

# EVALUATING THE CARBON IMPACT OF INVESTMENT IN HIGH-SPEED ROLLING STOCK

METHODOLOGY APPLIED TO SNCF'S 2021 GREEN BOND  
PROGRAMME FOR HIGH-SPEED ROLLING STOCK

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# 1. INTRODUCTION

## 1.1. BACKGROUND

A green bond is debt issued on financial markets by a company, international organization or local government. Proceeds are used to finance a project or activity considered environmentally beneficial. Since rail is one of the eco-friendliest forms of transport, it falls within the category of activities eligible for this type of bond.

SNCF's first green bond, issued on 27 October 2016, was aimed primarily at financing long-term upgrades to our network. This made us the first railway infrastructure operator worldwide—and the first transport company in Europe—to issue a green bond.

From 2016 to 2020, SNCF Group carried out 13 green bond issues totaling €7 billion, including the world's first 100-year green bond in 2019. In 2020, we were the third-largest green bond issuer in France, ranking fifth both in Europe and worldwide (excluding sovereign, supra and bank issues).

In 2016, SNCF received the Climate Bonds Initiative's Green Bond Pioneer Award for the quality of our impact reporting for our inaugural issue, and in March 2019 we were awarded the prize for a second time. Both are testaments to the transparency and clarity of our investor relations.

At the end of 2020, and in the same spirit of innovation, we expanded the scope of our green bond programme to include high-speed rolling stock.

In doing so, we became the first mobility group in the world with a bond programme covering both infrastructure and transport assets.

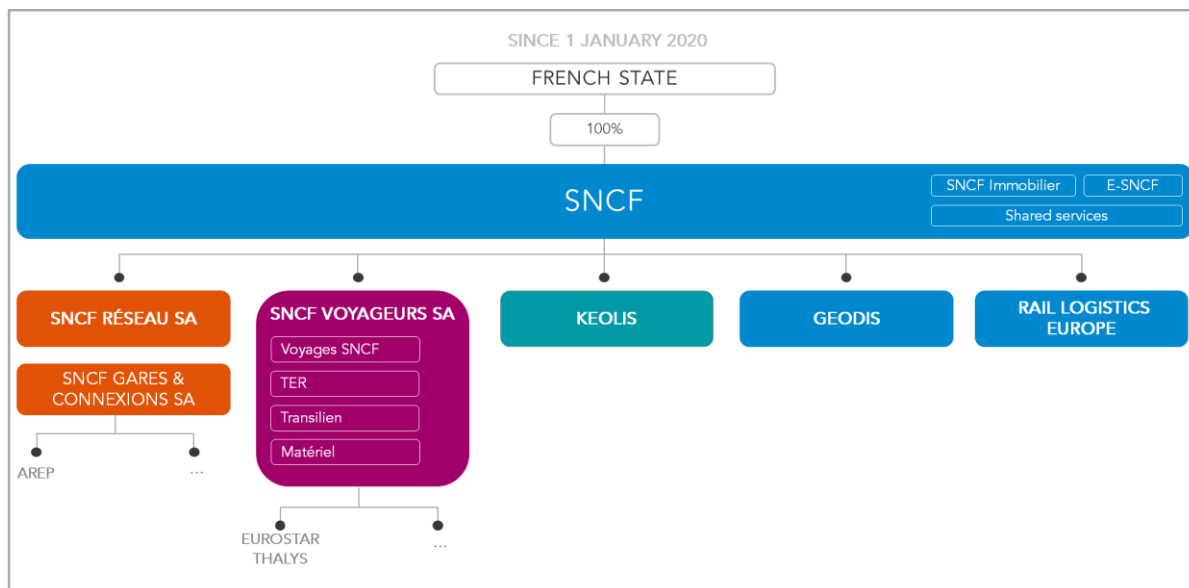
To highlight the benefits of these investments, and to offer maximum transparency to both investors and the general public, SNCF aims to quantify the impact of projects financed by green bonds in the drive to reduce greenhouse gas emissions.

This guide explains the methodology used for assessing the carbon impact of investments in high-speed rolling stock, rounding out the methodology developed for infrastructure investments.

These documents can be downloaded from the SNCF website at [sncf.com](https://www.sncf.com).

## 1.2. SNCF GROUP

SNCF is a global leader in mobility, with businesses throughout the transport industry value chain.



Each of our main subsidiaries is responsible for a different area of operations: (i) SNCF Réseau sells access to the French rail network, manages network traffic and upgrades and develops the network; (ii) SNCF Gares & Connexions operates, renovates and monetizes the 3,000 stations in the French rail network; (iii) SNCF Voyageurs provides mobility solutions in the Paris region with Transilien, regionally with TER, and across France and Europe with brands that include INOUI, OUIGO, Intercités, Eurostar and Thalys; (iv) Keolis provides mass transit solutions in France and internationally; (v) Rail Logistics Europe (formerly Fret and TFMM) oversees rail freight operations; and (vi) Geodis specializes in freight transport logistics in 120 countries.

More information on SNCF Group's structure and an overview of each subsidiary's results can be found [on our website](#).

### SNCF VOYAGEURS AND VOYAGES SNCF

▶ SNCF Voyageurs is Europe's second-largest rail operator, handling all SNCF passenger rail transport in France and across Europe. Within SNCF Voyageurs, Voyages SNCF operates long-distance, high-speed transport in France and Europe under some of SNCF's best-known brands. INOUI provides traditional high-speed rail, while OUIGO offers low-cost, high-speed service for budget-conscious travellers. Eurostar, Thalys and Lyria operate high-speed lines across Europe. For both revenue and passenger numbers, SNCF Voyageurs is at the forefront of low-carbon rail transport in Europe—one of many ways in which SNCF is positioned to play a key role in delivering the mobilities of tomorrow.



### 1.3. PROJECTS FINANCED BY GREEN BONDS

The proceeds of green bond issues are allocated to projects eligible in one of two categories related to high-speed rolling stock:

- Procurement or acquisition of new HS trains to replace the existing TGV fleet with new-generation trainsets (TGV M and TGV Euroduplex U3FC).
- Maintenance/refurbishment of HS trains: heavy maintenance involving the complete overhaul of a locomotive, self-propelled unit or multiple unit that is performed when the equipment reaches the midpoint of its potential life (referred to as OPMV, from the French *opérations mi-vie*).

Altogether these investments amount to around €200-300 million each year.

