Flagship Project 4-Rail4Earth
Project Overview
4/12/2025

L Nicod

ALSTOM

Project Coordinator

1. The project at a glance

- Green and Sustainable Railways
- Scope : Rolling Stock, Infrastructures, Stations and all related sub-systems and components
- KPIs : Energy, CO_2,Noise, LCC, Autonomy
- Total Project Cost : 95 M€ (including 38,4 M€ of public funding)
- **71 contributors** : 23 partners+48 Affiliated Entities
- 4 years Dec 2022-Nov 2026
- 38 demonstrations

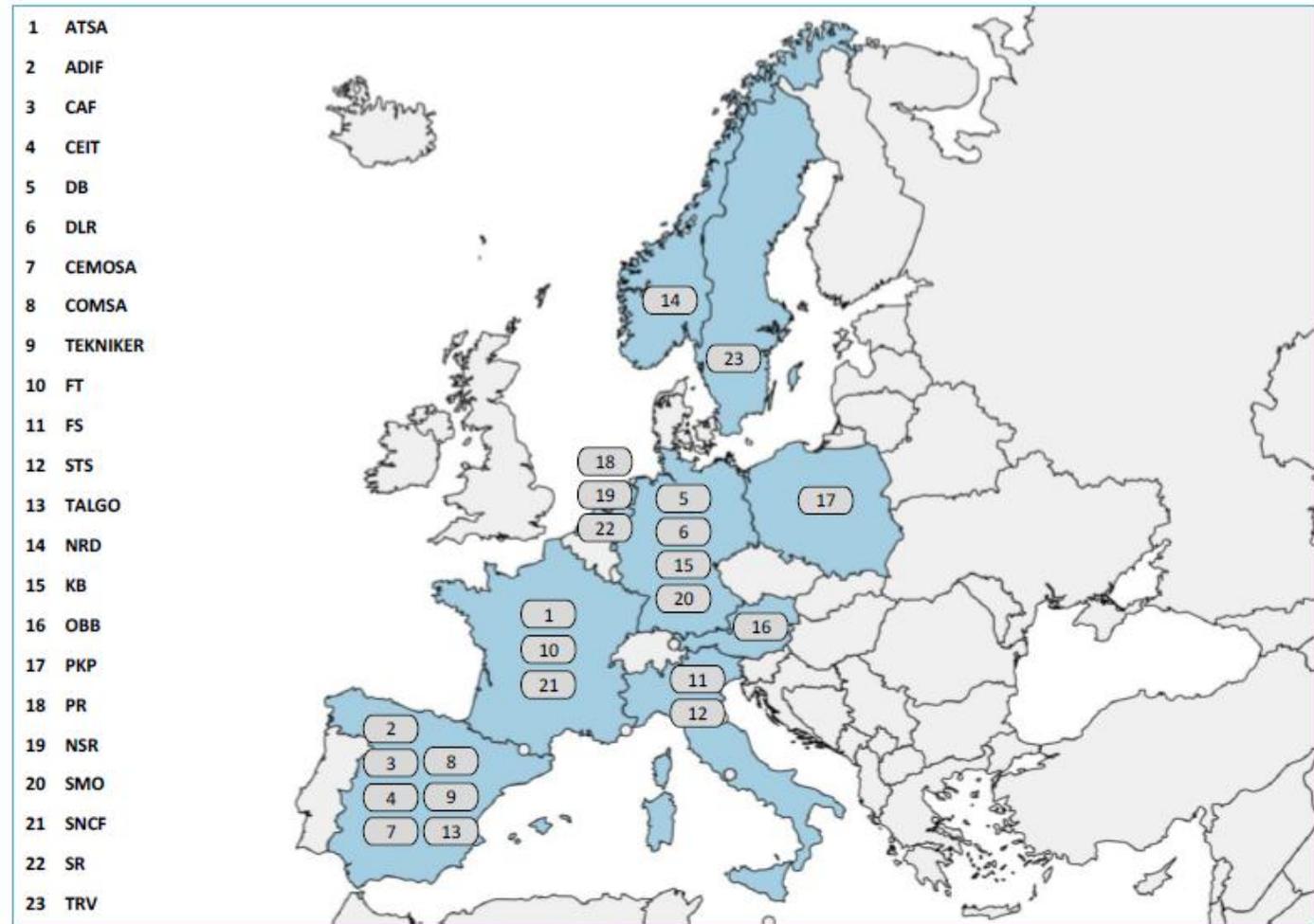# Main partners

2. Sub-Projects

- **Sub-project 1 Alternative (to Diesel)** energy solutions for the **rolling stock**, 6 Demos
  - High performances Battery powered Regional trains (200km), TRL6-7 in 2026
  - Hydrogen hybrid locomotive TRL 5-6 in 2026, Infrastructure inspection vehicles TRL 5 in 2026

- **Sub-project 2** Energy in rail **infrastructure and stations**, 7 demos
  - H2 refuelling station TRL6 in 2025
  - Smart low consumption electrical infrastructures (with local renewable energy **sources**, ground **energy storages**, etc), TRL6 in 2025
  - Smart stations as energy hubs, TRL 5 in 2025.
  - Methodologies/ guidelines for the optimal design/rehabilitation of stations including modularity and carbon footprint reduction TRL5/6 in 2025.

- **Sub-project 3 Sustainability** and **resilience** of the rail system, 3 demos
  - Software tool specification on European **climate variables** usable for railway assets Reports, TRL5 in 2025
  - **Noise** indicators, simulation tools and development of optimized components for noise and vibrations minimisation, TRL6 in 2025
  - Software tools and indicators to promote **eco-design**, assess **environmental performance** /standardised reporting of the environmental impacts of the rail sector, TRL5 in 2025.

2. Sub-Projects

- **Sub-project 4 Electro-mechanical components** and sub-systems for the rolling stock, 18 demos
  - (Airless) electro-mechanical braking system, pantograph and suspensions, TRL7 2025
  - Optimised (energy, weight) motors and gearboxes, TRL6 in 2025
  - Replace hydrofluorocarbon refrigerants by HVAC system using green refrigerants or new cooling technologies, TRL6 in 2025
  - Enhanced experimental and numerical methods on train **aerodynamic** optimization, TRL6 in 2025

- **Sub-project 5 Healthier** and **safer** rail system, 2 Demos
  - Healthier HVAC **- air quality** improvement, contaminant (particle / aerosol) removal, reduced virus/bacteria lifetime, TRL7 in 2025

- **Sub-project 6** Trains **Attractiveness** (Interiors), 2 demos
  - Reinforce train attractiveness via on-demand comfort for users (access, lighting, thermal and acoustic comfort), TRL5-6 in 2025.
  - Reinforce the facility to adapt rolling stock interiors (like modular architecture) to support the increase of capacity of the rolling stock targeting TRL5-6 in 2025.

3. Partners

- **Major Operators**
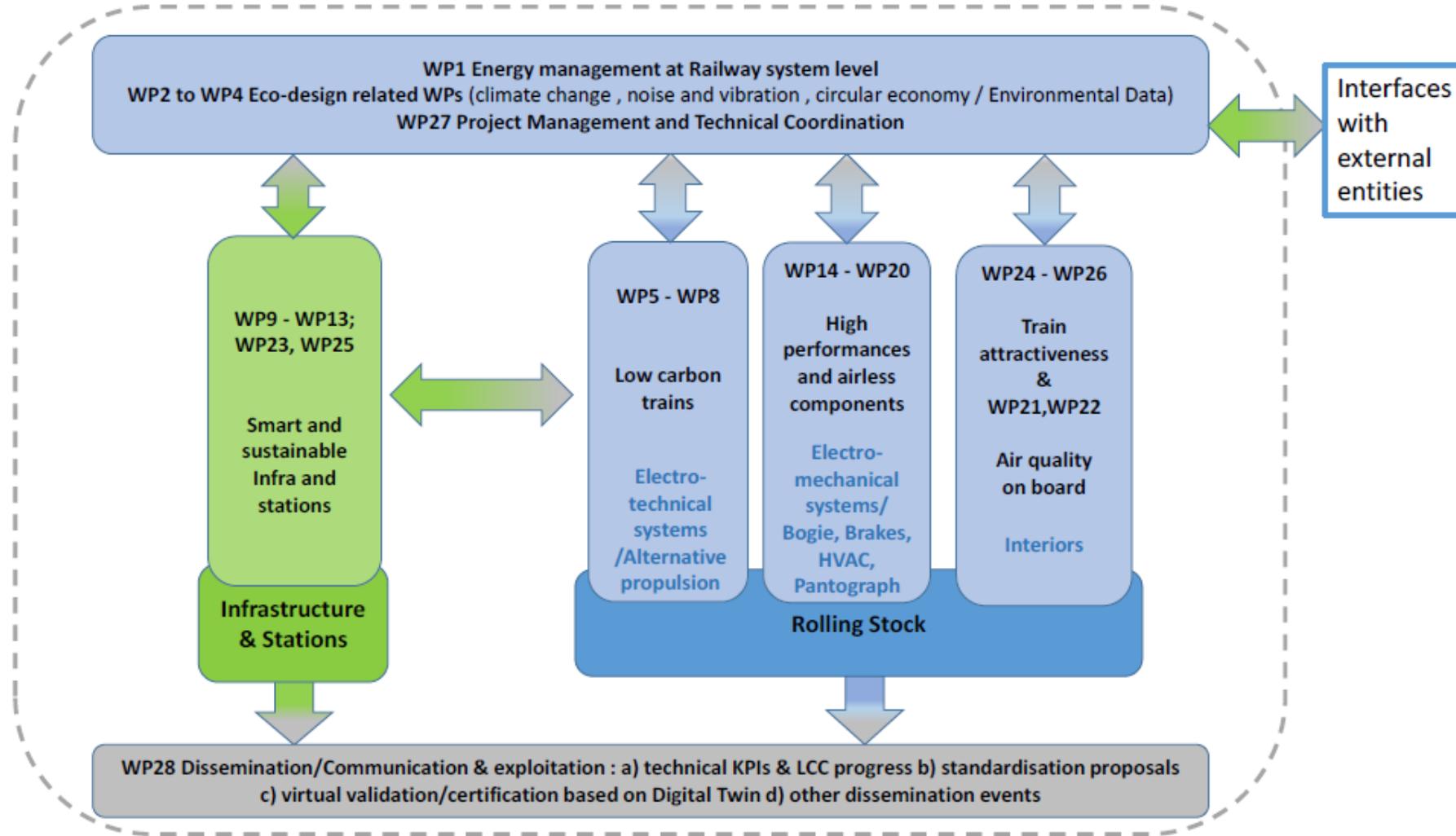- **Railway integrators & suppliers**
- **And research centers**

1	ATSA
2	ADIF
3	CAF
4	CEIT
5	DB
6	DLR
7	CEMOSA
8	COMSA
9	TEKNIKER
10	FT
11	FS
12	STS
13	TALGO
14	NRD
15	KB
16	OBB
17	PKP
18	PR
19	NSR
20	SMO
21	SNCF
22	SR
23	TRV

5. Project structure

Figure 1: Schematic diagram of Rail4EARTH

Deliverables

Public : see on EU-Rail Website

- Project at a glance

- News

- Public reports of the project

- Project confidential Report "executive summaries"

Confidential Reports : 78% (19/88)

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SUB PROJECT 1
Alternative energy solutions for the rolling stock

CAF: Sergio Fernandez

TALGO: Eduardo de la Guerra

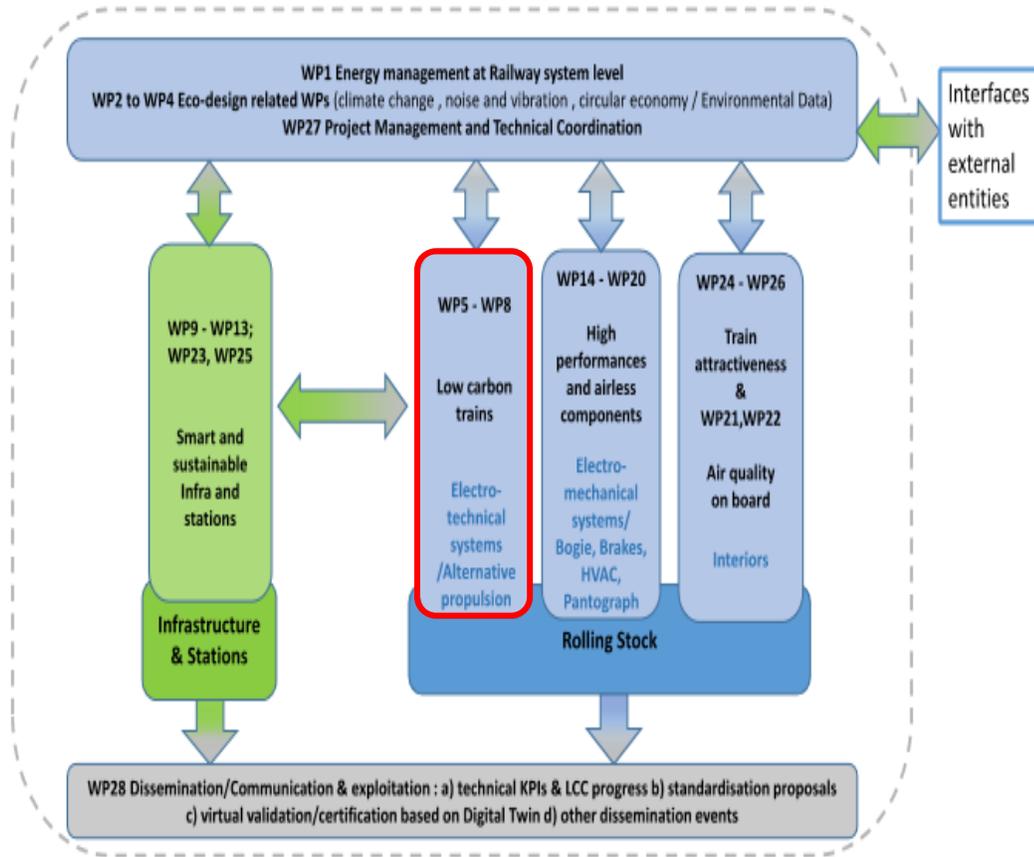## SP1 Alternative energy solutions for the rolling stock

