CLIMATE CHANCE

2018

GLOBAL OBSERVATORY ON NON-STATE CLIMATE ACTION

TRANSPORT

BOOK 1

Sector based action

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TRANSPORT

The "Road" Towards Low Carbon Mobility

The Paris Agreement encourages raising mitigation ambition in Nationally Determined Contributions (NDCs) by reviewing and assessing the strength of their ambition and to formulate long-term low greenhouse gas emission development strategies. The current NDC's identify the transport sector as a significant mitigation source whose decarbonisation is critical in achieving economy-wide decarbonization.
This chapter is a synthesis report analysing the most recent data from the road sector and the factors behind its growth and development. The main ambition is to provide a status of global climate action related to the road transport sector, and the synergies between the State and non – state actors.

Head Editor • **SUDHIR GOTA** • *Consultant, Partnership on Sustainable Low Carbon Transport (SLoCaT))*

CONTENTS

1 • STATUS OF ROAD TRANSPORT CARBON EMISSIONS

In 2016, the transport sector constituted about 23% share in total fuel combustion carbon emissions[1]. **Most of the Carbon emissions within the transport sector are from the road transport sector, which constitutes about three-quarters of transport carbon emissions[2]** i.e. about 6GT of direct Carbon emissions in 2017. Since 2000, road transport carbon emissions have increased at an annual rate of 2% becoming one of the fastest growing sub-sectors of fuel combustion emissions[3] over the past half-century. **However, since 2015, road transport carbon emissions growth has grown at a slower annual rate of 1.4% when compared with historic annual growth of 2%.** However, this slowing down of emission growth is not yet compatible with the findings of the IPCC Special Report on Global Warming of 1.5°C[4] i.e. ***limiting climate change to 1.5-degree Celsius means nothing short of de-carbonizing road transport sector around mid-century or soon afterwards and thus necessitates transformational changes in thinking, behaviour, and the combined actions of all stakeholders.***

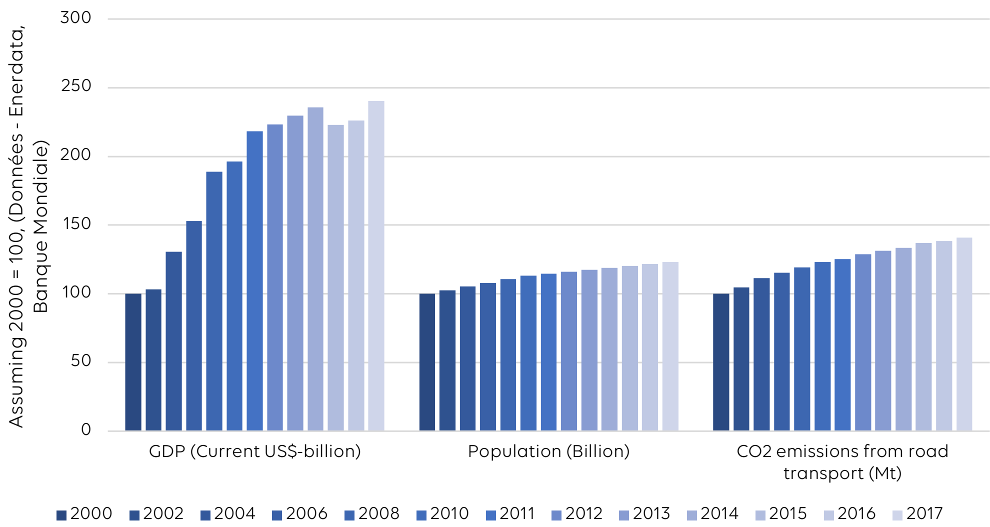


FIGURE 1. GROWTH IN ROAD TRANSPORT EMISSIONS

The entire growth in the road transport carbon emissions post-2000 has come from non-OECD countries (Table 1). The non-OECD countries share increased from 31% in 2000 to 47% in 2015[5] and most of the growth concentrated in Asian and African countries where road transport carbon emissions have doubled (Enerdata et Edgar). **However, in the last couple of years i.e. from 2014 to 2016, road transport emissions annual growth in the non-OECD countries have slowed down with an annual growth of 2%[6] mainly due to slowing down of growth in emissions in countries like Brazil, China, India, Indonesia, Malaysia and Saudi Arabia (Global Energy Statistical Yearbook, Enerdata).** The decline in Brazilian emissions underlined in this report, is an example of this link between growth and CO_2 emissions from road transport (Country profil Brazil – Road Transport section, Book 1), while the increase in Indian emissions underlines the strong impact on CO_2 from the increase in the car fleet (Country profil India – Road Transport section, Book 1).

	2005	2010	2016	2017
World	4,809.3777	5,237.1766	5,883.8007	5,983.9182
Italy	116.9636	103.7557	98.3021	96.5156
Netherlands	33.4361	32.7982	28.7313	29.2687
France	126.1286	118.9547	117.9526	118.646
United Kingdom	118.7426	110.2636	114.0851	114.2115
Sweden	21.2929	20.6226	18.3109	17.8555
Poland	33.4424	46.2345	51.1971	57.8695
Germany	150.1151	143.9549	157.2153	161.1553
Russia	114.881	143.3387	157.11	153.9852
Canada	126.0199	141.9901	142.0916	145.9141
United States	1 561.1449	1 469.1629	1 509.7615	1 516.4608
Australia	71.2071	74.8835	81.0902	84.3928
Japan	208.0171	193.8698	187.7446	186.2568
China	314.5042	467.6695	693.5187	717.2486
India	103.2084	176.0312	243.0412	260.7791
Indonesia	62.1026	88.2062	112.2836	116.3845
Mexico	125.7182	146.5216	151.9731	145.7665
Brazil	123.7752	149.6977	179.9659	184.7932
Colombia	19.9236	20.9936	29.9612	30.9587
Saudi Arabia	73.9228	103.3289	133.0469	130.3684
Algeria	19.3229	29.2905	41.4319	40.7904
Ivory Coast	1.0552	1.3077	2.8659	n.a.
Nigeria	28.5036	27.4846	23.7578	25.3636
South Africa	40.1567	45.0207	47.5597	49.7997

TABLE 1. GREENHOUSE GAS EMISSIONS (MTCO$_2$) BY COUNTRIES

(Source: Enerdata)

Within the road transport segment, the light-duty vehicles (cars) constitute about 60% of road transport emissions[6]. The road-based public transport services such as bus (including minibus) and two-and-three-wheelers constitute about 6% each respectively. However, there are significant variations in the magnitude of carbon emissions among different sub-modes across different countries. For example, the two-and-three-wheelers constitute about 2% and 11% of total road transport carbon emissions in OECD and non-OECD countries[7]. The two-wheelers are a significant source of emissions in the ASEAN, China, India and Africa[8].

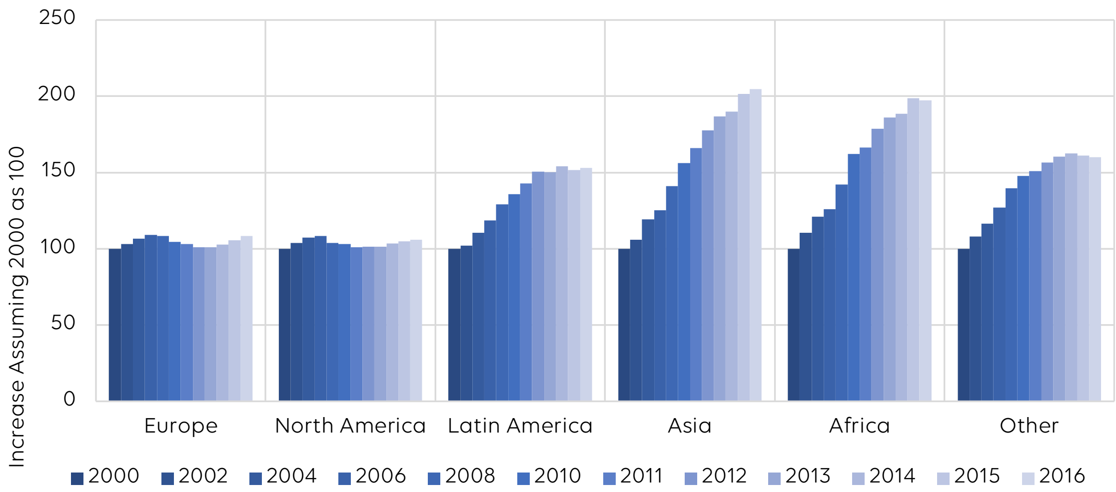


FIGURE 2. REGIONAL GROWTH IN ROAD TRANSPORT CARBON EMISSIONS (COMPARED TO A BASE 100)

An increasing share of CO_2 emissions is associated with road transport in and around cities. In 2013, the International Energy Agency estimated that urban road transport constitutes about half of road transport carbon emissions. In heavily urbanised countries like the US, urban transport constitutes about 60% of road transport carbon emissions while developing countries like India and South Africa, this share is about 41% and 44% respectively[9].

By 2050, the continuation of existing business-as-usual growth in road transport carbon emissions will result in global road transport carbon emissions increasing to about 10 Gt[10] to 17 Gt[11]. However, there is a large differentiation among road transport emissions trends between individual modes and countries. The road transport carbon emissions in the OECD countries could decrease by close to 30%, while it could increase by 100% in the non-OECD countries[12]. However, the scale of the transformation ahead in the road transport sector on the path toward a decarbonized transport system is well illustrated by recent studies on transport sector decarbonisation which illustrate a need to decarbonise to 2 to 3 Gt by 2050[13].

2 • WHY HAVE CARBON EMISSIONS INCREASED IN THE ROAD TRANSPORT SECTOR?

An understanding of CO_2 emissions from road transport globally requires a clear picture of several interlinked factors, i.e. transportation demand (activity), mode of travel, modal energy efficiency and carbon intensity (ASIF Framework[1]).

• HIGH GROWTH IN ROAD TRANSPORT DEMAND (ACTIVITY) • Globally, road transport accommodates nearly about 90% and 70% of passenger and surface freight demand[14]. Historically, growth in the demand for both passenger and freight road transport has been closely correlated with growth in economic activities. The global motorised road passenger mobility measured in motorised passenger-kilometres (pkm) increased from 27 trillion passenger kilometre in 2000 to about 41 trillion passenger kilometres in 2015 i.e. an increase from about 4400 passenger-kilometres to about 5600 passenger-kilometres per capita[15]. **The global road passenger transport demand experienced a sustained period of robust growth until the economic crisis of 2008. Since 2008, the OECD and non-OECD countries show diverse trends.** For example, in Europe[16], road passenger transport demand increased from about 10,180 km/capita in 2000 to about 10,570 km/capita in 2008. Since its peak in 2008, it had remained broadly stable, with only a slight overall reduction being a result of the economic recession from 2009 to 2012. In 2015, total passenger per-capita transport demand was the same as in 2000. The OECD passenger road passenger transport demand decreased from 13000 to about 10000 kilometres per capita. The non-OECD countries passenger transport demand measured in pkm increased from 2400 to 4600 kilometres per capita.

Passenger Transport Demand

In OECD countries, since 2008 financial crisis, the volume of passenger transport relative to GDP has reduced by 35 percent in Lithuania, 20 percent in Ireland, 9 percent in Switzerland and 8 percent in United Kingdom. In cities, implementation of demand management policies has resulted in reduction of vehicle travel. For example, implementation of the congestion charge scheme has reduced vehicle travel by more than 15 percent and reduced congestion by 30 percent and in the Stockholm congestion charge implemented in 2007 reduced kilometres driven in the inner city by 16 percent, and outside the city by 5 percent despite economic and population growth.

In non-OECD countries, the passenger mobility has been growing faster than the GDP. In countries like Burundi, China, Nigeria, Zambia, Vietnam, India, Georgia and Panama, the Car ownership has been growing with an annual rate of more than 10% since 2000. To reduce passenger transport demand, cities have been implementing several transport demand management strategies. For example, Singapore in 2018 has implemented zero growth strategy for vehicle ownership to move towards car-free society.

TEXT BOX 1

The global road freight transport demand increased from about 8 trillion tonne-kilometre in 2000 to about 24 trillion tonne-kilometres in 2015 i.e. an increase from about 1300 tonne-kilometres to about 4000 tonne-kilometres per capita. **Historically, the global road freight transport demand in terms of tonne-km bore an extremely stable relationship with economic growth, i.e. GDP with the road freight volumes showing very strong correlation to the economic environment, i.e. for every 1% increase in GDP per capita, road freight movement i.e. tonne-km per capita increases by 1.07% on average[17].** However, the intensity of freight demand and its growth could vary significantly among countries. For example, the OECD road freight transport demand increased from 4500 to about 9500 tonne-kilometres per capita and the non-OECD countries demand increased from about 500 to 2800 tonne-km per capita.

Freight Transport Demand

Since 2000, the freight vehicle ownership has grown by an annual rate of more than 10% in low- and middle-income countries like Lao PDR, Indonesia, Panama, Barbados, Vietnam, Morocco and Chile. In EU-28, the freight transport demand increased considerably between 2000 and 2007 with a reduction due to economic downturn in 2008 and, after a limited recovery, freight volumes have since remained largely stable. The total road freight transport demand (in tonne-km) in 2015 is about 14% higher than in 2000.

TEXT BOX 2

Increase in passenger and freight mobility has resulted in rapid expansion of vehicles on roads and thereby generating high motorised trips. From 2000 to 2015, the vehicle kilometre travel has increased by about 66% in global, 24% and 166% in OECD and the non-OECD countries[18]. If population and incomes grow in accordance with the expectations, and if there is no paradigm shift in the relationship between income and the demand for mobility as illustrated in *Figure 3*, then mobility will grow strongly in future with entire growth outside of the OECD region. The International energy agency estimates that by 2050, the road passenger and freight transport demand could increase to about 72 trillion passenger kilometres and 85 trillion tonne-kilometres[19].

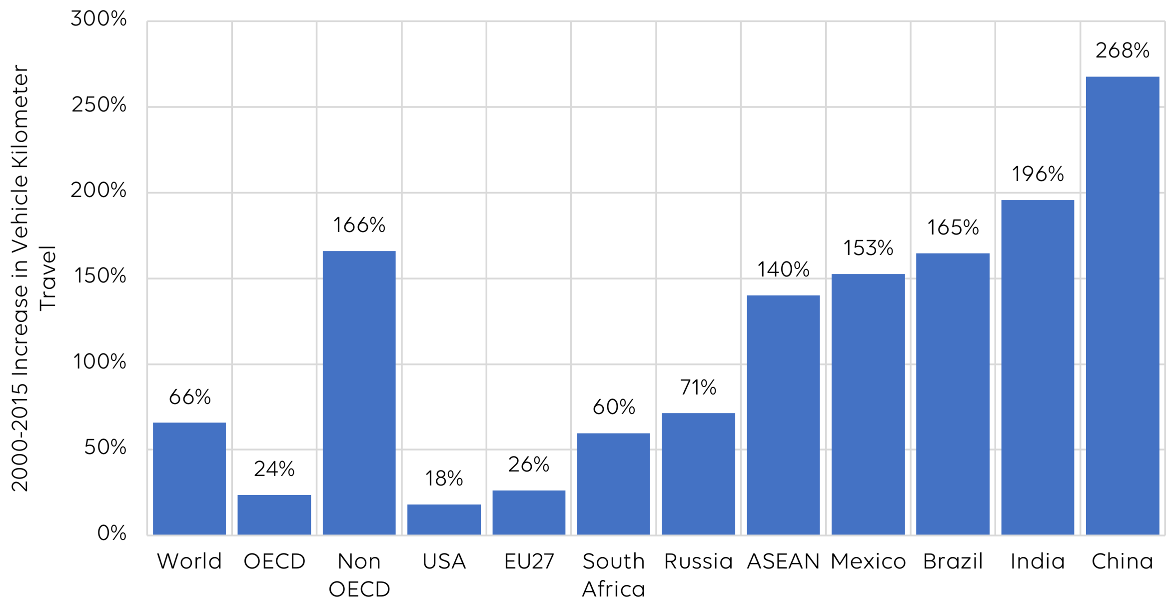


FIGURE 3. INCREASE IN VEHICLE KILOMETER TRAVEL

The policy response to reduce transport demand involves the use of "Avoid" strategies to change travel behaviour. These strategies reduce unnecessary travel through e.g. urban planning, logistics redesign and by behavioural changes. Reducing transport demand is perhaps the most difficult of the transitions as it has historically received less attention from stakeholders[20]. However, there exist several best practice examples from countries, cities and companies which have initiated transportation demand management strategies to reduce transport demand (in vehicle kilometres or in passenger/ tonne-kilometres travel) and have resulted in very high positive co-benefits. These strategies often consist of a mix of push and pull strategies to change travel behaviour using disincentives and incentives (few examples below).

Example	Description
Singapore	In October 2017, the Land Transport Authority (LTA) of Singapore announced that its vehicle growth rate would be reduced to zero (from 0.25%), effective February 2018. The main policies to reduce urban transport demand include urban planning (smart growth), electronic road pricing (ERP), vehicle quota system, public transit policies and improving walking and cycling facilities. The ERP scheme tackles traffic conges-tion by individual charging point, the direction of travel, time of day and vehicle type (based on road space occupancy).
London	London charge scheme (Introduced on Feb 2002) considers charging not only for crossing a cordon but also for movements within the cordon. The new transport strategy (2018) targets 80% of trips by foot, by cycle or by public transport by 2041 and full network road pricing. The London's congestion charge scheme has reduced vehicle travel by more than 15 percent and reduced congestion by 30 percent (im-mediate impact) and created an additional funding source for public transport and non-motorised transport improvements.
Mexico	In 2017, Mayor of Mexico City announced the "limitation of parking spaces in the city construction code". This new norm changes minimum parking requirements to maxi-mum depending on the land use of the construction.
China	Several Chinese major cities are limiting the number of annual vehicle registrations with auctions (or lotteries). In recent years (2016 and 2017), the Beijing municipal government has proposed the implementation of dynamic tolls, dynamic parking fees according to the parking location, length of stay and arrival/departure time of parking, and consideration of congestion charging and dynamic fees for public transport and taxis to reduce road transport demand.
Unilever	'Big Bang' project in Europe focuses on using trucks and pallets efficiently. In 2017, the project increased truckload fill rates by 2% thus reducing truck trips. In China, Unilever made changes to the pallet size – adding one extra layer to increase load fill by 11%, creating savings of €500,000 as well as reducing CO_2 emissions.

TABLE 2. EXAMPLES OF AVOID STRATEGIES

State and non – state actors are implementing several initiatives to reduce transport activity. For example:

• The Paris Process on Mobility and Climate (PPMC) has developed a Global Macro-Roadmap (GMR)[21] for complete decarbonisation of the transport sector. The Roadmap is relevant for all continents and comprises eight components that are phased and articulated in synergy with each other. The avoid related components include urban transformation, optimizing supply chains to manage freight transport emissions, avoiding vehicle kilometres through greater intermodality and shared transport for commuting, shopping and accessing services. Some of the targets (2040/2060) include

- urban passenger trips are reduced to 20%, while, the combined share of trips by walking, cycling, and shared transport trips rises to 80% of all trips. A 50% reduction in private passenger vehicle kilometres travelled.
• The Shared Mobility Principles[22] for Livable Cities were launched at the 2017 Ecomobility World Festival in Kaohsiung, Taiwan. The shared mobility principles are designed to guide urban decision-makers and stakeholders toward the best integration of shared modes with the city land-use and transport networks.
• C40's TOD Network[23] and ITDP's TOD Standard[24] promotes integrated urban places designed to bring people, activities, buildings, and public space together, with easy walking and cycling connection between them and near-excellent transit service to the rest of the city.

• MODE SHARE (SHIFT IN TRANSPORT DEMAND) • Global motorised road transport demand comprises several modes and segments. **Globally, passenger cars contribute to about 52% of the global passenger mobility, bus-based public transport about 34%, and two-and-three wheelers about 14% of total passenger transport demand (in passenger-kilometres)**. However, there exists great diversity in the mobility pattern among different geographical regions and income levels. The passenger cars (LDV's) constitute about 84% (OECD) and 37% (non-OECD) of road passenger transport demand. The two-and-three-wheelers share in road passenger transport demand varies from 3% in OECD countries to 19% in non-OECD countries.

Since 2000, global motorised passenger transport volumes (in pkm) across the different modes have changed as follows:

• Passenger cars: -5%;
• Powered two-and-three-wheelers: +5%;
• Buses and mini-buses: 0%;

However, in the non-OECD countries, there has been tremendous mode shift from the buses and mini-buses to Cars and two-and-three-wheelers. The bus road passenger mode share has reduced from 58% (2000) to 43% (2015). About 60% of the global road passenger-kilometres travel occurs in the urban area. In the OECD countries, the urban share of passenger activity is about 66%, while in the low-and-middle income countries like India it is about 59%.

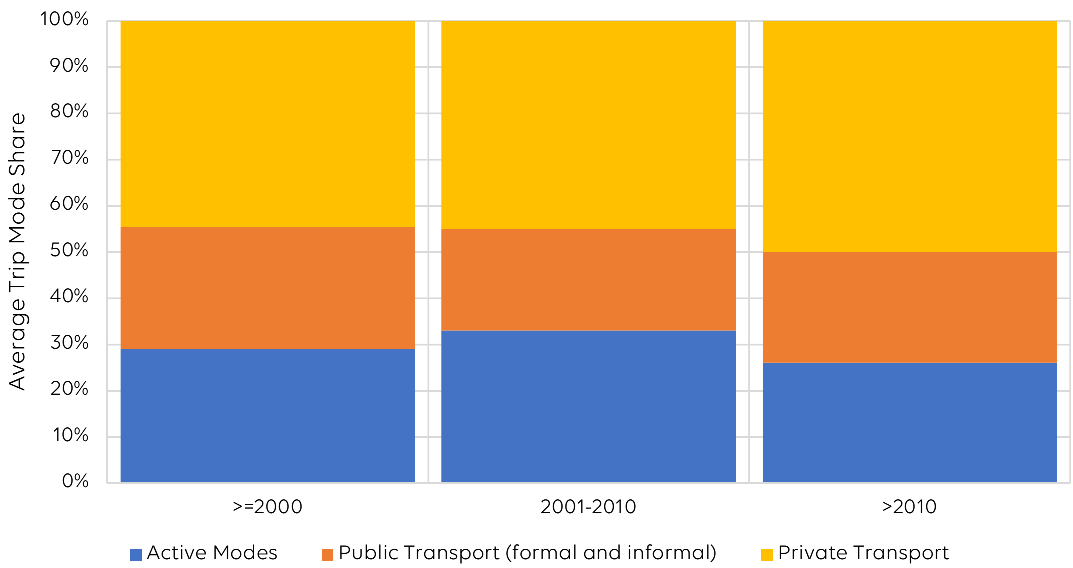


FIGURE 4. GLOBAL TRIP MODE SHARE (URBAN)

Urban freight constitutes only about 12% of the road freight activity (tonne-kilometres) but generates about 50% of freight road vehicle kilometre travel[25] as final products get delivered in low volumes, and at high frequencies in congested traffic conditions. The road transport plays a leading part in carrying surface freight in all countries. Since 2000, there is tremendous mode-shift towards road freight with its mode share (in total freight) increasing from 12% (2000) to 22% (2015)[26].

The policy response to change transport structure involves the use of the "Shift" strategies to improve trip efficiency. **These strategies induce a modal shift from the most energy and emission intensive mode (i.e. cars, road freight) towards more environmentally friendly modes (walking, cycling, public transit, railways, waterways).** The New Urban Agenda (NUA) adopted in 2016 with an overall emphasis on human-scale and people-centered planning, makes explicit references to improvement in walking, cycling and public transit infrastructure i.e. "*A significant increase in accessible, safe, efficient, affordable and sustainable infrastructure for public transport, as well as non-motorized options such as walking and cycling, prioritizing them over private motorized transportation*".

There exist several best practice examples from countries, cities and companies which have initiated modal shift strategies. For example, the EU's 2011 whitepaper[26] – "Roadmap to a Single European Transport Area" targets "thirty percent of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050, facilitated by efficient and green freight corridors. To meet this goal will also require appropriate infrastructure to be developed". The EU's Trans-European Transport Network (TEN-T) policy[28] daims at the development of multimodal core-network corridors, promoting modal shift and sustainable infrastructure and equipment.

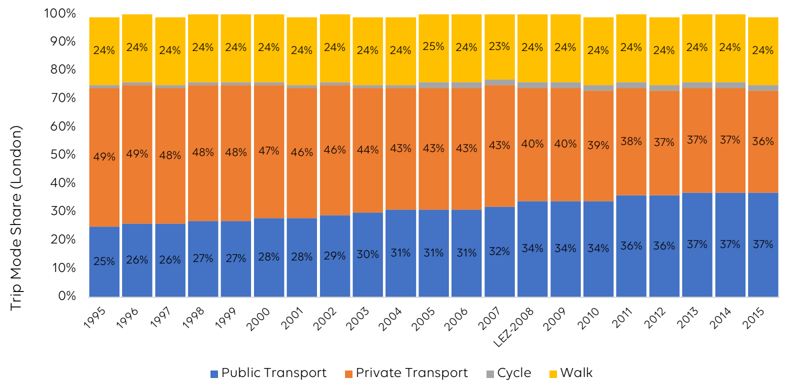
In recent years, many cities have increased investments in public transport, walking and cycling infrastructure. **Globally, since 2000, the bus rapid transit system, light rail transit and metro rail infrastructure expanded by 835%, 88%, and 67%, respectively. By 2018, there are more than 1700 bike sharing systems globally[29].**

The State and non – state actors are also implementing several initiatives for modal shift. For example:

- The Global Sidewalk Challenge[30] raises the voice and profile for walking internationally and sets a challenge to governments, private businesses and NGO's to collaborate and invest in walking infrastructure, especially dedicated, safe and barrier-free sidewalks at transport hubs, to benefit the people who walk most by focusing on the places most walked in order to reduce traffic externalities.
- In 2012, the European Commission launched the Sustainable Urban Mobility campaign "Do the Right Mix[31]" aiming to support sustainable urban mobility campaigners in 31 countries. The main objective of this initiative is to promote the advantages of combining different modes of transport. The campaign works with diverse stakeholders to take steps towards changing mobility behaviour in their neighbourhoods and cities by running their own 'actions'.
- Public Transport - UITP's Declaration on Climate Leadership targets doubling the market share of public transport by 2025 and pledged over 350 projects to climate action in over 80 cities around the world. The UIC Low Carbon Sustainable Rail Transport Challenge proposes 50% increase in rail's share of passenger transportation by 2030 and doubling by 2050 (2010 baseline), rail freight activity equal to that of road freight by 2030, and exceeding road freight volumes by 50% by 2050.
- In 2015 the UN Environment Share the Road Programme - with the support of the FIA Foundation - helped the Nairobi City County Government launch an NMT Policy for Nairobi which included a first of its kind commitment in Africa - earmarking 20% of their road construction budget to NMT investment[32].

Trip Mode Share

In London, the private transport trip mode share has declined from 49% in 1995 to about 36% in 2015, whereas those made by public transport have increased from 25% to 37% during the same period. Central London has seen the largest reduction in motor vehicle kilometres since 2000. The mode shift is mainly due to improvement in bus services, metro systems, walking, cycling and due to implementation of congestion charges. The 2018 London Mayor's Transport Strategy has the bold ambition to achieve about 80 percent of all trips in London by walking, cycling and by using public transport by 2041.



TEXT BOX 3

City	Mode Shift targets
Adelaide	Double the number of people cycling in the City (baseline 2011), Increase the number of car share vehicles available in the City to 100 vehicles.
Chengdu	65% Public Transit share by 2020 (of which metro to have a 35% share)
Chongqing	47% Public Transit trip share by 2020 (Metro to take 21% of total daily trips by 2020)
Copenhagen	By 2025, the city wants 75% of trips to be made by foot, bike, or public transit
Gothenburg	By 2035, A doubling of the number of journeys on foot or by bicycle. A doubling of the number of public transport journeys. A reduction by a quarter of the number of car journeys (compared to 2011)
Greater Kuala Lumpur/Klang Valley	Target 40% modal share for public transport in the urban areas by 2030 during AM peak periods
Hô Chi Minh	Public transport mode share of 47-50% by 2020
London	80 per cent of all trips in London to be made on foot, by cycle or using public transport by 2041
Nairobi	By 2025, Public Transit mode share to be 35%, Cycling to be 10% and walking to be 50% of trip mode share (for up to 5km trip length)
Phnom Penh	Public Transit mode share to be 30% of trip mode share by 2035
Shanghaï	Metro to take 60% of Public transport trips by 2020
Shenzhen	Public Transit and non-motorised vehicles to take 65% of overall trips by 2020
Singapore	A 75% public transport modal share during both the morning and evening peak hours by 2030, up from today's 64%.
Stockholm	The proportion of all journeys at peak hours performed by bicycle must be not less than 15 per cent by 2030. The proportion of local journeys made on foot will be at least 60 per cent in the inner city and 50 per cent in the suburbs by 2030
Taipei	12 per cent modal share for bicycles by 2020
Vancouver	By 2040, at least two-thirds of all trips will be made by foot, bike, and transit.

TABLE 3. CITIES WITH MODAL SHIFT STRATEGIES

• CHANGES IN ENERGY INTENSITY AND LOW CARBON FUEL • The transport energy intensity (defined as the ratio of energy consumption with passenger or freight activity) of the road transport sector varies significantly among modes and regions as illustrated in the figures below. All modes of passenger transport show improvement in transport energy intensity with light-duty vehicles showing the least progress. For individual modes, the energy intensity is much higher in OECD countries when compared with the non-OECD countries, mainly due to factors such as occupancy or loading, fuel efficiency, fleet composition, vehicle size i.e. bigger SUVs and mode split. International Energy Agency analysis of fuel economy for the past decade for new light-duty vehicles (LDVs) reveals about 1.5% annual improvement globally between 2005 and 2015[33]. Overall, globally, from 2005 to 2015, the energy intensity of passenger and freight road transport has improved by about 22% and 6% respect.[34]

Road Transport remains very dependent on oil, with the transport sector accounted for about two-thirds of global oil consumption in 2015 with the road sector alone accounting for half[35]. **At present, the transport sector is the least diversified energy end-use sector due to the high emphasis on energy density. About 93% to 98% of road transport modes are powered by petroleum products with limited penetration of biofuels and electricity. Liquid biofuels (ethanol and biodiesel) share in global road transport fuel is about 4%[36].**

Electricity share in road transport energy consumption has only increased marginally over the past 15 years in different modes. However, two-and-three wheelers are an exception and currently, they constitute about 20% of the fleet. In 2015, close to 38 million electric bikes were sold globally and out of which more than 90% was in China alone[37]**. For electric vehicles, it is important to consider how electricity is generated and its exposure to people/proximity of emissions to people. In 2016, globally, 26% of the electricity consumed by electric vehicles were renewable[38].** However, the transport sector could benefit from decarbonizing efforts in the electricity sector. By 2030, renewables could become the leading source of electricity by 2030 and the carbon intensity of the power sector is projected to improve by 30%[39].

The policy response to improve modal efficiency involves the use of "Improve" strategies to improve vehicle and fuel technologies and by optimising transport infrastructure. There exist several best practice examples from countries, cities and companies which have initiated such improvement strategies.

For example:

- The number of countries that have adopted a biofuel obligation/ mandate increased from 36 in 2011 to 68 in 2017 [41].
- In 2016, Brunei, Ethiopia, India, Morocco, Nigeria, United Arab Emirates & Viet Nam proposed reducing fossil fuel subsidies[42].
- In 2016, about 34 countries proposed energy efficiency improvement strategies for implementation in the Nationally determined contributions[43].
- About 83% of new LDV sales are in countries which have proposed fuel economy standards for LDVs[44]. For example, countries and regions like China, EU, Japan, Canada, US, Mexico, South Korea and India have established LDV fuel economy standards.
- About 48% of the new heavy-duty vehicle (HDV) sales are in countries which have proposed fuel economy standards for HDVs. For example, countries and regions such as China, EU, Japan have established HDV fuel economy standards.
- Countries and cities like Norway, Ireland, Netherlands, Slovenia, Paris, Scotland, Reykjavik, United Kingdom, France, etc. have announced target deadlines for a ban of new vehicles with gasoline and diesel engines.[45]

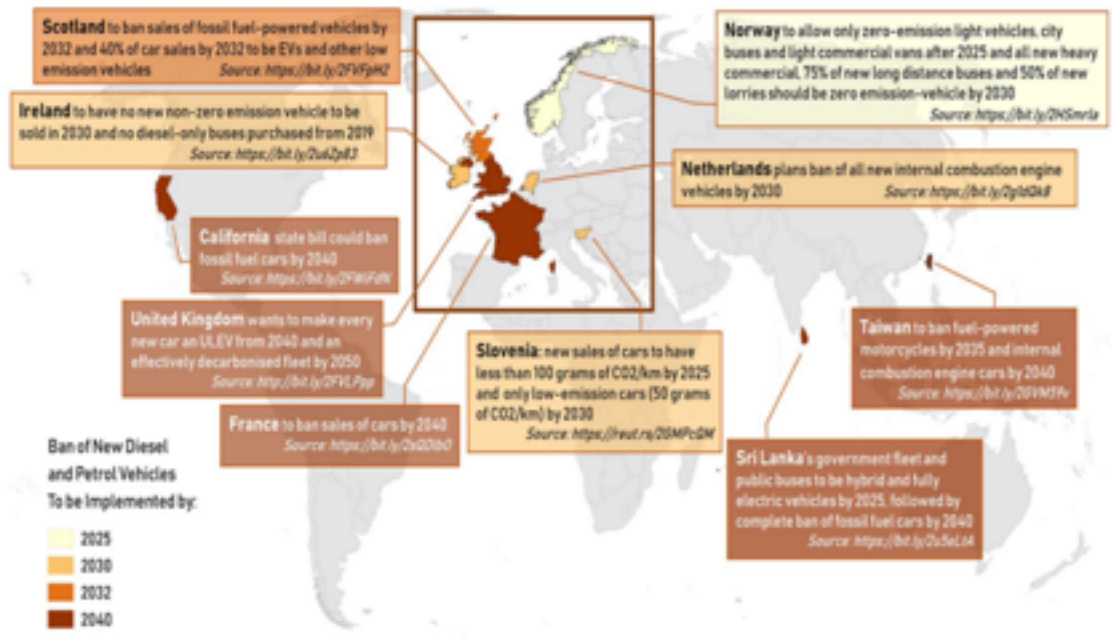


FIGURE 7. BAN ON NEW DIESEL AND GASOLINE VEHICLES (TARGETS)

The collapse of the diesel fleet and growth in the share of SUVs lead to an increase of emissions in Europe

Target because of its impact on human health, and progressively hunted in European cities (Hamburg, Paris ...), diesel is progressively losing its privilege and favour.

In France, the alignment of taxes on gasoline and diesel have led to rapid changes in behavior. In 2017, the market share of diesel vehicle sales decreased by 5% compared to the previous year. For number of companies, where this type of motorization has been almost hegemonic since the 1970s, the lastest results are spectacular; sales fallen by 34% in one year (September 2017 - September 2018).

But this rapid change has had a reverse effect on CO_2 emissions. In its annual report on new vehicle sales, the agency AAA Data notes that the average CO_2 emissions of new vehicles sold in 2017 were 111 grams per km, compared to 110 grams in the previous year. This is the first increase since 1995. Diesel production is one of the reasons for these changes. Diesel vehicles can emit up to 20% less CO_2 per km, and this mutation is one of the reasons for this increase.

The analysis of new vehicle emissions in Europe carried out by the Jato Dynamics institute reveals no other conclusion: 118.1 grams of CO_2 per km in 2017, against 117.8 g / km in 2016. This is a very disturbing trend that is moving Europe further and further away from the European Commission's target of 95 g / km on average by 2021 for new vehicles. But the return of the gasoline engines is not the only reason for this increase. The explosion in sales of SUVs, which are more powerful and heavier, is another key reason. SUV vehicles represent 30% of total vehicle sales in Europe in 2017, contributing significantly to this increase.

The improvement of technologies and motors, particularly electric motors, is necessary to achieve this goal 2021. However, sales of SUVs are struggling to take off, despite its advertisement campaigns: Renault Zoe, the best-selling electric vehicle in Europe, has reached sales level of only 30,000 units in 2017. Manufacturers' emissions (see figure 8) give some idea of the efforts required, although the good sales of Toyota due to success of its hybrid vehicles (300 000 units sold) is an interesting benchmark of a possible change of trend.

