CARBON IMPACT OF RAIL INFRASTRUCTURE INVESTMENTS

METHODOLOGY APPLIED TO THE GREEN BONDS PROGRAMME OF SNCF RÉSEAU

September 2017

carbone 4

SNCF RÉSEAU

SUMMARY

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SUMMARY

LIST OF ACRONYMS

ADEME	French environment and energy management agency.
AOT	Passengers Transport Authority.
IEA	International Energy Agency.
BPL	"Brittany – Pays de la Loire"HSL.
CCR	Centralised Network Control System.
CGDD	French General Commission on Sustainable Development.
CNM	"Nîmes Montpellier" bypass.
EE 2	"Est Européenne" HSL, phase 2.
EF	Emissions Factor.
GHG	Greenhouse Gas Emissions.
GOPEQ	Equivalent Planned Large Operation.
IdF	"Île-de-France".
IFTE	Electrified Fixed Traction Infrastructure (EFTI).
LGV	High-Speed Line.
RS	Rolling Stock.
ES	Engineered Structure.
EW	Earthworks.
OA/OT	Bridges & Tunnels.
RER	Regional Express Network.
SEA	"Sud Europe Atlantique" HSL.
SLO	Freely Organised (Bus) Services.
SNBC	National Low-Carbon Strategy.
TAGV	High-speed trains and equivalent.
TER	Regional Trains.
TGV	High-Speed Train.
UIC	International Union HST of Railways.

REFERENCES CITED IN THIS DOCUMENT

GHG Protocol – *Methodology for carbon accounting*, 2017

ADEME – *Base Carbone*, 2017

AIE – *Energy Technology Perspectives 2017*

CGDD – *Long-term transport demand forecasts)*, 2016

INSEE – *Projections de la population à horizon 2030*

RTE – *Bilan prévisionnel de l'équilibre offre-demande d'électricité en France*, 2014

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01

INTRODUCTION

1.1. CONTEXT

A Green Bonds Programme involves the issuance of bonds by a company, international organisation or local government on the financial markets to finance a project or activity having an environmental benefit. Since rail transport is one of the most environmentally friendly forms of transport, it falls within the category of activities that are eligible for this type of bond.

On 27 October 2016, SNCF Réseau issued its first Green Bond for the most part to finance the sustainable modernisation of its network. SNCF Réseau thereby became the first railway infrastructure operator in the world and the first transport company in Europe to set-up a Green Bonds Programme. The company plans to adopt this as a long-term strategy through the issuance of one Green Bond each year.

This methodology guide now supplements the section of the 2016 report on the SNCF Réseau Green Bonds section, which can be found on the SNCF Réseau website. Further information on the company and the programme can also be found there.

1.1.1. PROJECTS FINANCED BY GREEN BONDS

Collected funds are allocated to projects deemed eligible falling under three categories:

- **Investment in maintenance, modernisation and energy efficiency of the rail network.** This mainly concerns renewal of track, plants providing power to trains and signalling systems, and electrification of the line, etc.

- **Investment in the building of new lines.** This generally concerns high speed lines, allowing for marked improvement in the mobility of individuals and goods on the routes concerned, for example the Eastern Europe HSL, the Southern Europe Atlantic HSL, the Brittany - Pays de la Loire HSL, and the Nîmes and Montpellier Bypass Route.

To highlight the positive consequences of such investment, and in the interests of clarity for investors and civil society, SNCF Réseau wishes to quantify the impact of projects funded by Green Bonds in terms of cutting greenhouse gas emissions.

• **Other Investments** in the fight against climate change, protection of biodiversity and natural resources, by refurbishing the existing network.

The eligibility criteria set down by SNCF Réseau concern renewal projects on the main lines of its network, namely:
– high speed lines, which were brought into service in 1981;
– standard lines grouped 1 to 4 using the UIC classification.
In total there are around 15,000 km of totally electrified lines, out of a total of 30,000 km of lines on the national rail network.

THE UIC CLASSIFICATION

The International Union of Railways (UIC) established a railway line classification method based on traffic levels and also based on the traffic loads supported by the infrastructure and the type of traffic. UIC group 1 is for lines with very heavy traffic and conversely UIC 9 is for lines with very little traffic.

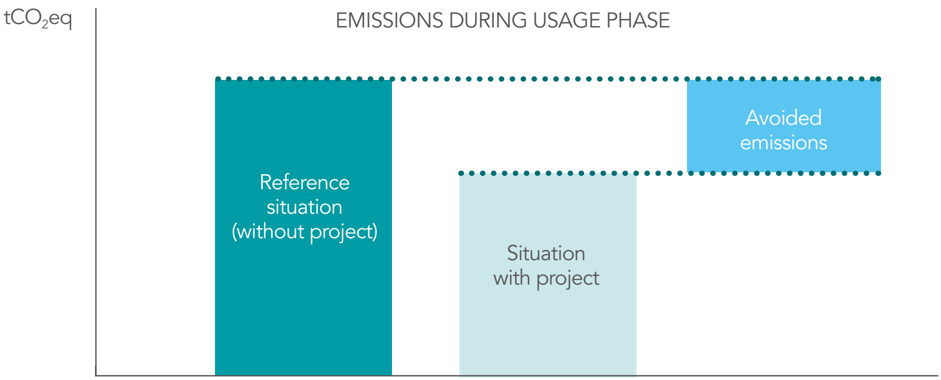
The main French railway lines come under UIC groups 1 to 4. Major lines with less traffic (e.g. Paris – Caen, Poitiers – La Rochelle and Toulouse – Bayonne) fall under UIC groups 5 and 6. The low traffic lines in groups UIC7 to 9 are generally regional lines.

1.1.2. ESTIMATING THE CARBON IMPACT OF PROJECTS FINANCED BY GREEN BONDS

For all transport infrastructure projects, a distinction should be drawn between a project's "carbon footprint" and its "carbon impact".
In this document, the carbon impact of a rail project and the comparison of emissions during the usage stage with a baseline (without the project). An infrastructure project's carbon footprint is composed of the direct and indirect GHG used in its creation (consumption of site machinery, etc.), and particularly including upstream emissions (manufacture of materials used, etc.).

This conception of a carbon footprint is therefore a "site-based" one, and fails to include emissions from usage, which are covered in the analysis of avoided emissions.
Usage of any infrastructure project also generates GHG emissions, through the operation of trains. Executing such a project would improve rail competition with competing modes of transport – for which GHG per unit transported are higher than the train – and therefore reduce transport system emissions.
A comparison of these generated usage emissions with a reference scenario (without the project) is specified below for "avoided emissions".

EXAMPLE CALCULATION OF AVOIDED EMISSIONS DURING THE USAGE PHASE



Accordingly, GHG emissions generated by the infrastructure project will ultimately avoid emissions during the subsequent use phase: comparing these two overall factors provides us with a carbon impact evaluation for the project under study.

Site's carbon footprint
– avoided emissions during use
= carbon impact

Therefore although emissions generated by execution of a project are lower than those avoided during the use phase the project studies may be considered as contributing to the fight against climate change. Since this is the case for the vast majority of SNCF Réseau projects, their financing through Green Bonds adds value to rail over more GHG emitting modes of transport.

SNCF Réseau designed a calculation method to quantify the carbon footprint and impact of projects financed using Green Bonds:
– renewal and modernisation of railway infrastructure;
– construction of new lines.

SNCF Réseau highlights that most of assumptions required in the present methodology are related to the French context. This applies specifically to emission factors of transport modes and electricity production, to the geographic structure of the territory, to competition intensity between transport modes and to the exceptionally high volume of traffic performed by high speel rail in France. Implementing this methodology to other rail networks needs to adapt its assumptions to the related context, with a likely significant impact on the final result.

1.2. DOCUMENT GOALS AND CONTENT

1.2.1. DOCUMENT GOALS

SNCF Réseau is the first railway infrastructure manager operator in the world and the first transport company in Europe to issue Green Bonds. The innovative nature of the approach has led to the development of a totally new methodology for the computation of the carbon footprint and impact applied to financed investments, which was until now applied as standard in the transport infrastructure management sector. SNCF Réseau is seeking through this document to publicly disseminate the calculation methodology used for its past and future Green Bonds. Its publication also reflects the SNCF Réseau – and more broadly the SNCF Group – to demonstrate transparency on the traceability of funding for investors. Once present in the public domain and translated into English, it will also serve as a methodology base for network managers wishing to thoroughly publish the carbon impact of their Green Bonds.

1.2.2. DOCUMENT CONTENTS

SNCF Réseau chose to provide two types of information in this document:

– **The methodological context within which SNCF Réseau wishes to conduct these evaluations:** this is composed of methodological principles that SNCF Réseau complied with to estimate the carbon footprint and impact of Green Bonds exclusively allocated to railway infrastructure.

– **The choices made by SNCF Réseau to carry out these analyses for the first time,** within the context of its Green Bonds issued on 27 October 2016: the approaches taken for this first year are set out explicitly and the concrete application of the previously mentioned principles, taking into account the unprecedented nature of the approach and the limited time available.

SNCF Réseau pursues a long-term, continuous improvement approach to evaluation of the carbon footprint and impact of investments financed by its Green Bonds. In future reports, the main methodological principles set out in this document will remain constant, and there will potentially be some changes to improve the quality of the evaluation.

1.3. SNCF RÉSEAU

Within the SNCF Group, which is one of the world's foremost mobility and logistics providers, SNCF Réseau develops, modernises and sells access to the French rail network. It is staffed by 54,000 employees who safeguard the safety and performance of its 30,000 km of lines, 2,700 of which is high-speed lines (HSL). SNCF Réseau makes the maintenance and modernisation of the infrastructure its absolute priority. Over €5bn have been invested annually and over 1,600 works have been executed for daily trains running on the standard network.
SNCF Réseau commissioned Carbone 4 to assist in the drafting of a methodological guide for calculating the carbon impact of a range of renovation projects on the existing network and projects for new lines, financed by Green Bonds.

This methodology forms part of the overall methodology for the Green Bonds 2016, available in a dedicated report.

1.4. GREEN BONDS 2016 ALLOCATION

Here is the emissions allocation of the SNCF Réseau 1.875% November 2031 Bond Issue amounting to €900m (net amount of €885,330,000).

Note: throughout this document, the adding up (rounded) by the reader could lead to a slightly different result (+/-1 counting unit) from the totals specified since numbers are rounded to the nearest whole number. The totals set out here will prevail.

GREEN BONDS 2016 ALLOCATION

INVESTMENTS IN €m	PERIMETER GREEN BONDS		ALLOCATION GREEN BONDS 2016	
	AS OF 31 DEC. 2016	SPLIT	ALLOCATION	SPLIT
Maintenance & upgrade	**1,303**	**88%**	**710**	**80%**
Track, ballast and sleepers…	889	68%	484	
Switches	195	15%	106	
Signalling's system renewal	183	14%	100	
Catenary's system renewal	36	3%	20	
New lines and line extensions	**175**	**12%**	**175**	**20%**
LGV EE phase 2	14	8%	14	
SEA	73	42%	73	
BPL	53	30%	53	
CNM	36	20%	36	
Other projects	**0**	**0 %**	**0**	
Total	**1,479**		**885**	

1.5. CARBONE 4

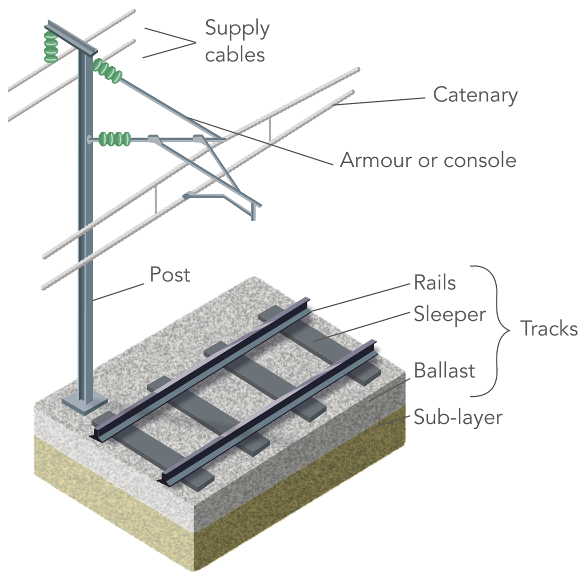
Carbone 4 is an independent, dedicated and specialist low carbon consulting firm for low-carbon strategies and adaptation to climate change. Its name refers to the goal set by France to cut its GHS emissions "fourfold" by 2050 compared with 1990 levels.

