Welcome to the best practice workshop

RENEWABLE ENERGY INTEGRATION IN RAILWAYS

Proposed by
the UIC Energy efficiency and CO_2 Emissions Sector

Organised by the Sector's core members:

Gerald Olde Monnikhof, ProRail
Susan van Leeuwen, ProRail
Bart Van der Spiegel, Infrabel
Christophe Gueudar Delahaye

Philippe Stefanos, UIC

17 November 2022

Workshop timeline

09h 35	**Welcome Introduction**	**Chairs and UIC**	
09h 40	Energy strategy - Vision and lessons learned	**Maarten Plasschaert**	**Infrabel**
10h 05	Photovoltaics installation – Strategy, Challenges	**Delia Harder** **Marcel Reinhard**	**SBB**
10h 30	Energy and decarbonisation of stations	~~**Violaine Jacolin**~~ **Laurent Mahuteau**	**SNCF Stations**
10h 45	*Break*		
11h 05	Photovoltaics partnership with EDF Renewables	**Denzel Collins**	**NR**
11h 30	Renewable power management into rail grid and storage	**Zhongbei Tian**	**Liverpool Univ.**
11h 55	Connecting a solar plant to ProRail's 1.5kV DC network	**Robert Heuckelbach**	**DNV**
12h 10	Study, technical and economic analysis for a large scale solar plant connection	**Paul Tobback**	**TUC Rail**
12h 30	*Lunch*		

Workshop timeline

12h 30	*Lunch*		
13h 45	Photovoltaics on stations program	**Jorien Maltha**	**ProRail**
14h 05	Solar panels deployment on stations	**Laurent Mahuteau**	**SNCF Stations**
14h 25	Insights from Innovation in Traction Energy in the UK	**Colin McNaught**	**Ricardo Rail**
14h 50	RaccorD – Smart DC for green traction energy	**Tony Letrouvé** **Hervé Caron**	**SNCF (IM)**
15h 15	NEWRAIL: Solar panels on existing noise barriers	**Gerald Olde Monnikhof** **Robert Bezemer**	**ProRail** **TNO**
15h 35	*Break*		
16h 00	*Technical visit or presentation* *Hyperloop test field*	**TU Delft**	

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INFRABEL

Energy strategy - Vision and lessons learned

INFRABEL

Maarten Plasschaert

ENERGY STRATEGY

Vision and lessons learned

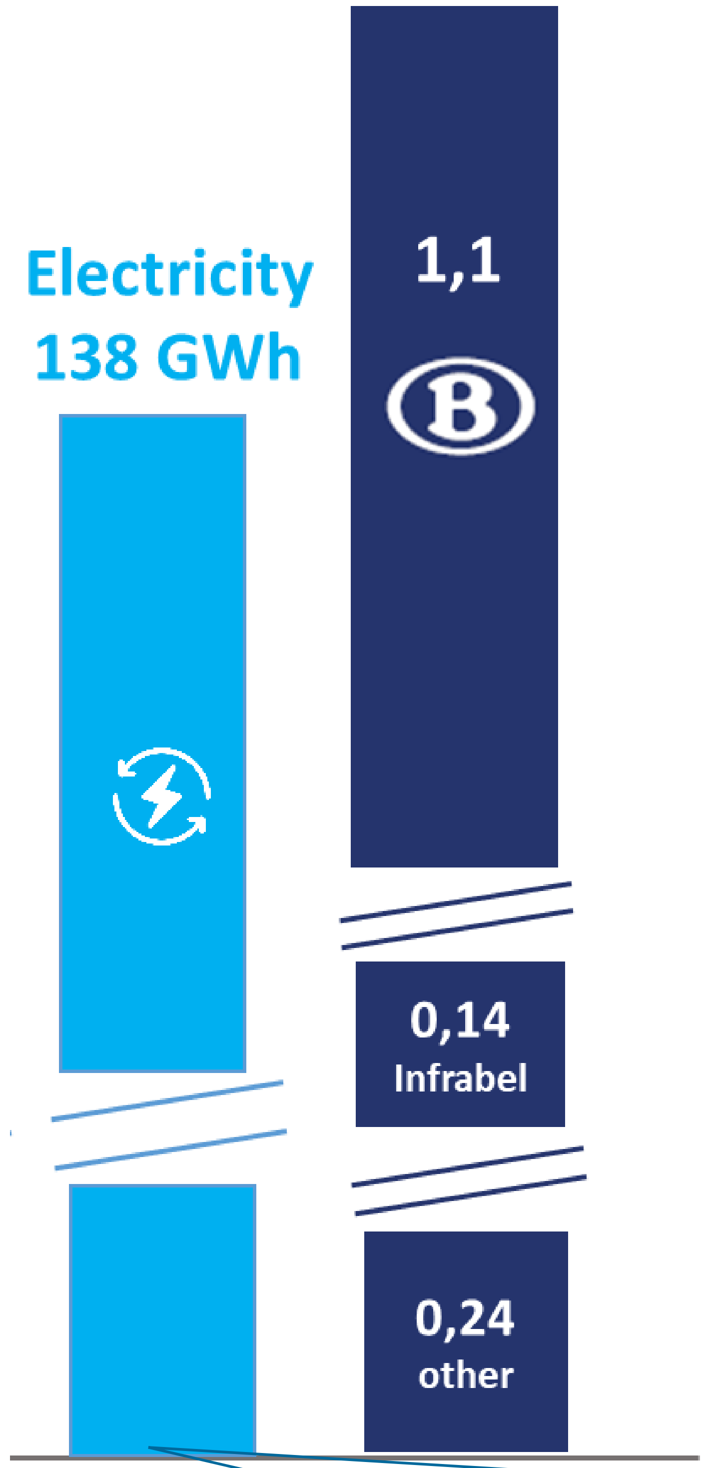
Maarten Plasschaert
CEO Advisory

Nov 2022

Basics about Infrabel- Belgian Infrastruct Mgr

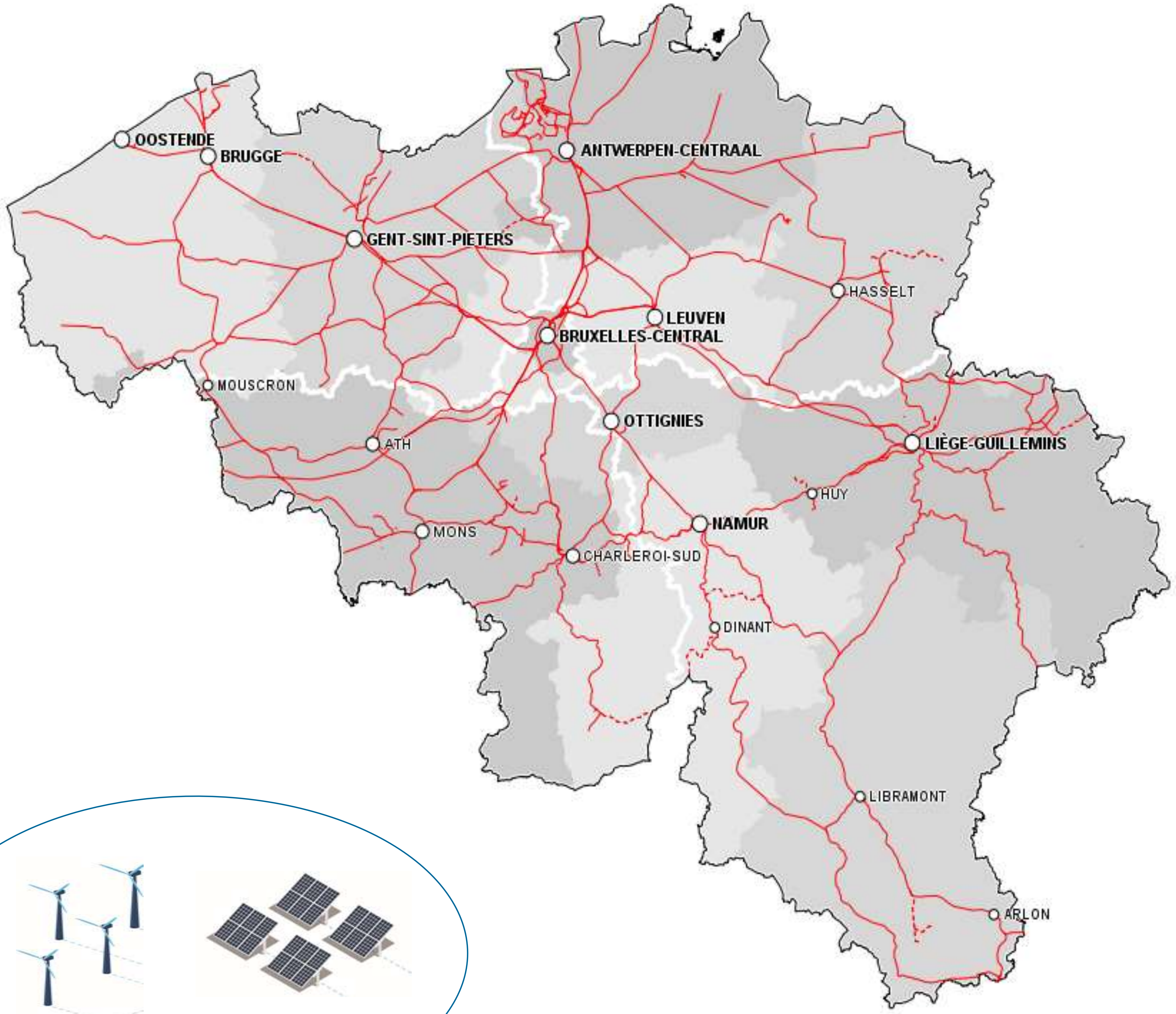
Purchased electricity railway 1,5 TWh

Electricity 138 GWh



23 Gwh

5 Gwh



Regular Segment

3398 km

3kv DC

High Speed Segment*

214 km

25kv AC

** Some lines in Ardennes*

Energy Transition & Savings projects

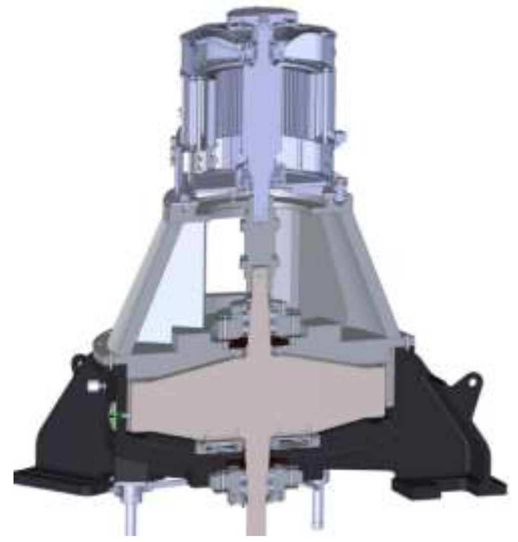
Bi-mode Measurement trains

Reduce nr of
buildings

Transition & reduction car park

Reëvaluate energy scans

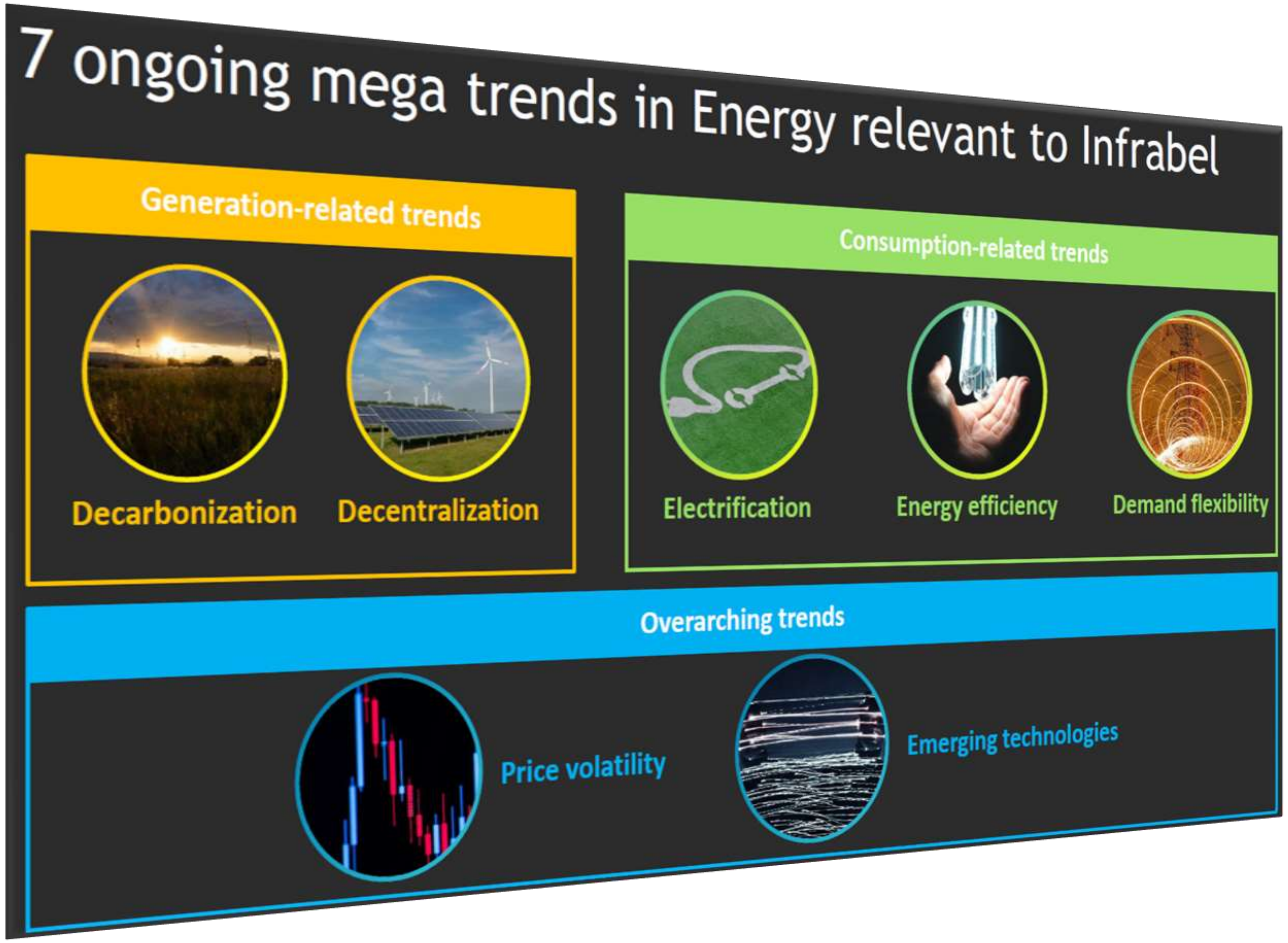
Roll-out automated steering swtich
heating



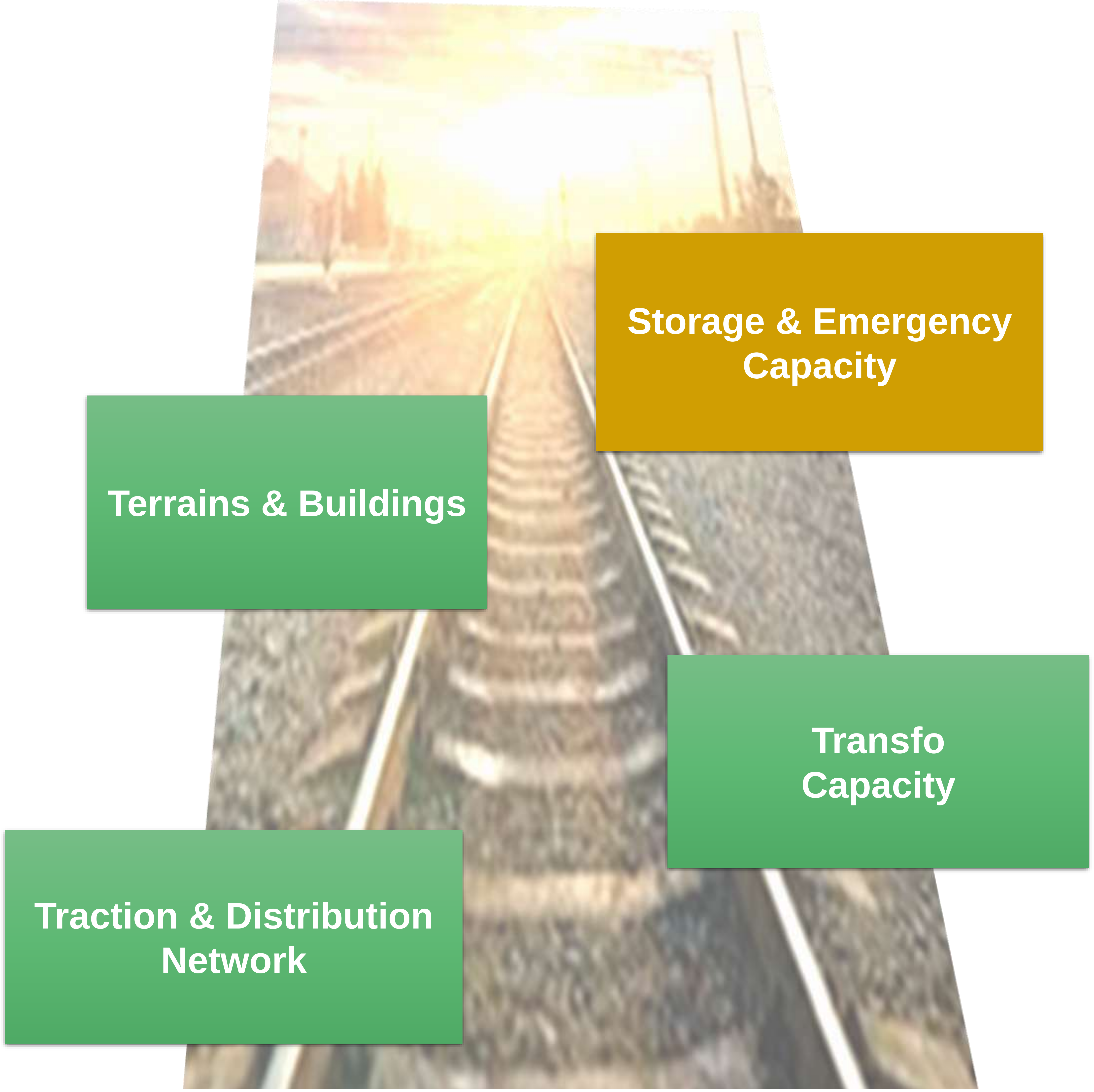
Temporary storage
traction energy

Ambition for Climate Neutrality

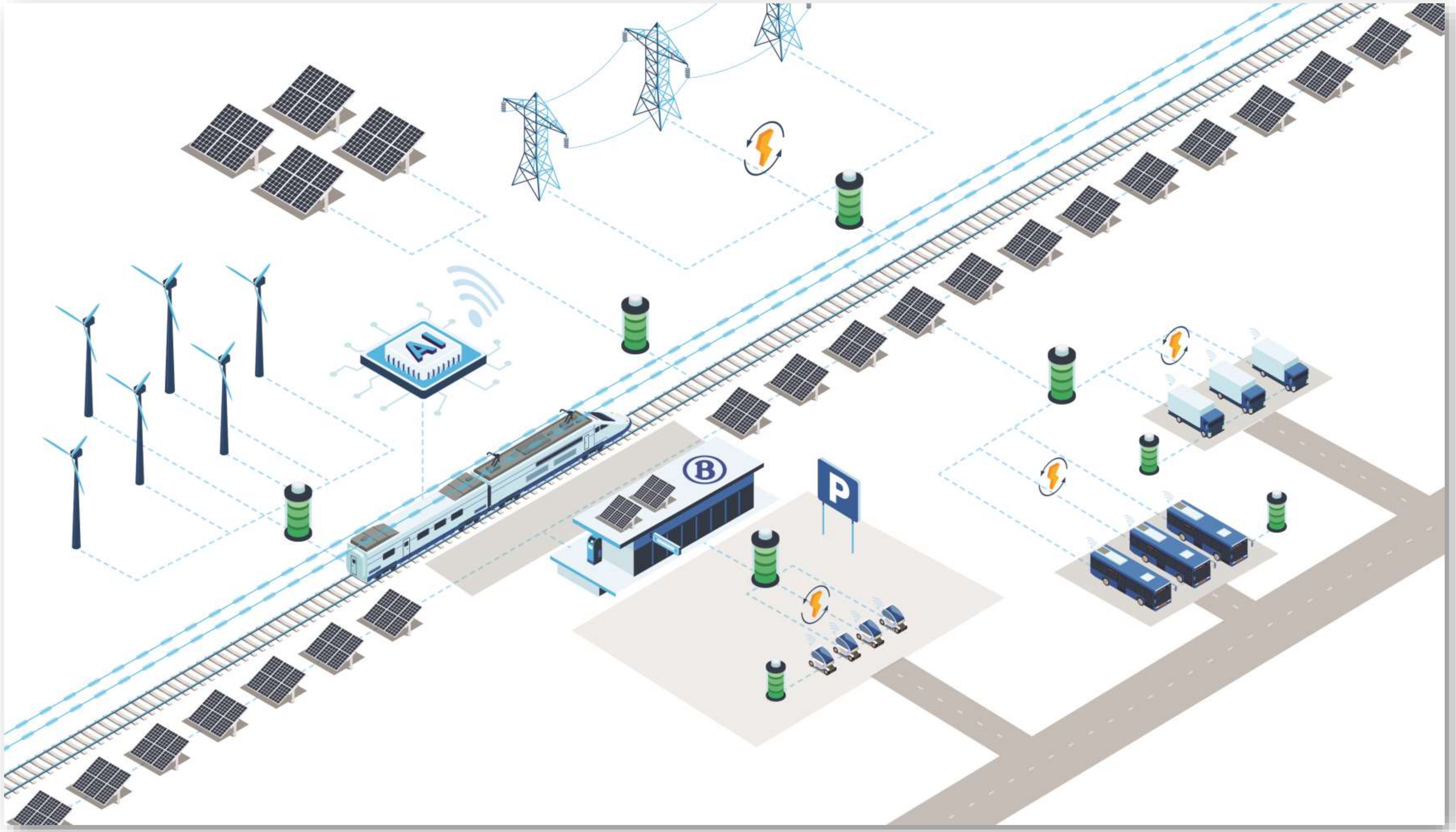
Energy Strategy Assessment

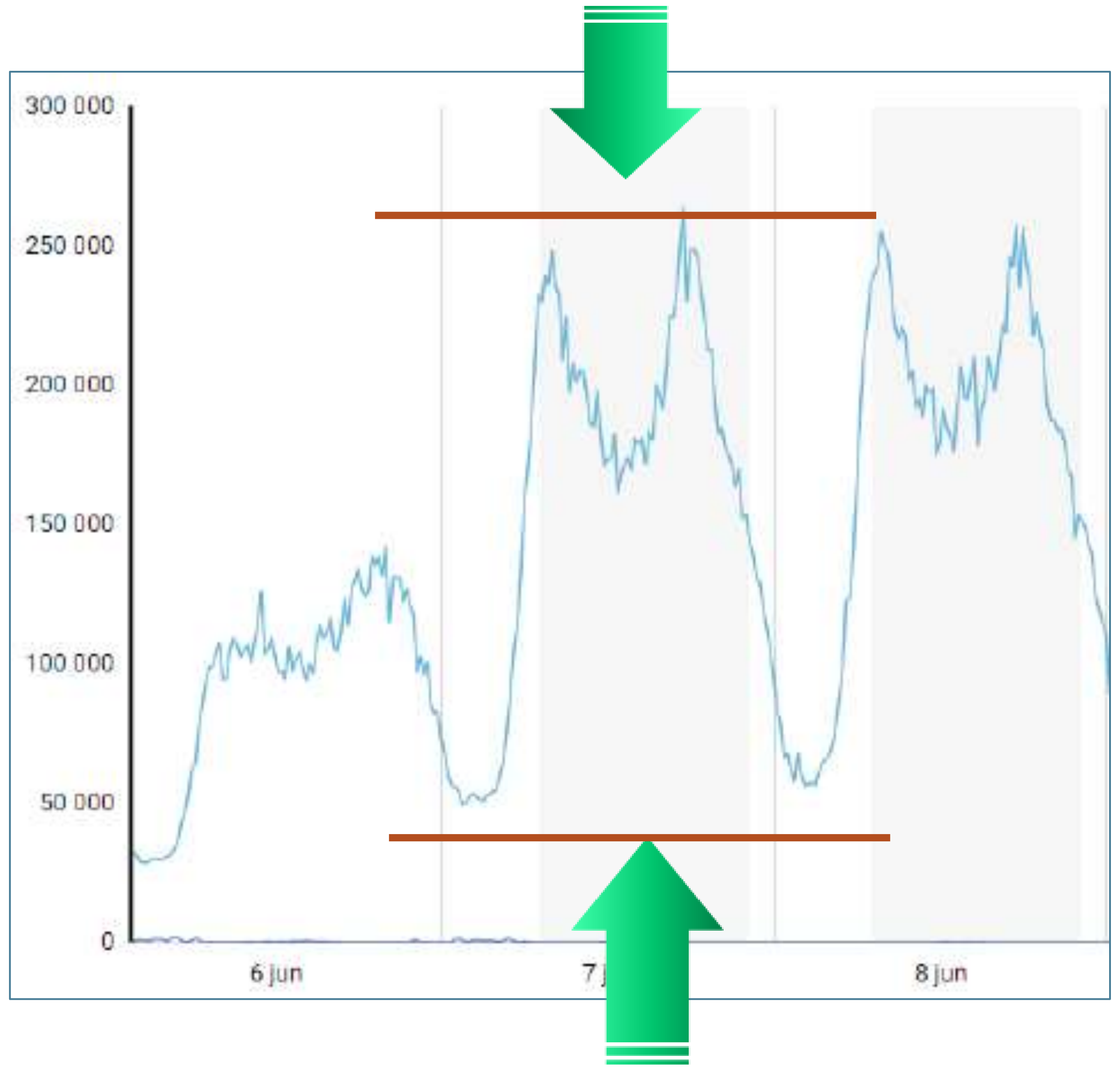


SWOT Analysis



Infrabel Energy vision

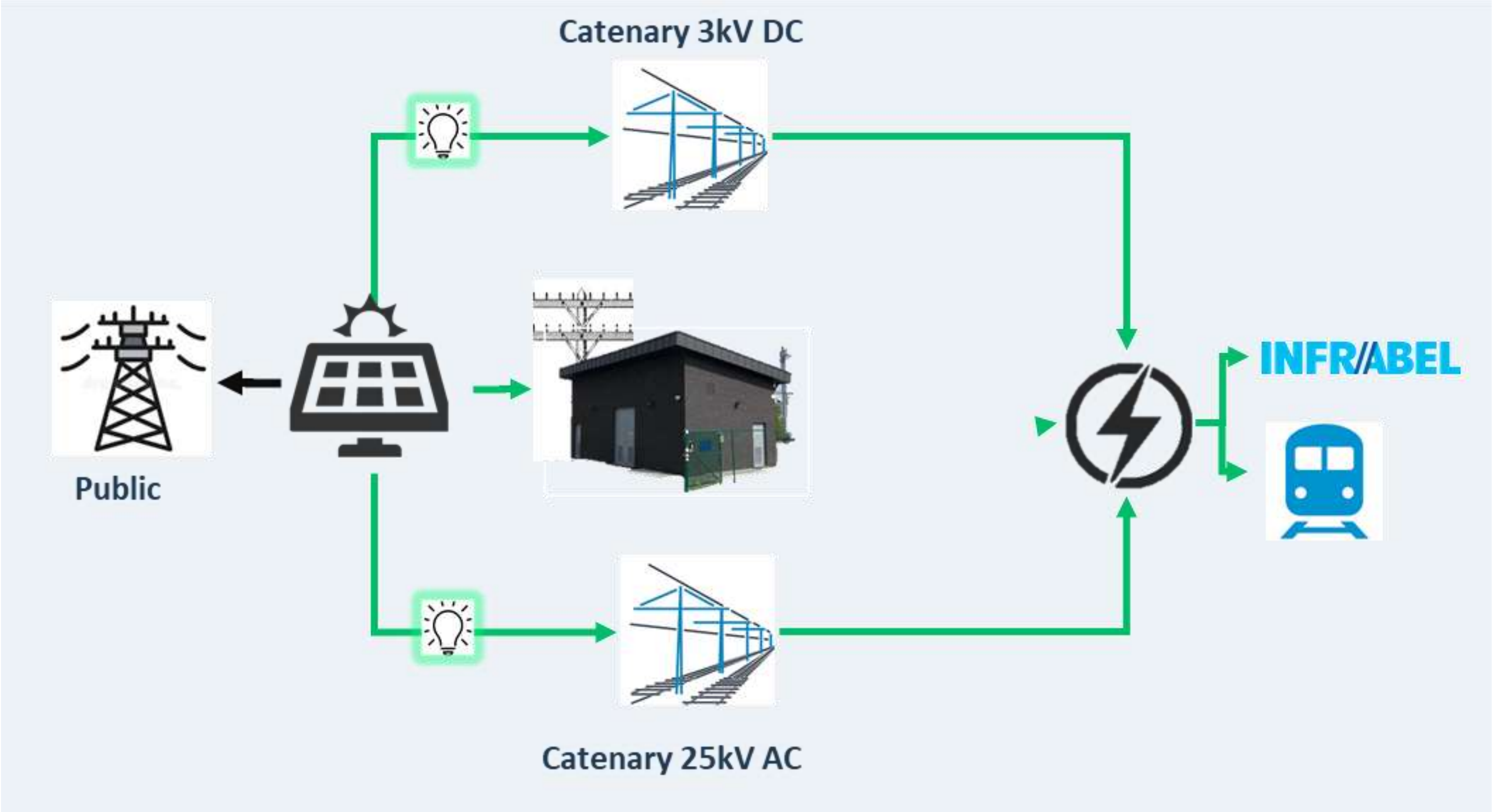


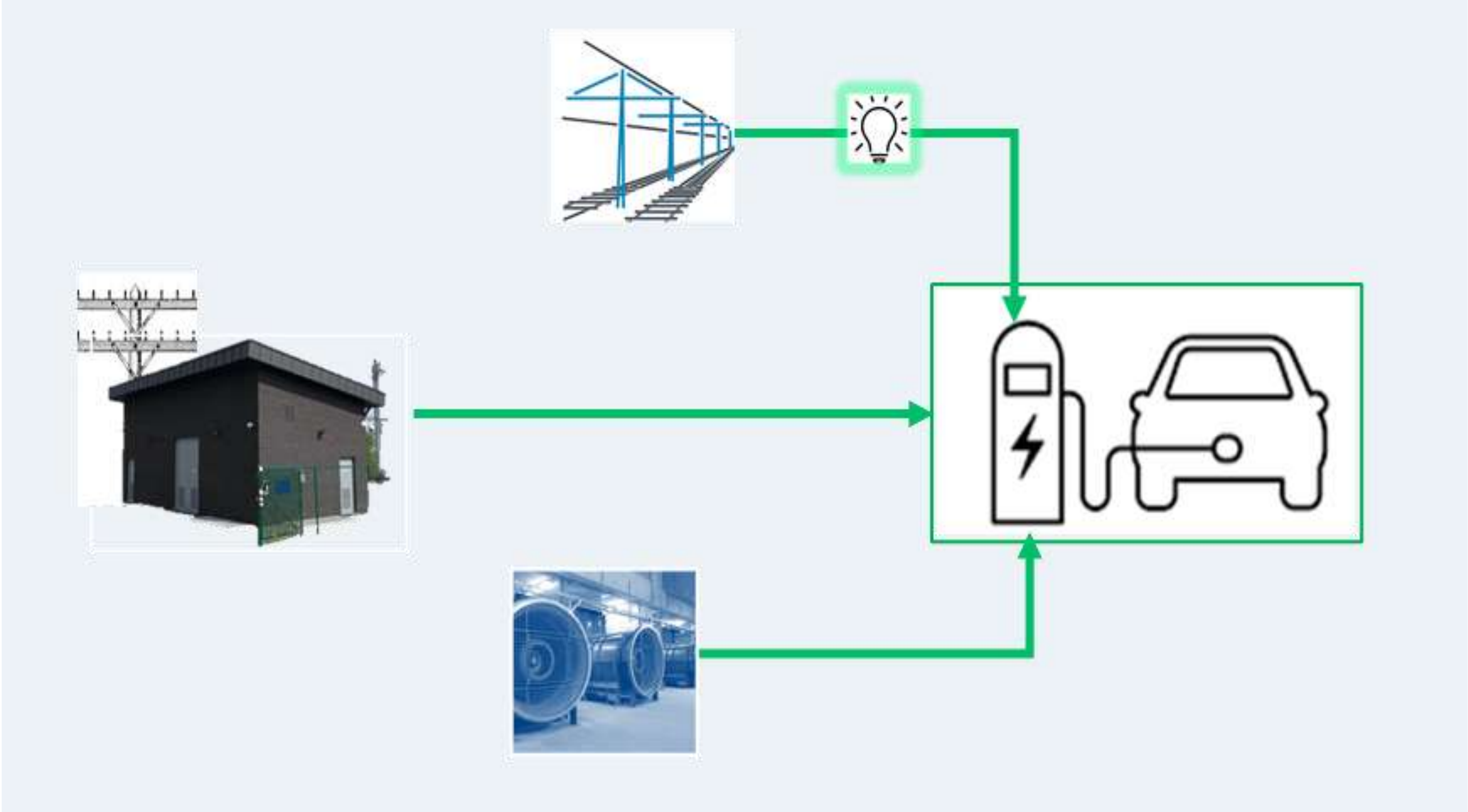


Energy Strategy 1.0

Solar Panel installation

Electric feed for EV charging





Challenges & Lessons learned

Challenges

- Regulations limit Infrabel's opportunities
- Negotiations with railway undertaking
- Uncertainty price EV panels & electricity
  ⬄ LT commitment
- Funding projects

Lessons Learned

- The Infrabel ⚡ net is not known publicly
- New opportunities allow for innovation
- There is a strong demand for transfo capacity

The train is leaving the station.....but you can still hop on...

Questions

Discussion

Thank you for your attention.

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INTERNATIONAL UNION OF RAILWAYS

SBB

Photovoltaics installation – Strategy, Challenges

SBB CFF FFS

Delia Harder Marcel Reinhard

SBB CFF FFS

PV strategy, projects and challenges.

UIC Meeting «Renewable energy integration in railways»

Delft, November 17th, 2022

Delia Harder, Marcel Reinhard

PV strategy

Photovoltaics 50Hz (household electricity)

Roof-mounted and roof-integrated PV systems for the generation of electricity for self-consumption on SBB buildings such as railway stations, industrial plants or office buildings. Financing through PV contracting or commercial/governmental financing.

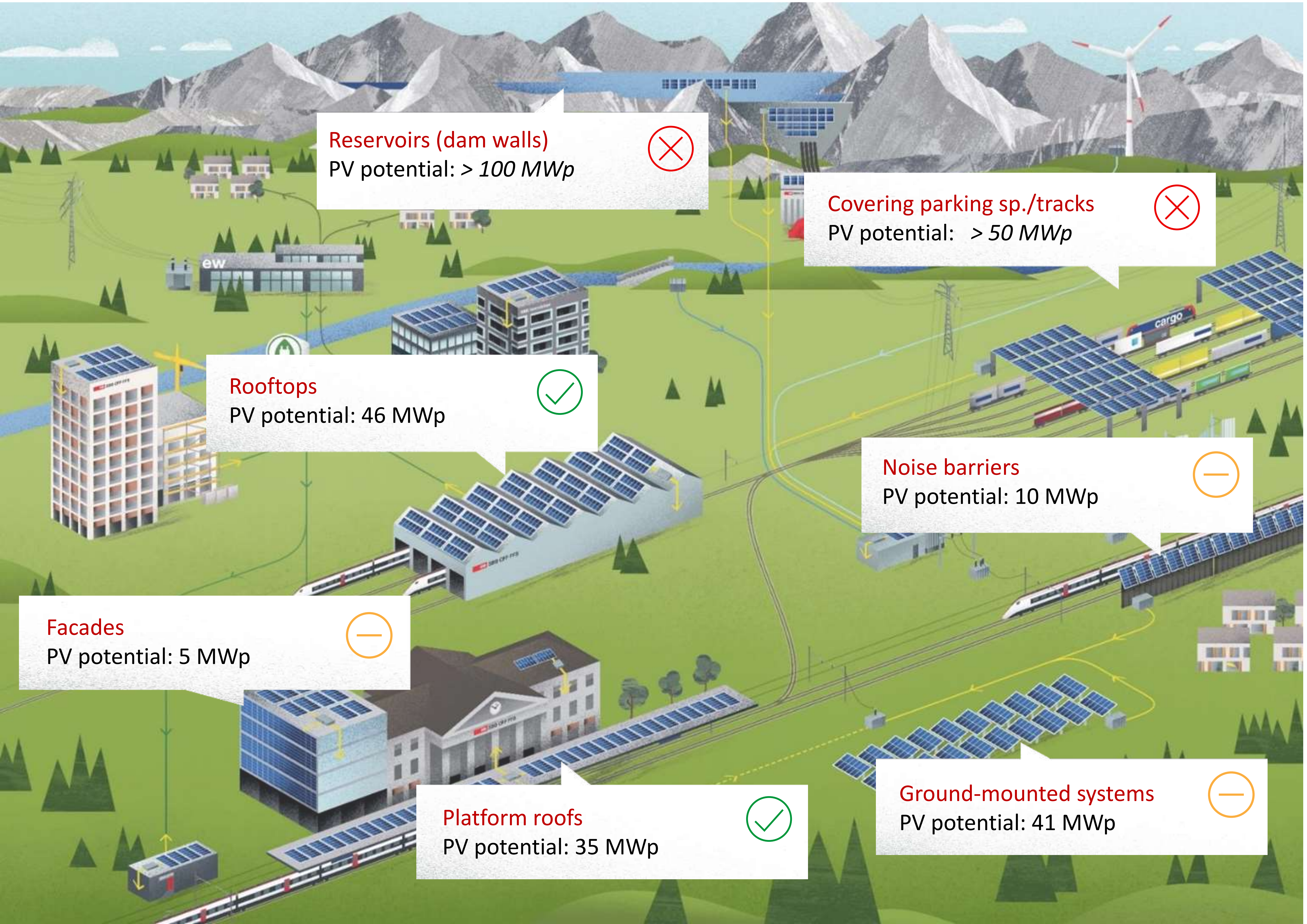
30 MWp by 2030

Photovoltaics 16.7Hz (traction current)

Direct feed-in of PV power into the 16.7Hz traction power grid to supply trains and railway facilities, with a focus on large-scale systems from approx. 0.5 MWp (rooftop or ground-mounted systems). Implementation via PV contracting or electricity supply contracts.

120 MWp - expected economic potential

PV potential 50 and 16.7 Hz



PV potential of the SBB

Technical-economic PV potential of SBB of around 150 MWp.

Implementation status

48 PV plants in operation
→ 6.0 MWp

153 technically and economically feasible
→ 18.4 MWp

51 Feasibility proven through studies
→ 12.9 MWp

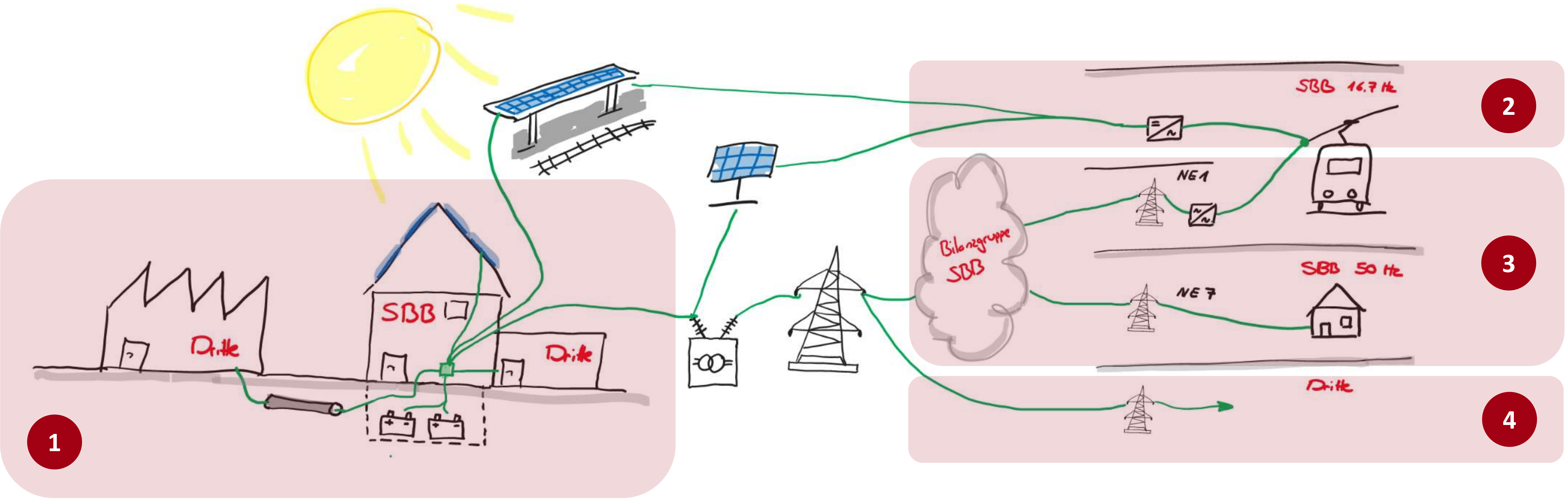
27 First-cleared properties
→ 8.6 MWp

In implementation

Piloting underway, rollout pending

In-depth analysis necessary, piloting pending

Own consumption and marketing of electricity



1. Optimisation of own consumption (Inter-connection for own consumption, DSM,…)
2. Direct feed-in into the overhead contact line network
3. Balance group
4. Electricity marketing

PV on noise barriers (NB) – facts and restrictions

SBB owns 400 km noise barriers.
→ Biggest PV Potential is on existing barriers.
→ New NB projects only 1.6 km per year till 2030 (average).

- PV only allowed on the side facing away of the tracks (reasons: wind load & blinding & noise protection)

- PV not protruding the wall (static reason – wind load)
- NB must remain inspectable, see construction example.

- PV on NB is more expansive than on roofs. Rentability depends on feeding point and self-consumption which is mostly not the case.

Next steps: Building PV prototypes for a) existing walls and b) new wall in an infrastructure expansion

a) Challenges: Get money for a not existing process! PV installation time 2 years.

1. pre-study with examination of 2 possible site
2. Pre-project with exact feeding point, static examinations, cabling…, approval process (6-9 month through federal office of transportation)
3. Building-project
4. Install a new process: “Building PV on existing NBs”

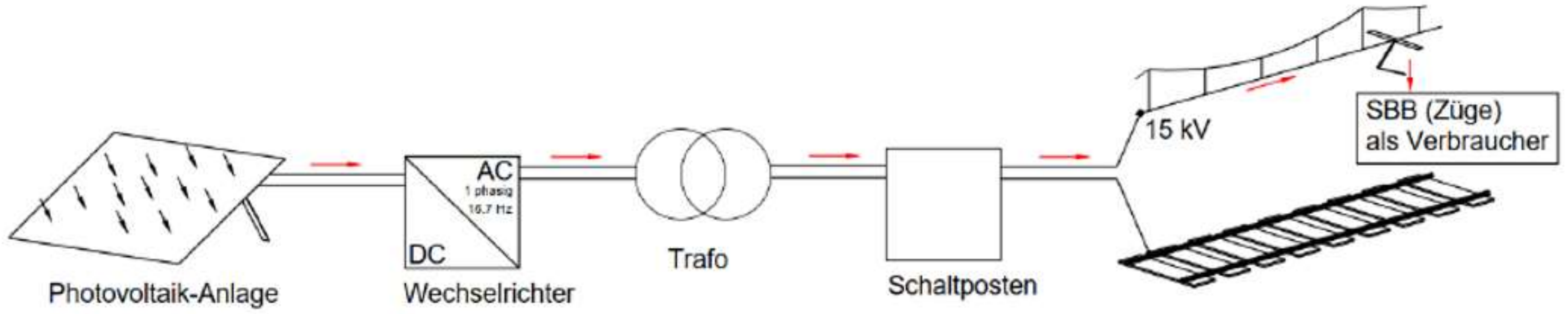
b) Challenges: PV will be built in 5-10 years, but financing is easier. Less potential.

1. Implement a PV check in the regular building process infrastructure.
   If a new infrastructure project contains a NB, then check the possibility of PV according the delivered documents (as SBB does on buildings).
2. Follow the project phases and install PV, if rentable (financing through the project).

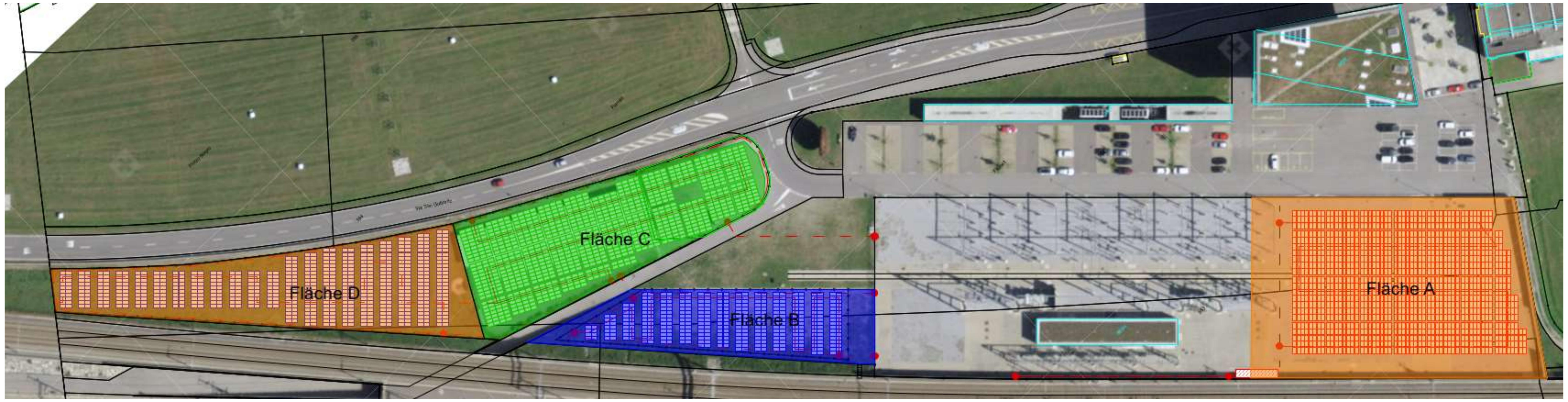
PV UW Pollegio

Pilot project ground-mounted PV system with direct feed into the overhead line network

- Power: 1’163 kWp / 1’000 kVA
- Grid connection via substation busbar
- Inverter: 4 x Vensys Vencon 250 kVA
- Phase number, frequency and voltage:
  - 16.7Hz, 15 kV, 1 phase



- Expected price of electricity ~ 9.5 Rp./kWh
- In operation end of 2023 / beginning of 2024




SBB CFF FFS
Thank you.

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SNCF GARE & CONNEXIONS (STATIONS)

Energy and decarbonisation of stations

Laurent Mahuteau

SNCF Group

SNCF

Jean-Pierre FARANDOU
PDG

SNCF RESEAU

Luc LALLEMAND
PDG

SNCF GARES & CONNEXIONS

Marlène DOLVECK
DG

SNCF VOYAGEURS

Christophe FANICHET
PDG

SNCF FRET

Frederic DELORME
PDG

KEOLIS

Marie-Ange DEBON
Pres. Du directoire

GEODIS

M-Christine LOMBARD
Pres. Du directoire

SNCF Gares & Connexions is the specialist of the station, from its design to its operation, through the marketing of its spaces. It serves carriers of all modes, communities and the 10 million travelers, visitors and residents it welcomes every day. It is renovating and developing the 3,000 railway stations in the French network. These missions call for a strong commitment from its teams to improve the quality of operations, imagine new services and modernize the heritage.

Group S.A. | Subsidiary

Key figures

ACTIFS

4 700
EMPLOYEES
AND 15 000
PEOPLE WORKING IN
STATIONS

10 MILLIONS OF M²
INCLUDING 8 MILLIONS OF
M² OF PLATEFORM

10 MILLIONS OF
VISITORS PER DAY

180 000 M²
OF RETAIL

+ de 3 000
STATIONS (OF VARYING
SIZES)

RESULTS 2020

322 MILLIONS €
OF INVESTEMENTS

1,5 BILLION €
IN SALES

157 MILLIONS €
OF RETAIL SALES IN
STATIONS

878 MILLIONS €
OF TRAIN TOLLS

SNCF GARES & CONNEXIONS

Our roadmap pillars to 2025

CLIENTS
Être le catalyseur de la révolution en cours des usages de la mobilité pour tous nos clients, BtoB et BtoC

HUMAIN & SOCIETAL
Être une entreprise inclusive où il fait bon travailler

QUALITÉ DE PRODUCTION ET DE SERVICE
Être en capacité de délivrer une exécution de grande qualité dans tous nos métiers

PERFORMANCE ECONOMIQUE
Être dans une dynamique de croissance du chiffre d'affaires et de baisse des coûts

TERRITOIRES
Être le spécialiste de la gare au service de tous les territoires

ENVIRONNEMENT
Être le spécialiste de la gare verte

SÉCURITÉ ET SÛRETÉ
Être le garant de la sécurité et de la sûreté dans les gares

ENERGY & CARBON

SNCF Gares & Connexions

Violaine JACOLIN

Energy consumption & carbon footprint of the SNCF Group

Legal context imposes a reduction in the energy consumption, buildings>1 000 m², 336 stations **- 40% by 2030, - 50% by 2040 and - 60% by 2050,** compared to a year selected between 2010-2021 (baseline).

Energy : Comitment of the group SNCF to decrease -25% throught 2030 (vs 2019)

Energie & carbon Performance

Get out of the fuel (2022 : in remain 96 stations) à 2025

Energy : Comitment of the group SNCF to decrease -50% throught 2030 (vs 2019)

Energy consumption & carbon footprint of the SNCF Group

	Carbon emissions	Energy consumption	
SNCF group	1 079 kt CO_{2eq} in 2021	16 411 GWh in 2021	Including traction energy (train) 9 405 GWh
Gares & Connexions	34,4 kt CO_{2eq} in 2021	268 GWh in 2021	

Our energy mix breakdown :

- 68% electricity
- 23% gaz
- 4% Heating network
- 4% fuel

SNCF has the aim of been “carbon neutral” in 2050.

2 guides lines :

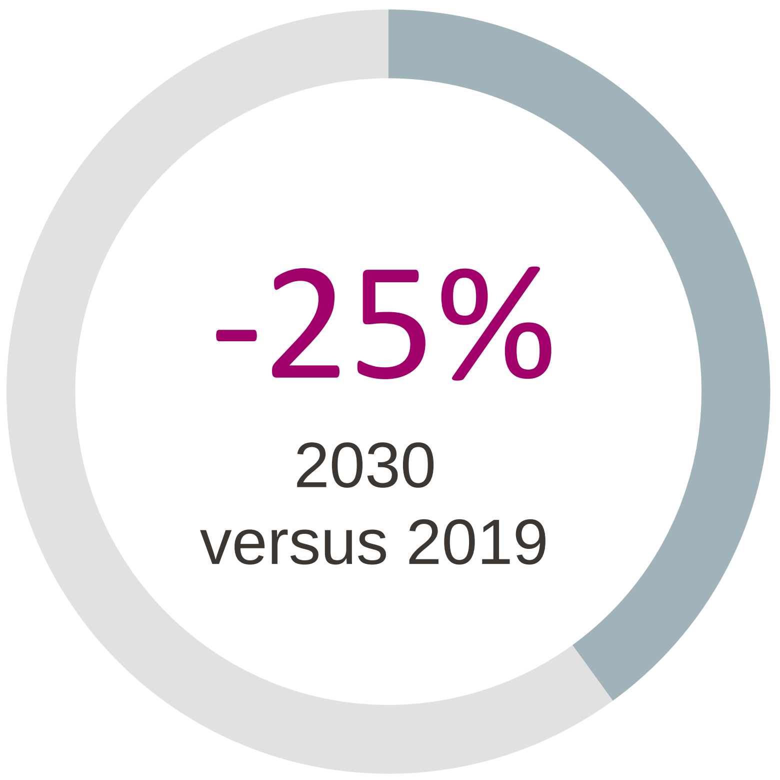
- Get out of the fossil energy
- Decrease strongly the energy consumption

The carbon neutrality is the aim of the French Government which has voted a Low Carbon National Strategy (SNBC : Stratégie National Bas Carbone) in 2015.

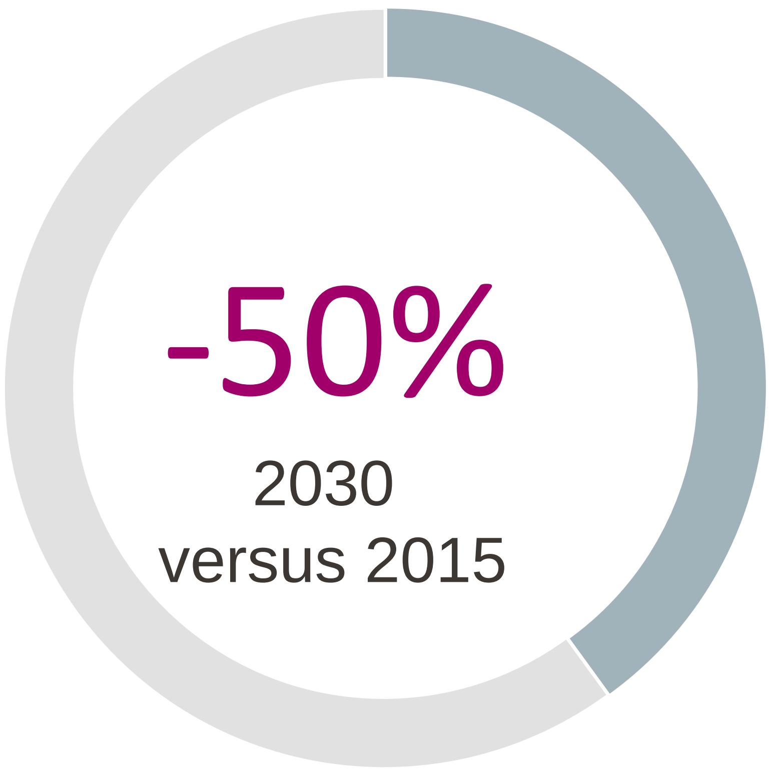
Energy consumption & carbon footprint of SNCF Gares & Connexions

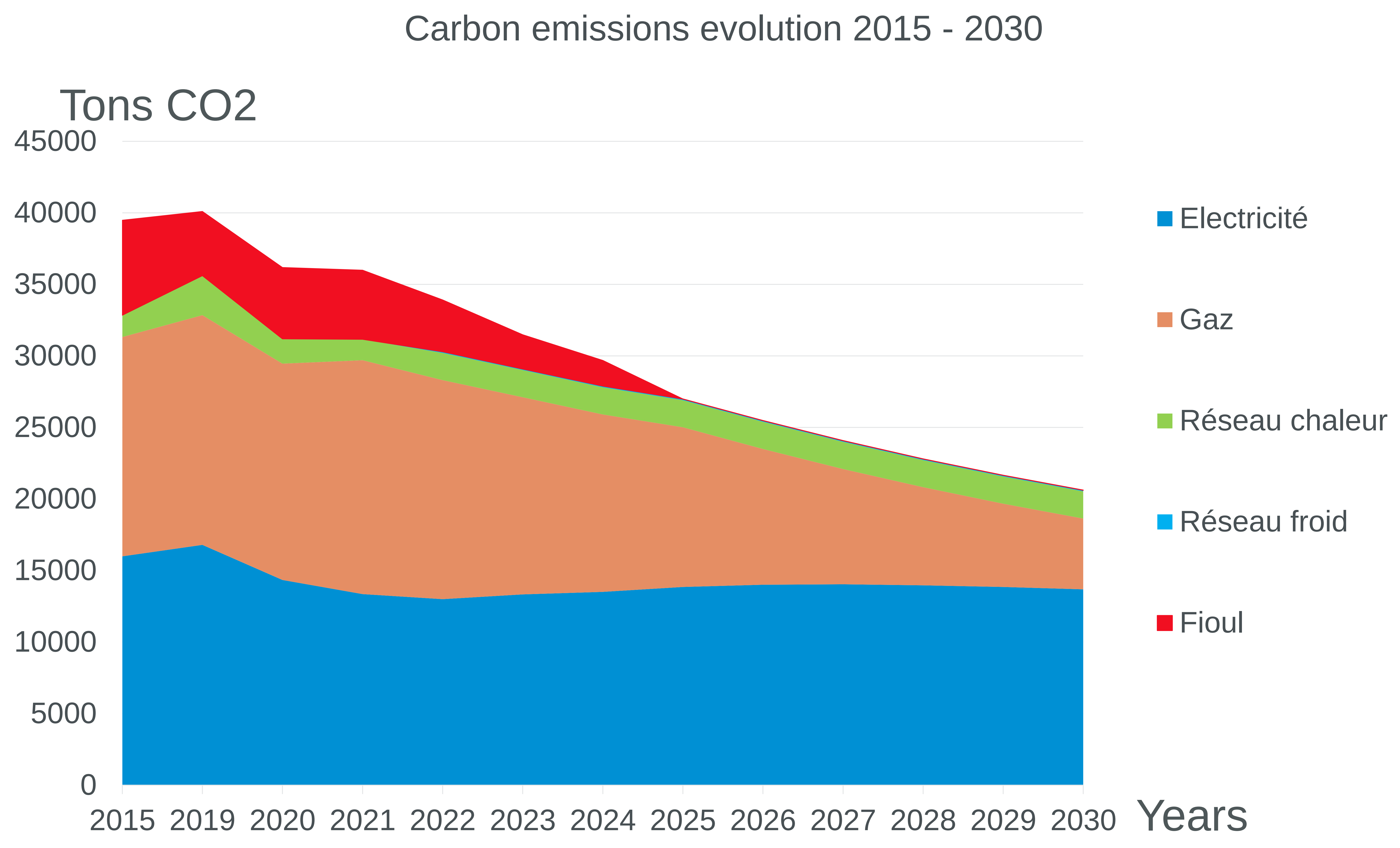
Objectives in 2030

ENERGY CONSUMPTIONS



CARBON EMISSIONS





Strategy for the decrease of Energy & carbon

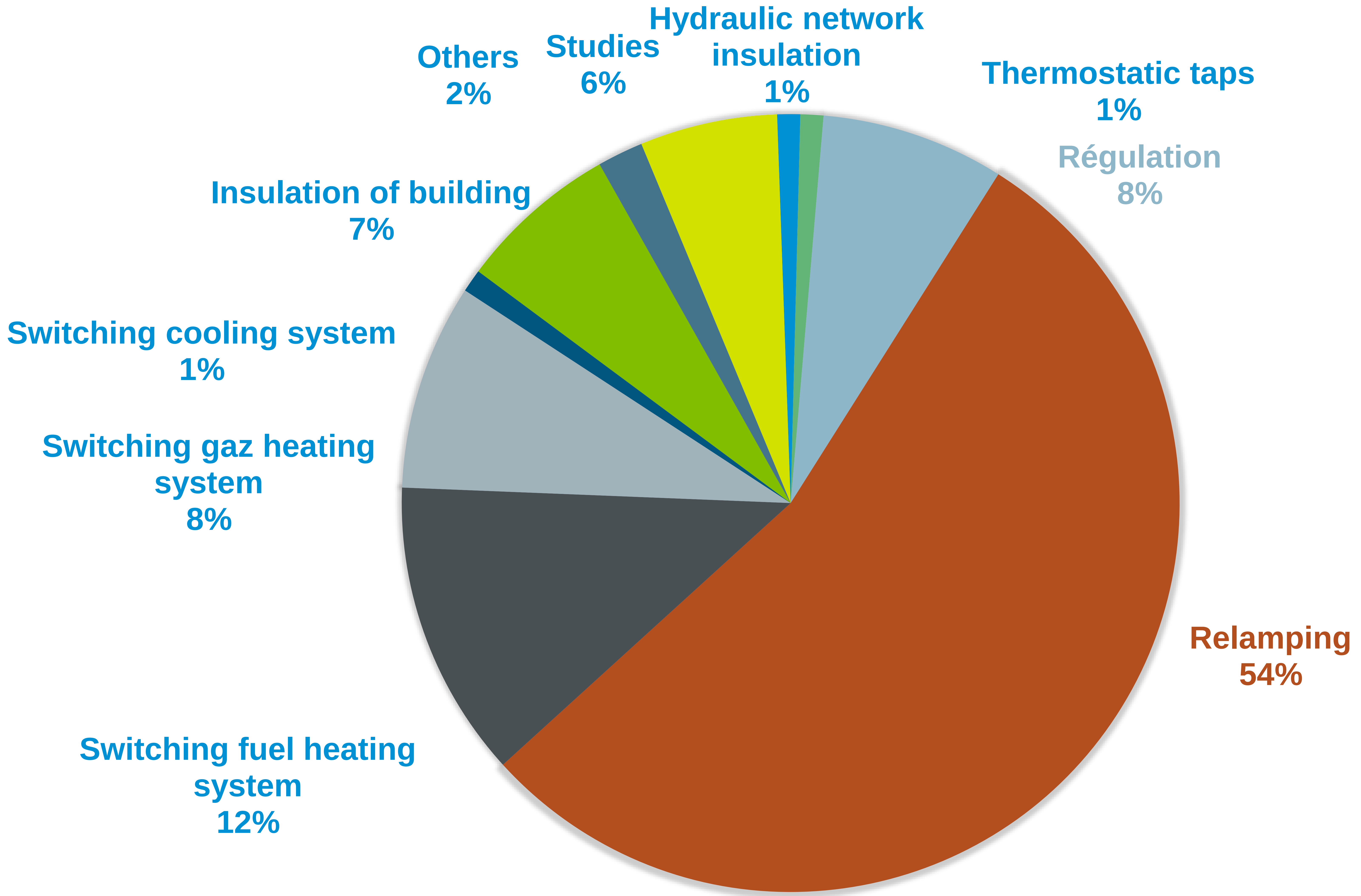
SNCF Gares & Connexions aims to invest **120 Millions € through 2030**

- We've already identified this kind of projects :
  - Relamping
  - Switching the heating system
  - Tools to control the equipments
  - Building renovation (insulation, new windows…)
  - Sensibilisation & formation of the employees

We also work with Retail & Connexions in order to reduce impact of our shops.