Main objectives

- High performance Batteries Electric Multi-Unit (BEMU) train (reaching TRL6/7)
- Hydrogen hybrid trains with test of heavy-duty inspection vehicle and loco for freight-passengers
- Sub-urban catenary trains with on board Energy Storage Systems (ESS)

Main innovation ideas

- Major increase of the energy density stored on board
- Extend the range in catenary-free mode from ≈80km to 200 km
- Improving the efficiency of the H_2 traction system and standardize interface

SP1 Alternative energy solutions for the rolling stock

WP1 Energy management at Railway system level
WP2 to WP4 Eco-design related WPs (climate change , noise and vibration , circular economy / Environmental Data)
WP27 Project Management and Technical Coordination

Interfaces with external entities

WP9 - WP13;
WP23, WP25

Smart and sustainable Infra and stations

Infrastructure & Stations

WP5 - WP8

Low carbon trains

Electro-technical systems /Alternative propulsion

WP14 - WP20

High performances and airless components

Electro-mechanical systems/ Bogie, Brakes, HVAC, Pantograph

WP24 - WP26

Train attractiveness & **WP21,WP22**

Air quality on board

Interiors

Rolling Stock

WP28 Dissemination/Communication & exploitation : a) technical KPIs & LCC progress b) standardisation proposals c) virtual validation/certification based on Digital Twin d) other dissemination events

Physical energy consumption
kWh/passenger.km | kg CO2/year.m2 | kg H2/vehicle.ton.km

Physical CO_2 equivalent emissions
kg CO2/passenger.km | kg CO2/year.m2

Life Cycle Costs reduction
(for specific use cases including externalities costs)

Autonomy
km

Noise emitted per component
dB

SP1 Alternative (to Diesel) energy solutions for the rolling stock

- **High performances Battery powered Regional trains (200km), TRL6-7 in 2026**

  - **WP5:** Development of alternative propulsion based on ESS [M1 – M24]

  - **WP6:** Train demonstrators of alternative propulsion based on ESS [M25 – M48]

- **Hydrogen hybrid locomotive TRL 5-6 in 2026, Infrastructure inspection vehicle TRL 5 in 2026**

  - **WP7:** Development of alternative propulsion based on hydrogen [M1 – M24]

  - **WP8:** Hybrid battery/H_2 vehicle demonstrators [M25 – M48]

WP5 Development of alternative propulsion based on ESS

Main Objectives

- Develop **innovative propulsion systems** based on ESS as alternative to the use of fossil fuels
- Replace **diesel EMUs by battery EMUs**

to

- Move towards a zero CO_2 emission rail system
- Reduce LCC

Achievements

- WP already closed
- Gathering of requirements for the operation of BEMUs and H" powered trains in European countries
- Developed, manufactured and validated innovative propulsion and OESS system components [TRL5: HIL and power laboratory]
- Testing scenarios and tools according to the new requirements
- Energy management models and systems
- Methods and tools for virtual validation/certification
- Main KPIs of the project consolidated by simulations and first tests in lab at component level

WP6 Train demonstrators of alternative propulsion based on ESS

Demonstrators

- High performance North Europe BEMU demonstrator

- High performance South Europe BEMU demonstrator

- Low traffic BEMU demonstrator

- Suburban demonstrator with OESS

High performance North Europe BEMU Demonstrator
- Leader: CAF
- Participants: Trafikverket, DLR, NO Rail Directorate
- New brand train
- DEMU reconverted to BEMU
- Range up to 200kms in battery mode
- Dual-mode (catenary and battery-only)
- Catenary 15kV 16,7Hz AC
- Low temperature environment
- Tested in Sweden

Non-electrified
750 V DC
1,5 kV DC
3 kV DC
16 kV, 16.7 Hz AC
25 kV, 50 Hz AC
1,5 kV + 25 kV
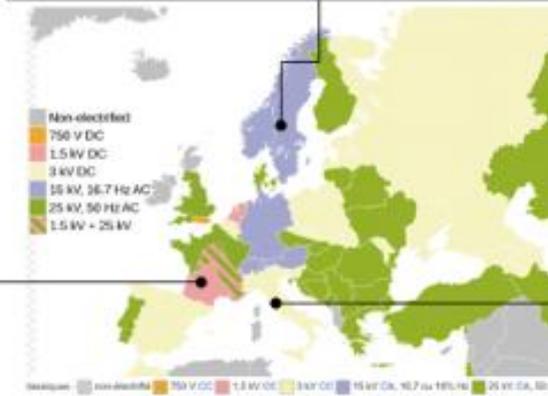
High performance South Europe BEMU Demonstrator
- Leader: ALSTOM
- Participants: SNCF, DB
- Refurbished train
- DEMU reconverted to BEMU
- Range up to 200kms in battery mode
- Dual-mode (catenary and battery-only)
- Catenary 25kV 50Hz AC and 1,5kV DC
- Hot temperature environment.
- Tested in France

Low traffic BEMU Demonstrator
- Leader: HITACHI
- Participants: FSI
- Recently delivered train
- Hybrid BDEMU reconverted to BEMU
- Range up to 120kms in battery mode
- Dual-mode (catenary and battery-only)
- Catenary 3kV DC and 15kV 16,7Hz AC
- Hot temperature environment
- Tested in Italy

WP6 Train demonstrators of alternative propulsion based on ESS

Main Objectives

- Work at the **train "system" level** the innovative propulsion systems based on ESS

- Develop **three complementary physical demonstrators** of BEMUs

- Develop a "virtual demonstrator" (TRL4) on the use of **on-board energy storage systems (OESS) for rolling stock on electric suburban lines**

To

- Demonstrate functionality at HIL and in combined tests in power laboratories being these scenarios relevant environments (TRL6)

- Prepare the demonstration of the feasibility of the innovations in operational environment at precommercial scale (TRL7/8) in the future

Achievements

- Work in progress

- Complete optimized traction chain tested in lab

WP7 Development of alternative propulsion based on hydrogen

Main Objectives

- Implementation of alternative energy solutions based on hydrogen for the rolling stock up to TRL6
- System for improving the efficiency of the H2 traction system or higher-pressure tanks adapted for railway environment.
- New tank and a system for using the low enthalpy energy coming from the cooling of the fuel-cell system (wasted energy).

Achievements

- WP already closed
- H2 Storage system: Progressing on modelling, lab-scale testing, and characterization. Health Monitoring System tested on standardised test and exploring the instrumentation of commercial tank on the demonstrator
- H2 hybrid Locomotive. Installation completed, pending for testing on track
- System to improve the efficiency of the H2 power plant and the energy management system defined
- Requirements for hydrogen refuelling. Link with standardization activities and refuelling stations

WP8 "Hybrid battery/H2 vehicle demonstrators" (M25-M48)

Main Objectives

- Implement the different developments of WP7 on demonstrators.

- Energy storage through H2 high-pressure tank will be implemented on infrastructure inspection vehicle. This vehicle is linked to FA3.

- Energy management solution to improve efficiency and range will be implemented on a hydrogen hybrid locomotive for freight-passengers.

- Technical recommendation for sharing with WP9 for refuelling interfaces.

Achievements

- Work in progress

WP8 "Hybrid battery/H2 vehicle demonstrators" (M25-M48)

Demonstrators

Demonstrators		
Hydrogen hybrid locomotive for freight-passengers.	Energy saving	**Enabler 2:** Hydrogen hybrid trains: infrastructure inspection/maintenance heavy duty vehicle and loco for freight-passengers at TRL 5/6 (powered with gas H2 or liquid H2).
Hydrogen hybrid trains: infrastructure inspection vehicle	CO_2 savings	
Higher-pressure tanks		
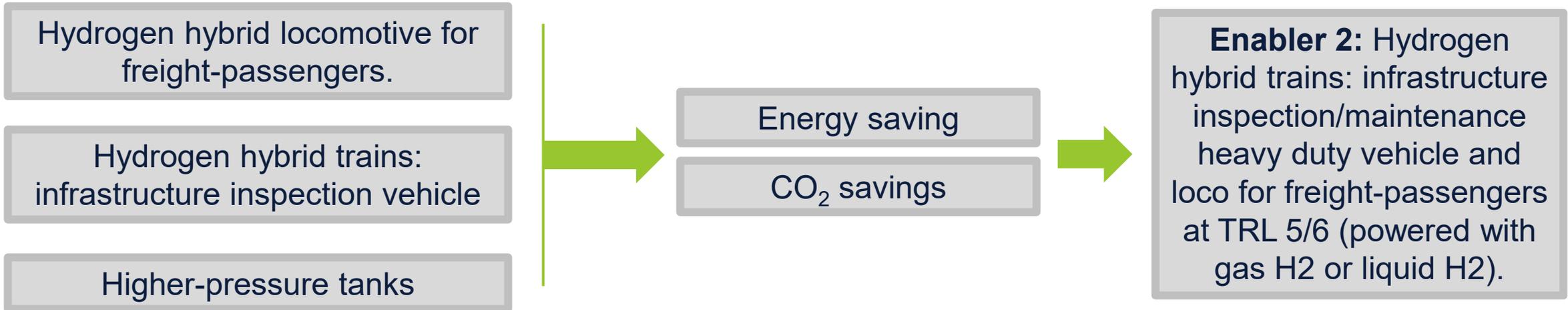
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SUB PROJECT 2
Technical progress

4.12.2025

Sub-project 2: Energy in rail infrastructure and stations Demonstrators progress in 2025:

- H2 refueling station, TRL6 in 2025;

- Smart low consumption electrical infrastructures (with local renewable energy sources, ground energy storages, etc.), TRL6 in 2025;

- Smart green railway stations, TRL6 in 2025;

- Energy hubs in railway infrastructures, TRL5 in 2025;

- Methodologies/ guidelines for the optimal design/rehabilitation of stations including modularity and carbon footprint reduction, TRL5/6 in 2025

Task 9.1 Analyse of refuelling station location and configuration

A thorough assessment was carried out to identify optimal locations and configurations for hydrogen refueling stations in Poland, considering operational needs and future scalability. Simulation models for hydrogen refuelling stations were developed (Monte Carlo-based and FlexSim-based), providing visualization of the refuelling process and enabling the optimization of hydrogen procurement policy to minimize supply costs and inventory holding. First modelling results for the Polish case study were developed and successfully validated.

Task 9.2 Safety and risk management

A comprehensive update of the hydrogen-specific risk register was completed, identifying hazards across the refueling process and guiding mitigation strategies. Some exchanges with international partners, including UIC, allowed to align with evolving safety standards and ensure compliance with EU regulations.

Task 9.2 Safety and risk management – Hydrogen Risk Analysis

Risk assessment

A System definitione
Risk analysis including:
- Identification of risks
- Analysis of consequences
- RAP* selections
- Risk evaluations

B Specification of system requirements
List of identified risks combined with security measurements
Security requirements:
- Selected practice codes
- Objectives derived from the ERE
- **Reference system specifications

D Additional risks
Conditions of application

C Threat analysis
General analysis
- Hazard identification
- General case analysis
- Demonstrate consistency

