DEEP DECARBONIZATION PATHWAYS

# CLIMATE AMBITION BEYOND EMISSION NUMBERS

## Taking stock of progress by looking inside countries and sectors

## TRANSPORT

*Emily Hosek, Mark Major and Yann Briand*

**SEPTEMBER 2021**

IDDRI

SLOCAT Partnership

***Citation***

*Emily Hosek, Mark Major and Yann Briand* (2021). *Climate ambition beyond emission numbers, Taking stock of progress by looking inside countries and sectors, Land use*. Deep Decarbonization Pathways (DDP) Initiative-IDDRI. Paris.

***Contact***

Henri Waisman, henri.waisman@iddri.org

The report is available online:
https://ddpinitiative.org/wp-content/pdf/DDP_AmbitionReport_LandUse.pdf

***Financial support from***

The report "Climate Ambition Beyond Emission Numbers" is made possible thanks to an array of projects supporting in-country capacity on climate mitigation research across the targeted geographies. It is also is financially supported by the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) as part of the "Climate Action After Paris" project (nr. 18_I_326) and the French government as part of the programme "investissements d'avenir" under the reference ANR-10- LABX-01.

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

Production: IDDRI.
Editing: Marta Torres Gunfaus, Anna Pérez Català, Lola Vallejo, Henri Waisman.
Layout: Ivan Pharabod.

# CLIMATE AMBITION BEYOND EMISSION NUMBERS

## Taking stock of progress by looking inside countries and sectors

*Emily Hosek and Mark Major (SLOCAT), Yann Briand (IDDRI)*



## Disclaimer

The results presented in this report are outputs of the academic research conducted under the DDP BIICS project as per the contractual agreement. The academic work does not in any way represent our considered opinion for climate negotiations and also does not reflect the official policy or position of any government.

# How is this document relevant to the Global Stocktake?

This document is part of a collective report that assesses the evolution of climate ambition in 26 countries and 3 hard-to-abate sectors through a granular and context-specific analysis of trends and progress of national and sectoral transformations.[1] This approach allows identifying what hinders and spurs action in countries and sectors, and understanding the conditions that can support enhanced ambition, which could be political, social, economic, governance.

These insights are directly relevant to four overarching functions of the Global Stocktake in support of its desired outcome, i.e. "to inform Parties in updating and enhancing, in a nationally determined manner, their actions and support in accordance with the provisions of the Paris Agreement, as well as enhancing international cooperation for climate action" (Article 14.3 of the Paris Agreement):

- Create the conditions for an open and constructive conversation on global cooperation (on e.g., technology, trade, finance, etc.), based on an in-depth understanding of the international enablers of enhanced country ambition.
- Organize a process for knowledge sharing and collective learning, based on concrete examples of actions already in place or being discussed, including best practices.
- Create space for open dialogues across different stakeholders to support better coordination of actions, based on a detailed understanding of the levers to be activated to enhance ambition in national and sectoral transitions
- Facilitate ownership by decision-makers of the climate challenge and the risks and opportunities of the low-emission and resilient transition, based on context-specific and granular analysis of barriers and enablers.

More specifically, the collective report in general – and this document in particular – can contribute to address some of the key guiding questions for the Global Stocktake[2], notably:

- What actions have been taken to increase the ability to adapt to the adverse impacts of climate change and foster the climate resilience of people, livelihoods, and ecosystem? To what extent have national adaptation plans and related efforts contributed to these actions (Decision 19/CMA.1, paragraph 36(c))?
- How adequate and effective are current adaptation efforts and support provided for adaptation (Article 7.14 (c) Paris Agreement)?

1 The full report « Climate ambition beyond emission numbers - Taking stock of progress by looking inside countries and sectors" can be found at: https://www.iddri.org/en/publications-and-events/report/climate-ambition-beyond-emission-numbers-taking-stock-progress

2 Draft Guiding Questions for the Technical Assessment of GST1 (version 20th October 2021), available at: https://unfccc.int/sites/default/files/resource/Draft%20GST1_TA%20Guiding%20Questions.pdf

- What are the barriers and challenges, including finance, technology development and transfer and capacity-building gaps, faced by developing countries?
- What is the collective progress made towards achieving the long-term vision on the importance of fully realizing technology development and transfer in order to improve resilience to climate change and to reduce greenhouse gas emissions referred in Article 10.1 of the Paris Agreement? What is the state of cooperative action on technology development and transfer?
- What progress been made on enhancing the capacity of developing country Parties to implement the Paris Agreement (Article 11.3 Paris Agreement)?
- To achieve the purpose and long-term goals of the Paris Agreement (mitigation, adaptation, and finance flows and means of implementation, as well as loss and damage, response measures), in the light of equity and the best available science, taking into account the contextual matters in the preambular paragraphs of the Paris Agreement:
  - What are the good practices, barriers and challenges for enhanced action?
  - What is needed to make finance flows consistent with a pathway towards low GHG emissions and climate-resilient development?
  - What are the needs of developing countries related to the ambitious implementation of the Paris Agreement?
- What is needed to enhance national level action and support, as well as to enhance international cooperation for climate action, including in the short term?
- What is the collective progress made by non-Party stakeholders, including indigenous peoples and local communities, to achieve the purpose and long-term goals of the Paris Agreement, and what are the impacts, good practices, potential opportunities, barriers and challenges (Decision 19/CMA.1, paras 36(g) and 37(i))?

# Foreword

Henri Waisman, Marta Torres Gunfaus, Anna Perez Catala, IDDRI.

Country commitments as reflected in enhanced Nationally Determined Contributions submitted to the UNFCCC are insufficient to put the world on track to achieve the collective objective of the Paris Agreement to hold temperature increase below 2 °C or 1.5 °C above pre-industrial levels. Furthermore, concrete policies and actions adopted by countries on the ground are often not sufficient to achieve these NDC targets. These conclusions highlight the need to increase ambition and to provide convincing evidence to accelerate action in the immediate and short term to give effect to this ambition. Yet these assessments are not sufficient to effectively guide the progressive increase of ambition, as organized by the cyclical process of the Paris Agreement.

## APPROACH

With this imperative in mind, this report adopts a different, complementary, perspective on climate ambition. It seeks to open the box of emission pathways, by considering multiple dimensions of the conditions that will make these pathways possible. These are technical, economic, political, social and governance considerations in need of attention to enable the required far-reaching and systemic transformation towards the long-term goal. On the one hand, the revision of emission targets needs to be directed by an assessment of how drivers of emissions should change to trigger transformation. On the other hand, converting emissions' targets into pertinent concrete implementation requires well-designed policy packages and investment plans that are also informed by a clear and detailed understanding of the starting point, priorities and interplays between the available levers of transformation.

This bottom-up assessment aims at contributing to the process of collective learning in support of the progressive increase of collective ambition, as inserted at the core of the Paris Agreement paradigm. Approaching climate ambition through the lens of underlying transformations calls for reflecting the heterogeneous nature and the multi-faceted aspects of transitions in different sectors and countries. This forces a move away from a purely global perspective to a more granular approach based on country- and sectoral perspectives. Thus, the report explores trends and progress on these transformations, as locally observed over the past years, notably since the Paris Agreement. This 'backwards looking' approach can help identify where developments are going in the right direction, where they should be accelerated and where major tensions remain that should be addressed as a priority to avoid undermining the transition. The picture of the state of the ambition discussion, firmly embedded in the country and sectoral realities, can provide means for reflection and action within the international climate community, particularly to inform focus areas for advancing the collective ambition agenda.

## STRUCTURE OF THE REPORT

This sectoral report highlights a selection of the main recent advances and remaining barriers for a far-reaching sectoral transformation towards, and where relevant beyond, net zero sectoral emissions. It examines relevant scientific and academic debates, as well as relevant sectoral- and climate policy influencing the climate- and environmental impact of the sector.

This report is part of a full series of 26 country chapters and three sectoral chapters. The full report includes a "summary for decision-makers" to present 10 cross-cutting messages emerging from the country and sector analysis, as a guide to the selection of priorities for collective action in the post-COP26 period.

.

You will find the full report at: https://www.iddri.org/en/publications-and-events/report/climate-ambition-beyond-emission-numbers-taking-stock-progress

## A narrative of climate ambition in key hard-to-abate sectors

# The transition to zero-emission transport

*This chapter has been written thanks to the support of the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).*

## CONTEXT

Transport is one of the most interconnected and cross-cutting development areas. It has profound impacts on all facets of sustainable development - social, environmental, and economic - with 'multiplier effects' that go well beyond the scale of development and financial investment. Enabling more sustainable, low carbon development pathways for transport and mobility is therefore necessary to achieving more sustainable development overall, including implementing the Sustainable Development Goals outlined in the 2030 Agenda for Sustainable Development. The COVID-19 pandemic has highlighted how critical transport is to a functioning society – from enabling access to jobs and essential services such as healthcare and education, to delivering food and other goods, and supporting overall equitable economic development.

