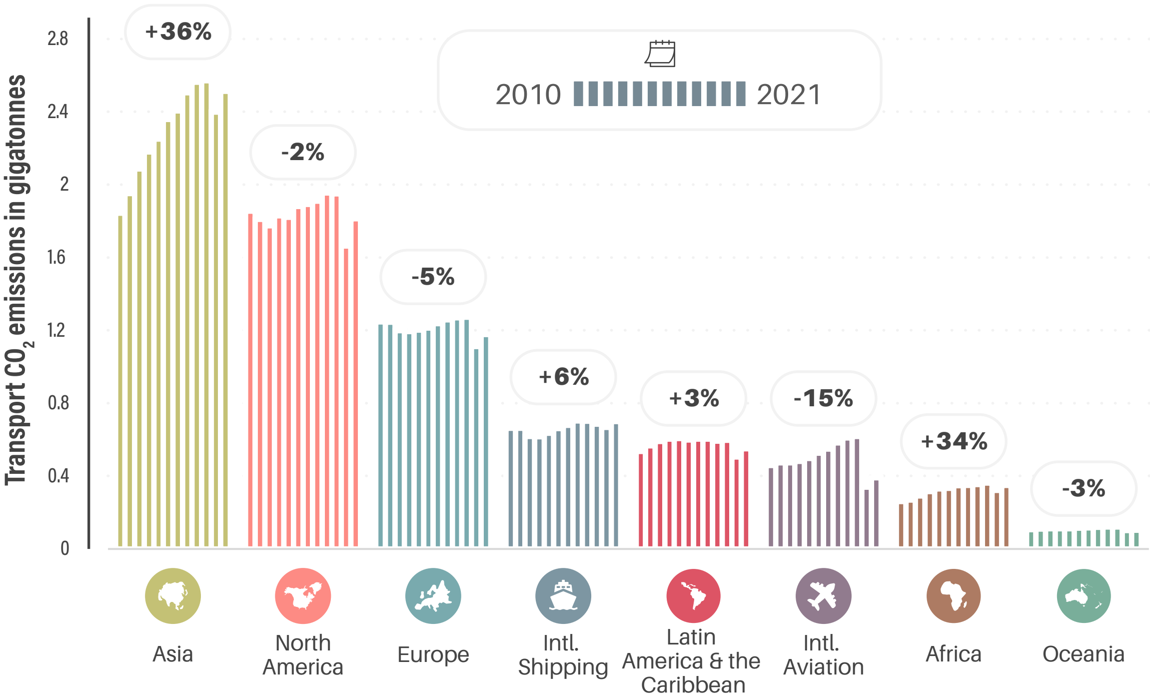
Emissions by income level

In 2021, high-income countries were responsible for 50.7% of transport CO_2 emissions, while low-income countries contributed less than 1% (see Figure 5).[27] Per capita transport CO_2 emissions totalled 2.8 tonnes in high-income countries, 0.53 tonnes in middle-income countries and 0.07 tonnes in low-income countries.[28] **Per capita transport CO_2 emissions have doubled in middle-income countries since 1980, while barely changing in low-income countries.**[29]

Examining income inequalities further, the top 1% of individual emitters globally contribute more than 1,000 times the CO_2 emissions of the bottom 1%, with the highest disparities being experienced in transport.[30] In North America, road transport makes up as much as one-quarter of the CO_2 emissions from the richest income group.[31] Globally, the gap in transport emissions between the 38 member countries of the Organisation for Economic Co-operation and Development (OECD) and the 160 non-OECD countries has nearly closed, with OECD countries contributing 51% of transport emissions in 2021.[32]

FIGURE 6. Transport CO_2 emissions, by region and for international shipping and aviation, 2010-2021

Source: See endnote 33 for this section.



Regional transport emissions

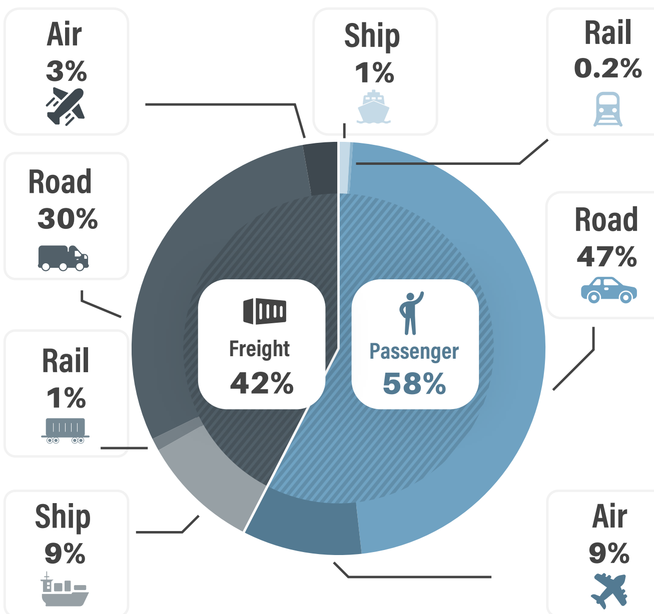
During 2010-2021, Asia experienced the highest growth in transport CO_2 emissions among regions, at 36%, followed closely by Africa at 34% (see Figure 6).[33] However, Africa's absolute emissions were the second lowest regionally, after Oceania's, in 2021.[34] **Transport emissions continued to fall 2-6% in Europe, North America, and Oceania in 2021 due to the pandemic, but grew 3% in Latin America and the Caribbean.**[35] (*See Sections 2.1 to 2.6 Regional Overviews.*)

Passenger and freight transport emissions

Emissions from freight transport comprise a growing share of transport emissions. In 2018, freight accounted for 40% of global transport CO_2 emissions, and passenger transport accounted for 60%.[36] **In 2019, freight's share of emissions increased to 42%, while passenger transport's share fell to 58%** (see Figure 7).[37] Freight was less affected by the impacts of the pandemic, with the CO_2 emissions from road freight in 2021 estimated to be only 1% below 2019 levels.[38] Freight transport emissions will likely continue to grow with rising demand for deliveries and transport of goods, as well as shifts to air freight.[39]

FIGURE 7. Transport CO_2 emissions by activity and mode, 2019

Source: See endnote 37 for this section.



Road transport (passenger and freight) contributed 77% of global transport CO_2 emissions in 2019 (see Figure 7).[40] Road transport was responsible for 82% of passenger transport emissions and 69% of freight transport emissions that year.[41] In 2020, urban travel contributed one-third of the total emissions from passenger transport.[42]

Aviation and shipping emissions

Aviation (domestic and international) is responsible for around 4% of the human-induced climate change to date, despite contributing only 2.4% of annual global CO_2 emissions.[43] This is because, in addition to the CO_2 emitted through the combustion of jet fuel, aircraft release water vapour that leads to the formation of cirrus clouds, trapping additional heat in the atmosphere.