Risk control

Legal framework

Responsibilities of the infrastructure manager and operator
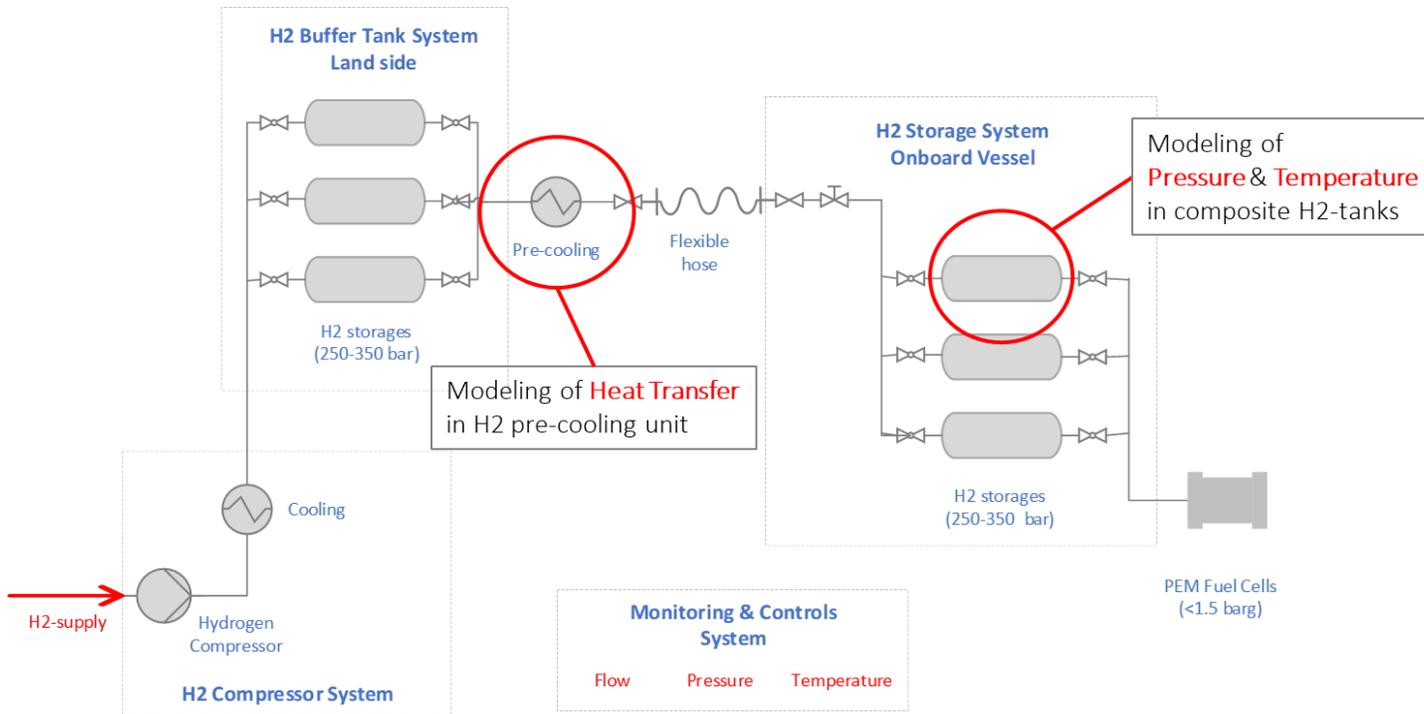
Supplier responsibilities

*Risc Analysis Program
**Energy Regulatory Authority

WP9: Interoperable Hydrogen Refueling Station

Task 9.3 Modelling of hydrogen refuelling systems and processes
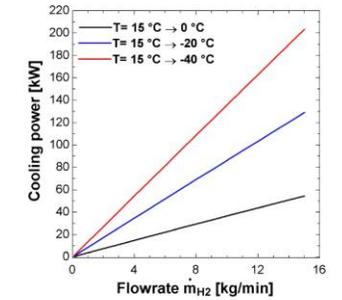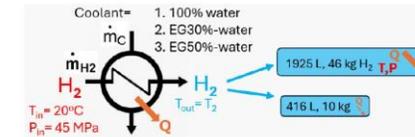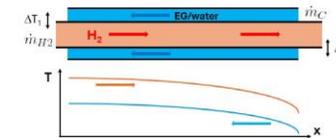
Advanced simulations of the hydrogen refueling process were performed using railway vehicle data. These models enable optimisation of key factors such as energy consumption, thermal dynamics, and refueling duration. The thermodynamic modelling tools by IFE and the draft of a technical report were completed.

WP9: Interoperable Hydrogen Refueling Station
Refueling simulation
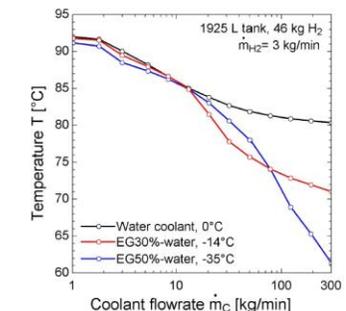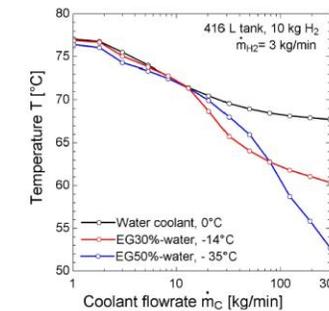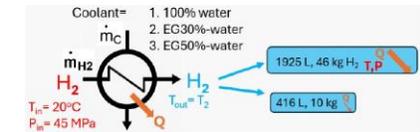
Task 9.4 H2 refueling Interface between vehicle and station

A preliminary design of a universal mechanical interface was developed to ensure compatibility between various types of rolling stock and hydrogen refueling systems. In parallel, the definition of a data exchange interface between the vehicle and refueling infrastructure was studied. This is a key step toward automation, safety monitoring, and interoperability across different systems and manufacturers. All the major interoperability challenges due to the scale of hydrogen storage planned for future locomotives (~2000 kg) were identified and a safer physical communication interface to replace infrared transmission was suggested.

Task 10.1 Double side feeding of 50 Hz AC traction substations using FACTS

The generic requirements useful for the design of the Railway Interline Power Flow Converter (RIPFC) and Static Frequency Converter (SFC) systems and their control strategy have been delivered. Two topologies and two control strategies have been proposed for RIPFC. The main work has been to simulate a line equipped with RIPFC to observe the transient behavior of RIPFC depending on the topology chosen and the control strategy that will be applied to the converter. Use cases on French and Italian railway networks have been modelled and simulated. Models of SFC and RIPFC are being implemented on the SNCF load flow tool to help determine the field of application of the converters and locate a potential experiment site.

WP10: Smart infrastructure power supply

Task 10.1 Double side feeding of 50 Hz AC traction substations using FACTS

First results of Italian use case initial situation simulation

Task 10.2 Energy storage solution for AC railway grid

A global simulation model of the Swedish railway traction power system has been successfully developed based on real-world field data. Advanced energy storage systems (ESSs) and corresponding interface converter technologies have been explored to address voltage instability and power quality. To support these ESSs, a dedicated DC-AC converter topology was developed and integrated in the existing traction power substation.

Task 10.3 Optimisation and management tools for AC & DC railway grid

New tools and methods related to energy use, CO_2 equivalent emissions, and the reduction of Life Cycle Costs at grid level on different use cases were created. The development of the load-flow simulation tools has been completed and validated with a real dataset of train on board and substation measurements. The specific use cases, centred on the Madrid-Levante high-speed railway line for the AC model and on the Zeeland railway line for the DC model, provided a practical scenario for analysing operational and power grid design parameters. Preliminary results of optimization based on Multi-Objective Differential Evolution (MODE) algorithm

The RET Energiebank in Rotterdam four other pilots

The pilots explore:

• how energy hubs can exchange power & energy between renewable sources, batteries, and train loads;

• capture both braking energy and renewable energy on the 3 kV DC rail system;

• how to store and manage energy on the AC side of the power system

All pilots improve the same KPIs: reduced energy use, lower CO_2 emissions, improved cost-efficiency, and smarter use of space and grid connections. Some even give a second life to old EV batteries, reducing waste and raw material demand.
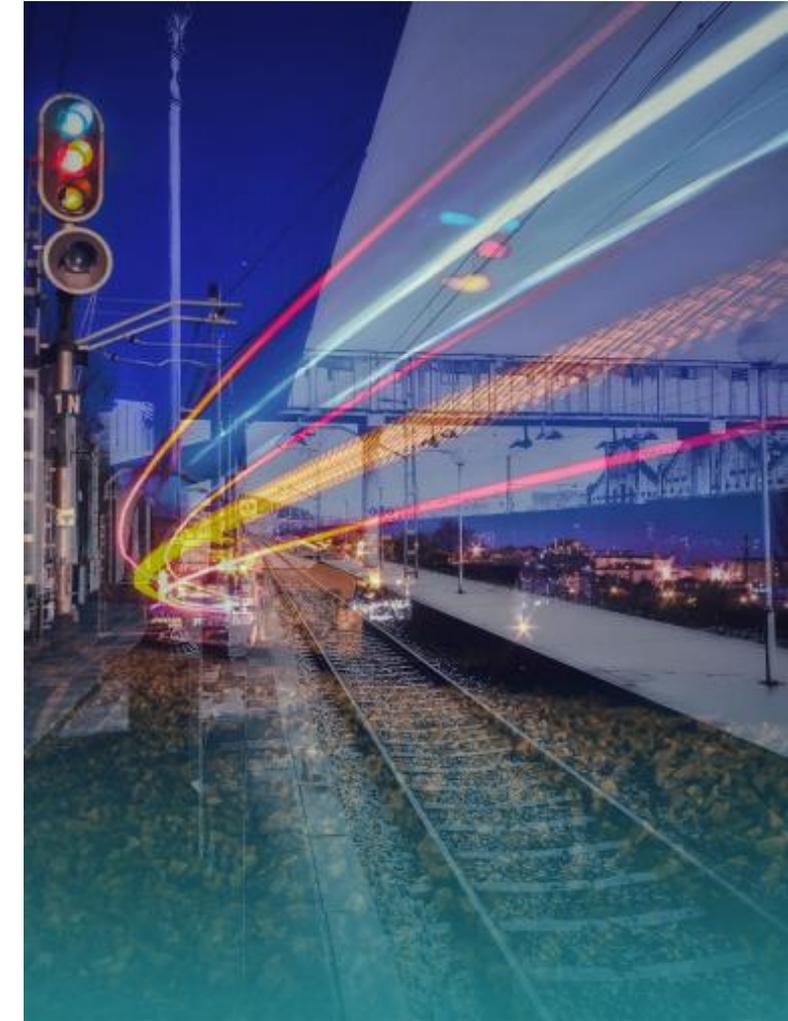
WP13: Building the Green Station of the Future

Task 13.1 Technologies for a new smart green modular station

The development of new type of stations using modular construction, digital technology, and renewable energy have been realised. One of the main results is a flexible, scalable station concept based on modular units (from small shelters to full-service stations). The design uses energy-efficient materials like Structural Insulated Panels (SIPs) and is prepared for off-grid operation with solar panels and battery storage. Energy simulations show that the most advanced modular variant reduce by 40% the energy consumption and emits 78% less CO_2 (in the construction phase) than a traditional station.

The project applies Building Information Modelling (BIM), Common Data Environments (CDE), and Digital Twins to support design, construction, and operation. These tools allow real-time monitoring of energy performance and remote management. Pilots in Poland and Spain have already started using these tools, with the goal of reducing both costs and environmental impact over the station's life cycle.

Task 13.2 Energy Digital Twin for existing railway stations

The development of the different modules of the digital twin have been realised. Heatmaps processing & visualization, sensors data aggregation & visualization, sensors alarms generation, simulation models and algorithms for automatic calibration and calculation of KPIs and ECMs are ready for connection to station data. Development and implementation of efficiency and maintenance alarms is still in progress.

Work is underway to adapt the information compatibility between the different data collection devices so that, once the sensors can finally be installed, the results collected and transmitted by the dataloggers can be monitored to feed the Digital Twin.
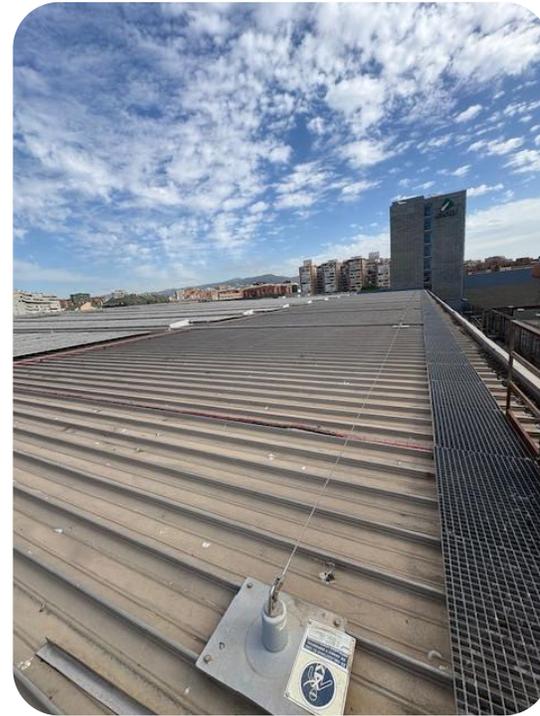
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SUB PROJECT 3
SUSTAINABILITY AND RESILIENCE
OF THE RAIL SYSTEM

Philippe CLÉMENT (SNCF Voyageurs)

