Foresight Report

FOD-Report for Shift 2 Rail JU

13 May 2020

Shift2Rail Joint Undertaking (S2R JU) Request for services - High Level Position Paper on the next Rail R&I Institutional Partnership

Framework contract 2018/RTD/A2/OP/PP-07001-2018 "Impact Assessments, Evaluations, Foresight and Strategic Analyses of Research and Innovation policies and programmes" - LOT 1 (Foresight on Demand in Science, Technology, Research and Innovation Policy (FOD))

Contents

Section 1. Abstract

As part of the on-going process to setup a new Rail Research & Innovation Partnership that picks up from the existing Shift2Rail Joint Undertaking, this is a quantitative analysis in order to estimate the impacts that new EU ambitions from the European Green Deal especially can mean for rail freight and rail passenger traffic and modal share, for climate change, for jobs, for the economy and for the export potential of the European rail supply industry. With the use of case studies and scenarios, considerations on the need to transform Europe's rail system through innovations in order to increase capacity, multimodality, cost efficiency and attractiveness of rail compared to other more polluting transport modes.

Section 2. Executive summary

Scope

This report provides a high level long-term quantitative analysis of the potential impact of the next rail R&I program on the European society, more specifically in terms of:

- Climate change
- Jobs
- Economic growth
- Passengers' evolution
- New market share within the freight business
- Industrial competitiveness / Export

Analyses and estimates have been based on ambition scenarios from both a technological development and policy implementation point of view. These are considered to be fundamental preconditions for transforming the current rail system into the dominant transport mode of tomorrow's European mobility, particularly for freight.

Context

- *R&I activity in the rail sector is expected to deliver improvements in terms of the following key metrics of the Rail System:* ***capacity, punctuality (reliability) and life cycle cost.*** *Capacity is a key (physical) condition to meet future demand, punctuality and life cycle cost are crucial aspects to increase competitiveness of the rail system compared to alternative transport modes.*
- *Rail volumes are expected to grow massively and depending on final ambitions within the overall decarbonisation of the European transportation system.*

Section 2. Executive summary

What we have done

1. The assessment process has been conducted considering a new market outlook for the rail transportation system, with improved scenarios in terms of:
   - Supply and competitiveness of rail services, thanks to current and future push from R&I, and
   - Demand projections and the increasing EU policy pull effect towards more rail in the modal mix

2. Achievements, ambitions and possible time to market of the current R&I program (S2R 1) have been analysed along with the possible building effect of the new R&I program (S2R 2) in terms of increased competitiveness of the rail system.

3. Rail traffic growth has been projected considering different levels of ambition of the EU policy for the transport sector by 2050, including overall emissions and shift to rail scenarios.

4. Proportionately with the increased share of the rail system as transportation mode it was possible to estimate the growing dimension of the rail industry by 2030, 2040 and 2050. The future scale of the rail industry was the base for assessing its interaction and impact on the areas in scope.

5. The estimated capacity increase considered in the moderate growth scenario or beyond is only sustainable with a substantial strategic investment in R&I. The case study (Annex 2) provides evidence of capacity gap in the medium to long term that can be overcome thanks to deployment of high TRL S2R 1 outputs and the new TPs in S2R2

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Results

- Our estimates show that, compared to 2017, by 2050 rail transport can achieve the following impacts:

	Impact area	Measure	Moderate scenario	Maximum scenario
	Climate change	Avoided CO2 emissions	> 6.300 MtCO2	> 8.400 MtCO2
	Jobs	Direct & indirect jobs	4,8 million	6,4 million
	Economic growth	Gross value added	> €350 billion	> €470 billion
	Passengers' evolution	Traffic (% modal share)	> 1.800 billion pkm (20%)	> 2.200 billion pkm (25%)
	Rail freight	Traffic (% modal share)	> 1.500 billion ton-km (45%)	> 2.600 billion ton-km (76%)
	Industrial competitiveness / Export	Export levels of turnkey solutions		

- Additional details related to the evolution of impacts in 2030, 2040 and 2050 together with scenarios applied are provided in section 4.

Section 3. Methodology statement

Our approach

We have targeted our literature review in order to understand:

- What has the rail sector to-date achieved in terms of performance after several years of policy actions?
  - From 2011 to 2016, 56% of investments on the rail network were for maintenance and renewal of an ageing network.
    - *Can the rail network, terminals, nodes accommodate the additional traffic? Will there be sufficient capital to invest in enhancements and new lines to accommodate additional traffic? How to transform a rail network where today 82% of traffic is made of passenger trains? Is it possible to build new lines in densely populated urban areas?*
  - The rail modal share in inland freight transport declined to 17%
    - *Can rail-related services handle extra cargo? Is rail sufficiently interconnected in logistics supply chains? Is rail attractive enough in terms of reliability, speed and cost?*
  - The rail modal share in passenger transport stagnated at less than 7% since 1995
    - *Are trains interconnected enough to serve at best passengers? Can rail become more multi-modal, digital and a real service-oriented transport mode?*
  - Numerous EU legislative actions in the rail industry have taken place over the last 30 years.
    - *Will new policy actions be effective in achieving modal shift? Is rail innovative enough to meet the future traffic challenge?*
- What can the Shift 2 Rail innovations deliver by 2030 on capacity, cost efficiency and punctuality and what can be achieved by 2050 when scaling up technology across the rail value chain?

  A classification of Transforming Projects to deliver by 2050 based on the key industry metrics and a ranking of impacts generated

- How to assess the impacts that the transformed railways can generate on the set of impact areas relevant for the EU priorities?

  A set of indicators to model minimum, maximum and moderate scenarios based on literature findings and specified assumptions of the European Green Deal and 2011 Transport White Paper

Section 3. Methodology statement

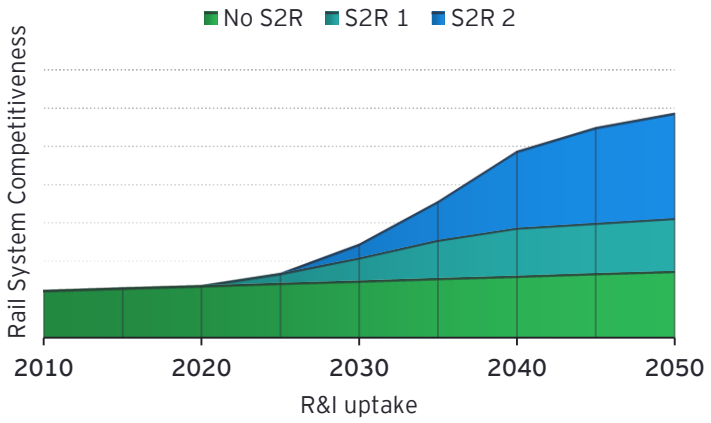
Approach to assess the Transforming Projects

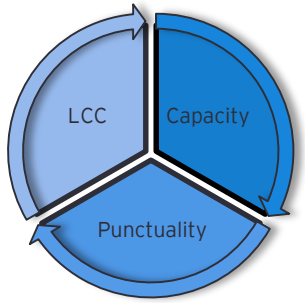
Under Horizon Europe, the new rail R&I Program (S2R 2) will focus on eight 'Transforming Projects' (TPs):

1. **Assets for Automatic & Autonomous Operation**
2. **Railways Digital Twin, Simulation & Virtualisation**
3. **Smart Asset Management**
4. **Smart Integration for Door to Door (D2D) Mobility**
5. **M.O.D. Systems for Pods**
6. **Environmentally Friendly and Attractive Sustainable Mobility**
7. **Rail Freight – The backbone of a green logistic chain**
8. **Network management Planning and Control**

The TPs (see description in Annex 1) will build on the previous Institutional Partnership and R&I Program (S2R 1) with the view to enabling and contributing to a transformed and more competitive Rail System.

A qualitative assessment of the 8 TPs above sheds light on a set of enablers and disruptive innovations for the rail system and the overall competitiveness of rail transportation services.