For example, sustainable, low carbon transport increases equitable access to jobs and other socio-economic opportunities for people of all ages, genders, and abilities. It powers a just transition to green jobs in a circular economy and employs millions of people in urban and rural areas. It reduces air pollution from transport, improving air quality and providing significant benefits to public health. It reduces congestion, fuel imports and infrastructure costs. And sustainable, low carbon transport is essential to reach global carbon neutrality by mid-century compatible with the 1.5 degree celsius goal of the Paris Agreement.

Yet, while transport is essential to a thriving society, the current paradigm – in which transport is primarily powered by fossil fuels – is coming at a dire cost to people and our planet. The transport sector is now the fastest-growing source of emissions from fuel combustion in the world, and was the second largest source of $CO_2$ emissions after the power sector in 2019 (Crippa et al., 2020).

Annual emissions from transport grew continuously from 5.7 Gt $CO_2$ in 2000 to around 8 Gt $CO_2$ in 2018 (IEA, 2019), representing 24% of global energy-related emissions and 14% of global greenhouse gases emissions in 2018 (IEA, 2020).

Given the concerning global trends in the growth of transport $CO_2$ emissions, ambitious targets to decarbonise the sector and associated action strategies must be set as a matter of urgency. However, thus far, these ambitions have fallen short in countries' Nationally Determined Contributions (NDCs). As of May 2021, only 15% of updated NDC submissions (representing 7 countries and the EU-27, out of 54 total submissions) had set transport mitigation targets (GIZ and SLOCAT, 2021).

To keep global temperature rise well below 2°C and towards 1.5°C, economies must reach carbon neutrality as soon as possible (and by mid-century at the latest). According to the Intergovernmental Panel on Climate Change (IPCC), this will require "rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings)", "unprecedented in terms of scale" and "imply deep emissions reductions in all sectors" (IPCC, 2018). This will require the transport sector to approach absolute zero emissions by 2050, which cannot be achieved without structural and systemic transformations (Rogelj et al., 2018) which go beyond, for example, relying on carbon offsets to compensate for emissions. The sustainable decarbonization of the sector is possible, through a combination of scaling up existing solutions and taking a more comprehensive approach to reaching carbon neutrality.

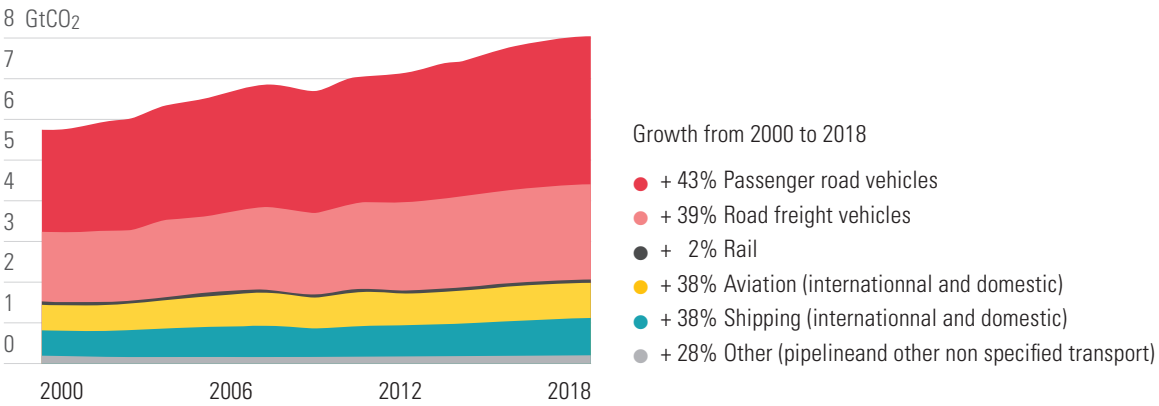
### *Chapter objectives*

The objective of this chapter is to contribute to a balanced assessment of current progress and challenges of approaching absolute zero transport emissions by 2050 to better understand what it will take for the sector to achieve the goals of the Paris Agreement. While the targets and plans set in countries' Nationally-Determined Contributions (NDCs) reveal current levels of ambition, they do not paint a complete picture of the global trends and developments which are both leading to and helping mitigate the transport sector's impact on the climate.

This chapter assesses some of these current trends to help identify the structural transformations which will be necessary to reach carbon neutrality. It starts by assessing the implementation of four key sectoral transformations before outlining a list of enabling conditions which are believed to be critical to the success of the overall sustainable decarbonization of the transport sector.

**Figure 1.** Global Transport $CO_2$ Emission Trends by Mode: 2000-2018.

Rising global demand for mobility and goods has led to a rapid growth in transport emissions from 2000-2018. For more information on the major trends and drivers leading to this growth, see:



## ASSESSING THE IMPLEMENTATION OF FOUR KEY SECTORAL TRANSFORMATIONS

Four key areas have been identified in which structural transformations are necessary to sustainably approach absolute zero transport emissions from the transport sector by 2050. Some of these transformations are already under way but will need to be greatly accelerated. Each area includes details on progress, remaining challenges, and proposed solutions. The four areas identified include:

1. **(Re)developing metropolitan areas to be less car-dependent**
2. **Revamping supply chains towards more local and circular production and consumption systems**
3. **Transitioning from fossil-fuel powered to zero-emission road vehicles**
4. **Employing a multifaceted approach to reduce emissions from aviation**

### 1. *(Re)developing metropolitan areas to be less car-dependent*

Cities and their metropolitan areas are currently facing numerous challenges caused by car-oriented mobility systems, such as air pollution, $CO_2$ emissions, congestion, and traffic crashes and current development patterns in cities are characterised by uncontrolled urban sprawl. These challenges have helped evoke a global movement in which cities are adapting the built environment and related social, transport and land-use policies to reduce travel distances and encourage the use of active and collective mobility for daily activities and deliveries. To achieve this, some cities are beginning to redesign and adapt their built environment to include multiple compact centres in which citizens are able to access most of their daily needs (housing, employment, shopping, health care, schools and leisure) within a limited radius, where walking, biking or public transport are the most efficient modes of transport in terms of time and cost (Ewing and Cervero, 2010). This transformation of urban environments has been gaining popularity through the "15-minute city" concept, based on residents' ability to meet the majority of their daily needs within a 15-minute (walk/cycle/public transport) trip from their home. The concept was first popularised by Mayor Anne Hidalgo of Paris and has been adapted and implemented in a number of cities around the world.

For example, several European cities, such as Barcelona, Spain, have incorporated superblock systems made up of neighbourhoods of several blocks, where traffic is restricted to major roads around the periphery of the superblock, opening up entire groups of streets to pedestrians and cyclists. These developments, which are cheap and reversible, are designed to create more open space for citizens to meet, talk and carry-out daily activities (C40 Cities Climate Leadership Group and C40 Knowledge Hub, 2020; Nanda, 2019). Paris, France is achieving 15-minute cities by turning over 70% of on-street car parking space to other uses, including bicycle paths on every street and bridge. The concept is also relevant for less dense cities, such as Houston, Texas, which has proposed a Walkable Places ordinance to create six distinct central business districts aligned with 15-minute city principles, with the aim of reducing commuter traffic across the city. Chengdu, China also has plans to move towards a more polycentric development approach by creating a smaller, distinct satellite city in its outskirts, where essential goods and services will be within a 15-minute walk of the pedestrianised center and connected to current urban centers via mass transport (C40 Cities Climate Leadership Group and C40 Knowledge Hub, 2020).

This shift in spatial organisation and development is particularly relevant for cities in the Global South, where today, more than half of urban residents must travel 60 minutes or more to access jobs and services (Venter et al., 2019). The Global South is also experiencing the fastest growth in urban development, so this shift in the conceptualisation of urban and transport planning can be helpful in avoiding car-oriented transport development patterns. It also does not cost more than car-oriented development, and can lead to long-term savings for cities, who will be able to avoid some of the costs associated with congestion, air pollution, and maintaining more extensive transport infrastructure.

