Europe's Rail

Co-funded by the European Union

Sustainable and Green Rail Systems

WP2 - Adaptation to Climate Change (ACC)

progress and approach

European Workshop – 3rd June 2026

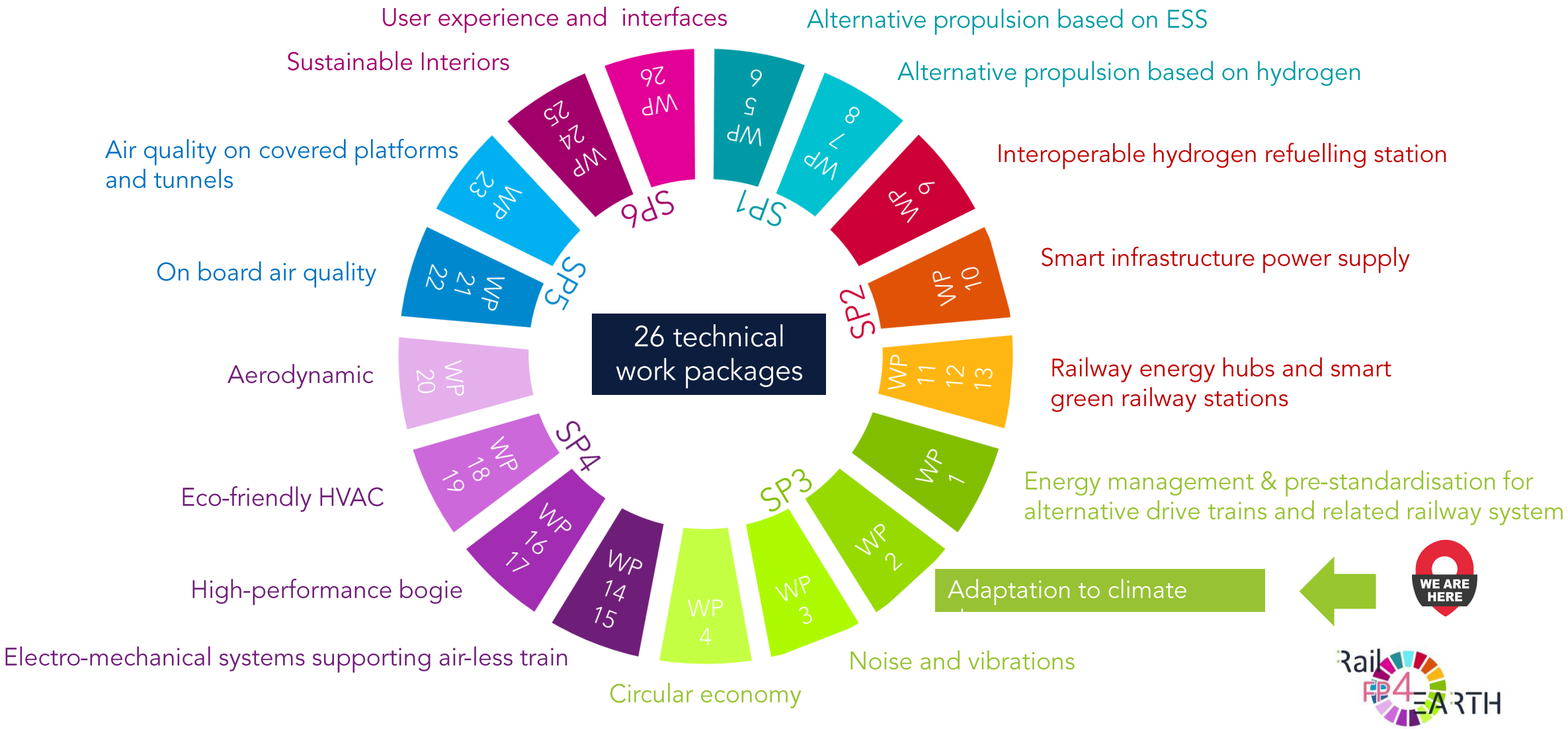
Hubert MULLARD / SNCF Voyageurs

WP2 leader

Rail4EARTH
Overview

- Improve the existing sustainability performances of railways, to build a more attractive and **resilient mode of transport**
  & provide new tools, methodologies and standards evolutions related to eco-design
- Activities on **rolling stock, infrastructure, stations** and all of their related sub-systems
- 38 demonstrators
- **4 years duration** : 12/2022 - 11/2026
- Budget : 64 M€ (IKOP + fundings)