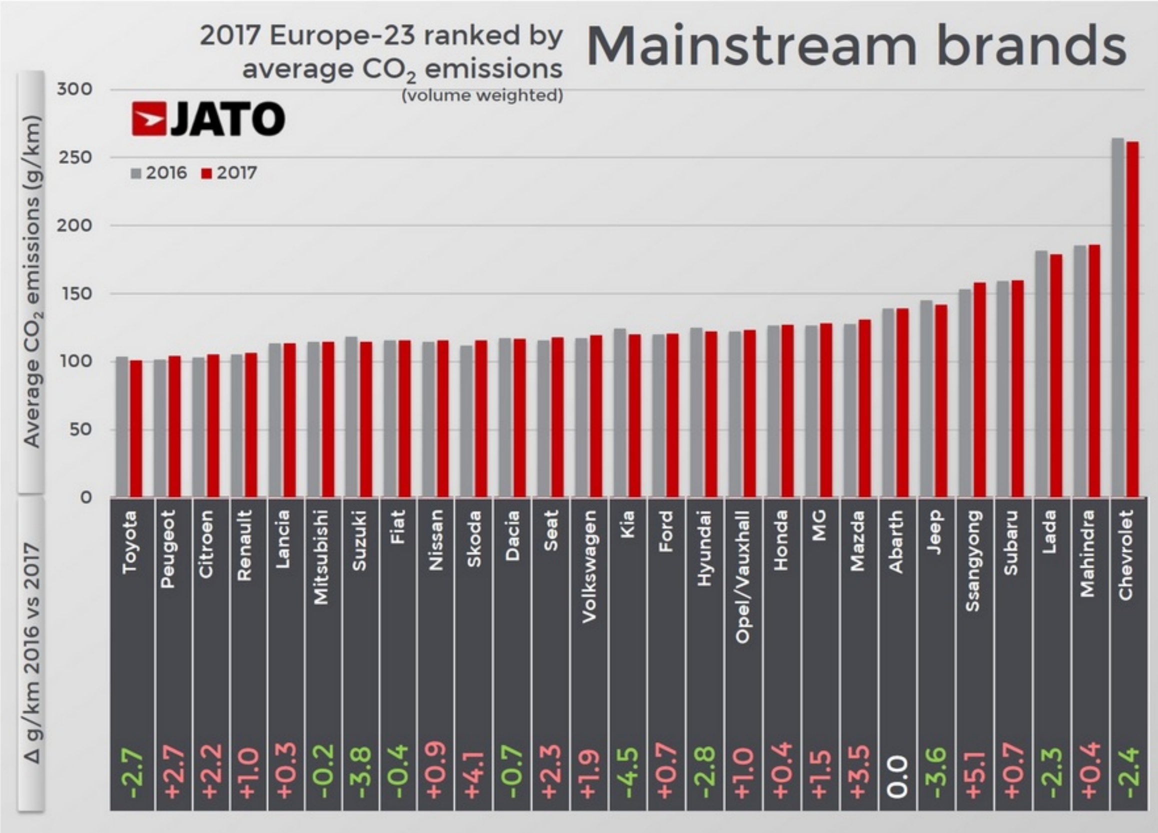


FIGURE 8. EMISSIONS OF CAR MANUFACTURERS IN EUROPE, IN 2016 AND 2017

Source: Jato Dynamics, 2018 - https://www.jato.com/brands-average-co2-emissions-110-130-g-km-counted-73-european-car-regs-2017/

TEXT BOX 4

State and non – state actors are implementing several initiatives for supporting government policies and actions on energy efficiency and decarbonising fuel.

For example:

• The Global Fuel Economy Initiative (GFEI) is supporting countries to put in place fuel economy strategies. The main ambition is to achieve an average improvement across all vehicles by 50% by 2050 (30% improvement of new car fuel economy, worldwide, by 2020 and 50% by 2030). The GFEI's campaign – '100 for 50by50' – was developed to gather new country commitments to the improvement in fuel economy. Currently, GFEI is supporting over 70 countries and the target is to get commitments on "50 by 50" mission from 100 countries.

• Global Macro-Roadmap (GMR) has proposed milestones as shown below to be considered as fleet averages for the concerned vehicle sector. For cities, the proposal suggests Zero Emission Zones (ZEZs), followed by Zero Emission Cities (ZECs), for both air pollutants and GHGs. Front-runners (leading cities) will aim for 2025 or 2030 as can be seen from the examples of Copenhagen and Oslo who have already committed to zero carbon by 2025. The recent announcements by France and the United Kingdom to ban the sales of petrol and diesel cars by 2040 also set important precedents for the transition to ZECs.

• The C40 Clean Bus Declaration of Intent was officially announced in March 2015. The main goal of this initiative is to incentivize and help manufacturers and other stakeholders, such as multilateral banks, develop strategies to make clean bus technologies more affordable for cities. Currently, the 23 C40 signatory cities have committed to having over 40,000 buses (out of a total fleet of 166876) operating via clean technologies by 2020. Estimates suggest that, if these cities reach their 2020 clean bus targets, it would result in a cumulative 880,500 tons per year in GHG savings.

• The Electric Vehicles Initiative (EVI) announced a new campaign in 2017 called EV 30@30 to speed up the deployment of electric vehicles and target at least 30 percent new electric vehicle sales by 2030.

• The International Zero-Emission Vehicle Alliance (ZEV Alliance) is a partnership of governments acting together to accelerate the adoption of zero-emission vehicles (electric, plug-in hybrid, and fuel cell vehicles). The main objective is to accelerate the adoption of zero-emission vehicles. The target is to ensure that all passenger vehicle sales in their jurisdictions ZEVs by no later than 2050.

• US Smartway Initiative which is launched by the United States Environmental Protection Agency (EPA) has about 3,600 North American companies in the partnership. It helps companies identify and select more efficient partners i.e. freight carriers, transport modes, equipment, and operational strategies to reduce operational costs and improve supply chain sustainability. Since 2004, SmartWay has helped its partners save 215.4 million barrels of oil- equivalent and about $29.7 billion on fuel costs.

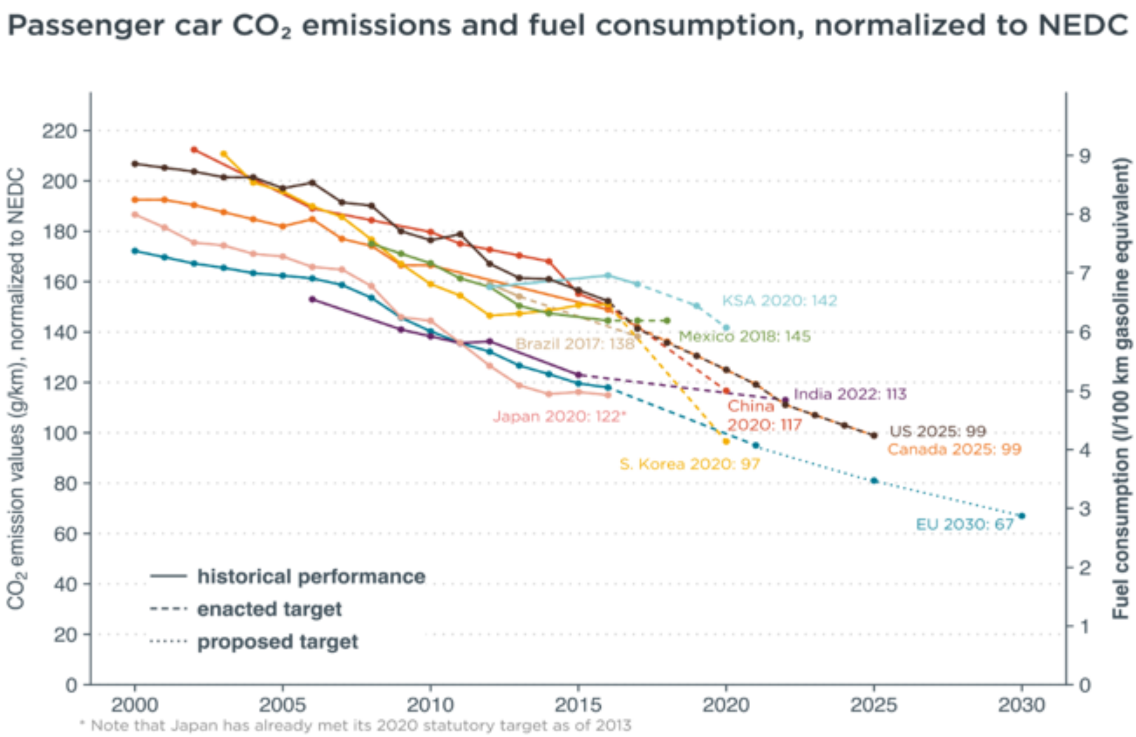


FIGURE 9. PASSENGER CAR CO_2 EMISSIONS (FUEL ECONOMY)

• L'initiative étasunienne Smartway, lancée par l'Environmental Protection Agency (EPA) des États-Unis, regroupe environ 3 600 entreprises nord-américaines. Il aide les entreprises à identifier et à sélectionner des partenaires plus efficaces, comme les transporteurs de fret, les modes de transport, les équipements et les stratégies opérationnelles, afin de réduire les coûts opérationnels et d'améliorer la durabilité de la chaîne d'approvisionnement. Depuis 2004, SmartWay a aidé ses partenaires à économiser 215,4 millions de barils d'équivalent pétrole et environ 29,7 milliards de dollars en coûts de carburant.

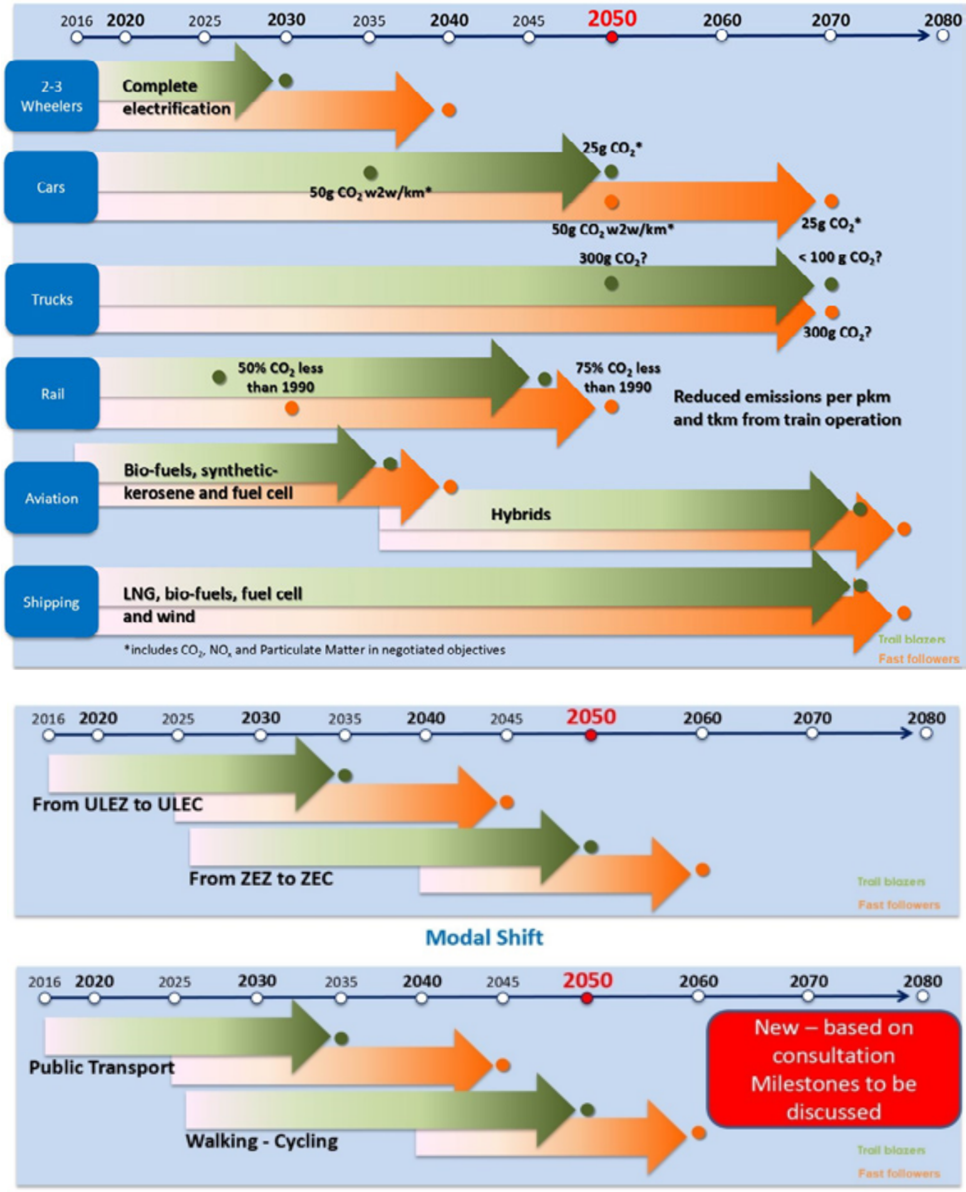


FIGURE 10. GLOBAL MACRO ROADMAP CONSULTATION TARGETS

CONCLUSION

Road transport carbon emissions are the result of a complex mix of human behaviour, economic growth, public policy and transport regulations. Overall, the global road transport carbon emissions have increased when compared with 2000 levels. The rapid increase in the travel demand (growing in non-OECD countries), modal-structure (shift towards energy-intensive modes, especially in non-OECD countries), energy intensity (minor improvement due to new technologies) and high carbon content of fuels (lack of penetration of low carbon fuels) interacted to determine overall increase in global road transport carbon emissions.

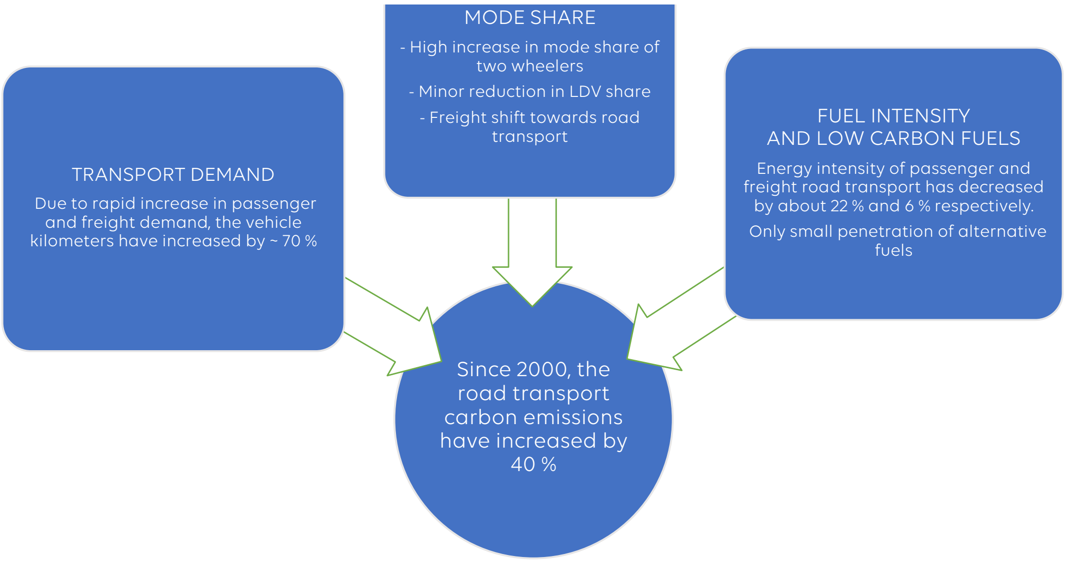


FIGURE 11. TREND IN ROAD TRANSPORT (2000 TO 2015)

The large differentiation among road transport emissions trends between individual modes and countries underscores the necessity of a heterogeneous approach to tackling current and future road transport sector emissions worldwide. Policy responses have been successfully implemented in OECD and non-OECD countries, demonstrating the potential of the road transport sector to contribute to rapid steps toward decarbonization on a global scale. However, there is no silver bullet to decarbonize road transport sector, instead, it is a range of strategies and initiatives that must be embraced in a comprehensive manner covering all modes of transport. A typical road transport low-carbon policy response includes a combination of 'Avoid' strategies, which reduce the need to travel (e.g. transport demand management); 'Shift' strategies, which move transport trips to more efficient modes (e.g. public transport improvements); and 'Improve' strategies, which increase the efficiency of existing trips (e.g. fuel economy standards).

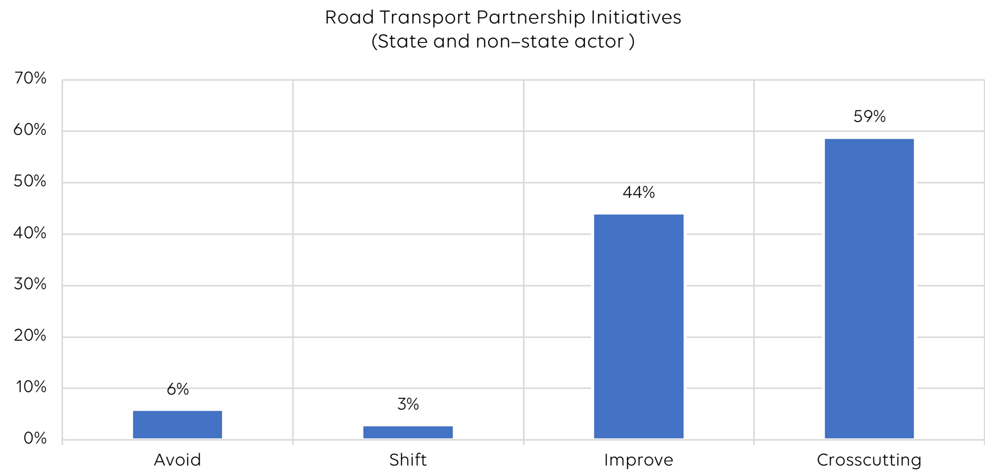


FIGURE 12. AVOID-SHIFT-IMPROVE INITIATIVES

Currently, road transport is one of the fastest growing sub-sectors in the economy-wide emissions indicating that the policies, measures and non-state actor initiatives over the past decade h**ave only been marginally effective**. An immediate lack of emission performance does not in itself suggests failure. However, as the best practice examples illustrate - policies, measures and non-state actor initiative's **effectiveness are increasing over time due to better awareness and capacity.** The role of the non-state actors in this transformation (especially in setting agenda) has been critical.

• To date, transport sector mitigation efforts have relied heavily on the technological transformation (i.e. 'Improve' measures)[36] . However, the non-state actor initiatives were more balanced (since not subject to the same political constraints as state-actors), promoting all three instruments of low carbon road transport thereby filling a critical gap.

• Non-state actors have financed the development of nearly one-quarter[37] of total transport sector carbon emissions quantification methodologies and tools to ensure that the action on transport and climate change is not held back by the absence of tools to analyse transport interventions for their climate impact.

• Recently, several countries and companies have set ambitious targets for the reduction of the carbon emissions from the transport sector, however, globally, there is a complete lack of transparency on the progress towards transport sector targets. Non-state actors play an essential role in reviewing voluntary pledges, measuring, verifying and communicating transport sector emission impacts outside the UNFCCC (sometimes even in enforcement as in Dieselgate).

• Many transport interventions (especially avoid and shift related) take longer to deliver first results due to slow turnover of stock and infrastructure and the huge sunk costs in the present transport system. By limiting future infrastructure deployment for carbon-intensive modes and by prioritising infrastructure for low carbon modes, the carbon trajectory can be lowered while at the same time enhancing the co-benefits and lowering the overall cost of the infrastructure. There is an increasing recognition that low carbon measures within the transport sector could be successful if widely supported by state and non-state actors, with strong political leadership and private sector commitments and if implemented at scale.

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ANNEXURE - GLOBAL AND REGIONAL INITIATIVES

	AVOID	SHIFT	Improve	CROSS CUTTING	CROSS-SECTORAL
"30 BY 30" RESOLUTION	Y		Y		
21ST CENTURY TRUCK PARTNERSHIP			Y		
BELOW 50			Y		
C40 CITIES CLIMATE LEADERSHIP GROUP (C40)				Y	Y
C40 CLEAN BUS DECLARATION			Y		
CARBON NEUTRAL CITIES ALLIANCE				Y	Y
CARING FOR CLIMATE					
CCAC: DIESEL INITIATIVE			Y		Y
CIVITAS				Y	
CLEAN AIR ASIA				Y	Y
COMPACT OF MAYORS				Y	Y
COVENANT OF MAYORS				Y	Y
"DO THE RIGHT MIX"-SUSTAINABLE URBAN MOBILITY CAMPAIGN	Y	Y			
DECARBONISING TRANSPORT INITIATIVE				Y	
EST INITIATIVE				Y	
ECOMOBILITY ALLIANCE				Y	
EUROCITIES				Y	Y
ELTIS, THE URBAN MOBILITY OBSER-VATORY				Y	
EV100			Y		
GLOBAL FUEL ECONOMY INITIATIVE (GFEI)			Y		
GLOBAL GREEN FREIGHT ACTION PLAN				Y	
GLOBAL STRATEGY TO INTRODUCE LOW-SULFUR FUELS AND CLEANER DIESEL VEHICLES (THE "GLOBAL STRATEGY")			Y		
GREEN FREIGHT ASIA NETWORK (GFAN)				Y	

	AVOID	SHIFT	Improve	CROSS CUTTING	CROSS-SECTORAL
GLOBAL MACRO ROADMAP				Y	
ICLEI - LOCAL GOVERNMENTS FOR SUSTAINABILITY				Y	Y
INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION (ICCT)			Y		
INTERNATIONAL ZERO-EMISSION VEHICLE ALLIANCE (ZEV ALLIANCE)			Y		
INITIATIVE FOR CLIMATE ACTION TRANSPARENCY				Y	Y
IPIECA			Y		Y
ITS FOR CLIMATE				Y	
KYOTO DECLARATION FOR THE PROMOTION OF ESTS IN CITIES				Y	
LCTPI LOW CARBON TRANSPORT FUELS			Y		
LCTPI: LOW CARBON FREIGHT				Y	
LEAN AND GREEN				Y	
LOGISTICS CARBON REDUCTION SCHEME (LCRS)			Y		
LOW CARBON ROAD AND ROAD TRANSPORT INITIATIVE (LC2RTI)			Y		
LOW CARBON VEHICLE PARTNERSHIP (LOWCVP)			Y		
LOW EMISSIONS DEVELOPMENT STRATEGIES (LEDS) GLOBAL PARTNERSHIP				Y	Y
MOBILISEYOURCITY				Y	
MARKET PLACE OF THE EUROPEAN INNOVATION PARTNERSHIP ON SMART CITIES AND COMMUNITIES				Y	Y
PARIS DECLARATION ON ELECTRO-MOBILITY ON CLIMATE CHANGE			Y		
PARTNERSHIP ON SUSTAINABLE, LOW CARBON TRANSPORT (SLOCAT)				Y	
PARIS PROCESS ON MOBILITY AND CLIMATE (PPMC)				Y	
PARTNERSHIP ON TRANSPARENCY IN THE PARIS AGREEMENT				Y	Y
PRIVATE FINANCING ADVISORY NETWORK (PFAN)			Y		
PUBLIC TRANSPORT DECLARATION ON CLIMATE LEADERSHIP (UITP)		Y			

	AVOID	SHIFT	Improve	CROSS CUTTING	CROSS-SECTORAL
REN21 (RENEWABLE ENERGY POLICY NETWORK FOR THE 21ST CENTURY)			Y		
SIDEWALK CHALLENGE	Y	Y			
SMARTWAY				Y	
SCIENCE BASED TARGETS				Y	Y
SUSTAINABLE MOBILITY FOR ALL (SUM4ALL)				Y	
TAXI4SMARTCITIES			Y		
TRANSPORT DECARBONISATION ALLIANCE (TDA)				Y	
THE CLIMATE REGISTRY				Y	Y
THE PRINCE OF WALES'S CORPO-RATE LEADERS GROUP (CLG)				Y	Y
TRANSFORMATIVE URBAN MOBILITY INITIATIVE (TUMI)				Y	
UITP DECLARATION ON CLIMATE CHANGE LEADERSHIP				Y	
UNDER2 COALITION				Y	Y
UNEP PARTNERSHIP FOR CLEAN FUELS AND VEHICLES (PCFV)			Y		
URBAN ELECTRIC MOBILITY INITIA-TIVE			Y		
URBAN ELECTRIC MOBILITY INITIA-TIVE (UEMI)			Y		
URBAN-LEDS PROJECT				Y	Y
VERRA (FORMERLY VERIFIED CAR-BON STANDARD)				Y	Y
WBCSD URBAN INFRASTRUCTURE INITIATIVE (UII)				Y	Y
WE MEAN BUSINESS COALITION				Y	Y
WORLD CYCLING ALLIANCE (WCA) AND EUROPEAN CYCLISTS' FEDERA-TION (ECF) COMMITMENT	Y				
WWF CLIMATE SAVERS				Y	Y
ZEV ALLIANCE			Y		

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Transport in Sweden, the automotive sector's transformation is taking shape

In a European context marked by an almost universal increase in CO_2 emissions from motor transport, Scandinavia, and especially Sweden, is demonstrating that this evolution is not inevitable by showing a significant and regular decrease in emissions. In this chapter we have tried to analyse the factors related to this evolution, and in particular the links between the Swedish government's long-standing and very proactive policy on carbon taxation, and the strategy of the economic players. This case study ultimately attempts to answer this important question: to what extent are the elements of success of the Swedish stakeholders' strategy sustainable and reproducible?

Head editor • *Climate Chance Observatory*

CONTENTS

1 • ACCELERATED DECLINE IN DOMESTIC TRANSPORT EMISSIONS

Since 2007, Sweden has seen its carbon emissions decline continuously. Statistics from the Swedish Environmental Protection Agency, as part of its 2017 annual inventory of greenhouse gas emissions, in accordance with the UNFCCC guidelines, show that this trend continued in 2016 with a 1.99% decrease in emissions compared to 2015 (see Figure 1).

Carbon Dioxide (CO_2) (kt)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
NATIONAL TOTAL (excluding LULUCF, excluding international transports)	52,816.5	50,723.1	47,153.2	52,927.3	48,970.0	46,403.6	44,769.0	43,225.7	43,385.6	42,568.0
Domestic transport, total	20,970.1	20,350.7	20,037.2	20,090.1	19,643.6	18,418.9	17,910.6	17,703.8	17,661.7	16,686.1

FIGURE 1. EVOLUTION OF OVERALL CO_2 EMISSIONS AND THOSE FROM TRANSPORT BETWEEN 2007 AND 2016 IN SWEDEN

Source : Statistical database sweden, SMED on behalf of the swedish environmental protection agency, 2017

This decrease was as a result of the domestic transport sector in particular, which recorded a significant decrease of 5.6% in CO_2 emissions between 2015 and 2016. This drop in overall emissions from motor transport comes after a decrease of 11.76% between 2010 and 2016 (see Figure 2). This sustainable trend and its remarkable acceleration over the last year is nevertheless occurring against a background of stable, or even increasing, transport emissions in Europe, reaching 1029 $MtCO_2eq$ in 2014 and 1048 $MtCO_2$ in 2015.

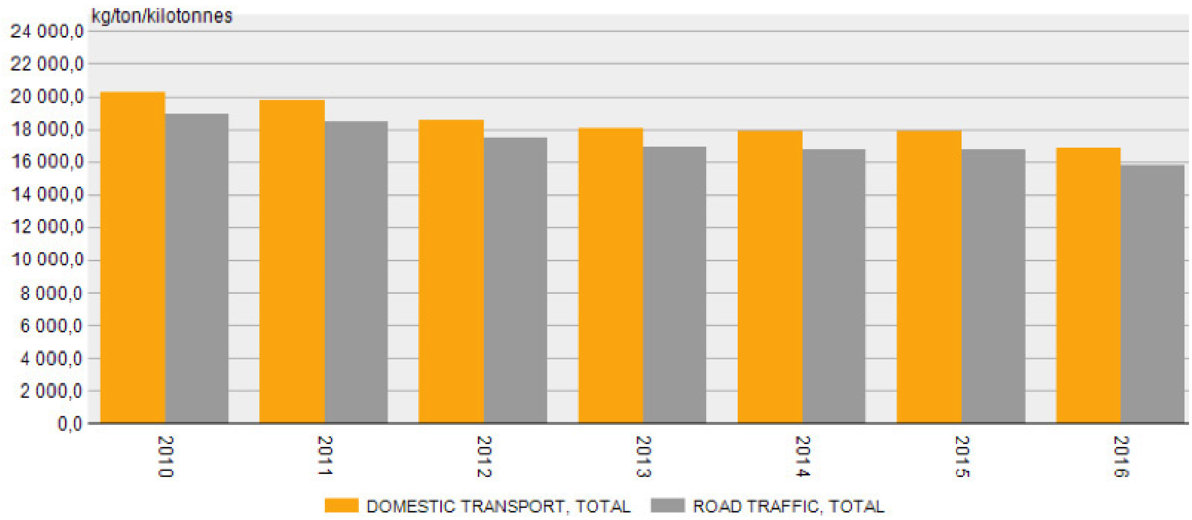

FIGURE 2. GREENHOUSE GAS EMISSIONS FROM TRANSPORT IN SWEDEN, 2010-2016

Source : Swedish Environmental protection agency, 2017

Sweden's distinctiveness comes first and foremost from the State's proactive policy to abandon fossil fuel energy, from ecological taxation and from the overall transformation of the transport sector, a coherent action which was analysed in particular in 2017 in the report "CO_2 emissions and economic incentives" for the Nordic Council of Ministers (Jordal-Jorgenssen et al., 2017). It would not make much sense to analyse the actions developed by non-state stakeholders, if we did not first focus on the policies being pursued by the Swedish state.

2 • THE SWEDISH STATE'S PROACTIVE POLICY IN THE FIELD OF TRANSPORT

Le gouvernement suédois est l'un des premiers pays au monde à utiliser la fiscalité écologique co The Swedish government is one of the first countries in the world to use ecological taxation as a cornerstone of its environmental policy (Millock, 2010). **Thus, Sweden was the first country to introduce a carbon tax in 1991 at EUR 27 per tonne of CO_2 (Akerfeld & Hammar, 2015). This tax is now 96€/tCO_2, making Sweden the country with the highest carbon tax (I4CE, 2017).**

This significant taxation is combined with ambitious objectives to reduce its greenhouse gas emissions. The Swedish government announced the "Fossil Free" initiative within the framework of COP21 in 2015, in order to highlight the drive of national companies, institutions and organisations to contribute to the climate effort. The ambition is to make Sweden the first country without fossil energy. **The Free Fossil Declaration states that the stakeholders signing up to it must carry out concrete and coordinated actions with a view to reducing their national greenhouse gas emissions:**

"The ambition is to make Sweden one of the first fossil free welfare countries in the world. Not only because it is our responsibility to future generations, but because it makes economic sense. To achieve this, all actors in society must work actively to reduce emissions. Fossil Free Sweden is open to all actors who support the declaration drawn up for the initiative."

Source : Free fossil declaration, government officies of sweden, 2015

In its third biennial report to the UNFCCC, the Swedish government sets a goal of a 70% reduction in GHG emissions in 2030 compared to 2010, excluding domestic air traffic (Ministry of the Environment & Energy, 2017).

In the transport sector, **in 2016, the Swedish government set out an infrastructure investment plan for the 2018-2029 period** totaling SEK 622.5 billion (EUR 60.9 billion) for the entire plan (Swedish Transport Agency, 2017). While the investments are mainly aimed at maintaining existing rail and road infrastructure, the Swedish government has six main objectives: accessibility, environmentally-friendly mobility, development of regional networks, security, entry of the Swedish transport network into the EU market and, the sixth objective that must be highlighted, reducing the environmental and climatic impact of the transport sector:

"Consequently the Government proposes several policies and measures aimed at the transport sector in the budget proposal for 2018. Lately the local climate investment program has granted support for infrastructure for the introduction of electrical vehicles [...] a bonus/malus-system for new light vehicles and an emission reduction obligation for petrol and diesel to further spur emission reductions in the transport sector. Moreover, the Government proposes that a tax on air travel will be introduced with the aim to reduce the climate impact of aviation."

Source : Sweden's third biennial report under the UNFCCC, Government officies of sweden, 2015

In addition to this infrastructure investment plan, Sweden is pursuing its policy of developing mobility backed by biofuels, including air transport with the first test flight of an ATR plane using biodiesel in 2017. According to EurObserv'ER's analysis, "Sweden is not exactly aiming to totally eliminate fossil fuels in transport. The definition given by the commission of experts in charge of implementing this plan is "establishing a fleet of vehicles independent of petroleum fuel mainly fueled by biofuels and electricity" (EurObserv'ER, 2017).

3 • A REDUCTION OF EMISSIONS BACKED BY THE DEVELOPMENT OF THE BIOFUELS SECTOR

• THE RISE OF THE SWEDISH BIOFUELS SECTOR •

Definition and categorisation of biofuels

The first generation of biofuels refers to those derived from food products (more precisely the storage organs of crops: seeds, beet roots, oil palm fruits). They are therefore in competition with agricultural products dedicated to human and animal nutrition. There is a difference between the petrol (bioethanol) sector based on the industrial fermentation of sugar contained in sugary and starchy plants (wheat, maize), and the diesel (biodiesel) sector obtained from vegetable oils or animal fats converted into fatty acid esters (fatty acid methyl esters - FAME). Within the "oil" sector, it is important to note the increasing share of biodiesel obtained by hydrotreating oils (HVO), which, despite its superior properties and increasing use of waste oils and residues and agro-industrial waste, remains a first generation biofuel.

Second generation fuels are derived from the transformation of lignocellulose from agricultural residues (straw), forest residues (woods, leaves, and so on) or from dedicated energy crops with high biomass productivity (short-rotation coppice). This transformation is thermo-chemical to obtain a synthetic biodiesel (the Biomass to Liquid or BtL industry), or biochemical to produce ethanol. These biofuels are still in the development phase and their commercialisation should be confirmed by 2020.

Source : Ministère Français de la transition écologique et solidaire

TEXT BOX 1

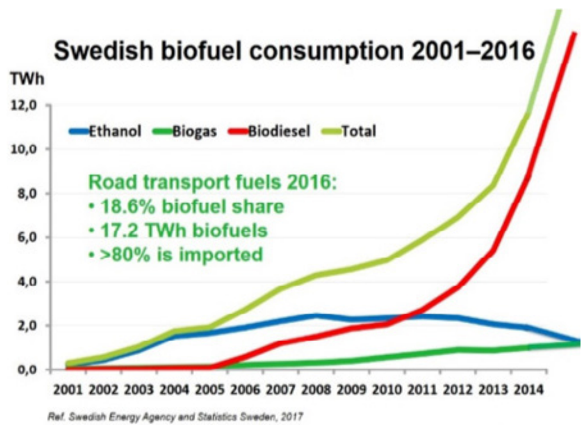

FIGURE 3. BIOFUEL CONSUMPTION IN SWEDEN, 2001-2016

Sources figures 3 et 4 : SVEBIO, 2017

The consumption of biofuels in Sweden has increased significantly in recent years (see Figure 3). While ethanol and biogas consumption has been slowly developing, biodiesel consumption has increased exponentially. Comparison of the fuels used (see Figure 4) confirms the growing trends of Swedish consumption of biofuels in 2016 (1.32Mtoe, +23.77% compared to 2015), with, notably, an increase in biodiesel consumption (1.096 Mtoe, +34.36%), far ahead of the declining consumption of ethanol (0.11Mtoe, -21.68%) and biogas fuels (0.11Mtoe, -1.83%) (EurObserv'ER, 2017).

In 2016, this impressive increase in the consumption of biofuels, especially biodiesels, largely accounts for the observed reduction in CO_2 emissions from motor transport, as the evolution of the car fleet and changes in behaviour do not appear to have had a significant impact on emissions at this stage.

According to the Swedish Energy Agency, the representation of biofuels in the sector reached 19% in 2016 compared to 15% in 2015 and should continue to increase in the coming years to reach a volume of nearly 2 million tonnes in 2020, 80% of which being biodiesel. The biofuels sector benefits from the strong responsiveness of Swedish economic players, with massive investments in advanced biofuel production units, including biodiesel (see Figure 6). Their organisation within a very active professional association, the Swedish Association of Bioenergies (Svebio), bears witness to this.