Strategy for the decrease of Energy & carbon

In 2022, we have already decided to invest **10 Millions €** on 120 projects.

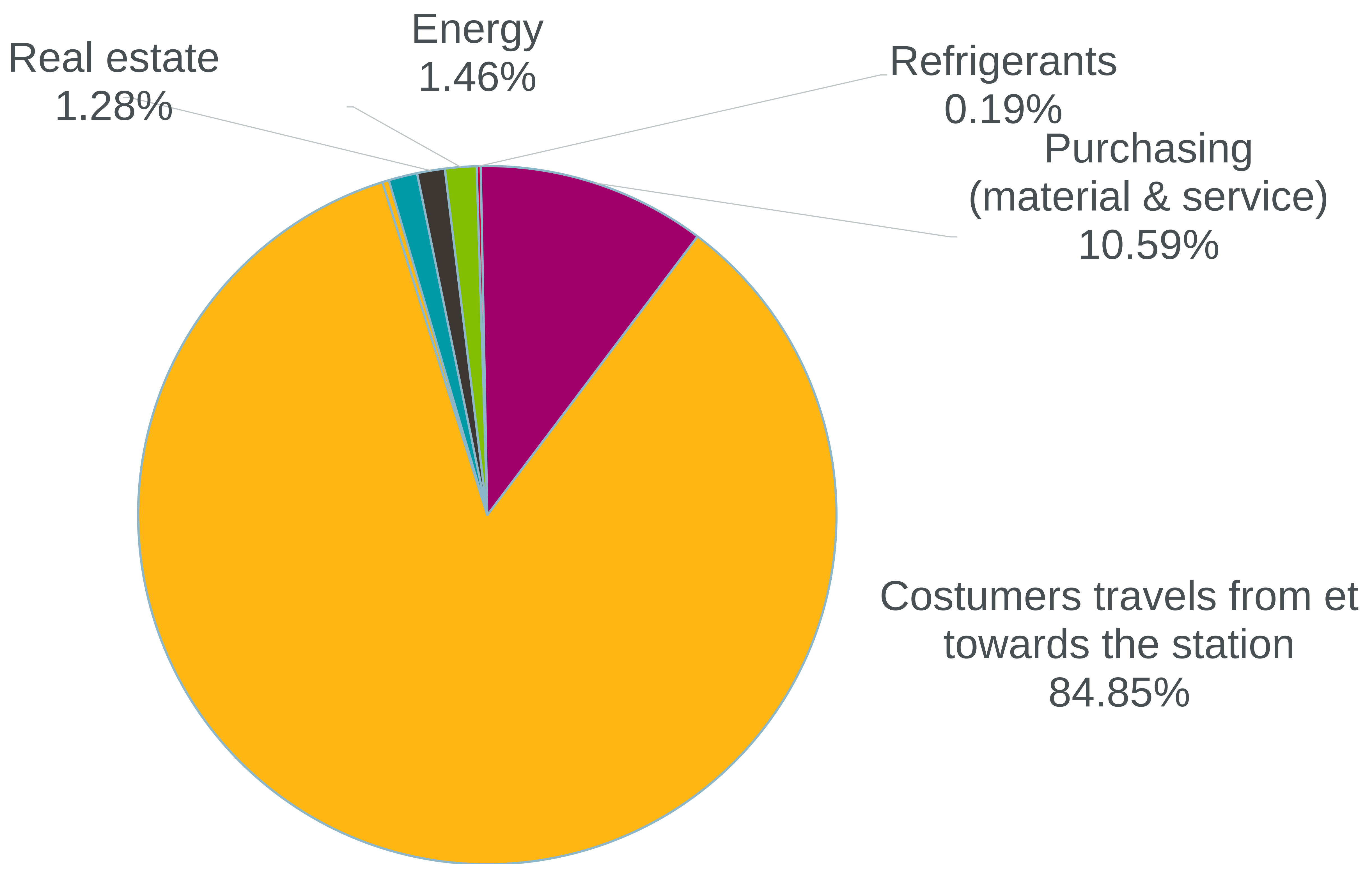


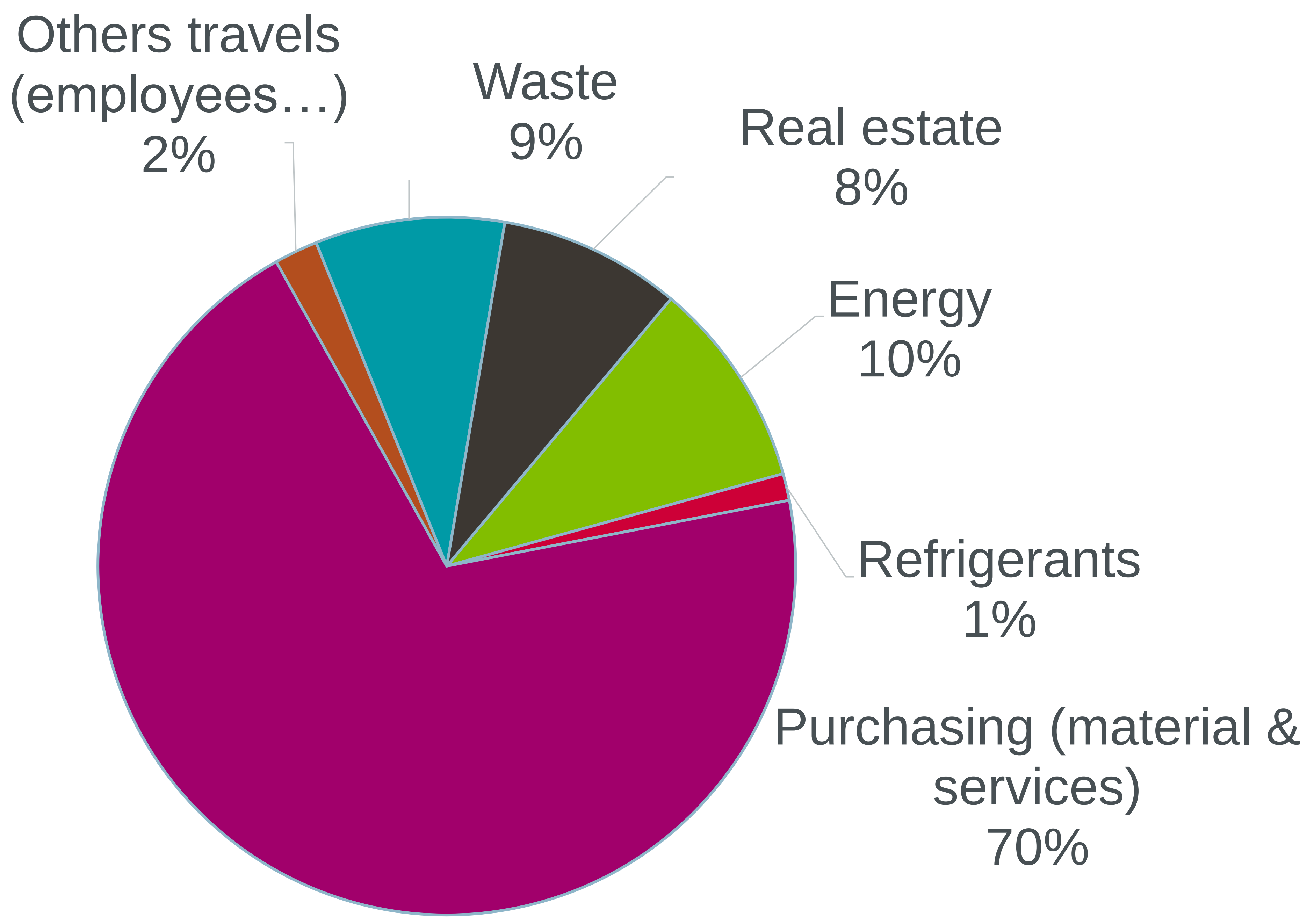
Carbon emissions for Gares & Connexions

Carbon evaluation

We need to work on :

- The way the costumers go to and from stations
- The way we build our buildings





Emissions Gares & Connexions
Without costumers travels

Questions

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Thank you for your attention.

Break

until 11h05

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NETWORK RAIL

Photovoltaics partnership with EDF Renewables

Denzel Collins

NETWORK RAIL

Solar PV Partnership with EDF Renewables

Denzel Collins

17th November 2022

NetworkRail

Low Emission Strategy Milestones

Serving the nation with the cleanest, greenest mass transport (Environmental Sustainability Strategy, 2020).

- **2022** – 25% of cars and vans are ultra low emission vehicles
- **2023** – Achieve PAS 2080 compliance
- **2024** – Establish whole life carbon baseline
- **2024** – Reduce energy use by 18% and carbon emissions by 25%
- **2025** – *75% of our suppliers by emissions to set science based targets.*
- **2026** – Demonstrator projects to support locally-generated renewables to power traction.
- **2027** – 100% of cars and vans are zero emission vehicles
- **2029** – Transition away from natural gas
- **2030** – Directly feed in 100% electricity from renewable sources.
- **2035** – 100% entire road fleet are zero emission vehicles
- **2050** – Network Rail will be net zero (2045 in Scotland).

Network Rail's Renewable Energy Strategy

- Strategy sets out a plan to transition from purchasing renewable energy to directly feeding electricity from renewable sources by 2030.

- A large majority of our energy needs will be backed by Corporate PPAs with the remainder covered by private-wire PPAs or self-funded schemes.

- First Corporate PPA to provide up to 20%of our non-traction energy and demonstrate carbon savings (additionality) at an affordable unit price.

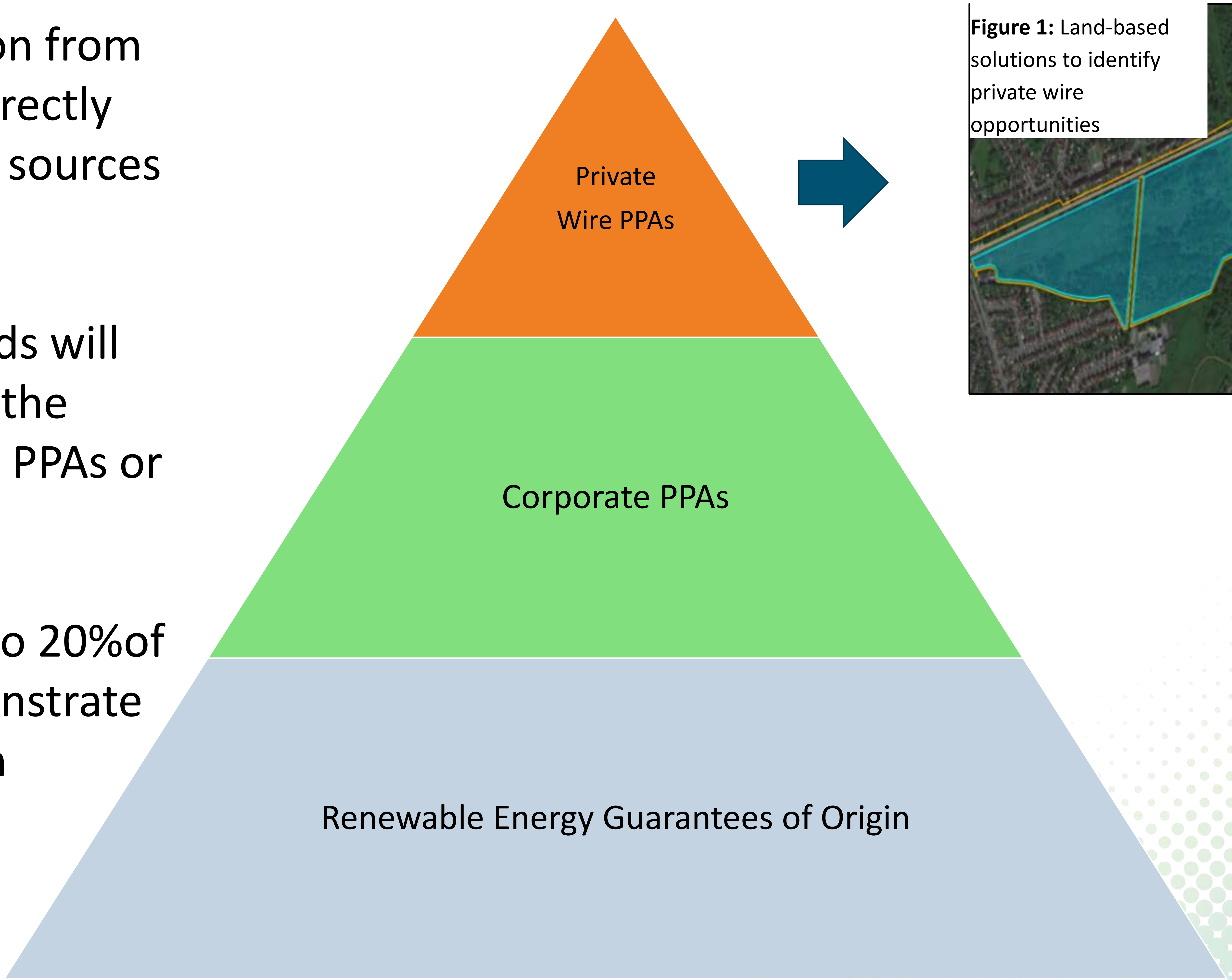


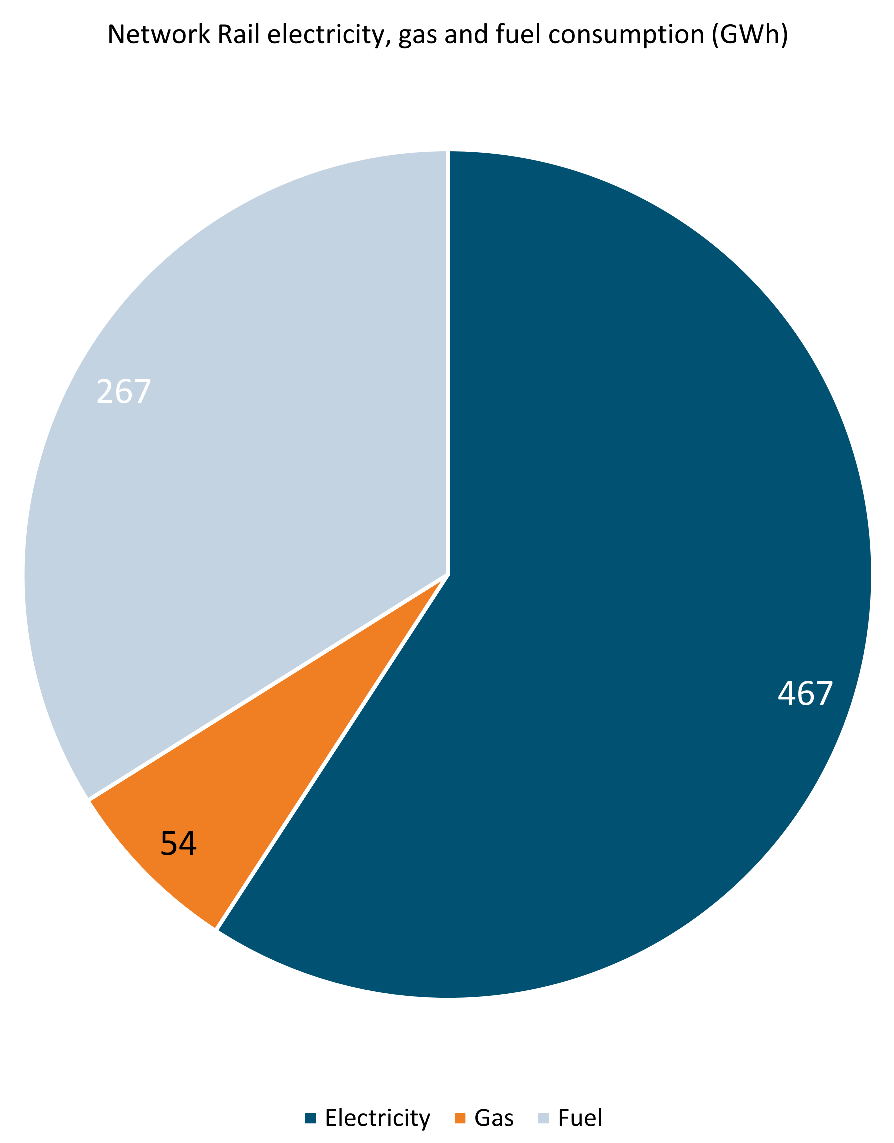
Figure 1: Land-based solutions to identify private wire opportunities

Solar PV Partnership with EDF Renewables

Network Rail

1. Biggest single user of electricity representing 1% of the UK's entire demand.

2. Ambitious Environmental Sustainability Strategy launched in 2020 which supports Network Rail becoming net zero by 2050.

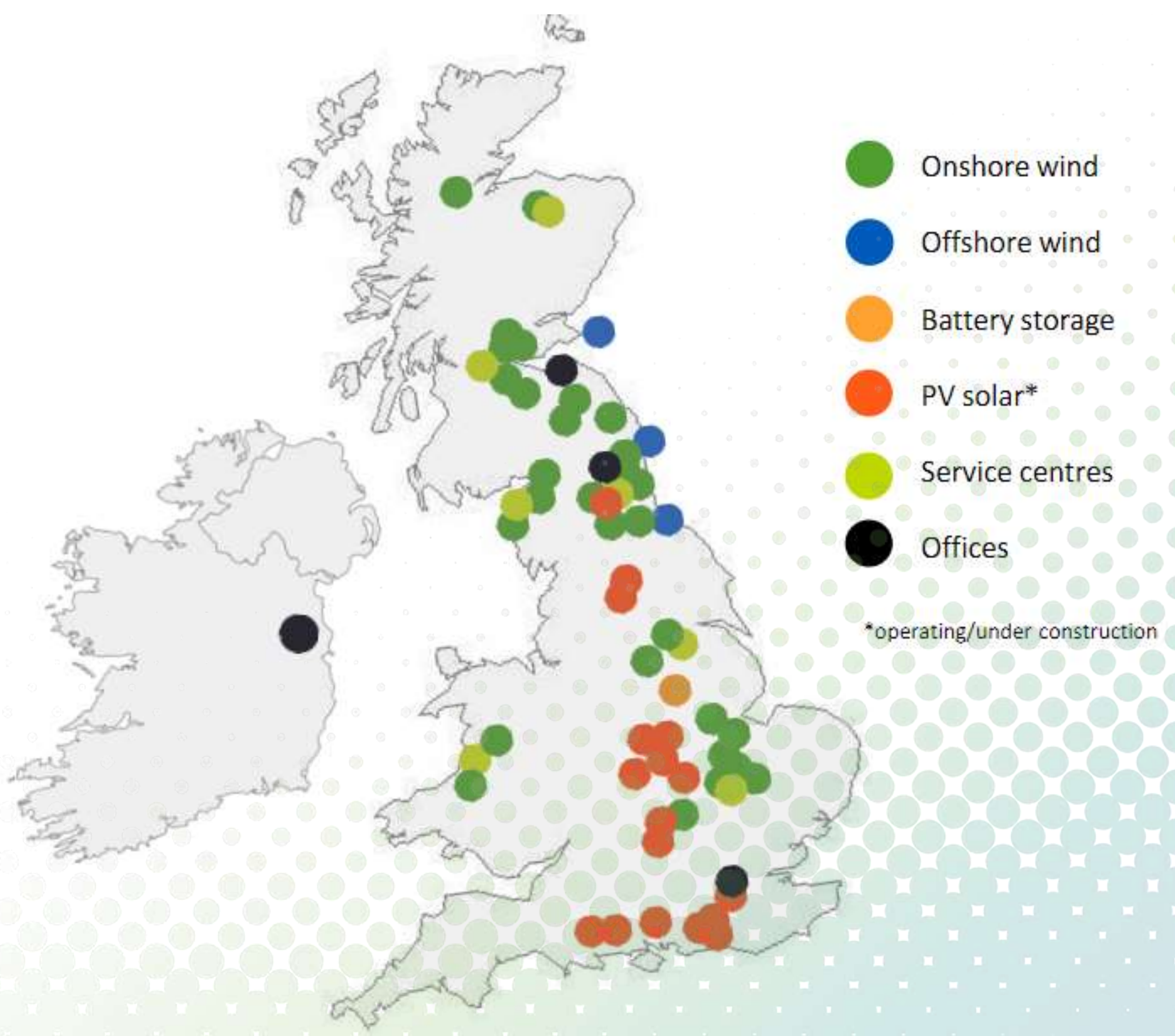


EDF Renewables

1. Large operational portfolio in UK and Ireland

2. Signed PPAs with other major demand users to deploying solar and wind technologies

3. Network Rail has an existing traction energy supply partnership between the wider EDF Group in Britain.

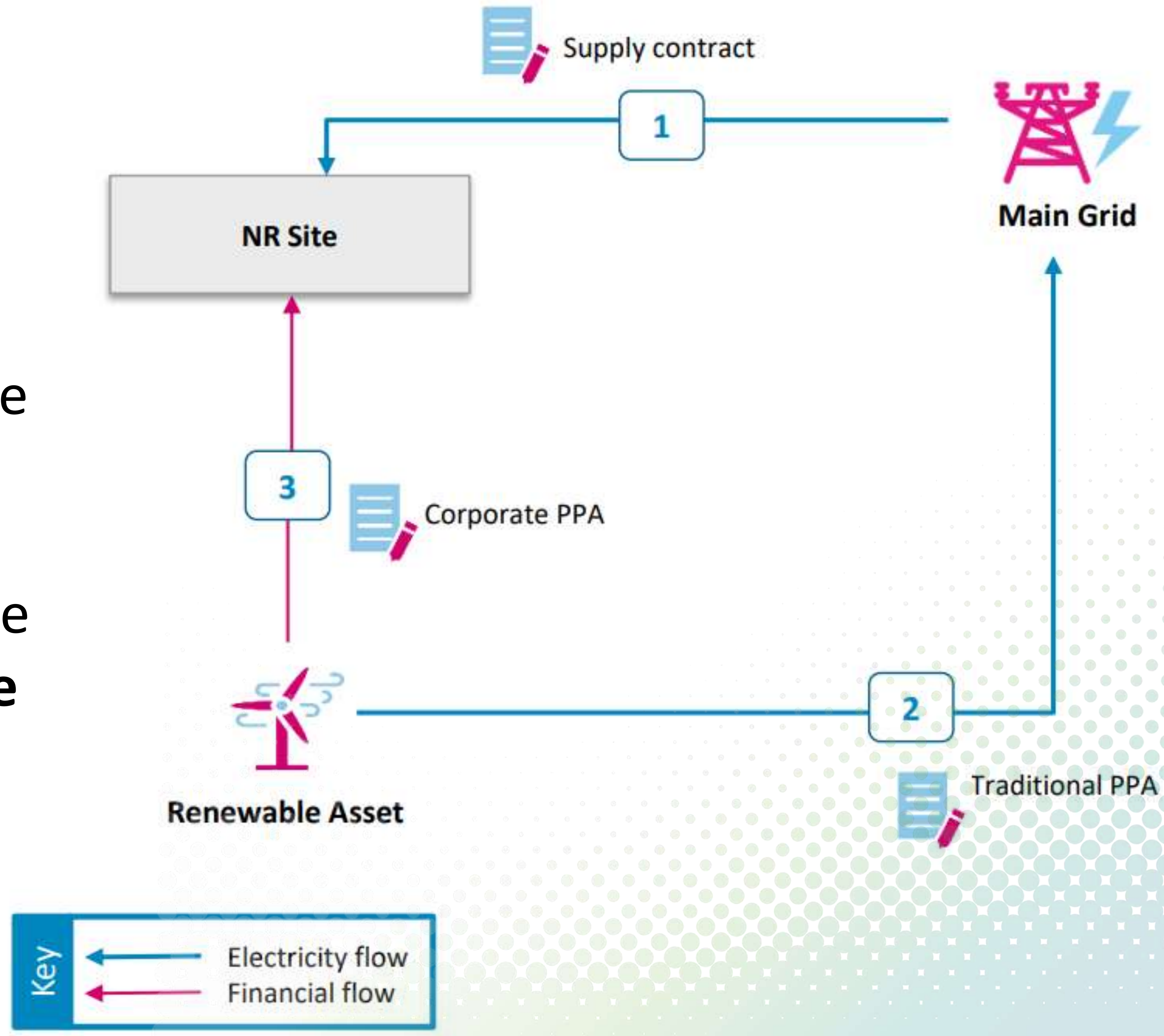


Solar PV Partnership with EDF Renewables

EDF Renewables (EDFR) and Network Rail have signed a corporate power purchase agreement to build, install and operate a solar farm that will deliver renewable power to the railway estate in 2024.

What is the corporate power purchase agreement?

- A contractual agreement between Network Rail (corporate offtaker) and EDF Renewables (renewable generator).
- Renewable power will be delivered to the site via the grid for a given **volume** of generation at a fixed **price** over the length of **contract** (typically 15-20 years).



NetworkRail

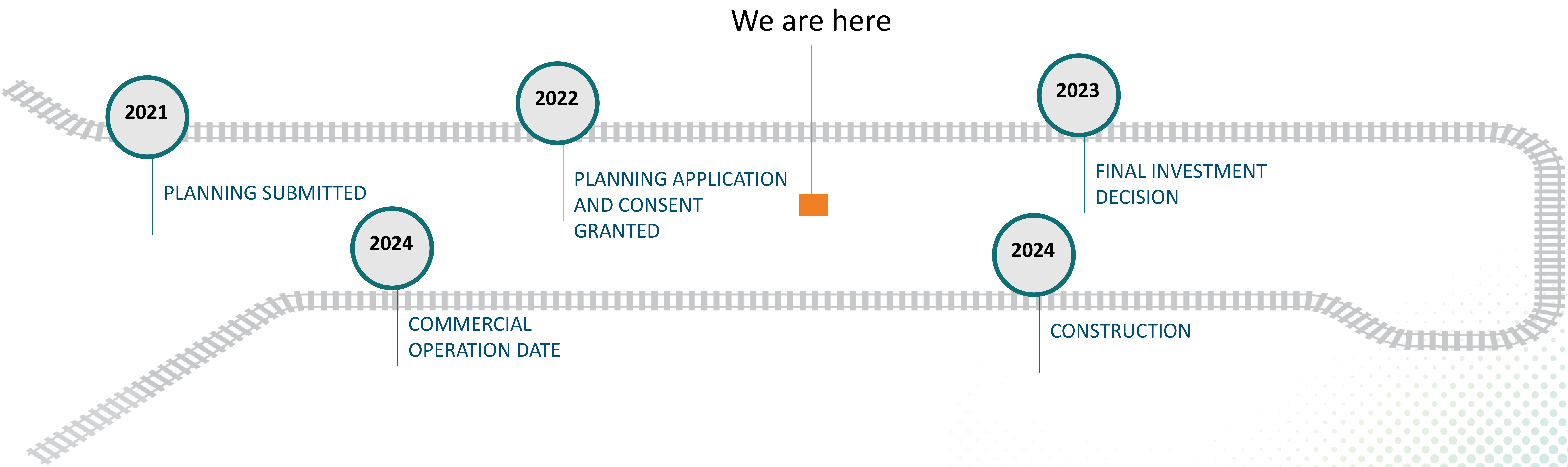
Solar PV Partnership with EDF Renewables

The energy will be provided from EDF Renewables UK's Bloy's Grove new solar farm between Swainsthorpe and Mulbarton in Norfolk.

Project Information	
Technology	Solar PV
Installed Capacity	49.9 MW
Forecast Generation Volume	64 GWh per annum

Solar PV Partnership with EDF Renewables

Timeline



NetworkRail

Thank you

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Energy and Carbon Strategy Manager
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LIVERPOOL UNIVERSITY

Renewable power management into the rail grid and storage

Zhongbei Tian



Renewable power management into rail grid and storage

Dr Zhongbei Tian zhongbei.tian@liverpool.ac.uk

Assistant Professor in Electrical Energy Systems, University of Liverpool

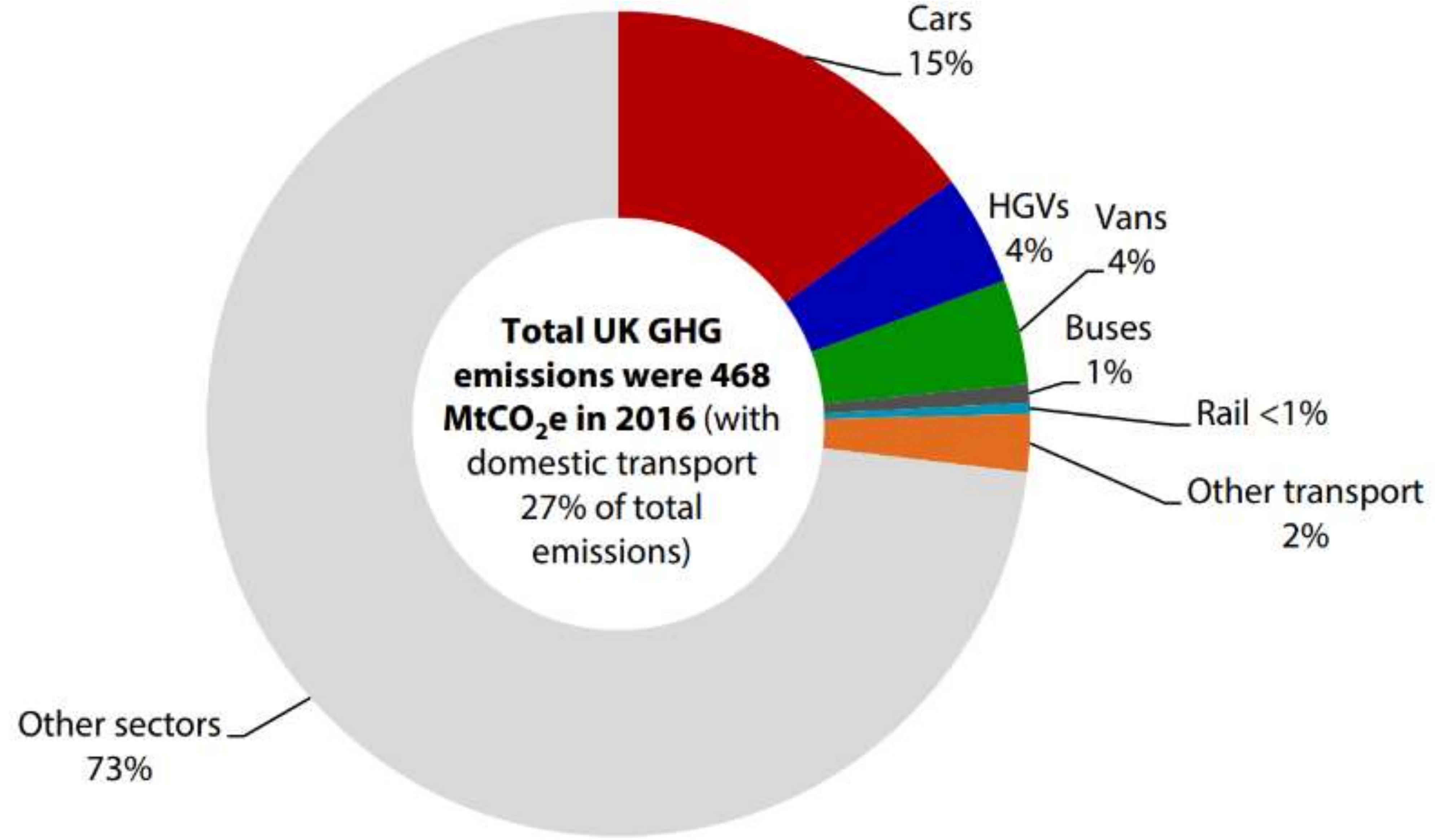
Honorary Researcher at Birmingham Railway Group, University of Birmingham

Contents

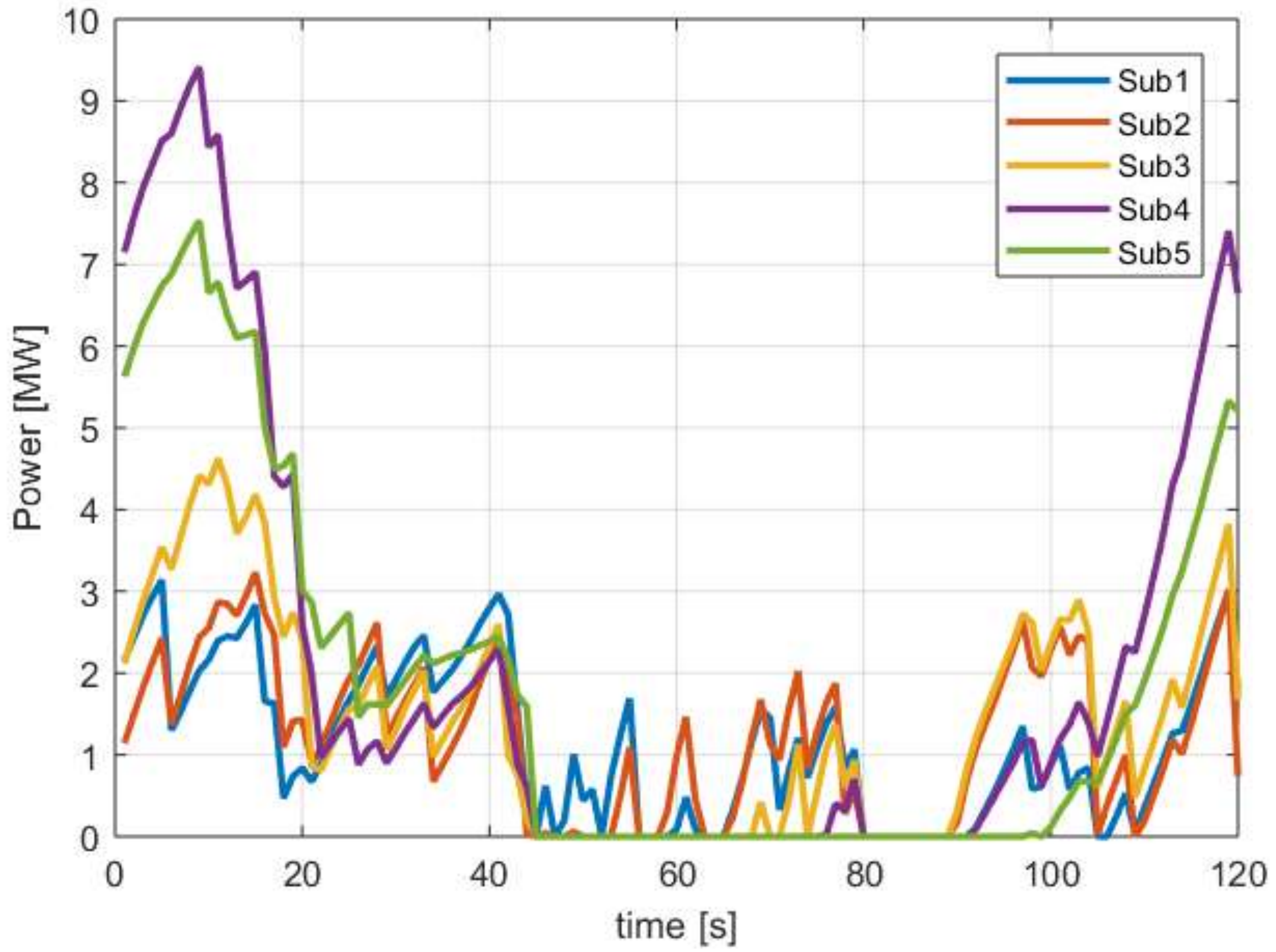
UNIVERSITY OF LIVERPOOL

Background and challenges

- ❑ Transport = 27% of greenhouse gas
- ❑ Zero emission for all new cars and vans by 2040.
- ❑ The rapid change of transportation system
- ❑ Railway challenges
  - ➢ UK railway electrification rate is 38% in 2020
  - ➢ Reduce railway CO2 by 50% in 2030
  - ➢ Peak power demand
  - ➢ High electricity bills
  - ➢ Energy efficiency



CCC Progress Report 2018

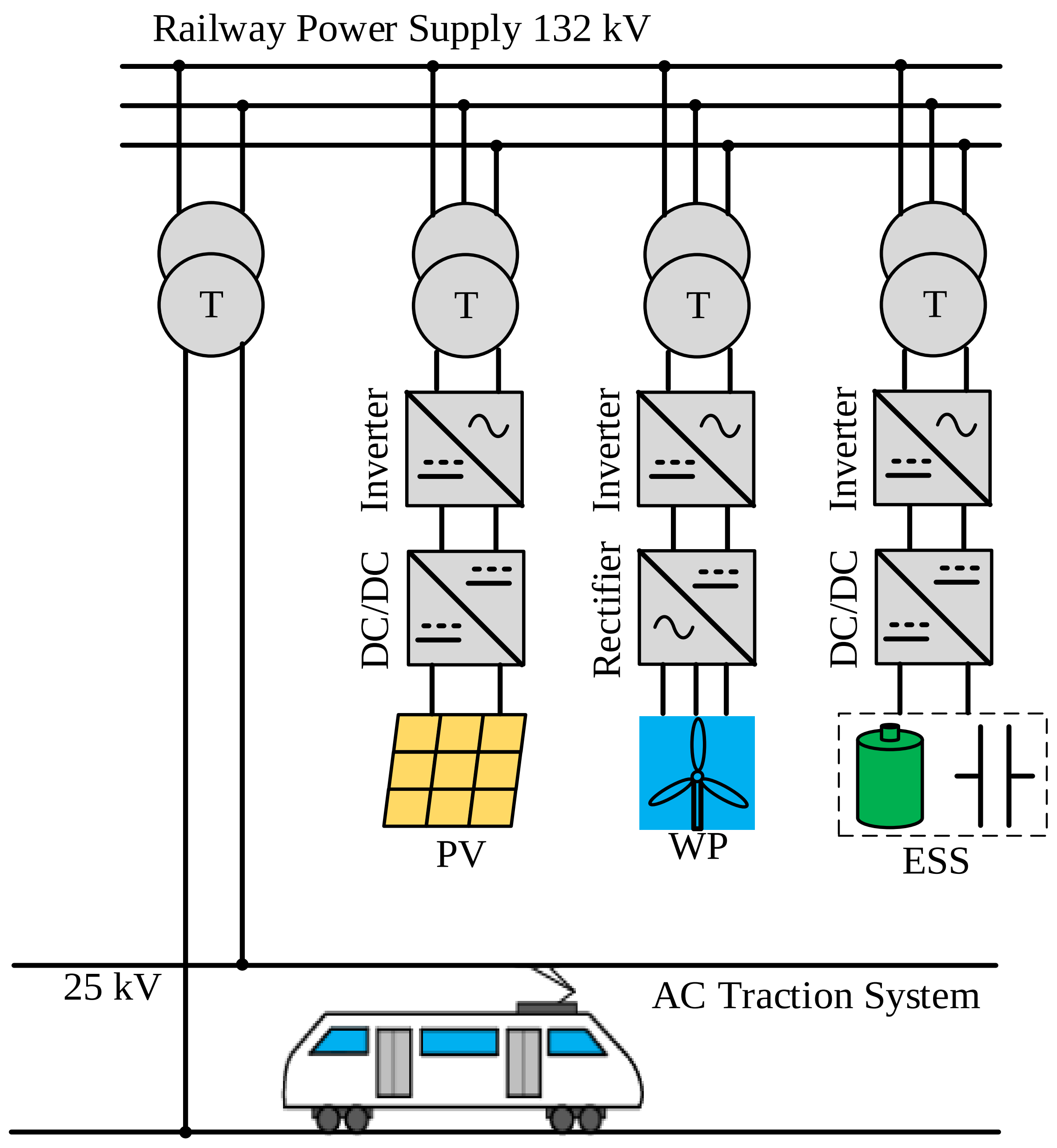


Recent renewable railway projects

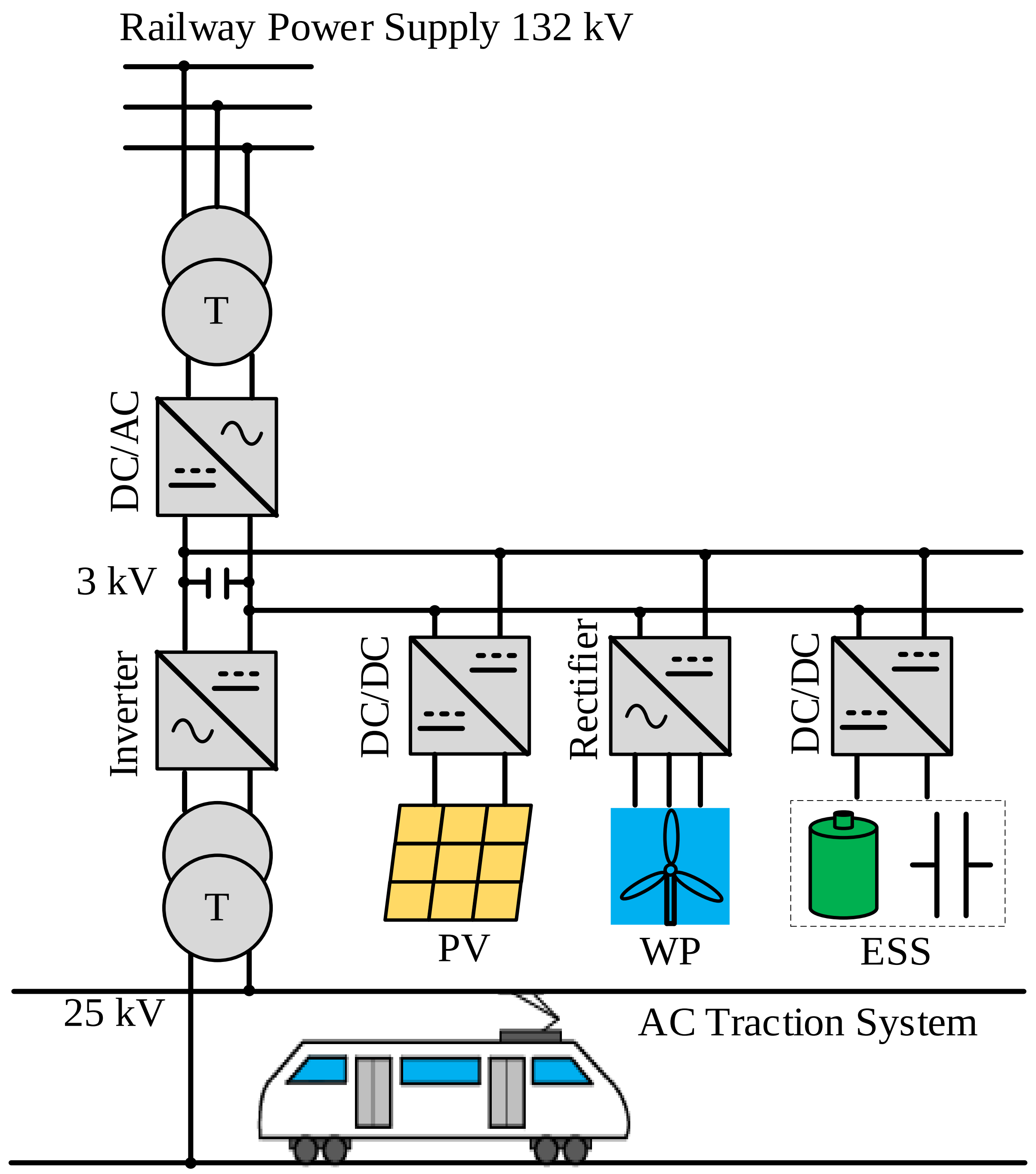
- The Renewable Powered Railway: Renewable Railway Power Network Design with Optimal Energy Management
  - Funded by EPSRC
  - Merseyrail case studies
- Alternative energy sources for electrified rail and energy storage technologies for regenerative braking
  - Funded by Network Rail
  - With University of Birmingham, Capgemini, Enerail
- E-Lobster: Electric LOsses Balancing through integrated STorage and power Electronics towards increased synergy between Railways and electricity distribution networks
  - Funded by EU Horizon 2020
  - Madrid Metro case study and demonstration

Renewable railway topologies

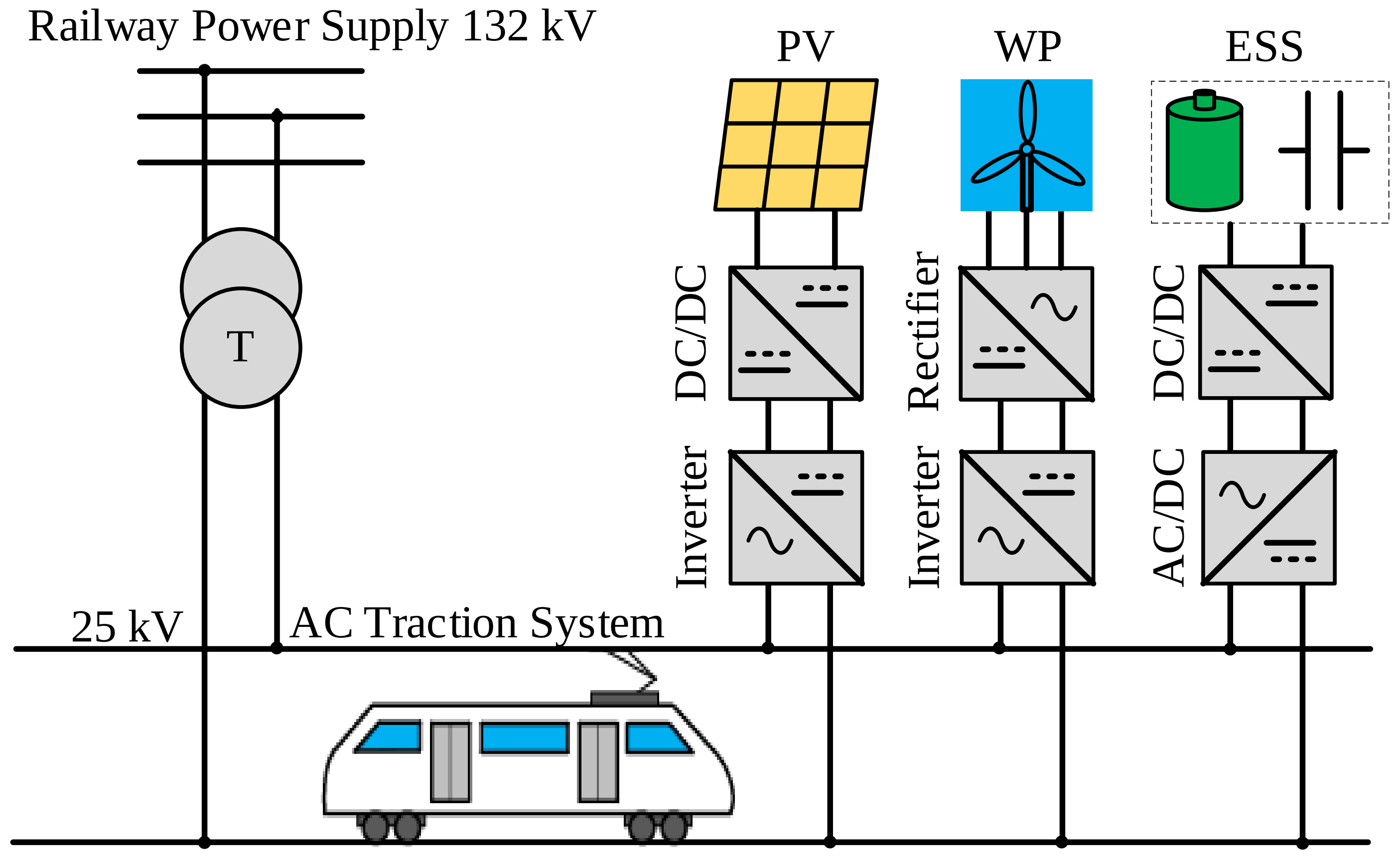
❑AC railway connections



3-phase utility grid/railway



Substation connection with the DC bus of power converters



Single-phase directly

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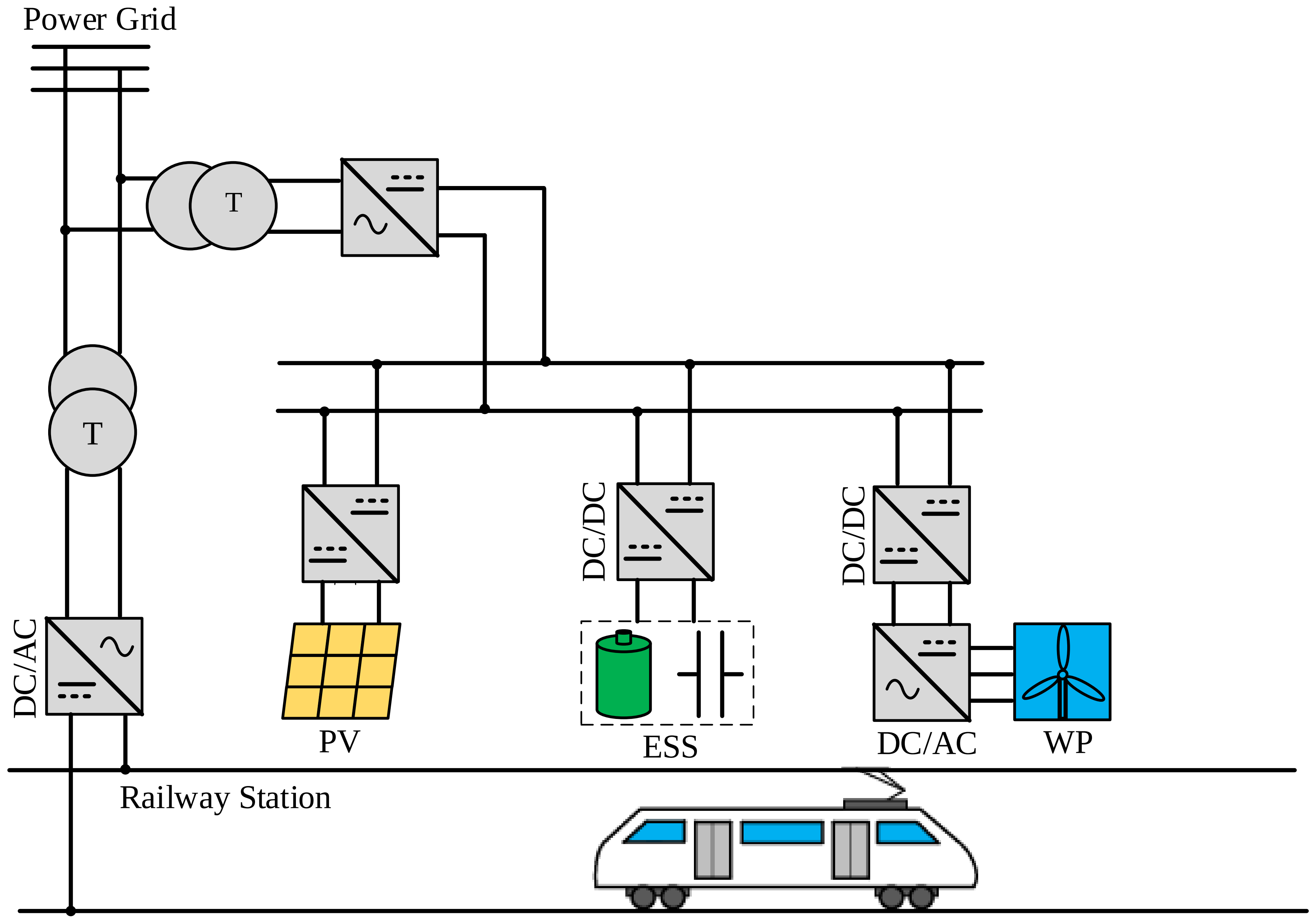
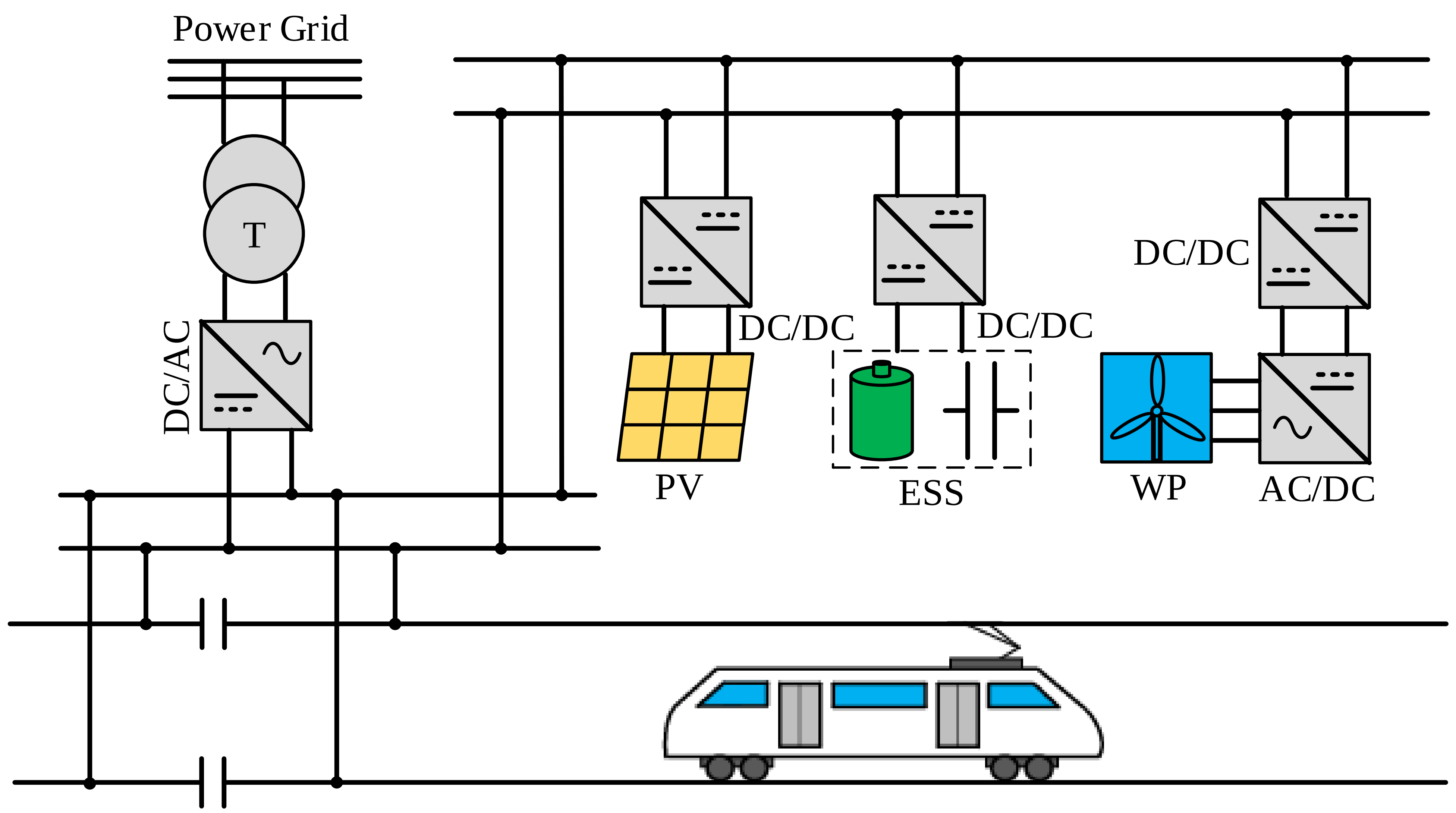
Renewable railway topologies

❑DC railway connections



3-phase connection at substation



DC bus connection

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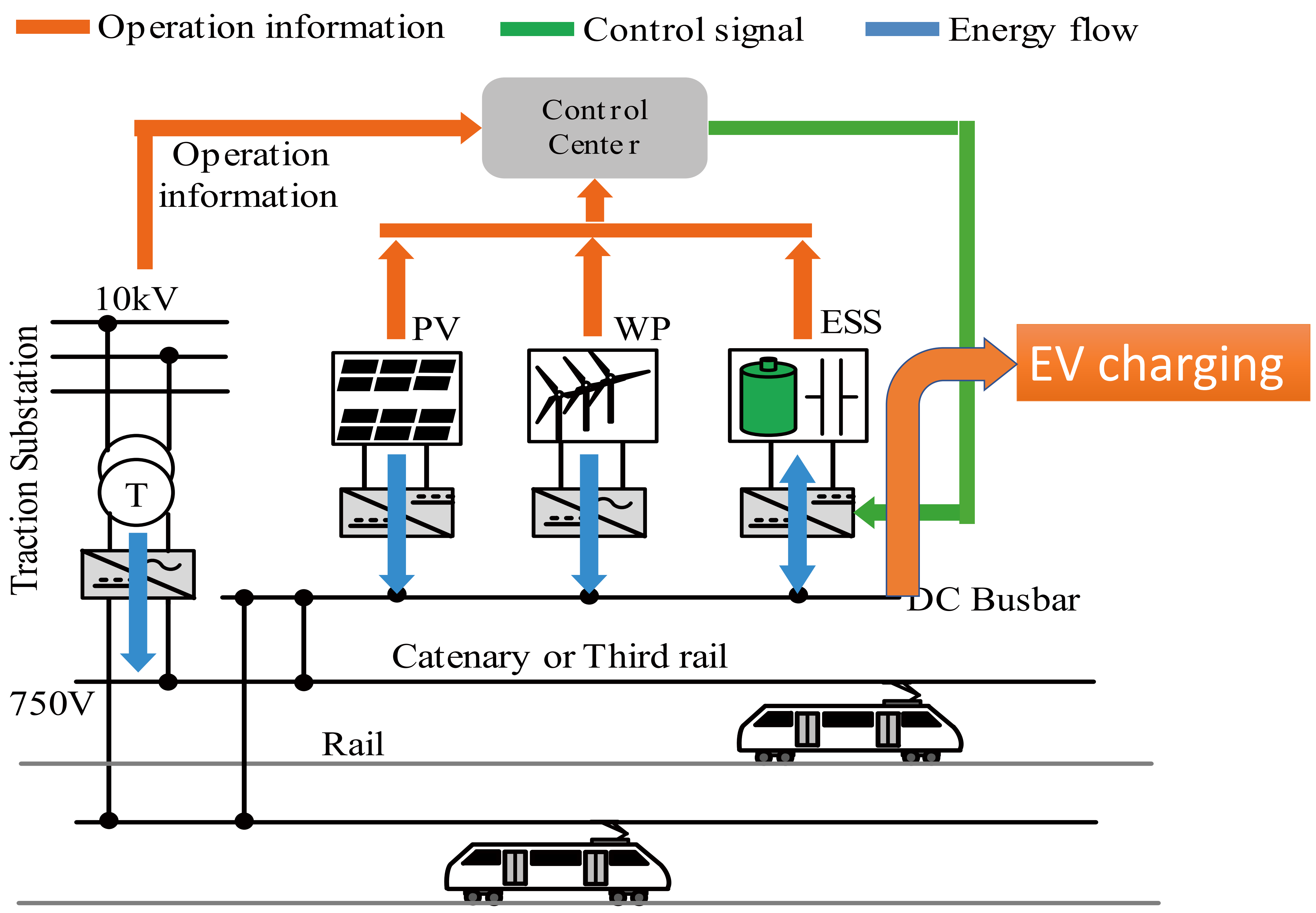
Energy management methodology