- The timeline considered has been derived according to the ERRAC Technology and Innovation Roadmaps. This has been derived from a qualitative mapping of the TPs compared to the ERRAC agenda and roadmap.
- A case study for the nodes of Munich and Bern on actual need for the TPs (further rail network capacity enhancement over the timeline above) is presented in Annex 2.

Section 3. Methodology statement

Metrics for impact areas and scenarios applied

We have focussed our quantification effort around the below key impact areas that help to frame the contribution rail can provide. We have framed the growth of rail traffic according to scenarios based on forecast and EU policy ambitions for modal share. We believe that among the modal share scenarios, the 'Moderate' one is the most realistic and reasonable.

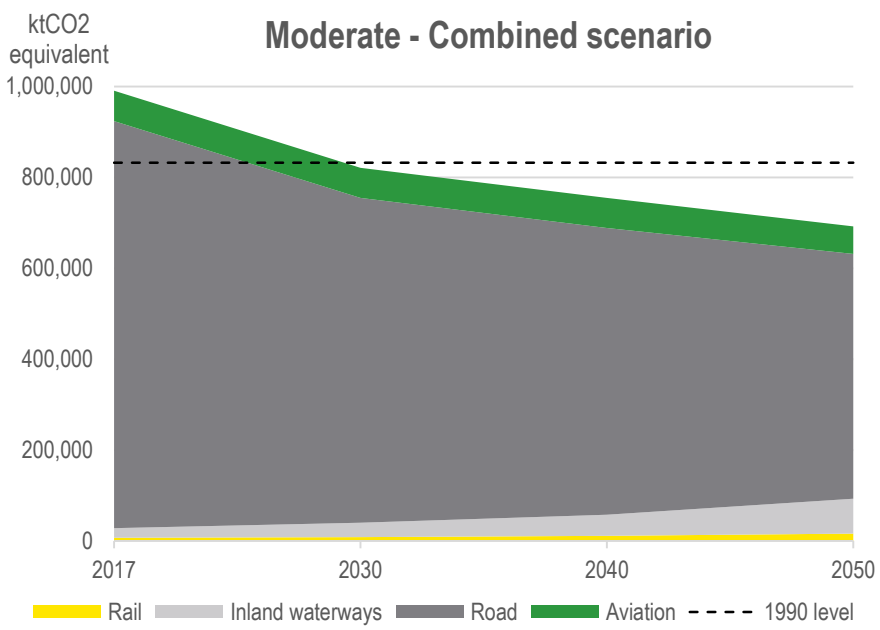
Impact area	Measure
Climate change	Avoided CO_2 direct emissions as a result of modal shift to rail for freight and passenger traffic together with some technological innovations in the competing transport modes
Jobs	Direct jobs created and increased productivity thanks to automation for railway undertakings and infrastructure managers achievable through innovation and in terms of indirect jobs created in the rail supply industry and related services
Economic growth	Gross Value Added generated from increased rail traffic and a reduction of life cycle costs achievable through innovation
Passengers' evolution	Passenger-km and modal share in transport compared to rail, road and aviation
Rail freight	Ton-km and modal share in inland transport compared to road and inland waterways
Industrial competitiveness / Export	New concepts and products created by a joint collaboration of operators and suppliers in order to increase Europe's potential on the global market.

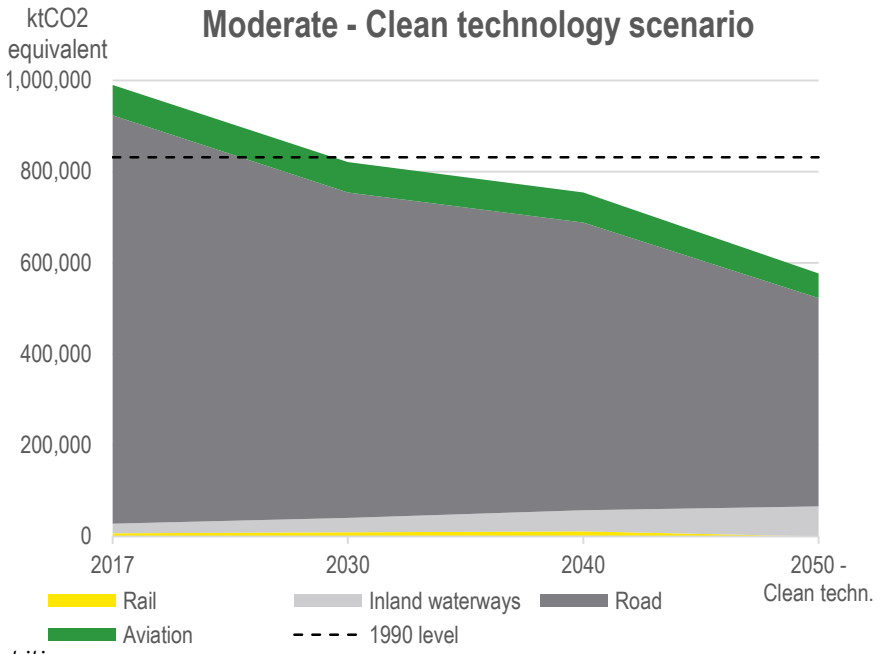
Ambition	By 2050
European Green Deal	Up to 75% of road freight traffic shift to rail and inland waterways.
2011 White Paper	> 50% of medium-distance passenger transport by rail

Scenario	Description
Minimum	Traffic forecast from EU Reference Scenario 2016. Base year applied is 2017, modified from source based on actual traffic data from Eurostat. No EU policy ambitions considered.
Moderate	*Adding…* **For freight:** moderate ambition of the European Green Deal (35% of road traffic shift to rail by 2050) **For passenger:** moderate ambition of the 2011 Transport White Paper (less than majority of medium-distance transport by rail by 2050)
Maximum	*Adding…* **For freight:** full ambition of the European Green Deal (whole 75% modal share at 2050 of road traffic shifting to rail, no gains for inland waterways) **For passenger:** full ambition of the 2011 Transport White Paper (majority of medium-distance transport by rail by 2050).

Section 4. Results – Climate change

Total direct CO2 emissions





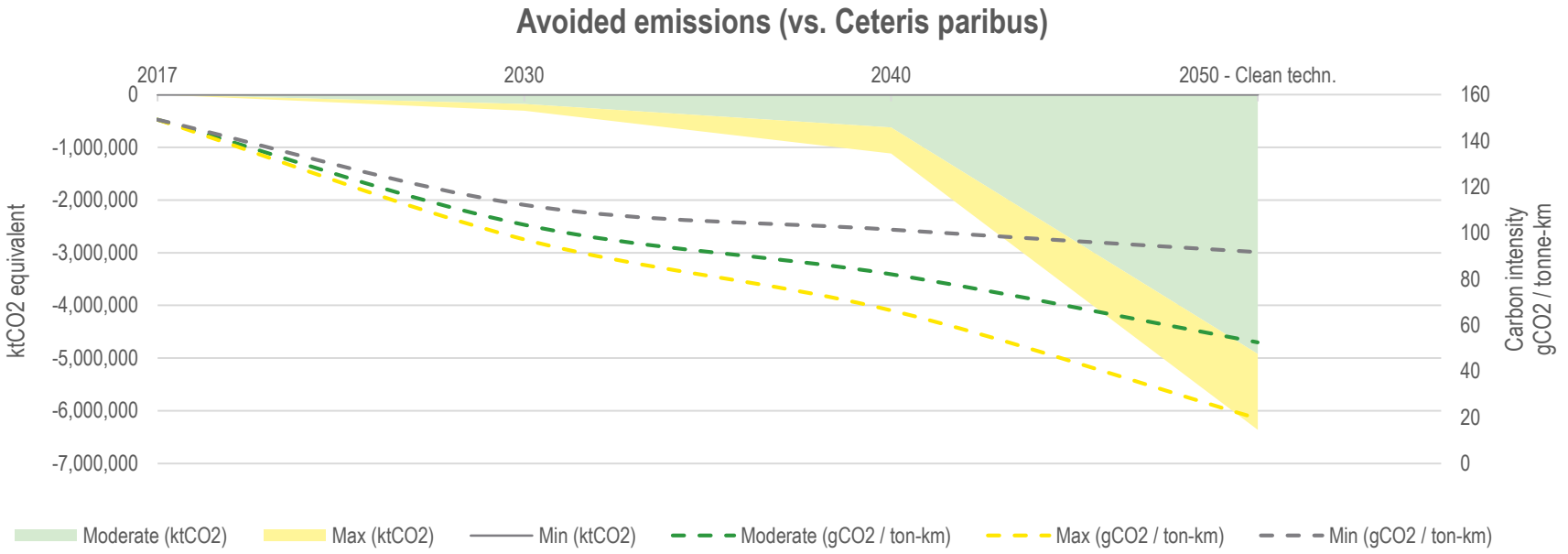
** Combined scenario stands for the combination of freight and passenger traffic ambitions*