Since its creation in 2007, Carbone 4 has helped public and private sector actors in the construction of new climate change resilient economic models. From diagnosis to the elaboration of a strategy compatible with the Paris Agreement's goal of 2°C, Carbone 4 develops operating tools tailored to the specific requirements of its customers and their field of activity. The consultancy's expertise, built up over the execution of 800 assignments, extends to a number of sectors, with particular focus on mobility, energy, finance and construction.

02
EVALUATION OF THE CARBON IMPACT OF INFRASTRUCTURE RENEWAL PROJECTS

2.1. FOREWORD

2.1.1. PRESENTATION OF THE KEY COMPONENTS OF RAILWAY INFRASTRUCTURE



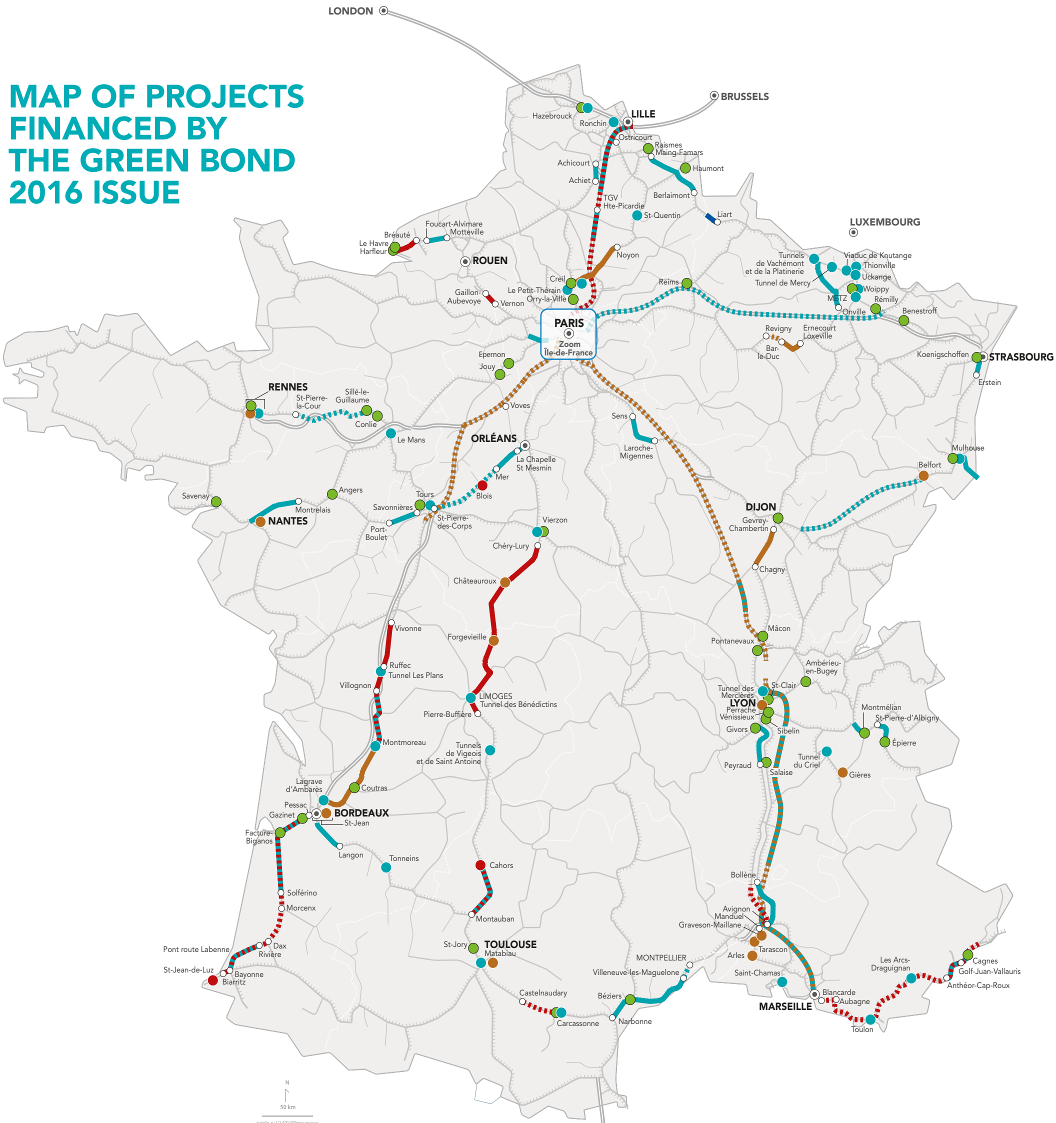
Four key components make up a railway infrastructure:

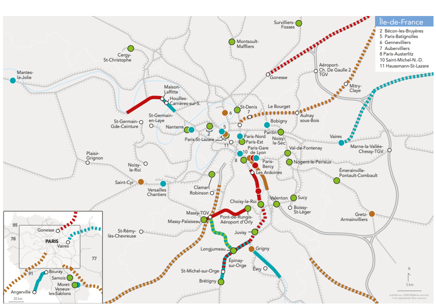
– track, principally made up of two lines of rails, sleepers and ballasts to allow trains to run;
– Electrified Fixed Traction Infrastructure (EFTI), supplying electrical power to trains;
– engineered structures (bridges, tunnels, etc.) and earthworks, enabling the track to overcome natural and artificial obstacles;
– signalling, to control traffic flow[1] (including the Centralised Network Control System).

The lifespan of this equipment varies according to their characteristics and usage. It must be regularly maintained and renewed at the end of its life to maintain performance of the infrastructure, which requires between 2 and €3bn per year for the French network.
The following map page shows the geographical breakdown for works carried out in 2016. This document concerns renewal of this equipment in particular.

1. Rail signalling is a way of providing instructions to the train driver to prevent risks inherent to rail traffic: derailing (limiting speed on bends, areas around switches and works), rear-end collisions, collisions at level crossings, etc. Signalling is composed of various type of signal: light signals, mechanical signals, hand-held/mobile signals (lamps, flags), acoustic signals (bangers, horn blasts). Renewal of signalling makes rail traffic run more smoothly.

MAP OF PROJECTS FINANCED BY THE GREEN BOND 2016 ISSUE





LEGEND

LGV (HIGH-SPEED LINES) UNDER CONSTRUCTION WITH CONNECTIONS TO THE CONVENTIONAL NETWORK.

TRACK WORK, INCLUDING "SUITE RAPIDE" OPERATIONS.

SIGNALLING INSTALLATIONS/CCR.

SWITCH.

CATENARY WIRES.

Most projects listed in the map below represent an individual amount of €1m or more.

2.1.2. BREAKDOWN OF FINANCING OF INFRASTRUCTURE RENEWAL PROJECTS FOR 2016

In 2016, renewal projects amounted to €1,304m of investment for SNCF Réseau, or 88% of expenses falling within the scope of Green Bonds. These expenses may be broken down as follows:

BREAKDOWN OF RENEWAL EXPENDITURE IN 2016 WITHIN THE SCOPE OF GREEN BONDS

INVESTMENTS IN €m	PERIMETER GREEN BONDS	
	AS OF 31 DEC. 2016	SPLIT
Maintenance & upgrade	**1,303**	**88%**
Track, ballast and sleepers…	889	68%
Switches	195	15%
Signalling's system renewal	183	14%
Catenary's system renewal	36	3%

These amounts represent the financing of hundreds of works projects carried out in 2016 across the whole French rail network, chief among which are those included in the previous map.

Green Bonds issued in 2016 partially financed these projects[2]. Out of the €885m collected, €710m was allocated to renewal projects (80% of the total), and the breakdown was as follows:

PARTIAL ALLOCATION OF FINANCING OF RENEWAL EXPENDITURE TO GREEN BONDS

INVESTMENTS IN €m	ALLOCATION GREEN BONDS	
	AS OF 31 DEC. 2016	SPLIT
Maintenance & upgrade	**710**	**80%**
Track, ballast and sleepers…	484	
Switches	106	
Signalling's system renewal	100	
Catenary's system renewal	20	

2. For the 2016 operation, SNCF Réseau chose not to finance the renewal of engineering structures. It is quite probable that part of the financing bought in by future Green Bonds will be allocated to this type of project.

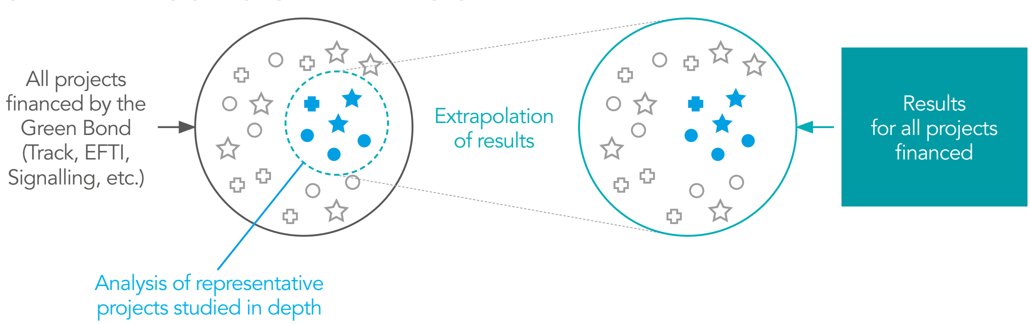
2.2. METHODOLOGICAL PRINCIPLES

Green Bond issuance finances several hundred renewal projects annually. Evaluating the carbon impact of each project calls for very cumbersome reporting and resource mobilisation. Furthermore, the majority of the investment concerns a limited number of projects and the majority of projects only represent a small proportion of the total amount invested. Any thorough examination of all projects, therefore, would provide only a marginal improvement on the end result.

The considerable number of renewal projects financed therefore requires the use of some essential methodologies:
– For certain parameters, **preference is given to the use of average values,** rather than the use of data specific to each project. For example, passenger numbers on each train on each section of the line is not known by SNCF Réseau. For now therefore recourse is made to national averages for passenger numbers per type of train. The bias introduced by this type of hypothesis is lower as the number of projects is higher and spread out across the network, which may be verified for a group of work projects overall for a given year.
– **An extrapolation method is used.** The footprint and impact of every project financed by Green Bonds are therefore calculated using certain projects that are representative of the basket of projects offered and then extrapolated out to the whole project basket. The bias introduced by this type of hypothesis is also low since projects examined individually are chosen based on how representative they are of the projects financed by Green Bonds.

Finally, as previously mentioned, the application by SNCF Réseau of the methodological principles set out in this document is part of a desire for continuous improvement. Indeed, SNCF Réseau implements a "carbon approach", the goal of which is to progressively fine-tune knowledge of GHG emissions from its works and thereby support its analyses for future Green Bonds carbon evaluations.

ILLUSTRATION OF AN EXTRAPOLATION OF THE RESULTS OF ANALYSIS



2.3. CARBON FOOTPRINT OF INFRASTRUCTURE RENEWAL PROJECTS

2.3.1. GENERAL PRINCIPLES

Evaluation of the carbon footprint of a renewal project involves the application of existing carbon analysis methods that are already widespread, for example the Bilan Carbone® (Carbon Balance Sheet) and the GHG Protocol.

As previously explained it is not possible at this stage to measure an exact carbon footprint for each type of renewal project. An extrapolation approach is therefore applied to all projects, using the carbon footprints of representative projects that were estimated for 2016.

Since the projects covered by SNCF Réseau Green Bonds have very varied characteristics (materials, lifetime, etc.), they needed to be grouped into coherent wholes, within which projects have the same "carbon profile". Indeed, two similar renewal projects (in terms of renewal techniques, the materials renewed or the material used, etc.) can have very similar levels of carbon intensity[3].

To accurately evaluate the overall carbon footprint for projects eligible for Green Bonds 2016, carbon profiles for the various different types of infrastructure renewal are therefore needed.

2.3.2. CARBON PROFILES FOR INFRASTRUCTURE EQUIPMENT

For SNCF Réseau, each infrastructure renewal project can be likened to one of the following carbon profiles:

- **Track renewal:** Approximately half of this is high-output (see detail on next page), and the rest is non-high-output, track devices (switches);
- **Renewal of fixed installations for electric traction** (EFTI): 1,500 or 25,000 V systems (catenaries, supports, sub-stations, etc.);
- **Renewal of signalling:** centralised network control system (CCR), and non-CCR signalling systems;
- **Renewal of engineering works and earthworks** (N.B : not financed by Green Bonds 2016): railway bridges, tunnels, cut and fill.