During 2010-2019, CO_2 emissions from international aviation grew 3.6% annually on average.[44] In 2018, commercial aviation contributed the vast majority of global aviation emissions (an estimated 88%), followed by military operations (8%) and private flights (4%).[45]

In 2020, CO_2 emissions from international aviation fell 45%, returning to pre-millennium (1999) levels at 338 million tonnes.[46] **They then increased 15% in 2021, to 390 million tonnes, but were still 37% below 2019 levels.**[47] Domestic and international aviation accounted for more than 2% of global energy-related emissions in 2021, reflecting faster growth than road, rail or maritime transport emissions since 2000.[48]

An estimated 1% of the world's population is responsible for more than half of all CO_2 emissions from passenger air travel.[49] In 2018, only around 11% of the global population travelled by air, and only 2-4% took international flights.[50] The vast majority of the global population (90%) flies only one time a year or not at all, whereas 6% flies more than twice a year and 1% flies more than five times a year.[51] An analysis of private jets owned by US celebrities found that these jets emit 482 times more CO_2 emissions collectively than the average person emits in a year.[52]

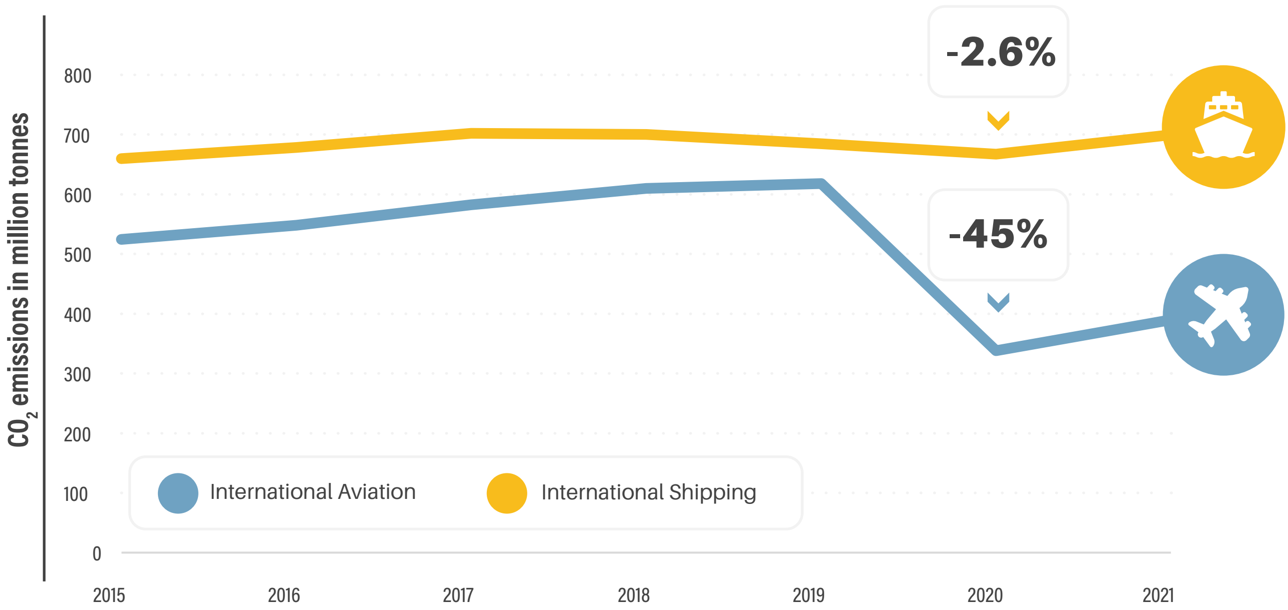
The Russian Federation's invasion of Ukraine has stalled the recovery of the airline industry and driven up jet fuel prices.[53] Moreover, closure of the Russian and Ukrainian airspaces has led to longer-distance rerouting of some flights between Asia and Europe or North America, likely driving up emissions.[54] In 2022, Finnair reported 40% longer flights to China, British Airways had a 20% longer diversion to China, and other European airlines added flight times of 15-40% for the same routes.[55] (*See Section 3.7 Aviation.*)

International shipping produces more transport CO_2 emissions than the regions of Africa and Oceania combined.[56] As much as 40% of maritime trade consists of transporting fossil fuels (including coal, oil and liquefied natural gas) from points of fuel production to points of fuel consumption.[57]

Emissions from international shipping decreased 2.2% in 2019 due to a stagnant economic year.[58] **In 2020, despite the pandemic's drastic impacts on global trade, international**

FIGURE 8. CO_2 emissions from international aviation and shipping, 2015-2021

Source: See endnote 59 for this section.



shipping CO_2 emissions fell only 2.6%, and they grew 5% in 2021 to nearly 700 million tonnes, returning to 2017 levels and exceeding pre-pandemic (2019) levels (see Figure 8).[59]

The Russian invasion of Ukraine added to the prevailing pandemic-related impacts on maritime transport (port congestion, disrupted trade, etc.), resulting in rising energy costs, higher food prices and the rerouting of supply chains (including port delays and pressure on storage).[60] It is yet unclear how this will affect shipping emissions. *(See Section 3.8 Shipping.)*

Transport emissions in a business-as-usual scenario

Under business as usual, transport activity is projected to nearly double by 2050, rising 1.8 times for passenger transport and 2.0 times for freight transport compared to 2019 levels.[61] Growing demand for freight and passenger services is expected across all transport modes, particularly in Africa and Asia.[62] The global passenger car fleet is projected to reach between 1.4 billion and 1.55 billion vehicles by 2050, up from nearly 1.2 billion vehicles in 2020.[63]

BOX 1. Nationally Determined Contributions and Long-Term Strategies under the Paris Agreement

To achieve the goals of the Paris Agreement, the transport sector must accelerate climate action immediately. Under the agreement, Parties to the UN Framework Convention on Climate Change are required to submit Nationally Determined Contributions, or frameworks and strategies outlining their specific targets and actions to reduce emissions. NDCs communicate planned mitigation and adaptation actions by countries, including plans to achieve resilient, low carbon transport systems. To complement the NDCs, the Paris Agreement invites (but does not require) countries to formulate and communicate Long-Term Strategies (or long-term low greenhouse gas emission development strategies) (LTS) to help establish low carbon trajectories to 2050. *(See Section 1.3.1 Transport in National Climate and Sustainability Strategies to Achieve the Targets of the Paris Agreement and SDGs.)*

