INTERNATIONAL UNION
OF RAILWAYS

Welcome to the workshop

LONG TERM PROSPECTS

FOR ENERGY EFFICIENCY AND DECARBONISATION IN RAIL

Proposed by
the UIC Energy efficiency and CO_2 Emissions Sector
Funded by UIC Members:
ADIF, CP E.P.E., FS, FTIA/VÄYLÄ, INFRABEL, KORAIL, NETWORK RAIL, PRORAIL, SBB CFF FFS, SNCB/NMBS

Organised by UIC & the Sector's core members:

Gerald Olde Monnikhof, ProRail

Philippe Stefanos, UIC

SUSTAINABILITY
Action Week

11 March 2025

INTERNATIONAL UNION
OF RAILWAYS

LONG TERM PROSPECTS

FOR ENERGY EFFICIENCY AND DECARBONISATION IN RAIL

Welcome / Introduction

Introduction

We are in the middle of transitioning to carbon free systems

Not a lot behind us (experience)

Not a lot remains in front of us
(time until needed decarbonisation)

Purpose of the workshop

Initial idea

Explore long-term developments opportunities and different roadmaps, to better plan ahead a clean transition to renewable energy or carbon free operations, adapted to the rail sector specificities

Why

It is especially important to plan ahead, as the transition to cleaner fuels or electricity, or even partial electrification, could be implemented short term, but has to be compatible with the rail sector’s long lifespan and renewal cycles

PURPOSE OF THE WORKSHOP

How

- **Deciding on new technologies & early adoption?**
- Transition to clean energy sources, **feasibility short term/long term**
- Relevancy of technologies & energy sources **for rail**
- **Digitalisation (management of energy, maintenance)**
- **Energy storage systems**
- Energy production & transmission efficiency
- Share of energy saving & energy efficiency
- Harmonisation / standardisation

You are all invited to introduce the findings and challenges regarding long term:

- Developed solutions
- Solutions in development
- Experience
- Pros & Cons
- Roadmaps / Strategies
- Technical aspects

SUSTAINABILITY
Action Week

Workshop timeline

10:00	**Welcome / Introduction**	UIC
10:10	**Keynote introduction** IEA's world outlook key findings, technology and innovation	Oskaras Alsauskas, IEA
10:30	**Session** **Operation / Rolling stock**	202 and 203
10:30	**Session** **Infrastructure / Buildings / Stations**	202 and 203
12:30	Lunch break	Mezzanine (1st floor, reception side)
13:30	**Continued sessions**	
15:00	Coffee break	
15:15	**Prepare session summary – Async. support by Flatland for visual recording and summarising**	
16:00	**Share the summary for plenary**	Session moderator/voluntary participant
	Closing discussion **End of workshop**	
18:00	**Networking drinks and reception (Atrium)**	

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IEA

International Energy Agency

Oskaras Alsauskas

Keynote presentation:

IEA’s world outlook key findings, technology and innovation

Energy Modeler & Analyst – World Energy Outlook Team

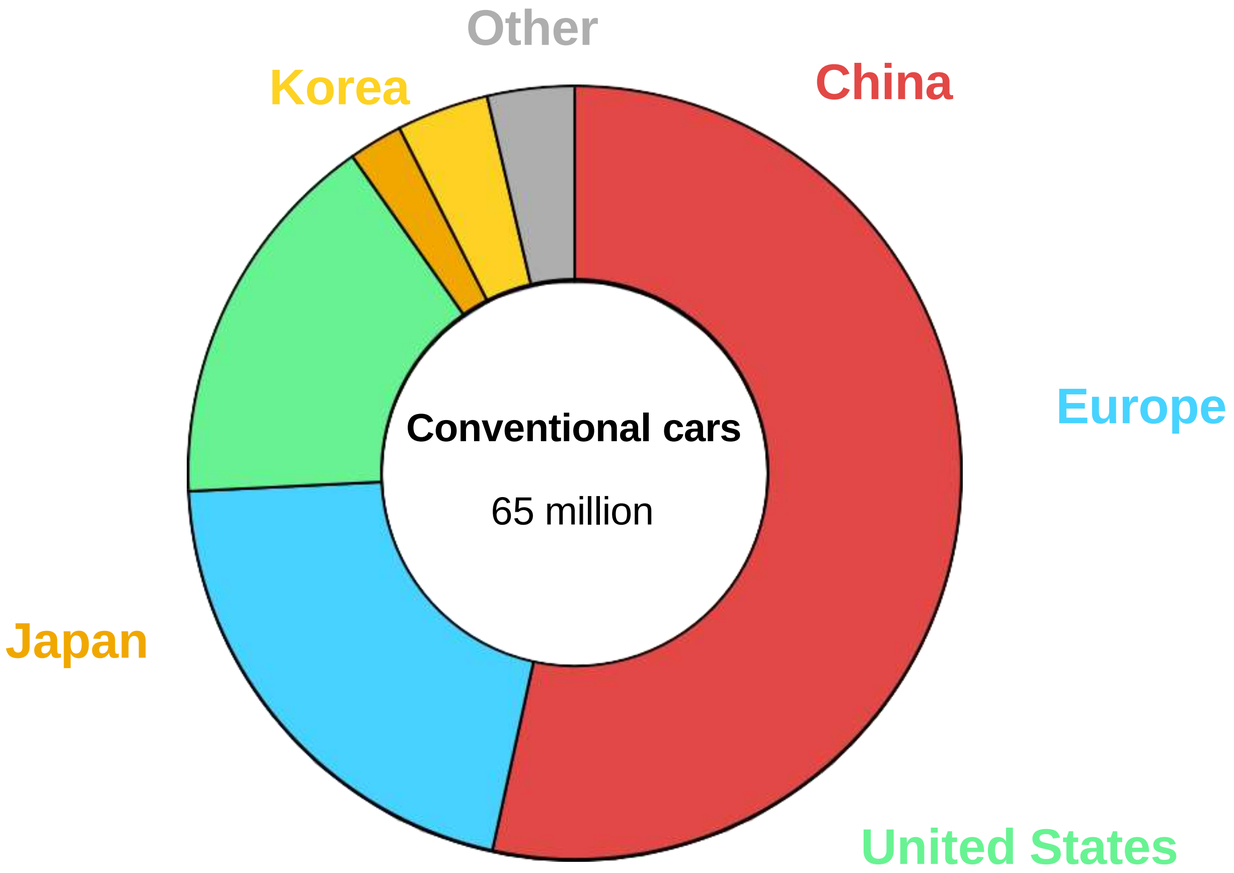
Energy Outlook for Transport

Oskaras Alšauskas

UIC Sustainability Action Week, Paris, 2025-03-11

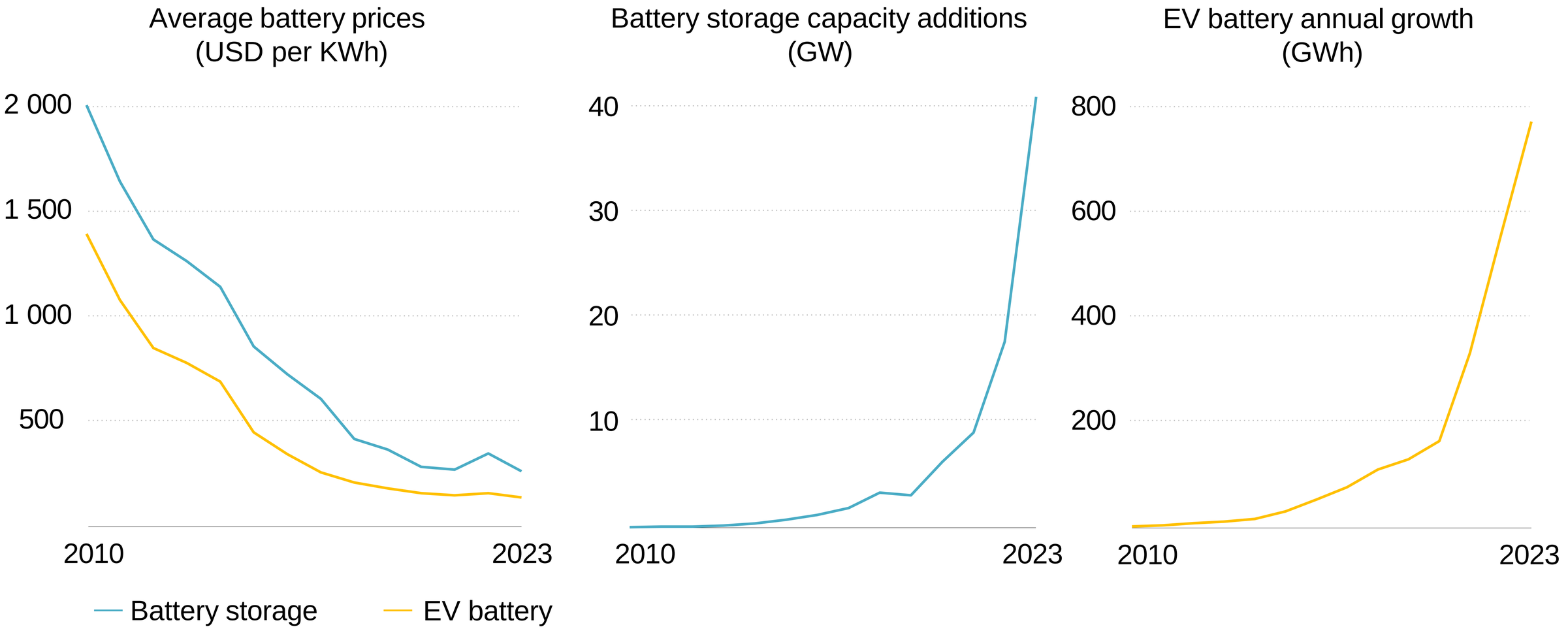
A new electric car industry is emerging

Share of global car markets by automaker headquarters, 2023



Chinese companies provide more than half of global electric car sales, compared with just 10% for conventional cars.

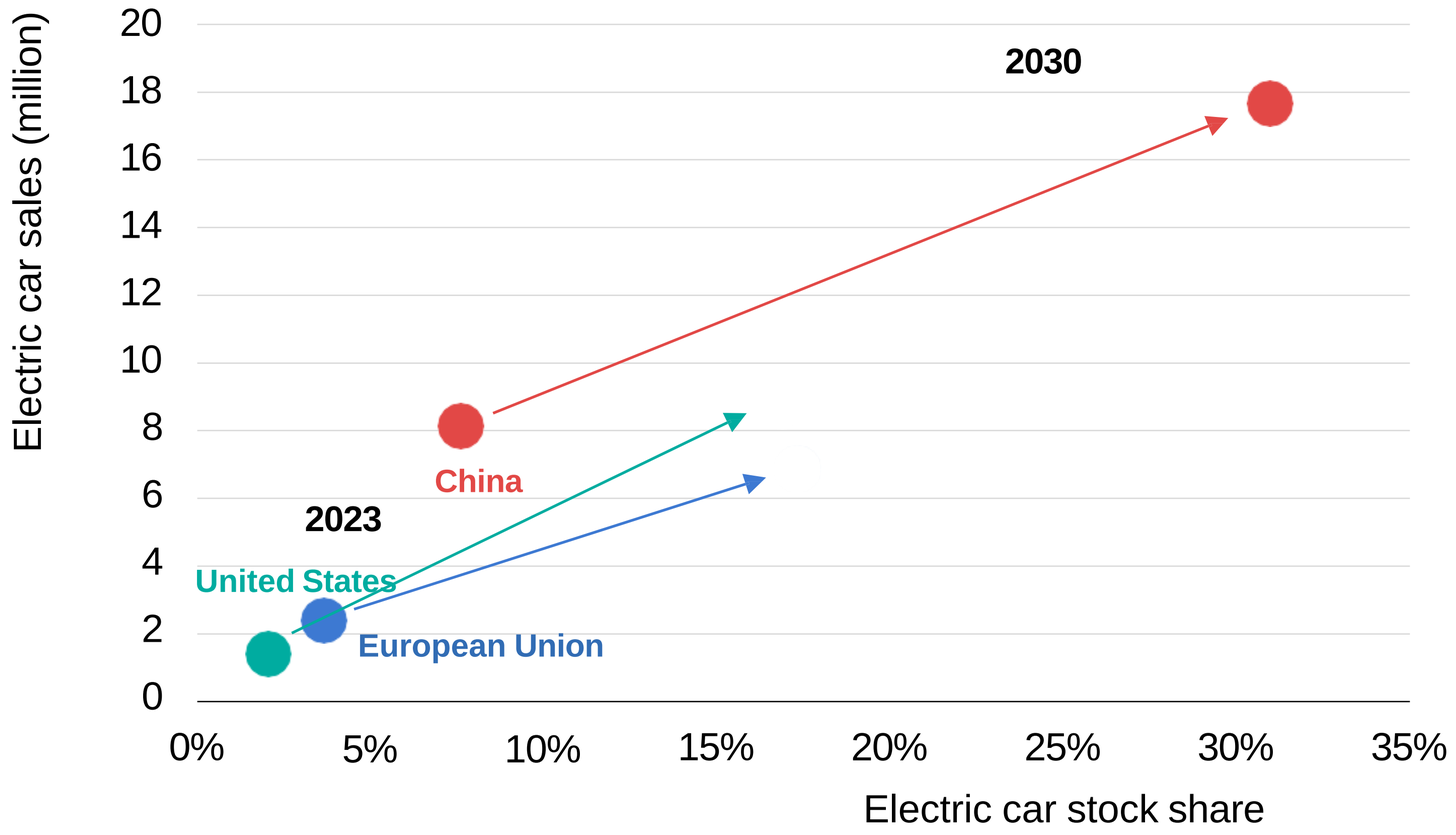
Batteries are taking off and transforming electricity and transport

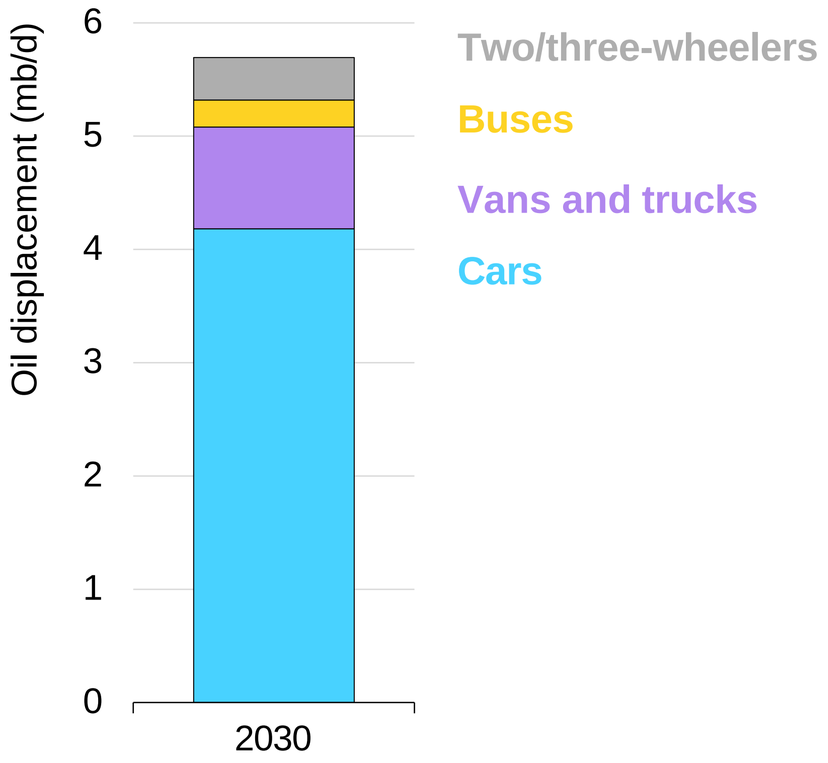


Battery costs have fallen 90% since 2010, creating new opportunities for EVs and battery storage in the power sector. Battery storage is the fastest growing clean technology while EVs account for most battery sales today.

The electric car fleet is set to grow quickly

Electric car sales, stock share and oil displacement in the Stated Policies Scenario, 2023-2030

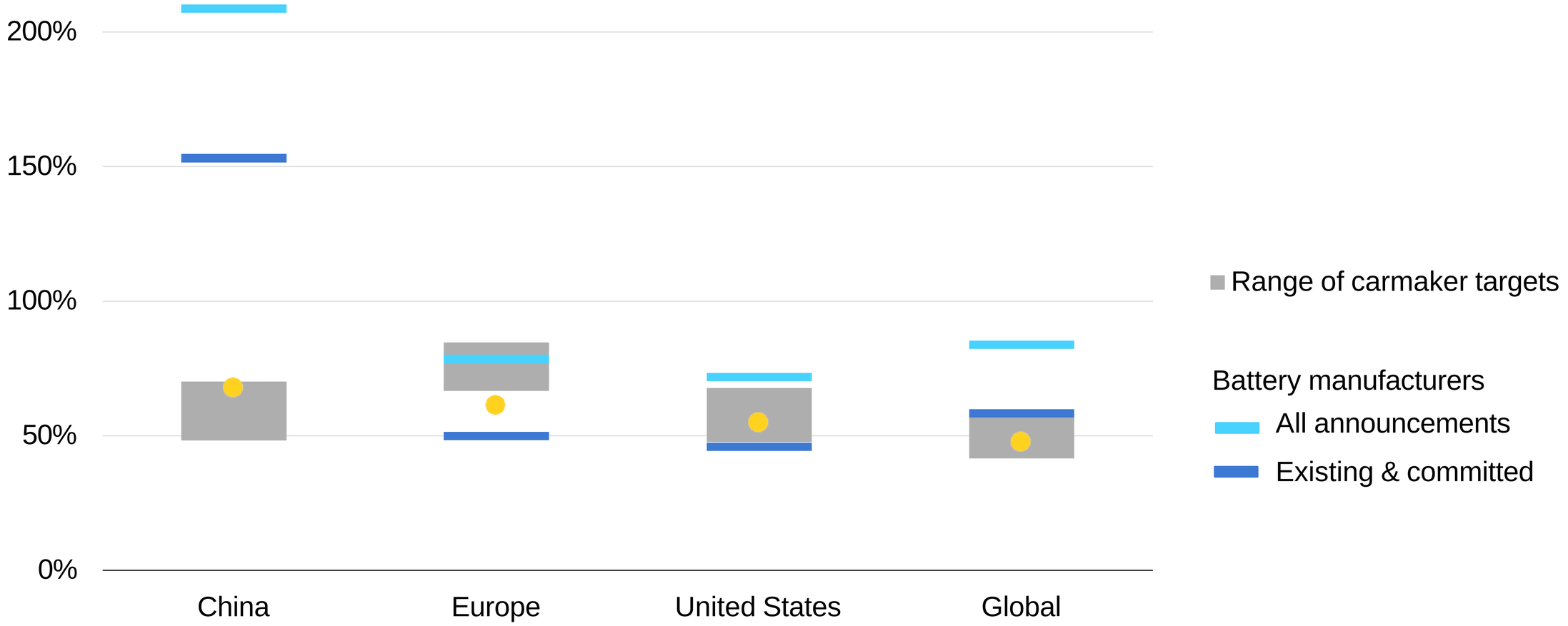




By 2030, under current policy settings, electric cars represent more than 30% of the China's car fleet and around one-fifth of the car stock in the European Union and United States.

Manufacturers could deliver government ambitions

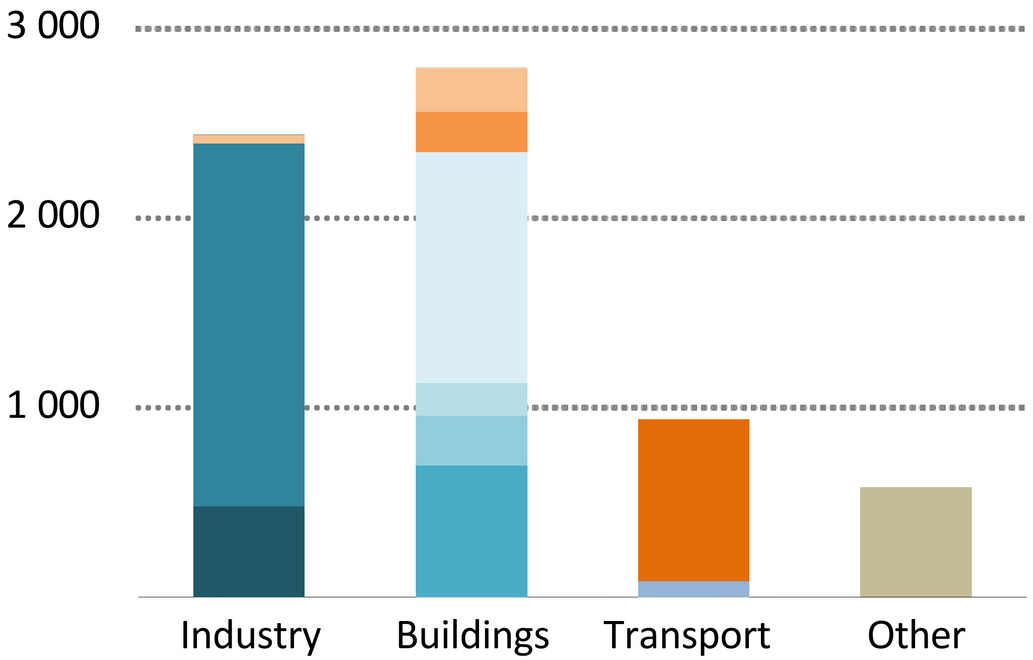
Electric car sales shares compared to industry announcements, 2030

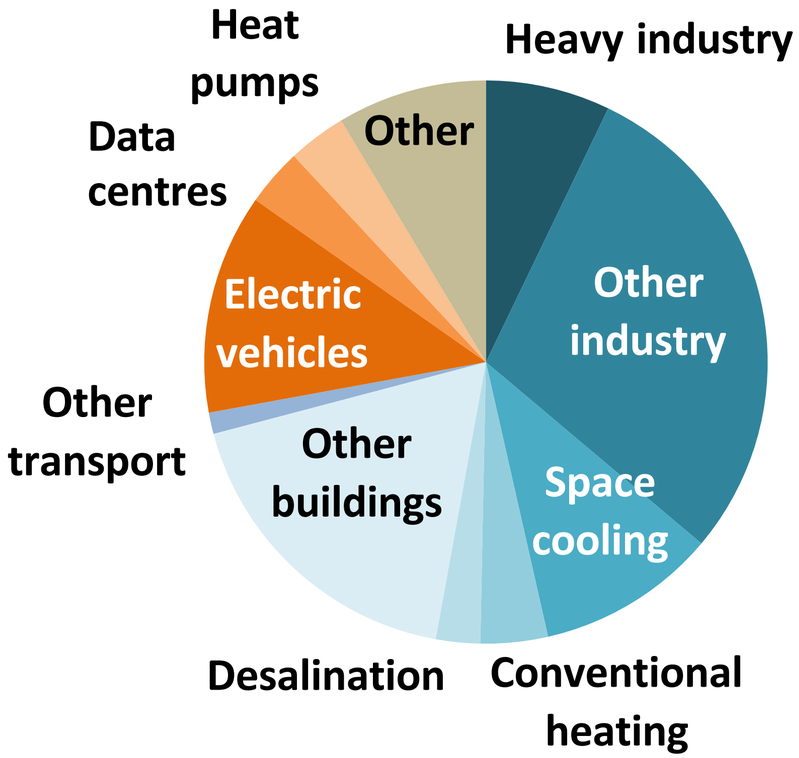


Automaker targets and battery manufacturing plans are in line with 2030 government targets. Existing & committed battery manufacturing projects are practically sufficient to reach NZE deployment needs across all of road transport.

New energy uses make inroads in electricity demand growth

Global electricity demand growth in the STEPS, 2023-2030 (TWh)

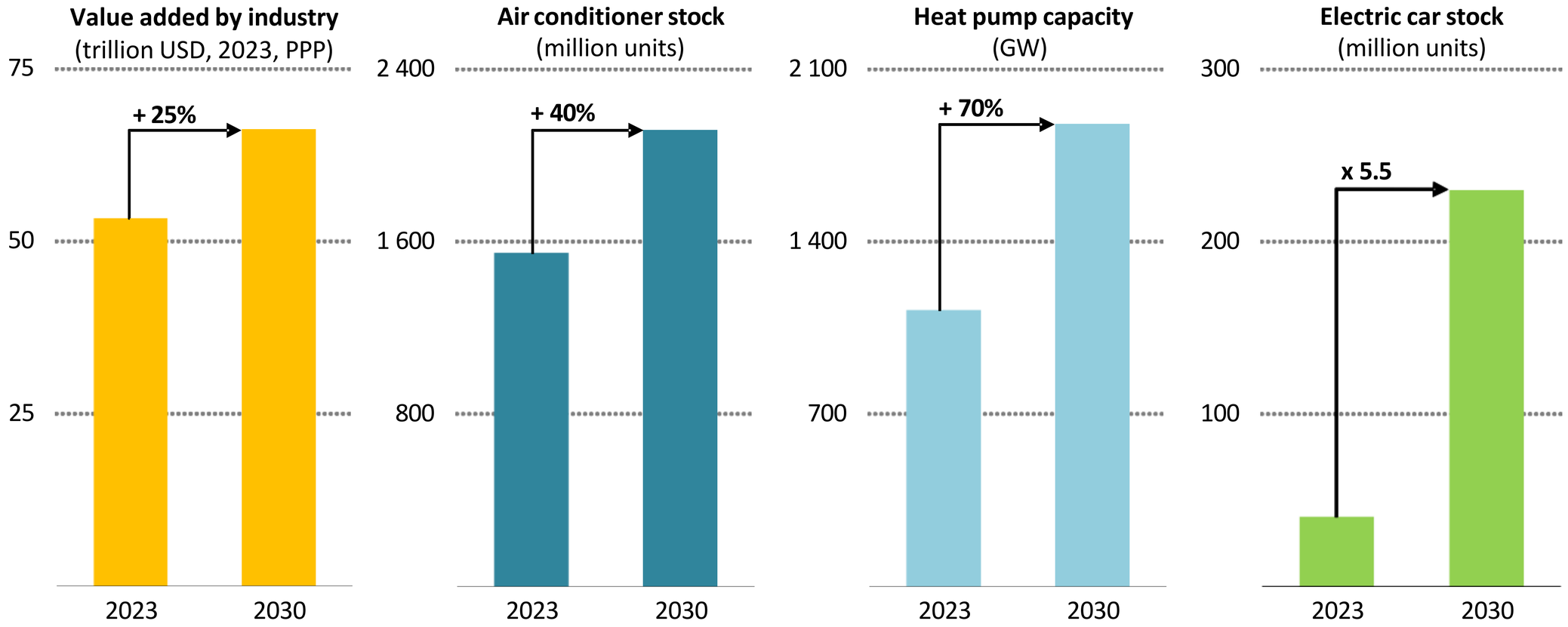




Electricity demand rises nearly 6 800 TWh by 2030, with conventional uses accounting for 80% of the growth. Electric mobility, heat pumps and data centres become increasingly important demand drivers

Both conventional and new technologies shape the Age of Electricity

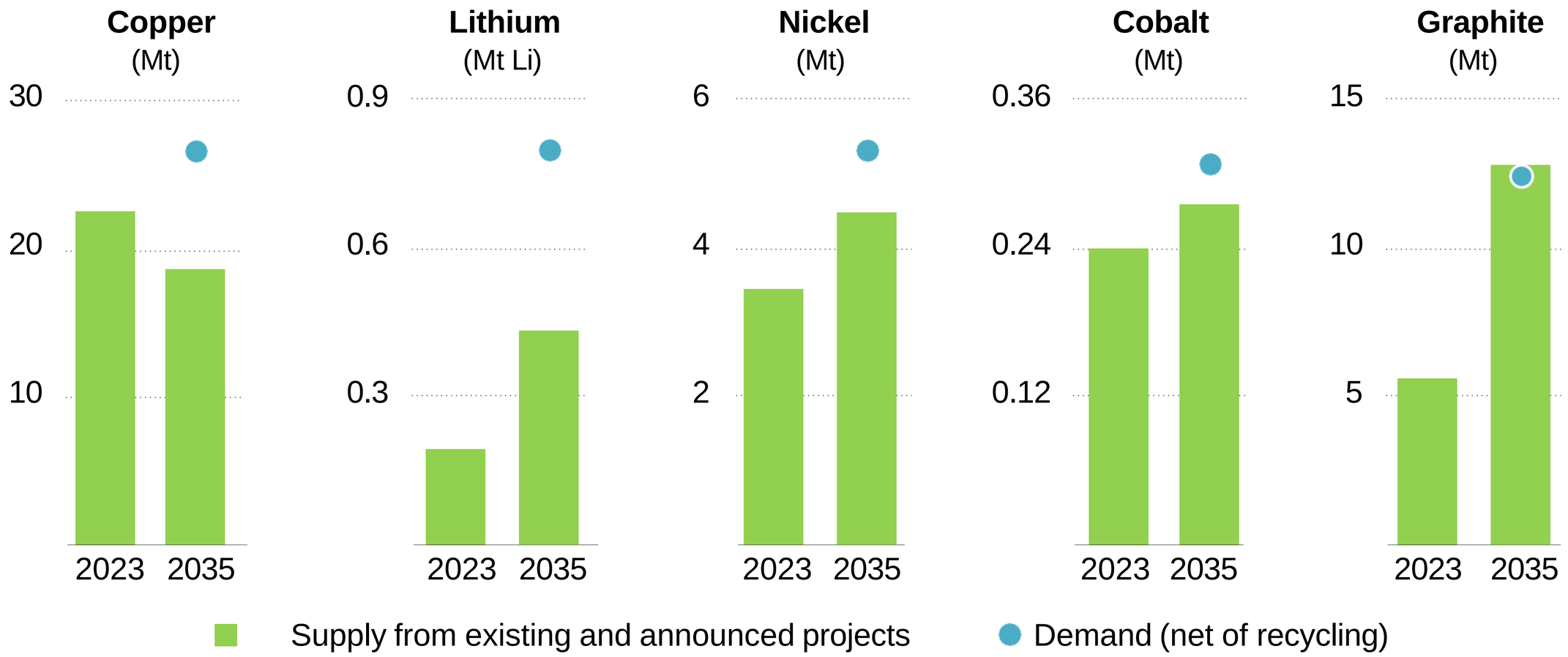
Global electrification enabling technologies and sectors in the STEPS



Light industries and air conditioners continue to enable electricity share growth in total energy demand. Heat pumps and electric cars further shape end-use electrification

Not all projected supplies are abundant

Mineral supply requirements and expected supply from existing and announced projects



Supply from existing and announced projects falls short of 2035 requirements for some key minerals, notably copper and lithium: additional efforts on recycling and new project development are needed to close the gap

Thanks for your attention

Questions

Discussion

Session 202

Rolling stock / Operation

Session 203

Infrastructure / Stations / Buildings

ProRail

Dutch Infrastructure Management

Matthijs Doesburg
Robin Schipper
Gerald Olde Monnikhof

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Futureproof rail grinding & milling

Futureproof rail grinding & milling from 2027

- ✓ Decarbonization
- ✓ ERTMS / ETCS
- ✓ Condition data
- ✓ Less posessions & less crew
- ✓ Affordable

Market consultation 2024

Contracts from 2027

- ✓ Technical optimization
- ✓ Existing machines
  - ERTMS / ETCS → not applicable other than external traction
  - Decarbonization → biodiesel

Contracts from 2031

- ✓ Retrofit or engineering new machines
  - ERTMS / ETCS → standard
  - Decarbonization → catenary / hydrogen / battery pack / biodiesel
- ✓ Certainty needed

Two step strategy

1x Milling contract **2027 – 2030 + extensions**
1x Grinding contract **2027 – 2030 + extensions**

- ✓ New maintenance concepts
- ✓ Stimulating biodiesel (certified)
- ✓ Emission-free car transports from 2028

→ *To be awarded mid 2025*

1x Milling contract **2031 – 2041**
1x Grinding contract **2031 – 2041**

- ✓ Specs emissions
- ✓ Specs ERTMS / ETCS
- ✓ Specs condition data
- ✓ Specs single track posessions & crew inside machine

→ *To be awarded mid 2026*

New machine as licence to start in 2031

- ✓ GO – NO GO in 2029
- ✓ Delay in scope contractor → 2032 – 2041 → loss of turnover
- ✓ Delay out of scope contractor → 2032 – 2042 → keeping turnover
- ✓ Activating extensions if needed

Power supply

	Geography	Share network (2025; indicative)	Share network (2035; indicative)	Share grinding & milling shifts (2035; indicative)
1.500V DC	• Mainlines • Some regional lines	80%	85%	90%
25.000V AC	• Cargo corridor Rotterdam – Germany • High Speed Line Schiphol – Belgium	5 %	5 %	5%
No catenary	• Regional lines	15%	10%	5%

The search for proportionality

	Specifications	Possible solutions	Cost increase
V1	• All shifts must be emission-free	• Hydrogen • Catenary & hydrogen	??
V2	• Shifts under any catenary: must be emission-free • Shifts without catenary: incentive for emission free or biodiesel	• Hydrogen • Catenary & hydrogen • Catenary & biodiesel	??

ProRail

Futureproof Linsinger rail milling machine

railmaster®

HIGH PERFORMANCE RAIL MILLING TECHNOLOGY WITH TWO INDEPENDENT POWER SOURCES

... POWERED BY HYDROGEN, PANTOGRAPH OR DIESEL

- **MODULAR DESIGN**
  Future technologies easily adaptable
- **VARIABLE ENERGY SUPPLY CONCEPTS**
  powered by panthograph, hydrogen or diesel
- **HIGH OUTPUT**
  Cutterhead and rail profile changes on the fly
- **ONBOARD OPERATION WITHOUT TRACK ENTRY**
- **TRACTION OPTIMIZATION**
  Travel drive & working drive on separate axles
- **ELIMINATION OF HIGH-PRESSURE HYDRAULICS**
- **PREPARED FOR "ROBOT-MILLING"**

ProRail

INTERNATIONAL UNION
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Infrabel

Belgian nfrastructure Management

UIC IRS 90930

Traction energy settlement & data exchange
(Data exchange for energy billing)

Bart Van der Spiegel
bart.vanderspiegel@infrabel.be
11/03/2025

Agenda

Framework on Traction Energy Settlement

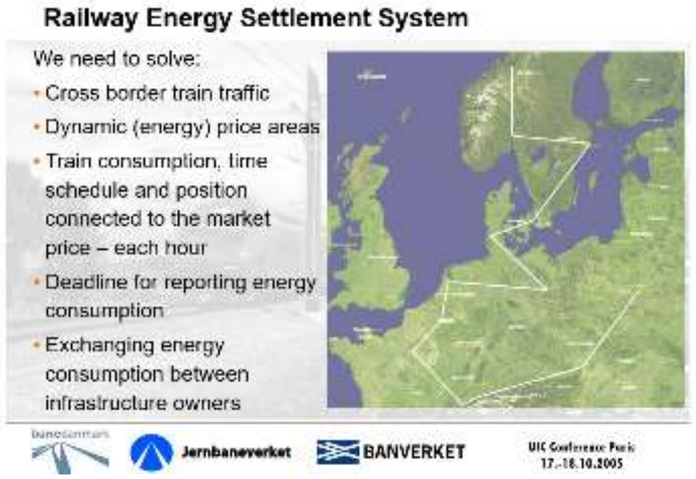
- TSI
- EN 50463
- IRS 90930
- Sector Declaration

High level framework

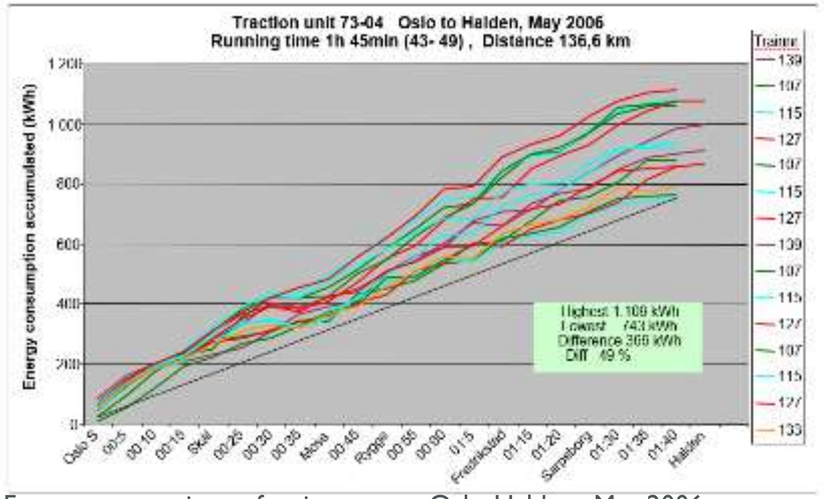
1. Directives
   by European Parliament and European Council
2. Commission regulation
   by European Commission
3. Technical Specifications of Interoperability (TSI)
   by European Union Agency for Railways (ERA)
4. European Standards
   by CENELEC
   When a TSI refers to a standard, that part of standard is then mandatory (legally binding)

Pre-history

- Germany and Norway had meters on-board of trains.
- Germany considered it mandatory to be able to invoice electricity. Norway considered that there was a huge opportunity to save energy.
- A symposium on Railway Energy Billing in October 2005 was a catalyst.
- In November 2005 the UIC project started.



Symposium Railway Energy Billing, UIC, Paris, October 2005



Famous comparison of train-runs on Oslo-Halden, May 2006

Presentation of Jan Vetle Moen, NSB, September 2007

Technical Specification of Interoperability (TSI)

- ERA started on request of European Commission in 2007.
- A Request for Standardisation was sent to CENELEC.
- A dedicated group at ERA was working in parallel with UIC and CENELEC.
- Based on a draft of the EN 50463, an appendix of the LOC&PAS TSI for conventional rail in 2011 was giving the first requirements regarding an on-board Energy Measurement System (EMS).
- This was the first time it became mandatory to install EMS on-board of trains.

EN 50463: history

- Started on request of European Commission and ERA in 2007.
- First edition of EN 50463 series published in 2012.
- TSI LOC&PAS and TSI ENE of 2014 referred to EN 50463:2012. EMS became mandatory on all new, renewed and upgraded trains.
- An interface between two TSIs shall be uniquely defined.
- A second edition of EN 50463 series was published in 2017. This version included a first protocol for the communication between the Energy Measurement System (EMS) on-board and a Data Collecting System (DCS) on ground.





Technical Specification of Interoperability (TSI)

- In July 2018 the Commission Implementing Regulation EC/2018/868 was published.
- This legally binding document introduced changes to of the LOC&PAS TSI (regarding the EMS) and the ENE TSI (regarding the DCS).
- A DCS became mandatory to all Member States from January 2022.
- The EC/2018/868 itself required each Member State also to have a Settlement System by July 2020.
- Such a Settlement System shall be able to:
  - exchange data from EMS to the country where the consumption took place;
  - validate data coming from EMS (and estimate missing data);
  - allocate it to the correct end user.

EN 50463: start of new Working Group 37

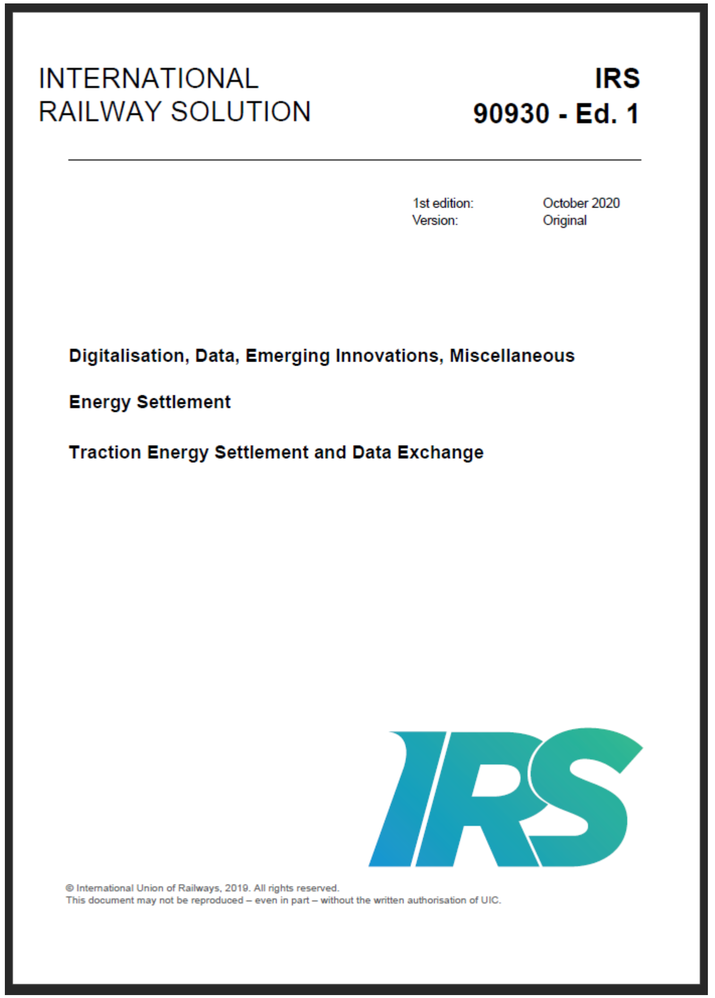
- June 2023: request to start new Working Group to revise EN 50463
- November 2023: approval to start the revision
- Aim of this revision of EN 50463 is to publish a new version in parallel with IEC 62888.
- 40 members from 12 National Committees (incl. an observer from ERA)
- September - November 2025: enquiry and voting
- September - October 2026: editorial commenting and voting on final draft
- December 2026: publication

IRS 90930: from first publication to maintenance

- September 2009: UIC published the first leaflet 930
- October 2015: first meeting of new WG
- October 2020: publication of IRS 90930
  - improved role model (adjusted to terms used in commission implementing regulation, TSI and EN 50463)
  - describing tasks and responsibilities
  - adjusting the EN 50463:2017-protocol for the use betv actors on ground
  - freely available on UIC shop
- 2021-2023: 1st maintenance phase
- 2024-2026: 2nd maintenance phase

What is IRS 90930?