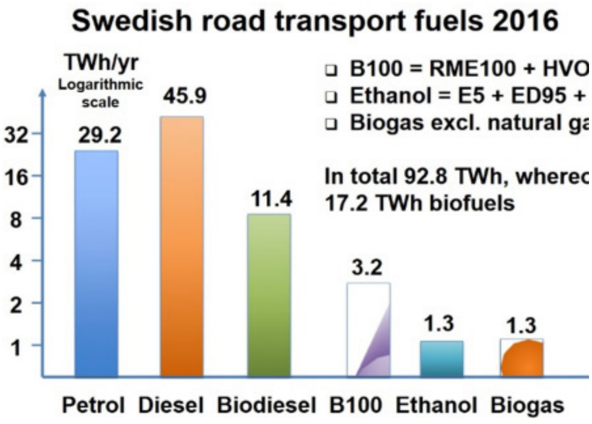

FIGURE 4. COMPARISON OF THE FUELS USED IN SWEDISH ROAD TRANSPORT IN 2016.

In 2017, Svebio noted a certain stagnation in the development of traditional biofuel production units, with only three new ethanol production centres by St1, Agroetanol and SEKAB, two new FAME biodiesel units by Perstorp, and a few additional Biogas centres by E.ON, Swedish Biogas, Strängnäs, and so on. Conversely, the organisation recorded a significant wave of new pilot and commercial projects for HVO biodiesel (hydrotreated vegetable oils) for which, the Swedish oil company Preem, for example, has planned a 600% increase in its production capacity to reach 1.3 million m^3 in 2023. This increase in projects shows the extension of the HVO market, and the erosion of the quasi-monopoly of the Finnish company Neste which currently represents more than 50% of world capacity with 2.5 million tonnes (Greenea, 2017).

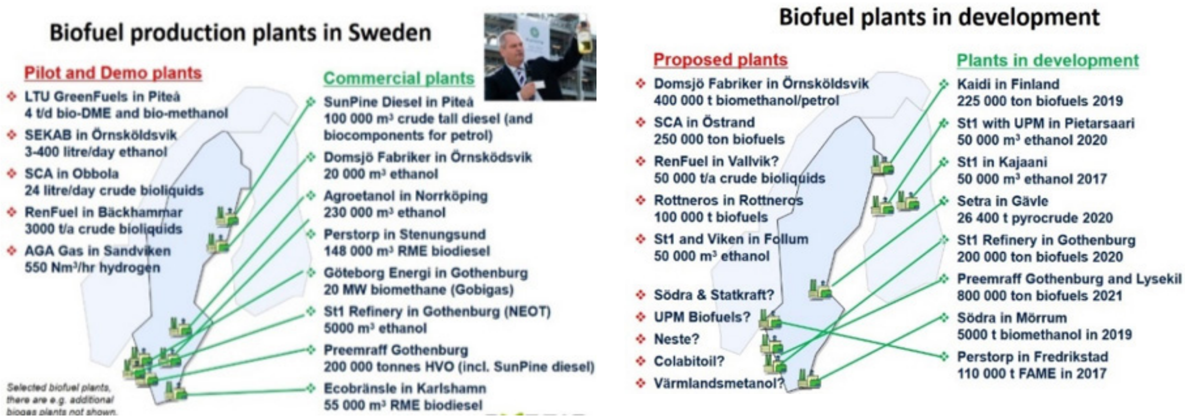

FIGURE 5. DEVELOPMENT OF BIOMASS PRODUCTION PROJECTS IN SWEDEN.

Source : SVEBIO, 2017

HVO biodiesel from Neste

The Finnish company Neste has developed and patented a process for the hydrogenation of vegetable oils for the production of biodiesel. As in the traditional process, it is a catalytic reaction. The difference is that, this time, the oil is brought into the presence of hydrogen, instead of methanol which is used for other types of biodiesel and in particular for FAME biodiesel. The product obtained is a synthetic diesel fuel that, technically, can be used at almost 100% in a conventional engine. This technology also makes the final product more stable with a higher combustion index. It also avoids the co-production of glycerin, for which there are not always local outlets.

Source : Eurobserv'er, 2017

TEXT BOX 2

• HVO BIODIESEL ENABLING EUROPEAN TARGETS TO BE EXCEEDED • The rapidly expanding sector enabled the country to achieve the 30% renewable energy threshold for final transport energy consumption in 2016, an increase of 6 points compared to 2015 (Eurostat), and more than three times the European target of 10% renewable energy in the transport sector by 2020.

This performance by Sweden is linked to the specific accounting procedure that HVO partly benefits from as an advanced fuel. The raw materials used are still mainly of an agricultural nature and similar to those used for first generation FAME-type biodiesel. However, it allows for the more attractive use of agricultural residues and waste, especially those mentioned in Directive 2009/28/EC (Annex IX). HVO biodiesel operators using these raw materials are considered to be using advanced biofuels by the European Union, so they can claim double accounting of their real energy value and contribute doubly to the achievement of European objectives.

The consumption of biofuels in Sweden complies with EU directives

The development of the European Union's market for biofuels for transport is currently, and will be until 2020, governed by Directive 2015/1513 of 9 September 2015, the so-called CASI Directive, which amends Directive 98/70/EC on the quality of petrol and diesel fuels; and Directive 2009/28/EC on the promotion of the use of energy from renewable sources. These two guidelines have been revised to recognise and mitigate the detrimental impact that first generation biofuel production can have on the environment, due to greenhouse gas emissions associated with cases of indirect land-use change (ILUC), that is, the conversion of farmland to crops for biofuel production. Thus, the share of agrofuels from these dedicated crops (cereals, starch-rich plants, sugary plants and oilseeds) has been capped at 7% of total energy consumption in transport. The EU, however, is aiming for a 10% renewable energy target in the transport sector by 2020. The remaining 3% can therefore be obtained through electric transport, or through the use of so-called "advanced" biofuels produced from specific raw materials that can claim double accounting (Annex IX).

Respect of European criteria is a requirement to be able to count biofuels in the share of renewables in total energy consumption and to be able to benefit from public support schemes. It results in the issuing of "certificates". They stipulate, on the one hand, a reduction of at least 50% of GHG emissions from biofuels compared to fossil fuels, and 60% for installations after 5 October 2015. On the other hand, they render ineligible biofuels derived from raw materials coming from land of high value in terms of biodiversity or with a large carbon stock (primary forests, wetlands, peatlands, and so on). Finally, Member Countries have an obligation to carry forward GHG emissions related to indirect changes in land use according to the type of plants used. On the other hand, it considers those from "advanced" biofuels, derived from the raw materials mentioned in Annex IX, as nil due to the current lack of data for their estimation.

Source : 2017 Biofuel barometer, european directives

TEXT BOX 3

This high-quality biodiesel has the other advantage of being able to be used in a high concentration in diesel engines, or even in pure form since the marketing of HVO100 in 2015. To promote their consumption, Sweden applies different tax exemption rates according to the type of biofuel (ethanol, FAME or HVO), and according to the content of the mixture in biofuels. HVO 100 is thus 100% exempt from both the carbon tax and the energy tax, and its price remains competitive with that of fossil diesel. The total consumption of HVO doubled between 2015 and 2017 to reach 73% of liquid biofuel shipments (see Figure 5), making it the third most consumed fuel in Sweden, behind petrol and diesel.

Year	FAME (m^3)	HVO (m^3)	Ethanol (m^3)
2011	250,563	44,943	619,161
2012	294,009	131,085	607,208
2013	292,895	289,095	354,569
2014	431,015	438,813	326,560
2015	422,590	704,687	263,446
2016	341,203	1,203,680	213,446
2017	330,847	1,441,780	205,367

FIGURE 6. DELIVERED VOLUME OF RENEWABLE FUELS IN SWEDEN (M^3), 2011-2017

Source : Swedish Institute of petroleum and biofuels, 2017

Conversely, FAME biodiesel and bioethanol production are gradually decreasing and only accounted for 17% and 10% respectively in 2017. This industrial strategy is consistent with the reduction of biofuels from dedicated agricultural production encouraged by the European Union.

4 • AN ENVIRONMENTAL ASSESSMENT OF SWEDISH BIOFUELS: STILL TO BE CLARIFIED

The Swedish strategy, however, raises questions in relation to the foreseeable evolution of the world market for biofuels intended in particular for transport in the European Union. A study commissioned by the European Commission in 2015 shows that biodiesels from vegetable oils (rapeseed, palm, soybean, sunflower) may ultimately be more emitting than conventional diesel, by including the "*ILUC emission*" factors due to land use changes caused by their production - up to three times more in the case of palm oil. 70% of these emissions are attributed to peatland degradation in Malaysia and Indonesia caused by palm plantations.

Faced with the environmental problems caused by the massive production of biofuels, the European Union wants to support "*advanced*" and second generation biofuels, by gradually reducing the authorised ceiling for the inclusion of biofuels from agricultural products (see Text box 3), which is currently under discussion in the context of the revision of the 2030 energy package.

To reduce the impact of its production, **the Swedish biofuel industry is relying on the definition given to a number of materials considered by Swedish national authorities to be residues that theoretically do not compete with food production.** It falls within the scope of "*advanced*" biofuels and is therefore not subject to the same traceability requirements. This is the case, for example, with Palm Fatty Acid Distillate (PFAD), a processing residue derived from the refining of crude palm oil. The bulk of biofuel production destined for the Swedish market remains linked to European production. However, there was a significant increase in imports of raw materials for HVO biodiesel from Indonesia and Malaysia between 2015 and 2016 (see Figure 8), which corresponds to the imports of PFAD.

	Sweden	Europe excluding Sweden	Indonesia	Malaysia	USA	Other	Total
2011	32,452	2,489					**34,941**
2012	59,021	55,946	8,502	6,734	9,399		**139,602**
2013	101,836	189,354	49,239	24,892	25,876		**391,196**
2014	93,405	286,729	56,110	17,874	28,994		**483,111**
2015	99,664	429,792	86,107	20,310	96,031		**731,904**
2016	46,269	573,770	182,596	73,104	142,134	344,999	**1,220,738**

FIGURE 7. HVO USED IN SWEDEN, BY COUNTRY OF ORIGIN, SINCE 2011, VOLUME (M3)

Source : Swedish energy agency, 2017

In 2016, for the first time since 2011, no palm oil as such was used for the production of HVO biodiesel. PFAD, in contrast, represented 22% of the raw materials in 2016, whereas it was absent in 2015.

	Tall oil	Vegetable or animal oils	Slaughter-house waste	Palm oil	Animal fat	Rapeseed	PFAD	Corn	Other	Total
2011	32,452	2,489	0	0	0	0				**34,941**
2012	64,589	30,034	29,743	15,236	0	0				**139,602**
2013	100,113	5	201,409	74,131	15,540	0				**391,196**
2014	106,419	108,447	168,708	73,984	25,554	0				**483,111**
2015	112,114	227,009	220,713	106,418	0	65,651				**731,904**
2016	84,283	459,473	234,807	0	0	101,416	276,593	43,240	20,926	**1,220,738**

FIGURE 8. RAW MATERIALS FOR THE MANUFACTURE OF HVO USED IN SWEDEN, SINCE 2011, BY VOLUME (M^3)

Source : Swedish energy agency, 2017

Substituting PFAD for palm oil allows Sweden to reduce the emissions ascribed to indirect changes in land use, since suppliers are not subject to the obligation to carry forward the emissions due to the production of agricultural residues and waste, nor are they subject to the same traceability requirements.

Le Palm Fatty Acid Distillate (PFAD)

Considered a residue, Directive 2015/1513 considers it to have "estimated indirect land-use change emissions of zero". This is in line with Neste, which believes that the demand for PFAD will not put additional pressure on arable land in favour of palm oil, but rather will incentivise improvements in processes to reduce its quantity. This position relies on its low concentration in crude palm oil of around 4 to 5%, and on its market price, which is 15% lower than that of a tonne of refined palm oil (Zero and Rainforest Foundation Norway, 2016). Neste has nevertheless announced that it will implement the same level of traceability for PFAD as for palm oil by 2020.

TEXT BOX 4

However, the evolution of the PFAD market shows that the increasing exploitation of agricultural residues gradually gives them a similar impact on land use. **Added to the opportunities that PFAD also finds in the food and cosmetics industry, its use in the transport sector could increase economic pressure on land, making its use a temporary solution.** With 57 million tonnes of palm oil produced by Malaysia and Indonesia in 2017 (USDA), their potential for producing PFAD can be estimated at nearly 2 million tonnes. This is just 8 times the current Swedish demand for PFAD in 2016, which could develop very quickly. **It is therefore very clear that use of this resource is not reproducible on a large scale.**

The Norwegian government, reconsidering its emissions related to palm oil production, has moreover re-designated PFAD as a "co-product" in 2017, and Sweden should do the same from 2019. It will thus fall within the scope of the sustainability criteria of the directive, which impose stricter reporting of emissions and traceability on operators, and it will lose the benefit of double accounting. The debate over redefining the status of PFAD could lead to the reclassification of other derived products such as technical corn oil (TCO), which is considered to be a residue from the production of ethanol used for the production of biodiesel, or Tall Oil Fatty Acid (TOFA), a residue from paper production.

The special attention given by Sweden to biodiesel, especially HVO, therefore allows it to comply, for the time being, with European requirements and to have a leading role in reducing emissions and in energy transition in the transport sector. **The environmental impact of the Swedish strategy nevertheless remains to be clarified and will depend heavily on future developments in the local production share of second-generation biofuels.** In the long term, the evolution of the Swedish car fleet could play a bigger role in Sweden meeting its emission reduction targets.

Relocating the production of raw materials in the long term

Sweden currently occupies 0.39 hectare per capita of the available arable land in the world, which should be compared to the available arable land per capita on a world scale, which was estimated at only 0.194 ha in 2016 by the Food and Agriculture Organization. Of these 0.39 ha, approximately 0.05 ha represent land dedicated to Swedish biofuel production, of which almost 80% (or about 0.04 ha) of this land is located abroad (see Figure 7). To meet these challenges in part, the Swedish Knowledge Center for Renewable Transportation Fuel, a research institute funded by the Västra Götaland region and by industrialists and universities active in the biofuels sector, believes that the country is in a position to relocate, by 2030, the production chain of around 20 TWh, that is the total current biofuel consumption in Sweden. They believe that this can be done without indirect land-use changes, but rather through the increased use of residues from agriculture, forestry, industry and so on, and also (a point on which the report is very proactive) by reconverting land currently used for alcohol and meat production, which represent the majority of land use in Sweden. Sweden could thus triple its timber harvest and continue to sustainably manage its resources (De Jong-Akselsson et al, 2017).

In order for Sweden to be a pioneer country in the transition to a fossil fuel free transport sector, we need to include a high realisation of domestic biofuel production. We should not shift a dependency on imported fossil fuels, for a dependency on imported biofuels.

Source : Biofuels from agricultural biomass - Land use change in swedish perspective, the swedish knowledge centre for renewable transportation fuels, sweden, 2017

TEXT BOX 5

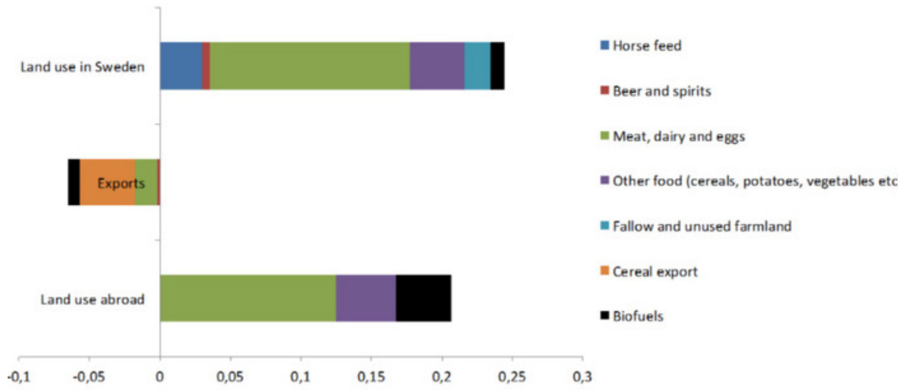

FIGURE 9. ARABLE LAND USED BY THE AVERAGE SWEDE, IN SWEDEN AND ABROAD (IN HECTARE PER PERSON)

Source :Swedish knowledge centre for renewable transportation fuels, 2017

5 • THE EVOLUTION OF THE SWEDISH CAR FLEET

• AN INCREASE IN THE FLEET DOES NOT LEAD TO AN INCREASE IN EMISSIONS •

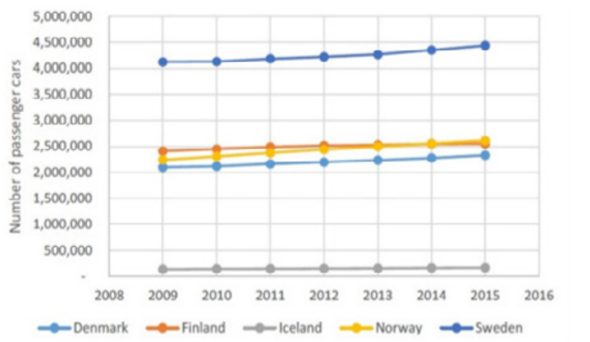

FIGURE 10. EVOLUTION OF THE CAR FLEET IN THE NORDIC COUNTRIES FROM 2009 TO 2015

The trajectory of carbon emissions by Sweden's transport sector shows a steady decline since 2007. However, as stated in the report "CO_2 emissions and economic incentives" for the Nordic Council Minister (Jordal-Jorgensen et al., 2017) on motor transport, the Swedish car fleet has increased since 2009 from 4.30 million cars in 2009 to 4.67 million in 2015, an increase of 9.11% (see Figure 10). This increase, which is greater than in the rest of Scandinavia, can be partly explained by the lack of registration taxes linked to the size and power of vehicles, unlike its Nordic neighbours (Swedish Transport Agency, 2017).

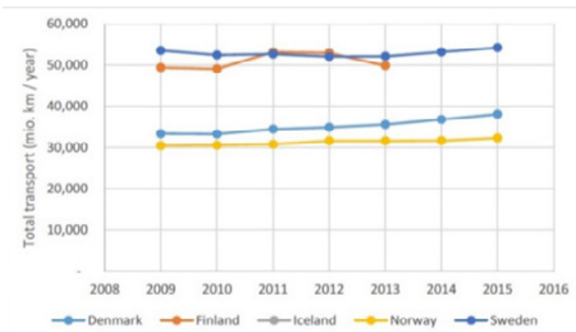

FIGURE 11. EVOLUTION OF DISTANCES TRAVELLED BY CAR IN THE NORDIC COUNTRIES BETWEEN 2009 AND 2015

Added to this is the significant increase in car travel in Sweden (see Figure 11), from 63.28 million km in 2008 to 65.82 million km in 2015 (TRAFA, 2017). This occurred despite the initiatives of several Swedish communities, such as Stockholm and Gothenburg, to introduce a "congestion" tax to reduce urban traffic.

The reduction of CO_2 emissions in Sweden can therefore be explained primarily by the improvement of vehicles, new types of engine and the use of biofuels, rather than by changes in behaviour. This improvement in vehicle quality is particularly striking in Sweden, according to the European Environment Agency and the European Commission services (see Figure 12), which shows the considerable progress made since 2000 in reducing CO_2 emissions per kilometre.

The figures provided by Bil Sweden, the Swedish trade association for manufacturers and importers of cars, trucks and buses, show a significant evolution of the car fleet between 2016 and 2017 with 379,393 new cars in 2017, an increase of 1.9% compared to 2016, the highest figure ever recorded (Bil Sweden, 2018).

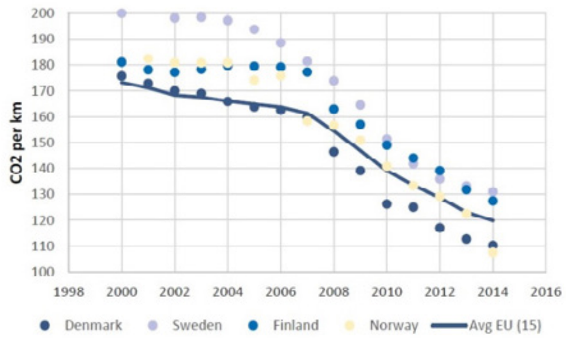

FIGURE 12. CO_2 EMISSIONS PER KILOMETRE OF NEW CARS IN THE NORDIC COUNTRIES BETWEEN 2000 AND 2014

Sources Figures 10 à 12 : Nordic Council of ministers, 2007, P39 et 43

As in the rest of Europe, there has been a significant decrease in the share of newly registered diesel cars with a decrease of 4.3% in 2017. This type of car thus represents only 49.1% of the new car fleet compared to 52.3% in 2016 (Bil Sweden, 2018). However, the decline in the diesel fleet did not lead to an increase in CO_2 emissions in 2016 (diesel vehicles are less CO_2 emitting than petrol vehicles), as was announced on the European scale by the Jato Dynamics Institute. This institute attributed the increase in average CO_2 emissions of new cars from 117.8 g/km in 2016 to 118.1g/km in 2017 to the drop in diesel car numbers (and the increase in SUV vehicles) (study presented at the Geneva Motor Show in March 2018).

• SUPER "GREEN CARS" AND THE PROACTIVE INDUSTRIAL POLICY OF THE MANUFACTURERS •

The distinctive position of Sweden regarding diesel biofuels, as well as the use of a significant proportion of ethanol in petrol vehicles, help explain this result, but the rapid development of the sale of "super green cars", a label given to vehicles that emit less than 50gCO_2/km, should also be taken into consideration.

In 2017, a record year of new vehicle sales, super green cars accounted for 5.1% (19,000 cars) of new cars registered, an increase of 1.6 percentage points over 2016 (3.5%). Bil Sweden's 2018 forecast, confirmed so far by the first quarter sales results, provides for 34,000 "super-clean" cars to be newly registered in 2018, representing 9.4% of the total expected market of 360,000 new cars. **This change in the Swedish car fleet through the rapid deployment of "super-green cars" is a major hope factor for the reduction of CO_2 emissions, which shows the importance of a synergy between government financial incentives and the dynamism of manufacturers.**

Super-Green Cars and the Ecological Taxation of Vehicles in Sweden

The 2011-2018 Super-Green Car Premium Ordinance, which came into force in January 2012, aimed to promote the sale of energy-efficient and low-emission cars, which refers to cars that emit less than 50g of CO_2 per kilometre (2016 threshold). The "super-green car premium" consisted of a purchase bonus of SEK 20,000 (EUR 1,960) for a hybrid vehicle and SEK 40,000 (EUR 3,920) for electric vehicles. The Swedish government has decided to replace this premium from 1 July 2018 by a bonus/malus system for passenger cars, which extends to low-emission buses and trucks.

The malus applies to both diesel and petrol vehicles and continues for the first three years on the road. It is 82 SEK/gCO_2/km (8 €/gCO_2/km) between 95 gCO_2/km and 140gCO_2/km, then rises to 107 SEK/gCO2/km (10.50 €/gCO_2/km). The bonus for zero emission vehicles is progressive up to 60 gCO_2/km to reach SEK 10,000 (EUR 977), within a limit of 25% of the purchase price of the vehicle. The aim is to reach an average of 95 gCO_2/km for all vehicles on the road by 2022, which corresponds to the threshold to be reached by 2021 set by the European Union.

TEXT BOX 6

At this stage, super green cars do not yet represent a significant share in the Swedish car fleet, and the weak development of the electric car (only 0.8% of the Swedish car fleet in 2015) raises questions about the adequate development of the electrical charging infrastructure throughout Sweden. Gas-powered vehicles are falling (1.4% in 2015), while hybrid power still accounted for only 2% in 2015. According to the report "CO_2 emissions and economic incentives", if the average age of the car fleet in Sweden was 10.2 years in 2014, lower sales prices for electric vehicles (EUR 30k on average), simple hybrids (EUR 25k on average) and hybrid plug-in vehicles (EUR 38k on average) would actually make it possible to envisage the rapid renewal of the fleet with less emissive vehicles, even though the average prices of petrol cars (EUR 12k) and diesel cars (EUR 23k) would remain stable (Jordal-Jorgensen et al., 2017, p.47-50).

Volvo's commitment to the end of internal combustion engines

Swedish vehicle manufacturer Volvo announced in early July 2017 that all new models it would release from 2019 would be fully electric or hybrid. Models launched before this date will still have combustion engines. It will gradually introduce models ranging from all-electric to hybrids with rechargeable batteries into its range. Volvo's strategy must be related to that of its owner, the Chinese manufacturer Geely, which aims to develop an offer of electric vehicles in China, and to open an innovation centre for their development in Gothenburg, Sweden.

TEXT BOX 7

Other research initiatives to be closely monitored have also been launched, such as "electric light trucks" by the truck manufacturer Scania, in partnership with Siemens, Volvo and Alstom (ICCT, 2017) to move towards zero-emission freight transport. The November 2017 Global Electric Trucks Market Research Report states that while the global electric truck industry suffered a slowdown in 2016, the overall trend over the past four years is positive (+55% between 2013 and 2016,+ USD 41 million) and it should maintain its momentum in the coming years to reach USD 159 million in 2021. A technologically complementary infrastructure is important for these plans to convert to electric power. For example, Scania, in partnership with Siemens, is developing "e-highway" highway electrification projects (Siemens, 2015) based on the omnibus model. The University of Lund has initiated the "Elonroad" project (ICCT, 2017) on the basis of a conductor rail that allows electric cars and trucks to recharge while driving.

• SUV'S CONTRASTING WITH THE POSITIVE TRAJECTORY OF THE SWEDISH CAR FLEE • The massive development of the market for sport utility vehicles (SUVs), which mainly have diesel engines, is a worrying signal that increases the risks of increased CO_2 emissions and microparticles cancelling out the positive effects of "super-green cars". The Volvo XC60 SUV was the best-selling car in Sweden in 2017, with 21,419 models sold (Statistica, 2018). Foreign manufacturers have also established themselves on the Swedish market with, for example, the Volkswagen Tiguan SUV, which is the 7th best-selling car in the country.

The growing SUV market in Europe

Between 2006 and 2016, sales of SUVs in Europe grew by 300% (from 1.12 million vehicles in 2006 to 3.88 million in 2016). This trend seems to be confirmed in the coming years as Jato Dynamics' forecasts predict 6 million SUVs will be registered in 2020 (Jao Dynamics, 2017, p. 4). With only 3.9% of SUVs benefitting from electric engines in 2017, the increase in SUV sales contributed to the recorded increase in European CO_2 emissions of at least 0.1% over the 2016-2017 period.

TEXT BOX 8

CONCLUSION

In conclusion, Swedish national policy has given stakeholders in the various road transport sectors a strong incentive base for their investments in technological innovation in both vehicle and biofuel performance. However, the Swedish situation presents contradictory trends, as evidenced by the development of the diesel SUV market and the increase in car journeys, despite traffic limitations in urban areas. The issue of accounting for CO_2 emissions related to biofuel consumption in Sweden will be central in the coming years. Changes to supply (especially for palm oil) and relocation of production will be essential choices if Sweden is to demonstrate the sustainability of its biofuel-based strategy for reduction of emissions, which for now appears to be a temporary solution and one which is not reproducible on a global scale. How these contradictory trends develop will determine whether Sweden will be tomorrow's showcase for climate-compatible road transport.

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Make road transport a solid pillar in combatting greenhouses gas emissions

Following the example of the international community in response to the climate challenge, the South African government aims to reduce national carbon dioxide (CO_2) emissions by 34% in 2020 and 42% by 2030. The transport sector, one of the main contributors to atmospheric pollution and the 2nd emitter of CO_2, is one of the key sectors of this fight. In road transport in particular, which includes freight and passenger transportation, the technologies currently used and the modes of operation are not in line with these objectives and must be reconsidered.
In this regard, the state and municipal authorities have taken various initiatives to meet the targets set. The materials used and the modes of operation are constantly being re-examined. Indeed, support for the renewable energy sector through investment programmes and substantial subsidies is expected to make compelling contributions to reducing greenhouse gas (GHG) emissions in the South African road transport sector. This paper presents the evolution of emissions in the road transport sub-sector in South Africa, the explanatory factors for the trends observed and the mitigation actions being carried out.

Head editor • **ALIOUNE THIAM** • *Transport and Urban Mobility Expert, Eco-Access*

CONTENTS

1 • THE ROAD TRANSPORT SUB-SECTOR IS A KEY CONTRIBUTOR OF EMISSIONS IN THE SECTOR

• THE EMISSIONS OF THE ROAD TRANSPORT SUB-SECTOR ARE STRONGLY CORRELATED WITH DIESEL CONSUMPTION • The changing trend in emissions from the road sub-sector is relatively similar to that of the transport sector taken overall. This is hardly surprising since it represents over 99% of the emissions of the sector. Their respective evolutions over the 2002-2017 period are very close: 3.02% for road transport compared to 3.21% for the transport sector.

From year to year, a slight progression can be observed, except in 2016 when reductions were recorded for both the transport sector in its entirety (-4.43% in comparison to 2015) and the road transport sub-sector (-5.11% relative to 2015).

The evolution of road transport emissions follows the same rhythm as emissions from fossil fuels, notably diesel. This is the case for the 2002-2017 period where an increase of over 6.59% in diesel emissions was observed. The recent reductions recorded were made possible by a steep reduction of $_2$ from the combustion of diesel, i.e., a fall of 2.59% between 2014 and 2015, and 10.66% between 2015 and 2016 (Enerdata, 2018).

		2002	2006	2010	2012	2014	2015	2016	2017
Transport (fuel consumption)	Quantity (in Mt)	36.97	44.45	48.14	51.20	52.93	53.73	51.36	54.80
	Evolution average/ year	-	5.06%	2.08%	3.17%	1.69%	1.53%	-4.43%	6.70%
	Evolution 2002-2017	3.21%							
Road transport	Quantity (in Mt)	34.29	41.28	45.02	47.69	49.43	50.12	47.56	49.80
	Evolution average/ year	-	5.10%	2.26%	2.96%	1.82%	1.40%	-5.11%	4.71%
	Evolution 2002-2017	3.02%							
Petrol consumption	Quantity (in Mt)	22.51	24.54	24.85	26.02	24.15	25.50	25.47	26.25
	Evolution average/ year	-	2.27%	0.31%	2.35%	-3.58%	5.57%	-0.12%	3.06%
	Evolution 2002-2017	1.11%							
Diesel Consumption	Quantity (in Mt)	11.76	16.71	20.16	21.66	25.25	24.60	21.97	23.38
	Evolution average/ year	-	10.52%	5.17%	3.72%	8.28%	-2.59%	-10.66%	6,41%
	Evolution 2002-2017	6.59%							
GPL Consumption	Quantity (in Mt)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Gas consumption	Quantity (in Mt)	0.0000	0.0000	0.0000	0,0004	0.0004	0.0004	0.0004	0.0004

FIGURE 1. EVOLUTION OF CO_2 EMISSIONS FOR TRANSPORT, 2002-2017

Source: ENERDATA

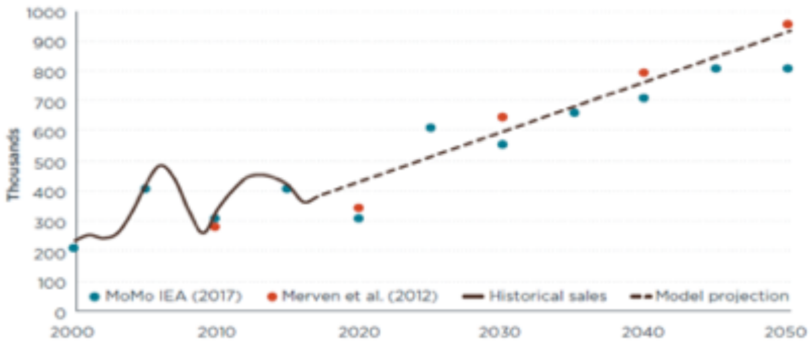
Fossil fuel emissions from the road sector represent on average 99.89%, with a contribution of 44.79% for gasoline and 55.11% for diesel. Thus, the near-constant, slight and progressive rise noted over the 2012-2017 period is primarily the result of a variation in emissions of these two sources of transport energy (diesel and gasoline) at a time when alternative energies (electric, biofuels and compressed natural gas) have made only a very timid market appearance since 2012 (Enerdata, 2018).

• THE REASON: URBAN FORMS AND MODES OF TRAVEL • Economic success naturally leads to perceptible social changes in ways of life, behaviour and actions. South Africa, the biggest economy on the continent, is no exception to this rule. **A high rate of motorization has hit the country not only because population income levels are rising, but also due to the strong presence of the automobile industry (Volkswagen, Toyota, etc.)**. Competition in the domestic automobile market has made cars easily accessible to individuals.

Evolution of the car fleet

In 2015, manufacturers sold over 400,000 cars on the South African market and exported over 300,000 units. One of the two largest industries on the market, Toyota, is well positioned in the production of small and medium-sized cars as well as sports utility vehicles (SUV). These types of vehicles, preferred by South Africans, produce 43% of the CO_2 emissions of the fleet. The high emissions for SUVs is explained by the fact that 62% of these vehicles run on diesel (Posada, 2018). In 2015, the share of petrol/diesel consumed by the transport sector was 43.8% (GIZ, 2017).

In line with the International Energy Agency's Mobility Model (MoMo), the projections for 2050 predict a rise in sales of new vehicles of 600,000 to 800,000 units. Equally, estimations by the University of Cape Town show a rise in sales of between 640,000 and 950,000 units from 2030 to 2050. Based on these two projections, the fleet is set to rise by 4% in 2020 then fall by 2.1% until 2050 (Posada, 2018).



MODÈLE ICCT: PROJECTION DE CROISSANCE DU PARC AUTOMOBILE PARTICULIER

TEXT BOX 1

Moreover, the urban form of South African cities characterised by non-dense residential zones and urban sprawl is also an explanatory factor of the rise in motorization rates. The apartheid had very negative effects, especially on the transport sector. **Indeed, public transport development was constrained by the problem of population cohabitation, meaning that the services provided were aimed at a fixed group of customers**. This meant that individual modes of transport became preferable and their growth has made a large impact on environmental pollution levels through the amount of greenhouse gases produced.

2 • THE STATE'S INTENTIONS ARE STILL RATHER TIMID

The South African authorities have long claimed to have real ambitions to combat climate change through programmes and policies to reduce greenhouse gas (GHG) emissions at a national level. However, beyond the few legislative and regulatory measures, meaningful actions are late arriving.

• ADHERENCE TO INTERNATIONAL AGREEMENTS AND A FOCUS ON THE MOST POLLUTING SECTORS • In its Defined National Contribution (DNC), the State claims to be pressing hard on the "Transport" lever to contribute effectively to the global effort to reduce GHG emissions across the world. It is now committed to **mobilizing financial means to invest in the promotion of sustainable transport systems that respect the environment.**

Since the Copenhagen negotiations in 2009, the option of **a reduction in domestic emission of greenhouse gases of 34% in 2020 and 42% by 2025** (GIZ, 2017) was adopted by the South African government, through its DNC.

• PARTICULAR ATTENTION PAID TO THE TRANSPORT SECTOR, ESPECIALLY ROAD TRANSPORT, THROUGH INNOVATIVE MECHANISMS • Through the "National Climate Change Response Paper (NCCR)", South Africa intends to **improve the energy efficiency of its vehicle fleet, thus encouraging green technologies such as electric and hybrid vehicles.** The goal set by the state authorities is to put **3 million electric cars into circulation by 2050 and make an investment programme worth 6.5 million Rands available to green technology industries** (GTS, 2016-2021).

One of the key battles planned by South Africa is **the introduction of environmental taxation which will make it one of the first countries in Africa to implement such a reform.** This taxation system aims, among other things, to reduce the use of fossil fuels such as petrol, diesel and gasoline in the energy production and transport sectors (Letter on Environmental Taxation Reform Policy, in 2006). **The law is currently being considered by the National Assembly, and the Government plans to implement this reform at the beginning of 2019.** These fiscal measures promote the development of renewable energy sources (electric, biofuel, biogas, ethanol, etc.) which could be used in the road transport sub-sector with the view to achieving an energy transition.

Beyond the legislative and regulatory measures, the public authorities have put in place **programmes aimed at developing renewable energy sources for use in the road transport sector.**

For example, the decarbonisation initiatives in the goods transport domain. **The introduction of a system of road tolls** by the South African government is another example. Across the whole network, **16% of roads are equipped with toll booths**. The reduction of traffic on these roads resulting from the cost of the toll would result in a gain for the country in terms of reducing CO_2 emissions in the road sub-sector (SANRAL, 2013).

3 • REMARKABLE CONTRIBUTIONS FROM PRIVATE ACTORS

Although road transport emissions continue to dominate the transport sector overall, we should note that the quantity of CO_2 it generates has remained stable in the last few years with slight, and occasionally negative, variations. This situation is in many ways down to private initiatives.