- ❑EPSRC funded: Renewable Railway Power Network Design with Optimal Energy Management
- ❑Smart train operation + power network management

Multi-source traction system (MSTS) structure



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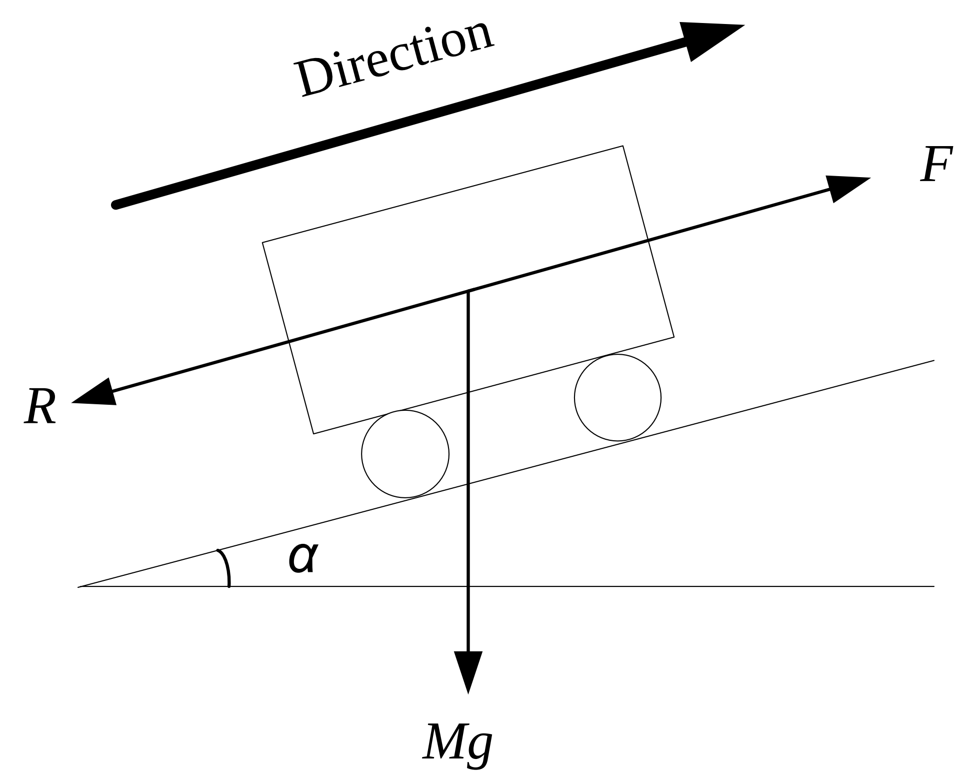
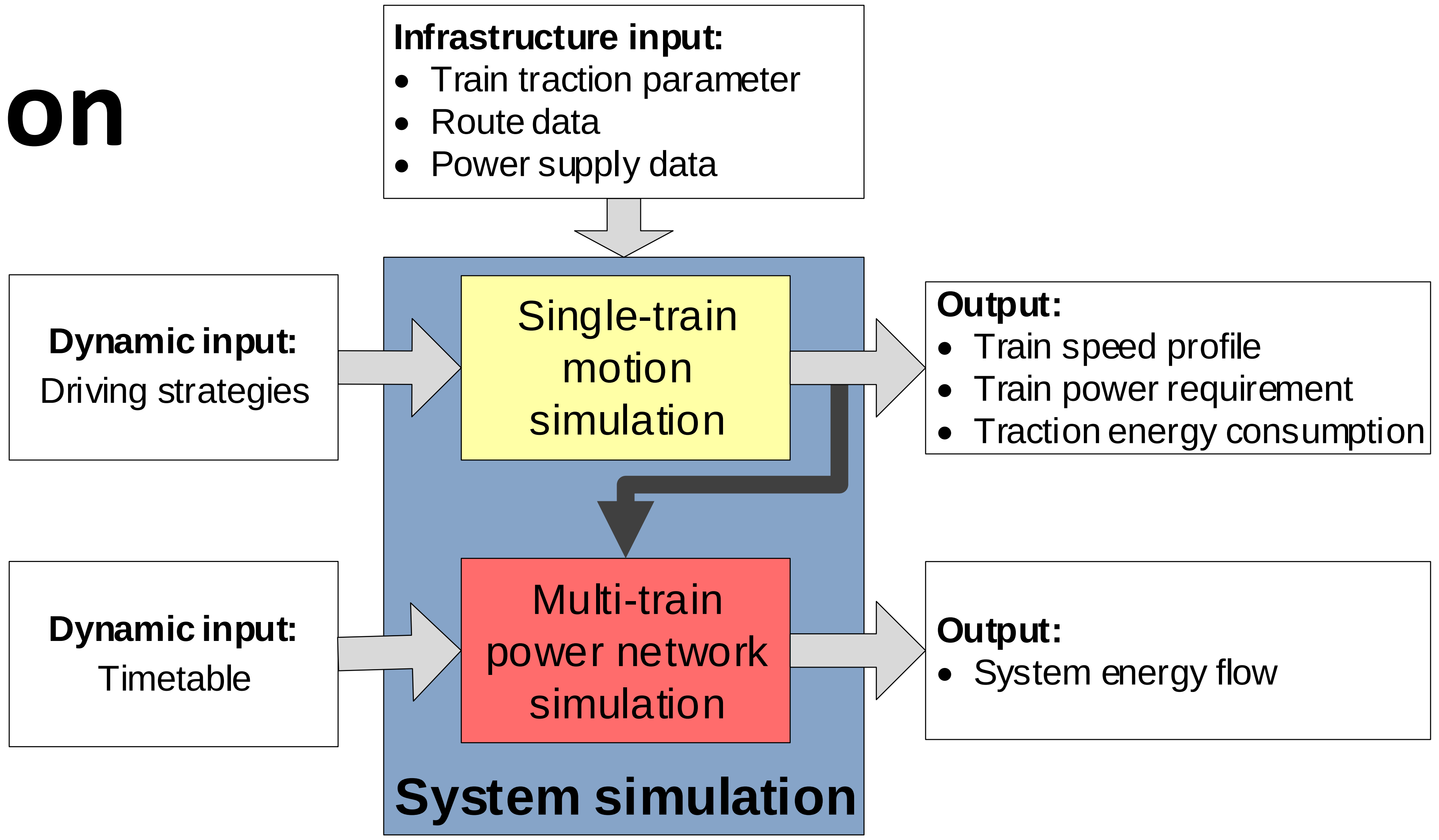
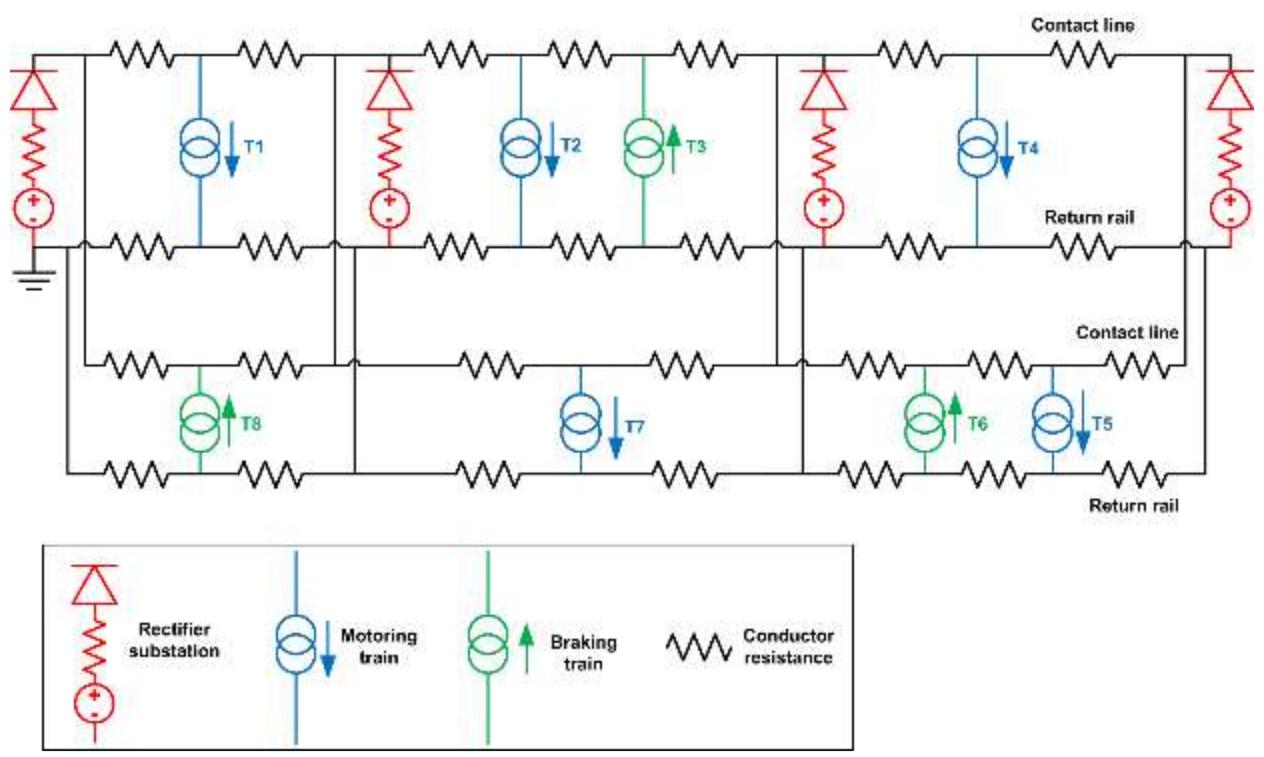
Methodology

❑Railway system simulation

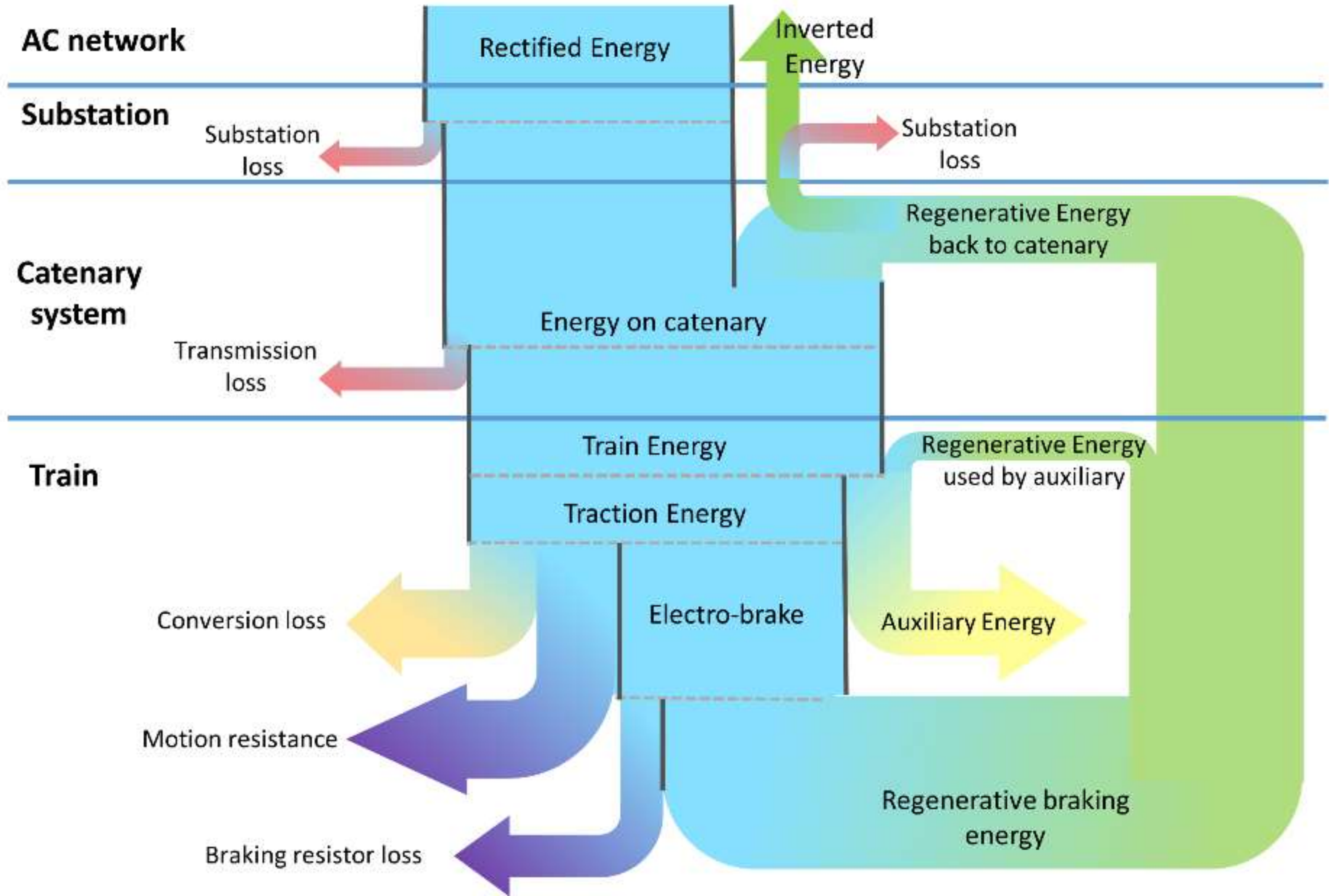


Train traction system





Electrical infrastructure



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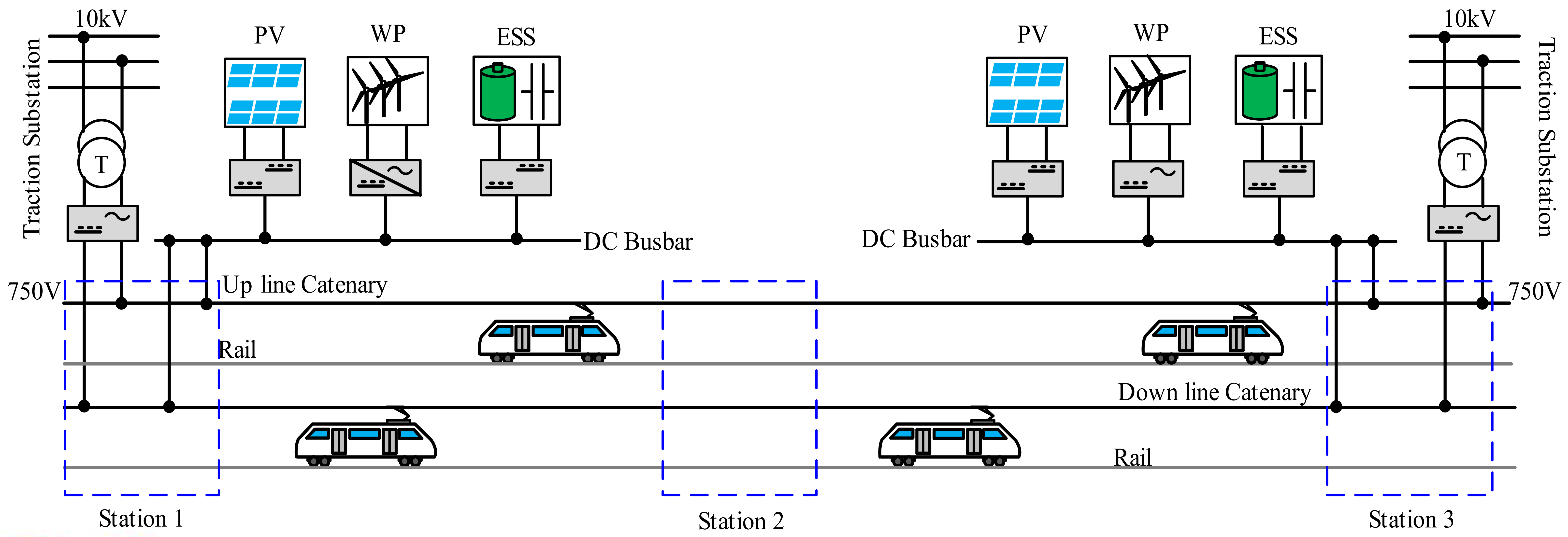
Methodology

❑Railway + Energy storage + Renewable energy

- ➢Railway traction substation.
- ➢Train vehicle.
- ➢Energy storage system.
- ➢Renewable energy: wind power and photovoltaic power.



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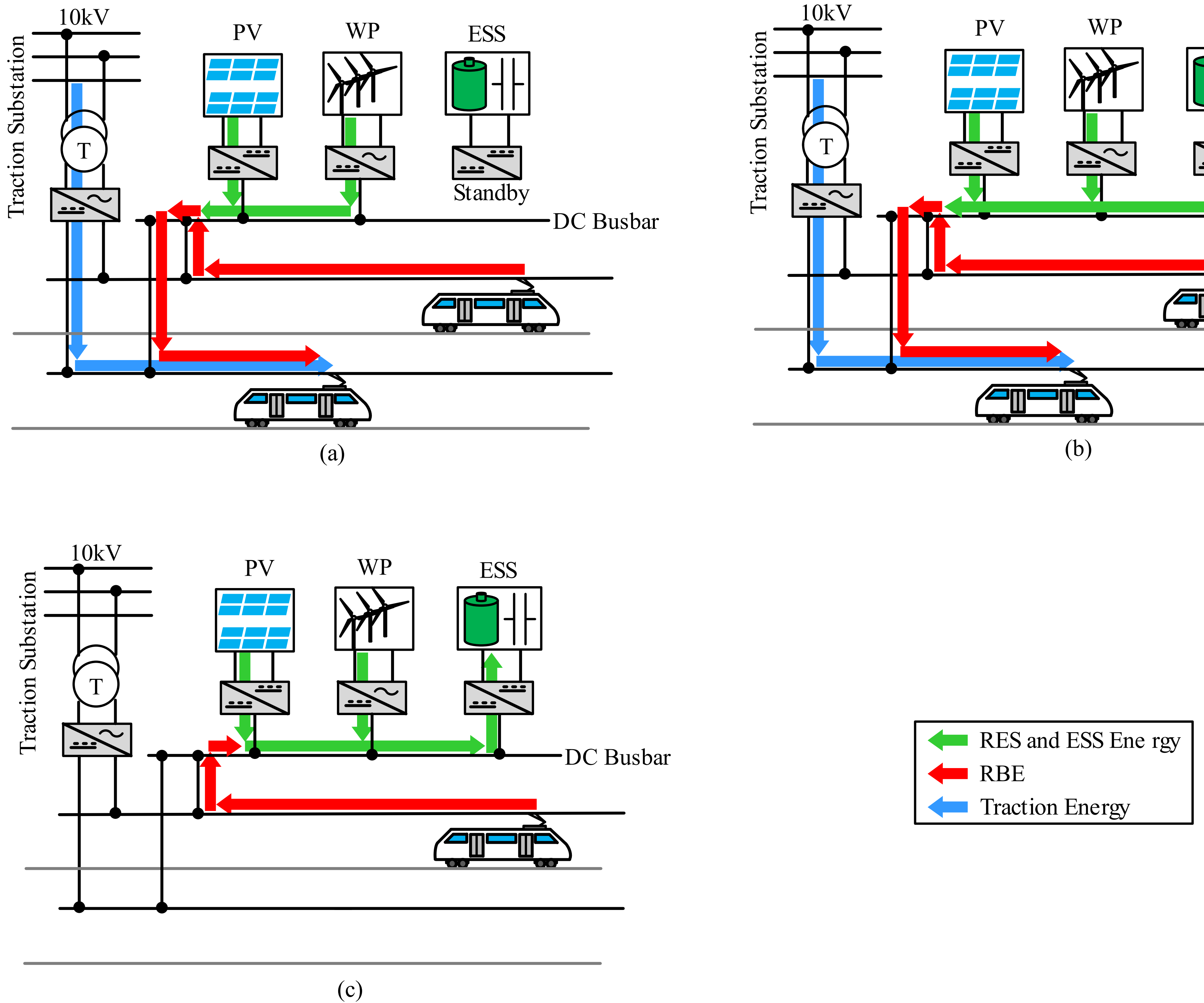
Methodology

❑Operation modes

- ➢Under different active power demands, the proposed MSTS has three main operation modes
- ➢Standby, discharging and charging



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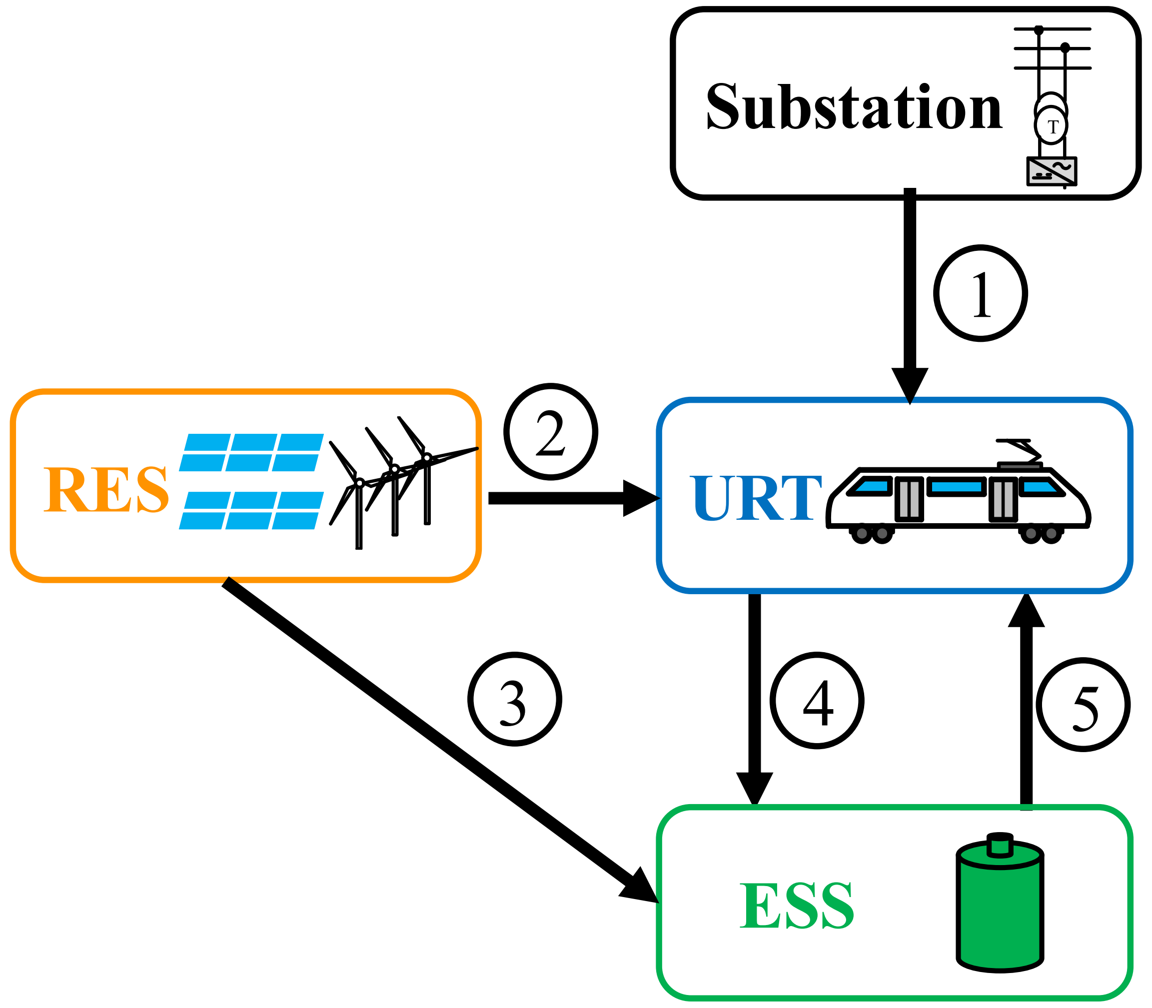
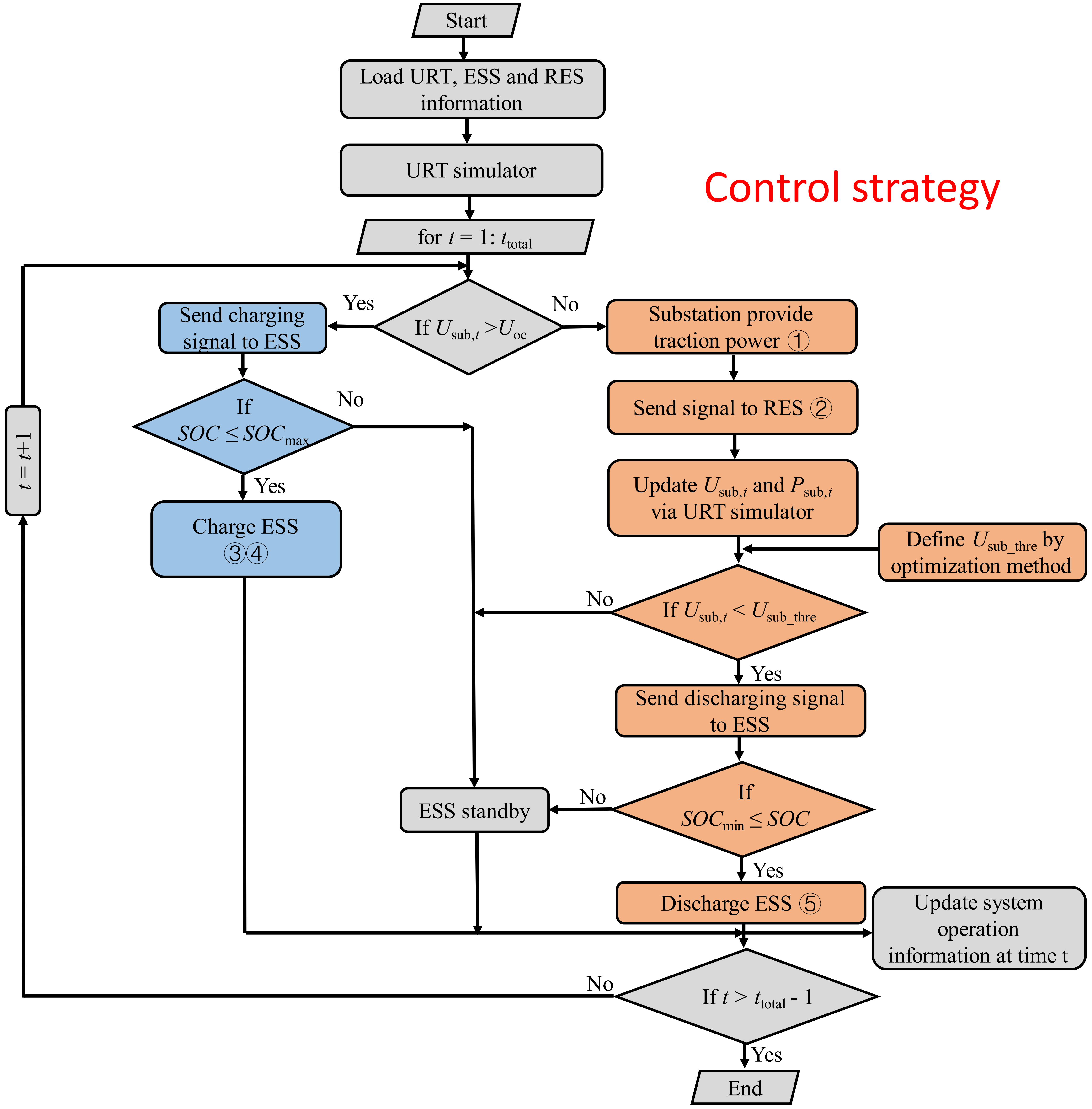
Methodology

❑ Coordinated control strategy

➢ Control flow chart



Energy flow



Control strategy

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Methodology

❑ESS control Optimization

➢Performance index

Define a performance index J_1, J_2, and J_3, α and β are the weight of performance index, and $\alpha+\beta=1$

$$J=\alpha J_1+\beta(J_2+J_3) \Rightarrow \begin{cases} J_1=\sum_{i=1}^{n}\dfrac{\int_0^T\left(P_{\text{sub\_os},i}(t)-P_{\text{sub\_up}}\right)dt}{TP_{\text{sub\_up}}} & \text{Power overshot index} \\ J_2=\sum_{i=1}^{n}\dfrac{\int_0^T\left(U_{\text{sub\_os},i}(t)-U_{\text{sub\_up}}\right)dt}{TU_{\text{sub\_up}}} & \text{Voltage overshot index} \\ J_3=\sum_{i=1}^{n}\dfrac{\int_0^T\left(U_{\text{sub\_down}}-U_{\text{sub\_us},i}(t)\right)dt}{TU_{\text{sub\_down}}} & \text{Voltage undershot index} \end{cases}$$

Minimize $J=\alpha J_1+\beta(J_2+J_3)$

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Case study – Verification by simplified model

System infrastructure

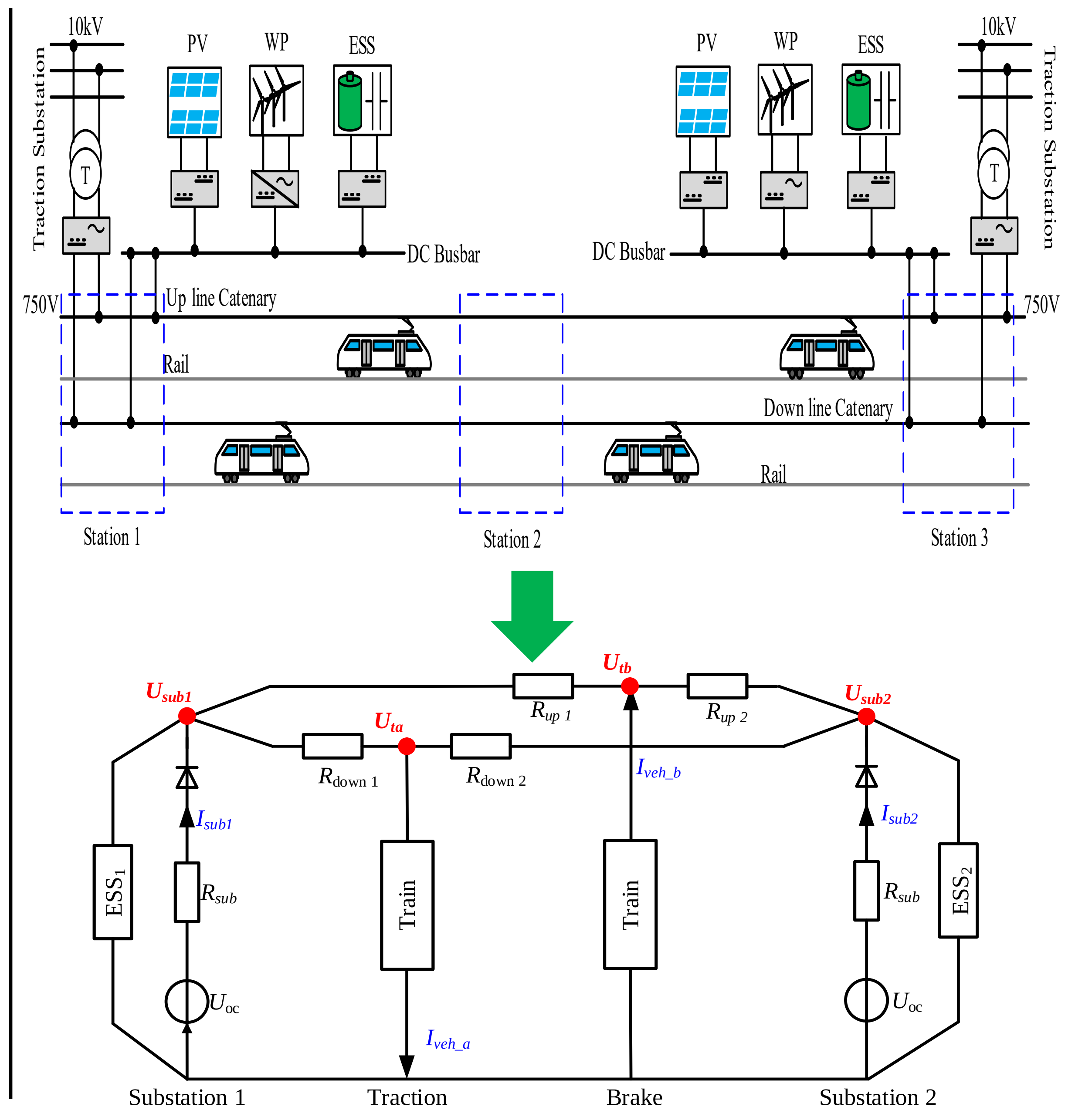
- The simulation is based on two substations including three stations. The detailed parameter of the urban railway system below. Each substation is equipped with an ESS (supercapacitor), and the parameter of the supercapacitor is shown in Table.

Parameters of the railway system

Length	1750 m	**Headway**	120 s / 300 s
Line resistance	0.016 Ω/km		
Train type	3M3T	**Tran mass**	210 t
Train resistance	0.015 Ω	**Pt_rate**	750 V
Pb_rate	825 V	**Pau**	90 kW
Substation resistance	0.0161 Ω	**Uoc**	860 V

Parameters of the ESS

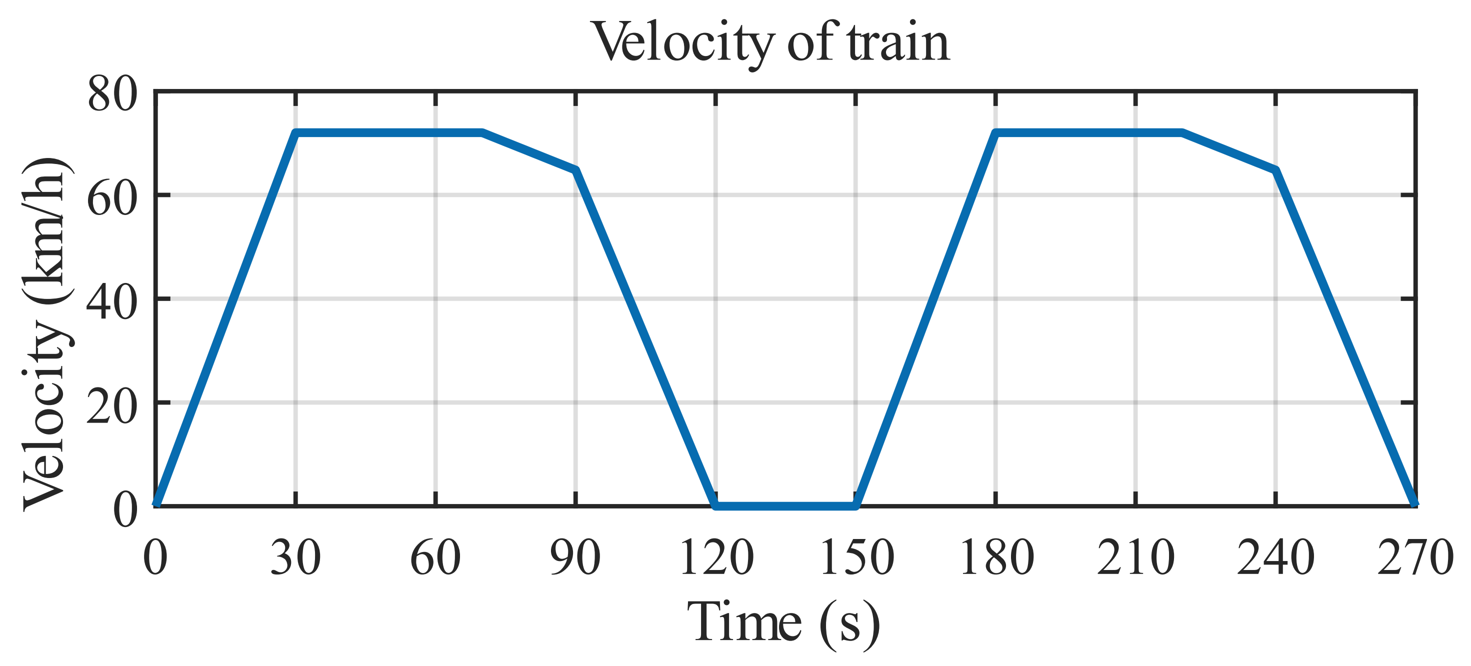
Capacity	294F	**Rated voltage**	750V
Rated power	1.3MW	**Total stored energy**	8.4kWh
SOC_{max}/SOC_{min}	0.9/0.2	**Initial SOC**	0.8/0.7
U1/U2/U3	850/840/800V	**U4/U5/U6**	870/880/920

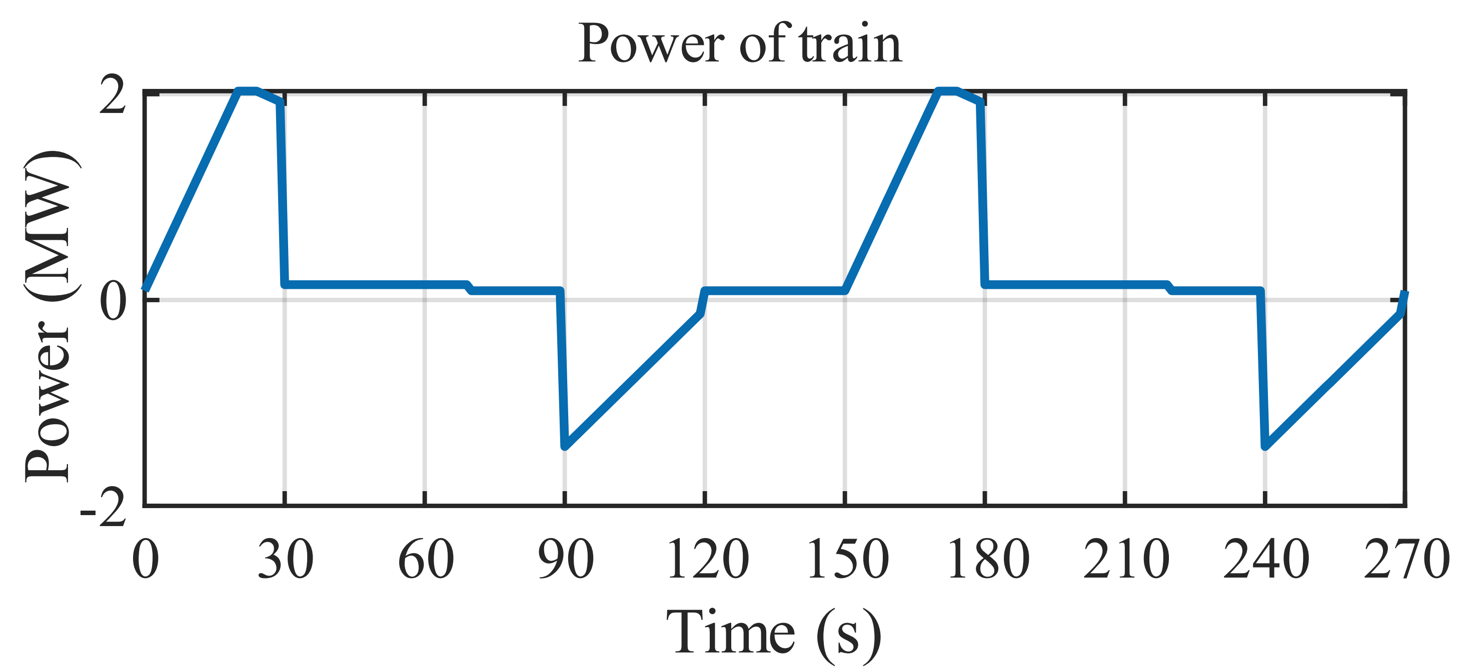


Case study – Verification by simplified model

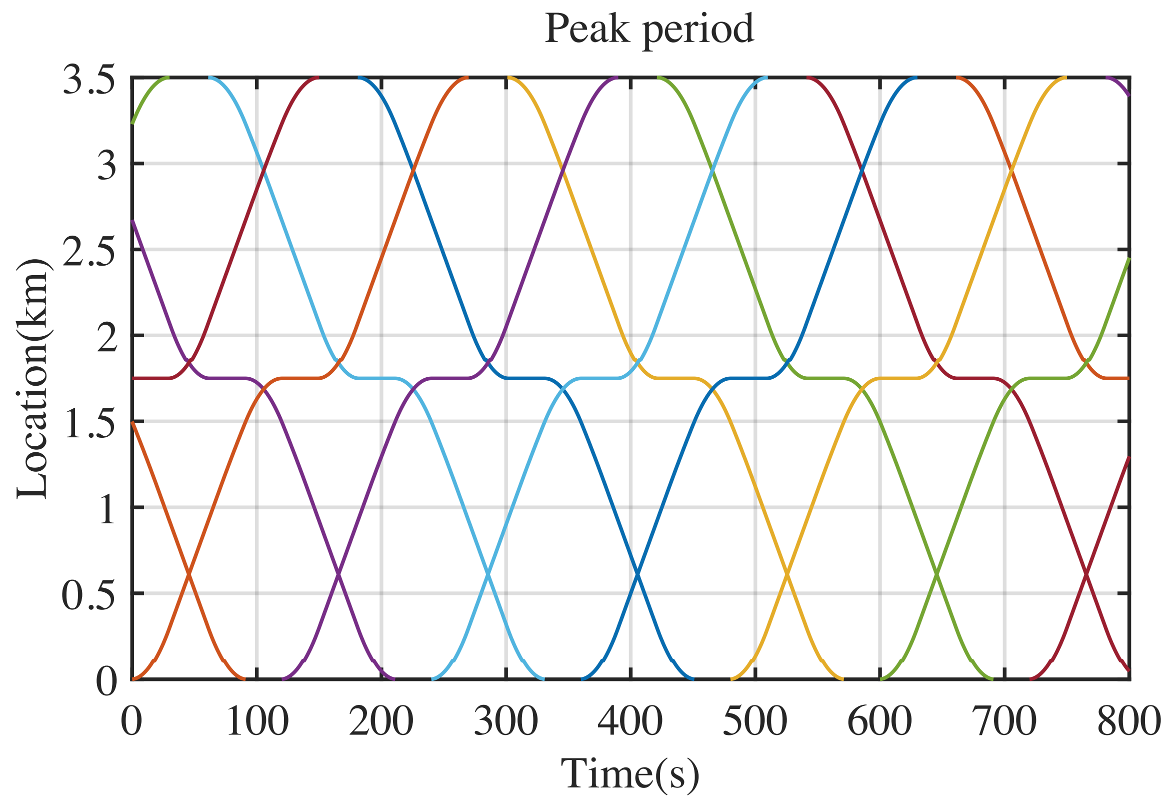
Driving profile and timetable

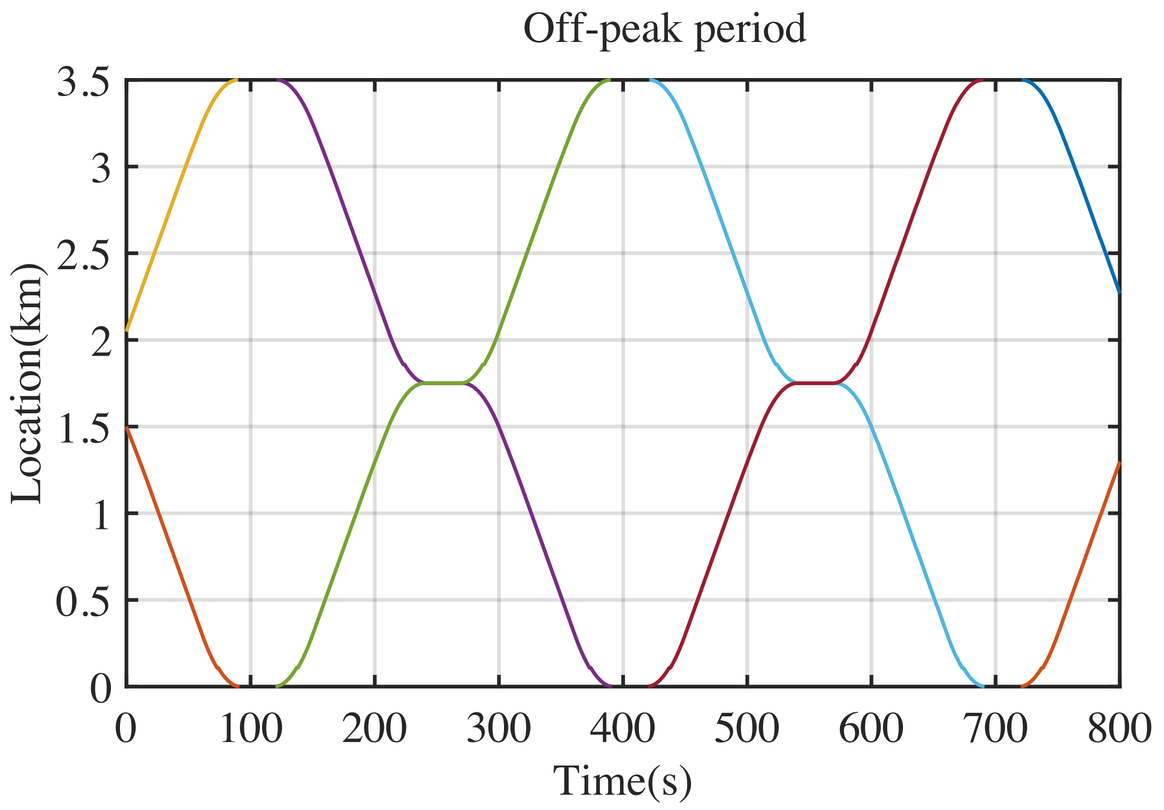
- Single train simulator





- Timetable (headway=120 s or 300 s)





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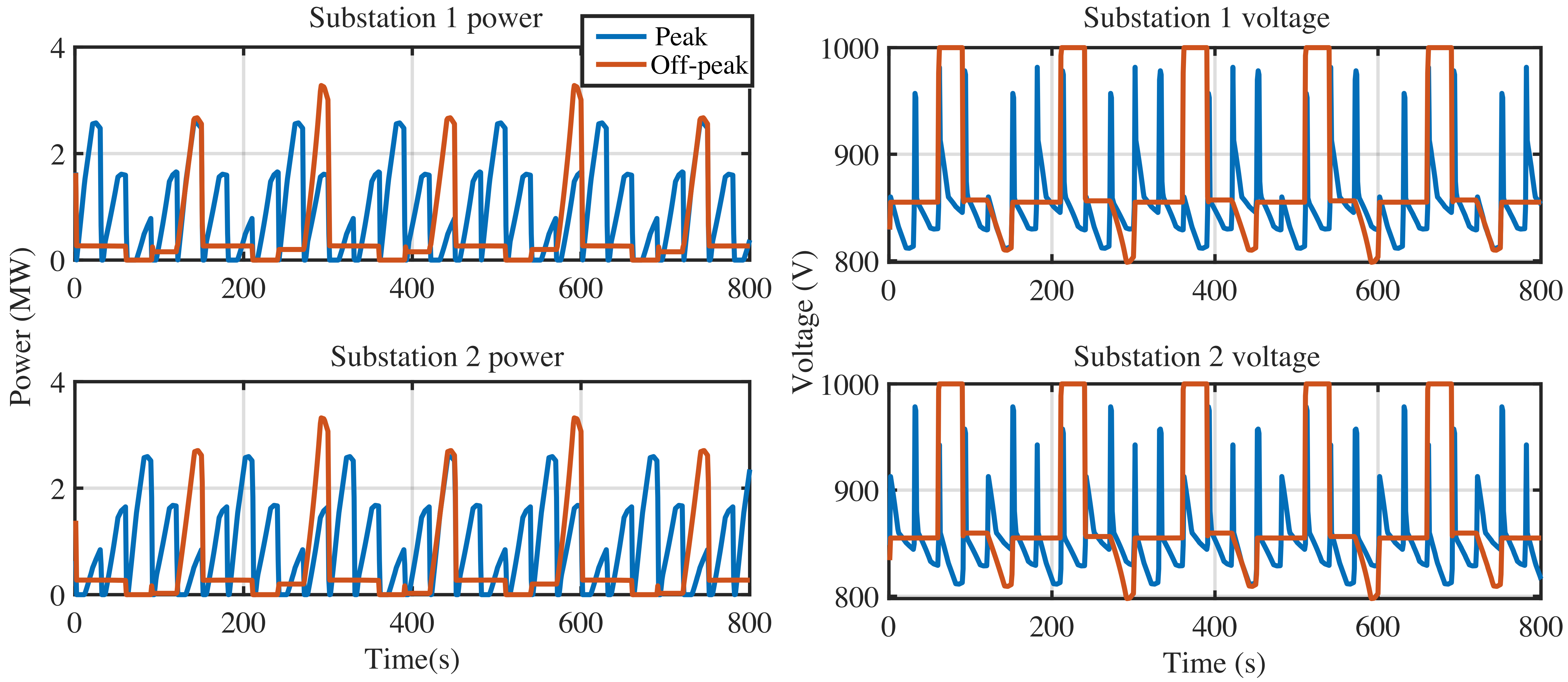
Case study – Verification by simplified model

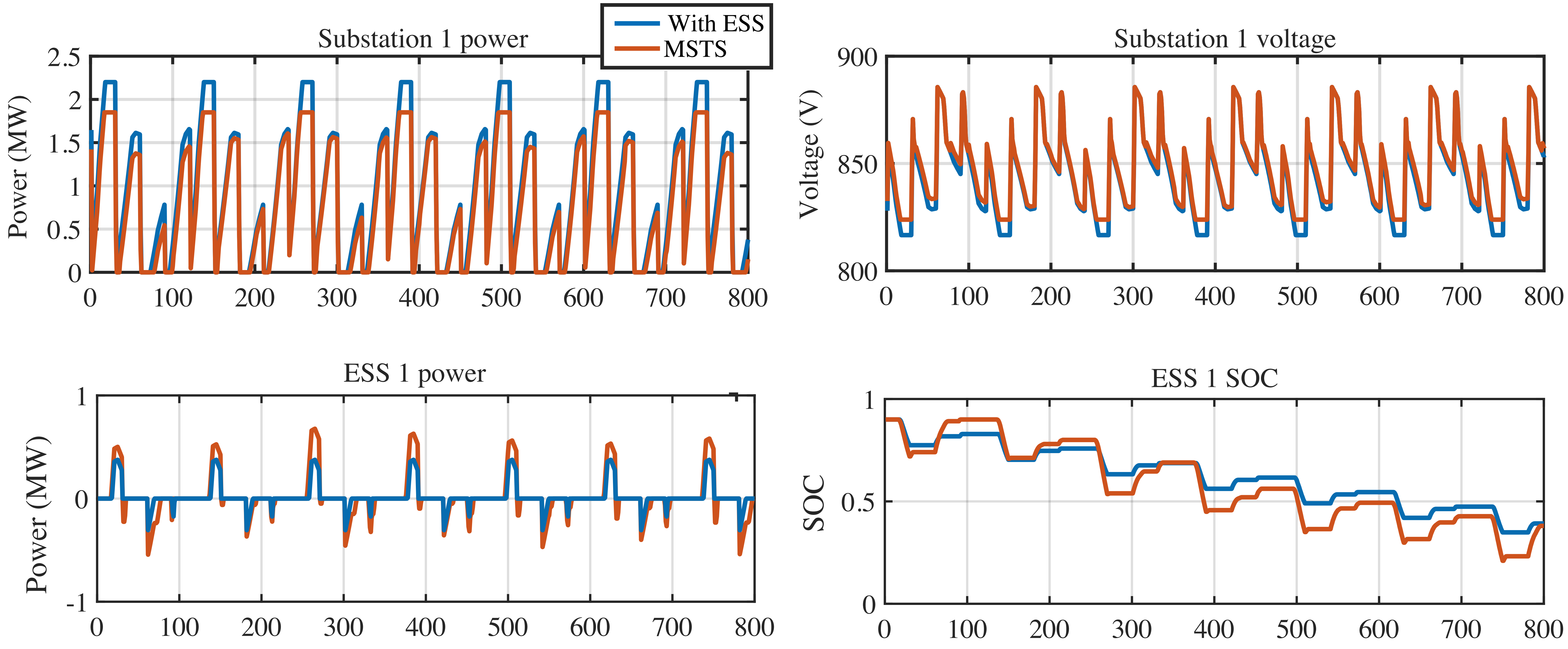
❑Conventional traction system (CTS)



- Peak power: 2.59 MW at peak time; 3.32 MW at off-peak time
- Voltage: 811-981V at peak time; 798-1000V at peak time

Case study – Verification by simplified model

❑CTS with ESS and Multi-source traction system (MSTS)



❑Peak power: 2.20MW in CTS with ESS; 1.85MW in MSTS

❑Voltage: 816-885V in CTS with ESS; 824-885V in MSTS

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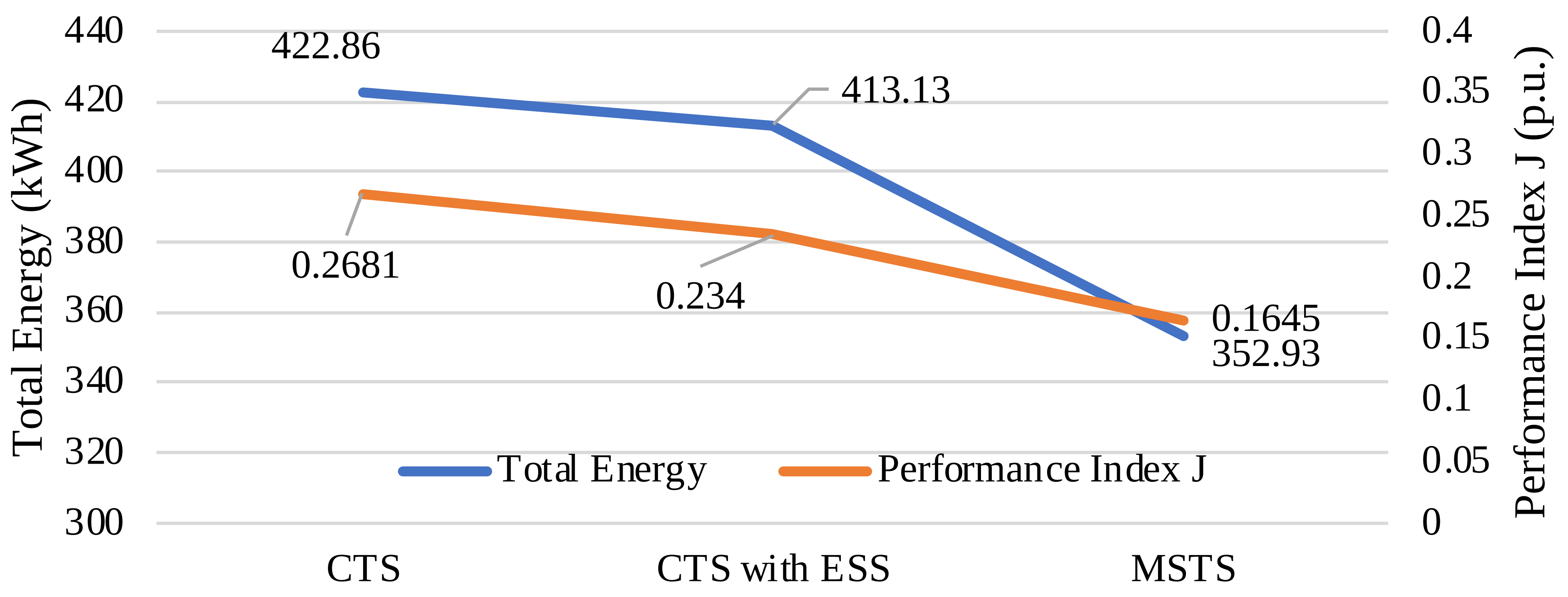
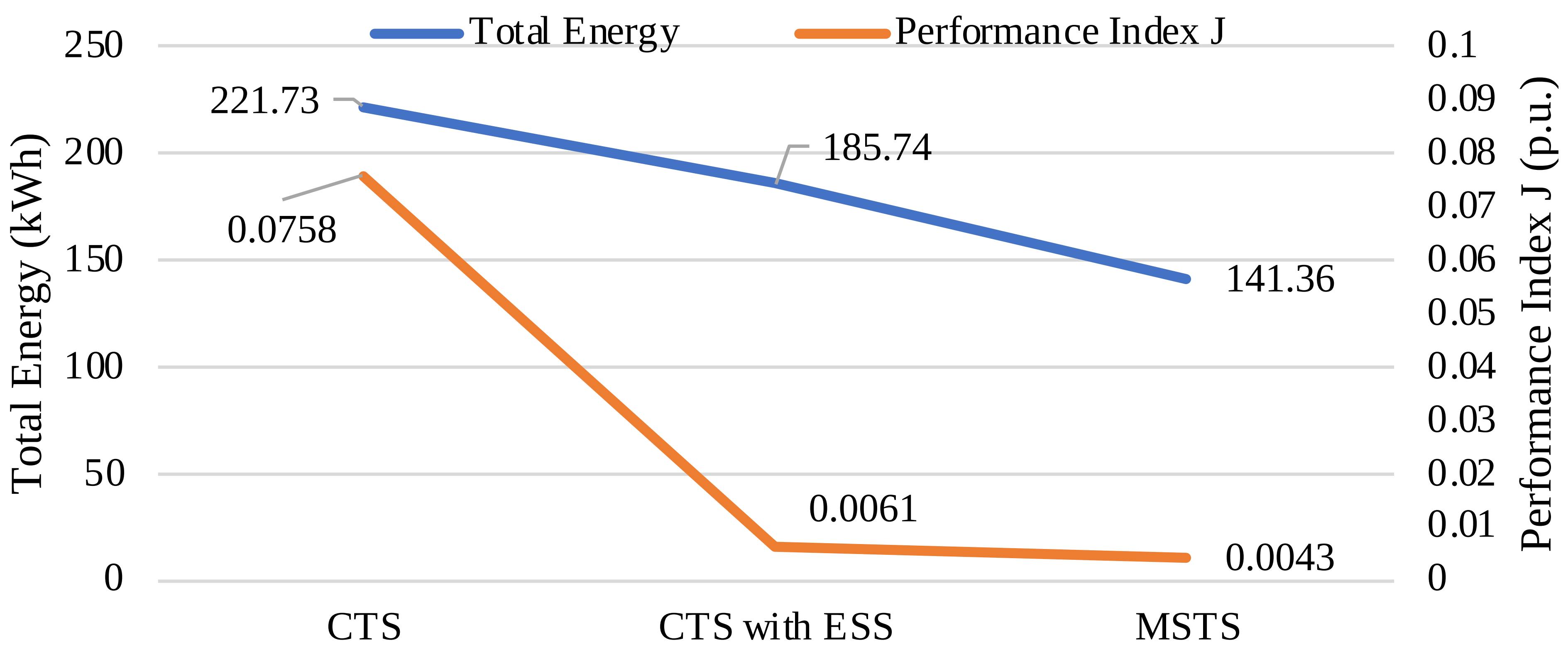
Case study – Verification by simplified model