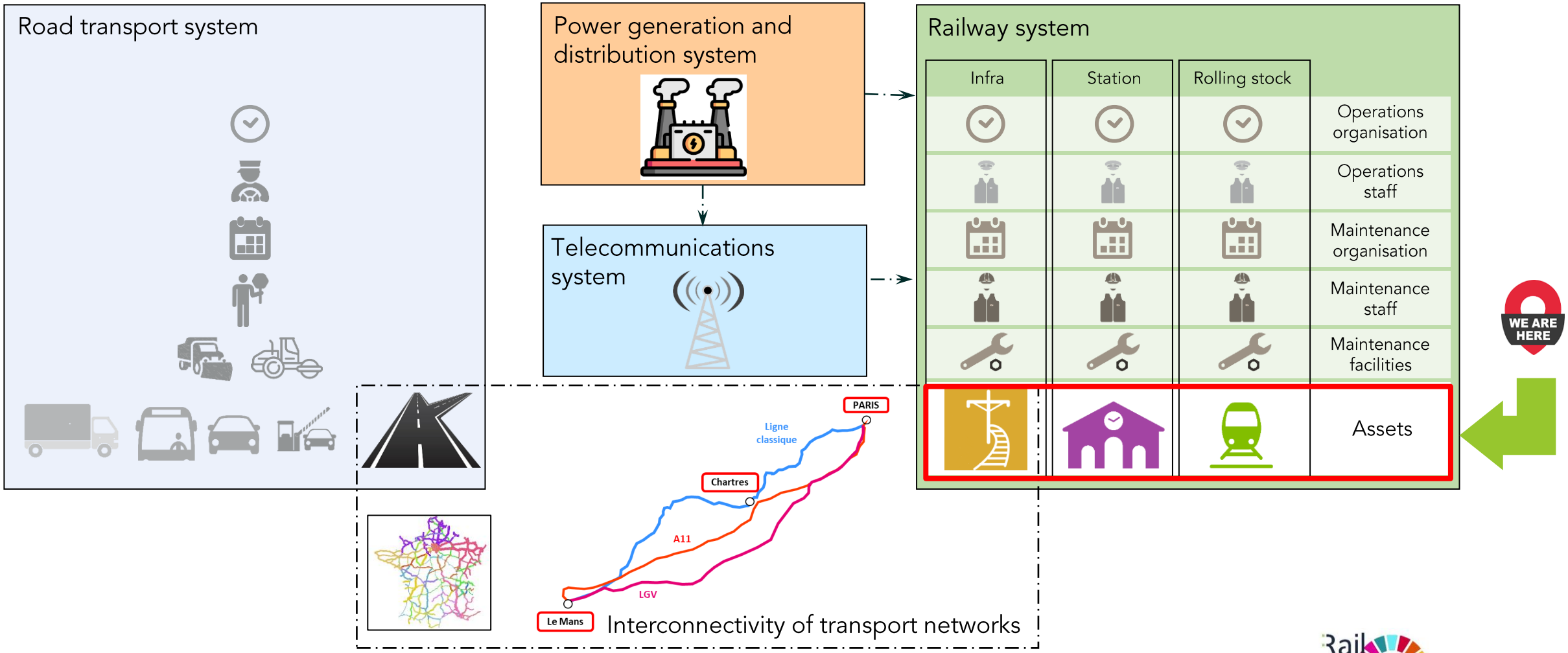
Rail4EARTH
Activities



Rail4EARTH
WP2 - Scope

- Method: implement the **EU adaptation strategy to the railway sector**
  - **Smarter adaptation**
    - Develop knowledge on climate adaptation
    - Provide European rail sector with standards and tools to help define resilience strategy
  - **Faster adaptation**
    - Current geographical areas in the World facing the future climate conditions of Europe
    - Benchmark the technical solutions already implemented for railway in these areas
  - More systemic adaptation
  - Stepping up international action for climate resilience
- Only technical adaptation, excluding mitigation measures
- Only railway assets: rolling stock, infrastructure, and station

Rail4EARTH
WP2 - Background



Summary

- **Smarter adaptation**
  - Learnings from literature review & return of experience
  - Risk assessment methodology to mitigate the impact
  - Design standards potential evolutions
  - Climate Database tool demonstrator
- **Faster adaptation**
  - Benchmark and catalogue of existing solutions
- **Railway resilience**
  - Definitions
  - KPIs
- **Europe’s Rail - Wave 2**
  - Content proposal

Smart adaptation

Learnings from literature review & return of experience

Literature review & Return of experience
Risk assessment methodologies for railway sector

- ISO 14090, ISO 14091, ISO 31000 provide guidelines for climate risk management and risk assessment
- General methodological guides still need to be adapted to the rail sector
- Two different approaches should be adopted for railway assets
  - Assets occupying a static geographical position (stations, bridges, tunnels, etc.) affected by local climate conditions
  - Assets spread over a vast area (rolling-stocks, trackside equipment, etc.) impacted by a wider variety of climate hazards

Literature review & Return of experience
Weather-related failures and adaptation solutions

- Rolling stock
  - Rolling stock assets suffer malfunctions or even breakdowns in their air conditioning and/or electrical/electronic systems due to extremely high outside temperatures
  - Adaptation to heat waves is a priority
  - Adopt high-performance cooling systems to maintain thermal comfort and equipment availability
- Infrastructure and station
  - Railway station and infrastructure assets encompass flooding, landslides, rail buckling, bridge scouring, over headlines, signalling failures, and drainage issues
  - Need to deploy advanced technologies for their monitoring and management: adopt detection systems and modelling tools to anticipate the impacts of climate change
  - Design structures capable of withstanding higher temperatures or more intense rainfall, and the installation of water management systems are all necessary

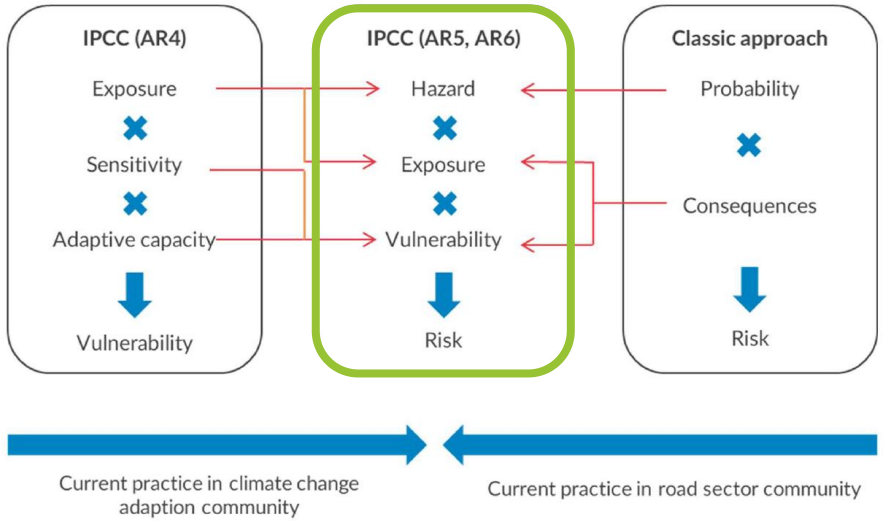
Smart adaptation

Risk assessment methodology to mitigate the impact

Risk assessment
Situation

- 72 documents selected among 300 from our bibliography
- 18 documents with the highest level of relevance, analysed in depth
- Lessons learned