• HIGH PARTICIPATION OF NON-STATE ACTORS • This stability is mainly the result of a **high participation by non-governmental organizations, local authorities and private firms in supporting the South African government in meeting its environmental objectives.**
In this sense, the actions of **transport and logistics companies** can be cited as an example, notably **their participation in the process of decarbonizing freight road transport**. Many of the South African leaders in transport logistics have invested in the country's environmental policy. **The TIMBER programme (Technology, Infrastructure, Market Changes, Behaviour, Energy and Regulation),** launched in 2011 with the aim of reducing carbon emissions in goods transportation, benefits from the participation of many private sector firms**.**

Some initiatives by private companies

In 2014, Barloworld introduced the "Green Trailer" in its fleet. This technology operates at a constant speed of 70 to 80km/h, thus saving 11% in fuel for the firm and reducing CO_2 emissions by 66.8 tonnes over a period of 10 months (Henderson, 2014).

In the forestry and wood industry, the use of "Smart Trucks" is growing. These trucks are generally long and have more capacity to transport heavy loads than any other vehicle. The use of this type of equipment will reduce the amount of freight traffic and, at the same time, increase the productivity of the sub-sector. In environmental terms, South Africa will benefit from a significant reduction in its carbon emissions and avoid wear on its roads. With a futuristic design, they possess in particular improved safety systems and simulation and assessment tools (analysis of the impact on road wear; GeoTrack to simulate the manoeuvrability of vehicles at low speeds, etc.). The transportation and logistics operators (Unitrans, Barloworld, Buhle Betfu and AB InBev) have noted a reduction of 39% in accidents and an average decrease of 12% in fuel consumption thanks to increased payload efficacy enabling a reduction of over 84,000 trips per year (Infrastructure Naws, September 2018). South Africa today has over 300,000 registered heavy goods vehicles, of which 270 are intelligent.

Since 2014, Imperial Logistics has been running the "Extra Distance" campaign: the title refers to the difference between the number of kilometres driven by the vehicles and the number of kilometres required in optimal planning conditions. "The first indications are that eliminating the extra distance in their Gauteng and Cape Town fleet could lead to a reduction in costs of 29 million rands" (De Swardt, 2014).

ECO_2Fleet is a data collection and reporting service on the management of vehicle fleets based on the internet. Its purpose is to measure carbon emissions and provide emissions declaration data in conformity with the international norms. Nearly 500 companies (40,000 vehicles) are currently subscribing to this product. "A client reports that by using this data, the average fuel consumption per vehicle for the 900 vehicles of the firm has fallen below an average of 10 litres/100km for the first time, an improvement that could reach 30% for some vehicle categories" (De Swardt, 2014).

TEXT BOX 2

The congestion of the main traffic arteries in the large South African cities is the result of a sharp rise in vehicle numbers. Truck commercial speeds have fallen as a consequence, resulting in an excessive fuel consumption, and in parallel, an accumulation of greenhouse effects in the atmosphere. An estimation of the costs induced by this situation shows an extra 4 billion rands (or 10%) are added to the total costs of domestic externalities (Tom Tom, 2014).

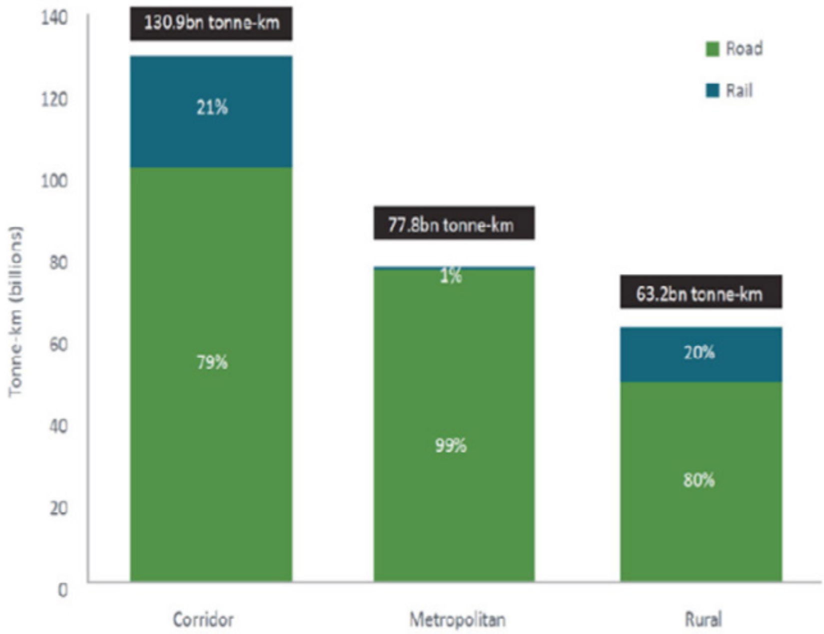


FIGURE 2. DISTRIBUTION OF THE GENERAL DEMAND FOR FREIGHT IN SOUTH AFRICA IN 2014

Source: Havenga, JH, et al. (2016), Logistics Barometer South Africa 2016, Stellenbosch University

In 2013, according to WWF, 45% of national freight emissions came from the use of two key corridors (Johannesburg-Durban and Johannesburg-Cape Town).

An intermodal terminal project in the cities with high freight activity was then implemented for a better interconnection of logistics hubs through strong incentives to shift part of the road freight over to rail. Road traffic benefits in this case from improved fluidity and the decarbonisation initiatives in goods transportation in the country are thus advanced.

As such, in 2012 **Transnet** introduced a new generation of locomotives in the rail freight sub-sector ("**Rail freight**"). The deployment of this new technology across the **Transnet** network demonstrates the firm's ambitions to be more respectful of the environment in its operations. With this initiative, the rail sector will be well equipped with modern technologies to fulfil its role in the context of a modal shift from road freight to rail.

A desire to promote intermodality

"The construction of three intermodal terminals to connect the three main industry centres - Gauteng, Durban and Cape Town - through an intermodal solution could reduce the transport costs of the 22.9 million tonnes of intermodal freight identified on the two key corridors generating externalities, leading to savings of 1.2 million tonnes of CO_2". Havenga et al. (2015)

TEXT BOX 3

Today, the actors **in transport logistics, particularly private firms, are particularly invested in the idea of intermodality**. This vision was taken into consideration in the **Annual Shareholders Agreement between the National Department of Public Firms (the shareholders) and the national railroad operators. Moreover, the signing in 2013 of a protocol agreement between the largest South African logistics service providers (Imperial Logistics, Barloworld Logistics and Transnet)** further promotes this desire to integrate the different modes.

Finally, the actions outlined above demonstrate an emerging awareness among non-state actors in South Africa for the need to combat climate change. **In the road transport sector, the involvement of several transport and logistics operators has led to an increased coherence between their programmes and those enacted by the government. However, so far we are seeing more intention than action for the latter, the measures aimed at the private sector provide little incentive to participate fully in the challenge to reduce national greenhouse gas emissions.**

However, the actions of these private firms are strengthened by the initiatives of local authorities involved in implementing sustainable urban mobility policies.

4 • STRATEGIES OF LOCAL PUBLIC ACTORS

In 2015, South Africa had 55 million inhabitants, or 0.8% of the global population. The country is the most urbanised in Africa, with 64.8% of its inhabitants living in urban zones in 2015, and over 2/3 in 2017 (GIZ, 2017). The urban structure is characterised by low population densities in the cities (Johannesburg: 2,894 habitants/km²; Cape Town: 1,560 habitants/km², in 2016) and a sprawling urban growth over large distances making urban mobility an important issue for individuals.

• COORDINATING THE TOWN PLANNING AND TRANSPORT POLICIES TO REDUCE THE NUMBER OF JOURNEYS • The urban sprawl is a legacy of the Apartheid regime, which encourages residents to use private cars. In the large agglomerations both in the north and south of the country, an effort to develop inland connections and mobility followed by a harmonious expansion of the peripheries and the creation of more or less complete centralities, has had the effect of bringing economic activities and households geographically closer. Thus, the urban morphology has undergone significant transformations in which transport and mobility have played a major role (Vermeulin and Kahn, 2010).

Overview of CO_2 emissions by transport mode: a great potential for reduction remains untapped

The contribution of cars to carbon dioxide emissions in urban passenger transport is very high in South Africa. In 2014, Gauteng recorded 68.8% of CO_2 emissions from the use of private cars (PCs), 22.8% of emissions by taxis, 3.2% of emissions by buses and 0.1% by BRT (Bus Rapid Transit). For Cape Town, 86% of emissions came from PCs, 7% from minibus taxis, 4% from buses and 1% from motorcycles (WWF, 2016).

In 2014, the number of passenger kms by mode was distributed at 45% for private cars (PCs), 50% for buses and 5% for rail (GIZ, 2017). In view of this modal distribution and the contribution potential of each mode (Cf. figure 3), it is evident that the GHG reduction potential remains significant.

TEXT BOX 4

3 - https://www.acare4europe.org/sites/acare4europe.org/files/document/volume1.pdf
4 - https://www.acare4europe.org/documents/delivering-europe%E2%80%99s-vision-aviation-sria-2017-update
5 - L'ICSA est composée de l'Aviation Environment Federation (AEF), Carbon Market Watch, EDF Environmental Defense Fund, the International Council on Clean Transportation (ICCT), Transport & Environment, et le WWF.

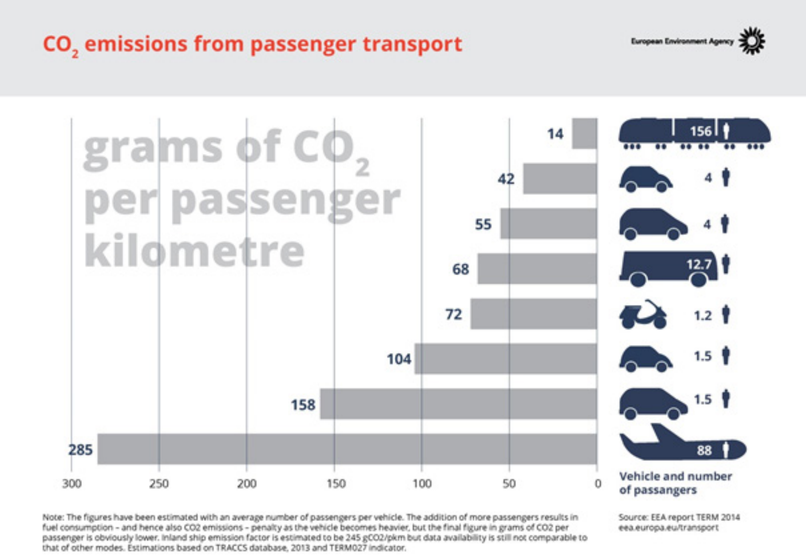


FIGURE 3. COMPARISON OF EMISSIONS PER MODE

Source: European Environment Agency (http://www.consumovehicular.cl/)

• PARADIGM CHANGE FOLLOWING THE URBAN PUBLIC TRANSPORT CRISIS: TOWARDS SUSTAINABLE MOBILITY • The issue of sustainable development is a national priority and should be addressed at all levels of the territory. **At a local level, the municipalities, whose powers were expanded in 1995, integrate sustainability in all of their urban planning and development actions.**

However, this has not always been the case. During the Apartheid era, high levels of discrimination in favour of the "whites" and to the detriment of the "non-whites" was a feature of public transport on the central and pericentral routes. Indeed, black, mixed-raced and Indian workers would travel on networks often managed by illegitimate authorities with few resources, such as the Bantustans. Following this, to fill the gap left by these companies, small private operators of buses and taxis-minibuses began to appear in the townships. Their number grew rapidly and their network spread in the neighbourhoods.

This artisanal, informal and sometimes very turbulent sector spread across all the South African cities when the Apartheid regime fell. The African National Congress (ANC), who came to power in 1994, had no choice but to accept the major role this informal sector played in urban passenger transport, and was forced to delay addressing the sensitive issue of regulating the sector (Vermeulin and Kahn, 2010). In this atmosphere of public transport deregulation and disorganization, the use of non-sustainable transport modes grew, as did their negative impacts on people's lives.

Today, urban mobility governance is a pressing topic in South African towns. Many municipalities have opted to create a local regulating authority for urban transport. (Vermeulin and Kahn, 2010)

As such, in 2003, **the municipality of Thekwini in Durban was the first to introduce an Urban Transport Organizing Authority (UTOA)**, an independent body under local government supervision where local elected representatives make up the governing board. The municipality then became an "arbitrator" of the urban transport sector and was thus obliged to let go of its own bus company (Bellangère et al., 2004).

This phase of introducing the UTOA was followed by the privatization and externalization of public transport services. However, apart from the transport authorities, the municipalities benefit from a relative control over use of lines since they can attribute national subsidies to operators of their choosing. **Today, with their agendas integrating the environmental aspect, the municipalities are all involved in setting up a sustainable transport system.**

The football World Cup held in South Africa in 2010 helped to accelerate the development of sustainable transport infrastructures in South African cities. The increase in the number of Bus Rapid Transit (BRT) lines and the exploitation of Metrorail and Gautrain buses has provided the

municipalities with a modern image of urban transport. Since then, local authorities have been taking ever more interest in sharing infrastructures and in economic modes that are more respectful of the environment. **In line with this, the town halls have often relied on the support of non-governmental organizations (NGOs) acting to raise awareness, provide advice and strengthen capacity, alongside their financial support.**

• INNOVATIONS IN THE PUBLIC TRANSPORT SECTOR • In all South African cities, taxi-minibuses are the most widely used mode of public transport, while buses and trains are gaining low market shares. **Sustainable urban transport theory stands in opposition to systems dominated by ad-hoc small businesses, which perform badly in terms of accessibility, comfort, reliability, regularity, punctuality and safety. Additionally, the prices charged are not attractive for poor people. Moreover, their vehicle fleets do not conform to new environmental norms that require more energy-saving and less polluting modes of transport.** The age of their fleet increases road danger and atmospheric pollution is harmful to the health of populations living in urban spaces.

South African cities are showing their commitment to "greening" their municipal vehicle fleets. In Gauteng, for example, the use of compressed natural gas (CNG) as a fuel for buses and minibus taxis is already on the rise. This ambition of the South African municipalities thus appears feasible as long as the projected municipal demand for new buses is sufficient to sustain the local manufacture of green buses. Also, the cities are currently engaged in introducing a centralised supply mechanism that could provide bus manufacturers with the necessary guarantees to justify such an investment. One of their concerns is the need to adapt to the different technical requirements in each city as well as to each local political authority (SACN, 2015).

In Johannesburg, Metrobus, as a public urban transport supplier owned by the municipality, committed in 2015 to transforming some of its diesel buses by equipping them with bi-modal fuel tanks, fuel - duel-fuel (DDF), in addition to new acquisitions. It also acquired Euro-5 DDF buses, which are better for the environment in terms of carbon emissions. In all, 150 buses running on compressed natural gas (CNG) are available (50 transformed; 100 new acquisitions). This project required an investment of over 355 million USD for the buses. The supply contract was awarded to Sandown Motor Holdings (Pty) Ltd, a dealer in Mercedes-Benz utility vehicles in South Africa. Moreover, a sum of around 1.67 million USD has been set aside to supply and deliver a compressed natural gas (CNG) service station; this bid was won by NGV Gas (Pty) Ltd.

Compressed biogas and other sources of energy such as electric energy and biofuels should also be adopted to make a significant impact on city pollution. **Many South African municipalities are promoting these types of energy. They are not only better for the environment than gasoline and diesel but also allow for the recycling of household and industrial waste in cities. (SACN, 2015).**

Compressed natural gas (CNG) and biofuels, an important step towards sustainable urban transport

• Compressed natural gas (CNG) channels

Compressed natural gas (CNG) has been used as a vehicle fuel since at least the 1930s. It has recently become profitable on a large scale and it is widely used today. A mix of gas (mainly methane) is extracted, either from dedicated gas wells or alongside petroleum, and is then treated, compressed and consumed in a specially designed engine.

CNG could potentially reduce public transport emissions in South Africa, which would be an important step towards sustainability. **In Gauteng, CNG is already being used as a fuel for buses and public transport (TMS).**

In March 2014, the first public CNG service station in South Africa was ope-

ned in Langlaagte Johannesburg, and other service stations are planned for the near future. Like other substitution fuels, CNG requires a substantial infrastructure: depots must be converted and staff retrained to man and maintain the CNG buses (SACN, 2015).

• Biofuel Channels

Biofuels come in various types such as biogas, listed below, bioethanol and biodiesel. These energies are biological combustibles that have no major impact on the environment. They are part of a class of renewable energy sources that are cleaner than classic fuels. However, although biofuels can be produced through waste treatment, they are generally made from crops with high carbohydrate levels such as sugar cane, sugar beet and starches. This production leads to a reduction in land used for food production and thus leads to food insecurity and sovereignty issues (SACN, 2015)

Recently, South Africa put in place an industrial strategy for biofuels seeking to attenuate the potential impacts on food security by excluding some biofuel crops. It aims to reach a penetration of 2% of biofuels in the national supply of liquid combustibles in the short term. This could be accomplished by using around 1.4% of the arable land of South Africa, of which approximately 14% is currently under-used - mainly in the former homelands (DME, 2007). In practice, this objective has been shown to be hard to attain. (SACN, 2015).

• Biogas Industries

To produce biogas, organic waste is placed in an anaerobic digester containing a specific mix of bacteria (rather than taken to landfill). Over a period of around two weeks and with a minimum of additional inputs, these bacteria decompose the waste into methane and CO_2 in a process similar to that of a landfill site. However, in an anaerobic digester, the process is controlled, faster and allows the gas to be captured, purified, compressed and used. The same process can be used to treat both agricultural and sewer waste. This process used to be standard in many waste treatment plants in South Africa, but many of the digesters used are now in a state of disrepair. A recent study suggested that South Africa could produce around three million cubic metres of raw biogas per day near to urban centres, with municipal solid waste making the largest contributions (EcoMetrix, 2015; SACN, 2015).

The municipality of Thekwini has several projects underway to identify clean development mechanisms that produce biogas from landfill sites, waste water and agricultural effluents. Long term viability is even more important than short term gains and these biogas infrastructures will remain important in the treatment of waste and production of energy. In contrast to all other sources of energy, biogas increases with the population, which is important since not only will population and economic growth lead to a rise in energy demand, but it will also contribute to producing waste and to the pressure on waste water (Greben et al. 2009: 1).

South Africa will benefit from international and national support for biogas. Finland, Austria and the United Kingdom have been the main donors to biogas projects in South Africa, while the World Bank and the Development Bank of Southern Africa (DBSA) have also been closely involved in biogas initiatives. The DBSA wishes to provide financial support to pertinent biogas propositions that will take independent power producers (IPP) in South Africa to a bankable stage. The Energy Department possesses the necessary information on the potential of biogas, the legislative landscape and the intentions of the decisions-makers. Through SANEDI, it carried out research that suggests there are sufficient numbers of potential biomass sources for the production of biogas at a level required for transport. (SACN, 2015.)

TEXT BOX 5

• A GROWING AWARENESS IN CIVIL SOCIETY AND IN THE GENERAL PUBLIC IN FAVOUR OF HYBRID AND ELECTRIC VEHICLES • The use of hybrid and electric vehicles in South Africa, despite the newness of the fleet, demonstrates a rising awareness in civil society and, more generally, of populations experiencing the inconveniences of non-economic and non-environmentally friendly modes of transport such as private vehicles running on petrol or diesel which are still very common.

In 2018, the analysis group Lightstone revealed that only 375 electric vehicles have been sold in South Africa since 2013 (the year electric vehicles were introduced in the national fleet) which represents 0.2% of new registrations over this period. It thus appears that "South Africa is not an early adopter of electric vehicles", compared to Norway, the current world leader with 6.6% of electric vehicles, or 135,000 (Business Tech, 2018).

• LOCAL INITIATIVES WITH STRONG SUPPORT FROM NGOS • The actions of NGOs such as S**ustainable Energy Africa - SEA, World Wildlife Fund - WWF, South Africa Cities Networks – SACN, Greencities, African Association of Public Transport – UATP** and its parent company, **the International Association of Public Transport - UITP, are remarkable in South Africa.** These organizations often take the **role of catalysts in the implementation of sustainable mobility strategies in South African cities.** "*There also exists an emerging non-governmental sector focusing on transport, climate change and the related problems linked to urban design and accessibility, as proven by the* ***Low Carbon Programme on Transport by WWF and the Africa Sustainable Energy Project adopted in many African municipalities all characterised by their desire to promote lower carbon transport systems***" (Cape Town Briefing Paper).

Overview of co-operations between local authorities and NGOs

World Wildlife Fund (WWF) aims to help South Africa transition to a low carbon economy through innovations and transformations. By educating and supporting the South African government, the organization has set an objective to transform the country and ensure that renewable energies are used at 100% by 2050. In its last report published in 2016, an analysis based on two studies ("Attenuation in the Long Term" and "Analysis of Attenuation Potential") allowed the WWF to make the following recommendations to reduce GHG emission in South Africa: (1) increase the use of rail transportation for goods, (2) transfer private car passengers to public transport, (3) increase the occupation rate of vehicles, (4) increase the number of hybrid vehicles on the roads, (5) introduce electric vehicles, (6) improve the efficiency of tourist vehicles, (7) increase the number of private diesel vehicles (which produce less CO_2 than petrol vehicles), (8) progressively substitute petrol and diesel for biofuels.

Sustainable Energy Africa (SEA) is also very active in South Africa. Through various studies, the organization provides guidance to the South African state to support the goal of sustainably reducing GHG emissions. Based on the observation that 18 metropolitan areas and secondary towns in South Africa consume 37% of the country's energy, it recommends introducing concrete actions at a local level to promote reductions in national emissions, especially in the transport sector which is characterised by inefficiency, road congestion and a high reliance on private cars (SEA, 2015).

The African Association of Public Transport (UATP): in Africa, and particularly in South Africa, the UATP is currently playing an important role in promoting public transport. Through forums, conferences and meetings of decision-makers in the urban transport domain, the UATP makes pertinent recommendations for the introduction of effective urban public transport networks. As an example, we can cite the third congress and exhibition on African public transport held in South Africa in 2014 in collaboration with the road and transport department of Gauteng and the Management Agency of Gautrain. On the theme of "The growth of Africa through an efficient public transport system", over 300 local and international participants, delegates and exhibitors shared their diverse experiences on this subject. In 2015, the 7th AFRICITES summit in Johannesburg allowed the **UATP and African Water Association - AFWA** to produce guidance on the challenges and sustainable solutions for transport, energy, water and sanitation for emerging African cities.

TEXT BOX 6

CONCLUSION

The stabilization of CO_2 emissions from the road transport sub-sector in Africa in the last few years is the result of rising environmental awareness in the central State and local authorities, with the strong support of non-state actors.

However, for all the encouragement it provides, this drive from the state requires more commitments and concrete actions on the challenges faced in terms of reducing greenhouse gases generated by road transport, which is the greatest polluter in the transport sector.

Indeed, the emissions levels of the road transport sub-sector remain high and the potential for reduction is significant.

Also, the question should be raised as to whether, at the current rate of energy transition in the road transport sector and also in terms of individual and collective awareness of the issue, the objective of using 100% renewable energy in the transport sub-sector at the 2050 horizon is in fact feasible.

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Policies for low carbon pathway and role of non-state actors in India

An efficient transport system is crucial for India as it witnesses rising demand for transport services and related infrastructure. As mobility needs of the country are increasing, the subsequent impacts are also intensifying. With road transport sector becoming one of the major contributors towards GHG emissions, air pollution, congestion and several other negative externalities, various policy measures are being implemented to make the sector more efficient. Coordination and collaboration between government policies and actions of non-state actors in the form of awareness campaigns, capacity building initiatives and policy research can strengthen the implementation of these policy measures. To this end, the focus of this study lies on how efforts of non-state actors are aligned towards promoting low-carbon road transport sector in India. We will focus here only on normative and technical developments in road transport, bearing in mind that urban development and the development of public transport remain essential for the stabilization of emissions from the sector.

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CONTENTS

1 • ROAD TRANSPORT SECTOR : AN OVERVIEW

Transport plays a vital role in the path of economic development; by moving passenger and goods, it fosters personal & economic growth (United Nations, 2016). Hence, the provision of a safe, sustainable and efficient transport system becomes crucial for a growing economy like India. The transport system in India consists of diverse modes such as rail, road, shipping, civil aviation, inland water transport and pipelines. India has one of the largest and densest roads and rail network in the world and transport in the country is dominated by rail and roads (World Bank, 2011) Transport demand in India is primarily driven by population growth and increase in economic activity. As India's population is expected to exceed that of China by 2024 (UNDESA, 2017), this coupled with increasing industrial and commercial activities will bring about a rapid transition in the way people and goods move.

Over the past few decades, better installed infrastructural capacity, focussed policy and investments have led to rapid expansion of road transport in India (NTDPC, 2014). Road network in India consists of National Highways, State Highways, District Roads, Rural Roads, Urban Roads and Project Roads. National Highway (NH), the principal network connecting metropolitans and major cities has played a pivotal role in the development of road transport sector in the country. **NH constitutes less than 2% of the road network but carries more than 40% of the total traffic volume** (NHAI, 2017).

Road transport sector has always held a dominant share of total traffic flows in the country with the sector currently accounting for 90% of the passenger movement and 67% of the freight movement (MoRTH, 2016). Statistics from the Road Transport Year Book (2016) reveals that between 2005-06 and 2015-16, the total tonne kilometres by road increased at a CAGR of 11% while total passenger kilometres increased at a CAGR of 14% (Figure 1).

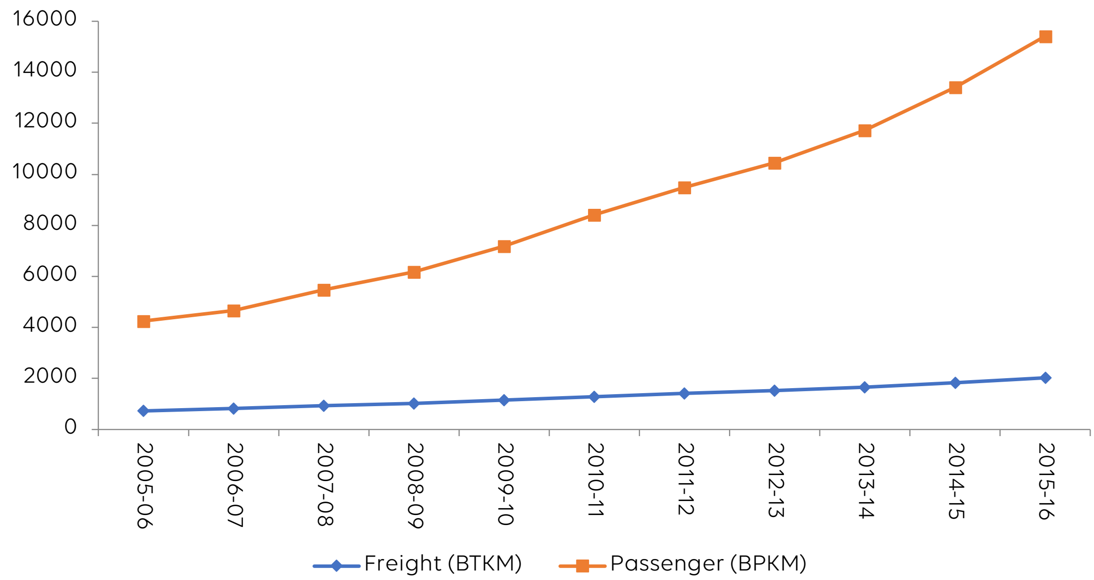

FIGURE 1. FREIGHT AND PASSENGER MOVEMENT BY ROADS

(Source : MoRTH)

Urbanisation is also a key factor that has contributed to rapid motorisation (IUT, CSTEP, 2014). As more and more people have moved to urban areas in search of economic opportunities, the demand for motorised transport has increased. As per the Census data 2011, Indian urban population increased at a rate of 31.8% over the decade and accounted for a share of 31.6% in the total population of the country. Reaching a figure of 230 million in 2016, motor vehicles in India grew at a CAGR of 9.9% between 2006 and 2016 (Figure 2) (MoRTH, 2016). An increase of urban agglomerations/million plus cities in the country from 35 in 2001 to 51 in 2011 has led to higher proliferation of motorised vehicles in these cities with them comprising 31% of the total registered motorised vehicles in the country. Growth of cities and changing land use pattern has resulted in urban sprawl which has led to increased travel demand. A large share of this travel demand has been met by high ownership of two wheelers and cars which at present account for 86.6% of the total registered vehicles in the country.

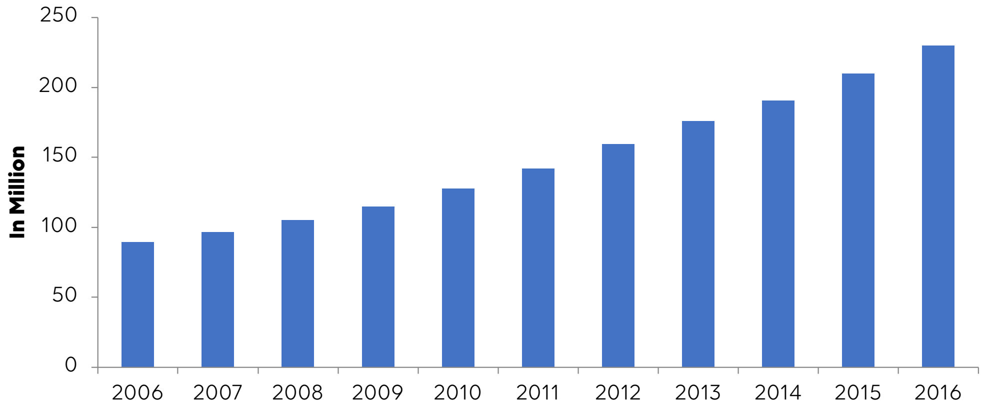

FIGURE 2. TOTAL NUMBER OF REGISTERED MOTOR VEHICLES

(Source : MoRTH)

2 • TRANSPORT DEMAND : IMPLICATION ON ENERGY AND EMISSIONS

Increase in transport demand has made the transport sector as one of the most energy intensive sector in the country. **Presently, the transport sector accounts for 24% of the total energy consumption in the country (TERI, 2018) and 98.5% of which is met by petroleum products (TERI, 2016). India's transport sector accounts for 99.6% of the total petrol and 70% of the total diesel consumption in the country (Nielsen, 2013). As per estimates by the International Energy Agency (IEA), India's transport sector accounts for almost 3% of the total transport sector fuel consumption in the world.** Between 2005 and 2015, India's transport sector fuel consumption grew at a CAGR of 8.3% from 38.8 million tonnes of oil equivalent (MTOE) in 2005 to 86 MTOE in 2015 (Figure 3). While over the same period, the world transport fuel consumption grew at a CAGR of 2% from 2212 MTOE to 2704 MTOE.

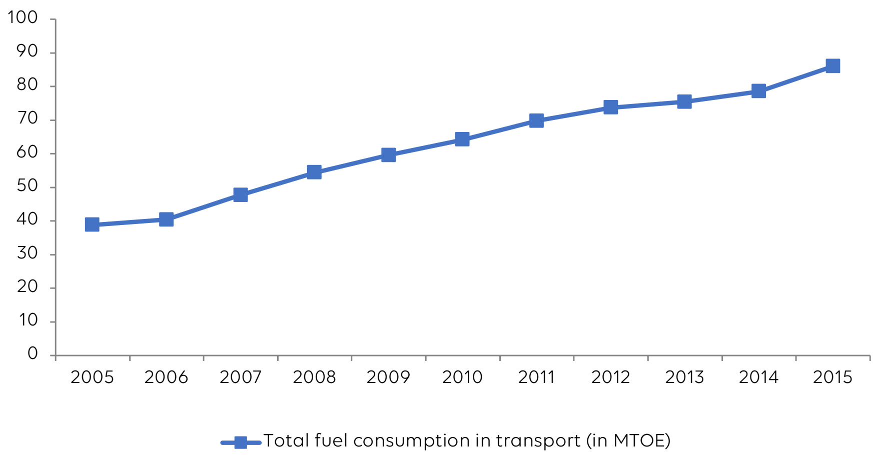

FIGURE 3. FUEL CONSUMPTION BY TRANSPORT SECTOR IN INDIA

(Source : IEA)

In India, transport sector accounts for 10% of the total Green House Gas (GHG) emissions [1] (MoEF, GoI, 2015). Since, a predominant share of the transport sector's energy requirements are met through conventional fossil fuels like petroleum and diesel, the emission intensity of fuel combustion in the sector has increased from 10.5% in 2000 to 11.5% in 2014 (World Bank, 2018)[2] . **Transport sector in India accounts for 13.2% of the total CO_2 emissions from fuel combustion across sectors in the country, of which road transport accounts for the highest share of 87% (UIC/IEA, 2016).**

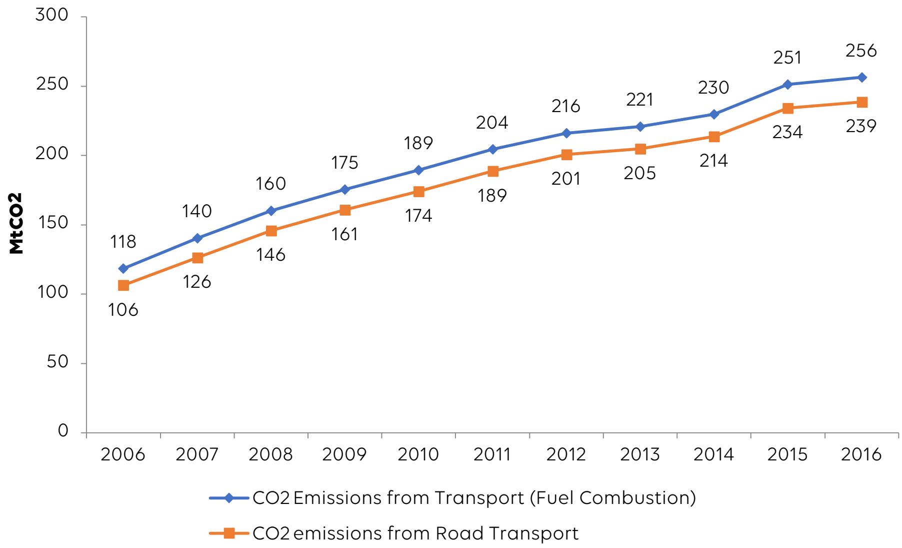

FIGURE 4. CO_2 EMISSIONS FROM FUEL COMBUSTION IN TRANSPORT SECTOR IN INDIA

Source : Enerdata

At the current rate of growth, this manifold increase in road transport demand can have huge implications on the overall energy demand of the sector and the concomitant emissions. India's CO_2 emissions are projected to triple by 2040 from 2013 levels if sectoral policies to manage energy demand are not put in place (Busby & Shidore, 2017). Considering the high reliance of the sector on fuel consumption coupled with India's high import dependence of crude oil (83% of total oil consumption) it is imperative to plan for sectoral policies that can manage fuel and energy demand from the sector in the coming decades and can influence the future carbon emissions (Pal, Singh, Wilson, & Joshi, 2015).

In this context, mitigation and adaptation strategies in the transport sector will play a significant role in achieving the Nationally Determined Contributions (NDCs) targets, which represent a unique opportunity for India to scale down its emissions and energy consumption. Under the NDCs a set of strategies to reduce the emissions intensity of its GDP by 33%–35% below 2005 levels by 2030 has been developed (UNFCCC, 2015). To this end, India is focusing on several mitigation initiatives to develop energy efficient and low carbon transport systems to reduce emissions from the transport sector.

With an objective of promoting energy efficient low carbon growth of the road transport sector, government has introduced several policies and programmes across passenger and freight segments. In terms of fuel quality and vehicle emission standards, India lags behind the international standards (NTDPC, 2014). Hence, the major focus of the policies in the road transport segment is towards improving vehicular technology through the implementation of progressive fuel efficiency norms, emission standards, electrification and bio-fuel blending. Adoption of these policies will lead to significant fuel savings and emission reduction, thereby promoting a low carbon and sustainable future for the road transport sector.

