UIC HIGHSPEED
Morocco 2023

HIGH-SPEED RAIL : THE RIGHT SPEED FOR OUR PLANET
Under the High Patronage of his Majesty King Mohammed VI

Session2.5, Room Fez 2
Environment / CO2 emissions

Moderator : Ms. Lucie Anderton
Head of Sustainability, UIC, France

ONCF UIC

Session2.5
Environment / CO2 emissions
Speaker Lists;

1

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Mr.Ragi Edge

Spain

5

Mr.ABDULLAH MURAT ESER

Turkey

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11TH WORLD CONGRESS OF HIGH-SPEED RAIL

Marrakech, 7-10 MARCH 2023

THE ROLE OF RAILWAY IN THE FIGHT AGAINST CLIMATE CHANGE

Jonathan Sánchez García
Deputy Director of Corporate Responsibility, Sustainability and Brand. Adif. Spain
Session5-2.5 Environment / CO2 emissions

CONTEXT
Regulation and goals

13 CLIMATE ACTION

PARIS2015 UN CLIMATE CHANGE CONFERENCE COP21·CMP11

The European Climate Law

2030 (EU):
- 55% GHG emissions reduction
- 38,5% Renewable energies in final consumption
- 36% Improving energy efficiency

2040 (EU):
- 60% GHG emissions reduction

2050 (EU): carbon neutral

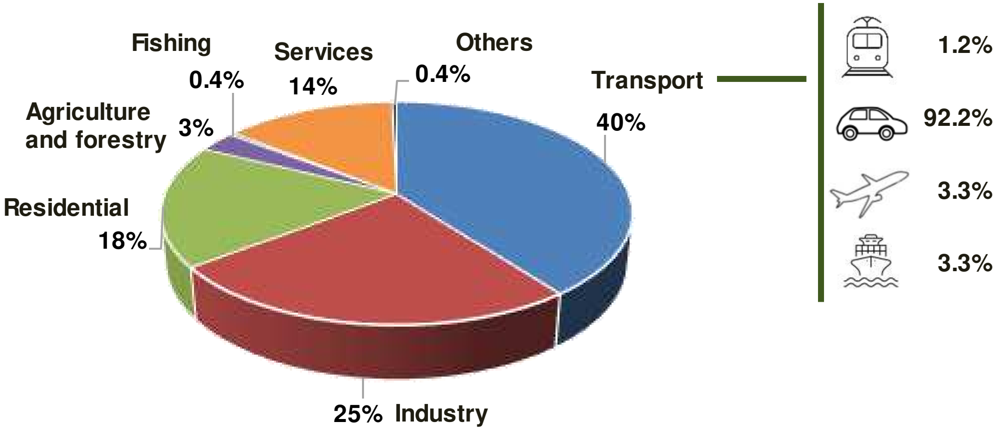
2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050

2030 (Spain):
- 74% Renewable energies in electricity generation
- 23% GHG emissions reduction
- 42% Renewable energies in final consumption
- 39,5% Improving energy efficiency

2050 (Spain):
- 90% Renewable energies in electricity generation
- 60% GHG emissions reduction
- carbon neutral

CONTEXT

Railway energy consumption and GHG emissions in Spain

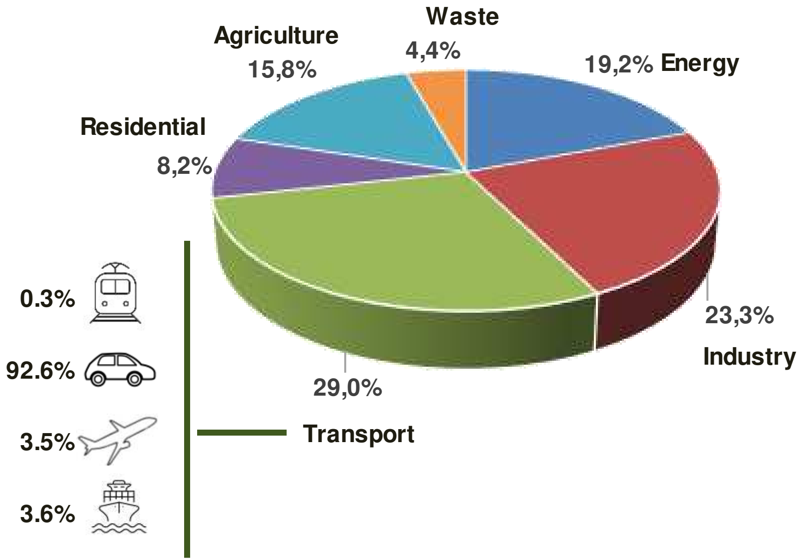


Energy consumption by sectors (2019)

Source: OTLE https://observatoriotransporte.mitma.es/

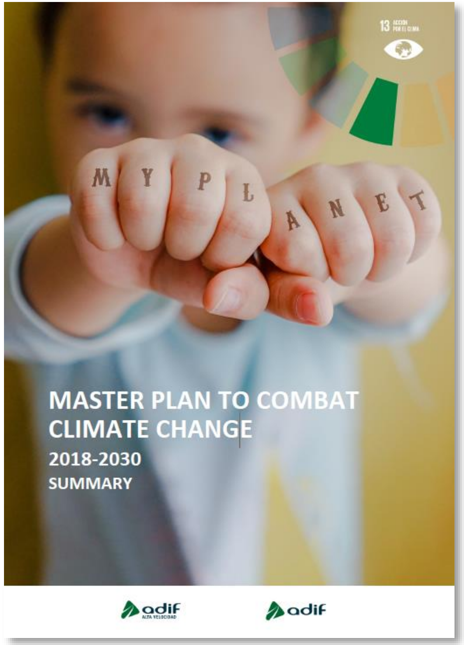
GHG emissions by sectors (2019)

Source: OTLE https://observatoriotransporte.mitma.es/



MASTER PLAN TO COMBAT CLIMATE CHANGE

Strategic framework



MASTER PLAN TO COMBAT CLIMATE CHANGE

Main lines of action and goals

INCREASING THE CONTRIBUTION OF ADIF AND ADIF-AV TO COMBAT CLIMATE CHANGE

MITIGATION

Reducing energy consumption and GHG emissions

ADAPTATION

Improving resilience of railway infrastructure

CULTURE AND AWARENESS

Promoting environmental awareness among stakeholders

MASTER PLAN TO COMBAT CLIMATE CHANGE

Plan structure

SCOPE

LINES OF ACTION	PROGRAMMES
1. Energy Management	1.1 Smart Grid implementation 1.2 Telematics measurement and control systems 1.3 Management measures
2. Energy Efficiency	2.1 Lighting improvement 2.2 Efficiency in HVAC and DHW equipment 2.3 Equipment improvement 2.4 Reversible Substations 2.5 Reactive power reduction
3. Decarbonisation and renewable energy	3.1 Electrification programme 3.2 Fossil fuel substitution 3.3 Renewable energies promotion 3.4 Rail modal shift promotion
4. Improving resilience of railway infrastructure	4.1 Monitoring and follow-up of CC impacts 4.2 Climate impact assessment of railway infrastructure
5. Culture and awareness	5.1 Actions for employees 5.2 Actions for partners and suppliers 5.3 Transparency and information improvement

MASTER PLAN TO COMBAT CLIMATE CHANGE

Gobernance model and implementation

Working Group on Climate Change

IMPLEMENT

ANNUAL Implementation Plan

- Project sheets

FOLLOW

BIANNUAL Plan Monitoring

- Monitoring sheets
- Monitoring reports

COMMUNICATE

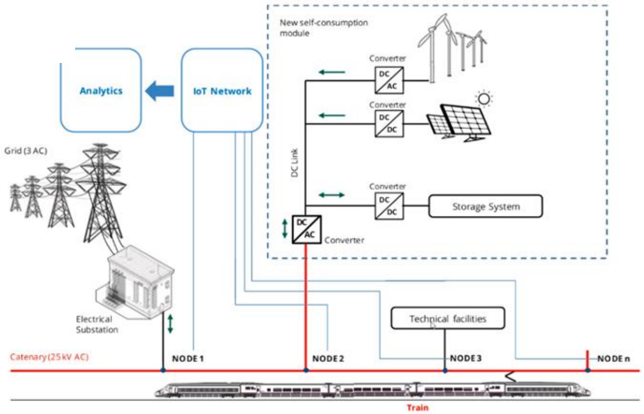
Internal and external communication

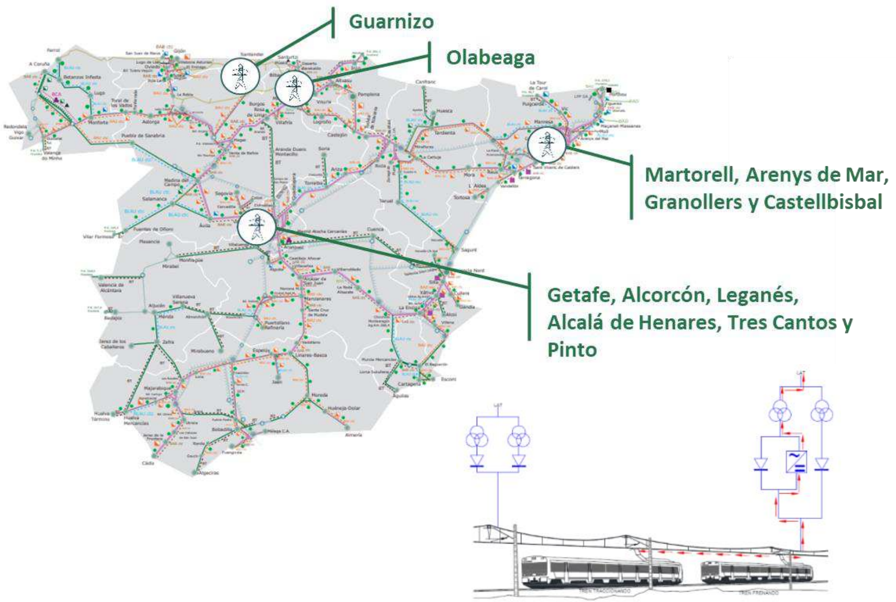
- Content dissemination
- State of progress information