Without more ambitious policies, transport CO_2 emissions could grow 16-50% by 2050.[64] As a result, CO_2 emissions from freight transport would be 22% higher in 2050 than in 2015.[65] Without proper interventions, international aviation CO_2 emissions would grow from 617 million tonnes in 2019 to more than 1,500 million tonnes by 2050.[66] International shipping CO_2 emissions would increase 40% over this period.[67] Under current policies, urban transport emissions would decrease slightly, by 5%.[68] In Asia, the largest regional emitter in 2019, transport CO_2 emissions could grow an estimated 1.5% annually to 2030, with the share of freight in Asia's transport emissions rising from 48% in 2000 to 57% in 2030.[69]

Current transport policies and measures are insufficient to put transport on a decarbonisation pathway in line with the 1.5°C target of the Paris Agreement. A 2022 assessment of 13 transport targets (such as public transport development, cycling infrastructure, sustainable aviation fuels, etc.) found that none of them were on track, with 2 of the targets (electric light-duty vehicle sales and electric bus sales) showing promise (although off track) and 7 of the targets heading in the right direction but well off track.[70] The indicator showing the least progress was kilometres travelled by passenger cars, with private passenger cars accounting for as much as 44% of the total kilometres travelled in 2020.[71]

The International Energy Agency considers electric vehicles to be the only transport-related area that is on track with global scenarios for net zero emissions.[72] In 2022, electric car sales surpassed 10 million to account for 13% of the global new car market, resulting in 25 million electric passenger cars on the world's roads.[73] For road freight, technical solutions are less mature and not yet readily available, but important developments are under way.[74]

Countries have made progress in developing long-term visions for addressing climate change in transport through their Nationally Determined Contributions (NDCs) and Long-Term Strategies (LTS) under the Paris Agreement (see Box 1)**, with a growing number of countries committing to net zero targets.**[75] **However, the current policies announced or implemented will still contribute to average global temperature rise of 2.8°C by 2100.**[76] Achieving unconditional and conditional targets set in NDCs would reduce this to 2.6°C and 2.4°C respectively.[77] By 2030, an emissions gap will remain of 15 gigatonnes of greenhouse gases for a 2°C pathway and 23 gigatonnes for a 1.5°C pathway, reflecting the difference between emissions under business as usual and those required to achieve the Paris Agreement goals.[78]

Even if all 23 countries with transport greenhouse gas mitigation targets in their NDCs (as of the end of 2022) meet them, emissions will still grow.[79] In many cases, targets for reducing transport CO_2 emissions are relative to business-as-usual scenarios that imply absolute growth in transport emissions. Therefore, the growth in emissions will only be slowed; the 23 countries with transport targets would slow the emission growth 50% below business as usual.[80] (*See Section 1.3.1 Transport in National Climate and Sustainability Strategies to Achieve the Targets of the Paris Agreement and SDGs.*)

Pathways for transport decarbonisation

Total economy-wide greenhouse gas emissions need to peak before 2025 to limit global warming to 1.5°C (with no or limited overshoot).[81] Because the remaining carbon budget is limited, rapid and deep mitigation of emissions is needed until 2050. Net zero CO_2 emissions are required by 2050 for pathways limiting warming to 1.5°C, and by the early 2070s for pathways limiting warming to 2°C.[82]

Achieving low carbon transport pathways that limit global warming to 1.5°C (with no or limited overshoot) will require a 59% reduction in transport-related CO_2 emissions by 2050, compared to 2020 levels.[83] The previous edition of this report in 2021 noted that to comply with the 1.5°C target, transport CO_2 emissions must be reduced to roughly 3 gigatonnes or less by 2050.[84] This would mean a decrease in per capita transport CO_2 emissions from 0.83 tonnes in 2021 to 0.20 tonnes in 2050.[85] Global reports released between 2021 and 2023 share similar CO_2 thresholds for 2050:

- International Transport Forum (ITF) Transport Outlook: 1.6 gigatonnes
- IEA net zero emission pathway: 0.68 gigatonnes
- IPCC Sixth Assessment Report scenarios for 1.5°C: between 0.7 and 2.9 gigatonnes
- International Renewable Energy Agency pathway: 0.4 gigatonnes.[86]

In the IEA's net zero emission scenario, a 90% drop in transport CO_2 emissions (below 2020 levels) is required by 2050, with transport modes contributing differently to these reductions (see Figure 9).[87]

Shipping and aviation will contribute less than other modes due to the differing levels of technology maturity and readiness of scalable solutions.[88] To achieve a transport low carbon pathway, several key milestones need to be met (see Table 1), including shifts to more energy-efficient modes, such as electric vehicles powered by renewable electricity

FIGURE 9. Global CO_2 transport emission trajectories by mode required to achieve IEA net zero emissions scenario

Source: See endnote 87 for this section.