❑ Performance compare



- Energy consumption:
- MSTS vs CTS: 16% energy reduction in peak time
- Performance index:
- MSTS vs CTS: 39% performance improvement in peak time

- Energy consumption:
- MSTS vs CTS: 32% energy reduction in off-peak time
- Performance index :
- MSTS vs CTS: 94% performance improvement in off-peak time



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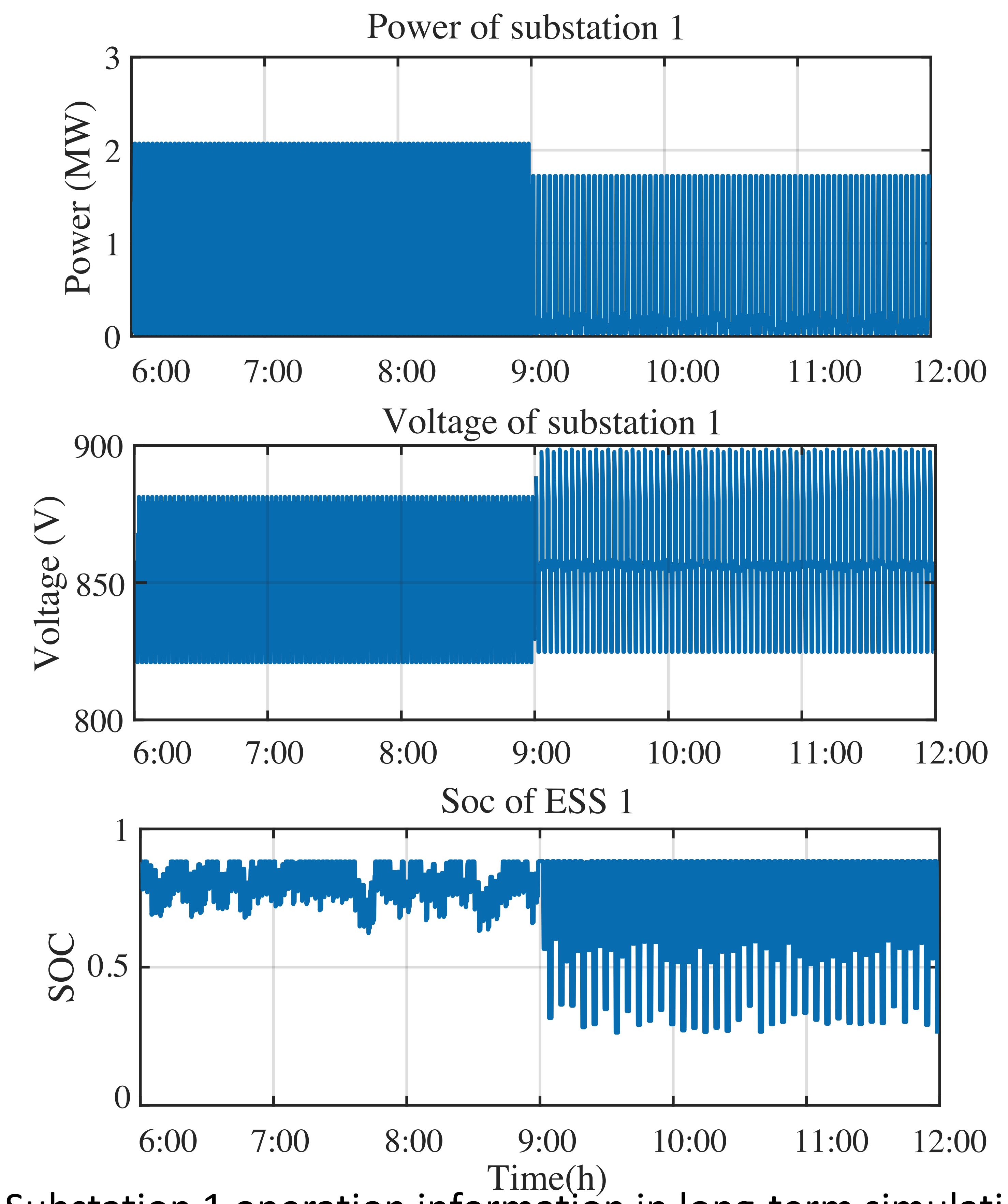
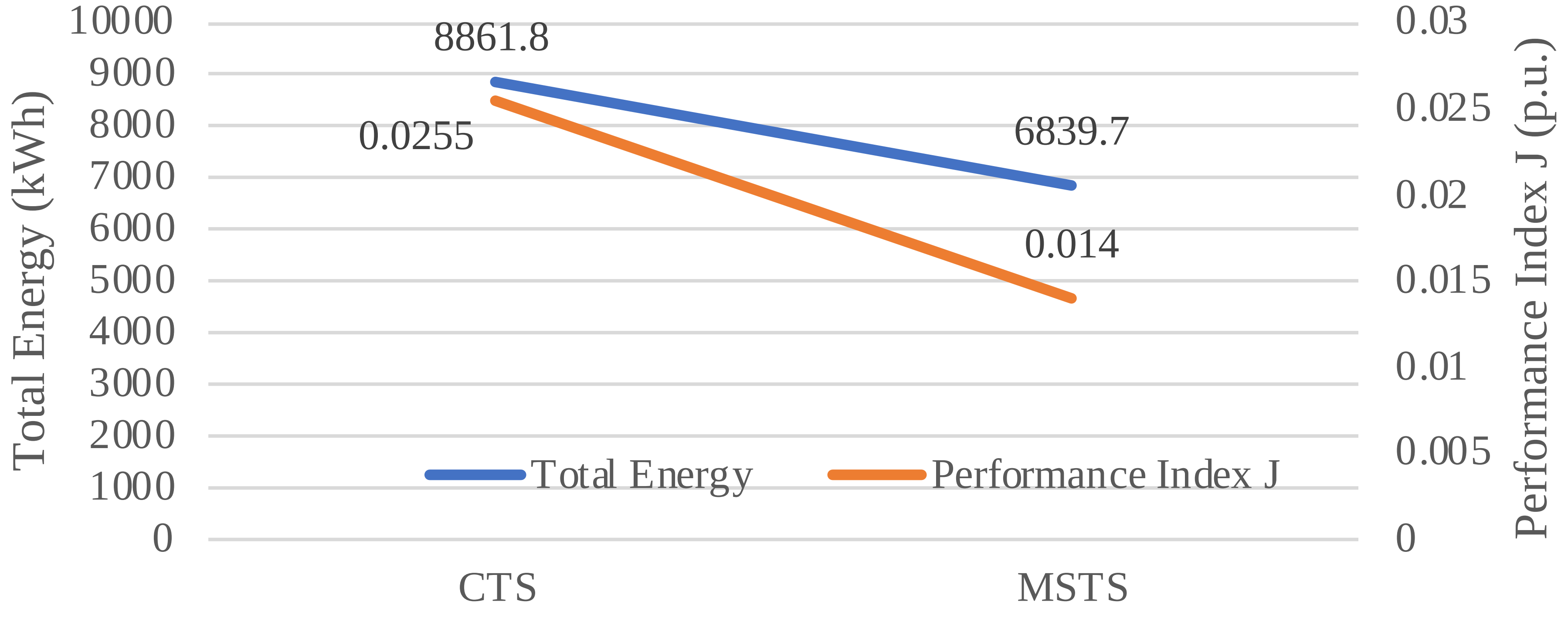
Case study – Verification by simplified model

❑ Long-term simulation



Substation 1 operation information in long-term simulation



Comparison between CTS and MSTS

- ❑ The peak power of substation 1 is kept below 2.05 MW and 1.70 MW in peak and off-peak period, respectively.
- ❑ ESS is used more frequently in off-peak period

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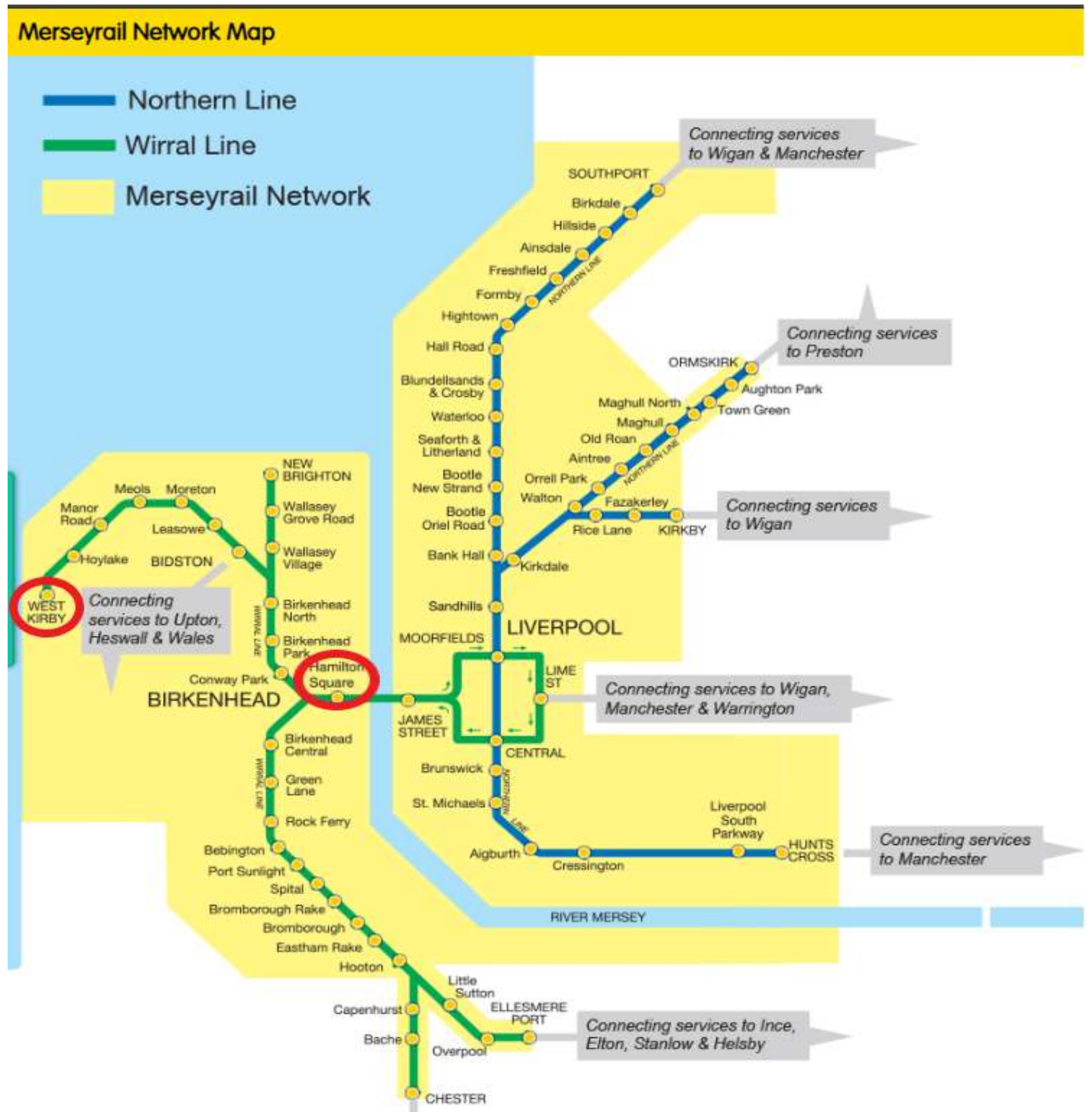
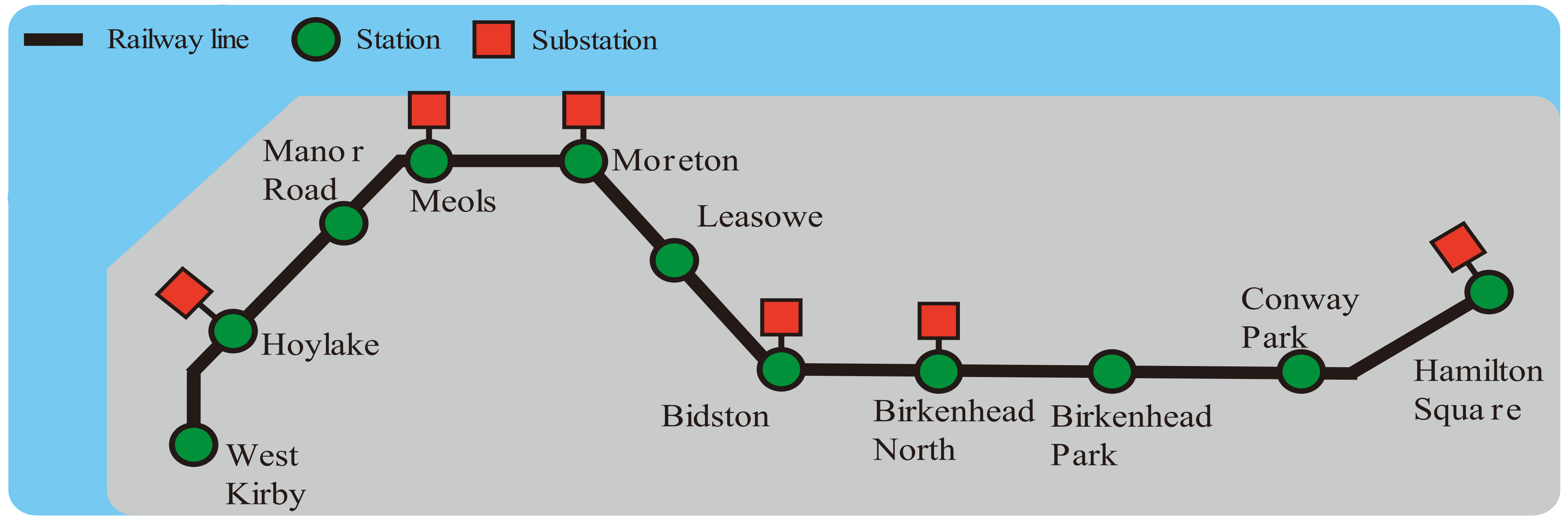
Case study – Merseyrail data

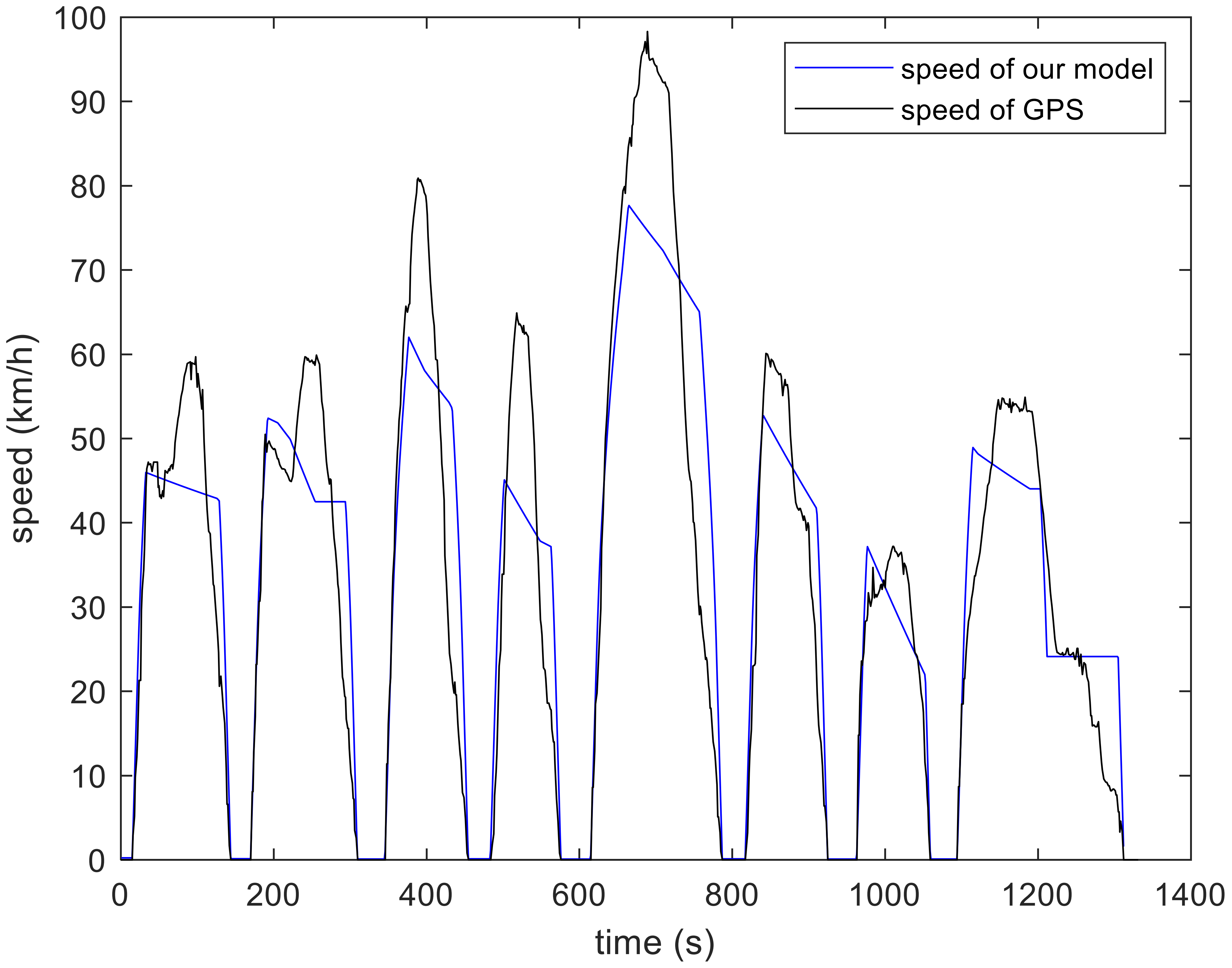
- Data collection
- Class 507
  - Traction power 656 kW
  - Top speed 120 km/h
- Substation
  - DC 750 V nominal
  - No load voltage 800 V
  - Rated power 2 MW
- Current timetable
  - 20 min

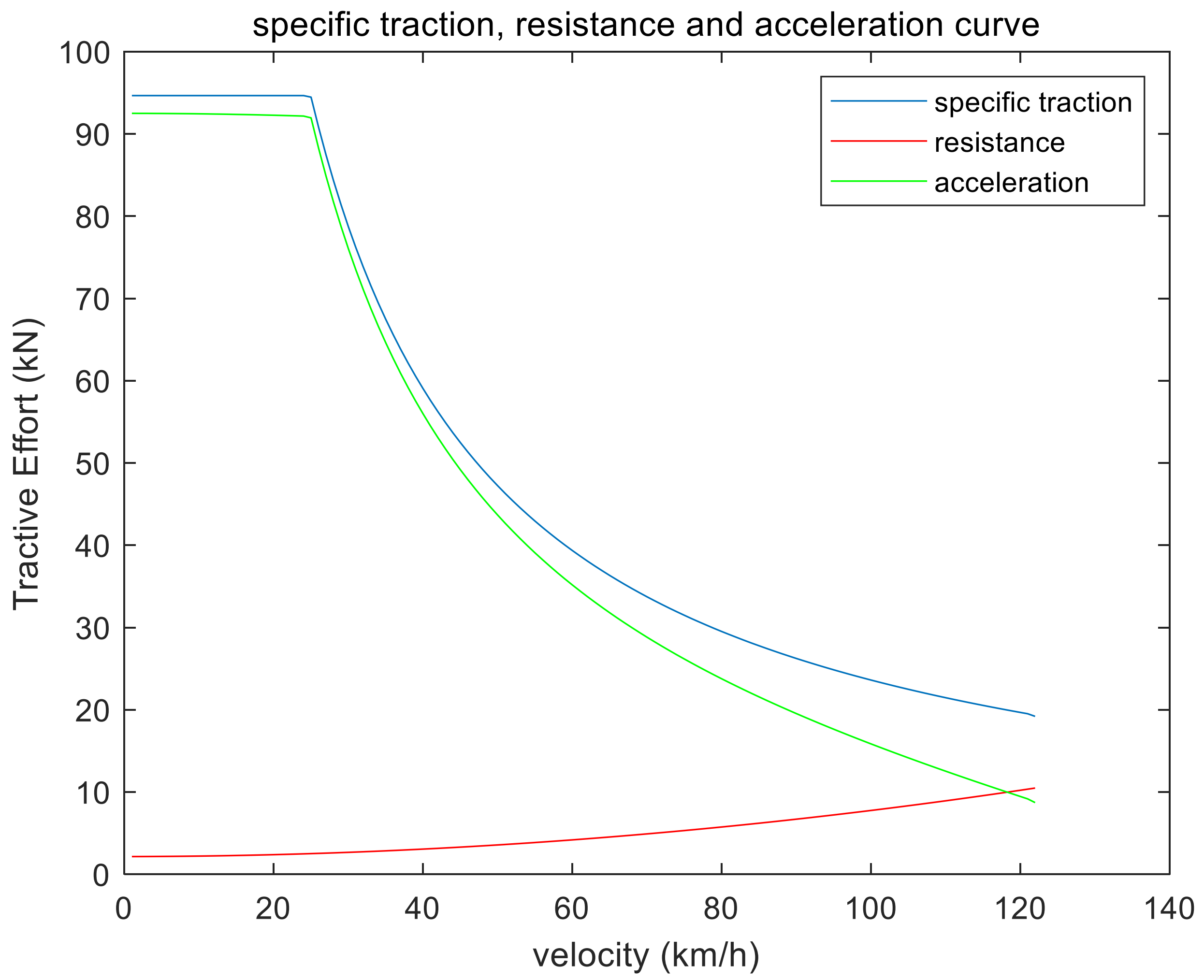




Energy-efficient driving: simulation vs GPS

❑Speed-time



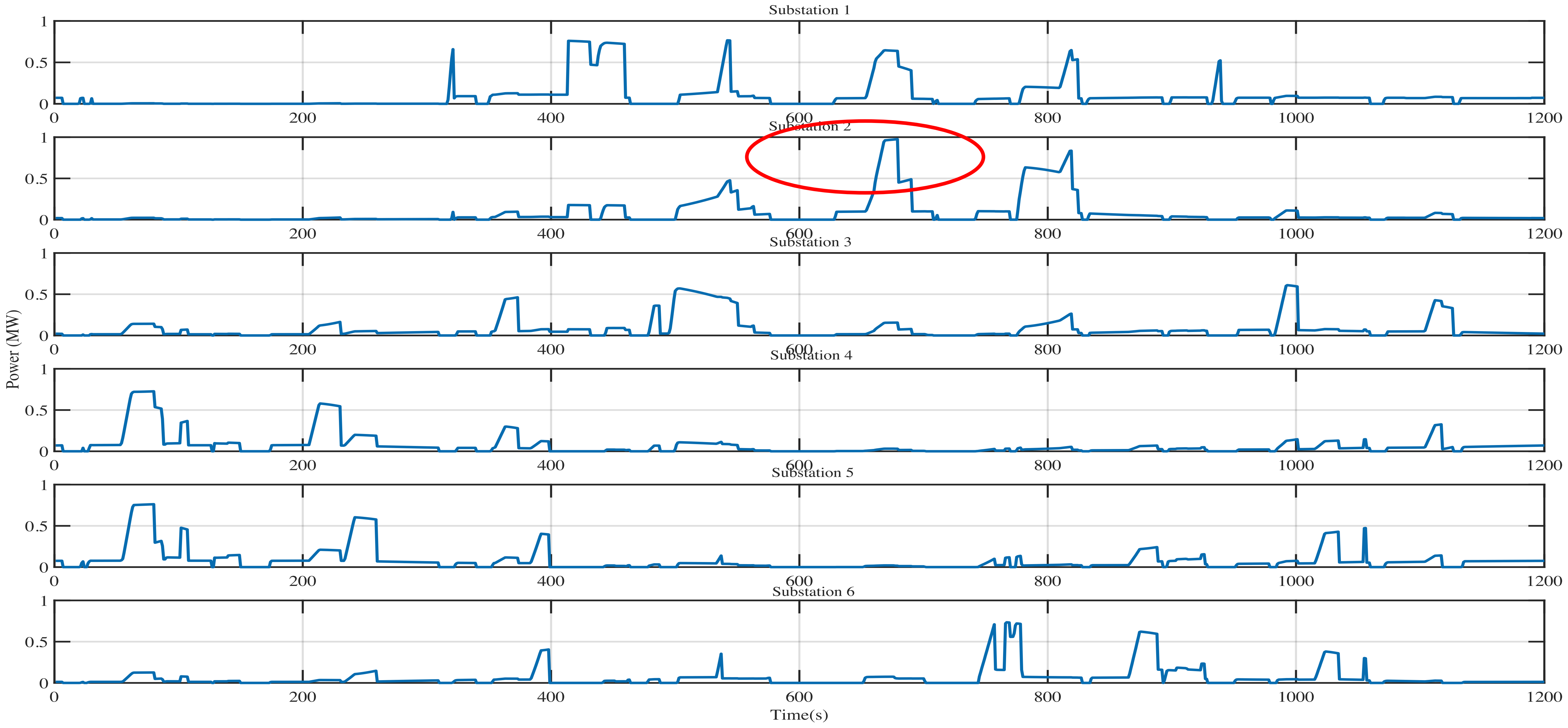


- The **maximum speed** of the simulator is **no higher** than the recorded speed.
- The **deceleration rate** of the simulator is **higher** than the recorded data.

Inter-station No.	1	2	3	4	5	6	7	8	Total
Running time (s)	129	140	109	92	172	108	96	218	1064
GPS calculated energy (kWh)	5.9	5.8	8.4	5.3	14.1	5.0	2.5	5	52.0
Simulation energy (kWh)	2.5	3.3	5.0	2.5	8.3	3.6	1.7	3.1	30 (-42%)

Power network modelling

- Current traction system simulation (headway time 20 min)
- Peak power exceeds 0.5 MW, especially substation 2
- Utilization rate of RBE is 61.51%
- Total energy consumption is 162.42 kWh per headway



Power of substations

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Result summary

Result summary

System	CTS	CTS with ESS	CTS with ESS and RES
ESS discharging threshold	/	792.4 V	797.5 V
Total substation energy (kWh)	162.42	157.61	135.20
Total Rectified energy (kWh)	162.42	157.61	135.20
Total Rectified loss energy (kWh)	4.87	4.72	4.06
Total substation loss (kWh)	4.87	4.72	4.06
Total Traction demand (kWh)	101.34	101.34	101.34
Total braking energy (kWh)	48.56	48.56	48.56
Transferred braking energy (kWh)	29.87	36.75	32.22
Regeneration energy efficiency	61.51%	75.68%	66.35%
RES generation total (kWh)	0	0	59.79
RES generation utilization (kWh)	0	0	21.07
RES utilization rate (kWh)	0	0	35.24%
Substation 3 minimal voltage (V)	784.75	792.42	797.49
Substation 3 peak power (MW)	0.61	0.30	0.10

Conclusions

Conclusion

- The results show the proposed MSTS with the coordinated control strategy can reduce the peak power and voltage sag.
- In long-term simulation, the MSTS save 22.8 % energy consumption compared with CTS.
- Besides, the robustness of the MSTS is verified by simulating extreme situations like RES fault.

Future research challenges:

- Multiple optimisation objectives (substation power, voltage, RES utilisation, ESS SoC and life time)
- Coordinated control strategy and configuration design of ESS, RES with trains
- Various operation scenarios in Merseyrail and mainline railway case studies
- Multimodal transportation integration

Recent publications

- J. Chen, Y. Ge, K. Wang, H. Hu, Z. He, Z. Tian, and Y. Li, “Integrated Regenerative Braking Energy Utilization System for Multi-Substations in Electrified Railways,” *IEEE Transactions on Industrial Electronics,* vol. 70, no. 1, pp. 298-310, 2023.
- N. Kano, Z. Tian, N. Chinomi, and S. Hillmansen, “Comparison of renewable integration schemes for AC railway power supply system,” *IET Electrical Systems in Transportation,* vol. 12, no. 3, pp. 209-222, 2022.
- T. Kamel, Z. Tian, M. Zangiabadi, N. Wade, V. Pickert, and P. Tricoli, “Smart soft open point to synergically improve the energy efficiencies of the interconnected electrical railways with the low voltage grids,” *International Journal of Electrical Power & Energy Systems,* vol. 142, pp. 108288, 2022.
- S. Fang, Z. Tian, C. Roberts, and R. Liao, “Special Section on Towards Low Carbon industrial and Social Economy of Energy-Transportation Nexus,” IEEE Transactions on Industrial Informatics, pp. 1-3, 2022.
- Y. Zhang, Z. Tian, C. Roberts, S. Hillmansen, and M. Chen, “Cost optimization of multi-mode train conversion for discontinuously electrified routes,” *International Journal of Electrical Power & Energy Systems,* vol. 138, pp. 107993, 2022.
- M. Chen, Z. Liang, Z. Cheng, J. Zhao, and Z. Tian, “Optimal Scheduling of FTPSS with PV and HESS Considering the Online Degradation of Battery Capacity,” IEEE Transactions on Transportation Electrification, pp. 1-1, 2021.

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Welcome to Liverpool and Birmingham

- Dr Zhongbei Tian (zhongbei.tian@liverpool.ac.uk)

Thank you!

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INTERNATIONAL UNION
OF RAILWAYS

Questions

Discussion

Thank you for your attention.

Workshop timeline

09h 35	**Welcome Introduction**	**Chairs and UIC**	
09h 40	Energy strategy - Vision and lessons learned	**Maarten Plasschaert**	**Infrabel**
10h 05	Photovoltaics installation – Strategy, Challenges	**Delia Harder** **Marcel Reinhard**	**SBB**
10h 30	Energy and decarbonisation of stations	**Violaine Jacolin**	**SNCF Stations**
10h 45	*Break*		
11h 05	Photovoltaics partnership with EDF Renewables	**Denzel Collins**	**NR**
11h 30	Renewable power management into rail grid and storage	**Zhongbei Tian**	**Liverpool Univ.**
11h 55	Connecting a solar plant to ProRail's 1.5kV DC network	**Robert Heuckelbach**	**DNV**
12h 10	Study, technical and economic analysis for a large scale solar plant connection	**Paul Tobback**	**TUC Rail**
12h 30	*Lunch*		

DNV

Connecting a solar plant to ProRail's 1.5kV DC network

Robert Heuckelbach

INTERNATIONAL UNION
OF RAILWAYS

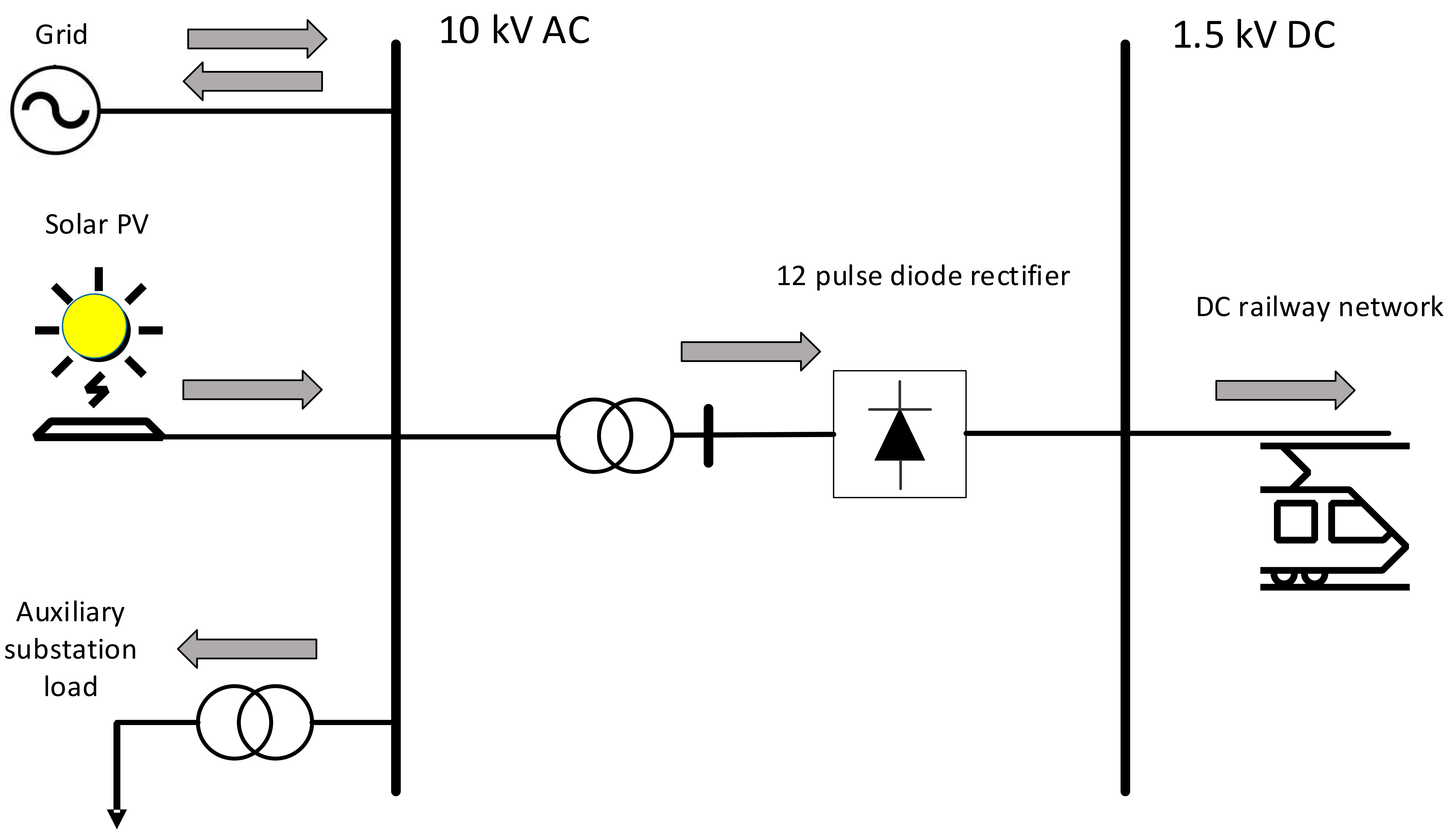
ASSESSMENT RENEWABLES IN TRACTION POWER SUPPLY

Integration of a PV plant into the 1500 VDC traction power supply

Heuckelbach, Robert
Senior Specialist

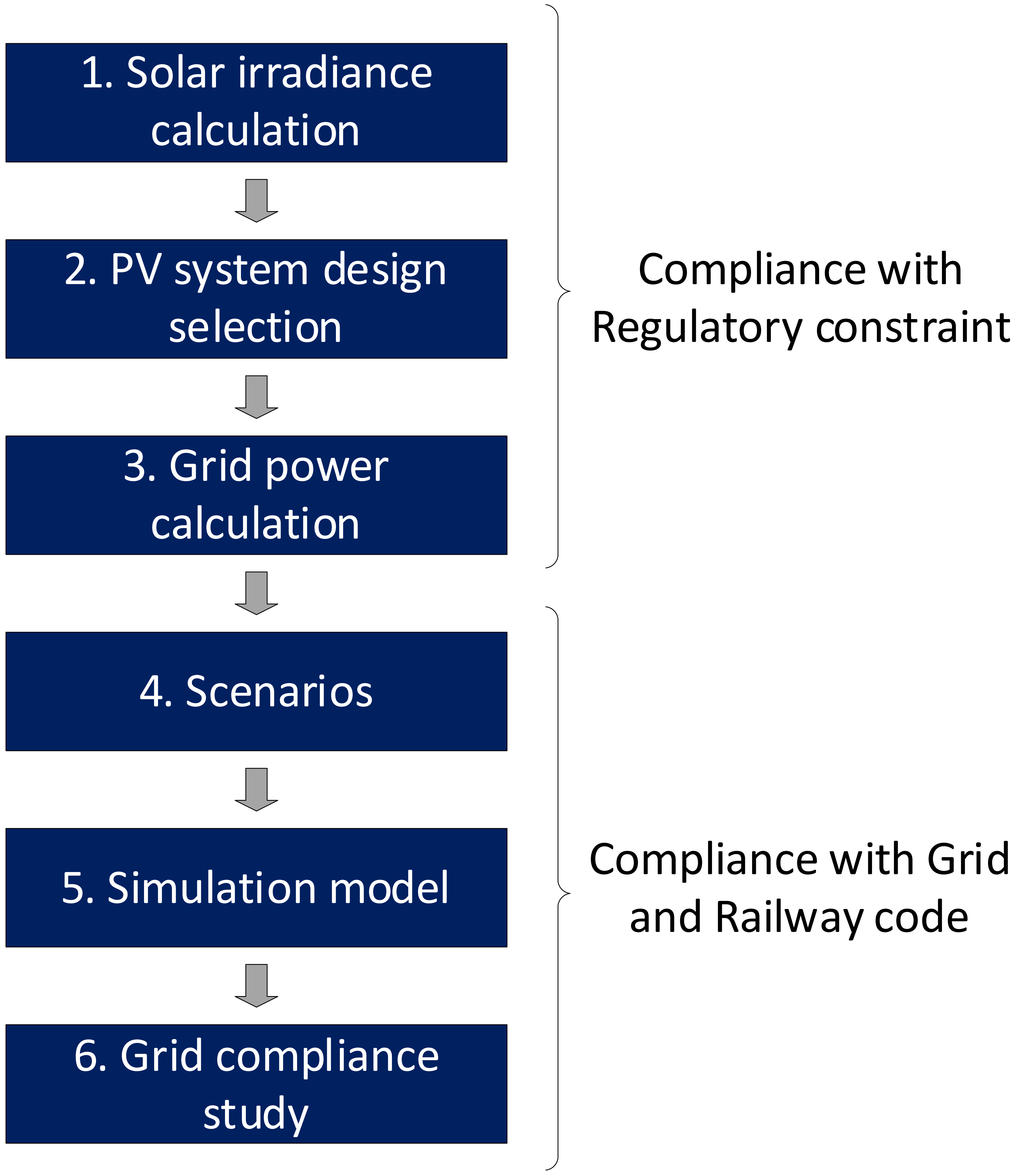
November 17, 2022

Design overview, introduction DC traction



Assessment methodology

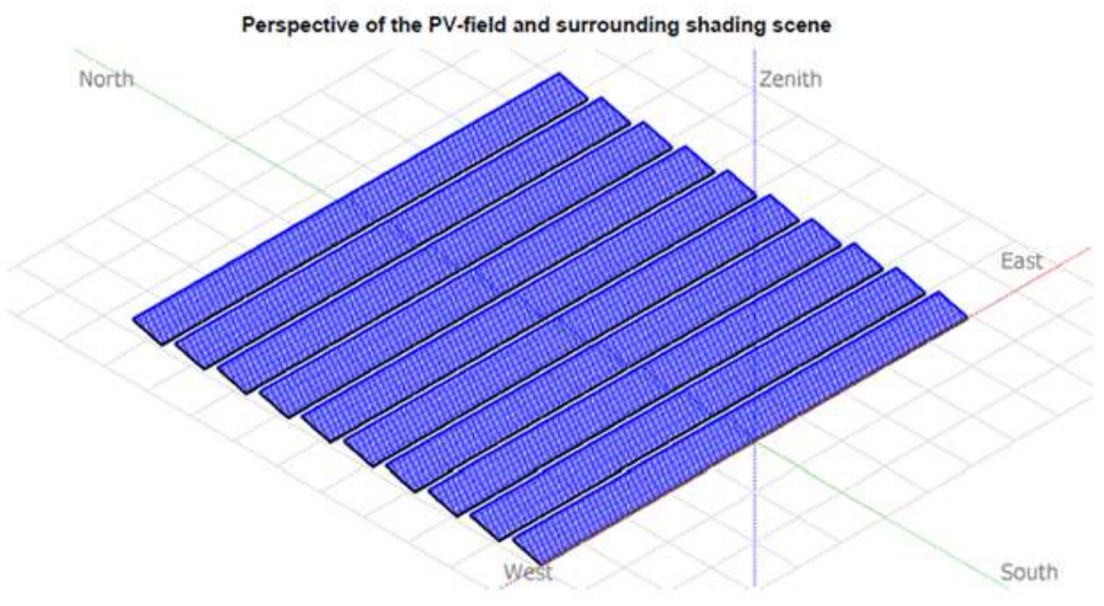
- To assess the compliance, a PV plant has been designed and integrated in a substation for this case.
- The railway operator is constrained by the regulator to transfer the whole PV generation to the railway network. No power should flow towards the distribution grid to avoid congestions in the DSO grid. The compliance with this regulatory constraint was evaluated.
- The compliance with the grid code (DSO) requirements, but also with the railway network requirements was assessed.



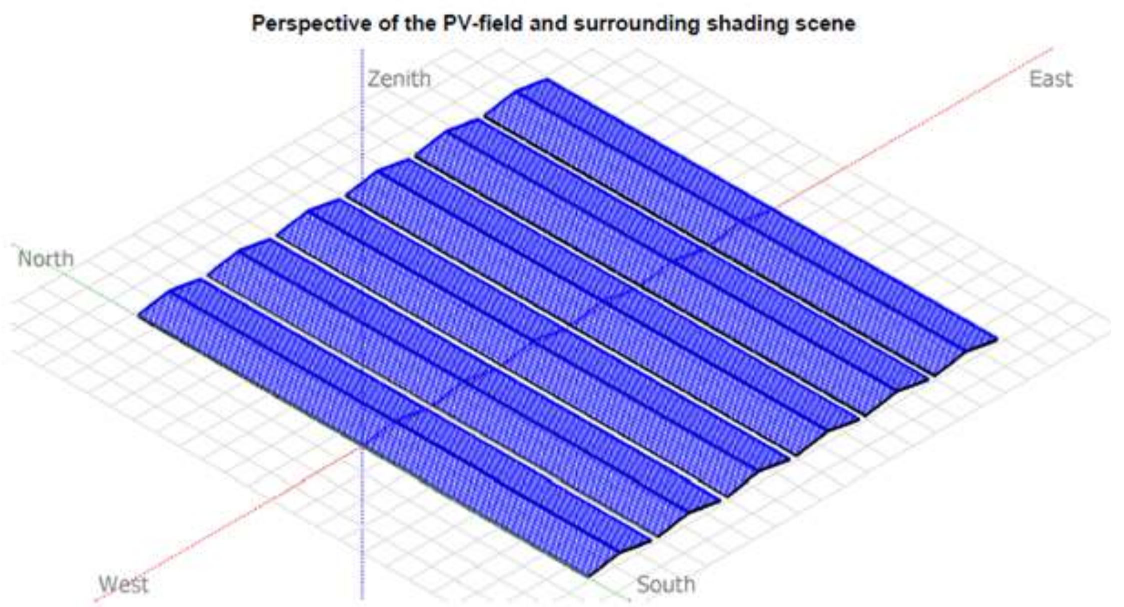
PV plant, design

Step 1: Solar irradiance calculation

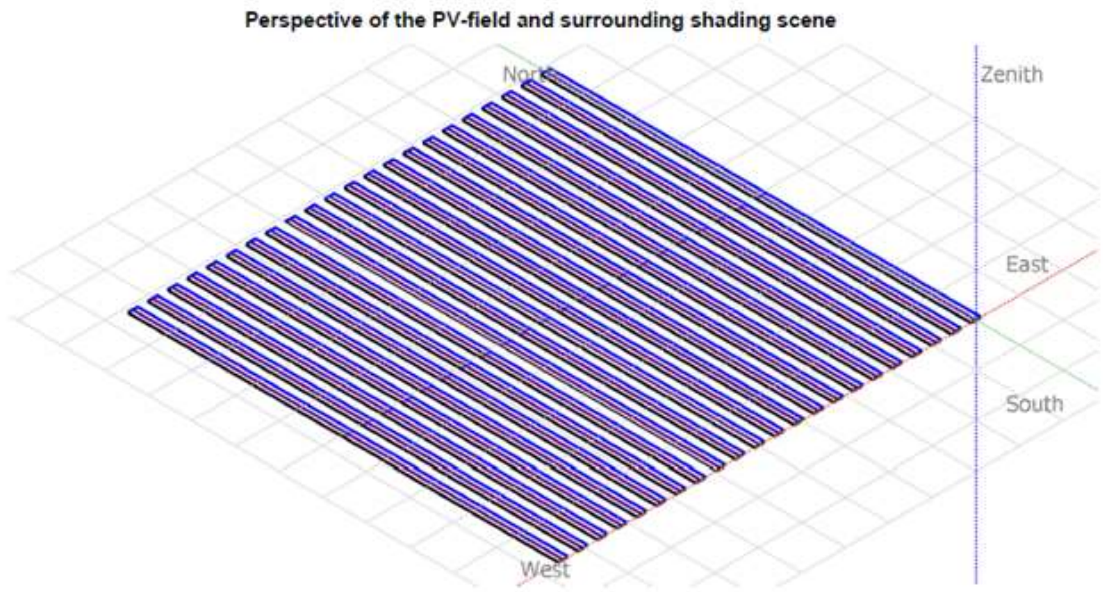
- The global horizontal irradiance (GHI), diffuse horizontal irradiance (DHI) and the ambient temperature were derived in monthly resolution.



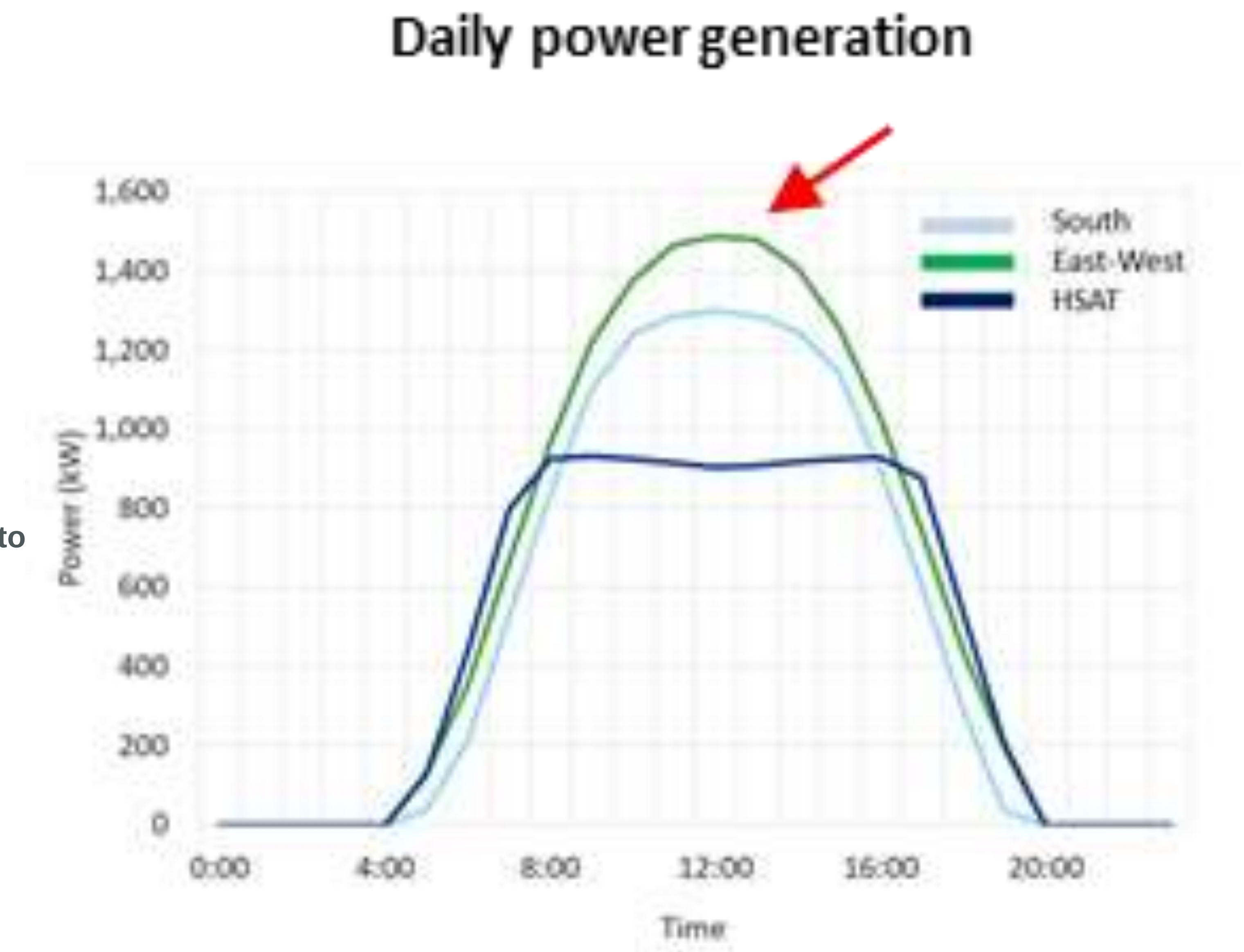
South facing (“South”), fixed tilt angle, 15 degrees



East-West facing (“East-West”), fixed tilt angle, 10 degrees



Horizontal single-axis tracker (“HSAT”), variable angle, -60 to



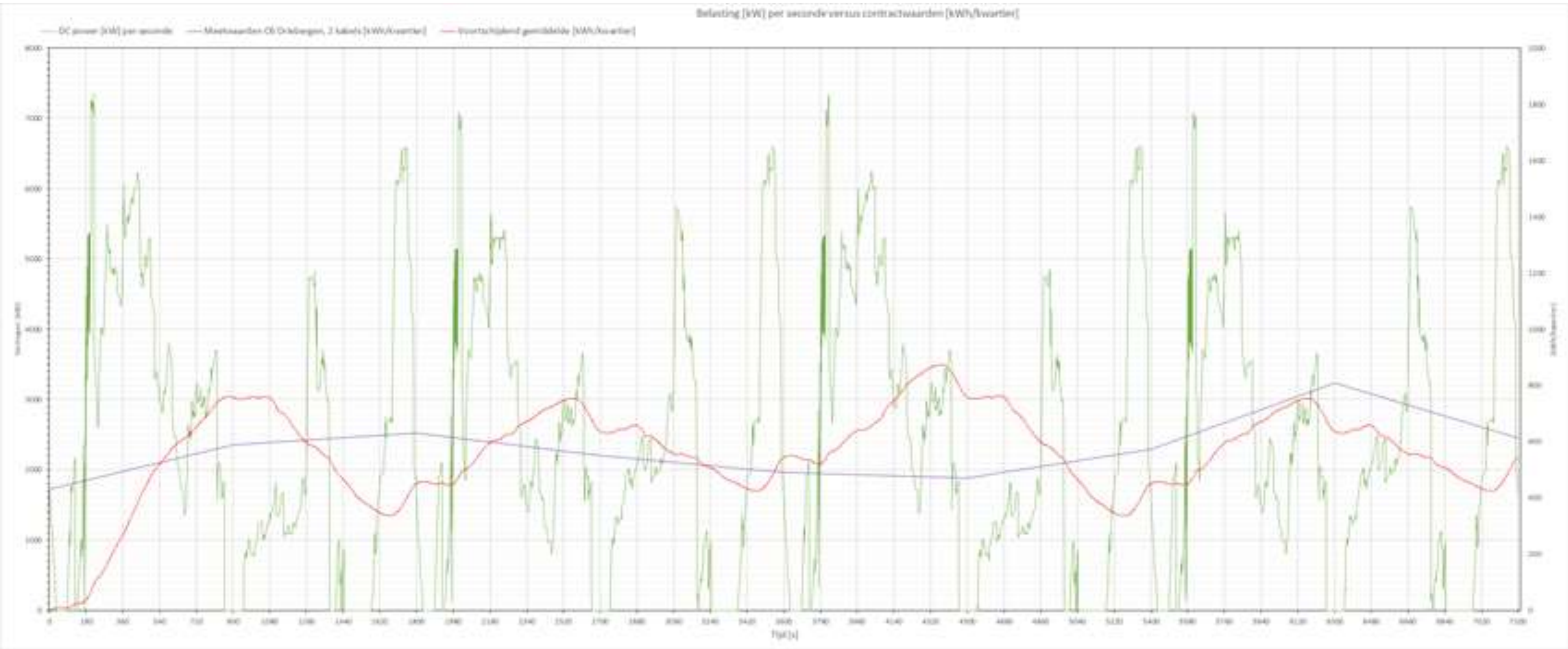
Step 2: PV system design and selection

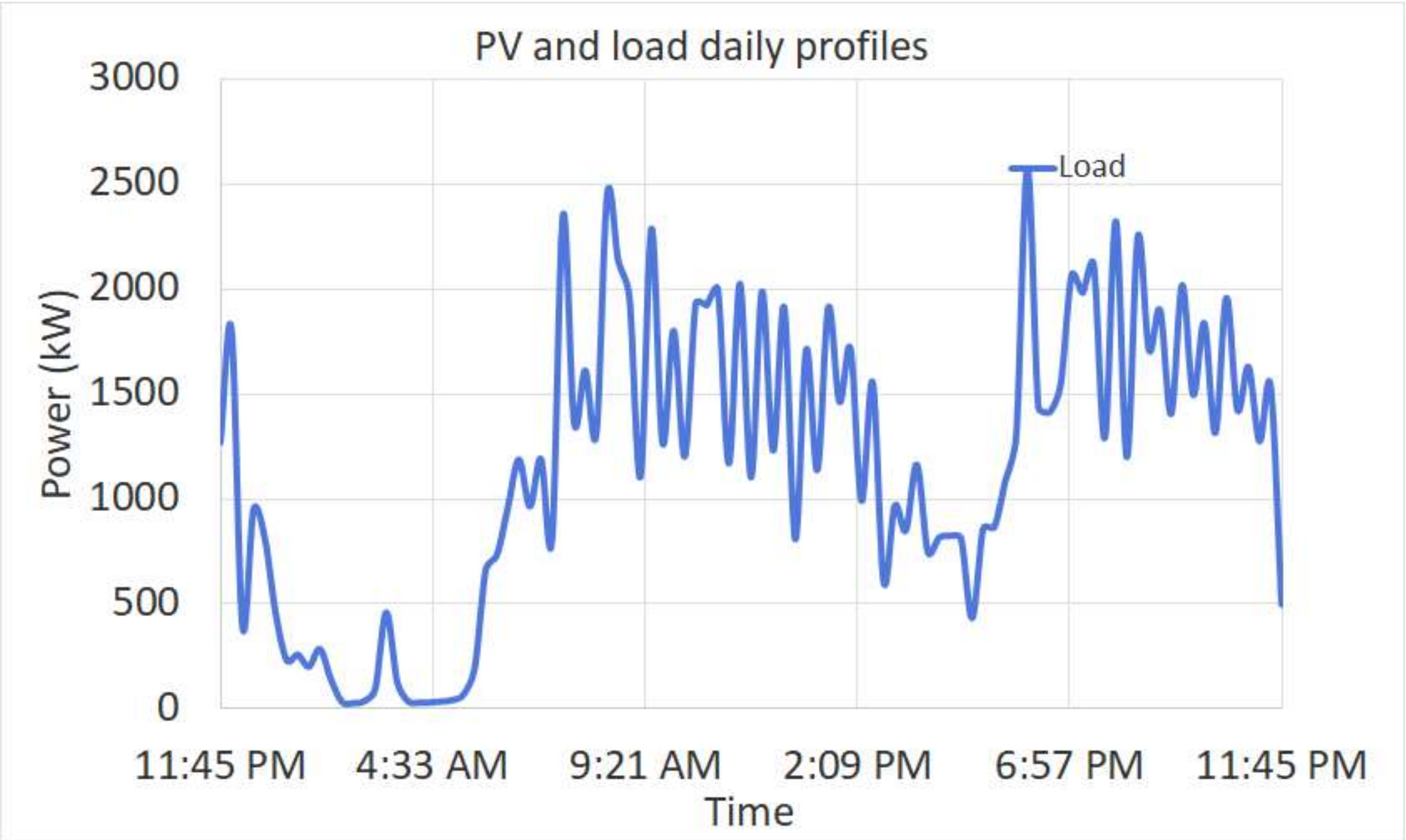
- The potential energy yield and hourly production profiles of three hypothetical solar PV systems at the specific location were generated.
  All 3 types have the same surface area of 1 hectare (100 m x 100 m).
- An East-West orientation was selected due to highest energy production.
- Based on the available ground space a 1,5 MWp PV plant was possible.

Parameter	South	East-West	HSAT
Total system capacity	1393 kWp	1672 kWp	1010 kWp
Net energy production	1255 MWh	1390 MWh	987 MWh

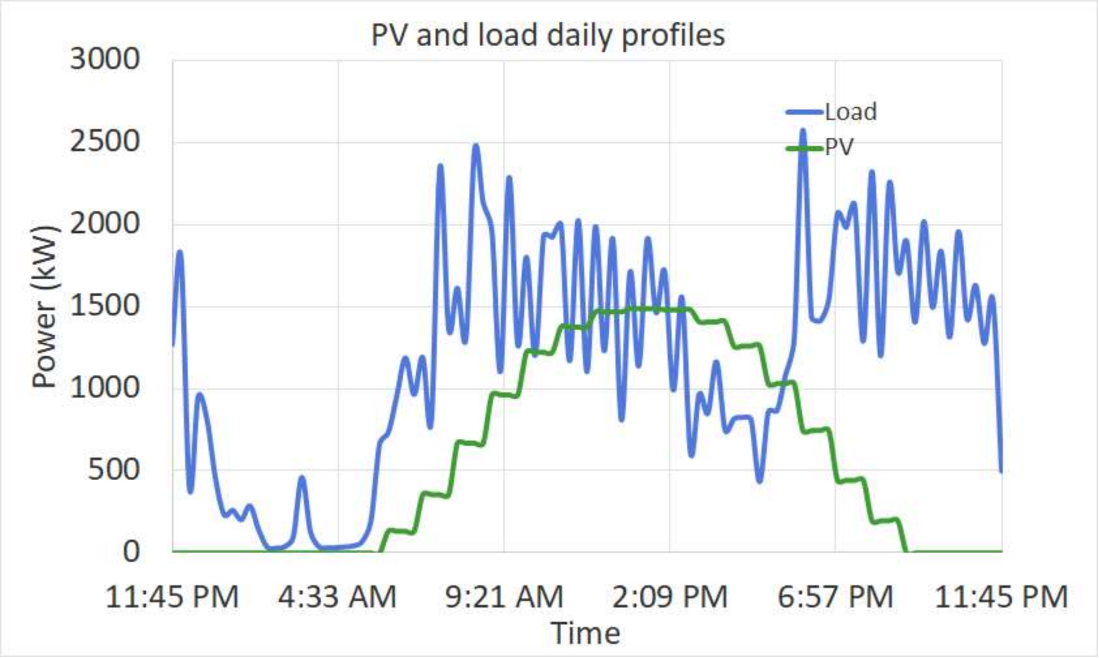
Load due to traction

- The load on the traction power supply depends on the timetable and rolling stock.
- The traction load pattern is erratic.
- kWh quarter-hour values measurement data of the energy consumption is available from the substation.