For renewal works for SNCF Réseau, a carbon footprint needs to be established to use as a reference for extrapolation for each of the profiles identified above as part of this first Green Bonds evaluation exercise. This categorisation could be fine-tuned by SNCF Réseau in subsequent evaluations and when supplementing carbon analysis for its activities.

3. The concept of carbon intensity consists in a footprint that is reflected as a unit of work such as the length renewed or the amount invested. Therefore, where two projects theoretically have a similar carbon intensity the carbon footprint of the first project may be extrapolated to the second using work units common to both projects.

TRACK RENEWAL

Track renewal works entails replacement of all or part of its constituent parts: ballast, sleepers, rails and rail fixing systems. Track may be renewed because it worns or to ensure comfort, performance and productivity. In fact, after a certain age, the track's condition no longer guarantees, with standard maintenance methods, the resistance of structural elements and suitable performance. Renewal involves major, costly works to replace the components having a lifespan between 20 and 50 years. Work is carried out by means of two procedures:
- For the largest operations: by a "Hight Intensity Track Renewal Unit" (see below);
- For other operations: using the standard method with many construction machines (this process is termed "non-high-output track renewal").

HIGHT INTENSITY TRACK RENEWAL UNIT
This is like a factory on wheels and can restore all track components to pristine condition in a very short period of time since the main priority is to cause the least possible disruption to commercial trafic .
There are 4 track renewal trains in France, one of which is allocated solely to areas with dense track coverage such as the "Ile-de-France region".
The track renewal train is several hundred meters long and is composed of many machines placed in sequence. It is capable of renewing up to 1,000 metres of track in one night whilst allowing commercial traffic to pass between works. This industrial plant needs 400 workers, technicians and engineers to work on it at the same tisme.

2.3.3. SCOPE OF CARBON FOOTPRINT OF A REPRESENTATIVE PROJECT

Carbon accounting rules break down an entity's emissions (project, authority, local government, etc.) into three areas, or scopes:
Scope 1 groups together all of the entity's direct emissions. These can be emitted from the burning of fossil fuels, through the direct release of GHG into the atmosphere, or where there is a change of soil usage (deforestation, man-made changes to natural shorelines, etc.).
Scope 2 groups together the indirect emissions of an entity associated with energy consumption. Accordingly, this category is composed of emissions associated with electricity consumption (not directly emitted by the entity but by the electricity generation company) and consumption of heat, cold and steam.
Scope 3 groups together all other indirect emissions contained in the entities value chain. Upstream, this means emissions from freight, the manufacture of goods and services purchased and capitalised or professional trips and employee commuter journeys.
Downstream, scope 3 groups together emissions associated with upstream freight, treatment of generated waste or the use of sold products.

Regulations currently in effect (both in France and internationally) concerning the carrying out of carbon assessments of projects only relate to the limits of scopes 1 and 2.

In calculating the carbon footprint of its Green Bonds, SNCF Réseau goes a step further, setting a boundary for evaluating the carbon footprint of a project covering all direct and indirect emissions (scopes 1, 2 and 3) within the value chain of the works carried out:

– Escape of coolant fluids from works machines and swap bodies (scope 1);
– Energy consumed at the works site (scopes 1 and 2);
– Manufacture of inputs: construction products and equipment (scope 3);
– Upstream and internal freight (scope 3);
– Construction of swap bodies, works machines and materials (scope 3);
– Professional work site visits (scope 3);
– Site commuting for employees (scope 3);
– Transportation and handling of direct waste (scope 3).

This area does not cover upstream GHG emissions due to the operation and maintenance of the infrastructure concerned, or to future train traffic using it. Application of the carbon footprint calculation method is in line with the methodological principles of the GHG Protocol, to ensure its consistency and transparency at the international level.

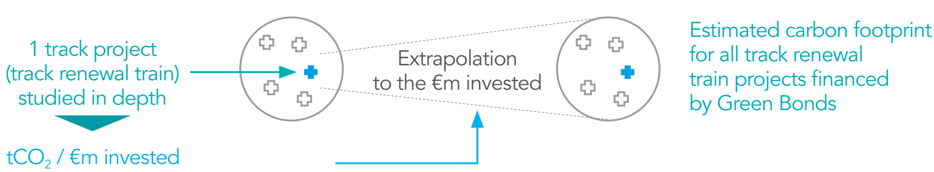
2.3.4. ALLOCATION OF PART OF THE FOOTPRINT TO FINANCING FROM GREEN BONDS

Green Bonds are not directly allocated to the full financing of renewal projects but play a role in financing an overall annual projects programme. It is therefore necessary to correlate the carbon footprint allocated to Green Bonds with its share in the financing of the whole to prevent double accountings for the carbon footprint and to convert the actual contribution from Green Bonds 2016 to the renewal of the equipment in question.

2.3.5. EXTRAPOLATION TO ALL PROJECTS FINANCED BY GREEN BONDS

Once all of the projects have been broken down into categories according to their carbon profile, the carbon footprint of representative projects within each of these categories is uniformly applied using the relevant working units (line length, weight of stock, amounts, etc.). Within a given category the work unit chosen will depend on the data available for related projects.

EXAMPLE OF EXTRAPOLATION TO TRACK RENEWAL USING A HIGH-OUTPUT TRACK RENEWAL TRAIN FROM THE AMOUNTS INVESTED



Application to the SNCF Réseau Green Bond 2016

Stage 1 - Selection of carbon profiles studied

For 2016, three carbon profiles were studied, reflecting the three major plant categories within the infrastructure: Track, EFTI and Signalling.
The analysis of Green Bonds 2016 is based solely on these three categories, due to the lack of available data for sub-categories of material, as was proposed in the end in 2.1.1. Operations pertaining to track devices are provisionally treated as track, due to the relative similarity of the components (steel rails, sleepers).

Stage 2 - Carbon footprints for representative projects of the standard profiles chosen

A carbon footprint was determined for the renewal of the following equipment categories:

• **Track:** the Bilan Carbone® (Carbon Balance Sheet) of a renewal works site of 90 km of track using a track renewal train was calculated during renewal of one of the two tracks on the Montpellier – Narbonne line in 2015. By analysing this project it was possible to define an average emissions ratio of 533 tCO_2eq/km of renewed track. At a cost of €132.4m (i.e. €1.47m per km, which is close to the average cost of operations for a track renewal train on a standard line UIC 1-4), giving a ratio of 361 tCO_2eq/€m invested. Firstly, 90% of GHG from high-output renewal are due to the consumption of materials and secondly the materials used are the same both for high-output track renewal trains and for the non-high-output process, it may be presumed that the carbon footprint of a non-high-output renewal works project is similar to that of a high output works project.

• **EFTI:** carbon footprint of an average catenaries renewal was estimated based on analyses of the life cycle for 1500 V and 25 kV catenaries. This analysis led to the average emissions ratio of 73 tCO_2eq/km of renewed EFTI, i.e. taking into account average costs for this type of operation – a ratio of 86 tCO_2eq/€m invested.

• **Signalling:** due to a lack of relevant data to estimate the carbon footprint of signalling renewal works, a ratio was used of 380 tCO_2eq/€m invested, which was derived from the average of the following monetary units set down by ADEME[4]:
– IT, electronic and optical products (400 tCO_2eq/€m), since signalling installations are essentially
made up of these types of materials;
– Construction (360 tCO_2eq/€m), investment in signalling by SNCF Réseau is in large part composed of the construction of buildings for hosting CCR.

In the interests of continuous improvement, SNCF Réseau will consolidate the carbon footprint of its infrastructure equipment renewal projects with the preparation of new carbon balance sheets.
Three carbon balance sheets are planned for renewal works, two of which concern high-output track, the first being in 2017, the second in 2018 and a third one concerning a Centralised Network Command System, will be prepared in 2018.

4. Monetary emission factors for products and services a http://www.bilans-ges.ademe.fr/documentation/UPLOAD_DOC_FR/index.htm?ratio-monetaires.htm.

Stage 3 - Extrapolation
The carbon footprint for these projects is then correlated with the amount invested, which is the only working unit common to the various types of installation (signalling investments cannot all be related to km of line). The result is a reference value applicable to other projects within the same category.

EXTRAPOLATION VALUES OBTAINED FOR 2016 (IN TCO_2EQ/€m INVESTED)	
Renewal of track and track devices	361
Renewal of EFTI	86
Renewal of signalling	380

2.4. AVOIDED EMISSIONS FROM INFRASTRUCTURE RENEWAL PROJECTS

2.4.1. GENERAL PRINCIPLES

2.4.1.1. Baseline and situation with renewal project

Renewals carried out on the rail network allow infrastructure to be kept in service at their rated performance level, thus securing the attractiveness of the rail network for users.
Without these renewals, the quality of railway infrastructure would deteriorate, bringing about a steady reduction in the speed of train traffic in order to maintain their safety. The slowing down of trains would add time to journeys in increasing proportions. Travellers and transporters would be increasingly inclined to give preference to other modes of transport which would in the meantime have become more efficient than rail.

Despite current stepped-up maintenance, the condition of infrastructure would become increasingly variable and its performance increasingly unpredictable. Slowdowns would continue driving customers to other forms of transport until trains were virtually empty. The drop in usage would cast doubt over service consistency and many trains would be taken out of service. The high cost of maintaining infrastructure for poor performances and marginal usage would lead to questioning of its maintenance. Finally, traffic would be suspended until the infrastructure was renewed.
This sequence of events has been seen all too many times on the secondary lines of the French rail network.
Regular renewal of equipment is definitely the way to prevent the main lines from going in this direction.

Within this context, avoided emissions calculation involves comparing the carbon footprint of passenger and freight transport in two illustrative cases:
– **Situation with equipment renewal:** the renewal operation allows for the level of service to be maintained on the section in question, guaranteeing maintained traffic.
– **Baseline (without renewal):** infrastructure is not renewed, it steadily deteriorates ultimately leading to its closure. Rail users change to other modes of transport.
The diversity of practices for maintaining a railway reveals **the possibility of an intermediate situation between renewal and common maintenance: stepped-up maintenance.** This involves replacing

infrastructure components one by one, with regular resources (human, material, capital), rather than on an industrial scale in project mode.
Firstly, the age of the underlying network in France is generally speaking too old to allow for stepped-up maintenance without a loss of performance. Renewal needs to be on an industrial scale.
Secondly, as far as GHG emissions are concerned, stepped-up maintenance would over time lead to a write-down of renewal works:
– the use of the same volume of materials the manufacture of which accounts for 80% of emissions for renewal works. Stepped-up maintenance certainly allows for greater selectivity in the replacement of constituent materials but does not allow for the re-use of such a large proportion of the materials (ballasts in particular);
– different organisation of work sites, which are certainly less cumbersome but more numerous and require more transport (unbundling of transportation of personnel and materials).
The main difference between stepped-up maintenance and renewal therefore concerns the scattering over time of the same volume of GHG emissions (largely all at the same time for renewal, and on a regular basis for stepped-up maintenance), which ultimately has little effect on the overall result.

Renewal is compared to the steady deterioration of infrastructure that is inherent when maintenance is not carried out. From the point of view of GHG emissions, stepped-up maintenance does not present itself as a different scenario to that of renewal.

2.4.1.2. Prevention of double accounting: setting in place of allocation rules

Financed projects are not for the renewal of all of the infrastructure on a given section: they generally only pertain to one type of equipment (track, signalling, EFTI, OA/OT, as was stated in the foreword on 2.1.1), on a limited section of line. Moreover, Green Bonds are liable to finance only part of the expenses that a project requires.

It therefore appears that all of the avoided emissions cannot simply be attributed to the element renewed and financed by Green Bonds, but only a fraction of avoided emissions correspond to the section of the infrastructure renewed. This principle prevents double counting of avoided emissions when both renewal projects (e.g.: renewal of track and then catenaries) are situated on the same section of line.

To guard against these double counts, an allocation of avoided emissions is necessary depending on which elements are to be renewed through Green Bond's financing. A renewal project can therefore allocate a share of the overall emissions that would be prevented if all of the section's infrastructure were renewed. This share is determined based on the type of equipment renewed and with regard to all the equipment required for operation of the rail service provided to end users.

This also reflects the individual contribution of a project to the maintenance of a rail service.

> Allocation rules must be framed in such a way as to prevent the double counting of avoided emissions for several operations relating to the same section of line, over the lifespan of the renewed equipment.