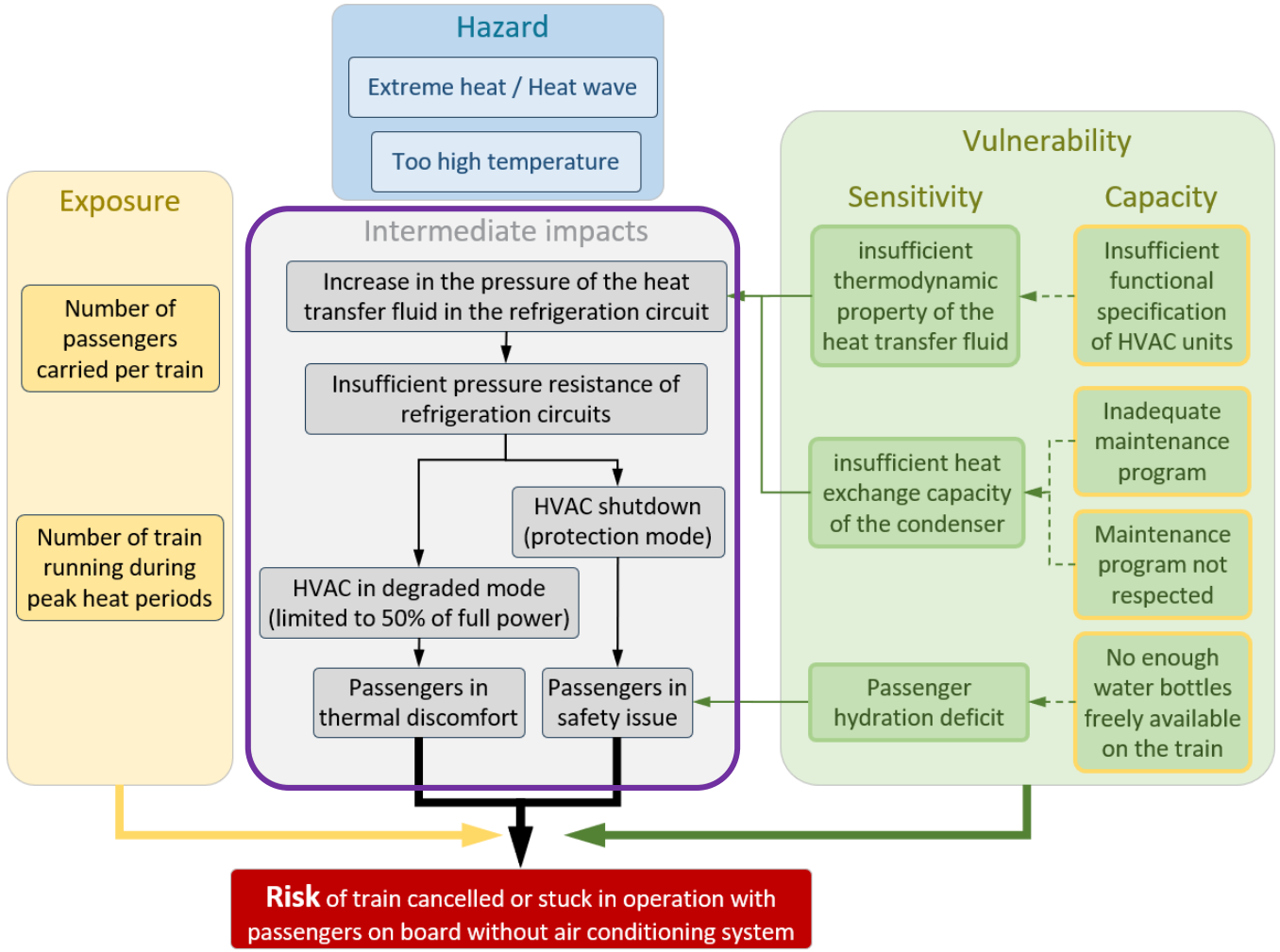
  - Detailed use cases in railway context only available for specific routes (Ex. RailBaltica, NR WRCCA)
  - No formal methodology to assess climate risks for railway assets
  - In climate change context, the likelihood of the classic approach not applicable
  - Risk instead connected to the concepts of “vulnerability” and “exposure”
  - IPCC approaches = the most accepted framework, where risk = hazard x vulnerability x exposure
  - Impact chain best approach for defining risks



Main methodological frameworks from IPCC (AR4, AR5 and AR6) vs the common risk analysis (source ICARUS, 2022)

Risk assessment
Impact chains approach

- Strengths
  - Compliance with last IPPC approach
  - Clear description of the impacts
  - Quantification of the risk
- 7 Impact chains under construction
  - RS – HVAC & Extreme Heat
  - RS – Electronic & Extreme Heat
  - Infra – Drainage & Pluvial Flood
  - Infra – Earthwork & Landslide
  - Infra – Track (rail) & Extreme Heat
  - Infra – Bridge & River Flood
  - Infra – Headline & Extreme Heat