### 1.4. METHODOLOGY

To align our methodology with the market's best practices, we have based our policy on five principles:

- **Additionality**: proceeds from the Group's green bonds can be allocated only to new projects with a look-back period of no more than 24 months.
- **Assessment for environmental impact over projects' entire life cycle**: our carbon impact assessment includes direct emissions from operations, as well as indirect emissions related to upstream (construction) and downstream (recycling) phases. Even where upstream emissions are not produced by SNCF, we include them to reflect the real ecological benefits of our investments.
- **Exhaustivity**: as far as possible, we include scopes 1 (direct emissions), 2 (indirect emissions from energy consumption) and 3 (indirect emissions from upstream/downstream phases) for all our emissions.
- **Objectivity**: assumptions for changes in the French energy mix and in other transport modes are reviewed on the basis of the latest reports published by key external bodies, such as ADEME (the French Environment and Energy Management Agency) and the public utility RTE. SNCF Group's internal assumptions are explicitly stated in the methodology.
- **No double counting**: to link each asset to its proper share of avoided emissions, SNCF applies allocation rules that prevent double counting of such emissions. This means that (i) independently of the project financed, 80% of avoided emissions are allocated to infrastructure and 20% to rolling stock, and that (ii) for partially subsidized or co-financed projects, SNCF allocates to itself the avoided emissions as a pro rata share of its contribution to financing.

In addition, SNCF verifies once a year that its green bond framework complies with the principles set out by key market benchmarks, the green bond principles of the ICMA and the

Climate Bond Initiatives (CBI) criteria. SNCF Group also prepares a summary annual report on its green bond allocations and their environmental impact. This document is reviewed by an outside audit firm independent of any work carried out by the statutory auditors.

Most of the assumptions used for calculations in this methodology apply to operations within France. These include emission factors for transport modes, the carbon content of electricity, the geographical structure of the French network, competition between transport modes and traffic on the country's high-speed network.







## 2. DESCRIPTION OF ELIGIBLE PROJECTS

### 2.1. HIGH-SPEED ROLLING STOCK

#### 2.1.1. Models and commercial use

By the end of 2020, SNCF group will have a fleet of around 400 high-speed trainsets, made up of 15 different models. Apart from OUIGO trains, these are generally assigned to routes within one of the four sectors that make up France's National Railway Network (RFN): the North sector for TGV destinations north of Paris; the Atlantic sector for destinations on the Atlantic coast; the East sector for destinations in Champagne, Lorraine and Alsace; and the South-East sector for services to Lyon, Auvergne, Savoie and the Mediterranean. Excluding OUIGO trains, 30% of the trains are allocated to the Atlantic sector, 30% to the South-East sector, 15% to the North sector, 15% to the East sector, and slightly less than 10% to European traffic.

#### 2.1.2. Train models and capacity

Depending on their capacity (number of seats on offer), the 15 train models used by SNCF can be grouped into 6+1 different types (+1 = TGV M).

**The first type** is TGV A for TGV Atlantique. These trains have 456 seats, and as their name suggests they serve the west of France from Paris-Montparnasse station, running on the Atlantic high-speed network. They are electric-powered, can run at 300 km/h, and came into service between 1989 and 1992 when the first western branch of this network opened. TGV A trainsets have 10 cars—three 1<sup>st</sup> class and seven 2<sup>nd</sup> class—and completed their mid-life refurbishments between 2005 and 2010. With the arrival of the new Euroduplex models, decommissioning started in December 2015.



Exterior view of a TGV A train



Interior of a TGV A train

**The second type**, with 361 seats, consists of TGV R DOM (TGV R bi-current) and POS trains. These are electric trains that run mainly on North and East routes and can operate at 320 km/h (POS). On 3 April 2007, POS train 4402 set a world rail speed record of 574.8 km/h. POS trains



were rolled out between 2007 and 2008, and mid-life refurbishment is complete for all passenger cars, though not the locomotives. Likewise, all mid-life refurbishments have been completed for R-DOM trainsets, which consist of eight cars, with three 1<sup>st</sup> class and five 2<sup>nd</sup> class.



A locomotive and car are paraded on the Seine after the May 2007 speed record



Exterior view of a TGV POS train

The **third type**, with 353 seats, includes TGV R TRI and PLT trains (where R is for *Réseau/network*, TRI is for "tri-current" and PLT is for "Paris Lyon Turin"). This is the second sub-series of TGV Réseau trainsets introduced between 1994 and 1996, as high-speed service to the north got underway. These trains are electric and can run at 320 km/h. Six PLT trainsets are used for Voyages SNCF's Italy service between Paris and Milan, while R TRI trains run in the North sector and between Brussels and Marseille or Strasbourg. TRI & PLT trains are made up of 8 cars, including three 1<sup>st</sup> class and five 2<sup>nd</sup> class. Mid-life refurbishments were carried out between 2010 and 2013.



Exterior view of a TGV TRI train



Interior of the 1st class of a refurbished trainset created by French designer Christian Lacroix

The **fourth type**, with 509 seats, includes R-Duplex RNAI, Duplex, R-Duplex, Dasye and Euroduplex trains. These electric trains went into service between 1995 and 2015 and can run at 320 km/h. As their name suggests, they are made up of double-decker cars, three 1<sup>st</sup> class and four 2<sup>nd</sup> class. They operate on all routes, and the Duplexes were delivered in several

waves—the first between 1995 and 1998, the second between 2001 and 2006, after the Mediterranean high-speed line started up in 2001, and R-Duplex trains after 2007. Mid-life refurbishment is complete for Duplex RNAI trainsets and for R-Duplex train locomotives, but not for R-Duplex passenger cars. The most recent Dasye and Euroduplex trains are also awaiting mid-life refurbishments.



Exterior view of a TGV Dasye train



Exterior view of a Euroduplex TGV train

**The fifth type**, with 556 seats, includes the Euroduplex 3UFC (Océane) and renovated Duplex models. The former are new trains first rolled out in 2016, while renovated Duplex trains are double-decker models that have undergone mid-life refurbishment since 2019 and now feature an interior design similar to the Euroduplex 3UFC. They can operate at up to 320 km/h. Both the 3UFC and renovated Duplex models run mainly in the Atlantic and South-East sectors. Mid-life refurbishment of Océane Duplex models is currently in progress.

**The sixth and last type**, with 634 seats, is OUIGO trains, consisting of Dasye locomotives and Duplex passenger cars—converted during their mid-life refurbishment to accommodate 20% more passengers. Thirty-eight trains of this type are in operation, all on heavily used lines. Seating was increased by reducing luggage space, eliminating first class and café-bar space, and installing different seat models.