2.4.1.3. Estimation of emissions avoided by a renewal project

The calculation method for estimating emissions avoided by a renewal project is split into two stages:
– calculation of the emissions avoided by maintaining rail service throughout the entire section of the line;
– allocation of part of these emissions to the eligible financed project.

2.4.1.4. Extrapolation to all projects financed by Green Bonds

As was previously explained, within the context of SNCF Réseau, there is no scope for calculating the avoided emissions for the very high number of renewal projects. Extrapolation is therefore used to cover all projects based on the avoided emissions of representative projects.

2.4.2. METHOD FOR CALCULATING AVOIDED EMISSIONS BY MAINTAINING RAIL SERVICE ON A SECTION OF THE RENEWED LINE

The calculation of avoided emissions involves the use of several parameters. The principles used to determine these and their application for SNCF Réseau's Green Bond 2016 are set out below.

2.4.2.1. Types of trains travelling across the renewed section of the line

Different types of trains generally travel across a renewed section of a line.
On the French railway network, there are five different train categories:
– **high-speed trains and equivalent** (TGV, Eurostar, Thalys, etc.) that cover long distances mainly on high-speed lines and additionally on the standard network, with few stops and a high or very high speed;
– **standard long-distance trains** (mainly Intercités), covering relatively long distances on the standard network, with few stops and at a high speed;
– **Regional Express Trains** (TER), covering a very wide range of distances (generally within a single administrative region), with varying numbers of stops and at variable speeds depending on their classification (omnibus, express, etc.);
– **Transilien trains,** which are regional trains under the authority of the "*Syndicat des transports d'Île-de-France*", covering short distances at low speeds;
- **Freight trains,** owned by Fret SNCF or other transporters, covering all distances at very variable speeds.

Each type of train meets a certain mobility demand; their characteristics differ considerably. Therefore, it is vital to analyse them separately when estimating avoided emissions on a section of line.

Application to the SNCF Réseau Green Bond 2016

SNCF Réseau knows the number of trains that use the network annually, by type and by section of the line. However, calculating traffic on hundreds of renewed sections every year is too cumbersome a task. The decision was therefore taken to calculate avoided emissions from a panel of sections of line that is representative of the renewal programme for the year (cf. 2.4.4). Train numbers are given for the closest whole year to the execution of the works.

2.4.2.2. Trains Occupancy Rate

The rail transport emissions factor is generally referred to as GHG emissions per passenger-km or tonne-km, and not by train-km. It is therefore necessary to quantify the volume of passenger and freight traffic on the section of the line in question.

The traffic data available for SNCF Réseau is expressed as the number of trains travelling on each section of line, so occupancy hypotheses are used to determine the number of passengers and the number of tonnes transported and the associated passengers-km and tonnes-km.

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Train occupancy rate is determined using national averages observed on the rail network for 2016 for each type of train (see 2.4.2.1).

The following figures were observed in 2016.

AVERAGE OCCUPANCY OF TRAINS TRAVELLING IN 2016 ON THE FRENCH NATIONAL RAIL NETWORK

High-speed trains and equivalent	408 passengers per train
Other long distance trains	207 passengers per train
Regional Express Trains (excluding TER buses)	75 passengers per train
Transilien	238 passengers per train
Freight Trains	473 passengers per train

Source: SNCF Réseau calculations

2.4.2.3. General process to compute emissions avoided by renewal projects

The calculation method for emissions avoided by maintaining a line in service is formulated as follows:

For each type of train travelling across the section of line:

A. Calculation of emissions in the renewal project scenario

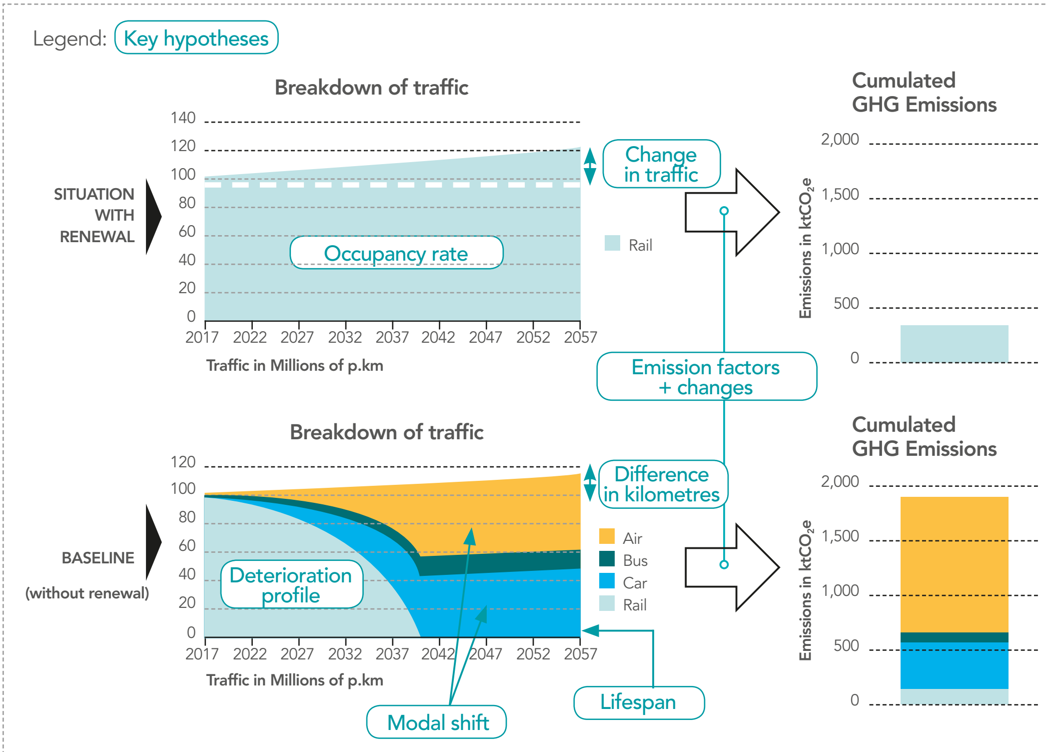
1. Estimation of the traffic circulating on the section of the line during the year prior to the renewal;
2. Application of a projected evolution of this traffic during the service life of the renewed equipment;
3. Application of rail transport emission factors, including hypotheses for changes over the lifetime of the equipment in question (including, for example, changes to the factor of emissions from the electricity used by trains).

B. Calculation of emissions in the reference scenario

1. Transfer of the results of points s1 and 2 given above;
2. Application of the hypotheses of a modal shift related to deterioration of the equipment on the non-renewed section of the line;
3. Application of emission factors for modes of transport benefiting from the modal shift, including hypotheses for change over the lifetime of the equipment in question (including for example changes in the emissions factor of private vehicle emissions).

Comparing emissions in both situations allows for an estimate for each train type of the level of avoided emissions through the renewal of the section of the line. Once this process has been completed for each train type, avoided emissions are added together to arrive at the total avoided emissions through the renewal of the section of line. The following illustration presents the calculation method for a given train category and highlights the key hypotheses for the method. These hypotheses are explained in more detail afterwards.

GENERAL PROCESS TO COMPUTE EMISSIONS AVOIDED BY TRAIN TYPE



2.4.2.4. Duration of the study

The period studied for the calculation of avoided emissions must take into account the impact of renewal on the lifespan of the equipment in question. This corresponds to the time interval between two renewals which vary depending on the equipment.

For example, track must be renewed more often than EFTI. Accordingly, the period taken into account when calculating avoided emissions attributed to track renewal is shorter than the one used in the case of renewal of EFTI.

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For track renewal, the study period used is 40 years which corresponds to the time interval observed between two complete renewals on lines UIC 1 to 4.

A longer lifespan of 43 years is used for EFTI, and 33 years for signalling installations (Source: SNCF Réseau).

2.4.2.5. Changes to traffic

Studying the emissions avoided by a renewal project spans several decades (see previous point). During this lengthy period, one must take into account demographic, economic, social and societal changes (among others). Therefore a hypothesis needs to be formulated for changes in rail traffic on the section of renewed line. This change in traffic is categorised as being *extrinsic*.

Apart from this extrinsic change in traffic, renewal can sometimes improve equipment compared with the previous situation. Its effects are considered using a hypothesis for *intrinsic* traffic change, i.e. this time directly linked to the renewal operation carried out. Renewal can indeed have considerable impacts on traffic, for example in following cases:

– a badly deteriorated line on which regular passengers have already opted for different modes of transport (exceptional case for a main line on the French network): renewal would make it possible to bring the rail mobility offer up to scratch, enabling those passengers who were lost to be retrieved;

– a renewal operation providing a major modernisation of the line, and therefore an improvement in its performance: the renewal could potentially attract new passengers.

Application to the SNCF Réseau Green Bond 2016

SNCF Réseau opted for a traffic change hypothesis in line with the population growth of continental mainland France (INSEE forecast) for the period studied (40 years), or +0,3% per annum. Accordingly, it is assumed that the distance travelled by train by each inhabitant and for each year will remain stable. The assumptions of this hypothesis draw upon the stability of the rail network observed since 2011, both in terms of passenger and freight traffic.

It should be noted that this is a prudent hypothesis compared with the forecasts of transport demand prepared by the civil service (French General Commission for Sustainable Development), which makes provision - for information – for the following changes:

Among the rail transport growth hypotheses selected by the State, the most prudent end up with traffic growth of 70% between 2012 and 2050. As a reminder, over an equivalent past period of 38 years (1974-2012), passenger rail traffic increased by 87% and freight fell by 56%. By opting for a traffic growth hypothesis that is equal to population growth (+0.3%/year), for this evaluation, the future volume of traffic under consideration is much lower which reduces estimates of the volume of avoided emissions for the lifespan of equipment.

A. RAILWAY TRAFFIC FORECASTS PREPARED BY GOVERNMENT DEPARTMENTS

TRAFFIC FORECASTS AND AVERAGE ANNUAL CHANGE		2012	2030	2050
Passenger rail transport for journeys over 100 km	Without car-sharing and FOS*	65.5Bn vkm	88.9Bn vkm (+1.7% per year)	125.8Bn vkm (+ 1.7% per year)
	With car-sharing and FOS*		78.0Bn vkm (+1.0% per year)	112.0Bn vkm (+ 1.8% per year)
Rail transport of goods	Trend-based	32.5Bn tkm	47.2Bn tkm (+2.1% per year)	70.5Bn tkm (+2.0% per year)
	SNBC guidelines*			54.6Bn tkm (+0.7% per year)

** FOS: freely organised services (long distance buses). SNBC: National Low-Carbon Strategy.*
Source: CGDD, Projections de la demande de transport sur le long terme (Long-term transport demand forecasts), 2016.

B. RAIL TRAFFIC FORECAST CHOSEN FOR CALCULATING AVOIDED EMISSIONS

TRAFFIC FORECASTS AND AVERAGE ANNUAL CHANGE	2012	2030	2050
Passenger Rail Transport	89.1Bn vkm	94.0Bn vkm (+0.3% per year)	99.8Bn vkm (+0.3% per year)
of which journeys over 100 km	65.5Bn vkm	69.1Bn vkm (+0.3% per year)	73.4Bn vkm (+0.3% per year)
Rail transport of goods	32.5Bn tkm	34.3Bn vkm (+0.3% per year)	36.5Bn vkm (+0.3% per year)

Also, SNCF Réseau chose to use a hypothesis with zero intrinsic traffic change for the period under study. This choice was informed by two arguments:
– SNCF Réseau generally carries out its renewal operations on the network before the effect of any deterioration in infrastructure have any effect on traffic. Renewal therefore allows for the level of service to be maintained and is not for bringing it back into compliance.
– Although it is true that certain renewal operations modernise the section in question, renewal is generally carried out whilst maintaining basic operations or without any significant impact on traffic. SNCF Réseau therefore decided not to take account of traffic that could be generated through mixed renewal and modernisation operations.

2.4.2.6. Traffic speed reduction trajectory and its impact on traffic

Should it not be renovated, the infrastructure is likely to deteriorate and therefore result in the steady reduction of speed. As a consequence, the more the speed is reduced, the more passengers (and transporters) are likely to favour other means of transport which might have meanwhile become more efficient.
This decline in traffic in favour of other modes of transport would not be immediate, rather it would be steady as infrastructure deteriorated and the resulting reductions in speed occurred as a consequence. A traffic speed reduction trajectory therefore needs to be established, along with that of the sensitivity of passengers and transporters.