However, in order to realise the vision of a sustainable and low carbon road transport sector an effective engagement of concerned stakeholders is necessary. In this regard, initiatives by

1 - In terms of CO_2 equivalent
2 - Global emission intensity from transport sector decreased from 22% to 20.4% between 2000 and 2014

non-state actors such as Central Road Research Institute (CRRI) a premier national laboratory, and also a constituent of Council of Scientific and Industrial Research (CSIR), engaged in carrying out research and development projects for transport , Automotive Research Association of India (ARAI) a co-operative industrial research association by the automotive industry under the Ministry of Industries, Government Of India, Society of Indian Automobile Manufacturers (SIAM), the apex industry body representing automobile manufacturers in India, other industrial & technological research organisations, corporates and policy think-tanks to cut down emissions are becoming increasingly significant. **While the Government of India has planned a policy roadmap for the sustainable movement of passenger and freight, the successful implementation and adoption of these policies will be significantly determined by the actions and contributions of the non-state actors.** To assess the role of non-state actors in achieving a low carbon pathway for the road transport sector, it is first important to understand the current policies aligned towards achieving it.

3 • INITIATIVES TO DECARBONIZE ROAD TRANSPORT SECTOR

• ELECTRIC MOBILITY • Globally, electric mobility has emerged as one of the most aspiring solution towards the development of sustainable transport solutions. This is primarily due to increasing costs of energy, depletion of fossil fuels and rising emissions (DHI, 2012). Regulatory interventions by governments to promote zero-emission vehicles have also led to the shift towards Electric Vehicles (EVs); with zero tail-pipe emissions and long term economic viability, worldwide EVs are proving to be a favourable alternative technology solution (ASSOCHAM, EY, 2018).

India being a fast growing economy is also experiencing a rapid increase in transport demand for moving people and freight over distances. This increase in transport demand is largely being met by road transport which is highly energy intensive. High demand for petroleum products by road transport sector has subsequent economic, environment and social implications in the form of rising oil import bill, energy costs, depletion of fossil fuels and rising emissions. Hence, faster adoption of EVs is one of the policy interventions that Government of India (GoI) has taken to increase the efficiency of transport sector and to mitigate the adverse economic and environmental impact from the sector.

The history of electric vehicles in India dates back to 1996, when 400 EVs were made and sold by Scooters India Ltd. Bharat Heavy Electricals (BHEL) also developed an electric bus in 2000 and with support from government 200 electric vans were built in Delhi. However, the major leap came in 2001, with the introduction of REVA, an electric car which was more efficient and consistent than the earlier vehicles. The major concerns with respect to mass adoption of electric vehicles were high cost of charging, charging infrastructure, low battery life, etc. (DHI, 2012). Hence, in order to promote the mass and faster adoption of EVs in India, GoI launched the National Electric Mobility Mission Plan (NEMMP) 2020 in 2013 and the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME India) scheme under it. As part of the scheme, subsidies were introduced to promote the sales of electric and hybrid vehicles. Till date, the implementation of the scheme has led to 77000 tonnes of CO_2 emission reduction and 31 million litres of fuel savings (DHI, 2018).

Initiatives by Start-ups :

In 2015, in a move to make Bangalore's air cleaner, Lithium Urban Technologies, entered the EV domain. Lithium is a B2B organisation and is India's first electric cab service. With a fleet of 200 vehicles, it saves nearly 11 tonnes of carbon emissions everyday by covering a total distance of 60,000 kilometres. In order to run these pollution free vehicles, the company has also setup 200 high-speed charging stations around the city (The Better India, 2017).

TEXT BOX 1

In order to spearhead the adoption of electric vehicles in India, an investment outlay of INR 795 crore was approved under FAME-I for technology development, infrastructure creation, boosting demand through subsidies and pilot projects (ASSOCHAM, EY, 2018). Government has also selected 11 cities to ensure the penetration of EVs in public transport (Buses, three-wheelers and taxis) for several pilots (PIB, 2015). **The implementation of electric mobility in India is further being expanded by collaborative and coordinated actions of the governments, non-state actors and private sector players. Automobile manufacturers such as Mahindra and TATA through their partnerships with the central and state governments' are facilitating the implementation of policy frameworks**. To support the eMobility awareness campaign of the State of Karnataka, Mahindra Electric (pioneer of electric vehicles in India) along with Baghirathi Group (shared mobility service provider) deployed a fleet of 50 electric cars with an additional investment announcement of INR 400 crore over five years. With an aim to promote low carbon, zero emission and sustainable mobility solution, the Baghirathi Group also plans to deploy 1000 Mahindra electric cars for corporate mobility (Mahindra & Mahindra Ltd., 2018). In a similar move towards reducing the country's carbon footprint, Tata Motors signed a MoU with the state of Maharashtra in India to support the state's EV Policy. As a part of the collaboration, Tata will deploy 1000 EVs across passenger and commercial segment and will also setup 100 EV charging stations in the state (Tata Motors, 2018) (ET, 2018).

Apart from the private vehicle segment, government is also introducing EVs in multi-modal public transport. **In 2017, Nagpur became the first city in India to launch the electric mass transport project in India. The pilot was launched in collaboration with Mahindra Electric, Kinetic Green Energy and Power Solutions and Ola.** A fleet of 200 electric vehicles was procured, out of which Mahindra Electric manufactured the 100 'e20' electric taxis and Kinetic Green Energy and Power Solutions supplied 100 e-rickshaws and Ola, a cab aggregator provided the service platform for running the vehicles. Ola also built four charging stations having 53 charging points to power the fleet of 200 e-vehicles (live mint, 2017).

In 2018, Centre for Study of Science, Technology and Policy (CSTEP) which is a private policy think tank along with support from Shakti Sustainable Energy Foundation (SSEF) developed an e-bus fleet implementation plan for Bengaluru. As a part of the study, a detailed route analysis was conducted to identify suitable routes for installing Electric Vehicle Supply Equipment (EVSE) and charging infrastructure. An analysis of transport and electricity distribution was also carried out along with Bangalore Metropolitan Transport Corporation (BMTC) and Bangalore Electricity Supply Company (BESCOM) (CSTEP-SSEF , 2018).

Eco-friendly Intermediate Public Transport (IPT)

In a move to bridge the gap of first and last mile connectivity e-rickshaws were launched by the Delhi Government in the year 2010. Since then, e-rickshaws have gained tremendous popularity in the city and have increased from 4000 units in 2011 to 0.1 million units in 2015 (CEED, 2017). In order to further promote the uptake of these battery-operated vehicles, Delhi Government has also initiated the process of providing subsidies of INR 30,000 to drivers for retrofitting the old vehicles and registration of vehicles (ET, 2016).

TEXT BOX 2

• IMPROVED FUEL TECHNOLOGY STANDARDS • Globally, one third of the oil demand and around 50 per cent of all the transport related GHG emissions are accounted by passenger cars, two-wheelers, three-wheelers and light commercial vehicles (ICCT, 2018). Growth in road-based transport makes energy management in the transport sector a challenging task (AITD, 2000). Hence, adoption of vehicle based norms can play a crucial role in determining the future energy demand of any country. Considering the fact that demand for automobiles in India will remain strong and will subsequently impact country's energy security and climate mitigation strategy, the Government of India through its Auto Fuel Policy has recognised the importance of regulatory measures such as fuel economy norms and progressive emission standards (Ministry of Heavy Industries & Public Enterprises, 2018).

- **Fuel Efficiency Norms**

In April 2017, Ministry of Road Transport and Highways (MoRTH) came up with first set of fuel economy norms for Light Duty Vehicles (LDVs) in passenger segment. These standards are based on Corporate Average Fuel Economy (CAFE) norms and define the targets in terms of fuel consumption in litre/100 km. In order to ensure compliance, these standards are converted into CO_2g/km for petrol, diesel, Liquefied Petroleum Gas (LPG) and Compressed Natural Gas (CNG) passenger vehicles with Gross Vehicle Weight (GVW) under 3.5 tons. The policy will lead to continuous reduction in CO_2 emissions through setting the efficiency standards for new vehicles at 130g/km in 2017 and 113g/km in 2022 for every automaker (TransportPolicy.net). **As India is expected to have highest number of cars on road in the world by 2050 (SSEF) and with rapidly increasing sales, India is presently the fourth largest automobile market in the world (ET, 2018)**. In view of the fact that India's future transport demand will be largely driven by cars, the efficiency standards for LDVs are expected to reduce CO_2 emissions by 50 million tons by 2030 (UNFCCC, 2015) and will achieve energy savings of 22.97 MTOE by 2025 (BEE, 2017). However, to achieve significant impacts, energy demand management of the remaining modes of passenger and freight segment also need to be addressed simultaneously, (AITD, 2000). Apart from this, it is also expected that India's demand for High-Speed Diesel (HSD) will increase from 76 million metric tonnes (MMT) in 2016-17 to 110.8 MMT in 2021-22. Since 38% of this demand is accounted by commercial vehicles, an absence of regulatory measures in this segment of vehicles can have serious implications on India's energy security (Nielsen, 2013).

Considering that Heavy Commercial Vehicles (HCVs) account for more than 50% of the CO_2 emissions from road transport in India, several research entities are focussing on the regulatory framework for fuel efficiency norms for HCVs. The Energy and Resources Institute (TERI) undertook a study to develop pathways for the adoption of fuel efficiency in HCV sector in India. The study exhibits several methodologies to formulate fuel efficiency standards and also identifies various technologies available for improving the fuel efficiency. The aforementioned study was carried out with support from SSEF which works collaboratively with policy makers, think tanks, civil society and industry and aids in designing and implementation of energy efficient and cleaner transport policies.

- **Emission Standards**

On- Road vehicles are a key contributor to air pollution in the country. Pollutants like Carbon Monoxide (CO), Hydrocarbons (HC), Oxides of Nitrogen (NOX) and Particulate Matter (PM) emitted by vehicles not only increase the local air pollution but also significantly impact the health of the people. In order to reduce the vehicular air pollution, emission standards were instituted in India by the Government of India.

The first set of mass emission limits were implemented in 1991 for petrol vehicles and in 1992 for diesel vehicles, which were gradually made stringent during 1990s. In the year 2000, India 2000 norms were implemented for passenger cars and commercial vehicles which were equivalent to Euro I norms (DieselNet). In 2001, Bharat Stage II (Equivalent to Euro II) norms were implemented for all the vehicles in cities of Delhi, Mumbai, Chennai and Kolkata (SIAM). The National Auto Fuel Policy (2003) laid out the roadmap for nationwide implementation of Bharat Stage II (BS II) norms by 2005 and of BS III (equivalent to Euro III) along with implementation of BS IV norms in 13 cities by 2010 (PIB, 2015). In 2015, the draft Auto Fuel Policy and Vision 2025 recommended the roadmap for implementation of BS IV norms across the country in a phased manner and it further envisaged advancing the introduction of BS VI norms by 2020 by leapfrogging the BS V norms (SIAM). The implementation of BS IV was a major step towards addressing the issue of extremely high levels of pollution across Indian cities. The implementation reduced the limit on sulphur content in petrol and diesel to 50 ppm from 150 and 350 ppm respectively. With the implementation of BS VI norms by 2020, it is expected to further reduce sulphur content up to 10 ppm for both diesel and petrol vehicles (TransportPolicy.net).

Emission from vehicles is majorly determined by factors like vehicular technology, fuel quality, inspection & maintenance of in-use vehicles and road & traffic management. In order to control and regulate these factors a multi-agency approach is necessary. While the task of setting up the emission standards is carried out by the Ministry of Road Transport and Highways (MoRTH) in India; the enforcement happens through industrial stakeholders like Society of Indian Automobile Manufacturers (SIAM), the apex industry body in the country which represents the leading vehicle and vehicular engine manufacturers in India and several industrial research associations.

• MOVE TOWARDS ALTERNATIVE FUELS : BIOFUEL POLICY • As India is going through demographic dividend its energy demand is also increasing. The existence of strong correlation between energy consumption and economic growth is highly reinforced by the critical role that energy plays in the socio-economic development of the country. Given the fact that a significant share of India's energy demand is met by fossil fuels which are highly polluting and non-renewable it is important to give impetus to renewable resources which are indigenous, non-polluting and inexhaustible (National Policy on Biofuels, 2018).

Due to India's high dependency on fossil fuel based energy sources, energy security is also a key area of concern. Road transport sector which contributes 6.7% to India's total GDP accounts for the highest share of this energy consumption. The limited domestic production of crude oil in India has led to a rising import dependency with India currently importing 82% of the crude oil (National Policy on Biofuels, 2018). In order to address these concerns Government of India announced the National Biofuel Policy in 2009 and was further amended in 2017 to increase the targets and has been named as National Policy on Biofuels-2018.

The policy aims to increase the penetration of biofuels (derived from renewable biomass resources) in the energy and transportation sector of the country. As the production of biofuel will mainly rely on domestic feedstock, this substitution for fossil fuels will subsequently promote energy security, climate change mitigation and will create additional employment opportunities for farmers and cultivators in a sustainable manner. **At present, ethanol blending in petrol is around 2% and biodiesel blending in diesel is less than 0.1%.** The policy proposes to achieve the target of 20% ethanol blending in petrol and 5% biodiesel blending in diesel by 2030. As the major thrust area of this policy is to ensure generation of biofuels from indigenous feedstock, Government plans to create a National Biomass Repository by conducting assessment of biomass and feedstock samples across the country. (National Policy on Biofuels, 2018)

Effective implementation of the biofuel programme is largely dependent upon active participation from the central and state governments, farmers, industry and professionals. **With an assured policy support from the central government, several public and private sector industries are generating biofuels. Pune based Praj Industries Limited has developed technology to produce ethanol by utilising agri-waste like sugarcane trash, rice and wheat straw, etc. The process is based on techno-socio-commercial model as farmers are getting better prices for their produce and the agri-waste which was traditionally burnt for household cooking is being utilised sustainably.**
In Assam, a joint venture between Numaligarh Refinery Limited, a public sector enterprise and Chempolis Oy, a Finnish technology firm plans to produce 60 million litres of ethanol every year by using bamboo. In addition to this, several of the Indian oil companies are investing in biofuel refineries to increase the production of ethanol from non-molasses sources and to promote the green-fuel use.

Cultivator's and Farmer's Perception of Biodiesel

Sugarcane molasses is the main source for ethanol production and oil from jatropha & other oilseeds is used for biodiesel production. It has been observed that promotion of biofuels is dependent on various factors among which feedstock supply and management is the key issue at local level. To understand the feasibility scenario of Jatropha cultivation, Integrated Research and Action for Development (IRADe) and IT Power India Pvt Ltd undertook an analysis based on surveys conducted in 41 villages of Rajasthan and Orissa.

In Rajasthan, enthusiastic participation was observed from farmers for Jatropha cultivation. The State has initiated several programmes for supporting the plantation. Additionally, many private sector companies are also promoting farming through contracting farmers.

In Orissa, farmers have taken up cultivation of Jatropha on their waste lands without compromising on the growth of the plantations. Several Self Help Groups (SHGs) have also been established in the process. It was observed that in both the states the additional economic benefits from the use of waste land have been the driving force for the cultivation. Please give reference to the below table somewhere in the text.

	Analysis of Survey Data : Farmer's Perception for Choosing to Plant Jatropha	
Reasons for Planting Jatropha	Rajasthan	Orissa
Economic Benefit	92%	96%
Best Use of Wasteland	54%	77%
Low Inputs Requirement	77%	-
Support from local organisations	-	32%
Protection from cattle not required	46%	-

Source : (IRADe, IT Power India Pvt Ltd., 2011)

TEXT BOX 3

CONCLUSION

To counter the trend of increasing fuel consumption and rising emissions along with meeting the national commitments, a set of policy measures is being implemented by the Indian government in the transport sector. However, in order to ensure that these policy measures are effective in decarbonizing the road transport sector, it is important to build a holistic approach for confirming strong implementation and compliance of various policy goals. To this end, a multi-stakeholder approach which includes contribution and actions from civil society, corporates, think tanks and other public and private actors through decentralised action can play a crucial role in bringing down emissions from road transport sector.

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Stabilization of road transport emissions in the country of ethanol

Brazil's attenuation target is a 37% reduction in national GHG emissions by 2025 and 43% by 2030 compared to the 2005 baseline. While the country's main efforts are focused on increasing the share of renewable energies in the energy matrix, achieving zero deforestation and recovering 12 million hectares of forests in the Amazon, the challenge is also important in the transport sector: diesel and petrol account for 75% of the energy consumption of the sector and forecasts predict that transport-related GHG emissions will be 45% of the national total in 2025 (Waycarbon, 2018). This chapter analyses the factors explaining the evolution of emissions in the transport sector and the various actions in progress.

Head editor • **GHISLAIN FAVÉ** • *Consultant*

CONTENTS

1 • RECENT STABILISATION OF EMISSIONS

Driven by the reduction in illegal deforestation, Brazil has seen a 28% reduction in its emissions over the 2008-2014 period (see Figure 1). However, in 2015 and 2016, GHG emissions increased by 12.3%, driven by the resumption of illegal deforestation. **Transport sector emissions increased by 40% over the 2008-2014 period and stabilised in 2015 and 2016 at around 190 million tonnes of CO_2eq, i.e. the same level as in 2012.**

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Transport domestique (hors aérien)	144	150	147	164	179	196	203	209	193	194
Total national	2,682	2,807	2,003	1,925	1,927	1,947	2,107	2,022	2,091	2,278

FIGURE 1. EVOLUTION OF CO_2EQ EMISSIONS IN TOTAL AND IN THE TRANSPORT SECTOR IN BRAZIL (MILLIONS OF TONNES).

Source : From the databases of the SEEG (System for Estimates of Emissions and Removal of Greenhouse Gases), 2018

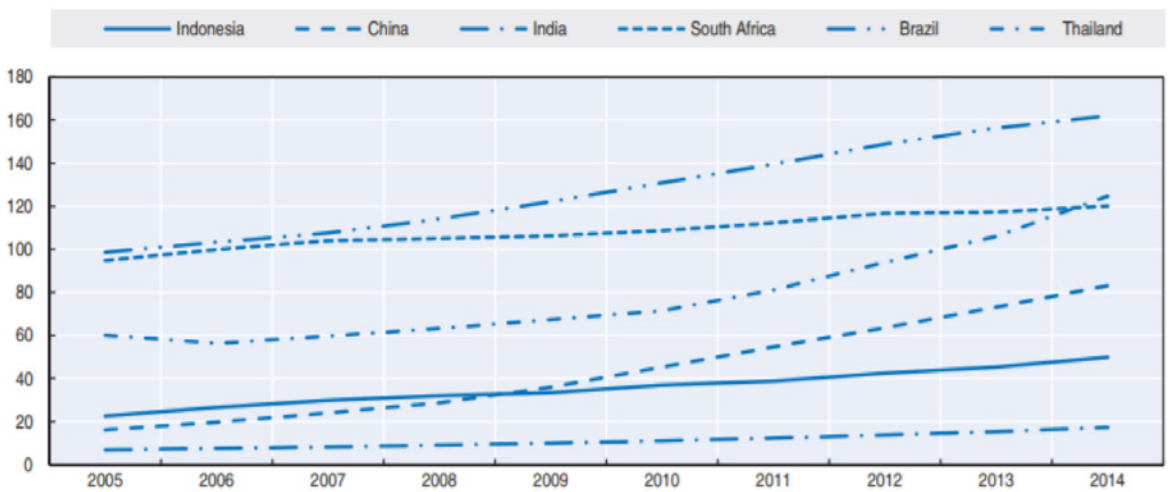

FIGURE 2. EVOLUTION OF THE RATE OF MOTORISATION IN SELECTED DEVELOPING COUNTRIES

Source : ITF Transport Outlook, 2017

Strong economic growth rates in emerging economies have led to a rapid rise in motorisation rates, and it is no different in Brazil, with growth of 60% between 2005 and 2014 (see Figure 2). This has been particularly significant in Brazil where economic growth between 2001 and 2015 led to a large part of the population on low incomes moving up into the middle class. In addition, this dynamic has been reinforced by the encouragement of the Brazilian government for the motorisation of households to support the automotive industry, which is important for the country's economy. Thus, in 2008, during the global financial crisis, the state reduced taxes on industrialised products (IPI); this measure was renewed in 2012. Other factors, such as easier access for households to credit and financing for new cars, also contributed to this growth in individual motorisation. According to the production and sales statistics released by the ANFAVEA (National Association of Motor Vehicle Manufacturers), the total volume of sales of new vehicles in Brazil increased from 1.4 million vehicles in 2002 to 3.8 million in 2012, a growth rate of 11.5% per year (ANFAVEA, 2015). These elements make it possible to understand the major increase in GHG emissions from the transport sector between 2008 and 2014, from 150 to 209 million tonnes of CO_2eq (see Figure 1).

The economic crisis that Brazil has been experiencing since 2015 largely explains the recent stabilisation of emissions in the transport sector. Thus, GDP fell by 3.8% in 2015 and 3.6% in 2016, which is reflected in the GHG emissions of the Brazilian energy sector: over this 2015-2016 period, emissions in the energy sector fell 7.3% (SEEG, 2016). Further proof of the effect of the current crisis on transport sector emissions is the 30% drop in new car sales between 2012 and 2015 (PwC, 2016).

If the recent stabilisation of transport sector emissions appears above all cyclical, we should try to analyse the main drivers of these and identify the strengths and weaknesses of the sector in Brazil.

2 • URBAN MOBILITY UNDERGOING TRANSFORMATION

• THE CRISIS OF PUBLIC TRANSPORT • Brazil's economic growth since the 1950s has been accompanied by rapid urbanisation: while only 45% of Brazil's population was urban in 1960, more than 80% of Brazilians were living in cities in 2010 (IBGE, 2010). This rapid urban growth has been shaped by automobiles and structured along major highways. The ex-nihilo creation of the federal capital Brasilia in 1960 is the perfect example: its ambitious urban plan was conceived based on the car, as a symbol of this era when the car was presented as the only solution to urban travel.

This powerful urbanisation was accompanied by a rise in property prices and property speculation, which pushed the poorest populations in marginal areas further and further away, all the more so as informal housing was increasing. Transport infrastructures struggled to keep pace with this urban sprawl and transport times became considerably delayed, prompting people to turn increasingly to individual methods of motorisation to cope with their travel needs.

The response from municipal, regional and federal governments is, in most cases, investment in infrastructure, which may include an ever-growing car fleet, to the detriment of public transport, which is confirmed by analysis of the evolution of the index of passengers per kilometre on the urban bus network. **The figures provided by the Associação Nacional das Empresas de Transporte Urbano on the cities of Belo Horizonte, Curitiba, Fortaleza, Goiânia, Porto Alegre, Recife, Rio de Janeiro, Salvador and São Paulo, show a 38% drop in this index between 1994 and 2015, a reflection of a public transport system that can no longer attract Brazilians.**

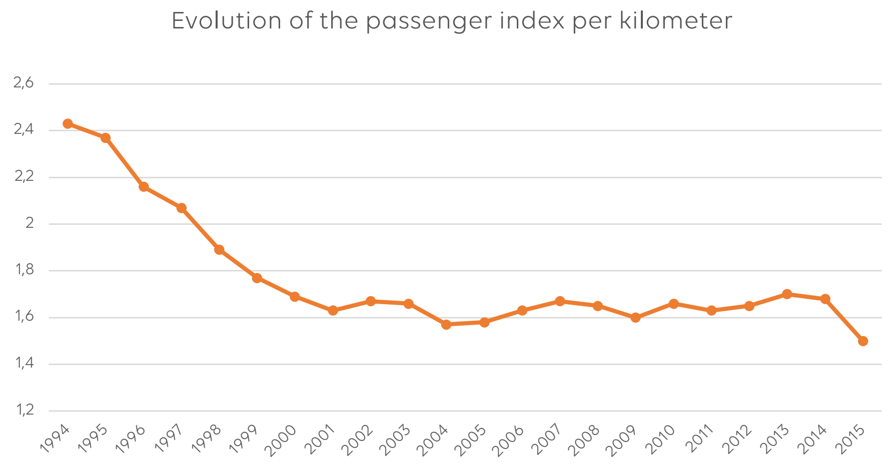

FIGURE 3. EVOLUTION OF PASSENGER INDEX PER KILOMETRE BETWEEN 1994 AND 2015 IN THE CITIES OF BELO HORIZONTE, CURITIBA, FORTALEZA, GOIÂNIA, PORTO ALEGRE, RECIFE, RIO DE JANEIRO, SALVADOR AND SÃO PAULO.

SOURCE: Based on data from the Associação Nacional das Empresas de Transporte Urbano (NTU)

Alternate traffic in São Paulo

São Paulo, a megalopolis of more than 12 million inhabitants and the economic heart of Brazil, is frequently plagued by traffic jams. According to a study by the specialised firm INRIX, the inhabitants of São Paulo spent an average of 86 hours per year in traffic jams in 2017, i.e. the 4th city in this study, which covers 1360 cities. On average, traffic congestion totals 300km per day in this metropolis, at an estimated cost of 69.4 billion reais or 7.8% of local GDP, according to a technical study published in July 2014 by Firjan.

In order to improve the situation and especially to reduce air pollution, from 1997 the city introduced restrictions on traffic in the extensive centre of the city: the rodizio. Every working day, based on the last number on their number plate, traffic is prohibited between 7am and 10am and between 5pm and 8pm in the city centre. The rodizio, by removing 20% of the vehicles from traffic, initially led to lower congestion and atmospheric pollution. The results are now more mixed: the vehicle fleet has grown by 40% since the establishment of this measure, especially because many people have acquired a second car with a different registration, to escape the rodizio.

TEXT BOX 1

One of the consequences of this crisis in the demand for urban public transport and the increase in the motorisation rate is the deterioration of urban air quality, and high GHG emissions linked to the transport sector in Brazilian cities. Thus, urban transport represents 68.2% of the emissions of the city of São Paulo (municipal inventory 2011), 57.6% in Belo Horizonte (municipal inventory 2015) and 54.5% in Recife (2015). By comparison, the transport sector accounts for around 26% of GHG emissions in European cities (Covenant of Mayors in Figures: 8-year assessment, 2017). This greater share in Brazilian cities is also linked to the low carbon intensity of the electrical energy consumed in Brazil and, consequently, to the lower share of the energy sector in municipal emissions. Even though the car ownership rate is still growing strongly and is much lower than in other countries, the trend is towards growth of urban transport in GHG emissions, which represents the biggest challenge in terms of mitigation for Brazilian cities: the city of Recife predicts that emissions associated with transport will account for 75% of the city's emissions in 2040, if the current trend continues.

Mobilisation of civil society

At the beginning of 2013, following the announcement of an increase in bus fares, demonstrations broke out at the call of the Movimento Passe Livre, a movement calling for free public transport. Soon, these events spread to the whole of Brazil, mobilising up to one million people and the demands extended to education and health, along with criticism of the expenses related to the organisation of the 2014 World Cup. Following this unprecedented mobilisation, urban mobility became the symbol of these public policies that struggle to meet the expectations of the population.

TEXT BOX 2

• URBAN MOBILITY PLANS, INSTRUMENTS OF LOW-CARBON MOBILITY • In April 2012, the law establishing the Política Nacional de Mobilidade Urbana (National Urban Mobility Policy - PNMU) came into force. It stipulates that towns with more than 20,000 inhabitants must produce their Urban Mobility Plan (UMP), in way that is integrated with their master plan, within three years. Previously, only cities with more than 500,000 inhabitants were under this obligation; with this new law, there are now 1663 municipalities that must submit a UMP, otherwise they will no longer be able to receive federal funds intended for urban mobility (CODATU, 2015).

The PNMU defines public transport and active modes as priorities for cities, instead of individual motorised transport. It provides guidelines for sustainable urban development: the development of cycle lane networks and bus lanes, restriction of vehicle traffic at certain times, pricing of public parking, etc. To fight against air pollution and against GHG emissions, the law also provides for the control of the level of emissions, the introduction of pollutant emission limits, and traffic restrictions if thresholds are exceeded. This law, contrary to the reduction in vehicle taxes renewed in 2012 by the federal government, stimulated the transformation of urban mobility in Brazil.

Fortaleza, the latest Brazilian example of sustainable mobility

Fortaleza, the 5th largest city in Brazil with a population of almost 3 million, has been transforming urban mobility since 2014: prioritising active modes and public transport (development of 108km of bus lanes, modernisation of bus terminals, refurbishment of the fleet with air conditioning and wifi), 225km of cycle paths (240% growth in the last 5 years), a shared bike programme integrated with the public transport system, the launch of a pilot programme of shared electric cars and traffic calming initiatives. **The results are already measurable: road mortality has been reduced from 14.66 per 100,000 in 2014 to 9.71 in 2017, the shared bike system is now the most used in Brazil, and on some bus routes, journey times have been halved.** With these actions, the city aims to reduce its emissions by 20% in 2030 compared to developments if current trends continue. These achievements have brought international recognition to Fortaleza, with the "Sustainable Transport Award" being awarded to the city in 2018 by the ITDP.

TEXT BOX 3

TransCarioca, the heritage of the Rio de Janeiro Olympics

As a result of Rio's commitment to hosting the FIFA World Cup and the Olympic Games (2014 and 2016 respectively), the city has been the focus of major investments in transport infrastructure, including the development of a network of 150km of BRT (Bus Rapid Transit) lines. The TransCarioca, a 39km line inaugurated shortly before the World Cup, is the main legacy of these events. With a cost of about $550 million and 75% funding from the BNDES, the national development bank, the TransCarioca connects Barra da Tijuca district, where most of the sports facilities of the Olympics were concentrated, in the southern districts of the city, with Rio International Airport.

FIGURE 4. MAP OF THE BRT TRANSCARIOCA

SOURCE: Rio de Janeiro City Councilo

Today, approximately 320,000 passengers use the line every day and nearly 500 buses have been removed from traffic, reducing travel times, congestion and GHG emissions. This line crosses many more disadvantaged neighborhoods of the northern area of the city and provides a major development opportunity for this region.

TEXT BOX 4

3 • FUELS: BETWEEN SUCCESSES AND CHALLENGES

• ETHANOL FUEL: THE BRAZILIAN MODEL • The production of ethanol, from the fermentation of sugar contained in sugar plants such as sugar cane, has been developed in Brazil for many years, but it is since the oil shocks of the 1970s that its use as a substitute to gasoline has intensified. In response to the rise in oil prices, Brazil, then increasingly dependent on oil imports, implemented in 1975 the Programa Nacional do Álcool (National Alcohol Programme) - PROALCOOL. Support measures for the production of fuel ethanol were taken: enhanced credit for investments and price setting. **The sector benefited from the very strong responsiveness of economic actors with massive investments in fuel ethanol production units and the launch of hydrated alcohol vehicles**

(operating only with ethanol) by all car manufacturers. The programme was very successful with the production of 5.6 million ethanol vehicles between 1975 and 2000. It is estimated that this programme prevented the emission of 110 million tonnes of carbon equivalent over the same period (EPE, PNE 2030).
The early 2000s saw the emergence of productivity gains in both the agricultural and industrial sectors, as well as the emergence of flex-fuel engines that work equally well with gasoline, ethanol, or a mixture of both (in 2003, the first flex-fuel model, the Volkswagen Gol flex-fuel). Today, all car manufacturers offer flex fuel models, which accounted for almost 90% of light vehicle sales in 2015 (EPE, 2015). These factors led to a sharp increase in fuel ethanol consumption between 2003 and 2009, reaching a peak in 2009 of more than 100 million tonnes of oil equivalent (MMA, 2014).
Over the 2009-2012 period, ethanol fuel lost market shares: it was more profitable to produce sugar than ethanol, investments in the means of production were reduced, and the price of petrol fell and became more competitive. In fact, over these three years, the share of fuel ethanol in the energy matrix of passenger transport declined from 33% to 22% (SEEG, 2018). The increase in the compulsory fraction of anhydrous alcohol in petrol (now 26%) has helped recover consumption growth and in 2016, ethanol accounted for 29% of energy consumption in the passenger transport sector (SEEG, 2018).

With this success, is Brazil continuing to develop its fuel ethanol sector and is now resisting the electrification of its car fleet: **despite the enormous potential for reducing emissions that this technology represents, especially since the electrical matrix in Brazil is clean with more than 68% hydropower (EPE, 2018), ethanol is defended by the entire productive chain and the federal government.** The Transport and Urban Mobility Sector Plan for climate change mitigation plans for a penetration of only 3% of hybrid gasoline vehicles in 2021, while the consumption of fuel ethanol would reach 52 billion litres in the same year.

Biofuels are often criticised for their environmental impacts, mainly due to land use changes induced by their production. In some regions, for example, growing production accelerates deforestation and increases the price of food. Attentive to maintaining the forest-fuel-food balance, the Brazilian government established the zoning of sugar cane in 2009, delineating 70 million hectares for its cultivation. The northern region of Brazil is excluded from this zoning as the planting of sugar cane in the Amazon basin is prohibited. Brazil does not lack space to develop a sustainable ethanol sector, the demarcated area being 10 times larger than the area needed for production in 2020. The largest production areas are concentrated in the Centre-South region and their growth does not threaten the Amazon rainforest. In these areas, expansion of sugar cane cultivation is

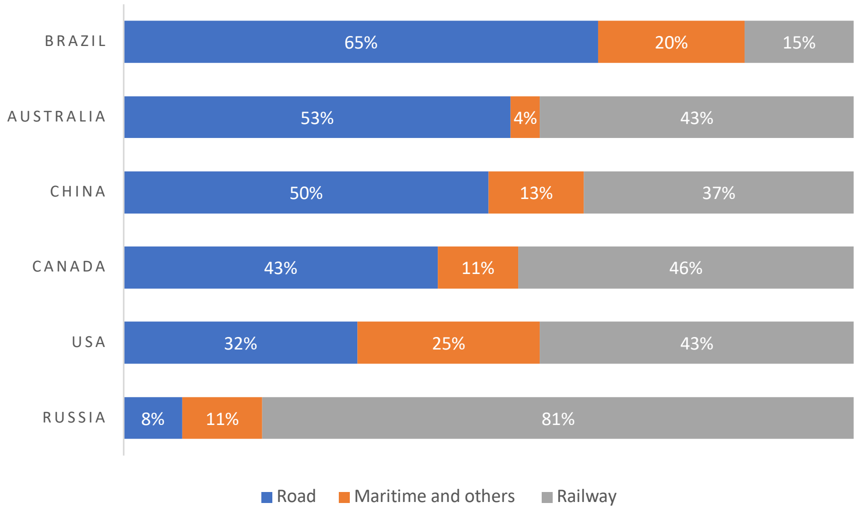

FIGURE 5. MODAL DIVISION OF FREIGHT TRANSPORT IN CONTINENTAL-SIZED COUNTRIES IN 2015.

Source : SEEG, 2018.

mainly on degraded or abandoned pastures and does not compete with food production. On the other hand, the remarkable Cerrado and Mata Atlântica biomes could be subject to strong agricultural pressure (Feres et al., 2011).

• DEPENDENCE ON THE ROAD FREIGHT AND ON DIESEL • While the rail network was developed at the beginning of the 20th century, it was gradually replaced by a road network during the post-war period, partly to promote the growth of the car industry. **The transport of goods is today heavily dependent on road transport, which accounted for 65% of freight in 2015, much more than in other continental-sized countries like Brazil (see Figure 5).**

Trucks are essential for regional freight transport in Brazil and diesel is the most consumed fossil fuel, accounting for 53% of transport sector consumption in 2005 (PNE 2030, 2007). As a result, freight transportation is a major source of GHG emissions, not only in the transportation sector but throughout the energy sector. According to SEEG's analysis, in 2016, road transport emitted 101.9 $MtCO_2eq$, i.e. half of the emissions from the transportation sector and one-fifth of the emissions associated with the energy sector, more than the total emitted by power plants in the same year (54.2 $MtCO_2eq$).

In addition to this environmental cost, this predominance of road transport represents a high economic cost for the Brazilian production chain. The National Logistics Plan (2007) thus designates the transport of goods as one of the main factors limiting the country's competitiveness, as the current matrix prioritises the highest cost modes. A better balance of freight transport modes is therefore needed.

The Plano Nacional de Mudança do Clima (National Climate Change Plan or PNMC) emphasises the importance of reducing the volume of transport by HGV and of a shift towards less carbon-intensive modes such as rail and river transport. Despite this understanding, this modal shift requires major investments and the migration will be slow: roads in Brazil will remain the dominant mode in the transportation of goods. Between 1999 and 2008, the truck fleet increased three-fold (ANFAVEA, 2009) and the National Energy Plan 2030 forecasts a growth of 3.5% per year of diesel consumption over the 2005-2030 period.