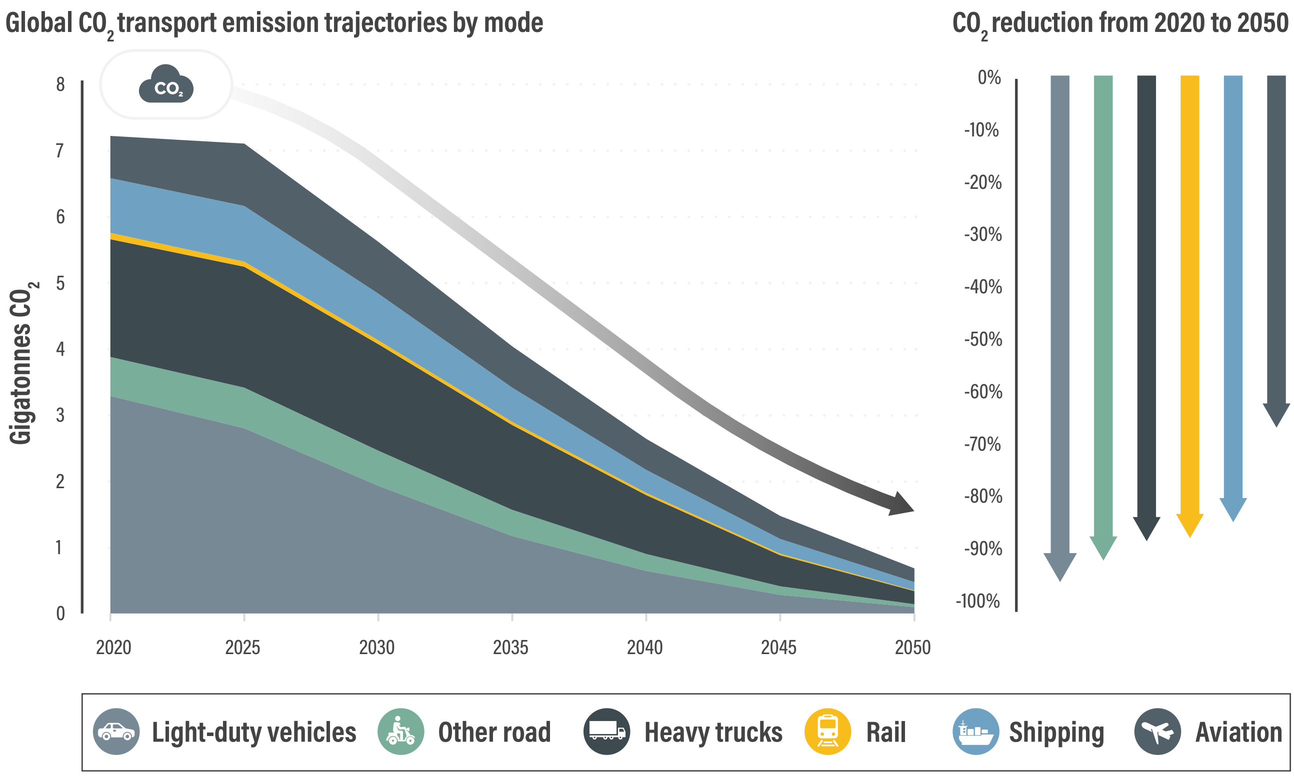


TABLE 1. Milestones towards net zero transport emissions, according to the IEA Net Zero Scenario

Source: See endnote 89 for this section.

2030	2035	2040	2045	2050
■ 65% of rail is electric ■ 60% of global car sales are electric ■ 13% of energy consumption is from advanced biofuels ■ 20% of aviation fuels are sustainable aviation fuels	■ 50% of heavy truck sales are electric ■ No new internal combustion engine cars and two-/three-wheelers are sold after 2035	■ 50% of fuels used in aviation are low emission ■ 60% of shipping is based on low-emission fuels	■ All heavy trucks sold are electric or fuel cell	■ Passenger rail nearly doubles its share of total transport activity, to 20% ■ Regional flights are shifted to high-speed rail where feasible

sources, as well as public transport.[89] A 2023 World Bank report highlights that electric buses and electric two- and three-wheelers can be cost-effective, feasible entry points for transitioning to electric mobility in low- and middle-income countries, while at the same time promoting inclusive mobility, improving air quality and enhancing energy security.[90]

Transport mitigation actions except biofuels have been identified as providing more benefits than costs over their lifetime.[91] Transport is the only energy end-use sector where this is the case for all identified actions.[92]

However, even in a low carbon pathway, transport will be the second highest emitter of CO_2 among energy end-use sectors (after industry) by 2032, and by 2050 transport will be the most-polluting sector due to long-distance air travel.[93] The reduction of direct and indirect emissions from transport will contribute only 16% of the total reductions required to reach net zero emissions economy-wide, less than the 28% reductions by buildings and 29% reductions by industry.[94]

Looking at transport demand, in a low carbon pathway, the maximum increase in passenger transport activity should be 50%, and in freight activity should be 20%, over the 2020-2050 period.[95] **Overall, the carbon intensity of the energy used in passenger and freight transport and of the fuels consumed needs to be halved by 2050.**[96] The CO_2 intensity for passenger and freight transport needs to be cut 45-51%, which corresponds to average annual energy efficiency improvements of 2.0-2.4%, to contribute to the Paris Agreement goals.[97] In parallel, the carbon intensity of fuels and other direct energy used needs to decrease 37-60% by 2050, compared to 2020 levels.[98]

For freight transport, the picture is less clear, although at least moderate reductions are needed. Freight transport emissions could be reduced 76% below 2020 levels by 2050 with policies that support higher operational efficiencies, optimised routing and asset sharing, freight consolidation, enhanced collaboration in supply chains, shift to railways or inland waterways, standardisation and low carbon solutions.[99] Ambitious actions on urban passenger transport can reduce emissions more than 80% below 2019 levels by 2050.[100]

Fossil fuel dependence in road transport needs to decline drastically, from 95% in 2020 to 10% by 2050, with electricity becoming the dominant fuel in transport by the early 2040s.[101] Advanced biofuels will play a role in the transition to a zero-emission vehicle fleet in the short to medium term.[102] Biofuels will represent a 15% blending share in oil by 2030, and thereafter be used mainly for aviation and shipping.[103]

Vehicle electrification will happen faster in high-income countries, with a delay of only around five years for low- and middle-income countries.[104] Electric cars will represent 20% of all cars globally by 2030 and 60% by 2040, resulting in 350 million electric cars on the roads by 2030.[105] Electric two- and three-wheelers will double from the current 300 million to 600 million by 2030 and surpass 1.2 billion by 2050.[106] For buses, 23% of all buses in operation will be electric by 2030 and 79% by 2050, when more than 50 million electric buses will be in operation.[107] Vehicle electrification will raise electricity demand. The electric vehicle fleet consumed around 100 terawatt-hours annually in 2022 and will add another 380 terawatt-hours of electricity demand by 2030.[108]

In addition to the transition of technologies ("Improve" measures), behavioural changes ("Avoid" and "Shift" measures) are needed to support transport decarbonisation, as emission reductions will not be achieved without critical shifts in transport modes. In urban areas, a shift of 20-50% of all car trips to public transport, ridesharing, walking and cycling is required.[109] Car ownership can be reduced 35% by providing adequate public transport services and ridesharing schemes.[110]

For **international aviation,** pathways towards net zero emissions require aviation CO_2 emissions to peak in 2025 at 950 million tonnes and then fall to 210 million tonnes by 2050.[111] Governments will need to reinforce a shift to high-speed rail and constrain long-distance business travel. The difficulty is that aviation fuels require a high energy density.[112]

In 2021, the International Air Transport Association, the trade association of the world's airlines, committed to achieve net zero emissions by 2050.[113] In 2022, the International Civil Aviation Organization (ICAO) adopted a similar long-term aspirational goal for international aviation.[114] The most ambitious scenario for achieving the ICAO goal aims to reduce aviation CO_2 emissions from 600 million tonnes in 2019 to 203 million tonnes by 2050.[115] Technological improvements would contribute 21% of the reductions, operational improvements 11% and fuels 55%.[116]