- IRS 90930 describes functions, roles and interchanges in traction energy settlement
- The document describes a consensus of participants in the UIC
- It refers to the protocol defined in EN50463
- IRS 90930 is a good framework for progressing to a world where we measure railway energy, and do settlements based on those measurements


INTERNATIONAL
RAILWAY SOLUTION

IRS
90930 - Ed. 1

1st edition: October 2020
Version: Original

Digitalisation, Data, Emerging Innovations, Miscellaneous

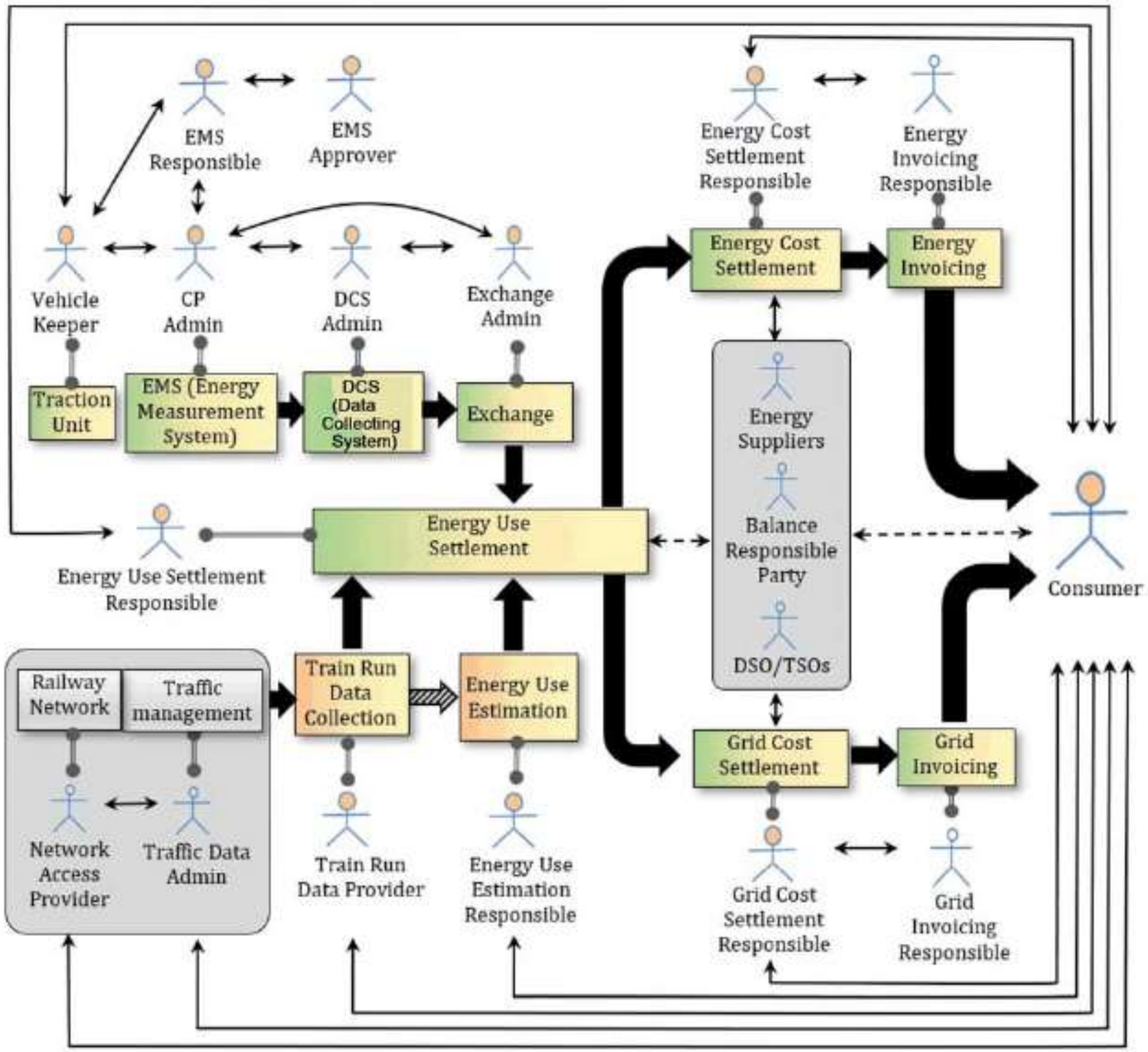
Energy Settlement

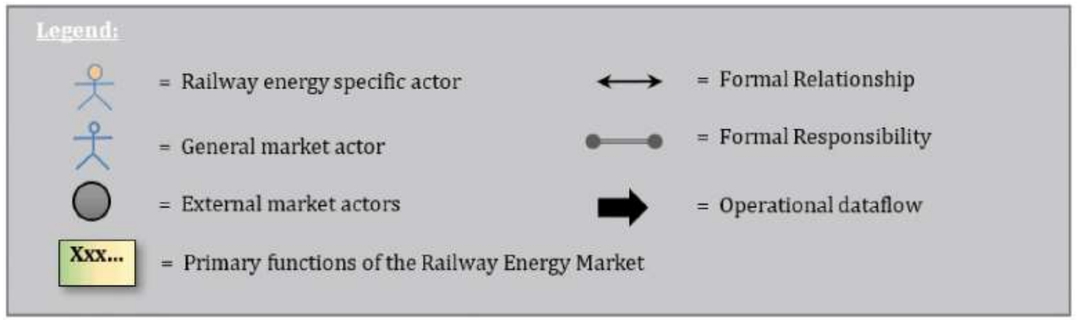
Traction Energy Settlement and Data Exchange

IRS

Role model

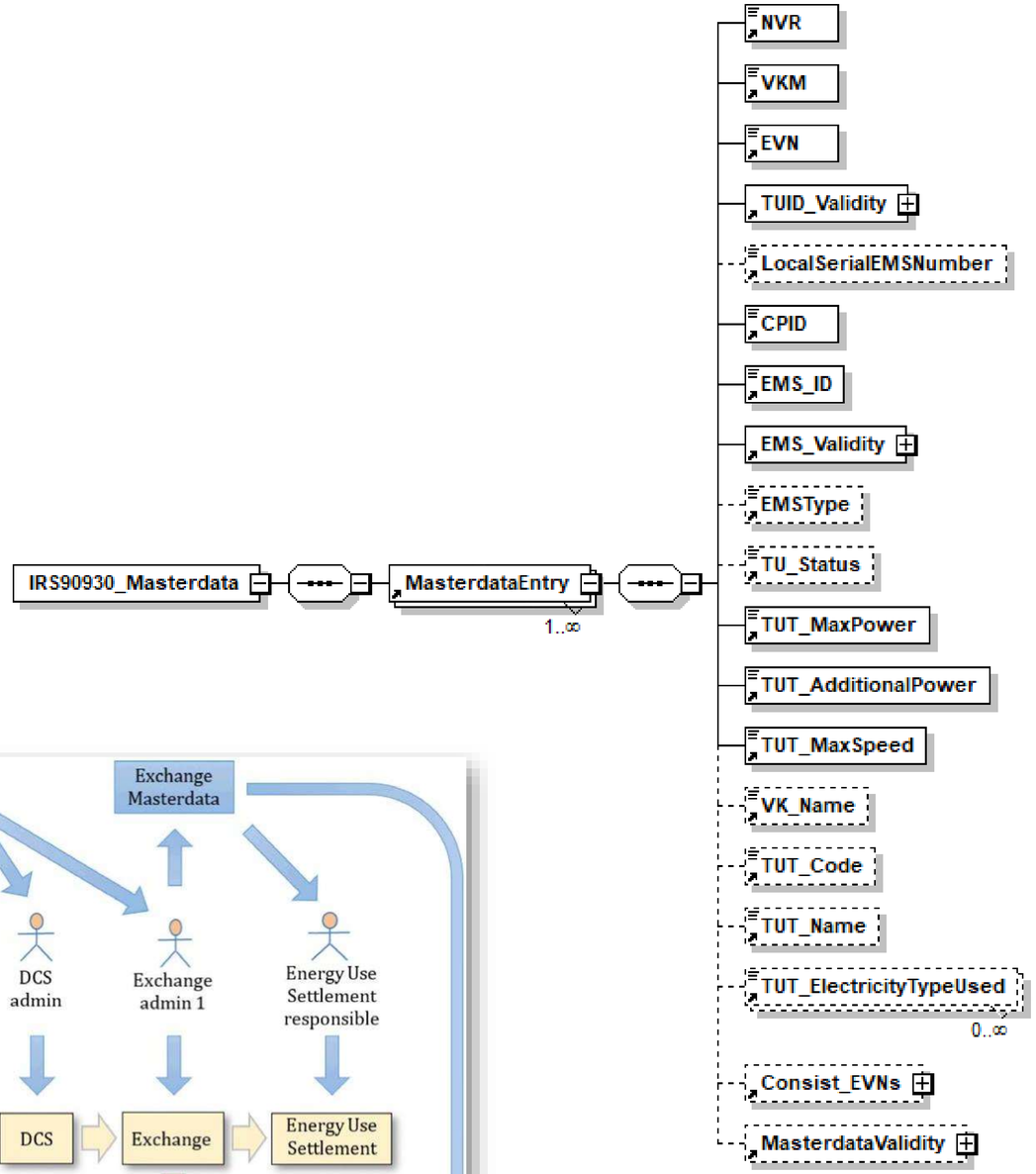
- The Role Model describes functions and roles in traction energy settlement.
- A single organisation may have multiple roles, or a role may be held by multiple organisations.
- A system may perform more than one function.

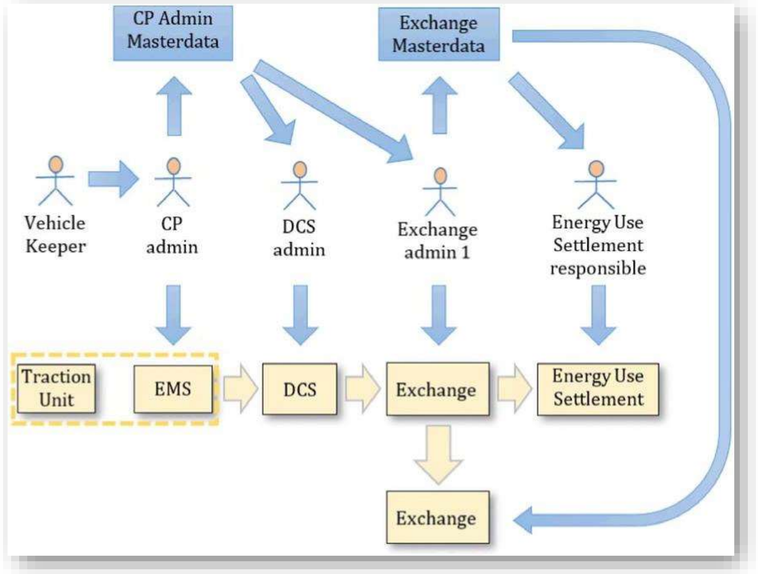




Masterdata

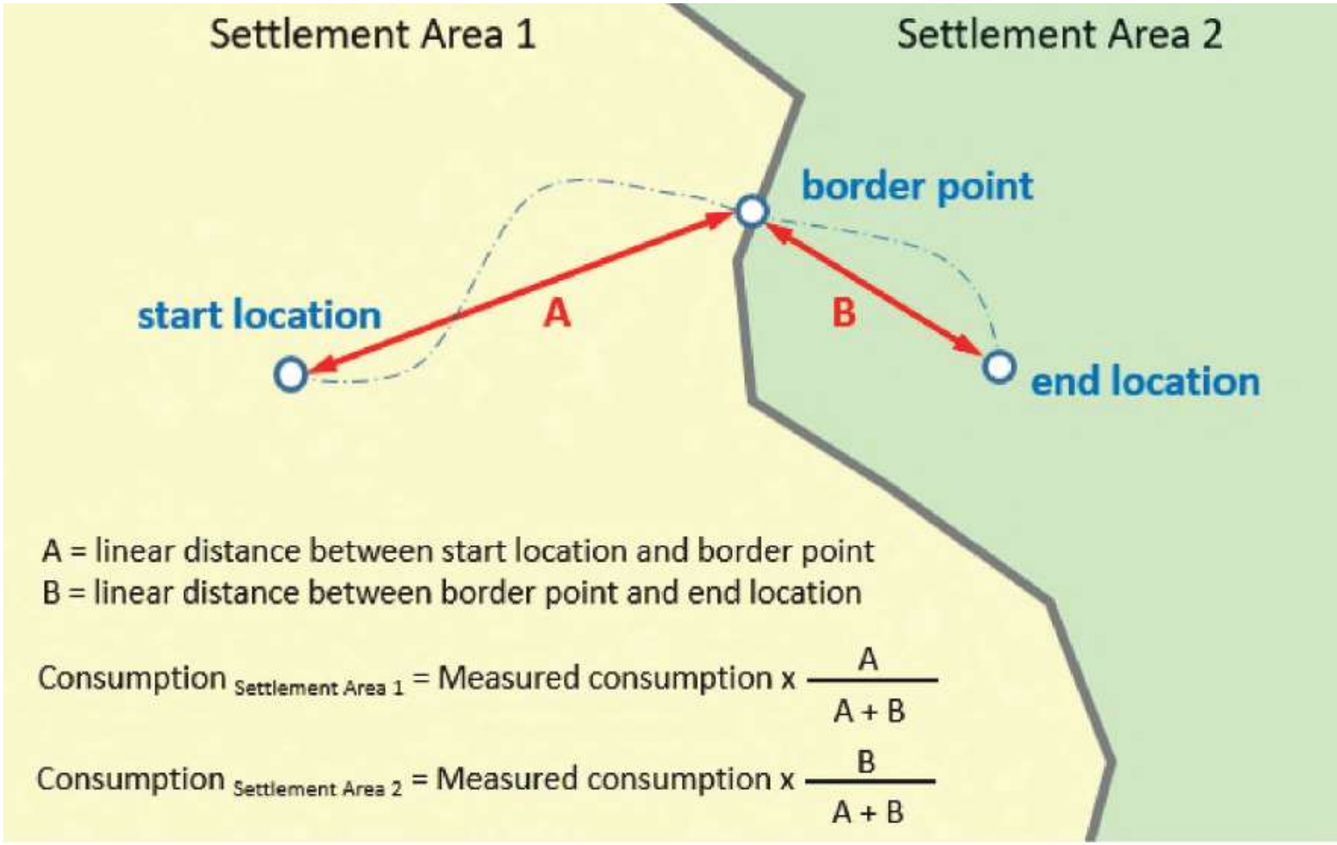
- Master data is a collection of information about functions and roles in energy metering data.
- The most important masterdata we deal with in the IRS is the data related to EMS.
- It is necessary to ensure the flow of Energy Metering Data





Exchange of Energy Metering Data

- The IRS provides a set of commonly agreed set of borders and border crossing points.
- There are rules for allocating Energy Metering Data when crossing borders



Sector declaration

- Sector Declaration defines how sector commits to be compliant with European Regulation (EC/2018/868).
- It has 4 commitments for Railway Undertakings and 5 commitments for Infrastructure Managers.
- Published on 10th November 2020.

- See: https://uic.org/com/enews/article/eu-railway-sector-declaration?page=modal_enews

Railway Undertakings:

1. RU will install EMS on all traction units where this is technically and economically feasible. This should result in 60% equipped in 2025 and 90% in 2030.
2. All EMS on new traction units shall by fully compliant with LOC&PAS TSI:2018. Non-compliances on retrofitted EMS shall be stated.
3. All new and renewed EMS shall send data to DCS at least every 4 hours and before intentional powering down.
4. RU shall be able to deliver to the IM train compositions by 2023. This shall be done preferably at departure of train-run.

Infrastructure Managers:

1. IM shall provide DCS in accordance with ENE TSI:2018 latest in January 2022.
2. IM shall process data fast in DCS and exchange-function of Settlement and forward data without further delay in accordance with clause 5.4 of IRS 90930:2020.
3. International data exchanges will be in accordance with IRS 90930:2020.
4. IM enables a pragmatic approach to increase the possibilities of the RUs in the electricity purchasing strategy.
5. All relevant information is publically available.

Technical Specification of Interoperability (TSI)

- In 2023 many TSIs were updated.
- The new TSI only made a small change regarding EMS. It is now possible to keep existing measurement transformers on the train and integrate them into an EMS. You can use the accuracy class according to older versions of EN 50463 or according to other standards.
- There are no changes regarding DCS nor Settlement. Both remain mandatory in all Member States.
- In the new mandate from Commission to ERA, a study is requested regarding the implementation of DCS and Settlement in all Member States.

Process overview

Railway Undertaking

commodity (€)

grid fee (€)

operates trains

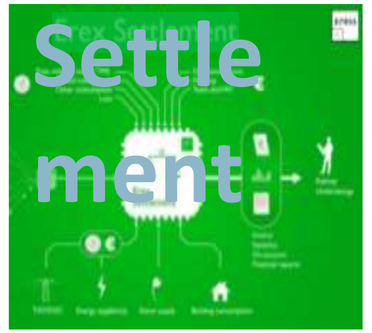
requests train-runs
TAF/TAP TSI
Sector declaration

Infrastructure Manager

kWh

kWh

data for validation, estimation and allocation



Allocate:

- allocate consumptions to the correct end user
- distribute to correct actors in energy market

Validate/estimate:

- validate data coming from EMS
- estimate missing data

EC/2018/868 – Sector Declaration – IRS 90930

new, renewed and upgraded shall have EMS

Energy Measurement System on-board
LOC&PAS TSI
EN 50463

Data Collecting System on ground
ENE TSI
EN 50463 / IRS 90930

Exchange:

- allocate consumption to country where consumption took place
- distribute to correct settlement system

EC/2018/868 – Sector Declaration – IRS 90930

How to get the IRS 90930?

Main text of IRS 90930 Ed1:

- Go to: https://shop.uic.org/en/
- Search for 90930. Select the preferred language.
- You will have to register to be able to download the IRS

Appendices:

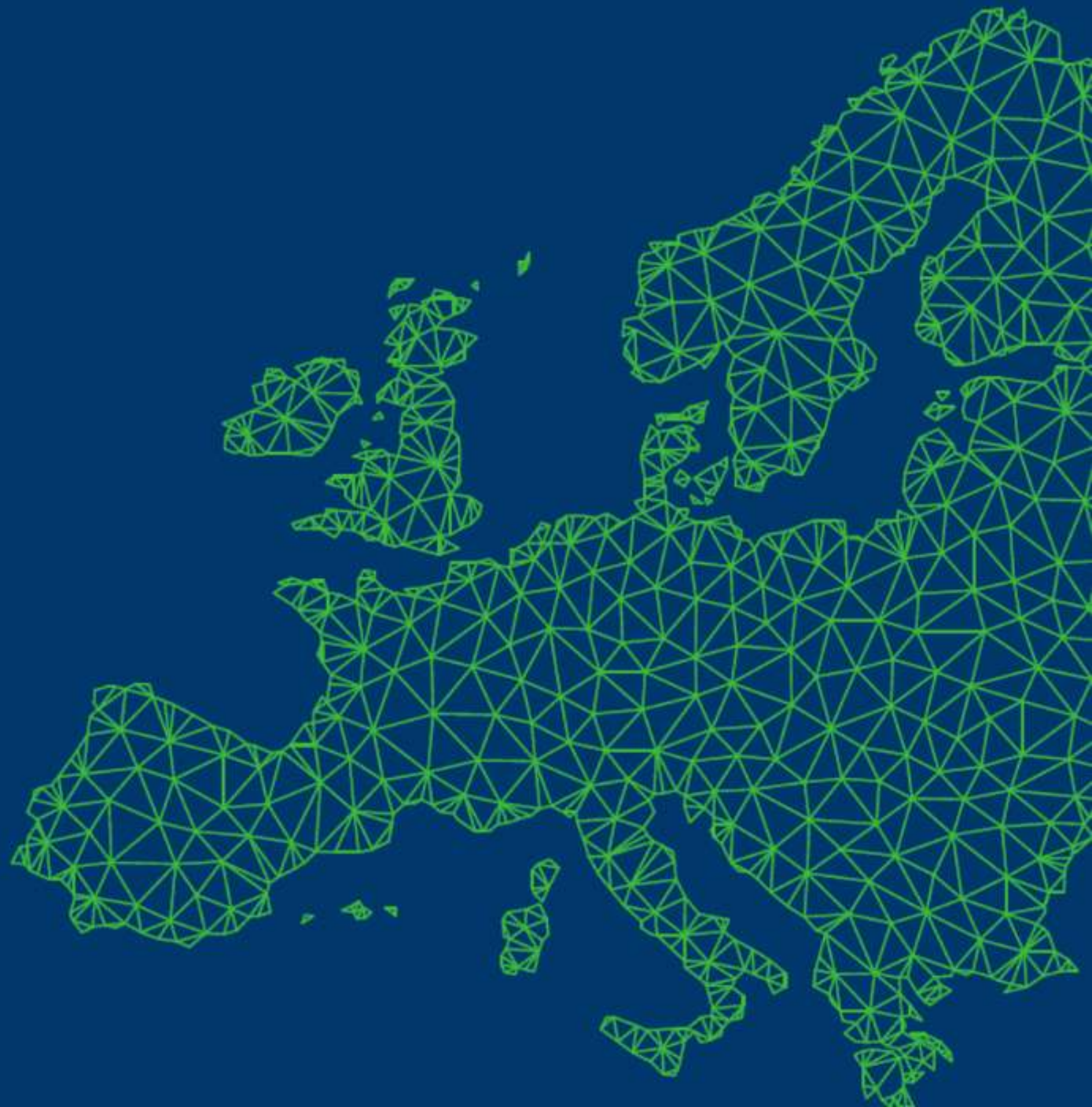
- Go to: https://appendices.uic.org/IRS-90930
- You can download readme, changelog and the set of appendices of 31st May 2024
- A new update is expected soon. We will have

Workshop on March 18th in Warsaw (and online)

- At PGE Polish national stadium in Warsaw
- Agenda:
  - 10:00-12:30: presentations (also online accessible)
  - 13:30-15:30: more explanations at posters (only in Warsaw)
  - 15:30: guided tour through the stadium
- Registration: https://uic.org/events/uic-traction-energy-settlement-stakeholder-workshop

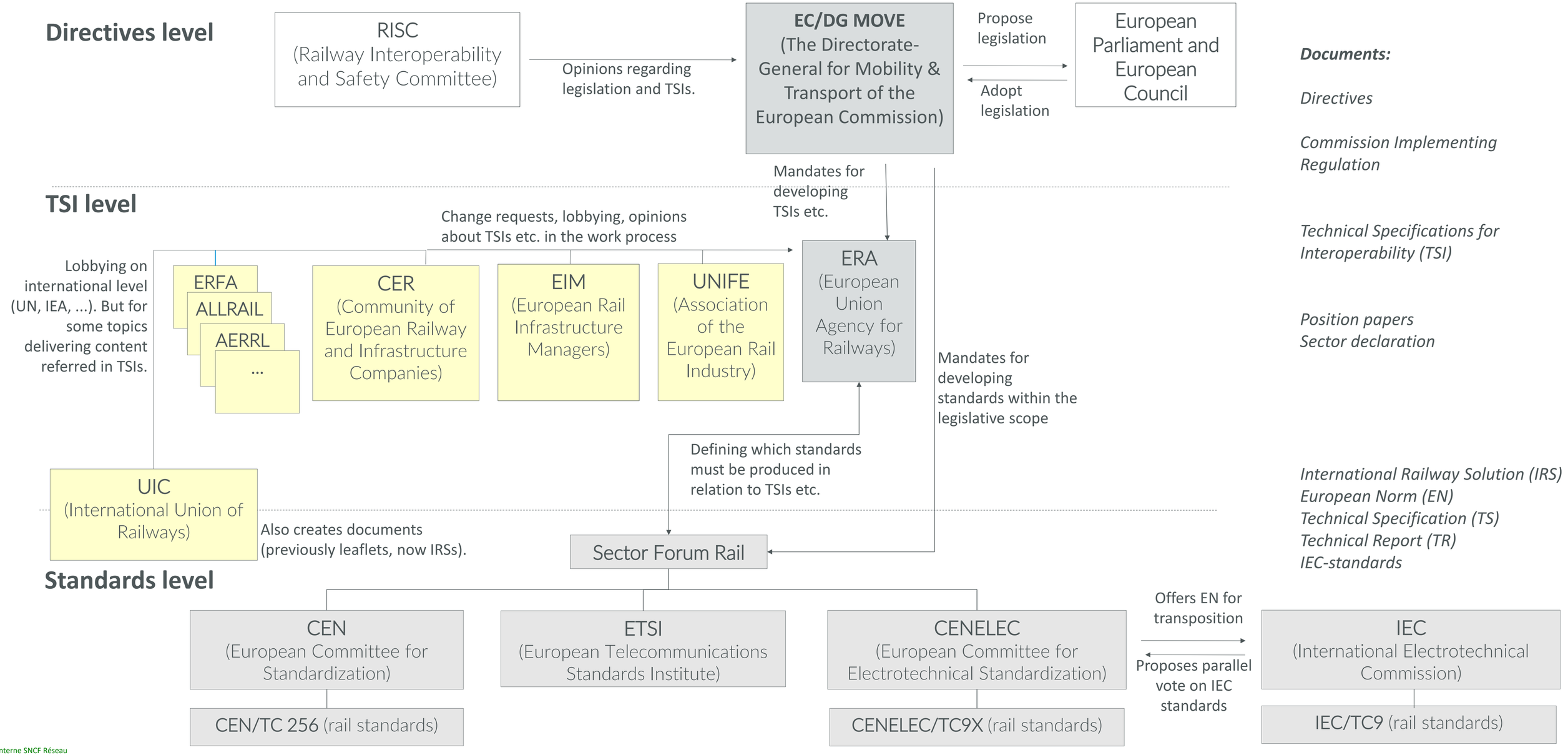
You can’t manage what you don’t measure.

Adding an on-board EMS helps you to get return on investment on energy savings.



Thank you for your attention

Back-up slide: Who is who?



Documents:

Directives

Commission Implementing Regulation

Technical Specifications for Interoperability (TSI)

Position papers
Sector declaration

International Railway Solution (IRS)
European Norm (EN)
Technical Specification (TS)
Technical Report (TR)
IEC-standards

INTERNATIONAL UNION
OF RAILWAYS

SNCF Voyageurs

French main operator

Luis Alonso | André-Philippe Chamaret

Energy ditigal twin

Energy digital twin for energy saving and CO2 reduction

Luis ALONSO / André CHAMARET

MATÉRIEL

SUSTAINABILITY
Action Week

SNCF
VOYAGEURS

In this presentation we will talk about:

01

Limited energy resources & climate change threats to railway

02

European project for a greener railway and SNCF Voyageurs' energy digital twin approach

03

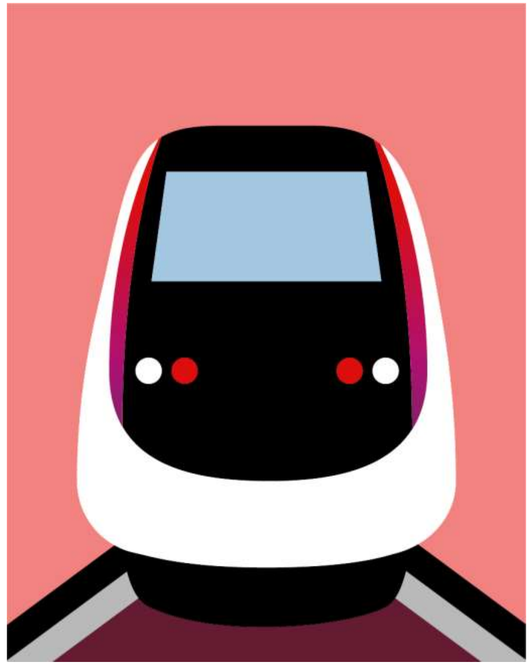
Two uses cases of the digital twin:

- **Long range BEMU**
- **Battery equipped suburban EMU**

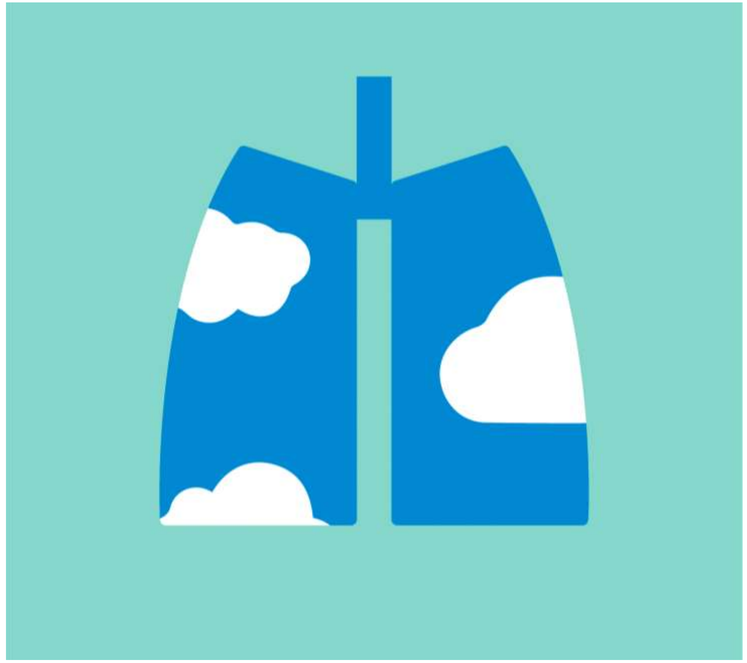
Limited energy resources & climate change threats to railway

Damages related to energy crisis & climate changes involved to speed-up for actions

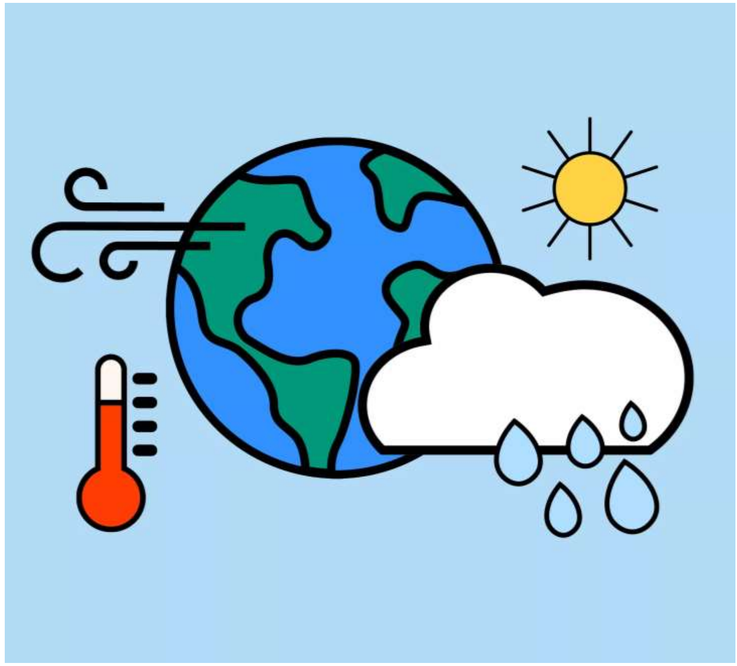
Improving energy efficiency



Decarbonise railway

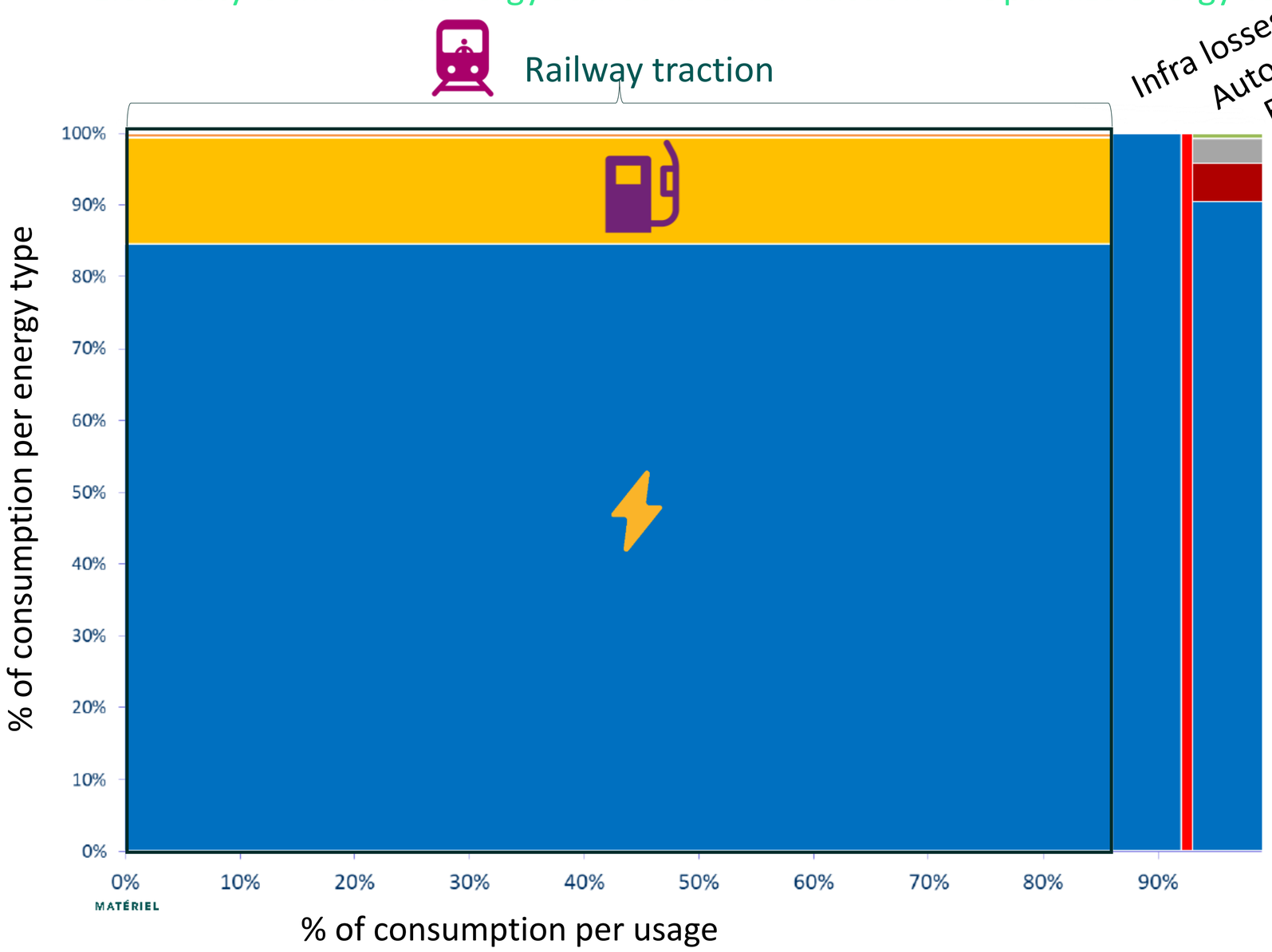


Adaptation to climate change



SNCF Voyageurs energy consumption:

Electricity is the main energy source used for traction → Optimize energy consumption of electric rail vehicles



7,3 TWh of energy consumption in 2023

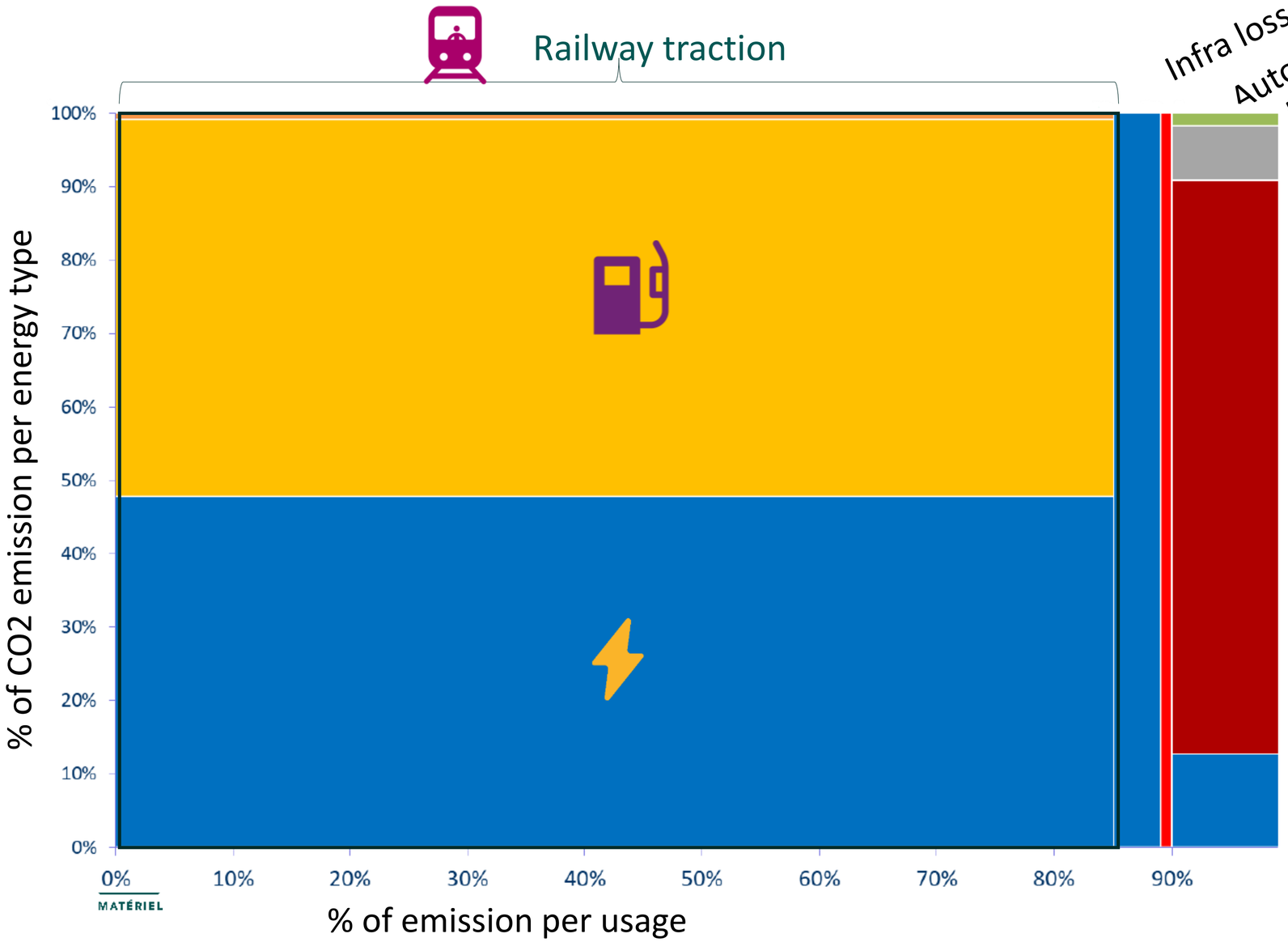
- Electricity
- Diesel (rail)
- Gas
- Fuel oil
- Bio fuels
- Diesel (road)
- Heat network

SNCF VOYAGEURS

SUSTAINABILITY Action Week

SNCF Voyageurs GHG emission:

Diesel remains the most important CO2 producer energy source → Decarbonisation of rolling stock



699 ktCO2 emission in 2023

- Electricity
- Diesel (rail)
- Gas
- Fuel oil
- Bio fuels
- Diesel (road)
- Heat network

Rolling stock Engineering / Luis ALONSO & André CHAMARET

SNCF VOYAGEURS

SUSTAINABILITY Action Week

European project for a greener railway

Work Package 1
« Energy Management & Pre-Standardisation for Alternative drive trains and related railway system”

- **Developing optimized energy management between rolling stock, infrastructure, and operations to improve energy efficiency, cost savings and resilience towards climate changes.**

Work Package 5/6
« Development of alternative propulsion based on ESS ”
&
“Train demonstrators of alternative propulsion based on ESS”

- **Developing long range Battery train (BEMU) with the objective of 200 km autonomy**
- **Studying the benefits of suburban catenary train with on-board energy storage system**

SNCF Voyageurs' energy digital twin approach

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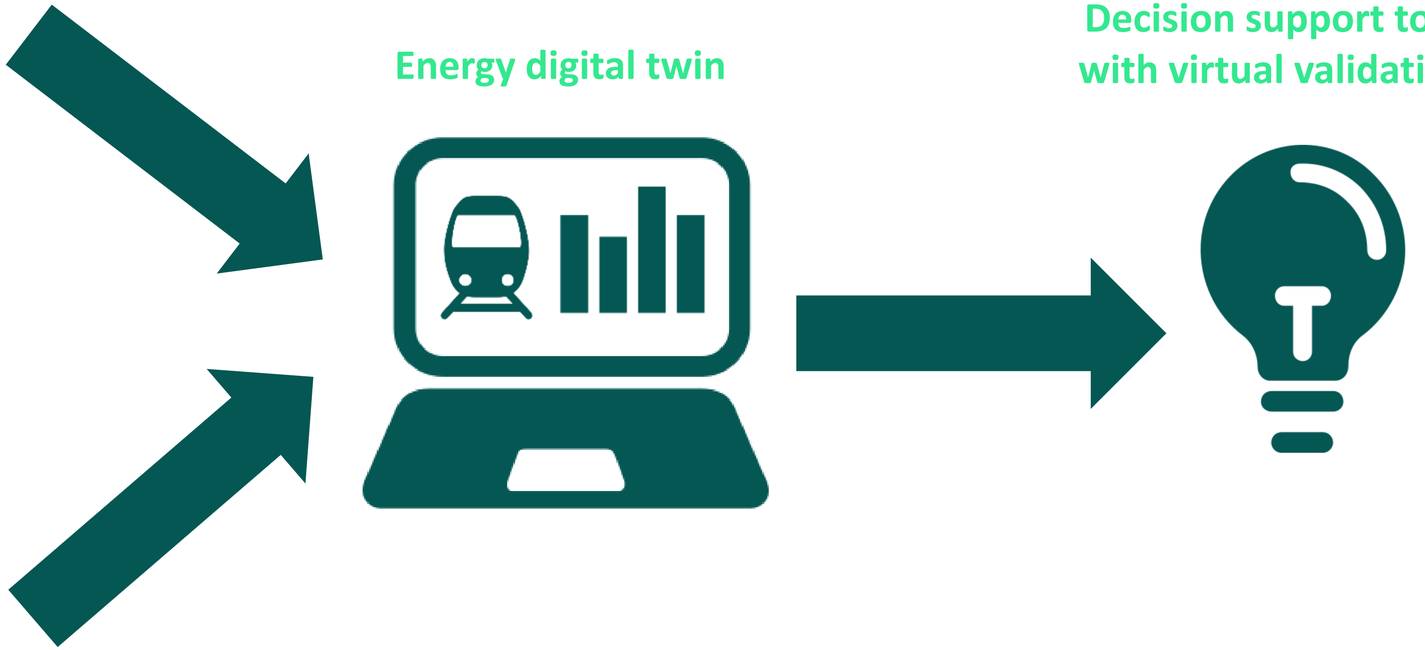


SNCF Voyageurs' energy digital twin approach

Energy digital twin's parameters:

Timetable

Journey profile:

Number of stops

Arrival/Departure in station

Mandatory gate point

Turnaround time

Switching location between different traction modes

Driver (or ATO)

Driving styles :

All-out

Timetable

Eco-drive (manual)

Eco-drive (ATO)

Speed tracking

Rolling stock

Vehicle characteristics:

Weight

Aerodynamic

Traction/Braking

…

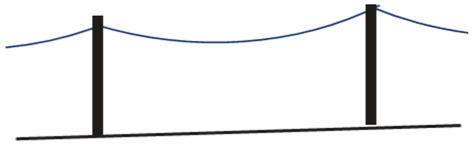
Battery model:

Thermal effect
Battery Ageing

Charge/Discharge Power

…

Infrastructure



Infrastructure data:

Distance

Station location

Electrification location

Voltage / Current

Slop

…

Environmental conditions

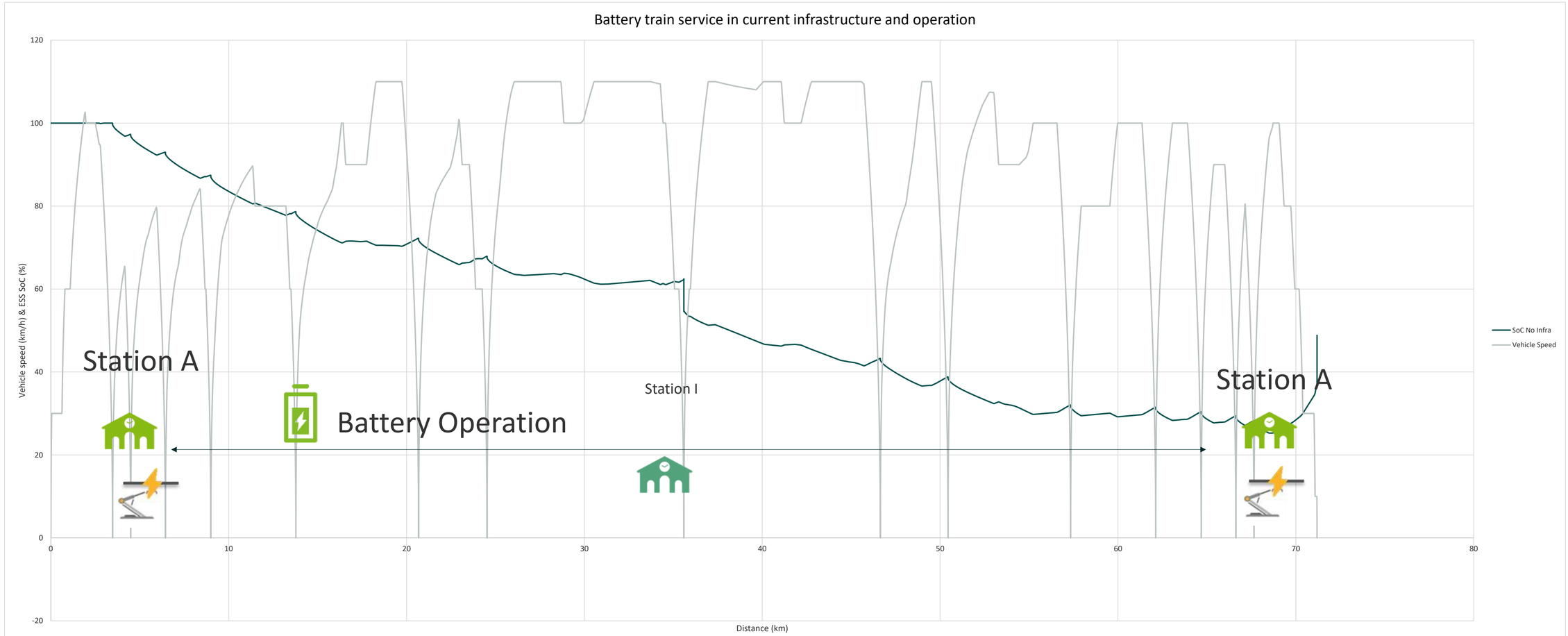
Environmental parameters:

External temperature

Wind speed

Use case of energy ditigal twin with a battery train

Step 1: Analysis of a 1st gen BEMU with the existing line characteristics & operation timetable



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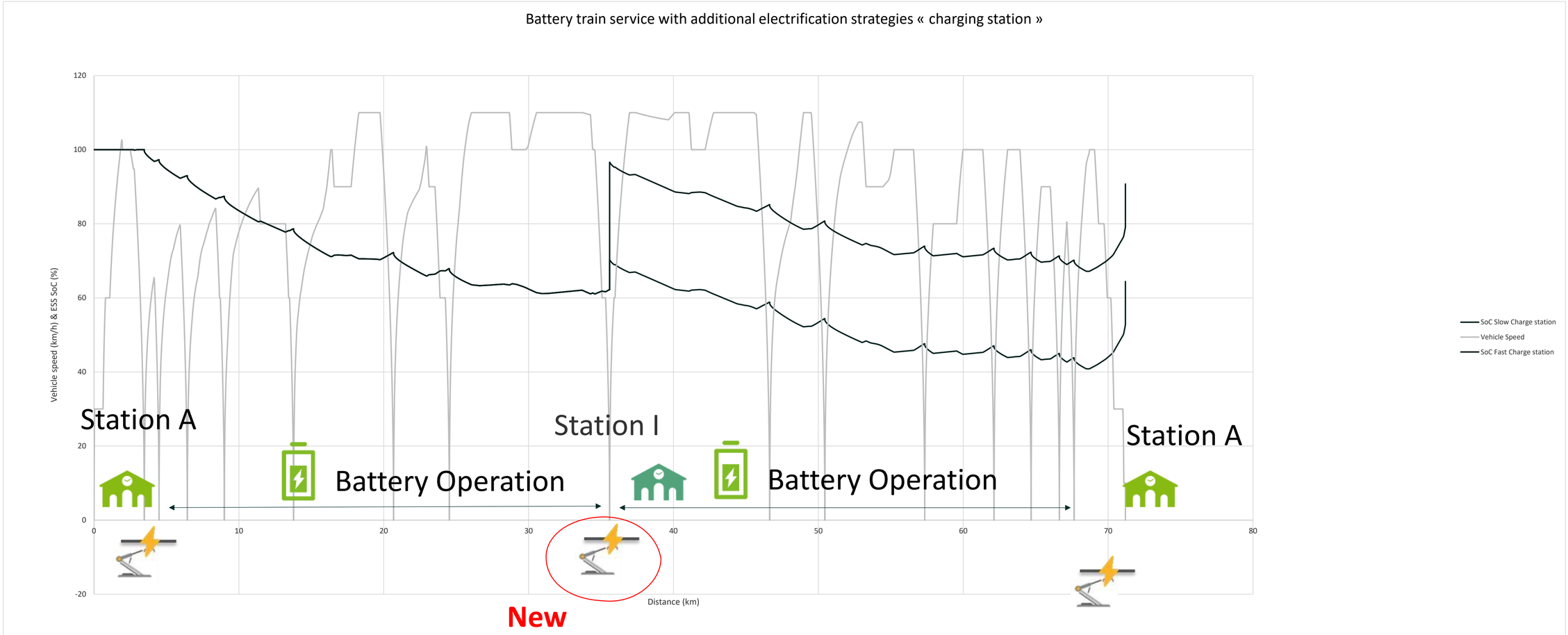
Use case of energy ditigal twin with a battery train

Step 2: Analysis of a 1st gen BEMU with the additional charging infrastructure → Charging station



Use case of energy ditigal twin with a battery train

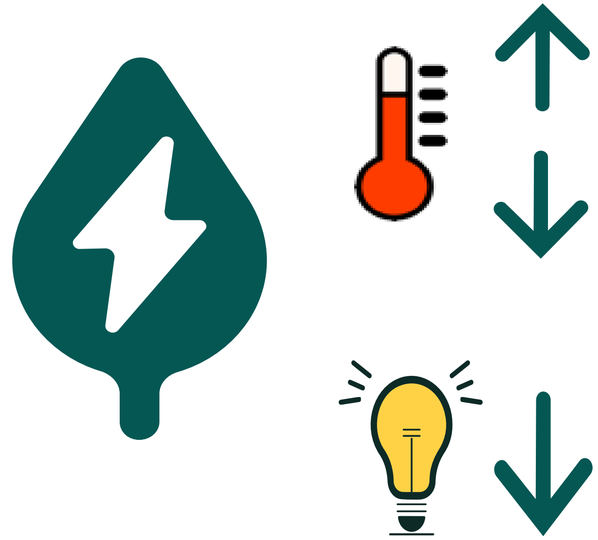
Step 3: Development of long range BEMU solution → Several way to increase the autonomy

Using new & more performant battery cell technology

Generation	1	2		3		4			5
		2a	2b	3a	3b	4a	4b	4c	
Type	Current	Current	State-of-The-Art	Advanced Lion HC	Advanced Lion HC	Solid State			Beyond Li-ion
Expected Commercial-isation	Commercial-ised	Commercial-ised		2020	2025	>2025			
Cathode	NMC/NCA LFP LMO	NMC111	NMC424 NMC523	NMC622 NMC811	HE NMC Li-rich NMC HVS	NMC	NMC	HE NMC	
Anode	Modifed Gaphite $Li_4Ti_5O_{12}$	Modified Graphite	Modified Graphite	NMC910 Carbon (Graphite)+Si	Silicon/ Carbon (C/Si)	Silicon/ Carbon (C/Si)	Li metal		Li metal
Electrolyte	Organic LiPF6salts			(5-10%)	Organic+ Additives	Solid electrolyte -Polymer (+Additives) -Inogranic -Hybrid			
Separator	Porous Polymer Membranes								

Improving battery packing

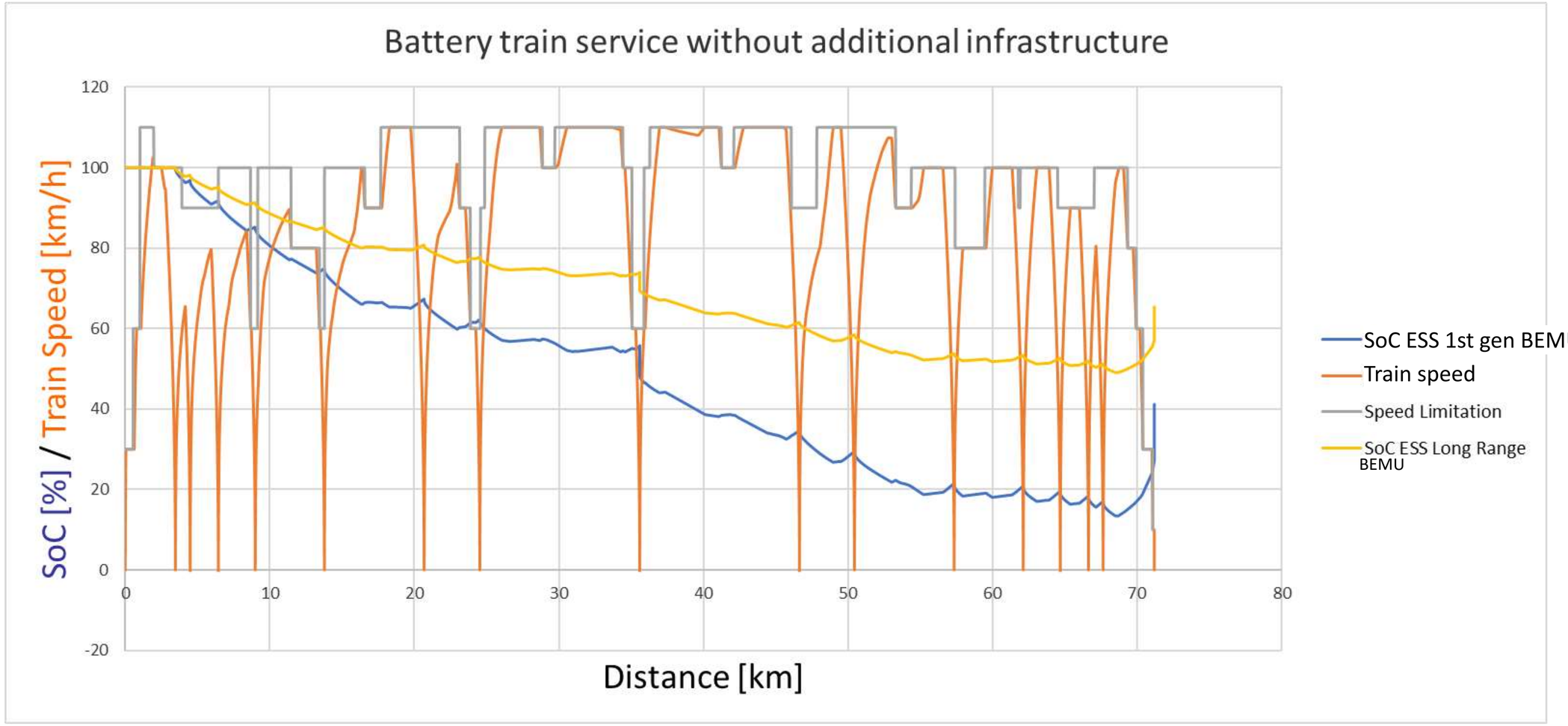
Developing energy management functions



Use case of energy ditigal twin with a battery train

Work Package 1
Work Package 5/6

Step 3: Analysis of the long range BEMU solution on the use case



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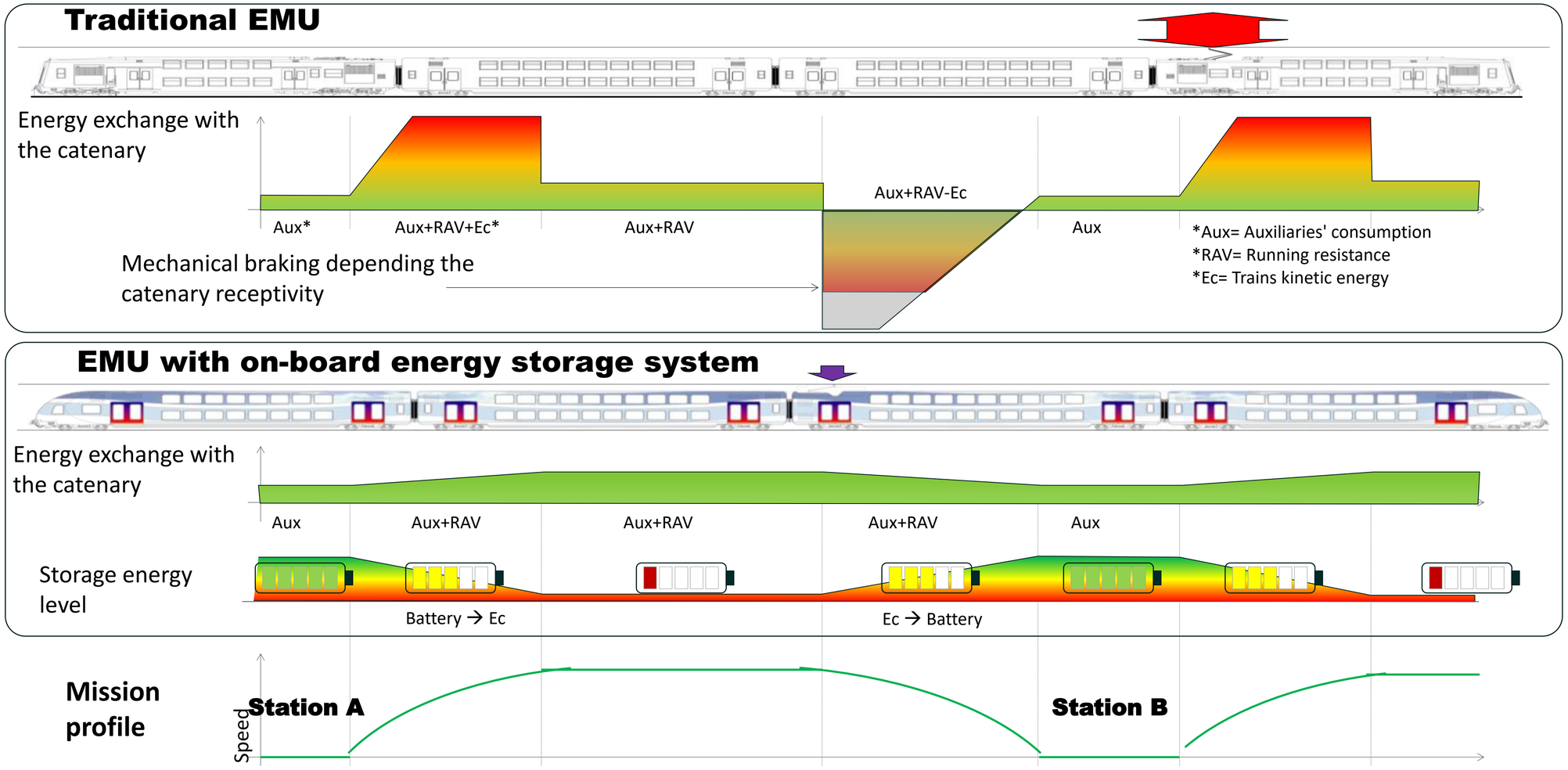
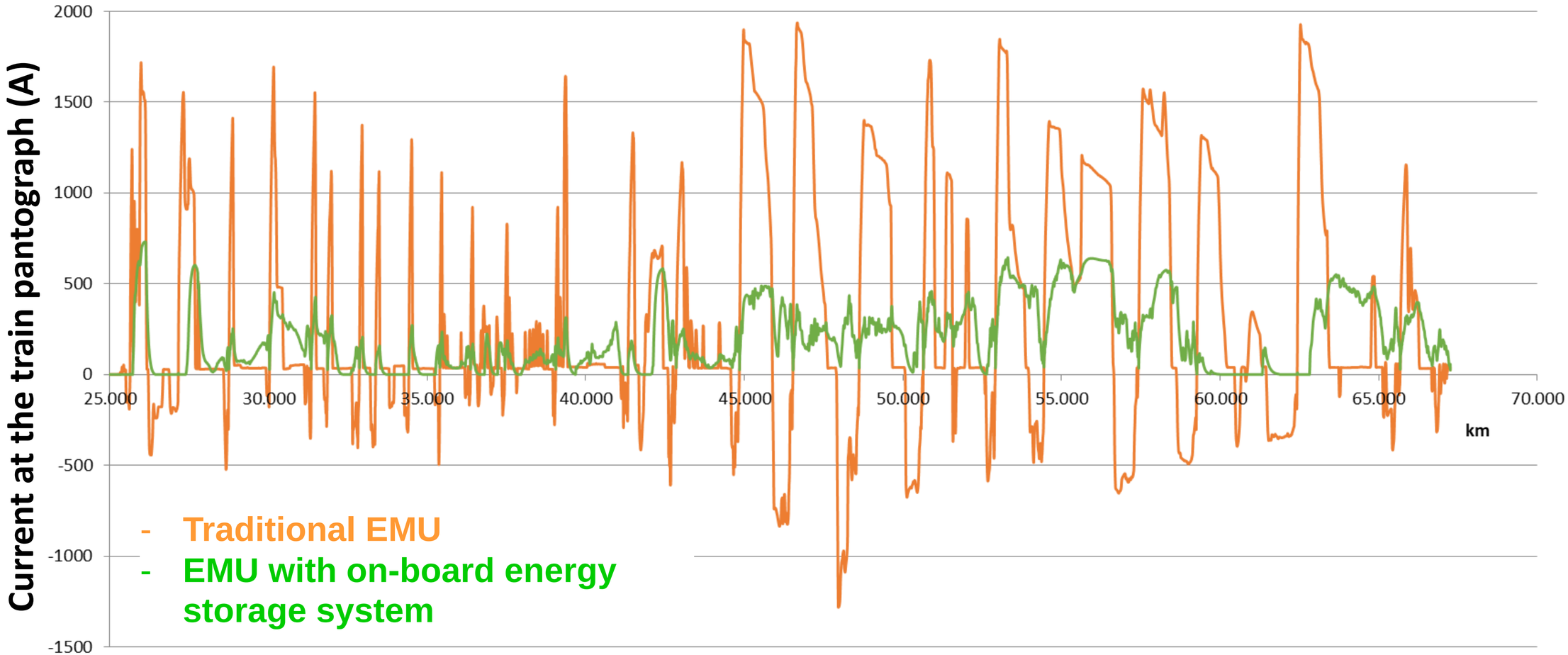
Suburban catenary train with on-board energy storage system

Hybridization strategy



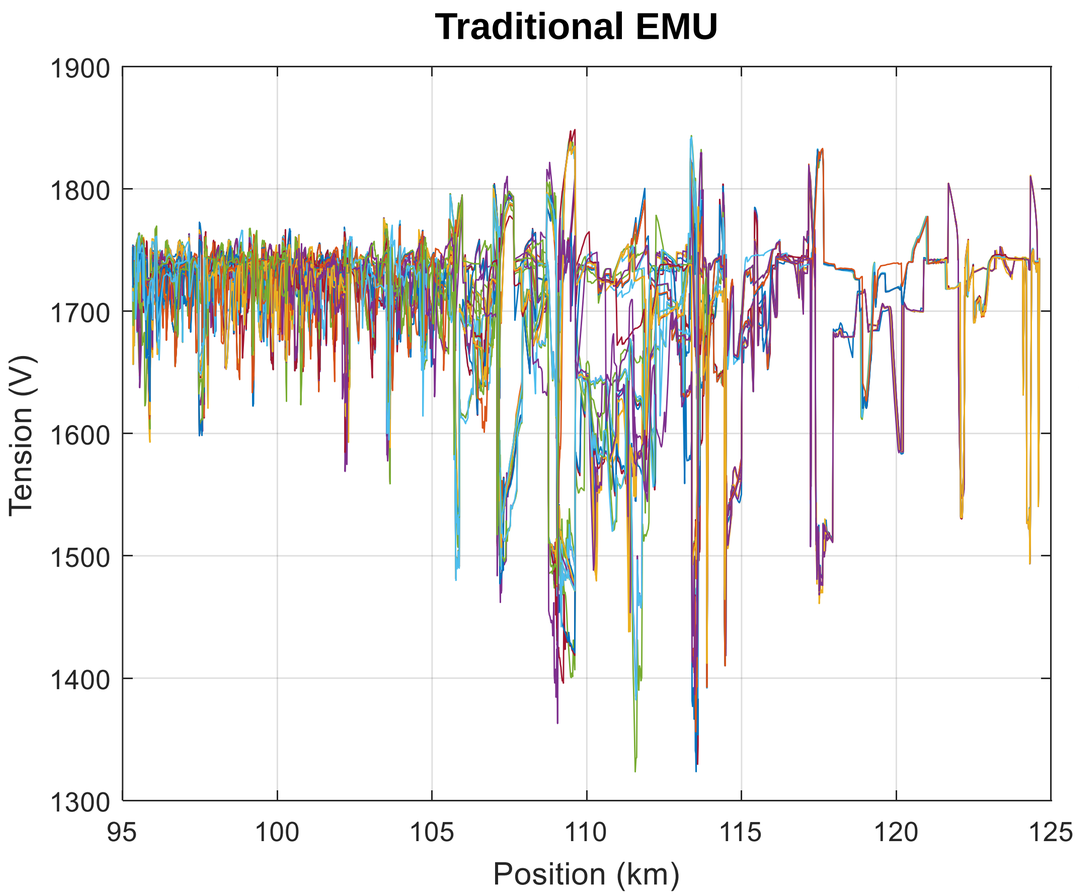
Suburban catenary train with on-board energy storage system

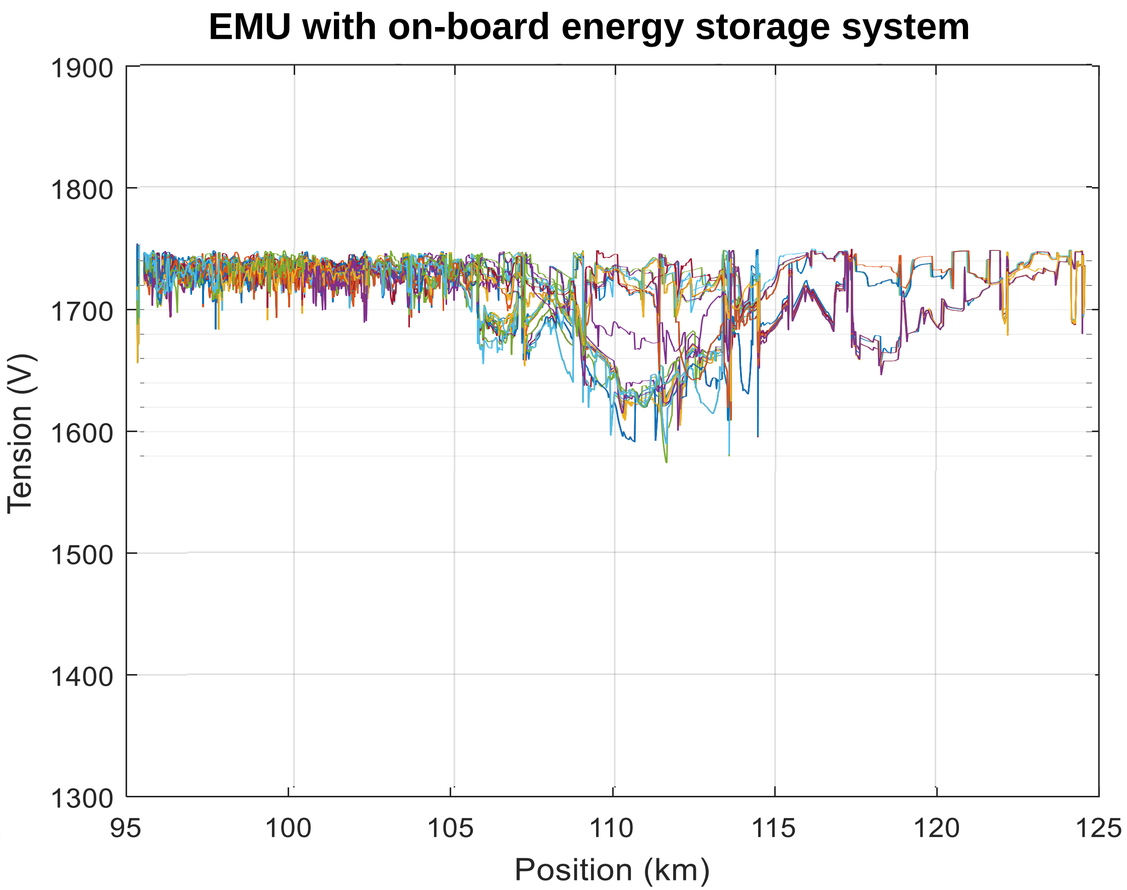
Current profile at the pantograph level



Suburban catenary train with on-board energy storage system

Voltage level at the pantograph during a whole day between two substations





Suburban catenary train with on-board energy storage system

Other major advantages:

Infrastructure works/ disruption:

- ✚ **Possibility to maintain the comfort auxiliaries (heating/cooling, lighting, WIFI…) at nominal operation**
- ✚ **Possibility to reach next station without catenary power**

Lower wear of mechanical braking parts:

- ✚ **Less emissions of fines particles and longer service intervals**

A down-size of the high voltage traction chain parts is possible:

- ✚ **Reducing high-voltage losses → Improving efficiency**
- ✚ **Using more “standard” medium voltage components → Reducing cost**

Thank you for your attention

MATÉRIEL

Ingénierie du Matériel

SNCF VOYAGEURS

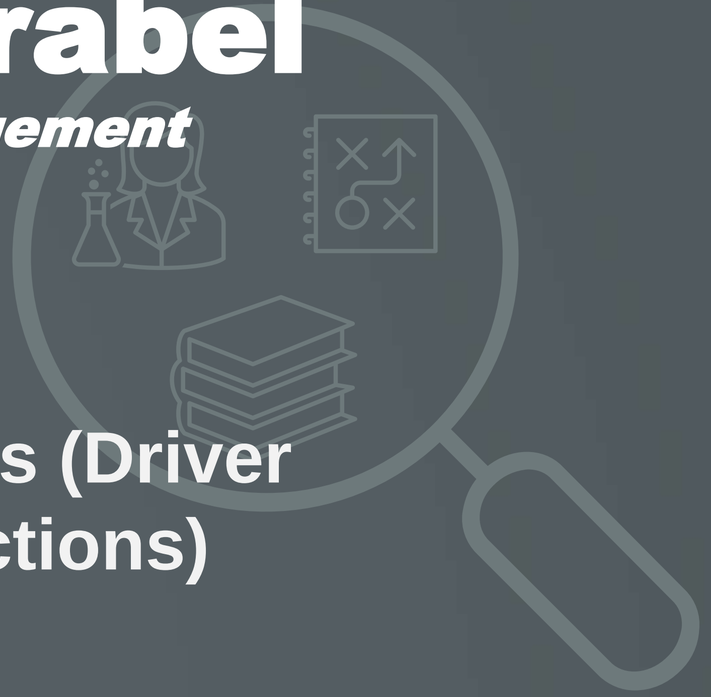
Lunch time

Until 13h30

INTERNATIONAL UNION
OF RAILWAYS

SNCF Réseau & Infrabel

French & Belgian nfrastructure Management



SFERA (Smart communication For Efficient Railway Activities)

Data exchange with onboard devices (Driver Advisory System & Digital Instructions)

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Bart Van der Spiegel
bart.vanderspiegel@infrabel.be

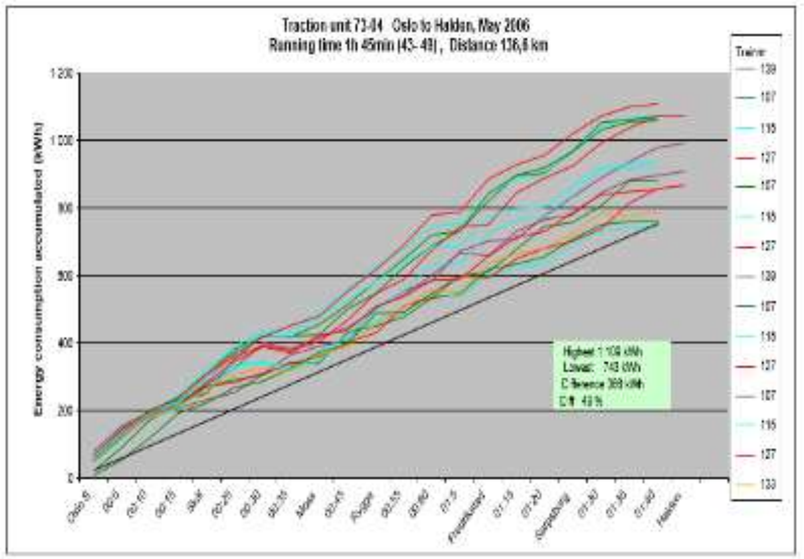
11/03/2025

Agenda

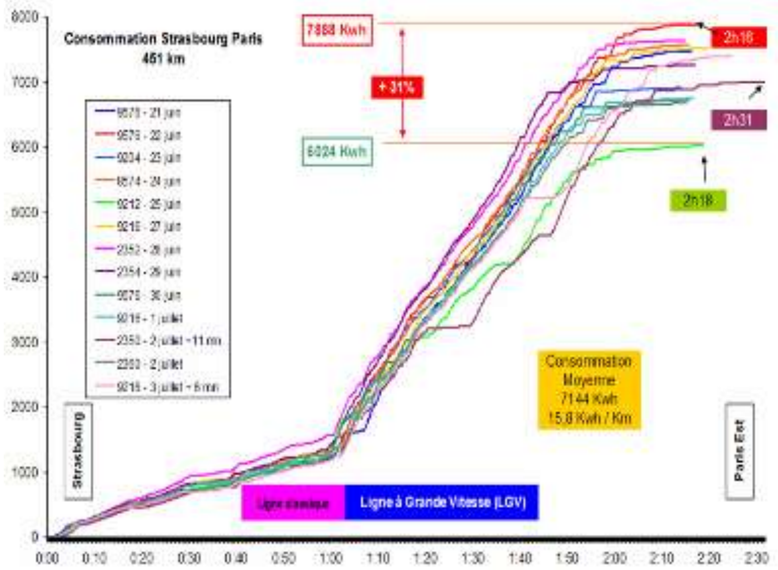
- Starting from standalone DAS
- Road towards connected DAS
- Deployment status
- Adding extra functions : Digital Instructions and Free Text Communication

Why do we need Driving Advisory Systems (DAS)?

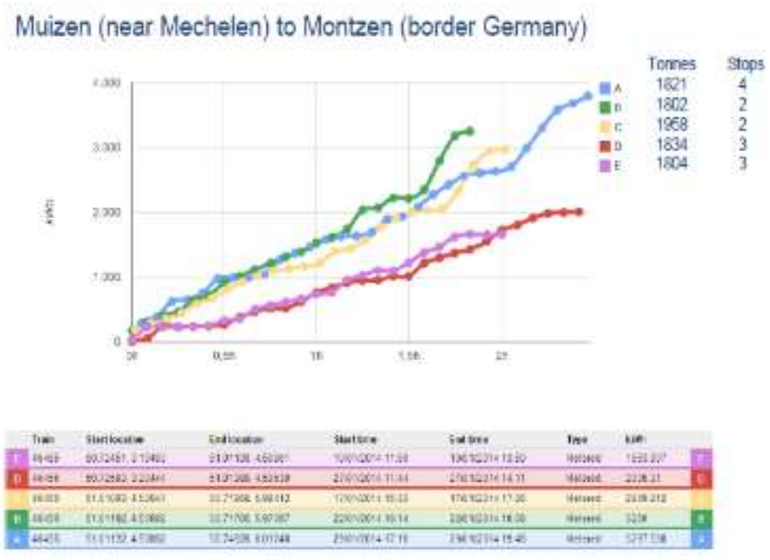
There is a huge variation in energy consumptions of trains running the same trajectory in same month on same line. This needs to become more optimised.



Passengers, Oslo-Halden, 2006



High speed, Strassbourg-Paris, 2010



Freight, Mechelen-Aachen, 2014

The phases of the SFERA Project

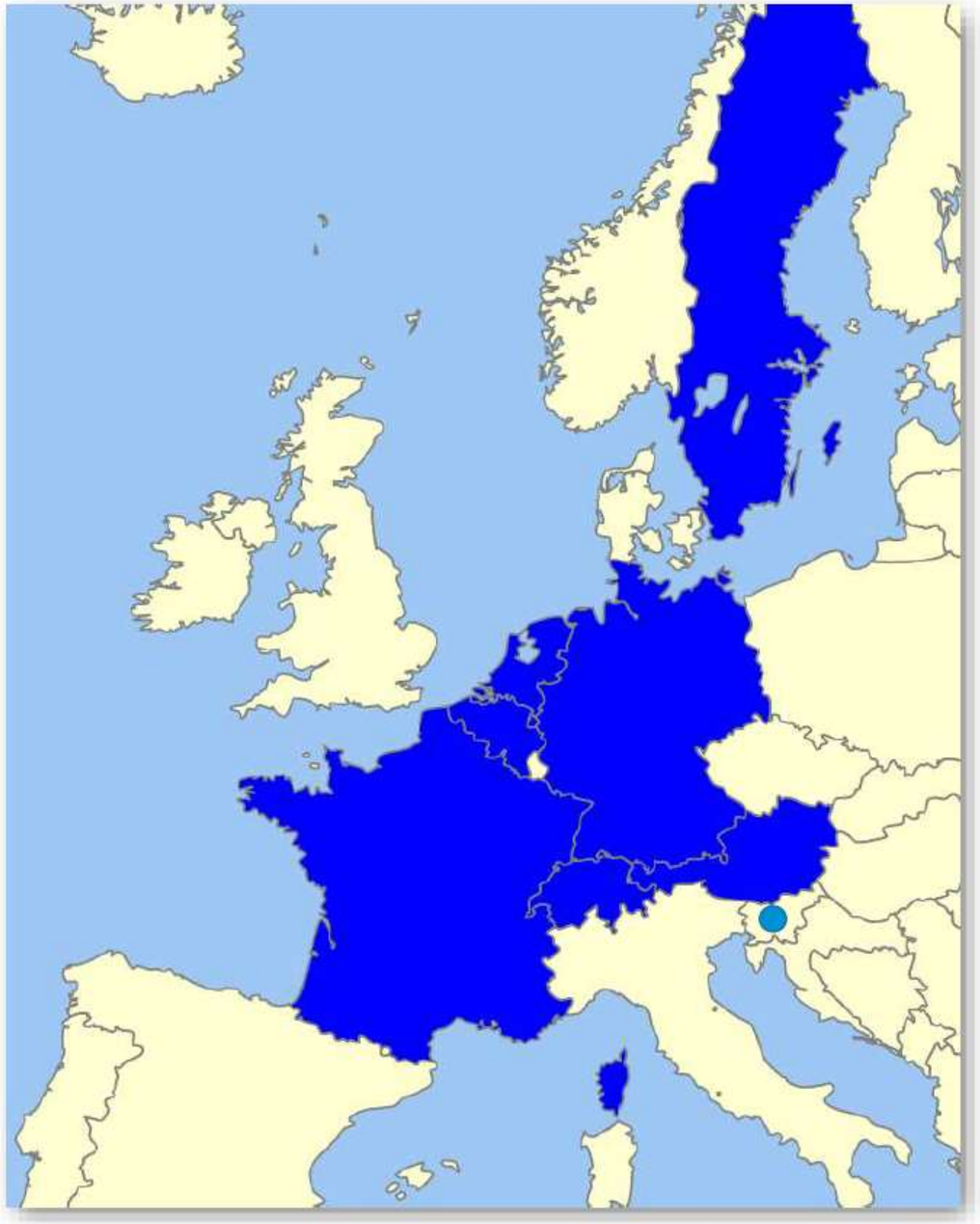
SFERA development: 2017-2019

SFERA II: 2021-2023

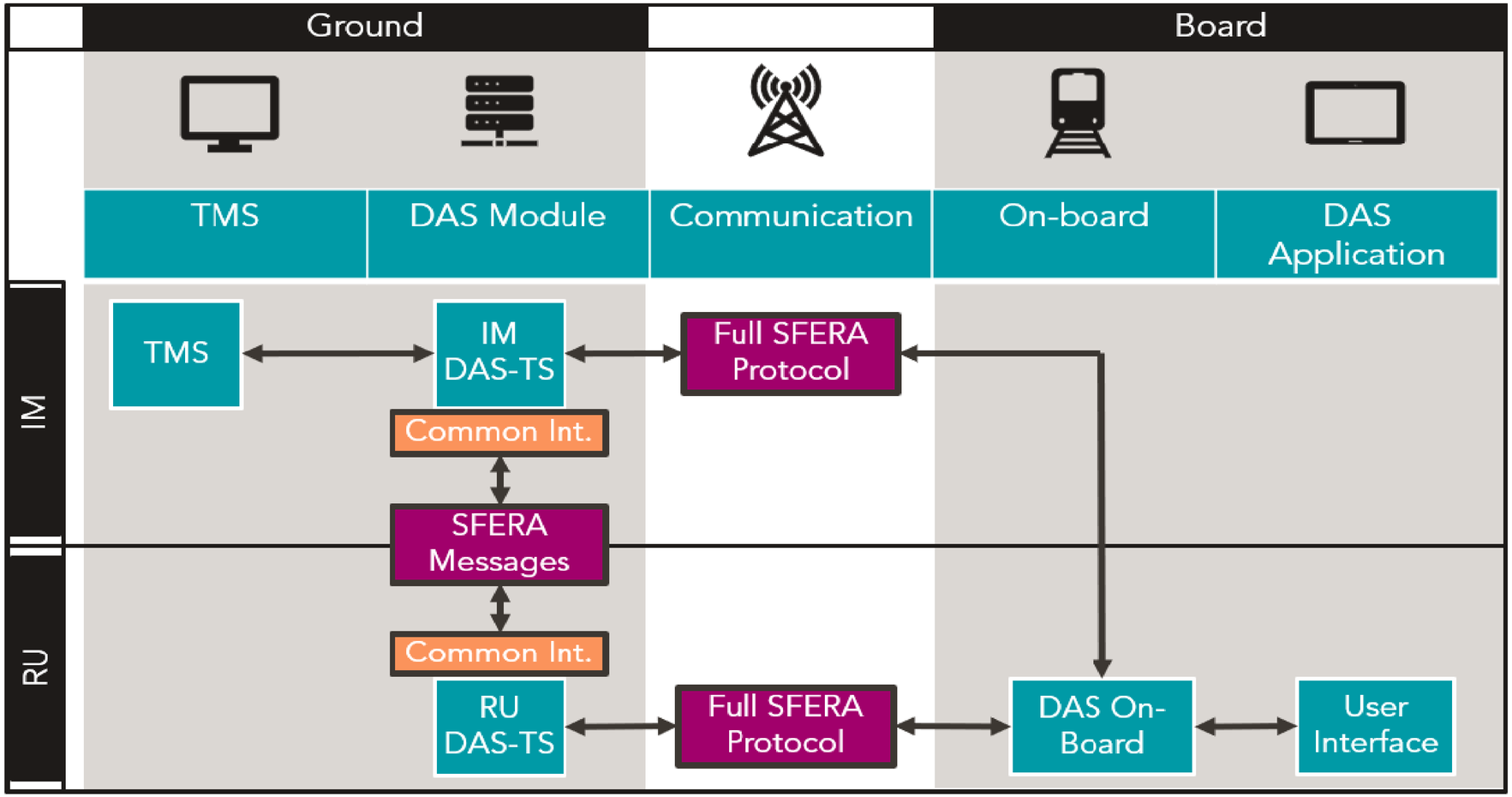
SFERA III: 2024-2026

Working Group

- IMs and RUs from France, Belgium, Netherlands, Germany, Switzerland, Austria and Sweden.
- Slovenia joined in 2024.
- UIC Members can join at any time: contact sfera@uic.org.



The IRS 90940 describes the SFERA-protocol



DAS Operating Modes

On-board device sends all supported triplets [Driving Mode, Architecture and Connectivity]. Track side selects the pair [Architecture, Connectivity].