Mobilisation of truck drivers and the diesel crisis

From 2011 to 2015, the Brazilian government artificially controlled the price of petrol and diesel fuel at the pump, with the main aim of controlling inflation and avoiding consumer price instability caused by high volatility of international tariffs. This policy heavily indebted Petrobras, the national oil company, and therefore ceased in 2016. Petrobras began to index its prices on those of oil and the dollar. Following the rise in the price of a barrel and the rise of the dollar against the Brazilian real, the price of diesel at the pump increased significantly in 2018, provoking the anger of truck drivers who went on strike in May 2018. The country, which is highly dependent on road transport, was paralysed as many cities faced shortages of food and fuel. Faced with the difficulty of transporting goods, some international airports were affected, and cancelled flights due to a lack of kerosene. A state of emergency was declared in many cities and the army received the order to free up the highways. After 11 days of strike action – the biggest strike in the sector in the history of Brazil – the Temer government yielded, announcing an immediate reduction of 0.46 reais in the price of a litre of diesel, based on a reduction in taxes on diesel at 0.10 reais per litre as well as direct subsidies in the amount of 0.30 reais per litre. The government estimates that these two measures will respectively represent a shortfall of 4.01 billion reais in 2018 and a cost of 9.5 billion reais.

TEXT BOX 5

• EMERGENCE OF BIODIESEL • Si l'éthanol biocarburant est fortement implanté au Brésil, les débuts du biodiesel sont plus timides. La compagnie nationale Petrobras, après avoir investi dans des usines biodiesel, n'a jamais atteint le seuil de rentabilité et a même enregistré des pertes record entre mai et juin 2015, totalisant 304 millions de réais. En 2016, elle a annoncé son retrait progressif de l'activité, fermant l'une de ses principales unités de production.

L'augmentation de la part de biodiesel dans le diesel a un potentiel de réduction des émissions considérable et est l'une des stratégies du Brésil pour atteindre ses objectifs d'atténuation. Dans le document *"Fundamentos para a elaboração da Pretendida Contribuição Nacionalmente Determinada (iNDC) do Brasil no contexto do Acordo de Paris sob a UNFCCC"*, le Ministère de l'environnement définit l'objectif d'une fraction de 10 % de biodiesel dans le diesel (diesel B10) d'ici 2030.

Cities invest in low-emission buses

Beyond this government objective, cities and manufacturers are already undertaking a more ambitious transformation, starting notably with low-GHG urban bus programmes. In 2012, the city of Rio launched a pilot programme of urban buses running on 30% biodiesel. São Paulo has also initiated a B20 bus project called "Ecofrota" (a mixture of 20% biodiesel). The most ambitious programme comes from the city of Curitiba which, in partnership with Volvo and the Swedish government, is being equipped with hybrid buses with biodiesel engines.

TEXT BOX 6

CONCLUSION

The recent stabilisation of transport sector emissions at the 2012 level is more the result of the current economic crisis in Brazil than of pro-climate actions. It will be interesting to observe the evolution of the sector's GHG emissions as the country recovers economic growth. Many initiatives are under way to decarbonise transport, at the federal level in terms of biofuel, but also at the municipal and civil society level; will these actions reverse the emissions curve?

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Air transport: efforts are still in the state of experimentation

With regard to climate change, air transport has two major characteristics. First, a strong growth in emissions that the technological and organisational progress is currently unable to contain. Second, international air transport has been excluded from the climate negotiations and the sectors covered by the United Nations Framework Convention on Climate Change (UNFCCC). The file was entrusted to the International Civil Aviation Organization (ICAO) that brings together the dominant players in the sector (manufacturers, airlines). This resulted in a proposal for the long-term management of air transport emissions: the CORSIA scheme for "*Carbon Offsetting and Reduction Scheme for International Aviation*".

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SUMMARY

1 • AIR TRANSPORT EMISSIONS ARE STEADILY INCREASING

When calculating emissions from the air transport sector, international transport emissions (530 million tonnes of CO_2 equivalent in 2015, i.e. approximately 60% of the total) and those from domestic transport (345 million tonnes of CO_2 equivalent or 40%) are always differentiated. The temporal dynamics of these emissions are the result of the growth of air transport and the improvement of its energy efficiency.

	2015
international aviation	
World	529.69
Europe	136.08
France	17.78
National aviation	
World	345.44
Europe	18.98
France	3.64

TABLE 1. DOMESTIC AND INTERNATIONAL AVIATION EMISSIONS IN 2015 (MTCO2E)

Source: International Energy Agency (IEA), Enerdata

International aviation is a driver of emission growth. Between 1990 and 2015, its emissions increased by 104.6% worldwide, 88.1% in the European Union and 88.8% in France (AIE, 2017, p.109). **At the global level, emissions from domestic aviation are growing three times slower than international aviation emissions (+ 15% between 2000–2017) (Enerdata)**

In Europe, these emissions remained stagnant and even decreased in France by 13% between 2000 and 2016 (source Enerdata), probably because of the increased use of the high-speed rail. The European Union accounts for 26% of international aviation emissions and 5.5% of domestic aviation emissions, which is easily explained by the small size of the member countries. France accounts for 13% of European emissions from international aviation and 19% from domestic aviation, which reflects both the lower propensity to travel abroad (tourist trips) compared to the countries of Northern Europe and the size of the country (1,000 km of diagonal distances across the “Hexagone”), favouring certain domestic links by plane.

	Unit	2015	2016	2017
European Union		**$MtCO_2$**	**18,9757**	**19,8323**
North America	$MtCO_2$	172.8483	179.9023	188.1661
Latin America	$MtCO_2$	15.5112	14.6124	14.5108
Asia	$MtCO_2$	94.0161	101.2096	103.9358
Pacific		**$MtCO_2$**	**10.1798**	**10.9321**
Africa	$MtCO_2$	8.4273	8.1547	8.3436
Middle-East	$MtCO_2$	4.0618	4.117	4.0657
World	$MtCO_2$	345.4379	359.9141	371.7467

TABLE 2. DOMESTIC AVIATION GREENHOUSE GAS EMISSIONS BY REGION

(Source: Enerdata)

The radiative forcing of aviation

The figure of aviation's contribution to anthropogenic CO_2 emissions of around 2% is frequently put forward; it can be discussed for two reasons:

- An alternative calculation results in less optimistic figures. According to the International Energy Agency, in 2015 aviation accounted for 7.5% of world oil consumption, or 288 Mtoe (excluding ground fuel use). By multiplying it by the Base Carbone ® coefficient of Ademe (3,642 tCO_2/toe) which includes emissions from extraction, transport and refining, we obtain a figure of 1,049 million tonnes of CO_2, i.e. 3.2% of global fuel emissions (32,294 million tonnes in 2015). In addition to CO_2, aviation produces in-flight nitrogen oxides that are not greenhouse gases but are the precursors of ozone, which is a potent greenhouse gas with a short life span on the one hand, and on the other hand, it contributes to the destruction of methane, which has the opposite effect of cooling. The net result is a warming effect.

Especially, at very high altitudes, planes produce contrails that can turn into cirrus clouds. These clouds are formed at very cold temperatures (-40°) in very high humidity and are also dependent on the dust emitted by the combustion of kerosene(Kärcher, 2018). The issue of their contribution to global warming has long been known (Penner, Lister D.H., Griggs D.J, Dokken D.J, & M., 1999); existing evaluations show that this contribution is important, but they present a very high margin of uncertainty. This was the pretext for excluding this issue from the discussions on aviation's contribution to climate change, thereby minimising its impact.

However, it should be noted that cirrus clouds have a short life span: if the flights stop, the effect disappears within 24 hours unlike CO_2 whose life span is one hundred years or more. There are ways of reducing cirrus clouds, the main one being the reduction of combustion dust (the use of biofuels could be useful in this respect), which could decrease the formation of these clouds ten-fold (Kärcher, 2018).

The estimate by a group of researchers (Lee et al., 2009) shows an aviation contribution to global warming of 4.9% in 2005 (with a 90% probability of being placed between 2% and 14%).

TEXT BOX 1

2 • INSTITUTIONAL AND POLITICAL RESPONSIBILITY FOR AVIATION EMISSIONS: THE ICAO PROPOSAL

• THE SCHEME • The UNFCCC has excluded international air transport emissions from targets set for the countries because of the difficulty in allocating them. National emissions may be included in the voluntary national contribution (Art. 31)[1] . Already in 1992, the Kyoto Protocol specified that Annex I countries should continue to limit emissions of gases not covered by the Montreal Protocol. The International Civil Aviation Organization (ICAO) has been in charge of the file since 1998 in addition to its usual tasks (management of conventions between countries, security, etc.) However, there is a clear gap between the UNFCCC's mission to reduce greenhouse gas emissions and ICAO's mission to protect and promote international aviation (Lyle, 2018).

By the end of the Kyoto Protocol period (2012), ICAO had made little progress in establishing mechanisms for managing international aviation emissions. It set targets: a voluntary energy efficiency improvement of 2% per annum and carbon-neutral aviation growth from 2020 consisting in the use of economic tools, technological and organisational progress and the use of alternative fuels. In parallel with ICAO, the International Air Transport Association (IATA) had a fairly similar outlook with an emission reduction target of 50% in 2050 compared to 2005 levels (Bows-Larkin, 2015). **Starting in 2013, ICAO began to clarify its intentions: to use a market mechanism and tradable emission permits, biofuels and to set new technical standards for aircraft starting in 2016.**

During this period, the European Union advocated for territorialised measures and eventually included aviation in its emission trading system (EU-ETS).

Failure of the European ETS against the opposition from China and the United States

The inclusion of aviation in the European emission trading system (EU-ETS) entered into force in 2009. The global allocation for European Union internal and external air transport was then set at 95% of the average emissions for the 2004–2006 period. All flights departing and arriving within the European Union were taken into account.

In 2009, airlines and airline associations based in the United States and Canada brought forward an action for the annulment of the United Kingdom's transposition of the EU Directive. The English court referred this to the Court of Justice of the European Union (CJEU), and the Advocate General of the CJEU gave unfavourable conclusions to the airlines in early October 2011. Far from easing tensions, these conclusions foreshadowing a defeat for the airlines have raised the tension even more: two weeks later, the House of Representatives passed a bill prohibiting US airlines from complying with European regulations. In early November 2011, the International Civil Aviation Organization (ICAO) Council adopted a position urging the EU and its member states to refrain from including airlines based outside the EU in the EU-ETS. This was a move that triggered a strong reaction from Connie Hedegaard, the European Commissioner for Climate, and the Association of European Airlines (AEA) who lamented a disappointing political position. China and India have also vigorously opposed the inclusion of aviation in the European carbon market, denouncing the political and economic decision against them. However, the Chinese Academy of Social Sciences, while recommending Chinese airlines to take legal action against the EU, also urged them to limit their CO_2 emissions by using biofuels, improving the efficiency of engines and optimising airlines. As a result of these pressures, the field of application of the EU-ETS was restricted to flights within the European airspace and the allocation was reduced accordingly. 82% of emission permits were distributed free of charge, 15% auctioned and 3% allocated to a reserve for new operators on the market. For the reasons

1 - At COP 21 in Paris, the part of the text relating to air and maritime emissions was withdrawn during the negotiations. This issue therefore continues to be managed by ICAO. However, the climate negotiations have taken a bottom-up approach, with the countries setting their contribution via the "INDC", quite in opposition to the top-down approach of ICAO consisting in developing standards to be applied by all parties.

of compatibility, the European Community has proposed the indefinite retention of flights from or to the European Economic Area outside of the EU-ETS, which results in a shortfall in reducing emissions of approximately 1/3. In addition, for intra-European flights, the Community proposed to align the requirements for aviation with those of other sectors, which amounts to a reduction in permits of 2.1% per year from 2021.

TEXT BOX 2

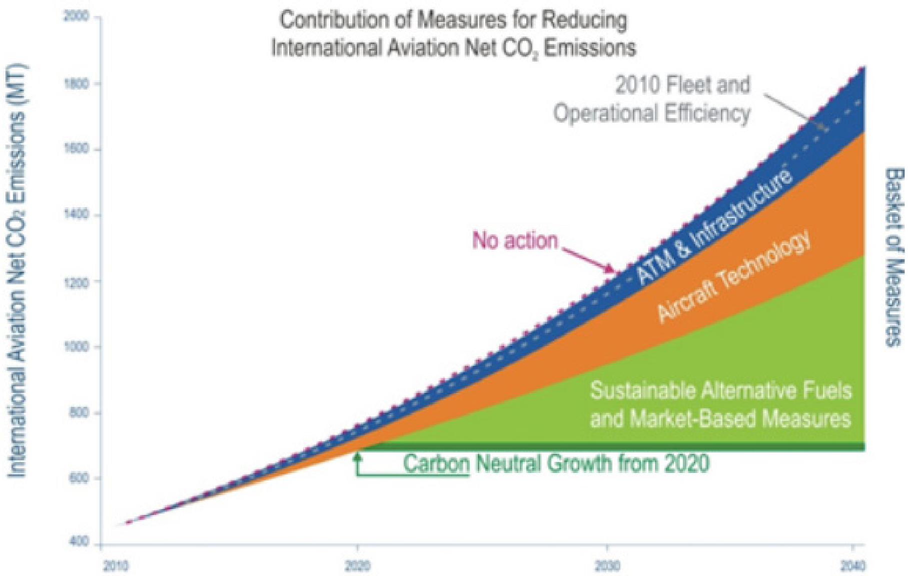

FIGURE 1. AO'S VISION FOR REDUCING EMISSIONS

Source: ICAO, 2013

The emissions estimated by ICAO in its forecast of the distribution of measures for the reduction of net CO_2 emissions due to international aviation are those of the airlines for each journey they make. In particular, this principle results in circumventing the principle of "common but differentiated responsibilities" between countries fundamental in international climate negotiations but contradictory to the equal treatment by ICAO. The responsibility for monitoring, reporting and verification (MRV) of the international airlines rests with the individual countries. Beyond MRV, an important carbon offsetting and reduction scheme (CORSIA) is being carried out by ICAO which plans to keep a consolidated register.

• CORSIA • In October 2016 after several years of discussions, the air transport sector signed a future emissions management plan called CORSIA (Carbon Offset and Reduction Scheme for International Aviation) developed by the Committee on Aviation Environmental Protection (CAEP) composed of country representatives and private sector experts who play a leading role (Lyle, 2018). CORSIA is a global scheme of market-based measures designed to offset CO_2 emissions from international aviation in order to stabilise their levels starting in 2020 (CNG2020). The draft standards and recommended practices (SARP) and related guidance material form the "CORSIA Package" to help offset CO_2 emissions through aircraft operators acquiring and cancelling emission units from the global carbon market.

For this, every three years, ICAO member countries participating in CORSIA must verify that their aircraft operators comply with the CORSIA offsetting requirements in addition to the MRV of annual CO_2 emissions. The plan includes a pilot phase starting in 2021 until 2023 and a first operational phase from 2024 until 2026. These two phases rely on the voluntary participation of the countries. Finally, there is a phase of full application from 2027 until 2035 including all countries whose individual share of international aviation activities in 2018 is greater than 0.5% of the world total or whose cumulative share accounts for 90% of the world total. **The least developed countries, small insular developing countries and landlocked developing countries are exempted from this scheme unless they voluntarily join it. These numerous ICAO exemptions mean that this agreement to reduce emissions from the international aviation sector ultimately cover only approximately 75% of emissions(Lyle, 2018, p.110).**

Calculation procedure for emission offsets required from operators under the CORSIA system

The quantities of CO_2 to offset is calculated according to the following formula:

Annual emissions of operator x, growth factor = amounts of CO_2 to be offset

The growth factor in this equation changes each year according to the growth of emissions of each sector and each operator. The growth factor is calculated by ICAO based on the percentage increase in the quantity of emissions from the base year to a given future year. This calculation of the offsetting requirements to be allocated to the different airlines will go through different phases. Over the 2021–2029 period, this factor will be indexed only on the growth factor of the emissions from the sector. The objective is to gradually move to a factor calculation based solely on the evolution of emissions of the operators.

After this calculation, the operator reports on the use of sustainable airplane fuels during the compliance period. The government therefore deduces the benefits of using sustainable aviation fuels and informs the operator of its final offset requirements for the compliance period. Finally, the operator submits a validated emission unit cancellation report to the government that it verifies by informing ICAO.

Source: ICAO, Presentation of the CORSIA scheme, 2018

TEXT BOX 3

The position of the European Union concerning the ETS system was first to wait for the implementation of the international CORSIA management plan and to take timely measures to adapt to it. An assessment of the effects of CORSIA for the European Economic Area accompanied the study of the implementation of the EU-ETS. The following table shows the main features of CORSIA and EU-ETS; it highlights the gap in ambition and the problems of compatibility between the two systems.

CORSIA	EU ETS
Unlimited growth	Scalable ceiling
Nothing on emissions below the 2020 level	Total coverage of emissions, with a “temporary” exclusion of aviation to or from locations outside Europe
Partial coverage of emissions (exceptions)	
Completely based on offsetting	Excludes offsetting starting in 2020
Offsetting criteria currently unknown	List of what cannot be retained as offsetting
Voluntary until 2027	Binding
Absence of sanctions	Financial penalties

TABLE 3. DIFFERENCES BETWEEN CORSIA APPROACH AND EU EMISSION TRADING SCHEME

Source: Adapted from Carbon Market Watch, 2017

Similar to the EU-ETS, the establishment of the CORSIA system is questionable. There are many differences of opinion between ICAO and other non-state actors on the subject of reducing emissions from the international aviation sector, which shows the complexity of the positions of each of the actors with regard to the possible actions

• THE POSITION OF THE PLAYERS WHEN FACING LARGE OFFSET SYSTEMS • Manufacturers and airlines intervene through various associations whose aim is to provide expertise in the debate on methods to reduce CO_2 emissions in the aviation sector. The main associations are ATAG and ACARE[3] on the manufacturers side and IATA for airlines. These actors have certainly played a decisive role in the rather opaque development process of the ICAO proposals, and they absolutely adhere to a strategy of using biofuels and an offsetting system for the remaining emissions. Their communication highlights expected technological and organisational changes. For example, they state a 75% reduction in passenger CO_2 emissions by 2050 compared to 2005 levels (source ACARE)[4]. An objective to be adhered to in the context of increased development of global air traffic. In fact, in October 2018 IATA planned a doubling of global air traffic by 2037.

However, according to the 2016 Carbon Market Watch annual report, CORSIA's maximum contribution to the reduction of aviation emissions is estimated to be 0.3 GT of CO_2 equivalent per year, while the extra emissions from the sector should be around 0.6 GT in 2030 compared to 2017 levels. The International Coalition for Sustainable Aviation (ICSA)[5] published a report in February 2018 entitled "*Understanding the CORSIA scheme: a critical guide to the key provisions of the draft standards and recommended practices and related guidance material for the carbon offsetting and reduction scheme for international aviation (CORSIA)*", in which it gives a critical opinion on the implementation of this system and on several elements of its functioning.

First, it considers that CORSIA's monitoring, reporting and verification (MRV) system as proposed in the CORSIA Package is not transparent enough. For ICSA, allowing third parties to access reports on emissions submitted by airlines would help to ensure the environmental integrity of CORSIA and avoid market distortion by deterring any preferential treatment of transport companies. In addition, the coalition suggests that ICAO refrain from awarding credits to alternative aviation fuels under CORSIA as long as the provisions on sustainable aviation fuels including sustainability criteria have not been strengthened. According to ICSA, these strict and comprehensive sustainability criteria should be included in the final implementation elements of CORSIA before the launch of the 2021 pilot phase.

• SWEDEN, THE PIONEER IN TAXING FLIGHTS • In Sweden, a law passed on 30 November 2017 introduced an aeronautical tax starting on 1 April 2018. The Swedish government requires airlines to declare and pay tax on all commercial flights departing from Sweden, chartering aircraft with more than 10 seats. The tax rate depends on the final destination of the passenger: €6 to continental Europe, €25 to countries outside Europe (Middle East, Africa, USA, Central Asia), and €40 to other countries. The law provides for exemptions for children under 2 years of age, crew members on duty, flights following a technical stop, flights returning to the airport for weather reasons or following a mechanical failure.

The consequences of introducing this tax were very quickly felt. **On 1 October 2018, the Swedish transport agency lowered its air traffic forecasts for 2018 and 2019 by 500,000 passengers compared to the forecasts published in the spring of 2018. The number of passengers departing from Swedish airports should therefore only increase by 1.3% in 2018, totalling 23.7 million passengers, and 2.3% in 2019 (totalling 23.9 million passengers)**. External traffic is expected to increase, while domestic traffic is expected to decrease. The Swedish transport agency has attributed the relatively small

3 - https://www.acare4europe.org/sites/acare4europe.org/files/document/volume1.pdf
4 - https://www.acare4europe.org/documents/delivering-europe%E2%80%99s-vision-aviation-sria-2017-update
5 - The ICSA is comprised of the Aviation Environment Federation (AEF), Carbon Market Watch, Environmental Defense Fund (EDF), the International Council on Clean Transportation (ICCT), Transport & Environment, and WWF.

increase in the number of passengers to the Swedish air transport tax, which came into force in April 2018, and the bankruptcy of Nextjet, the main regional airline, which has led to a reduction in supply, particularly in the domestic aviation market. Moreover, following the implementation, the airlines reacted strongly via IATA, warning that in the short term, this tax would cause the loss of 7,500 jobs in Sweden and would have a negative impact on Sweden's economic competitiveness, with the sector currently accounting for 4% of the GDP and 240,000 jobs in the country. It should be noted that IATA did not refer to the 1944 Chicago Convention, the reference document for the regulation of international air traffic which gave rise to the creation of ICAO, stating that the fuel contained in the tank of an airplane cannot be taxed upon arrival in a country. This agreement is regularly used to prevent any taxation of kerosene.

3 • VOLUNTARY OFFSET SYSTEMS

Environmental protection NGOs and small companies specialising in sustainable development consulting are seeking to produce and sell "carbon credits" to companies not covered by the Kyoto Protocol. **This market mechanism is called a voluntary carbon offset market. These promoters are therefore seeking companies in various sectors that do not have a legal obligation to invest in offset services for their GHG emissions (Valiergue, 2018).** Some of them even extend their proposals by promoting categories of projects not listed by the UN as potentially producing carbon credits, for example selling improved ovens or distributing water filters. Establishing this voluntary offset market is based on the implementation of various systems and practices that monetise these carbon offsetting services. As such, many economic players implement support services for voluntary carbon offsetting by customers during their purchases, particularly in the tourism and aviation sector.

• VOLUNTARY OFFSET PUT IN PLACE BY AIRLINES IN SUPPORT OF LABELLING • Ryanair offers customers the option to check an option when buying their ticket to "*donate to offset the carbon footprint of my flight and contribute to other environmental initiatives*". Meanwhile, Air France sends an email to customers after a flight to promote its "*Trip and Tree*" initiative. Consumers can also choose to go directly through private organisations or specialised NGOs to monetarily offset the carbon emissions of their travels. The principle is always the same: after calculating the carbon equivalent of the trip, the total is converted into a sum of money which the passengers can pay to an association of their choice who will use it to plant trees, for example. Labelling becomes an essential tool so that the consumers can find their way around the multitude of offsetting offers.

Evaluation differences in calculating the offsetting needs when buying a plane ticket

As part of a news story, in October 2018 the French newspaper Libération tried a test ticket purchase for a direct ticket between Paris and Cape Town, South Africa, on several platforms integrating calculators. It is deduced that a passenger in economy class consumes:

• The equivalent of 932 kg of carbon if we trust the Air France calculator;
• 1.735 tonnes according to the German atmosfair.de, which also considers the aircraft model;
• 1.8 tonnes of CO_2 according to myclimate.org;
• 1.98 tonnes according to CO_2solidaire.org, climatmundi.fr and greentripper.org;
• 2.05 tonnes on GoodPlanet.org (the Yann Arthus-Bertrand foundation);
• 2.31 tonnes based on CO_2balance.com;
• On the website of the French Ministry of the Environment (MTES) (Directorate General of Civil Aviation), Cape Town is not listed as a destination. However, a consumption of 891 kilograms of CO_2 equivalent is indicated for a flight between Paris and Johannesburg (South Africa).

In conclusion, the various calculators differ by a multiple of 2.5 in their consumption estimate for the same flight, which adds to the uncertainty as to the effectiveness of the voluntary offsetting actions, and it causes a loss of readability for consumers.

Source: Libération, 20/10/2018

TEXT BOX 4

An operator's membership in an international label therefore appears as more beneficial. Commonly recognised as the most successful, the Gold Standard was created in 2003 at the initiative of international NGOs WWF, SouthSouthNorth and Helio International. It is considered to currently guarantee the best traceability of offsetting projects. Other labels also position themselves as references, such as the "VCS" created in 2006 and adopted by Caisse des Dépôts for the creation of its carbon credit registry in March 2009.

In addition to the labels, project selection remains paramount. For example, reforestation projects are highly controversial, to the extent that Climat Mundi (a consulting firm specialising in supporting economic and institutional players in integrating climate issues and emission reduction into their development policies) is refusing to finance it. Currently, the two main problems are the difficulty of evaluating the amount of carbon stored in a forest and the diachrony between CO_2 emitted by humans and effective offsetting by a forest of at least thirty years.

• TOUR OPERATORS ALSO RELY ON VOLUNTARY OFFSET LABELLING • Tour operators are also mobilising to promote voluntary offsetting to their customers. The ATR (Acting for Responsible Tourism) label, entirely renewed in 2015, wanted to open up to major operators demonstrating that sustainable tourism should not be confined to a niche. Until now, the airlines were invited to determine their annual carbon footprint based on the choice of offers offered to their customers. To go further, the management of the ATR label has announced a proposition that starting in the second half of 2018, 100% of the emissions from airlines shall be offset. The argument put forward by the label is that it seems indispensable that instead of asking for voluntary offsetting from their customers, the airlines themselves must be proactive on the issue. Some companies already operate with this change such as the travel agency Les Ateliers du Voyages (Travel Lab group), which has the ATR label, which for example, on the occasion of the World Responsible Tourism Day on 2

June offset the carbon of all the trips sold that week. This approach was based on a partnership with the CO_2 Solidaire platform of GERES that was launched in 2004 and is currently serving four project leaders (GERES, Initiative Développement, Microsol and Bleu-Blanc-Cœur) with the aim of offering carbon credits with high social quality and direct distribution.

Impact of the development of global tourism on the aviation sector

A study published in May 2018 in Nature Climate Change (Lenzen & al., 2018) states that tourism is responsible for approximately 8% of global GHG emissions. Between 2009 and 2013, the carbon footprint of the sector at the global level increased from 3.9 to 4.5 billion tonnes of CO_2 equivalent considering transport-related emissions and also those resulting from the consumption of goods and services by tourists and business passengers. Given the estimated strong growth of the world tourism sector corresponding to +7% over 2017, the authors of this study conclude that tourism will continue to constitute a growing share of global GHG emissions in the coming years and therefore will increase travel needs, especially air travel. Most of these emissions come from high-income countries because of domestic travel (supported by the development of low-cost domestic flights) but also because of their nationals traveling abroad.

TEXT BOX 5

Other tour operators were also interested in the subject in the early days, such as the Voyageurs du Monde company. Since 2007, the tour operator has offset 100% of its employees' emissions and up to 20% of those of its customers with reforestation programmes through the "*Insolite Bâtisseur Philippe Romero*" foundation. Since 1 January 2018, the group has gone even further by covering 100% of the CO_2 emissions generated by air and ground transport for each trip made by Voyageurs du Monde and Terres d'Aventure. In total, this measure costs approximately €500,000 per year for Voyageurs du Monde and €200,000 for Terres d'Aventure. This is an important choice for the two companies which will replace voluntary offsetting on the part of their customers, which they consider to be inefficient. Others have developed hybrid offsetting systems: 50% of the amount of the carbon offset is provided by customers, and the tour operator pays the remainder to finance energy-efficient tools and equipment in developing countries in partnership with NGOs and local associations. The tour operator Double Sens has implemented this system of traveller commitments in its projects from 2017 and gained interesting results with 30% of travellers participating in the voluntary offsetting process.

4 • TECHNOLOGICAL CHOICES

As part of the preparations for the COP 21 in Paris in 2015, aircraft manufacturers made commitments alongside the world's major airlines to significantly reduce the CO_2 emissions due to the engines from their production lines. **In a letter of commitment issued by the Air Transport Action Group (ATAG), 28 leaders of the main commercial aviation manufacturers, engine manufacturers and airline trade groups and airports have pledged an annual 1.5% improvement in global fleet energy efficiency, carbon-neutral growth from 2020 and a 50% reduction in CO_2 emissions by 2050 compared to 2005 levels.** To comply with this roadmap, manufacturers and companies are working on three major axes: reducing the weight of planes, new engine technologies and alternative fuels instead of kerosene. Developments in airport infrastructure and companies' directives for ground crews also make it possible to participate in the effort of the sector.

• ENGINES • Aircraft construction companies, particularly the two largest companies worldwide – Airbus and Boeing – rely on a series of engine manufacturers. Two major competing companies

– one French-American (CFM International) and the other American (Pratt & Whitney) – compete for the world market. Their numerous collaborations, notably with Airbus, resulted in 2016 in the delivery of 68 A320neo aircraft including the first model with LEAP-1A engines delivered to the Turkish company Pegasus Airlines.

With the A320neo, Airbus gained a 15% reduction in fuel consumption per seat as soon as it was commissioned and 20% by 2020 compared to the current A320 model. As a result, CFM International's engine gives the operators a two-digit improvement in fuel consumption and CO_2 emissions compared to the best CFM engines in service, as well as a reduction in nitrogen oxide emissions and noise pollution. CFM International, the 50–50 joint venture between General Electric (GE) and Safran, has planned to deliver approximately a hundred LEAP engines in 2016, then 500 in 2017 and 1,200 in 2018.

There were more than 11,100 orders and purchase intentions for the LEAP engine at the end of July 2016 (compared to 8,400 GTF from P&W in mid-December). According to the manufacturers, the set of used technologies will lead to an optimisation of the operating conditions combined with the reliability and low maintenance costs of the CFM engines. According to Safran, they will allow greater fleet availability, increased longevity and will help reduce costs and maintenance operations.

The era of hybrid electric engines opens for the aeronautical sector

A hybrid electric propulsion aircraft will fly in 2020. This commitment was made in December 2017 in a tripartite agreement between Airbus, the engine manufacturer Rolls-Royce and German company Siemens. This cooperation completes the agreement planned in April 2016 between Airbus and Siemens to develop hybrid electric engines for airplanes, helicopters and drones by 2020. Industrialists are relying on a project called E-Fan X to design a plane that is less dependent on fossil fuels in order to meet the global objectives of reducing CO_2 emissions. This programme replaces the E-Fan, a two-seat aircraft equipped with a 100% electric engine which Airbus had abandoned in March 2017.

Within this project, along with Airbus responsible for the global integration of the hybrid propulsion system and batteries, Rolls-Royce will develop the turbine engine, the two-megawatt generator and the power electronics. Siemens will supply the electric motors and their electronic power control unit as well as the inverter, the DC/DC converter and the power distribution system.

The E-Fan X aircraft is scheduled to fly in 2020 after a full set of tests on the ground. It will be a BAe 146 test aircraft with one of the four reactors replaced by a two-megawatt electric engine. Subsequently, arrangements will be made to replace a second turbine with an electric engine once the maturity of the system has been demonstrated, as specified by the three manufacturers involved.

Source: Airbus Newsroom, 2017

TEXT BOX 6

• **BIOFUELS** • During the preparations for the Paris climate agreement, aircraft manufacturers have highlighted the importance they attach to biofuels, potentially reducing CO_2 emissions by 50 to 80% compared to fossil fuels, with the establishment of "*sustainable aeronautical biofuels*" sectors. **In the context of mass utilisation of biofuels, industry players and ICAO member countries have identified a set of measures for the deployment of sustainable alternative fuels of the "drop-in" type** (fuels with a chemical structure analogous to fossil fuels facilitating their incorporation in large quantities). The integration of alternative fuels in the pilot phase of the CORSIA carbon offset system in 2021 is already planned. Moreover, in the next version of the Renewable Energy Directive expected in 2018, Europe plans to integrate the aviation sector into the ENR8 objectives of the transport sector. Meanwhile at the end of 2017, the French government signed a public/private partnership in the form of a commitment for green growth (ECV) about establishing a sustainable aerospace biofuels sector in France from waste biomass.

Based on the first test of an airplane that flew on biofuel in 2008, IATA launched its Sustainable Aviation Fuel (SAF) programme in 2011 expecting that 100,000 flights would be flown using biofuel by 2017 and that approximately one million flights would be affected in 2020. Eventually, the projection leads to 1 billion passengers potentially travelling on biofuel flights in 2025. Achieving this goal assumes the creation of many bilateral commitments between producers and airlines and sometimes also manufacturers in the coming years. **Since the first partnership was declared in 2009, these commitments have multiplied and counted 28 in total between 2010 and 2015 involving regional stakeholders** (IATA, 2015). The flight of Hainan Airlines on 21 November 2017 was made using biofuel manufactured by the local unit of Sinopec Group, a Chinese petrochemical company. China made its first transoceanic flight from Beijing to Chicago using green fuel and carrying 186 passengers and 15 crew members. The Boeing 787 aircraft flew on biofuel produced from used cooking oil supplied by China Petroleum and Chemical Corp., a subsidiary of Sinopec Group based in Ningbo, Zhejiang Province. The manufacturer and the company welcomed this success; however, the biofuel used in this case was composed of only 15% cooking oil and 85% conventional aviation fuel.

Although a number of airlines have signed biofuel purchase agreements, the results do not match the ambitions envisioned by IATA. Based on $51 to $55 per barrel of fossil fuel, the use of biofuel accounted for an additional cost of approximately 27% for airlines in 2017 (US Department of Energy, 2017).

The SAS and Preem agreement for the use of biofuel

In Sweden, SAS, an airline, and Preem, an oil company, have signed a letter of intent for an agreement to produce and use renewable aviation fuel. SAS aims to replace the current domestic aviation fuel volume with biofuels by 2030. This letter of intent notifies that SAS and Preem intend to collaborate to jointly produce biojet (renewable aviation fuel or biofuel) as part of the planned expansion of Preem's capacity at the Göteborg refinery. The preliminary start of production will begin in 2022, and the total capacity of biofuels is estimated at over one million cubic metres of which a subset can be biojeted on the plane.

TEXT BOX 7

In order to boost the development of the initiatives, the ICAO secretariat published a very large-scale proposal for the use of biofuels ahead of its top-level conference on alternative fuels in Mexico from 11 to 13 October 2017. **The proposal involves 5 million tonnes of biofuels per year used by airplanes by 2025 corresponding to 2% of projected aviation fuel use; 128 million tonnes per year used by 2040 representing 32% of projected aviation fuel use; 285 million tonnes per year used by 2050 corresponding to 50% of projected aviation fuel use. However, beyond the quantities of production and consumption, the quality of the biofuels used is an important issue not only in terms of fuel efficiency but also in terms of environmental impact and reduction in the use of conventional fossil fuels**. Six aeronautical biofuels are already certified by ASTM (*American Society for Testing and Materials*) for use in combination with fossil kerosene, and several new technologies are being certified.

Les technologies biocarburants aéronautiques certifiées ASTM en juin 2018. Source : ANCRE

Technologies certifiées	Ressources biomasses	Taux de mélange certifié	Maturité technologique	Principaux acteurs impliqués sur l'ensemble de la chaîne (dont industriels et acteurs R&D français)
HEFA (1) Hydrotraitement d'huiles	Huiles végétales, huiles usagées, graisses animales, huiles microbiennes	50 % vol.	**TRL9** : Technologie mature dont usine Total en cours d'ouverture à la Mède (France)	**Axens, Total,** IFPEN Neste (Finlande, Pays-Bas, Singapour), UOP-ENI (Italie, USA)
HEFA (1-bis) Hydrotraitement d'huiles	Idem HEFA (1) en coprocessing avec des résidus du raffinage	5 % vol.	**TRL9** : Technologie mature	Idem HEFA (1)
FT-SPK (2) Gazéification & Fischer-Tropsch	Biomasse lignocellulosique	50 % vol.	**TRL8** : Fin du programme R&D BioTfueL en France en 2019	**Bionext (BioTfueL),** IFPEN, CEA, **AVRIL** BELT (Canada), Fulcrum (USA), RedRock (USA), Velocys (USA)
FT-SPK (2-bis) + aromatiques	Biomasse lignocellulosique	50 % vol.	Démontré sur ressources fossiles **TRL7** à partir de biomasse	Idem FT-SPK (2)
SIP (3) Farnesane par voie biologique	Sucres issus de plantes sucrières, Sucres lignocellulosiques	10 % vol.	**TRL9** :Technologie mature à partir de canne à sucre au Brésil, **TRL4** : R&D sur voie lignocellulosique	Amyris (Brésil) en partenariat avec **Total et Airbus** pour l'importation
ATJ (4) iso-butanol ou éthanol	Sucres issus de plantes sucrières, Sucres lignocellulosiques	50 % vol.	Technologie mature pour la production d'alcool, **TRL7** sur la chaîne complète, **TRL4** à démontrer sur biomasse lignocellulosique	GEVO, Lanzatech, Byogy (USA) Ethanol lignocellulosique : **Procethol2G (Futurol),** INRA, IFPEN, **ARD, Lesaffre.** Biochemtex (Italie), Clariant, Poet-DSM (USA), Praj (Inde)

(1) Hydrotreated Esters And Fatty Acids ; (2) Fischer-Tropsch - Synthetic Paraffinic Kerosene ; (3) Synthesized Iso-Paraffins ; (4) Alcohol To Jet.