Interior of a OUIGO train



Exterior view of a OUIGO train



### FOCUS ON TGV M: THE 5<sup>TH</sup> GENERATION OF HIGH-SPEED TRAINS

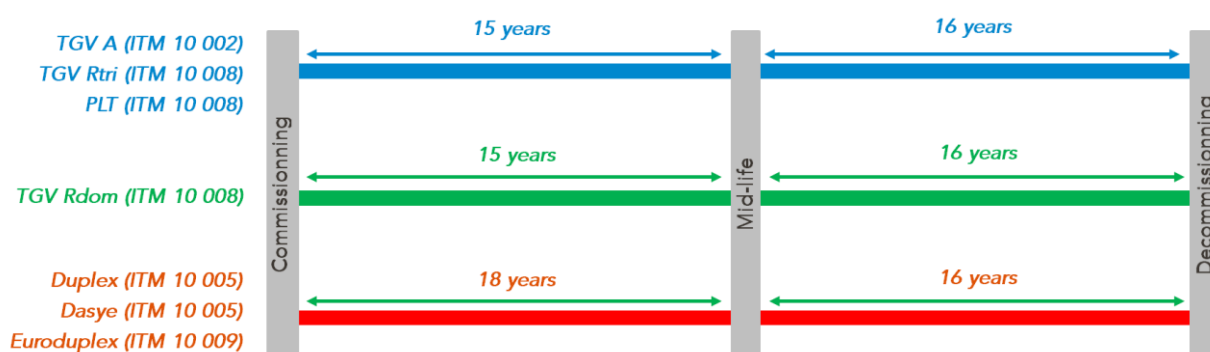
In 2018, SNCF ordered 100 TGV M trains at a total cost of €2.7 billion. The first deliveries are slated for 2023, and the new models will gradually replace end-of-life trains. Developed jointly by SNCF and Alstom, TGV Ms are cheaper to produce and maintain. They also use 20% less energy, thanks to the combined impact of their aerodynamic design, eco-driving, and the charge fed back to the catenary when braking. Built with more eco-friendly materials, they will be 97% recyclable, offering a carbon footprint that is 32% smaller than trains now in operation. The purchase price is also 20% lower than that of conventional trains, with maintenance costs 30% cheaper.

### 2.1.3. Train life cycles

Train life cycles are defined in maintenance work schedules (ITM) and include three main events:

- **Commissioning:** initial purchase of the train
- **Mid-life refurbishment (OPMV):** major maintenance work involving the complete overhaul of a locomotive, self-propelled unit or multiple unit, performed when the equipment reaches half of its potential life;
- **Decommissioning:** the end of the train's service life.

The commissioning-to-mid-life period is 15-18 years, depending on the series. The second period, after mid-life, is 16 years for standard TGVs and 12 years for OUIGO trains.

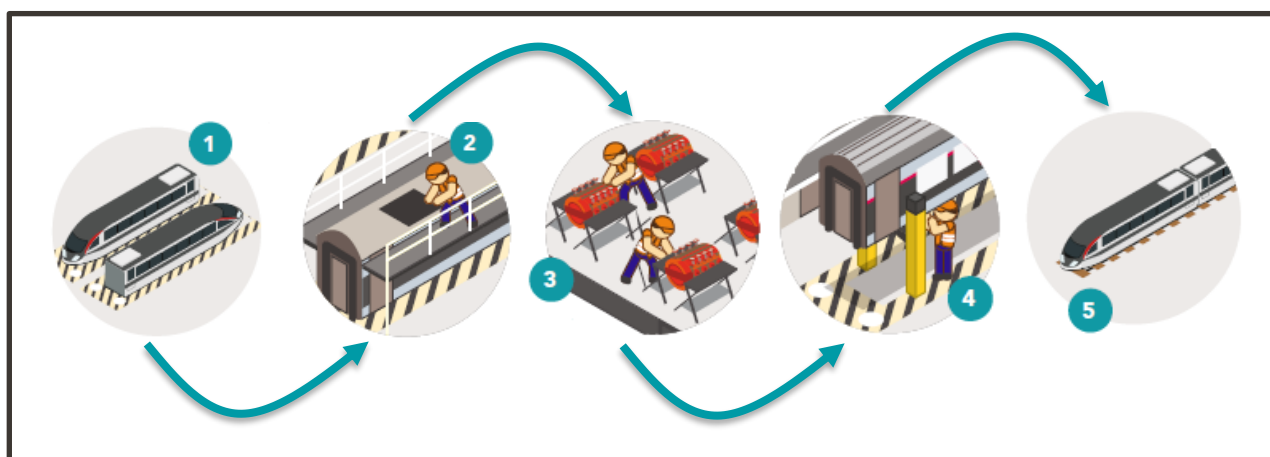


Around 92% of the materials in SNCF Group's current TGV trains are recycled. Main materials recovered are steel, copper, aluminium, stainless steel and glass, but large-scale salvage of parts for reuse on active fleets also generates savings in raw materials and investment.

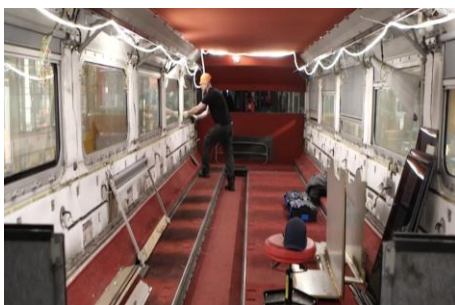
### 2.1.4. How an OPMV is performed

SNCF Group's mid-life refurbishments are performed at two intensive maintenance facilities, the Bischheim Technicentre in eastern France and the Hellemmes Technicentre in the north. It takes four to five months on average to refurbish a TGV train, and the process goes as follows: (1) preliminary operations (uncoupling of engines, passenger cars and carriages), (2) dismantling of bodies for access to interior structures, (3) refurbishment proper (structure inspected, repaired and painted; new livery fitted), (4) reassembly, re-coupling and putting the train back into service, (5) a subsequent line-testing stage. Between 2014 and 2020, SNCF refurbished a total of 73 Voyages trainsets, 9 Eurostar trainsets and 18 Thalys trainsets.