Driving Mode:

- Inactive: not giving information to driver
- Read-Only: device operated by another user
- Timetable: only timetable given
- DAS not connected to ATP: device operated by driver, data can be inconsistent with signalling system
- GoA1: device operated by driver, data is consistent with signalling system
- GoA2/3/4: Automatic Train Operation is applied

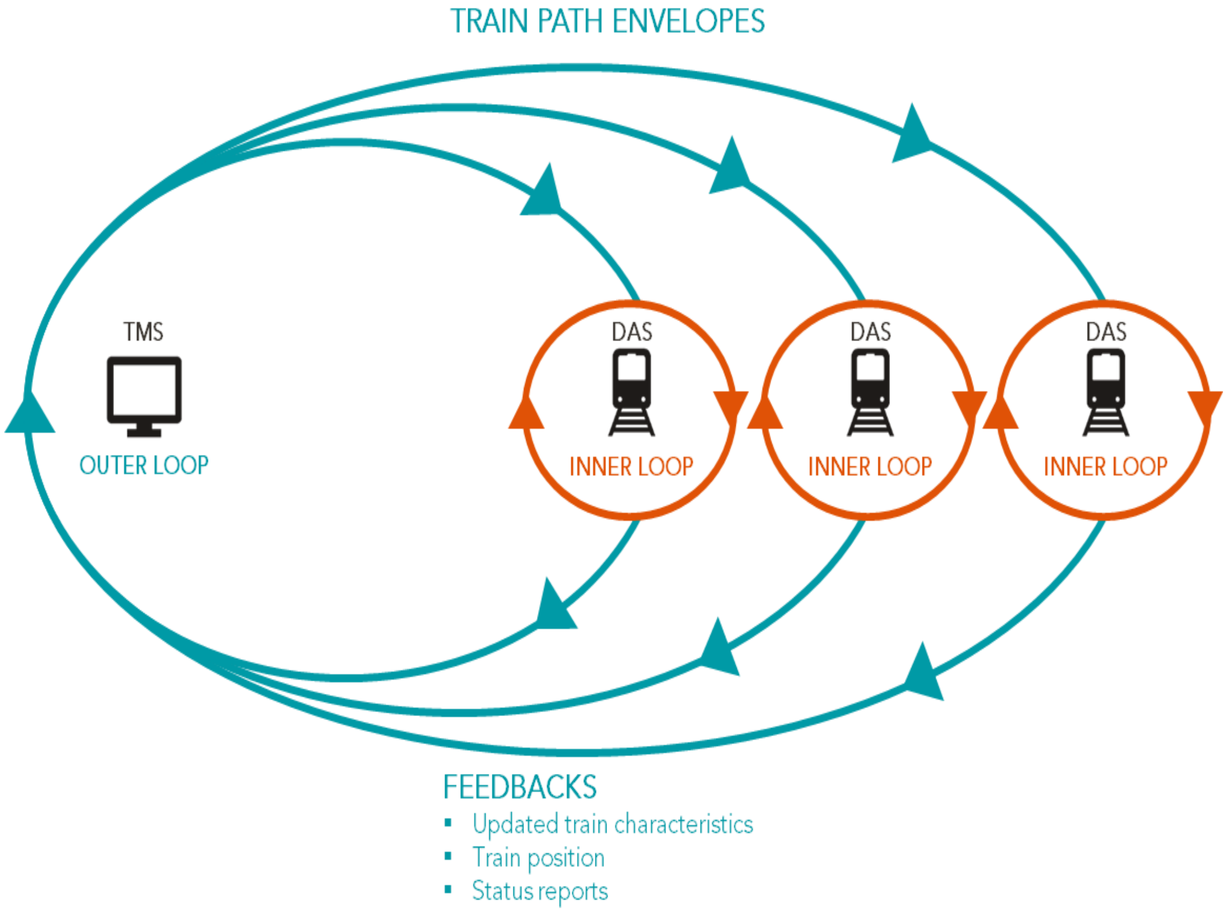
Architecture:

- Ground Advice Calculation (DAS-C)
- Board Advice Calculation (DAS-O)

Connectivity:

- Standalone (S-DAS)
- Connected (C-DAS or ATO)

Functioning of connected DAS

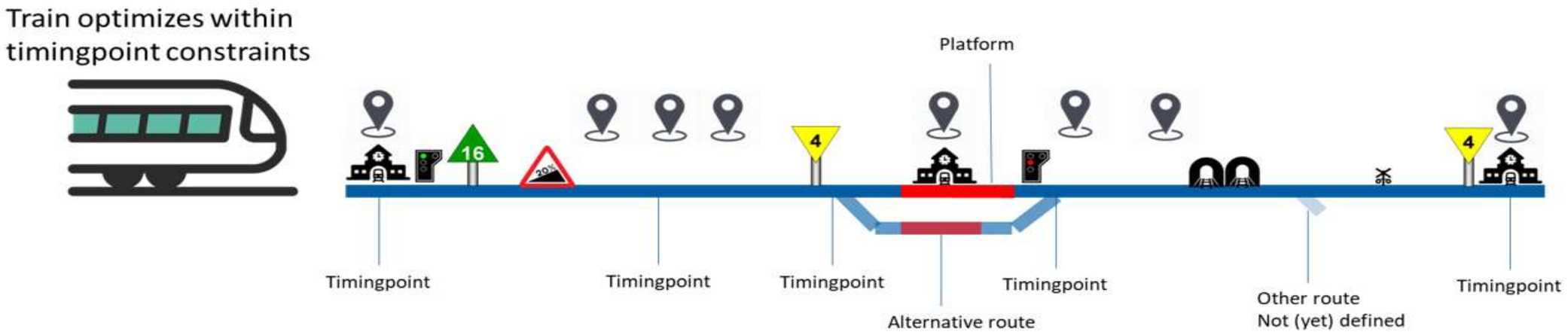


- Each DAS has its own optimisation algorithm.
- Each DAS sends feedback to the Traffic Management System (TMS).
- TMS detects conflicts, defines optimal solution and adjusts Train Path Envelopes.
- A Train Path Envelope contains the periods of time in which a train can pass each of the significant locations of its train-run.

Journey Profile, Segment Profile, Train Characteristics

We have chosen a model based on the ERTMS/ATO:

- Journey Profile: describes the train-run (with timing e.g. at stops and temporary constraints)
- Segment Profile: describes the infrastructure of the trajectory (permitted speed, gradients)
- Train Characteristics: as DAS might be on a tablet, we added information on the train
- Status Report: feedback loop (e.g. location, speed, estimated time of arrival)



Making DAS future proof

The protocol has possibility to add a lot of extra data:

- Low adhesion: feedback of adhesion observations via status report
- Traction limitations: possible to request to lower consumption on certain area or period of time
- Improve regenerative braking: possible to send when and where train wants to return energy, trackside checks, can ask other trains to increase consumption and informs first train
- Charging infrastructure: battery trains can get information on the power they can use for charging during running and at standstill
- Last minute rerouting: it is possible to send alternative routes e.g. to other platforms or by using a parallel track in case an update of the Journey Profile from the TMS can’t be received in time

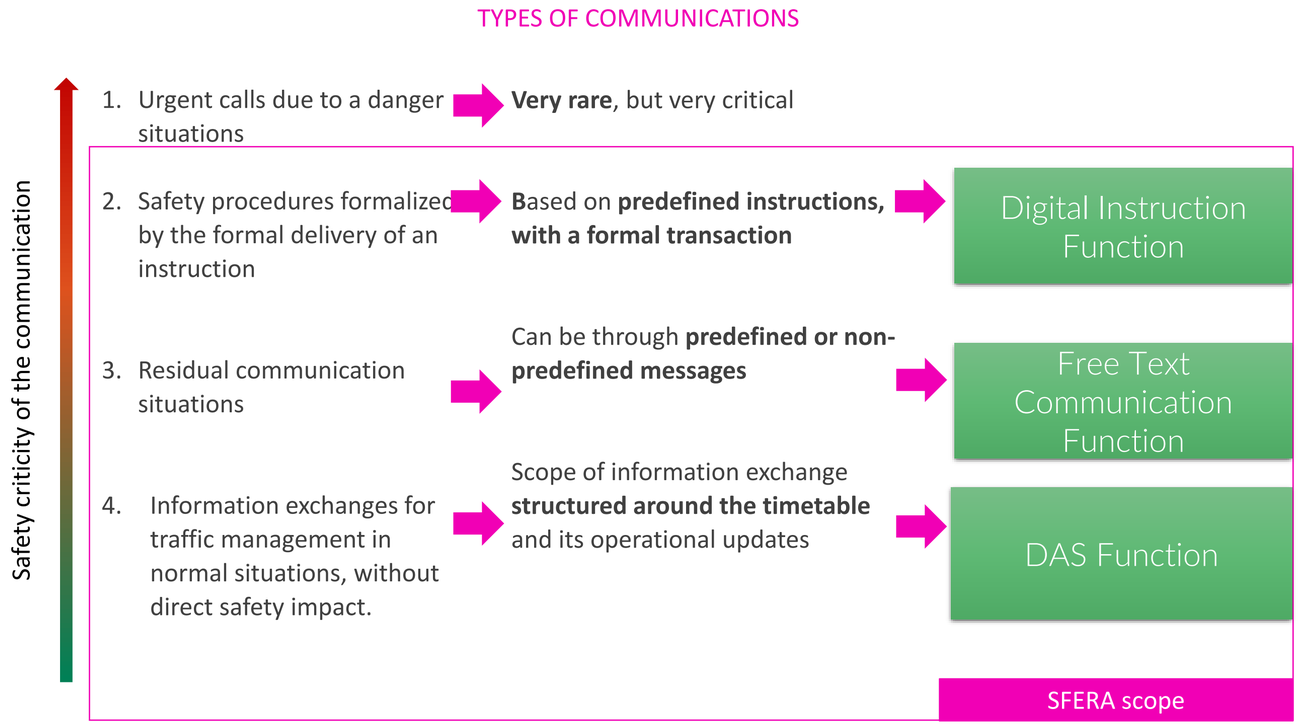
Implementation

Country	S-DAS	C-DAS-C	C-DAS-O
Austria		Testing ongoing with one RU In production this year for all RU	Working on a concept
Belgium	By NMBS Tool to convert data to SFERA	Testing ongoing with multiple freight operators on multiple lines	
France	By SNCF Voyageurs First SNCF Réseau data in 2025		SFERA implementation starting in 2025
Germany		DB Infra GO with DB Cargo (open for all RU, but not implemented) Transition to SFERA in 2025.	Pilot with DB Cargo (not SFERA)
Luxemburg			Full roll-out by CFL
Netherlands			By NS (with JP Updates and RouteLint by ProRail) ProRail works on C-DAS-O
Sweden	By SJ		Light version on a few lines Pilot wit RUs in 2025
Switzerland		Implemented by SBB (not SFERA)	System IM to be ready in 2026

Adding extra functions on the communication

With connected DAS we now have a bidirectional communication from Trackside towards the drivers. Can we use this communication for other purposes?

Communication between driver and ground

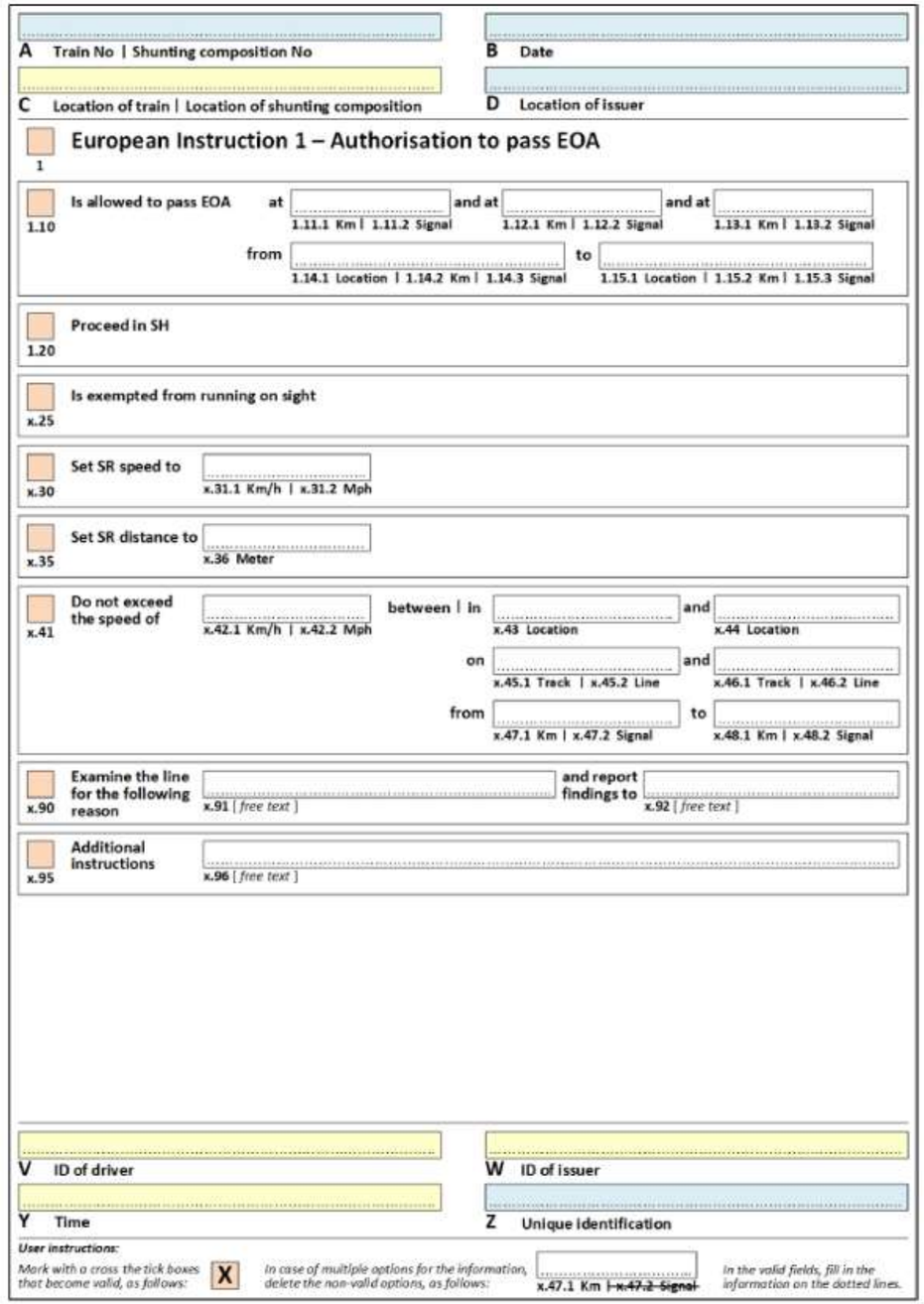


What are European Instructions?

- Safety of train operation is primarily ensured by technical systems (signalling…).

- Instructions are used to give drivers:
  - Authorisation to bypass those technical systems
  - An order to adopt a more restrictive behaviour

- OPE TSI defines standard instructions that are set to replace national instructions.



A Train No | Shunting composition No
B Date
C Location of train | Location of shunting composition
D Location of issuer

1 European Instruction 1 – Authorisation to pass EOA

1.10 Is allowed to pass EOA at ____ (1.11.1 Km | 1.11.2 Signal) and at ____ (1.12.1 Km | 1.12.2 Signal) and at ____ (1.13.1 Km | 1.13.2 Signal)
from ____ (1.14.1 Location | 1.14.2 Km | 1.14.3 Signal) to ____ (1.15.1 Location | 1.15.2 Km | 1.15.3 Signal)

1.20 Proceed in SH

x.25 Is exempted from running on sight

x.30 Set SR speed to ____ (x.31.1 Km/h | x.31.2 Mph)

x.35 Set SR distance to ____ x.36 Meter

x.41 Do not exceed the speed of ____ (x.42.1 Km/h | x.42.2 Mph) between | in ____ (x.43 Location) and ____ (x.44 Location)
on ____ (x.45.1 Track | x.45.2 Line) and ____ (x.46.1 Track | x.46.2 Line)
from ____ (x.47.1 Km | x.47.2 Signal) to ____ (x.48.1 Km | x.48.2 Signal)

x.90 Examine the line for the following reason ____ x.91 [free text] and report findings to ____ x.92 [free text]

x.95 Additional instructions ____ x.96 [free text]

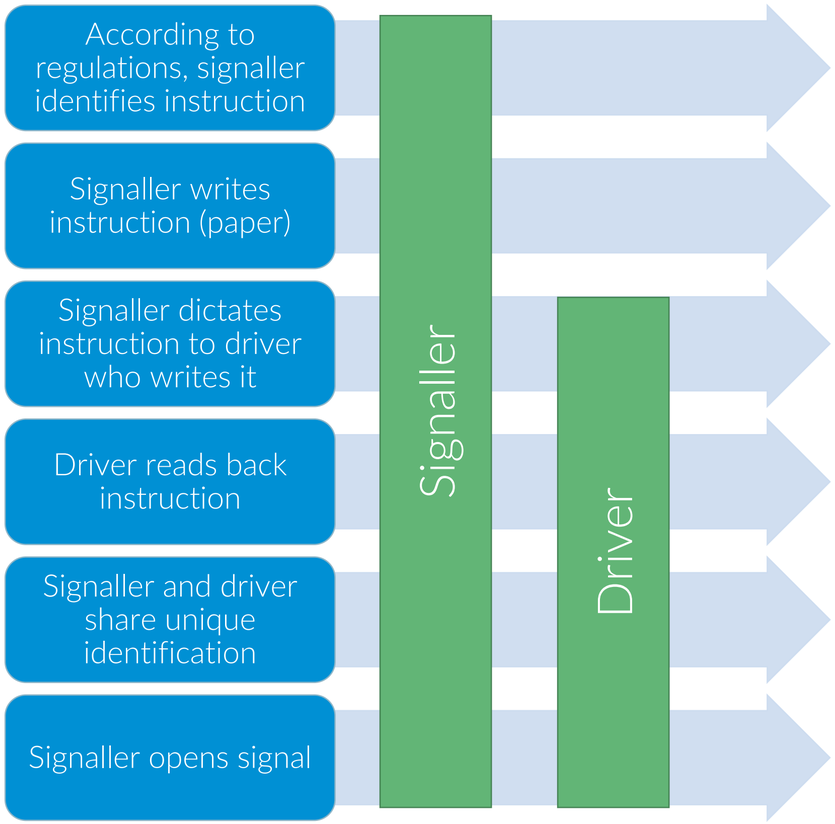
V ID of driver
W ID of issuer
Y Time
Z Unique identification

User instructions:
Mark with a cross the tick boxes that become valid, as follows: X
In case of multiple options for the information, delete the non-valid options, as follows: x.47.1 Km | ~~x.47.2 Signal~~
In the valid fields, fill in the information on the dotted lines.

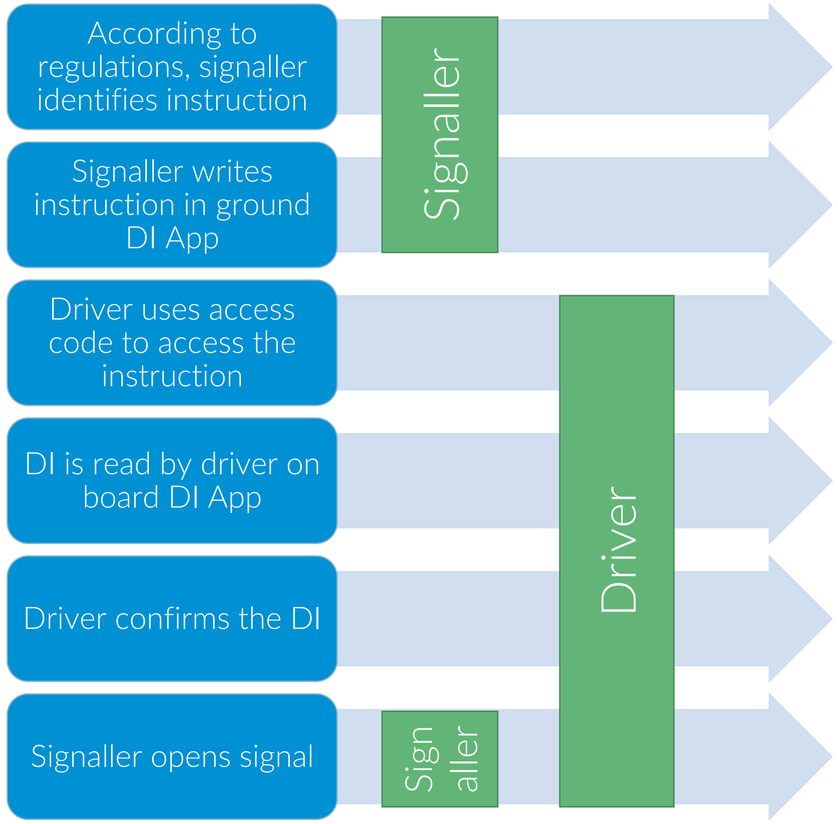
Work in progress

What are Digital Instructions?

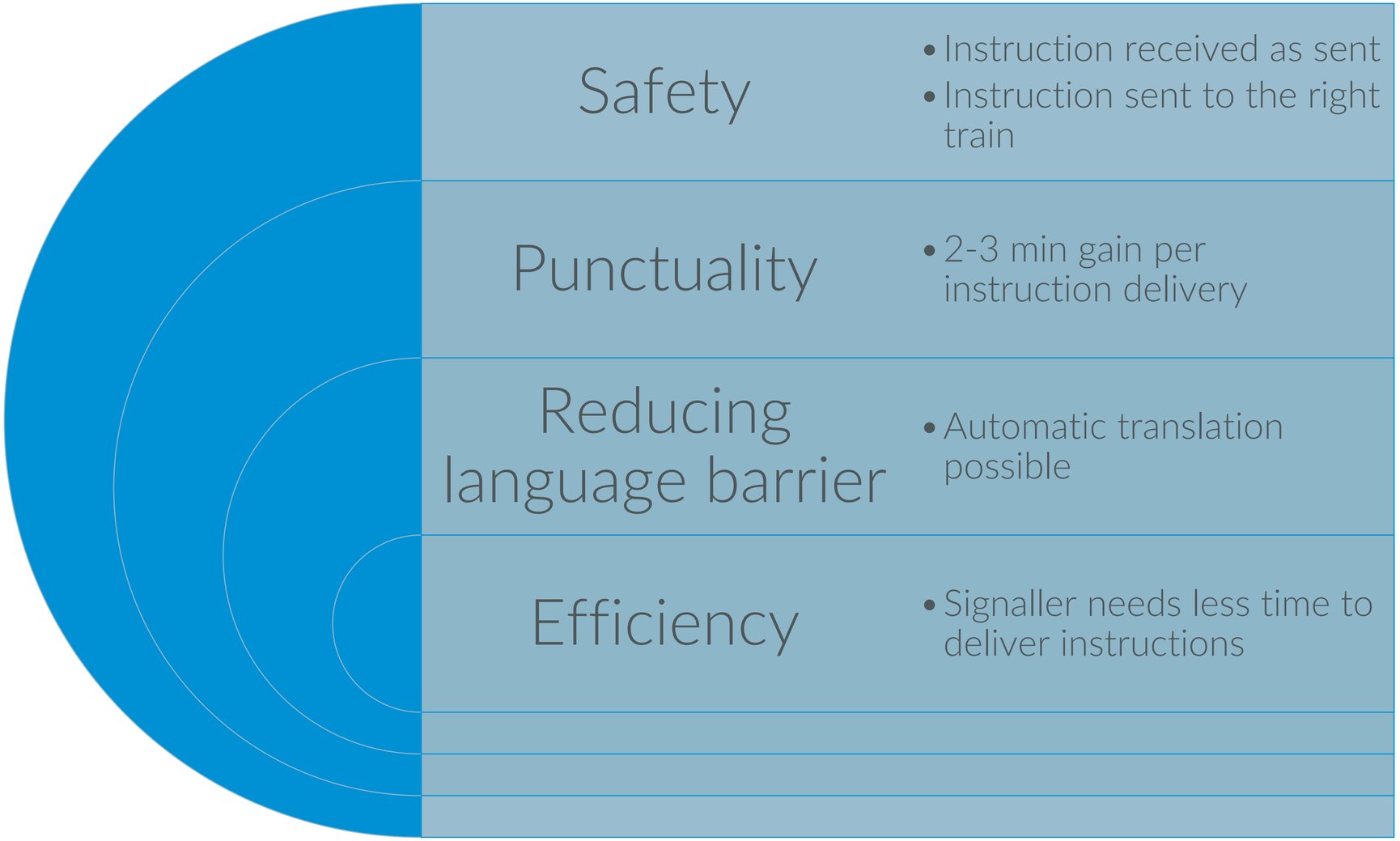
- Today:



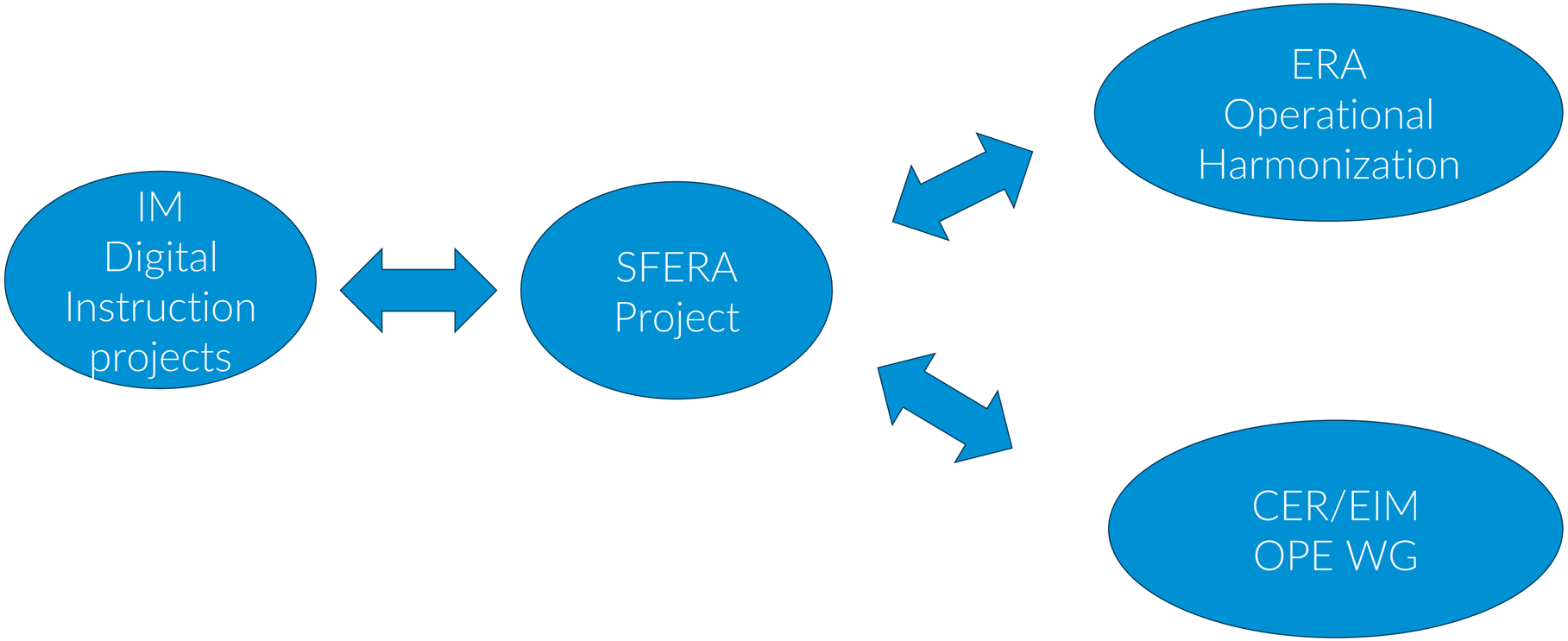
- Tomorrow: digital instructions (DI)



Why Digital instructions?

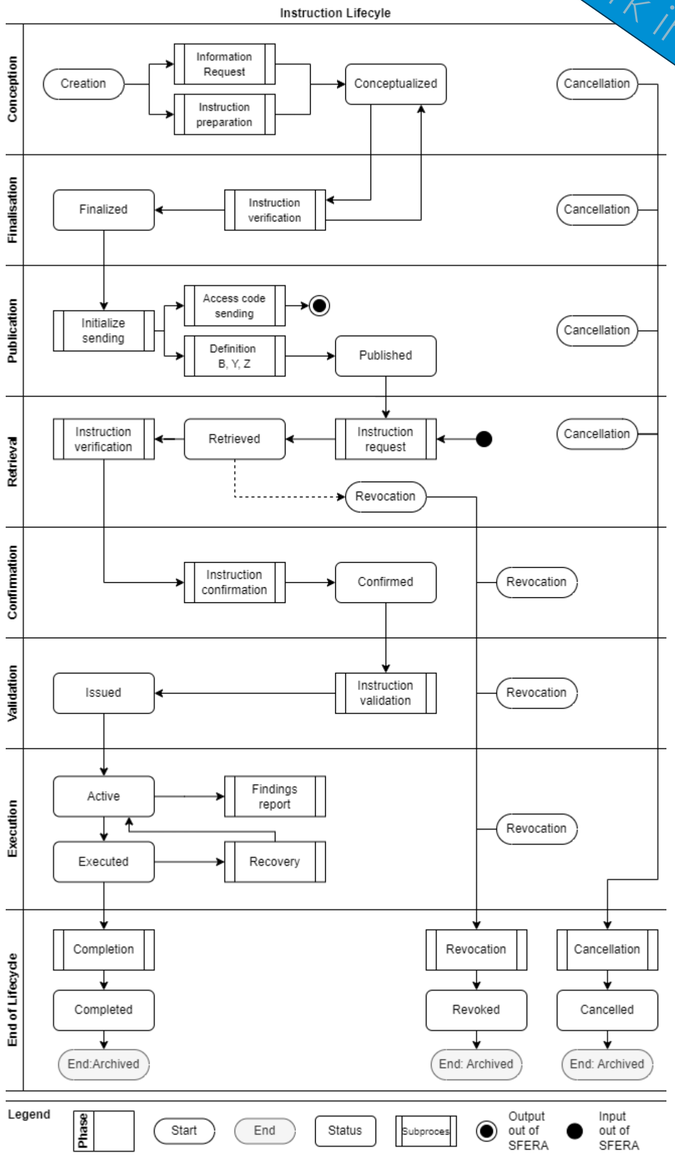


Parties involved



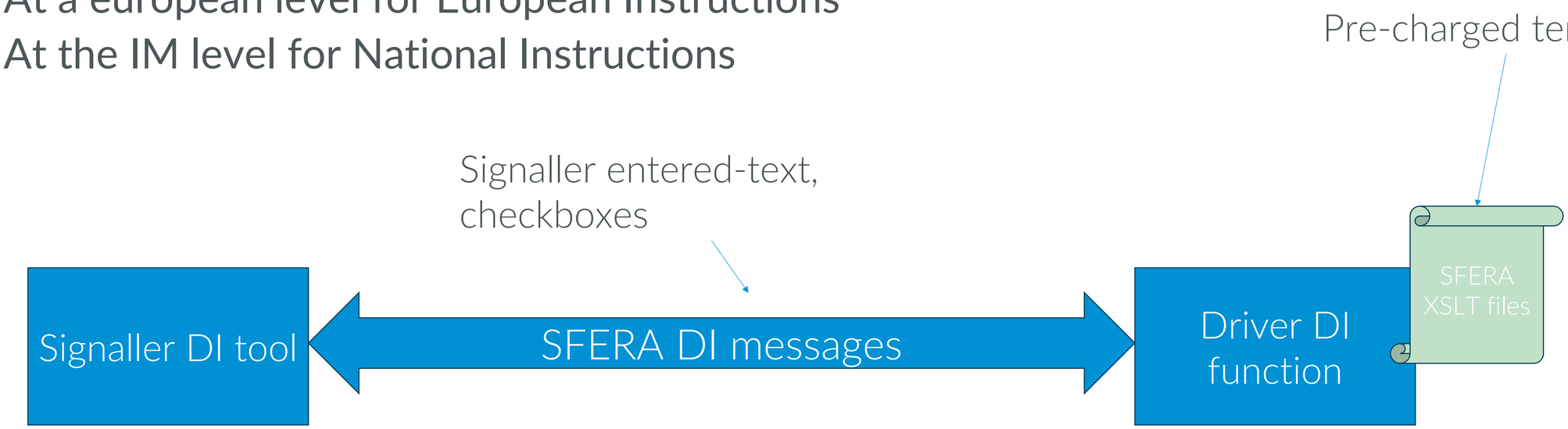
Defining a harmonized workflow

Work in progress



Guaranteeing harmonized representation

- SFERA defines a file format (XSLT) that predetermines the « template » :
  - all static texts of the instructions (multilingual)
  - Display format
- Content of file determined :
  - At a european level for European Instructions
  - At the IM level for National Instructions



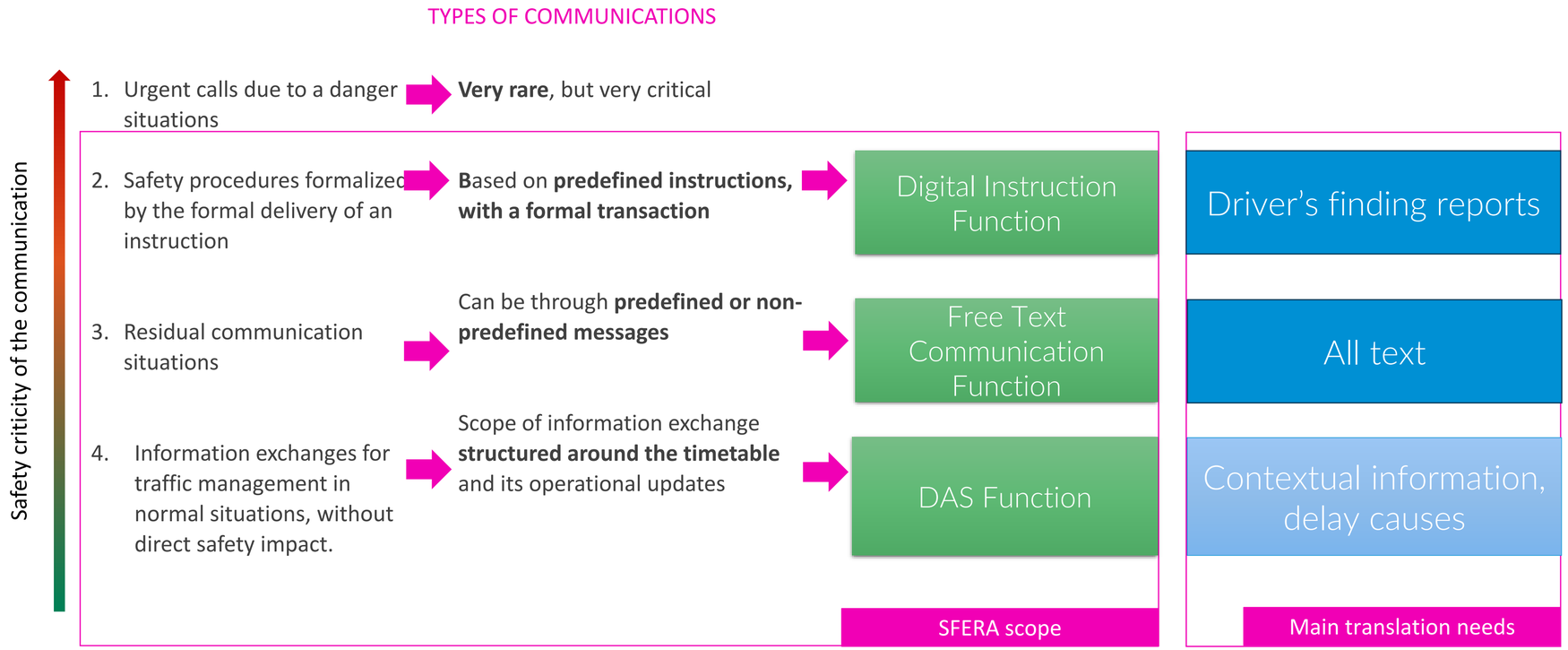
Free Text Communication

- Driver <-> Ground actors (e.g. signaller)
- Text messages
- Multiple languages
- Conversation (Answering to a specific message)

Complementarity with language projects (Translate4Rail, ATHENA…)
which focus on translation

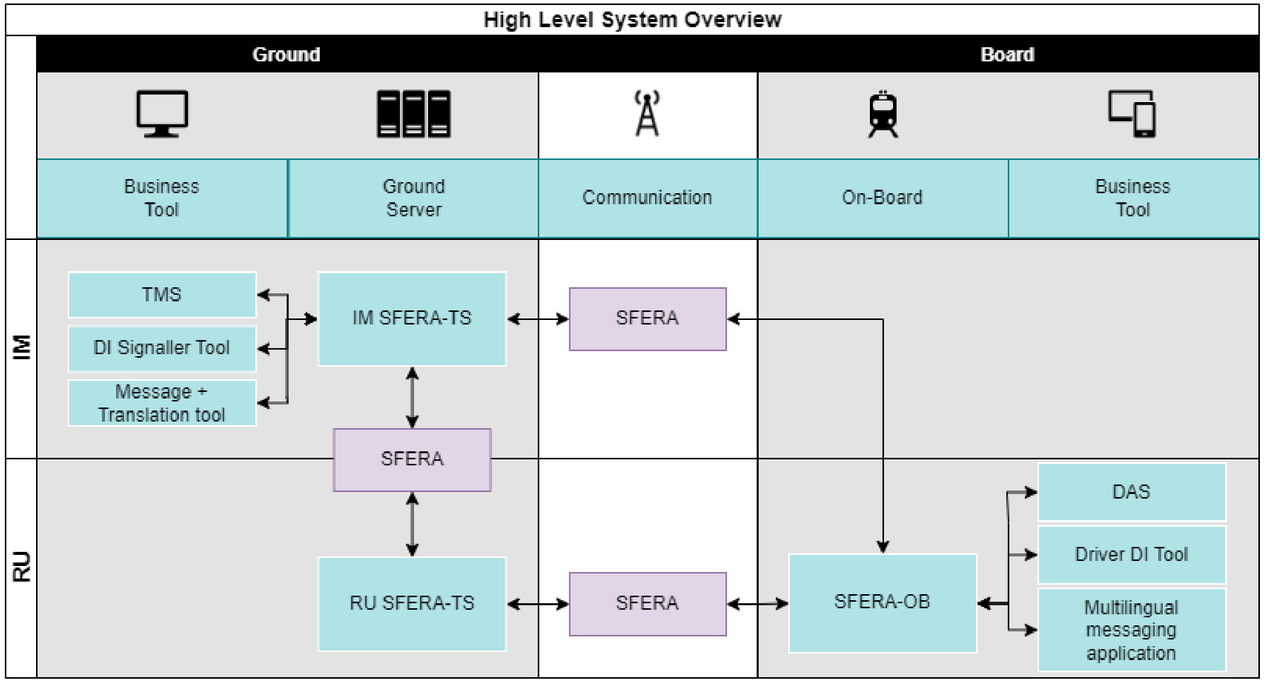
SFERA brings an interoperable data protocol

Communication between driver and ground



Mutualization and Modularity

- All 3 functions
  - one common architecture
  - can be deployed independantly or together, on board or on ground



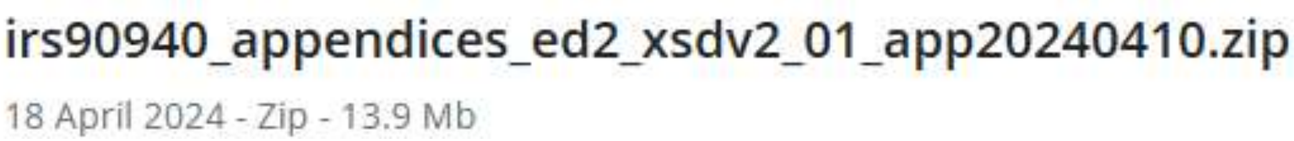
How to get the IRS 90940?

Main text of IRS 90940 Ed2:

- Go to: https://shop.uic.org/en/
- Search for 90940
- You will have to register to be able to download the IRS

Appendices:

- Go to: https://appendices.uic.org/IRS-90940
- You can download readme, changelog, an erratum and the set of appendices of 10th April 2024



Workshop on May 13th in Paris

Registration: https://uic.org/events/uic-sfera-protocol-train-operation-data-exchange-workshop

Session Restitution

Rolling stock / Operation

Session Restitution

Infrastructure / Stations / Buildings

INTERNATIONAL UNION
OF RAILWAYS

KRRI

Korea Railroad Research Institute

Kayoung Shin

Carbon neutrality technologies

11 March 2025

SUSTAINABILITY
Action Week

2050 Carbon neutrality technologies dedicated to railways from a life cycle perspective

Kayoung, SHIN
Senior Researcher (Post-doctor)

SUSTAINABILITY
Action Week

CONTENTS

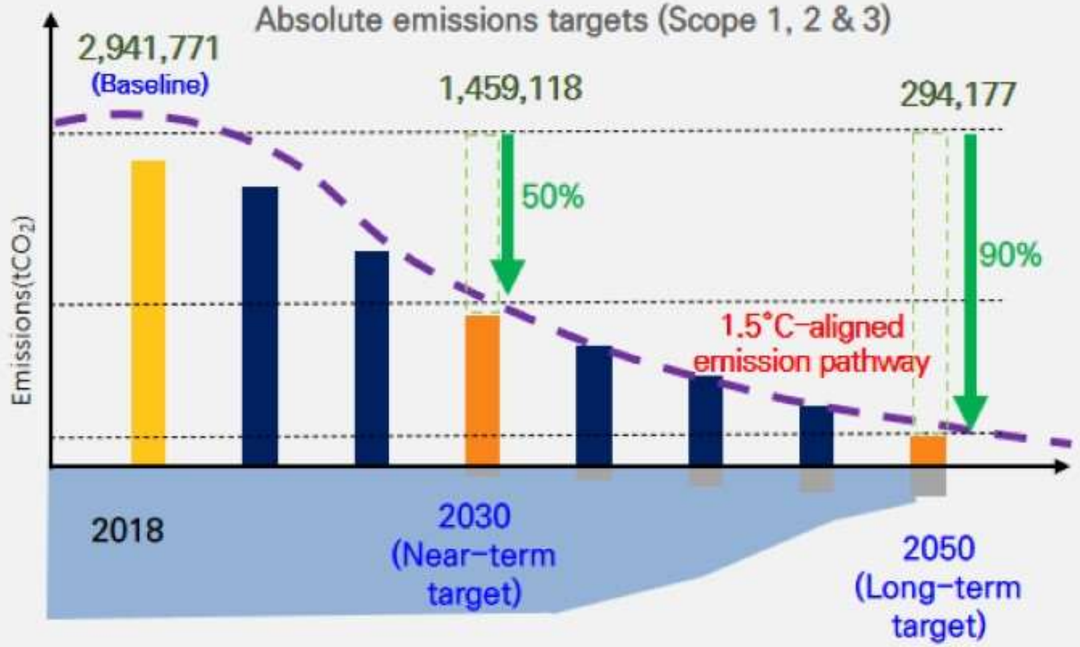
01 Net Zero 2050 Roadmap

01 2050 Net Zero Roadmap of Rail Sector

KRRI SUSTAINABILITY Action Week

- (Applying SBTi methodology) The near-term goal is to reduce emissions by 50% by 2030 and the long-term goal is to achieve net zero by 2050, compared to the base year of 2018.
  - The base year emissions are based on the rail operating services(rolling stocks and stations) emissions (Scope 1 & 2) + the construction phase emissions of rail infrastructure.
- (According to MoLIT) Transport sector emitted 98.1 million tons in 2018, with the rail sector accounting for 3%, indicating a need to reduce approximately 0.14 million tons by 2030.