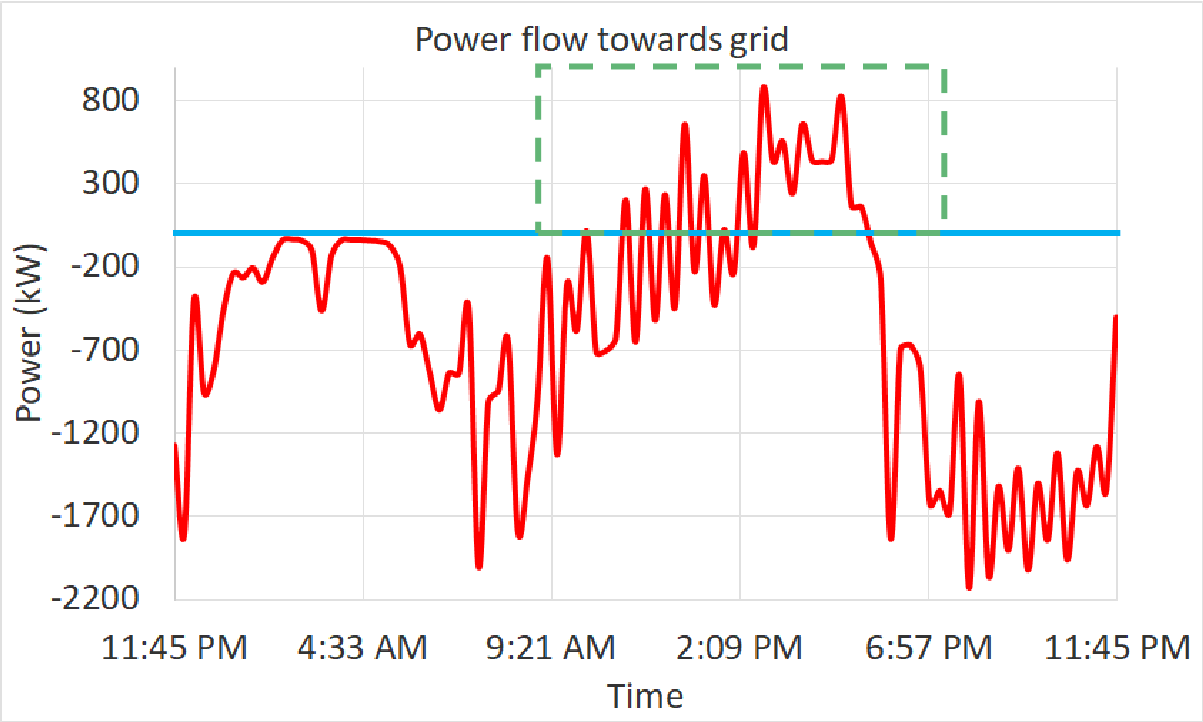


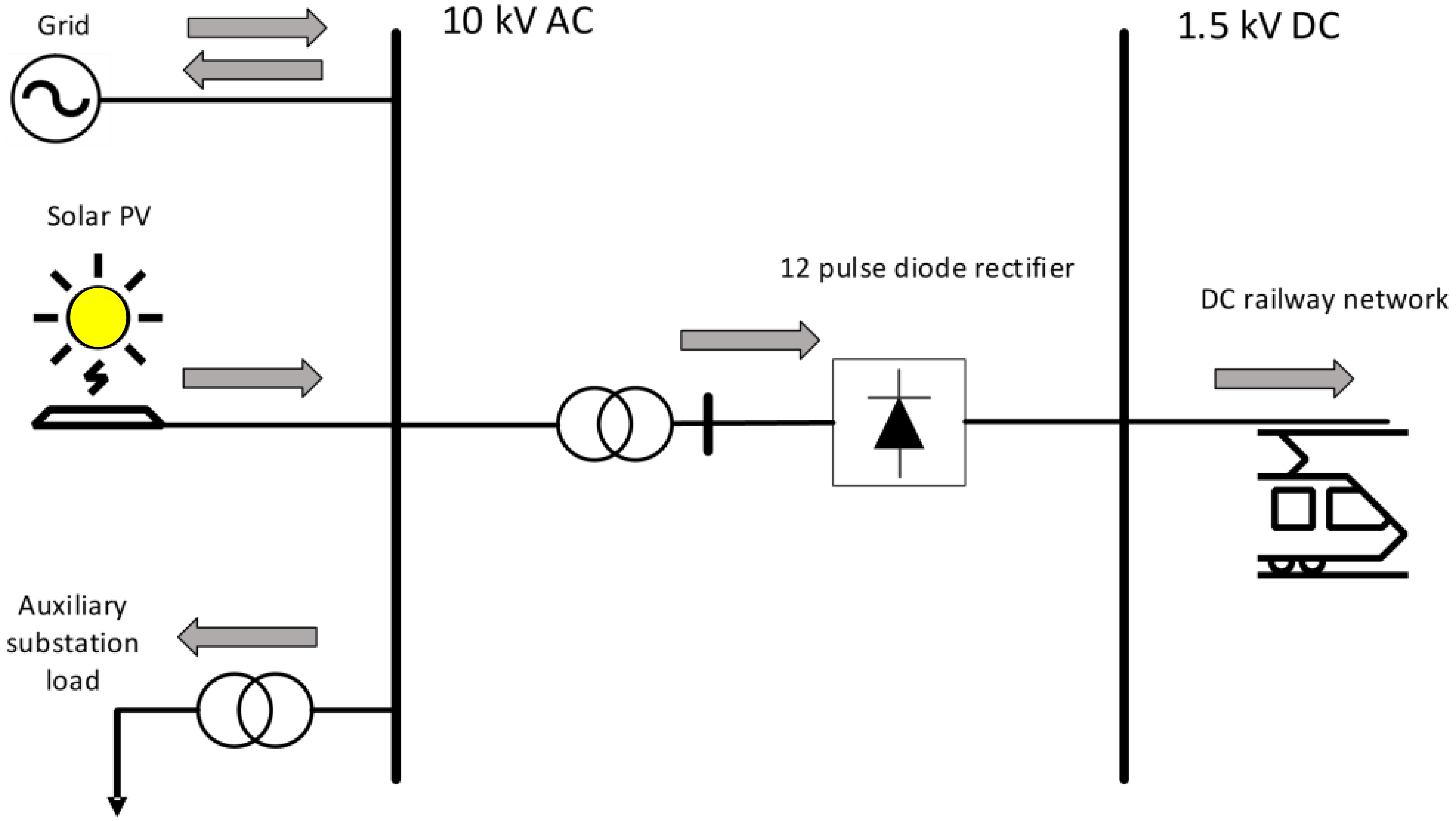


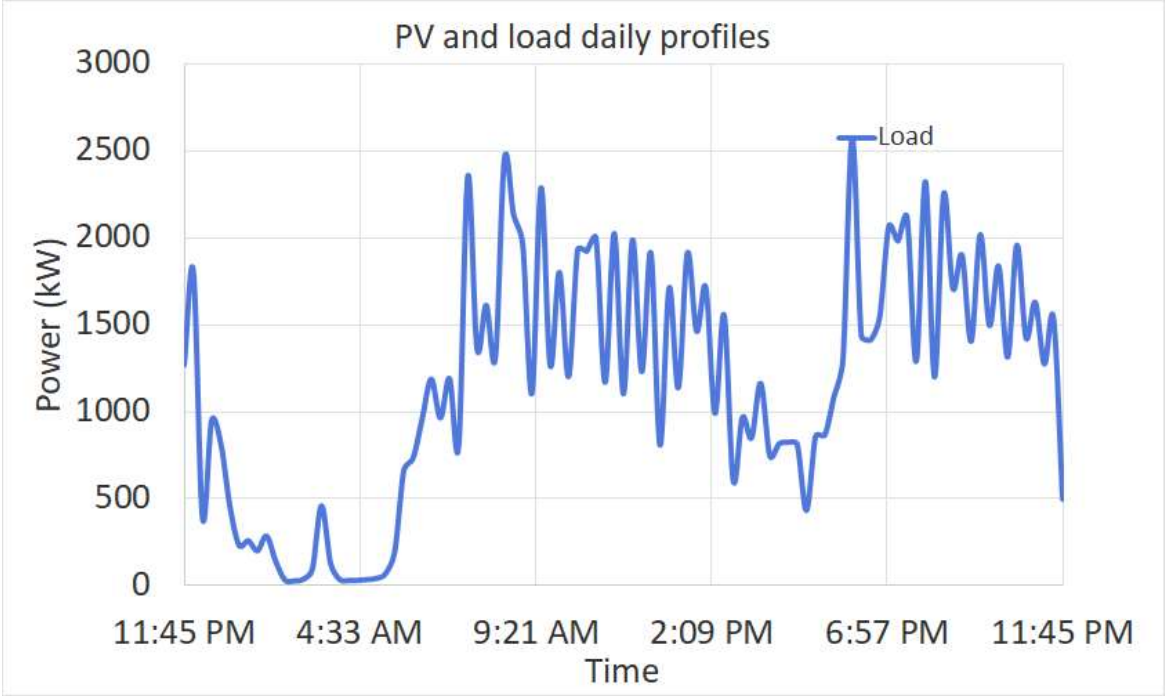
Overview, energy balance substation

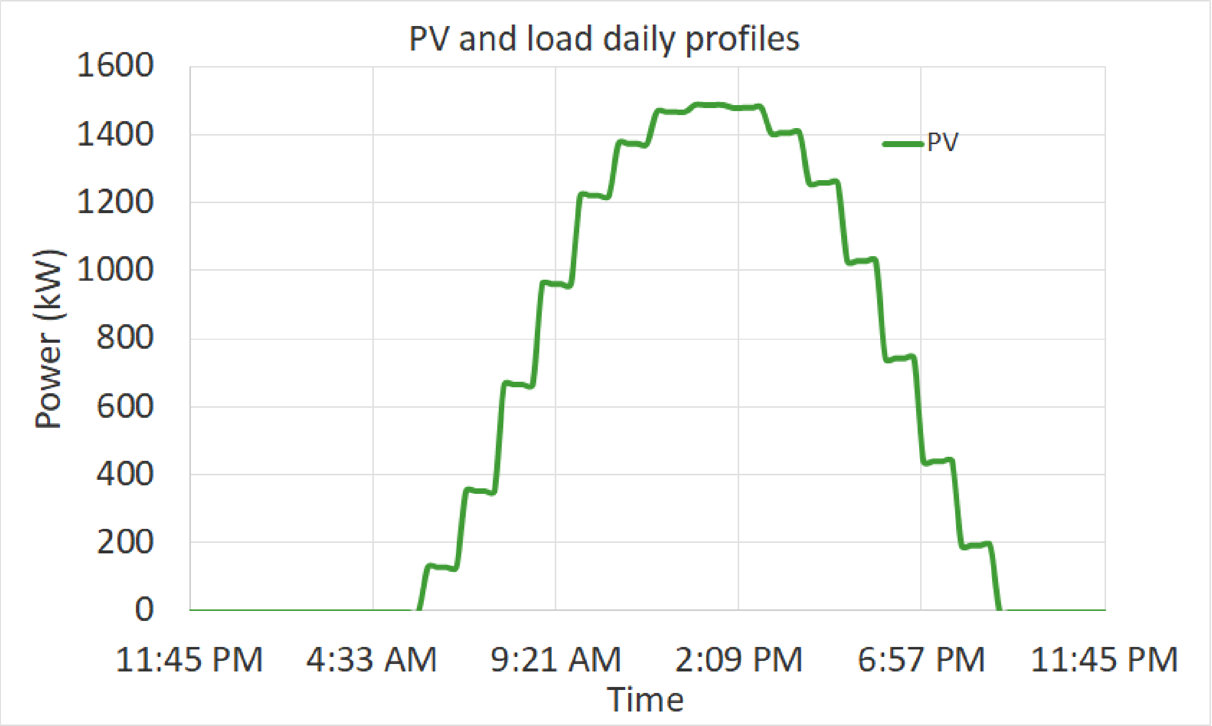


Energy balance (1^{st} Kirchhoff's law)

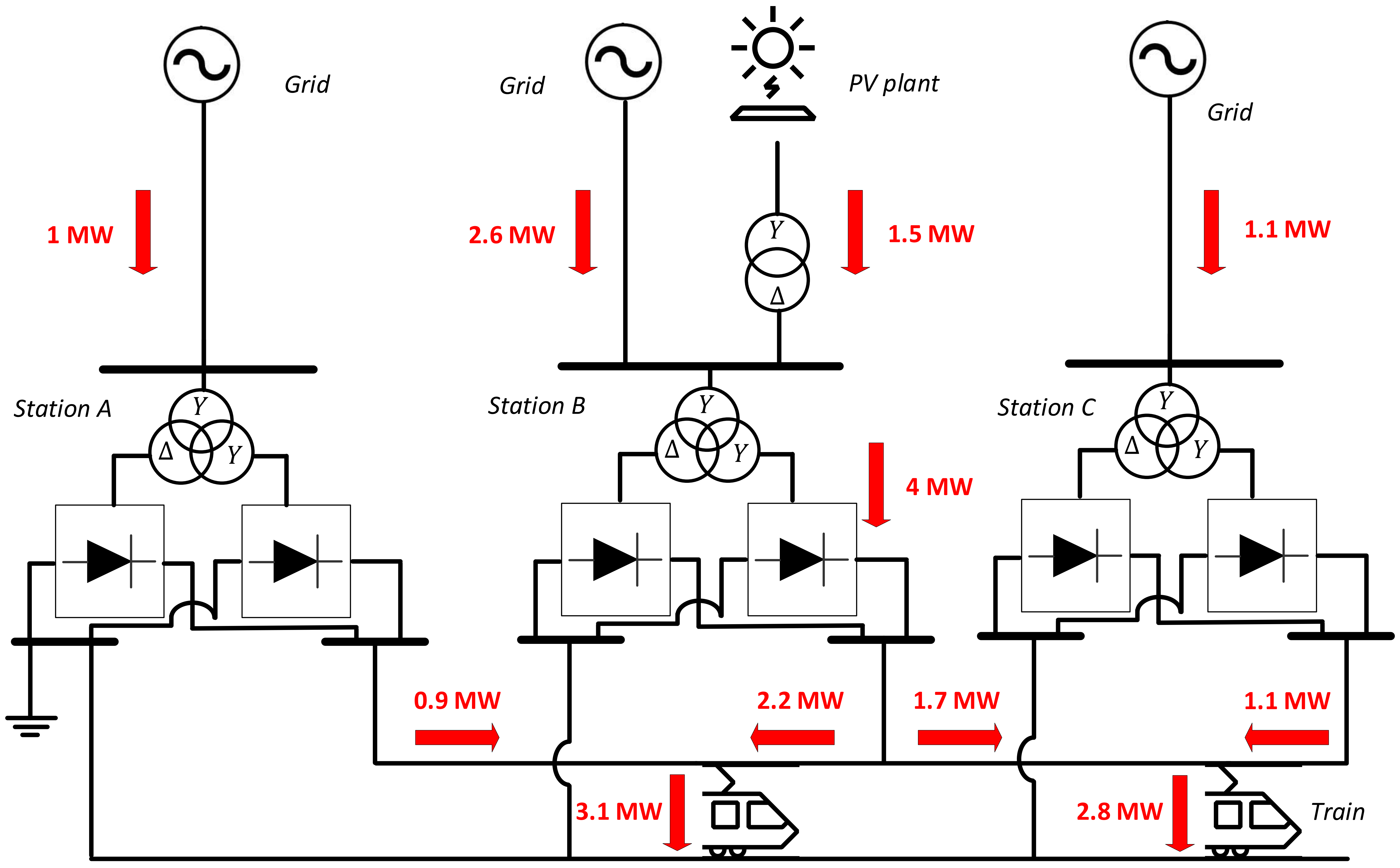








Grid compliance, traction side

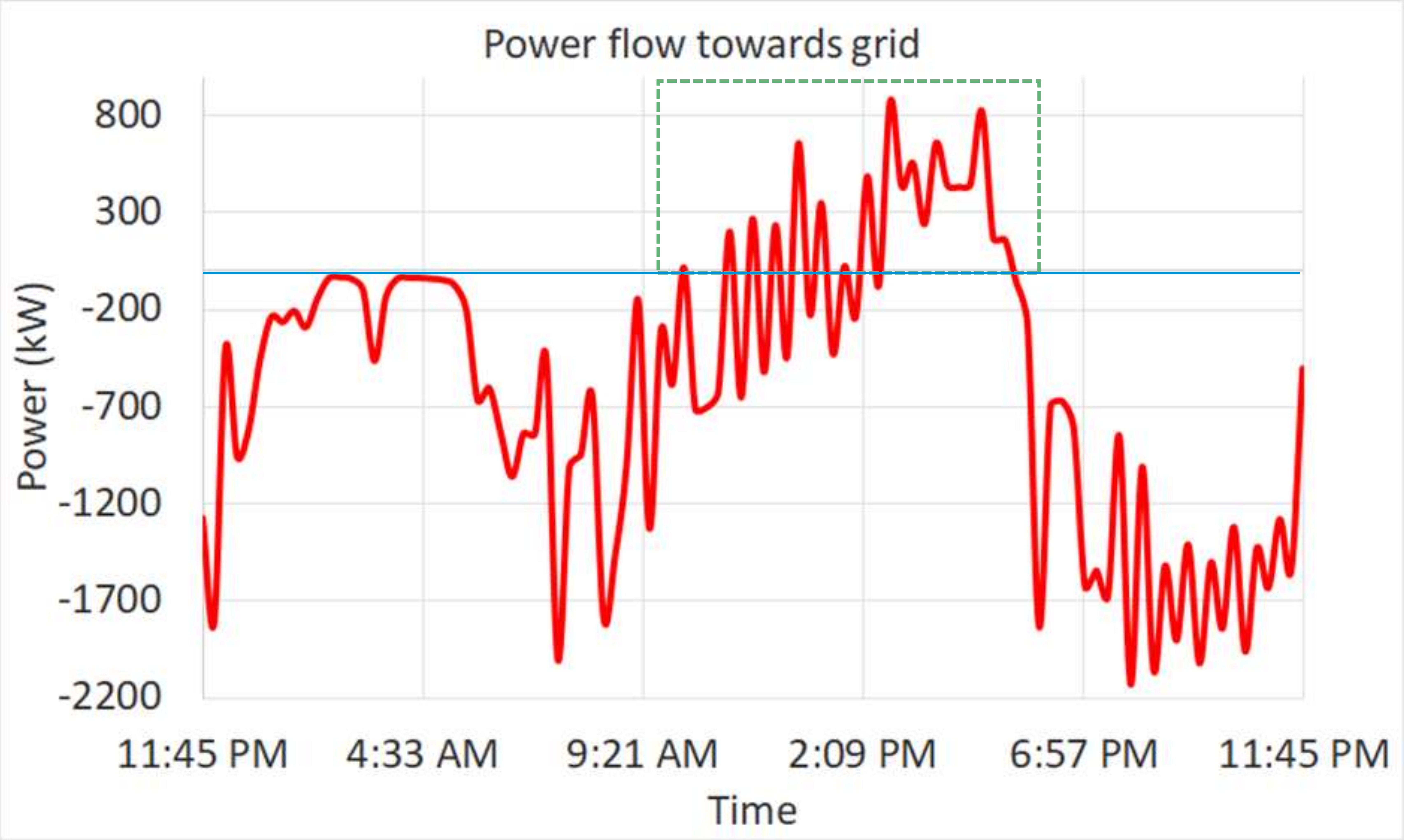


Scenarios	PV power	Load of substation B
Scenario 1	PV_{max}	0
Scenario 2	0	$Load_{max}$
Scenario 3	PV_{max}	$Load_{max}$

Network Compliance Criteria

1. Network components should not be overloaded.
2. DC load voltage variation should be maintained within the acceptable range: 1350 – 1810 V. (Maximum DC voltage on the catenary 1950 V).
3. Short circuit current should not exceed the rated equipment values.
4. Maximum load of substation: 4000 kW.
5. Maximum continue load of catenary per track: 1800 A

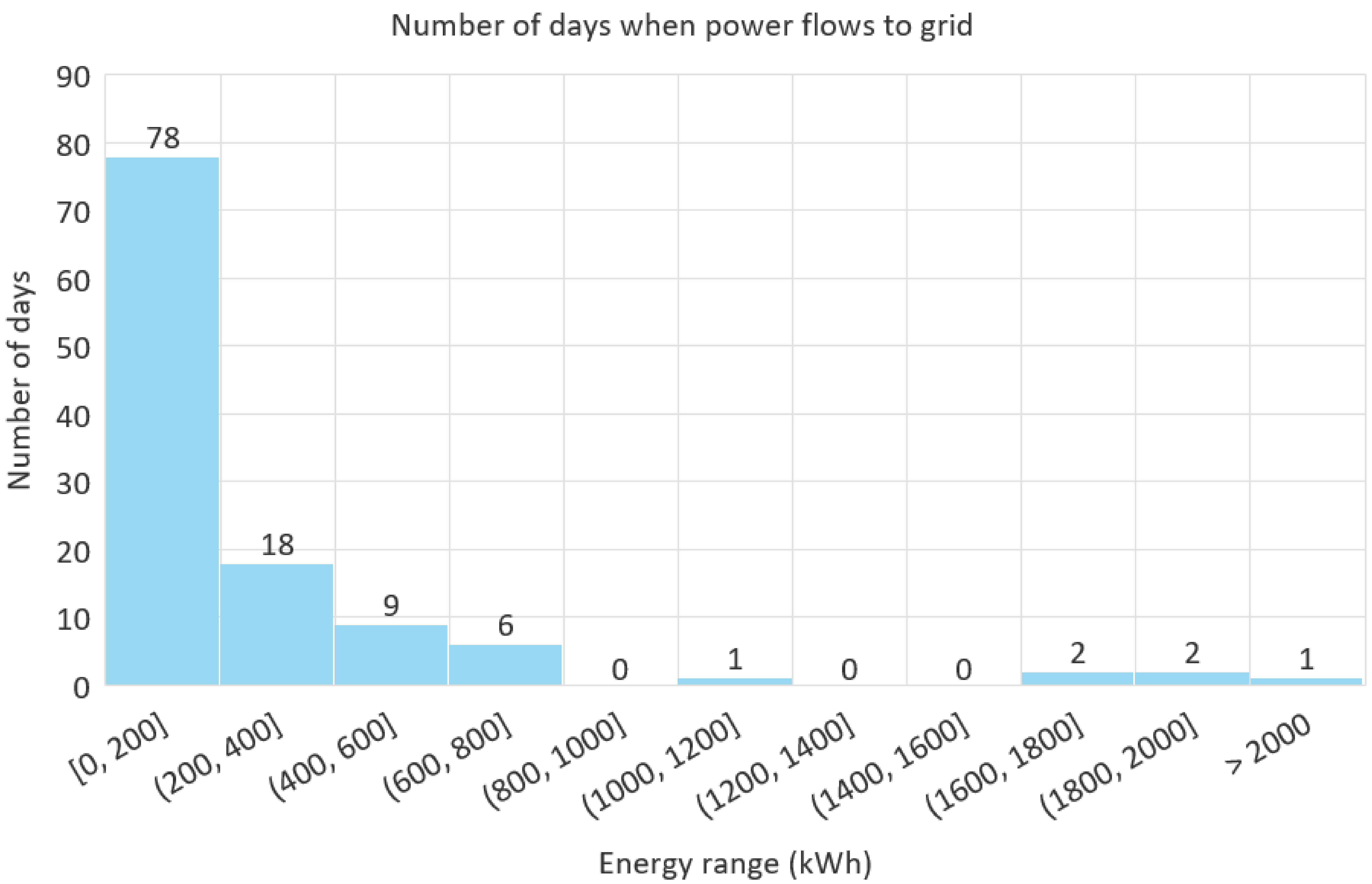
Grid compliance, grid side



Network Compliance Criteria

- ✓ Network components should not be overloaded.
- ✓ Energy to the grid can cause overloads in the DSO grid.
- ✓ Voltage distortion at PoC should be acceptable (IEC, IEEE harmonic limits and THD < 5%).
- ✓ Voltage magnitude variation at PoC within ± 5 % of nominal value.
- ✓ Short circuit current should not exceed the rated equipment values.

Additional energy analyse regarding the constrains



Energy balance:

- Because the generation and consumption are determined per quarter of an hour, more energy can be returned to the grid.
- If instantaneous power is considered, then only the OS's own consumption can be generated.
- It is shown that PV power can flow towards the grid throughout the year.
- For 117 days over a year, energy flows towards the grid.
- Therefore, the regulatory constraint cannot be respected at all times!
- So, the PV power (plant controller) or the size of the PV plant need to be reduced or the constraint at the DSO side need to been upgraded due to respect the congestion for delivering the energy to the grid.

Thank you for your attention

Any question?

DNV

ProRail

Assessment Renewables in traction power supply

Michalis POIKILIDIS*, Robert HEUCKELBACH*, Teun PLOEG*, Fedor TEN HARVE, Gerald OLDE MONNIKHOF****
DNV*, ProRail**

Questions

Discussion

Thank you for your attention.

Workshop timeline

09h 35	**Welcome Introduction**	**Chairs and UIC**	
09h 40	Energy strategy - Vision and lessons learned	**Maarten Plasschaert**	**Infrabel**
10h 05	Photovoltaics installation – Strategy, Challenges	**Delia Harder** **Marcel Reinhard**	**SBB**
10h 30	Energy and decarbonisation of stations	**Laurent Mahuteau**	**SNCF Stations**
10h 45	*Break*		
11h 05	Photovoltaics partnership with EDF Renewables	**Denzel Collins**	**NR**
11h 30	Renewable power management into rail grid and storage	**Zhongbei Tian**	**Liverpool Univ.**
11h 55	Connecting a solar plant to ProRail's 1.5kV DC network	**Robert Heuckelbach**	**DNV**
12h 10	Study, technical and economic analysis for a large scale solar plant connection	**Paul Tobback**	**TUC Rail**
12h 30	*Lunch*		

100 YEARS ANNIVERSARY uic INTERNATIONAL UNION OF RAILWAYS

TUC RAIL

Study, technical and economic analysis for a large scale solar plant connection

TUC RAIL BELGIAN RAIL ENGINEERING

Paul Tobback

LARGE-SCALE SOLAR PLANT CONNECTION TO AN OVERHEAD CONTACT LINE

Technical and economical analysis

Paul TOBBACK
Lead Design Engineer & OCL expert

Renewable energy integration in railways Workshop - 17 November 2022

ENERGY TRANSITION

Does anyone has some space left ?

Railway lines have !

TUC RAIL
BELGIAN RAIL ENGINEERING

INFRABEL
Right On Track

Summary

The installation of elongated strings of PV modules on the embankments of Belgium's high-speed line 2 (HSL2) differs significantly from industrial projects.

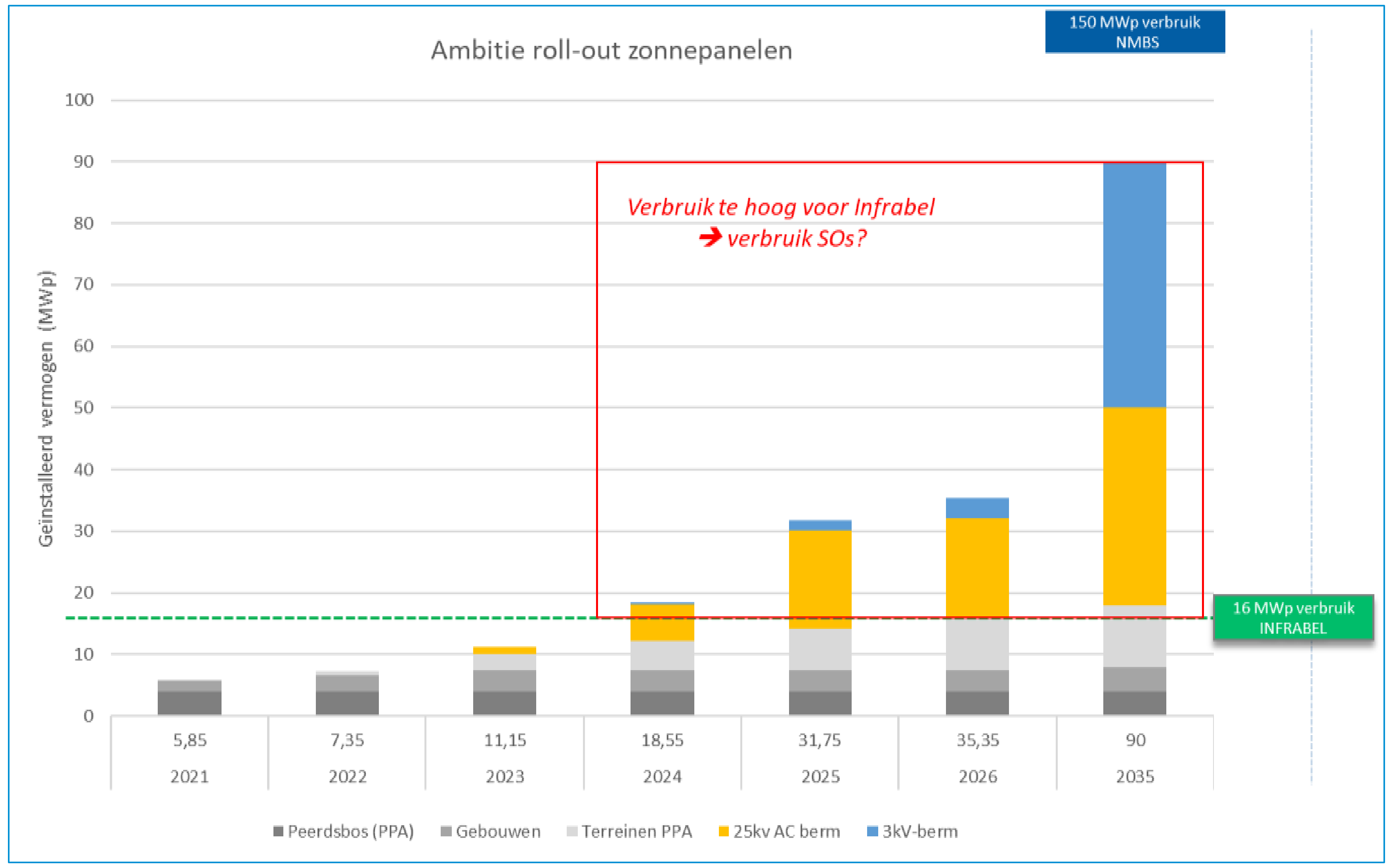
The panels are connected directly to the 2x25 kV AC 50 Hz “catenary” (better Overhead Contact Line or OCL), which requires special single-phase DC/AC inverters.

A feasibility study is presented with:

- simulations to determine the influence on short-circuit detection,
- maximum ampacity of the catenary and

- an optimal connection scheme with variants.

Energy strategy 1.0 Infrabel



Solar panels for **<u>Infrabel consumption</u>** (max 16 MWp):

1. 7,35 MWp on Buildings / tunnel Peerdsbos

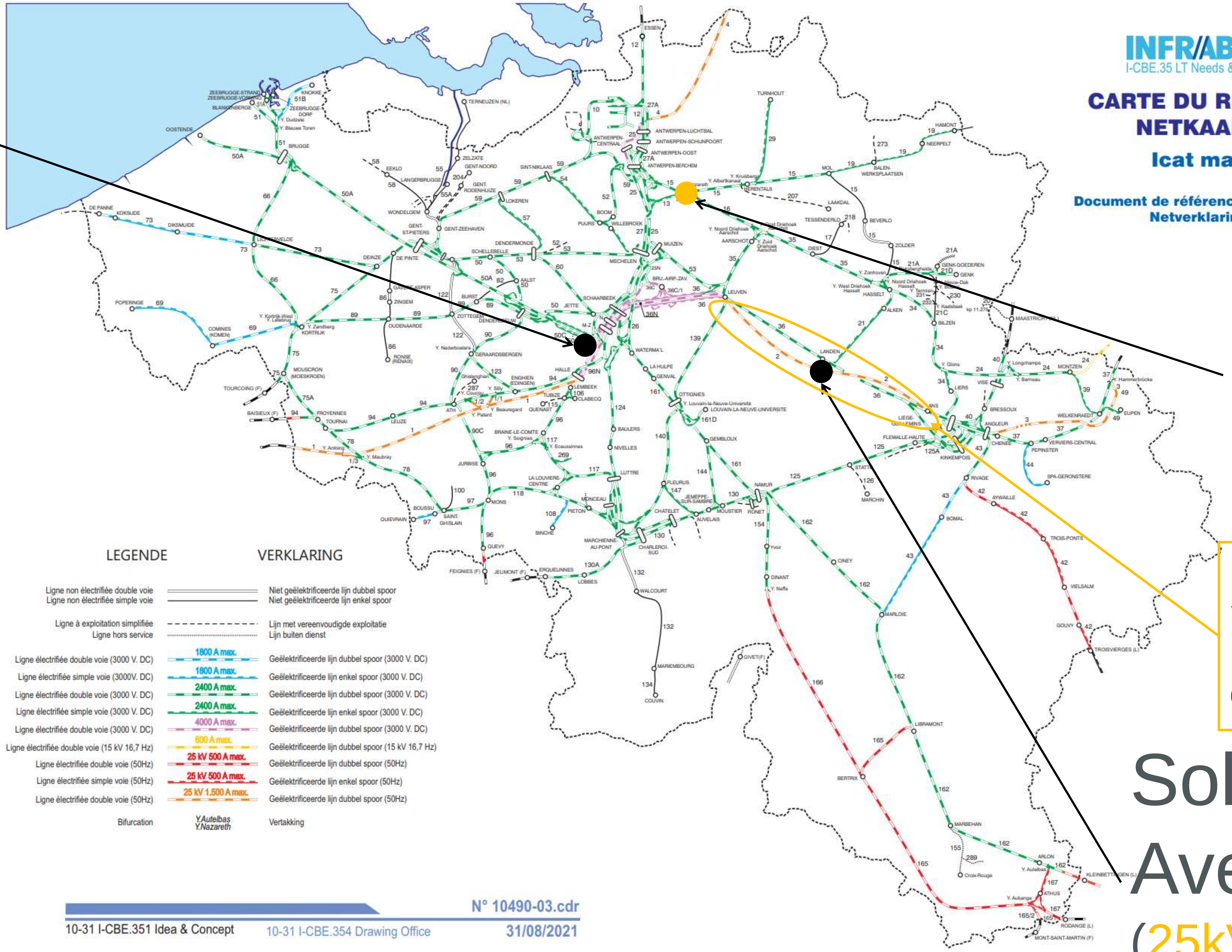
	Production capacity
Buildings	2.2 MWp (but 600kWp not yet operational)
Peerdsbos tunnel	4 MWp
Deinze	45 kWp
Antwerp-N. Building	1 MWp (50% Infrabel)

2. **8,65 MWp** still to be installed

Avernas 2 MWp (traction substation) + Boutersem 2 MWp (25 kV catenary) = **4 MWp**

Renewable energy within the Belgian railways

Solar panels Itterbeek & Anderlecht
(3 kV DC substations)

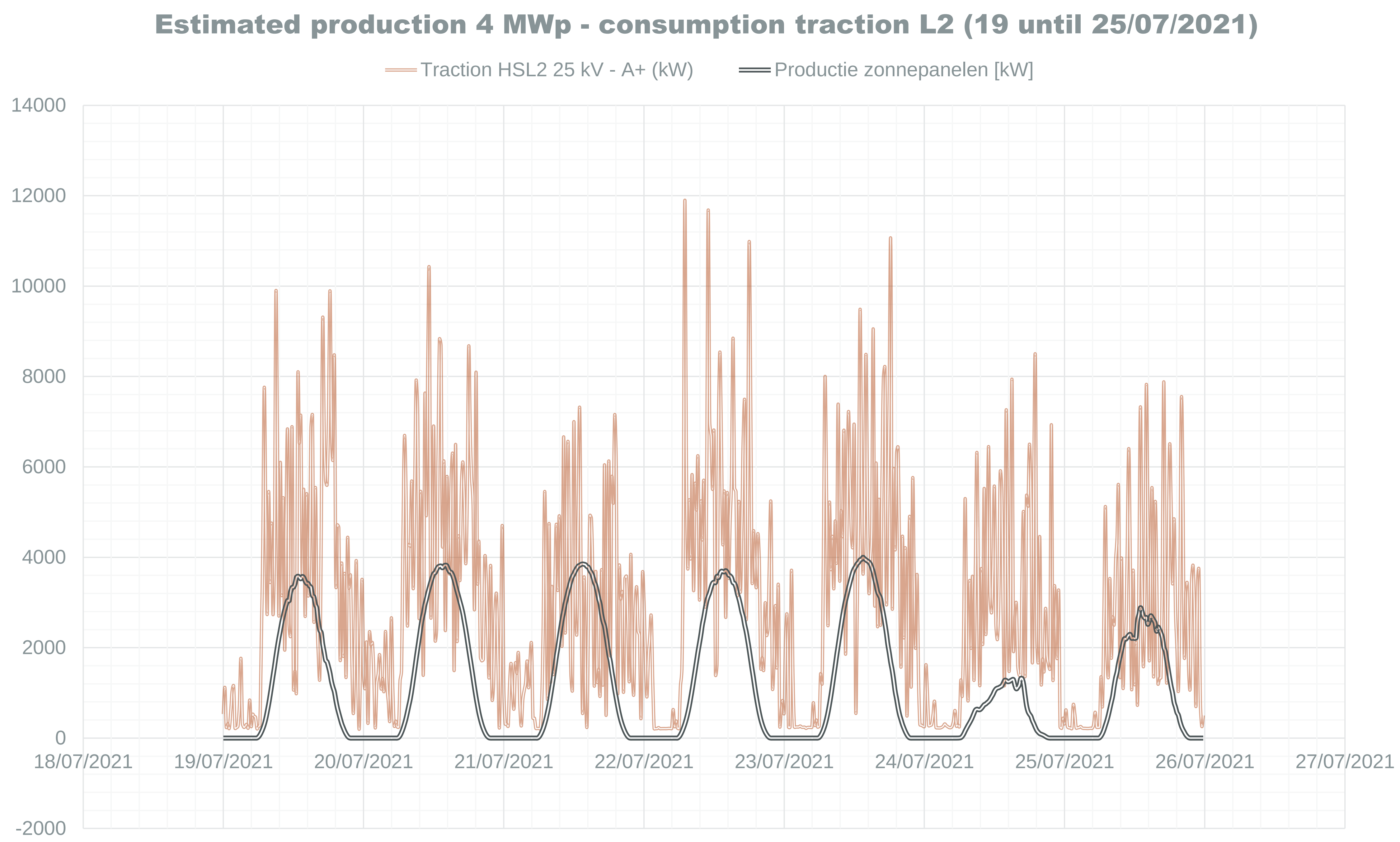


Solar panels + energy storage

Solar panels along HSL2

Solar panels Avernas
(25kV AC traction substation HSL2)

Why 2x 2 MWp on HSL2 ?



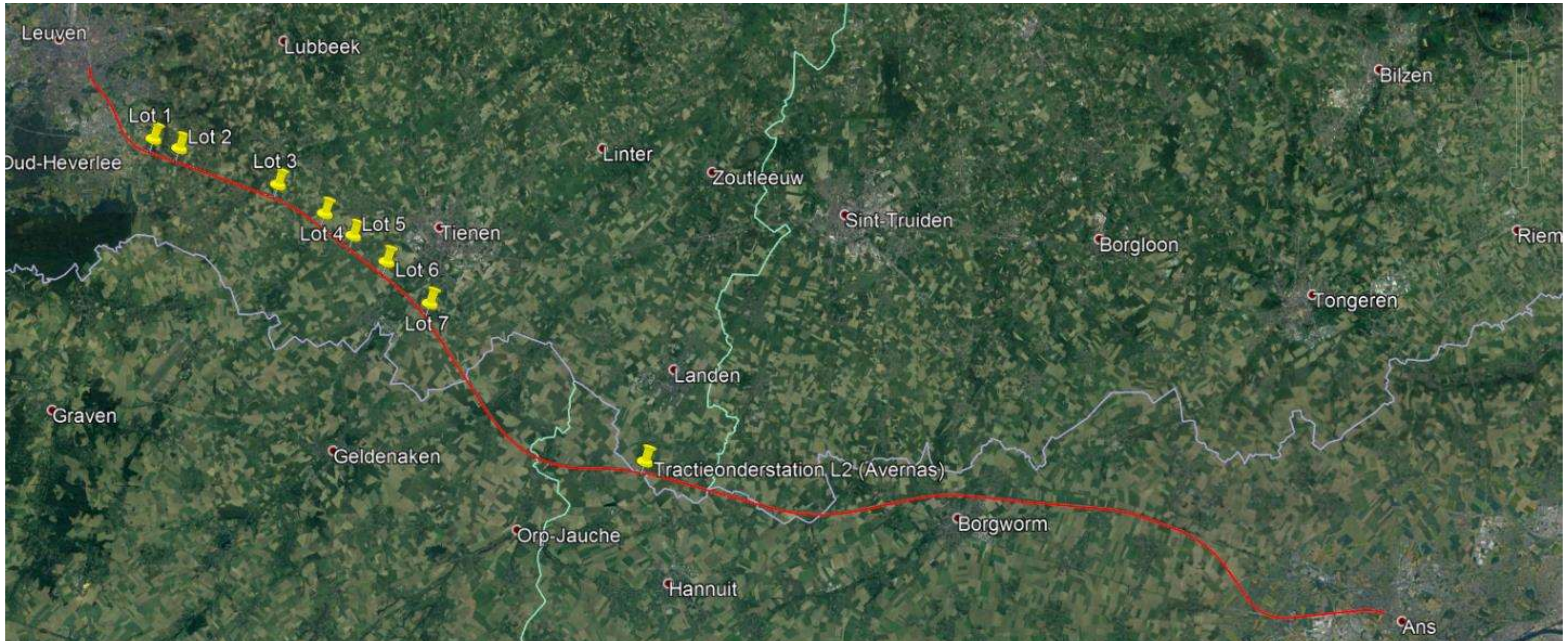
Where to connect solar panels ?

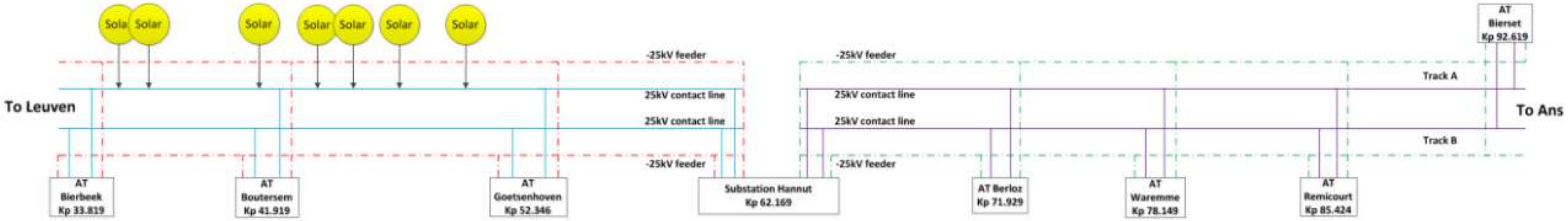
In 2016 there where 7 lots identified in Flemish Region only (substation area excluded)

In total 87820 m² → +- 16 MWp

No tenderers: connection via distribution system operator (DSO) economically not feasible ?

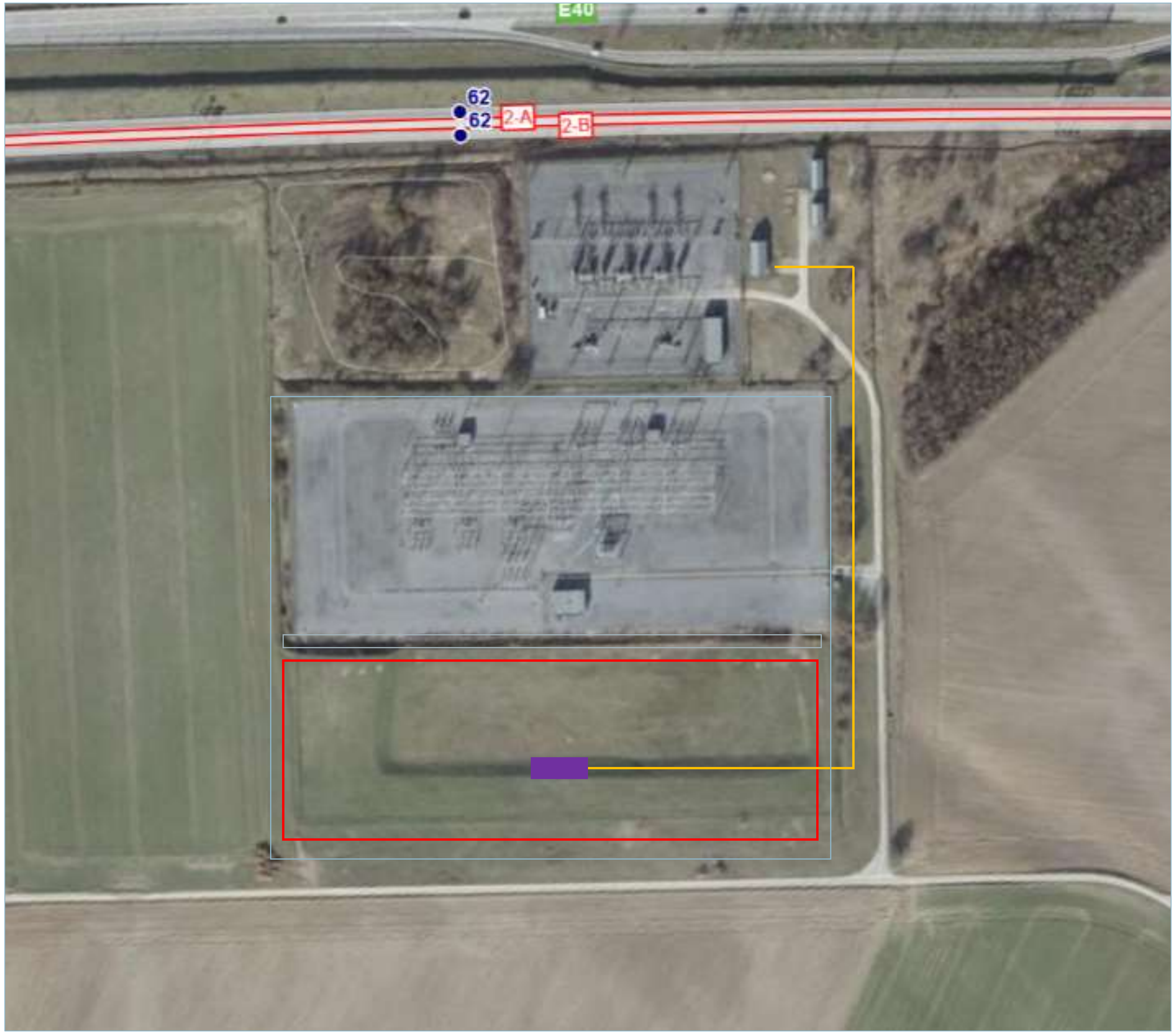
Connection to the catenary ?



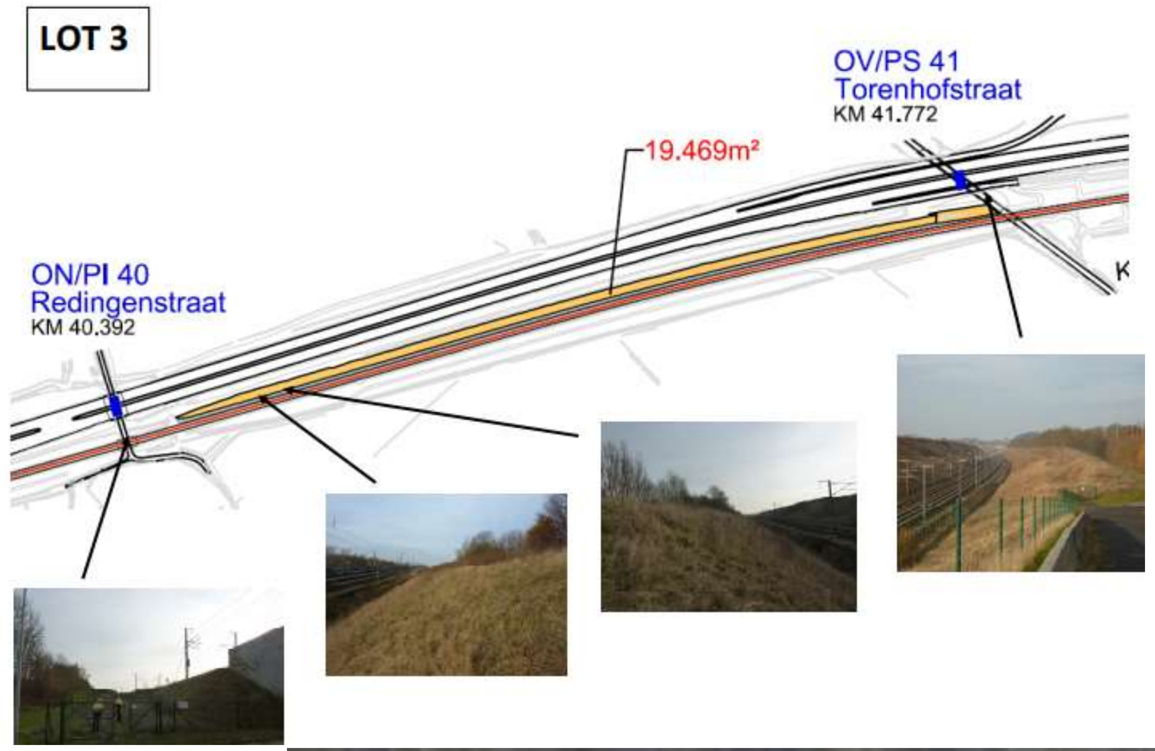


Avernas layout

Red: solar park
Yellow: cables



Lot 3 (Boutersem) layout

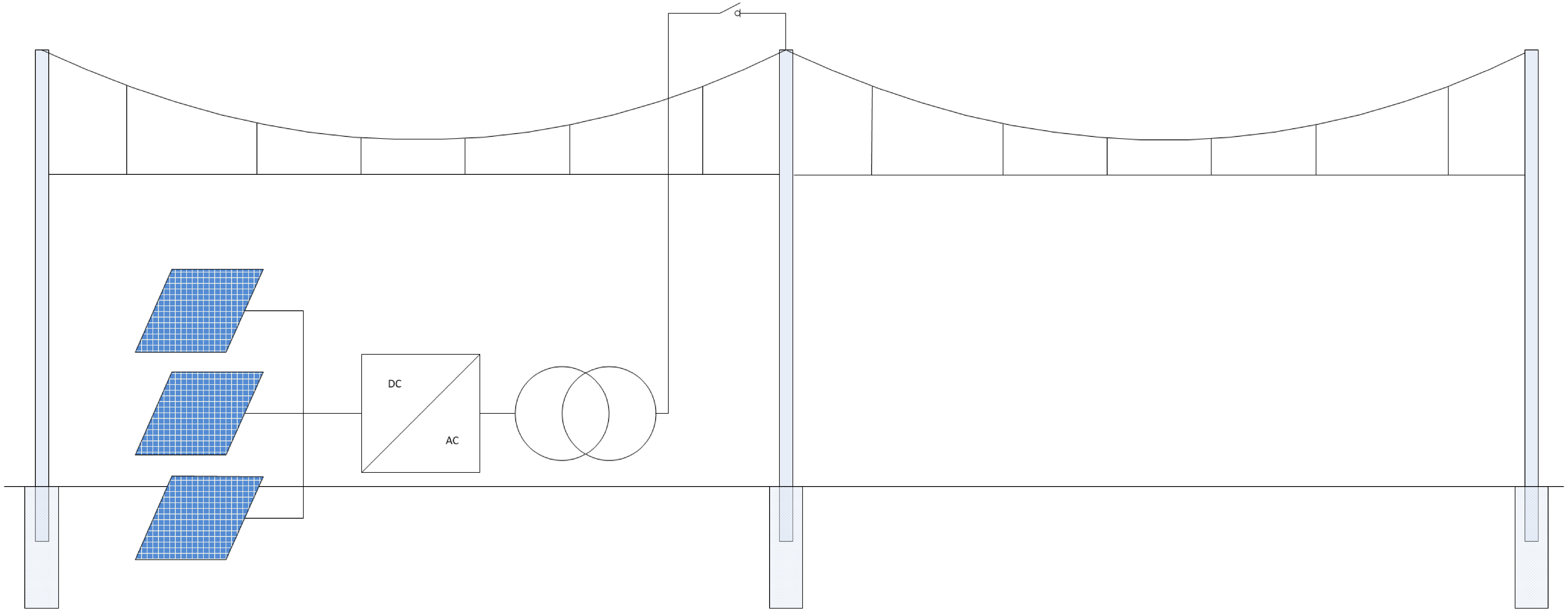


Red: solar park

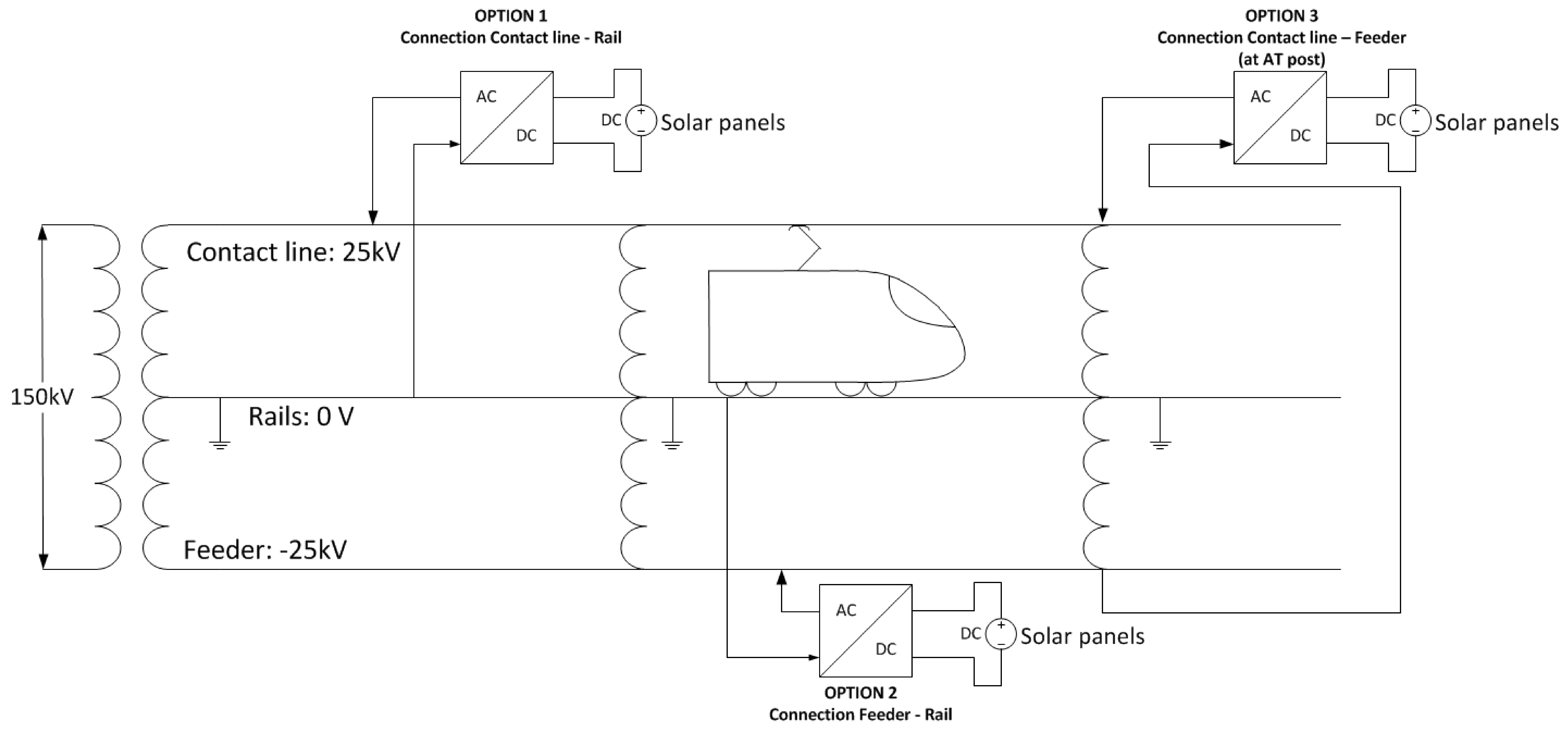
Yellow: access road

Connection scheme solar park

Solar panels: DC voltage (low)
Inverter: conversion from DC to AC (low voltage)
Transformer: transform up to 25 kV (high voltage)



Traction power supply system 2 x 25 kV catenary



Traction substation & auto-transformer substations

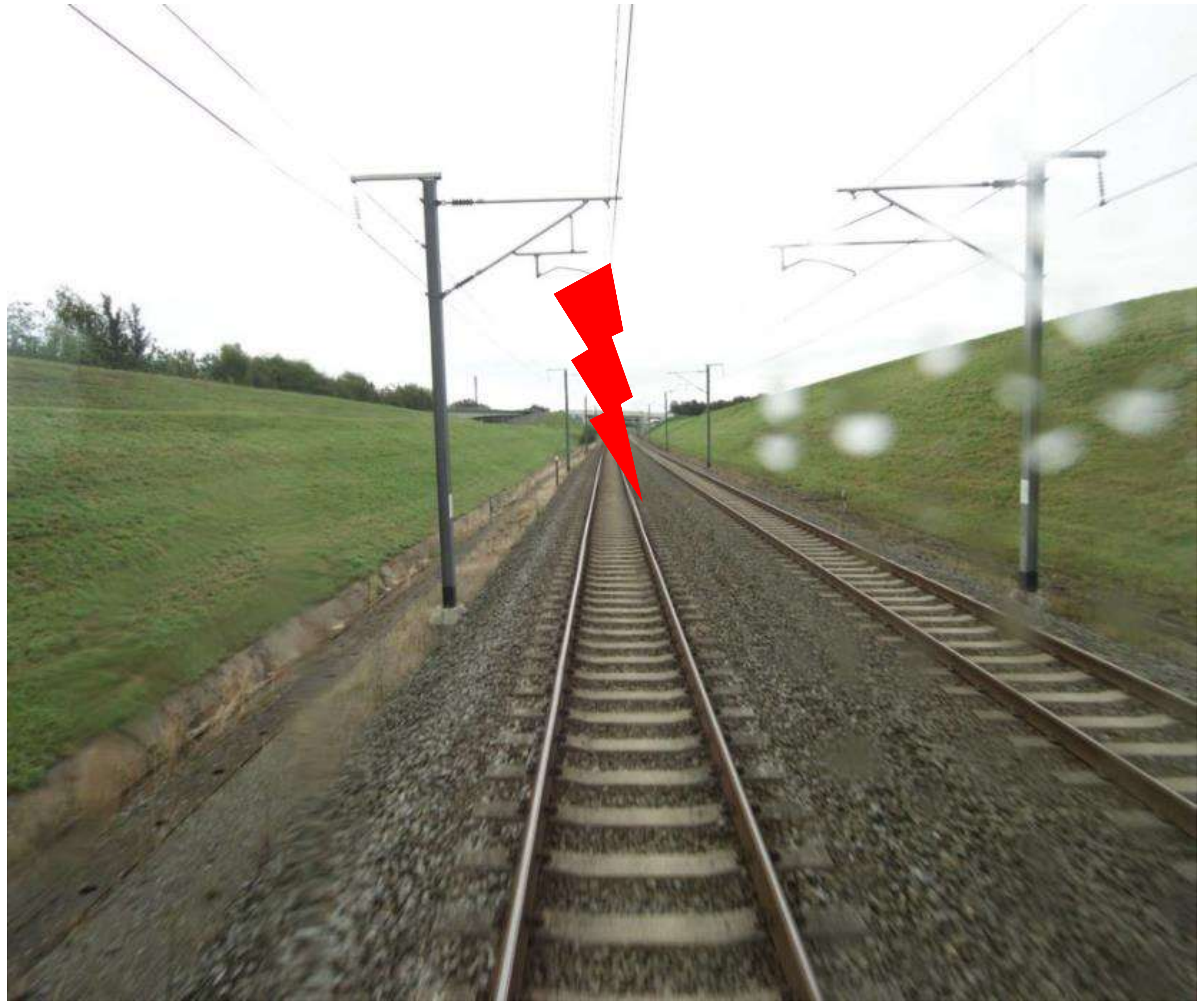
Feasibility Study

Preliminary analysis by TUC RAIL for Infrabel (1)

Feasibility of the connection on the OCL system:

1. Fault detection: Matlab-simulations to determine the influence on short-circuit detection

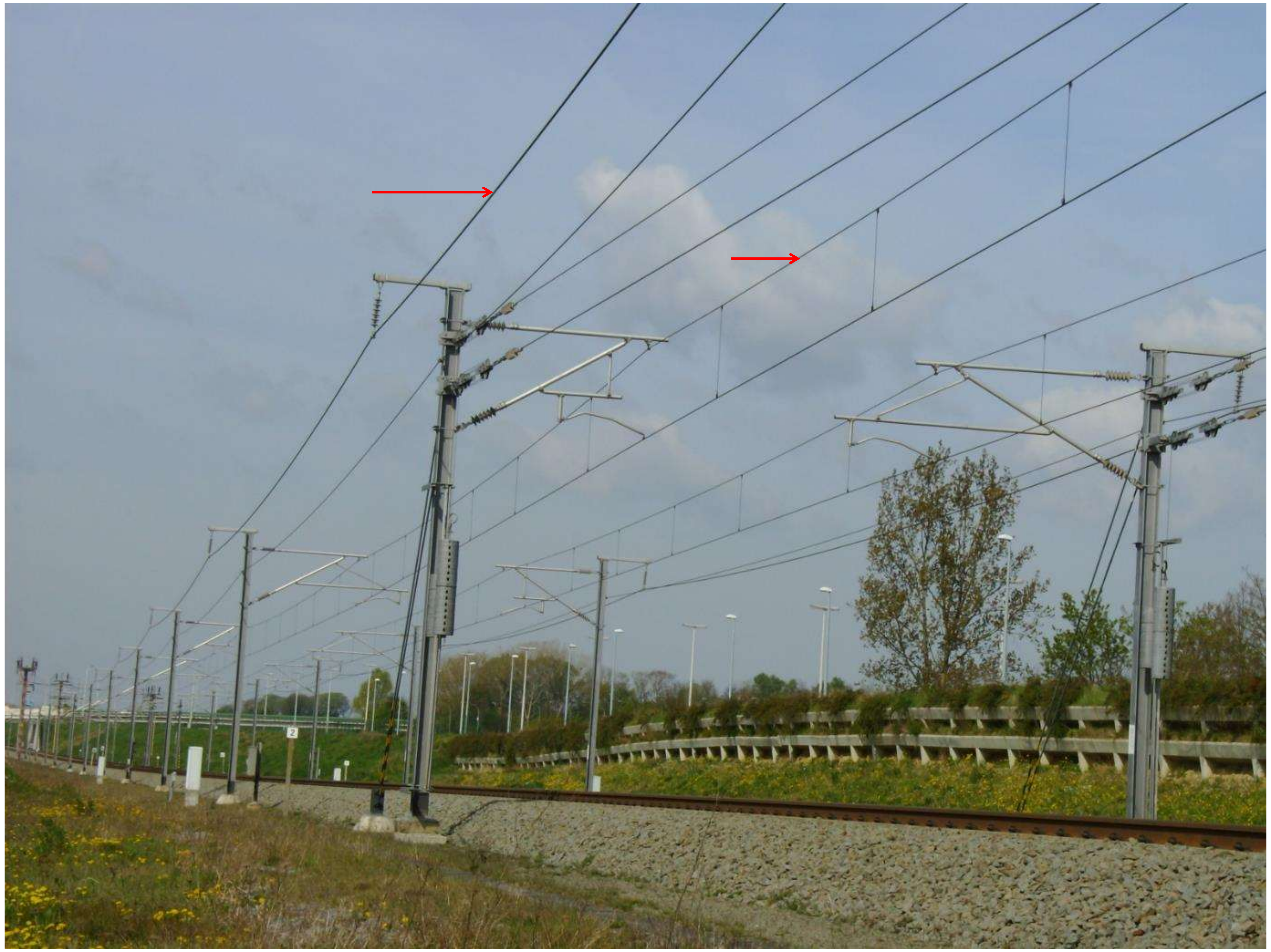
2. Maximum allowable wire temperature: maximum current carrying capacity or ampacity of the catenary



Fault detection : connection to the traction substation

Fault detection : connection to an auto-transformer substation (AT substation)

Fault detection : connection to an OCL or feeder



Fault detection: principle

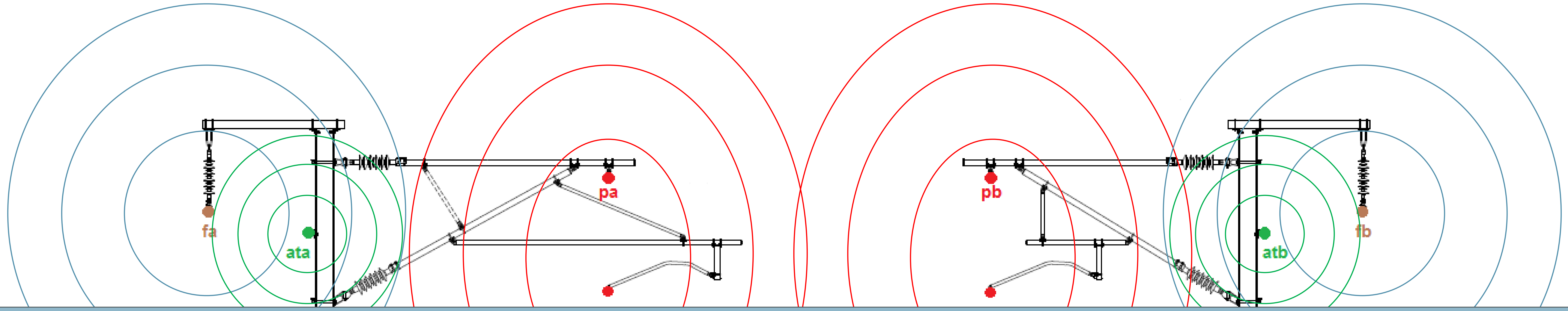
Short circuit current or normal current ?