Simplified example of the impact chain “rolling stock – HVAC & Extreme Heat”

Risk assessment
Expected results

- Expected results by the end of Rail4EARTH
  - Risk quantification and all the relevant characterisation and comparisons that this allows
    - Risk comparison from one area to another
    - Risk comparison to one impact chain to another
    - Quantified risk mitigation through adaptation measures
    - Quantified comparison of the risk mitigation of one adaptation measure compared to another

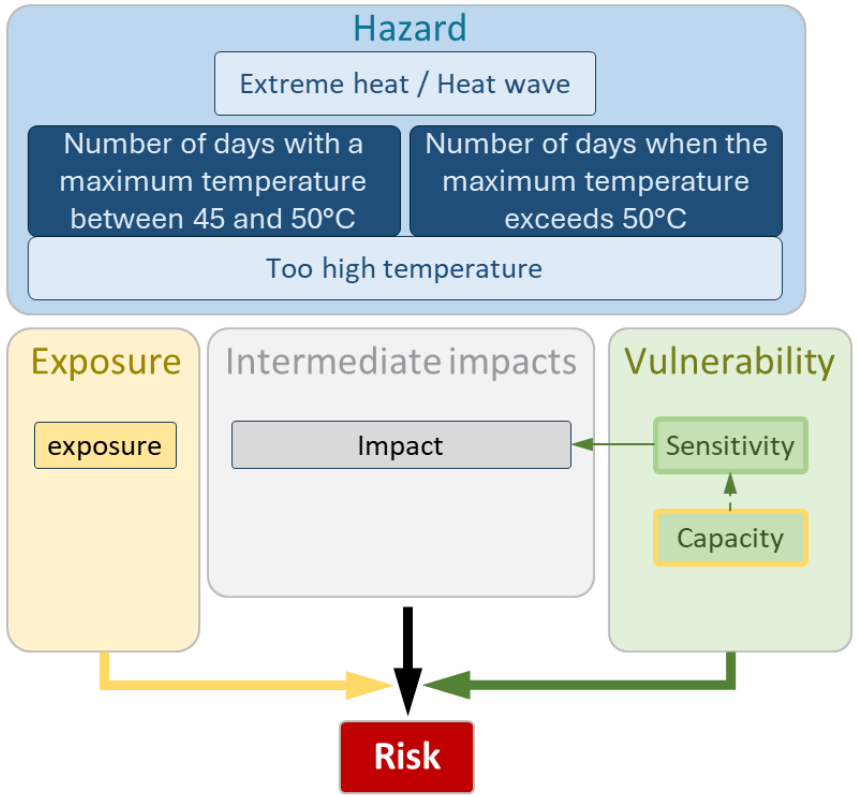
Smarter adaptation

Climate database tool demonstrator

Climate database tool

Scope

- Objective: to be able to provide climate data usable for the design of railway equipment by using the best of climate science to exploit meteorological records as well as available climate projection models
- Expected gains
  - Meteorological data collected, formatted and usable in the context of railway assets to feed vulnerability studies to past and present local climatic conditions
  - Access to projected statistical climate data that can be used in the context of railway assets
    - to feed risk evaluation
    - to help design resilient equipment
    - to develop design standard in the long term



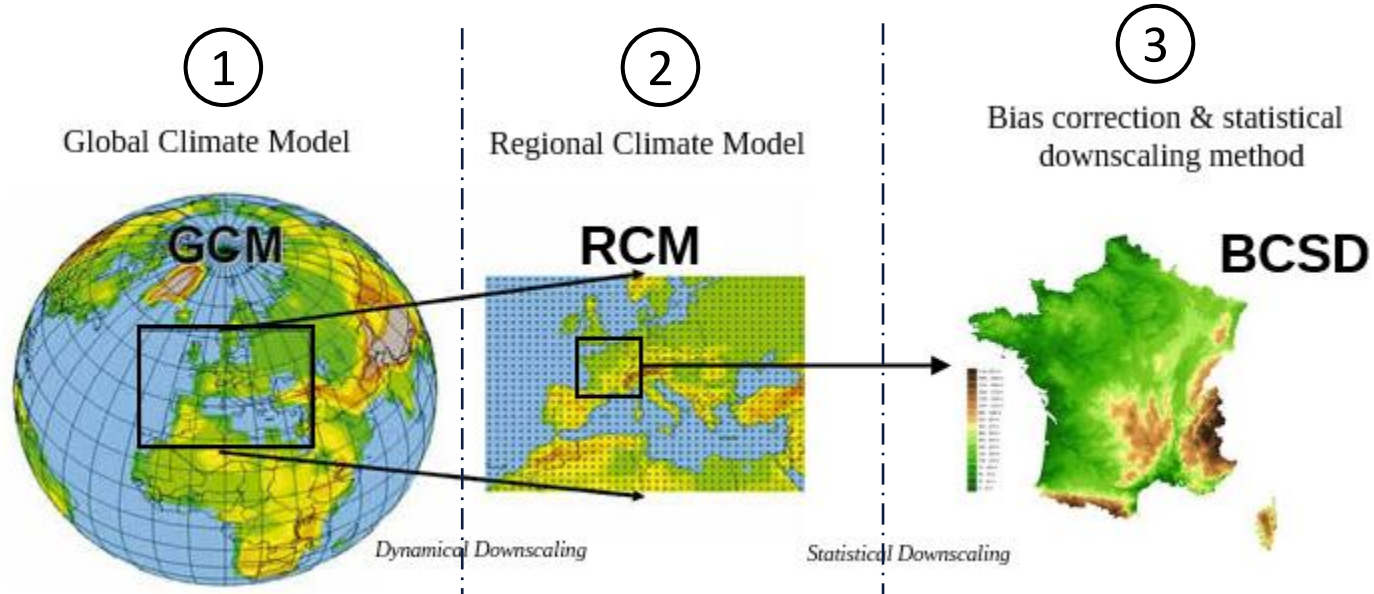
Simplified example of the impact chain “rolling stock – HVAC & Extreme Heat”