MASTER PLAN TO COMBAT CLIMATE CHANGE

Main actions in mitigation

Railway smartgrid

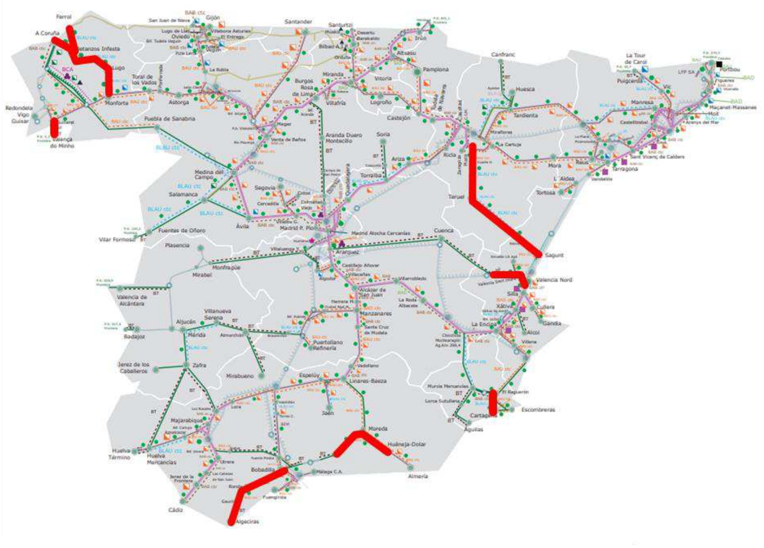




Reversible traction power substations

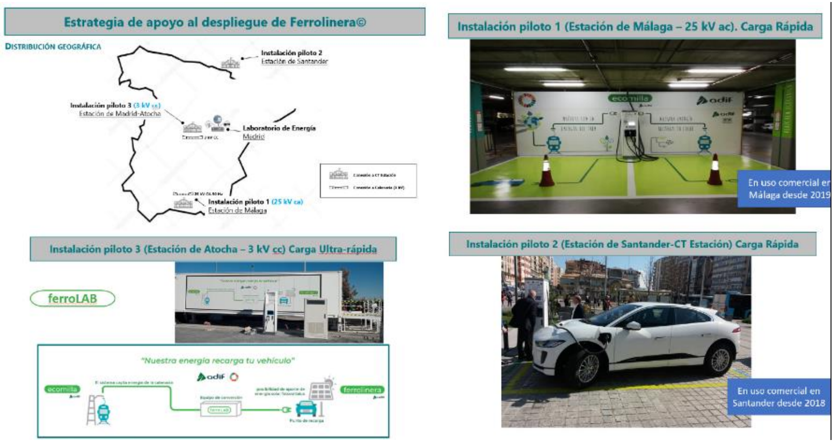
MASTER PLAN TO COMBAT CLIMATE CHANGE

Main actions in mitigation



Electrification of railway sections

Charging points for electric vehicles



MASTER PLAN TO COMBAT CLIMATE CHANGE

Main actions in mitigation

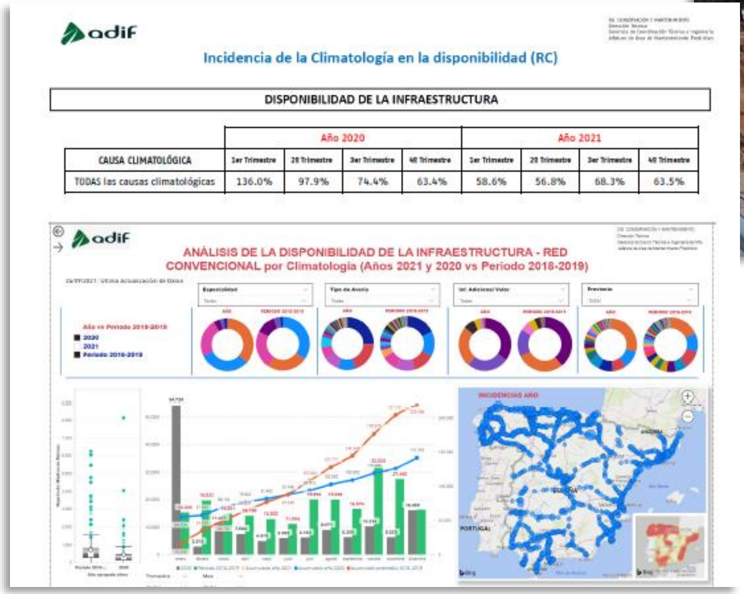
‘Green’ electric power supply (with Guarantees of Origin)

Power self-supply Plan

MASTER PLAN TO COMBAT CLIMATE CHANGE

Main actions in adaptation

Monitoring the impact of climate change on railway infrastructures


adif

Incidencia de la Climatología en la disponibilidad (RC)

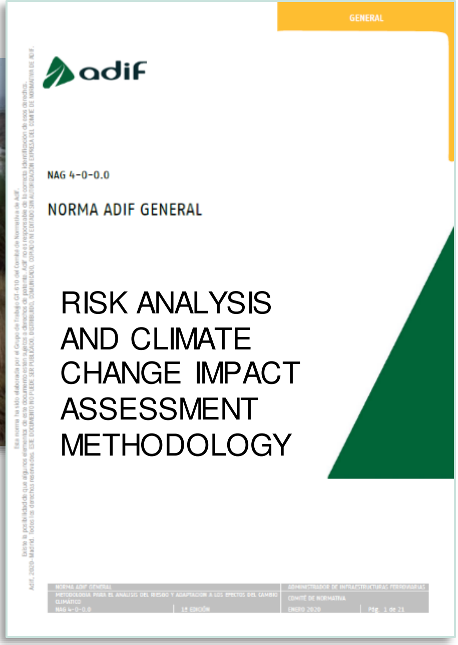
DISPONIBILIDAD DE LA INFRAESTRUCTURA

CAUSA CLIMATOLÓGICA	Año 2020				Año 2021			
	1er Trimestre	2º Trimestre	3er Trimestre	4º Trimestre	1er Trimestre	2º Trimestre	3er Trimestre	4º Trimestre
TODAS las causas climatológicas	136.0%	97.9%	74.4%	63.4%	58.6%	56.8%	68.3%	63.5%

adif

ANÁLISIS DE LA DISPONIBILIDAD DE LA INFRAESTRUCTURA - RED CONVENCIONAL por Climatología (Años 2021 y 2020 vs Periodo 2018-2019)

Nudo de La Encina (railway junction). September 2019



Assessing the impact of climate change on railway infrastructures

THANK YOU

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AUDITED CARBON REDUCTIONS FOR ENCOURAGING SUSTAINABLE MODAL SHIFT

Yangbo DU
Managing Partner - Investments, INNOVO Net Zero, United States
Session 5 – 2.5 Environment / CO2 emissions

ONCF UIC

OUTLINE

Overview of audited carbon reductions [ACRs] and how they can encourage shift to rail

- Precedents for promoting clean growth and development and sustainable modal shift
- How ACRs compare against traditional carbon credits
- Business and climate case for ACRs

Implications for climate-smart urban and territorial development

- Double materiality and induced impacts
- Case studies
  - Established: Tokyo (Shinagawa), Toyama, Lyon (Part Dieu), Amsterdam (Zuidas)
  - Emerging: New York (Queens), Albany (Rensselaer), Baltimore (Penn), Buffalo (Central)

Integrating ACRs into practice – launch of Greenhouse Gas Initiative [GHGi] and Net Zero Marketplace