Critically, none of the current ICAO scenarios are able to reach zero CO_2 emissions by 2050.[117] Moreover, the ICAO's long-term goal does not cover non-CO_2 gases, which account for two-thirds of aviation's climate impacts, nor does it reflect any short- or medium-term targets or binding commitments by countries. This goal would result in global warming of between 1.6°C and 2.3°C.[118] It has been criticised for these reasons and for its failure to create incentives to take meaningful action towards the goal.[119]

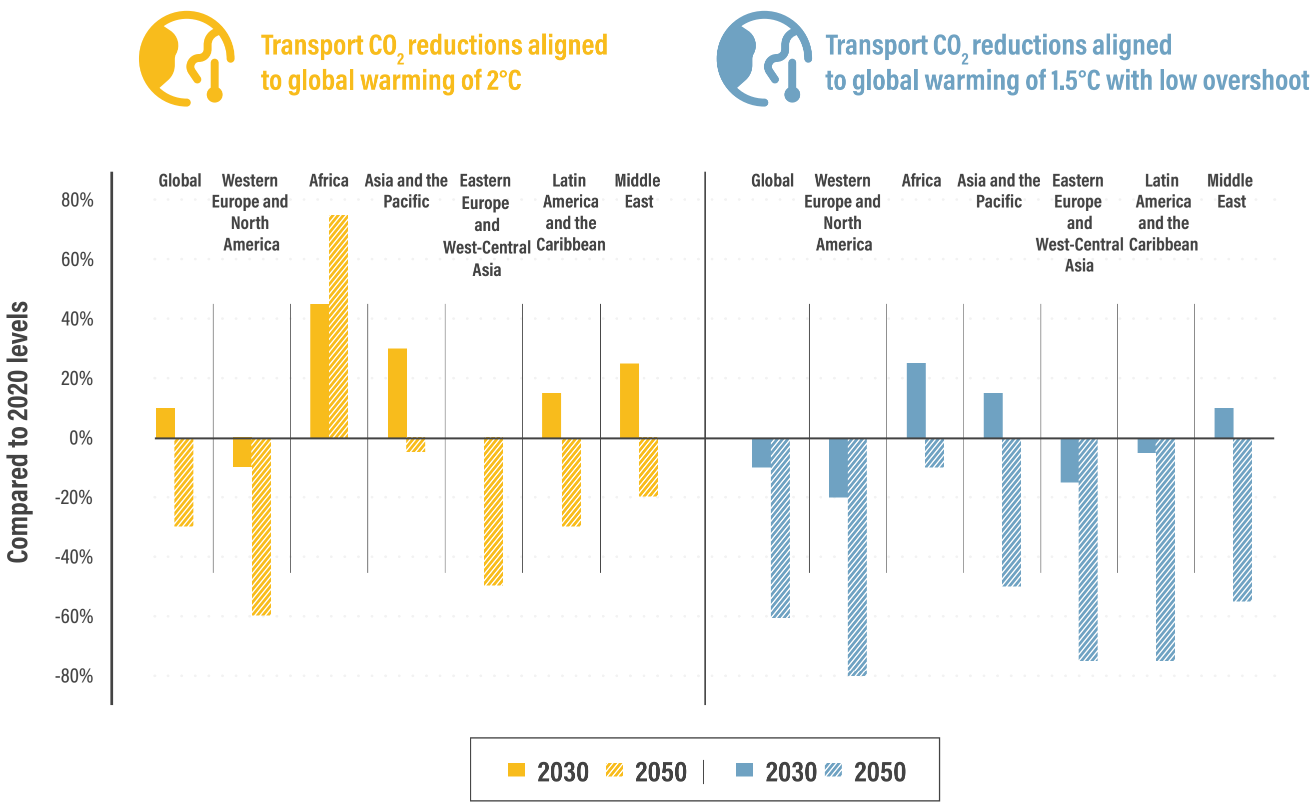
To contribute to achievement of the Paris Agreement targets, **international shipping** will need to become more efficient in the short term and to switch to low carbon fuels in the medium to long terms. This requires implementing approaches such as low steaming, wind-assistance technologies and low carbon fuels (ammonia, biofuels and hydrogen). Advanced biofuels can supply 20% of the shipping sector's energy consumption by 2050, while ammonia and hydrogen can cover 60%.[120]

In 2023, the International Maritime Organization (IMO) planned to release a revision of its 2018 Initial Greenhouse Gas Strategy.[121] The IMO's current targets are to reduce the carbon intensity of international shipping at least 40% by 2030 and 70% by 2050 and to reduce total annual greenhouse gas emissions from international shipping at least 50% by 2050 (compared to 2008 levels).[122] National governments have pressed the IMO to strengthen its regulations and targets, moving towards new interim goals for 2030 as well as zero emissions no later than 2050.[123]

Looking at regional transport decarbonisation pathways, different regions need to contribute differently to the reduction of transport CO_2 emissions (see Figure 10)**, with stronger reductions required in high-income countries than in low- and middle-income countries.**[124]

FIGURE 10. Regional transport decarbonisation pathways for 2030 and 2050, by scenario

Source: See endnote 124 for this section.



- **Western Europe and North America** need to reduce their transport CO_2 emissions drastically – at least 60% by 2050 to be aligned with the 2°C scenario and at least 80% by 2050 to be aligned with the 1.5°C scenario with low overshoot (compared with 2020 levels).[125]

- **Eastern Europe and West-Central Asia** will require extensive reductions of at least 50% below 2020 levels by 2050 for the 2°C scenario and 75% for the 1.5°C scenario with low overshoot.[126]

- **Asia and the Pacific** should reduce their transport CO_2 emissions 50% below 2020 levels by 2050 to be aligned with the 1.5°C scenario with low overshoot.[127]

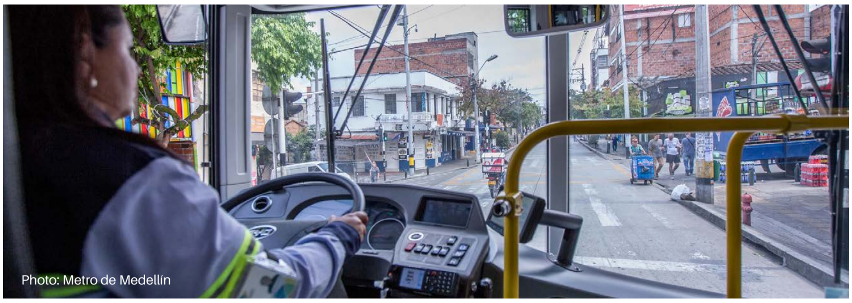


Photo: Metro de Medellín

- **Latin America and the Caribbean** will require transport CO_2 emission reductions of 30% below 2020 levels by 2050 for the 2°C scenario, and 75% for the 1.5°C scenario with low overshoot.[128]

- To be aligned with the 1.5°C scenario with low overshoot, countries in **Africa** can increase their transport CO_2 emissions around 20% by 2030, more than any other region, as long as emissions are at least 10% below 2020 levels by 2050.[129]

- Like Africa, the **Middle East** can increase its transport CO_2 emissions by 2030, but then should achieve significant reductions below 2020 levels – at least 20% by 2050 for the 2°C scenario and 55% for the 1.5°C scenario with low overshoot.[130]

Transforming transport and mobility systems for more sustainable societies

A just transition to equitable, healthy, green and resilient transport and mobility systems is central to socio-economic prosperity for the people and the planet.