The above graphs are based on the Moderate traffic modal share scenario, combined in terms of direct CO2 emissions from freight and passenger transport. The left hand side graph shows the reduction of emissions as a consequence of higher modal share for rail while the right hand graph also considers additional greening technologies for all modes. Emissions for each transport mode are assumed to evolve in line with growth in traffic adjusted for emission efficiency gains supported by literature (see Annex 3). In either scenario, rail plays a key role in achieving the forecasted emission reduction as a result of the modal shift from carbon intensive transport modes.

- **Moderate scenario *combined*:** we forecast a decline from 990 mtCO2 in 2017 to 821 mtCO2 by 2030 and 692 mtCO2 by 2050. Accordingly, this represents a 17% decrease from 1990 level of the transport modes within scope.
- **Moderate scenario *combined (clean technology)*:** in this scenario we apply expected additional emission reductions by 2050 resulting from a higher rate of network electrification and use of innovative rolling stock (e.g. hybrid, battery-powered trains) for zero emissions for rail, increased EV penetration for road and greener air transport (see Annex 3). As a result, the forecasted emissions in 2050 decline to 577 mtCO2. Accordingly, this represents a 31% decrease from 1990 level of the transport modes within scope.

Section 4. Results – Climate change

Avoided emissions - Freight

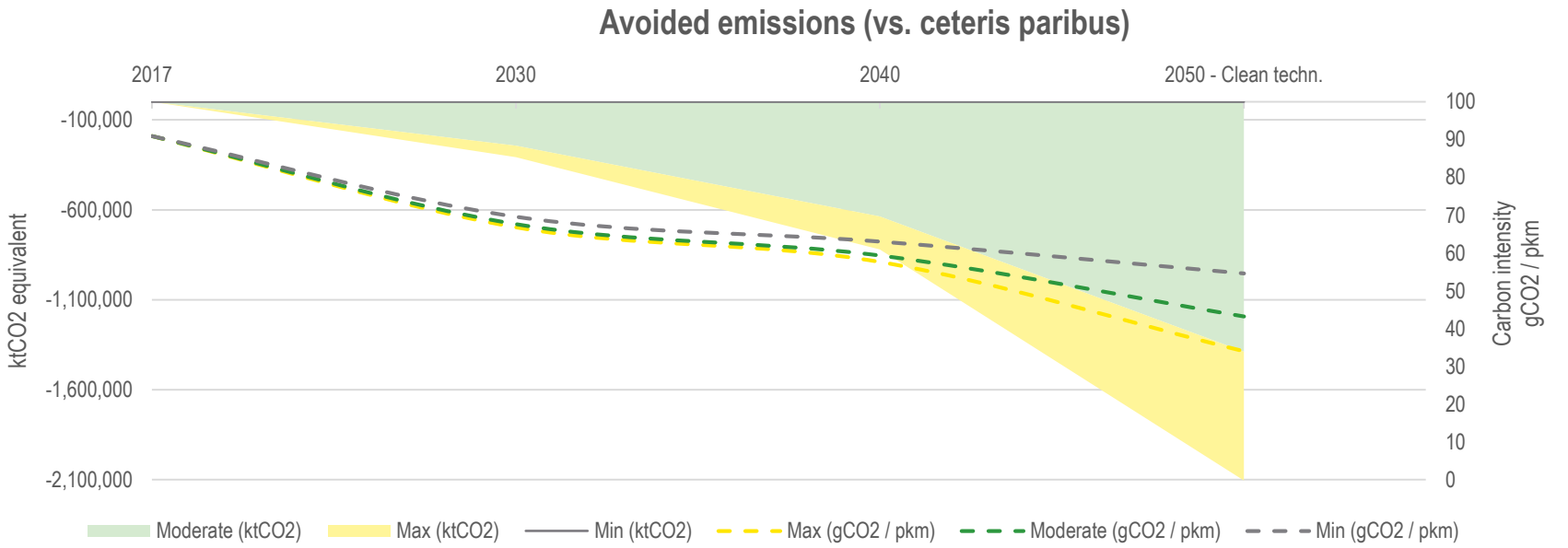


The above graph illustrates the total avoided emissions (left axis) and carbon intensity (right axis) for freight transport in each modal shift scenario based on additional green technologies for all modes (Clean technology scenario for road, inland waterways and zero emissions at 2050 for rail). Avoided emissions are calculated as the cumulative difference in total emissions between the i) moderate and (theoretical) maximum scenario and ii) the minimum scenario which is our baseline forecast for traffic evolution. Carbon intensity is measured as CO2 emission per freight traffic unit.

- **Minimum scenario**: Based on the ceteris paribus forecast and assumes increases in emission efficiency, mainly driven by green technologies. The resulting carbon intensity decreases from 149 gCO2/ton-km in 2017 to 112 gCO2/ton-km in 2030 and 92 gCO2/ton-km in 2050.
- **Moderate scenario:** By applying the same emission efficiency gains thanks to green technologies but a higher rail modal share, we estimate carbon intensity to decline to 104 gCO2/ton-km in 2030 and 53 gCO2/ton-km in 2050. As a result, total avoided emissions amount to 174 MtCO2 by 2030 and 4.924 MtCO2 by 2050, compared to the minimum scenario.