How mid-life refurbishment avoids emissions



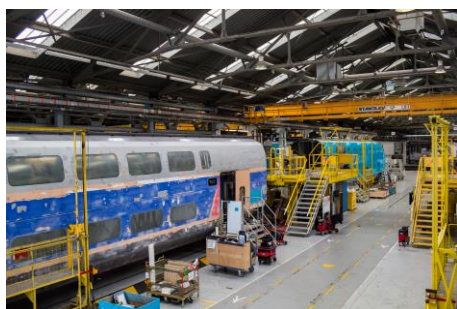
Source: SNCF



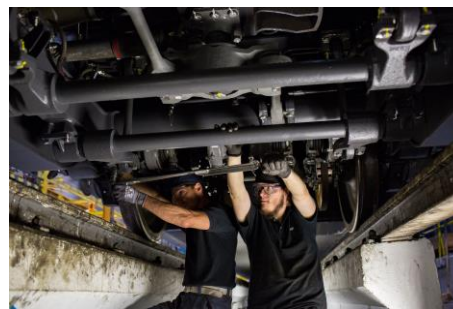
Refitting a passenger car



Recoupling segments of a OUIGO trainset



Mid-life refurbishment of a train



Mid-life refurbishment of a train

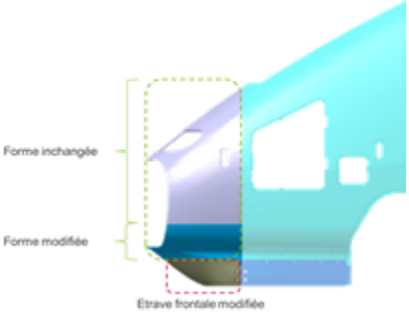
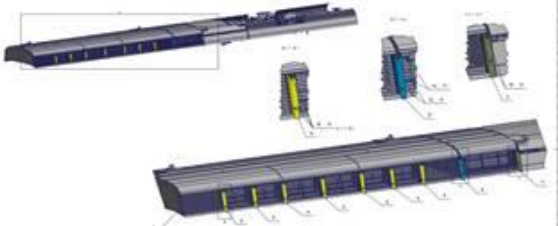
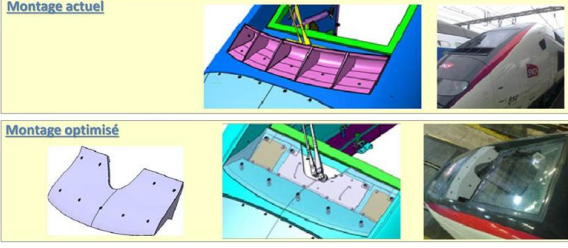
### 2.1.5. Energy optimization projects (not funded by GB)

At SNCF Group we believe in continuous innovation and we are already working on new ways to make our rolling stock even greener. Examples include:

- **Installing energy meters:** Accurate measurement is the first step towards cutting the energy consumption of our trains even further.
- **Modifying on-board software to reduce energy consumption (Eco-Doors TGV):** When cleaning or maintenance teams pass through idled TGVs, the train doors stay open, creating thermal bridges that lead to energy loss. In response, SNCF has modified trains' on-board computer systems to activate a timed closure 30 minutes after trains go on standby, a move that saves 48 MW/trainset/year.

A number of research projects are also underway to improve trains' air penetration coefficients (Cx):

#### Projects to improve trainsets' air penetration coefficients

Design: aerodynamically optimized front fairing for double-decker high-speed trains	
Spoilers are fitted at strategic points to make trainsets more aerodynamic.	
Windscreen fairing is replaced by an optimized model, lowering the train's overall drag by 1% and reducing mid-frequency noise by 1.3 dBA at a speed of 300 km/h.	

Source: SNCF



### 2.1.6. Future expansion of assets for green bond financing

With a view to gradually shifting to all-green financing, SNCF Group is developing indicators and approaches that will expand our base of eligible assets. As assets are added, they will be covered by new methodologies or added to existing ones.

Ideas under consideration include:

- **Financing CapEX of other SNCF Voyageurs businesses:** Although the rolling stock used by SNCF's TER and Transilien services is almost entirely financed by the relevant public authorities, some types of CapEX are still borne by the Group. SNCF plans to expand green bond financing to some of these assets.
- **Financing construction/renovation of "maintenance" Technicentres:** These facilities carry out light maintenance (levels 1, 2 and 3) on rolling stock. In 2021, SNCF plans to round out the methodology described in this document (assessing the carbon impact of high-speed rolling stock for green bonds) to include operating costs incurred by Technicentres.
- **Financing construction/renovation of "industrial" Technicentres:** These facilities handle heavy maintenance (levels 4 and 5) in four key areas: (i) rolling stock maintenance (including OPMV), (ii) management of components such as bogies and axles, (iii) processing of repairable parts, and (iv) upgrades of complete series as new technologies are developed. In 2022, SNCF plans to develop an ad hoc methodology for CapEX of this type.

SNCF will keep investors informed of progress on these projects at regular intervals.



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### 3. CARBON IMPACT OF PROJECTS

#### 3.1. ANALYTICAL FRAMEWORK

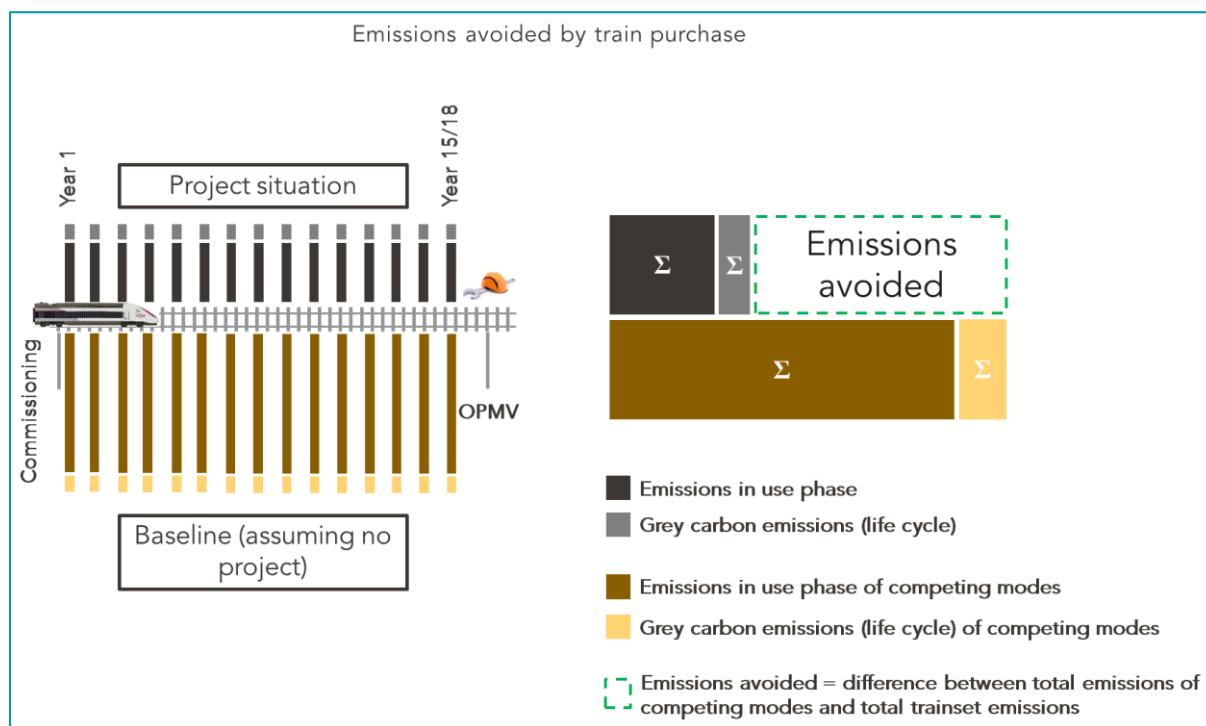
To measure the environmental benefits of eligible investments, SNCF calculates the carbon impact of the projects that we finance. Carbon impact and related principles of methodology are explained below.

##### 3.1.1. Carbon impact: definition and general principles

A project's carbon impact is based on the ratio of total emissions to emissions of a baseline (counterfactual) scenario. If a project's emissions are lower than the baseline, the project is deemed to contribute to the fight against climate change.