To achieve equitable, healthy, green and resilient transport and mobility systems, a series of key transformations in land transport - linked to wider socio-economic transformations, are needed (see Figures 11 and 12).

The SLOCAT Wheel on Transport and the SDGs defines equitable, healthy, green and resilient transport and mobility systems based on the positive interactions with the UN 2030 Agenda and its SDGs (Figure 11). Under each theme, fundamental notions related to socio-economic and environmental systems on which sustainable, low carbon transport can affect positive change are highlighted. The analysis is complemented by a detailed list of targets across all SDGs for which action on sustainable, low carbon transport and mobility has the strongest impact.

FIGURE 11. SLOCAT Wheel on Transport and SDGs

FIGURE 12. SLOCAT transformations for sustainable, low carbon land transport

I Transport connects people and prosperous societies, and works for them as a system of multiple modes and services.

II Cities are compact and managed to maximise access to socio-economic opportunities, health and equity for all.

III Rural and interurban mobility services are low in emissions and focus on users' needs to improve access.

IV Walking, cycling and public transport get priority.

V Well-managed transport demand reduces kilometres and car use.

VI Electrification drives low carbon land transport and puts the most sustainable modes first.

VII Digital technologies increase access and transport efficiency.

VIII Pricing and fiscal policy guide market forces and, together with finance, channel public and private funds towards the most sustainable transport services.

IX Freight systems efficiently combine different low carbon modes, share capacities and rely on sustainable first and last mile delivery.

X Industry, trade and transport are shaped to support a circular economy, local value creation, and short and resilient logistic chains.

XI Transport systems and services are resilient in extreme weather events and other shocks.

Click on the icons to read the details of each of the key transformations

Achieving equitable, healthy, green, and resilient transport and mobility systems has both explicit and implicit implications for the success of the UN 2030 Agenda and its 17 Sustainable Development Goals. Areas where transport has the greatest positive impacts include: ending poverty (SDG 1); ending hunger (SDG 2); promoting healthy lifestyles and well-being (SDG 3); empowering women and girls (SDG 5); ensuring sustainable and modern energy (SDG 7); building resilient infrastructure (SDG 9); making cities sustainable (SDG 11) and taking action to combat climate change and its impacts (SDG 13) (see Box 2).[131]

However, the reality is that most of the world's population does not have access to affordable, sustainable transport. Efforts to transform transport systems to achieve the SDGs are faced with a variety of weaknesses and threats (see Table 2).[132]

Important synergies and trade-offs exist between transport actions to implement the SDGs and actions for transport decarbonisation, adaptation and resilience. For example, every mitigation option listed in Figure 13 has a relation to SDG 7 (affordable and clean energy) and SDG 8 (decent work and economic growth).[133] Electric light-duty vehicles have both synergies and trade-offs with several SDGs (SDG 3 on good health and well-being, SDG 7 on affordable and clean energy, SDG 10 on reduced inequality and SDG 12 on responsible consumption and production), as this option continues to support car dependency and has strong infrastructure investment needs. Biofuels have synergies and trade-offs with SDG 2 (zero hunger) and SDG 3 (good health and well-being), because biofuels take land away from food production.[134]

Overall, synergies exceed trade-offs. The trade-offs can be further minimised by emphasising activities, such as capacity building, finance, technology transfer and making considerations for governance, gender and equity and with participation of Indigenous peoples, local communities and vulnerable populations.[135]

Since the 2015 adoption of the landmark 2030 Agenda and the Paris Agreement, rising inequalities coupled with the COVID-19 pandemic and geopolitical conflicts have led to significant setbacks in the accomplishment of these agendas and their transport-related targets. The gap between carefully agreed words in global agreements and real actions is growing ever wider.

A report from the Sustainable Development Solutions Network revealed that the pandemic has inflicted "massive humanitarian costs".[136] Coupled with geopolitical conflicts such as the Russian invasion of Ukraine, this has hampered progress towards SDG 2 (zero hunger) and SDG 7 (affordable and clean energy) and "crowd[ed] out space for long-term thinking and investments".[137]

BOX 2. Voluntary National Reviews under the 2030 Agenda for Sustainable Development

The High-Level Political Forum on Sustainable Development is the UN's apex body on sustainable development. It has a central role in the follow-up and review of the 2030 Agenda and the SDGs at the global level. The 2030 Agenda encourages UN member states to "conduct regular and inclusive reviews of progress at the national and sub-national levels, which are country-led and country-driven". This mechanism, known as the Voluntary National Review (VNR), aims to facilitate the sharing of experiences among countries, including successes, challenges and lessons learned, with a view to accelerating the implementation of the 2030 Agenda.

The VNRs from 2016 to 2022 revealed consensus about transport being a key contributing factor for the implementation of the SDGs. In 2022, 21% of the VNRs mentioned specific transport targets, up from 20% in 2021, 18% in 2020 and 17% in 2019. A number of 2022 VNRs highlight sustainable transport actions in the context of COVID-19 pandemic recovery and the urgent transition from fossil fuels to renewable energy sources. However, most 2022 VNRs only describe the adverse impacts of the ongoing crises instead of presenting concrete policy measures. And when they do, the measures do not fully address the urgent systemic transformations necessary to enable equitable access to transport and mobility for all.

(*See Section 1.3.1 Transport in National Climate and Sustainability Strategies to Achieve the Targets of the Paris Agreement and SDGs.*)

TABLE 2. Weaknesses and threats facing efforts to transform transport systems to achieve the SDGs

Source: See endnote 132 for this section.