* MoLIT, Ministry of Land, Infrastructure and Transport of Korea



SBTi Target (1.5℃ pathway) (Unit: million tons)

Classification	Baseline (2018)	2030	2050
Rail Sector	0.29 (3% of transport sector)	0.14 (50% ↓)	0.03 (90% ↓)

Korea's NDC (Unit: million tons)

Classification	Baseline (2018)	2030	2050	
			Option A	Option B
National emissions	727.6	436.6 (40% ↓)	80.4	117.3
Transport Sector (MoLIT)	98.1 (13.5%)	61 (37.8% ↓)	2.8 (97.1% ↓)	9.2 (90.6% ↓)

02 2050 Net Zero Roadmap of Rail Sector

SUSTAINABILITY Action Week

02 Establishment of Decarbonization Management Framework

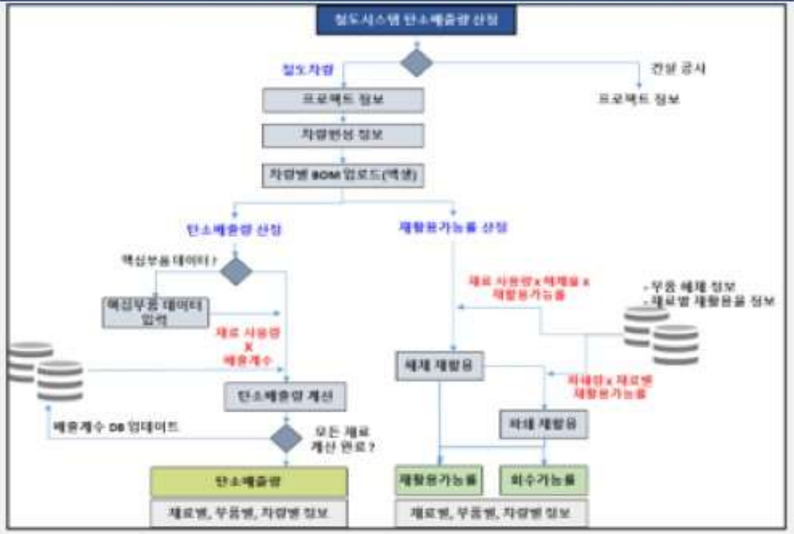
01 Carbon DB & Tool

SUSTAINABILITY Action Week

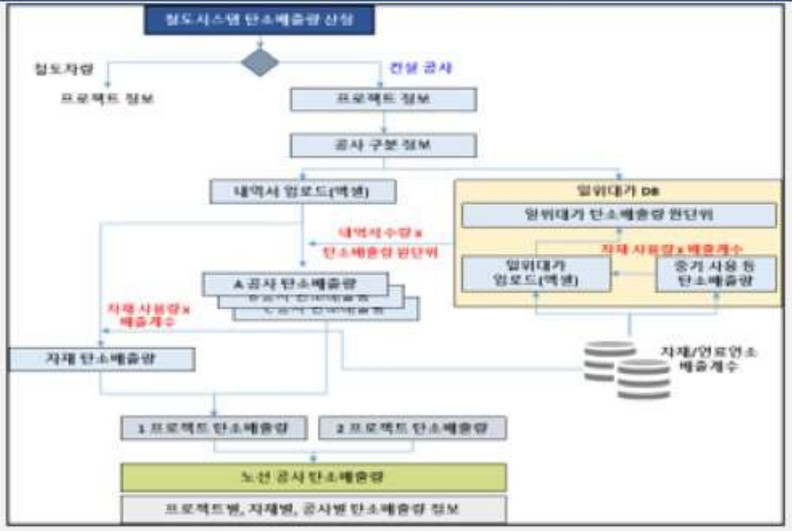
- Developing databases and tools for a carbon supply chain management system to analyze and reduce emissions, designing eco-friendly railway vehicles and infrastructures with higher recyclability, and improving waste management to increase resource recyclability.
- (Railway vehicles) Link to BOM to calculate the life cycle carbon emissions, recyclability, and recoverability rates
- (Railway infrastructure) Calculate the life cycle carbon emissions in connection with the BOQ and unit price

Establishment of Life-cycle Carbon Emission Factor Database

Rolling Stock Carbon Emission and Recyclability Calculation Tool



Rail Infrastructure Carbon Emission Calculation Tool



03

Scope 1 Decarbonization

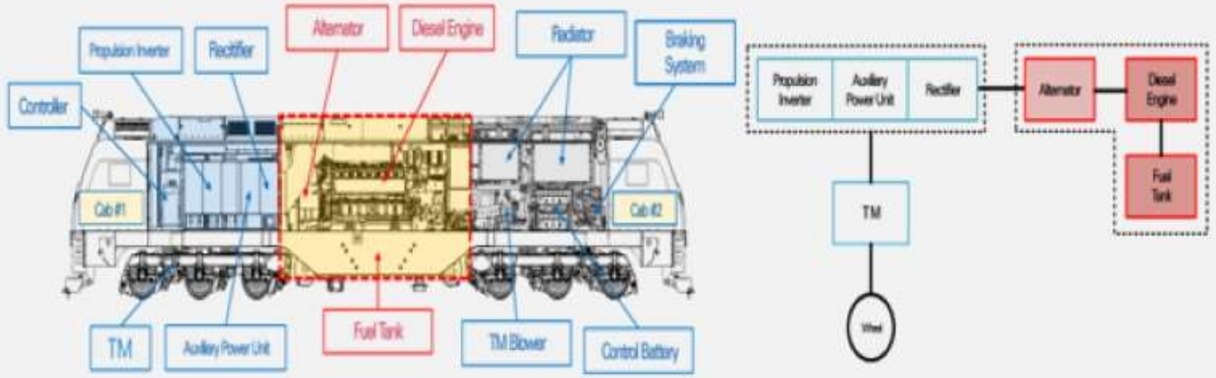
01 LCA for Hydrogen-powered Train

KRRI SUSTAINABILITY Action Week

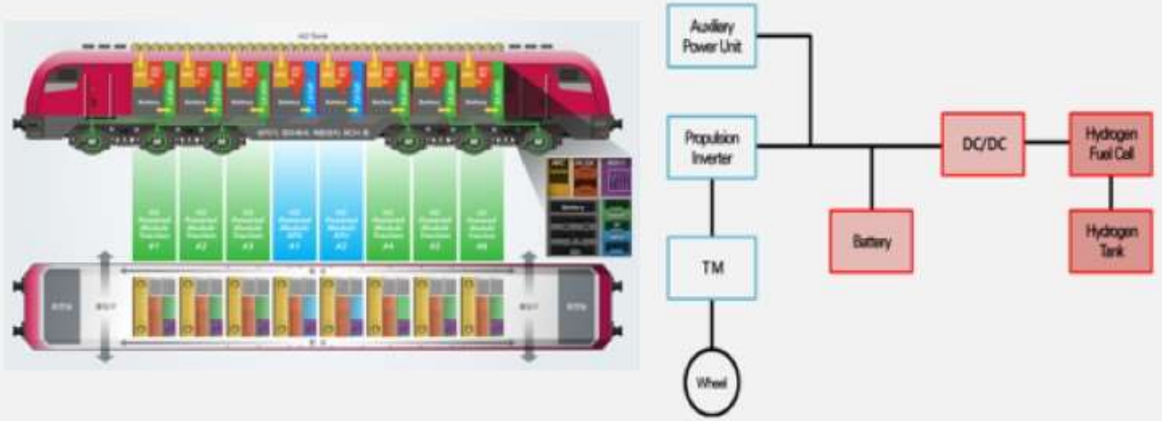
- Transition from diesel to zero-emission hydrogen-powered rail vehicle
- Development of life cycle assessment (LCA) methodologies and tools for measuring and verifying carbon reduction impacts

Classification	Diesel Locomotive / Diesel Multiple Unit (DMU)	Hydrogen-powered Locomotive/ Hydrogen-Electric Multiple Unit (HEMU)
Key Component Differences	• Diesel Engine • Fuel Tank • Alternator	• Hydrogen Fuel Cell • Hydrogen Tank • Battery
Newly Developed Components due to Changes in Propulsion System Functions	• Rectifier (Converter) • Propulsion Inverter • Auxiliary Power Unit (APU)	• DC/DC Converter • Propulsion Inverter • Auxiliary Power Unit (APU)

Structural & Electrical System Schematics of Diesel Locomotive



System Concept & Electrical System Block Diagram of Hydrogen-powered Locomotive



04 Scope 2 Decarbonization

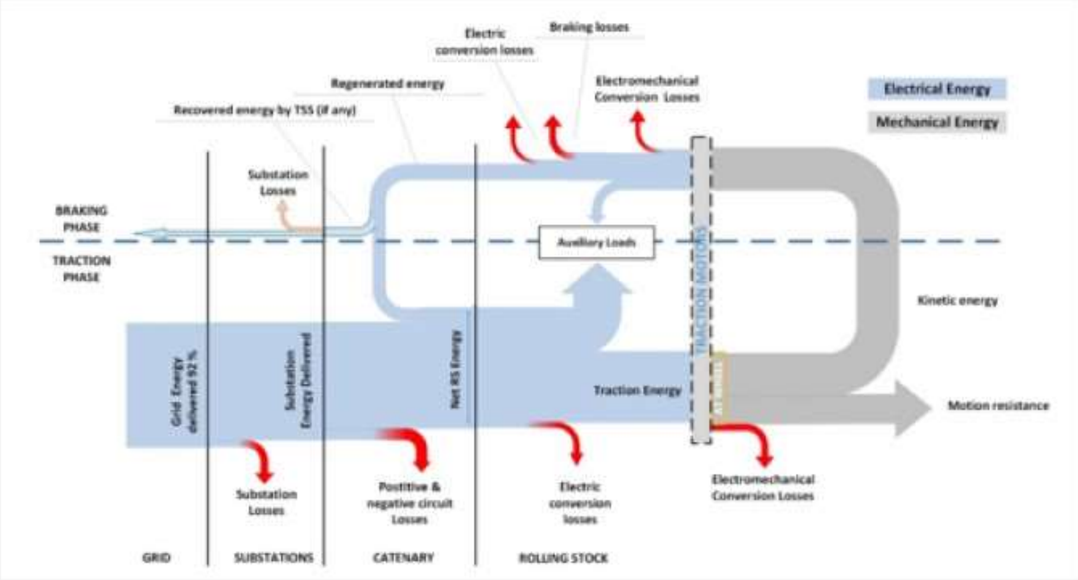
01 Heat Pump HVAC System

(Rolling Stocks)

SUSTAINABILITY Action Week

- Rolling stock operation power consumption reduction technology for HVAC systems
- Analysis and optimal design of HVAC systems with inverters and heat pumps to reduce power consumption
- Carbon reduction effect of expanding the use of inverters and heat pumps: a total reduction of 1,202 tons CO_2e (2,430 MWh/unit of power consumption reduced on application to 540 rolling stocks)

Energy Flows for Train Operation



*Source) UIC Energy saving in rail

Overview of Heat Pump Technology

[KTX-이음 HVAC 시스템 / 히트펌프 및 인버터 적용 HVAC 시스템 구성 비교]

- 인버터 및 히트펌프 적용 냉난방기의 냉난방 운전사이클

02 Solar Photovoltaic Noise Barriers

(Rail Infrastructure)

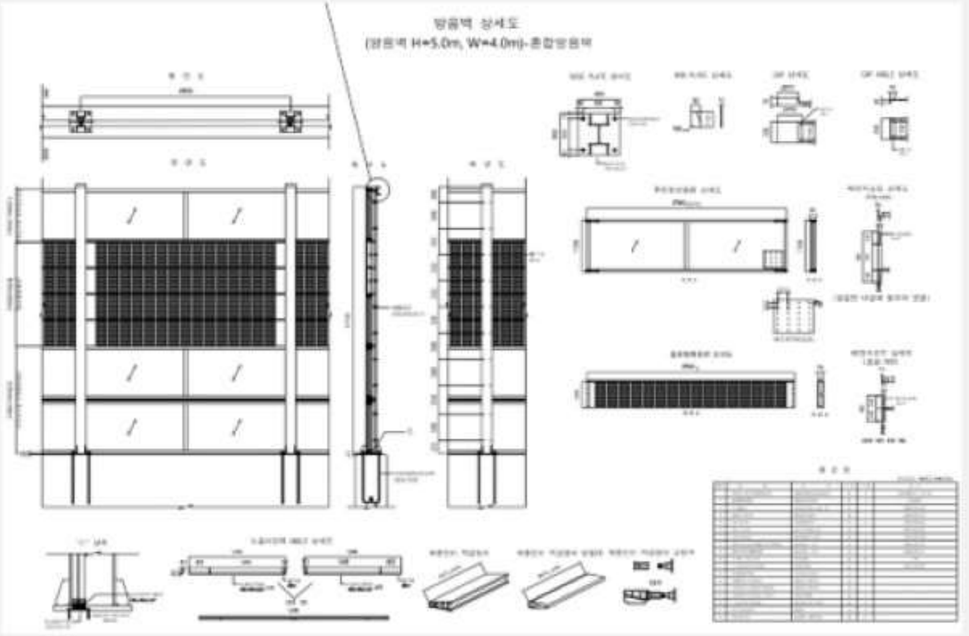
SUSTAINABILITY Action Week

- Development of core technology for a solar module integrated with a noise-reducing and sound-absorbing dual-sided solar system in a noise barrier
- The carbon reduction effect of installing solar photovoltaic noise barriers: a total reduction of 96,755 tons CO_2e (by replacing 398,981 m of conventional barriers with 6,650 m of a solar-integrated noise barrier)

Installation of Solar Noise Barriers




Detailed Drawings



03 RE 100 for Railway Station

KRRI SUSTAINABILITY Action Week

- Research on Achieving RE100 for Railway Stations
- As it is challenging to achieve carbon neutrality with power generated from fossil fuels and zero-energy buildings (ZEBs limited to the five major energies), it is necessary to explore ways to realize net zero through the application of RE100.
- The carbon reduction effect of implementing RE100 in railway stations: a total reduction of 54,517 tons CO_2e (with a 20% reduction in operational energy for railway stations by 2030 based on RE100).

2022~2023년 공공건축물 신재생에너지 의무 공급 비율

	연면적 [m^2]	태양광 설치용량 [kW]	태양광 생산량 [kWh/yr]	지열 설치용량 [kW]	지열 생산량 [kWh/yr]	신재생 총량 [kWh/yr]	예상사용량 [kWh/yr]	신재생E 공급비율 [%]
312역사	1,870.79	41.08	87,027.16	152.43	143,551.54	230,578.70	700,554.73	32.91
313역사	1,604.62	35.55	75,311.96	157.11	147,959.91	223,271.87	600,882.05	37.15
314역사	2,920.10	55.30	117,151.94	241.60	227,526.39	344,678.33	1,071,620.05	32.16
223역사	4,362.42	80.58	170,707.12	349.50	329,147.95	499,855.07	1,633,595.42	30.59

신재생에너지 의무공급 비율

RE100에 필요한 태양광 예상 발전량: 운수시설 기준 사용량 (374.14 kWh/(m^2*yr))

	연면적 [m^2]	태양광 설치용량 [kW]	태양광 일평균 발전시간[h]	태양광 연간 발전량[kWh/yr]	예상사용량 [MWh/yr]	지열 생산에 필요한 전력량 [MWh/yr]	RE100 전력량 [MWh/yr]	태양광 공급비 [%]
312역사	1,870.79	41.08	3.60	53,979.1	700.6	41.0	502.3	10.7
313역사	1,604.62	35.55		46,712.7	600.9	42.3	396.5	11.8
314역사	2,920.10	55.30		72,664.2	1,071.6	65.0	757.4	9.6
223역사	4,362.42	80.58		105,882.1	1,633.6	94.0	1,179.1	9.0

RE100

실제 사용량 통계에 따른 RE100에 필요한 태양광 예상 발전량: 예, 철도역사 205 kWh/(m^2*yr)

	연면적 [m^2]	태양광 설치용량 [kW]	태양광 일평균 발전시간[h]	태양광 연간 발전량[kWh/yr]	예상사용량 [MWh/yr]	RE100 전력공급비율 [%]
312역사	1,870.79	41.08	3.60	53,979.1	383.5	14.1
313역사	1,604.62	35.55		46,712.7	328.9	14.2
314역사	2,920.10	55.30		72,664.2	598.6	12.1
223역사	4,362.42	80.58		105,882.1	894.3	11.8

RE100

05

Scope 3 Decarbonization

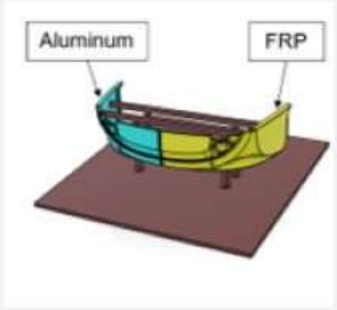
01 Resource Circulation

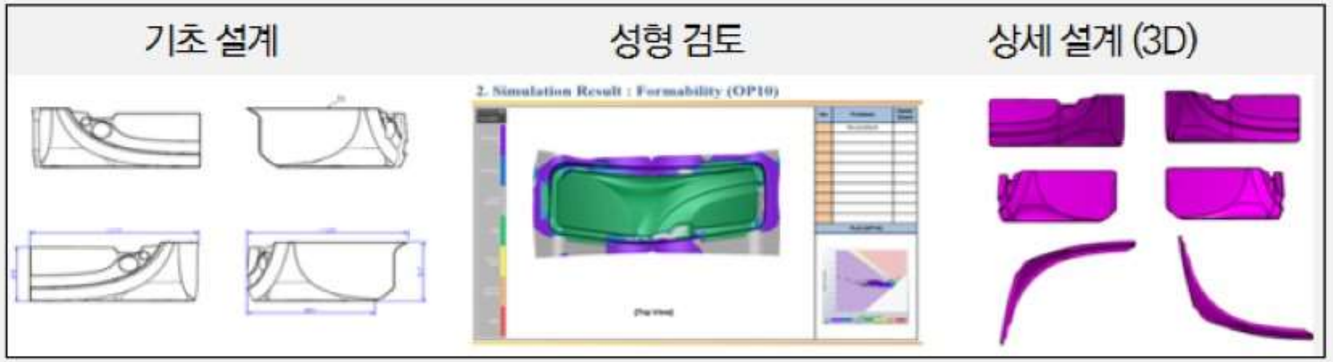
(Rolling Stock)

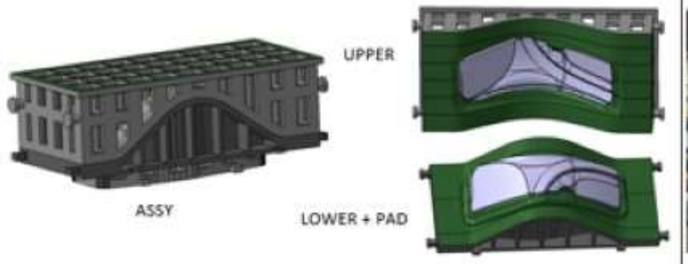
SUSTAINABILITY Action Week

- Development of technology to replace the existing FRP-applied Cap Skirt with aluminum, a material with a higher recyclability rate, and to substitute with recycled aluminum material

〈바르샤바 트램〉





금형 사이즈				금 형 도 면	금 형 사 진
가로 (mm)	세로 (mm)	높이 (mm)	무게 (kg)		
2,500	1,150	915	5,520		

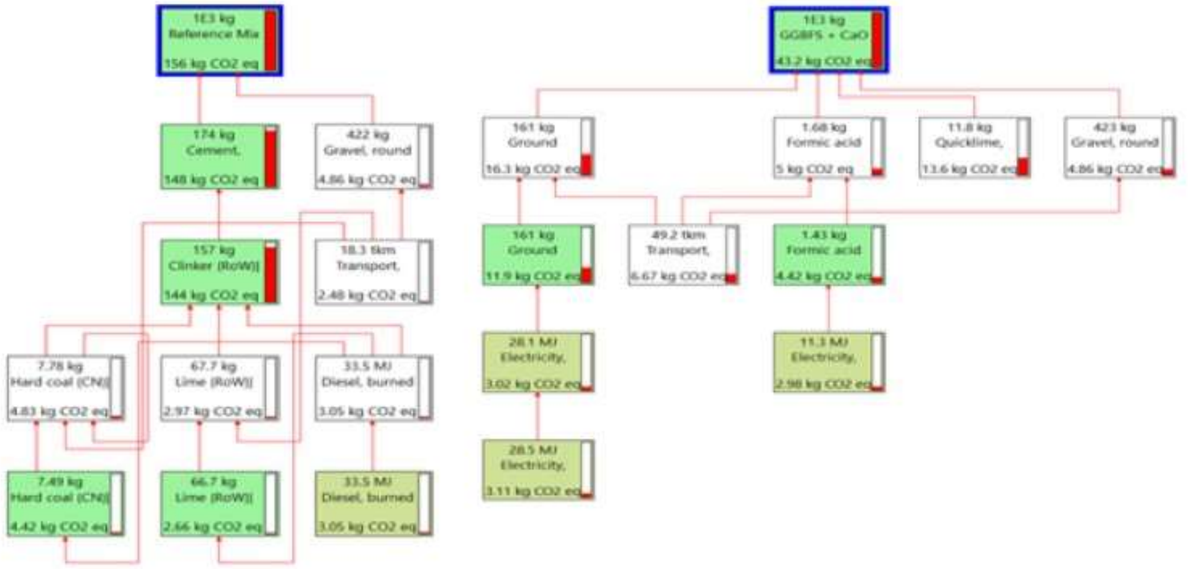
02 Emission Reduction Technology

(Rail Infrastructure)

SUSTAINABILITY Action Week

- Cement-Free Rail Infrastructure Materials
- Substitution of cement in traditional PSC sleepers with industrial by-products such as ①blast furnace slag (79%), and ② silica fume (14%) for a 100% cement-free solution
- Conventional cement-based concrete mix vs. when applying cement-free concrete mix, carbon emissions are reduced by 72%.

[실제 PSC침목 양산 라인에서 시멘트 제로 콘크리트 침목 생산 모습]



[시멘트 기반 콘크리트 배합과 C2S 콘크리트 배합의 이산화탄소 배출량 비교]

03 Resource Circulation

(Rail Infrastructure)

SUSTAINABILITY Action Week

- Contributing to 'Zero Waste' by building sustainable railway infrastructure based on eco-friendly resource circulation
- Enhancing resource recovery and reducing waste generated at the disposal phase of railway infrastructure, achieving over 90% of recovery of waste concrete sleepers, cutting down on waste ballast generation by more than 20% and reducing waste particles from wheel-rail contact by over 30%
- Estimated carbon reduction effects from recycling waste concrete sleepers: a total of 3,200 tons CO_2e (based on generation rates over the past five years)

04 ISO 21106:2019

SUSTAINABILITY Action Week

- Establishment of the first international standard in the rail sector led by Korea: Recyclability and recoverability calculation method for rolling stock (Convenor: Cheul Kyu, LEE)

ICS > 45 > 45.060 > 45.060.01

ISO 21106

Railway applications — Recyclability and recoverability calculation method for rolling stock

GENERAL INFORMATION

Pre-treatment	Extraction of fluids → send for recycling, energy recovery or dispo De-pollution: removal of hazardous components
Dismantling	Dismantling parts for reuse or to facilitate the separation of materi for recycling or disposal As much manual material separation as possible Metals: send for recycling Polymers: send for recycling or energy recovery
Shredding	The remaining part of the vehicle: send for shredding Recycling of ferrous metals
Residue	The non-metallic shredder residue: preferably recycled before sending to incineration process

6 Calculation methods

6.1 Recyclability rate

The recyclability rate, R_{cyc}, of the rolling sto

$$R_{cyc}(\%) = \frac{m_{P,Reuse} + m_{P,R} + m_{D,Reuse} + m}{m_V}$$

where all masses are expressed in kilogram

6.2 Recoverability rate

The recoverability rate, R_{cov}, of the rolling st

$$R_{cov}(\%) = R_{cyc} + \frac{m_{P,E} + m_{D,E} + m_{S,E}}{m_V} \times 10($$

where all masses are expressed in kilogram

$$F_{MR,i} = \frac{m_{R,i}}{}$$

Rail Delivery Group

National Rail

KTR v6

(4):

Key Train Requirements

Version 6

(4)

a (5):

(5)

Prepared by: David Polhill, ex RDG Senior Rolling Stock Engineer – Interfaces, now semi-retired and the V/V SIC KTR Sub-group

On behalf of: V/V SIC

05 New Standardization Work

SUSTAINABILITY Action Week

- Standard work with PCR for EPD of rolling stock for global compatibility of environment performance

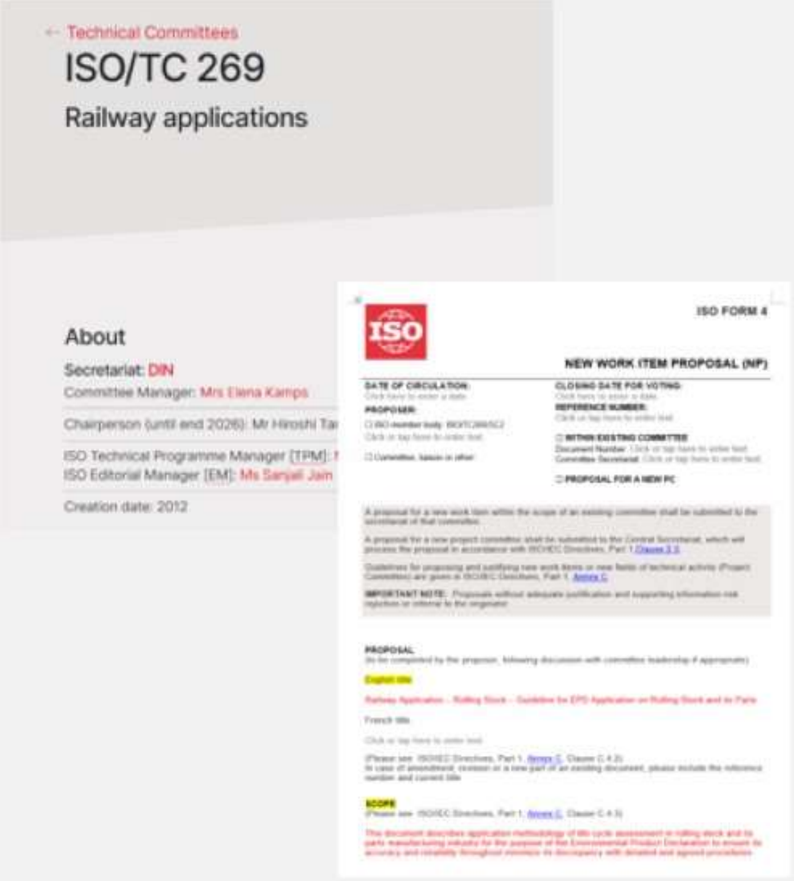

PRODUCT CATEGORY RULES (PCR)
DATE 2023-07-31

EPD®

ROLLING STOCK AND PARTS THEREOF
PRODUCT CATEGORY CLASSIFICATION: UN CPC 495

2009:05
Version 4.0.1

Valid until: 2027-07-06


← Technical Committees

ISO/TC 269

Railway applications

About

Secretariat: DIN

Committee Manager: Mrs Elena Kamps

Chairperson (until end 2026): Mr Hiroshi Ta

ISO Technical Programme Manager [TPM]:

ISO Editorial Manager [EM]: Ms Sanjali Jain

Creation date: 2012

ISO FORM 4

NEW WORK ITEM PROPOSAL (NP)

DATE OF CIRCULATION:

CLOSING DATE FOR VOTING:

PROPOSER:

REFERENCE NUMBER:

WITHIN EXISTING COMMITTEE

PROPOSAL FOR A NEW PC

IMPORTANT NOTE:

PROPOSAL

SCOPE

06 Decarboization Policy

01 2050 Net Zero Achievement Strategy

SUSTAINABILITY Action Week

- Expected reduction due to decarbonization technology (Heat pump HVAC System, solar noise barriers, RE100 station, cement-free sleeper, waste concrete sleeper): Total reductions expected to be 99,595 ton CO_2e by 2030 and 446,222 tonCO_2e by 2050
- Contribution: 9.0% by 2030, 15.3% for Option A, 16.4% for Option B by 2050 in comparison to national reduction targets, 6.8% by 2030, 16.5% by 2050 compared to the SBTi reduction target

Classification	2018 (Baseline)		2030				2050					Remark
			NDC	SBTi Target	Expected reduction due to decarbonization technology		NDC		SBTi Target	Expected reduction due to decarbonization technology		
							Option A	Option B				
Scope 1	300,921		1,829,782	149,256	-		85,311	276,526	294,177	-		Estimated value
Scope 2	1,034,261	Rolling stock		648,194	1,755	Heat pump				4,096	Heat pump	
	272,583	Station			19,351	Solar noise barrier				96,755	Solar noise barrier	
					54,517	RE100 station				272,583	RE100 station	
Scope 3	1,334,006			661,667	23,332	Cement-free sleeper				59,588	Cement-free sleeper	
					640	Waste concrete sleeper				3,200	Waste concrete sleeper	
Total	2,941,771		1,829,782 (1,111,989)	1,459,117 (1,482,654)	99,595		85,311 (2,856,460)	276,526 (2,665,245)	294,177 (2,647,594)	446,222		
Contribution		-	9.0% reduction compared to the NDC reduction goals 6.8% reduction compared to the SBTi reduction targets				15.3% / 16.4% reduction compared to the NDC reduction goals 16.5% reduction compared to the SBTi reduction targets					

02 2050 Net Zero Achievement Strategy

(Low-carbon Procurement)

SUSTAINABILITY Action Week

- International rail industry has introduced carbon certification systems and applied existing environmental labelling systems such as EPD to the rail sector.
- There is an urgent need for rail sector supply chain in Korea to reflect a carbon certification system, encouraging Scope 3 emission reductions through incentives provided by such certifications.
- (Promotion of low-carbon material and construction method development through prioritizing the purchase of low-carbon railway vehicles or assessing carbon emissions during the construction stages of new railway routes.)

Environmental Product Declaration (EPD)

System to prioritize the purchase of low-carbon products

Environmental specifications for new rolling stock

Spécifications environnementales pour le matériel roulant neuf
Umweltspezifikationen für neue Schienenfahrzeuge

03 2050 Net Zero Achievement Strategy

(Resource Circulation)

SUSTAINABILITY Action Week

- For a sustainable rail industry, there is an increasing demand for a resource circulation system within the rail sector, mandating the provision of recycling rate information for rolling stocks (ISO 21106 etc.)
- Thus far, policies related to the resource circulation of rolling stocks and rail infrastructure have been insufficient in Korea.
- With the shift towards minimizing waste generation policies (one of national carbon neutrality strategies of Korea), the rail industry also needs to focus on reducing waste from decommissioned rolling stocks and infrastructure materials.

Recyclability & recoverability of End-of-Life Rolling Stocks

Resource Circulation of Rail Infrastructure

WHITEMOOR RAIL RECYCLING CENTRE PROMISES ECONOMIC AND ENVIRONMENTAL BOOST FOR MARCH

04 2050 Net Zero Achievement Strategy

SUSTAINABILITY Action Week

- In addition to efforts to reduce carbon emissions in the procurement and supply chain for achieving 2050 net zero, efforts are also needed to reduce emissions at the operational stage.
- For Scope2 emissions reduction, expanding the use of renewable energy in railways is essential, such as the application of photovoltaic noise barrier.
- Revisions of technical standards, such as fire safety regulations, are necessary to facilitate the adoption of renewable energy technologies in rail sector.

Renewable Energy Applications

*Source) greentechlead & Railway gazette & https://www.solar365.nl/producten/solid-solrif-65a8b1b4.html

Related Standards


철도용 방음벽 관련규정 현황

철도건설공사 전문시방서
(노 반 편)


태양광 방음벽 화재성능 가이드라인(안)

건축자재등 품질인정 및 관리기준

방음시설의 성능 및 설치기준

05 2050 Net Zero Achievement Strategy

SUSTAINABILITY Action Week

- Among the methods for achieving SBTi target, direct air carbon capture and storage (DACCS) is included in beyond value chain mitigation (BVCM).
- The carbon reduction technologies within the supply chain are not enough to achieve net zero. Therefore, the introduction of DACCS technology to the rail sector is necessary. (Progressed by other ministries including Alchemist Project* by MoTIE)
- The development of DACCS technology is necessary, utilizing spaces with high carbon density in the railway (such as underground stations, platforms, etc.) and rolling stocks.

* The Alchemist Project by MoTIE of Korea is designed to transform future industries through the development of bold and innovative technologies. It aims to support the creation of future new industries and markets. In 2022, the project had a total budget of approximately 300 million EUR, and in 2023, it is supported with a budget of 17.8 million EUR.

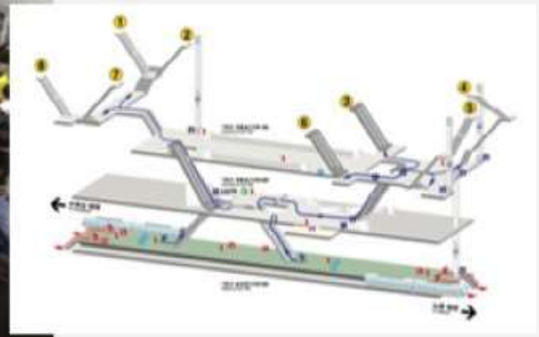
Support Status of DACCS by Other Ministries

Urban DAC

「이산화탄소 포집·수송·저장 및 활용에 관한 법률안」 국회 통과

정부 '공기중 직접 탄소포집' R&D 지원한다...SK·GS '주목

Rail-centered DACCS Technologies



Thank you for your attention!

INTERNATIONAL UNION OF RAILWAYS

Bane NOR

Norwegian Infrastructure Management

Karoline Hjertø
Dereje T Asefa

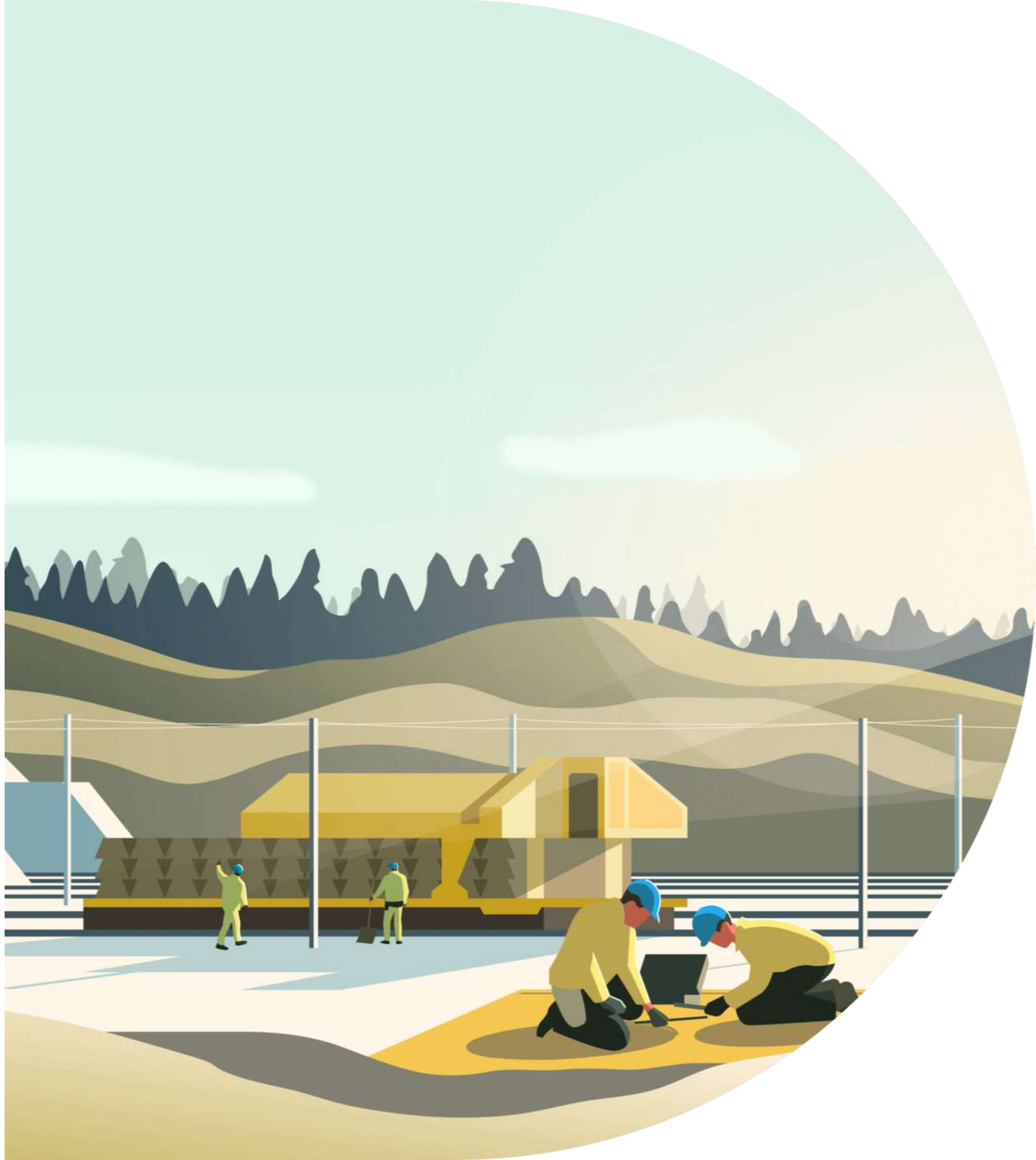
Green transition

Green transition in Bane NOR

Karoline Hjertø - Sustainability Director
Dereje T Asefa - Project leader – Sustainabilty

Question

- Have you started the work on the climate transition plan?



BANE NOR Corporate strategy - 2025

Mission

→ Delivering a reliable and sustainable railway service to Norway

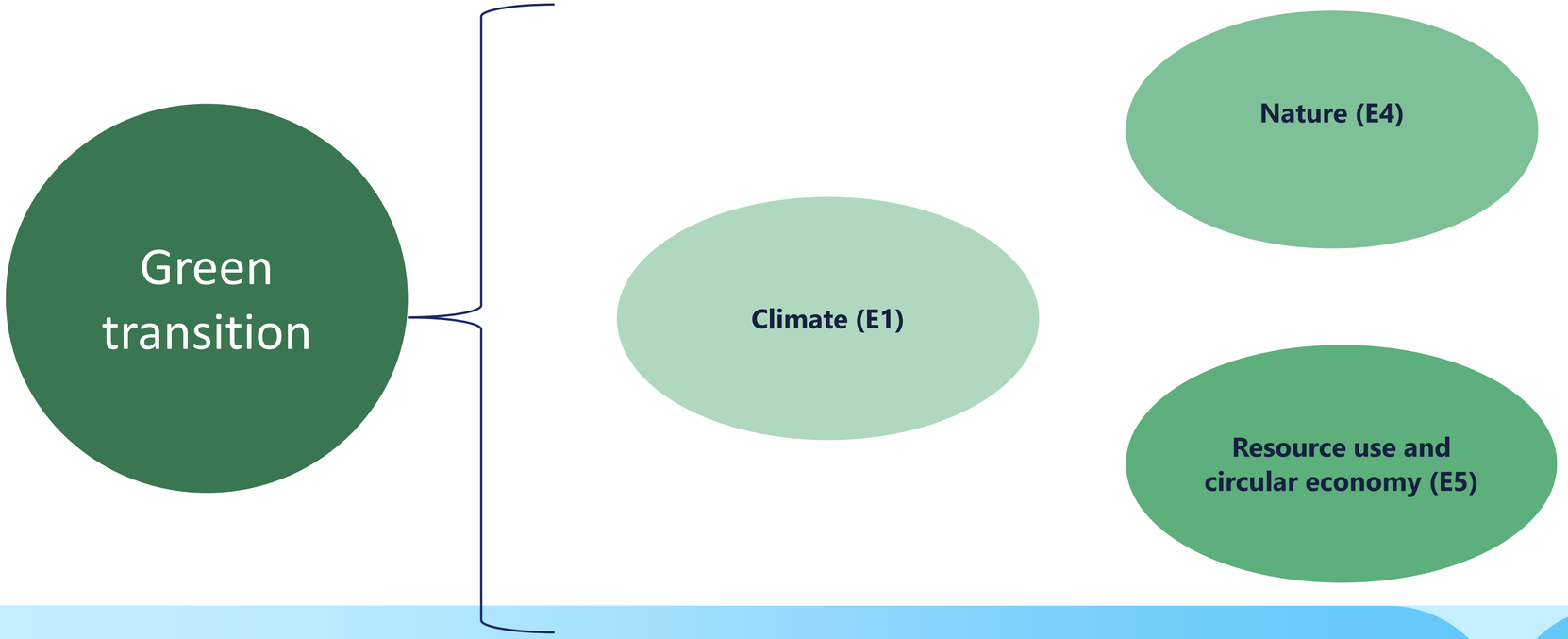
Sector and Bane Nors goals	Must win battels	By focusing on
Easier mobility and promote competitiveness	**Punctuality Reliability**	• Planned and effective maintenance and upgrading activities that promotes safe and predictive railway operation
Contribute to Norway's **Climate and environmental targets**	**Green transition**	• Reduction of climate gas emission (CO2-eqiv.) and Ecosystem disturbance • Optimized use of affected land areas
Zero death and critical incidences related with our activities	**Safety**	• Safe work environment and safe railway operation
Effective use of **new technologies**	**Digitalization**	• Factual and effective decision making and implementation processes
More value for the money	**Optimization**	• Productivity via standardized and professionalized procurement processes

Together towards the Goals

Open, Responsible, Cooperative

Approved 29.08.24

Bane NORs focus areas -2025



Questions

- Do you have climate as one of your material topics?