Rail4EARTH information session – Teams – 04/12/2025

SUB PROJECT 3
SUSTAINABILITY AND RESILIENCE OF THE RAIL SYSTEM

SP6
ATTRACTIVENESS
OF **THE ROLLING STOCK**

SP1
ALTERNATIVE ENERGY SOLUTIONS FOR
THE ROLLING STOCK

SP5
HEALTHIER AND
SAFER RAIL SYSTEM
**ROLLING STOCK,
INFRASTRUCTURE &
STATION**

SP2
ENERGY IN RAIL
INFRASTRUCTURE & STATION

SP4
ELECTRO-MECHANICAL
COMPONENTS AND SUB-SYSTEMS
FOR **THE ROLLING STOCK**

SP3
SUSTAINABILITY AND RESILIENCE OF
THE RAIL SYSTEM

SUB PROJECT 3
SUSTAINABILITY AND RESILIENCE OF THE RAIL SYSTEM

SP3

WP 1 — Energy management at railway system level & related standardisation

WP 2 — Adaptation to climate change

WP 3 — Noise and vibrations

WP 4 — Circular economy & environmental data management tools and solutions

Planning : M1-M48

WP1 Energy management at railway system level & related standardisation
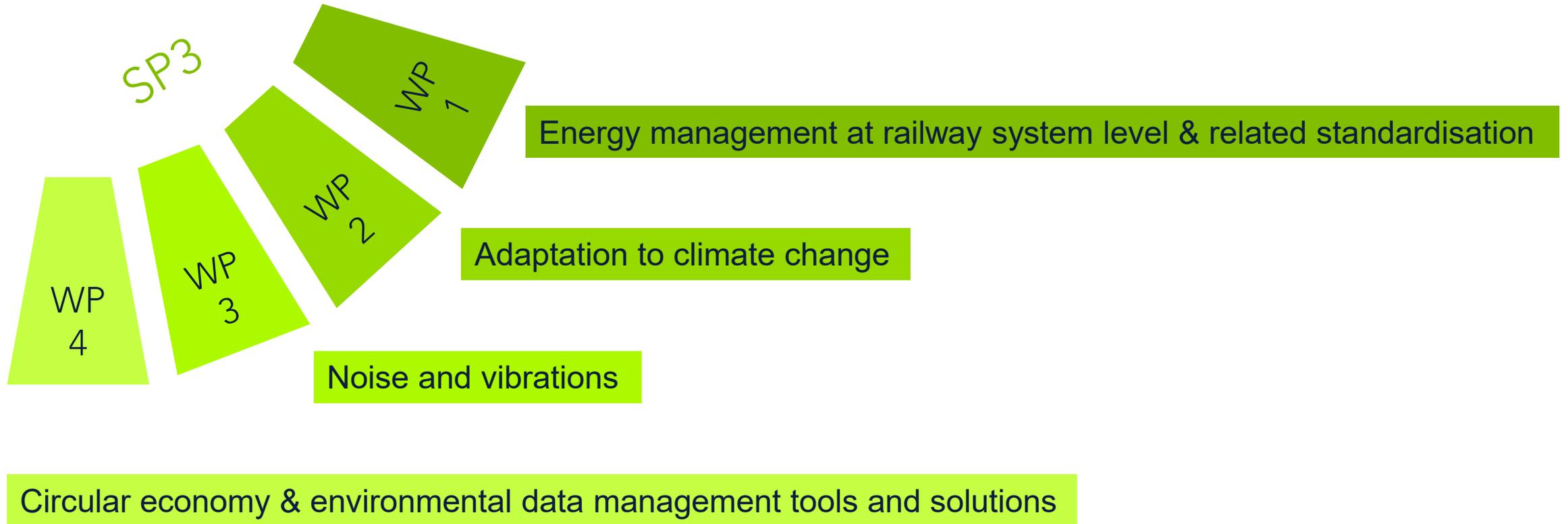
Tasks

1.1 - Pre-standardisation for trains with alternative drives (M1-M48)

1.1.1 Pre-standardisation of **battery interfaces**

1.1.2 Pre-standardisation of **interfaces between train and operation**

1.1.3 Pre-standardisation of **interfaces between train and infrastructure**

　　　1.1.3a Interfaces for high power <u>battery charging stations</u>

　　　1.1.3b Electrical <u>energy supply</u> for pre-conditioning in parking areas and termination stations

　　　1.1.3c Interface for <u>refuelling of hydrogen</u> trains

1.2 - Smart Energy Management (M1-M48)

1.2.1 Pre-standardisation of **energy management functions** (eco-mode on-board, preconditioning, peak shaving, Driver Advisory System, etc.)

1.2.2 Optimisation of **energy management at railway system level**

WP1 Energy management at railway system level & related standardisation

Achievements & on-going work

1.1 - Pre-standardisation for trains with alternative drives (M1-M48)

Pre-standardisation of **data exchange** between vehicle and TMS / Infrastructure

Pre-standardisation of **interfaces between BEMU train and infrastructure**: Voltage system for AC catenary islands

& Voltage system for electrical shore energy supply for overnight parking and longer daytime stops

Pre-standardisation of **ESS interfaces**:

High voltage connection of ESUs

Cooling interface

Low voltage interface for communication and safety relevant signals

ESS parameters for driver display and predictive maintenance

Pre-standardisation of the **H2 refuelling interface**, vehicle identification, methodologies to achieve 100% SoC

WP1 Energy management at railway system level & related standardisation

Achievements & on-going work

1.2 - Smart Energy Management (M1-M48)

State-of-art of existing ESS, management techniques and **optimisation of energy functions** for a reliable operation, for energy saving and predictive maintenance of BEMUs

Simulations and modelling of railway system level to **optimize the energy efficiency**

Definition of 6 scenarios (regional virtual profile) to model **battery train energy consumption**

Simulation activities for the **management and optimisation of onboard power**, auxiliary power consumption, etc

Study on **optimisation of BEMU charging**

Collection of studies related to optimise **charging strategies** in consideration of energy costs and grid production

Dissemination

WP2 Adaptation to climate change

Tasks

2.1 - Smarter adaptation

2.1.1 - Knowledges and tool : develop robust data

2.1.2 - Provide risks assessments

2.1.3 - List of railways standards to be updated

2.2 - Faster adaptation: identify existing solutions

WP2 Adaptation to climate change

Achievements & on-going work

2.1 - Smarter adaptation

Worldwide bibliography: Standards and regulations, Climate change prediction tools (databases and models), Risk assessment methodologies on climate change, Impacts of climate change on railway assets

Development of a tool/database on European climate variables usable for railway assets design: tool requirements defined, Météo-France service proposal received

Identification of the **main railway assets** affected by each climate variable in each area of Europe

Risk assessments : methodologies identification and 'impact chain' analysis on railway assets

List of standards vs assets sensitive to climate change

2.2 - Faster adaptation: identify existing solutions

Benchmark of **existing solutions** throughout the world

Dissemination

WP3 Noise and vibrations

Tasks

3.1 - Further improvement of noise source characterization

3.2 - Noise perception indicator

3.3 - Noise and vibrations emission over lifespan

3.4 - Development of effective mitigation measures of ground-borne vibration

3.5 - Squealing noise

WP3 Noise and vibrations

Achievements & on-going work

3.1 - Further improvement of noise source characterization

Methodology for **aeroacoustics source characterization**: first bogie, inter-coach gap

Virtual certification and application case: Comparison simulation for different rolling stock at standstill and pass by operating mode

3.2 - Noise perception indicator

Filed tests on **tonality perception**

High-speed indicators : lab experiment to study the effect of train passage duration and suddenness on annoyance

3.3 - Noise and vibrations emission over lifespan

Assessment vibration emission of **NeoBallast track concept**

Benchmark of **track degradation models** & comparison of railway track degradation with help of models

Fiber optic data communication cables for vibration emission measurements

WP3 Noise and vibrations

Achievements & on-going work

3.4 - Development of effective mitigation measures of ground-borne vibration

Ground-borne vibrations **calculation model and prediction tool**: use of STEM model & SILVASTAR tool

Ground-borne vibration **mitigation measures** catalogue

Effective **mitigation measures**: Production of Neoballast made of limestone aggregates for the dynamic tests

3.5 - Squealing noise

Catalogue with practical **mitigation solutions**

Insight in relationship between **squealing noise and meteorological parameters** on the basis of long-term measurements

Comparison of squeal noise **measurements** data with output of the WERAN calculation **model**

Application of **ACOUTRAIN procedures** for squeal behaviour of trains and railway curves

Data from the **long-term measurements** collected

WP3 Noise and vibrations

Dissemination

PHILIPPE CLÉMENT - Rail4EARTH information session - SP3 - Teams

Tasks

4.1 - Environmental data management tool and environmental indicators

4.2 - Circular economy solutions

Achievements & on-going work

4.1 - Environmental data management tool and environmental indicators

Design of an ecolabel for rolling stock and infrastructure on :

- Global Warming Potential of materials

- Circularity of materials

- Energy efficiency

Calculation methodologies description and application

Achievements & on-going work

4.2 - Circular economy solutions

Market place: mock-up realised

Linear materials: works on copper, renewable materials, thermoset composites, steel, additive manufacturing

Sharing and leasing: works on yellow machines for infrastructure, fiber optic network, FRMCS

Circular sleepers: railway tie developed using recycled thermoset composites from sidewalls

Circular catenary system: railway-specific Life Cycle Assessment (LCA) database developed, key catenary components for circular reuse identified

Circular stations: modular station developed with reduced material use and embodied carbon

Dissemination

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SUB PROJECT 4
Electro-mechanical components and sub-systems for the rolling stock

WABTEC : Yannick Brunaux

Contributors (12 CFMs)

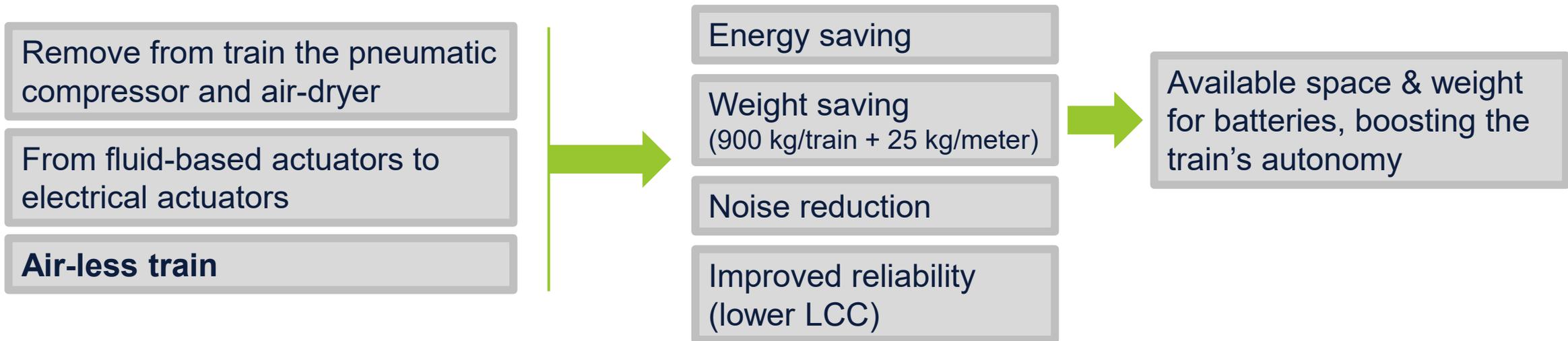# Objectives

Developing and introduce to the market **(airless) electro-mechanical braking system, pantograph and suspensions** while targeting energy savings on the involved subsystems and reduce associated maintenance costs by reaching TRL6 for 2025 and prepare for later evolutions.

Remove from train the pneumatic compressor and air-dryer
From fluid-based actuators to electrical actuators
Air-less train

Energy saving
Weight saving (900 kg/train + 25 kg/meter)
Noise reduction
Improved reliability (lower LCC)

Available space & weight for batteries, boosting the train's autonomy

- <u>**Demonstrators**</u>**: air-less brake, air-less pantograph and air-less suspension systems**
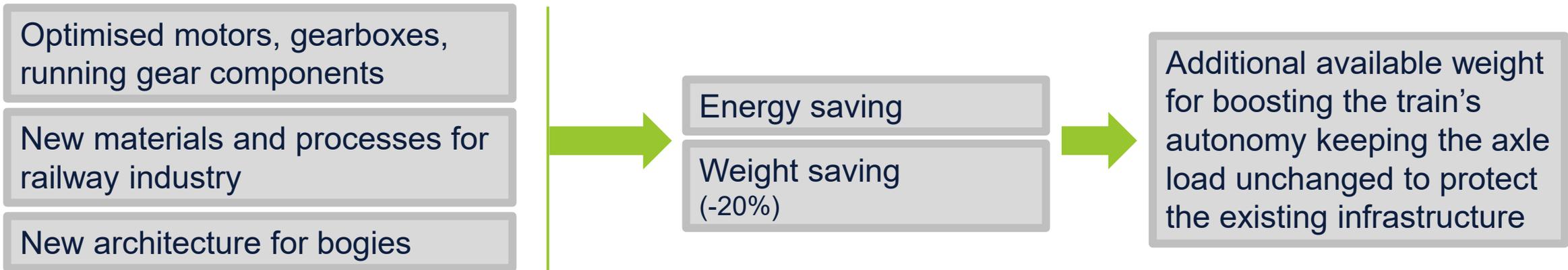- **Collegial work for interoperability standards adaptation**

Objectives

Work packages **16** and **17**

Introducing **optimized (energy, weight) motors and gearboxes**, high performance **bogies**, suspensions and **new materials following circular economy** principles and reaching TRL6 in 2025.

Optimised motors, gearboxes, running gear components

New materials and processes for railway industry

New architecture for bogies

Energy saving

Weight saving
(-20%)

Additional available weight for boosting the train's autonomy keeping the axle load unchanged to protect the existing infrastructure

- **Demonstrators: new running gear architecture based on conventional axle and independent rotating wheels, active steering systems, innovative gearbox, light-weight axle, IM and PMSM motors.**
- **Common work for standards adaptation (EN 13749) and the creation of new ones (CEN/TC256/SC2/WG54)**
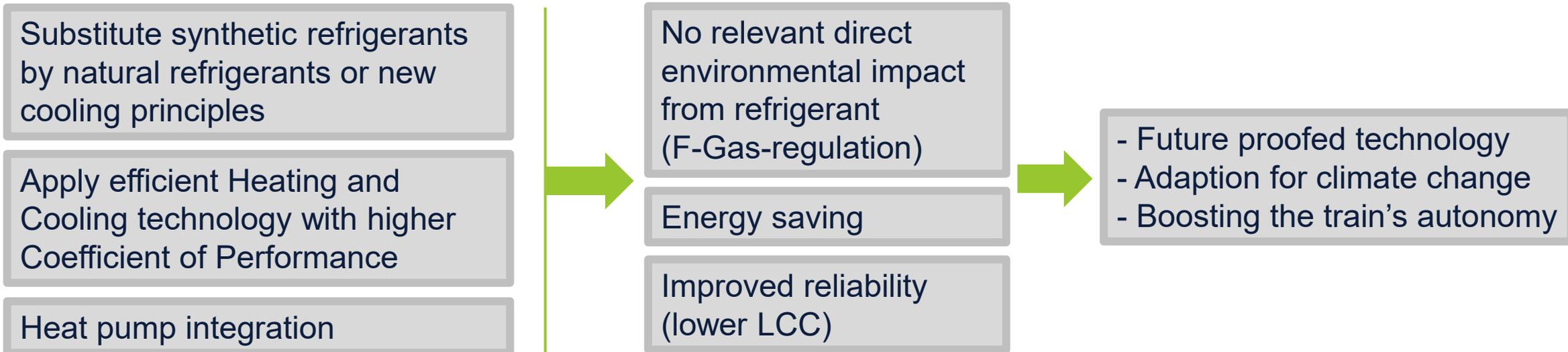
Objectives

Enabler 12

Delivering alternative technologies to **replace hydrofluorocarbon refrigerants by HVAC system using green refrigerants or new cooling technologies** with reduced energy consumption and targeting TRL6 in 2025.