SDG 3 (healthy lifestyles and well-being)	The number of road deaths fell 2% annually on average during 2010-2019. In 2020, road fatalities dropped a remarkable 19.2%, although this was still well below the target of 50% reduction by 2020 set under the United Nations Decade of Action for Road Safety.
SDG 7 (ensuring sustainable and modern energy)	Fossil fuel subsidies nearly doubled in 2021, and the Russian invasion of Ukraine drove energy prices higher while eroding energy security and geopolitical stability.
SDG 9 (building resilient infrastructure) **SDG 11** (making cities sustainable)	In rapidly urbanising areas of low- and middle-income countries, access to transport and mobility services is inequitable. In Africa, the average person walks for 56 minutes per day, and 95% of roads fail to meet an acceptable level of service. Only 32% of the urban population in Africa and 38% in Asia has convenient access to public transport.
SDG 7 (ensuring sustainable and modern energy) **SDG 13** (combating climate change and its impacts)	Electric vehicles are the fastest growing sector of the clean energy industry, with sales of electric cars, vans, trucks, buses more than doubling in 2021 to reach a record 6.7 million units. However, most of the attention is focused on private electric vehicles, and many current narratives fail to consider realities in the Global South.
SDG 13 (combating climate change and its impacts)	In most countries and regions, transport CO_2 emissions are not trending in the right direction. During 2010-2019, transport showed the fastest growth in CO_2 emissions among combustion sectors globally (excluding "other sectors"), rising 2% annually on average and 18% overall. Several international bodies and frameworks exist to support greater resilience and adaptation in infrastructure, but few activities focus on transport. Transport resilience to climate change impacts is not receiving the attention required in country plans (*see Section 1.2 Transport Adaptation and Resilience*).

FIGURE 13. Synergies and trade-offs between transport mitigation options and the SDGs

Source: See endnote 133 for this section.

Mitigation options have synergies with many Sustainable Development Goals, but some options can also have trade-offs. The synergies and trade-offs vary dependent on context and scale.

Type of relations:
- + Synergies
- – Trade-offs
- • Both synergies and trade-offs

Blanks represent no assessment

Confidence level:
- High confidence
- Medium confidence
- Low confidence

Transport | **Relation with Sustainable Development Goals**

Transport	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17
Fuel efficiency – light-duty vehicle	+ (high)		+ (high)				+ (high)	+ (medium)			+ (high)			+ (medium)		
Electric light-duty vehicles			• (high)				• (high)	+ (low)	+ (high)	• (medium)	+ (high)	• (medium)				
Shift to public transport	+ (high)		+ (high)	+ (high)	+ (high)		+ (high)	+ (high)	• (high)	+ (high)	+ (high)	+ (high)				
Shift to bikes, e-bikes and non-motorised transport	+ (high)		• (medium)	+ (medium)	+ (medium)		+ (high)	+ (medium)	+ (high)	+ (medium)	+ (high)	+ (high)		+ (medium)		
Fuel efficiency – heavy-duty vehicle	+ (high)		+ (high)				+ (high)	+ (medium)						+ (medium)		
Fuel shift (including electricity) – heavy-duty vehicle			+ (medium)				+ (medium)	+ (low)	+ (high)			• (medium)				
Shipping efficiency, logistics optimisation, new fuels							+ (medium)	+ (low)	+ (high)							
Aviation – energy efficiency, new fuels							+ (medium)	+ (low)	+ (high)							
Biofuels		• (medium)	• (medium)				+ (high)	+ (low)	+ (high)		+ (medium)		• (high)	• (high)		

Similarly, the SDG Index revealed a slight decrease in the average national performance on SDG 1 (no poverty) and SDG 8 (decent work and economic growth) and noted particularly poor performance on SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), SDG 13 (climate action), SDG 14 (life below water) and SDG 15 (life on land).[138] The 2022 International Spillover Index showed that rich countries generate negative socio-economic and environmental spillovers, including through unsustainable trade, overconsumption, and inefficient supply chains, where the transport sector plays a critical role.[139]

In the past couple of years, most transport and mobility systems globally have become more vulnerable to systemic shocks, disproportionately affecting people living in vulnerable situations. Global shocks – such as the COVID-19 pandemic, extreme weather events, disrupted global value chains and conflicts – have revealed the fragility of transport systems and services**.**

On top of that, natural hazards present a substantial threat to transport systems around the world that is only expected to increase due to climate change, reinforcing the need for climate adaptation and resilience. Cascading impacts of disruptions to other sectors, as well as macroeconomic and geopolitical shocks or societal events, can also disrupt transport networks, and the monetary impacts of transport disruptions far exceed the damage to physical assets alone. This reinforces the need for increased adaptation and resilience of transport systems, as well as for holistic notions of socio-economic resilience through transport. (*See Section 1.2 Transport Adaptation and Resilience.*)

However, the magnitude of the challenges should not obscure the opportunities that lie ahead. The trends of recent years have contributed to greater understanding that decarbonised, resilient, and sustainable transport and mobility systems are an essential service that can increase the social return on investment, reduce impacts of shocks and speed recovery. Countries experienced that shifting to active modes of transport can deliver a host of resilience, social and environmental benefits. Pressures on energy supply have reinvigorated discussions on energy efficiency and independence, as well as interest in reforming energy policies to transform transport.

In a world of interconnected challenges, the opportunity lies in finding solutions for systemic transformation that cut across transport, sustainability and climate action. The current circumstances confront us with the urgent need for profound and systemic socio-economic transformations, many of which directly impact the ability to transform transport systems over the coming decade. The current policy responses to transport and mobility challenges remain insufficient and too slow.

Applying "Avoid-Shift-Improve" (A-S-I) measures across passenger and freight transport through integrated, inter-modal and multi-dimensional approaches remains critical to deliver such cross-cutting solutions for systemic transformation (see Figure 14). The A-S-I framework has been central to transport decarbonisation and sustainability efforts for more than a decade. It calls for transport and mobility systems that, while guaranteeing access to transport and mobility:

- *Avoid* unnecessary motorised trips based on proximity and accessibility;
- *Shift* to less carbon-intensive modes – that is, from private vehicles to public transport, shared mobility, walking and cycling, water-based freight, electrified road-rail freight, and cargo bikes for last-mile deliveries, among others; and
- *Improve* vehicle design, energy efficiency and clean energy sources for different types of freight and passenger vehicles.