Section 4. Results – Climate change

Avoided emissions - Passenger

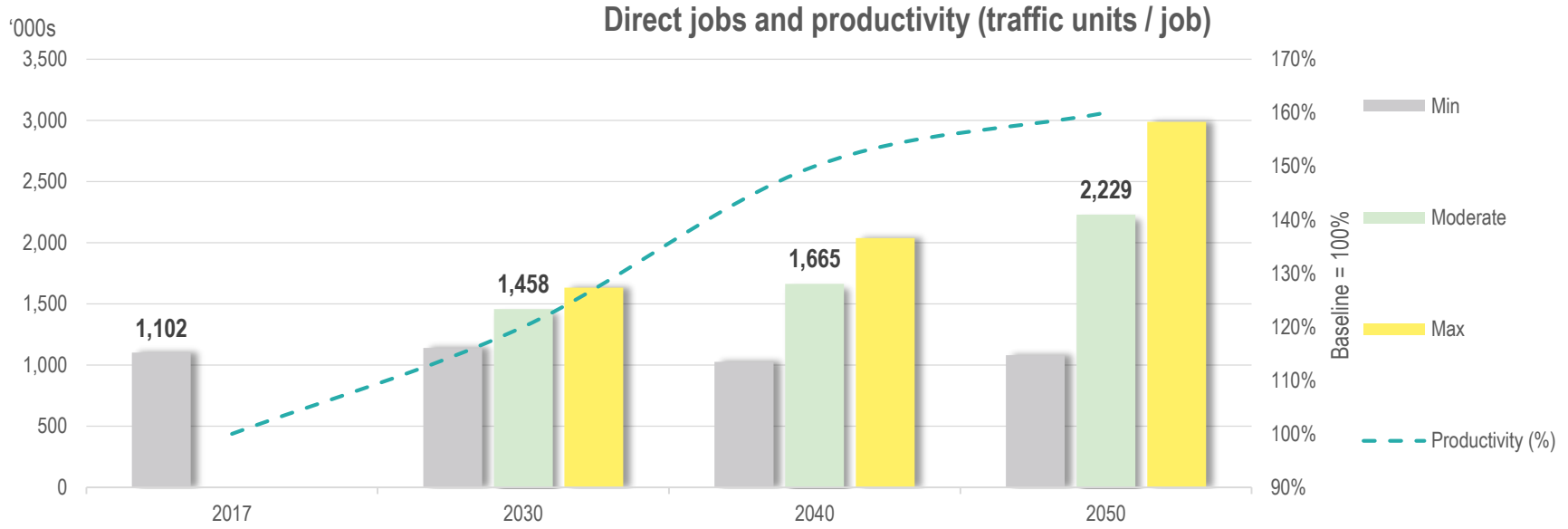


The above graph illustrates the total avoided emissions (left axis) and carbon intensity (right axis) for passenger transport in each modal shift scenario based on additional green technologies for all modes (Clean technology scenario for road, aviation and zero emissions at 2050 for rail). Avoided emissions are calculated as the cumulative difference in total emissions between the moderate and (theoretical) maximum scenario and the minimum scenario which is our baseline forecast for traffic evolution. Carbon intensity is measured as CO2 emission per passenger traffic unit.

- **Minimum scenario**: Based on the ceteris paribus forecast and assumes increases in emission efficiency, mainly driven by green technologies. Carbon intensity decreases from 91 gCO2/pkm in 2017 to 70 gCO2/pkm in 2030 and 55 gCO2/pkm in 2050.
- **Moderate scenario:** By applying the same emission efficiency gains thanks to green technologies but a higher rail modal share, we estimate carbon intensity to decline to 68 gCO2/pkm for 2030 and 43 gCO2/pkm for 2050. As a result, total avoided emissions amount to 243 MtCO2 by 2030 and 1.388 MtCO2 by 2050, compared to the minimum scenario.

Section 4. Results – Jobs

Direct jobs and productivity gains



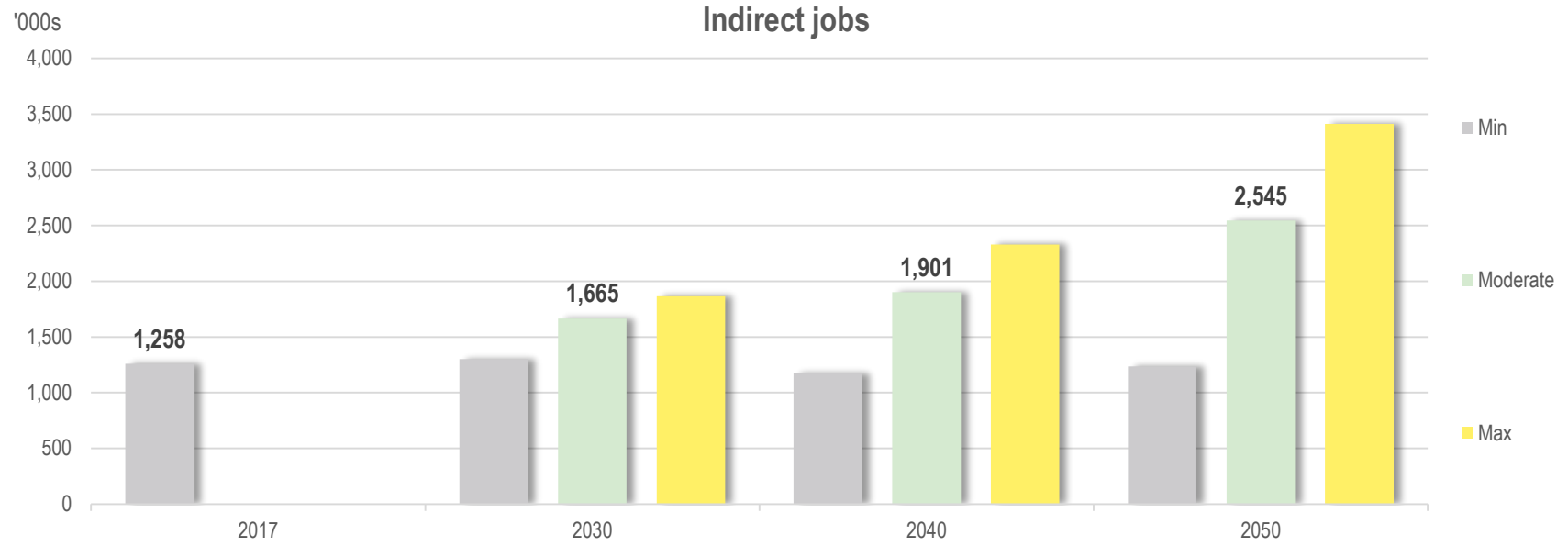
** Combined scenario stands for the combination of freight and passenger traffic ambitions*

The above chart depicts the evolution of direct jobs and productivity measured as traffic unit per job for each scenario. Total direct jobs within rail are considering the key segments of rail operations: i) freight ii) passengers and iii) infrastructure. These are assumed to evolve in line with traffic units for each scenario after adjusting for innovation as a parameter of the automation, digitalisation and robotics brought by Shift2Rail research into the rail system. This has an important positive effect on productivity, expressed as traffic units (ton-km, pax-km or train-km) per job shown as an index on the right hand side of the chart.

- **Minimum scenario *combined***: Based on the ceteris paribus traffic forecast, it assumes increases in productivity thanks to automation amounting to 20%, 50% and 60% for 2030, 2040 and 2050, respectively. As a result, we forecast total direct jobs to stay flat at 1,1 million in 2017 to 2050 when automation is at its peak. Over the period, minor fluctuations of total direct jobs are driven by higher rates of automation into a scenario of limited traffic growth.
- **Moderate scenario *combined*:** In line with the moderate ambition of traffic modal share for freight, passengers and infrastructure while assuming identical efficiency gains thanks to automation as above. This results in total direct jobs of 2,2 million by 2050 on a growth rate which is not linear to traffic levels due to the increase of productivity brought by innovation.