Minimum impedance instead of current intensity

Current from substation is being recalculated towards an impedance

→ $Z = U_{substation}/I_{substation} = R+jX > Z_{min}$

Fault detection : calculations (1)



$$Z = \begin{pmatrix} Z_{11} & \cdots & Z_{1n} \\ \vdots & \ddots & \vdots \\ Z_{n1} & \cdots & Z_{nn} \end{pmatrix}$$

$$Z_{ii} = r_i + 9{,}86 \cdot 10^{-7} f + j2\pi f \cdot 2 \cdot 10^{-7} \ln\left(\frac{D_e}{GMR_i}\right) \ \Omega/m$$

$$Z_{ij} = 9{,}86 \cdot 10^{-7} f + j2\pi f \cdot 2 \cdot 10^{-7} \ln\left(\frac{D_e}{D_{ij}}\right) \ \Omega/m$$

Fault detection : calculations (1)

Draft of the admittance matrix ($Y = Z^{-1}$)

- Model traction substation (Norton model)
- Model AT substation
- Model line (mutual interaction between different conductors)

Y*V = I → Y^{-1}*I = V

$$Y^{-1} \cdot I = \begin{pmatrix} Y_{11} & \cdots & & \cdots & Y_{1n} \\ \vdots & \ddots & \vdots & & \vdots \\ & \cdots & & \cdots & \\ \vdots & & \vdots & \ddots & \vdots \\ Y_{n1} & \cdots & & \cdots & Y_{nn} \end{pmatrix} \begin{pmatrix} I_1 \\ \vdots \\ \vdots \\ \vdots \\ I_n \end{pmatrix}$$

Y is a matrix of e.g. 23000x23000

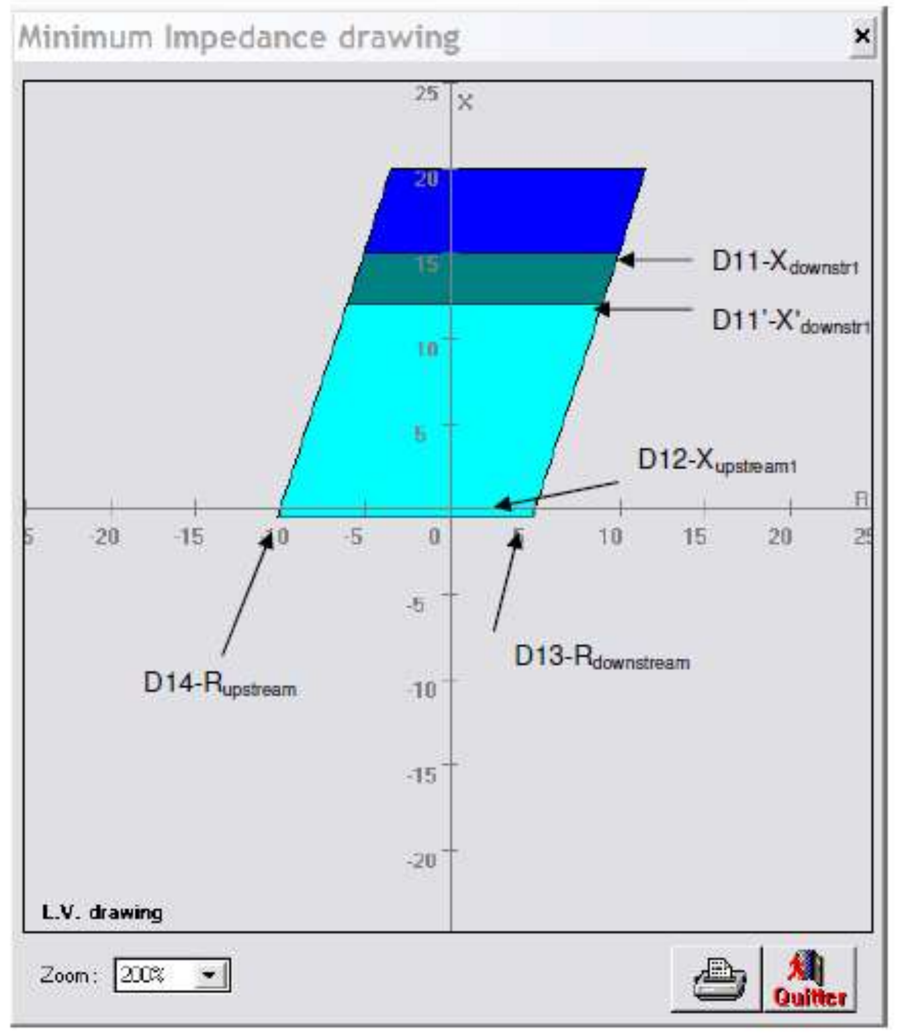
Fault detection : calculations (2)

Calculation of the impedance seen by the substation for several cases
→ Will the impedance ever become bigger than Z_{min}?
Only in border cases there possibly is a detection problem

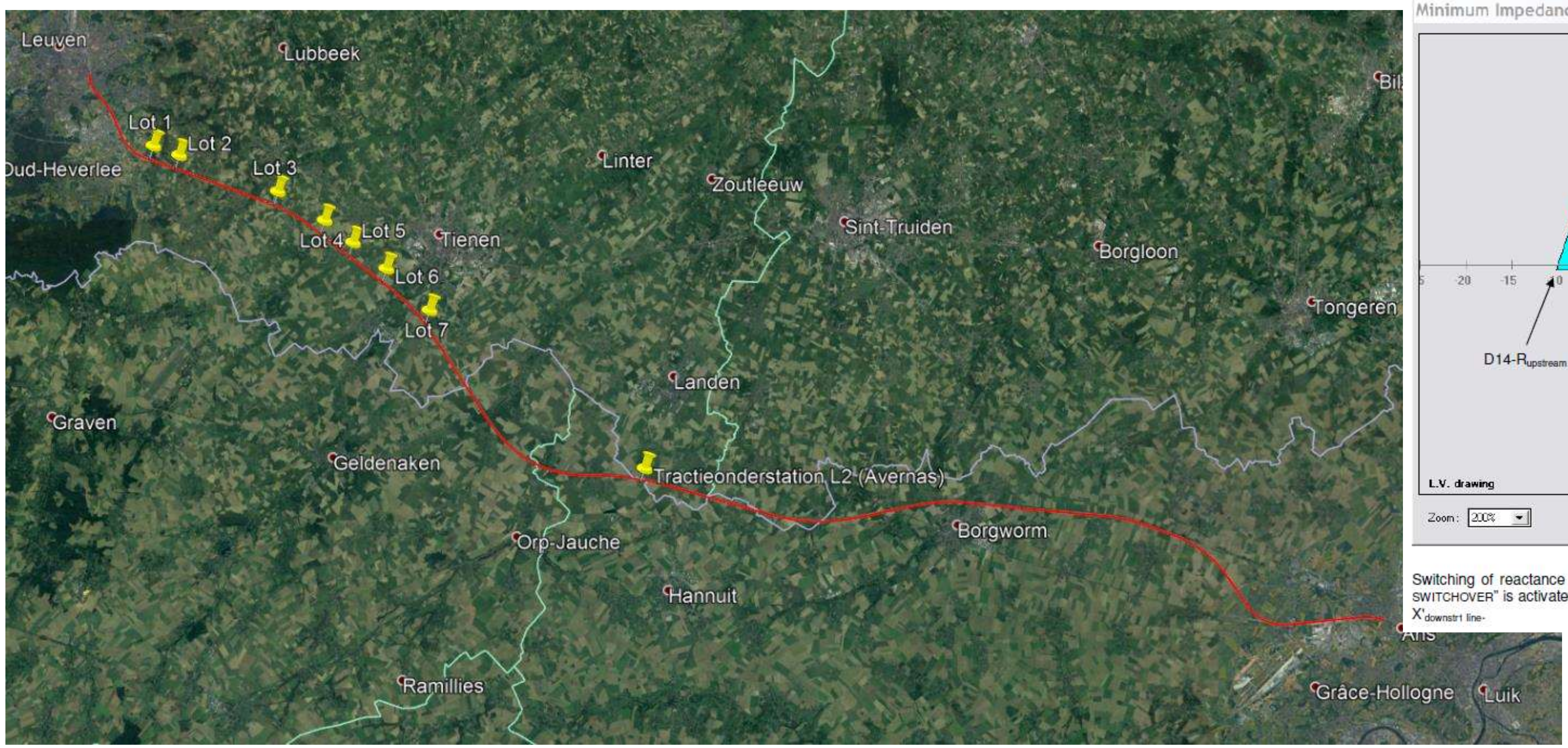
3.1.2 First stage parallelogram

The characteristic of the first stage is bounded:

- By two bent parallel lines D14-$R_{upstream}$ and D13-$R_{downstream}$, on both sides of the X axis
- By two parallel lines D11-$X_{downstream1}$ and D12-$X_{upstream1}$, on both sides of the R axis.



Switching of reactance threshold by external command: when the external command "MIN. Z THRESHOLD SWITCHOVER" is activated, the downstream reactance can be replaced by another value defined by the D11-X'$_{downstr1}$ line-

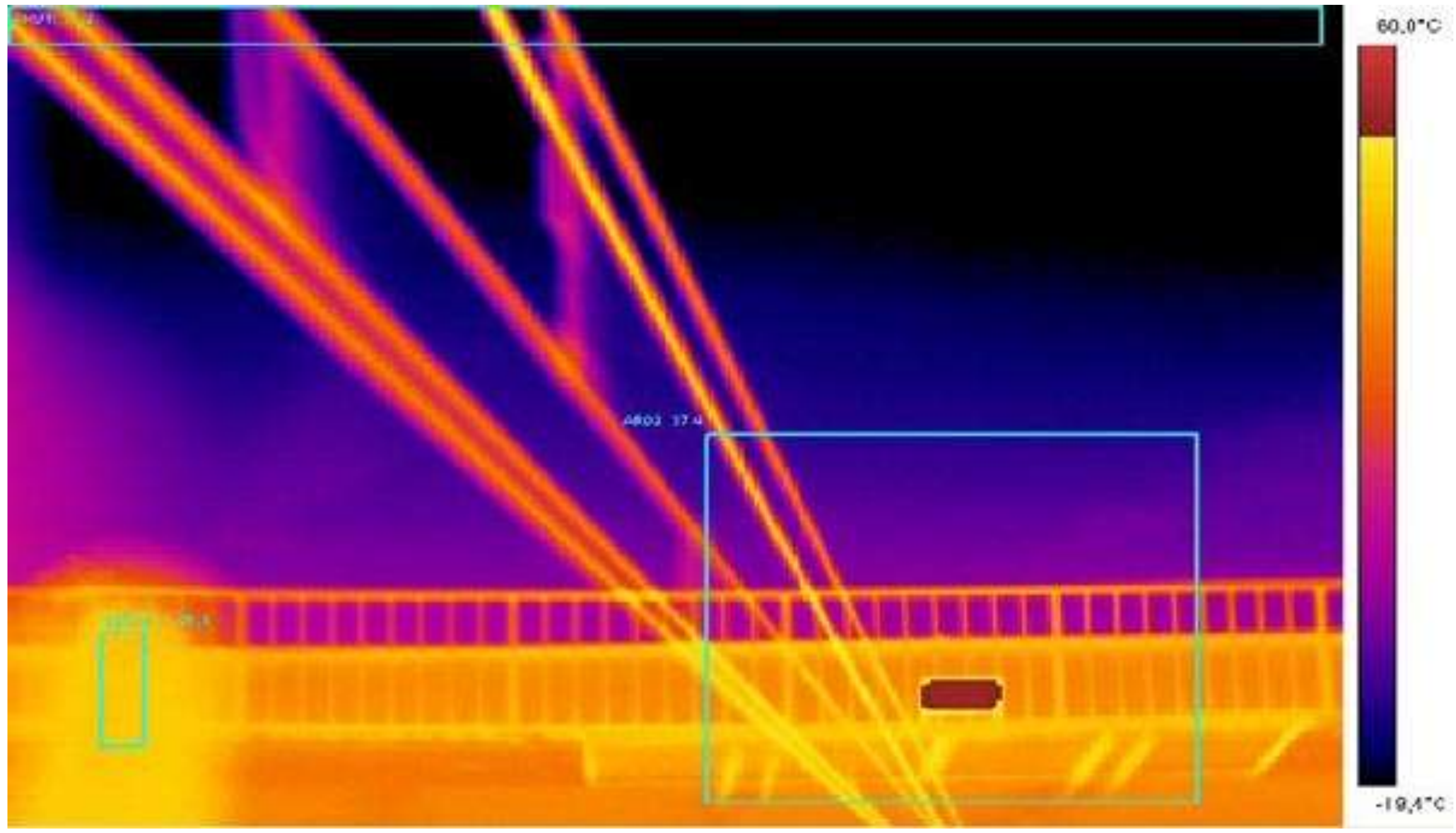


Preliminary analysis by TUC RAIL for Infrabel (2)

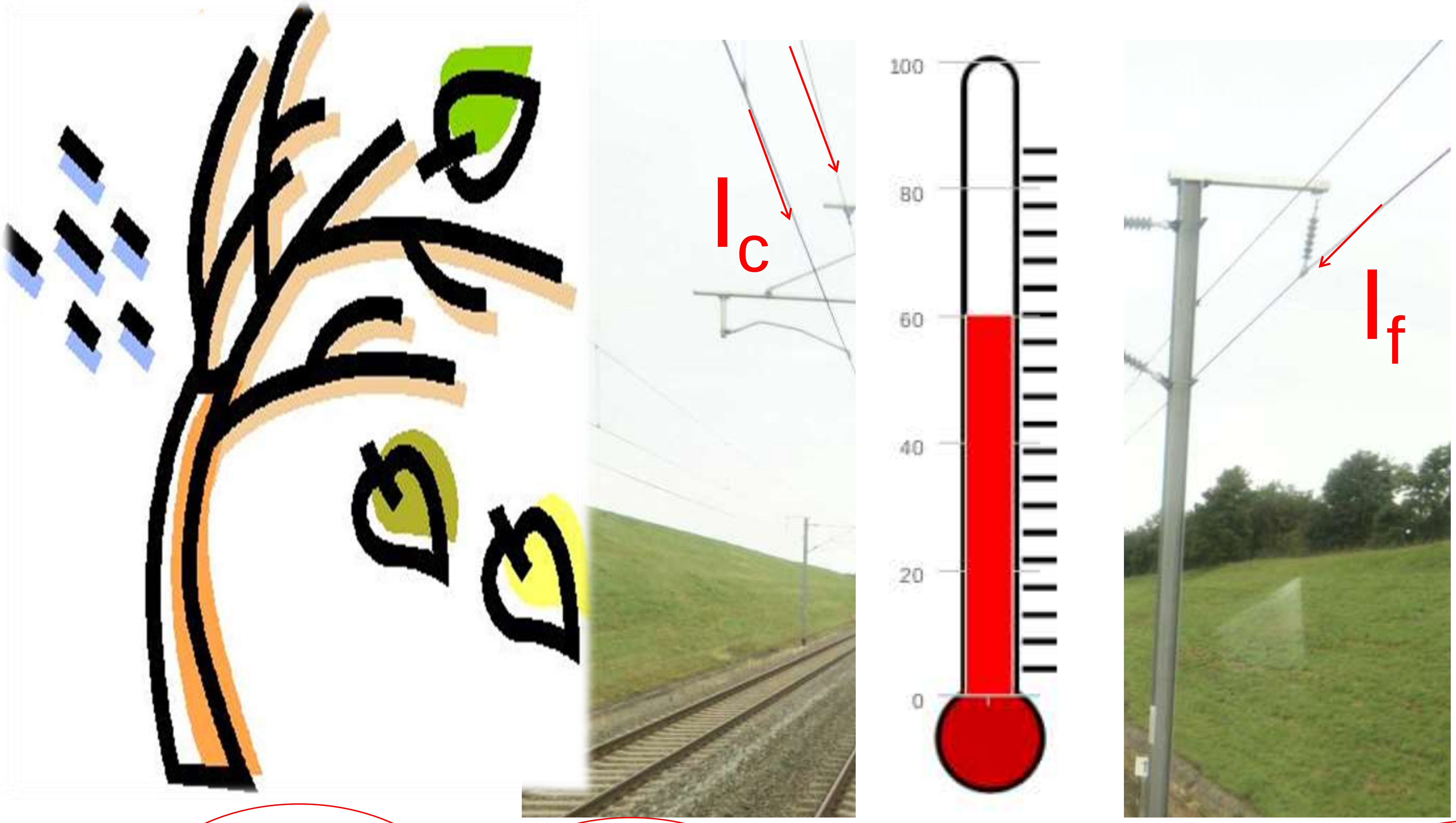
Feasibility of the connection on the OCL system:

1. Fault detection: Matlab-simulations to determine the influence on short-circuit detection

2. Maximum allowable wire temperature: maximum current carrying capacity or ampacity of the catenary



Maximum wire temperature



$d\theta$

Results

Several configurations for power supply by solar panels

- On the along-track negative feeder
- On the catenary
- In an AT substation

Potentially a maximum of **64 MWp** for HSL2
(because of the wire temperature)

- Regenerative braking is the critical use case (with the highest ambient temperature of 40°C, maximal solar radiation on the wires and maximal solar power generation)

Optimal Connection Scheme with variants

Technical & economical analysis by Tractebel

different connection options to the bi-phase 2x25kV AC catenary system and a technical and economic analysis of the solar panel park:

- Calculation of the expected energy yield of the solar panels
- Determination of the optimum tilt angle of the solar panels
- Proposal of the optimal electrical connection configuration or topology

PV-production

Large PV-farms are typically rectangular shaped whilst in the case of PV-farms installed along the railways the shape is more like a strip or a string. Therefore, longer cabling will be necessary to collect all the energy.

An interesting figure is the average peak power accumulation of 1,8 kWp per meter along the railway.

From this we can deduct this thumb rule: a set of PV-arrays along the railway induces 1 MW peak power for each 500 to 600 m.

PV-production calculations have been realized for tilt angles 15° and 40°. The difference in yearly energy yield between tilt angle 15° and the optimal tilt angle 40° is about 4%.

Given the tilt angle has only little impact on the energy production, the PV-panels can be installed in a parallel plane to the existing slope of the embankments.

5 CONNECTION ALTERNATIVES

Solution 1 - DC/DC conversion and DC/AC 1-ph conversion

Solution 2 - Photovoltaic DC/AC 1-ph conversion

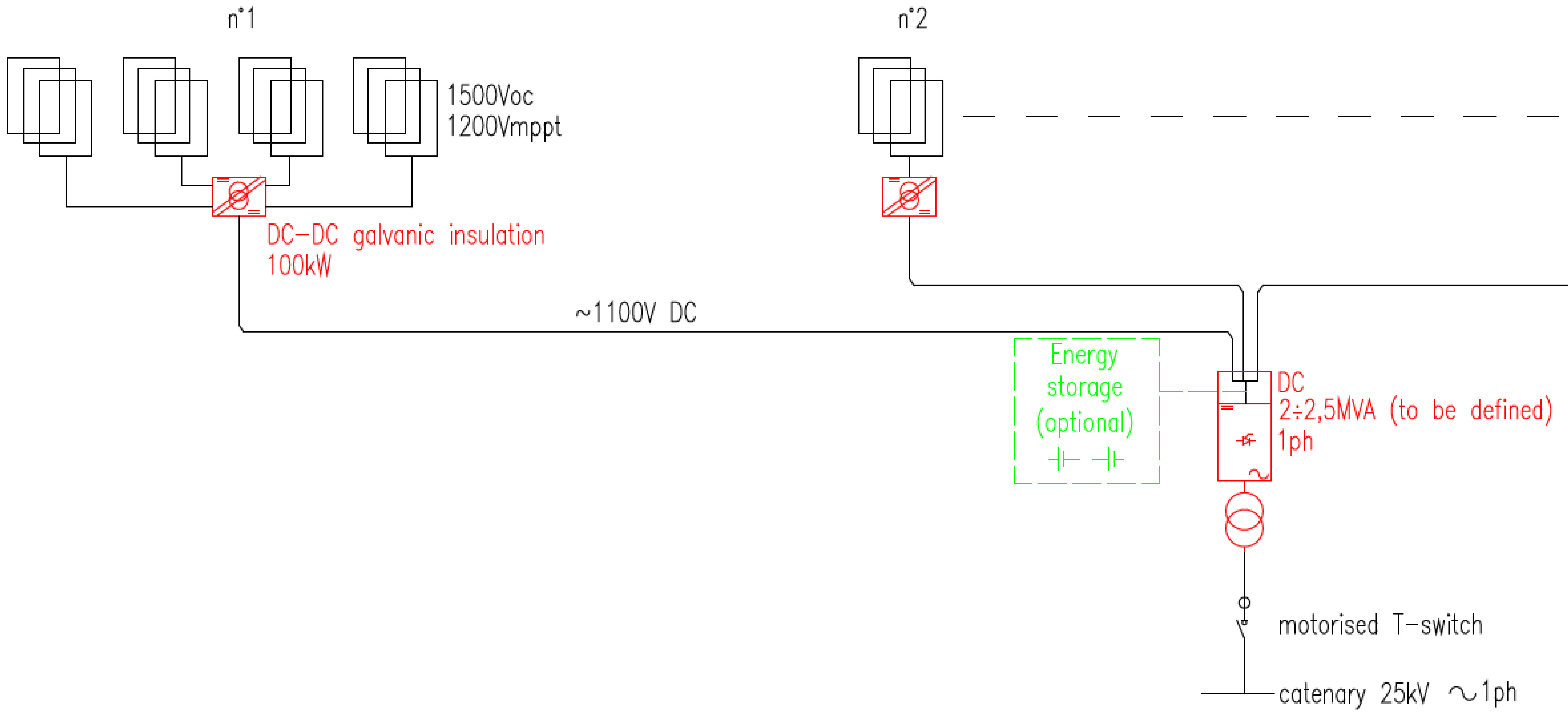
Solution 3 - Photovoltaic DC/AC 3-ph conversion and AC 3-ph/AC 1-ph conversion

Solution 4 - Multiple 1-ph invertors and distribution transformers

Solution 5 (as a reference) - 3-phase 36 kV Connection to Avernas substation

1 - DC/DC conversion and DC/AC 1-ph conversion

DC-solar panel power is converted into DC/DC-convertors assuring a galvanic insulation. The ±1100Vdc outputs are collected and converted through one DC/AC single-phase convertor 2MVA.

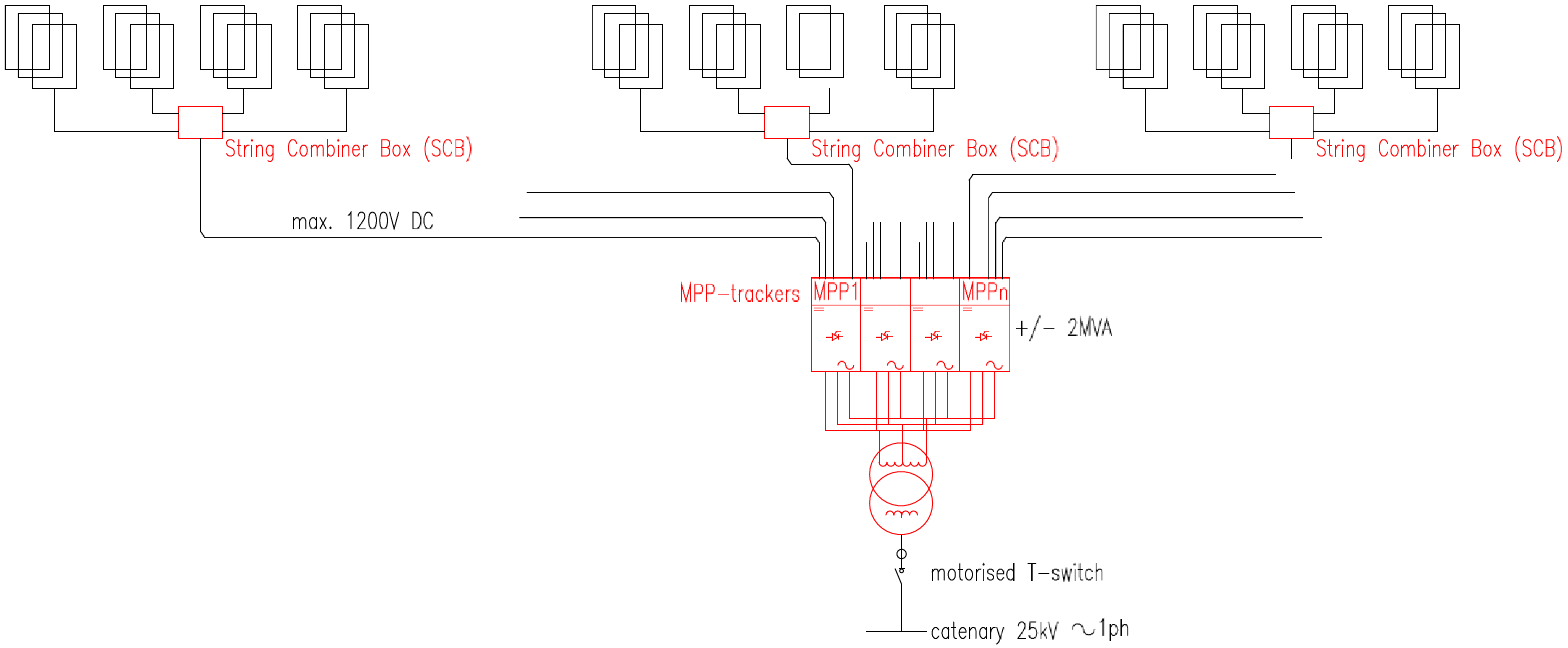


2 - Photovoltaic DC/AC 1-ph conversion

DC-solar panel power is collected through so called string combiner boxes.

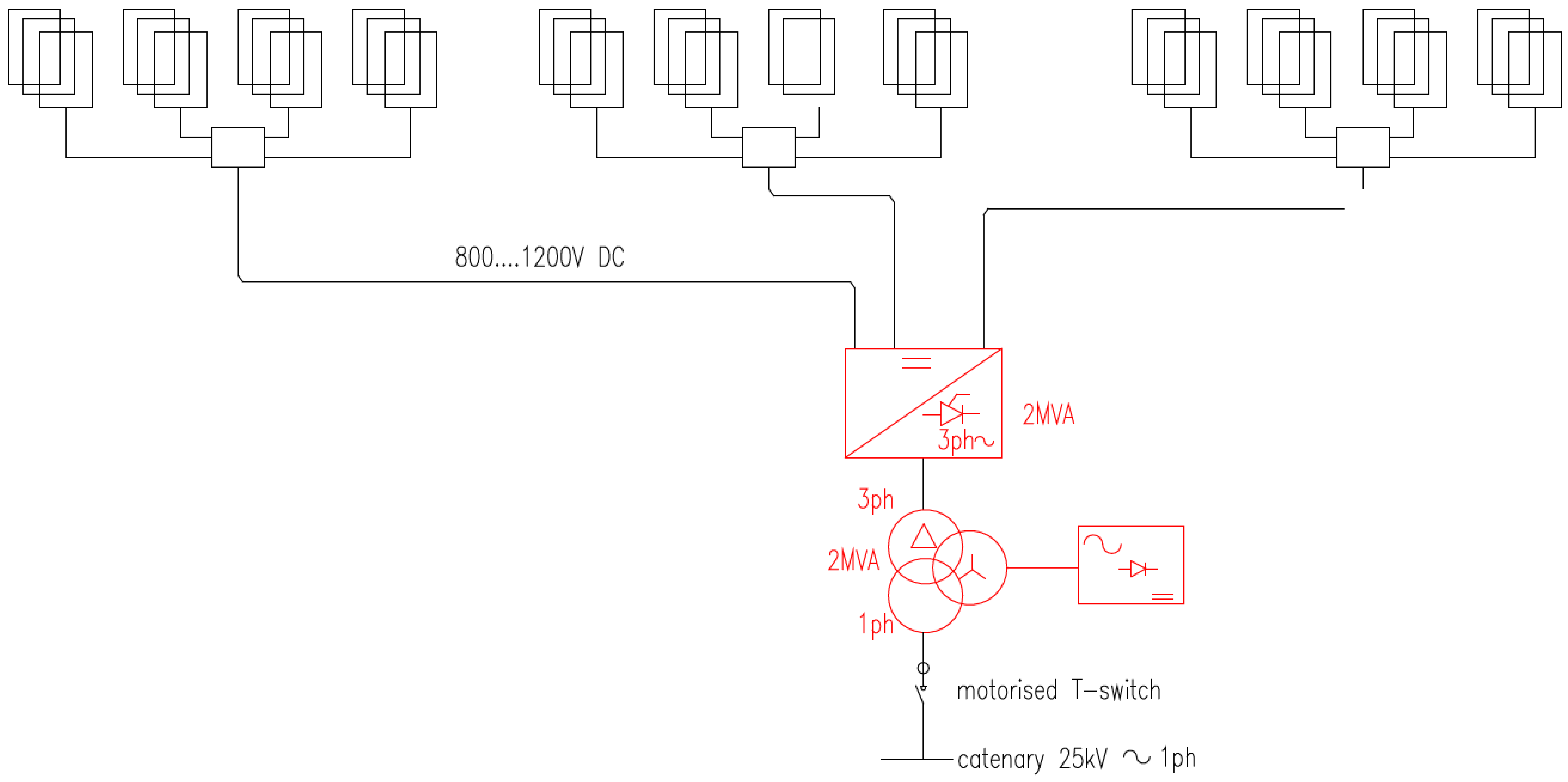
Modular single-phase photo-voltaic inverter concept special engineered for railway applications. PV system is realised by multiple independent Maximum Power Point Trackers (MPPT).

A step-up transformer with center-tap on the convertor side is required.



3 - Photovoltaic DC/AC 3-ph conversion and AC 3-ph/AC 1-ph conversion

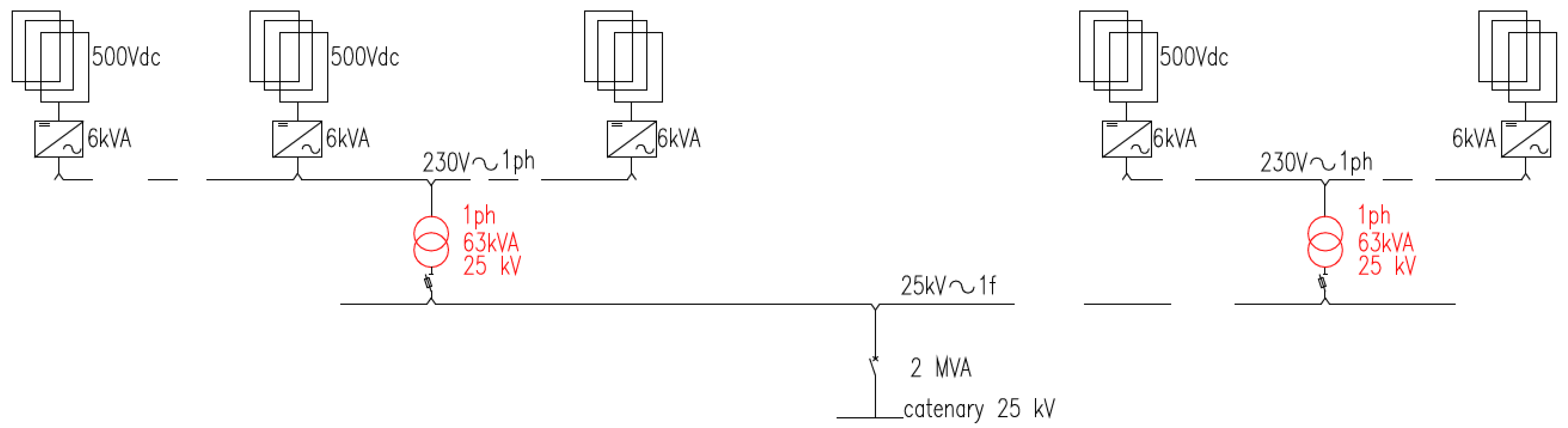
In this solution standard 3-phase photo-voltaic inverters are used. 3-phase solar power invertors are installed world-wide and is a well known and mature technology. Many suppliers and invertor sizes are available on the market. The 3-phase power is then converted to single phase by means of a special 3-winding transformer. The unbalance induced by the single-phase load is compensated by voltage source converter connected on the 3rd winding.



4 - Multiple 1-ph invertors and distribution transformers

Solar single-phase invertors are products used for residential housing and are limited in AC-power (<10kW), DC-input voltage (<600Vdc) and AC-output voltage (230Vac).

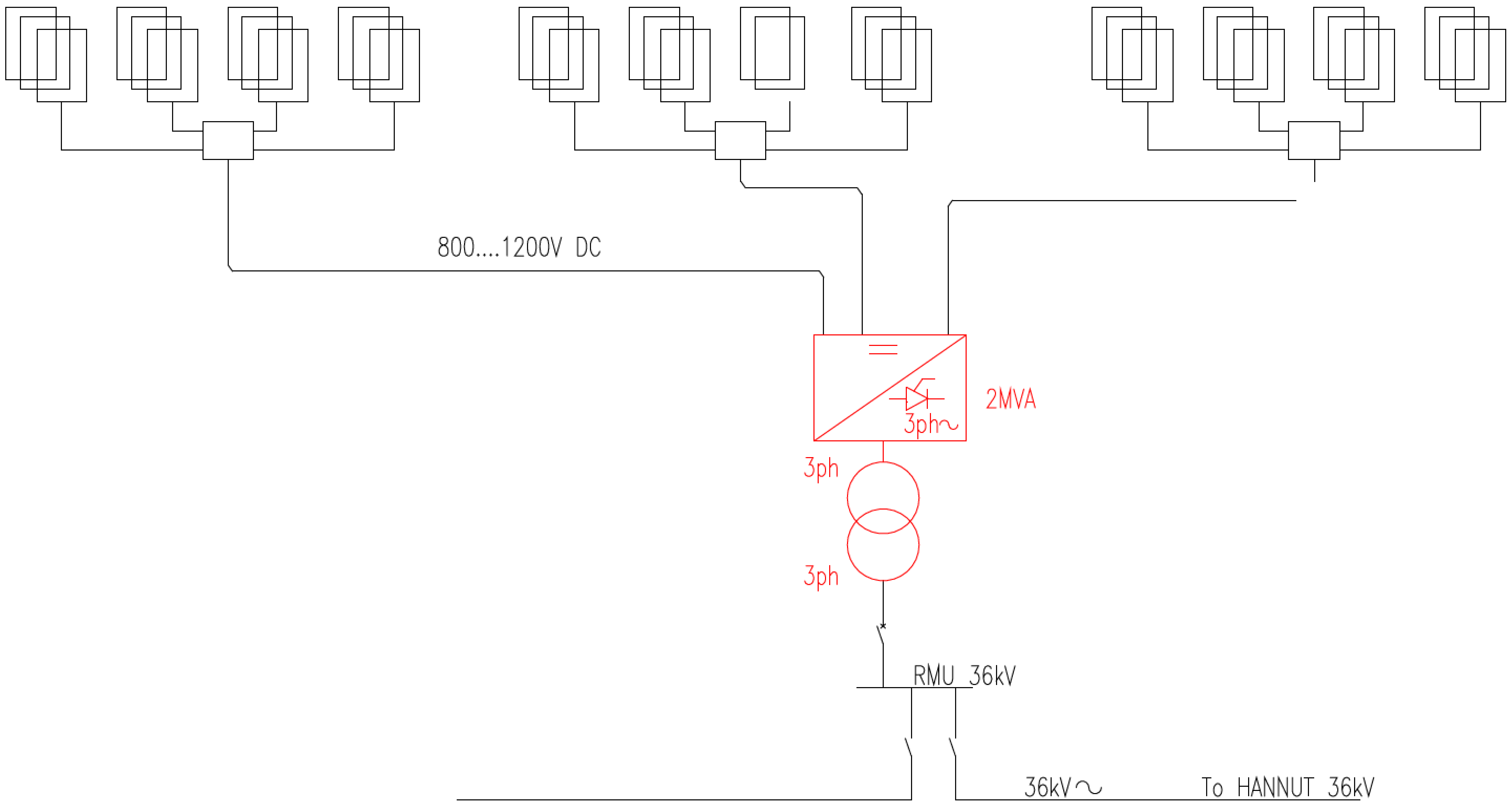
This solution requires a large amount of the main components such as invertors, LV-cabling and distribution transformers.



5 - 3-phase Connection 36 kV to Avernas substation

This solution makes only use of conventional solar three-phase power convertors combined with step-up transformers LV/36 kV. Each transformer has its own circuit-breaker as part of a 36 kV Ring Main Unit.

36 kV Cabling along the solar power plant (13,7 km) up to the 36 kV substation in Avernas (12 km).



Qualitative and quantitative comparison

	Solution 1 - DC/DC conversion and DC/AC 1-ph conversion	Solution 2 - Photovoltaic DC/AC 1-ph conversion	Solution 3 - Photovoltaic DC/AC 3-ph conversion and AC 3-ph/AC 1-ph conversion	Solution 4 - Multiple 1-ph convertors and distribution transformers	Solution 5 - Connection 36kV 3-phase to Hannut 36kV
CAPEX E-connexion (for total 15,7MWp installed power)	28,2 MEUR	5.0 MEUR	5,7 MEUR	9,2 MEUR	7,5 MEUR
CAPEX E-connexion (Unit cost)	1,80 kEUR/kW	0,32 kEUR/kW	0,36 kEUR/kW	0,59 KEUR/kW	0,48 kEUR/kW
Complexity Operations & Maintenance	OK	OK	OK	NOT OK (Large amount of small components)	OK
Concept already realized	NO	YES **	NO	NO	YES
Technical feasibility confirmed by at least 1 supplier	YES	YES	YES	NO	YES
Electrical losses	+	+ + (only 1 conversion)	+	- - (Small convertors less efficient)	- - (multiple transformations 36/150kV and 150/25kV)

Questions

Discussion

Thank you for your attention.

Workshop timeline

12h 30	*Lunch*		
13h 45	Photovoltaics on stations program	**Jorien Maltha**	**ProRail**
14h 05	Solar panels deployment on stations	**Laurent Mahuteau**	**SNCF Stations**
14h 25	Insights from Innovation in Traction Energy in the UK	**Colin McNaught**	**Ricardo Rail**
14h 50	RaccorD – Smart DC for green traction energy	**Tony Letrouvé** **Hervé Caron**	**SNCF (IM)**
15h 15	NEWRAIL: Solar panels on existing noise barriers	**Gerald Olde Monnikhof** **Robert Bezemer**	**ProRail** **TNO**
15h 35	*Break*		
16h 00	*Technical visit or presentation* *Hyperloop test field*	**TU Delft**	

Lunch

until 13h30

Thank you for your attention.

Workshop timeline

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15h 35	*Break*		
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INTERNATIONAL UNION OF RAILWAYS

PRORAIL

Photovoltaics on stations program

ProRail

Jorien Maltha

Solar energy at Dutch railway stations

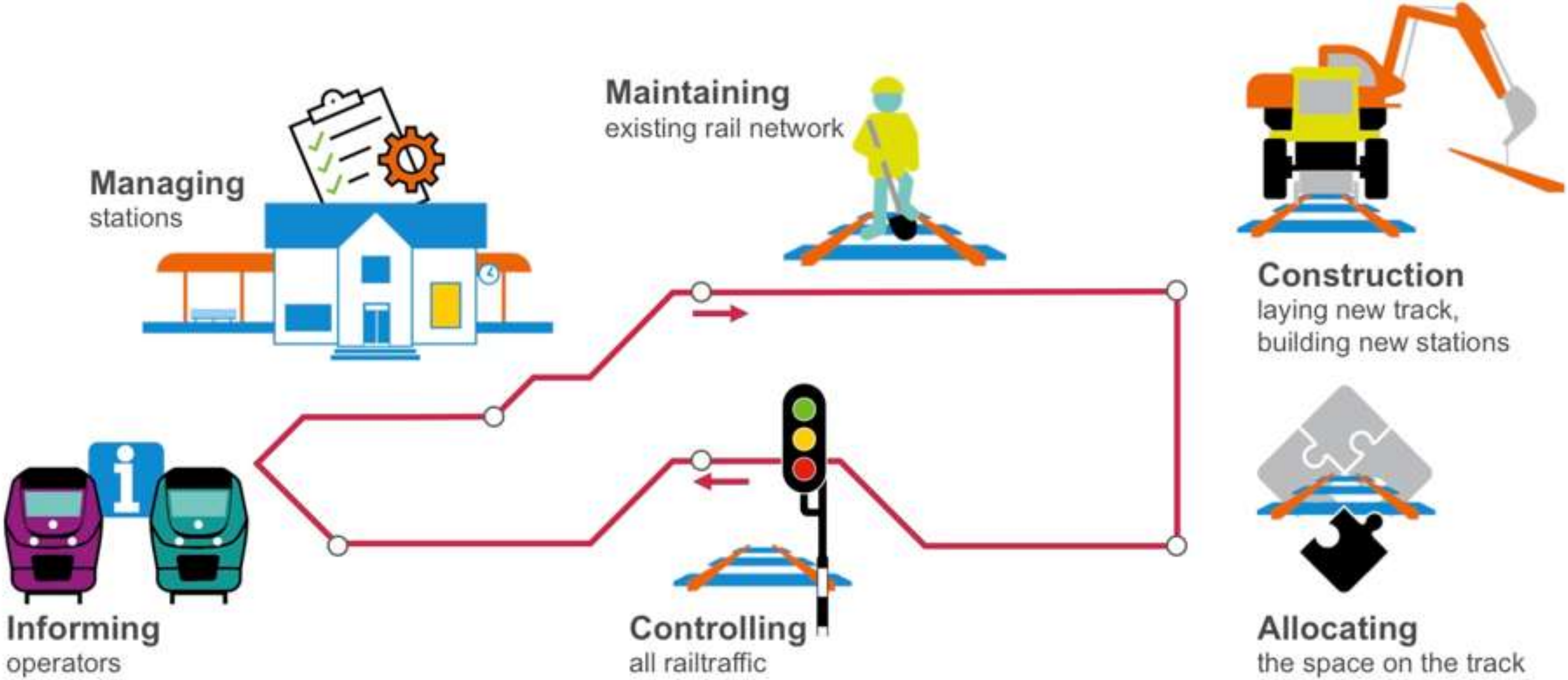
UIC Workshop – 17 November 2022

Jorien Maltha

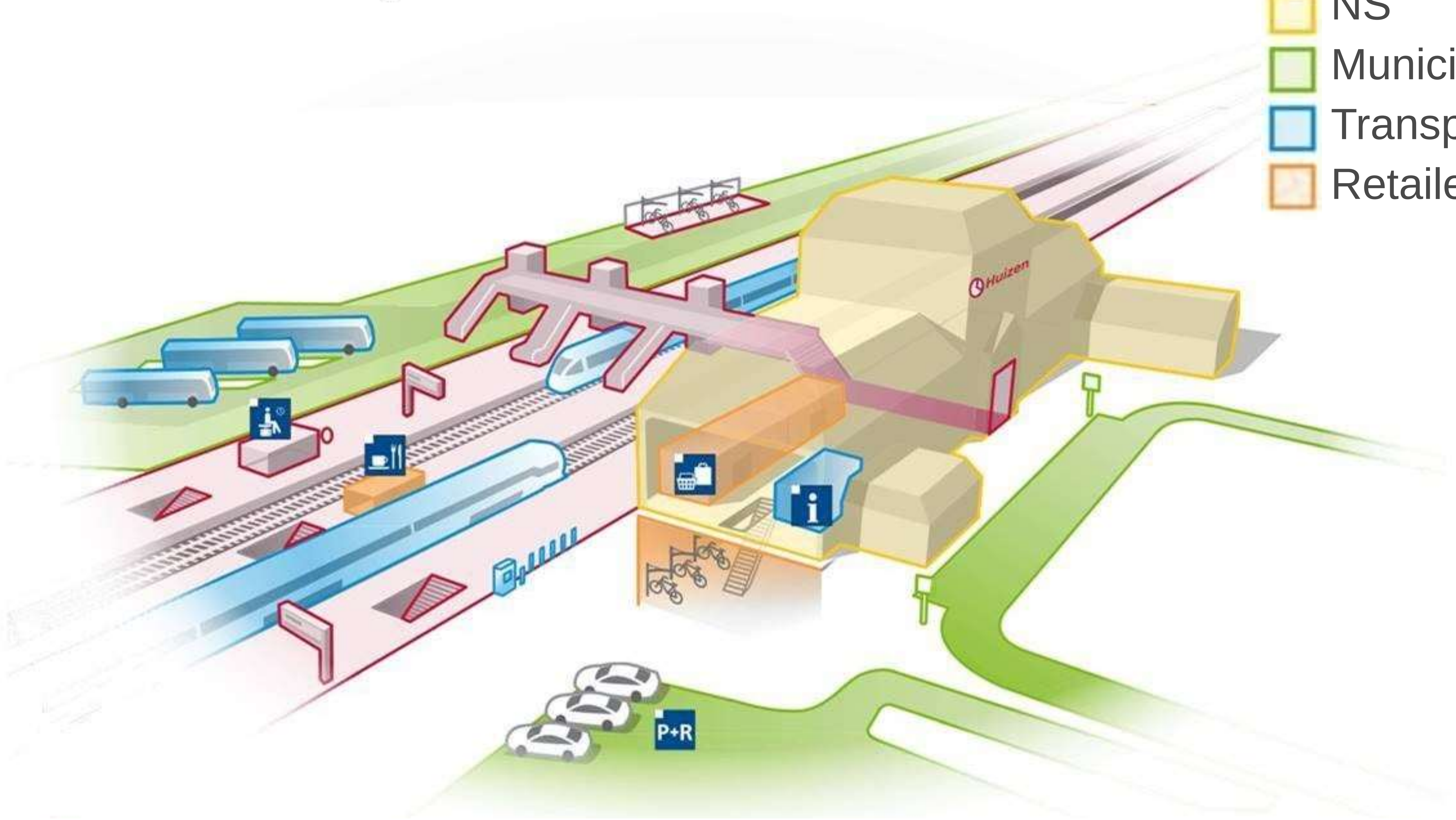
Contents

- ProRail and our sustainability ambitions
- Current energy generation
- Renewable energy program
- Solar energy at stations
  - Approach
  - Roofs in development
  - Policy and tools
  - Progress and forecast
  - Lessons learned
  - Developments and research

ProRail


Managing
stations
Maintaining
existing rail network
Construction
laying new track,
building new stations
Informing
operators
Controlling
all railtraffic
Allocating
the space on the track

Stations



- ProRail
- NS
- Municipality
- Transporter
- Retailer

Our sustainability ambitions

Mobility
More (inter)national trains instead of trucks, cars and planes is our largest Co2 reduction.

Energy
A sustainable rail sector generates its own renewable electricity and improves its energy efficiency.

Materials
A circular rail sector preserves (scarce) resources for future use ans manages to replace polluting materials.

Nature
Our land as link between nature conservation areas, as breeding ground and save haven for new nature.