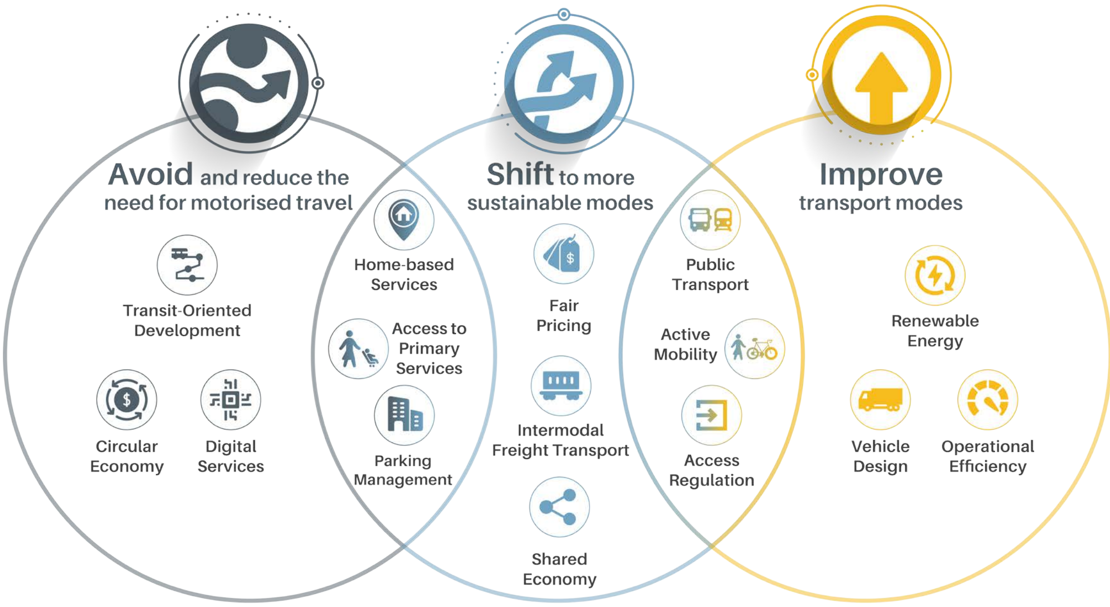
"Avoid" and "Shift" actions will contribute to half of the mitigation efforts needed by 2050. A 2021 study on demand-side mitigation actions found that, on average, emission reductions in land transport will be 10% through "Avoid" measures, 15% through "Shift" measures and 50% through "Improve" measures (compared to the 2050 baseline).[140] For aviation, "Avoid" measures (such as the implementation of carbon pricing) can lead to an average 40% reduction in emissions.[141] For shipping, on average, "Avoid" represents 47% of reductions, "Shift" 1% and "Improve" 40%.[142]

Shortly after the beginning of the Russian invasion of Ukraine in 2022, the IEA released a 10-point plan outlining how to cut oil use in advanced economies. The plan featured a detailed breakdown of how 2.9 million barrels of oil per day could be saved in the transport sector, revealing that quick measures related to "Avoid" can have a significant impact (see Figure 15).[143]

As a direct reaction to the Russian invasion of Ukraine, in March 2022 the European Commission presented the REPowerEU plan, with the aim of accelerating a shift to clean energy and reducing the region's reliance on Russian fossil fuels. Key steps relevant for transport are the transition to natural gas, liquefied natural gas and hydrogen; increased ambition to increase energy efficiency in transport; and a shift to more public transport, walking and cycling.[144]

Despite these and other steps, global fossil fuel subsidies have continued to rise, whereas strong financial support is lacking for sustainable, low carbon transport and mobility options. A fundamental reform of transport economics is urgently needed to deliver the necessary just transformations at the speed and scale required to achieve the targets of the Paris Agreement and the SDGs. (*See Section 5.1 Financing Sustainable Transport in Times of Limited Budgets.*)

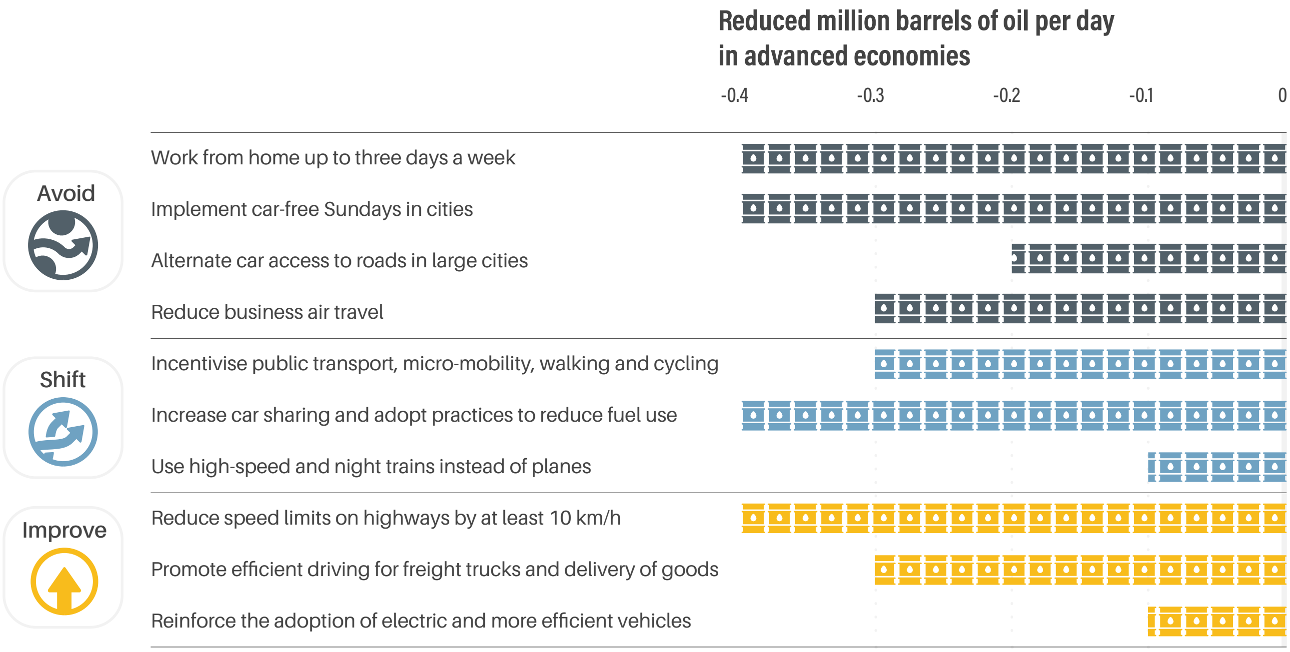
FIGURE 14. Avoid-Shift-Improve framework for transport



The A-S-I diagramme presents a non-exhaustive list of measures for illustrative purposes only.

FIGURE 15. Actions to reduce oil dependency in transport, through Avoid-Shift-Improve measures

Source: See endnote 143 for this section.



Endnotes

1.1
TRANSFORMING TRANSPORT AND MOBILITY TO ACHIEVE THE TARGETS OF THE PARIS AGREEMENT AND THE SUSTAINABLE DEVELOPMENT GOALS

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