Section 4. Results – Jobs

Indirect jobs in the rail industry



** Combined scenario stands for the combination of freight and passenger traffic ambitions*

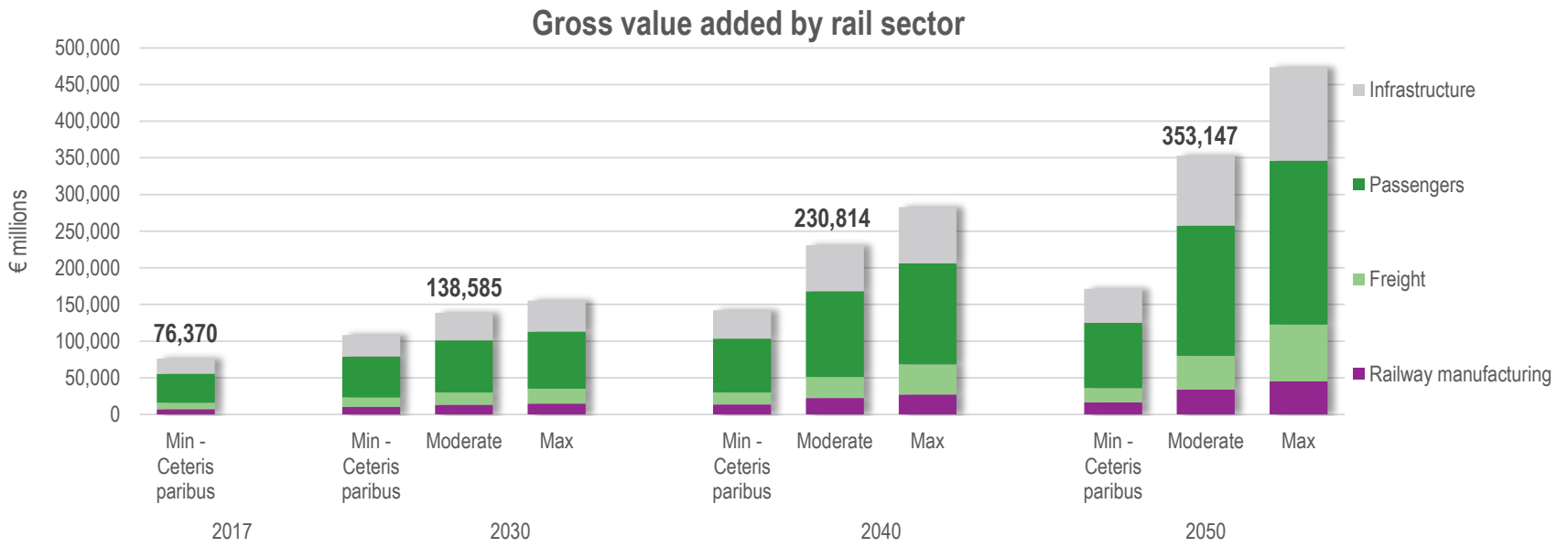
Indirect jobs, railway manufacturing and related services, stemming from the growth in the rail industry are estimated based on the ratio of indirect to direct jobs of 1,14 (Ecorys, 2012). In order to provide a clear forecast of future indirect jobs, we have assumed to keep the ratio constant throughout the 2017-2050 forecast period, resulting in indirect jobs growing in line with the direct jobs for each scenario.

- **Minimum scenario *combined***: Given the ceteris paribus traffic forecast, we expect total indirect jobs to largely remain flat from the baseline of 1,2 million in 2017 over the forecast period. Minor fluctuations of total indirect jobs are driven by higher rates of innovation into a scenario of limited traffic growth.

- **Moderate scenario *combined*:** In line with the limited ambition of traffic modal share for freight, passengers and infrastructure, we expect indirect jobs to grow substantially from 1,2 million in 2017 to 2,5 million in 2050.

Section 4. Results – Economic growth

Gross Value Added



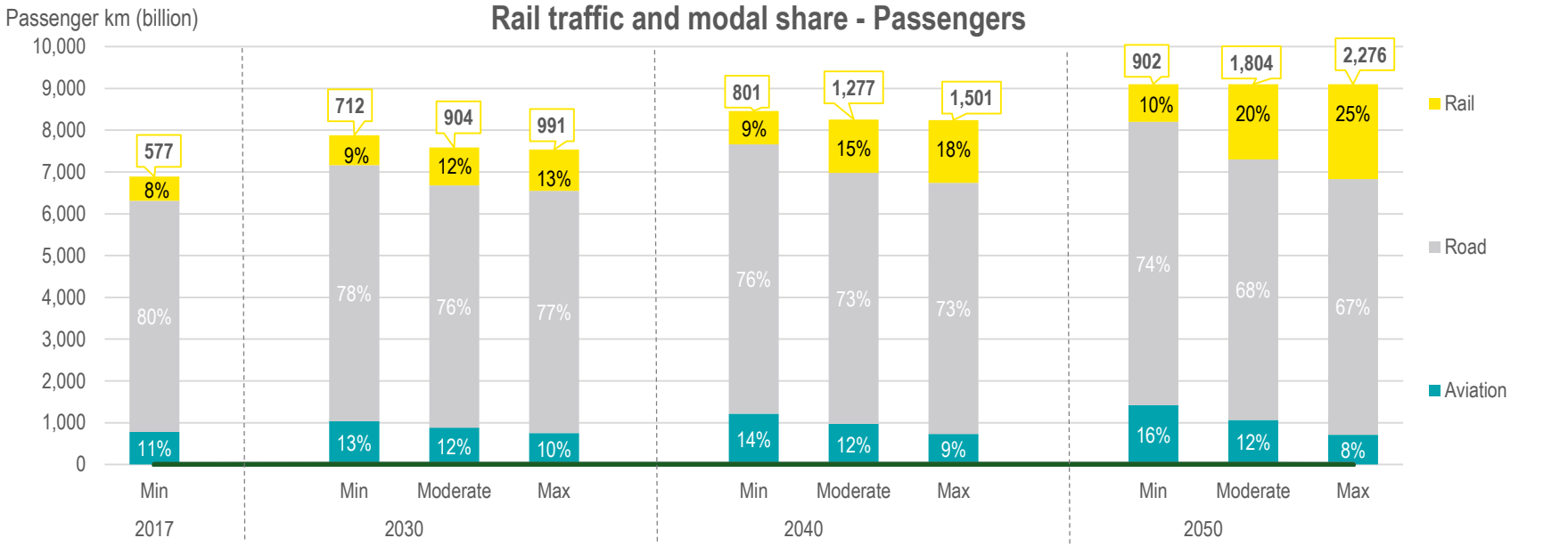
** Combined scenario stands for the combination of freight and passenger traffic ambitions*

Total gross value added within the rail sector as of the baseline is split by i) railway manufacturing ii) freight iii) passengers and iv) infrastructure and assumed to evolve in line with traffic units for each scenario after adjusting for a parameter of Life Cycle Cost reduction. For infrastructure and railway manufacturing train-km are used as a simplistic metric for traffic unit. Cost savings are based on S2R 1 evolution at present time and assumed to be -25% by 2030, -50% by 2040 and -60% as total cost reduction by 2050 compared to baseline. This continuous cost reduction is assumed to be possible thanks to innovation, automation and digitalization. We assume the additional value added will be transferred to customers for 50%, the rest will likely be retained by the rail industry improving its margins.

- **Minimum scenario *combined***: Based on the ceteris paribus traffic forecast and assumed increases thanks to LCC reduction, gross value added is forecasted to increase from € 76,4 billion in 2017 to €171,2 billion by 2050 corresponding with an annual growth rate of 2,5%.
- **Moderate scenario *combined:*** Driven by the increase in traffic unit as a result of limited ambition of modal share, the resulting gross value added is forecasted to increase to € 353 billion in 2050.