The current COVID-19 pandemic has highlighted the often inequitable use of public space between

cars and pedestrians and cyclists. It has also offered opportunities for cities to rapidly implement short-term measures which are consistent with a long-term transformation towards less car-dependency. For example, in 2020, more than 194 cities across the world launched open streets programmes (prioritising pedestrians and cyclists over cars) and in Europe(Combs, 2020), cities quickly built 1,500 kilometres of bicycle lanes, allocating EUR 1.7 billion (USD 2 billion) towards the promotion of cycling (European Cyclists' Federation, 2020).

***Ongoing challenges and proposed solutions:***

*1.a. Urban and spatial planning, transport planning, economic development, and social services are not designed and implemented in unison.*

Transport planning traditionally focuses on the operation, provision, and management of transport infrastructure and services. However, transforming metropolitan areas to be less oriented around the use of cars requires an articulated and systemic long-term approach which includes socio-economic and land-use policies (*See Enabling condition 1 - Adopt a comprehensive and long-term strategy towards transport decarbonization which includes a focus on the underlying drivers of transport demand)*.

Land-use planning and local financial incentives and regulations play a key role in enabling the shift towards less car-oriented development. These policies and regulations can help enable a diversification of activities (residential, commercial, places of employment and leisure, etc.) to exist in the same spatial radius. It is important that these policies take into account the diverse needs of different households and businesses, developing measures to make these activities affordable and accessible for all. This requires targeted social and economic policies such as developing relevant housing regulations to avoid unwanted relocation of low-income households or local financial incentives to facilitate the development of specific jobs and economic activities (Braeuninger et al., 2012).

Sustainable Urban Mobility Plans (SUMPs) are a tool that can help support this more systematic and integrated planning approach. SUMPs are strategic plans designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. SUMPs build on existing planning practices and take due consideration of integration, participation, and evaluation principles. SUMPs are based on the following principles: plan for sustainable mobility in the "functional urban area"; cooperate across institutional boundaries; involve citizens and stakeholders; assess current and future performance; define a long-term vision and a clear implementation plan; develop all transport modes in an integrated manner; arrange for monitoring and evaluation; and assure quality.

MobiliseYourCity has developed a SUMP toolkit to provide support to cities in the various phases of SUMP development and implementation. The EU also has developed a set of guidelines for defining and implementing SUMPs (Changing Transport, 2021; Rupprecht Consult, 2019) which can complement transport emission reduction strategies in NDCs.

*1.b. Local competencies and resources are often insufficient to design and implement integrated planning.*

Cities must have both the financial and human capacity to plan in a more integrated manner, which requires higher levels of communication and coordination between different city departments. Many major cities and economic centers have this financial capacity and should reallocate funding and restructure workflows towards more integration between transport planning, urban planning, and economic development. However, for many less economically-developed cities, including many mid-sized cities, national governments play an important role in allocating sufficient financing and human and technical resources to local governments to support more sustainable long-term planning. In large part, these resources exist today, but are being used on more carbon-intensive and less sustainable city organisation and modes of transport (*See Enabling condition 3 - Redirect international and national financing away from fossil fuels and towards more sustainable, low carbon transport options*).

Training is also needed to build human resource capacity for this more integrated approach to planning mobility in metropolitan areas. Capacity development activities for those working on urban and transport planning and economic development will be required and can support the use of existing tools, such as SUMPs.

## 2. *Revamping supply chains towards more local and circular production and consumption ecosystems*

Freight accounts for an estimated 40% of emissions from transport (2018) (SLOCAT, 2021), and current projections show global freight demand tripling by 2050 (ITF, 2019). With technological solutions such as zero-emission vessels, aircraft, and long-distance trucks still far from maturity, the revamping of global supply chains to support net zero development objectives must receive greater attention. This means moving towards a more local and circular production and consumption system -- from long and complex to shorter and simpler supply chains; the development of a less resource-intensive sharing economy combined with a reduce, reuse, and recycle production strategy; and focusing shipment and stock management strategies on ensuring efficiency by aggregating deliveries (which at times may require a delay in shipment times). This structural and systemic reorganisation could reduce unnecessary transport distances, facilitate the use of intermodal systems and shorter-haul electric trucks and cargo bikes in cities, and contribute to the transition towards a carbon neutral freight and logistics sector.

Companies, especially shippers and freight forwarders, are on the front line of this transformation. Momentum is growing, as 2020 saw increasing corporate commitments to supply chain sustainability following growing public pressure for companies to demonstrate greater environmental stewardship and social responsibility (Bateman et al., 2021). For example, Unilever has set a target to achieve carbon neutrality by 2039, which includes reaching zero emissions from transport in their product supply chains (Unilever, 2021).

The COVID-19 pandemic has also reinforced the need to increase supply chain resiliency, highlighting a number of structural economic transformations, such as the relocation of essential manufacturing activities closer to markets, which could accelerate progress towards more long-term equitable and carbon neutral supply chains. However, in order for this transformation to occur at scale, it will need to involve the multitude of stakeholders who impact supply chains -- including producers, distributors, and consumers.

*Ongoing challenges and proposed solutions:*

### *2.a. Most companies do not have clear long-term and systematic decarbonization strategies which look beyond improving business-as-usual operations.*

Of the companies that have committed to carbon neutrality by mid-century, few have outlined the full set of structural and systemic transformations necessary to reach their vision. Most focus on improving the environmental impact of current business-as-usual (BAU) operations while necessary structural transformations, such as the reorganisation of supply chains, receive less attention. However, carbon neutrality by mid-century is currently not achievable by simply improving BAU operations and shifting towards more local and circular production and consumption is one of the key components of reducing global carbon emissions. This transformation will require profound changes in companies' business models, with significant impacts on their use of freight and logistics services.

Companies must therefore go beyond measuring and reporting $CO_2$ emissions, and focus on developing comprehensive and systematic strategies to reorient their business models towards carbon neutrality. Once companies have identified these strategies and pathways, it is important that they work closely with governments to ensure relevant policies and regulations are aligned with the changes necessary to reach carbon neutrality (*See Enabling condition 2 - Ensure the active engagement and effective cooperation of a broad range of stakeholders in transport decarbonization)*.

### *2.b. Most companies are not providing transparent information on the carbon footprints of their supply chains.*

The visibility and traceability of each component of a supply chain (from the procurement of raw materials, to where and how they are assembled, stocked, distributed, consumed, and disposed of) is essential for setting, implementing, and monitoring environmental and social goals. This information can help to identify the types of interventions and where along the supply chain they should be implemented in order to progress towards carbon neutrality.

Several companies have developed transparent and accessible tools to track the social and environmental impacts of the different components of their supply

chain. For example, for each of their products, Guerlain, a French cosmetics company, provides information on the location and environmental impact of the product's raw materials, packaging, production, transport, points of sale and recycling (Bee Respect: Guerlain, n.d.). These types of tools help respond to a growing demand from consumers and shareholders for more information on the environmental footprint of products to help inform their purchasing and investment decisions. Companies should therefore strive to provide this information for each step of their supply chains, and include the carbon footprint (and ideally, how it was calculated) on product labels. This is a critical first step to help identify concrete actions and build momentum towards achieving carbon neutral supply chains.

### *2.c. Production and transport costs do not reflect social and environmental externalities.*

Because the true environmental and social costs of the production and distribution of goods are not reflected in their prices at a global level, there has been a large outsourcing of production to countries with less stringent social and environmental regulations, leading to longer travel distances to distribute goods (with higher associated emissions), and making local markets less competitive.

Production costs are an important driver for site location and the reorganisation of supply chains, especially for labour-intensive industries (Comerford and Spano, 2010) with limited margins. As companies have outsourced their production to countries with looser emissions constraints to reduce costs, this has led to carbon leakages and higher emissions along the supply chain. In order to implement more sustainable global development and ensure producer and consumer responsibility over the social and environmental impact of goods, countries or regions should consider developing importation tariffs and mechanisms which take into account these externalities and simultaneously support stronger standards in producing countries. For example, in efforts to avoid carbon leakages and take into account the full climate impact of goods, the European Union is currently proposing a Carbon Border Adjustment Mechanism (CBAM). The CBAM could apply to imports of goods at the price of carbon determined by the EU Emission Trading System through the system of auctions. Importers would either be charged on the basis of a default value or based on the actual emissions embedded in the imports (European Commission, 2020).