WE ARE HERE

Risk = Hazard x Exposure x Vulnerability

Climate database tool
Available climate models

Climate models constantly evolving requiring regular post-treatment



CMIP6 ~100 models ✓ Several dozen models (Euro-Codex)

CMIP6 ~100 models → 6 models (Copernicus PECD4.2)

Availability date ?

Available now

CMIP: Coupled Model Intercomparison Project
CDS : Climate Data Store
PECD: Pan-European Climate Database

Climate database tool

Main features

Features		Recorded data	Projected data
Climate variables		Absolute ambient temperature Total precipitation	
Climate indicators		A dozen from the impact chains	
Geographical perimeter	Scope	244 European regions (NUTS level 2)	
	Resolution	0,25° x 0,25° (~25 km x ~25 km)	
Temporal perimeter	Scope	1991 → 2020	2021 → 2100
	Resolution	1 day	4 periods of 20 years
Reference warming trajectories (based on IPCC)		Not applicable	SSP1-2.6 SSP2-4.5 SSP3-7.0 SSP5-8.5

NUTS: Nomenclature of territorial Units for Statistics
SSP: Shared Socio-Economic Pathway

Climate database tool

Expected results

- Expected results by the end of Rail4EARTH
  - A dozen quantified climate indicators corresponding to a given input data

➔ Fictitious example

Climatic Indicator

Number of days with a temperature between two thresholds

- Number of days with a temperature between two thresholds
- Number of days with a temperature above a threshold
- Number of days with rainfall exceeding a threshold in less than a given minimum time
- Maximum number of consecutive days with no (or negligible) precipitation

Lower temperature threshold

40°C

- 25°C
- 30°C
- 35°C
- 40°C
- 45°C
- 50°C

Upper temperature threshold

50°C

- 25°C
- 30°C
- 35°C
- 40°C
- 45°C
- 50°C

Period

2041 - 2060

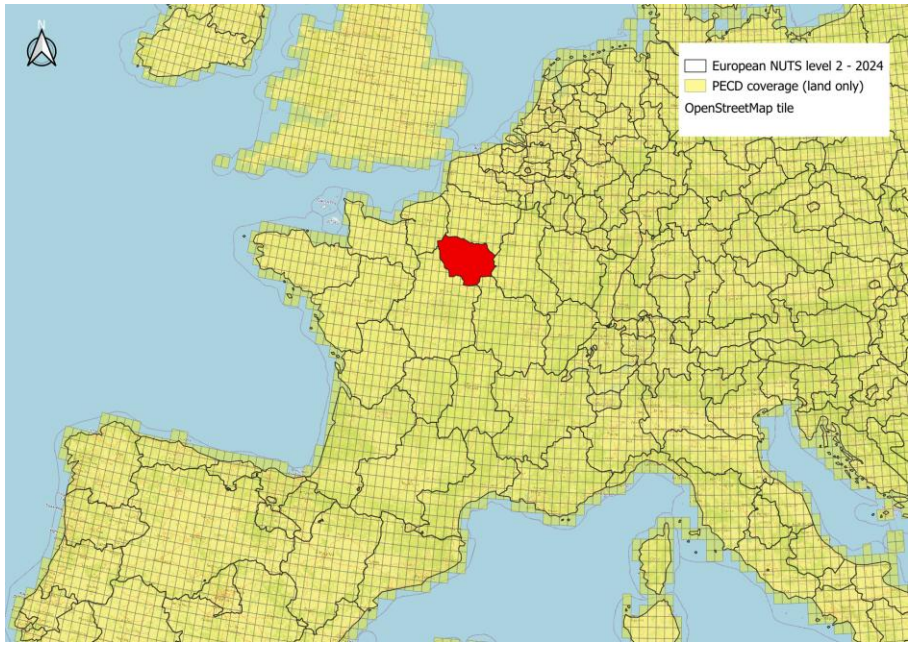
- 2021 - 2040
- 2041 - 2060
- 2061 - 2080
- 2081 - 2010

Scenario

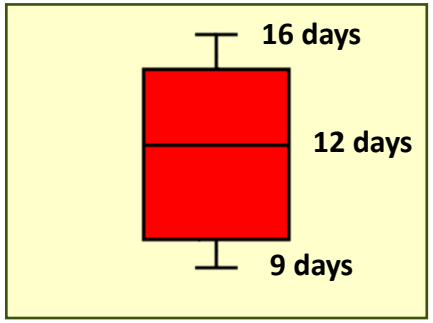
SSP5-8.5

- SSP1-2.6
- SSP2-4.5
- SSP3-7.0
- SSP5-8.5

Pixel selection



Results



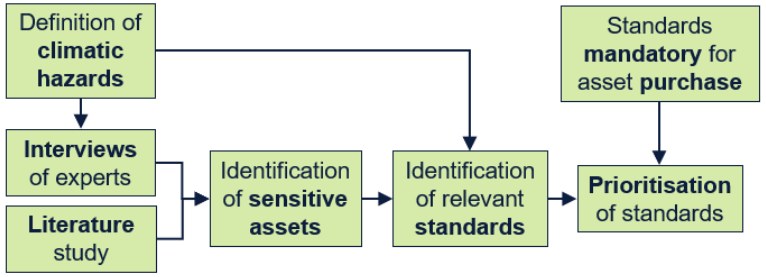
Smarter adaptation

Design standard potential evolutions

Design standard potential evolutions

Sensitive assets and relevant standards identified

- Identification of sensitive assets and relevant standards base on expert interviews and literature review
- More than a hundred combinations of asset and climatic hazard considered
- 38 relevant standards identified
- 19 high-priority standards selected