PRECEDENTS UNDERLYING AUDITED CARBON REDUCTIONS

Clean Development Mechanism [CDM] - UN Framework Convention on Climate Change

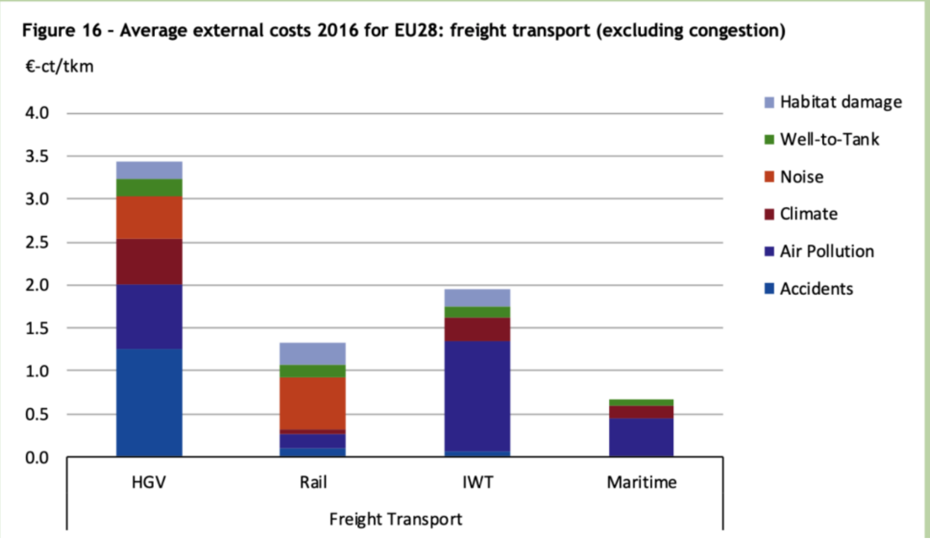
- Delhi Metro Rail Corporation – over half a million tonnes of additional CO2 emissions avoided each year since 2011
  - First urban rail system to earn carbon credits

External Costs of Transport Handbook – European Commission

- Basis for True Cost Calculator by Solutionary Rail (2021)
  - Developed in support of efforts to shift medium/long-haul freight in U.S. to rail

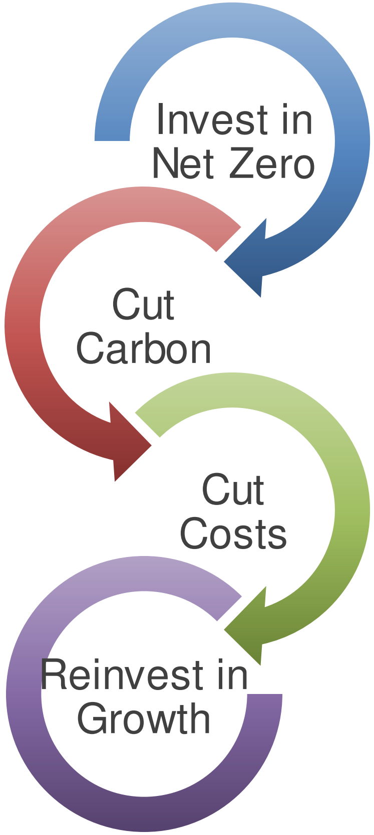
Private sector supplier engagement on reducing Scope 3 greenhouse gas emissions

2019 EU Handbook on the External Costs of Transport

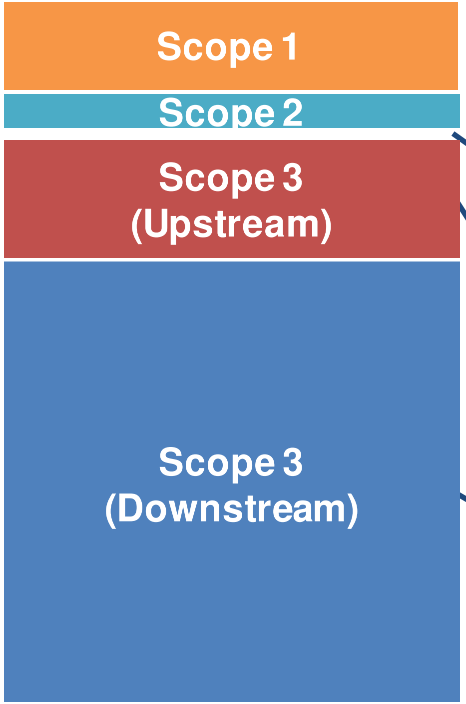


WHAT ARE AUDITED CARBON REDUCTIONS?

TRADITIONAL CARBON CREDITS	AUDITED CARBON REDUCTIONS
Sold off for cash value	Passed from suppliers to buyers along supply chains
External market	Internal market (pricing less of a concern)
Offset or abatement	Abatement only



WHY AUDITED CARBON REDUCTIONS?



Scope 1 (13%)
Direct emissions from owned or controlled sources

Scope 2 (5%)
Indirect emissions from purchased electricity, steam, heating, or cooling

Scope 3 – Upstream (17%)
Indirect emissions from purchased goods & materials

Scope 3 – Downstream (65%)
Indirect emissions from use of product or service

87%

outside direct control
(Accenture, 2021)

IMPLICATIONS FOR CLIMATE-SMART, EQUITABLE TERRITORIAL DEVELOPMENT

Double materiality principle – broader economic, social, and environmental impact of a firm's decisions

- Another incentive to site destinations with location efficiency in mind

Reducing induced emissions ("Scope 3+"/"Scope 4")

- Reversing "job sprawl" by encouraging clustering of destinations in walkable and transit-accessible places
  - Multi-sectoral coordination advised

Integrated planning essential given path dependence

- Best to have a strong urban core to "seed" activity centres along rail lines
  - Opportunity in normality of hybrid work

EXTENDING AN ALREADY-STRONG CENTRAL BUSINESS DISTRICT

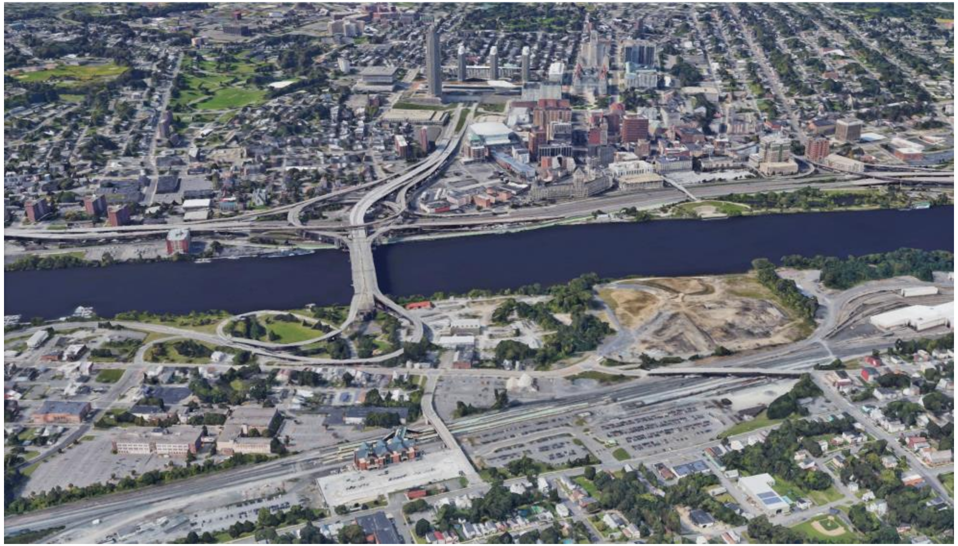
Shinagawa Station area, Tokyo (left) and Sunnyside Yard area, New York (right)

- Each station (or future station) area as an extension of main central business district

STRENGTHENING AN URBAN CORE BY HSR LINK TO A LARGER METROPOLIS

Toyama Station area (left) and Albany-Rensselaer Station area (right)

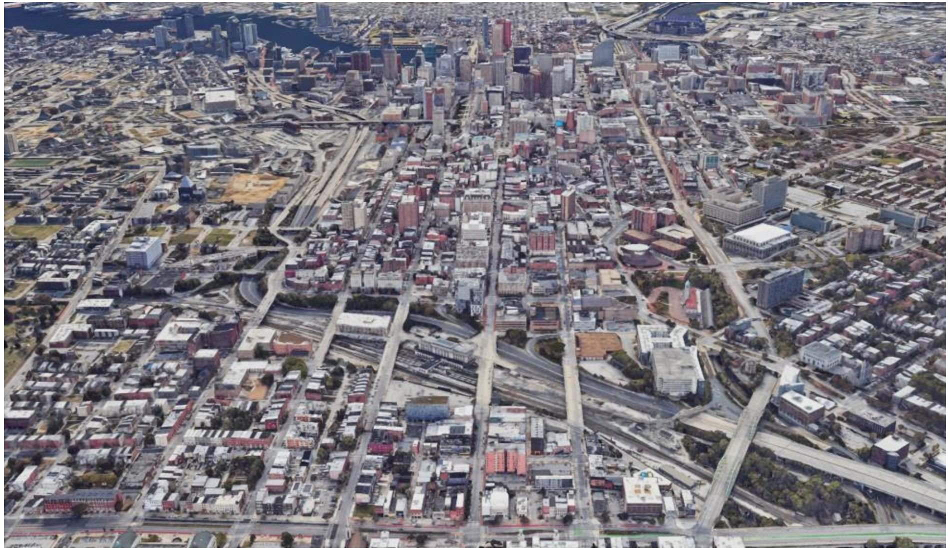
- Fast existing rail link to Tokyo (within two hours) and future rail link to New York (within one hour)