Application to the SNCF Réseau Green Bond 2016

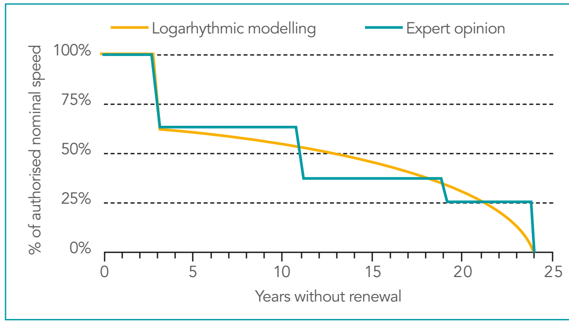
- **Traffic speed reduction trajectory**

A maximum authorised speed is set for each section of line in the network depending on infrastructure characteristics and sometimes the rolling stock.
When infrastructure components are not renewed, it ages and after a certain amount of time, it can no longer provide the rated service in total safety (risk of derailment in particular), even with increased maintenance. Safeguarding traffic safety then requires the maximum authorised speed to be reduced which is termed "slowing down".
Where maximum authorised speed reduction is concerned, there are two different types of line in the event of non-renewal of infrastructure: standard lines and high-speed lines (LGV).
Two speed reduction trajectories were therefore modelled.
In the following charts, year 0 is the year in which renewal should have occurred, which reflects an optimal time based on track quality, the cost of maintenance and its usage.
When there is no renewal, the hypothesis used was that the maximum authorised speed would be maintained for an average initial period of 3 years. Beyond this time, the track condition would require the authorised speed to be reduced – in the typical case of a standard line UIC 1-4 – from 160 to 100 km/h, which is a 63% reduction in rated speed.
The view was taken that the maximum speed would steadily decline over a twenty year period, after which traffic would need to be suspended.

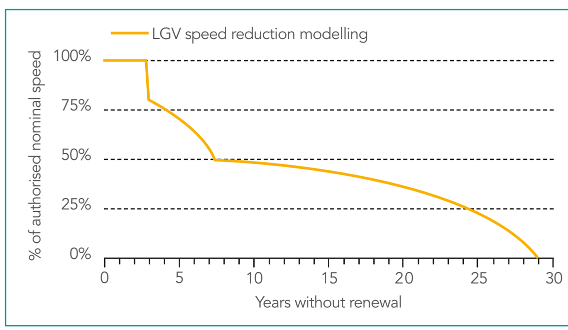
These models for after year 3 are based on the in-house expertise of SNCF Réseau, which has set an average speed reduction rate in successive stages depending on the age of the track. These stages were then smoothed to avoid any threshold effects and to take into account the fact that speed reductions are not automatically applied depending on the age of the track but rather based on its condition, which can vary significantly depending on the situation on the ground.

In the case of HSL, based on the in-house expertise of SNCF Réseau, the speed reduction in question is broken down into three phases:
– A first phase of three years, similar to that of standard lines, during which the authorised rated speed is maintained.
– A second phase of five years, which takes effect in year 3 through a typical reduction in speed from 320 to 250 km/h[5] (i.e. to 78% of its rated speed) and ends in year 8 at a speed of 160 km/h, i.e. 50% of its rated speed. The significant speed reduction during this phase is due in part to the fact that infrastructure on which high speeds are used deteriorates more quickly than standard infrastructure and furthermore to the fact that high-speed traffic is highly demanding in terms of track quality.
– A third phase of 20 years, which is similar to the trajectory of a standard line.

REDUCTION IN MAXIMUM AUTHORISED SPEED ON STANDARD LINE



REDUCTION IN MAXIMUM AUTHORISED SPEED ON HSL



5. High speed is defined within the EU by a maximum authorised speed of at least 250 km/h on dedicated track (EU Directive 96/48 EC, annex 1).

• Sensitivity of rail transport demand to a reduction in traffic speed

The reduction in traffic speed results in train journeys becoming longer, making the rail network offer less attractive for end customers than before. Depending on each individual's means, do these end customers choose to undertake the anticipated journeys and if so using which mode of transport? With a reduction in speed, demand for rail transportation would also logically decline.

SNCF Réseau calculated sensitivity trajectories for rail demand based on the following considerations:

– SNCF Réseau's reference value for socio-economic analysis provide figures for demand elasticity depending on how train journey times change. Because this reference value is always used for long distance rail transportation improvement projects, it takes the view that cutting the journey time by 10% increases demand by 9%. Inverse values are used to smooth the sensitivity curve.

– Competition between the rail and air, amply documented internally at SNCF réseau and in the public sphere, charts a trend in the market share of rail depending on journey time. The trend it reveals makes for greater elasticity.

– The various types of passenger train operate within very different markets. Taking a percentage-based approach to loss of traffic enables differences in volumes or distance covered to be provided for.

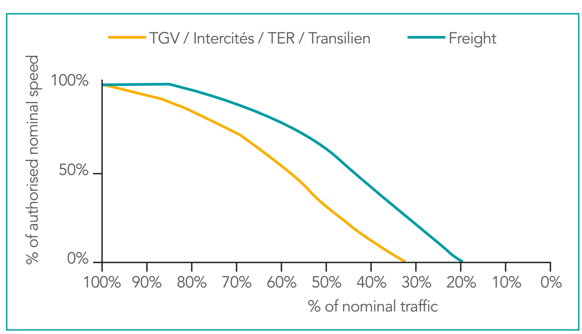
– All passenger trains faced constraints from the competition that should lead to a decrease in traffic that is more or less equivalent as their journey time increases (increasing a TGV or Transilien journey time by 20% results in a loss of passengers in the same amount).

– Goods are less sensitive to an increase in journey time, so their sensitivity curve does not fit the passenger curve trend.

– Rail demand should disappear when a journey time becomes three times longer than the current one (by five for freight trains). This level is determined by the current or potential offer of competitor modes of transport.

The following diagram presents the sensitivity curves selected.

SENSITIVITY OF TRAFFIC TO A REDUCTION IN TRAFFIC SPEED



6. *For example: Lebœuf, M. (2013).*
Grande vitesse ferroviaire*, Cherche midi, 853 p.*

• Decreased traffic in response to a reduction in speed

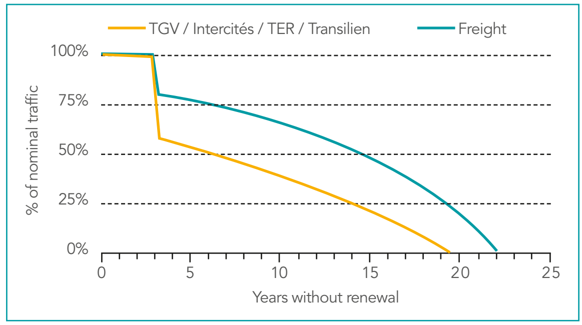
The combination of the trajectory of reduced speed with sensitivity of demand to this speed reduction allows for the following curves to be plotted, representing traffic trends (expressed in passengers-km or tonnes-km) following non-renewal of infrastructure.

It may be seen that traffic falls to zero before expiry of the residual lifespan in the case of non-renewal (24 years for a standard line and 29 for a HSL) due to the very long journey times that would result from low speed travel over long distances.

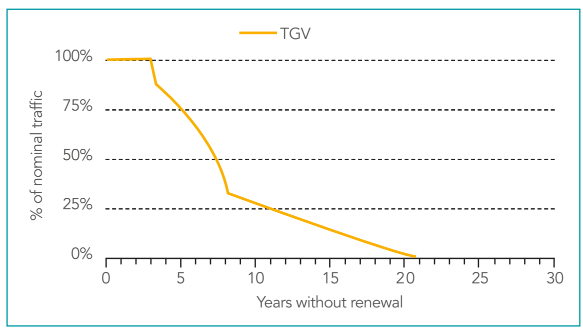
This appears to validate the consistency of the hypotheses set out previously.

Evaluating avoided emissions over the lifespan of a renewal project is therefore based on this two trajectories. In particular, year after year it includes this change in rail traffic with other parameters such as the emission factors of competing modes of transport (see 2.4.2.9).

TRAJECTORY FOR DECREASED TRAFFIC ON NON-RENEWED STANDARD LINE



TRAJECTORY FOR DECREASED TRAFFIC ON NON-RENEWED LGV



2.4.2.7. Change in demand after reduction of traffic speeds

In the case of a rail service whose journey time is lengthened due to non-renewal of infrastructure, passengers and transporters can make a number of choices (source: SNCF Réseau in-house expertise):
- make no change to their mode of transport or route and directly assume the longer train journey time;
- no longer make certain journeys, owing to a lack of a service that adequately meets their needs or restrictions (dissuading traffic);
- use another rail route;
- use another mode of transport (air, car, bus), for the same journey (modal shift).

• Dissuading traffic

When transport conditions between two points improve, traffic increases significantly. For example, this fact has been demonstrated with the entry into service of each HSL in France, where time savings resulted in a 20-40% increase depending on the individual case compared with the initial situation. It may therefore be supposed that a deterioration in transport conditions due to the non-renewal of infrastructure would result in the opposite phenomenon, with traffic dissuaded, to varying degrees, depending on the transport alternatives available to users. Traffic dissuasion therefore includes journeys no longer made, either by train, or by any other modes of transport (since they are too expensive, too slow, too restrictive, etc.).

Traffic dissuasion due to a decline in performance is a complex phenomenon. Without efficient transport, the location of activities and the competitiveness of the economy – multi-factorial phenomena – would be fundamentally different. In the same way as for the increased demand generated by an HSL, identifying dissuaded traffic appears possible on a given axis, with a limited number of start and end points and a given increase in journey time.

By contrast, with an overall approach that encompasses hundreds of projects network-wide, it would appear impossible to estimate traffic dissuasion and its repercussions in terms of GHG emissions. In fact it is thought that the total closure of the rail network in France would in theory have major repercussions on national activity, due to dissuasion such as the abandoning of certain heavily rail-dependent activities (chemistry, quarrying, etc., which are themselves GHG emitters), a general contraction in the tourism sector, relocation of households relying daily on rail transport or reduced economic competitiveness by geographically restricting areas where markets and employment are located. These changes would have significant consequences on GHG emissions for the country for which it would be impossible to determine the scope or exact causal links.

Application to the SNCF Réseau Green Bond 2016

Given that, firstly, the goal of evaluating the impact of long-term upkeep of the rail network on GHG emissions and secondly the complex nature of large-scale dissuasion phenomena, SNCF Réseau does not take into account traffic dissuasion (and accordingly changes in associated indirect emissions) in estimated GHG emissions avoided through the renewal of infrastructure across the entire network.

It is therefore thought that each passenger lost to rail travel would make use of another mode of transport.
By contrast, it would be possible to evaluate the effect of dissuasion in a limited area, for example on an isolated renewal project in a simple geographical environment. The result – in theory highly dependent on the local context – could not however be generalised nationwide.

• Changes to rail itineraries

As explained on the previous page, a traveller or transporter could react to the deterioration in rail service of a non-renewed line by changing rail route, where a number of itineraries are possible.
For example, HSL in France are all located on axes that are also served by standard lines, which could become more attractive if the renewal of HSL was not provided.
In practical terms, traffic would accordingly be shifted to the replacement line, undoubtedly with a longer journey time but without the suspension of service that would occur after a certain time on a non-renewed HSL. The longer train journey time would in a certain sense be limited to the journey time on the standard line - assuming that renewals were carried out – thus limiting the modal shift.

This line of argument requires:
– calculation of flows on a case-by-case basis (sometimes even by departure and destination point) for axes where departure and destination points are served by several lines, generally on long journey routes (HSL axis, Saône-Rhône axis, Paris-Nord axis, etc.) and sometimes also regional routes (Lyon – SaTrack, Paris – Montereau, etc.);
– the definition of optional values on replacement lines, so that emissions potentially avoided due to the existence of these lines can be accounted for under their renewal projects, the time frames for which would differ from renewal projects on the line from which traffic originated. This would require cross-linked estimates which would significantly increase the complexity of the calculations.

Application to the SNCF Réseau Green Bond 2016

According to the national scale of the renewal programme, the numerous hypotheses to be formulated and the significant complexity of implementation, SNCF Réseau takes the view that changes to rail itineraries cannot be taken into account in calculations.

• Modal shifts

Due to the longer journey time by train on non-renewed sections of the line, part of passenger and freight traffic would shift toward to other means of transport, which would by then have become more attractive than the train. Their proportion would increase as train journey times increased over the years.
Two components are used to estimate changes in mode of transport:
– the breakdown of changes between different modes of transport;
– the rate of modal shift depending on increased train journey times.