Asset	Climatic Impact	Relevant standards
Full train	Heat	EN 50125 TSI Loc&Pas
Electronic equipment	Heat	EN 50155
HVAC	Heat	EN 13129 EN 14750-1 & 2 EN 14813-1 & 2
Tracks	Heat Water	EN 13146-6 EN 752 DIN 1986
Switches	Ice & Snow	EN 1991-1-3
Noise protection walls	Storm	EN 1991-1-4

Example of assets with high climatic impact and associated relevant standards

Faster adaptation

Benchmark and catalogue of existing solutions

Benchmark and catalogue of existing solutions

Methodology to identify adaptation measures

- Benchmark
  - Collect input data from partners, EU projects, Literature review
  - Analyse the solution using characterisation criteria (Maturity, effectiveness, cost…)
- Catalogue of adaptation measures
  - Structure by asset (Infrastructure, Rolling stock, Station)
  - Structure by type of measure
    1. In asset design or upgrade phase (i.e., increased HVAC capacity)…
    2. In maintenance phase (i.e., more frequent cleaning)……
    3. In operation phase (i.e., speed limitation) ……..

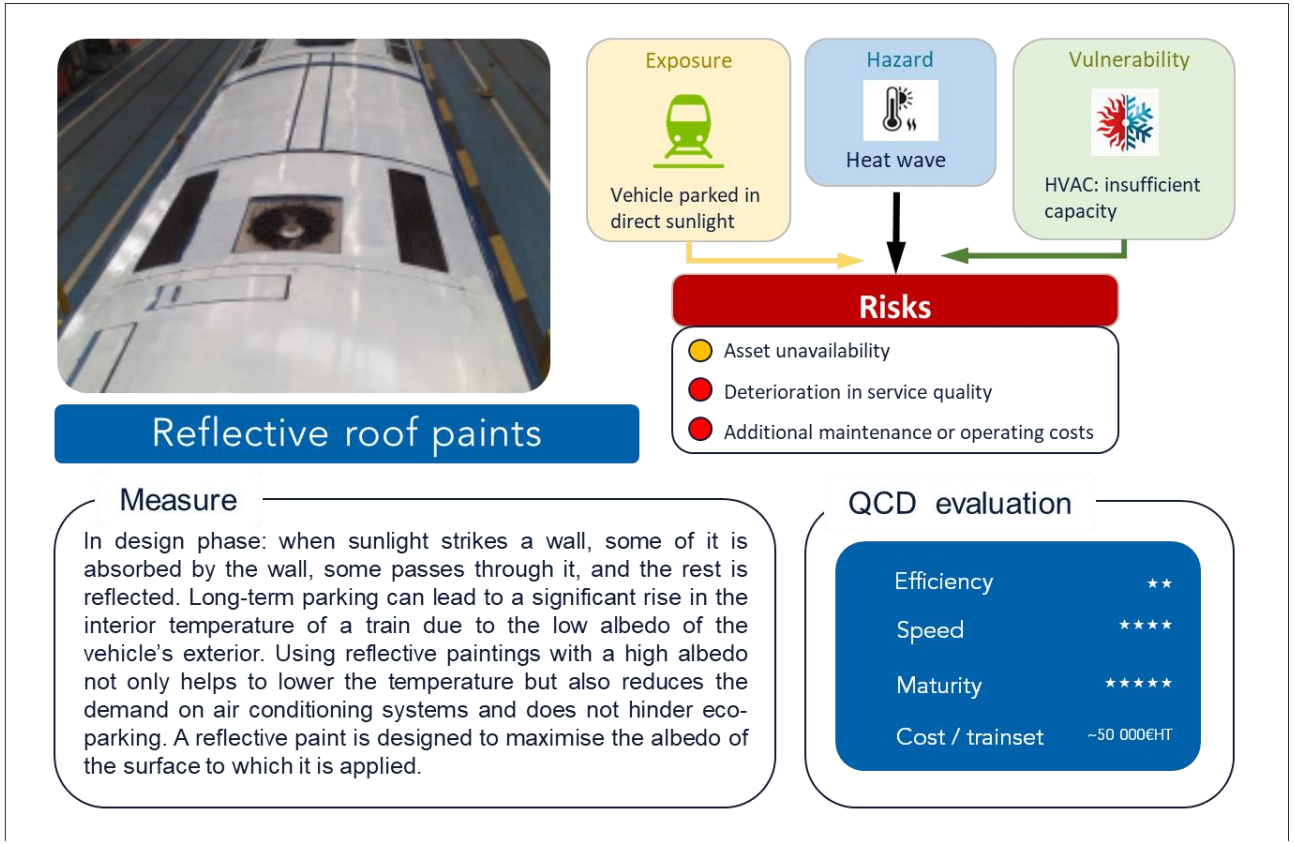
Exported constraints from phase to phase

Benchmark and catalogue of existing solutions

Expected results

- Expected results by the end of Rail4EARTH
  - A catalogue compiling a description, on a single page, of as many adaptation measures as possible