The cost of transport is another key driver in the organisation and operation of supply chains. Today, the price of transport does not reflect all of the social and environmental costs associated with its use, such as costs related to air pollution, crashes, GHG emissions, etc. (*See Enabling condition 3*). This has led to issues such as the recent expediting of delivery times in many markets. Because the environmental costs associated with reducing shipment times are largely not reflected in prices, consumers have been demanding faster delivery times in recent years. In order to make deliveries more efficient from an environmental perspective, the true costs of expedited deliveries must be more properly reflected in the price of goods.

## 3. *Transitioning from fossil-fuel powered to zero-emission road vehicles*

The transport sector remains 97% powered by fossil fuels and is the least diversified of all energy end-use sectors (IEA, 2018). Road transport is the biggest driver of global transport emissions, and is the most common mode of transport, fulfilling 78% of total transport demand (IEA, 2016). Within road transport, passenger vehicles account for approximately 60% of all energy consumption (2017) (IEA, 2021). The challenges of decarbonising road transport vary significantly between countries and regions. For example, second-hand vehicles are often exported from the Global North to countries in Africa, Central Asia, and Latin America. These vehicles are usually less efficient, have lower emission standards and lead to higher levels of pollution(UNEP, 2020). In North America and Europe, buyers' preferences are moving towards larger and larger vehicles, namely sport utility vehicles (SUVs), which were the second largest source of new $CO_2$ emissions globally between 2010 and 2018, after the power industry (Cozzi and Pretropoulos, 2019).

The transition towards zero-emission road vehicles is an essential element in reaching carbon neutrality in the transport sector by mid-century, and electric technologies are seen as playing a major role in supporting this transition. Advances in battery technologies are currently reshaping the landscape, as plunging battery prices are making electric vehicles more affordable for many users, especially in the Global South. Lithium-ion battery pack prices have decreased 36% over the last five years, reaching 137$/kWh on average in 2020 with

projections for further decreases to 62$/kWh by 2030 (BloombergNEF, 2020). More-affordable batteries are facilitating the rapid scale-up of electric bicycles in Europe, North America, and South Asia, and of electric bus fleets in countries such as China, Chile, and Colombia. In addition, it is anticipated that internal combustion engine and battery-electric cars with approximately 250 kilometres of autonomy could reach price parity by 2025 (Lutsey and Nicholas, 2019).

These developments have helped lead to a global movement to end the production of internal combustion engines (ICEs). At least 19 countries, 11 cities and regions, and a number of automobile manufacturers have announced ICE phase-out commitments, with many targeting the year 2030 or 2035 (SLOCAT, 2020). For example, in November 2020, the government of the Canadian province of Québec announced plans to end the sale of new light-duty ICE vehicles by 2035 as part of its "2030 Plan for a Green Economy." The plan states that by 2035, 100% of new motor vehicle sales will be electric (or another form of zero-emission vehicle), and the sale of new fossil fuel-powered vehicles will be prohibited (Wappelhort, 2021). This year (2021), the automobile manufacturer General Motors also pledged to stop making gasoline-powered passenger cars, vans, and sport utility vehicles by 2035. The company has committed to investing USD 27 billion in electric vehicles and associated products between 2020 and 2025, including refurbishing factories and investing in battery production. As part of its plan, General Motors will manufacture roughly 30 different types of electric vehicles, and by 2025, 40% of the company's U.S. models will be battery-powered electric vehicles. It has also pledged to make its factories and other facilities carbon neutral by 2040 (Mufson, 2021).

On top of this technological progress, national fuel economy and emission standards for light- and heavy-duty vehicles have been increasing in numbers and ambition since 2015. For example, 30 countries have actively improved fuel economy-related policies since 2018, and nearly 80% of all light-duty vehicles sold as of 2017 are subject to such regulations (Yang and Bandivadekar, 2017; IEA, 2019). Local governments are also taking measures to restrict the use of cars in cities. Several cities have introduced low-emission zones (LEZs), which are specific areas within cities where access by some polluting vehicles is restricted or banned. LEZs have proven to reduce vehicle emissions and yield measurable benefits in air quality. For example, in November 2018, Madrid, Spain implemented a LEZ, and within a month of its launch it had led to a 38% decrease in nitrogen dioxide concentrations and a 14% decrease in $CO_2$ emissions (Nelsen, 2019). The LEZ has also helped to avoid an estimated 3,000 premature deaths annually (Porter, 2018). LEZs should be combined with relevant urban and land-use policies and offer a greater focus on shared fleets in order to avoid simply leading to cleaner congestion (See Transformation 1: Re–developing metropolitan areas to be less car-dependent).

***Ongoing challenges and proposed solutions:***

*3.a. Fuel economy and emission standards are still not ambitious enough to support the shift to zero-emission fleets.*

While fuel economy and emissions standards for road vehicles are steadily improving, they are still not sufficient to drive the level of innovation necessary to drastically decarbonise the sector. In many countries, standards only enable a reduction of fossil-fuel consumption per vehicle, which is often offset by an overall increase in demand. Improved national fuel economy and emission standards for new vehicles are critical, and these regulations should be better aligned at the global level. Other policies can also support this shift, such as limiting imports of polluting second-hand vehicles to the Global South. This is seen in recent commitments from 18 countries in Africa, Asia, and Latin America (UNEP, 2020). Zimbabwe, for example, has recently banned the importation of vehicles more than ten years old (Xinhua, 2021).

*3.b. The transition to zero-emission road vehicles could be delayed if governments don't provide targeted support to those most impacted by the transition.*

Strategies to transition to zero-emission fleets require the inclusion of all stakeholders central to the process, including the automobilie industry, service operators, and vehicle users. For example, depending on the relative importance and technological choices of the national automobile industry, the transition to electric vehicles could represent a direct threat to their current activities. National plans to support the de-

velopment of electric vehicles and their components should therefore be developed in close cooperation with the automobile industry to identify effective regulatory and financial incentives to shift production.

Another example concerns the transition of paratransit or "informal transport" fleets, including mini-buses and vans in rapidly urbanising cities throughout Africa, Asia and Latin America. Paratransit is a major global supplier of transport, but operations often rely on privately owned, second-hand vehicles for hire, which can result in highly-polluting and poorly maintained vehicles. Governments should work in cooperation with vehicle owners to establish adapted regulations and incentives to address the renewal of fleets while ensuring that these vital mobility services continue to be provided for a large segment of the global population (SLOCAT, 2021).

Finally, citizens need transport to access essential goods, activities, and services, and in many countries, low-income households rely on the use of older fossil-fuel powered private vehicles. Pricing reforms and incentives to support citizens to transition to lower-emission vehicles must therefore be developed carefully, with a deep understanding of how these policies will affect different socio-economic classes living in locations where collective transport may or may not be accessible. This will be essential to avoid mass social protests, such as those that occured in Ecuador in 2019, when the government attempted to quickly remove subsidies on fossil fuels (Monahan, 2019). One of the main challenges to pricing reform is ensuring that viable alternatives are in place which are financially accessible to citizens and companies. Countries must focus on developing these alternatives and structure stakeholder dialogues to identify the best solutions *(See Enabling condition 2 – Ensure the active engagement and effective cooperation of a broad range of stakeholders in transport decarbonization)*.

### *3.c. Technical challenges remain for the future of zero-emission long-distance trips.*

Battery-electric vehicles using the most commercialised lithium-ion battery technologies currently face limitations in terms of weight and battery capacity, and charging infrastructure is not yet well-developed in most countries. As a result, long-distance trips remain a technological challenge for electric vehicles.

Currently, the most popular alternatives to fossil fuel powered vehicles for long-distance trips are hybrid vehicles (gasoline and electric) or internal combustion engines powered by liquid or gaseous biofuels. However, biofuel development is not a viable or sustainable long-term solution for road transport, as it creates additional challenges and pressures on the agriculture, forestry, and land-use sectors, in direct competition with objectives to protect biodiversity and ensure global food security (Deprez et al., 2019). Other fuel technologies for long-distance use are under development in the first stages of commercialisation, such as hydrogen-powered vehicles. The development of hydrogen production and distribution from non-fossil fuel energy, however, remains a key challenge which requires additional research and investment.

In addition to these "fuel shift" solutions, reducing the length of both freight and passenger trips and incentivising modal shifts in long-distance travel towards shared and collective mobility and mass-freight will also be key to reaching zero emissions in the transport sector.

## *4. Employing a multifaceted approach to reduce emissions from aviation*

In the past decade, a surge in global demand for air travel and the rapid movement of goods has led to double-digit growth in aviation emissions (Topham, 2019). Aviation currently emits an estimated one 1 gigatonne of $CO_2$ emissions annually, and is one of the fastest-growing and most difficult transport modes to decarbonise from a technological standpoint (IEA, 2020). Implementation of effective strategies to reduce aviation emissions will therefore be critical to achieving zero emissions in the transport sector in the coming decades.