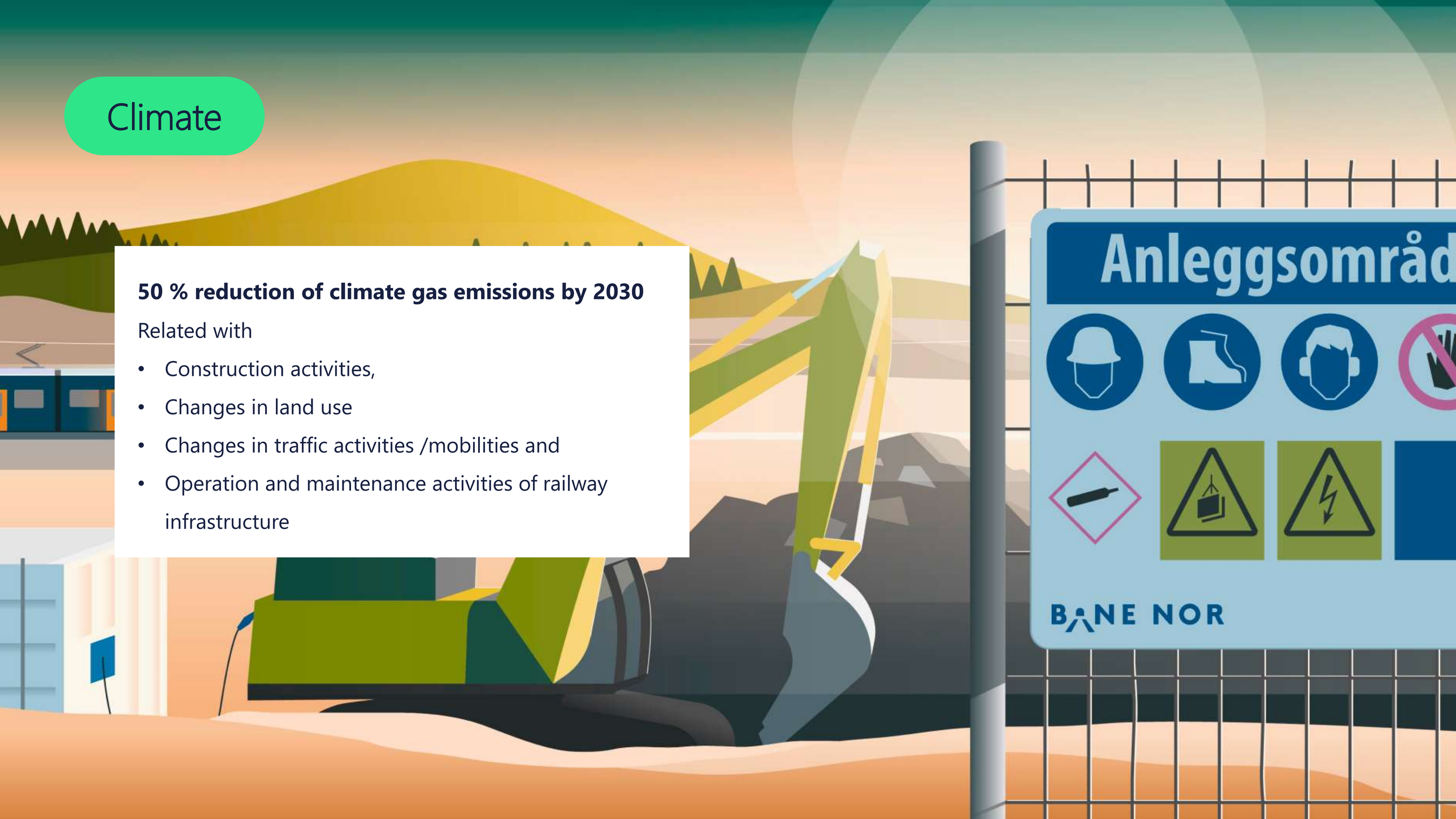
- Do you have strategic ambitions/targets for climate approved by the managment?

Climate

50 % reduction of climate gas emissions by 2030

Related with

- Construction activities,
- Changes in land use
- Changes in traffic activities /mobilities and
- Operation and maintenance activities of railway infrastructure



Emission from Bane NOR related activities – ton CO2 eqiv.

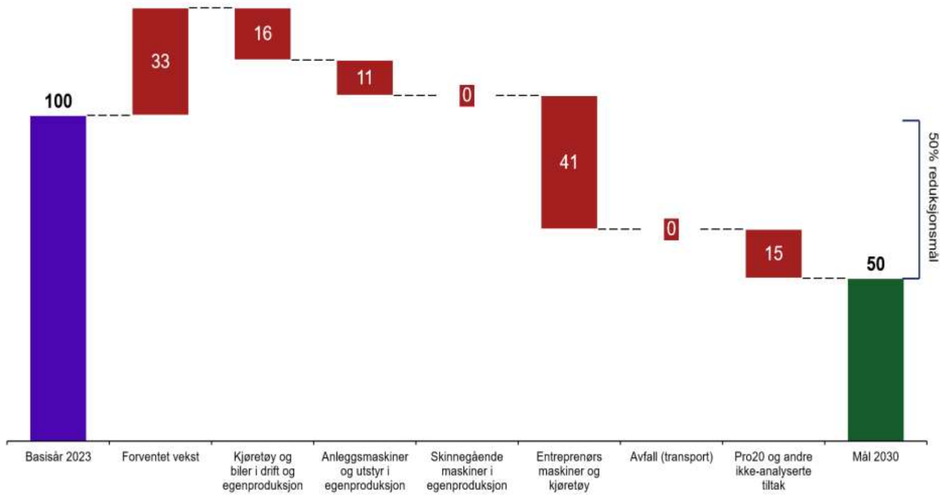
	Retrospektivt		
	Basisår 2019	Sammenligningsår 2023	2024
Scope 1 klimagassutslipp			
Brutto Scope 1 klimagassutslipp (t CO2-ekv)	7 424	8 869	9 255
Prosentandel av Scope 1 klimagassutslipp fra regulerte kvotehandelssystemer	-	-	-
Scope 2 klimagassutslipp			
Brutto lokasjonsbaserte klimagassutslipp (t CO2-ekv)	1 915	2 884	2 587
Brutto markedsbaserte klimagassutslipp (t CO2-ekv)	-	-	-
Vesentlige Scope 3 utslipp			
Totalt brutto indirekte (Scope 3) klimagassutslipp (t CO2-ekv)	968 911	942 329	1 031 527

Questions

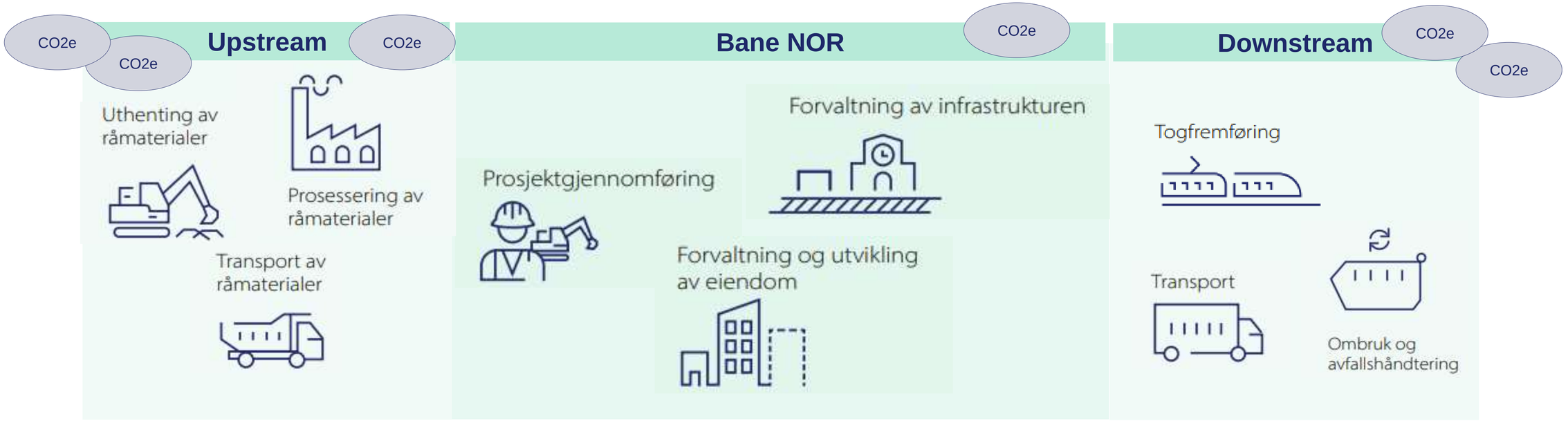
- How many of you have a climate budget?
- How are the results- do you see reduction or increment? Why?

«Klimabanen – Project » - Climate Transition Plan – SBT as a methodology

- National carbon neutrality ambition by 2050, as well as Bane NOR 50% reduction in 2030 target
- Demand from the Ministry of transport (SD)
- Prioritize direct emission related with own activities:
  - emission related with fuel usage, changes in land use, as well as energy consumption related with train operation
- **<u>«Klimabanen» an internal project to</u>**
  - Quantify emission related to activities and identify sources
  - Identify mitigation measures related with the major sources
  - Recommend applicable and cost-effective mitigation measures



SBT as a methodology -



Push for a cut anywhere in the value chain – but not a priority (scope 3)

SBT: mainly cut emission related with Bane NORs own activities (scope 1+2)

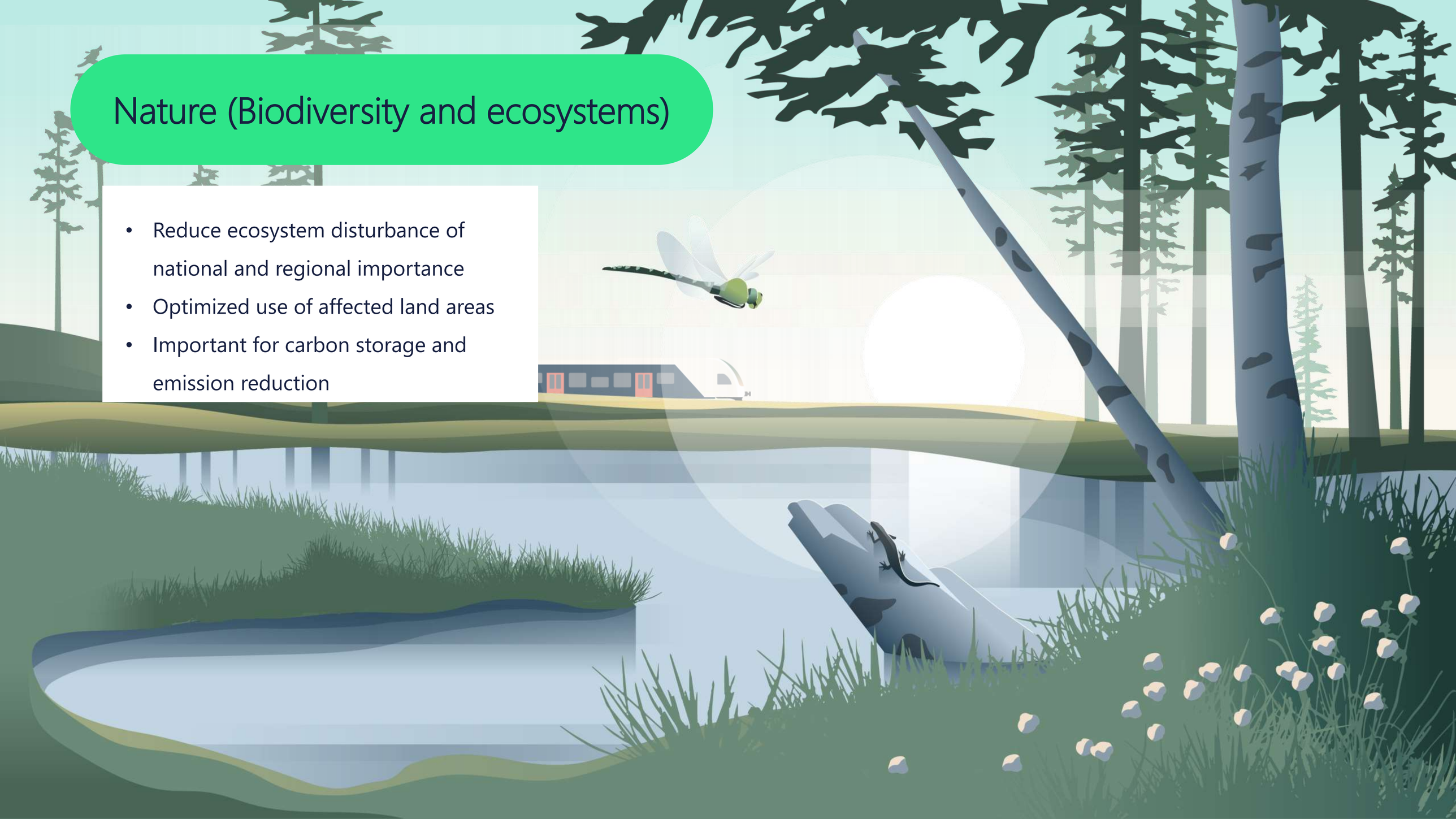
Push for a cut anywhere in the value chain-but not a priority (scope 3)

Government: Prioritize emission cut related with fuel usage and change in land use (scope 1 + scope 3 + scope 4)

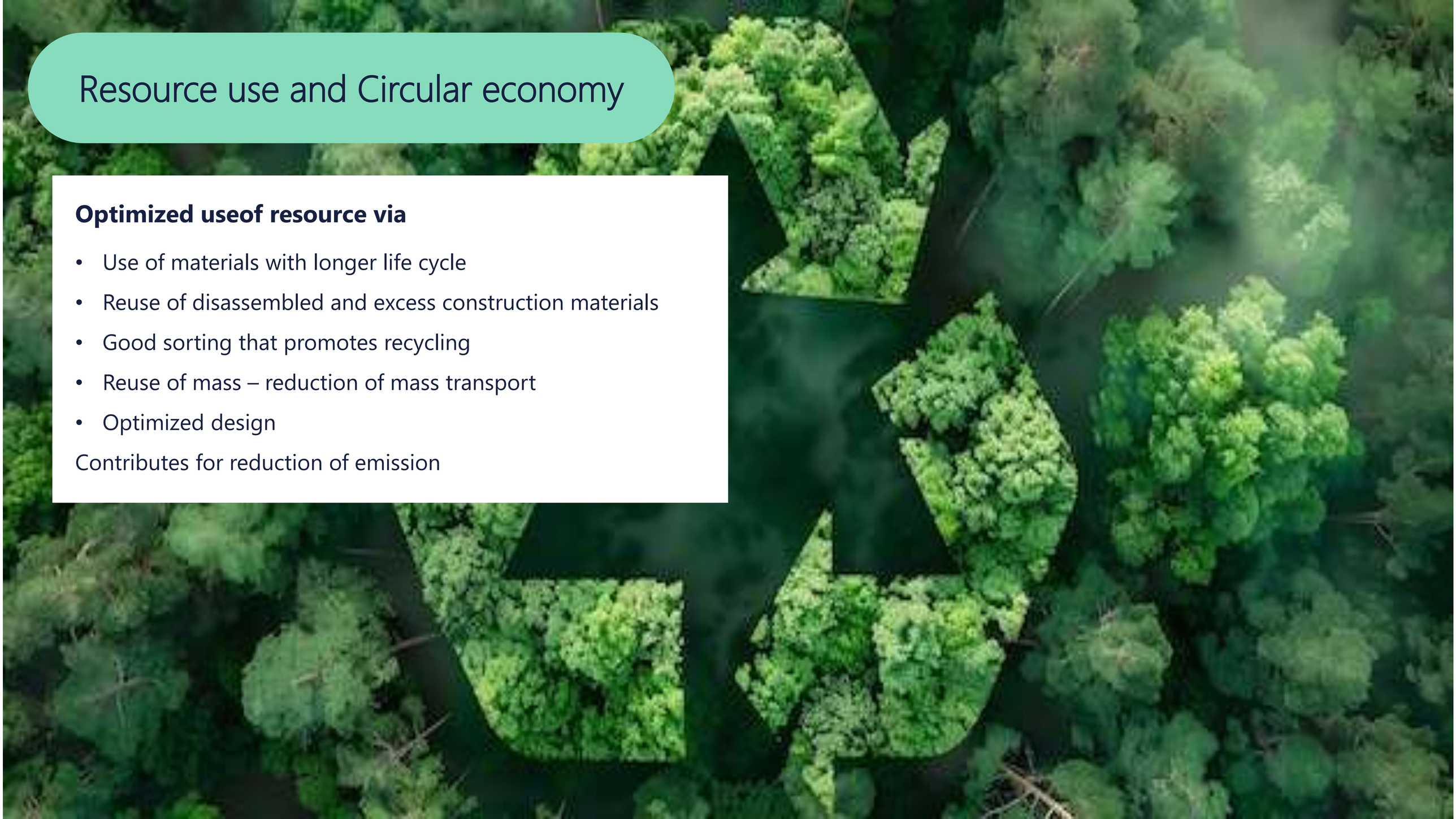
BANE NOR

Nature (Biodiversity and ecosystems)

- Reduce ecosystem disturbance of national and regional importance
- Optimized use of affected land areas
- Important for carbon storage and emission reduction



Resource use and Circular economy



Optimized useof resource via

- Use of materials with longer life cycle
- Reuse of disassembled and excess construction materials
- Good sorting that promotes recycling
- Reuse of mass – reduction of mass transport
- Optimized design

Contributes for reduction of emission

Results from Klimabanen project will be used

- To update internal documents- adjust ambitions
- Promote sustainable procurement by adjusting requirements or evaluation criteria - (National rule- 30 % weight to sustainability)
  - Use of cost-effective sustainable solutions as
    - ✓ Electrification - electric machines, equipment for OM and during infra. Dev.
    - ✓ Optimized use of energy/ local production of energy
    - ✓ Reuse and recycling measures of resources – such as excavated soil mass
    - ✓ Use of low emission construction material with a longer lifetime
  - Delivery of CO_2 emissions reduction plan
  - Delivery of Climate budget and climate accounts – LCA prospective
  - Delivery of plan to avoid new ecosystem disturbance

BANE NOR

Vi forbedrer og moderniserer
for at flere kan ta mer tog

INTERNATIONAL UNION
OF RAILWAYS

TUCRail

Belgian rail engineering

Paul Tobback

Development for battery trains and partial electrification

TUC RAIL in a nutshell

- Dedicated railway engineering company : High-speed & conventional rail
- Subsidiary of Infrabel : Belgian railway infrastructure manager's engineering department
- ± 1200 staff : project management, design, procurement, work supervision, T&C, RAMS, …
- Entire project life cycle expertise / experience : end-to-end delivery of railway projects
- All technical railway fields : civils + systems
- Neutral towards technologies : building interoperable railway systems using different technologies
- Working experience in more than 15 countries : continuous improvement and technology watch
- Highest safety, ethical & technical standards : part of railway culture

Flexible thinking, reliable results

CERTIFIED ISO 9001:2008 COMPANY

transQ empowered by Achilles

RISQS AUDITED

INFRABEL SAFETY APPROVED

About me

Lead Design Engineer & OCL expert

paul.tobback@tucrail.be

(°1972) I started in 2000 for TUC RAIL as a construction manager and overhead contact line (OCL) design engineer for Brussels South station. After the Antwerp Central Station & tunnel project an international career started in 2006 on the international high speed project Perpignan (FR) – Figueres (ES), studying and supervising with a small team all railway related & tunnel equipment. Returning to Belgium in 2009 focus shifted towards a theoretical approach of OCL design and interoperability. Whilst designing and providing expertise on many Belgian conventional line projects like the Diabolo Brussels Airport project, another 2,5 years on a high-speed line construction in France between Le Mans and Rennes, and a 2-year term as manager of the electrification department, I became in 2018 the Infrabel representative in the EIM Energy Group and deputy speaker towards ERA. Since June 2023 I chair this meeting and a multistakeholder task force to include trains with batteries for traction purposes in EU regulation and participate in CENELEC standardisation on charging infrastructure based on dedicated contact line sections (future TS 50729).

Picture: Alstom

Find the *really* new kind of rolling stock and look for the differences !

Picture: Siemens

Introduction

What about the infrastructure ?

Charging station in Paris

Picture: Von Scanné par Claude Shoshany - Collection personnelle, Gemeinfrei, https://commons.wikimedia.org/w/index.php?curid=1516434

Picture: Bombardier

TUC RAIL

BELGIAN RAIL ENGINEERING

INFRABEL

Right On Track

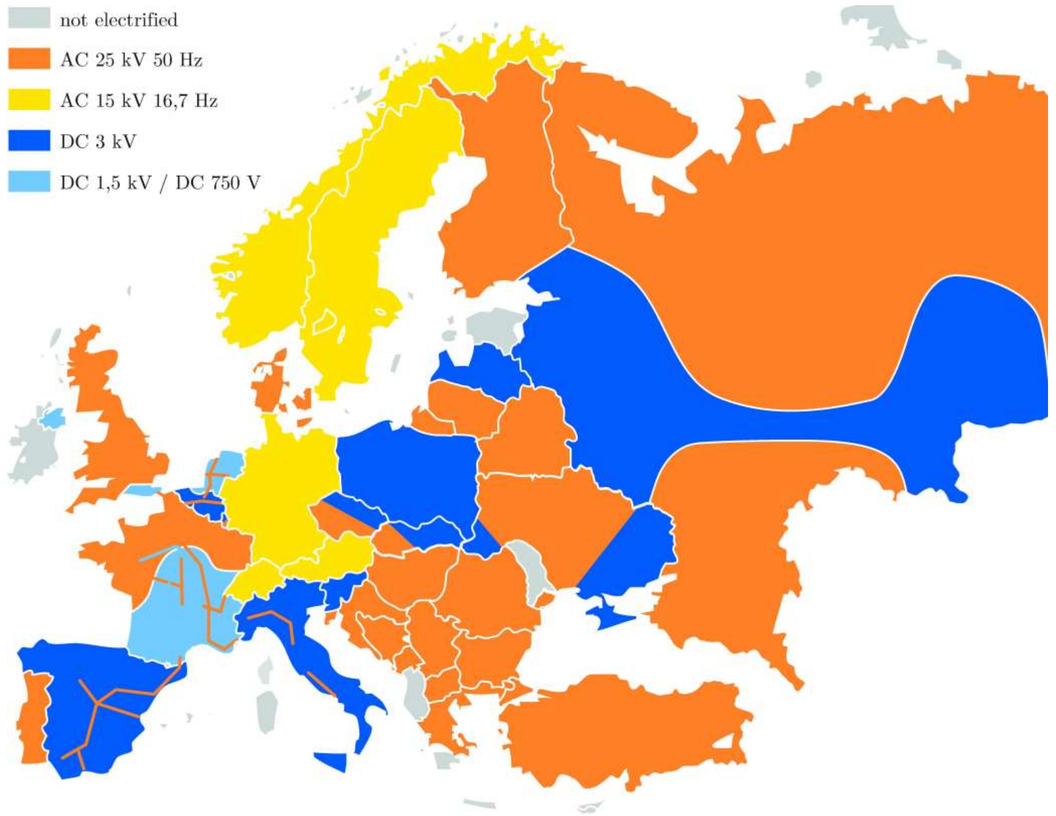
Railway power supply basics

TSI Energy (EU law): 4 traction power supply systems

- 25 kV ac 50 Hz
- 15 kV ac 16,7 Hz
- 3 kV dc
- 1,5 kV dc

Other systems: 3rd rail

- 750 V dc
- 600 V dc
- Etc.



Challenges for the OCL (Overhead Contact Lines) & power supply (energy subsystem)

Legal (EU): TSI's (Technical Specifications Interoperability) & (parts of) EN-standards when referenced

Technical: standards (UIC550, UIC552, EN50546, EN50119, EN50367, EN50388, etc. and their IEC counterparts)

Legal or technical, these documents were not written for trains with batteries for traction purposes !!

Legal - Joint Task Force EIM/CER/EPTTOLA/NBRAIL

Kick off 17/03/2021

Up till now participation from different stakeholders like infra managers, railway undertakings, lessors and Notified Bodies:

- Trafikverket / Bane NOR / Infrabel / SNCF / DB / ÖBB / ČD / RFI / Angel Trains / Sconrail

UNIFE (rolling stock manufacturers) judged it too early to support it already

Despite non-participance by UNIFE a clear interest was expressed during bilateral meetings with Siemens Belgium and Bombardier, but no priority for ERA (European Railway Agency)

→ *unofficial TF, but not forgotten by ERA and the EC (European Commission)*

→ please join if interested and contact your representative body

In parallel on technical level:

Cenelec workstream in CLC/SC9XC for TS 50729 on "*Railway applications - Fixed installations and rolling stock - Interface requirements between charging infrastructure with dedicated contact line sections and electric traction units with onboard electric traction energy storages and current collectors*".

- Corresponding CLC WG 25
- The contact line section can or cannot be connected to other overhead contact line systems of electrified railway lines and can or cannot be fed separately

Objectives Joint Task Force

- Facilitate interoperability and support the EU Green Deal
  - Supporting phase-out of diesel traction => **less CO_2-emissions for railway sector**

- Key objective short term:

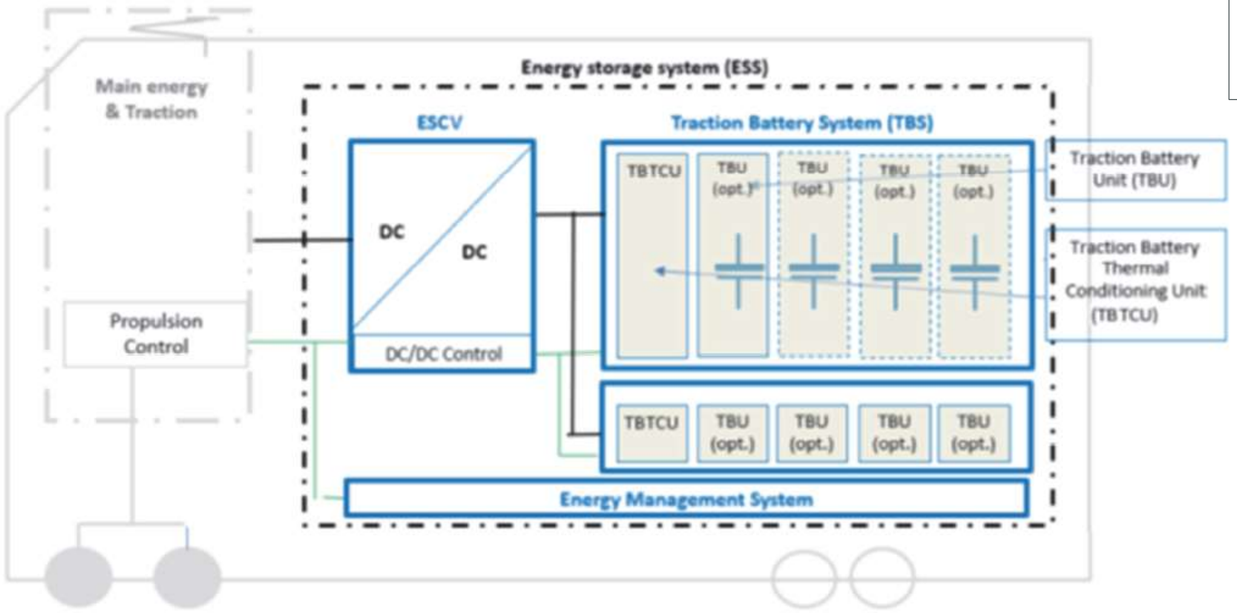
  interoperability requirement proposals for TSIs on short term objectives to allow and facilitate full charging of trains with batteries, without changing other existing requirements neither without blocking other modes of operation for battery train charging purposes **by April 2021** (for next TSIs 2022 version)

- Long term objectives:
  - provide inputs for European standardisation needs
  - reduce costs for the ENE subsystem enabled by the usage of battery trains

Regional passenger traffic in France

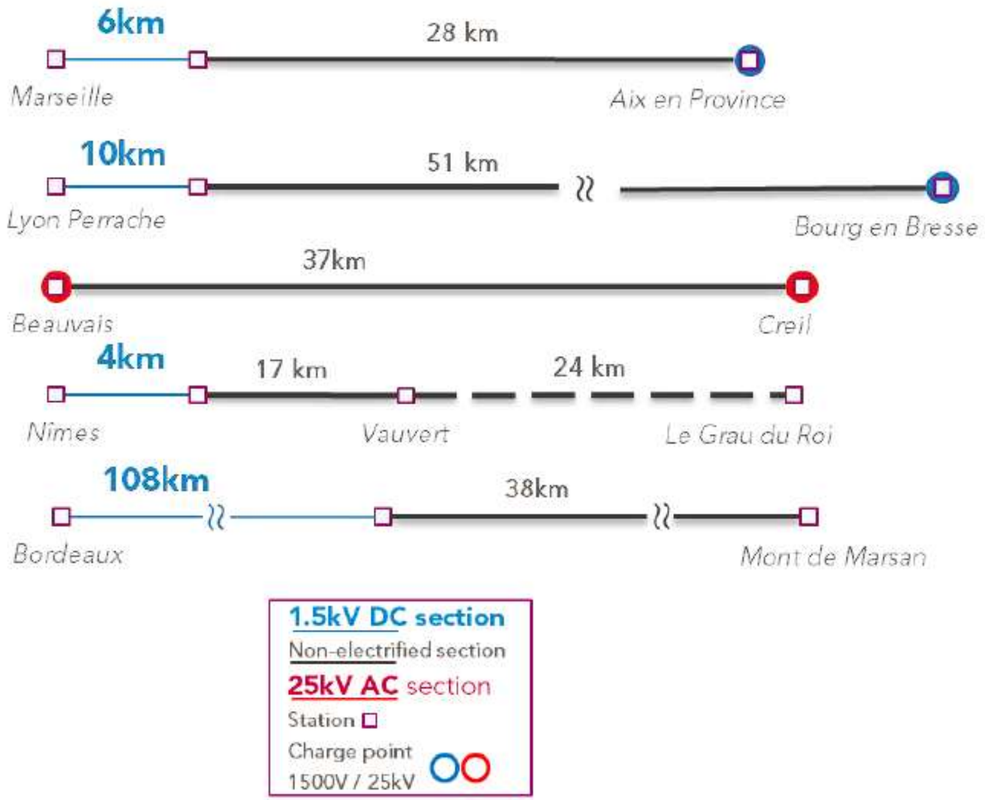
SNCF Voyageurs schedules midlife revision of more recent 3-vehicle DMUs for regional traffic and will create BEMUs out of them.

- Energy Storage System: 2x210 kWh (2x420 kWh train level)
- Peak power charging: 640 kW
- Peak power discharging : 800 kW
- Energy savings: up to 20% (enabling regenerative braking)
- Less noise, less maintenance costs



Source: Luis Alonso and Heinz Flerlage, ICT for Railways, 15th and 16th November 2023

Regional passenger traffic in France



Source: Luis Alonso and Heinz Flerlage, ICT for Railways, 15th and 16th November 2023

Study from lessor federation

- More than 50 % of locomotives in EU are still using diesel traction.
- Investors require lessors to phase-out diesel traction.
- Study made by Eolus: see website of AERRL.
- HVO (hydrotreated vegetable oil) is a possible bridge solution.
- For heavy freight green hydrogen is best solution (but this is not yet mature).
  Hydrogen: power-electrolyser (70%)-liquefaction (70%)-transport (90%)-evaporation (95%) => Overall 40%
  + Back to power by fuel cell: overall 25%
- 85% of traffic is possible with battery/electric locomotives.
- This study recommends supporting primarily the use of Dual-Mode Battery/Electric trains combined with partial electrification for the long-term future.
- ÖBB considers partial electrification is only needed on 26% of non-electrified lines.

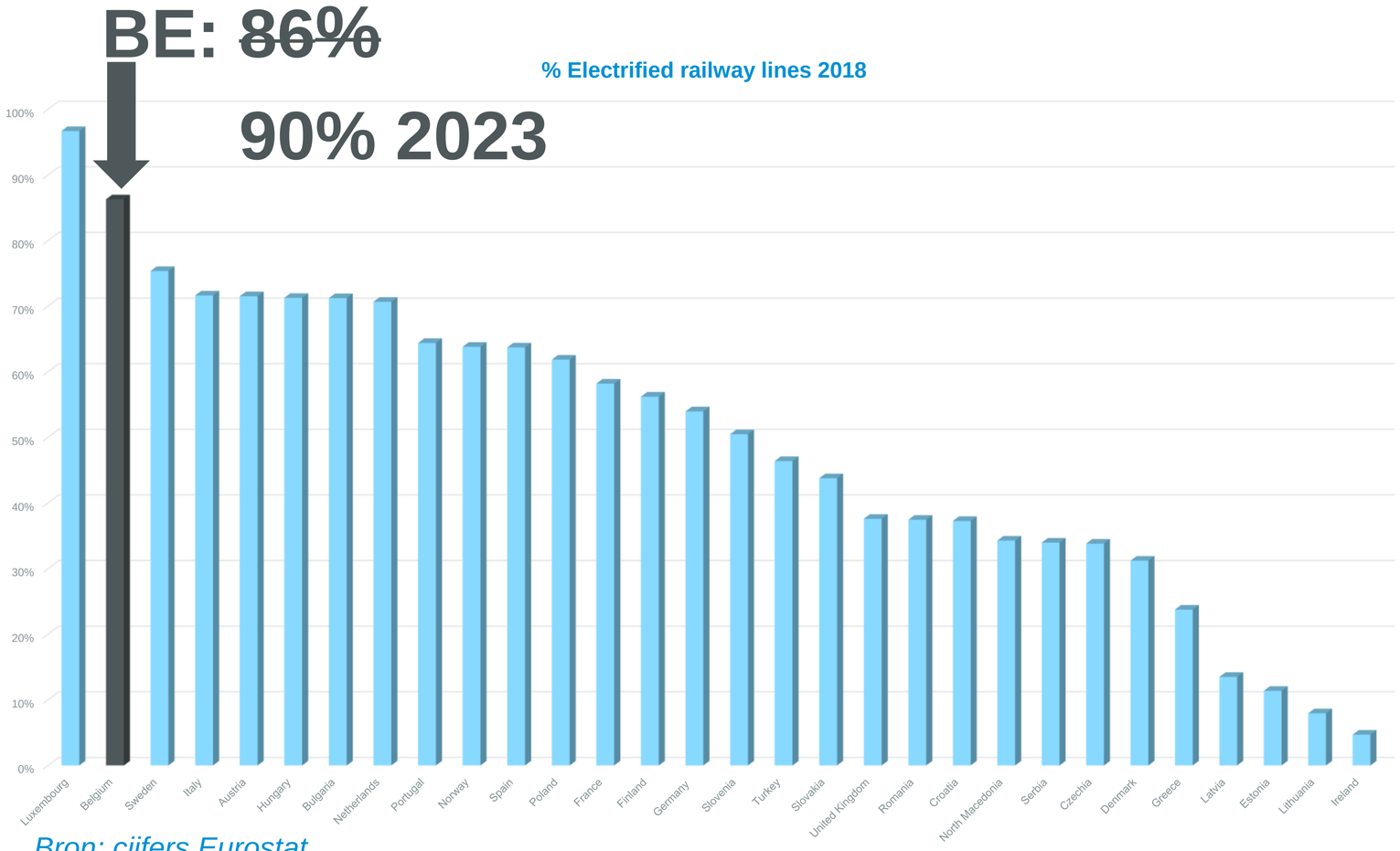
Source: Carole Coune, ICT for Railways, 15th and 16th November 2023

what about the BE case (mostly 3kV DC)?

Study TML ! Infrabel & SNCB strategy 2040 !

SNCB: “no H_2 please, only EMU (or BEMU)”

Electrification | Benchmark & Key Figures EU



Bron: cijfers Eurostat

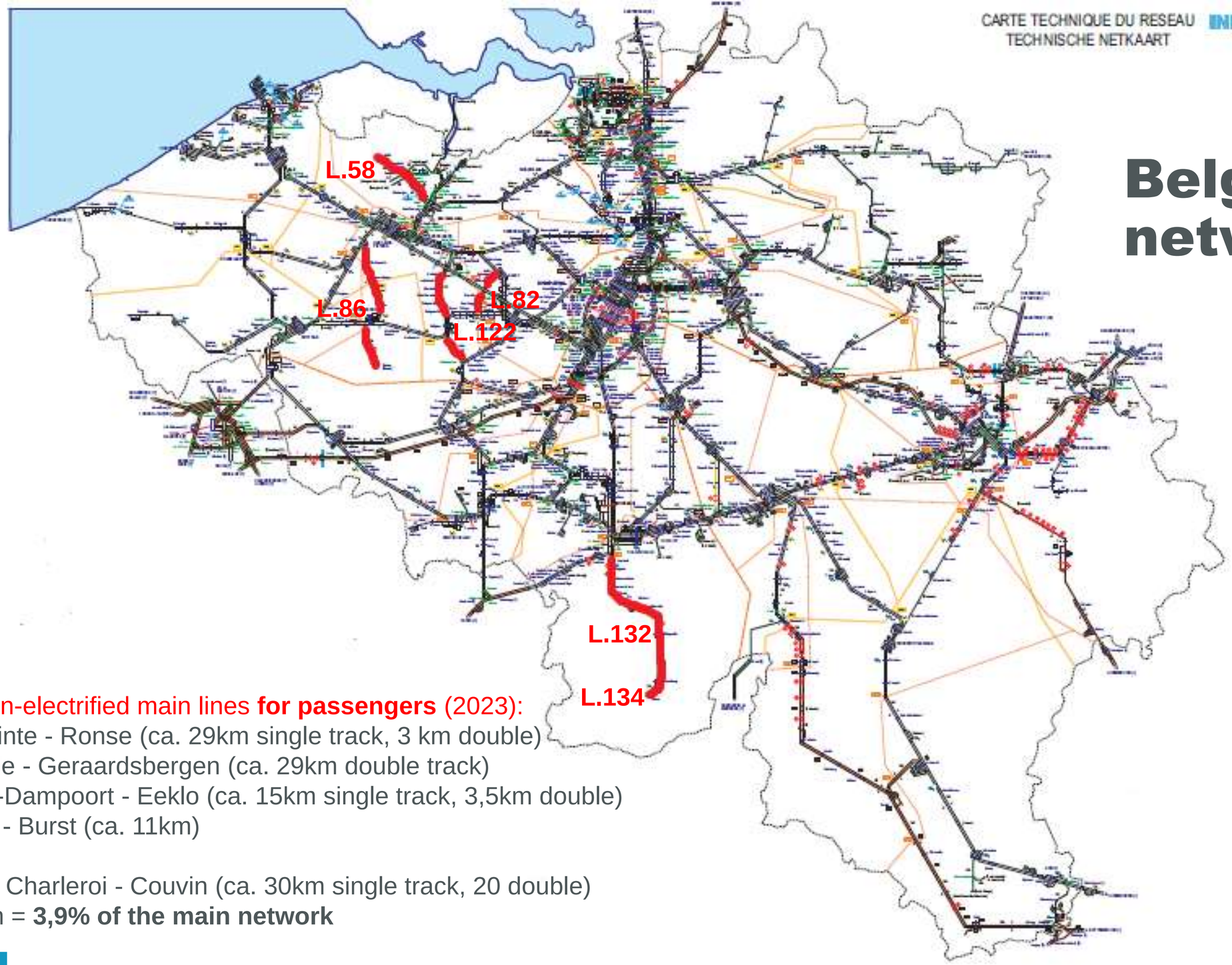
% ton-km elektrisch

Passenger traffic **97%**

Freight traffic **73%**

TOTAL (2021) **89%**

Belgian network



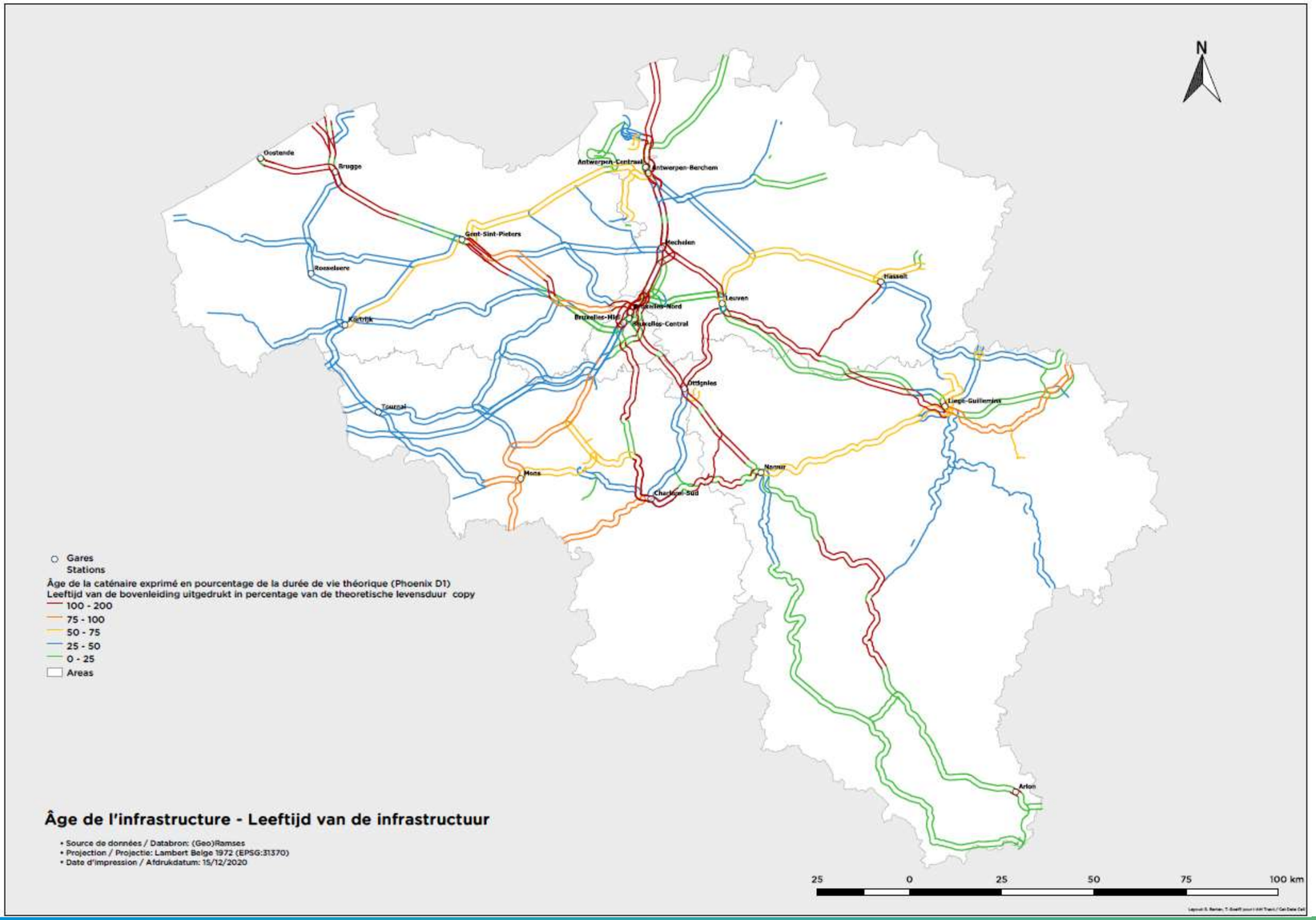
Remaining non-electrified main lines **for passengers** (2023):

- L.86 De Pinte - Ronse (ca. 29km single track, 3 km double)
- L.122 Melle - Geraardsbergen (ca. 29km double track)
- L.58 Gent-Dampoort - Eeklo (ca. 15km single track, 3,5km double)
- L.82 Aalst - Burst (ca. 11km)

- L.132-134 Charleroi - Couvin (ca. 30km single track, 20 double)

140 / 3600 km = **3,9% of the main network**

What will the situation be over 10 years ? An OCL is built for 80 years !



Renewal Strategy OCL & substations

After 20 years

→mid-life upgrade substation

After 40 years

→renewal substation

→mid-life upgrade OCL

After 60 years

→mid-life upgrade substation

After 80 years

→renewal substation

→re-electrification with OCL ? Partly ??