This is obviously the case for all new purchases (procurement) and all renovations of existing equipment (refurbishment) for SNCF's high-speed TGV fleet because of the type of energy used (electricity) and the traffic density of the HS network. Financing these expenditures with green bonds underscores the benefits of rail compared with other forms of transport that produce higher greenhouse gas emissions (GHG).

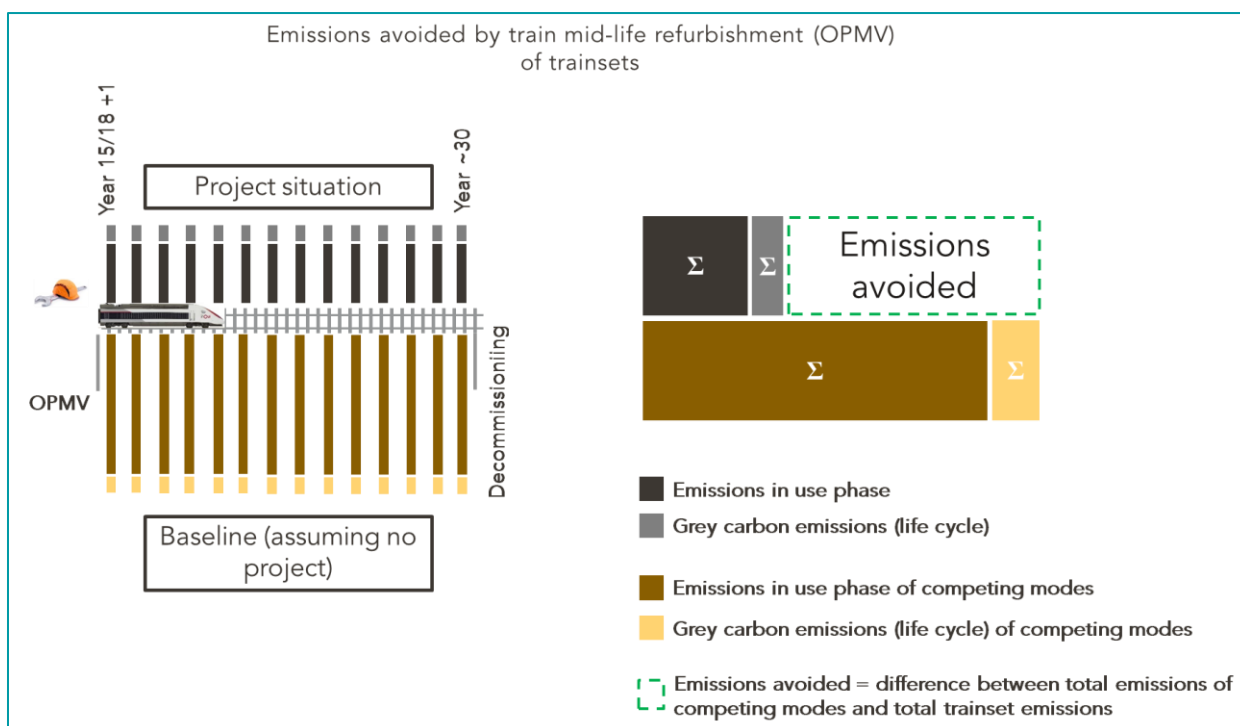
Carbon impact of HST procurement



Source: SNCF



## Carbon impact of HST refurbishment



Source: SNCF

## 3.1.1.1. The case for a baseline scenario

*“Emissions are avoided when there is a positive difference between a given project’s emissions and the baseline scenario which would occur if there were no project. In other words, an avoided emission is the difference between the project’s actual greenhouse gas emission and the estimated flow which, by definition, did not occur (the counterfactual scenario)”<sup>1</sup>.*

The carbon impact of trains cannot be assessed solely on the basis of train emissions. This is because where there is no rail service available, most passengers switch to other, more polluting modes of transport—modes that contribute to greater climate change. In this respect, while rail transport is not pollution-free, it substantially reduces GHG (greenhouse gas) emissions for the transport sector as a whole.

Reflecting this reality, we have created a baseline scenario in which:

- No investments are made in procurement or refurbishments and trains cannot (or can no longer) run.
- Passengers are forced to adopt another mode of transport (modal shift).

Conclusion: the carbon impact of eligible assets should be measured first in comparison with the emissions they avoid. The situation described above both justifies and legitimizes analysis of the carbon impact of investment in rolling stock.

<sup>1</sup> <http://www.carbone4.com/wp-content/uploads/2020/04/Carbone-4-Referentiel-NZI-avril-2020.pdf>

### 3.1.1.2. Similarity of procurement and refurbishment projects

Although buying new equipment (procurement) and renovating existing rolling stock (refurbishment) are different projects by nature, they present few methodological differences. In fact, both have similar consequences:

- Both allow trains to operate for a certain number of years.
- The carbon footprint for operations is calculated in the same way for both new and refurbished rolling stock.
- Both new and refurbished trains keep rail traffic at the same level, thereby avoiding a modal shift to other, more polluting modes of transport and the GHG these produce.

Main differences concern project type, the asset's useful life and the amount invested.

- **Project type:** A procurement project involves putting a new train into service on the network. A refurbishment project involves renovating a train already in operation.
- **Useful life of an asset:** A new train can run for 15-18 years. A mid-life refurbishment (OPMV) is then necessary, extending train life by 12-16 years.
- **Investment levels:** On average, buying a new train costs twice as much as refurbishing an existing one.

### 3.1.1.3. The competitive environment

Rail market liberalization in France began with reforms adopted in 2018, including a clearly delineated timeline for the three segments of passenger service: high-speed long-distance lines available on an open access basis; TET short- and medium-distance lines supporting economic development in France's regions; and TER short-distance regional trains. Since December 2020, the passenger market has been fully liberalized except for services offered under public-service contracts.

We have opted not to include rail market liberalization as a factor in allocating emissions avoided due to modal shift. This is because investing in rolling stock ensures continuity of service for travellers, whose choice of rail over other transport modes rewards those operators that invest.

## 3.1.2. Carbon impact: project-by-project analysis

SNCF plans to analyse the carbon impact of the projects financed by its green bonds. Each project can be seen as the intersection of a CapEX type (procurement or refurbishment) with a train type (TGV A, Euroduplex 3UFC, etc.). It can thus include one or more trains with similar features, in which case the total carbon impact is that of one train multiplied by the number of trains in the project. By working on a project basis, SNCF can group similar assets with similar carbon impacts.



## 4 projects in year n: 1 procurement project and 3 refurbishment projects

Train type	Capacity (seats)	Project type	
		Procurement	OPMV
TGV A	459	0	5 in year n
TGV RDOM & POS	361	0	0
TGV R PLT & TRI	353	0	0
TGV DUPLEX RNAI – RDUPLEX – DASYE - EURODUPLEX	509	0	0
TGV 3UFC – DUPLEX RENOV	556	0	4 in year n
TGV OUIGO	634	0	6 in year n
TGV M	600	7 in year n	0

Source: SNCF

Unlike the approach taken to assess the carbon impact of infrastructure investments, our rolling stock procurements or refurbishments are considered on a project-by-project basis. All projects eligible for green bond financing are analysed initially on their own specific features. As there are only a limited number of rolling stock acquisitions or refurbishments each year, SNCF does not apply extrapolated values to deduct the carbon impact of a project compared with a baseline project.