Existing renewable energy installations

Eindhoven

Zwolle

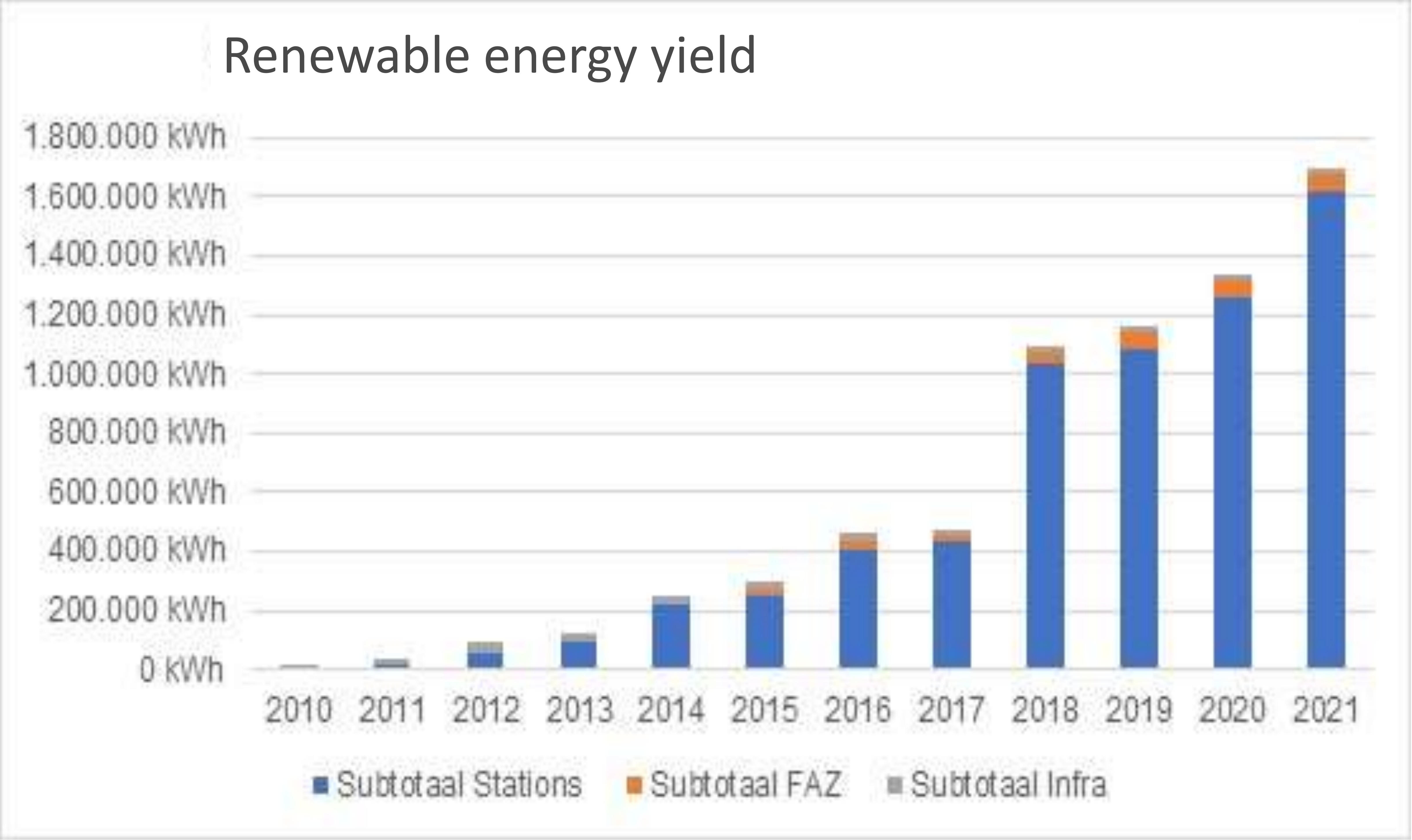
Utrecht Central

Harderwijk (bike parking)

Amersfoort

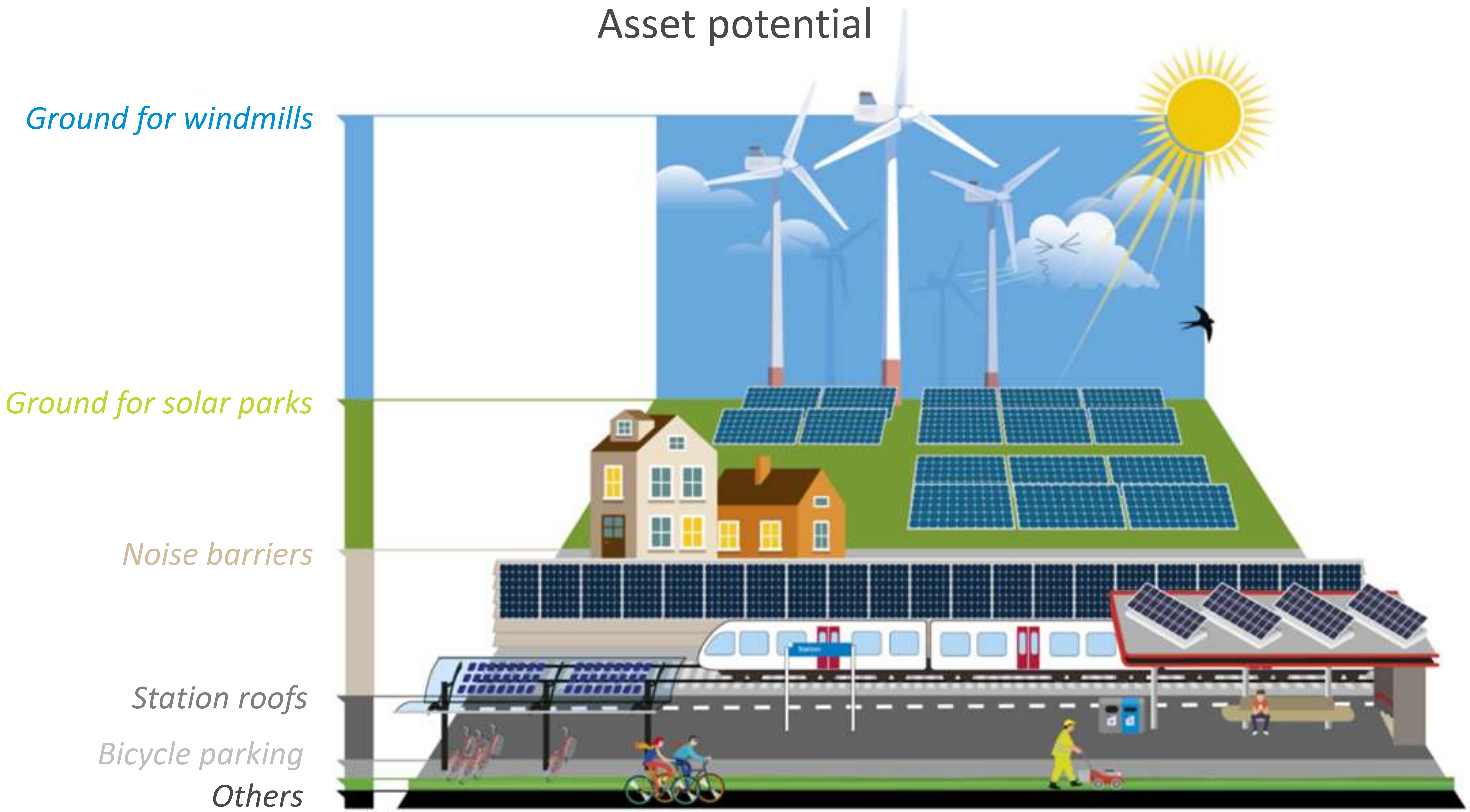
Helmond (noise barrier)

Current energy generation



= 1% of our energy consumption

Renewable energy program



Solar energy at Dutch stations

200 platform roofs

18 pedestrian bridges

50 bicycle parkings

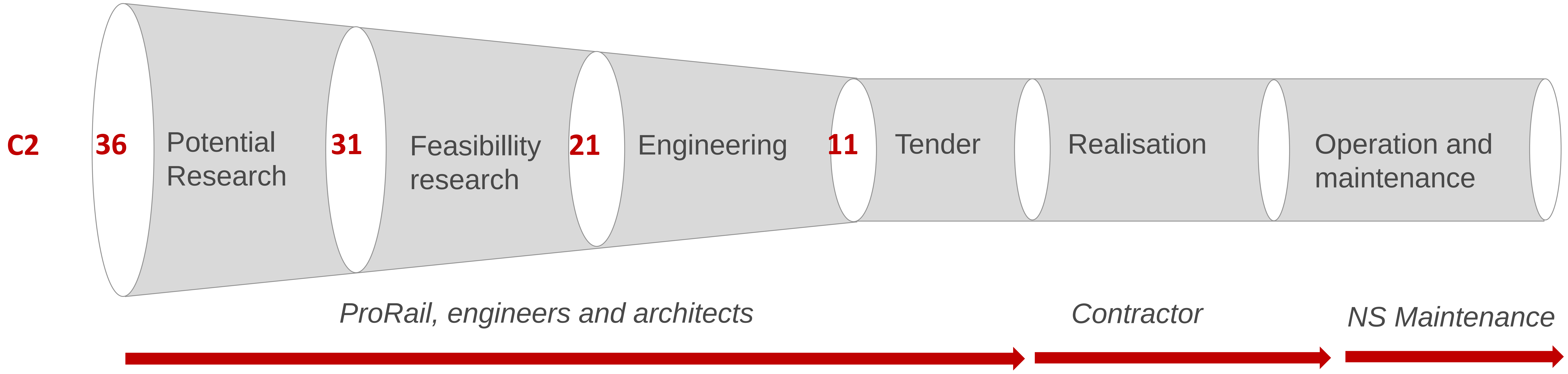
Potential = 30%

Station assignment

Scope:	+/- 70 stations
Impact:	20 GWh renewable energie
Costs:	investment 23,5 million, maintenance 10 million (until 2050)
Benefits:	net present value 34 million

Solar energy at Dutch stations - approach

- 2 types of realisation, in:
  - station projects (renovation, new build and maintenance)
  - station programme (locations without project)
- Programme locations divided in clusters (example cluster 2)
- Proces with several stages



Station roofs in development

Eindhoven (bicycle parking)

Barendrecht

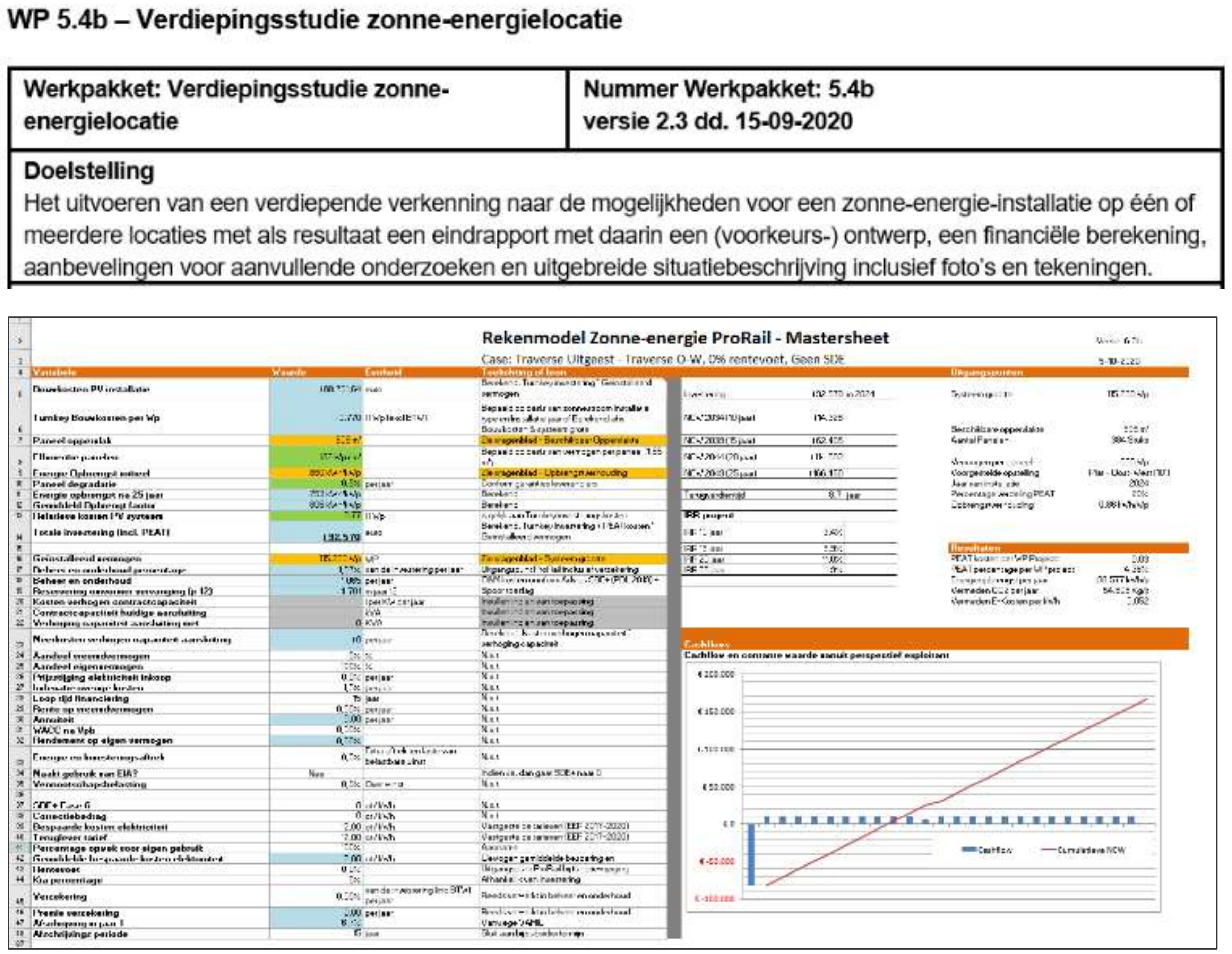
Almere Centrum

Uitgeest

Tilburg Reeshof

Policy and tools

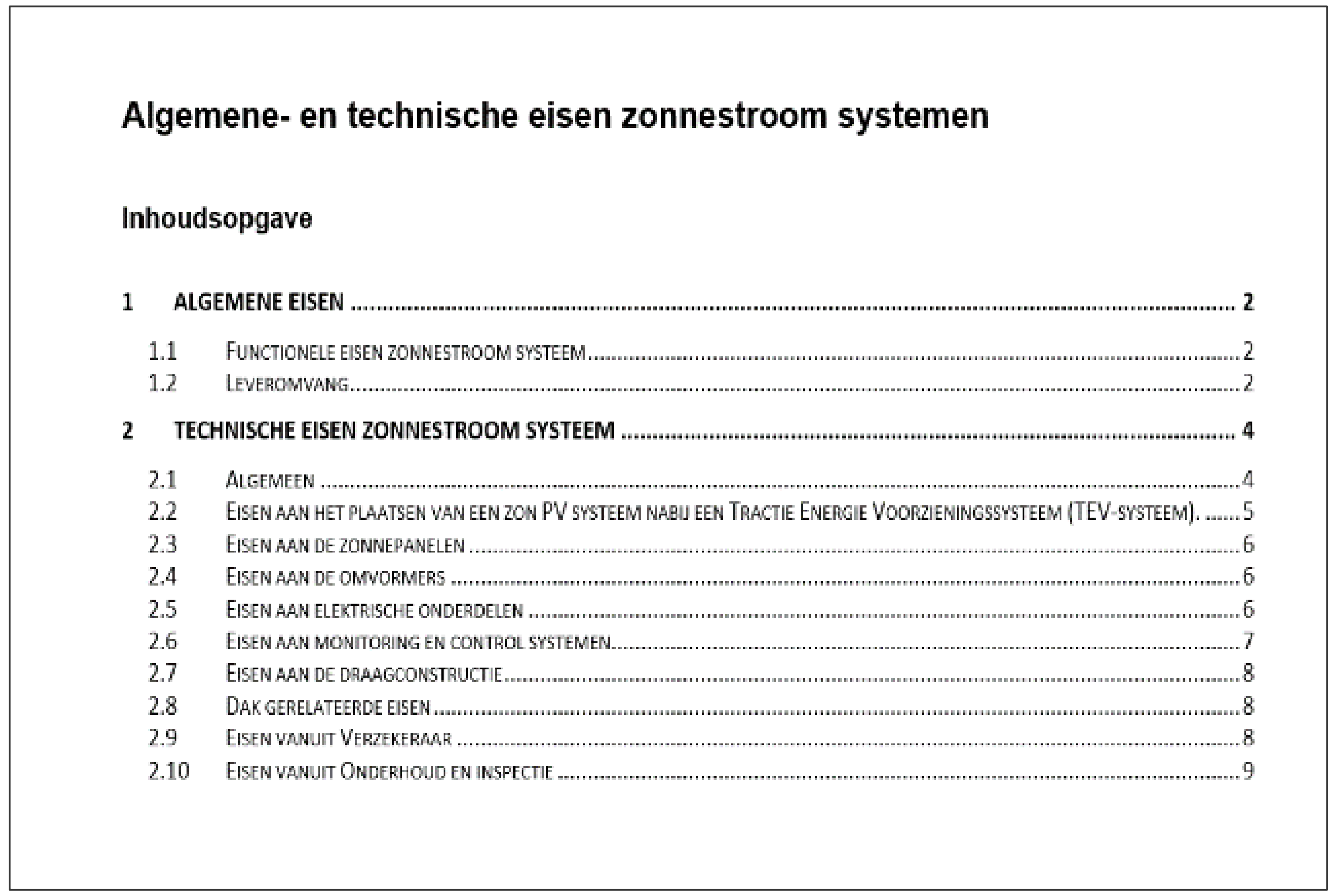
Every suitable station should get solar panels if the pay back time is <16 years.



WP 5.4b – Verdiepingsstudie zonne-energielocatie

Werkpakket: Verdiepingsstudie zonne-energielocatie	Nummer Werkpakket: 5.4b versie 2.3 dd. 15-09-2020
Doelstelling Het uitvoeren van een verdiepende verkenning naar de mogelijkheden voor een zonne-energie-installatie op één of meerdere locaties met als resultaat een eindrapport met daarin een (voorkeurs-) ontwerp, een financiële berekening, aanbevelingen voor aanvullende onderzoeken en uitgebreide situatiebeschrijving inclusief foto's en tekeningen.	

Work Package and calculation model



Algemene- en technische eisen zonnestroom systemen

Inhoudsopgave

Set of requirements

Manuel for the esthetic integration

Progress and forecast

<u>Progress</u>

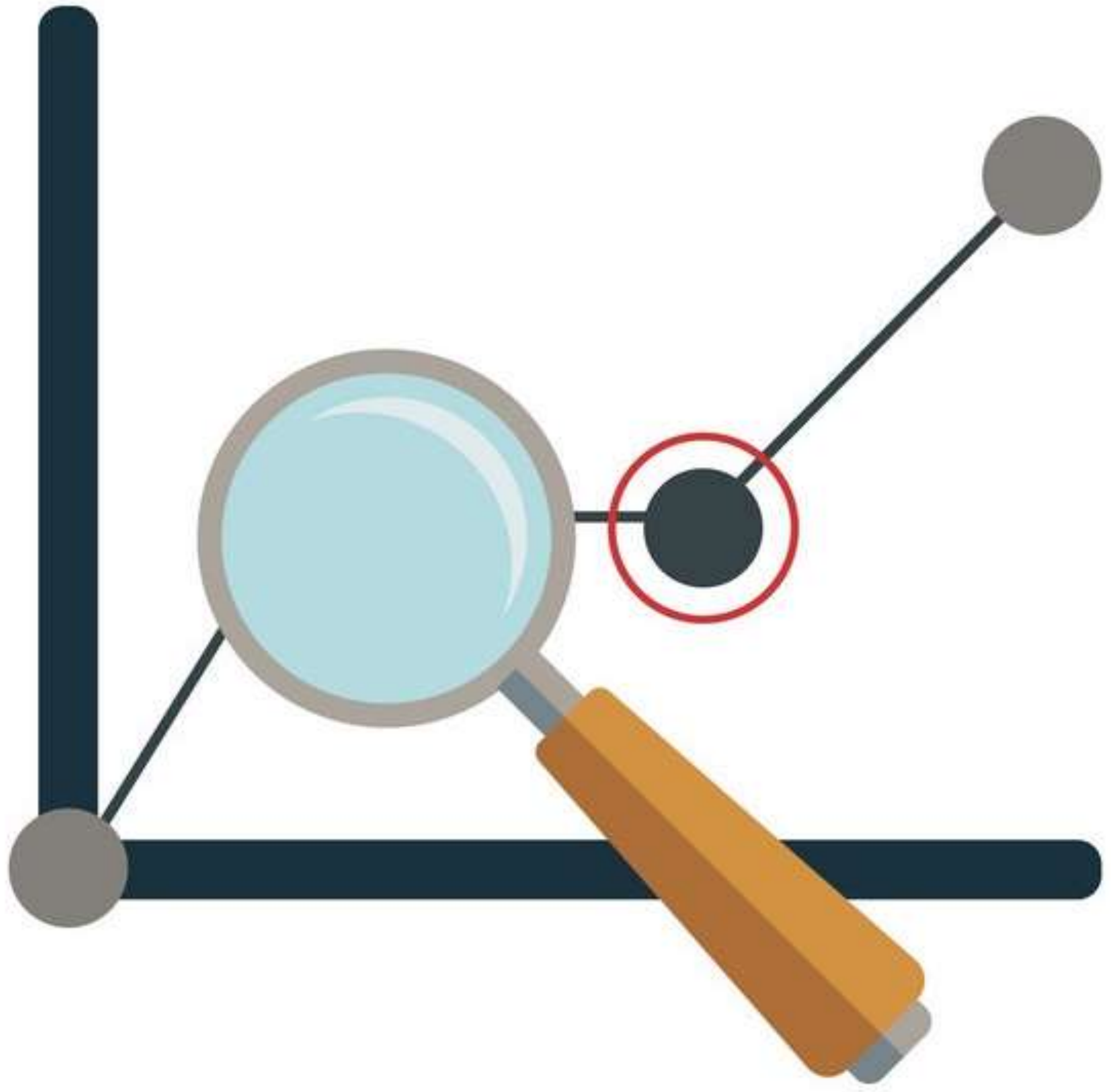
Station programme

- Cluster 1: in realization
- Cluster 2: preparing for tender
- Cluster 3: start feasibility study
- Cluster 4/5/6: haven’t started

Stations projects: at different stages

<u>Forecast</u>

Between 11 and 17 GWh



Lessons learned

1. Integrate PV systems in the design

2. Consider the interfaces with other assets

3. Examine the construction, integration and energy connection

4. Work together and combine the knowledge

Developments and research

Energy wall (tech. build.)

Bicycle shelter

Lamppost

Floor tiles

Environmental en social impact

Policy for monuments

ProRail

Connects. Improves. Makes sustainable.

Questions

Discussion

Thank you for your attention.

Workshop timeline

13h 45	Photovoltaics on stations program	**Jorien Maltha**	**ProRail**
14h 05	Solar panels deployment on stations	**Laurent Mahuteau**	**SNCF Stations**
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15h 35	*Break*		
16h 00	*Technical visit or presentation* *Hyperloop test field*	**TU Delft**	

100 YEARS ANNIVERSARY
INTERNATIONAL UNION OF RAILWAYS

SNCF GARE & CONNEXIONS (STATIONS)

Solar panels deployment on stations

SNCF GARES & CONNEXIONS

Laurent Mahuteau

SOLARIZATION OF TRAIN STATIONS

SNCF Gares & Connexions

Laurent Mahuteau

Objectives

Objectives of the solarization plan of SNCF Gares & Connexions, specialist in green stations:

- Production of as much electricity as it is consumed by the stations in 2030*
- The installation of about **1.1 million m²** of photovoltaic panels in stations by 2030 (10% of our total land area).
- A solar capacity of **47MWp** installed by 2025

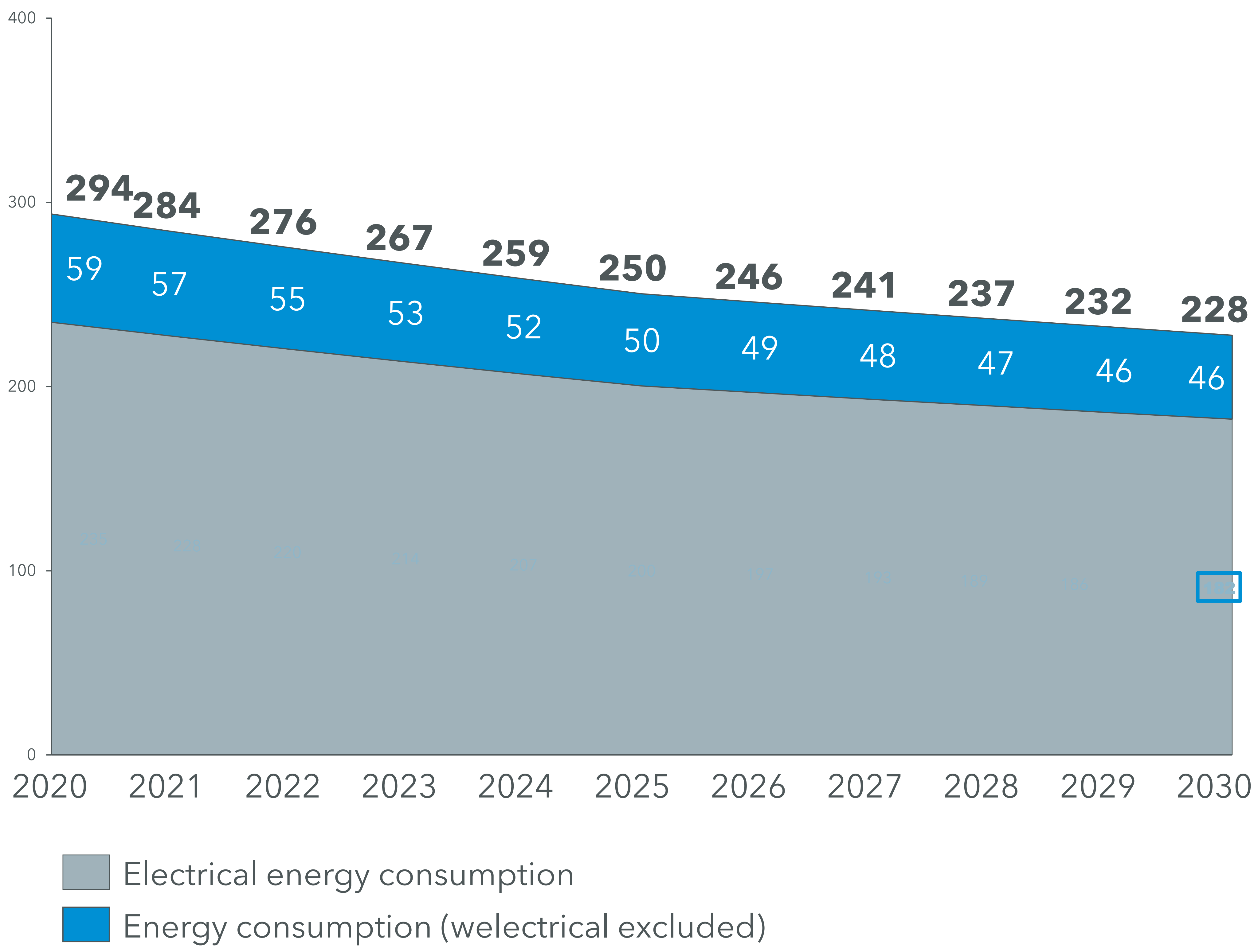
2022 objectives: implementation of pilot solar PV projects in the regions and implementation and rapid realization of the first projects. Accuracy of the census and the deployment trajectory in each region.

* i.e. approximately 180 GWh EF of electricity annually

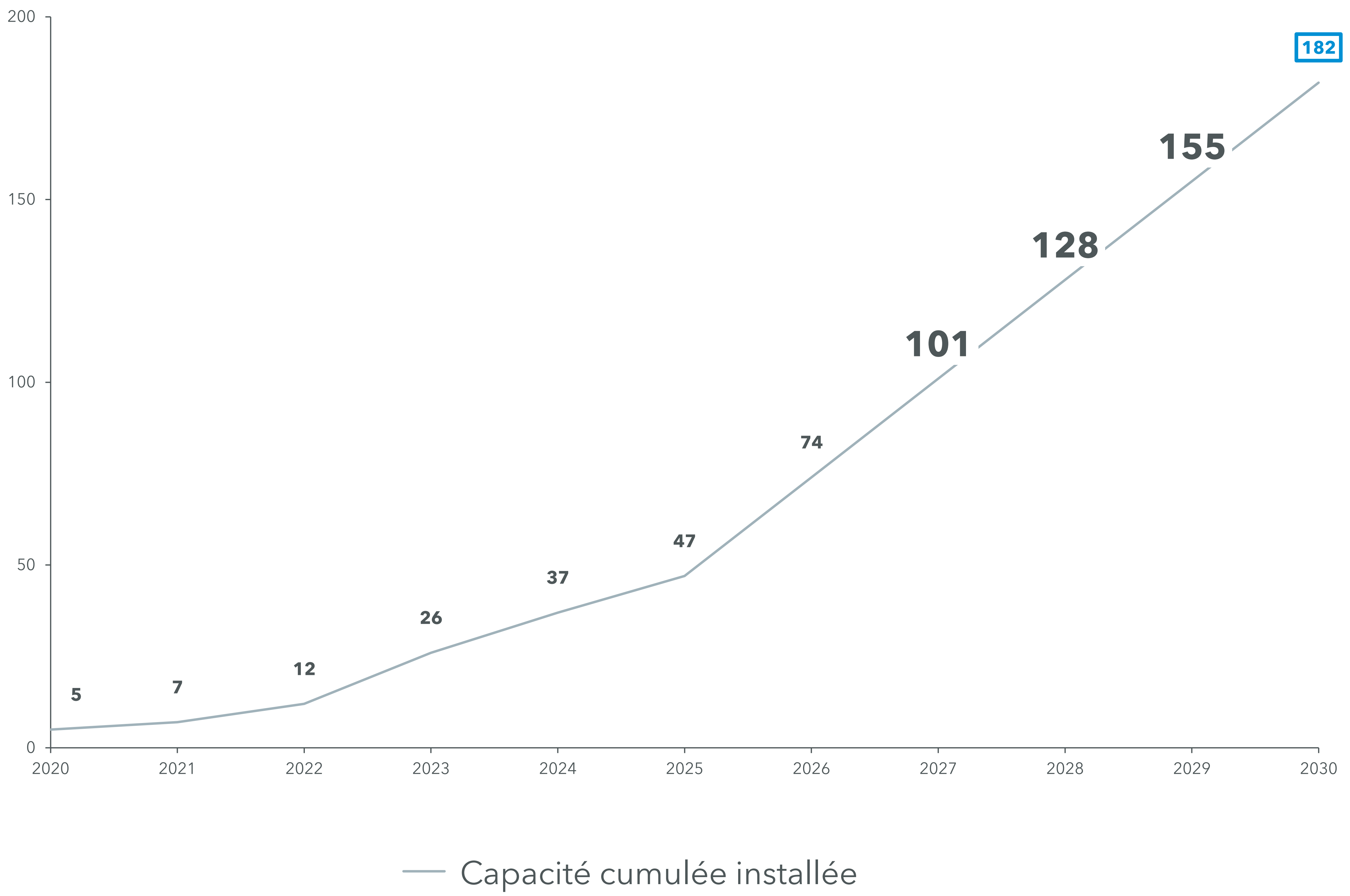
Ambition to enable the electricity production on our land equal to SNCF G&C electric consumption in 2030

SNCF G&C 2030 Objectif : 180 GWh generated on land and utilized by the stations

Evolution of the energy consumption of the stations 2020-2030 [GWh ef]

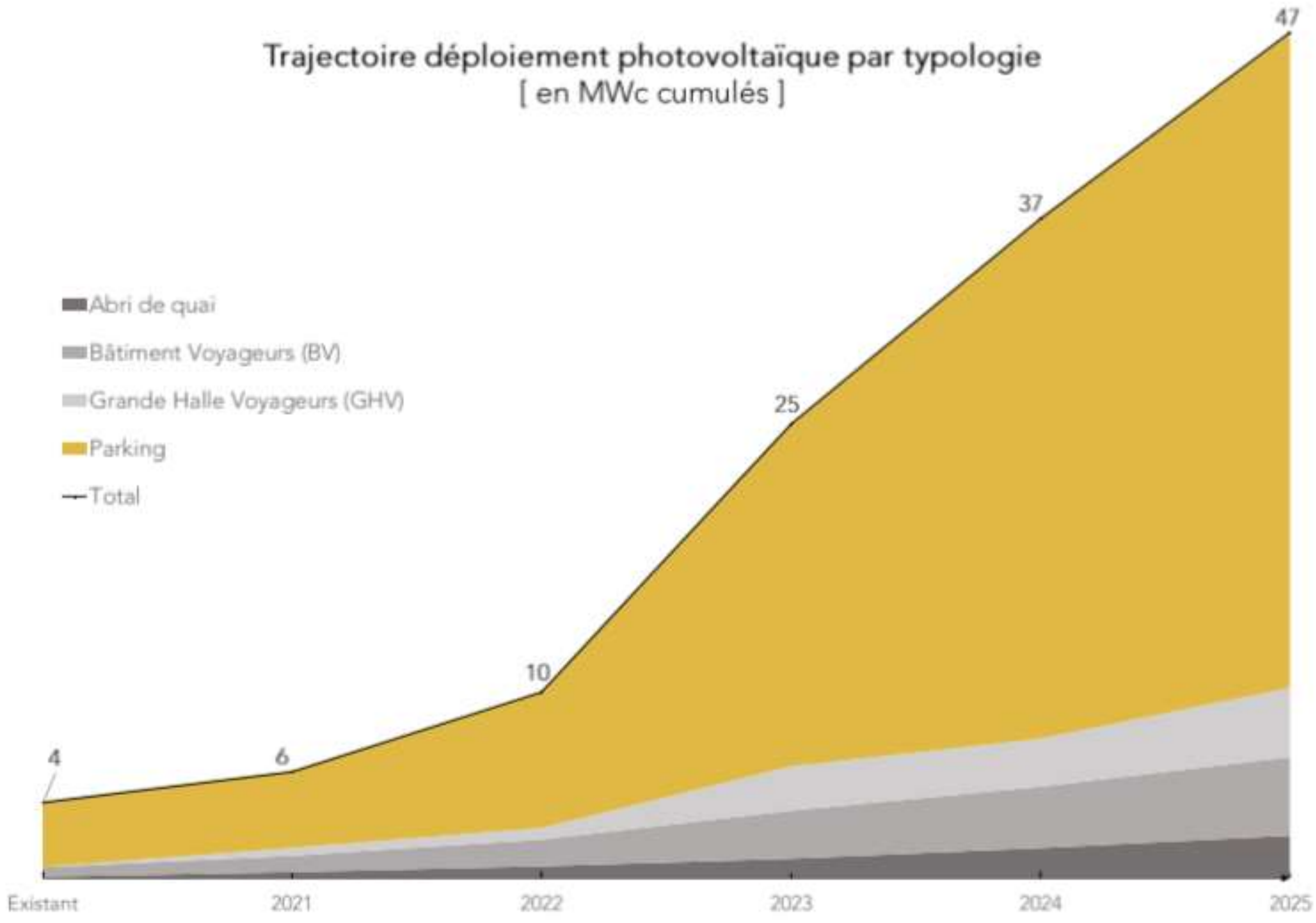


Objectives of total annual electricity production on the stations 2020-2030 [GWh ef]



* La part d'énergie électrique correspond à environ 80% des consommations de SNCF Gares & Connexions
GWH ef : GigaWatt Heure d'énergie finale

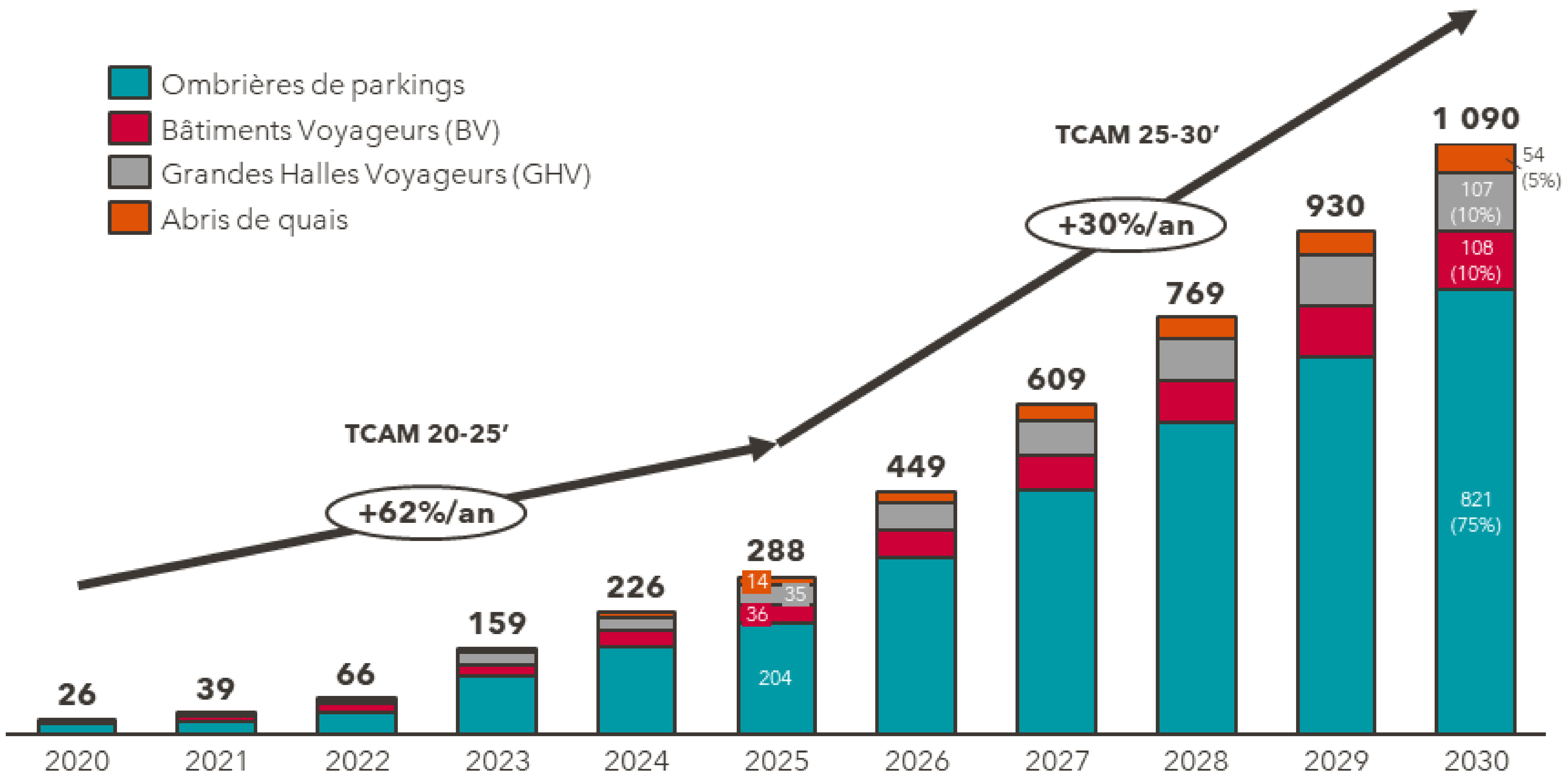
Solar photovoltaic strategy – equivalence in MWp



AREP

The installation of ~1 million m² of PV panels in stations, mainly o park shades but not only

Objectifs par support d'installation des panneaux solaires photovoltaïques 2020-2030 [milliers de m²]



	Surface totale existante *[milliers de m²]*	Couverture PV en 2025	Couverture PV en 2030
Ombrières de parking[1]	912	22%	90%
Bâtiments Voyageurs[2]	1 730	2%	6%
Grandes Halles Voyageurs[2]	370	9%	29%
Abris de quais[2]	915	2%	6%




Solar photovoltaic strategy

Four project typologies:

- Parking lots
- Buildings
- Station halls
- Platform shelters

Two ways to monetize the energy:

- Purchase agreement
- Self-consumption (with possible sale back of surplus energy)

Two project approaches (management and financing):

- by solar developer
- by SNCF G&C
- co-investment

⇒ Many variables and combination of solutions but only two retained at this stage by SNCF G&C:

1. Third party project owner
   - Project type: parking lots only
   - Valuation of electricity: purchase agreement
   - Financing: by third party
2. SNCF G&C project owner
   - Project type: Mostly buildings station halls, sometimes parking lots and platform shelters for the longer term
   - Valuation of electricity: self consumption (electricity bill savings)
   - Projects in the context of renovation of the stations or their roof tops
   - Financing: by SNCF G&C (through its pluriannual investment plan)

Solar PV project examples (in service)

In Service | SNCF Gares & Connexions

Nîmes Pont du Gard
- **Site:** : Parking lot
- **Area**: 8000 m² of PV modules
- **Power**: ~ 1,400 kWc
- **Business model** : Sale of electricity
- **Financing** : 2 M€ Effia/Reservoir Sun

Rosa Parks Paris
- **Site** : Train station plateform
- **Area** : 565 m² of PV modules
- **Power** : ~ 34,4 kWc
- **Business model** : Sale of electricity
- **Financing** : 100 k€ by SNCF G&C

La Valbonne
- **Site** : Train station rooftop
- **Area** : 45 m² of PV modules
- **Power** : ~ 7,5 kWc
- **Business model** : Sale of electricity
- **Financing** : 20 k€ by SNCF G&C

Solar PV project examples (to be in service)

Being permitted or to be constructed / to be deployed | SNCF Gares & Connexions

Paris Nord

- **Site** : New bicycle hall
- **Area** : 1000 m² of PV modules
- **Power** : ~ 200 kWc
- **Business model** : Self-consumption
- **Financing** : SNCF G&C

Angers

- **Site** : Train station rooftop
- **Area** : 860 m² of PV modules
- **Power** : ~ 180 kWc
- **Business model** : Self-consumption
- **Financing** : SNCF G&C

Mouchard

- **Site** : Parking
- **Area** : 700 m² of PV modules
- **Power** : ~ 100 kWc
- **Business model** : Self-consumption
- **Financing :** SNCF G&C

AREP

How to scale up

Launch of the Call for Expression of Interest (AMI) on February 21, 2022.
Candidates have until April 15, 2022 to send their applications and offers.

APPROACH

- Sampling of the portfolio for the provision of land as part of the first consultation **"Consultation #1 - 20 to 30MWp - Parking lots"** (without waiting for a complete national census).
- Standard third-party investor model (in total resale) with land of a certain size **to target the shortest project deadlines (100-500kWp),** outside the world / preferably rail risks (car parks) and **owned by SNCF G&C**
- Very precise definition and description of the land in the consultation to ensure the best possible results

COMMUNIQUÉ DE PRESSE

Le 22 février 2022

SNCF GARES & CONNEXIONS AMORCE L'INDUSTRIALISATION DE SON PLAN PHOTOVOLTAÏQUE

SNCF Gares & Connexions lance un Appel à Manifestation d'Intérêt (AMI) pour permettre l'installation des panneaux solaires sur le foncier des gares françaises. Cette consultation à l'échelle nationale va identifier un premier partenaire industriel dans le cadre d'un ambitieux plan photovoltaïque. Ce plan vise, d'ici 2030, à déployer, 1,1 million de m² de panneaux solaires sur le patrimoine des gares et place l'entreprise au cœur de la transition énergétique et des mobilités durables. Les candidats ont jusqu'au 15 avril 2022 pour se manifester.

C'est principalement sur les parkings des gares que seront déployées les installations de production d'électricité solaire. Un gisement initial de 190 000 m² a été identifié dans le cadre de l'Appel à Manifestation d'Intérêt dans le but de couvrir d'ombrières photovoltaïques les parkings de 156 gares. Il inclut optionnellement quatre grandes halles voyageurs.

Avec cette première consultation, SNCF Gares & Connexions souhaite industrialiser et massifier le développement d'une capacité solaire de 25 à 30 MWc* à mettre en service d'ici le début de l'année 2024. Le partenaire sélectionné à l'issue de l'AMI sera chargé de la conception, de l'investissement, la réalisation, l'exploitation et la maintenance des installations photovoltaïques. Ce projet s'inscrit dans le cadre d'une convention d'occupation temporaire (COT) du patrimoine foncier. L'électricité produite sera vendue par le futur partenaire au réseau public de distribution d'électricité et participera au verdissement du mix énergétique national.

LES GARES, DES LIEUX A ÉNERGIE POSITIVE

La solarisation du patrimoine foncier de SNCF Gares & Connexions s'inscrit pleinement dans le plan stratégique de l'entreprise. Portes d'entrée des mobilités durables, les gares doivent donner envie de prendre le train et être exemplaires en termes de standards environnementaux.

Spécialiste de la gare verte, SNCF Gares & Connexions poursuit ainsi plusieurs objectifs à l'horizon 2030 :

- le développement des capacités renouvelables sur ses emprises foncières,
- la réduction de moitié de ses émissions de gaz à effet de serre par rapport aux émissions de 2019,

Call for Tender

Car park shades only, projects relating to car parks with 40 to 200 spaces

- 500 – 2500 m² of PV panels i.e. 100 to 500 kWp

Other main features:

- EDF purchase obligations, project deadlines: 18-24 months
- Parking operator: G&C or communities

Excluded:

- Car parks with more than 500 spaces
- Car parks operated and commercialized by our partner
- Car parks not owned by SNCF G&C
- Car parks for which shade structures are compatible with a long-term vision (25/30 years)

Partner Selected

AN INDEPENDENT AND EXPERIENCED PLAYER

Created in 2008, Tenergie is a French independent renewable energy producer that develops, integrates and operates solar and wind power plants throughout France. For more than ten years, the company has provided long-term support to all regional players.

Their activities are dedicated to renewables and specifically solar PV:

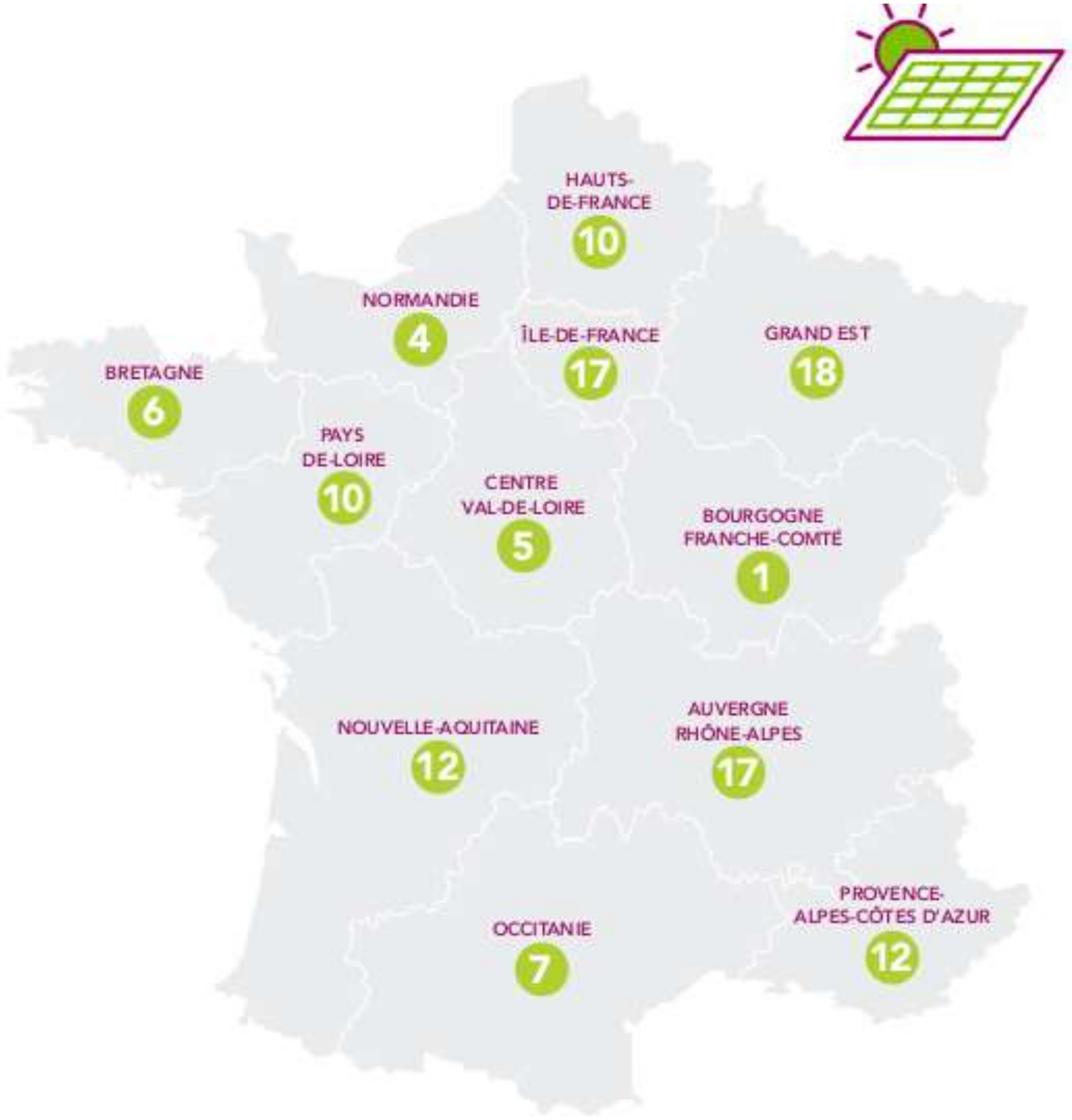
- Parking shade
- Photovoltaic roof
- Photovoltaïc on agricultural building
- Photovoltaic greenhouse
- Ground-mounted photovoltaic plant

1 400
Renewable energy plants

208 M€ CA
At the end of 2021

170
Number of employees

650 MW
Installed power



What's next?

- Make the photovoltaic production an inherent and integrated element of the train stations and the buildings through our renovations
- Continue our efforts to solarize the parking lots (land that is already artificialized) and the paid parking lots managed by our operators
- Go further and beyond and consider areas in railway technical constraints (platform shelters)
- Create a systematic approach to solarize buildings and station halls that are renovated.

Do it while learning from our European colleagues !

PORTA SUSA – TORINO

ROTTERDAM CENTRAL

100 YEARS ANNIVERSARY
INTERNATIONAL UNION OF RAILWAYS

Questions

Discussion

Thank you for your attention.

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INTERNATIONAL UNION OF RAILWAYS

RICARDO RAIL

Insights from Innovation in Traction Energy in the UK

Ricardo Rail
Formerly Lloyd's Register Rail

Colin McNaught
Technical Director

GB Rail & Energy Context

Physical Context

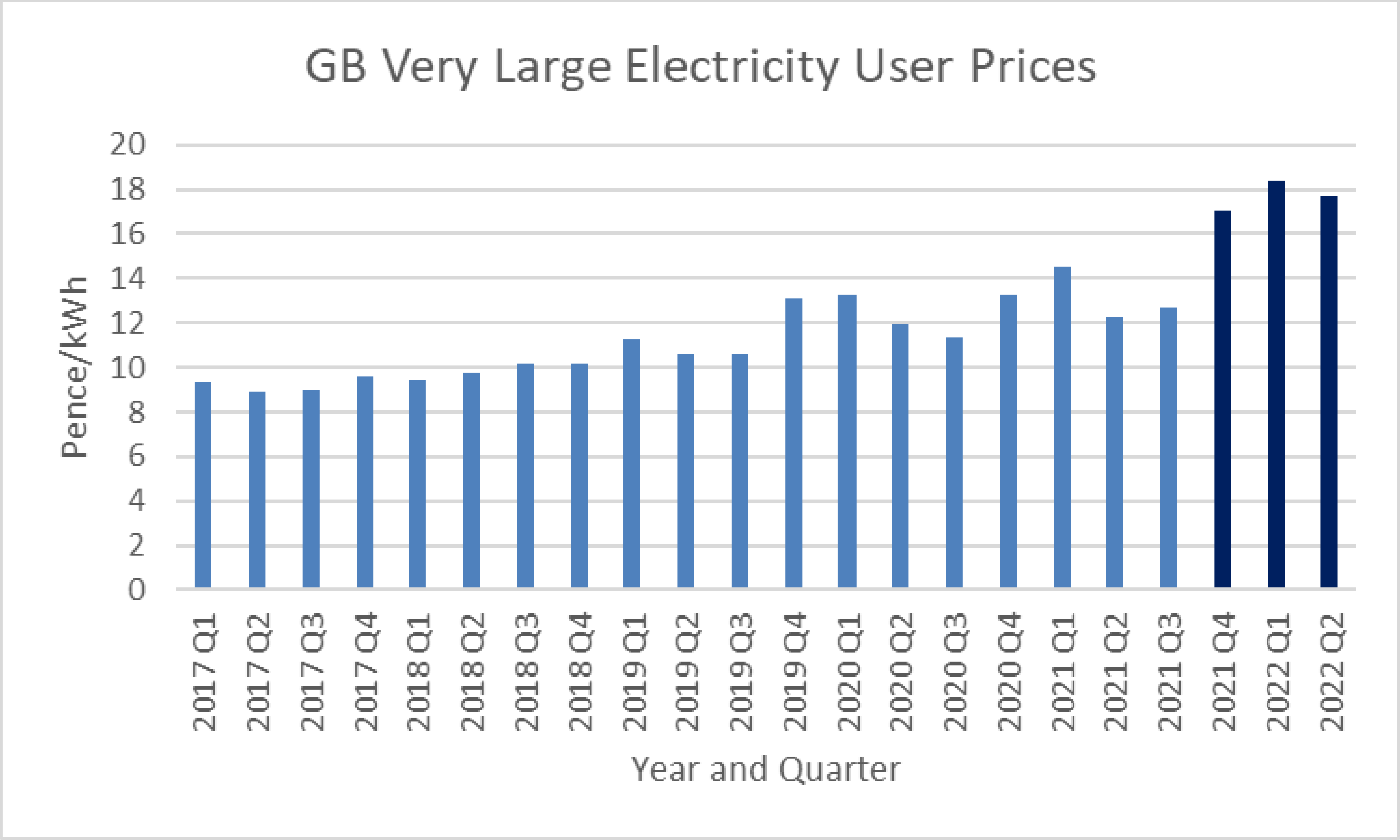
- 38% of route electrified
  - 2/3rd AC 25kV
  - 1/3rd DC 750V
- Rail infrastructure
  - Public ownership: Network Rail, build and own electrical infrastructure and charge for power and track access
- Rolling Stock: Mostly private:
  - Train Operating Companies (TOCs) – run services pay for power & track
  - Rolling stock company (ROSCO), lease trains to TOCs

Policy Context

- Remove diesel-only passenger services by 2040
- Traction Decarbonisation Network Strategy (2020) in Single Track km (STK)
  - Electrification: 13,000 STKs
  - Hydrogen train: 1,300 STK
  - Battery: 800 STKs
- Would increase traction electricity to around 3% of UK demand

GB Electricity

Price Movements to Q2 2022:



- Increase in traction electricity costs expected from 2022/23 to 2023/24
  - £595 to £885 million (150%)

Business Electricity Price:

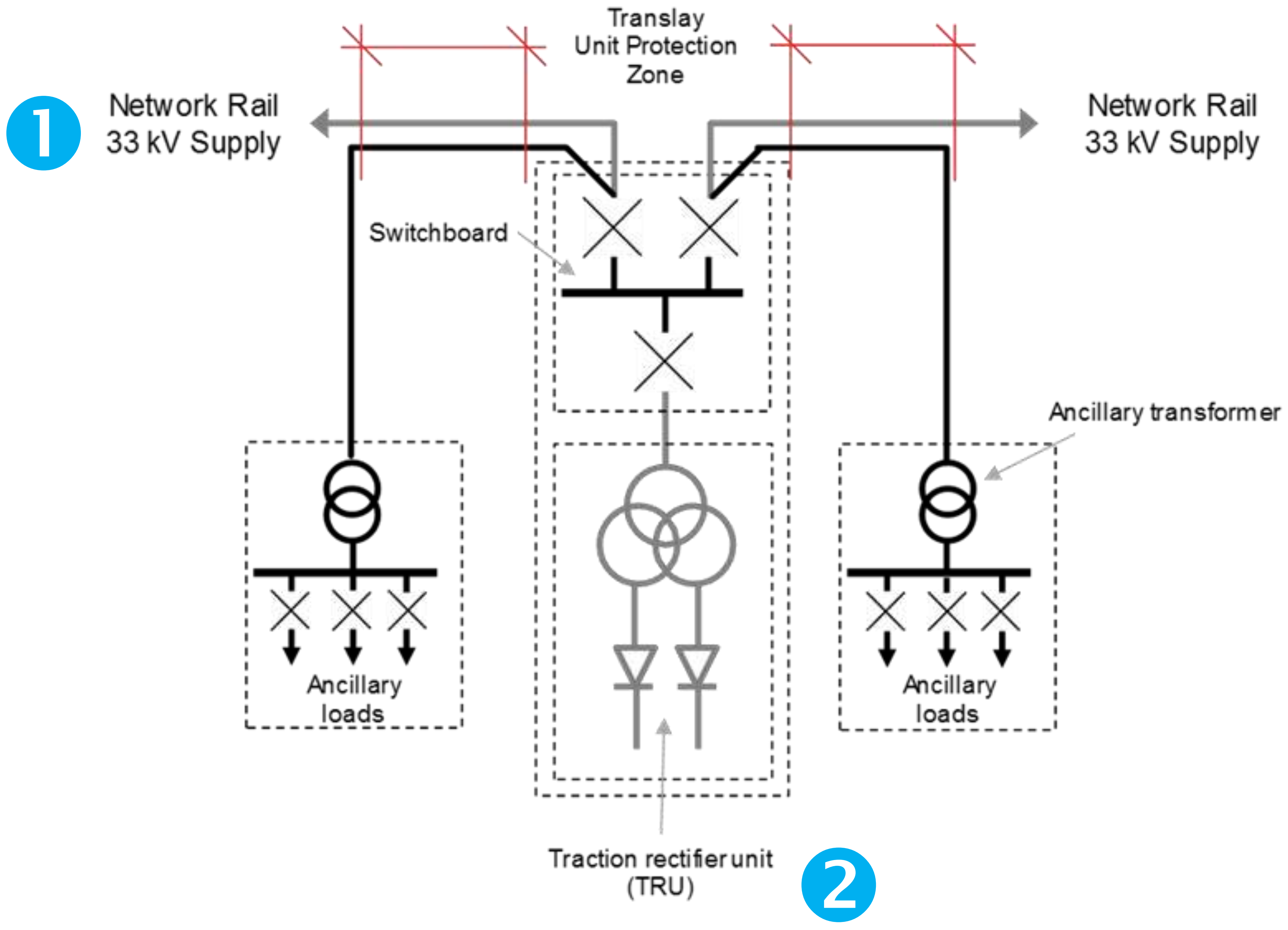
⅓ Electricity Generation
⅓ Electricity Transmission
⅓ Other (Environmental)

- Private wire renewables avoids:
  - Market price fluctuations
  - Electricity Transmission – as private wire direct from generator
  - Other (Environmental) – as direct contract with generator

Connection to 750V DC Traction

Two Options

1. 33kV AC side
2. 750V DC side



	33kV AC	750V DC
Pros	• Feed multiple DC sections = larger PV • Established PV connection solution • Wide range of PV connection points	• Can recover regenerative braking but need a battery
Cons	• Cant recover regenerative braking • Risk of export to grid	• Limited trains on each DC section = smaller PV

Pilot Solar PV Installation – DC Third Rail

30kW pilot scale system at Aldershot station

- 3 different inverters used:
  - Connected to AC system on the secondary side of an ancillary transformer
  - Installation outside railway boundary
  - No certification of PV equipment for simpler installation

Measurement of power & harmonics:

  - Voltage regulation – inverter loss of main detection
  - Harmonics (to 50^{th}) - sourced from NR and the solar PV inverters
  - Rapid changes in load – how will the inverter optimise solar PV output

PV Modules in plastic “buckets” – no ground disturbance

4.4 MW PV Installation – DC Third Rail

4.4MW PV feeding 33kV AC to third rail

- Busy line from Eastbourne to London
- PV site already under development
- Electrical cable ca 4km to railway

Challenges:

- Costs of sub-station upgrades
- Risk of electricity export

Project halted but many lessons learnt for future projects

Initial PV layout

Connection to 25kV AC

Conventional rail traction feeder stations:

- Transmission: 132kV, 275kV, 400kV
- Acceptable phase imbalance limits
- No power electronics
- Costs can be high: £10 to £40million

Solar PV (or wind) connection:

- From 2MW to 20MW
- 33kV or 132kV connections
- 3 phase
- Conventional feeder solution not affordable
- Co-locate with battery systems

	25kV AC
Pros	• Large track section so significant traction load • Larger PV/better generation match • Potential 33kV AC connection • Wide range of PV connection points
Cons	• Single phase connection • Imbalance • Need affordable convertor

25kV AC Test Site

Main Elements:

- Solar PV array ca 1MWp
- Daybreak converter: DC to LV AC
  - Small scale
  - Modular
  - Lower cost
- Step up transformer
- Connection to 25kV single phase

Key challenges

1. EMC
2. Funding

Empty bay with two 25 kV circuit breakers and the +25 kV & -25 kV busbar in the background.

Trackside Battery Systems

Assessment on rural lines in Wales
Solar PV and Wind

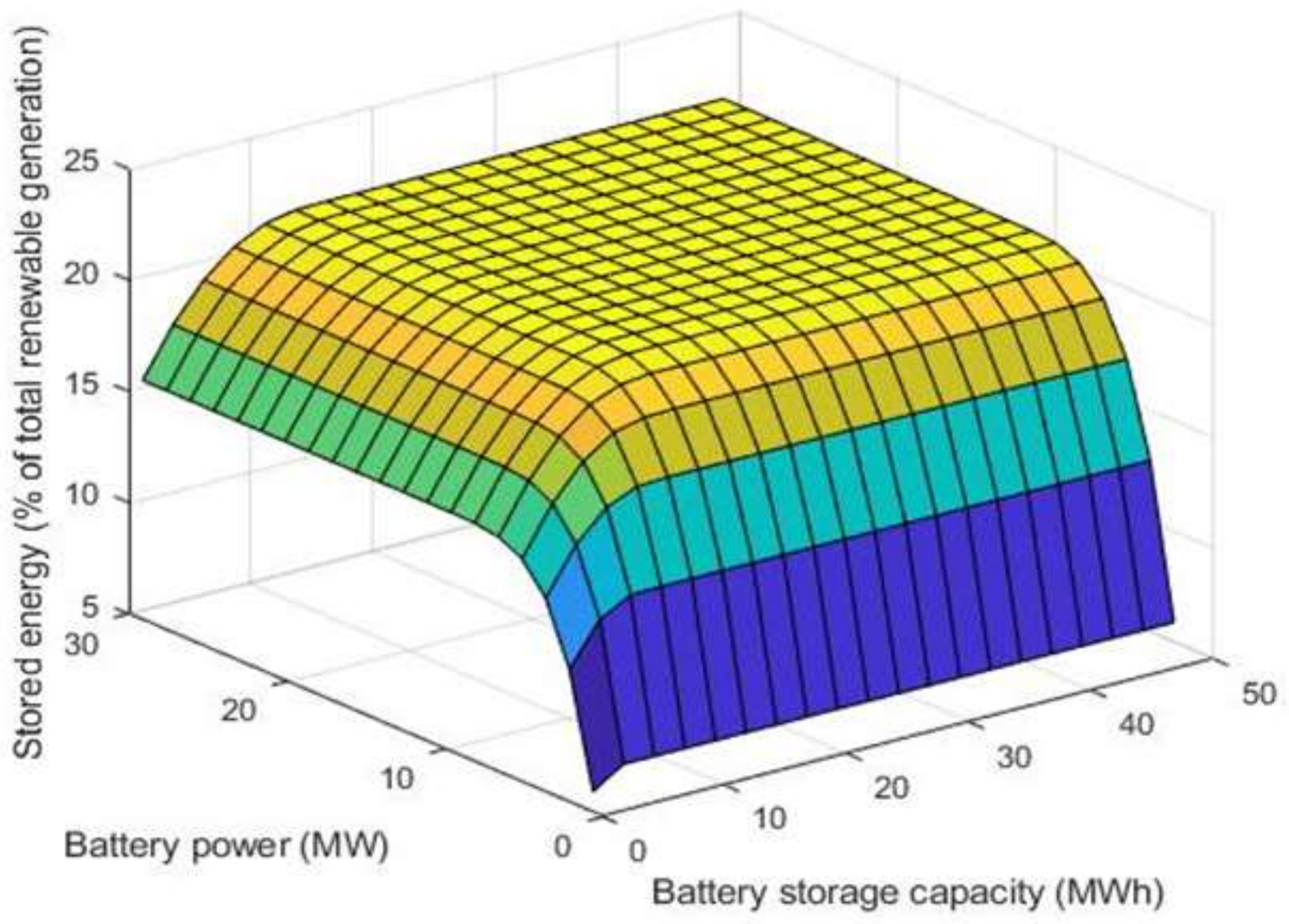
Developed optimisation model for trackside battery system

Sizes Solar PV 13.2MWp

18% of traction from solar

8.5MW/10MWh battery

24% of traction from solar



Holistic Assessment (H2H)

Holistic assessment covers:

- Electricity costs & benefits
  - Feeder stations
  - Grid flexibility
- Rail costs & benefits
  - Infrastructure & rolling stock

Rail context in Scotland

- Remove diesel passenger fleet by 2035
- Rail fully in public ownership

Far North Line

Holistic Assessment (H2H)

Preliminary Cost Benefit Assessment (CBA) – Far North Line

- 280 STK, 4 trains per day in each direction
- 30 year 3.5% NPV
- Avoids: 27 $ktCO_{2e}$ embodied carbon + 2.9$ktCO_{2e}$/yr from diesel

Two forces: Distance ➔ Infrastructure vs. Timetable ➔ Train and fuel

Next steps: Improved data & CBA for 4 lines

Holistic Assessment (H2H)

Demonstration phase

Application March 2023

Start Late 2023 up to 5 years and £10million

Elements:

- Demonstrate the energy system benefits from hydrogen
  - Reducing constrained renewables
  - Flexibility income streams
  - Avoided rail feeder stations
- Test hydrogen trains
- Potential trial hydrogen passenger service

100 YEARS ANNIVERSARY
INTERNATIONAL UNION OF RAILWAYS

Questions

Discussion

Thank you for your attention.