Section 4. Results – Passengers' evolution

Rail passenger transport volumes and modal share

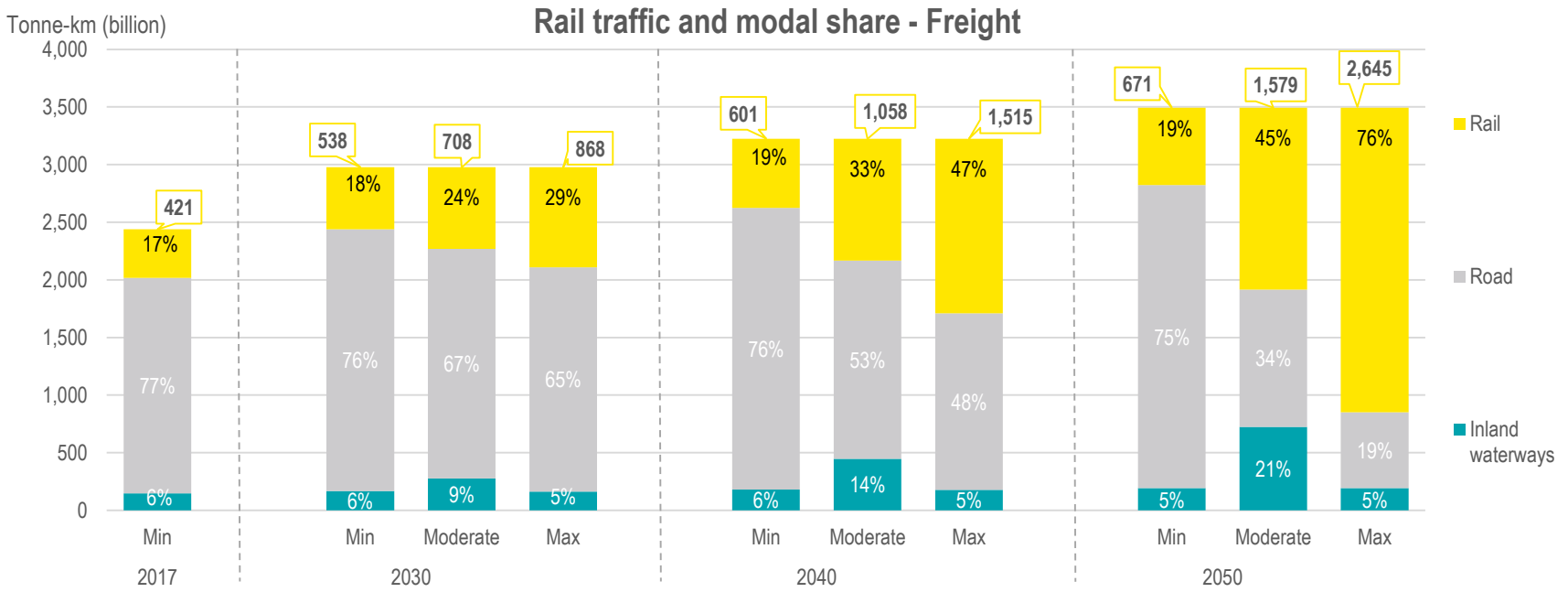


The above chart depicts the evolution of passenger rail traffic due to different degrees of modal share ambition for each scenario as per EU policy goals of the 2011 Transport White Paper and measured as passenger-km and %, respectively (see Annex 3 for further details, only medium and long distance passenger transport is considered in the scenarios). Total passenger traffic demand over the forecast period in the minimum ceteris paribus scenario is based upon the EU reference scenario (2016) and kept constant for each scenario.

- **Minimum scenario**: Based upon annual growth rates by mode from EU reference scenario 2016 and with current measures in place and no EU ambitions passenger rail traffic is estimated to grow from 577 billion passenger-km in 2017 to 902 billion by 2050, ceteris paribus.
- **Moderate scenario:** we forecast that if the rail modal share doubles by 2050 compared to the minimum scenario, rail traffic will peak at 1.804 billion passenger-km. As a result rail reaches a modal share of 12% by 2030 and 20% by 2050 as a limited but realistic ambition of rail modal share from the White Paper. Annualised growth rate in traffic is amounting to 3,5%.
- **Maximum scenario:** we estimate that if the rail modal share reaches 25% at 2050, corresponding to a 51% rail modal share in medium and long distance intra-EU traffic, volume will increase to 2.276 billion passenger-km by 2050.

Section 4. Results – New market share within freight business

Rail freight transport volumes and modal share



The above chart depicts the evolution of freight rail traffic due to different degrees of modal share ambition for each scenario as per EU policy goals of the European Green Deal and measured as tonne-km and %, respectively. Total freight traffic demand over the forecast period in the minimum ceteris paribus scenario is based upon the EU reference scenario (2016) and kept constant for each scenario.

- **Minimum scenario**: Based upon annual growth rates by mode from EU reference scenario 2016 in order to define transport demand in 2030 and 2050 with current measures in place and no EU ambitions, ceteris paribus.
- **Moderate scenario:** We forecast that only half of 75% of road freight inland transport from the ceteris paribus forecast shifts to rail, half of the remainder shifting to IWW and the rest of the traffic remains on road. As a result rail reaches a modal share of 24% by 2030 and 45% by 2050. This results in annualised growth rate in traffic amounting to 4,1% corresponding with 1.579 billion tonne-km by 2050.
- **Maximum scenario:** We estimate that 75% of road freight transport from the ceteris paribus forecast shifts entirely to rail. The rail modal share reaches 76% in 2050 corresponding with 2.645 billion tonne-km.

Section 4. Results – Industrial competitiveness / export

Potential for exporting European solutions

The rail supply market is expected to grow globally in the short term with the strongest focus in Africa/Middle East, Asia Pacific, Latin and North America (UNIFE). The market, although not entirely accessible to European suppliers, is structured according to segments:

- Services
- Rolling stock
- Infrastructure
- Rail control and signalling
- Turnkey integrated solutions

The global market for turnkey solutions is more and more promising. Below two examples of turnkey solutions implemented in and outside Europe:

- Private high-speed operator in Italy (NTV): first ever private HSR operator, fleet of 47 modern high-speed Alstom trainsets with ERTMS level 2, 8 years of operations, a 30% market share in Italy achieved through innovative product offering:
  - A turnkey integrated solution of Alstom, new private investors and initially SNCF to setup a HSR operator providing rolling stock, maintenance services, product marketing, revenue management systems and modal integration.

- High-speed line in Morocco (ONCF HSL): 200 km of Tanger-Kenitra line, put in service in November 2018 with 2.5 million passengers during first year of operations. A 2.1 billion EUR investment made of:
  - A turnkey integrated solution of Alstom and SNCF to provide product concept, construction, signalling, maintenance and training to ONCF;
  - A HSL developed according to European standards for interoperability and equipped with ERTMS Level 2;

In the long range up to 2050, the European rail sector is going to transform and innovate profoundly as well thanks to the Transforming Projects. These have the potential to bring together railway undertakings, infrastructure managers and suppliers. New products, innovative solutions to answer new concepts of operations tested and deployed in Europe by rail stakeholders can create opportunities for third countries looking for specific systems or integrated turnkey solutions for their national systems.

ERTMS is without doubts a successful European product and a promising example of the attractiveness of European rail technology. Currently it has been exported to more than 50 countries in the world equipping more than 21000 km of rail lines. Potential for exporting turnkey solutions is expected to grow proportionately with the European leadership in rail technology.

Annex 1 – Transforming Projects' description

Annex 1: Transforming Projects' description

- **Transforming Project n°1: Assets for Automatic & Autonomous Operation**
  - *Solutions proposed under this TP will have to be open and interface standardised, simple, affordable and safe. Solutions also will have to be modular and evolvable to allow progressive deployments, minimising the investment risk and ensuring upgradeability and component interchangeability. This should enable a smooth market introduction of advanced and innovative solutions to reach a GoA4.*
  - *Beyond the technical challenges, other important aspects, such as social acceptance or incorporating skilled staff on the new technologies, also need to be faced by this Transforming Project. Finally, the definition of a new set of operational rules is required to enable a European wide deployment of automatic and autonomous rail operation for a European Traffic Management Level.*

- **Transforming Project n°2: Railways Digital Twin, Simulation & Virtualisation**
  - *The Digital twin will present to various stakeholders in a comprehensive, adapted views, different views of the current state of the system (rolling stock, infrastructure) as well as its usage intensity along with its history (past services, history and contents of maintenance operations, etc.).*
  - *Digital twins require mathematical models that allow to mimic the real behaviour of (sub)systems. These models will physical/analytical laws, and new tools based on Machine Learning/Artificial Intelligence, expert knowledge, etc. The use of advanced computational techniques will be required in order to obtain quasi real time solutions.*
  - *Digital twin should have prediction capabilities coming from the combination of simulation models fed by operational inputs. Decision helping systems will also be of use to develop operational scenarios both for planning maintenance and later for operation recovery in case of an incident.*

Annex 1: Transforming Projects' description

- **Transforming Project n°3: Smart Asset Management**
  - *The overall objective of TP 3 is to implement holistic Asset Management, working across assets, intervention types and functional boundaries to further increase the capabilities of the system developed in Shift2Rail, to reduce downtime for infrastructure, systems and rolling stock, to utilize capacity and reduce costs.*
  - *This Transforming Project will be the enabler for prescriptive and automated maintenance, which will be simple, fast, integrated and cost-effective. Equipment health will be constantly self-checked, diagnosed and cured by performing maintenance tasks at the right time with the right method.*