When BEMUs and hybrid locomotives are generally used, future simplifications of the OCL network can be considered

For the remaining 5 non-electrified passenger lines in BE:

- flexibility in scope and timing of electrification

In the long term:

- Avoid difficult/expensive (re-)electrification (tunnels/turnouts…)
  → *Better for punctuality and maintenance costs*
- Less power demand on weak spots of the network / public grid
  → *Less investment needed just for one rush hour train per day*
- Possibility to run through earthed route sections
  → *Less impact of work possessions/detours*
- Possibility to avoid non-profitable re-electrifications (e.g. 12,5km *branch* line Pepinster-Spa, *but which did continue a long time ago !*; electrified >50 years ago)

L132 tunnel with interlaced tracks (and many more obstacles and difficulties)!!

What part to electrify if not the complete route ?

There can be huge differences in cost/km a few km further on a route !

Depends on mainly the terrain for OCL, but on the number of substations (cost/unit, not per km !) to be built and their specific locations with possibilities to connect to the public grid (invest in underground cables or overhead contact lines ?).

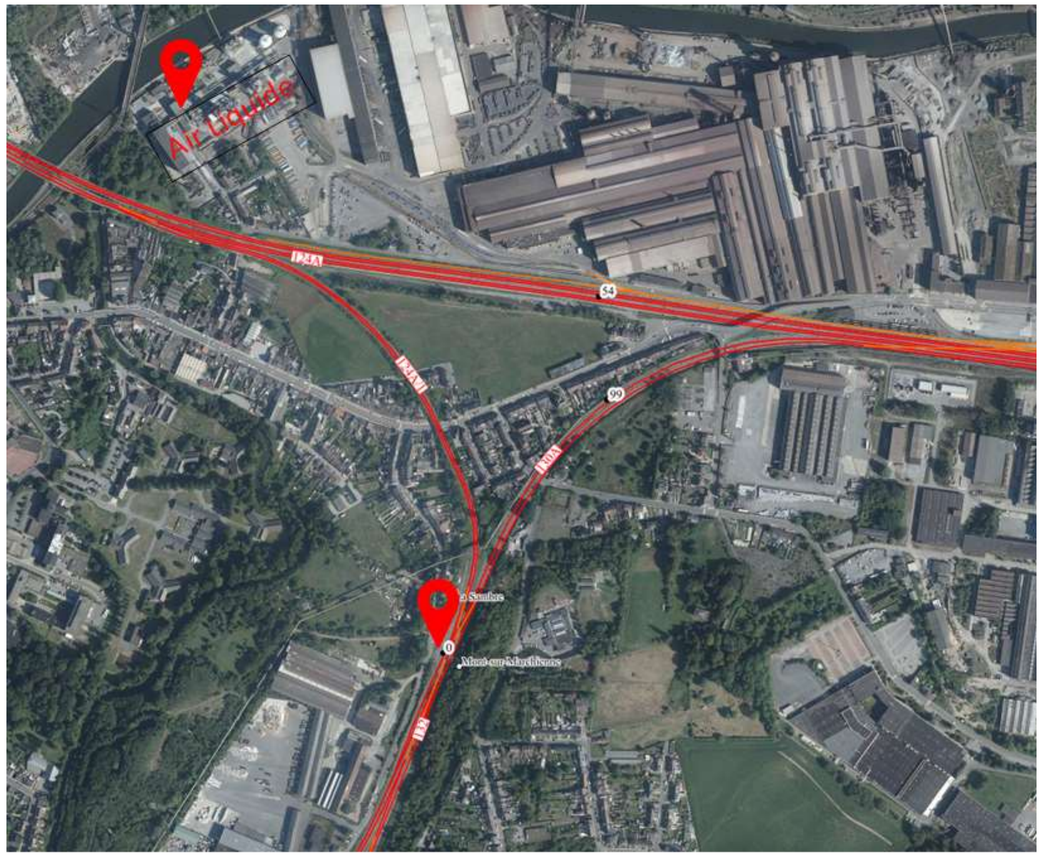
Here or here on L132 ?

Electrification revisited: never forget the H_2-option

(but that's another workshop)

L.132-134 Charleroi - Couvin (ca. 50km, the longest non-electrified main line in BE): H_2-pipelines in the immediate vicinity and even crossing the railway network !
And close to the start of the non-electrified part, but a bit further from the stabling yards & workshops !!

HEMU = BEMU with about 30-40% of the battery energy and a FC-range extender !



How can we achieve the objectives asap and accelerate the transition to more “electrification” ?

- On DC-networks charging battery trains in end stations will take too much time. **It should become possible to charge higher currents**.
- AC-electrifications are costly. On AC-networks cheaper charging infrastructure should become available. **It should be possible to connect to medium voltage grids**.
- Manufacturers should develop locomotives to be used for **international freight trains**. The **dimensioning of the on-board energy storage** will be crucial to know the **partial electrification needs in ports and industrial areas**.
- Battery trains will pass frequently to non-electrified lines. This causes **risks** in case **pantograph is not lowered or lifted on the right moment**. Solutions are needed.
- CENELEC **Fpr TS 50729** for the **interfaces** towards battery trains.
  Final voting will end soon ! Publication is expected later this year.

Key topics Joint Task Force on TSI

- In order to design correctly the OCL for battery trains while charging, it seems necessary to:
  1) define the train needs
  2) then work on OCL

- **Power demand from the batteries ?**

  3 Examples with proposals from Stadler for Bane NOR (15kV AC):

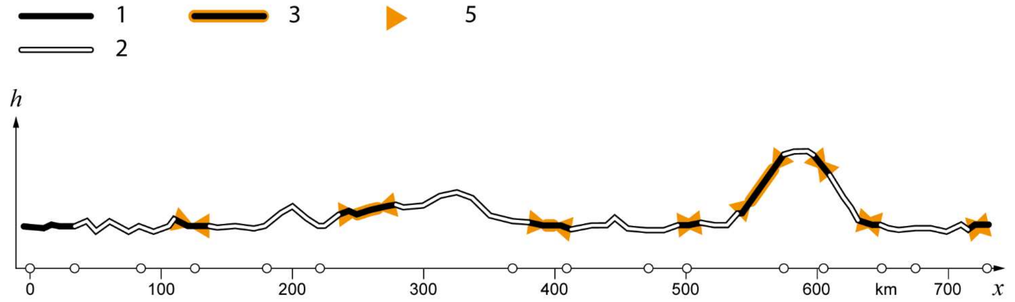
  2 MW = BEMU (common example in many countries and tested/in operation already; “Aramis”, FLIRT)
  3 MW (385ton train with 7 cars or last mile freight train; “Athos” locomotive = Eurodual)
  4 to 5 MW (1200ton freight train; “Porthos” locomotive = Euro9000 with battery tender)

  Train operation studied for Norwegian cases, e.g. a 729 km line Trondheim-Bodø, to be only partly electrified over a total of 210 km (28,8%, 8 separate electrified sections). This looks like this in TS 50729:

Key

1	electrified track (section)
2	non electrified track (section)
3	dedicated contact line section
5	border of trackside charging infrastructure
H	altitude above sea level

Figure 3 — Example for charging infrastructure Type II (vertical profile)



Key topics Joint Task Force on TSI

- Short term: main issue: previous TSI requirements on Current at standstill for DC systems only (because of much lower voltages compared to AC systems and thus higher currents to have enough power for auxiliaries like heating & air conditioning in modern rolling stock)

- **Requirements** for AC-systems included in latest TSI ENE (energy) and L&P (rolling stock) but referring to actual limits in the standards **(80 A), no assessment**

→ to be discussed again (see below) !

Available power at standstill - actual possibilities

A summary of all possibilities for charging at standstill & auxiliaries with their limits (2 MW at best):

Solution	System voltage	30 min per pantograph Max current	Max power	Standard
Current collector	25 kV ac 50 Hz	**80 A**	**2.0 MVA**	EN 50367 TSI ENE 2023 !!
	15 kV ac 16.7 Hz	**80 A**	**1.2 MVA**	EN 50367 TSI ENE 2023 !!
	3.0 kV dc	**200 A**	**0.6 MW**	TSI ENE
	1.5 kV dc	**300 A**	**0.5 MW**	TSI ENE
Plug UIC 552 (1 Phase)	3.0 kV dc	800 A	2.4 MVA	UIC 552
	1.5 kV dc	800 A	1.2 MVA	UIC 552
	1.5 kV ac 50 Hz	800 A	1.2 MVA	UIC 552
	1.0 kV ac 16.7 Hz, 22 Hz, 50 Hz	800 A	0.8 MVA	UIC 552
Shore supply plug (3P+N)	400 V ac 50 Hz 3~	63 A	0.044 MVA	EN 50546
(3P+N)	400 V ac 50 Hz 3~	125 A	0.087 MVA	EN 50546
(3P)	400 V ac 50 Hz 3~	600 A	0.416 MVA	EN 50546
Industrial plug (3P+E(+N))	400 V ac 50 Hz 3~	63 A	0.044 MVA	EN 60309-2
	400 V ac 50 Hz 3~	32 A	0.022 MVA	EN 60309-2
	400 V ac 50 Hz 3~	16 A	0.011 MVA	EN 60309-2
(1P+E+N)	230 V ac 50 Hz 1~	16 A	0.003 MVA	EN 60309-2

EN 50367, Table 5: Minimum current values per pantograph, for which the infrastructure (OCL) shall be designed to accept

For the pantographs, these values are considered as maximum ones.

315 A -> 0.9 MVA BE national rule

600 A -> 0.6 MVA more common value

The heavy 600 A connector is the existing UK standard three-phase shore supply connector which has a long service history

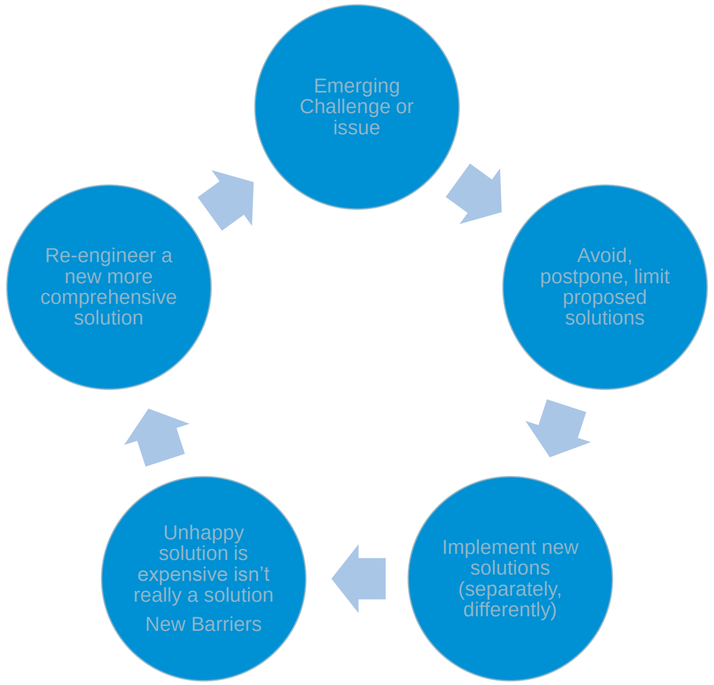
Key topics Joint Task Force on TSI

- **4 existing target systems** for traction power supply from the OCL through the pantographs
- Towards a **5th power supply system**: **15kV AC 50 Hz** for countries using already 15kV 16.7 Hz (D, A, CH, SE, N, …) ?
  shall be allowed, when agreed between infrastructure manager and railway operator.
  Increasing the frequency on separate charging facilities has a number of advantages for infrastructure, even regarding the public grid from which the power is sometimes taken, without major consequences on rolling stock, thus reducing overall investment costs.

- **Plug solutions** have limited power, but can be sufficient for slow charging (≥ 60min), e.g. overnight in stabling yards, using (smart) multiple socket units and offered as a service, with different management, metering and invoicing (per kWh or just per hour).

Example from DB Netze

Plug solutions revisited – risk of diverging innovation



- Croatian example BEMU & BMU : 736 kWh batteries on board, to be charged with the **MCS** under 1000 V & 500 A, so **2 x 500 kW**; quid standardisation (existing plugs: UIC 552 / TS 50534; EN 50546; EN 60309-2) ?
- **MCS:** any future increase of those values to 1250 V and 3000 A, so **3750 kW**, foreseen ? It's probably not possible and necessary for the current battery Li-Ion technology and timetables, but as infrastructure managers we tend to think on the long term (> 80 years). New types of hybrid batteries with far higher **C-rates** already available !

Current compromise between the performance and durability of the batteries.

no pantograph on the BMU train though ! 😊

Key topics

→ EVOLUTION of STANDARDS in TSI ENE:

EN 50119:2020

EN 50367:2020+A1:2022+A2:2024: adapted regarding **current at standstill**, but revision Annex A.3 necessary for battery train charging

EN 50388-1:2022: including some elements on battery train operation

already included charging in subclause 7.1 (Charging current or power to on-board energy storage systems, e.g. rechargeable batteries, for traction purposes are included in the mentioned traction current or power.).

EN 50388-2:2025: to be voted, FprEN available

TS 50729:2025: voting results expected March 2025; *future reference in TSIs* ?

Input/feedback from TS 50729 to EN 50388-1 necessary !!

Do all traction units fulfil the "**Automatic current or power limitation as a function of line voltage**" (subclause 7.3 of EN 50388-1 and Annex F) **at standstill ?**

The reason is in our "old" understanding the limitation was for traction – means for movement. Thus, it is nowhere written, that this function shall be also valid for standstill.

It is to be assumed, that **this function shall be also valid for standstill**.

EN 50206-1:2025 (no reference in TSI ENE): final committee draft ready; **current at standstill** references to EN 50367.

Standstill ≠ 0 km/h !!

Current and power limitation functions, as given in EN 50388-1:2022, apply for all electric traction units with onboard electric traction energy storages.

NOTE 1 The exception of EN 50388-1:2022 for train sets with a maximum power at wheel less than 2 MW to operate without this function is omitted, because the charging power could otherwise exceed applicable power limits.

In addition, electric traction units with onboard electric traction storages shall limit:

- the total current at standstill,
- the charging current while moving with a speed up to 8 km/h (e.g., shunting) and
- the total current while running under a contact line fed by a charging substation

because:

- the power of the charging infrastructure or
- the current at the interface contact strip/contact shoe - contact wire (in accordance with EN 50367:2020, EN 50702:2021 or other regulations)

can be limited.

NOTE 2 While moving with a speed up to 8 km/h, current for auxiliary and charging remains below the current limit at standstill.

NOTE 3 The total permitted current at standstill can be higher than stated in EN 50367:2020, Table 5 in case measures described in clause 7 are implemented on the dedicated contact line section.

NOTE 4 Also on higher speeds, the total traction current might have limitations, e.g., in case the contact line is fed from a small charging station (typically for a type III charging infrastructure).

The applicable limits shall be given by the infrastructure manager.
It may be wise to allow certain current steps below these limits for coordinated charging of several electric traction units.

→ How to test at low speeds ? Up to 5 km/h, 8 km/h or 10 km/h ??

Recent developments

Tübingen(D) 15 kV AC – 80A/pantograph – ROCL = Rigid OCL

October 2021 Tübingen
VOLTAP –Furrer+Frey
15/25 kV 50 Hz –2 x 1,2 MVA
© Stadtwerke Tübingen

VOLTTAP – RAIL POWER CHARGER – weltweit erste Schnellladestation für Batteriezüge (BEMU) - Stadtwerke Tübingen

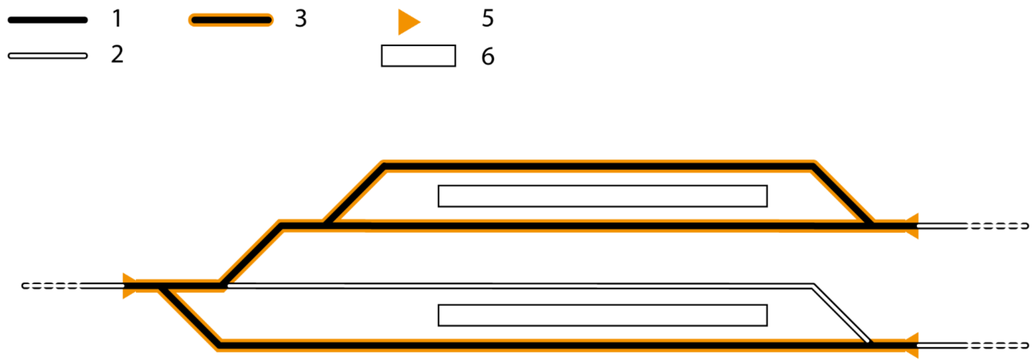
TS 50729 ?

Railway applications - Fixed installations and rolling stock - Interface requirements between charging infrastructure with dedicated contact line sections and electric traction units with onboard electric traction energy storages and current collectors

BEMU Charging Station (bemu-cs.de)

TS 50729

Type III: non TSI-compliant electrification of a contact line island within and around a railway station (an extension of a few km is possible depending on e.g. rated power and voltage drop)

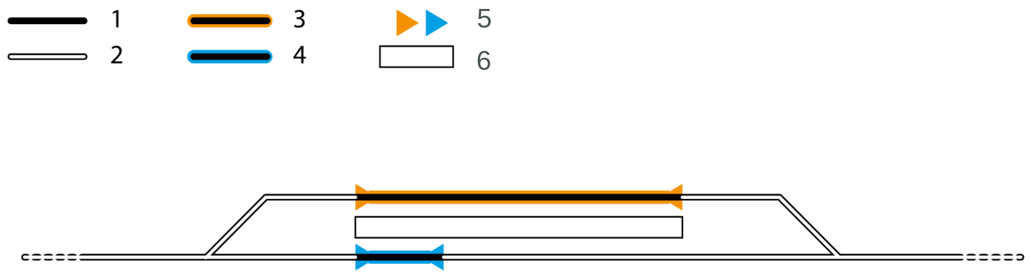


Key
1. electrified track (section)
2. Non electrified track (section)
3. Dedicated contact line section
5. Border of trackside charging infrastructure
6. platform

14 November 2024 Husum station
15 kV 16,7 Hz © ARD

TS 50729

Type IV: non TSI-compliant electrification of only a few contact line sections (only dedicated to charging at standstill)

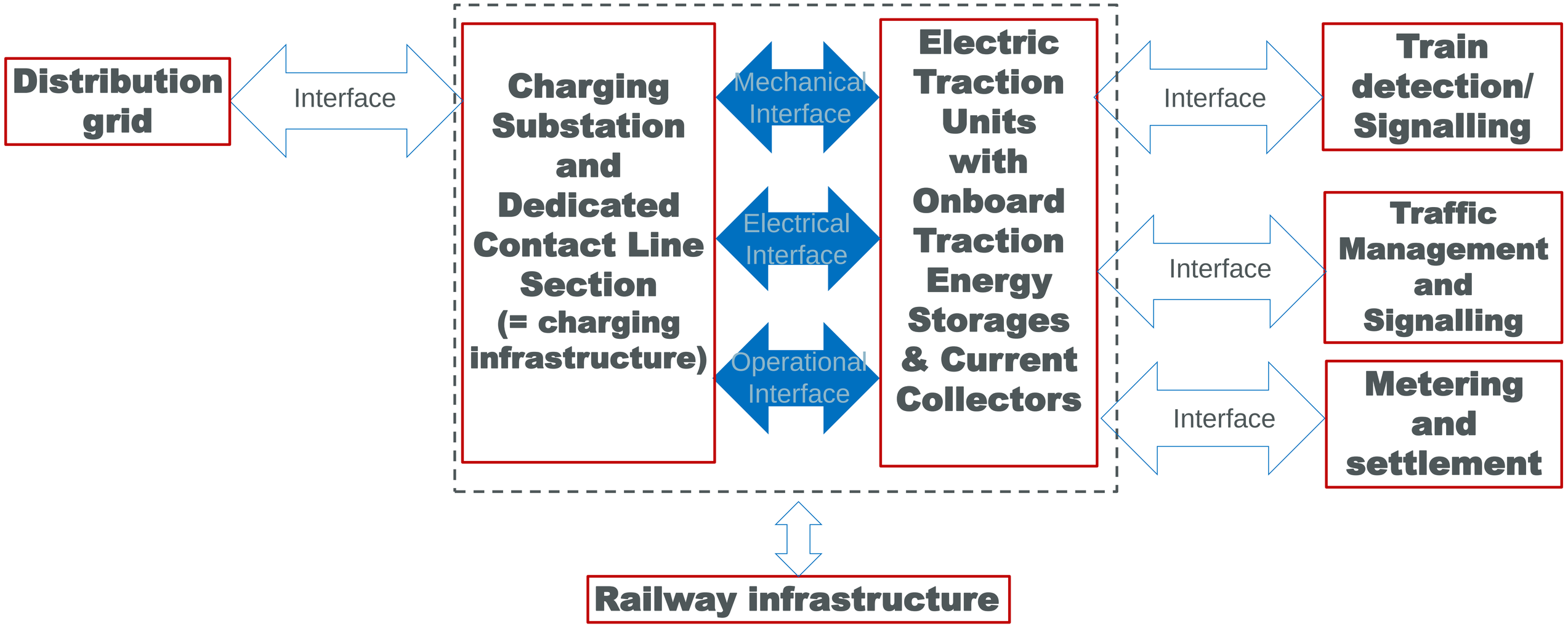


Key

1. electrified track (section)
2. Non electrified track (section)
3. Dedicated contact line section
4. dedicated contact line section – only at estimated current collector position of a charging vehicle
5. border of trackside charging infrastructure
6. platform

August 2023 Annaberg-Buchholz TRACFEED –RPS+F&S 15/25 kV 50 Hz –3 x 1,2 MVA© Alstom

Interfaces charging infrastructure <=> train



System design / dimensioning study

Aim: to support most cost effective solution

Coordination needed between Railway Undertakings, train builders and Infrastructure Managers on expected train offer, capabilities of traction units and dimensioning of the infrastructure.

This is crucial in case of:

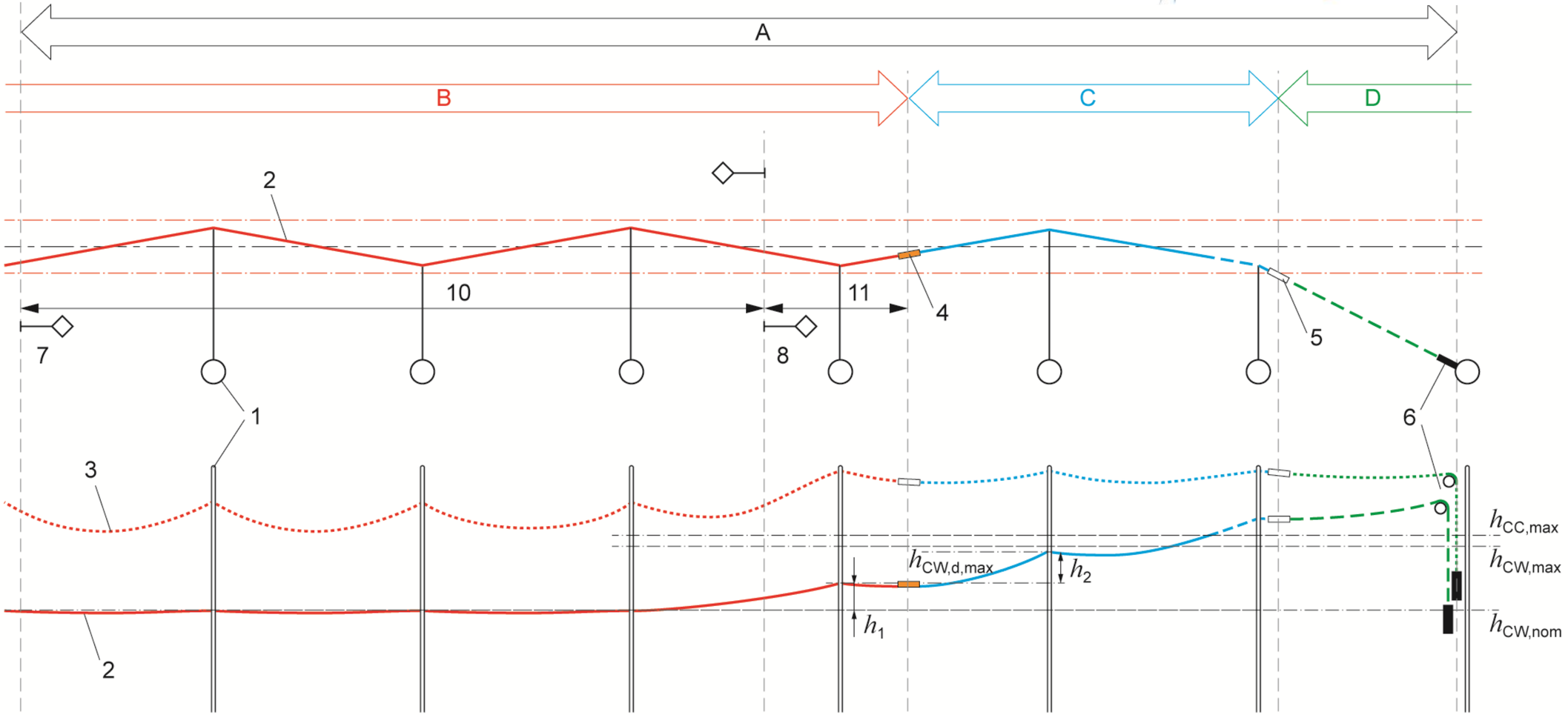
- limited flexibility in timetable (e.g. longer parts on single track),
- limited onboard energy storage (e.g. minimal size of battery, extended lifetime of battery) or
- weak performance of charging infrastructure (e.g. limited maximal power permitted from public grid).

Transition from/to non-electrified lines

Transition from/to non-electrified section shall be protected (lowering and rising of pantograph on intended moment). **A risk analysis is needed to avoid**:
-drawing an electric arc while leaving electrified section,
-mechanical interference with current collector head and fading contact line,
-hitting obstacles like bridges and tunnels,
-raising too late the current collector in electrified section,
-damaging/overheating the contact line.

This can be done using:
-protection by signalling (possibly with automatic execution of signalling commands),
-neutral section connected to return circuit,
-vertical fading of contact wire and automatic lowering of pantograph at a certain level

Transition from/to non-electrified lines



the maximum extension (see definition 3.2.17 in EN 50206-1) of a pantograph can reach 8 m !

→ $h_{cc,max}$ shall be at least as high

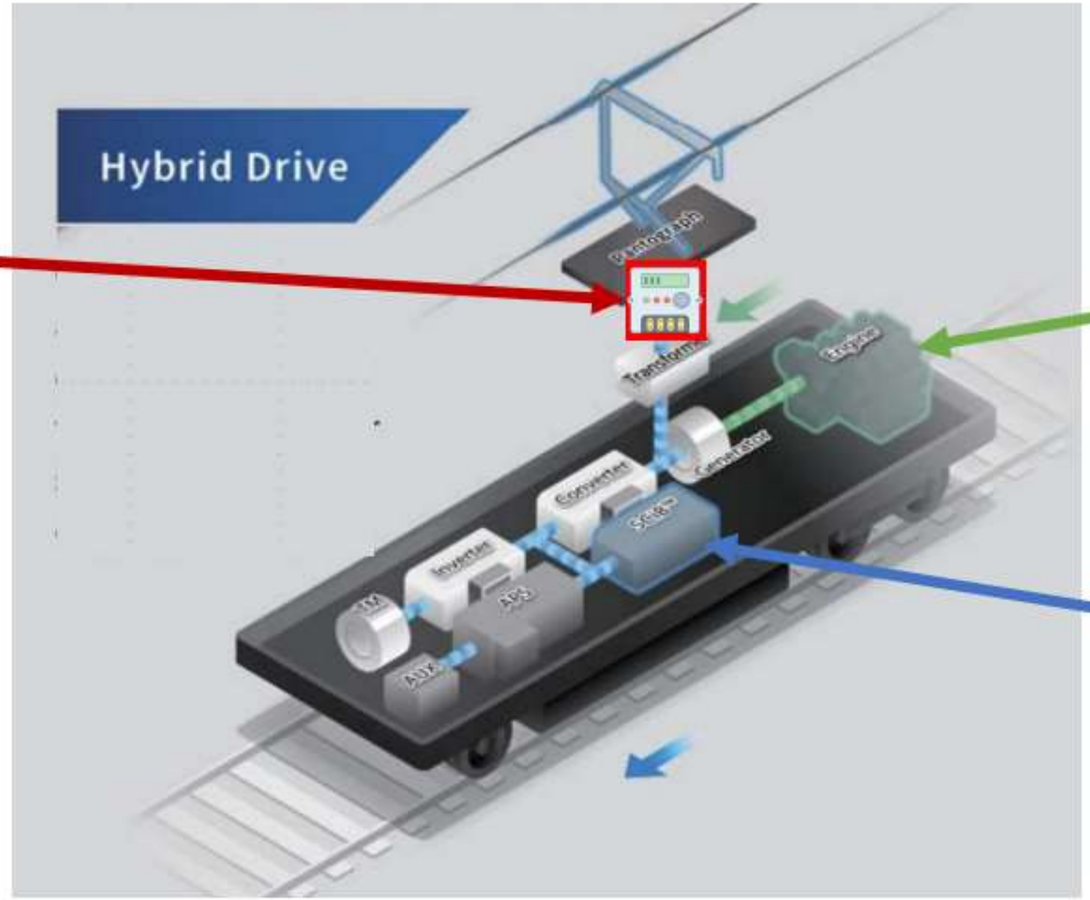
Operational interface

Information like:
-limitation of charging current,
-maximum current at standstill,
-maximum feedback current (e.g. for discharging),
-but also locations of transitions from/to non-electrified lines

can be transmitted via an interface from traffic management to Automatic Train Operations (ATO) or Driving Advisory Systems (DAS).

The types of Hybrid trains

(from workshop on Eress Forum, June 2023)



Picture: Toshiba Hybrid_locomotives_and_propulsion_systems.pdf

Collect Use Cases

- We expect to see a lot of new hybrid trains to enter the market in the next ten years.
- This might start with bi-mode locomotives combining electrical traction with diesel traction (mostly used for cargo trains). For passenger traffic many countries are seeing the first series of BEMUs (Battery Electrical Multiple Units). Other countries have pilots with HEMUs (Hydrogen Electrical Multiple Units).
- We need to be able to estimate electricity consumptions taken from or returned to Overhead Contact Line. This is needed to validate data from on-board Energy Measurement Systems (EMS) but also to be used in case of problems with EMS.
- Some use cases are regarded as most likely in daily business.
  In multiple use cases extra information might be useful to optimise the process.

Collect Use Cases

- But hybrid trains offer also new opportunities.
- The on-board energy source can be used in case of problems with the traction grid of the Infrastructure Manager or with the public grid of the Transmission System Operator. A group of trains can be offered to an aggregator in the electricity market. In case of problems with the public grid, the on-board energy source of this group of trains can be used instead of the energy delivered via the Overhead Contact Line.
- The on-board energy storage likely doesn’t have sufficient capacity to be part of such an agreement with an aggregator. But in many cases, it will be possible to select the best moment to charge the batteries. Certainly, on stabled trains, the charging should be done on a moment the electricity prices are lower.
- **other Use Cases?**

As for the battery cars, trains may have different battery charging strategies – ÖBB use case

→Sometimes a **weak local grid and/or traction power supply** exists: impossible to “fast” charge the trains with a lot of power

→ use case for battery trains and charging them to be evaluated for each line/route where they are intended to be operated;

“fast” charging (1,2 MW = 80 A in 15 kV AC-systems) not always necessary and strongly influences the lifetime of current Li-ion battery technology, limited to 2C or 3C (see Croatian example);

this could change to 10C or 20C with other battery technologies, like hybrid carbon-based power capacitors already on the market!

→ **4 charging strategies** for the Stadler Flirt BEMU considered:

- *“quick charge”* with 2 pantographs & 90% of the TSI-value for each pantograph; **2,16 MW**
- *“normal charge”* with 1 pantograph and TSI-value; **1,2 MW**
- *“sparing infrastructure”* with 2 pantographs & 50% of the TSI-value for each pantograph; **1,2 MW**
- *“sparing batteries”* with 1 pantograph & 75% of the TSI-value; **0,9 MW**

→it should be possible to charge with **6 pantograhs at the same time** !

→**when does standstill starts**, e.g. if a train stops 2-5 minutes at a stop

As for the battery cars, trains may have different battery charging strategies

- a) *Long time charging cycle*: energy taken from OCL per pantograph corresponds to the capacity of existing OCLs (300 A for 1500 V; 200 A for 3000V; 80 A for AC)
- b) *Medium* charging cycle: charge in a shorter time, with higher current
  e.g. for 1500 V DC: 600 A for 5 min, then 300 A indefinitely
- c) *Quick charging* cycle : charge in 15 min
  e.g. for 1500 V DC: 1000 A for 15 min, then 500 A for 30 min and 300 A indefinitely

→ We need charging management, certainly for multiple trains, considering State of Charge (SoC) of the batteries, timetable, *auxiliaries*, etc. Link to control & command systems to pass coded messages between infra & rolling stock

→ Pay attention to high inrush currents when switching on !
Hence 15kV AC 50 Hz !!

80 A or 1,2 MW in 15 kV AC achievable ?

Is the actual legal 80 A / pantograph for standard AC-systems with 1 contact wire realistic ?

Tests on a line with a Thermography Camera sometimes show a great difference to the measurements in the test laboratory according EN 50367 Annex A.3 !

Solutions

e.g. From the actual legal 300A under 1,5kV DC to +800A

A small reminder – 1,2 MW ?

= 80 A_{rms} in 15 kV AC

= 400 A in 3 kV DC,

> 200 A legally required,

but within reach without special dedicated contact line sections ?

= 800 A in 1,5 kV DC,

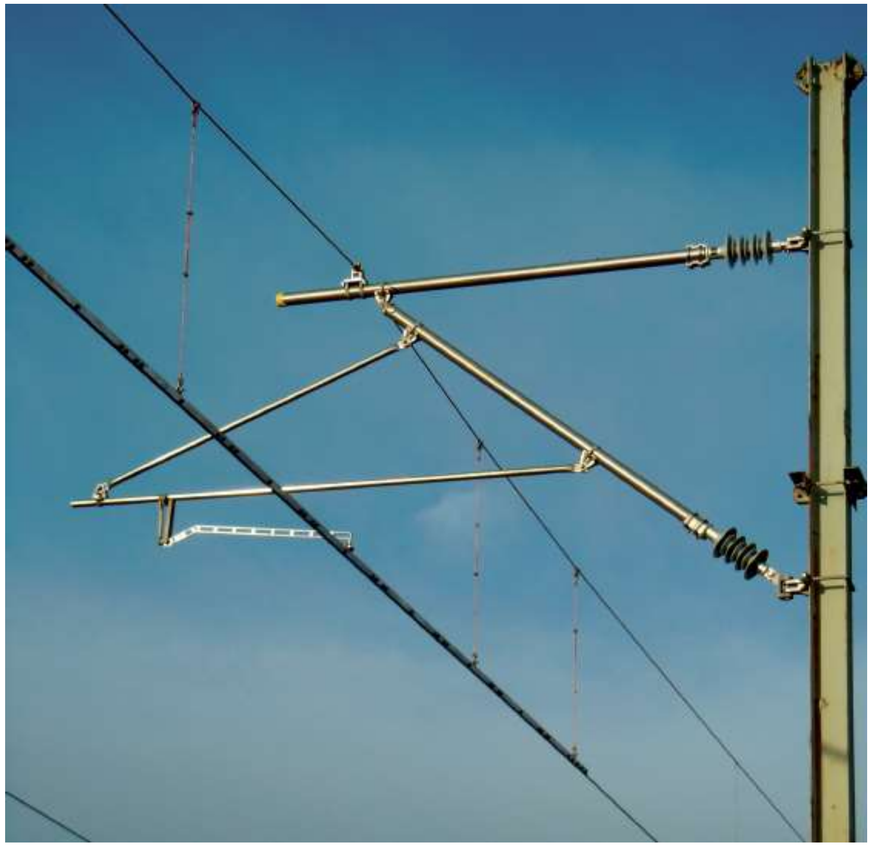
>> 300 A legally required,

WTF ??

For charging small BEMUs with +/- 2 MW and Li-ion battery technology !

On the INFRA side

Reinforced OCL – e.g. SNCF RER C (Dourdan) / Depot Sweden (Västerås) / Metro Line 5 India (Delhi)



Profile to be added on an existing catenary to better dissipate the heat at the contact point between the contact wire and pantograph Reinforced OCL

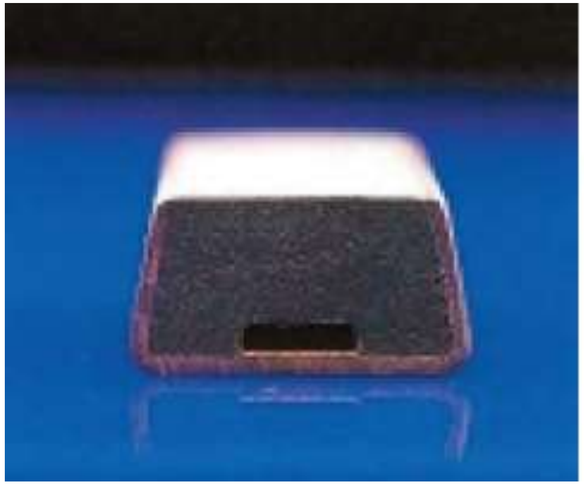
On the RST side

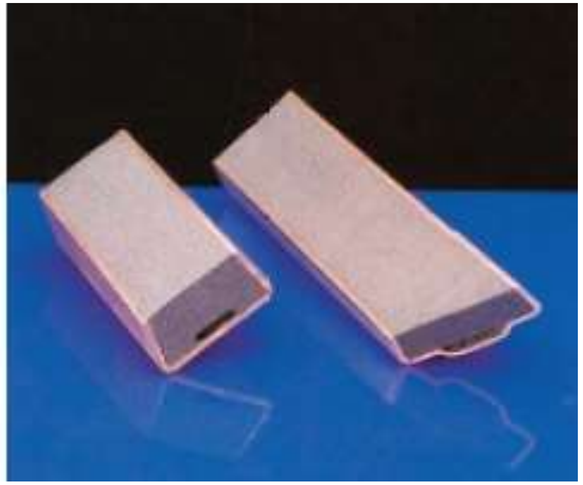
SNCF SALTO project (nothing new !):

- At standstill, a mobile copper strip on the pantograph is raised to the OCL
- It is lowered as soon as the train exceeds 8 km/h
- Under 1,5 kV, the equipment was tested up to 500 A and it worked. It could probably work with higher values.

On the RST side

“Kasperowski” contact strips (nothing new again ! Still used e.g. in BE, FR and CH on older type of heavy pantographs):



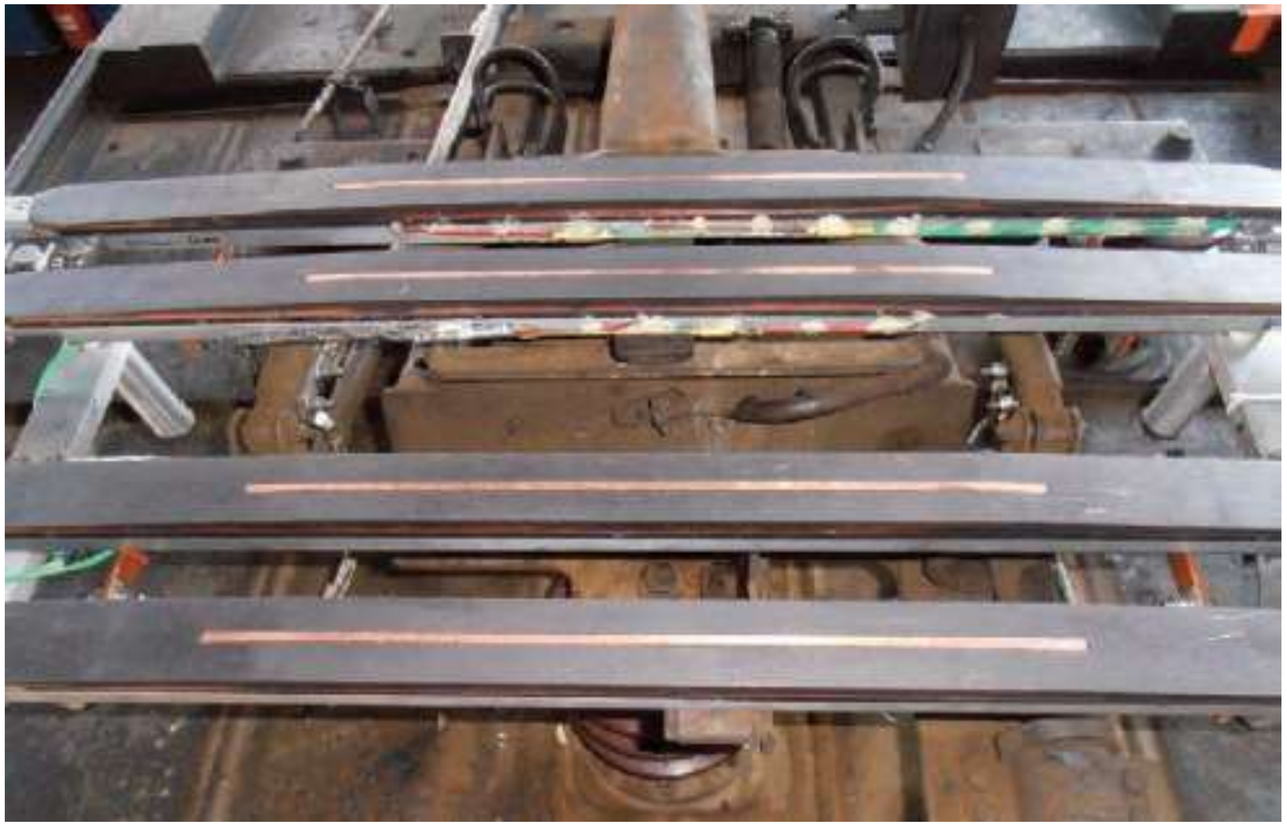


But some problems in winter time with frost on the contact wires: Cu melted because of arcs

On the RST side

Use of Cu inserts in the centre of the contact strips

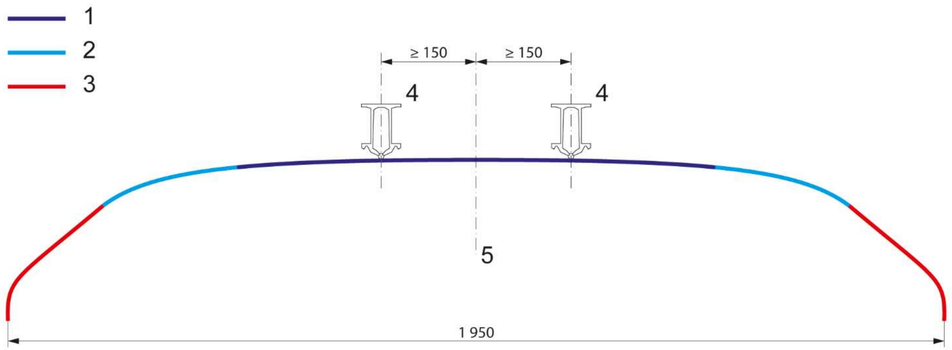
Revue Générale des Chemins de Fer, Decembre 2015, p.15-21

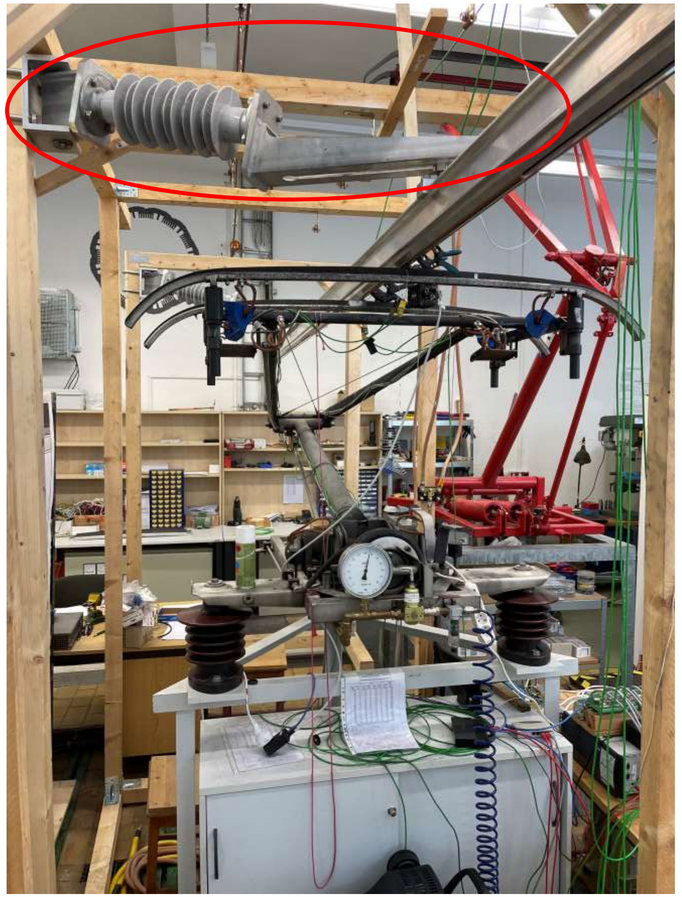


High-current Carbon Strip

On the INFRA side

Use 2 rigid overhead conductor rails on the contact strip
with sufficient distance because of the carbon (but still mountable on the same suspension arm)





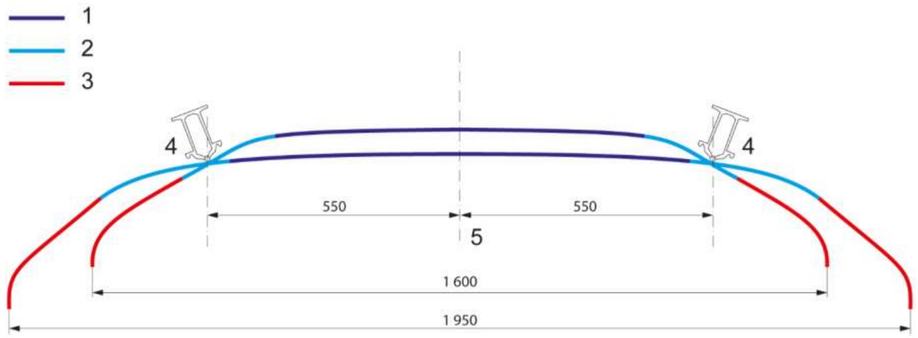
Key
1 contact strip (plain carbon or impregnated carbon)
2 parts of the working zone beyond the carbon strip (part of the conducting range)
3 horns (insulated or conducting)
4 rigid overhead contact line

NOTE to Key entry: a flexible overhead contact line may be used instead of rigid overhead contact line.