Some technological progress has been made to reduce energy consumption in aviation (IEA, 2020), but it has not been sufficient to counter an overall increase in demand. Challenges remain as advanced low-carbon fuel technologies are not yet mature enough to be developed at scale and alternative low-carbon engine technologies for aircraft are complex and virtually nonexistent.

At the international level, targets were adopted in 2009 by the International Air Transport Association

(IATA) - a trade association of the world's airlines, to mitigate $CO_2$ emissions from aviation including a cap on net $CO_2$ emissions from 2020 (carbon-neutral growth) and a reduction in net aviation $CO_2$ emissions of 50% by 2050, relative to 2005 levels (IATA, n.d.; A4A, 2021). In 2016, the International Civil Aviation Organization (ICAO), an intergovernmental organisation, adopted the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) to support this target. CORSIA is a market-based mechanism in which airlines will have to buy emissions reduction offsets from other sectors if they are not able to reduce their own emissions above 2020 levels (ICAO, 2021).

In addition, a number of major airlines have adopted new policies towards decarbonization in recent years for both national and international trips. For example, in early 2020, US airline Delta committed USD 1 billion over 10 years to mitigate emissions through strategies such as fleet renewal, biofuels and carbon offsets, although it later reduced its offset targets due to the impacts of the COVID-19 pandemic . Starting in November 2019, UK carrier easyJet pledged to purchase carbon offsets to equal the fuel used on all flights in its network (Kollmeyer, 2019). The same year, Lufthansa and Swiss International Air Lines began offering passengers the option to reduce their carbon footprints by selecting sustainable aviation fuel when booking flights (Holger, 2019).

However, it is important to note that there are significant risks associated with an over-reliance on carbon offsets in aviation decarbonization strategies. As carbon offsets do not amount to real emission reductions from aviation, relying on such mechanisms will not support reaching carbon neutrality by mid-century, as highlighted by many non-governmental organisations (Timperley, 2019). The potential environmental benefits of offsets are limited and will not be sufficient if each sector depends on them to achieve carbon neutrality.

Civil society movements have also emerged in recent years as a reaction to the failure of current measures to achieve meaningful emission reductions. For example, in Sweden, the "flygskam" (Swedish for "flight-shame") movement led to seven consecutive months of reductions in the number of air travel passengers, resulting in a 4% annual decreasein Swedish air travel in 2019 (Hervey-Bathurst, 2019).

***Ongoing challenges and proposed solutions:***

*4.a. International transport emissions are not accounted for in national emission reporting, resulting in insufficient ambition to decarbonise aviation.*

Although aviation emission reduction targets have been set at the international level, in order for meaningful progress to be made towards their achievement, governments must adopt the same (or more ambitious) targets at the national level. This can serve to both raise global ambition to decarbonise aviation and ensure that policies and actions are being implemented at the national level that are consistent with global targets.

To help ensure that national governments are adopting ambitious aviation decarbonization targets, international aviation emissions should be calculated as part of countries' national GHG inventories. For example, in 2019, the United Kingdom decided to include international aviation emissions in their whole-economy net-zero target for 2050, which will help support the implementation of international targets through direct national actions (Lord Deben, 2019).

*4.b. Current technical solutions are not sufficient to keep up with growing demand.*

The aviation sector faces several substantial technological barriers to decarbonization. First, the high initial investment costs for aircraft as well as their long life spans (roughly 40 years) pose significant challenges for fleet renewal. As electric mobility has limited potential in aviation except for light, small, and short-distance aircraft, most current developments and investments are related to biofuels, while existing engines continue to be powered by liquid fossil fuels. ICAO estimates that the need for liquid fuels could reach 400 million tonnes by 2050 (compared to 160 million tonnes in 2015), if demand stays on its current growth trajectory (ICAO, n.d.). In this scenario, sustainable aviation fuels (SAFs) will play an important role in meeting this demand for liquid fuels. SAFs should be made of advanced biofuels from agriculture and forestry residues, organic waste or non-food and non-feed energy crops to limit the impact on biodiversity and other essential land use for agriculture and human settlement (IRENA, 2016).

Growing demand for aviation will require unprecedented capital investments in advanced liquid biofuel

production infrastructure and could lead to consein-creases continue to incentivise and accelerate investments in this area.

It is important to note that the advancement of the use of SAFs can reduce but not eliminate airline emissions. Indeed, beyond the emissions emitted from SAF production, flying contributes to the radiative forcing of climate, and could therefore have a two to three times higher climate impact (Lee et al., 2009; Lee et al., 2021; Bannon, 2018; Ritchie, 2020).

### *4.c. Current incentives to manage aviation demand and support the shift towards alternative transport modes have not been sufficiently developed and integrated.*

Managing demand for aviation is a crucial and under-addressed topic. One way to help manage demand is by better integrating the socio-environmental costs of aviation into travel prices *(See Enabling condition 3)*. The challenge is to integrate these prices in a fair way which does not result in increasing inequalities.

Europe is leading the way in raising airline taxes to help manage demand. The EU's Green Deal, for example, creates a set of coordinated airline taxes that signal clear incentives to avoid unequal application of tax policies across national and corporate borders and in 2020, a consultation was launched to test the waters for a pan-European tax on jet fuel (European Commission, 2019; European Commission, 2002). Other pricing reforms have been taken in recent years. For example, in 2020, France introduced an aviation "eco tax" ranging from EUR 1.50-18 (USD 1.8-22) per ticket (FCC Aviation, 2019; Brandler, 2021). The parliament of Switzerland also approved a tax in 2020 on all departing flights, ranging from USD 33-133, depending on the class of travel and distance of the flight (Le News, 2020).

In addition, the development of transport alternatives for continental trips such as high-speed rail is necessary to shift demand and reduce emissions from aviation. Collaborative planning between aviation and rail systems (including high-speed and overnight rail services) can help drive the use of these more energy-efficient modes for shorter trips and help meet greenhouse gas reduction targets. For example, in 2020, Sweden proposed launching sleeper train services to Belgium and Germany to reduce dependence on aviation and minimise travel impacts (Duxbury, 2020), and in France, revenues from the country's eco-tax on flights will be spent on boosting domestic train services. Additional investments in rail infrastructure coupled with incentives to shift demand from short- and medium-haul aviation activity are still widely needed.

## ENABLING CONDITIONS FOR THE TRANSFORMATION TOWARDS ZERO-EMISSION TRANSPORT

To enable the comprehensive and structural changes required to transform the transport sector and put it on a pathway towards carbon neutrality, the overall approach to decarbonization will need to be more focused on understanding and influencing transport demand, finding effective ways to involve the broad range of stakeholders who influence travel behaviour and policies, and redirecting financing away from fossil fuels and towards more sustainable, low carbon options.

### *Enabling condition 1 - Adopt a comprehensive and long-term strategy towards transport decarbonization which includes a focus on the underlying drivers of transport demand*

Transport decarbonization measures are often categorised into three different types: *avoid* (avoiding and reducing unnecessary transport demand), *shift* (shifting to less carbon-intensive transport modes) and *improve* (improving vehicle and fuel efficiency) (GIZ, 2019).

The current discourse on transport decarbonization focuses largely on *improve* measures, such as improving fuel economy and electrifying vehicles. This is apparent in the transport content of countries' Nationally Determined Contributions (NDCs). Most countries focus strongly on *improve* measures (52% of all measures), with *shift* and *avoid* measures account for 38% and 10% of all transport measures in NDCs (SLOCAT, 2020). While *improve* measures are an important component of transport decarbonization, they are simply not sufficient to reach the goals of the Paris Agreement or 2030 Agenda for Sustainable Development. This reveals that countries need to develop more comprehensive and long-term strategies (LTS) by 2050 to ensure that short-term actions and NDC objectives are consistent with reaching carbon neutrality and socio-economic development goals by mid-century.

Such approaches will therefore facilitate the integration of more long-term and systemic *avoid* and *shift* measures, which could contribute to 40-60% reductions in total transport emissions (Bergk et al., 2016). To make more progress on *avoid* and *shift* measures, it is important for policymakers to understand that the demand for transport is a derived demand, meaning that people and companies use transport in order to access other goods, services or markets - and don't use transport services for their own sake. This understanding highlights the importance of a number of decisions and underlying determinants that influence transport demand, but which are not often considered within the scope of transport planning. These include supply chain and service models, socio-economic characteristics of households, urban and rural land use and development patterns, internet access, pricing and other fiscal decisions for example, that can all have a substantial impact on transport demand and behaviour, and consequently on modal choices and technology uptake (Briand et al., 2018). For example, if a government is trying to implement a modal *shift* from private car use to public transport, the strategy should not rely only on infrastructure and service development. It should also integrate targeted actions aimed towards specific household categories, distinguished by income or location, and specific types of trips, distinguished by purpose, distance or time.