Application to the SNCF Réseau Green Bond 2016

Concerning the breakdown of the different modes of transport, SNCF Réseau has set out the following hypotheses:

RAIL TRAFFIC IN FRANCE (2016) IN PASSENGERS-KM OR TONNES-KM		MODAL SHIFT HYPOTHESIS
High-speed trains and equivalent (TGV, Eurostar Thalys, etc.)	53.7Bn v-km	50% air 40% car 10% national bus
Standard long-distance trains (Intercités)	7.1Bn v-km	75% car 20% national bus 5% air
Regional Express Trains	13.1Bn v-km	80% car 10% national bus 10% regional bus
Transilien	14.4Bn v-km	70% car 10% motorbikes 10% metro 10% bus
Freight	32.6Bn v-km	90% truck 10% riverine

Source: CGDD, SNCF Réseau.

These hypotheses must be read as in the following example: "if rail transport no longer existed in France, 50% of high-speed trains and equivalent would change to air travel". We must emphasise the unprecedented nature of the reasoning used to formulate these hypotheses. These hypotheses are applied for general cases. In the case of a section of line that may have unique features in terms of the breakdown of modal shifts, more suitable hypotheses can be chosen.

The breakdown hypotheses above are based on the following factors:

TAGV: the nature of TAGV traffic (long distance and high speed) is quite similar to air traffic: average distance of a journey (TGV: 488 km in 2015), flows essentially between Paris and regional cities, comparable pricing principles, etc. Moreover, both modes of transport are regularly compared, by passengers as well as economic research. It is therefore thought that half of TAGV traffic would change to air travel. The other half of the traffic would essentially change to car travel (including car-sharing), especially where distances are not more than 500 km and the departure point or destination is not a city (otherwise an air link would be the mode of transport changed to). Finally a marginal component would use long-distance buses, which is clearly still in a growth phase in France. The regulatory authority for rail and road activities estimates that up until October 2016 around 1% of TGV passengers had switched to these buses, without the TGV service having undergone any major changes.

Intercités: Intercités trains (as their network stands now in 2016 and which are set for strong growth in coming years) may be distributed into three more or less similar categories in terms of traffic: radial long-distance lines, inter-regional lines and radial lines within the Paris basin. Since the average distance for Intercités train journeys was 237 km in 2015, cars (including car sharing) appears to be the mode of transport that should win over most traffic, whatever the Intercités train type. Buses are growing based on the fact they are comparable with Intercités (system organised for travelling long-distances, with timetables, retail prices, etc.) but having journey times that are longer than by car would probably limit its relative share. Finally air transport would capture a minority share of traffic from the first two categories, essentially for traffic between regional cities and those with a high level of purchasing power.

TER: car (including car-sharing) is the main competitor for regional trains, with passengers travelling 41 km per journey in 2015. A significant but minority share of traffic seems to have possibly be taken by buses, whether or not they have a collective agreement with a TOA (Transport Organising Authority). Freely organised services (national buses) appear to have captured part of the longer TER journeys and buses with a collective agreement (regional) have won over part of the shorter distance journeys.

Transilien: journeys in regional Ile-de-France trains (average: 17 km) can be grouped into three categories: 1) journeys within the densely populated area (i.e. Paris and nearby communes), where metro and trams together with buses could essentially replace the RER (NB: we are talking here about the shortest Transilien journeys); 2) journeys between densely populated and non-densely-populated areas, since they have no other rail transport than the train; 3) journeys in non-densely-populated areas. Public transport has been the recipient of the vast majority of journeys within the densely populated area and probably around half of the dense and non-densely-populated areas and very few journeys within non-densely-populated areas. Cars and motorcycles would appear to have taken the rest, as distances covered by Transilien are generally too great to be undertaken without a motor vehicle.

Freight: there are few possible alternative freight transportation modes. Road transport which already accounts for almost 85% of transport in France, would appear to have captured 90% of rail traffic, with the remainder switching to riverine transport principally along the key routes of the Seine, the Rhône and in the Nord region.

2.4.2.8. 2.4.2.8. Equivalences for distance travelled depending on the mode of transport used

The quantity of energy used (electricity, fuel), and therefore GHG emissions associated with a journey are directly linked to the distance run. Since the study concerns a section of line on which trains with known routes are, it is possible to estimate the total distance travelled by a passenger by train. With the same departure point and destination, the distance travelled may vary depending on the mode of transport. It is therefore necessary to formulate kilometric equivalency hypotheses depending on the mode of transport used.

Application to the SNCF Réseau Green Bond 2016

For a given point of departure and destination it is possible to determine distances exactly by mode of transport. Conversely, a given section of line is often travelled by passengers with a very high number of points of departure and destinations. For example the Dijon – Lyon section can be travelled by passengers travelling from Dijon to Lyon, but also from Strasbourg to Marseille, from Nancy to Montpellier or particularly from Besançon to Nevers. Each point of departure and destination displays distance variations between the most important modes of transport. Given that it is not possible to get a breakdown of all the points of departure and destinations of passengers, it is also not possible to compute the distance in kilometres between modes of transport for each section of line studied. Therefore, the approach taken by SNCF Réseau has been to think in terms of average values for all sections of lines concerned by renewal projects.

Actual distances[7] covered by trains and road vehicles are therefore compared on the basis of:

– the station to station route for the fastest direct trains;
– the fastest road route from centre to centre;

out of a range of points of departure and destinations made up of those:

– between Paris and the 100 other largest conurbations in France;
– between Paris and 30 TGV destinations abroad;
– between Lyon and 10 major destinations in France and nearby locations abroad.

7. A distinction must be made between the actual distance and the fare distance, which is in use particularly for TGV.

In 90% of cases, the distance by road was within the range of [90–110%] of the rail distance with outlying values of -19% and +34% of the distance by rail. On average (not weighted according to the population or number of passengers), the distance by road is only less than 1% shorter than the distance by train.
SNCF Réseau therefore opted for kilometre equivalency between road and rail transport. In the situation without renewal, a kilometre initially travelled by a train passenger would turn into a kilometre travelled by car, bus or truck.
Conversely for studying specifically certain line sections for which the kilometre difference between road and rail is significant, actual distances may be taken into account.

For the difference between rail and air routes, the view was taken that air route distances are 10% shorter than rail distances for the fastest direct journeys, as the air route (including airport approach banking) form more of a straight line than the rail route.
SNCF Réseau opted to keep for 2016 kilometre equivalence between air and road at 0.9: one kilometre initially travelled by a train passenger will be translated under the non-renewal scenario into 0.9 kilometres travelled by plane.

2.4.2.9. Emission factors for the modes of transport

Emission factors (EF) considered here concern the average GHG emissions per passenger or per tonne of goods to travel one kilometre depending on the mode of transport used.
Recent values for the majority of EF by mode of transport are known and may depend on the geographical area studied. Estimating the emissions avoided for a renewal project covers several decades: their volume is liable to evolve over time, under the effect of a huge number of parameters (improved energy performance of transport vehicles, increased vehicle filling, changes in practices or in GHG content for electricity, changing of the energy vector, etc.). Changing trajectories therefore need to be determined to take into account these dynamic parameters during the period under study.

Application to the SNCF Réseau Green Bond 2016

A number of sources were consulted concerning emission factors:
– The EF for modes of transport for 2016 were taken from the ADEME Carbon Database. These values include emissions associated upstream of fuel consumption and emissions from transport vehicle manufacture.
– The EF trend to 2050 is provided, for terrestrial modes of transport for passengers and rail freight, by a foresight study by the CGDD[8]. The EF trend for air transport is taken from the 4DS scenario of the International Energy Agency[9], which is seen to be the most realistic in terms of air transport emissions[10]. Finally the trend for rail transport (non-freight) is based on the emissions factor trend for electricity up to 2050, in accordance with the trend-based scenario established by the Electricity Transport Network RTE[11].

8. CGDD, Projections de la demande de transport sur le long terme (Long-term transport demand forecasts), 2016.
9. IEA, Energy Technology Perspectives 2016.
10. An ad hoc consistency study was carried out to estimate the direction in which the air transport emissions factor will trend. The values obtained are very close to the 4DS scenario from the IEA, which validates the relevance of choosing this scenario.
11. This is RTE's scenario A, "founded on a low-growth economic context, on a changing trend in manufacturing capabilities and inter-connexion and on maintaining the current share of nuclear in the production mix".

MODE OF TRANSPORT EMISSION FACTORS (GCO_2EQ PER V-KM OR T-KM)

MODE OF TRANSPORT		2016	% TCAM 2016-2030	2030	% TCAM 2030-2050	2050
Passenger train	TAGV	3.6	-0,6%	3.4	-0.6%	3.0
	Intercités	5.5	-0.6%	5.1	-0.6%	4.5
	TER (electrified)	8.8	-0.6%	8.1	-0.6%	7.2
	Transilien	5.6	-0.6%	5.2	-0.6%	4.6
Car	Interurban Itinerary	137	-2.7%	87.5	-2.1%	46.3
	Travel within the Ile de France region	230	-2.7%	147.4	-2.1%	78.0
Urban two-wheelers		223	-2.7%	151.8	-2.1%	87.7
Air	Domestic Air	275	-1.7%	214.9	-1.7%	151.2
Bus	Long Distance	59	-1.6%	30.0	-1.6%	21.8
	Regional Bus	154	-1.6%	123.1	-1.6%	89.4
Metro and trams in Ile de France Region		5.7	-0.6%	5.2	-0.6%	4.6
RATP Ile de France		154	-1.6%	123.1	-1.6%	89.4
Freight Trains		4,3	-0.6%	3.9	-0.6%	3.5
Truck	40 t HGV	105	-0.7%	83.9	-0.5%	61.0
Riverine Transport		67	-1.2%	55.9	-0.7%	43.6

Sources: see sections above.
Note: the EF of urban two-wheelers has been verified, although it sounds counter-intuitive.

2.4.3. ALLOCATION AVOIDED EMISSIONS TO FINANCE THE ISSUANCE OF GREEN BONDS

The principle and the need to allocate emissions was included in section 2.4.1.2 (Prevention of double accounting : setting in place of allocation rules. This allocation means it is possible to do away with double accounts, on one hand, and to estimate the contribution of the project to the maintenance of rail traffic on the other hand.

The allocation rules applied accordingly report three findings:
– renewal operations are generally only carried out on a single item of infrastructure (track, EFTI, signalling, OA/OT), with each being necessary for the maintenance of existing traffic on the section of line (except for EFTI for diesel traction trains, but this point is considered negligible);
– each renewal operation concerns a given section of line, which is more or less the same length as the traffic calculation section;
– Green Bonds do not finance the entire renewal programme, only part of it.
Three successive rules for the allocation of avoided emissions must therefore be defined.

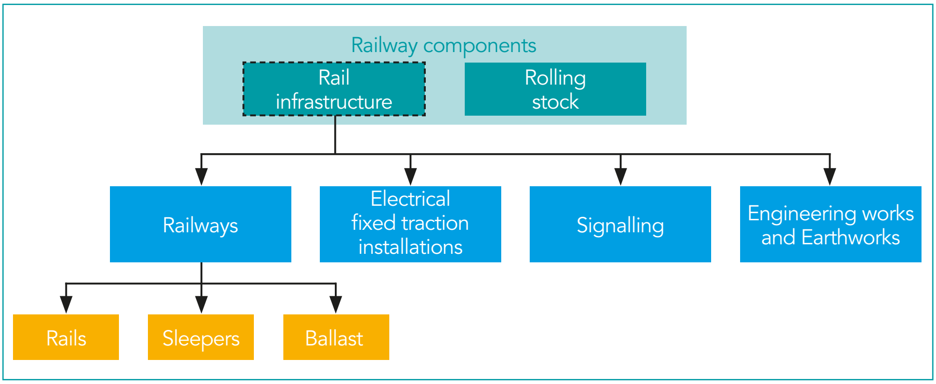
Application to the SNCF Réseau Green Bond 2016

1. Allocation by type of equipment renewed
The investments made by the infrastructure management operator on the existing network (track, EFTI, signalling, engineering works or earthworks) and by rail companies (rolling stock) are all for the transportation of passengers and freight.

However, the associated investment expenditure is highly unequal; attributing to them equal shares of avoided GHG emissions would not therefore reflect the financial effort to be provided to renew the asset concerned. **Emissions avoided due to renewal are therefore quotas applied by equipment type depending on their cost in relation to overall recurrent investment in the railway system.** It should be emphasised that operating expenditure (operation and maintenance) are not taken into account for calculation, insofar as they may not be financed by borrowing (rather they are covered by direct operating income).