FIGURE 2. ASTM CERTIFIED BIOFUEL TECHNOLOGIES AS OF JUNE 2018

Source: ANCRE, June 2018

In its report from October 2017, the NGO Biofuelwatch warned about the economic and environmental sustainability of the massive use of ASTM-approved biofuels (Biofuelwatch, 2017). Among these, HEFA is an aviation fuel derived from refined hydrotreated vegetable oil, involving the use of hydrogen (HVO process). It is a special type of HVO for aviation that is slightly different from HVO diesel used as fuel for the road sector. In its report, Biofuelwatch pointed out that HVO fuels, and specifically HVO diesel fuels, experience a huge increase in production. The NGO fears that this new market will create a growing demand for vegetable oils and especially palm oil. **Exponential increate in the use of HVOs in aviation under the pretext of reducing carbon emissions from the sector could thus provoke an additional massification of oil palm cultivation, leading to further deforestation – current surfaces cannot suffice to satisfy all demands for food and fuel**.

• AIRPORTS • Faced with the challenges of reducing the carbon emissions of the sector, airports also make commitments to support the necessary transition. According to the UNFCCC, there were 250 airports in 68 countries in October 2018 (out of 3,864 commercial airports worldwide) with climate change commitments and 44 of them already achieved climate neutrality as part of the Airport Carbon Accreditation programme run by the Airports Council International (ACI). 48 airports joined the programme in the 12 months leading to May 2018 – an increase of 25% from the previous year. In total, this covered 3.3 billion passengers last year, which represents 44.2% of global passenger traffic according to Airport Carbon Accreditation (ACA). ACI World is currently examining various options to ensure that airports around the world officially join the programme.

ACI identifies different sources of emissions by field of application for which airports must take action (ACI, 2009):

• Field of application 1: Sources owned or controlled by the airport. Power plants (heating, air conditioning and electricity production), vehicle fleet (passenger transport, service vehicles, machines used airside and landside), airport maintenance (cleaning, repairs, green spaces, etc.), handling and maintenance of aircraft on the ground, emergency energy, training in firefighting, waste treated on site.

• Field of application 2: Off-airport electricity production purchased by the airport operator.

• Field of application 3: Other activities and sources linked to the airport

Between July 2016 and July 2017, the airports that reported their emissions to the Airport Carbon

Accreditation platform reduced their CO_2 emissions by 202.8 $MtCO_2$, which is a lower result than in previous years (206 $MtCO_2$ in 2015–2016 and 212.4 $MtCO_2$ in 2014–2015).

Airport Carbon Accreditation programme of ACI

The Airport Carbon Accreditation programme run by the Airport Council International is managed independently, approved by the institutions and given support by UN Climate Change, UN Environment, the International Civil Aviation Organization, the US Federal Aviation Administration and the European Commission. To date, airport commitments being voluntary, 39 airports in North America, 17 in South America, 136 in Europe, 47 in the Asia-Pacific region and 10 in Africa carry this certification.

ACI issues four levels of accreditation covering all stages of carbon management:

- Level 1, Inventory: an inventory of sources and annual quantities of CO_2 emissions over which the airport operator has direct control (sources from scopes 1 and 2), with the possibility of including certain scope 3 sources and other greenhouse gases than CO_2. A list of other sources of emissions (scope 3) is also required.
- Level 2, Reduction: same as the inventory for level 1, and a management plan for carbon emissions produced by scope 1 and 2 sources must be developed and implemented. Evidence to support ongoing measures, reporting and emission reductions must also be provided.
- Level 3, Optimisation: the inventory needs to be expanded to include some scope 3 sources, (at least) taking into account the aircraft LTO cycle, the GAP, surface access and business trips. The carbon emission management plan must be expanded to involve other stakeholders and ongoing emission reductions must be demonstrated.
- Level 3+, Neutrality: same as the requirements for level 3, and the airport operator must demonstrate that they have offset their residual emissions from scopes 1 and 2 and have therefore reached "*carbon neutrality*".

Only the management of CO_2 emissions is mandatory under the ACA programme. The inclusion of other GHG emissions is optional.

TEXT BOX 8

Many airport initiatives are therefore to be highlighted with a view to reducing their emissions. **In October 2018, Côte d'Ivoire's busiest international airport, the Félix Houphouët-Boigny Airport serving Abidjan, renewed its Airport Carbon Accreditation at the highest level (3+ Neutrality). To date, this airport is the only one on the African continent to have reached this level of maturity in carbon management.** In September 2018, the partnership between Brisbane Airport headed by Brisbane Airport Corporation (BAC), Virgin Australia and Australia's leading supplier of transport fuels Caltex resulted in a series of conclusive tests regarding the use of biofuel for flights of the company. Successful testing is an important first step for stakeholders and the Queensland government is ensuring that Australian airports and the fuel supply chain are ready to provide biofuels on a regular basis while developing a genuine local sector. Flight path optimisation and tarmac taxiing on landing and take-off are also part of the solutions to reduce fuel consumption in airports. Air France – KLM, for example, encourages its pilots to use eco-friendly practices by optimising the transport of fuel or by cutting one of the two engines during taxiing.

On the ground, the airline is also using electric track vehicles (50% of the fleet). Objective for the Franco-Dutch group: improve its energy efficiency by 20% by 2020 compared to 2011 levels.

ur le groupe franco-néerlandais: améliorer son efficacité énergétique de 20% d'ici 2020 versus 2011.

CONCLUSION

The extremely fast growth of air transport as envisaged for the coming decades (increase in mass tourism, in particular) places all the players involved (manufacturers, airlines, airports) in the face of a major challenge of controlling carbon emissions. As an exception to the agreements between countries under the umbrella of the Climate Convention, air and maritime transport regulation was left to the responsibility of the players themselves through the intermediary of international organisations (ICAO, IATA), although national governments obviously continue to watch over their interests as we have seen with the European ETS. This system of regulation is also based on a refusal to limit the growth of the sector; it has not yet demonstrated its feasibility, and it raises a lot of scepticism about the two preferred tools – offsetting and the call for biofuels.

However, it should be noted that the players are truly investing in technological developments (engines and fuels) and forming industrial partnerships, both for flights and ground infrastructure. The impact of these new technologies in terms of raw carbon emissions and environmental sustainability (including biofuels consumed) will be a key issue in the coming years.

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Greenhouse gas emissions: a decisive asset for rail?

Globally, rail is a mode of transport that does not emit much in the way of greenhouse gases. It also has much opportunity for improving its energy efficiency and reducing emissions (electrification). That's why it is tempting to predict a bright future for it, but as this sheet shows, the reality is a little different…

Head Editor • **THE CLIMATE CHANCE OBSERVATORY TEAM** •

CONTENTS

1 • STATE OF PLAY

Rail transport is a sector encompassing multiple modes of urban travel (electrified or non-electrified trains, trams, underground rail, etc.), medium and long-distance journeys (regional or high-speed trains), as well as goods transport (freight). Since the first steam locomotive test in Wales in 1804, the development of rail infrastructure around the world has been very uneven not only across countries, but also over time.

In the current climate of concern surrounding climate change, the benefits of rail are mainly fourfold. Firstly, its ability to provide mass transport provides economies of scale that reduce energy consumption and emissions per unit transported. The possibility of using electrical energy then gives carbon-free and renewable energies an important place for the future of the sector. In addition, a permanent connection to the electricity network makes it possible, on the one hand, to recover braking energy, and on the other hand to optimise the use of the network's energy, or even to contribute to the resilience of this network. Finally, high speed access makes it possible to take a market share over less energy efficient and more polluting means of transport such as air transport, for example.

However, the rail sector's major handicaps still lie in the scale of investments required, especially for infrastructure, and the inability of this mode of transport to completely move goods and people in sparsely populated areas: it can't go that extra mile and lacks flexibility when it comes to travel adjustments. These handicaps have become more significant over time, with rural areas seeing their population decrease, even as the costs of infrastructure and investments have increased due to urban expansion or technical developments (the advent of high-speed rail for example). **This means that rail has lost ground in most countries around the world.**

Among the formerly industrialised countries, some have retained and developed intra- and inter-urban passenger transport, even though all have adopted the car en masse; as the case may be, rail freight has more or less held its own against road transport. Some large emerging countries (China, India, etc.) have a considerable rail network, possibly inherited from the colonial era, and others do not (Brazil). In many developing countries, the rail network left by colonisation has long been dormant (Ethiopia), and in some cases formerly precursor colonised countries, such as Mexico, have also completely abandoned their infrastructure in favour of road transport. In some other emerging countries, lines dedicated to private transport have been created (Mauritania) and new investments are now helping to renovate some lines (Addis Ababa, Djibouti, Nairobi).

This fact sheet attempts to factor in this extreme diversity and focuses on the spatial dimensions and promising developments in terms of decarbonisation.

2 • EVOLUTION OF CARBON EMISSIONS IN THE RAIL SECTOR

• LOW-EMISSION RAIL TRANSPORT IN TERMS OF LOAD CAPACITY • While in 2015 transport accounted for 24.7% of global CO_2 emissions and 28.8% of the final energy consumed, rail transport accounted for 4.2% of global CO_2 emissions from transport and 1.9% of its final energy demand. In the same year, it accounted for 6.7% of passenger kilometres and 6.9% of world freight (tonne kilometres). **From 2005 to 2015 CO_2 emissions from rail transport per passenger kilometre decreased by 21.7% and emissions per tonne kilometre for freight by 19%(IEA & UIC, 2017, p.18)**. In 2015, the top four emitters were China (43.8%), Russia (10.4%), the European Union (8%), and India (7.7%) (see Figure 1).

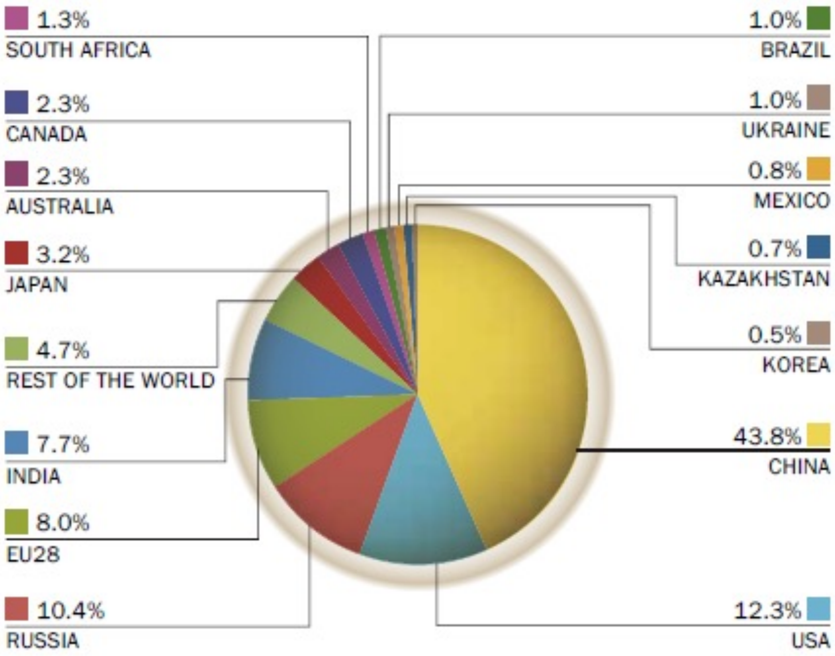

FIGURE 1. CO_2 EMISSIONS FROM RAIL TRANSPORT BY COUNTRY IN 2015

Source: Railway Handbook. Energy consumption and CO_2 emissions, IEA & UIC, 2017, p22.

Over the last two years (2015-2017), the share of rail transport in global emissions is trending downwards for China (-3%), upwards for India (+ 7%) and remains comparatively stable for the USA and Europe (Source: Enerdata).

Rail transport emits little greenhouse gas in terms of its contribution in volume to the transport of passengers or goods. In Europe, the sector's contribution is less than 1.5% of total transport emissions, while its modal share is 8.5% (CER & UIC, 2015, p.3). Comparison with other modes of transport appears favourable for rail, both for passenger and freight transport, as shown in the following graphs.

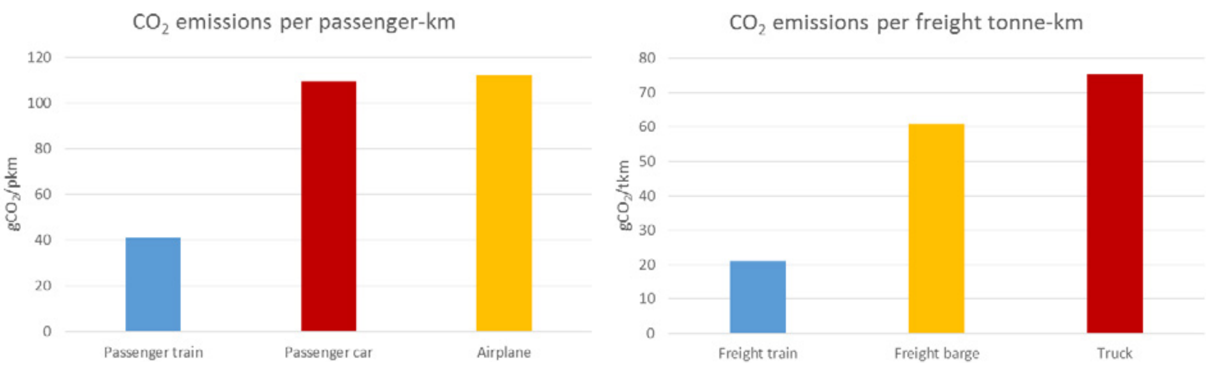

FIGURE 2. CO_2 EMISSIONS, IN PASSENGER/KM AND IN TONNE/KM, BY MODE OF TRANSPORT IN 2011

Source: (UNIFE & CER, 2016, p.4), based on data from the European Environment Agency (2013)..

Crude analysis of the evolution of CO_2 emissions related to rail transport is therefore complex. **Their increase may paradoxically appear as good news, if it reflects an increase in modal shift between road and rail. Conversely, the decline in emissions is not necessarily positive if it reflects a collapse of rail freight.** The emission reductions to be highlighted are therefore related to equipment and motorisation, for example the replacement of diesel with electricity produced by renewable sources.

• RAIL TRANSPORT PROSPECTS FUEL NATIONAL TARGETS FOR LOWERING CARBON EMISSIONS•

In view of the performance of rail transport in terms of load/emissions ratios, many governments and national bodies are betting on rail to try to meet the general objectives of reducing carbon emissions in their territory. So much so that the future of rail seems to be fed by the perspectives indicated by the political positions taken by Governments regarding the sector's development.

In India, a study on rail decarbonisation by 2030 examines the consequences of strong electrification, using solar and wind energy to power the grid. Scenarios produced by the Indian authorities conclude that decarbonisation saves 17% in the sector in terms of traction energy compared with a non-decarbonised scenario and 33% on all other rail energy needs.

In France, several scenarios deal with the place of rail transport and its emissions in 2050: the national low carbon strategy (SNBC) of the Commissariat général au développement durable (Office of the Commissioner General for Sustainable Development) (2016), the "visions" of the Ademe updated in 2017, the scenarios of the Institute for Sustainable Development of International Relations (IDDRI) 2017, the Negawatt scenario of 2017. The four scenarios predict a growth in railway development from 23% to 102% for passengers and from 68% to 203% for freight, due to an increase in demand and/or the increase in rail's modal share. Scenarios based on an increase in modal shares (from 10 to 25% for Ademe and 40% for Negawatt) imply a tight mesh around the supported territory, including the regional lines, with a diesel output. Other scenarios rely on energy substitution and improved energy efficiency to reduce emissions. This is the case in the SNBC scenario, and the TECH-first scenario of IDDRI. Depending on the ambition of this modal shift and other changes in transport demand, the potential emissions reductions in the transport sector by 2050 are more or less significant: -100% for negawatt, -91% for ADEME, -79% for TECH-first and -62% for the national low carbon strategy (Bigo, 2018).

Germany, too, supports the idea of using the railways to achieve climate change goals. The infrastructure plan for 2030, unveiled by the Federal Minister for Transport, provides for an investment of €270 billion, of which about 40% will be for rail. This will allow Germany to make a strong commitment in terms of European targets and increase the capacity of the German rail network by 20%, without the need for new infrastructure, and 70% of the national grid will be electrified.

In the light of these hopes, based on improvements in rail transport, industry players have made commitments to reducing their carbon emissions.

2 • LOW-CARBON VISIONS AND STRATEGIES ARE AMONG THE KEY PLAYERS IN THE RAIL SECTOR

In structuring the industrial strategies in the rail sector, the close relationship between the positions and initiatives of organisations representing the sector (e.g. the International Union of Railways (UIC) on a global level, Community of European Railway and Infrastructure Companies (CER) and Union of European Railway Industries (UNIFE) in Europe etc.) and the emission reduction targets of the political entities, is the factor that we are proposing to study more closely here. **Indeed, it appears that on many initiatives, some of which are detailed below, rail sector organisations are appropriating the political ambitions of states to develop their own goals and strategies.**

• COMMITMENTS OF THE REPRESENTATIVE INSTITUTIONS OF THE RAIL SECTOR • The interests of rail transport stakeholders are defended by several supranational entities such as the International Union of Railways (UIC), which was founded in 1922 and has 240 members on five continents: railway companies, infrastructure managers, research institutes and so on. Its mission is to promote rail on a global scale. The Community of European Railway and Infrastructure Companies (CER) brings together more than 70 railway companies, their national associations, infrastructure managers and rolling stock leasing companies. In the European Commission in particular, the CER advocates the idea of rail transport as the backbone of sustainable transport in Europe. UNIFE has represented the rail industry in Brussels since 1992. The organisation brings together 80 firms specialising in the design, manufacture and maintenance of rail.

In 2014 the UIC (UIC, 2014) proposed a strategy compatible with the + 2°C target, based on two pillars:

• Energy consumption and carbon intensity:

- reduction of final energy by 50% in 2030 (baseline 1990), and by 60% in 2050.
- reduction of CO_2 emissions by 50% in 2030 and by 75% in 2050 (baseline 1990).

• The modal division:

- rail share in passenger transport (p/km): +50% in 2030 compared with 2010, and +100% in 2050.
- rail share in land freight (t/km): equal to road freight in 2030, 50% higher than road in 2050.

In order to meet these objectives, the UIC is relying on private partners to support innovation and improved energy efficiency, as well as on public partners, governments and international institutions to promote modal shift in favour of rail: investment in new projects, in particular urban rail and freight corridors, internalisation of external costs, creation of a favourable context for private investment, urban planning and land use, investment aid for rolling stock and so on.

The CER acknowledges the European Union's desire to reduce its emissions from 80 to 95% in 2050 compared with 1990, with an intermediate target of a 40% reduction in 2030 (CER & UIC, 2015). In 2010 members of the CER (also members of the UIC) committed to reducing their specific CO_2 emissions by 50% in 2030 compared with 1990, and beyond then to be completely decarbonised by 2050(CER & UIC, 2015, p.8). To achieve this, the CER is betting on the continuation of the European rail network electrification (today only 60% of the lines are electrified), the development of intermodal facilities in the vicinity of railway infrastructures, the installation of electric charging points for individual vehicles near railway stations, all supported by the "Smart Grid" for optimised energy sharing. In addition, the CER, in partnership with UNIFE, the European Association of Train Manufacturers, strongly promotes the development of research and innovation in support of European credits, with, for example, the Shift2rail project, a major €920 million public-private partnership for the 2014-2020 period to innovate on the energy efficiency of rolling stock (UNIFE & CER, 2016). Private economic actors are therefore not only stakeholders in the rail sector's innovation process but also rely on it to regulate their own carbon emissions.

• PRIVATE ECONOMIC ACTORS ARE INCREASING THEIR USE OF RAIL SERVICES • The Carbon Disclosure Project (CDP) focuses part of its reporting and analysis on the impact of supply chains in the fight against GHG emissions According to this organisation, “these must be at the centre of the concerns of global organisations seeking to avoid risks and to take advantage of the opportunities offered by building a sustainable future" (CDP, 2017). As such, the CDP recalls that in 2016, the value of the combined purchasing power of the 89 organisations registered on its platform and requesting information for their suppliers on controlling their emissions (BMW, Johnson & Johnson, Microsoft or Walmart, for example), a 20% increase in the number of registrants in 2016, was $89 billion.

The Carbon Disclosure Project – CDP – is publishing its first ranking of companies that encourage their suppliers to engage in climate action the most

Greenhouse gas emissions in the business supply chain are four times larger, on average, than their own direct emissions. This is why the supply chain is increasingly considered as one of the most promising sources of emissions reduction in the private players' ecosystem. For the first time, in 2016 the CDP evaluated the work done by companies with their suppliers to encourage them to reduce their emissions and adopt climate strategies. These players, who thanks to their purchasing budget have a significant margin of negotiation, have particularly focused their efforts on raising awareness of sustainable development issues and on taking into account indicators inspired by the CDP from their suppliers, such as transparency or the amount of emissions reported.

According to the CDP report, the efforts made by 4,366 companies to reduce their emissions in their supply chain have prevented some 434 million tons of CO_2 in 2016 at their suppliers, a saving of $12.4 billion. In addition, the 4,818 projects provided significant quantifiable savings: 36% saved at least $100,000 USD, 12% saved $1 million or more, and less than 1% saved at least $100 million USD. In addition to savings from emission reduction projects, suppliers also report benefits upstream by engaging their supply chains, or downstream through innovations related to the commercialisation of low-carbon products or services. About 25% of the companies with projects would directly address climate issues by allowing their own suppliers to reduce their emissions, or by increasing their revenues through the sale of low-carbon products or services (energy efficient, more sustainable materials for products and packaging, process innovations for minimising water use and carbon emissions).

Source: CDP, 2017.

TEXT BOX 1

Many of these companies encourage their partners to choose rail transport for developing their activities. The Nestlé Group, aiming to reduce half of its CO_2 emissions in Switzerland between 2010 and 2020, has made a commitment, in cooperation with its distributor Migros, to reduce the number of lorries used to transport Evian water in Switzerland by one thousand. **The number of carriages used has thus increased from 170 to 700**. A collaboration with Swiss railways is also underway to organise this transport without disrupting the network's schedules[3]. Other companies outside of the CDP partnership have made commitments, such as Panasonic, which in 2016 modified the distribution logistics of its products in collaboration with its carriers, including Mitsui-Soko Logistics Co. Ltd., Japan Freight Railway Company and Nippon Express Co. Ltd. **In 2017, this resulted in the use of rail infrastructure for nearly ten thousand 5-tonne containers, reducing CO_2 emissions by almost 5,000 tonnes[4].**

•RAIL COMPANIES INITIATIVES • In February 2018, Eurostar presented a plan[5] considered to be a contribution to the Paris Agreement: reducing train energy consumption by 5% by 2020, eco-driving programs, eliminating all fossil energy used between now and 2030, and investments in renewable

3 https://www.nestle-waters.com/media/featuredstories/reducing-environmental-impact-by-moving-from-road-to-rail-transport
4 https://www.panasonic.com/global/corporate/sustainability/eco/co2/logistics.html
5 Cheul-Kyu Lee, et al. (2009). Global warming effect Comparison of each material for railway vehicle. Korea.

energies (solar panels). In addition, going beyond the mechanical operation of the trains, the company is committed to reducing indirect emissions from its operations by commissioning a company fleet entirely composed of electric vehicles between now and 2020, reducing the use of plastics and waste, and even the distribution of certified food products on board trains.

Still in Europe, the German company Deutsche Bahn plans to invest a "record amount" of €9.3 billion for the modernisation, repair and extension of railways, stations, bridges and tunnels in 2018, according to the chief of infrastructure, Ronald Pofalla. That is an increase of 9.4% compared with the previous year. Flagship projects include upgrading major roads, such as links between the northern ports of Bremen and Hamburg and cities further south, as well as two lines crossing the south-eastern border of Germany with Austria. Some 700 stations, including hubs such as Frankfurt, the Western financial capital, and East Germany, will also benefit from interventions worth a total of €1.2 billion.

SNCF's commitment to Global Climate Action on the NAZCA portal led by the UNFCCC (Global Climate Action)

In 2015, SNCF made a public commitment to reduce its CO_2 emissions by 20% by 2025 (2014 reference year). In 2017, SNCF set itself the new ambition of improving the carbon performance of 25% per passenger per kilometre and per tonne of goods per kilometre by 2025, and in particular, the end of thermal traffic by this time at the latest. In accordance with this, in 2018, SNCF partnered with Alstom to conduct the first TER Hybride experiments in France, in partnership with the Greater East, New Aquitaine and Occitaine Regions.

SNCF Réseau is committed to reducing its energy consumption and greenhouse gas emissions by 25% between 2015 and 2025. To achieve this, several actions have been implemented, including the use of environmental green bonds. SNCF Réseau finances part of its infrastructure works by issuing Green Bonds to help combat climate change and protect biodiversity. The projects financed by the Green Bonds in 2017 will prevent the equivalent of nearly 5.9 million tonnes of CO_2 over 40 years, which equals the carbon footprint of 12,000 French people over the same period. SNCF Réseau's strategic priorities have directed investments in the amount of €1.75 billion from its bonds issued in 2017 to network renewal and modernisation operations. In line with its commitment to become a benchmark in the Green Bonds market, SNCF Réseau has made a total of three Green Bond issues since 2016, for a total amount of €2.65 billion, becoming one of 15 largest issuers of Green Bonds (excluding China onshore) in the world.

Source: SNCF Réseau, 2018.

TEXT BOX 2

In 2018 the Canadian National Railway Company made a commitment to reduce its emissions per tonne-kilometre by 29% by 2030, compared with 2015. To this end it is proposing a $13.5 billion initiative, GO Regional Express Rail (RER), to transform the rail network by offering faster and more frequent services, with the electrification of key segments of the network, including the Union Pearson (UP) Express. This will result in a doubling of rush hour services and a four-fold increase in off-peak services from the 2015 level, with the number of GO Transit trips expected to increase from approximately 1,500 per week to nearly 6,000. Metrolinx, the transport authority for the Greater Toronto and Hamilton area and the MTO (Ontario Ministry of Transportation) are planning major improvements to the GO Transit rail system, including additional modifications to railway tracks and bridges, new stations and modernised rail/road and rail/rail level separations, new improved train control systems and new electric train systems (MTO, 2017).

3 • THE DECARBONISING POTENTIAL AND TECHNOLOGICAL COMMITMENT OF DEVELOPERS

Although rail transport is one of the lesser emitters of CO_2, the sector's decarbonisation potential remains significant. Efforts can be focused on infrastructure, facilities and rolling stock, traction energy, ancillary systems, or the use of artificial intelligence for energy management.

• INFRASTRUCTURE, FACILITIES AND ROLLING STOCK • Train aerodynamics also have an interesting potential for reducing energy consumption and associated emissions: a 25% improvement in the drag coefficient results in savings of 15% in traction energy for the Alstom high-speed railcar (AGV), commissioned for 2022, compared with a conventional TGV. There have been similar achievements at Bombardier (Zefiro) or in Japan with the Tokaido Shinkansen (700 series) (UIC, 2016, p.33). The use of new materials also reduces the weight of vehicles. Here, the development of composite materials for the construction of a passenger carriage can reduce its weight by about 20 to 30%; the corresponding potential for reducing traction energy and emissions is in the region of 5% (Lucintel, 2017). According to a report published in February 2017 by market research firm Lucintel, the market for composite applications in the global rail industry is expected to reach $821 million by 2021, with an annual growth rate of 3.6%. Research and trials are being conducted in this area, notably by Alstom, New Rail (UK), Indian Railways and in Korea for the Pendulum Express (UIC, 2016, p.37). CRRC's Next Generation metro train, Cetrovo, a joint venture project with CG Rail in Germany, was unveiled at the InnoTrans congress in September 2018 in Berlin. The carriage is composed of about 70% carbon fibre structures, which represents a weight reduction of 13 to 14% compared with a conventional metro vehicle.

A number of experiments using renewable energies (solar, wind turbines) in fixed installations, and even on rolling stock, have also been put in place. In July 2018, Ravindra Gupta, a member of the board of directors of Indian Railways, inaugurated carriages incorporating solar panels to operate the fans, lighting and mobile charging points inside passenger trains on the Rewari-Sitapur lines, and soon on the Taj Express and Shane-Punjab Express. In 2017 the Indian Railways Organization for Alternate Fuels (IROAF) also installed solar panels on diesel multi-unit (DMU) trains.

• THE POTENTIAL OF DECARBONISING TRACTION ENERGY • Traction energy represents about 85% of the total energy consumed by a moving train (CER & UIC, 2015, p.15). With a view to reducing carbon emissions from rail transport, the main challenge is to develop electrification, which represents a reduction in emissions from 19 to 33%[7] compared with the use of diesel engines on locomotives. Half of the European rail lines are electrified. Great Britain is the least equipped country in electric rail infrastructure with only 32% of its lines connected. However, a line electrification program has been underway in Scotland since 2009, with the aim of completely eliminating trains running on diesel alone by 2040. Sweden is the most electrified European country with 84% of the train lines covered. In Asia, 43% of the network is electrified, 18% in Africa and 0.5% in North America (CER & UIC, 2015, p.59).

Overall, it is estimated that by improving traction energy efficiency, the sector can potentially reduce emissions by around 15%. "Resibloc Rail", developed by ABB, is an oil-free traction transformer with 97% energy efficiency, the implementation tests of which were completed in Austria in 2018. The transformer reduces energy costs by 10% compared to conventional transformers and can reduce carbon dioxide emissions by 38 tonnes per year.

In order to ensure train traction in the non-electrified sections, the manufacturers put hybrid trains on the market, equipped with new engines using alternative energies, such as gas or hydrogen. European Lok Pool (ELP), a new European locomotive rental company specialising in hybrid traction,

6 Network Rail (2009) Network RUS electrification (UK). October 2009. London (UK). http://www.networkrail.co.uk/browse%20documents/rus%20documents/route%20 utilisation%20strategies/network/working%20group%204%20-%20electrification%20strategy/networkrus_electrification.pdf
7 Schaffler. Air conditioner power systems for rail. http://www.schaffler.com

announced in September 2018 that it had received the first order for 10 Stadler EuroDual locomotives, with a first delivery expected in the second half of 2019. The company is also considering adding four-axle bimodal locomotives to its portfolio. Gmeinder, a German locomotive manufacturer, also offers a hybrid model equipped with a Caterpillar engine and a lithium-ion traction battery, which can use electrification on a third rail or per 750 Vdc head. Steel producer ArcelorMittal ordered six units of this model in 2018. STADLER, a Swiss manufacturer, and Havellian Railway (HVLE), a regional rail authority in Pakistan, unveiled a new generation of six-axle Eurodual bimodal locomotives that can be powered by a 2.8 MW diesel engine or by electrical power up to 7 MW. HVLE ordered 10 Eurodual locomotives in 2017, thus becoming the customer to launch the new platform.

However, diesel seems to have a bright future ahead of it. General Electric Transportation announced the signing of a contract in 2018 for the supply of five of its PowerHaul (PH) diesel locomotives to Turkish private operator Korfez Ulastirma, the rail freight subsidiary of Tüpras, Turkey's largest oil refinery company, responsible for transporting petroleum products between its refineries. GE Transportation has also unveiled a new high-speed light diesel engine, which will debut on a new fleet of 300 shunting locomotives to be delivered to a Kazakh railway company in 2019. The engine is expected to offer a 5% reduction in life cycle costs, a 5% improvement in energy efficiency and a 10% reduction in maintenance costs. Finally, in September 2018, Gmeinder introduced the two-engine diesel variant of its modular DE75 BB locomotive, designed to allow the use of various traction configurations. The four-axle locomotive can be supplied by two Caterpillar 354 kW diesel engines.

Another non-carbon-free source is natural gas, which nevertheless reduces CO_2 emissions by 30% compared with diesel fuel; this option is of particular interest to Renfe, Union Pacific Railroad and Russian Railways (RZD), which are in the prototype development stage (UIC, 2016, p.79).

Hydrogen, the energy of the future for rail transport?

Presented as a powerful alternative to the use of fossil fuels, the use of hydrogen for rail transport has been the subject of important research in various countries for several years.

Some fifteen engineers are working on a train project in France, called "Space Train", running on hydrogen and moving two millimetres from the ground thanks to a propulsion on monorail, with induction motors creating a magnetic field. The engineers are aiming to reach top speeds of 720 km/h which would make this train the fastest in the world, compared to the TGV, whose optimal average speed (when it is not in operation) reaches 500 km/h and 574 km/h maximum, and the Japanese Maglev, the current world record holder, reaching the maximum of 603 km/h. Targeting inter-urban lines up to 300 km long, the first tests of the Space Train are scheduled for late 2019 or early 2020 for commercialisation in 2025.

In addition to ongoing research to improve the combustion system and reduce the environmental impact, hydrogen trains have already been put into service in recent years. In October 2017, China commissioned the world's first hydrogen tram, designed by China Railway Rolling Corporation (CRRC) Tangshan Co. Ltd. The tram can be refilled with hydrogen in 15 minutes and travel 40 km with a maximum speed of 70 km/h. It serves a railway line built 136 years ago in Tangshan, one of the country's leading industrial cities, and links several industrial heritage sites.

On September 16, 2018, the French manufacturer Alstom formalised the commissioning of two trains named Coradia iLint, the first trains in the world put into service and running on 100% hydrogen. These trains connect the cities of

Cuxhaven, Bremerhaven, Bremervörde and Buxtehude, located in the north of Germany. Reaching 140 km/h and with the capacity to cover 1,000 kilometres on one fuelling, this model has attracted the German regional companies and by 2021, 14 other trains are expected to be delivered to Lower Saxony. In March 2018, the Government of Sarawak State in Malaysia proposed that the Kuching light rail system be fuelled by hydrogen fuel cells, to be completed by 2024.

TEXT BOX 3

• THE IMPROVEMENT OF AUXILIARY SERVICES • While traction energy accounts for 85% of the trains' final energy consumption, a significant part of it is used in the auxiliary systems on board (heating, cooling, lighting) or outside the trains. **Refrigeration and heating account for most of the auxiliary energy consumption on board a train (up to 80%). Decarbonisation can come mainly from the use of new, more efficient refrigerants, and in the intelligent management of heating/cooling systems**[8]. For example, in Berlin, Liebherr-Transportation Systems will equip one of the city's tram lines with CO_2 sensors that will estimate the number of passengers and adjust the outside air intakes accordingly; this should reduce energy consumption by 13% (UIC, 2016, p.101). In 2018 the international supplier Thermo-King introduced its new system using the refrigerant R134A, a refrigerant whose global warming potential (GWP) has been reduced by more than 50%, but which maintains the same performance, reliability and comfort of passengers as current refrigerants.
More generally, the introduction of energy recovery systems, which can also store it (flywheel, battery, etc.), could reduce the energy consumption of a train by around 10 to 30%, and eventually lead to a sharp decline in peak energy demand (-50%). **Several manufacturers have developed systems using flywheels and saving up to 20% of the energy used during a journey (UIC, 2016, p.144): Piller-Powerbridge (Germany)[9] , Kinetic Traction (USA), Adif (Spain)[10].**

Railway stations are also sensitive areas, with the Asian Development Bank (ADB) pointing out inefficiencies in the management of heating, cooling and ventilation. Indeed, it believes that stations consume about 214 kWh/m²/year of electricity when the rest of the public buildings have an average consumption of 114 kWh/m²/year[11]. **That's why India has extended its program of installing solar panels on the roofs of railway stations and level crossings, aiming to gain 1,000 MW of solar energy to use. Guwahati Station, one of the largest in the State of Assam, has been running entirely on solar energy since mid-2018. Some 20,000 travellers pass through it every day.** All of its roofs have been equipped with photovoltaic panels with a capacity of 700 kilowatts, enough to supply the rail network as well as the structure's various services, which saves about 21,000 litres of diesel per train and 67.7 million Rupees each year (around €85,000), according to the Northeast Frontier Railway.