To accelerate progress, transport decarbonization strategies should therefore adopt comprehensive and long-term perspectives to go beyond *improve* measures and focus more on *avoid* and *shift* measures which consider on the above determinants of travel demand and behavior (Briand and Waisman, 2019).

### *Enabling condition 2 – Ensure the active engagement and effective cooperation of a broad range of stakeholders in transport decarbonization*

First, there is a clear need to reinforce the high-level political engagement of governments towards transport decarbonization. The design and implementation of the comprehensive policy packages needed for transport deep decarbonization requires strengthening the coordination between environment and transport ministries, which still often work in silos at the national level. Also, the enhancement of international cooperation on transport decarbonization requires stronger engagement of transport ministers in international climate processes. This would facilitate the sharing of best practives, the pooling of resources to accelerate innovation and the alignement of actions by different countries, which are all widely acknowledged as key enablers for ambitious climate action.

However, the transformation of transport is not limited to the actions of ministries and must include the participation of a large number of stakeholders from different sectors and segments of society -- far beyond the governments, planners, engineers, and companies who are traditionally seen as having the largest impact on transport. For example, as mentioned in Enabling condition 1, mobility patterns, which are key drivers of transport emissions, depend largely on the spatial organisation of human activities, which in turn result from decisions of multiple actors, including employers, schools, retailers, local businesses, entertainment venues, and medical facilities (among many others). Therefore, at the national level, those leading transport decarbonization efforts should review the structure of decision-making processes to ensure that the active engagement and effective cooperation of this diverse set of stakeholders. In parallel, at the global level, multi-stakeholder, which bring together national transport and climate ministers, international companies, scientists, and non-governmental organisations, among others, should be further developed to better align actions towards transport decarbonization. Some initiatives, such as the Transport Decarbonization Alliance (TDA), which brings together cities, countries, and companies working to achieve a net-zero emission mobility system by 2050, are helping to build capacity by sharing best practices and cooperation by developing articulated action plans. More initiatives like this will be needed to help accelerate action.

### *Enabling condition 3 – Redirect international and national financing away from fossil fuels and towards more sustainable, low carbon transport*

Achieving low carbon transport pathways will require substantial investments on the order of USD 2.7 trillion per year through 2030, with 60-70% of these investments in emerging economies (OECD, 2017).

These resources already exist today but are neither distributed fairly among countries nor directed towards sectoral transformations compatible with carbon neutrality. For example, two-thirds of infrastructure investments from the 50 largest economies (USD 586 billion) went to support road transport infrastructure, such as highways, in 2015 (Oxford Economics, 2017). While the development of highway infrastructure is not necessarily incompatible with achieving carbon neutrality, most of these investments are not being made as part of comprehensive strategies to reduce transport emissions, and are in fact leading to increases in emissions. COVID-19 recovery spending is also not supporting decarbonization of the sector. Only around a third of all transport investments in COVID-19 recovery packages are going to support clean transport, with the majority going to fossil fuel-focused investments (Climate Action Tracker, 2020).

In addition, current economic incentives, such as fossil fuel subsidies, since the Paris Agreement was adopted in 2015, G20 member countries have spent more than USD 3.3 trillion in subsidies for coal, oil, gas, and fossil-fuel power (BloombergNEF, 2021). With more efficient fuel prices, the IMF estimates that 28% of global $CO_2$ emissions and 46% of air pollution deaths could be avoided annually, increasing tax revenues by 3.8% and adding economic benefits worth 1.7% of global GDP (Coady et al., 2019).

The use of fossil fuel-powered road vehicles, for example, requires significant infrastructure investments and results in road crashes, air pollution, and congestion, which costs society billions of dollars. In the European Union, for example, it is estimated that private road freight operators only pay for 26% of the total costs associated with their operation (Schroten et al., 2019). Efforts should therefore be made to better integrate the cost of these externalities in user fees, this could be done using measures such as road tolls, parking fees, and congestion pricing. For example, the London congestion charge discourages some drivers from entering London - but the massive revenue stream it has generated has enabled the transformation of public transport services and urban space for the benefit of all (C40 Cities Climate Leadership Group, 2019). These types of measures will be critical to redirecting investments towards more sustainable, low carbon transport.

With such large investment needs, national and international transport stakeholders should work together to better align financial flows with actions and investments identified in long-term low-emission and resilient development pathways (OECD et al., 2018). Such pathways could be a useful tool to structure intersectoral dialogues around transport decarbonization (Waisman et al., 2021). For example, at the international level, climate and transport dialogues (as discussed in *Enabling condition 2*) could focus on the development of international and regional transport pathways compatible with carbon neutrality, with the aim of redirecting international financial flows towards the achievement of these pathways.

# REFERENCES


- Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Solazzo, E., Monforti-Ferrario, F., Olivier, J. G. J., & Vignati, E. (2020). Fossil $CO_2$ emissions of all world countries. *Luxembourg: European Commission*, 1–244. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC121460/kjna30358enn.pdf
- International Energy Agency. (2019, November 11). *Transport sector $CO_2$ emissions by mode in the Sustainable Development Scenario, 2000-2030*. International Energy Agency. https://www.iea.org/data-and-statistics/charts/transport-sector-co2-emissions-by-mode-in-the-sustainable-development-scenario-2000-2030
- International Energy Agency. (2020). *Energy Technology Perspectives 2020*. IEA. https://doi.org/10.1787/d07136f0-en
- Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) Gmbh, & SLOCAT. (2021, May 2). *Tracker of climate strategies for transport*. Changing Transport. https://www.changing-transport.org/tracker/
- IPCC. (2018). *Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. IPCC. https://www.ipcc.ch/sr15/chapter/spm/
- Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V., Handa, C., Kheshgi, H., Kobayashi, S., Kriegler, E., & Others. (2018). *Mitigation pathways compatible with 1.5 C in the context of sustainable development. In Global warming of 1.5° C* (pp. 93–174). Intergovernmental Panel on Climate Change. https://publications.pik-potsdam.de/pubman/faces/ViewItemFullPage.jsp?itemId=item_22900_3&view=EXPORT
- Ewing, R., & Cervero, R. (2010). Travel and the Built Environment. *Journal of the American Planning Association. American Planning Association*, *76*(3), 265–294. https://doi.org/10.1080/01944361003766766
- C40 Cities Climate Leadership Group, & C40 Knowledge Hub (2020, July). *How to build back better with a 15-minute city*. C40 Knowledge Hub. https://www.c40knowledgehub.org/s/article/How-to-build-back-better-with-a-15-minute-city?language=en_US ; Nanda, A. (2019, September 13). *Superblocks: Barcelona's car-free zones could extend lives and boost mental health*. The Conversation. http://theconversation.com/superblocks-barcelonas-car-free-zones-could-extend-lives-and-boost-mental-health-123295
- C40 Cities Climate Leadership Group, & C40 Knowledge Hub (2020, July). *How to build back better with a 15-minute city*. C40 Knowledge Hub. https://www.c40knowledgehub.org/s/article/How-to-build-back-better-with-a-15-minute-city?language=en_US
- Venter, C., Mahendra, A., & Hidalgo, D. (2019, May). *From mobility to access for all: Expanding urban transportation choices in the Global South*. World Resources Institute. https://files.wri.org/s3fs-public/from-mobility-to-access-for-all.pdf
- Combs, T. (2020). *Local Actions to Support Walking and Cycling During Social Distancing Dataset*. Pedestrian and Bicycle Information Center. http://pedbikeinfo.org/resources/resources_details.cfm?id=5209
- European Cyclists' Federation. (2020, June 12). *COVID-19 Cycling Measures Tracker*. European Cyclists' Federation. https://ecf.com/dashboard
- Braeuninger, M., Schulze, S., Leschus, L., Perschon, J., Hertel, C., Field, S., & Foletta, N. (2012). *Achiving sustainability in urban transport in developing and transition countries*. https://www.osti.gov/etdeweb/biblio/21545186
- Changing Transport. (2021, April). *Sustainable Urban Mobility Plan (SUMP) Toolkit*. Changing Transport. https://www.changing-transport.org/toolkits/sump ; Rupprecht Consult. (2019). *Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan, Second Edition*. https://www.eltis.org/sites/default/files/sump_guidelines_2019_interactive_document_1.pdf
- SLOCAT. (2021, June 28). *Tracking Trends in a Time of Change: The Need for Radical Action Towards Sustainable Transport Decarbonization, Transport and Climate Change Global Status Report – 2nd edition*. SLOCAT. http://www.tcc-gsr.com
- International Transport Forum. (2019). *ITF Transport Outlook 2019*. European Conference of Ministers of Transport. https://doi.org/10.1787/transp_outlook-en-2019-en
- Bateman, A., Betts, K., Cottrill, K., Pang, J., Deshpande, A. S., Cottrill, K., Grau, A., & McCool, D. (2021). *State of Supply Chain Sustainability 2021*. Massachusetts Institute of Technology. https://sscs.mit.edu/wp-content/uploads/2021/07/State-Sustainable-Supply-Chains-MIT-CSCMP.pdf
- Unilever. (2021, March 21). *Unilever Climate Transition Action Plan*. Unilever. https://www.unilever.com/Images/unilever-climate-transition-action-plan-19032021_tcm244-560179_en.pdf
- *Bee Respect: Guerlain*. (n.d.). Respect Code. Retrieved August 9, 2021, from https://guerlain.respect-code.org/en-GB/
- Michelle Comerford, Project Director and Industrial & Supply Chain Practice Leader, Biggins Lacy Shapiro & Co, & Frank Spano, Managing Director, Austin Consulting. (2010, July 23). *Labor costs: The Number-One site selection factor*. Area Development. https://www.areadevelopment.com/laborEducation/feb10/labor-costs-top-site-selection-factor001111.shtml
- European Commission. (2020, March 4). *EU Green Deal (carbon border adjustment mechanism)*. European Commission. https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12228-EU-Green-Deal-carbon-border-adjustment-mechanism-_en
- International Energy Agency. (2018). *IEA Sankey Diagram World Balance (2018)*. International Energy Agency. https://www.iea.org/sankey/
- International Energy Agency. (2016, June). *Energy Technology Perspectives 2016*. International Energy Agency. https://www.iea.org/reports/energy-technology-perspectives-2016
- International Energy Agency. (2021). *Data and statistics*. International Energy Agency. http://www.iea.org/subscribe-to-data-services/world-energy-balances-and-statistics
- United Nations Environment Programme. (2020). *Global Trade in Used Vehicles Report*. UNEP. https://www.unep.org/resources/report/global-trade-used-vehicles-report.
- Cozzi, L., & Pretropoulos, A. (2019, October 15). *Growing preference for SUVs challenges emissions reductions in passenger car market*. International Energy Agency. https://www.iea.org/commentaries/growing-preference-for-suvs-challenges-emissions-reductions-in-passenger-car-market.
- BloombergNEF. (2020, December 16). *Battery pack prices cited below 100/kWh for the first time in 2020, while market average*