POSITIONING STATION AREAS AS MAIN CORE ACTIVITY CENTRES

Lyon Part Dieu (left) and Baltimore Midtown (right)

- Effectively creating a second central business district comprising the station area (indicatively in the case of Baltimore)



CREATING STRONG SECONDARY BUSINESS DISTRICTS

Amsterdam Zuidas Station area (left) and Buffalo Central Station area (right)

- Transit-oriented outlying business districts enabled by frequent rail connections (indicatively in the case of Buffalo)

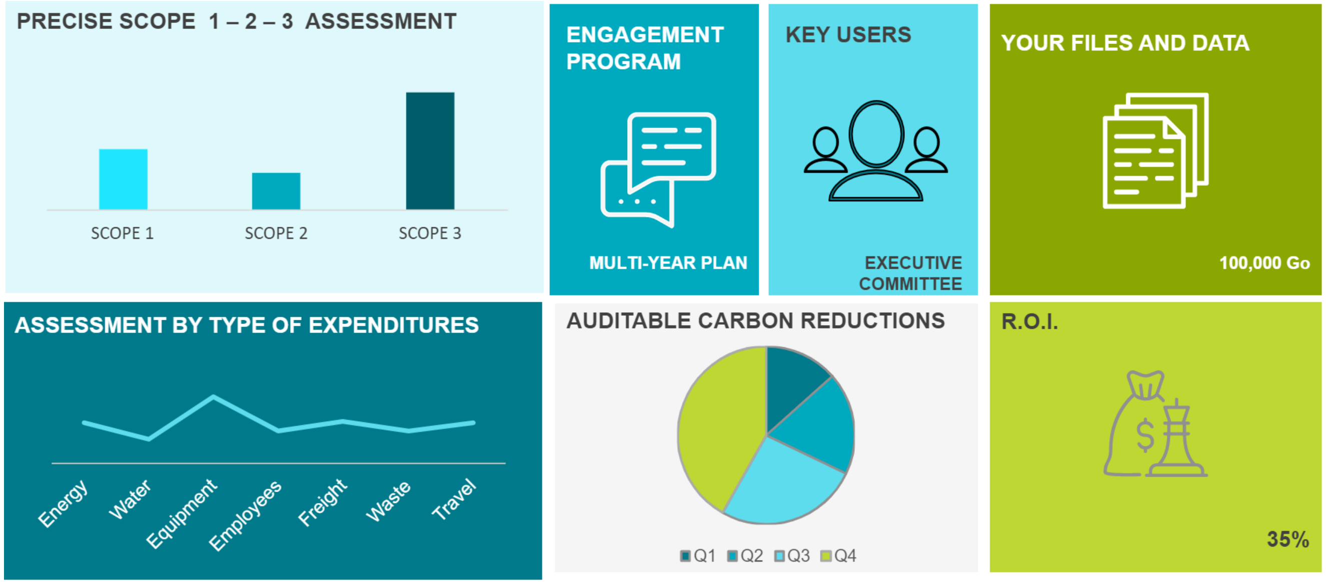
INTEGRATING AUDITED CARBON REDUCTIONS INTO MAINSTREAM PRACTICE

Greenhouse Gas Initiative [GHGi] (pilot assessments under way)

- Insights on GHG abatement potential – no full footprint exercise necessary

Profitable Net Zero Marketplace (now live)

- Platform for buying and selling with ACRs
- Progressive rollout through 2023



THANK YOU

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ikos Innovation&Technologies — LGi Laboratoire Génie Industriel — CentraleSupélec

Present this study of a

LIFE CYCLE ASSESMENT-BASED TOOL FOR LOW EMISSION TRAINS DEPLOYMENT

Benoît, Volant
PhD Candidate, Ikos, France
Session5-2.5 Environment / CO2 emissions

ONCF UIC

Context & motivations

France's regional trains are mostly **electric trains with pantographs and diesel tanks** for rails without catenaries

National strategy aims for a **28%** emission reduction of transports for **2030** compared to 2015
[French Ministry of transport, 2021]

Unelectrified lines could be closed if no low emission alternative is found

Emerging **low emission trains** could reduce unelectrified lines environmental impact

40 years

Trains lifetime

20 years

Trains mid-life : retrofit maintenance

2023 to 2034

Many France's regional trains reach mid-life

A complex technological context

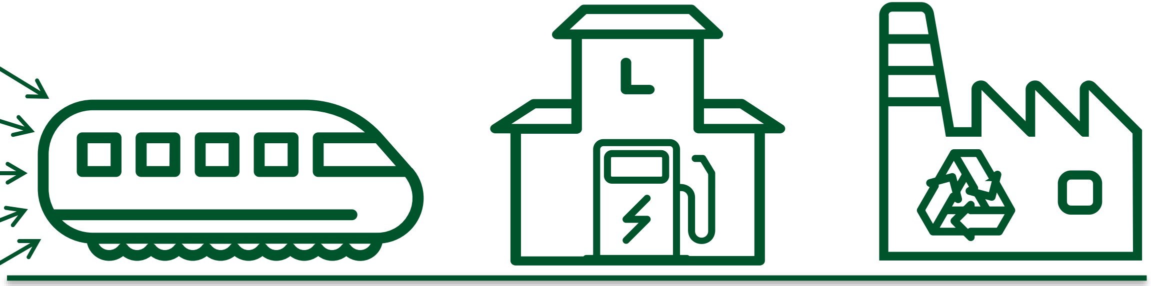
- **Which technologies will be mature enough to replace Diesel trains?**
- **Which analysis method of environmental impact is best suited to compare these technologies?**
- **Does the literature contains similar analysis for trains or other vehicles?**

Technologies	Characteristics	TRL [DoD 2010]	
Hybrid	**1000 km** max autonomy **20%** Consumption reduction	2022 2023	**8** **9**
Batteries	efficiency **>70%** Avoid direct emissions	2022 2024	**8** **9**
Hydrogen	**600 km** max autonomy Avoid direct emissions	2016 2024 2026	**7** **8** **9**
Biogas	**1000 km** max autonomy	2017	**6**
Biofuel	**1000 km** max autonomy	2019 2021	**7** **8**

Life cycle

Production Infrastructure Transport	Exploitation Alimentation Maintenance	End of life Elimination Revalorisation

technologies



Stakeholders

- State & Regions
- Operators
- Industrials
- Users

Choice Criteria [interview Nouvelle-Aquitaine]

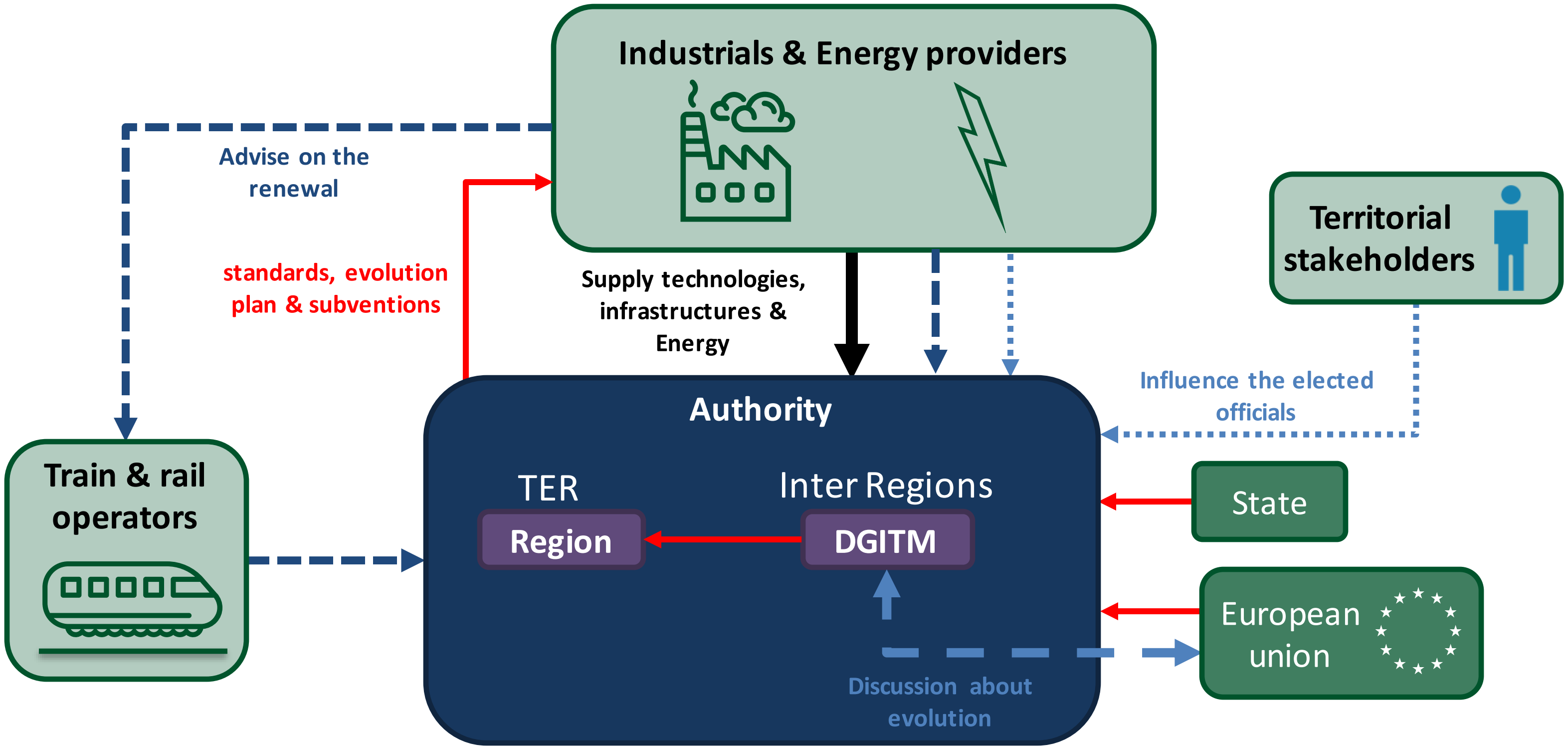
Environmental impacts	Cost	Delay before implementation	Exploitation conservation	Social impact	Energy sources homogenisation