Application of a ratio depending on the investment cost for materials also prevents investment being channelled into equipment that artificially appears to be more carbon efficient as in actual fact the equipment as a whole is really an individual whole. Using this allocation method, investing €1m in renewal of track therefore generates the same volume of avoided emissions as investing €1m in the renewal of signalling, EFTI or rolling stock.

The rule governing the allocation of investment to equipment is determined at different levels, using the following hierarchy:



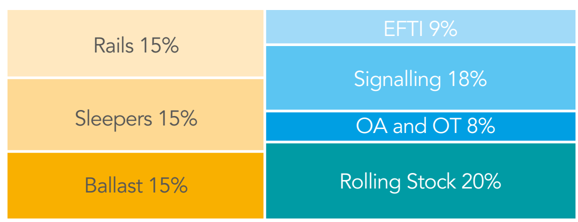
The share of avoided emissions attributed to each equipment type in the rail system was determined using different methods depending on the area in question.

– **Green Area:** depending on tangible fixed assets (excluding HSLLGV projects) entered into the financial accounts of SNCF Réseau and SNCF Mobilités from 2009 to 2016.

– **Blue Area:** depending on the renewal expenditure anticipated by SNCF Réseau from 2017 and 2030.

– **Orange Area:** depending on the GOPEQ[12] values of renewal operations of a single component (renewal of rails, sleepers and ballasts).

This gives the following breakdown:



E.g.: renewal of rails accounts for 15% of investments on renewal of the railway system. Total avoided emissions through renewal investment (infrastructure and rolling stock) on a given section of line are therefore allocated as 15% to this type of operation.

12. The GOPEQ ("grande-opération équivalent") is a working unit created and used by SNCF Réseau to weight renewal operations of unequal consistency in relation to the average cost for each type of renewal. For example, renewal of 1 km of ballast is 0.55, 1 km of sleepers is 0.58 and 1 km of a double line of rails is 0.35. As rails are renewed more frequently than sleepers and ballasts, the view is taken that the GOPEQ for rails is equivalent to two other components over the average lifecycle of a track. An equal share of avoided emissions is therefore allocated to the renewal of each of the three track components.

2. Allocation to a renewed section:
The bornes of the section of line on which traffic and avoided emissions are calculated rarely correspond to those of the section on which the renewal operation is carried out. Avoided emissions are therefore allocated to the operation on a prorata basis for the length renewed in the traffic measuring department.

E.g: if an operation consists in renewing rails along 20 km of track within a single-track section of line that is 100 km long, then 20% of emissions avoided through renewal of all of the rails on this section will be allocated to this operation (i.e. 20% of 15% = 3% of total avoided emissions for the 100 km of line through investment in renewal of the railway system).

3. Allocation to the source of financing:
Green Bonds alone do not finance the renewal investment by SNCF Réseau. Only part of these investments is attributed to the area of Green Bonds.
The share of SNCF Réseau renewal investments financed by Green Bonds is therefore applied to the result from the calculation in the previous stage.

E.g: if Green Bonds finance 40% overall of rail renewal, then the avoided emissions attributed to Greens Bonds for the example operation above constitute 40% of the avoided emissions attributed to that operation (i.e. 40% of 20% of 15% = 1.2% of total avoided emissions on that 100 km of line).

EXAMPLE SUMMARISING SUBSEQUENT ATTRIBUTIONS MADE FOR A PROJECT

Quantity for distribution: complete renewal of a section of line of 100 km: **3 $MtCO_2E$ avoided**

Allocation according to type of item renewed

Complete renewal of rails over 100 km: **450 $ktCO_2e$ avoided** (3 $MtCO_2e$ x 15%)

Allocation to renewed section

Renewal of rails over 20km of the section: **90 $ktCO_2e$ avoided, etc** (450 $MtCO_2e$ x 20%)

Allocation of a share financed by the Green Bond

Share of avoided emissions allocated to the Green Bond: **36 $ktCO_2e$ avoided**
(40% of financing coming from the Green Bond)

2.4.4. EXTRAPOLATION TO ALL PROJECTS

So far, we have presented the method for calculating the avoided emissions for a single renewal operation. SNCF Réseau undertakes over 1,000 of these operations annually, for which it would not be possible to separately calculate the avoided emissions. Creating a panel of representative operations is therefore needed in order to calculate a reference value which will then be extrapolated to the entire portfolio of eligible projects. The working unit is the amount invested, which is the only unit common to all types of project.

It should be stressed that the method used means this ratio can be applied to all railway equipment (track, EFTI, signalling, OA/OT, rolling stock…).
The panel of representative operations will be steadily expanded to different types of operations.

Application to the SNCF Réseau Green Bond 2016

The panel of representative operations is made up of the most significant renewal operations in terms of investment spending for the year in question. Track operations occupy first place in this classification, and have the advantage of being well identified geographically. However, EFTI and signalling renewal are characterised by lower amounts, more widespread dispersion and a more difficult if not impossible geographical demarcation.
The panel of line sections used to calculate the extrapolation value for avoided emissions will therefore be composed solely of sections and concern the main track renewal operations.
It should be emphasised that this choice, based on track renewal, does not significantly interfere with the quality of evaluation of EFTI and signalling.
It only provides guidance for choosing sections of line – and so mainly quantities of traffic - which serve as the basis for calculating avoided emissions.

The panel of representative operations, by decreasing expenditure in 2016:
- Out of the first 7 operations on conventional UIC 1-4 lines, all of which were with the track renewal machine (total: €397m);
- the first 3 operations using HSL (total: €74m).

This representative panel comes to a total of €471m, which is 35% of investment in infrastructure renewal in 2016 (and 51% of track renewal investments on UIC 1 to 4 and HSL).
This breakdown is set out in more detail in the following table.

From the calculations in this representative panel of operations, an average of the avoided emissions can be established of 108 tonnes equivalent CO_2 avoided per year for every million euros invested.
This average is applied to all other renewal operations according to the amount invested or their respective average lifespan.

COMPOSITION DU PANEL D'OPÉRATIONS REPRÉSENTATIVES DU PROGRAMME DE RENOUVELLEMENT

TYPE OF LINE	AXIS	SECTION OF LINE	COMPO-NENT RE-NEWED	LENGTH OF TRACK RENEWED (GOPEQ)	EXPENSES 2016 (€m)	TCO_2EQ AVOIDED THROUGH €m OF INVEST-MENT	TCO_2EQ AVOIDED PER YEAR THROUGH €m OF INVEST-MENT
UIC 1-4	Montpellier – Narbonne	Montpellier – Narbonne	Track	91	116	4,946	124
UIC 1-4	Chambéry – Turin	Chambéry – Les Chavannes - Saint-Rémy	Track	42	63	2,373	59
UIC 1-4	Orléans – Tours	La Chapelle-Saint-Mesmin – Mer	Track	56	55	1,653	41
UIC 1-4	Charleville-Mézières – Nancy	Longuyon – Onville	Track	43	47	826	21
UIC 1-4	Metz / Nancy – Strasbourg	Stambach – Strasbourg – Erstein	Track	38	43	6,823	171
UIC 1-4	Paris – Dijon	Sens – Laroche-Migennes	Track	53	38	1,311	33
UIC 1-4	Marseille – Nice	Anthéor-Cap-Roux – Golfe-Juan Vallauris	Track	16	35	2,903	73
LGV	Paris – Lyon (LN 1)	Ecuisses – Vaux-en-Pré	Ballast	32	26	10,607	265
LGV	Paris – Le Mans / Tours (LN 2)	Saint-Martin-de-Bréthencourt – Boisville-la-Saint-Père	Ballast	24	24	8,861	222
LGV	Paris – Lille (LN 3)	Conchy-les-Pots – Ablaincourt-Pressoir	Ballast	23	24	9,938	248
Totals				**418**	**471**	**4,304**	**108**

Note: Calculations based on 2014 traffic.

2.5. CARBON IMPACT OF INFRASTRUCTURE RENEWAL PROJECTS

The carbon impact for a project is obtained by adding:
- emissions from project execution (carbon footprint);
- emissions avoided during the usage phase of the projects.
The following table sets out the calculation in brief.

From the 252,500 tCO_2eq of carbon footprint allocated to renewal expenditure financed by Green Bonds in 2016 are subtracted 2,980,200 tCO_2eq on the usage phase of the renewed infrastructure. **Green Bonds therefore financed renewal expenditure providing a reduction of 2.7 $MtCO_2eq$ from the transport system for an average period of 40 years.**

Emissions from execution of associated projects are **offset after 3.3 years of operation** of the corresponding infrastructure (the lifespan of which is approximately 40 years).

CARBON IMPACT OF THE RENEWAL EXPENDITURE FINANCED BY GREEN BONDS

		TRACKS	TRACK EQUIPMENT	FIXED INSTALLA-TIONS FOR ELECTRIC TRACTION	SIGNAL-LING	TOTAL
Expenses financed by Green Bonds 2016 (€m)	A	484	106	20	100	710
CARBON FOOTPRINT (THOUSAND TCO_2EQ)						
For renovation operations per €m invested (cf. 2.3.5 (p.21)	B	361	361	86	380	-
Allocated to expenses financed by the Green Bonds	**C=A*B**	**175**	**38**	**2**	**38**	**253**
AVOIDED EMISSIONS (THOUSAND TCO_2EQ)						
Per annum per €m invested 2.4.4 (p.9)	D			0.108		
Per annum allocated to expenses financed by the Green Bonds	E=A*D	52	11	2	11	76
Per €m invested over the life cycle of installations	F	4	4	5	4	-
Allocated to expenses financed by the Green Bonds	**G=A*F**	**2,083**	**456**	**92**	**350**	**2,980**
CARBON IMPACT (FOOTPRINT – AVOIDED EMISSIONS) (THOUSAND TCO_2EQ)						
Allocated to expenses financed by the Green Bonds	**H=C-G**	**-1,908**	**-418**	**-90**	**-312**	**-2,728**
Carbon neutral time*	**I**	**3.4 years**	**3.4 years**	**0.8 year**	**3.5 years**	**3.3 years**

** Note: time to carbon neutrality is calculated as an average from the overall write-down period.*

03

EVALUATION OF THE CARBON IMPACT FROM NEW LINE PROJECTS

3.1. FOREWORD

3.1.1. SUMMARY OF FINANCING OF NEW LINE PROJECTS FOR 2016

In 2016, new line projects amounted to €175m of investment for SNCF Réseau, or 12% of expenses falling within the scope of Green Bonds. The following table provides a breakdown of these expenses by project:

In 2016, all expenses by SNCF Réseau for new line projects (€175m) were financed through Green Bonds, amounting to 20% of funds raised (€885m).

INVESTMENT PER NEW LINE PROJECT IN 2016 ALLOCATED WITHIN THE SCOPE OF THE GREEN BOND

INVESTMENTS IN €m	PERIMETER GREEN BONDS	
	AS OF 31 DEC. 2016	SPLIT
New lines and line extensions	**175**	**12%**
EE 2	14	8%
SEA	73	42%
BPL	53	30%
CNM	36	20%

INVESTMENT IN 2016 ALLOCATED BY THE GREEN BOND

INVESTMENTS IN €m	ALLOCATION GREEN BONDS 2016	
	ALLOCATION	SPLIT
New lines and line extensions	**175**	**20%**
EE 2	14	
SEA	73	
BPL	53	
CNM	36	

3.2. METHODOLOGICAL PRINCIPLES

New line projects are very limited in number – unlike renewal projects – and may therefore be treated differently.
The concepts of carbon footprint, avoided emissions and carbon impact for new line projects are similar to those for renewal projects.

Studies conducted for line renewal projects generally provide supporting data on the impact of these lines on GHG emissions. They are the best possible source for assessing the carbon footprint, avoided emissions and carbon impact for projects. It therefore appears unnecessary to make use of extrapolation methods to calculate these values. Accordingly, the following pages present the stages in the calculation of the carbon footprint and avoided emissions for each new line project.

3.3. CARBON FOOTPRINT FOR NEW LINE PROJECTS

3.3.1. GENERAL PRINCIPLES

As with infrastructure renewal, evaluating the carbon footprint of a new line project involves applying a method to analyse existing carbon in a similar way to the Bilan Carbone® or GHG Protocol.