5 track axis

On the INFRA & RST side

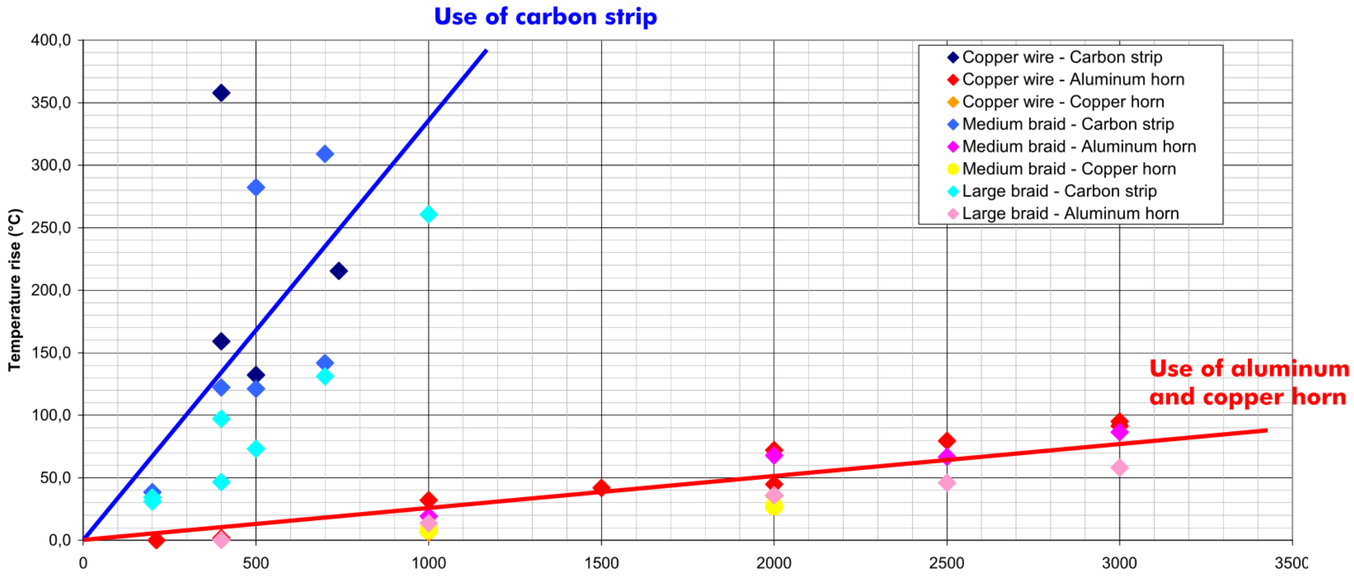
Use 2 rigid overhead conductor rails with contact beyond the carbon strip on the horn layers (copper or aluminium)



Project « STEEM » (Système de **tramway** à efficacité énergétique maximisée) & « WEST »

In 2009-2010, Alstom and RATP run the STEEM project : Test the feasibility of tramway fast charging through the pantograph and rigid catenary

- Objective : **600 A** during 25 s then 60 s of rest



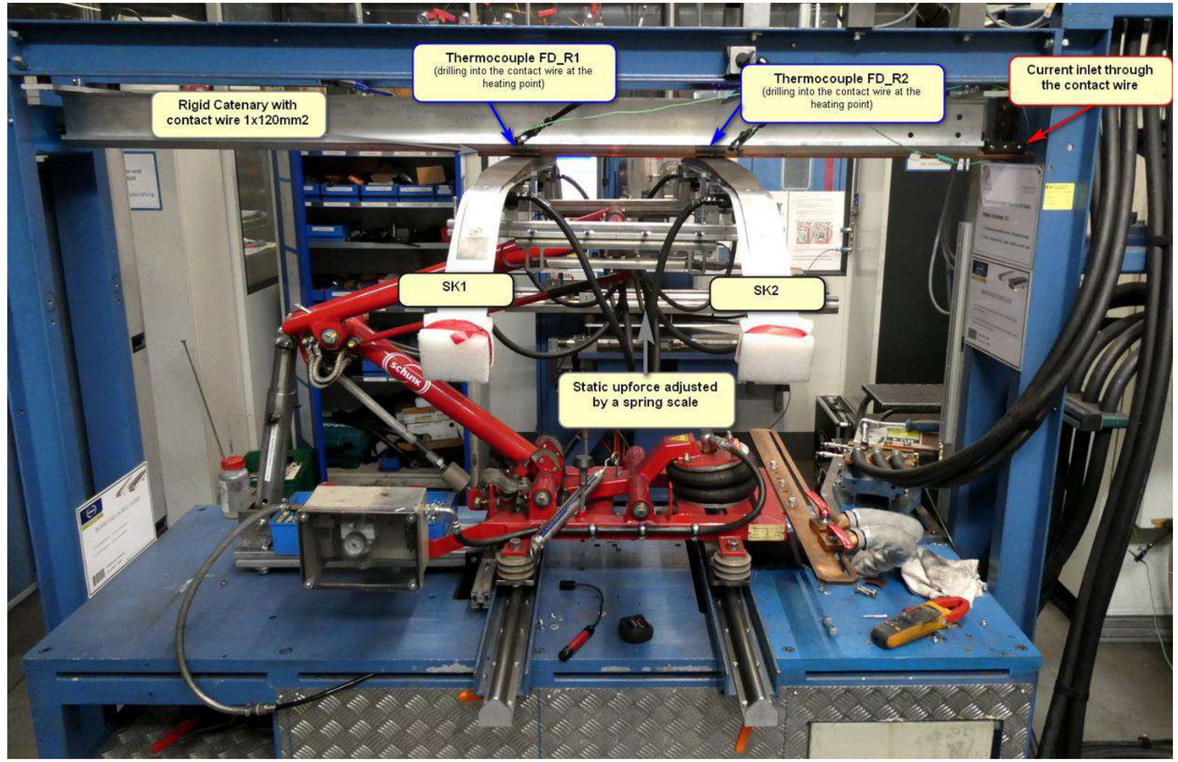
On the RST (& INFRA) side

Use **anisotropic** copper impregnated (e.g. SK85ACu), 60 mm wide carbon strips, not only for heavy DC systems as usual, but also in AC systems !

Requirements by TSI LOC&PAS

§ 4.2.8.2.9.4.2: ≤ 35 % in weight on AC lines or 40 % on DC lines.

OK for **440 A** or **462 A / pantograph** (440 A + 5%) on ROCL ?



Test bench Schunk (SK2488-a), with a short rigid catenary & 1x120mm² contact wire

research/projects

current at standstill : (on going) tests by RSSB (UK), TU Dresden (D), IfB (Infrabel), RFI, Ricardo (NL/F), etc.
→ EN50367 Annex A3.

to evaluate possibilities of charging from an OCL (rigid or flexible) under real circumstances (identify margins between more common circumstances and rare worst cases)

Overview of tests on current at standstill

Tests TU Dresden: see article Elektrische Bahnen 119 (2021) Heft 3, p.100-109

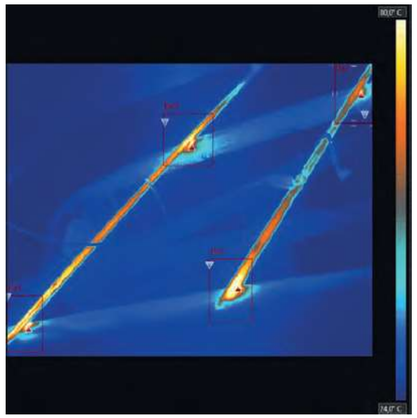
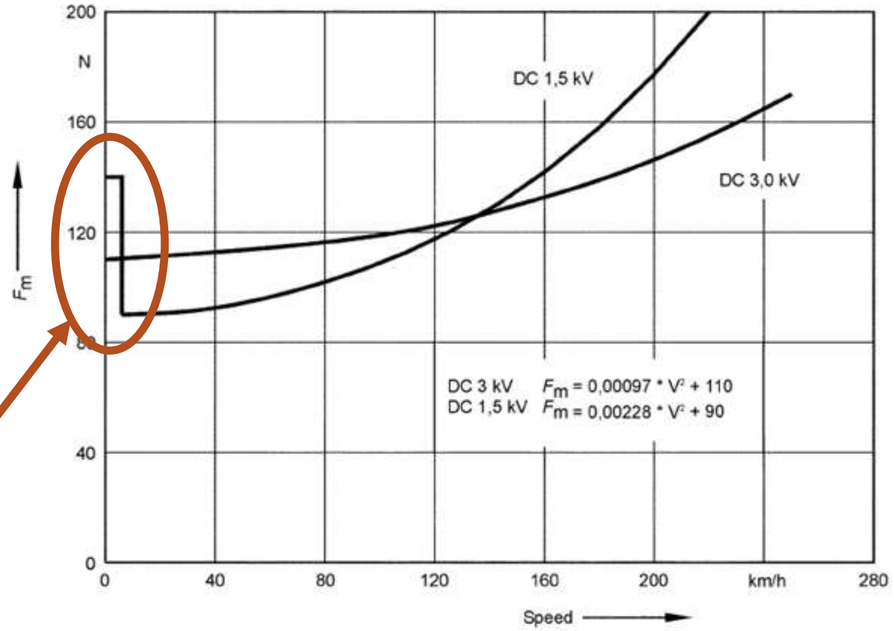


Figure 5.2

Target for mean contact force for F_m for DC 1,5 kV and DC 3,0 kV lines depending on the running speed



With plain carbon contact strips, depending on the configuration:

- 140N static contact force instead of 70N as usual in AC systems
- 2 rigid OCLs with a CuAg 120mm² wire, spaced 40 cm apart

it is possible to go from the actual legal 80A to 220A !

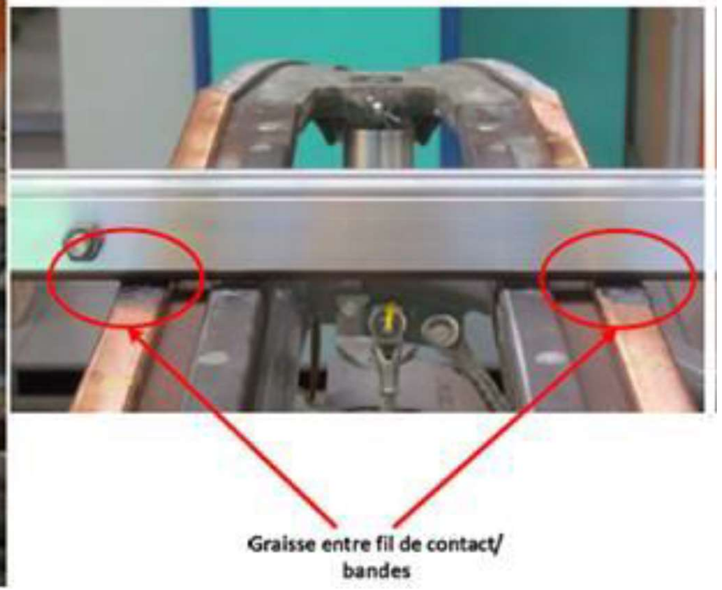
→ **3,3 MW** under 15kV AC

→ **5,5 MW** under 25kV AC !

→ With Cu impregnated carbon contact strips, this can even be improved.

Overview of ongoing tests on current at standstill

On contact wire with the reinforcement profile : SNCF test has demonstrated that it works under 1,5kV up to **1000A** during 30 minutes with a pantograph used on AGC trains (copper contact strips !)



Overview of ongoing tests on current at standstill

Infrabel: tests done in January 2021 on twin contact wires: huge margins towards temperature limits on **new** flat bottom wires (**as required by EN50367 Annex A.3**), but far less on **worn** wires due to contact force imbalances.

SNCF/PRoRail (1,5kV DC networks): more tests to be done soon (divergent results)

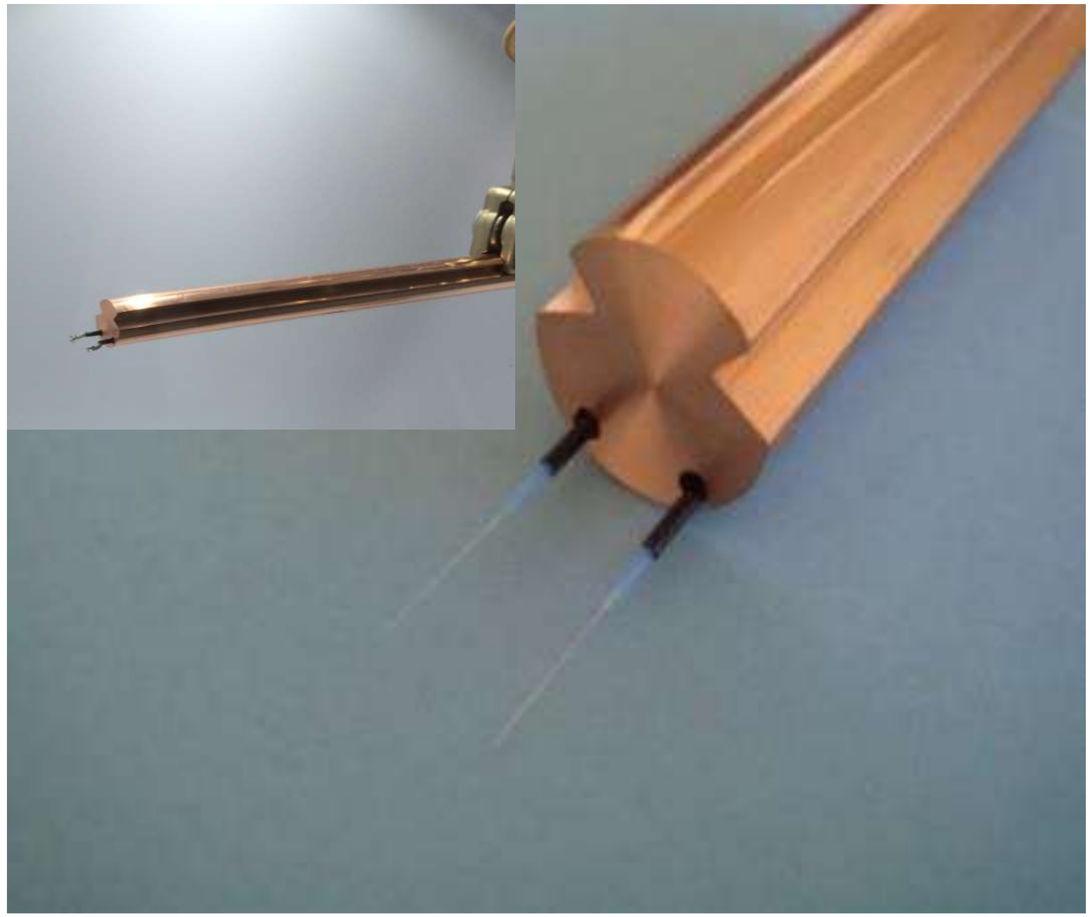
From previous tests by SNCF:

- Important parameter is the contact surface, more than the contact force
- 2 wires/ 1 wire or 2 strips/ 1 strip, it is not sufficient to divide by 2 or 4, test needed
- The more contact points the better
    - Increase the contact force increase the contact surface → Favourable
    - Increase the number of wire increase the contact surface → Favourable (even if spaced a few cm apart)

On the INFRA (RST??) side (part 2) – possible future solutions ?

Contact wire with integrated Optic Fibre to actively monitor in real time and under real environmental conditions the temperature of the contact point(s) instead of the current (and not the wear as already tested in Japan many years ago on Shinkansen)

- → Functional requirement on the critical parameter instead of an indirect one (but difficult to measure and manage, hence all the tests with divergent results)
- → Temperature in the contact surface therefore as criterium to proof compliance of the temperature limit barely appropriate ?
- → *If integrated in the contact strips* direct and automatic possibility on the trains themselves to cut power demand at standstill to protect the infrastructure (even more difficult to measure !)
- → Only if necessary, when the passive solutions presented above are not sufficient
- → Installation and repair procedures ?



On the INFRA side (part 2) – possible future solutions ?

Monitor the temperature of the contact point(s).

This could be needed to avoid tripping by the circuit breaker feeding the section and send a message to the trains to cut power demand in case more than 1 train is charging, without individually passing the temperature (or current) threshold, and there’s too much current demand in total (which in DC would be surprising compared to traction current, but maybe not in AC).

What should we do next as an IM ?

INFRABEL

Electrification & Alternative Traction

Benchmark EIM – WG ENE

Paul T – Bart VDS – Thomas L – Karim S - Valentin F

January 2025

10 + 4 questions: who replied ?

- 6 IMs
  - OCL & Engineering (senior) experts/advisors
  - Heads of Power Supply Design
  - OCL Head Engineers (Technical Management)

Electrification of the rail connected clients

By rail connected clients, we typically refer to factories, industrial/logistics hubs (e.g. ports) and railway undertaking facilities

Q1: Is the electrification a recent development? Do you see a trend towards more electrification of your clients?

It is a remnant of the past when companies still did a lot of transport by rail, such as the postal service. As far as I know they are not electrified. These ‘private sidings', owned by the companies, are still present. As far as I know, there are no plans to demolish or electrify them. Nowadays, transport takes place by road. Judging by the condition, they are hardly or not maintained at all. Train maintenance companies do have an electrified connection, but this is electrically separated from the main network by a switch. It is owned and managed by the maintenance companies.
It is not a recent development. No trend compared to earlier.
No
It is more an historical situation. New client such as railway companies will look toward electrification while freight clients are more likely to stay unelectrified
It is not recent, but there is a trend in connecting new facilities to the rail network
we have train depot that and owned and operated by the train manufacturer, and freight yards

CONCLUSION

The current situation results from historical (not recent) developments.
Apparently, a massive electrification of the connected clients is not expected.

Q2: Who was the requesting party for this electrification (client, hub, IM, RU, …) ?

In the past, the train maintenance companies were part of the incumbent RU, which also managed the infrastructure. So, it must have been the incumbent RU itself. I assume that the other companies that used the railway for transportation requested access. In the case of postal services, by the government as it owned the postal service at the time.
It was often in the beginning a part of our network for our own use or wanted by our customer. If wanted by our customer, we determine the suitability
Now its the Client, earlier it was IM.
clients
Normally the request comes from the client, or other administrations like port managers.
railway undertaking (RU)

CONCLUSION

In general, the request came from the clients (RU or port)

Q3: Are these overhead contact lines connected to the your OCL and if yes, how?

They are separated by a section insulator and fed by our traction power supply, just by a switch.
Yes, connected to our OCL and fed by our traction power supply system. How the connection is done varies. It can be section insulator or an overlap arrangement.
Yes
Short distance OCL are connected to our power grid. Very few clients such as Port Authorities have enough length of railway to look for an autonomous power supply (requested by law). They mostly subcontract power management to our company
Yes, the OCL is connected to the main network. Normally the connections is through a set of two asymmetric section insulators, and the feeder could be an independent one, if the substation is close an there is space for a new cabinet, or it is a derivation from the OCL. In the last case, a circuit breaker and a switch is needed to protect and isolate faults. Power supply from traction substations is only allowed for traction purposes , and not for other applications (welding, charging, cranes, etc).
all are fed from our system. Most have switching to provide a sectioning from the main line and the depot

CONCLUSION

OCL are always fed by the IM
(exception could be Port Authorities)

Q4: Do they have the same OCL systems as the ones on your own network or did they opt for other standards? Do they require the same life span as for your installations?

It is the same OCL that we used to build. In many cases it turns into a conductor rail
They have one of our systems.
Yes
They have the same OCL as us because it's easier to maintain (spare parts are easily available and knowledge is widespread within the market). The life span request depends short-term investors pressure. The smarter would go for a normal life span of more than 50 years. Some short-term profit seeker are ready to trade life span for cheaper acquisition costs
They normally use same type of OCL because of the available standards and materials. Specific OCL systems sometimes used in third party workshops, and not installed in our network, could be folding OCR (contact rail).
We

CONCLUSION

The OCL of their clients are the same as the IM’s

Q5: Is it a full electrification?

Battery power is not used.
Usually only "last mile" electrification. Not complete electrification.
Varies dependent on use.
It' s mostly binary: either they are fully electrified or not at all. battery power will be a game changer but is not available enough to reach client's list of choices. We have dedicated OCL design for charging batteries, but it is only used to keep passenger trains in condition while waiting for their next rotation. Fret doesn't request it (yet).
Normally the clients only electrifies some of their lines, but it depends on the specific business.
partial

CONCLUSION

Battery power is expected to allow for partial electrification, but not yet in place

Not everything is electrified, but a journey should be fully electrified with OCL (as there’s no battery yet)

Q6: Who paid for the investment?

I assume the companies themselves and in the case of postal services and train maintenance companies it must have been the government, because they were owned by the government.

The customer would pay.

The client

Investements are due by the client. We might predispsose installation on our side on our money only if we can synchronise this operation with a major maintenance operation.

The investment is always in the client side, including the modification of the main network. Only exception could be in public facilities like ports or hubs, where a specific agreement is sign to share costs.

the railway undertaking

CONCLUSION

General philosophy is that the client would pay.
Exceptions could be ports or hubs

Q7: Do you have any specific safety requirements

The safety requirements of the IM (and its predecessor *[integrated company]*) are applied, inclusive with regard to return circuit.
No special safety requirements from us.
No other than the ordenary requirements of buliding OCLs
we notice a request for automatised earthing to allow untrained people to realise this safety measure.
The client project must be approved by the IM, specially in relation to the connection. Electrical protections and parameters must fulfil national and European standards. When the feeder is from traction substation, earthing and return circuit have to be also connected to the main line. Specific safety requirements are the mentioned section insulators, circuit breaker and switches, so electrical faults are easily detected and cleared. Real time information of all electrical equipment status is also required , normally through the IM's Telecommand systems.
some installations have remote earthing facilities to provide resilience to the main line

CONCLUSION

In general, the same requirements as the main line is required.
Sometimes additional features are necessary (e.g. automatic earthing)

Q8: Who’s responsible for the maintenance of the overhead contact lines and, if relevant, traction power supply on their site?

Nowadays the companies themselves are responsible for maintenance of the OCL. Agreements have been made for the power supply. I don't know whether it is standard contract or a customized contract. Actually, I think customized.
The owner is responsible.
Mainly IM’s maintenance staff.
Depends on the client. Some will subcontract maintenance to us. Mostly the largest clients who privilege availability over cost. The smaller clients would punctually look for private companies when their OCL shows deficiencies. As far as I know, very few have multiannual maintenance contracts with private maintenance companies.
There are two possibilities: A) There is a contract between the Client and the IM, and the IM is paid for doing the maintenance of the OCL and electrical protections. B) If there is no contract or agreement, the Client is responsible for all the installation above the section insulators, including OCL , circuit brakers, etc. Normally the IM maintains the section insulator, the main switch (connected to the main line) and the cabinets inside traction substation, even if it is exclusive for the Client facility.
The railway undertaking contracts this. Sometimes it to with the IM maintenance team, otherwise it is carried by a contractor

CONCLUSION

There are 3 cases

1- Maintenance **by CLIENTS**

2- Maintenance **by IM**

3- Maintenance done **by CLIENT or IM**

Q9: Are you managing the electricity flows on your client site (among the different traction units) or have you placed an energy meter at the entry of the client site?

I'm not sure, but I think they are part of the cooperation managing the purchase and use of energy on the network. They certainly don't have an energy meter.
Al energy is measured or or estimated by schablones. No energy meter at the entry of the client site.
IM is supplying the electricity; energy meters are installed in the traction units.
Same as with OCL Maintenance. Power management is very specific and required skill hard to maintain on small scale network. So, client site with dedicated power supply usually subcontract their management to our power supervision
Normally there is an energy meter specific for the client.
Most of Gb trains have on board meters, so no need for depot meters

CONCLUSION

In general, the connected clients have the same energy manager as the trains (IM, or independent organisation/cooperation)
Energy meters are sometimes installed on the traction units (except maybe 1 IM that would have an energy meter for the connected client)

Q10: How is energy consumption of locomotives allocated on these lines?

I think they are part of the cooperation managing the purchase and use of energy on the network. I don't know what key is used.
The energy consumption is measured in the same way everywhere. That is energy meter on the train or schablone estimation from kilometer and weight.
Same as for shunting areas.
the OCL of rail connected clients equipped with electrified railways but without their own power supply is linked to our line through a switch to enable us to disconnect their network in case of malfunction on their side. There is usually no specific line from our power station to their OCL, and no specific counter. As such they are mostly considered as part of the main network.
I have no information about this.
We have an agreed estimation method for trains that are not metered

CONCLUSION

It seems that the allocation follows the same rules as on the main lines

Alternative traction

Panto-battery, panto-diesel, hydrogen, …

Q11: Is there any current or upcoming legal/reglementary restrictions to the use of diesel train on your network (CO2, NOx, …) ?

Diesel is mainly used on a number of regional lines. There is not yet a national policy to electrify. Regional authorities sometimes decide to electrify a line. Sometimes the use of battery trains is being considered, but this has not yet led to a positive decision.
No. There are no current or upcoming legal/reglementary restrictions for the use of diesel trains on our network.
No other than the political direction to reduce carbon emissions on a global perspective.
I dont know about law evolution but political regional leaderships promote the switch to battery train as a replacement of diesel trains.
Government specifications for diesel trains are based in EC rules for emissions.
"No diesel only trains on the network by 2024" is the government statement, but nothing specific in legislation

CONCLUSION

There’s a general shift away from fossil fuels, but not massively translated in actions yet.

Q12: What diversification of type Tractions on your network are you expecting within the 10 next years to replace diesel tractions ?

Electric traction and batteries. Given the long decision-making and financing time, I do not expect battery trains on lines that have not yet been electrified within 10 years
That is hard to say, but battery trains is the most likely on our non electrified lines.
Electrical units and bimodal units (electric/battery)
We expect to have battery train to come online within five years. They shall be with a capacity to run up to 80/100 km on batteries and are expected on local line currently served by diesel trains
Main investments are focused in extending the electrified conventional network in 25kV, for both passengers and freights. Also, we are converting 3kV DC lines to 25kV AC. Battery trains and charging OCL facilities are only a far future project. No project has been started. The incumbent RU, is making some tests with hydrogen trains in metric gauge, but the IM has no relation with it.
Electric / battery / diesel

CONCLUSION

Consensus towards more electrification (with OCL and/or batteries)
Exception: one RU continues tests with H2

Q13: Do you see movement of your Railways undertakings toward such new technologies ?

There is some movement from the congestion problem.
Batteries can help to absorb peak loads. These peak loads cause disputes with the operators of the high-voltage grid.

There are no clear movement in that direction from RUs. But locomotives for shunting are considered by companies.

Yes. Some undertakings has invested in bimodal units.

movement seems to be mostly induced by public transportation services.
I don't see fret companies seeing battery train as an opportunity to offer greener transport services.

RU is interested in developing battery trains, but we don't have specific information.

Yes, no one want to buy diesel only trains

CONCLUSION

There is indeed a general (but slow) movement, mostly towards battery trains

Q14: Would you consider to ‘de-electrify’ some lines when such Alternative traction will become more popular ?

There is no movement to de-electrify existing electrified lines.
Not considered so far. But not likely to be something that we would do.
No. Fully electrified units and lines are more cost efficient than bimodal units in the long run.
We are already exploring de-electrifying some lines. Maintenance cost are very expensive for small services line with historical OCL. Bringing them up to date, especially to integrate the rise of temperature is unaffordable when the traffic is too low. So, we are exploring discontinuous OCL to lower maintenance costs while allowing battery train enough OCL length to charge correctly. It's an ingenious balance to find to keep OCL where it is needed (on climbing ramps for example) and remove it where simulations show a charged battery.
No, that is not considered. Battery trains are though as an alternative solution for low traffic lines, where the full electrification would be very expensive.
No

CONCLUSION

De-electrification is never considered,
EXCEPT for 1 IM where local lines could see some km of OCL removed and operated with battery trains

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Thank you
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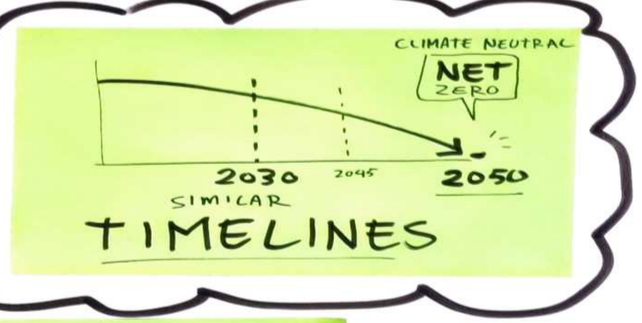
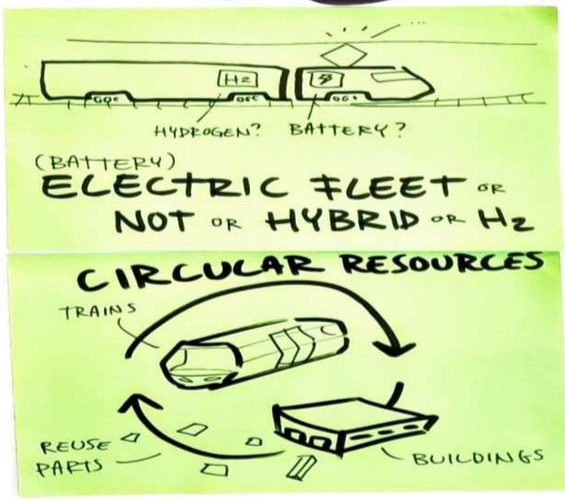
Feedback to plenary

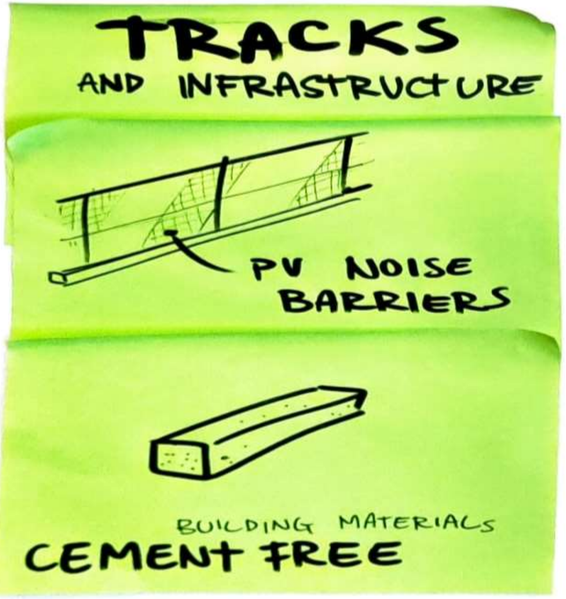
Rolling stock
Operation

Infrastructure
Buildings
Assets

LONGTERM ROADMAP for ENERGY EFFICIENCY and DECARBONISATION FOR INFRASTRUCTURE MGRS







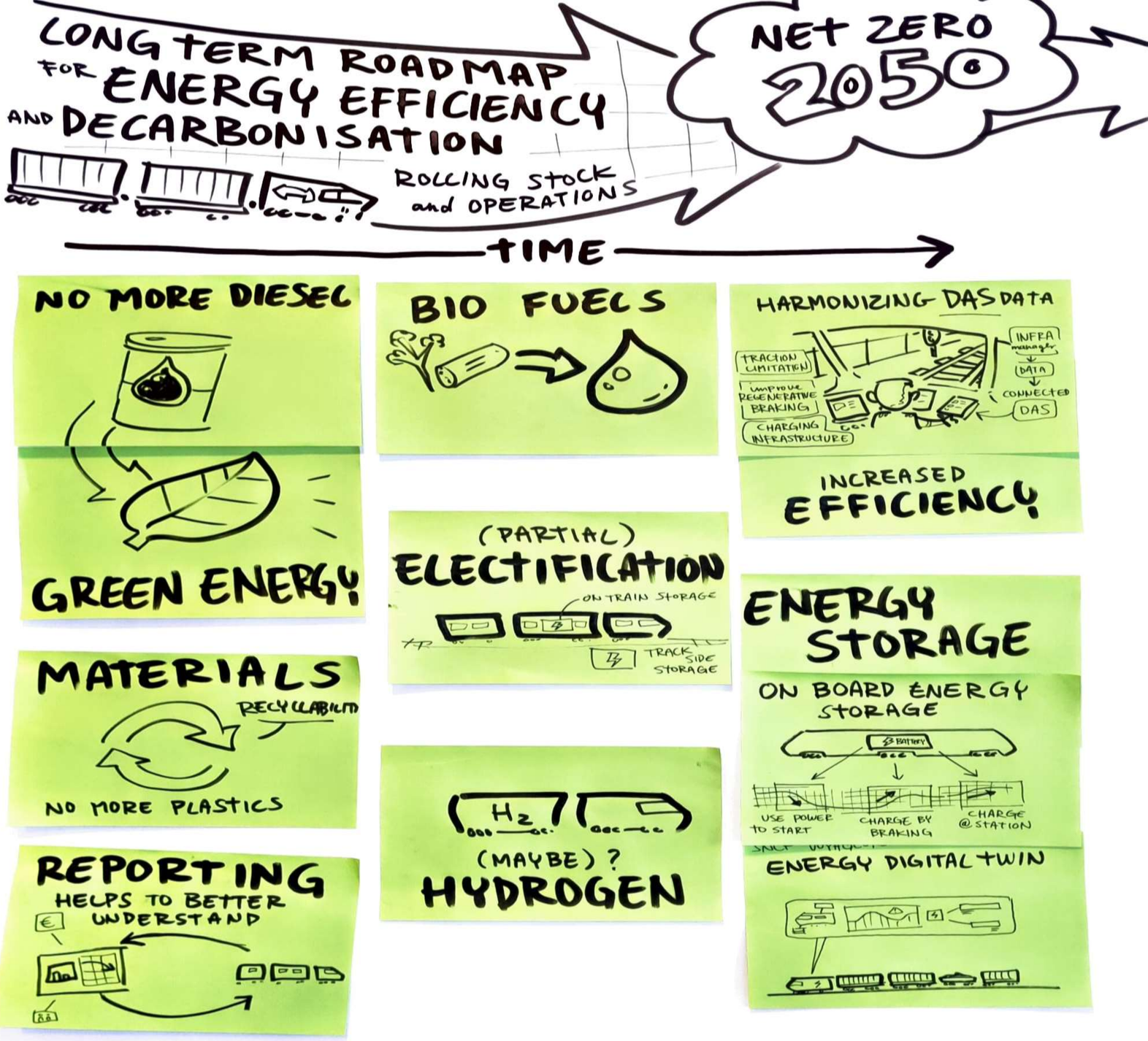
Infrastructure session feedback

- Good progress on data collection. Helps developing a good understanding on what to act. Still a lot of work to be done.
- Reuse of material is a new priority,

  Or reducing embedded CO2 with the supply chain.

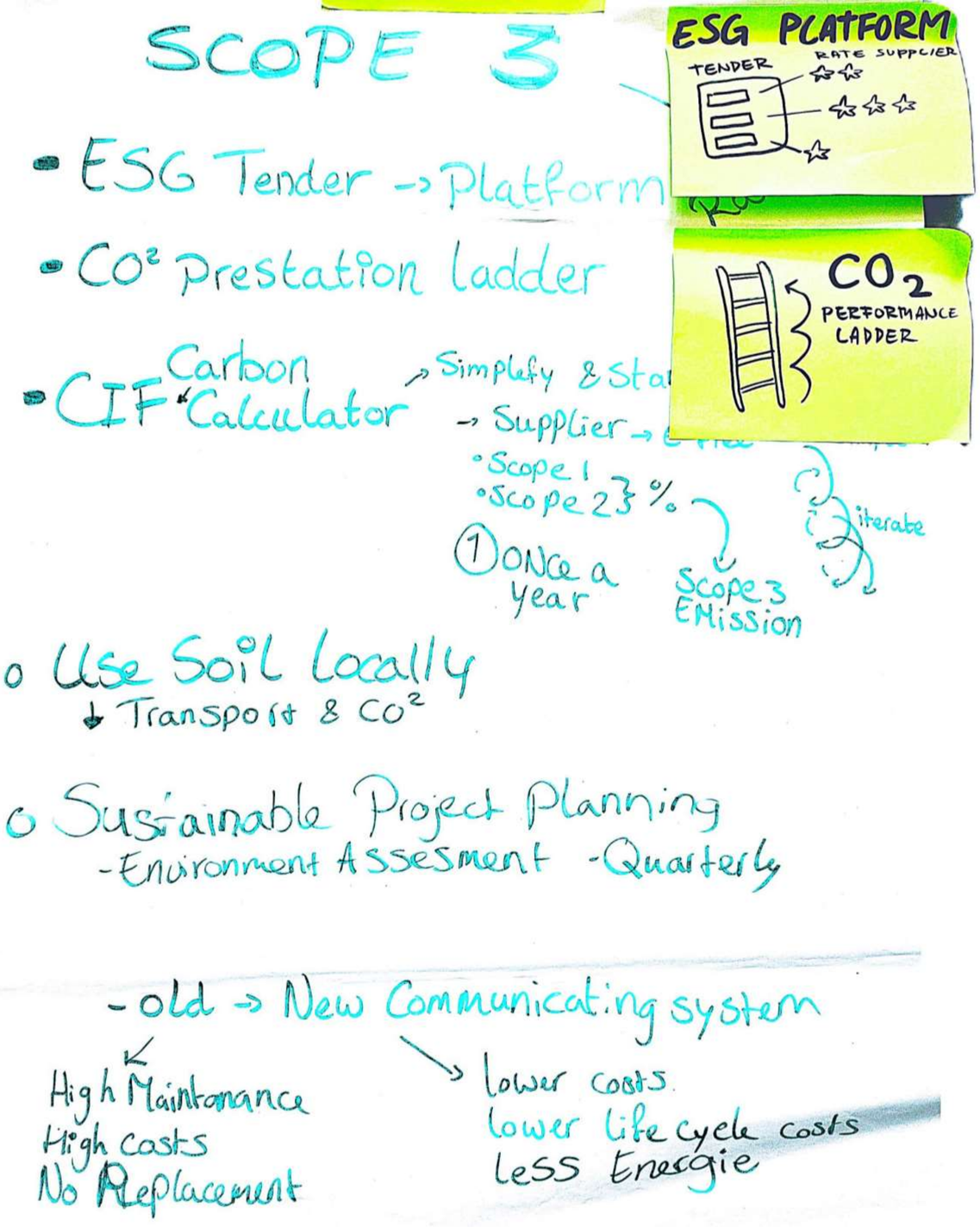
- A lot about yellow fleets has been discussed (Represents a lot of the IMs emissions). Reminds the strategy introduced by ProRail.
- Renewable energy integration is a pillar for IMs as well (mentions noise barriers)

Operation/Rolling stock session feedback



Feedback to plenary

ERPC
(European Railways Purchasing Conference)



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Media to be made available on the event page

Member repository

Thank you for your attention

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