- Green house gases
- Resources consumption
- Water & soil degradation…

- Power
- Autonomy

- Territorial development
- Security

Interactions between stakeholders



Low emission train design and deployment: a complex issue

Locks regarding the right choice of diesel trains replacement

- **Environmental vs. economic** performance depending on the territory
- **Operation vs. infrastructure costs** depending on the type of line
- Environmental and/or economic **performance vs. technological maturity**

Locks to developing the right evaluation method

- Measurement of **environmental performance vs. technological maturity**
  - maturity assessment
  - mathematical model of uncertainties
- Measurements **accuracy vs. complexity** of their implementation
- **Exhaustiveness of criteria vs. relevance & user friendliness**

Environmental assessment methods selection

Environmental risk assessment

- effects on the environment of a disruptor that may disrupt it
  - Pesticides, aliments and pharmaceutical products

Environmental performance KPI

- Identification and following of an organism environmental KPI

Environmental audit

- Information's review of the environmental impact of an economic activity
  - To show compliance with a regulation or to find a way to comply

Environmental Impact Assessment (EIA)

- A process that assesses the risks of environmental impacts arising from a project from the planning stage

Not designed to confront different **criteria** and **stakeholders** nor to apprehend **uncertainty**

Life Cycle Assessment (LCA) *[ISO 14044]*

- compilation of the inputs and outputs to evaluate the potential environmental impacts of a product system throughout its life cycle

Thought for comparison

Life Cycle Assessment

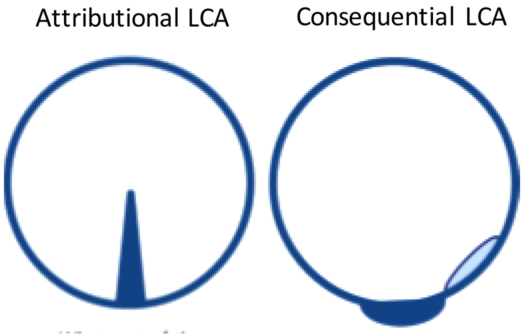
Different LCA definitions

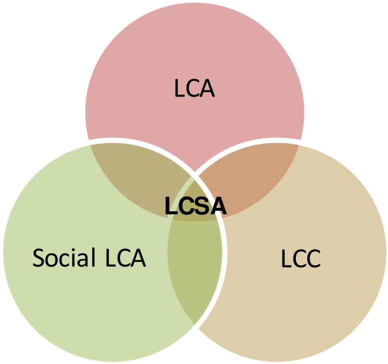
- Fast LCA
- Simplified LCA [Descos, 2017]
- Prospective LCA
- Attributional & Consequential LCA [Ekvall 2019]
- Social & Sustainability LCA [Kloepffer 2008]

Uncertain integration and sensitivity analysis [Leroy et al. 2013]

Methods to value & optimise LCA results [Moni et al. 2020]

- Communicate assumptions
- Use **multiple scenarios** in terms of co-products usage and allocation methods
- Relevance analysis to focus on more **relevant processes**





Benchmark

Vehicules LCA

- **Trains, parallel** with Netherland [Kapetanović et al. 2022]
  - The analysis encompassed the retrofit of a standard vehicle to its hybrid-electric, fuel cell-electric and battery-electric counterparts, and a comparative assessment of life cycle emissions during a **ten-year** time horizon.

- **Differences** with **electric cars** [Zackrisson et al. 2010]
  - lithium iron phosphate (**LFP**)
  - The functional unit was defined as a **10 kWh battery** for a plugin hybrid electric vehicle capable of sustaining 3 000 charge cycles at 80% maximum discharge giving at least a 200 000 km operation during the vehicle design lifetime.

- **Parallel** with **buses** [Ager-Wick Ellingsen et al. 2022]
  - Currently, Li-ion battery technology for BEBs mainly pertains to lithium titanium oxide (**LTO**), lithium iron phosphate (**LFP**), and lithium nickel manganese cobalt oxide (**NMC**).
  - **Catenaries**

Next steps

Tailor an **LCA-based tool**

- Hybrid between **Attributional** & **Consequential** LCA
- Importance of implementing **Social** & **Sustainability** LCA

Measure **uncertainty**

- Build a mathematical model
- Consider technological variability

Create an **analysis tool**

- considering all choice criteria and temporality factors
  - Each technology **maturity**
  - Current and future traction and infrastructure **aging**
  - Environmental impact reduction **deadlines**
- To help choose an adequate technology regarding **traction** and **infrastructures**

THANK YOU

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TALGO´s Avril train: A sustainable industrial landmark through EPD design

Ragi Edde
Head of Business Development Middle East & Africa
TALGO, Spain

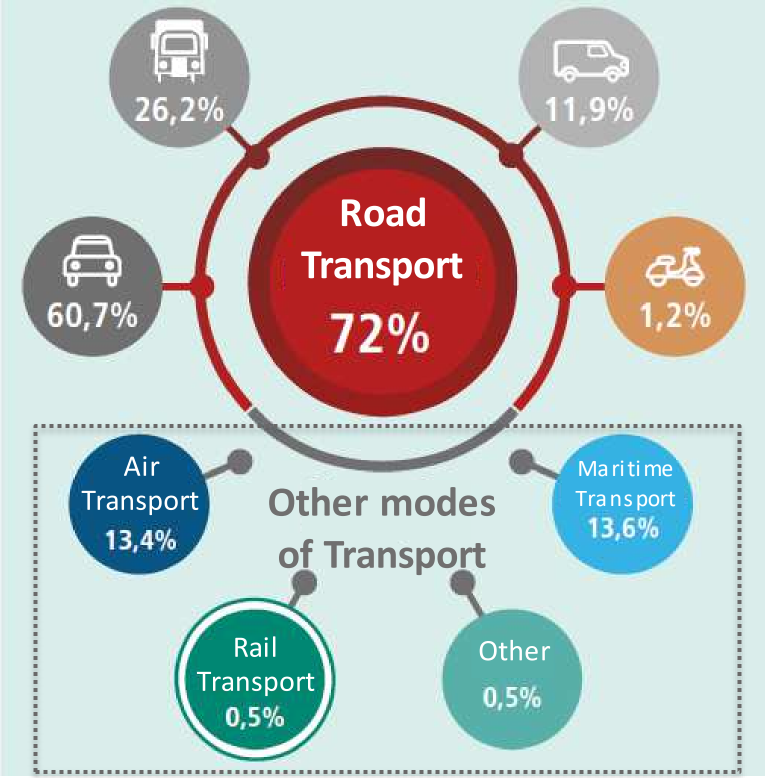
Session5-2.5 Environment / CO2 emissions