- **Transforming Project n°4: Smart Integration for Door to Door (D2D) Mobility**
  - *Solutions proposed in this TP will address challenges to provide the best multi-modal offer according to individual needs. This includes a shared and unified transport token, distributed general ledger and automatic contract execution, service bundle self-configuration, inclusive multi-modal journeys for people with reduced mobility, an end-customer data sharing framework, passenger's information in multimodal hubs and personalized and tailored flexible transport services built around mass public transport with rail as backbone.*
  - *TP aims to improve operations for a controlled multimodal transport offering: This includes enhancing the physical and digital integration of rail in a multi-modal offer, using artificial Intelligence for green D2D transport, making use of multimodal traffic event management, dealing with (cyber)security.*

- **Transforming Project n°5: M.O.D. Systems for Pods**

This Transforming Project will address a Game Changer for Railway Transport and other transport modes. This Transforming Project will:

- *Support the seamless door-to-door mobility paradigm and attract citizens to the public transport system with individual user experience.*
- *Redefine aspects of services to mobility on demand, last mile and to flexibility for alternative transport solutions (PRM, combination passengers & goods).*
- *Optimise the usage of all infrastructure with minimum energy consumption and environmental burden, no more or less parking cars.*
- *Increase the efficiency and flexibility of the system: always moving devices, none or little waiting time, standardised open platform with pod carriers for each transportation mode.*
- *Contribute to cleaner and more balanced transport options according to the policies, legislation and initiatives of EU with the main objective of decarbonising transport is a major challenge for the sake of EU citizens.*

- **Transforming Project n°6: Environmentally Friendly and Attractive Sustainable Mobility**

This Transforming Project addresses environmental topics leading to decarbonisation in mobility and a sustainable and attractive transportation for passengers and freight *through the following area:*

- *Attractive Environmentally Friendly Mobility.*
- *Energy Efficiency (System Development).*
- *Traction and On-Board Energy Storage Systems.*

- **Transforming Project n°7: Rail Freight – The backbone of a green logistic chain**

In order to enable a full integration of rail freight in the multimodal logistic chain ensuring a green, sustainable door to door logistic service, this Transforming Project will focus on:

- *Digitized customer interfaces providing real-time information and data exchange on various state of the art communication channels.*
- *Automated freight train operations based on GoA4 (fully automated) linked with a new generation of railway assets tailored to automation.*
- *The multimodal integration being based on the development of federated network of platforms that will be the center part of the integration of rail freight into a multi modal logistic chain.*
- *Automated train preparation and train composition, yard and terminal handling (shunting and marshalling; automated container handling, fully automated digital coupler).*
- *Energy efficient propulsion combined with electrification of freight wagons and energy autonomy for last mile and shunting operations.*

- **Transforming Project n°8: Network management Planning and Control**

This Transforming Project will perform realistic and relevant pilots and demonstrations and hand over research results for implementation. It aims to create:

- *Higher capacity, higher punctuality and a more efficient railway system.*
- *More competitive, automated and punctual railway transports for passengers and freight.*
- *A sustainable and environmentally friendly transport system for passenger and freight.*

Annex 2 – Case study
Transforming Project

Annex 2: Case Study

Technological impact on optimised capacity

- The nodes of Munich and Bern, being currently saturated in terms of capacity, represent an interesting case study to assess how R&I can help.
- Specific ERTMS implementation stages by 2030 and 2040 show capacity increase up to +33% (in the case of Munich) and additional possible capacity gains by 2050 up to +50% considering full implementation of the S2R 1 achievements.
- The table below compares the 2050 scenario of potentially achievable capacity in the two nodes and with the estimated traffic demand taken into account as moderate growth scenario in the present study.
- This high-level calculation highlights a potential gap of 20% in capacity still to be addressed by future R&I after S2R 1 in combination with other suitable investments.

	2030	2040	2050	2050
Node/Area	*Implementing ERTMS Level 2 by 2030 (compared to 2017)*	*Implementing ERTMS Level 3 by 2040 (S2R 1)*	*Scenario with S2R 2 enabling market uptake of S2R 1*	*Estimated traffic demand (moderate scenario assuming growth rates for EU compared to 2017 are applicable in these locations)*
Munich	+5%	+33%	From +33% to +50%	+ 73% freight / 68% passengers
Bern	+4%	+25,4%	From +25,4% to +50%	+ 73% freight / 68% passengers

Annex 3 – Assumptions and sources

Annex 3: Assumptions and sources

New market share within the freight business

N°	Assumptions	External source
1	Max scenario is based on ceteris paribus traffic forecast with a shift from road to rail of 75,0% of road transport forecasted in 2050, ceteris paribus. Projections for 2030 are based on fixed annual growth rates for rail and inland waterways to achieve modal shift by 2050.	EU Reference Scenario 2016
2	Moderate scenario is based on ceteris paribus traffic forecast, shift from road to rail of 34,5% of road transport in 2050, ceteris paribus - Ambition to achieve > 50% rail modal share in 2050 in medium/long-distance passenger transport.	European Green Deal & EU Reference Scenario 2016
3	Based upon annual growth rates by mode from EU reference scenario 2016 and compound annual growth rates for rail, road and inland waterways in order to define transport demand in 2030 and 2050 with current measures in place and no EU ambitions, ceteris paribus.	EU Reference Scenario 2016

Annex 3: Assumptions and sources

Passengers' evolution

N°	Assumptions	Source
4	Max scenario is in line with high level ambition of a 25,0% modal share of rail by 2050 based on the target as per 2011 White Paper of majority of rail in medium distance passenger transport. Projections for 2030 are based on fixed annual growth rates for rail and public transport to achieve modal shift by 2050. All scenarios forecast traffic demand based on the EU Reference Scenario 2016 and compound annual growth rates for rail, road and aviation to reach their respective 2050 targets.	2011 White Paper & EU Reference Scenario 2016
5	All scenarios forecast traffic demand based on the EU Reference Scenario 2016 and compound annual growth rates for rail, road and aviation to reach their respective 2050 targets.	EU Reference Scenario 2016
6	Moderate scenario is based on ceteris paribus traffic forecast, share of rail of 19,8% to double the share of rail in 2050 compared to the EU reference scenario 2016.	EU Reference Scenario 2016
	Aviation solely consists of intra-EU flights as we deem this mode to be relevant for potential modal shift to (high-speed) rail passenger traffic.	n/a

Annex 3: Assumptions and sources

Climate change

N°	Assumptions	Source
7	Baseline emission figures are sourced from the Statistical Pocketbook 2019 for rail, road and inland waterways and from the EEA for aviation.	Statistical Pocketbook 2019, European Environment Agency
8	Assuming zero emission traction for rail and EV penetration for road in line with high scenario included in analysis by M. Noussan and S. Tagliapietra (2020) for passengers. Assuming zero emission traction for rail and EV penetration for road in line with scenarios underlying Clean planet for all (EC 2018) for freight.	M. Noussan and S. Tagliapietra (2020) Clean planet for all (EC 2018)
9	Based upon a full electrification of rail and EV fleet forecasts of EU Reference Scenario (2016) with current measures in place, ceteris paribus.	EU Reference Scenario 2016
10	CO2 emissions for each transport mode are assumed to evolve in line with growth in passenger-kms for each respective scenario. Max scenario corresponds with a 33,8% decrease in emissions for rail, inland waterways and road compared to 1990 levels and a 54,6% decrease with full electrification. Moderate scenario corresponds with a 16,8% decrease in emissions for rail, inland waterways and road compared to 1990 levels and a 30,7% decrease with full electrification. All scenarios forecast traffic demand based on the EU Reference Scenario 2016 and compound annual growth rates for rail, road and aviation to reach their respective 2050 targets.	EU Reference Scenario 2016
11	Based on ceteris paribus traffic forecast, share of rail of 19,8% to double the share of rail in 2050 compared to the EU reference scenario 2016.	EU Reference Scenario 2016