Substitute synthetic refrigerants by natural refrigerants or new cooling principles	No relevant direct environmental impact from refrigerant (F-Gas-regulation)	- Future proofed technology - Adaption for climate change - Boosting the train's autonomy
Apply efficient Heating and Cooling technology with higher Coefficient of Performance	Energy saving	
Heat pump integration	Improved reliability (lower LCC)	

- **<u>Demonstrators</u>: HVAC systems with similar mechanical and electrical interface**
- **Collegial work for standards adaptation**

Objectives

Enabler 13

Work packages **20**

Introducing **enhanced experimental and numerical methods** at TRL6 on **aerodynamic** reaching certifications by 2025.

Reduce expensive and long-lasting test runs

Simplify certification of new geometries and technologies using newly developed methods

Improve positioning and geometry of installations and pantograph on train roof

Certification cost and effort reduction
Energy saving
Noise reduction

Fast, easy and convenient certification of energy efficient and safe trains

- **Demonstrators**: aerodynamic virtual certification method and aerodynamical optimised roof and pantograph

Main innovations

The air-less train
novel systems for brake, pantograph and suspension

1

New technology and/or alternative refrigerant for train's HVAC

2

Optimised motors & gearboxes, high-performance bogies, suspensions and new materials following circular economy principles

3

Virtual certification of aerodynamic systems

4

Links with other FPs

FP4
work packages 16-17

🔗

FP6
work packages 5-10

Light bogie/axle

Light regional trains

FP4
work packages 14-15-16-17

🔗

FP4
work package 6

High performance BEMU

FP4
work packages 14-15-16-17

🔗

Shift2Rail
PINTA, PIVOT, PIVOT2

Continuation/extension of R&I activities

KPIs impacted by sub-project 4

Physical energy consumption (train)
kWh/passenger.km | kg CO2/year.m2 | kg H2/vehicle.ton.km

Physical CO2 equivalent emissions
kg CO2/passenger.km | kg CO2/year.m2

Life Cycle Costs reduction
(for specific use cases including externalities costs)

Autonomy
km

Noise emitted per component
dB

Flagship Project 4-Rail4Earth

SUB PROJECT 5
# Healthier and safer rail systems

SP 5 coordinator:

Daniel SCHMELING (DLR) and Hesther PLATENKAMP (NS)

Partners:

ATSA, CAF, DB, DLR, FT, KB, NS, OBB, SMO, SNCF, STS, TRV

SP 5 – Introduction

- ~500-600 ml per breath (typ. tidal volume)
- ~10 breaths per minute

  → ~7.500 Litres air per day

  (~3 Litres drinking per day)

  → ~2.700.000 Litres inhaled air per year

  (Olympic-swimming pool (50m

  x 2m x 25m) → 2.500.000 Litres)


©: swimsportnews.de

SP 5 – Main Objectives
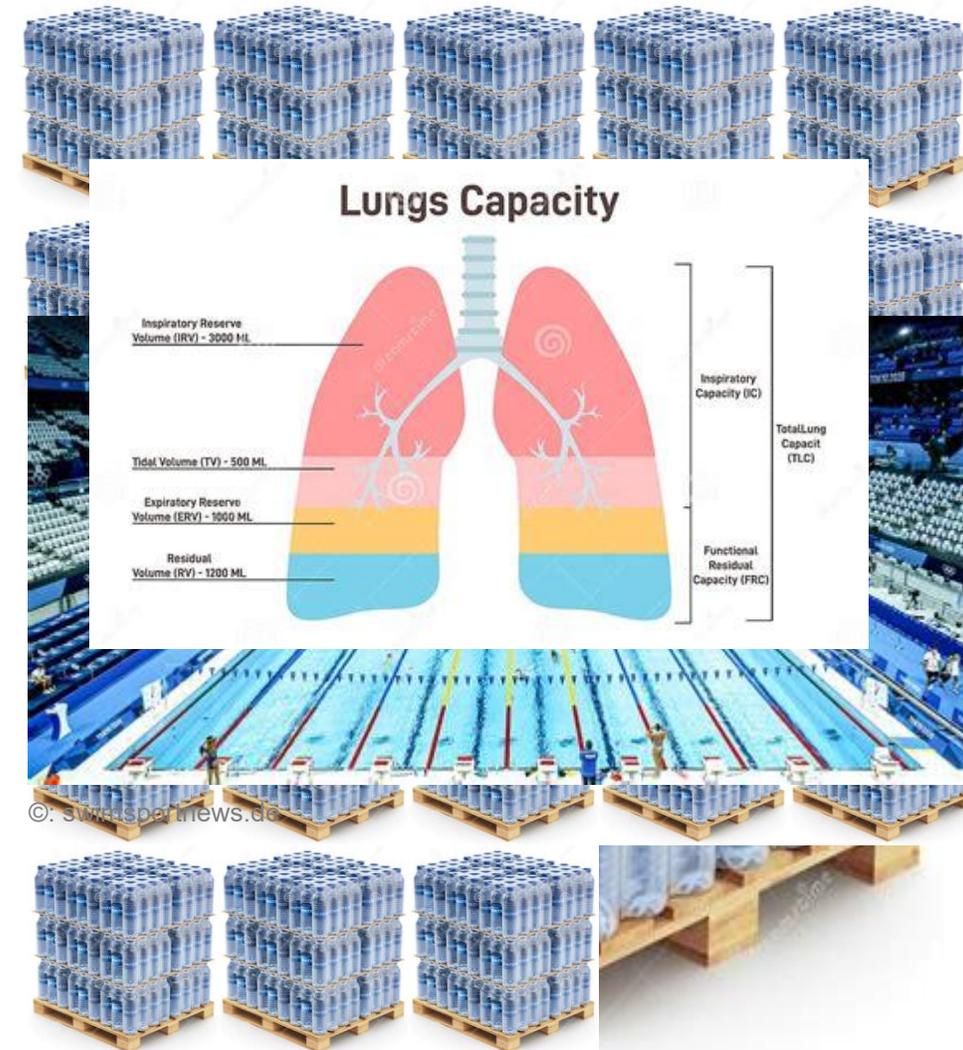
Developments of technologies and methodologies ensuring a reduced health risk for rail passengers and staff:

- Standardized measurement protocol to assess the efficiency of technologies to improve air quality (PM, VOC, virus/bacteria, …) on board, in stations and tunnels;

- Air-distribution and air-flow management concepts for a more effective removal of contaminants from the passenger compartment while maintaining the thermal comfort;

- Air-filtration and disinfection systems for an enhanced air cleaning in the HVAC system;

- Enhanced surface materials for reduced virus/bacteria lifetime;

Build a better understanding of the issue of non-exhaust emissions emitted by wear particles from brakes, wheels-rail contact, pantograph-catenary line contact and assess the risks.

- Analysis of air quality in underground station and tunnels;

- Air quality mapping: define a method to evaluate and report the non-exhaust emissions emitted by the railway activities;

- Define a method to evaluate and report the efficiency of air pollutants reduction solutions in operational conditions.

SP5 – Structure
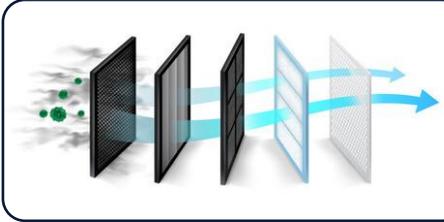
WP 21 – Rolling stock on board air quality developments

- M1 – M24
- Lead: Wabtec - Faiveley Transport

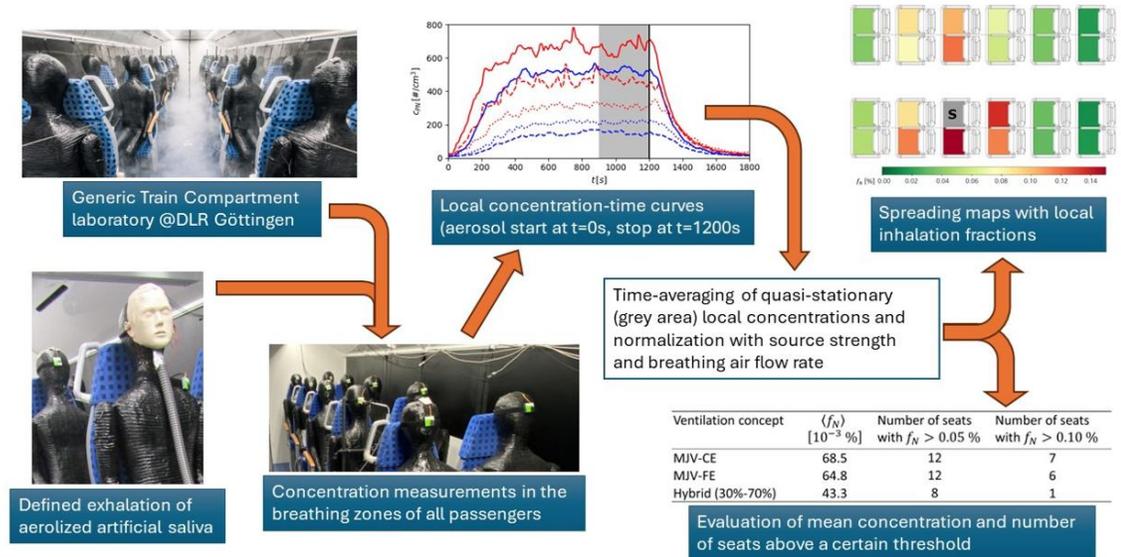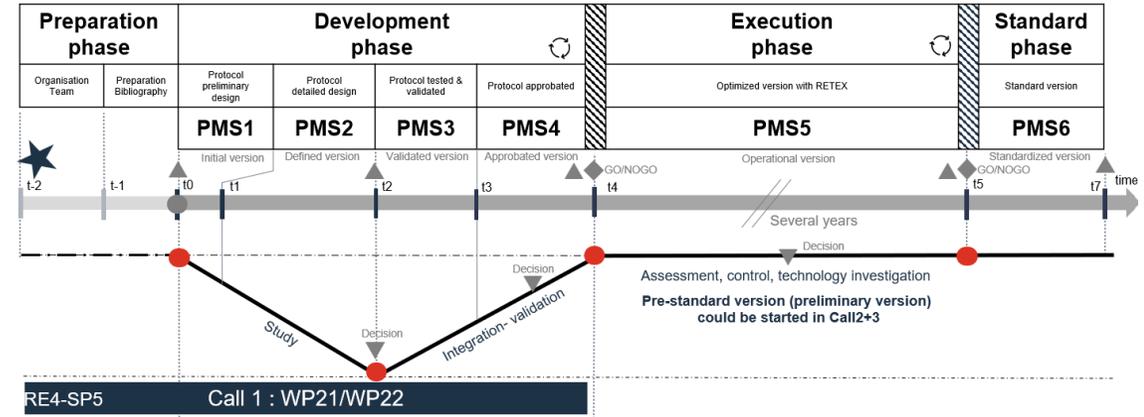## WP 22 – Rolling stock on board air quality demonstrations