• ENERGY MANAGEMENT BY INTELLIGENT SYSTEMS • The potential now offered by IT makes it possible to adjust the use of energy to the actual needs of railway equipment[12] and to reduce greenhouse gas emissions by the same amount. For example, improving the filling rate of vehicles (reservation system) can provide energy savings of around 15 to 17%. Improved driving modes, whether computer assisted or not, would mean that braking and acceleration can be minimised, saving up to 20% on traction energy. Computerised assistance would thus reduce braking needs by 30%, which would result in a 10% improvement in punctuality (UIC, 2016, p.134). Finally, the use of

8 Schaffler. Air conditioner power systems for rail. http://www.schaffler.com
9 Witthuhn, M. et al. (2001): Applications for energy storage flywheels in vehicles of Deutsche Bahn AG. Proceedings of the World Congress of Railway Research WCRR 2001, Cologne (Germany).
10 Iglesias, I. J. et al. A Kinetic Energy Storage System for Railways Applications. ADIF. Railways Infrastructure Manager, CEDEX Studies and Experimentation Centre of Public Works and Transportation (Fomento) Ministry, CIEMAT Centre for Energy, Environment and Technology Research, Madrid (Spain)..
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smart grids can better control the power demands of the trains in circulation or reduce them on a route segment. This is the case, for example, in Japan (East Japan Railway Co.). The Merlin Project (2012-2015)[13] ,carried out within the framework of projects financed by the European Union, made it possible to examine the feasibility of integrated electricity management systems in railways.

CONCLUSION

This comprehensive overview of the innovations initiated by players in the rail sector underlines the dynamism of a sector convinced about holding a part of the answer to reducing mobility-related CO_2 emissions. The significance of its contribution and speed of its deployment will depend on several economic factors: its ability to mobilise sufficient investment, particularly in developing countries, and its price competitiveness when compared with the road sector for freight; and compared with the car, bus and airline sectors for passenger transportation.

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13 http://www.merlin-rail.eu

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New initiatives in international maritime transport

Rapidly evolving over the past decade, international maritime transport contributes significantly to global anthropogenic greenhouse gas (GHG) emissions, exceeding those of the civil aviation sector. The establishment of the European Union MRV Regulation and the agreement adopted within the International Maritime Organization (IMO) can be a indicator of the beginning of a transition, provided that they lead to quantitative results. The past year has seen some interesting technological initiatives, driven by key industry stakeholders in the sector.

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CONTENTS

1 • GHG EMISSIONS CONCENTRATED ON SHIPPING ROUTES

• A RECENT INCREASE • Global CO_2 emissions from maritime shipping have been steadily decreasing since 2007, decreasing from 1.1 $GtCO_2$ to 932 $MtCO_2$ in 2015, representing 2.6% of total CO_2 emissions for the same year (compared to 3.5% in 2007). In 2015, emissions from international maritime transport alone accounted for 87% of total CO_2 emissions from maritime shipping, with 812 $MtCO_2$ emitted, a decrease of 8% compared to 2007 (881 $MtCO_2$). Nevertheless, the increase observed since 2013 (+1.4%) and according to unpublished estimates, **international maritime transport emissions should be 847 $MtCO_2$ in 2016 and 859 $MtCO_2$ in 2017, an increase of 5.8% compared to 2015** (Table 1). Regarding fishing vessels, their emissions have halved since 2007, from 86 $MtCO_2$ to 42 $MtCO_2$ in 2015 and stabilised in 2017. Emissions from domestic maritime transport decreased by 41% over the same period, from 133 $MtCO_2$ in 2007 to 78 $MtCO_2$ in 2015, and are also estimated to have stabilised in 2017. Finally, cruise ships emitted 38 $MtCO_2$ in 2015, or about 4% of emissions from the maritime sector (ICCT, 2017).

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016*	2017*
International transport	881	916	858	773	853	805	801	813	812	847*	859*
Domestic maritime transport	133	139	75	83	110	87	73	78	78	78*	78*
Fishing vessels	86	80	44	58	58	51	36	39	42	42*	42*
Total maritime shipping	1100	1135	977	914	1021	942	910	930	932	967*	979*
% global CO_2 emissions	3.5%	3.5%	3.1%	2.7%	2.9%	2.6%	2.5%	2.6%	2.6%		

TABLE 1. CO_2 EMISSIONS FROM GLOBAL MARITIME SHIPPING (SOURCE: ICCT, 2017).

* 2016 and 2017 data are estimates from an internal source of the ICCT (2018).

• EMISSIONS PROFILE OF THE MARITIME SECTOR • Between 2013 and 2015, three classes of vessels accounted for 55% of total GHG emissions from international maritime transport: container ships (23%), bulk carriers (19%) and oil tankers (13%) (Figure 1).

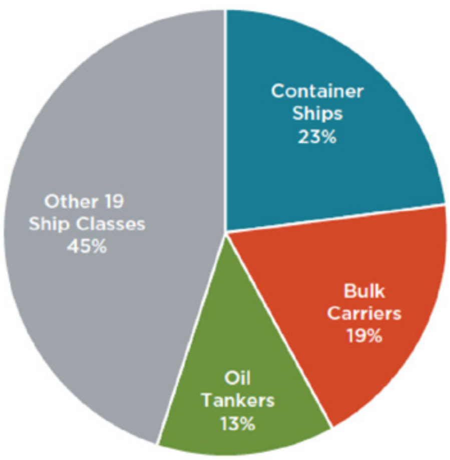


FIGURE 1. SHARE OF CO_2 EMITTED BY CLASS OF VESSEL BETWEEN 2013 AND 2015.

Source: ICCT, 2017

These emissions are defined by the International Maritime Organization (IMO) into four categories. Firstly, there are exhaust emissions, which are the largest volume of GHGs and come from main and auxiliary engines, boilers, and incinerators. Then there are refrigerant emissions, which are essential for refrigeration systems and air conditioners, but which also escape during maintenance operations and dismantling processes (emissions are allocated to the countries carrying out the operations). Then there are various emissions produced during transportation periods, including leaks and releases. In the final category are GHG emissions from testing and maintenance phases (Shi & Gullett, 2018). At the operational level, shipping routes were responsible for the majority of GHG emissions from major vessels in 2015. However, for some vessels (oil and methane tankers), berthing still represents a significant energy expenditure (respectively 17% and 14% of their total GHG emissions). Anchoring represents about 5 to 9% of GHG emissions for each class of vessel.

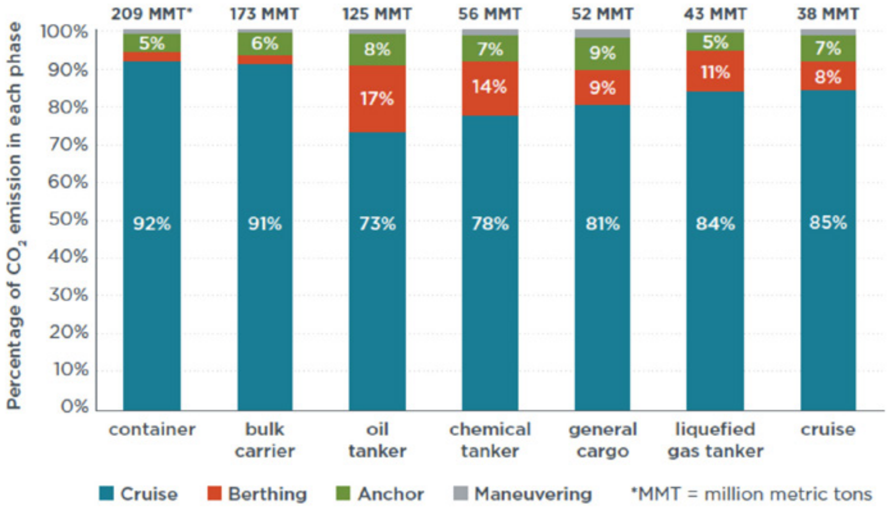


FIGURE 2. CO_2 EMISSIONS DURING THE OPERATIONAL PHASES OF THE MAIN EMITTING VESSELS, 2015.

Source: ICCT, 2017..

Of the 223 countries represented in maritime transport, **52% of emissions in 2015 were attributable to vessels operating under six flags:** Panama (15%), China (11%), Liberia (9%), the Marshall Islands (7%), Singapore (6%) and Malta (5%) (Figure 2). Global CO_2 emissions from the maritime shipping sector are concentrated on well-defined shipping routes around the globe (Figure 3).

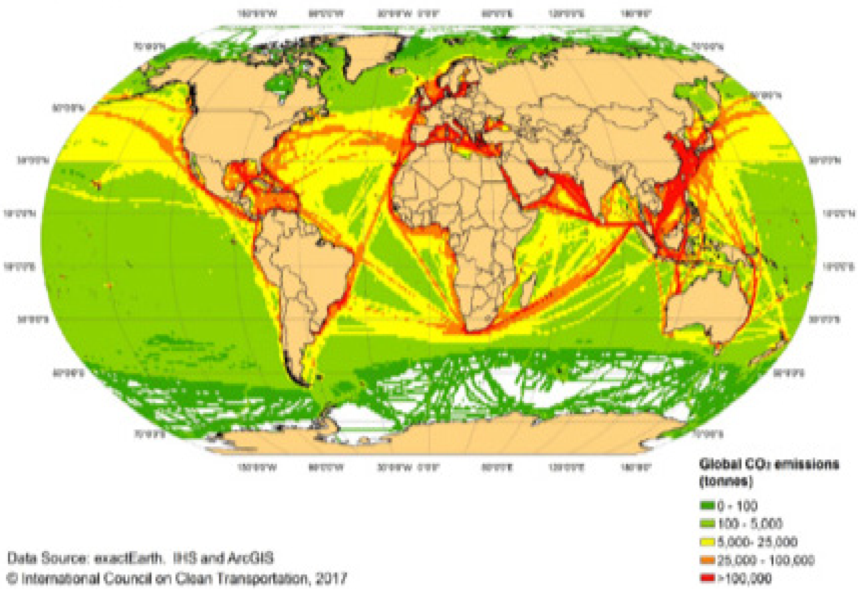


FIGURE 3. GLOBAL DISTRIBUTION OF CO_2 EMISSIONS FROM MARITIME TRANSPORT, 2015.

Source : ICCT, 2017.

• GHG EVOLUTION CORRELATED WITH VESSEL TONNAGE, SIZE AND SPEED • While the decline of CO_2 emissions from maritime shipping during the Kyoto period (2007-2012) is largely attributed to the global financial crisis of the time, an increase is to be expected over the coming years due to the growth of international maritime trade (Shi & Gullett, 2018). Smith et al. (2015) estimated that, as it stands, CO_2 emissions from the maritime sector could increase by anywhere from 50% to 250% by 2050. In the absence of measures, the sector's share could reach 17% of global GHG emissions by that date (Cames et al., 2015). In addition, the recent increase in GHG emissions from the sector comes as the CO_2 intensity of the majority of vessel categories improves, cancelling out these efforts (ICCT, 2017). One reason is the increase in cruising speeds. Indeed, between 2013 and 2015, container ships increased their average speed by 11% and oil tankers by 4% compared to the total average of international transport, leading to an increase in CO_2 emissions per tonnage transported.

With a volume approaching 9 billion tonnes of freight transported per year, the seaway is the primary mode of transport for commercial activities. Its share in global commercial transport has reached 80% in terms of volume and 70% in terms of value. **In terms of goods, the main resource transported in 2012 was still crude oil, at 1.863 billion tonnes (see Figure 4).** In terms of evolution, the world fleet of commercial vessels has been on an exponential curve since the 1970s, after a decline in the late 1990s. Representing 289,926 gross tonnes sailing the world seas in 1973, in 2016, it accounted for 6 times more at 1,862,000 gross tonnes. In 2017, it was estimated that 93,000 vessels make up this commercial shipping fleet (Cargill, 2017). The largest are cargo vessels used to transport goods such as bulk carriers (41%), which carry bulk solids (sand, aggregates, cereals), tankers (38%), such as oil tankers, methane tankers or refrigerated cargo vessels carrying liquid foodstuffs and container ships (14%), which, since February 2018, can carry more than 20,000 containers (compared to 1700 in 1970) and the inauguration of CMA CGM Antoine de Saint-Exupéry, the largest vessel of its kind. These three classes account for 84% of the total merchandise supply by seaway. In addition to goods, the world's maritime fleet consists of multipurpose vessels (6%), including all kinds of fishing vessels and large cruise ships belonging to a thriving cruise industry (1%) which carry millions of passengers to tourist destinations (Info Arte, 2016).

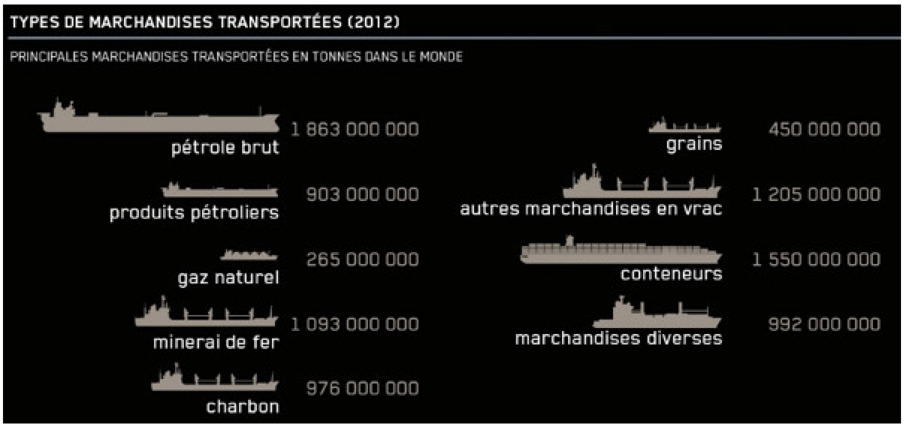


FIGURE 4. MAIN GOODS CARRIED IN TONS WORLDWIDE (2012)

Source: ARTE

Thus, the regulation of GHG emissions from international maritime shipping is based on a wide variety of vessels and activities. Nevertheless, cargo ships emit far more than other types of boats due to their size and tonnage, while being easier to regulate internationally as a result of their design and the international nature of their journey (Shi & Gullett, 2018). Therefore, reducing emissions can only come from concerted action by stakeholders to improve energy efficiency and develop alternative means of propulsion (ICCT, 2017).

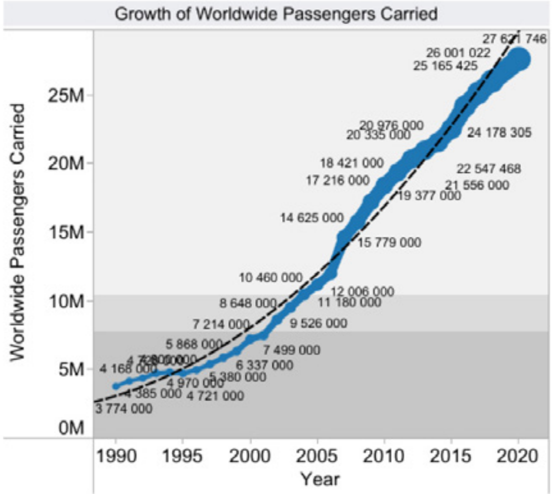
2 • THE ONSET OF AWARENESS

• THE ACTION OF THE INTERNATIONAL MARITIME ORGANIZATION (IMO) • The International Maritime Organization (IMO) is the international authority that regulates international maritime transport. The IMO defines international maritime transport as the maritime transport between ports of different countries, as opposed to domestic maritime transport, and excludes military and fishing vessels (IMO, 2014). **Maritime transport is the only sector (together with air transport) whose contribution to climate change mitigation is directly negotiated at the international level, and is not included or mentioned in the Kyoto Protocol or the Paris Agreement** (Wan et al., 2017). Discussions related to this sector, often blocked by several influential countries (China, the country that operates the most vessels), have been left to the IMO, which is expected to promote trade, set emission reduction efforts, and develop strategies to be put in place as a regulator of international maritime transport (Wan et al., 2017).

The future impact of the cruise industry

Although it only represented 4% of the maritime sector's total emissions with 38 $MtCO_2$ in 2015, the growth of international passenger transport has been exponential, and the cruise industry is evolving more strongly than other forms of tourism. Over the past 20 years, the average annual passenger growth has been 7% (Florida-Caribbean Cruise Association, 2015). In 2016, 23 million passengers worldwide were welcomed on cruise ships, most of them from North America. Cruise ships require a lot of energy, both for navigation and for the many services offered on board. For example, the Freedom of the Seas, one of the largest ocean liners in the world, burns 4200 litres of fuel per hour during the navigation period. As a matter of logic, the size, services offered, and cruising speed of the ships affect the GHG emissions. However, the construction of new passenger ships tends to increase their capacity, the diversity of the services offered, and their cruising speed, which cancels out the improvements generated by the new propulsion processes and the installation of electrical systems at the docking ports to encourage them to stop using their generators once at the dock.

TEXT BOX 1



Source Region of Passengers

Year	North America	Europe	Other	Worldwide Passengers Carried
2017	14 130 410	6 417 159	4 617 856	25 165 425
2018	14 167 168	6 764 273	5 069 580	26 001 022
2019	14 526 363	6 933 353	5 397 702	26 857 418
2020	14 829 278	7 075 424	5 717 044	27 621 746

FIGURE 5. GROWTH AND FORECAST OF THE CRUISE INDUSTRY BY EVOLUTION OF PASSENGERS TRANSPORTED BETWEEN 1990 AND 2020

(Cruise Market Watch, 2017)

• REGULATORY TOOLS IN PLACE • To date, there is only one regulation that focuses on the energy efficiency of vessels on a global scale, the Energy Efficiency Design Index (EEDI). Promulgated by the IMO in 2013, the EEDI subjects new vessel designs to requirements for the use of equipment and engines that pollute less (less CO_2 per nautical mile travelled) and more energy-efficient. It is expected that these requirements will be gradually increased every five years to encourage the integration of innovations and the development of new techniques, from the design phase of the vessel to the fuel consumption required for its operation. Vessels built between 2015 and 2019 must be 10% more efficient in terms of grams of CO_2 per tonne per nautical mile than those built over the 1999-2009 period and for those built between 2020 and 2024, the target is 20%, before reaching 30% beyond 2025. However, the EEDI is a non-normative, voluntary performance-based mechanism that leaves the choice of technologies to be used in vessel designs to the industry (ICCT, 2017).

The Ship Energy Efficiency Management Plan (SEEMP) is an IMO operational mechanism aimed at optimising the energy consumed by maritime shipping during the operation of ships. Developed with the World Maritime University, the SEEMP aims to promote energy-efficient technologies for new and existing vessels and to get them to use the Energy Efficiency Operational Indicator (EEOI), which allows for continuous monitoring of the energy consumed during the operation of a vessel. This tool provides an overview of the global fleet in terms of performance while allowing on-board engineers and mechanics to have continuous control of the energy efficiency of vessels during their operation, to report observations, better plan trips, estimate the propeller cleaning frequency, or even evaluate the efficiency of introducing new forms of propulsion (IMO, 2018).

The impetus of the European Union on the maritime sector

The European Union is keen to integrate the air and maritime sectors into international climate negotiations. Given the reluctance of many countries on the maritime issue, the EU has developed an MRV (Monitoring, Reporting, Verification) regulation for vessels visiting its ports. As such, the EU MRV entered into force on 1 July 2015 and requires shipowners and operators to monitor, report, and verify the CO_2 emissions on an annual basis of vessels of more than 5000 gross tonnage, in any port of the European Union and the European Free Trade Association. Data collection takes place per trip and started on 1 January 2018. The reported CO_2 emissions, as well as additional data, must be verified by independent certified bodies such as DNV GL, a Norwegian certification body, and sent to a central database managed by the European Maritime Safety Agency (EMSA). Aggregated emissions and vessel efficiency data will be published by the European Commission no later than 30 June 2019, then annually thereafter. Regarding the new agreement announced by the IMO, the objective of reducing maritime sector emissions by 50% by 2030 is less ambitious than the European Union wanted, but this timeframe makes it possible to include the maritime framework in line with the objectives of the Paris Agreement. During the discussions prior to this agreement, the European Union was able to play its full weight, using the 41% of the world fleet that it represents through its member countries, but also by relying on its new MRV regulation to encourage it to be applied in the future on a global scale.

TEXT BOX 2

• A RECENT AGREEMENT • At the 72nd meeting of the Marine Environment Protection Committee (MEPC 72) in April 2018, the 170 member countries of the IMO agreed to adopt a resolution codifying a GHG reduction strategy for international maritime transport. The agreement was found despite the reservations expressed by several countries (Saudi Arabia, United States, China) and the disproportionate influence of the five countries under which the majority of commercial vessels are registered (Bahamas, Marshall Islands, Liberia, Malta, Panama), which account for 43% of the total IMO funding. This strategy, which represents the first global climate framework for maritime transport, sets targets for reductions up to 2050 and sets 2023 as the deadline for its revision.

The strategy involves implementing policies to significantly increase the energy efficiency of the global fleet and to promote the deployment of innovative propulsion and alternative fuels in order to achieve:

- The reduction of GHG emissions (per tonne per kilometre) by at least 40% for vessels by 2030, while continuing to reach a 70% reduction by 2050,
- The reduction of emissions by at least 50% in 2050 compared to 2008, while continuing the action towards the total decarbonisation of maritime transport.

A list of short-, medium- and long-term measures to help achieve the objectives was developed by the ICCT (2018). Nevertheless, these measures must be made mandatory by an IMO convention before they become legally binding.

Type	Period	Measure	Target	Current status
Short term	2018-2023	New phases of the EDDI	New vessels	-10% en 2015
				-20% en 2020
				-30% en 2025
		Operational efficiency measures (SEEMP, standards)	Vessels in service	SEEMP planning required
		Existing fleet improvement programme	Vessels in service	-
		Speed reduction	Vessels in service	-
		Measures to combat methane and VOCs	Fugitive emissions and engines	-
Medium term	2023-2030	Alternative low carbon or zero carbon fuel programmes	Fuels - new vessels / vessels in service	-
		Additional operational efficiency measures (SEEMP, standards)	Vessels in service	SEEMP planning required
		Market-based measures [2]	Vessels in service - fuels	-
Long term	2030 +	Development and provision of zero-carbon or non-fossil fuels	Fuels - new vessels / vessels in service	-

TABLE 2. MEASURES WHICH COULD BE INCLUDED IN THE IMO'S INITIAL STRATEGY TO REDUCE GHGS (SOURCE: ICCT, 2018).

(Source : ICCT, 2018).

Beyond these measures, the ICCT (2018) has identified other measures that could indirectly support efforts to reduce GHGs, such as:

• Encouraging the development and updating of national action plans;

• Encouraging ports to facilitate reductions in GHGs from vessels;

• Initiating and coordinating Research and Development activities by setting up an International Maritime Research Board (IMRB);

• Promoting the search for zero-carbon or non-fossil fuels for the maritime sector, and developing robust guidelines on GHG lifecycles for replacement fuel;

• Carrying out additional studies on GHG emissions to inform political decisions and calculate the marginal cost curves of reduction for each measure;

• Encouraging technical cooperation and reinforcing capacity.

These ambitions should encourage ships to use alternative fuels to fuel oil, as the latter releases more than 3500 times more sulphur than the diesel used by road vehicles. On this subject, the OECD suggests a move towards biofuels, hydrogen, ammonia and a growth in the use of sails, with liquefied natural gas remaining a short-term alternative (OCDE, 2018).

3 • THE MOMENTUM OF SHIPPING COMPANIES

• STAKEHOLDER PARTNERSHIP SOLUTIONS • Several initiatives backed by non-state actors have sought to make the maritime sector sounder in terms of GHG emissions. Of these, **the Sustainable Shipping Initiative (SSI) it is backed by an independent body, which brings together shipping**

2- Market-based measures seek to address the market failure of "environmental externalities" by incorporating the external cost of production or consumption activities through taxes or royalties on processes or products, or by creating property rights and facilitating the establishment of an environmental services market. According to this definition, these measures aim to provide polluters (shipowners and economic operators) with an economic incentive to reduce their GHG emissions in line with the "polluter pays" principle (Shi & Gullett, 2018).

companies (shippers, shipyards, equipment) and other stakeholders (banks, technology companies, NGOs) with the aim of creating a more environmentally friendly, socially responsible, safer, and more economically profitable maritime industry by 2040. Members of this network include Maersk Line, Oldendorff and China Navigation, as well as environmental non-governmental organisations (NGOs): WWF and Forum for the Future. The roadmap to 2040 includes six main actions including action 6, which seeks to "Adopt a diverse range of energy resources, using resources more efficiently and responsibly, and dramatically reducing greenhouse gases". The measures put forward to achieve this include the introduction of significant improvements to the energy efficiency of vessel design; rehabilitation and navigation; a search for and use of renewable sources of energy in propulsion systems to improve energy intensity; and the involvement of partners in achieving energy gains in the supply chains.

Four other non-governmental organisations (The Global Maritime Forum, The North American Marine Environment Protection Association (NAMEPA), The Maritime Anti-Corruption Network, and The Women's International Shipping and Trading Association (WISTA)) are involved in an initiative backed by Cargill, a United States company specialising in supplying foodstuffs and trading in raw materials. With the help of these NGOs, Cargill seeks to boost sounder shipping by aiming to reduce GHG emissions from its 650 vessels by 15% in 2020 compared with 2016. **Furthermore, Cargill has announced that it improved the energy efficiency of its fleet in 2017 and reduced CO_2 emissions by 5.7% compared with 2016 on the basis of tonnage of cargo carried per mile (Cargill, 2017).**

• THE INDUSTRY IN SWEDEN LEADING THE SECTOR • The Swedish maritime transport industry is also extremely active in decarbonising its business. Its representative association has announced a zero-emission target by 2050 and several companies are pioneering low-emission maritime transport. Sweden boasts a growing number of initiatives: **Stena Line operates a ferry fuelled by methanol, Sirius Shipping has developed a boat fuelled by LNG, several companies (Terntank, Erik Thun, Rederi Gotland) also have vessels that run on LNG, and HH Ferries and Green City Ferries have launched electric ferries (OCDE, 2018).** This proactive approach is the result of cooperation between decision-makers, financial support from the Swedish government, the European Union, or the Norwegian NOx Fund, depending on the particular project, and support in terms of regulation. This convergence of interests between Swedish shipowners and maritime companies has encouraged other industries, such as energy companies, to embark on long-term partnerships; a factor which is critical to the success of this type of initiative. The best example can be seen in the **"Zero Vision Tool", a collaborative platform, which brings together the maritime transport industry, the government, and the research community with a view to solving the technical issues affecting pilot projects on LNG refuelling or fuelling vessels with LNG or methanol.** Finally, the introduction of sulphur-emission standards has also stimulated requests to convert to propulsion systems with lower GHG (OCDE, 2018).

• SUPPORT NEEDED TO STIMULATE THE MARKET • In France, it is important to note the involvement of the Agency for Environment and Energy Management (ADEME). In the area of Transport and Mobility in the Investments for the Future Programme (PIA), "Vessels of the Future" is a topic that includes some 49 projects to which ADEME makes a financial contribution. In 2017, ADEME launched a call for proposals seeking to fund R&D projects in the naval industry, which could lead to industrialisable products. The call related to boats, vessels and mobile floating platforms used for commercial transport (people, goods), work (fishing, marine energy, surveillance, research, dredging, resource development), or leisure (boating). Of the four thematic areas, Area 1 "Economical Vessels" aims to achieve energy efficiency through reducing resistance to forward motion (shape, materials, structures, hydrodynamics), improving propulsion and energy use (performance, systems), and developing innovative solutions based on renewable energy or through optimisation of the total energy balance by managing on-board needs (water, ventilation, air conditioning, etc.). This area also seeks to improve operational efficiency through optimising navigation operations, port manoeuvres and commercial operations (loading/unloading), optimising the preservation and recovery of cargoes, and enforcing interoperability with other modes of transport and onshore infrastructure.

The Honfleur project, winner of the ADEME prize

The aim of the HONFLEUR project, which was launched in March 2017 for a period of two years, is to achieve the replacement of the Normandie liner (1992) currently in service between the ports of Caen-Ouistreham (FR) and Portsmouth (UK). Over the next three decades, technological decisions affecting the design of the hull and its appendages, its diesel-electric motors, and devices used to manage and recover energy consumed should allow the HONFLEUR to consume 20% less energy compared with conventional vessels of its kind, and to be less polluting through its use of liquefied natural gas (LNG) as an alternative to oil fuel. This vessel will be the first LNG ferry to operate in the Channel-North Sea sector. The use of LNG allows for a drastic reduction in emissions of sulphur (-99%), fine particles (-90%), and nitrogen oxide (-87%) compared with the same amount of energy provided by marine diesel oil (MDO). It will also lead to a significant reduction in the carbon emissions of the vessel, which is also equipped with devices to manage electrical energy and energy recovery, and has diesel-electric motors. This all adds up to an average of 12,000 tonnes of CO_2 avoided per year compared with a conventional ferry. These environmental gains are important for air quality in port areas, which are generally close to areas with high population density (ADEME, 2018).

TEXT BOX 3

4 • TOWARDS RESPONSIBLE MARITIME TRANSPORT?

• ELECTRIFICATION OF THE SECTOR • Over the last ten years, there have been several initiatives in the engineering and naval construction sector to develop electric means of propulsion. These initiatives cover domestic transport vessels (Port-Liner), electrical cargo vessels (Hangzhou Modern Ship Design & Research Co.) and passenger transport (E-Ferry). These vessels, particularly passenger ships and ferries, are easier than any other type to equip with electrical propulsion due to their short journeys between the same ports. However, these initiatives do not specify the sources of energy used to recharge this new fleet's batteries, so it is difficult to estimate the reduction in GHG emissions attributable to shipping.

In addition to the electrification of vessels, ports have also embarked on electrifying their operations. In 2018, Nidec Industrial Solutions announced an advanced electrical supply system for the Port of Genoa in conjunction with the Western Ligurian Sea Port Authority. This project will enable berthed vessels to connect to a power supply once they have docked, eliminating the need to use their engines. This solution will reduce GHG emissions and limit the exposure of neighbouring residents to the atmospheric pollution and sound pollution produced by the generators normally used. This project follows numerous similar projects implemented in the ports of Livorno (Italy), Los Angeles and San Francisco (California), Juneau (Alaska), Gothenburg (Sweden) and Lübeck (Germany). In France, in 2017, the Port of Marseille Fos and La Méridionale introduced electrification of the quays to allow ferries to connect to an electricity supply from 30 minutes after passenger disembarkation until 2 hours before departure. It is now no longer necessary to use motors running on oil fuel during this period at dock. In 2018, Corsica Linea, a company that provides a regular ferry service between Marseille and Corsica, announced that it planned to equip three of its vessels so that they too could connect to the electricity network when berthed. The introduction of the equipment for this new electrical connection device required an investment of between 3 and 5 million euros per vessel, to which ADEME and the PACA (Provence-Alpes-Côte d'Azur) Region were to contribute.

Burgeoning electrical maritime transport projects

CONTAINER BARGE • Port-Liner, a Dutch shipping company, is due to launch its first electric container barge shortly. Dubbed the "Tesla Ship", this vessel will operate by electric propulsion powered by independent batteries, giving it 15 hours of power in the case of the first model (52 m long and 6.7 m wide with a transport capacity of 24 containers), and 35 hours of power for the second model (110 m long and 11.40 m wide with a capacity of 270 containers.

CARGO SHIP • China launched the first electric cargo ship at the end of 2017. The ship, 70 m long by 14 m wide and weighing 2000 tonnes, was designed by Hangzhou Modern Ship Design & Research Co. The cargo ship can reach a cruising speed of 12.8 km/h and is powered by a series of batteries that generate 2400 kWh and which can be recharged in two hours, which enable it to travel 80 kilometres. In dock, the cargo ship has just the time to fully recharge while its cargo is being loaded and unloaded. The company hopes that this technology will soon be used by passenger vessels.

FERRIES • In 2018, the Havyard shipyard (Norway) announced that it had won a contract to build seven battery-powered ferries for the Norwegian transport company Fjord1. This news comes at a time when the operators of the first electric ferry in Norway, Ampere, announced their statistics with savings of up to 80% of energy and a 95% reduction in GHG emissions after two years in service. This vessel, which was brought into operation in 2015 as a result of a partnership between Norled AS (shipping company and ferry operator), Fjellstrand (shipyard), Siemens AS and Corvus Energy, is equipped with a battery with a capacity of 1 MWh. These economies of scale have triggered a series of orders to build new electric ferries or to convert ferries currently running on diesel. This announcement also comes at a time when Fjord1 is in the process of modernising its fleet following a request from the Norwegian authorities to achieve a zero-emission fleet. In parallel, Stena Line (a Swedish company) announced that it would convert Stena Jutlandica, a 185 m-long vessel which operates between Frederikshavn (Denmark) and Gothenburg (Sweden), to be powered by electricity, which would make it the largest electric boat in the world.

THE E-FERRY PROJECT • The E-ferry project (E-ferry – prototype and full-scale demonstration of next generation 100% electrically powered ferry for passengers and vehicles), funded by the EU, it is about to launch a fully electric, medium-sized ferry designed to transport passengers, cars, lorries and goods. Targeting medium-haul vessels, it should be able to travel distances of more than 20 NM between each charge with a large battery pack of 4 MWh. It is to be brought into service on lines between the Danish towns of Soeby and Fynshav (10.7 NM), and between Soeby and Faaborg (9.6 NM). The current E-ferry project was developed so that a recent design concept for high-energy performance could be applied. There were also plans to develop a case study and a commercial model, and prepare the concept before its forthcoming market launch, after a demonstration period. The aim, beyond the immediate duration of the project, is to bring into service each year around ten additional E-ferries in Europe and in the world to reach a total of ten or more by 2020, 100 or more by 2030, and thereby avoid emitting 10 to 30,000 tonnes of CO_2 per year by 2020 and 100 to 300,000 tonnes of CO_2 per year by 2030.

TEXT BOX 4

• OTHER TRENDING SOLUTIONS • In addition to electrification projects, there are also other types of solutions, such as incentives for better navigation. Consequently, the slowing down of vessels at the entrance to ports (or slow steaming) is one solution advocated in Long Beach and Los Angeles Port, which offers a reduction of 25% in demurrage charges in exchange for reduced speed when berthing. More effective and fuel-efficient navigation, and a reduction of speed at sea are therefore encouraged. There are further measures for managing vessels to reduce GHG emissions during navigation, such as reducing speed over journeys, reviewing the cladding of the hull, developing systems to recover lost heat, working on optimising the envelope and the ballast, regularly reviewing propeller polishing, reviewing the setting of the main motor on each new trip and updating autopilot upgrades (ActuEnvironnement, 2018).

The SeaWing project

The SeaWing project, which was launched in June 2016 for a period of 3.5 years with support from ADEME, consists of developing and marketing an auxiliary vessel towing system using an automated kite. The project was developed by the Toulouse AirSeas start-up comprising former Airbus employees and brought together marine architects, LMG Marin, the French Maritime College and MaxSea, the world leaders in marine navigation software. Technically, the idea was to assist the propulsion of a vessel by towing it using an immense wing. Inspired by kite surfing, this 1000 m2 wing attached to the end of a 400 m cable should be able to reduce a vessel's consumption by 20%. Another advantage of the procedure is that it is automated; the wing, folded on the deck of the ship, can be hoisted on a collapsible mast and deployed to the end of its cable by a single automated command, which includes the reverse procedure of folding it again. In addition to this wing, AirSeas is working on a project for decision-making software to help captains find the optimal route for their vessel depending on wind and ocean conditions, alert them to the opportunity to use the wing, and help them find the most effective position for it (La Croix, 2017).

TEXT BOX 5

CONCLUSION

Actors in international merchant shipping have, with the new IMO resolution on the GHG emissions-reduction strategy, at least demonstrated their desire to meet the challenge posed by the GHG emissions caused by shipping. Given these innovations, particularly in the area of electricity, maritime companies and shipyards will, in the coming years, have at their disposal a wide range of technological options to modify the means of propulsion of their vessels. The IMO is an important coordinator on a global scale in ensuring the deployment of partnerships between state and non-state actors needed to achieve the ambitious objectives of an international maritime transport industry that is in step with the Paris Agreement. The increase in the size of vessels and their cruising speed are also challenges that must be part of the IMO's new GHG reduction strategy if it is to achieve a successful energy transition for the international maritime sector, a sector that constantly faces major issues in international commerce; its strategic importance for major exporting countries, first and foremost China, makes defining a binding regulatory framework a complex task.

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