CO2 emissions per passenger

Transport
is responsible for more than
30% in EU

Other modes of transport
emit
29.5%

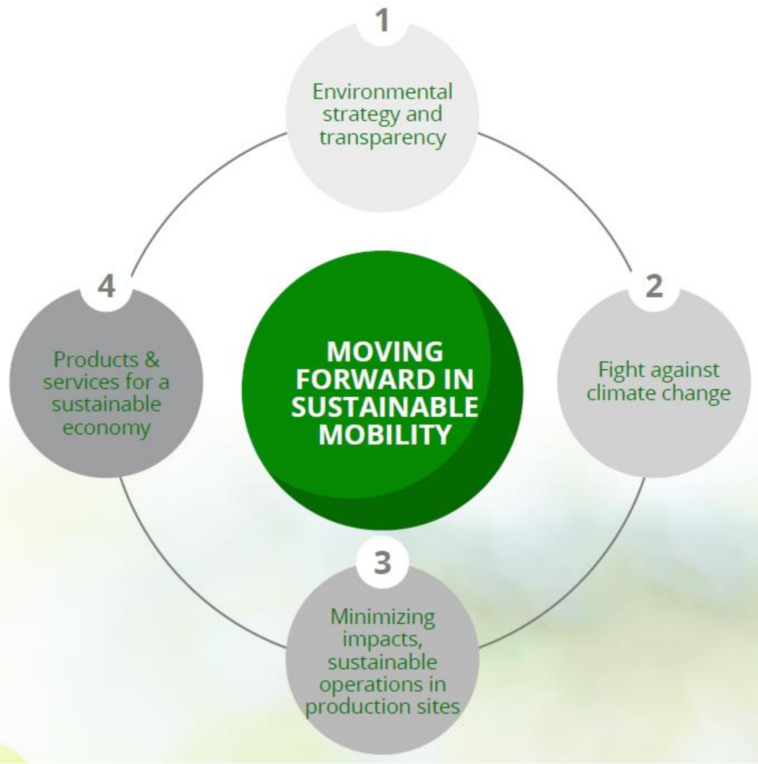
Rail Transport
emits only
0.5%



Rail Transport
represents for
9%
of global mobility demand

Efficiency in the capacity
to transport people

Advancing environmental sustainability and sustainable mobility



Talgo AVRIL product platform

MASS (kg)	**327.210,7**
LENGTH (mm)	202.000
CAPACITY (seats)	579 + 2 PRM
DOORS (per side)	10 - 1 per car
MAX SPEED (Km/h)	**363**
INTERIOR WIDTH (mm)	3.100
POWER SUPPLY VOLTAGE (kv)	25
POWER (kW)	8.000
ENERGY CONSUMPTION (kWh/km)	**< 13,7**
RECOVERABILITY/RECYCLABILITY (%)	**96,9% / 93,8%**
LIFE CYCLE (year)	**40**

Source: EPD Platform TALGO AVRIL

Talgo AVRIL product platform

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Short Coaches Configuration
↑↑Width Coaches
3+2 ↑↑CAPACITY

Lightweight design
↓↓30%

Unlimited Accessibility
deck = platform
↓↓20% Dwell Time

MAXIMUM EFFICIENCY

Source: EPD Platform TALGO AVRIL

Talgo AVRIL product platform

Short Coaches Configuration
↑↑Width Coaches
3+2 ↑↑CAPACITY

Lightweight design
↓↓30%

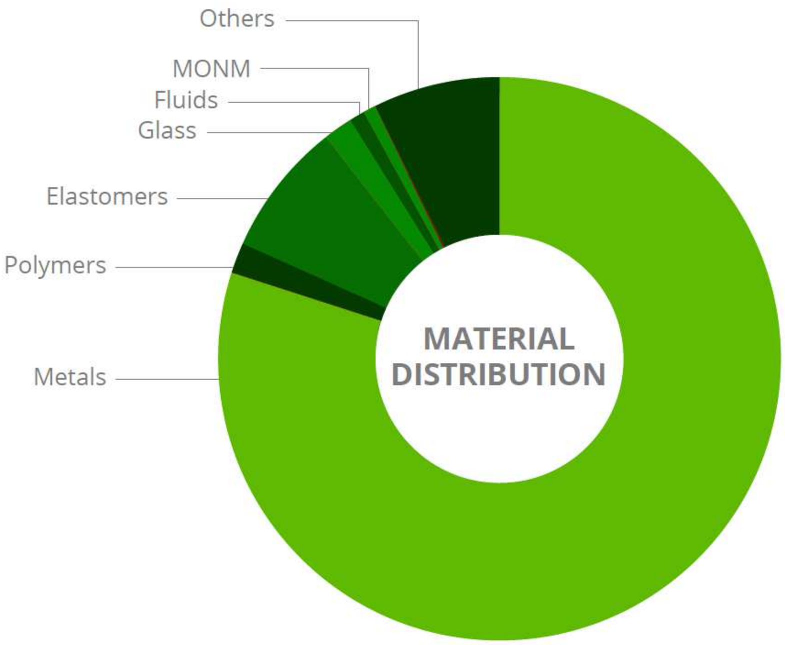
Unlimited Accessibility
deck = platform
↓↓20% Dwell Time

MAXIMUM EFFICIENCY

Source: EPD Platform TALGO AVRIL

Innovative Manufacturing

MATERIAL	
Metals	80,05%
Elastomers	1,33%
Polymers	8,46%
Glass	1,46%
Fluids	0,32%
MONM	0,34%
Others	8,03%



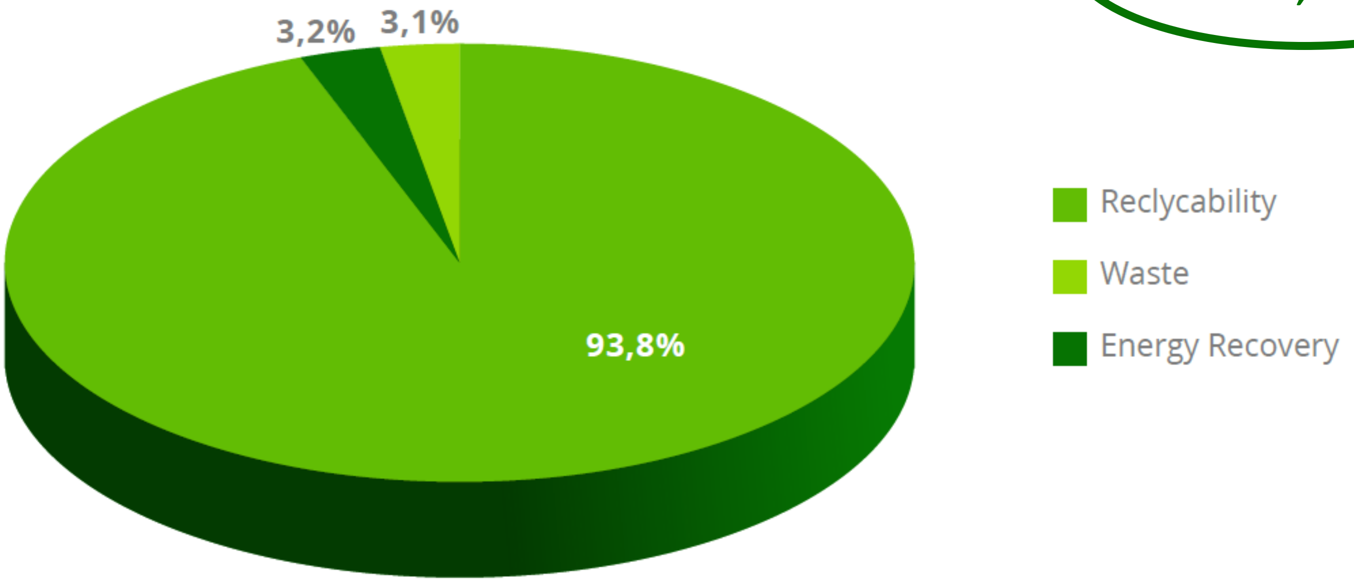
Material group distribution according to ISO 22628

Carbon Fibre
for the front of the driving parts

Source: EPD Platform TALGO AVRIL

Recyclability

Recoverability
96,9%



Recyclability, energy recovery and waste values according to UNI-LCA-001.00

Source: EPD Platform TALGO AVRIL

LCA - Life Cycle Analysis

LIFE CYCLE - cradle to grave

UPSTREAM
Production

- Extraction and production of raw materials
- Transport of raw materials

CORE
Production & Manufacturing

- Energy and water consumption
- Auxiliary materials
- Transport to consumer
- Waste generated and treatment

DOWNSTREAM
Maintenance & Use

- Energy consumption
- Maintenance materials
- Waste from maintenance materials
- Direct disposal at the end of life

Source: EPD Platform TALGO AVRIL

Model	Company	Mass (Tn)	Length (m)	Speed (km/h)	Capacity (nº pax)	Energy Consumption (kWh/km)	GWP Emissions ($g.CO_{2eq}$/pax.km)	Recoverability (%)	Recyclability (%)	Noise Stationary (dBA)	Noise Starting (dBA)	Noise Pass-by (dBA)
High Speed Train average	Trains Manufacturer	[400 – 500]	~200	[250 - 360]	[400 - 600]	[10 - 20]	[5 - 25]	[94 - 99]	[93 - 96]	[60 - 70]	[80 - 90]	[>90]
TALGO AVRIL	**TALGO**	**330**	**202**	**363**	**581**	**13,7**	**8,56**	**96,9**	**93,8**	**64**	**79**	**92**

Source: EPD

THANK YOU

11TH WORLD CONGRESS OF HIGH-SPEED RAIL

Marrakech, 7-10 MARCH 2023

Evaluation of Environmental Impacts and Economic Benefits of Greenhouse Gas Emissions of High – Speed Rail Lines in Türkiye