3.3.2. CARBON FOOTPRINT OF A NEW RAIL LINE

The evaluation scope of the carbon footprint of a new line project is identical to that of a renewal project and covers all direct and indirect emissions, whether upstream or downstream of the works carried out. The main emissions items are set out in the section devoted to the carbon footprint of renewal (see 2.3.3) and are aligned with the methodological principles of the GHG Protocol.

This scope does not cover GHG emissions from infrastructure exploitation (which essentially involves regulating train traffic on the line brought into service), or those arising from its general maintenance. This is exactly the same as for other modes of transport: GHG emissions for exploitation and maintenance of infrastructure are not included in the emission factors of modes of transport competing with trains. This point could nonetheless change in the medium-term.

3.3.3. ALLOCATION OF PART OF THE FOOTPRINT TO FINANCING FROM GREEN BONDS

Green Bonds do not fully cover the financing of SNCF Réseau new line projects; only part of these investments are allocated within the scope of Greens Bonds. Therefore an allocation rule must be applied to prevent double accounting for the carbon footprint in the results, in order to estimate the contribution of Green Bonds to the development of new lines.

Application to the SNCF Réseau Green Bond 2016

1. Estimating the carbon impact of new lines financed by Green Bonds issued in 2016

The carbon footprint of the four new rail line projects is obtained from the "Bilans Carbone®" carbon balance sheets completed by their respective project owners (SNCF Réseau for EE 2, Eiffage Rail Express for BPL, LISEA for SEA, Oc'Via for CNM). The following table summarises the results.

RESULTS OF CARBON BALANCE SHEETS FOR NEW RAIL LINE PROJECTS

PROJECT	LENGTH (lines, connections)	COST (€m)			GHG EMISSIONS ("BILAN CARBONE®")			
		Total	of which financed by SNCF Réseau	of which financed by Green Bonds 2016	in thousand tCO_2eq	in thousand tCO_2eq per km	tCO_2eq per €m invested	thousand tCO_2eq allocated to Green Bonds 2016
	A	B	C	D	E	F=E/A	G=E/B	H=D*G
EE 2	L: 107 km R: 9 km	2,191	580	14	1,049	9	479	7
BPL	L: 182 km R: 32 km	3,380	1,435	53	1,350	6	400	20
SEA	L: 302 km R: 38 km	7,546	2,098	73	1,671	5	221	16
CNM	L: 60 km R: 20 km	2,291	465	36	621	8	271	10
Total	L: 651 km R: 99 km	15,408	4,578	176	4,691	6	304	54

Sources: "Bilans Carbone®" of projects prepared by the projects owners for the respective scope of each project.
- EE 2: calculation table created by EcoAct for SNCF Réseau. 2017.
- BPL: Final carbon balance sheet prepared by ERE and additional exchanges 2017.
- SEA: CA prepared by LISEA within the scope of the concession (excluding connections): 1.48 $MtCO_2eq$. Hypothesis that the carbon balance sheet per km of connections is equal to that of the line. 2017.
- CNM: Carbon balance sheet prepared by Oc'via. 2017.

The "Bilans Carbone®" prepared by the project owners cover the scope of new lines, excluding adaptation works on the existing network – the impact of which is significantly less and even negligible in relation to the margin of error for this type of evaluation.
In addition, for SEA, the "Bilan Carbone®" was prepared for the scope of the LISEA concession (the line itself). Since the scope of SNCF Réseau (connections) has not been the object of any specific carbon balance sheet, the hypothesis used is a carbon intensity per km of line equivalent to that of the scope of LISEA (4,900 tCO_2eq per km), i.e. a total of 186,000 tCO_2eq for the scope of SNCF Réseau.

2. Allocation to financing from Green Bonds
For each project, a financial allocation was carried out to compute the carbon footprint allocated to financing from Green Bonds.

For example: if Green Bonds finance 10% of a new line, the emissions generated by Green Bonds for this project will equalize to 10% of the project's total carbon footprint.

3.4. EMISSIONS AVOIDED BY NEW RAIL LINE PROJECTS

3.4.1. GENERAL PRINCIPLES

3.4.1.1. Scenario with new rail line project and reference scenario

When a new line is brought into service, it is used by:
– passengers from rail services who have moved over to the new line;
– passengers who used other modes of transport (modal shift to train);
– passengers who would not have made the trip without the existence of this new service (induction of traffic).
Since rail is the mode of transport with the lowest GHG emissions, the commissioning of a new rail line reduces the overall emission levels of the transport system.
The calculation of avoided emissions consists of comparing the carbon footprint of the transport of passengers and goods in two scenarios:
– Reference scenario: the studied project is not executed and the initial situation continues.
– Project scenario: the commissioning of the new rail line results in a modal shift as well as a traffic induction that favours rail.

3.4.1.2. Prevention of double accounting: setting in place of allocation rules

Green Bonds do not fully cover the financing of SNCF Réseau new line projects; only part of these investments are allocated within the scope of Greens Bonds. Therefore, the share of avoided emissions attributed to Green Bonds should be equivalent to their contribution to the project financing.

3.4.1.3. Estimation of emissions avoided by a new rail line: a two-step approach

The calculation method for estimating emissions avoided by a new rail line project is split into two stages:
1. calculation of emissions avoided by the new rail line;
2. allocation of part of those emissions to financing from Green Bonds.

3.4.2. CALCULATION METHOD FOR A NEW RAIL LINE

3.4.2.1. General process of computing emissions avoided by a new rail line

The method used to calculate the emissions avoided by the commissioning of a new rail line is formulated as follows:

A. Calculation of emissions generated in the reference scenario (without project)
1. estimation of the traffic, per mode of transport, of passengers and goods circulating on the route impacted by the new rail line project;
2. application of the projected evolution of this traffic in the long term;
3. application of emission factors for different types of traffic, incorporating the projected evolution over the analysis period (for example: gCO_2/km for private vehicles).

B. Calculation of emissions generated in project scenario (usage emissions)
1. estimation of the traffic circulating on the commissioned new rail line and its origin (train, modal shifts, traffic induction);
2. application of the projected evolution of this traffic in the long term;
3. application of emission factors for different types of traffic, incorporating the projected evolution over the analysis period (for example: gCO_2/kWh of the French electricity mix).

The difference between the emissions generated in each scenario makes it possible to estimate the volume of emissions avoided during the use of the new line.

3.4.2.2. Duration of the study

The duration for the study period on avoided emissions must take into account the effect of the new line up until the date of renewal of its rail equipment.

Application to the SNCF Réseau Green Bond 2016

The study period chosen was 40 years, corresponding to the lifespan of rail equipment.

3.4.2.3. Changes to traffic

The emissions avoided by a new rail line project are broken down over a number of decades. During this lengthy period, one must take into account demographic, economic, social and societal changes (among others).
As with the analysis of emissions avoided by renewal works, a hypothesis for changes in traffic circulating on the line should be formulated.

Application to the SNCF Réseau Green Bond issued in 2016

Project studies estimate traffic and growth in traffic using socio-economic reference figures in effect at the time they are carried out.

3.4.2.4. Modal reports and traffic induction

Modal reports and traffic induction after entry into service of the new rail line must be quantified in order to calculate the GHG emissions avoided.

Application to the SNCF Réseau Green Bond issued in 2016

Socio-economic studies were conducted by SNCF Réseau for each new line project. Some of these were internal and others were disclosed in public surveys publications.

3.4.3. ALLOCATION TO FINANCING FROM GREEN BONDS

Green Bonds do not fully cover the financing of SNCF Réseau new line projects; only part of these investments are allocated within the scope of Greens Bonds. An allocation is necessary to attribute the avoided emissions corresponding to its share in the project financing.

Application to the SNCF Réseau Green Bond issued in 2016

Financing was allocated for each project: the rule used was exactly the same as for calculating the carbon footprint for the financing of new rail lines (see 3.3.3).

For example: if Green Bonds finance 10% of a new line, the emissions avoided by Green Bond for this project correspond to 10% of the emissions avoided by the project.

The table below sets out the GHG emissions avoided through he four new rail line projects and the share of those emissions allocated to Green Bonds.

GHG EMISSIONS AVOIDED BY NEW RAIL LINE PROJECTS

PROJECT	LENGTH (lines, connections)	COST (€m)			GHG EMISSIONS AVOIDED		
		Total	of which financed by SNCF Réseau	of which financed by Green Bonds 2016	in thousand tCO_2eq	tCO_2eq per €m invested	in thousand tCO_2eq allocated to Green Bonds 2016
	A	B	C	D	E	F=E/B	G=D*F
EE 2	L: 107 km R: 9 km	2,191	580	14	794	362	5
BPL	L: 182 km R: 32 km	3,380	1,435	53	2,285	676	36
SEA	L: 302 km R: 38 km	7,546	2,098	73	10,173	1,348	99
CNM	L: 60 km R: 20 km	2,291	465	36	6,682	2,917	105
Total	L: 651 km R: 99 km	15,408	4,578	176	19,935	1,294	244

3.5. CARBON IMPACT OF NEW RAIL LINE PROJECTS

The carbon impact for a project is obtained by adding:
– emissions from execution of the project (carbon footprint calculated by project carbon balance sheets);
– emissions avoided during the usage phase of the projects.
The following table sets out the calculation in brief.

From the 53,500 tCO_2eq of carbon footprint allocated to new rail line expenditure financed by Green Bonds in 2016 are subtracted 243.700 tCO_2eq on the usage phase of the new infrastructure constructed.
Green Bonds therefore financed development expenses providing a reduction of 190.300 $MtCO_2eq$ from the transport system over 40 years.

The slightly negative contribution of the second phase (116 km) of the HSL Est high-speed line project to this assessment should be noted, owing to the fact that the vast majority of the modal shift – and the associated avoided emissions – took place after entry into service of the first phase (EE 1, 300 km) in 2007.

Emissions from execution of the four new rail line projects were offset after 7.4 years of operation of the corresponding infrastructure.

CARBON IMPACT OF RENEWAL EXPENSES FINANCED BY GREEN BONDS FOR NEW RAIL LINE PROJECTS

		EE 2	BPL	SEA	CNM	TOTAL
Total project cost (€m)	A	2,191	3,380	7,546	2,291	15,408
Expenses financed by Green Bonds 2016 (€m)	B	14	53	73	36	175
CARBON FOOTPRINT (IN THOUSAND OF TCO_2EQ)						
Project totals (see table p.48)	C	1,049	1,350	1,671	621	4,691
Allocated to expenses financed by the Green Bonds	D= C*(B/A)	7	21	16	10	54
AVOIDED EMISSIONS (THOUSAND TCO_2EQ)						
Project totals over 40 years (see table p. 51)	E	794	2,285	10,173	6,682	19,935
Allocated to expenses financed by the Green Bonds	F= E*(B/A)	5	36	98	105	244
CARBON IMPACT (FOOTPRINT - AVOIDED EMISSIONS) (THOUSAND TCO_2EQ)						
Allocated to expenses financed by the Green Bonds	G=D-F	2	-15	-82	-95	-190
Carbon neutral time*	H	70.4 years	20 years	5 years	2.9 years	7.4 years

** NB: time to carbon neutrality is calculated in real time, in chronological order of the carbon impact, which increases over time.*

04

EVALUATION OF THE CARBON IMPACT FROM GREEN BONDS

The total carbon impact allocated to expenses financed by the Green Bonds 2016 is obtained by adding:
– the carbon impact allocated to expenses financed by Green Bonds for the renewal projects (see part 2);
– the carbon impact allocated to expenses financed by Green Bonds for new rail line projects (see part 3).

TOTAL CARBON IMPACT OF THE EXPENSES FINANCED BY GREEN BONDS

CARBON IMPACT ALLOCATED TO EXPENSES FINANCED BY GREEN BONDS	
renewal projects	-2,727,800 tCO_2eq
new rail line projects	-190,200 tCO_2eq
Total	**-2,918,000 tCO_2eq**
CARBON NEUTRAL TIME	
renewal projects	3.3 years
new rail line projects	7.4 years

In total, the expenses financed by the Green Bonds issued in 2016 reduce the GHG emissions of the transport system by 2.9 million tonnes equivalent CO_2.

For the sake of comparison, the carbon footprint per inhabitant in France (GHG emissions in France and imports) was estimated at 11.9 tCO_2eq in 2015[13].
The carbon impact of Green Bonds allocation in 2016 is therefore **comparable to the carbon footprint of approximately 6,000 French citizens over 40 years**.

13. Source: http://www.statistiques.developpement-durable.gouv.fr/fileadmin/documents/Produits_editoriaux/Publications/Documents_de_travail/2016/document-travail-27-empreinte-carbone-novembre-2016.pdf

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