- M25 – M48
- Lead: Alstom

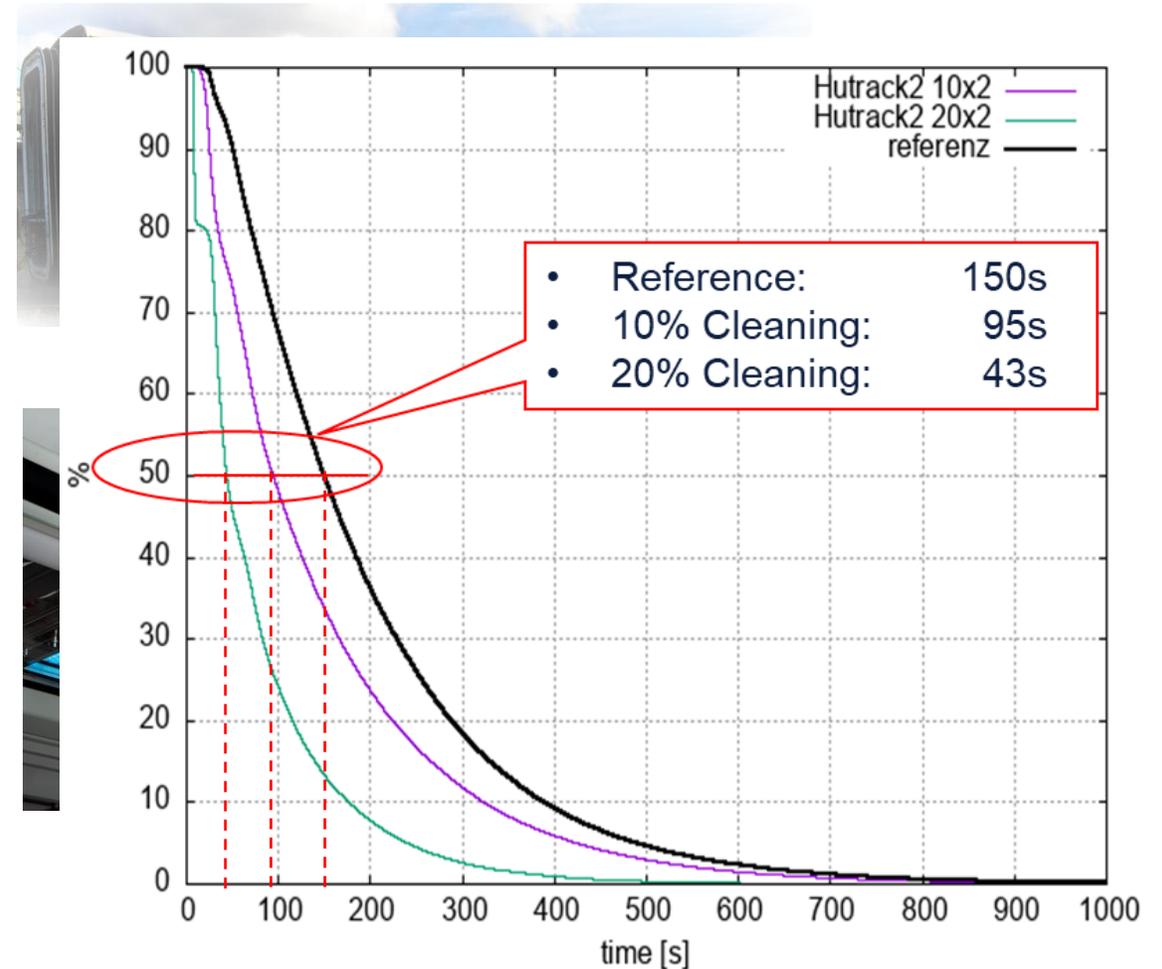## WP 23 – Air quality on covered platforms and tunnels

- M1 – M48
- Lead: SNCF

Images: Adobe Stock Photos / DLR

Air Quality Measurement Protocol

- **Solution:**
  A methodology for developing air quality validation protocols based on a V-model process combined with a protocol maturity scale and a systematic testing approach based on the target, the technology and scale of testing

- **Levels of Validation:**
  - component,
  - mock-up
  - train levels

- **Domains of Activity:**
  - air treatment
  - surface treatment
  - air quality measurements

- **Pollutants and Pathogens:**
  - particulate matter
  - VOCs
  - biological agents (bacteria, viruses, fungi), with surrogate models used for controlled validation.

- **Communication/dissemination:**
  - Paper and presentation at TRA2026

Generic Train Compartment laboratory @DLR Göttingen

Local concentration-time curves (aerosol start at t=0s, stop at t=1200s)

Spreading maps with local inhalation fractions

Time-averaging of quasi-stationary (grey area) local concentrations and normalization with source strength and breathing air flow rate

Defined exhalation of aerolized artificial saliva

Concentration measurements in the breathing zones of all passengers

Evaluation of mean concentration and number of seats above a certain threshold

Images: Pereira et al. TRA 2026

Measurement Campaign in Real Long-Distance Train Laboratory "DIRK"

- **Solution:**
  - Hatrack

- **Performance:**
  - Reduction of active (not settled or removed) particles within the passenger comaprtment by up to 50 %, calculated with CFD simulation with Lagrangian particle spreading

- **Implementation:**
  - Separate standalone modules to replace existing panels of the hatracks. Connection to electric power required. Future iterations as integrated parts thinkable.

- **Organizational/Scheduling:**
  - L3a: DB Dirk demo confirmed in October 2025 (W44+45), duration of 2 weeks. Localization in Germany.

- **Maturity:**
  - TRL5 to be reached in 2025 (see above).

- **Communication/dissemination:**
  - Applied for patent
  - Scientific journal publication in preparation

- Reference: 150s
- 10% Cleaning: 95s
- 20% Cleaning: 43s

Images: © DLR and © DB Systemtechnik

Air Purification Solutions

- **Further Solutions:**
  - High-efficiency anti-microbial filter elements (PEPA-F)
  - Bi-polarized ion generator
- **Performance:**
  - Filtering of recirculating particulate matter and potentially contaminant-laden particles
  - Generation of bi-polarized ions which inactivate biolocigal contaminants like viruses
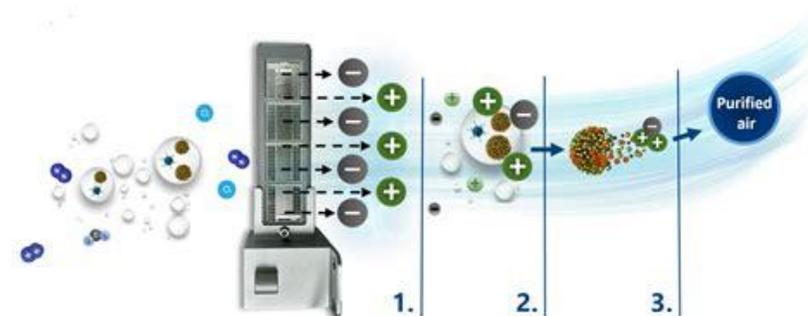- **Implementation:**
  - Test as replacement of existing filter units
  - Integration in supply air duct
- **Organizational/Scheduling:**
  - L3a: DB Dirk demo confirmed in September-December 2025, duration 5 weeks in total. Localization in Germany.
- **Maturity:**
  - TRL6 to be reached in 2025.

Images: © DB Systemtechnik / Alstom / railexpress.com

Air Quality Assessment on Platform and Prediction Tools

PM 10 Spatial distribution across the Arlanda Central platform

Sensor	Parameter	R²	K value
Sensirion Sen55 C998 Next to fidas	PM 1	0.93	5.29
	PM 2.5	0.88	5.73
	PM10	0.74	4.67

Fidas 200S

Sensirion SEK-SEN5x

IQ Air

Fidas
Sensirion Cage 1 Towards Stockholm
IQ Air
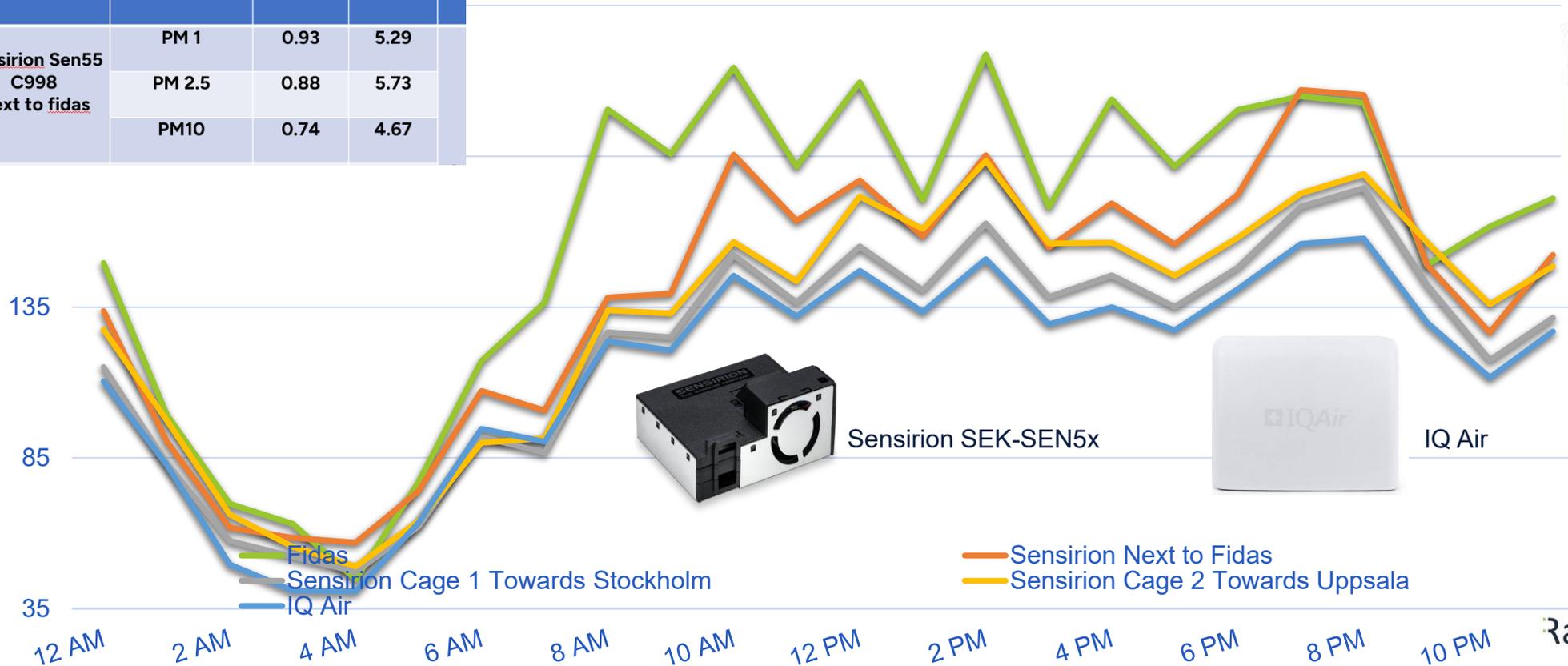
Sensirion Next to Fidas
Sensirion Cage 2 Towards Uppsala

Selecetd Publications:
Tu & Olofsson (2024): Estimating PM levels on an Underground Metro Platform by Exploring a New Model-Based. Atmospheric Environment: X(22), 100261
Schwartz et al. (2025): Short and Long-Term Air Quality Prediction in Underground Station; WCRR

Air Quality Assessment on Platform and Prediction Tools

Long-term data set

- A multi-factor linear mixed-effects model was applied using over two years of air quality data from the KTH metro station in Stockholm

- $R^2 = 0.8 – 0.85$
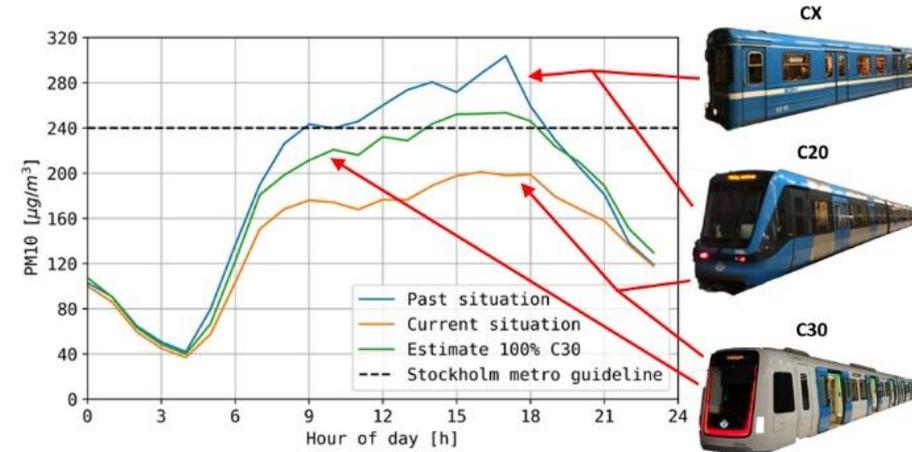
Tested models – Random forest model

- Employing air quality measurement data from the Sevran Paris railway system in 2023, alongside ten meteorological parameters (including rainfall, wind speed, etc.), train frequency and train types, as well as outdoor PM2.5, PM10, NO, NO_2, NO_X, and O_3 data, a random forest model was developed
- $R^2 = 0.62$

Predictions on test set
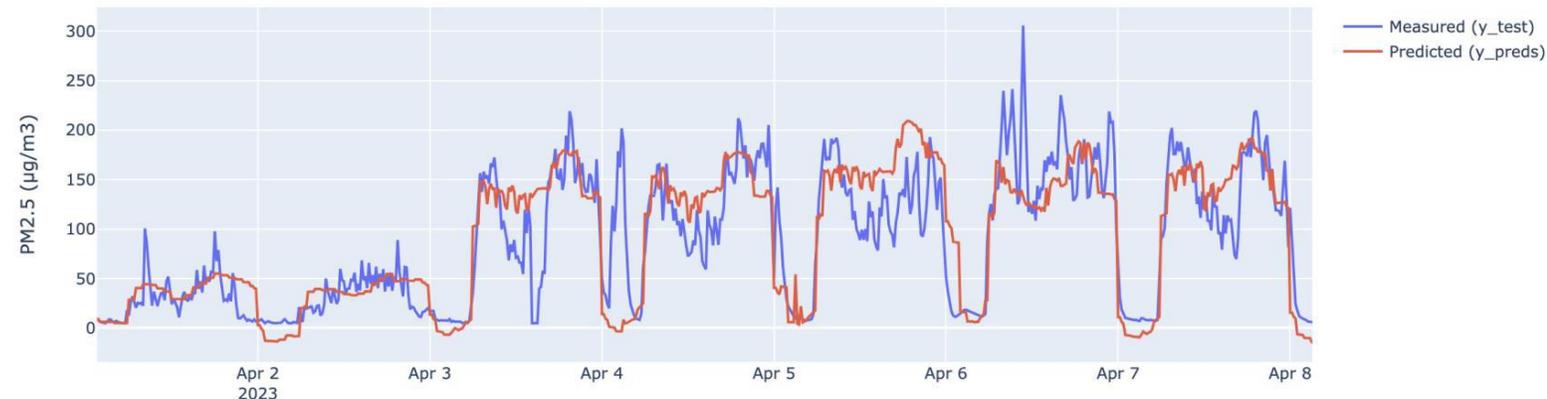
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Flagship Project 4-Rail4Earth

SUB PROJECT 6 ATTRACTIVENESS

Information Session

04/12/2025

SP Leader Robert DUMORTIER – SNCF

Co-leader Eduardo de la Guerra - TALGO

The Destination 6 Attractiveness

Attractiveness

This destination is expected to develop rolling stock interiors designed by modularity, plug and play fixation systems by innovative low-tech, circular design and comfort aspects, as well as to develop new architectures for driver's cabin to reach TRL7/8 in 2028.