➔ Fictitious example



Railway resilience

Definitions and KPIs

Railway resilience

Definitions

- Examples of definition in the literature
  - "Resilience can be described as the ability of the transport network to withstand the impacts of extreme weather, to operate in the face of such weather and to recover promptly from its effects." *Department of Transport (UK) - Transport Resilience Review – 2014*
  - "Resilience is defined as the ability of a rail organisation to provide services effectively and sustainably as the climate changes. This includes elements of robustness, the ability to resist disruption; redundancy, the ability to use backup facilities to provide service during disruption; and recovery, the ability to rapidly return to service after disruption." *UIC Rail Adapt - §1.Introduction - 2017*
  - "The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation." *IPCC AR6 - WGII - Annex II Glossary - 2022*

Railway resilience

ACC KPIs - from climate hazards to impacts

Climate hazards	Impacts on railway assets	Consequences on railway services
High temperatures / heat wave	• Track buckling • Catenary failure • Train air-conditioning shutdown • …	• Train delays • Train cancelation • Provision of alternative transportation • Maintenance works • Accidents
Extreme rainfall / flooding	• Landslides • Track erosion and wash out • Slippery track • …	
High winds / Storm	• Rolling stock instability • Falling foreign objects including trees and tree leaves • …	
…	• …	

Railway resilience

ACC KPIs proposed by WP2

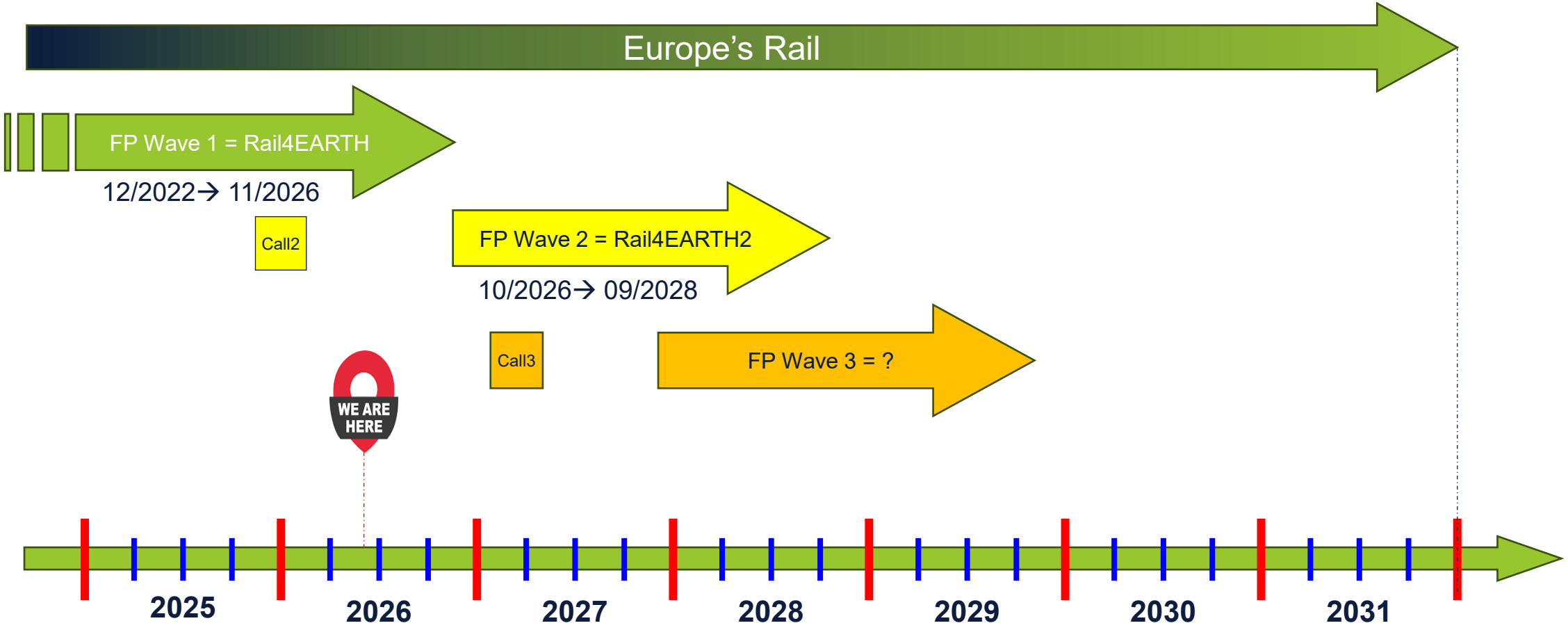
Asset	Category	KPIs	Metric
Rolling stock	**Asset utilisation**	Trains unavailable due to weather related failures	Number of days of unavailability
		Average recovery time per train incident due to weather	Number of recovery days
	Service quality	Train delays due to weather events	Number of minutes lost
		Train cancellations in operation	Number of trains cancelled
		Trains broken down due to weather conditions, necessitating transhipment	Number of trains broken down
		Uncontrolled interior temperatures (passenger area and driver's cab) during periods of high heat	Number of time units (minutes or hours) during which interior temperatures exceed the HVAC setpoint temperatures by more than x °C.
	Financial effectiveness	Corrective maintenance costs due to weather related impacts	€/passenger/km
		Preventive maintenance costs related to manage climatic conditions	€/passenger/km
		Loss of turnover and income caused by climate impacts on train in operation	€/year
		Social cost	€/year
		Upgradation expenditure fulfilling climate adaptation	€
		Societal cost	€/year
Infra	**Service quality**	Overall quality of the infrastructure network	Unitless rate between 0 and 1
		Segments of poor quality	Unitless rate between 0 and 1
		Closed for maintenance	(hours · km)/km
		Closed for renewal	(hours · km)/km
		Speed reduction in the network due to bad infrastructure condition	(hours · km)/km
	Financial effectiveness	Preventive maintenance costs related to manage climatic conditions	€/Asset cost/km
		Corrective maintenance costs due to weather related impacts	€/Asset cost/km
		Maintenance costs per km	€/km
		Renewal costs per km	€/km