N°	Assumptions	Source
12	Based upon annual growth rates by mode from EU reference scenario 2016 in order to define passenger transport demand in 2030 and 2050 with current measures in place and no EU ambitions, ceteris paribus. Passenger car emissions are assumed to grow in line with projected passenger-kms adjusted for an increase in emission efficiency based on projected gCO2/km in 2030 and 2050, respectively (EU Reference Scenario 2016).	EU Reference Scenario 2016

Clean technology / EV penetration		Freight			Passengers		
		2050			2050		
% total fleet		Rail	Inland waterways	Road	Rail	Road	Aviation
Max - Combined scenario	(a)	100,0%	30,0%	30,0%	100,0%	72,0%	13,0%
Moderate - Combined scenario	(b)	100,0%	15,0%	15,0%	100,0%	28,0%	11,6%
Min - Ceteris paribus	(c)	100,0%	1,0%	2,3%	100,0%	2,3%	10,7%

Annex 3: Assumptions and sources

Jobs

N°	Assumptions	Source
13	Baseline infrastructure in terms of traffic unit is based on total train kms. Forecasted infrastructure for each scenario is assumed to grow in line with freight and passenger traffic units and a 82,2% vs 17,8% split between passenger and freight traffic.	Statistical Pocketbook 2019
14	Baseline direct employment within freight and passenger is based on 660,7k railways jobs split between passenger (82,2%) and freight (17,8%) in line with the traffic split measured in train-kilometres sourced from the Statistical Pocketbook.	Statistical Pocketbook 2019
15	Total baseline infrastructure jobs within rail are based on employees of infrastructure managers as of 2016 and annual growth in staff of infrastructure managers between 2011 and 2016 (-0,18% adjusted for outliers) to estimate the 2017 baseline level.	RMMS 2018
16	We estimate the effects of automation to increase productivity in all scenarios of 20% (2030), 50% (2040) and 60% (2050) compared to the baseline.	n/a
17	The ratio of indirect to direct jobs of 1,14 is calculated by dividing 1,21 million persons indirectly employed in the railway transport sector by 1,06 million directly employed in 2012.	Ecorys 2012

Annex 3: Assumptions and sources

Economic growth

N°	Assumptions	Source
18	Traffic units for freight, passengers, infrastructure and railway manufacturing are tonne-kilometers, passengers kilometres and train kilometres, respectively. Baseline gross value added for each subsector is based on study on the cost and contribution of the Rail Sector (2015) by SDG for the Commission corresponding with a split of 30% for infrastructure and 70 % for operations (freight & pax). It should be noted that forecasts of gross value added includes subsidies paid by governments.	Ecorys (2012); SDG (2015)
19	Railway manufacturing gross value added in baseline amounts to 7,363 €million (6806+556,6).	Eurostat SBS railway supply industry data covering NACE Rev. 2 code 30.2 Manufacture of railway locomotives and rolling stock
20	Gross value added results are in nominal terms and do not take into account inflation	N/A

Automation & LCC reduction (%)		2030	2040	2050
Max - Combined scenario	(a)			
Automation		-20,0%	-50,0%	-60,0%
LCC reduction		-25,0%	-50,0%	-60,0%
Moderate - Combined scenario	(b)			
Automation		-20,0%	-50,0%	-60,0%
LCC reduction		-25,0%	-50,0%	-60,0%
Min - Ceteris paribus	(c)			
Automation		-20,0%	-50,0%	-60,0%
LCC reduction		-25,0%	-50,0%	-60,0%

N°	Assumptions	Source
21	Estimated traffic demand as per moderate scenario forecast. Relevant traffic growth rates for the EU compared to 2017 are applicable in these locations.	In fluence of the ETCS in the capacity of nodes (UIC May 2010).

Annex 4 – Résumé Executif

Annex 4: Résumé Executif

Domaine d'étude

Ce rapport fournit une analyse quantitative à haut niveau et à long terme de l'impact potentiel du prochain programme de R&I ferroviaire sur la société européenne, en particulier concernant :

- Le changement climatique
- L'emploi
- La croissance économique
- L'évolution des passagers
- La croissance des parts de marché du ferroviaire dans le secteur du fret
- La compétitivité industrielle / l'exportation

Les analyses et les estimations ont été basées sur des scénarios optimisés tant du point de vue du développement technologique que de la mise en œuvre des politiques. Ces scénarios sont considérés comme des conditions préalables fondamentales pour transformer le système ferroviaire actuel en mode de transport dominant de la mobilité européenne de demain, en particulier pour le fret.

Context

- *L'activité de R&I dans le secteur ferroviaire est destiné à améliorer certains paramètres clés du réseau ferroviaire, tels que: **sa capacité, sa ponctualité (fiabilité) et le coût du cycle de vie**. La capacité est une condition (physique) essentielle pour répondre à la demande future. La ponctualité et le coût du cycle de vie sont des aspects cruciaux pour accroître la compétitivité du système ferroviaire par rapport aux autres modes de transport.*
- *Les volumes ferroviaires devraient vraisemblablement augmenter massivement et dépendront des ambitions liées à la décarbonisation du système de transport européen.*

Base de référence: 2017 **2030** **2040** **2050**

Annex 4: Résumé Executif

Bases de travail

1. Le processus d'évaluation a été mené en tenant compte des nouvelles perspectives de marché pour le secteur du transport ferroviaire, avec des scénarios optimisés concernant :
   - L'offre et la compétitivité des services ferroviaires, grâce à l'impulsion actuelle et future de la R&I, et
   - Les projections de la demande et la politique de l'UE en faveur d'une plus grande part du ferroviaire dans la répartition modale.

2. Les réalisations, les ambitions et le délai de mise sur le marché des développements du programme actuel de R&I (S2R 1) ont été analysés, ainsi que la contribution du nouveau programme de R&I (S2R 2) sur l'amélioration de la compétitivité du système ferroviaire.

3. La croissance du trafic ferroviaire a été projetée en tenant compte des différents objectifs de la politique de l'UE pour le secteur des transports d'ici 2050, ainsi que des émissions du secteur et des scénarios de transfert au mode ferroviaire.

4. Compte-tenu de la proportion accrue qu'occupe le secteur ferroviaire dans les modes de transports actuels, il a été possible d'estimer la croissance de l'industrie ferroviaire d'ici 2030, 2040 et 2050. Les projections du secteur ferroviaire de demain ont servi de base pour évaluer l'interaction et l'impact du ferroviaire sur les domaines étudiés.

5. Dans le scénario de croissance modérée, l'augmentation de la capacité ferroviaire estimée ne sera durable que si elle est soutenue par un investissement substantiel en R&I. L'étude de cas (annexe 2) démontre le manque de capacité à moyen et long terme, pouvant être comblé grâce au déploiement de projets S2R 1 de maturité élevée et aux nouveaux projets de transformation de S2R 2.

Annex 4: Résumé Executif

Résultats

- Nos estimations montrent que, par rapport à 2017, le transport ferroviaire pourrait avoir les impacts suivants d'ici 2050 :

	Domaine d'impact	Mesures	Scenario Modéré	Scenario Haut
	Changement Climatique	Émissions de CO2 évitées	> 6.300 MtCO2	> 8.400 MtCO2
	Emploi	Emplois directs et indirects	4,8 million	6,4 million
	Croissance Economique	Valeur ajoutée brute	> €350 milliards	> €470 milliards
	Evolution des passagers	Trafic (% part modale)	> 1.800 milliards pkm (20%)	> 2.200 milliards pkm (25%)
	Fret ferroviaire	Trafic (% part modale)	> 1.500 milliards de tonnes-km (45%)	> 2.600 milliards de tonnes-km (76%)
	Compétitivité industrielle / Exportation	Niveaux d'exportation des solutions clés en main		

- Des détails supplémentaires concernant l'évolution des impacts en 2030, 2040 et 2050 ainsi que les scénarios appliqués sont présentés dans la section 4.

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