Within this Destination, the demonstrations will be supported on:

• **Enabler 15**: **The facilitation of on-demand/modular comfort** for users such as access, lighting, thermal and acoustic conditions as well as with new architectures to increase passenger capacity at TRL8 in 2028.
TRL 5/6 in 2026 (CALL1)

• **Enabler 16**: **The facilitation to adapt rolling stock** with refurbishment and innovative concepts to support the increase of capacity of the rolling stock, including accessibility to PRM at TRL7/8 in 2028 and prepare for later evolutions.
TRL 5/6 in 2026 (CALL1)

The Destination 6 Attractiveness

WP24 – Sustainable Interiors, Knowledge and Opportunities (M1-24)

Leader WP24 : SNCF Voyageurs

Task 24.1 – State of the Art (M1-M8)
Leader: SNCF-V Contributors: ALSTOM, HITACHI, NS/Pro-Rail, TALGO
Task 24.2 – Analysis of opportunities (M6-M12)
Leader: SNCF-V Contributors: ALSTOM, HITACHI, NS/Pro-Rail, TALGO
Task 24.3 – Proposal of the main aeras to develop (M10-M24)
Leader: SNCF-V Contributors: ALSTOM, HITACHI, NS/Pro-Rail, TALGO

WP25 – Sustainable Interiors, Pre-concepts and Mock-ups

Leader WP25 : SNCF Voyageurs

Task 25.1 – Ideation and pre-concepts of Ultra-modularity (M24-M42)
Leader: ALSTOM Contributors: HITACHI, NS/Pro-Rail, SNCF-V, TALGO
Task 25.2 – Ideation and pre-concepts of Circular design (M24-M42)
Leader: SNCF-V Contributors: ALSTOM, HITACHI, NS/Pro-Rail, TALGO
Task 25.3 – Demonstrators Sustainable Interiors (M36-M48)
Leader: ALSTOM Contributors: HITACHI, NS/Pro-Rail, SNCF-V, TALGO

WP26 – User experience and User Interfaces, Knowledge and pre-concepts

Leader WP26 : TALGO

Task 26.1 – State of the art and analysis of opportunities (M1-M14)
Leader: SNCF-V Contributors: HITACHI, SIEMENS, TALGO, ALSTOM
Task 26.2 – New architectures to facilitate the modularity, flexibility, ideation and pre-concepts (M12-M48)
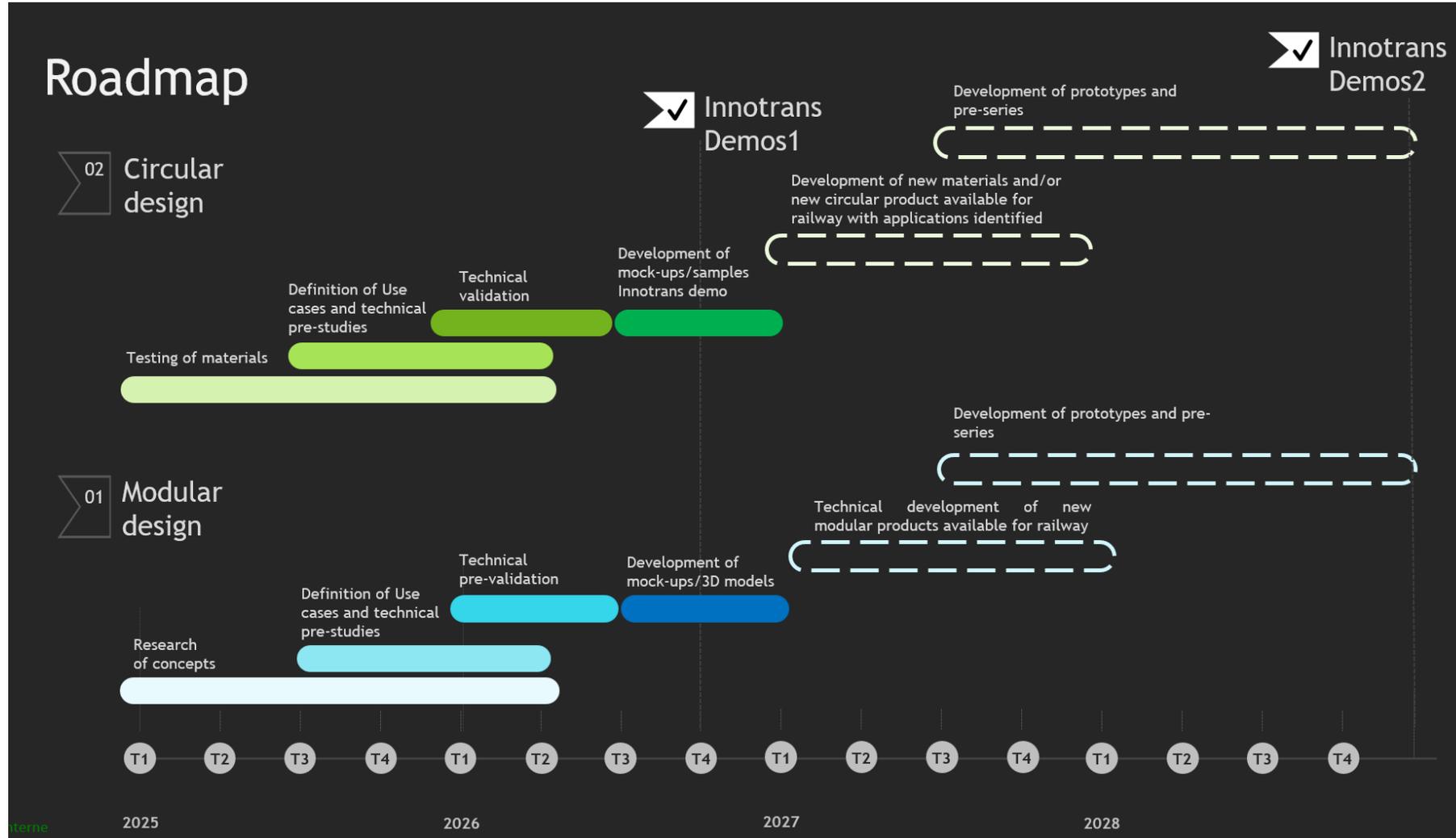Leader: TALGO Contributors: SIEMENS, SNCF-V, ALSTOM
Task 26.3 – New user interfaces, ideation and pre-concepts (M12-M48)
Leader: TALGO Contributors: HITACHI, SIEMENS, SNCF-V
Task 26.4 – Demos User experience-User Interface (M30-M48)
Leader: TALGO Contributors: HITACHI, SIEMENS, SNCF-V, ALSTOM

The Destination 6 Attractiveness

Attractiveness

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- **Enabler 16**: The facilitation to adapt rolling stock with refurbishment and innovative concepts to support the increase of capacity of the rolling stock, including accessibility to PRM at TRL7/8 in 2028 and prepare for later evolutions.

- Done
- In progress

| Circular material 1A recycled/reused materials	Circular material 1B rapidly renewable materials	Modular design 2A Quick fasteners	Modular design 2B Separable design	Less material 3A 3D printing	Less material 3B Simply design	Standardisation 4A Analysis EN standards vs sustainable	Standardisation 4B Analysis EN standards vs modular layout
ALSTOM interiors panels in recyclied and reused composite	ALSTOM -	ALSTOM strong part of interiors (seat, luggage rack, …)	ALSTOM interiors panels	ALSTOM -	ALSTOM -	ALSTOM contribution	ALSTOM leader
HITACHI -	HITACHI -	HITACHI -	HITACHI Ceiling panel and wall	HITACHI -	HITACHI One seat beam multi confort	HITACHI contribution	HITACHI contribution
NS -	NS interiors panels « Woodflow»	NS Fasteners for ceiling panels	NS Ceiling panels	NS interiors panels « Woodflow »	NS One ceiling panel multifunctions	NS leader	NS contribution
SNCF interiors panels with reused materials	SNCF -	SNCF strong part of interiors (seat, luggage rack, …)	SNCF partition wall	SNCF -	SNCF partition wall	SNCF contribution	SNCF contribution
TALGO seat beam in recyclied composite fiber	TALGO interiors panels « Woodflow »	TALGO sliding bowl of toilet day/night	TALGO Toilet panels	TALGO interiors panels « Woodflow »	TALGO One seat beam multicapacity One toilet day/night	TALGO contribution	TALGO contribution

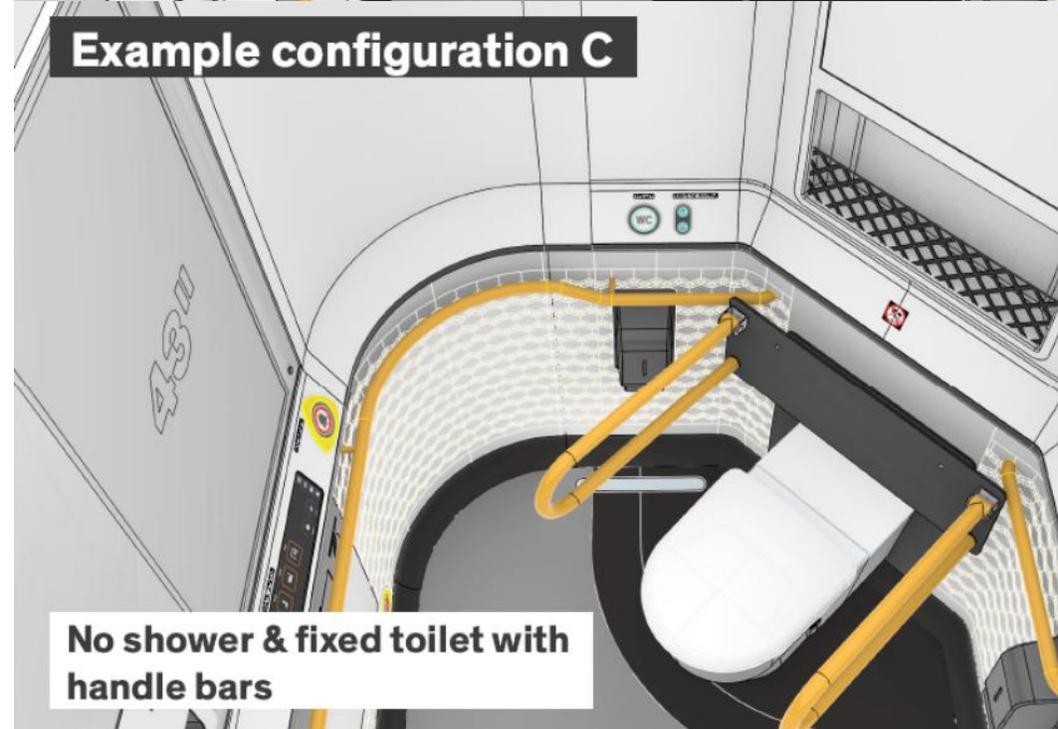# FOCUS – Modular toilet and new user experience