Europe’s Rail - Wave 2

Content proposal

Europe's Rail - Wave 2

Planning



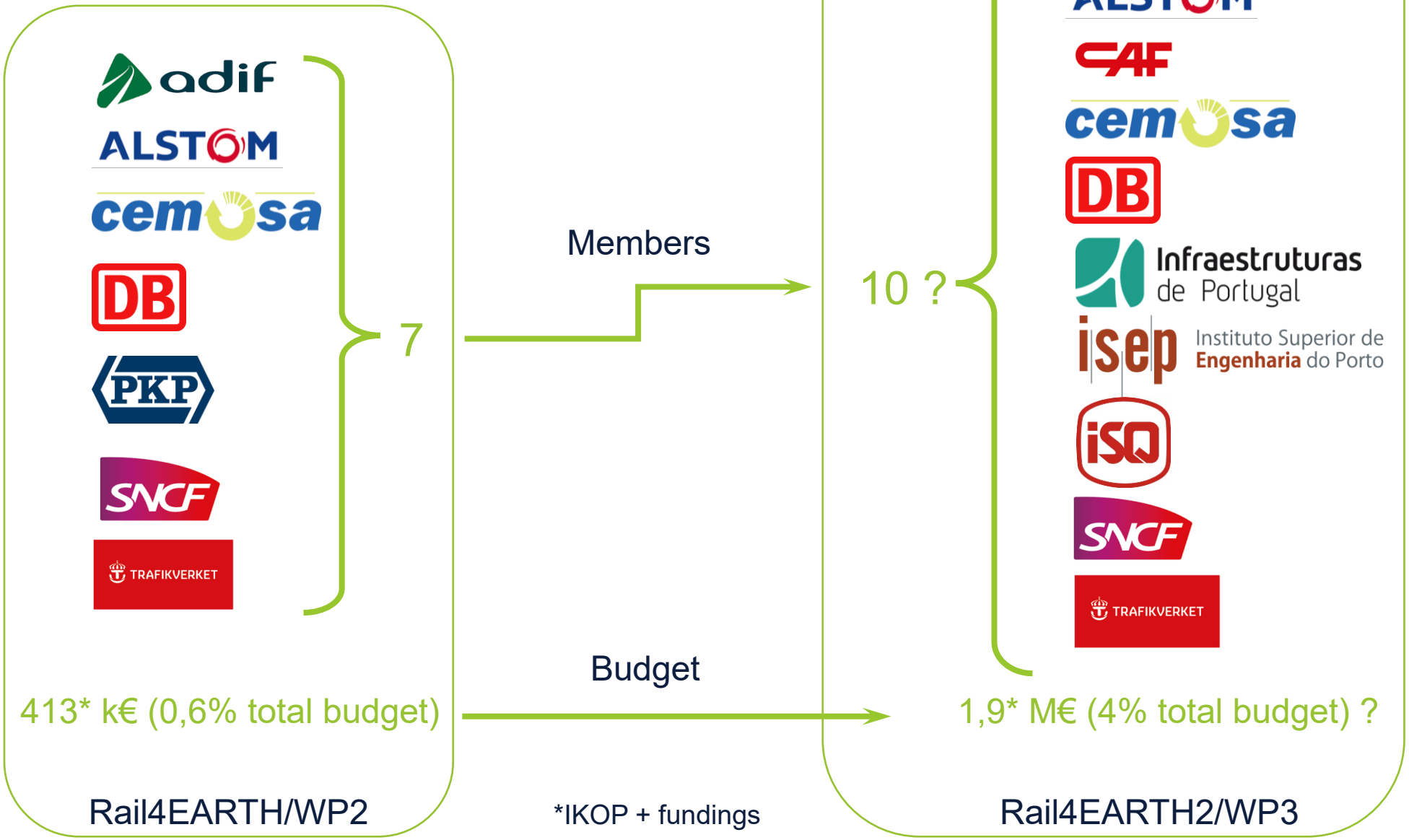
Europe's Rail - Wave 2

Content proposal

- The work aims to
  - Develop a model for the prediction of impact of climatic change on the railway system (Task 3.1)
    ➔ New: identification of climatic drivers and the prediction of failure likelihood
  - Analyse the risk of climate change on further critical assets (Task 3.2)
    ➔ Continuation of wave 1: Risk assessment including other critical assets
  - Evaluate robust data of critical climate hazards relevant to the railway system (Task 3.3)
    ➔ Continuation of wave 1: Climate database tool including other climate indicators
  - Develop adaption measures to improve the resilience of critical assets (Tasks 3.4 and 3.5)
    ➔ Continuation of wave 1: Evaluation of additional existing solutions
  - Assess the KPI-impact of measures for climatic resilience of the railway system (Task 3.6)
    ➔ Continuation of wave 1: calculation of KPIs in current and projected situation
  - Suggest modification of design standards with respect to climate resilience (Task 3.7)
    ➔ Continuation of wave 1: Proposals for modifications and initiation of standards change requests

Europe's Rail - Wave 2

Consortium evolutions



Europe's Rail

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