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).

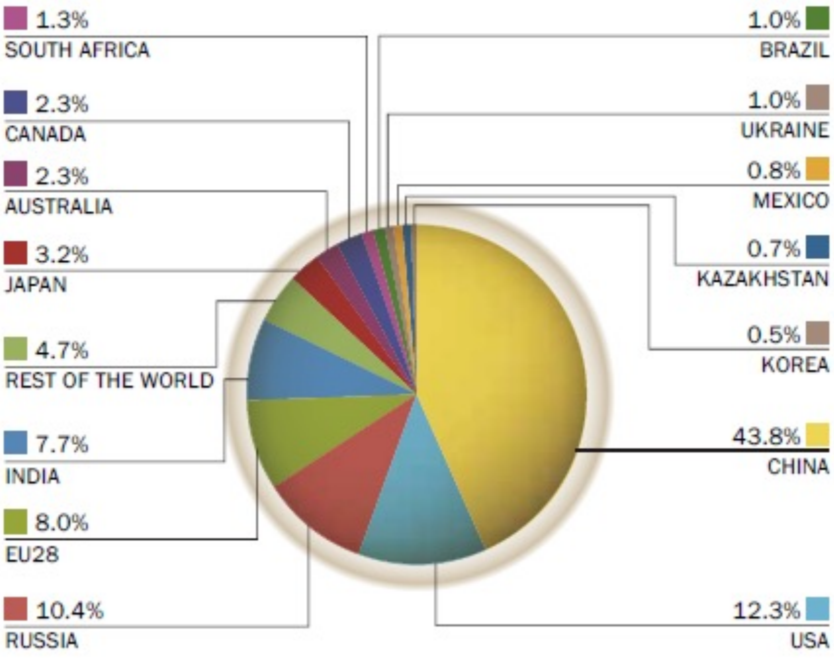

FIGURE 1. CO_2 EMISSIONS FROM RAIL TRANSPORT BY COUNTRY IN 2015

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.

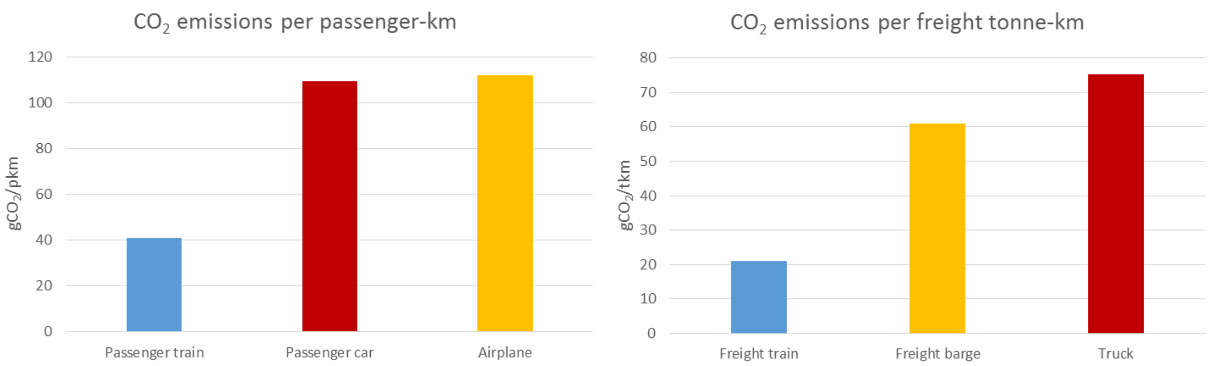

FIGURE 2. CO_2 EMISSIONS, IN PASSENGER/KM AND IN TONNE/KM, BY MODE OF TRANSPORT IN 2011

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)..
11 Improving energy efficiency and reducing emissions through intelligent railway station buildings. Asian development bank, 2015
12 Panou, K et al. (2013). Railway Driver Advisory Systems: Evaluation of Methods, Tools and Systems. 13th WCTR, July 15-18, 2013 – Rio de Janeiro (Brazil).

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.

PLEASE DO NOT HESITATE TO REACT TO THIS STUDY, AND NOTIFY US COMPLEMENTARY REPORTS AND DATA VIA THIS ADDRESS: CONTRIBUTION@CLIMATE-CHANCE.ORG

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

REFERENCES

PUBLICATIONS:

• Bigo Aurélien (2018), le train grand oublié de la transition énergetique ?, the Conversation

• BISWAS, S. et al. (2001). Composite Technology Development and Commercialization – An Indian Initiative. 6th ASEAN Science and Technology Week, Brunei Darussalam, September 2001.

• CAMPUS E. et al. (2017). Use of Composite Materials in Railway Applications". ALSTOM Transport in collaboration with SNCF Direction du Matériel Centre d'Ingenierie du Matériel

• CER, & UIC. (2015). Rail transport and Environment. Bruxelles-Paris.

• CDP. (2017). Missing link: Harnessing the power of purchasing for a sustainable future. Written on behalf of 89 organizations representing US$2.7 trillion of procurement spend. CDP Supply Chain Report 2016-2017.

• CHEUL-KYU L., et al. (2009). Global warming effect Comparison of each material for railway vehicle. Korea.

• GUNSELMANN W. et al. (2000. Energiespeichereinsatz im Statbahnnetz Köln. Elektrische Bahnen 98 (2000) z. 11-12. Cologne (Germany).

• IEA, & UIC. (2017). Railway Handbook. Energy consumption and CO_2 emissions. Paris.

• MTO. (2017). Ontario Minister's Climate Change Action Plan Progress Report 2017.

• NETWORK RAIL. (2009). Network RUS electrification (UK). October 2009. London (UK).

• NEWRAIL. (2004). The Research requirements of the transport sectors to facilitate and increased usage of composite materials. Part III: The Composite Material Research Requirements of the Rail Industry.

• PANOU, K et al. (2013). Railway Driver Advisory Systems: Evaluation of Methods, Tools and Systems. 13th WCTR, July 15-18, 2013 – Rio de Janeiro (Brazil).

• UIC. (2016) Technologies and potential developments for energy efficiency and CO_2 reductions in rail systems. Paris.

• UIC. (2014). Transport. Low carbon rail transport challenge. Action plan. Paper presented at the Climate Summit 2014, UN Headquarters New York.

• UNIFE, & CER. (2016). Rail as a key to decarbonising transport. Brussels.

• 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).