In addition, to the extent that all procurement and refurbishment projects provide latent carbon savings which are allocated over time, and which result mainly from operating the asset over a period of 15 to 20 years, the assessment is performed before the equipment is effectively put into circulation.

SNCF's approach for rolling stock projects remains consistent with that used for infrastructure.

## 3.2. CARBON FOOTPRINT AND GREY CARBON

For the sake of thoroughness and consistency with the methodology developed for investments in infrastructure, SNCF takes into account the full carbon weight of its rolling stock projects, namely (i) emissions from trainset construction/maintenance/end-of-life phases (grey carbon), and (ii) emissions while in use.

In this section (3.2.) we review how grey carbon is accounted for in the carbon footprint of eligible projects. Use-phase emissions are considered in section 3.3, Avoided emissions.

### 3.2.1. Including grey carbon in emission factors

Grey carbon refers to the carbon emissions from energy consumed during the life cycle of a piece of equipment or product, including manufacture, maintenance, and recycling.

Like the consumption of electricity, the consumption of grey energy implies the release of CO<sub>2e</sub> emissions that we include in our carbon footprint analysis. A grey carbon emission factor (EF) is assigned to each mode of transport. These EFs are expressed as g CO<sub>2e</sub>/pkm and are added to use-related EFs.

### 3.2.2. Updating emission factors

Grey carbon emissions linked to the life cycle of transport modes can be deduced from figures found in current publications. SNCF Group is working to develop an appropriate approach in this area. The emission factors used for competing modes of transport will be specified in our annual green bond impact reports.

Carbon footprint emission factors may be reassessed as new studies appear. These reassessments will be monitored and accounted for in the annual green bond impact reports.





## 3.3. EMISSIONS AVOIDED DURING THE USE PHASE

### 3.3.1. Emissions from our projects

#### 3.3.1.1. General principles and scope

The projects financed by our green bonds play a powerful role in reducing emissions, but trains still run on electricity, which means they emit CO<sub>2</sub>e. Before we show the environmental benefits of high-speed trains (HST), we need to measure emission levels from train operation, or “induced emissions”.

Calculation of induced emissions is based on the following parameters:

- the emissions level (EF) for HSTs in operation
- train use levels measured by distance travelled and passengers carried

#### 3.3.1.2. Arriving at HST emission factors

##### 3.3.1.2.1. Calculating HST emission factors

During the use phase, CO<sub>2</sub>e emissions from our trains reflect the electricity they consume. These are all *indirect* emissions relating to electricity generation, i.e. Scope 2 emissions (from power stations) and Scope 3 emissions (from the upstream phase).

Since our high-speed trains are fully electrified, SNCF Group does not record direct (“tail pipe”) emissions.

##### 3.3.1.2.2. Emission factors and train type

Each year SNCF’s Social Commitment and Ecological Transition Division (DESTE) recalculates train emission factors, represented as n-1. For each train type, average CO<sub>2</sub>e emitted per passenger-kilometre is determined by dividing annual energy consumption n-1 by the number of passengers carried and the distance they travelled.

SNCF calculates three different HST emission factors each year—one each for TGV INOUI, OUIGO and Lyría. For our green bonds programme, we also construct a TGV M EF based on the INOUI TGV EF.

Trainsets are assigned to three categories as follows:

- **Most high-speed trains (INOUI TGV)** for standard operation of existing trains, with no further distinction;
- **OUIGO trains**, offering larger capacity and used solely on high-demand routes;
- **TGV M trains**, offering their larger capacity and technology that means energy consumption per passenger-kilometre is 20% lower than for regular INOUI trains.

Emission factor by train model and type (g CO<sub>2</sub>e per passenger-kilometre)

Model	Train type per capacity	Capacity	EF type	2019 EF (gCO2e/pkm)
TGV A	TGV A	459	TGV INOUI	1.90
Rdom	TGV R DOM & POS	361		
POS				
Rtri	TGV R TRI & PLT	353		
PLT				
Duplex	DUPLEX RNAI - RDUPLEX - DASYE - EURODUPLEX	509		
R-duplex				
Néoduplex				
Dasye				
3UFC	3UFC - DUPLEX RENOV	556		
Duplex-Renov				
TGV M	TGV M en format INOUI	600	TGV M	1.27
OUIGO	OUIGO	634	TGV OUIGO	0.73

Source: SNCF

### 3.3.1.2.3. Changes in HST emission factors

Using the 2019 forecast by public utility RTE as a starting point, each year SNCF recalculates an electricity emission factor based on the energy sector's CO<sub>2</sub>e emissions (Mt CO<sub>2</sub>e) in relation to electricity generation levels (TWh). In 2018 this was around 38.5 grams CO<sub>2</sub>e/KWh. RTE's forecast value for 2025 is 19.2 g CO<sub>2</sub>e/KWh.

For each train type, emission factors change over time as follows:

- **For  $t \leq 2025$ :** Changes in train EFs mirror those in electricity generation. We use RTE's 2019 forecast to determine two fixed points—2018 and 2025—and apply a linear growth rate for the years in between.
- **For  $2026 < t \leq 2035$ :** From 2026 to 2035, train EFs will change at the same rate as electricity generation EF, or -0.9% per year up to 2035.
- **For  $t \geq 2036$ :** After 2036, train EFs will change at the same rate as the electricity generation EF, or -0.5% per year.

Actual EFs are updated annually and checked by our auditors before publication. Our EF calculation procedure complies with the French government's guide to GHG in transport services<sup>2</sup>.

### 3.3.1.3. Calculating passenger-kilometres and traffic growth

Passenger-kilometres (pkm) are a key factor in calculating each project's carbon impact and comparing this with other, higher-emission modes. In the rail industry, one way to estimate passenger-kilometres is to multiply the distance travelled by eligible trainsets by the number of passengers carried. This result is combined with trainset emission factors and compared with competing modes of transport to determine each project's net carbon impact.

Passenger-kilometre values are based on two assumptions for the entire fleet, and on one

<sup>2</sup> <https://www.ecologie.gouv.fr/information-ges-des-prestations-transport>



assumption relating to train type.

**Fleet-wide assumptions for minimum return on assets:**

- **Average annual distance travelled:** Regardless of train or project type, we assume that a train in operation travels 450,000 km on the French rail network every year.
- **Dynamic train occupancy:** The occupancy rate per train is based not on train type but on sales projections made by SNCF Group. At fleet level, it is calculated by comparing projected passenger-kilometres travelled with the total number of available seat-kilometres (ASK).