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Engineer, Turkish State Railways, Türkiye
Parallel Sesion 5 – 2.5 Environment/CO2 emssions

CONTENT

Existing and planned high – speed rail lines in Türkiye

- ❖ 1.432 km of high – speed rail line (HSR) is under operation
- ❖ 3.710 km of high – speed rail line (HSR) is under construction until 2027

Data collecting

- ❖ TCDD,Scientific studies, guidelines, handbooks and statistical datasets

Methodology

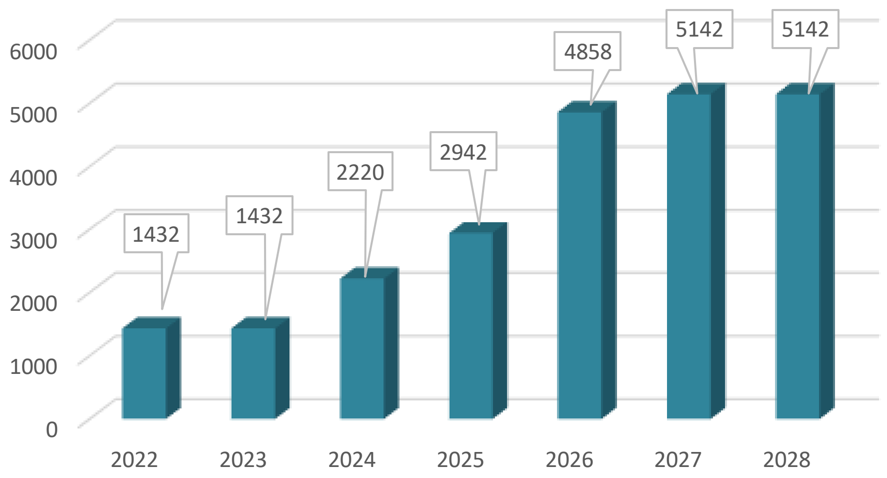
- ❖ Routes, passenger traffic demands and assumptions on HSR
- ❖ Environmental impacts – Greenhouse Gas Emissions
- ❖ Economic benefits – Externality costs

Conclusion

EXISTING AND PLANNED HIGH – SPEED RAIL LINES IN TÜRKİYE

Existing and planned high – speed rail lines were planned as double lines

Expected High - Speed Rail Lengths (km)



Stations		Distance (km)	Operating Status	Opening Date
Ankara	Eskişehir	219	Open	2009
Polatlı	Konya	225	Open	2011
Eskişehir	İstanbul	162	Open	2014
Konya	Karaman	110	Open	2021
Ankara	Sivas	394	Not Opened	2024
Halkalı	Kapıkule	229	Not Opened	2025
Karaman	Ulukışla	132	Not Opened	2025
Yenice	İzmir	547	Not Opened	2026
Bandırma	Osmaneli	201	Not Opened	2026
Adana	Gaziantep	210	Not Opened	2026
Yerköy	Kayseri	142	Not Opened	2027

DATA

Scientific studies

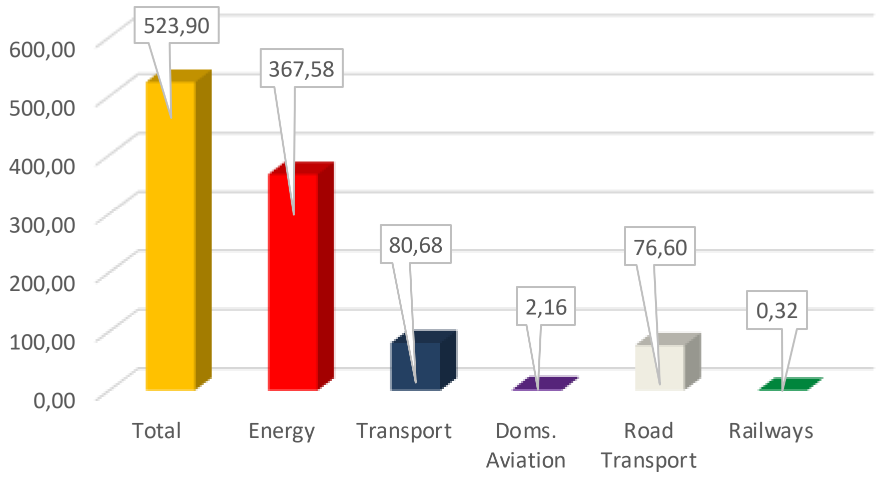
- Environmental impacts of HSRs and GHG reduction of HSTs

Guidelines and handbooks

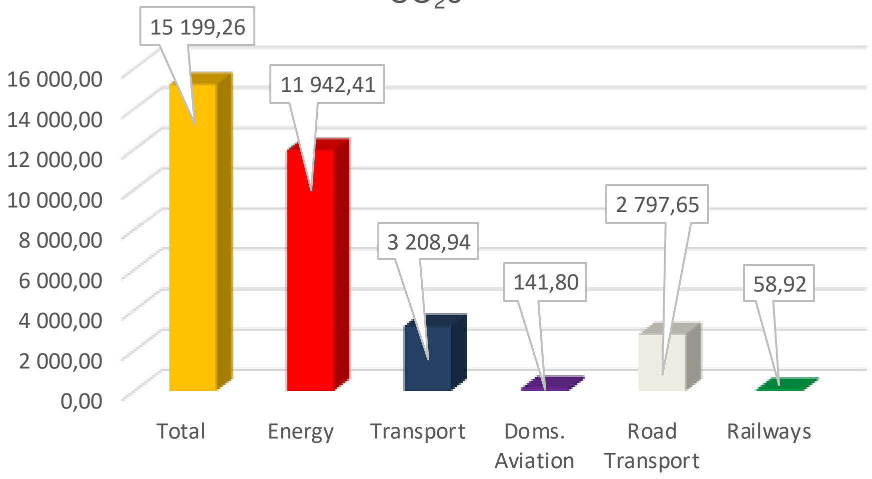
- IPCC Guidelines for National Greenhouse Gas Inventories, IPCC 2006
  - GHG emission calculations and coefficients according to modes of transportation, vehicle types and fuel types
- Guide to Cost – Benefit analysis of Investment Projects, European Commission 2014
  - Social discount rate (5 %) , cash flow, ENPV and etc.
- Handbook on the External Costs of Transport, European Commission 2019
  - Externality costs of transportation modes according to vehicle types

DATA / GREENHOUSE GAS EMISSIONS

Annual GHG emissions of Türkiye, in 2020 Mt CO_2e



Annual GHG emissions of Annex I Parties, in 2020 Mt CO_2e



GHG emissions of transport constitutes 15,40 % of Türkiye's total GHG emissions, while it constitutes 21,11 % of total GHG emissions of Annex I parties.

METHODOLOGY

Passenger traffic demands according to the HSR routes determined in the context of this study.

- Distances,
- Forecast for 2030 and 2040
- Passenger traffic were estimated between 2023 – 2042
- Traffic assumed as 20 % existing, 50 % diverted and 30 % generated
- The routes with aviation; 70 % cars, 20 % coaches and 10 % airplanes
- The routes without aviation; 75 % cars and 25 % coaches

Routes	Rail Dist.	Road Dist.	Aviation Dist.	Passenger Demands (Passanger)	
	Km	Km	Km	2030	2040
Ankara - İstanbul	381	322	323	3.540.108	5.295.468
Ankara - Eskişehir	219	233		1.100.924	1.675.931
Ankara - Konya	283	284		2.069.382	3.072.156
Ankara - Karaman	393	392		821.190	1.228.909
İstanbul - Konya	548	597	428	1.609.140	2.407.031
İstanbul - Karaman	658	705		321.828	481.406
İstanbul - Eskişehir	162	210		257.432	397.979
Ankara - Sivas	394	426	344	2.016.496	2.831.778
Ankara - Kayseri	299	306		1.106.376	1.643.381
Ankara - İzmir	627	581	543	1.773.751	2.653.655
Bandırma - Bursa	95	103		549.636	836.709
Bursa - Ankara	419	423		468.752	639.934
Bursa - Eskişehir	200	191		386.224	564.833
İstanbul - Bursa	174	153		632.172	1.035.997
Kapıkule - İstanbul	229	248		975.450	1.494.436
Konya - Karaman	132	111		821.190	1.228.909
Konya - Ulukışla	242	195		827.590	1.239.149
Adana - Gaziantep	210	222		1.720.538	2.609.679

METHODOLOGY / PASSENGER TRAFFIC

Routes	Passenger-km Million pkm	Total Passenger Million Passenger
Ankara - İstanbul	32.353	84,92
Ankara - Eskişehir	5.850	26,71
Ankara - Konya	14.031	49,58
Ankara - Karaman	7.684	19,55
İstanbul - Konya	20.226	36,91
İstanbul - Karaman	4.854	7,38
İstanbul - Eskişehir	969	5,98
Ankara - Sivas	17.089	43,37
Ankara - Kayseri	6.425	21,49
Ankara - İzmir	22.658	36,14
Bandırma - Bursa	1.073	11,3
Bursa - Ankara	3.827	9,13
Bursa - Eskişehir	1.556	7,78
İstanbul - Bursa	2.348	13,49
Kapıkule - İstanbul	4.798	20,95
Konya - Karaman	2.479	18,78
Konya - Ulukışla	4.253	17,57
Adana - Gaziantep	7.412	35,3
Average	7.994	23,32
Total	159.885	466,33

Expected HST passenger is 466,33 Million on total and 23,32 Million per year.