*sits at 137/kWh*. BloombergNEF. https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/

- Lutsey, N., & Nicholas, M. (2019, April 2). *Update on electric vehicle costs in the United States through 2030*. International Council on Clean Transportation; International Council on Clean Transportation. https://theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf
- SLOCAT. (2020, February 19). *E-mobility Trends and Targets*. SLOCAT. https://slocat.net/e-mobility
- Wappelhort, S. (2021, June). *Update on government targets for phasing out new sales of internal combustion engine passenger car*. International Council on Clean Transportation. https://theicct.org/sites/default/files/publications/update-govt-targets-ice-phaseouts-jun2021_0.pdf
- Mufson, S. (2021, January 28). *General Motors to eliminate gasoline and diesel light-duty cars and SUVs by 2035*. The Washington Post; The Washington Post. https://www.washingtonpost.com/climate-environment/2021/01/28/general-motors-electric/
- Yang, Z., & Bandivadekar, A. (2017). *2017 Global Update: Light-Duty Vehicle Greenhouse Gas and Fuel Economy Standards*. International Council on Clean Transportation. https://theicct.org/sites/default/files/publications/2017-Global-LDV-Standards-Update_ICCT-Report_23062017_vF.pdf ; IEA. (2019, March). *Fuel Economy in Major Car Markets. Technology and policy drivers 2005-2017*. IEA. https://www.iea.org/reports/fuel-economy-in-major-car-markets
- Nelsen, A. (2019, May 31). *Madrid could become first European city to scrap low-emissions zone*. The Guardian UK. https://www.theguardian.com/cities/2019/may/31/madrid-set-to-end-clean-air-project-in-rightwing-power-switch
- Porter, J. (2018, December 3). *Madrid's ban on polluting vehicles cuts traffic by nearly 32 percent in some areas*. The Verge. https://www.theverge.com/2018/12/3/18123561/vehicle-emissions-pollution-ban-madrid-spain-traffic-decrease.
- United Nations Environment Programme. (2020). *Global Trade in Used Vehicles Report*. UNEP. https://www.unep.org/resources/report/global-trade-used-vehicles-report.
- Xinhua. (2021, April 3). *Zimbabwe bans importation of cars older than 10 years*. Xinhuanet. http://www.xinhuanet.com/english/2021-04/03/c_139855393.htm
- SLOCAT. (2021, June 28). *Tracking Trends in a Time of Change: The Need for Radical Action Towards Sustainable Transport Decarbonization, Transport and Climate Change Global Status Report – 2nd edition*. SLOCAT. http://www.tcc-gsr.com
- K. Monahan (2019), "Ecuador's fuel protests show the risks of removing fossil fuel subsidies too fast", The Conversation, 31 October, https://theconversation.com/ecuadors-fuel-protests-show-the-risks-of-removing-fossil-fuel-subsidies-too-fast-125690.
- Deprez, A., Vallejo, L., & Rankovic, A. (2019, November). *Towards a climate change ambition that (better) integrates biodiversity and land use*. IDDRI. https://www.iddri.org/en/publications-and-events/study/towards-climate-change-ambition-better-integrates-biodiversity-and
- Topham, G. (2019, September 19). *Airlines' $CO_2$ emissions rising up to 70% faster than predicted*. The Guardian UK. https://www.theguardian.com/business/2019/sep/19/airlines-co2-emissions-rising-up-to-70-faster-than-predicted.
- International Energy Agency. (2020). *Aviation*. International Energy Agency. https://www.iea.org/reports/aviation
- IEA. (2020, December 2). *Global aviation fuel consumption, 2013-2021*. IEA. https://www.iea.org/data-and-statistics/charts/global-aviation-fuel-consumption-2013-2021
- IATA. (n.d.). *Working towards ambitious targets*. International Air Transport Association. Retrieved August 9, 2021, from https://www.iata.org/en/programs/environment/climate-change; A4A. (2021). *A4A's Climate Change Commitment*. Airlines for America. https://www.airlines.org/a4as-climate-change-commitment
- ICAO. (2021, June). *Carbon offsetting and reduction scheme for international aviation (CORSIA)*. International Civil Aviation Organization. https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx
- Cooper, R. (2020, February 18). *Delta Air Lines invests $1 billion in cutting carbon emissions*. Climate Action. http://www.climateaction.org/news/delta-air-lines-invests-1-billion-in-cutting-carbon-emissions
- Kollmeyer, B. (2019, November 19). *EasyJet's carbon-free pledge may win more green-conscious fliers*. MarketWatch. https://www.marketwatch.com/story/easyjets-carbon-free-pledge-may-win-more-green-conscious-fliers-2019-11-19
- Holger, D. (2019, November 14). *Lufthansa passengers can offset travel with green aviation fuel*. MarketWatch. https://www.marketwatch.com/story/lufthansa-passengers-can-offset-travel-with-green-aviation-fuel-2019-11-14
- Timperley, J. (2019, February 4). *Corsia: The UN's plan to "offset" growth in aviation emissions*. Carbon Brief. https://www.carbonbrief.org/corsia-un-plan-to-offset-growth-in-aviation-emissions-after-2020
- Hervey-Bathurst, I. (2019, May 28). *"Flygskam" – the very real impact of climate change on Swedish airlines*. Schroders. https://www.schroders.com/en/insights/economics/flygskam-the-very-real-impact-of-climate-change-on-swedish-airlines
- Lord Deben (2019, September 24). Net-zero and the approach to international aviation and shipping emissions, Letter of the Chairman of the Climate Change Committee of the UK to the Secretary of State for Transport.https://www.theccc.org.uk/wp-content/uploads/2019/09/Letter-from-Lord-Deben-to-Grant-Shapps-IAS.pdf
- ICAO. (n.d.). *Trends in Emissions that affect Climate Change*. ICAO. Retrieved August 9, 2021, from https://www.icao.int/environmental-protection/Pages/ClimateChange_Trends.aspx
- IRENA. (2016). *Innovation Outlook: Advanced Liquid Biofuels*. International Renewable Energy Agency; IRENA. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Innovation_Outlook_Advanced_Liquid_Biofuels_2016.pdf
- Aviation and global climate change in the 21st century from Lee, D. S., Fahey, D. W., Forster, P. M., Newton, P. J., Wit, R. C. N., Lim, L. L., Owen, B., & Sausen, R. (2009). Aviation and global climate change in the 21st century. *Atmospheric Environment* , *43*(22), 3520–3537. https://doi.org/10.1016/j.atmosenv.2009.04.024 ; The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018 from Lee, D. S., Fahey, D. W., Skowron, A., Allen, M. R., Burkhardt, U., Chen, Q., Doherty, S. J., Freeman, S., Forster, P. M., Fuglestvedt, J., Gettelman, A., De León, R. R., Lim, L. L., Lund, M. T., Millar, R. J., Owen, B., Penner, J. E., Pitari, G., Prather, M. J., … Wilcox, L. J. (2021). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmospheric Environment* , *244*, 117834. https://doi.org/10.1016/j.atmosenv.2020.117834 ; Bannon, E. (2018,