**Assumptions relating to train type:**

- **Train capacity (seats offered):** Train capacity corresponds to the number of seats on offer, and ranges from 353 to 634 seats. The number of passengers carried by each type of train can be deduced from the average dynamic occupancy rate for the HST fleet.

For each year and type of train, passenger-kilometres are calculated as follows:

$$\text{pkm}_{\text{year } n \text{ \& train } k} = 450\,000 \times \text{dynamic occupancy}_{\text{year } n} \times \text{train } k \text{ capacity}$$

### 3.3.1.4. Calculating emissions generated during the use phase

Emissions generated during a train's use phase are obtained by adding up emissions generated over the life of the asset, calculated as the product of passenger-kilometres and the train's EF.

A train's useful life naturally depends on whether the project concerns procurement or refurbishment: a new train can be expected to operate for 15 to 18 years, after which it will undergo mid-life refurbishment (OPMV) to extend its life by 12 to 16 years.

$$\text{Emissions generated by a project} = \sum_{t=1}^{12-18} FE(t) \cdot (V \cdot KM(t))$$

### 3.3.2. Emissions generated by the baseline scenario

#### 3.3.2.1. General principles and scope

SNCF buys new trains and refurbishes existing ones to keep rail service at an optimum level. Without these investments, the number of trains in circulation would decrease and, as already noted, users would be forced to switch to competing modes (modal shift). Financing for these procurement/refurbishment projects helps prevent the transfer of passenger-kilometres from trains to competing modes such as planes, cars and coaches.

Analysis of avoided emissions is therefore based on the following parameters:

- the level of emissions (EF) of competing modes during their use phase;
- the dynamics of the shift of passenger-kilometres from rail to competing modes.

How these factors are determined and applied is described below.

#### 3.3.2.2. Determination of EFs for competing modes

##### 3.3.2.2.1. Calculating competing EFs

For the sake of consistency, SNCF assesses use-phase emissions of competing transport modes by applying the same scope as for our own projects (direct and indirect emissions). Our calculation thus includes both (i) direct emissions generated by consumption of fossil fuels and (ii) indirect emissions relating to electricity consumption and (iii) the upstream phases of energy-generating fluids.

##### 3.3.2.2.2. Emission factors for competing modes

Emission factors used for competing transport modes are the average amounts of gCO<sub>2</sub> emitted per passenger over one kilometre, also expressed as grams of CO<sub>2</sub> / passenger-kilometre.

Recent values for most modal EFs are known and may depend on the geographical area concerned (see table below).

Emission factors (g CO<sub>2</sub>e / pkm) for competing transport modes

Transport mode	Detail	gCO <sub>2</sub> /pkm
Passenger trains	TGV (HST)	1.7
	Intercités	5.3
	Trains / Greater Paris RER	4.1
Car	Long distance (occupancy: 2.2 people)	79.1
	Short distance (occupancy: 1.4 people)	152.1
	Mixed journeys (occupancy: 1.6 people)	120.6
Air	Short haul, with vapour trail	258
	Long haul, with vapour trail	187
Coach	Diesel coach (occupancy: 30 people)	26
	Diesel coach (occupancy: 30 people)	35
	Diesel coach (occupancy: 30 people)	30
	Ordinary bus (conurbation <100 000 inhabitants)	146

Source: SNCF

### 3.3.2.2.3. Changes in emission factors

Estimates of emissions avoided through an investment project spanning several decades will inevitably change over time, reflecting many different parameters—energy performance of transport vehicles, vehicle occupancy, lifestyle changes, GHG content of electricity, changes in energy vector, and more. EF trends must take these changing parameters into account over the period under consideration.

We have drawn on several sources:

- EFs for transport modes in 2020 (based on work units from pre-pandemic years) are taken from the Base Carbone® database of the French Environment and Energy Management Agency (ADEME). These values include upstream emissions for energies used.
- For changes in EFs up to 2050, values for cars come from ADEME's 2035-2050 Energy-Climate Scenario, and values for long-distance coaches from a French General Sustainable Development Commission (CGDD) study<sup>3</sup>. Data for changes in EFs for air transport is from the International Energy Agency's 4DS scenario<sup>4</sup>, considered the most realistic for emissions in this industry<sup>5</sup>.

### 3.3.2.3. Assumed modal shift and allocation of passenger-kilometres

#### 3.3.2.3.1. Development of modal shift assumptions

The baseline scenario for calculating avoided emissions shows that passengers would gradually shift to competing modes if SNCF Group did not invest in rolling stock. Without new investments, current HST trains would remain in service until they could no longer be used reliably and cost-efficiently, then be decommissioned—reducing the transport capacity of the HST system and forcing passengers to shift to other trains or other modes, or even to cancel their journeys.

Shift assumptions are based on traffic models produced by the Business Development unit of Voyages SNCF. These models are used to generate traffic and revenue forecasts for infrastructure projects (new lines, new stations) and service changes.

- The models use a statistical base year that incorporates all actual market data. For rail, the data covers actual availability, tickets sold, connections and fares paid. For other modes, we use data from collecting bodies on use, fares and offers.
- The models allow us to estimate the modal shift to road, induction, air, coach and car-sharing.
- A distribution model estimates the allocation of rail traffic to different rail carriers.
- All of these models are sensitive to overall economic variables and service levels for each mode (frequencies, journey times, fares, feeder/onward travel times, etc.).

<sup>3</sup> Source: CGDD, Long-term transport demand projections, 2016.

<sup>4</sup> IEA, Energy Technology Perspectives 2016.

<sup>5</sup> An ad hoc consistency study was made to estimate changes in the air emissions factor. The values obtained are extremely close to those of the IEA's 4DS scenario, thus validating the relevance of adopting this scenario.



Our simulation is based on statistics for 2019.

It assesses the overall change in rail traffic resulting from a significant reduction in HST (INOUI+OUIGO) frequencies ("no project" scenario), for the 500 station-to-station Origin-to-Destination (OD) journeys that account for over 95% of Voyages SNCF's business in France. Alternate modes competing with HST are unchanged. To account for this, the modal share of air travel has been increased to that observed on HST routes with no high-speed service over the last twenty years.

### **3.3.2.3.2. Modal shift assumptions**

We have assumed that passenger-kilometres would shift away from HST as follows:

- 19% to conventional trains (17% to TER, 1.5% to Intercités)
- 53% to cars
- 22% to air
- 6% to coaches

### **3.3.2.3.3. Distance equivalence according to mode used**

The shift of traffic from rail to other transport modes in the baseline scenario must also be adjusted for the difference in distance from one mode to another. For example, there are 572 km between Paris and Toulouse as the crow flies (from Paris-Orly to Toulouse-Blagnac airport), 678 km by road (city centre to city centre), and 794 km by rail (station to station via Bordeaux).

This means a conversion coefficient must be applied to passenger-kilometres when traffic volumes shift from rail to other modes. The figures below are national averages weighted by traffic:

- HST => road: 0.869;
- HST => air: 0.754;
- HST => other trains: 1.