Total passenger recorded between 2017 – 2022* for 4 different HSR routes 37,59 Million on total and 7,52 Million per year. These routes which are in operation;

- Ankara – İstanbul
- Ankara – Eskişehir
- Ankara – Konya
- İstanbul – Konya

*Due to COVID-19 restrictions, records of 2020 is discarded and 5 years data is considered

METHODOLOGY / CALCULATION OF ENVIRONMENTAL IMPACTS

Environmental impacts of road vehicles are calculated by the formula illustrated, Tier 1 (Equation 1, 4, 5 and 6)*

Environmental impacts of aviation are calculated by the formula illustrated, Tier 2 (Equation 2 and 3)*

*Ref: IPCC Guidelines for National Greenhouse Gas Inventories

Equation 1: Emissions $= \sum_a$ *[Fuel Consumed* $_a$ *x Emission Factor* $_a$*]*

a: fuel type (gasoline, diesel, LPG)

*Equation 2: Total Emissions = LTO Emissions + Cruise Emissions**

Equation 3: LTO Emissions = Number of LTOs x Emission factor LTO

LTO: Landing Take off

**GHG emission during cruise emissions are neglected, in this study.*

Eq4: Fuel Consumption [TJ] = Fuel Consumption [t] x 10^{-3} *x Fuel Consumption [TJ/kt]*

Eq5: Carbon Content [Gg C] = Carbon Emission Factor [tC/TJ] x Fuel Consumption [TJ] x 10^{-3}

Eq6: GHG Emission [Gg CO_2e*] = Carbon Content [Gg C] x Conversion Factor*

METHODOLOGY / EVALUATION OF ENVIRONMENTAL IMPACTS

The 20 years total GHG emission avoided is **11.119,71 kt CO_2e** which means average annual GHG emission avoided is **555,99 kt CO_2e**.

This value constitutes only **0,69 %** of total GHG emissions of transportation of Türkiye, in 2020.

While, average value of emission is **69,548 g CO_2e/pkm**, these values change between **57,869 g CO_2e/pkm** to **93,806 g CO_2e/pkm** according to the routes.

Routes	GHG Emis. ktCO2e	gCO2e / pkm	KgCO2e /pss
Ankara - İstanbul	1.948,68	60,232	22,948
Ankara - Eskişehir	447,95	76,569	16,769
Ankara - Konya	1.014,52	72,305	20,462
Ankara - Karaman	552,27	71,873	28,246
İstanbul - Konya	1.532,48	75,767	41,520
İstanbul - Karaman	376,73	77,616	51,071
İstanbul - Eskişehir	90,89	93,806	15,196
Ankara - Sivas	1.300,33	76,090	29,980
Ankara - Kayseri	468,3	72,887	21,793
Ankara - İzmir	1.443,57	63,712	39,947
Bandırma - Bursa	83,18	77,513	7,364
Bursa - Ankara	276,9	72,361	30,319
Bursa - Eskişehir	106,34	68,339	13,668
İstanbul - Bursa	147,33	62,753	10,919
Kapıkule - İstanbul	373	77,739	17,802
Konya - Karaman	150,97	60,895	8,038
Konya - Ulukışla	246,1	57,869	14,004
Adana - Gaziantep	560,17	75,576	15,871
Average	559,99	69,548	23,845
Total	11.119,71		

METHODOLOGY / EVALUATION OF ECONOMIC BENEFITS

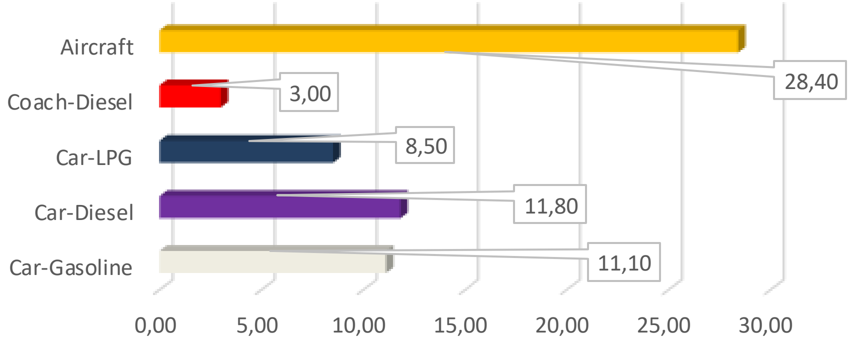
Routes	Econ. Benefits		
	Million EURO	EURO/1000 pkm	EURO/Passenger
Ankara - İstanbul	124,67	3,853	1,468
Ankara - Eskişehir	21,91	3,745	0,82
Ankara - Konya	49,91	3,557	1,007
Ankara - Karaman	27,17	3,536	1,39
İstanbul - Konya	95,34	4,714	2,583
İstanbul - Karaman	19,04	3,923	2,581
İstanbul - Eskişehir	4,57	4,717	0,764
Ankara - Sivas	80,72	4,723	1,861
Ankara - Kayseri	21,44	3,337	0,998
Ankara - İzmir	89,21	3,937	2,469
Bandırma - Bursa	3,89	3,625	0,344
Bursa - Ankara	13,11	3,426	1,435
Bursa - Eskişehir	5,00	3,213	0,643
İstanbul - Bursa	6,84	2,913	0,507
Kapıkule - İstanbul	17,88	3,726	0,853
Konya - Karaman	7,62	3,074	0,406
Konya - Ulukışla	11,82	2,779	0,673
Adana - Gaziantep	26,21	3,536	0,743
Average	**31,32**	**3,917**	**1,343**
Total	**626,35**		

To calculate Economic Net Present Value (ENPV) cash flow method and social discount rate (5 %)* were used.

*Ref: Guide to Cost – Benefit analysis of Investment Projects, European Commission 2014

Externality costs are available in Handbook on the External Costs of Transport, European Commission.

In the unit of EURO / 1000 pkm.

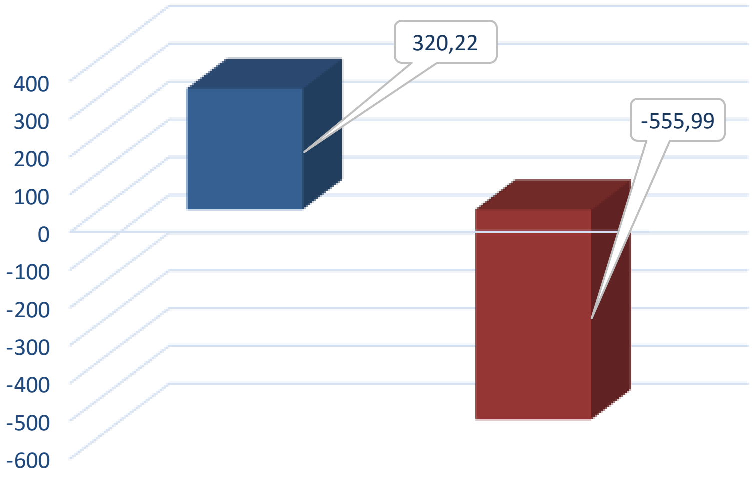


CONCLUSIONS

Annual average reduction of GHG of HSR during the 20 year period are calculated as 555,99 kt CO_2e.

Railway GHG emission in 2020 were 320,22 kt CO_2e.

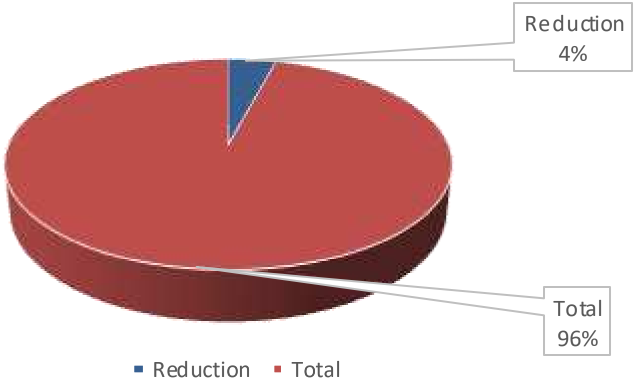
Average reduction is 1,74 times greater than emission.



Passenger demand scenario of this study accepts modal split share of railway as 1 % of total passenger.

If the modal split share of railway were increased to 5 % of total passenger, the GHG reduction of high – speed rail would be nearly 3.474,03 kt CO_2e

It means that 4,31 % of total GHG emissions of transportation of Türkiye, in 2020.



THANK YOU

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