Mock-up ready and under testing
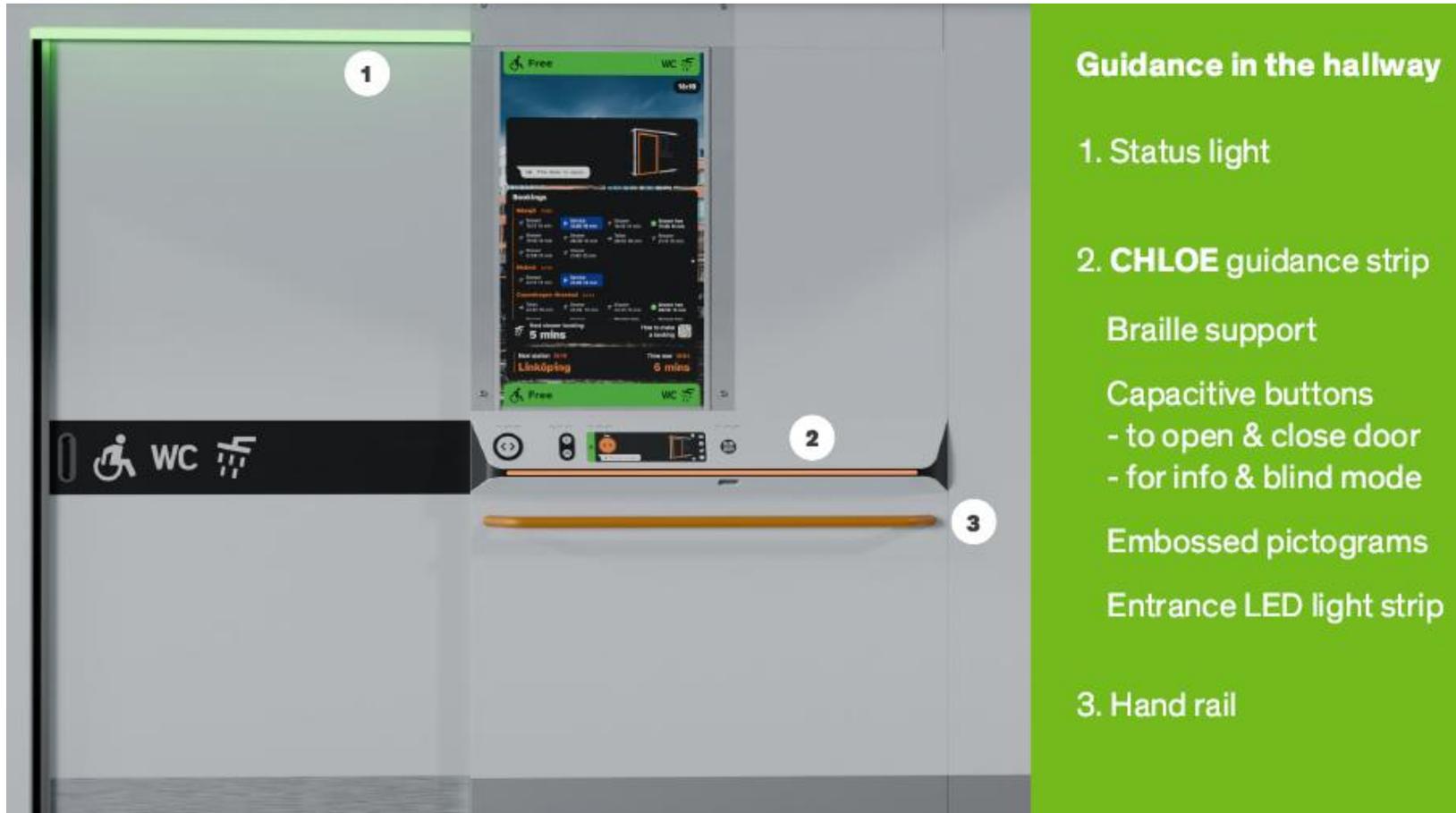
CALL#1
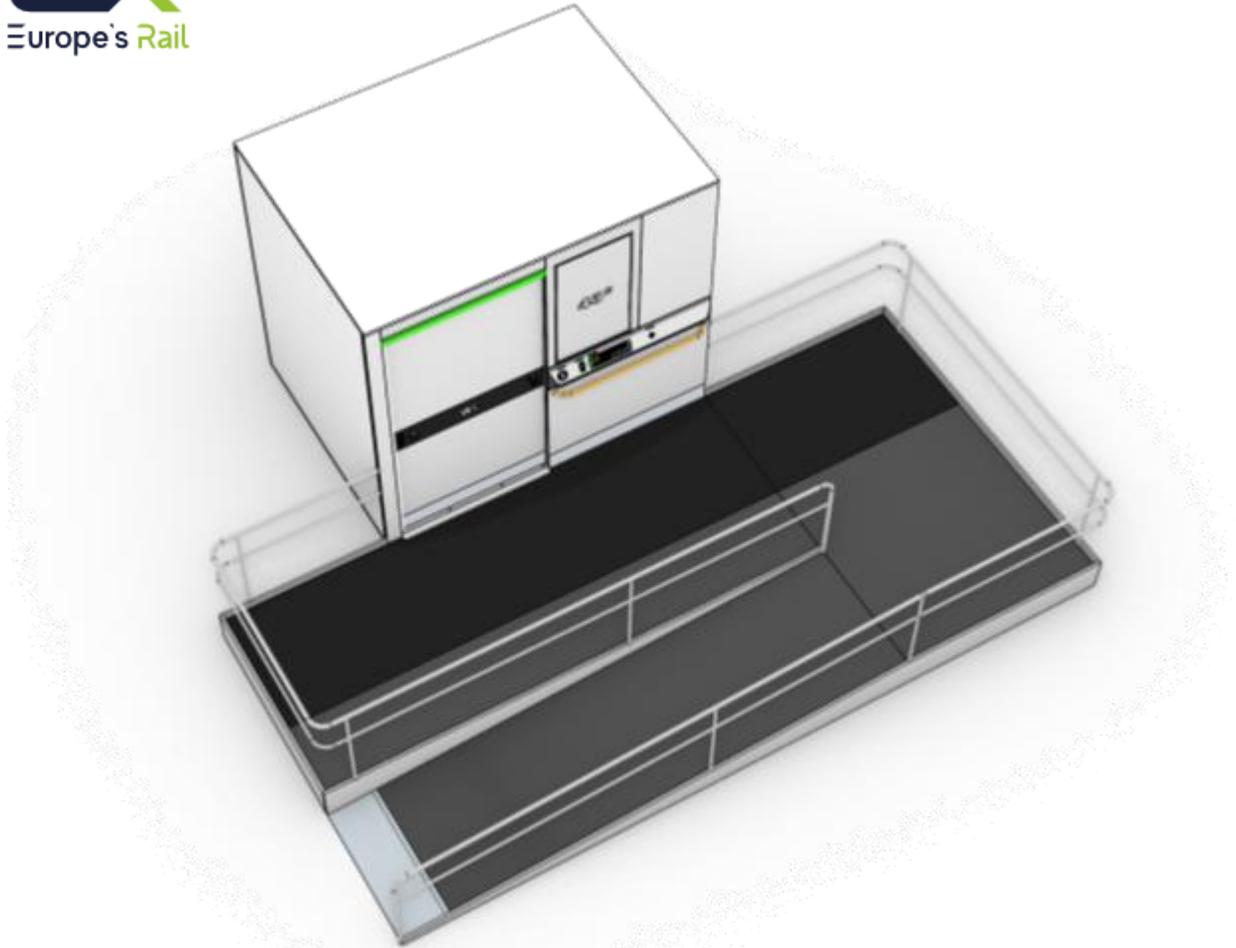
Example configuration A
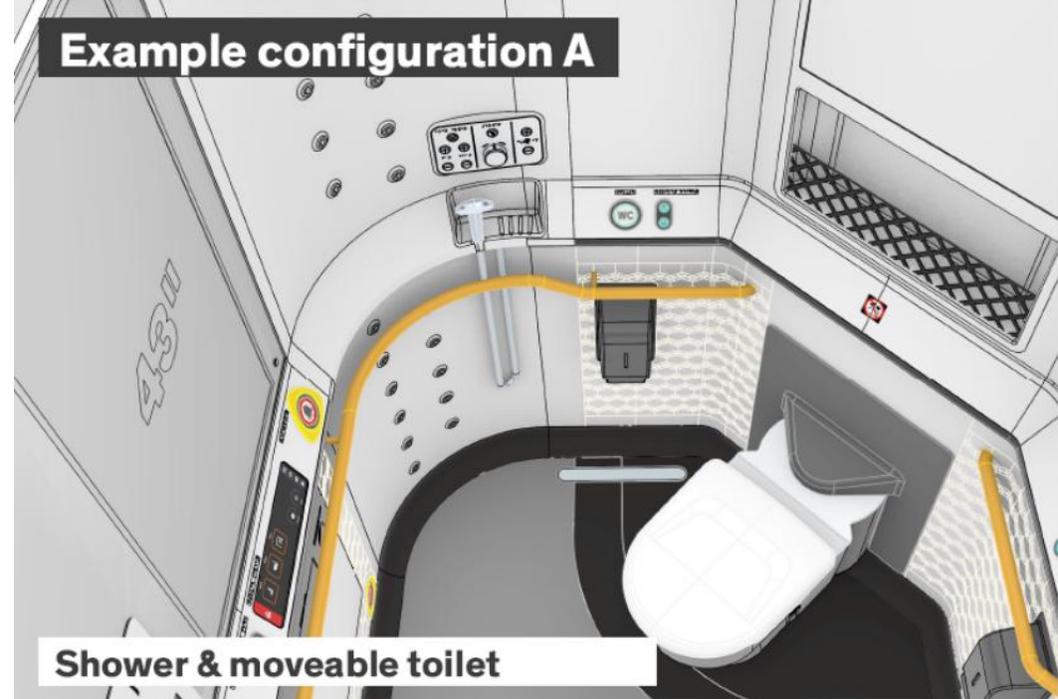
Shower & moveable toilet

Example configuration C

No shower & fixed toilet with handle bars

CALL#1

Really UNIVERSAL toilet concept from the entrance…

Really UNIVERSAL toilet concept from the entrance…

Status indication in the hallway

Standard colour coding (red and green) with intelligent status due to the context of the passenger and the door:

red for occupied lavatory
- while person is in the cabin
- while door is still open
- while door is closed only
- while door is locked

green for free & empty lavatory, see previous slide
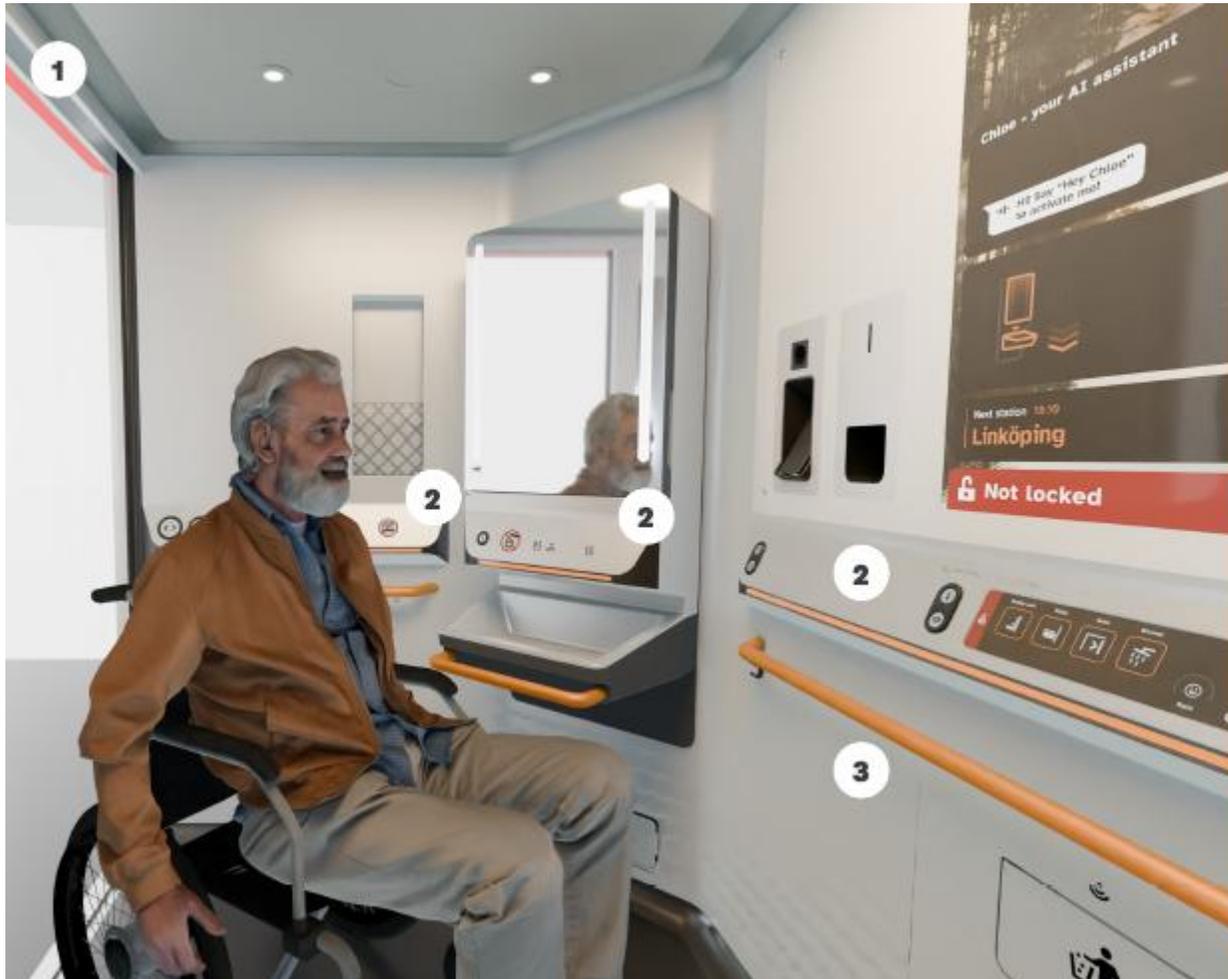
Really UNIVERSAL toilet concept from the entrance…

Really UNIVERSAL toilet concept from the entrance…

CALL#1

Really UNIVERSAL toilet concept from the entrance…

CALL#1

Really UNIVERSAL toilet concept from the entrance…

Adaptive vanity unit

Height adjustment via

1. voice activation "Hey Chloe, raise the vanity unit please"

2. capacitive buttons

3. touch screen interface

CALL#1

Really UNIVERSAL toilet concept from the entrance…

Founding Members

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