February 6). *Aviation: 2 to 3 times more damaging to the climate than industry*. Transport and Environment. https://www.transportenvironment.org/news/aviation-2-3-times-more-damaging-climate-industry-claims ; Ritchie, H. (2020, October 22). *Climate change and flying: what share of global $CO_2$ emissions come from aviation?* Our World in Data. https://ourworldindata.org/co2-emissions-from-aviation

- European Commission. (2019, November 12). *Communication From The Commission To The European Parliament, The European Council, The Council, The European Economic And Social Committee And The Committee Of The Regions: The European Green Deal*. European Commission. https://ec.europa.eu/info/sites/default/files/european-green-deal-communication_en.pdf ; European Commission. (2002, March 4). *EU Green Deal – Revision of the Energy Taxation Directive*. European Commission. https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12227-EU-Green-Deal-Revision-of-the-Energy-Taxation-Directive_en
- Aviation, F. C. C. (2019, September 8). *French Eco Tax*. FCC Aviation. https://www.fccaviation.com/regulation/france/eco-tax ; Brandler, H. (2021, January 20). *France and its new environmental eco tax on aviation*. Business Traveller. https://www.businesstraveller.com/features/france-and-its-new-environmental-eco-tax-on-aviation.
- Le News. (2020, June 12). *Swiss parliament votes in favour of flight tax*. Le News. https://lenews.ch/2020/06/12/swiss-parliament-votes-in-favour-of-flight-tax.
- Duxbury, C. (2020, May 19). *Sweden looks to break out of its northern isolation*. POLITICO. https://www.politico.eu/article/sweden-break-out-of-northern-isolation-trains-coronavirus
- GIZ. (2019, December 9). *Sustainable Urban Transport: Avoid-Shift-Improve (A-S-I) - SUTP*. Sustainable Urban Transport. https://sutp.org/publications/sustainable-urban-transport-avoid-shift-improve-a-s-i/
- SLOCAT. (2020, April 21). *Transport in Nationally Determined Contributions*. SLOCAT. https://slocat.net/ndcs.
- Bergk, F., Biemann, K., Heidt, C., Knörr, W., Lambrecht, U., & Schmidt, T. (2016). *Klimaschutzbeitrag des Verkehrs bis 2050*. Umweltbundesamt. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/texte_56_2016_klimaschutzbeitrag_des_verkehrs_2050_getagged.pdf
- Briand, Y., Bataille, C., Waisman, H. (2018). *How to structure the public debate on the low-carbon future of passenger transport? Lessons from the DDPTransport Project*. IDDRI, *Issue Brief* N°13/18.
- https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue%20Iddri/D%C3%A9cryptage/201811-IB1318-DDP%20transports.pdf
- Briand, Y., Waisman, H (2019). *Raising the ambition of NDCs through the analysis of sectoral transformations: the example of freight transport*. IDDRI, *Issue Brief* N°14/19. https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue%20Iddri/D%C3%A9cryptage/201911-IB1419-fret%2520NDCs.pdf
- Julien Lefèvre et al. (2020): A pathway design framework for sectoral deep decarbonization: the case of passenger transportation, Climate Policy. https://doi.org/10.1080/14693062.2020.1804817
- OECD. (2017). *Investing in Climate, Investing in Growth* [PDF]. Organization for Economic Co-operation and Development (OECD). https://doi.org/10.1787/9789264273528-en
- Oxford Economics. (2017). *Global Infrastructure Outlook*. https://cdn.gihub.org/outlook/live/methodology/Global+Infrastructure+Outlook+-+July+2017.pdf
- Climate Action Tracker. (2020, August 23). *Global update: Pandemic recovery with just a hint of green*. Climate Action Tracker. https://climateactiontracker.org/publications/global-update-pandemic-recovery-with-just-a-hint-of-green
- BloombergNEF. (2021, July 20). *New report finds G-20 member countries support fossil fuels at levels untenable to achieve Paris agreement goals*. BloombergNEF. https://about.bnef.com/blog/new-report-finds-g-20-member-countries-support-fossil-fuels-at-levels-untenable-to-achieve-paris-agreement-goals/
- Coady, M. D., Parry, I., Le, N.-P., & Shang, B. (2019). *Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates*. International Monetary Fund. https://play.google.com/store/books/details?id=FKMZEAAAQBAJ
- Schroten, A., van Wijngaarden, L., Schmidt, M., Morgan-Price, S., El Beyrouty, K., van Essen, H., Maffii, S., Sutter, D., Andrew, E., & Brambilla, M. (2019). *State of Play of Internalisation in the European Transport Sector*. Publications Office of the European Union. https://op.europa.eu/en/publication-detail/-/publication/696d402f-a45a-11e9-9d01-01aa75ed71a1.
- C40 Cities Climate Leadership Group. (2019, March). *How road pricing is transforming London – and what your city can learn*. Case Studies and Best Practice Examples, C40 Knowledge Hub. https://www.c40knowledgehub.org/s/article/How-road-pricing-is-transforming-London-and-what-your-city-can-learn
- **OECD/The World Bank/UN Environment (2018).** *Financing Climate Futures: Rethinking Infrastructure (OECD)*. https://doi.org/10.1787/9789264308114-en
- Waisman, H. et al. (2021). *A country-driven perspective on long-term low-emission development strategies (LT-LEDS). Implications for a COP26 Decision text or outcome*. IDDRI, Study N°07/21. https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue%20Iddri/Etude/202106-ST0721-LTS%20COP26.pdf

The DDP is an initiative of the Institute for Sustainable Development and International Relations (IDDRI). It aims to demonstrate how countries can transform their economies by 2050 to achieve global net zero emissions and national development priorities, consistently with the Paris Agreement.. The DDP initiative is a collaboration of leading research teams currently covering 36 countries. It originated as the Deep Decarbonization Pathways Project (DDPP), which analysed the deep decarbonization of energy systems in 16 countries prior to COP21 (deepdecarbonization.org). Analyses are carried out at the national scale, by national research teams. These analyses adopt a long-term time horizon to 2050 to reveal the necessary short-term conditions and actions to reach carbon neutrality in national contexts. They help governments and non-state actors make choices and contribute to in-country expertise and international scientific knowledge. The aim is to help governments and non-state actors make choices that put economies and societies on track to reach a carbon neutral world by the second half of the century. Finally, national research teams openly share their methods, modelling tools, data and the results of their analyses to share knowledge between partners in a very collaborative manner and to facilitate engagement with sectoral experts and decision-makers.
www.ddpinitiative.org

The Institute for Sustainable Development and International Relations (IDDRI) is an independent, not-for-profit policy research institute based in Paris. Its objective is to identify the conditions and propose tools to put sustainable development at the heart of international relations and public and private policies. IDDRI is also a multi-stakeholder dialogue platform and supports stakeholders in global governance debates on the major issues of common interest, such as actions to mitigate climate change, protect biodiversity, strengthen food security, and to manage urbanisation. The institute also participates in work to build development trajectories that are compatible with national priorities and the sustainable development goals.

www.iddri.org