### **3.3.2.3.4. Emissions from competing modes during the use phase**

Emissions from competing transport modes show emissions from all of the competing modes based on the percentage of train passenger-kilometres allocated to them as shown above (section 3.3.2.3.2.).

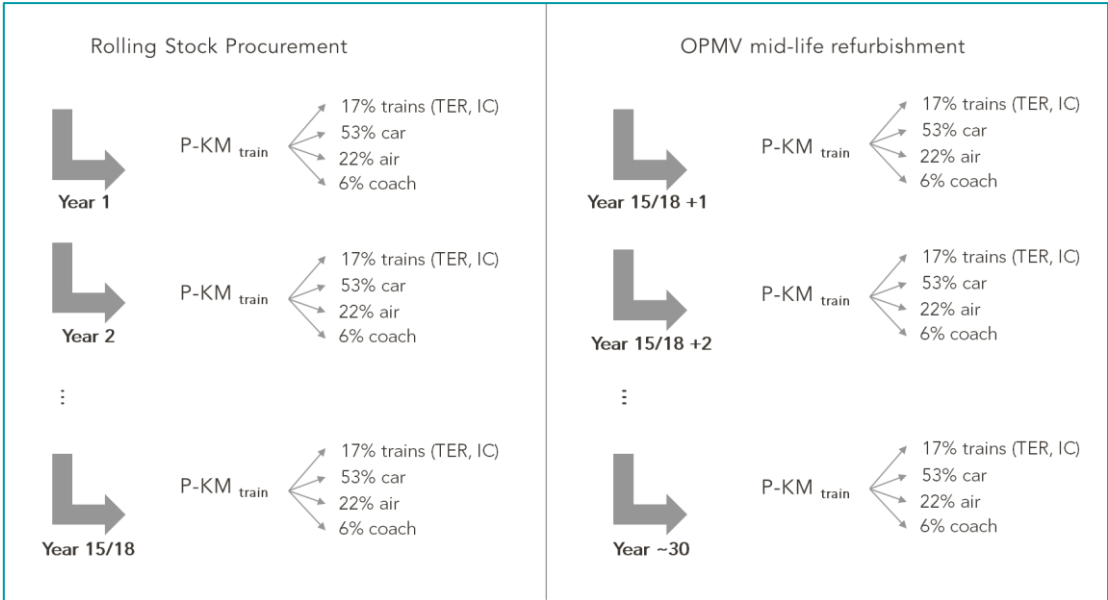
For each competing mode, and for each year, emissions generated are calculated as the product of the parameters noted above: **[mode pkm] x [mode equivalent distance coefficient] x [mode emission factor]**.

SNCF conducts this analysis for all competing transport modes and the full life of the rail project.

To determine the emissions avoided in the use phase by rail projects financed by SNCF green

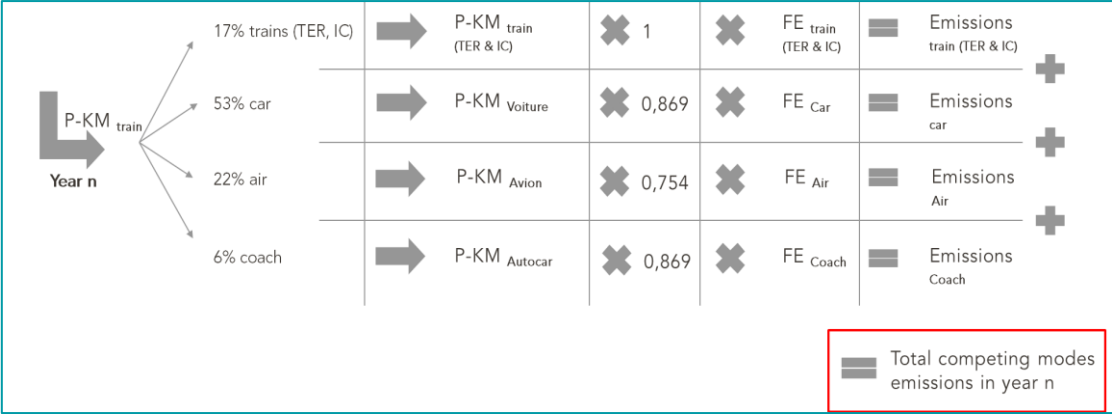
bonds, we compare the emissions from competing modes in the baseline (“no project”) scenario with the emissions generated by the project.

Allocation of train passenger-kilometres to competing modes



Source: SNCF

Calculation of emissions from competing modes in the use phase in year n



Source: SNCF

### 3.3.3. Differential analysis during the use phase

#### 3.3.3.1. Allocation rules to avoid double counting

In cases where we make multiple investments on the same route, our allocation rules keep avoided emissions from being counted twice by taking into account the relevant asset's fair contribution to delivering service as well as the investor's fair contribution to funding.

To accurately calculate an investment's carbon impact, all avoided emissions attributable to rail transport must be allocated among all assets that contribute to the service, in proportion to the investment required for each.

To date, SNCF Group's green bond methodology has assigned 20% of avoided emissions to investments in rolling stock, based on a breakdown of relevant CapEX. The remaining 80% is attributed to infrastructure.

#### 3.3.3.2. Net avoided emissions in the use phase

Pending an impact study of actual project parameters, we have simulated the indicative impacts of TCO<sub>2e</sub> avoided per million euros invested in procurement/refurbishment projects for SNCF's high-speed fleet.

We use the following parameters for new acquisitions:

- purchase price of €30m per unit;
- procurement-to-OPMV life of 15 or 18 years, depending on the model.

We use the following parameters for refurbishment (OPMV) projects:

- purchase price of €15m per unit;
- OPMV-to-decommissioning life of 16 years for all models and 12 years for OUIGO trains.

We allow for an impact of between 700-1,400 TCO<sub>2e</sub> avoided per million euros invested in procurement projects, and between 1,700-3,700 TCO<sub>2e</sub> avoided per million euros invested in OPMV projects.

Impact of projects financed by green bonds

Model	Type per capacity	Capacity	Pro. impact	OPMV impact
TGV A	TGV A	459	931	1 746
Rdom	TGV R DOM & POS	361	732	1 373
POS				
Rtri	TGV R TRI & PLT	353	716	1 342
PLT				
Duplex	DUPLEX RNAI - RDUPLEX - DASYE - EURODUPLEX	509	1 175	2 203
R-duplex				
Néoduplex				
Dasye				
3UFC	3UFC - DUPLEX RENOV	556	1 284	2 407
Duplex-Renov				
TGV M	TGV M en format INOUI	600	1 398	2 622
OUIGO	OUIGO	634	-	3 723

Source: SNCF





### **3.4. RESULTS FOR CARBON IMPACT**

Each project's full carbon impact includes the use and design phases for our rolling stock.

This part of our methodology will be updated as soon as SNCF's work on grey carbon emission factors is finalized.