SNCF RÉSEAU (INFRASTRUCTURE)

RaccorD project

Tony Letrouvé Hervé Caron

INTERNATIONAL UNION
OF RAILWAYS

RACCORD

RÉSEAU FERROVIAIRE A COURANT CONTINU INTELLIGENT
POUR LE VERDISSEMENT DE L'ÉNERGIE ÉLECTRIQUE

Tony LETROUVE & Hervé CARON
SNCF Réseau / DTR / Energy consulting and sustainable development team

UIC "Renewable energy integration in railways" Workshop - 17 November 2022

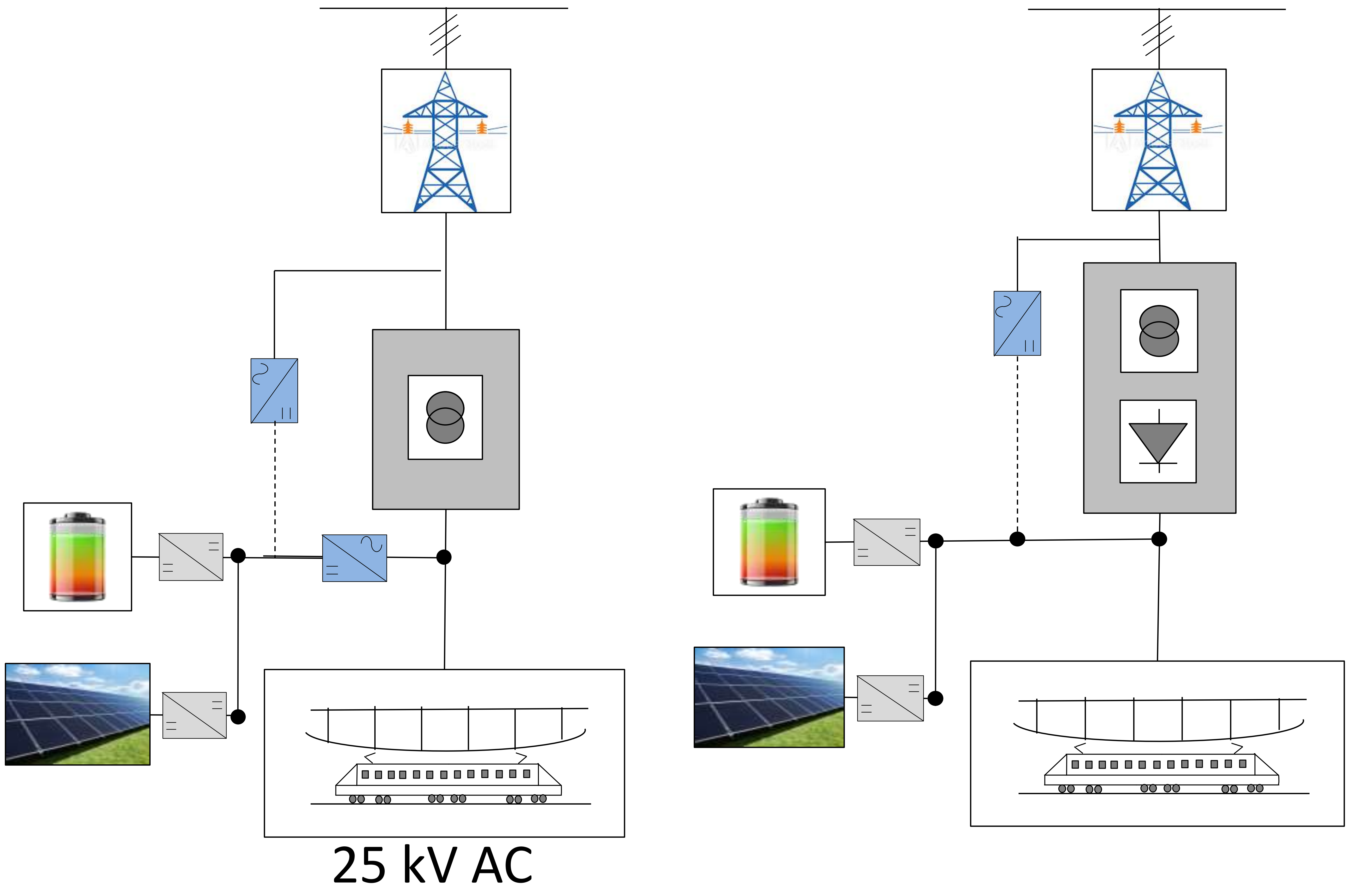
**SMART DIRECT CURRENT RAILWAY NETWORK FOR A GREENER ELECTRICAL ENERGY*

Interne

INTRODUCTION

How to integrate and how to position a Railway infrastructure manager in this topic?

- ✓Possibility to **exploit the railway area next to a substation** by installing a photovoltaic field and **what is the connexion** point with French railway system?
- ✓The photovoltaic field will be sized to **favor self-consumption and minimize the energy injected into the public grid**
- ✓A **storage system could be associated with solar panels** to optimize energy efficiency.



PROJECT PRESENTATION

1

CONSORTIUM

Network Operators

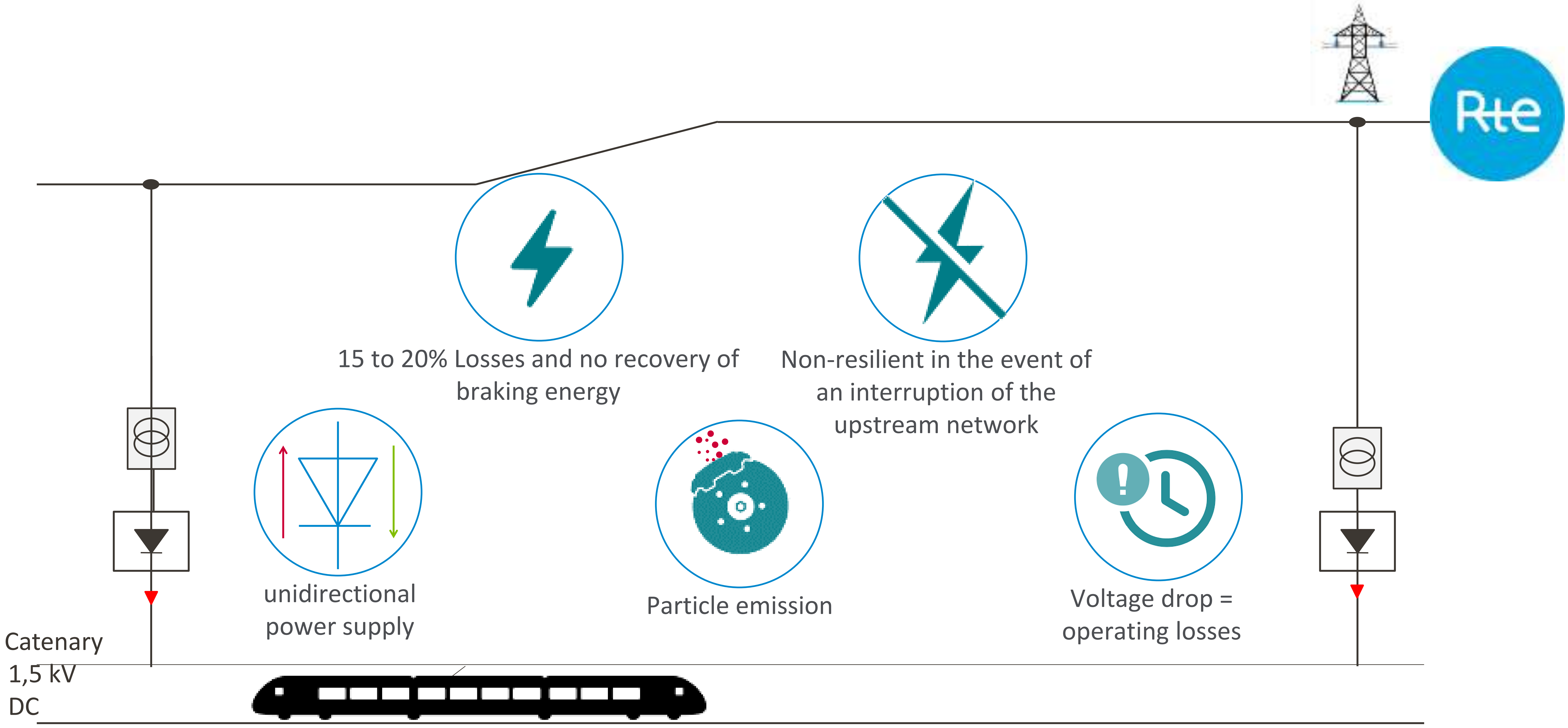
Industrial- EQUANS

Railway Technological Research Institutes

Scientific laboratories and research organisations

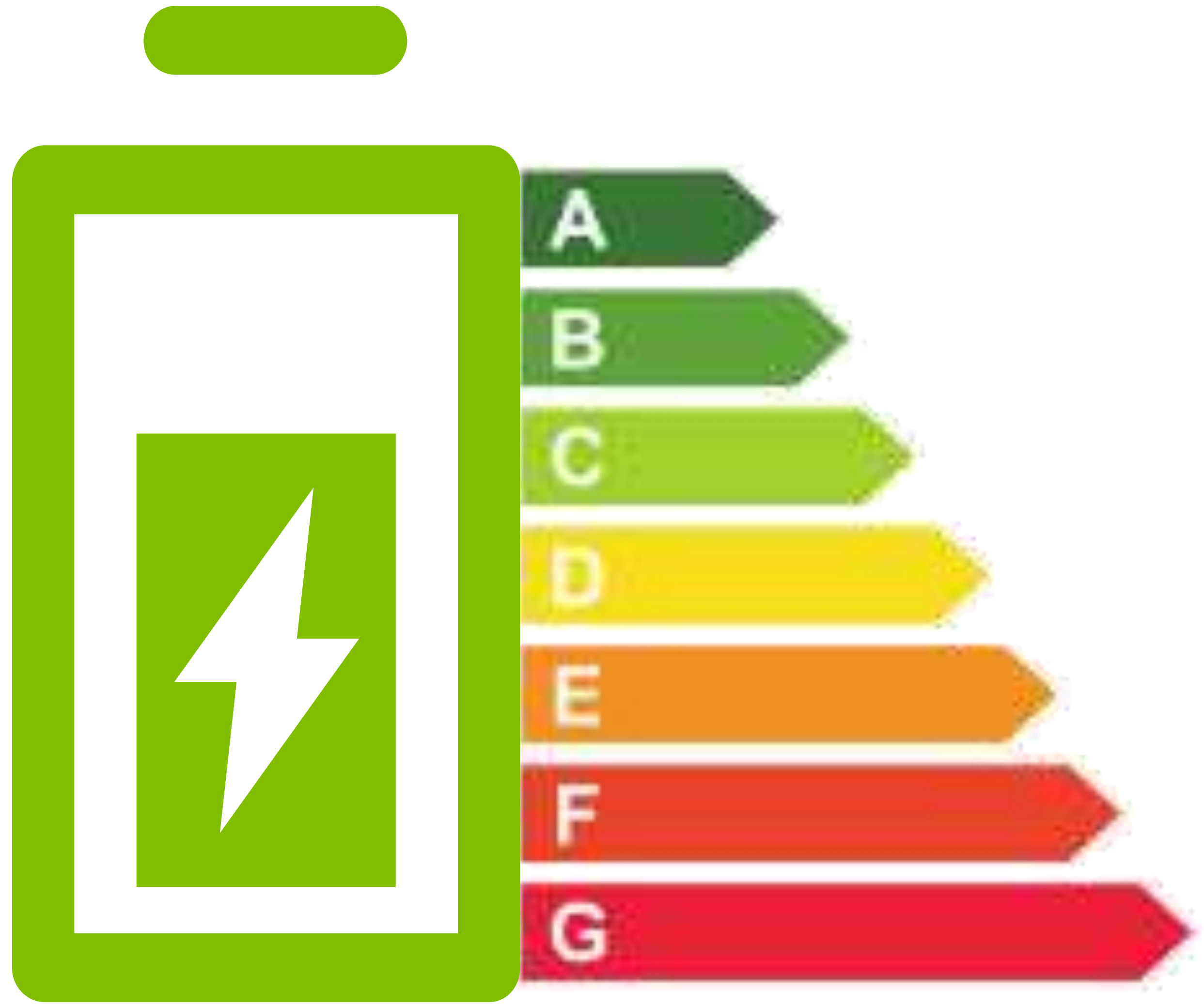
RACCOR-D *The RACCOR-D project was funded by the government as part of France 2030*

THE CONSTRAINTS OF THE DIRECT CURRENT NETWORK

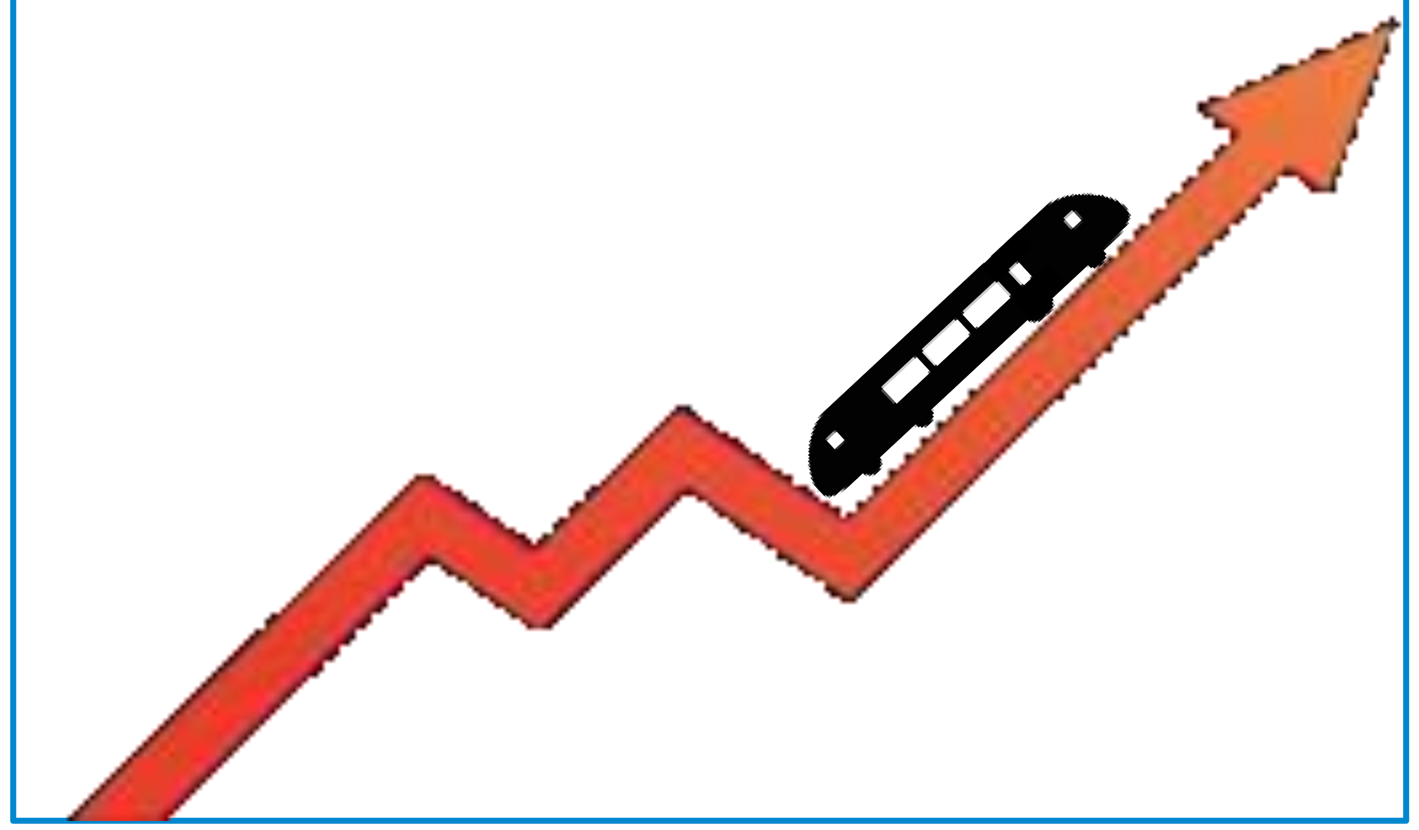


PROJECT'S OBJECTIVES

INCREASING THE ENERGY EFFICIENCY AND ROBUSTNESS OF THE RAILWAY SYSTEM

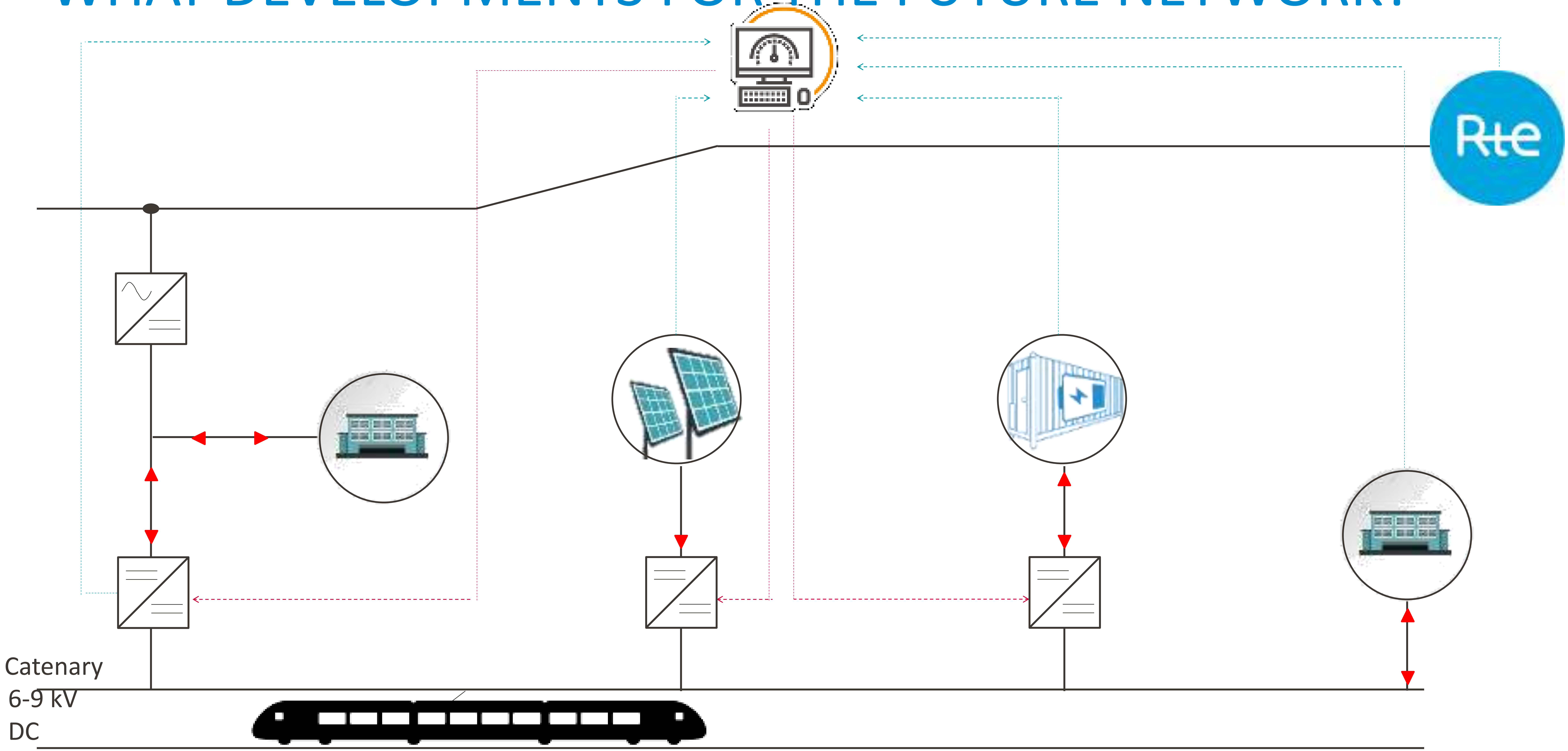


COPING WITH INCREASED TRAFFIC AND EVER MORE POWERFUL TRAINS

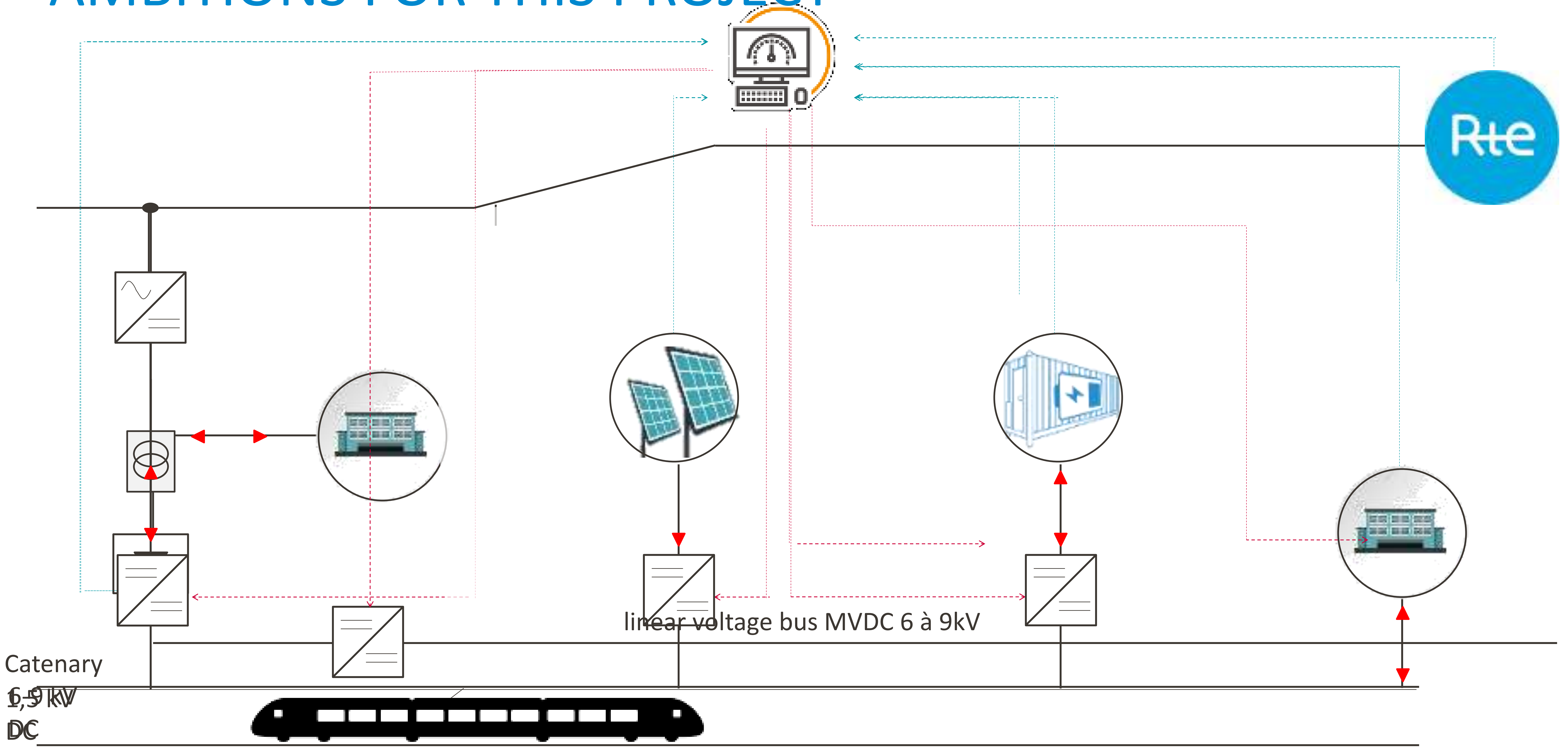


DECARBONISING THE GRID AND RATIONALISING THE USE OF PRIMARY RESOURCES

WHAT DEVELOPMENTS FOR THE FUTURE NETWORK?



AMBITIONS FOR THIS PROJECT



Interne

RACCOR-D EXPERIMENTAL SETUP

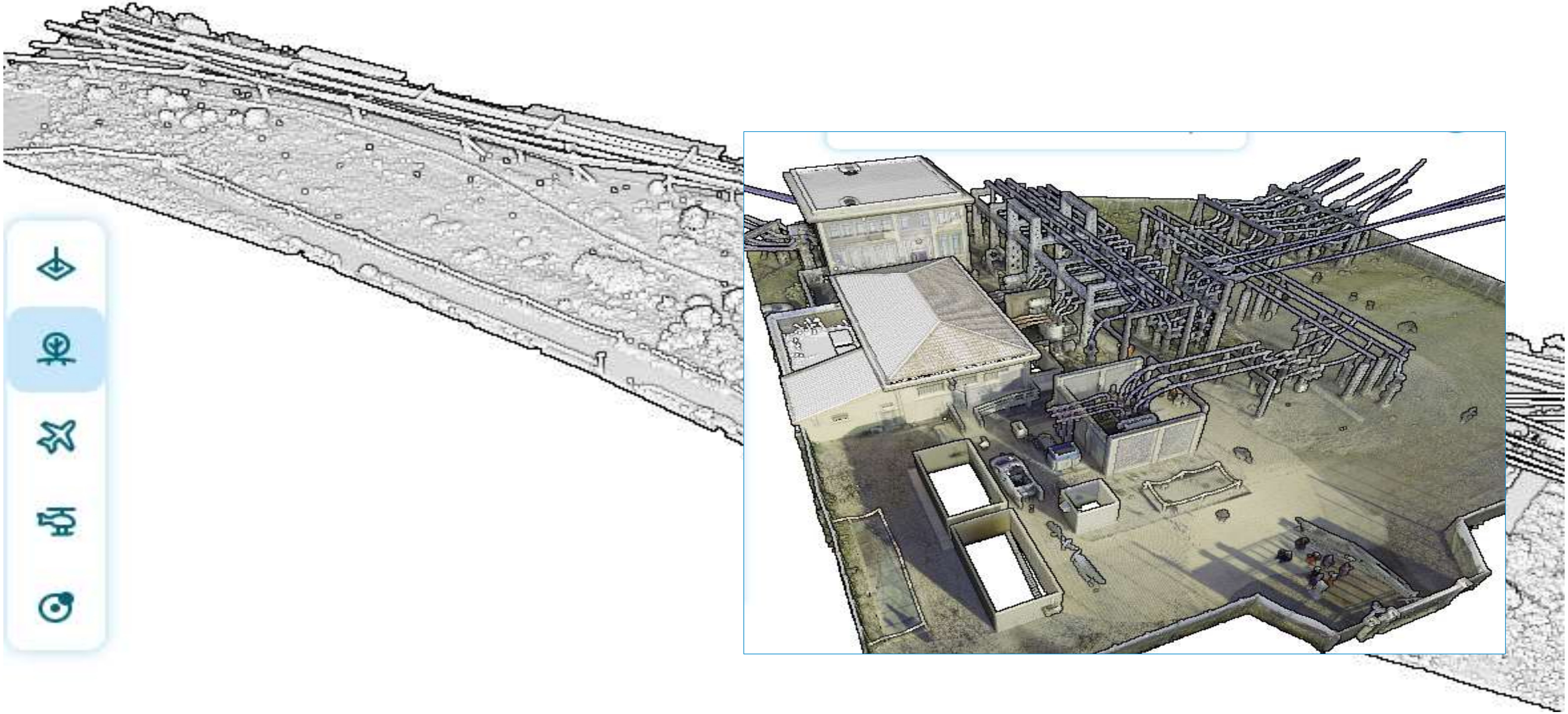
2

AN EXPERIMENTAL SITE UNIQUE IN FRANCE

STUDIES FOR THE DEVELOPMENT OF THE SITE | SUBSTATION PLAN OF LÉZIGNAN CORBIÈRE AND ITS INDUSTRIAL WASTELAND

AN EXPERIMENTAL SITE UNIQUE IN FRANCE

STUDIES FOR THE DEVELOPMENT OF THE SITE | SUBSTATION PLAN OF LÉZIGNAN CORBIÈRE AND ITS INDUSTRIAL WASTELAND



Interne

AN EXPERIMENTAL SITE UNIQUE IN FRANCE

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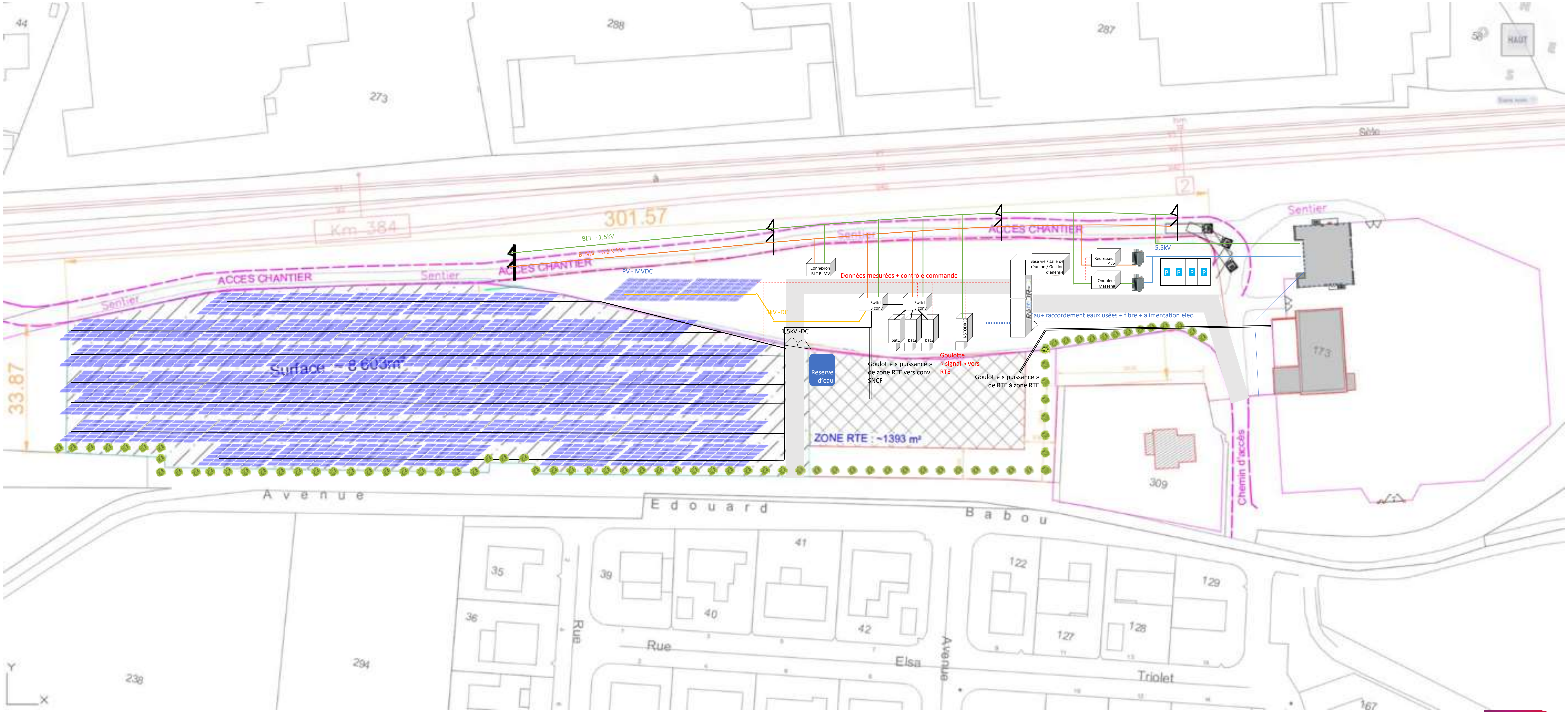


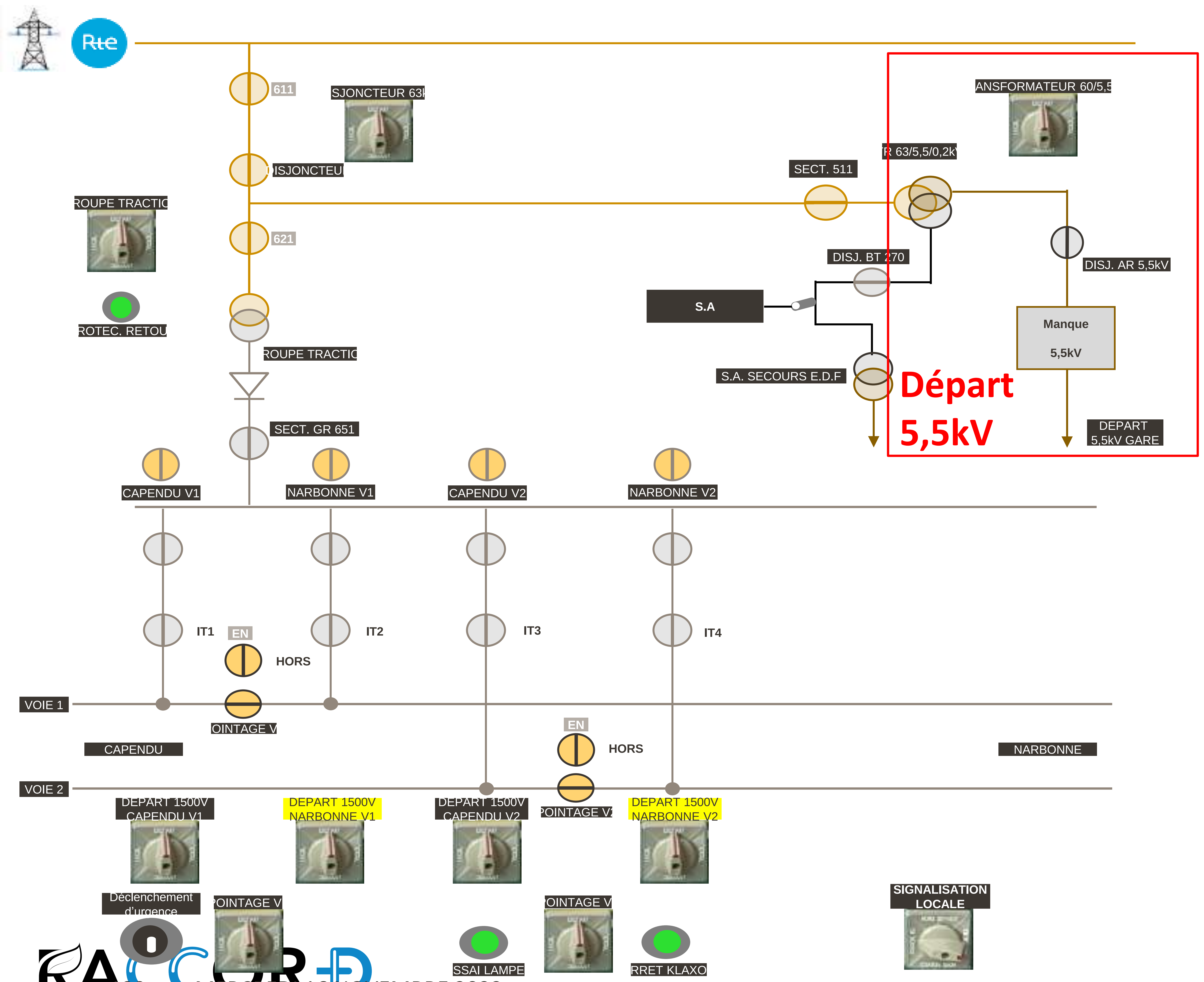
RACCOR-D

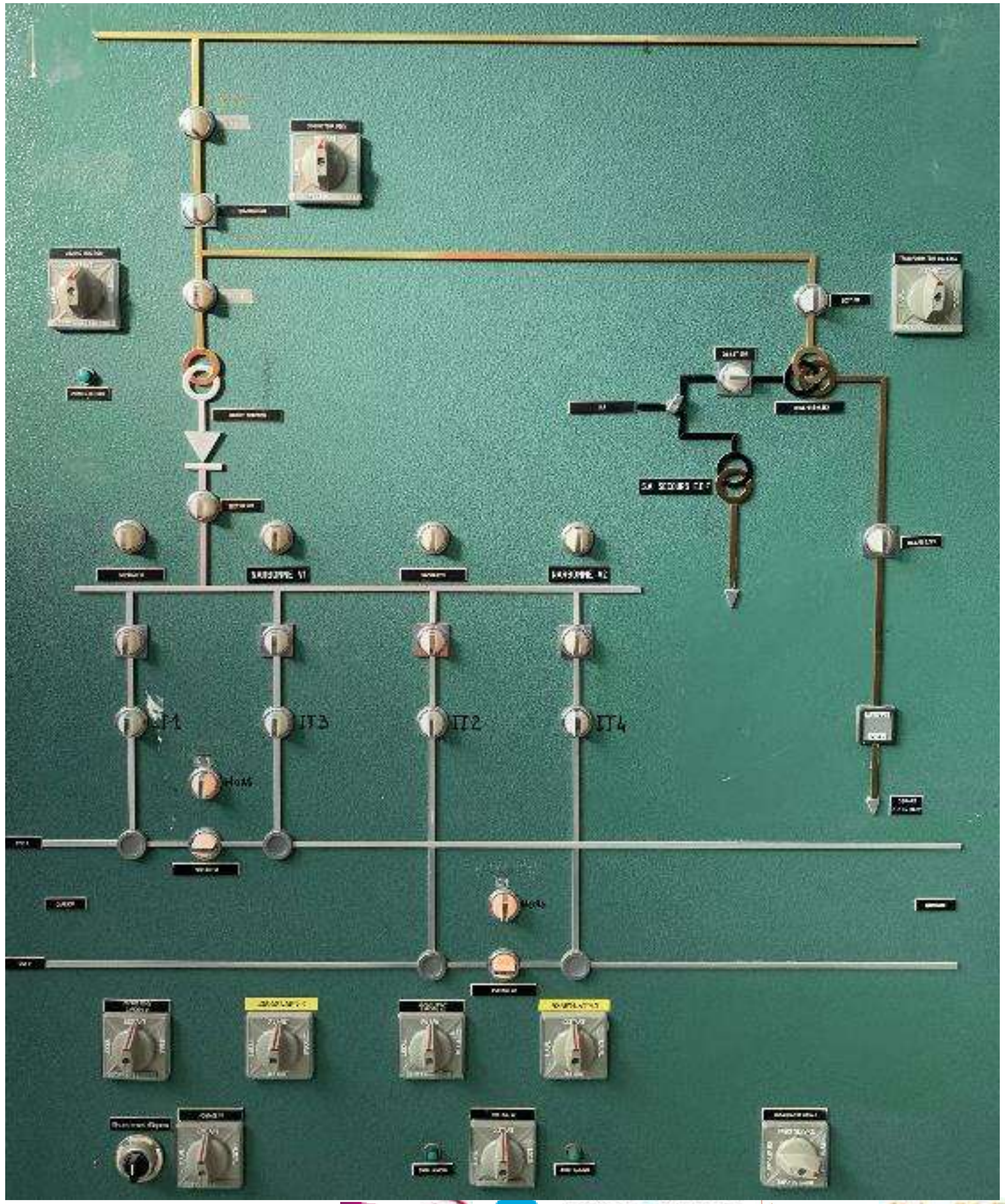
SNCF RÉSEAU

Interne

AN EXPERIMENTAL SITE UNIQUE IN FRANCE

CONNECTION ARCHITECTURES | SYNOPTIC OF THE LÉZIGNAN-CORBIÈRES SUBSTATION



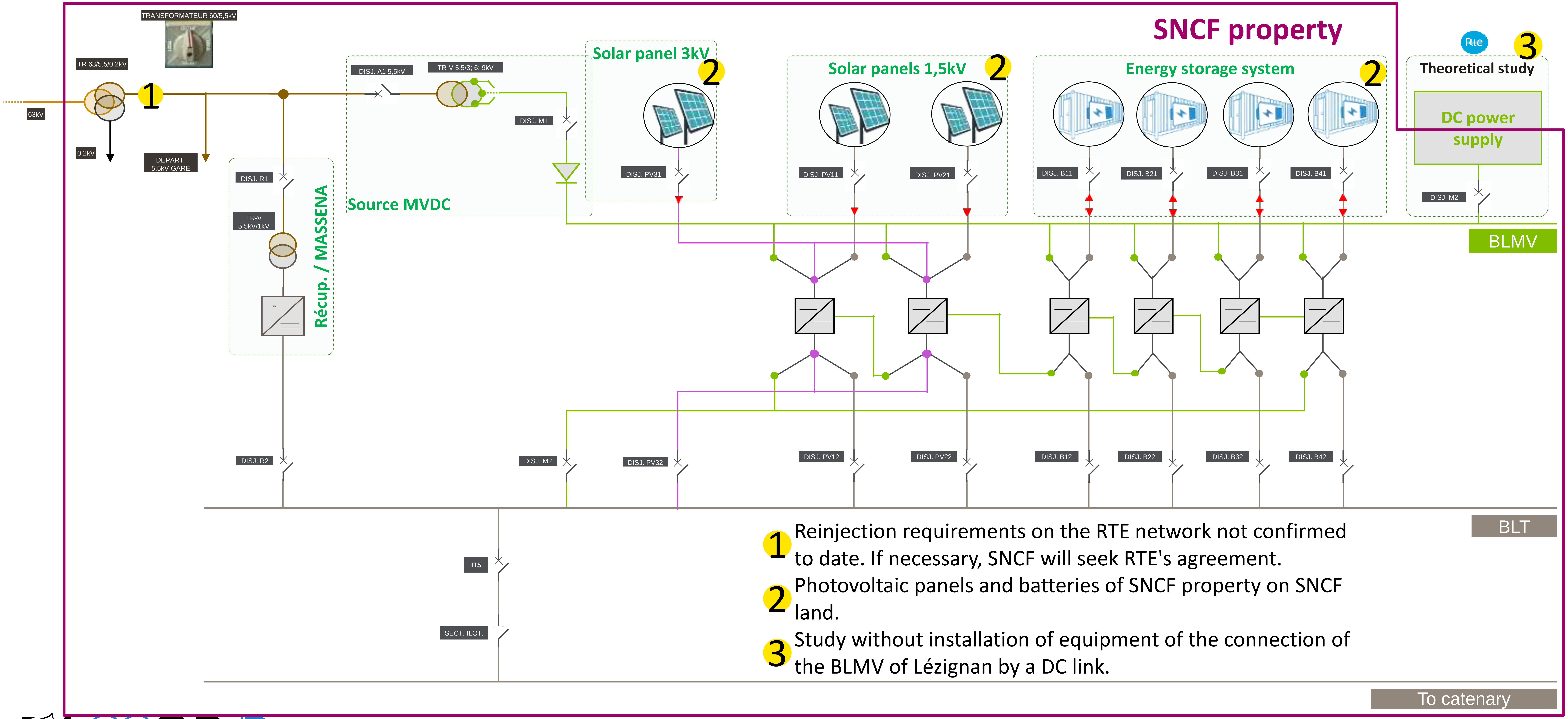


Interne

AN EXPERIMENTAL SITE UNIQUE IN FRANCE

CONNECTION ARCHITECTURES | PROJECTED CHANGES BY RACCOR-D

- BLT : Longitudinal Traction Bus (1,5 – 3kV)
- BLMV : Longitudinal Medium Voltage Bus (6 – 9kV)



1. Reinjection requirements on the RTE network not confirmed to date. If necessary, SNCF will seek RTE's agreement.
2. Photovoltaic panels and batteries of SNCF property on SNCF land.
3. Study without installation of equipment of the connection of the BLMV of Lézignan by a DC link.

SNCF SCLE RTE RAILENIUM Laplace L2EP
Interne

AN EXPERIMENTAL SITE UNIQUE IN FRANCE

RACCOR-D STEP BY STEP

2022

ENVIRONMENTAL STUDIES AND EXPERIMENTAL SITE PREPARATION

2023

INTEGRATION OF THE FIRST BATTERY ON THE NATIONAL RAIL NETWORK AT THE LEZIGNAN SITE

2024

INTEGRATION OF SOLAR PANELS FOR SELF-CONSUMPTION

2025

INTEGRATION OF STORAGE SYSTEMS AND MEDIUM VOLTAGE DC NETWORK EXPERIMENT

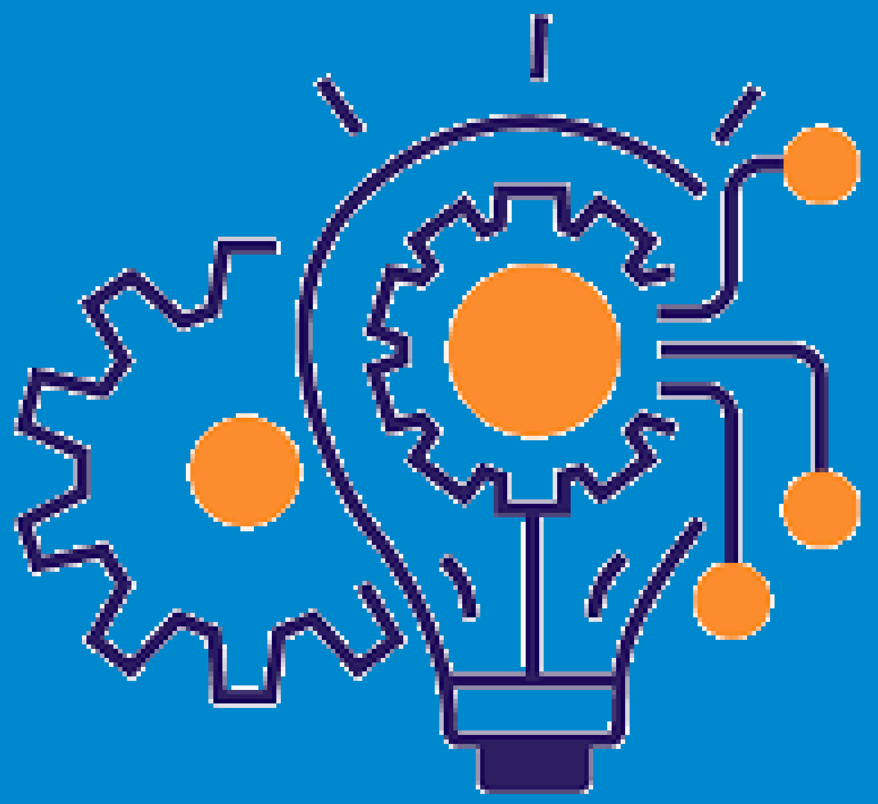
2026

FEEDBACK AND EXTRAPOLATION TO THE NATIONAL TERRITORY

RACCOR-D PERSPECTIVES

3

INNOVATIVE CONTENTS & TECHNOLOGICAL BARRIERS



- ✓ Smartgrid architecture
- ✓ Industrial production of high power isolated DC / DC converters
- ✓ High voltage isolated PV
- ✓ Artificial Intelligence

- ✓ Very few component suppliers
- ✓ Multi-service, multi-actor management

Interne

TARGETED MARKETS

Development of unused railway and other sites

+

Complementarity and Frugality of use of networks

+

Modular and Duplicable on other DC networks

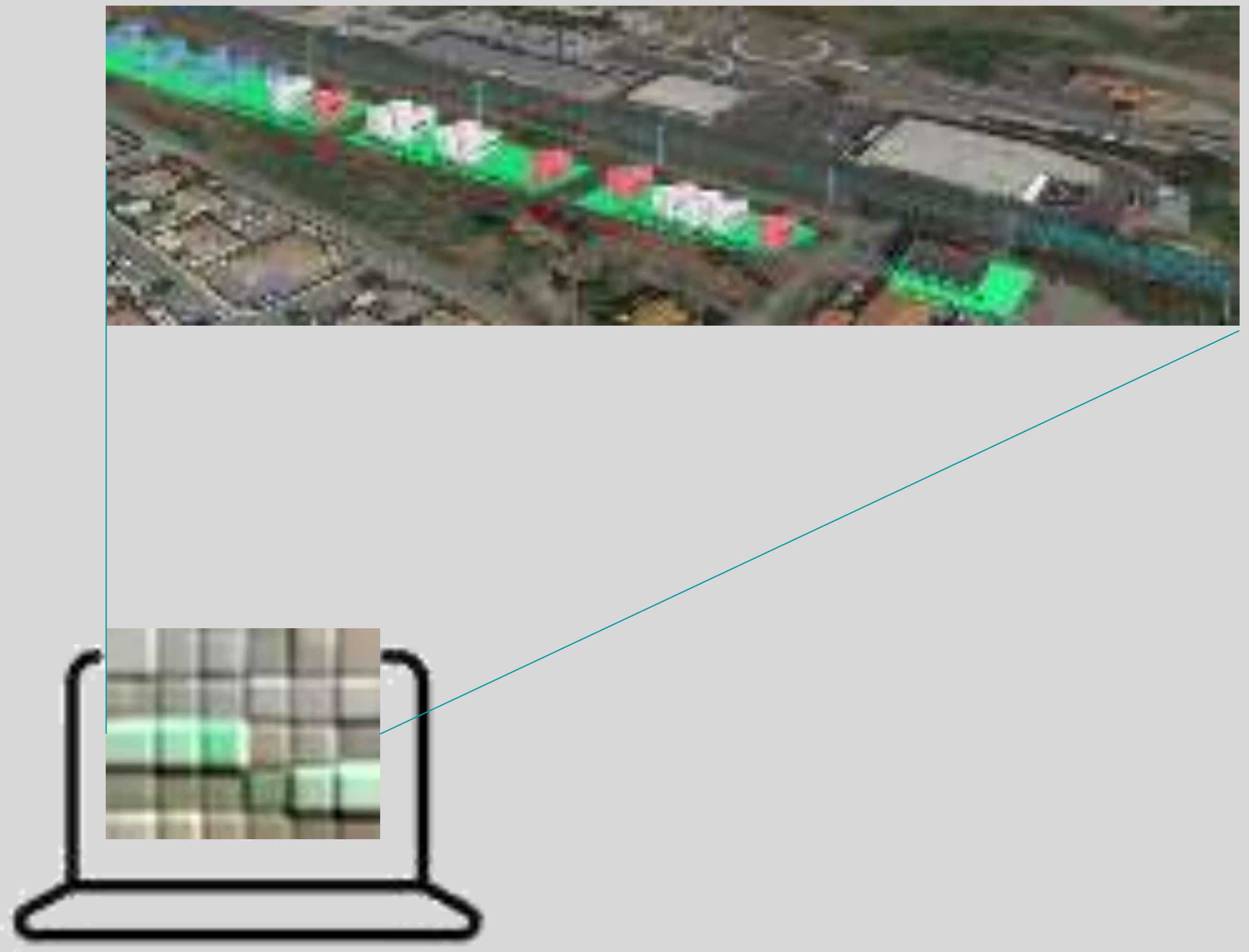
SCIENTIFIC BENEFITS

3 PhDs :

International conferences

publications

Development of a test site for railway innovations



AI

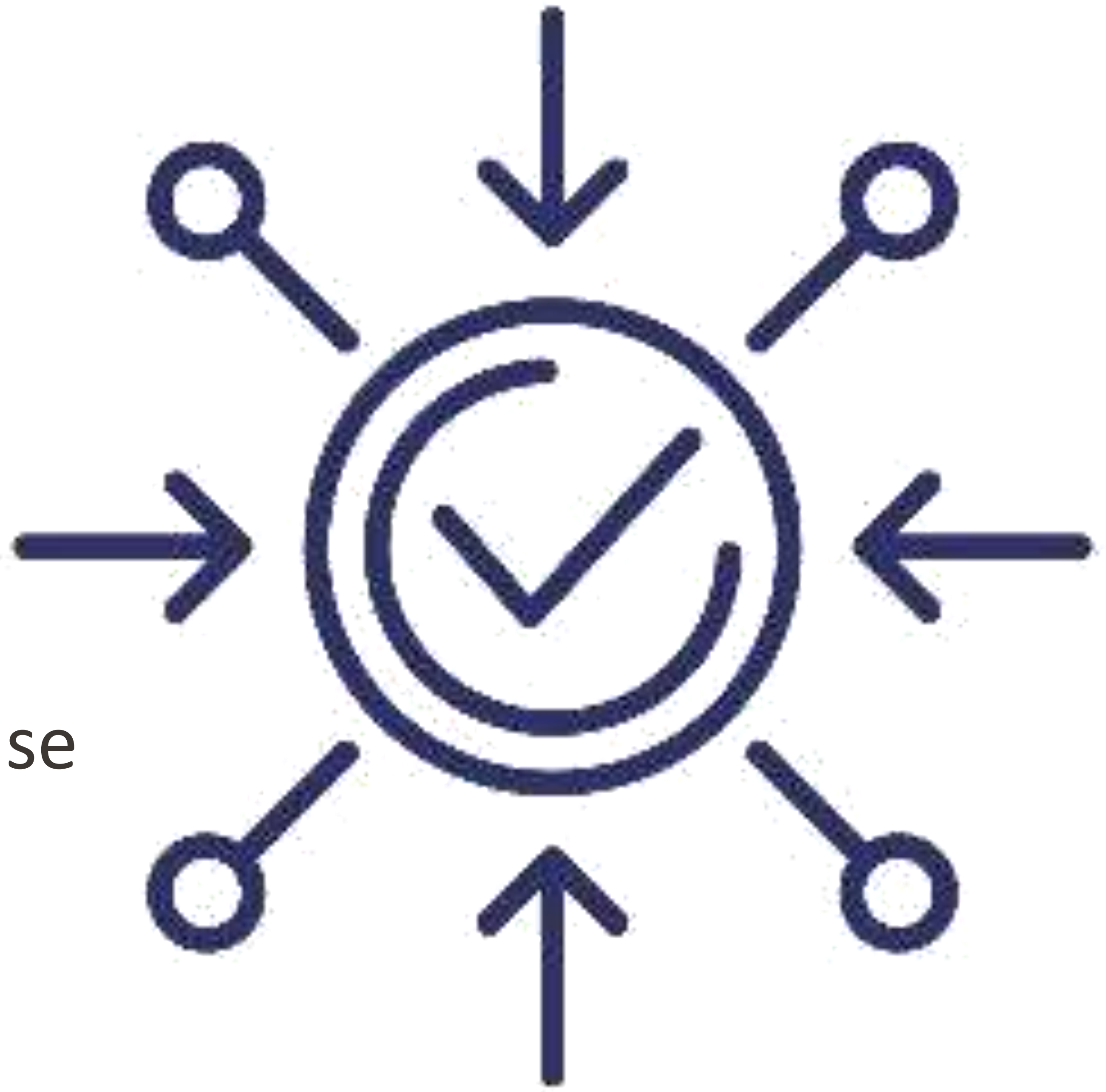
Robust and trustworthy algorithms, smart metering and opening a new field of research

IMPACTS

- **Preparing a French world first:** direct current connection of railways from the Public Transport Network!

- **Promote the integration of renewable energies and meet an emerging need on the electrical system for multiple users** (fast charging of electric vehicles, data centres, H2 electrolysers, etc.)

- To have a **unique experimental site in France** that will contribute to scientific and cultural influence.



- Allow the **DC voltage to rise** (Emergence phase for the LGV Bordeaux-Toulouse or LNPCA projects)

- Enhance further research in the fields of **smartgrids, associated power electronics** and the integration of **artificial intelligence.**

- **First step towards European standards**

Confidentiel | Crédits

–

Interne

VOS CONTACTS

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Questions

Discussion

Thank you for your attention.

Workshop timeline

13h 45	Photovoltaics on stations program	**Jorien Maltha**	**ProRail**
14h 05	Solar panels deployment on stations	**Laurent Mahuteau**	**SNCF Stations**
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15h 35	*Break*		
16h 00	*Technical visit or presentation* *Hyperloop test field*	**TU Delft**	

PRORAIL & TNO

NEWRAIL project

ProRail

TNO innovation for life

Laurent Mahuteau

NEWRAIL

Solar panels on existing noise barriers

Robert Bezemer (TNO),
Gerald Olde Monnikhof (ProRail)

November 17, 2022

An innovation and demonstration project

A cooperation of:

ProRail

TNO innovation for life

De Haagse Hogeschool

Reindonk energie & Co

A demonstration project to develop and test a modular PV system for fixation to existing and newly built noise barriers. Subsidized by ministry of Economic Affairs and Climate.

After the development of a concept, tendering and engineering stage we are now going to build this on existing barriers.


TOPSECTOR ENERGIE
Empowering the new economy

Home Missies Topsector algemeen TKI Wind op Zee TKI Urban Energy TKI Nieuw Gas

Home › Project in beeld › ProRail onderzoekt met partners zonne-energie op geluidsschermen

ProRail onderzoekt met partners zonne-energie op geluidsschermen

Geluidsschermen langs het spoor hebben 1 functie: de geluidshinder voor omwonenden beperken. Maar kunnen ze voor dezelfde omwonenden niet nog iets doen: zonne-energie opwekken? Samen met een breed consortium van partners gaat ProRail dit onderzoeken.

Subsidized by:

Rijksdienst voor Ondernemend Nederland

Content

1. Motivation and location project
2. Concept and development
3. Participation
4. Tendering
5. Engineering & building
6. Monitoring
7. Lessons learned

Motivation

- ProRail has a potential of 20 – 30 GWh/year with solar on existing noise barriers. This is significant in relation to the total energy consumption of ProRail (160 GWh).
- There are also many noise barriers alongside national and provincial roads. Rijkswaterstaat is supporting this project.
- Integration of PV on existing objects is desirable (efficient use of space). In their search for suitable locations to install PV, municipals are asking ProRail if the use of noise barriers is possible (horizontal roof).
- All known recent demonstration projects with PV on noise barriers were aiming on integration on new noise barriers. The innovation is about how to mount these on existing barriers and to make it easy to (dis)assemble.

Location

Originally the project would be realized on new 3 m high noise barriers on both sides of the track in America (village in province Limburg). Participation of the inhabitants was part of the project. Due to local resistance the project moved to Dronten.

The project is now being engineered and will be built begin 2023 at existing noise barriers near the Drontermeertunnel. The generated electricity will feed the tunnel.

Concept & development: Variants

Panel 1m x 1,65m / 1m x 2m
Landscape / Portrait

Angle 60° / 75°
North / South

edit: 17-9-2020

Concept & development: Criteria & solutions

Yield: optimum angle, maximum area → 60° / 75° give about equal yield

View: panels above the noise barrier → Higher ‘wall‘ → No problem relative to barrier

Safety: ability to walk under the panels (inside of barrier) → Inside: one row, angle 75°

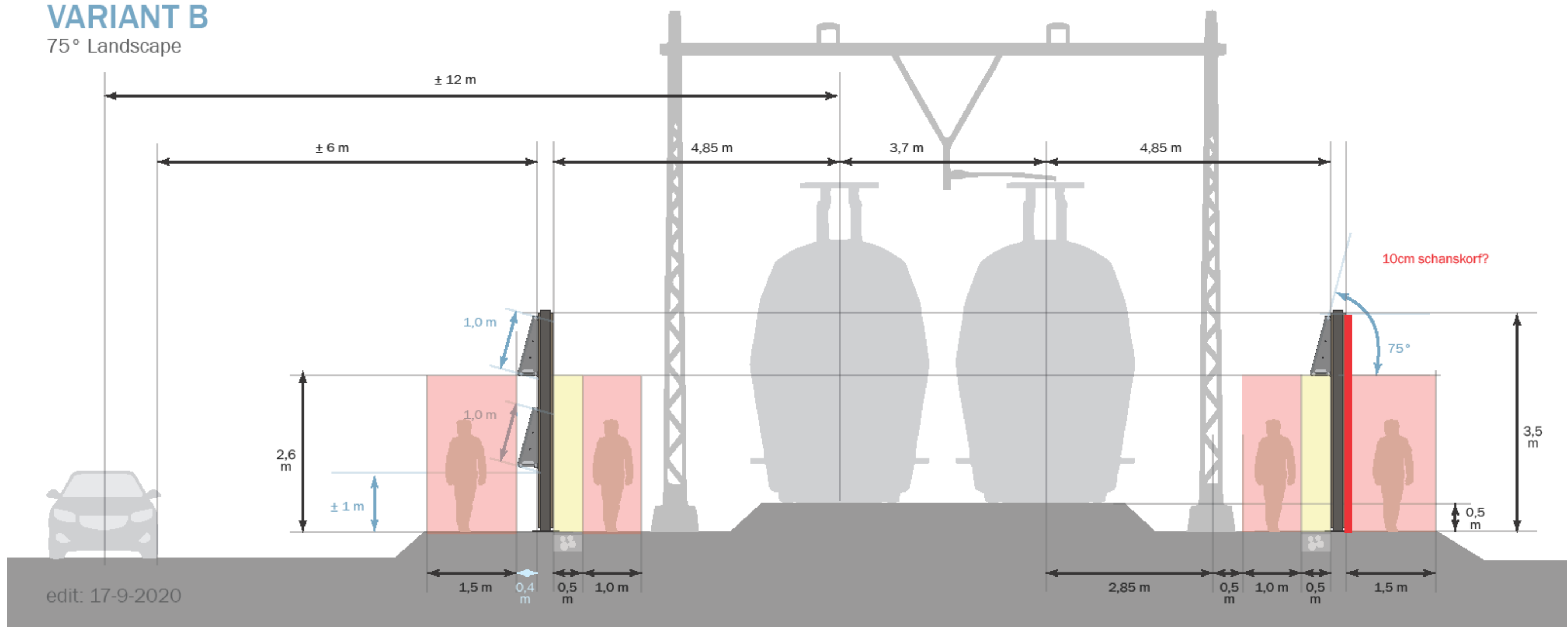
Safety: no hindrance from sun reflections on panels → No problem for east-west railway

Robustness: wind force and train shockwave resistant → Some room between panels

Environment: primary function (noise barrier) remains intact → Noise is ‘reflected away‘

Environment: not attractive for vandalism

⇨ south wall, outside: 2 rows landscape, 75°
or with 1,65m panels: 1 landscape, 1 portrait, 75°
north wall, inside: 1 row landscape, 75°



Concept & development: Construction

TNO engineered the concept and did the calculations (wind sheer, construction, light reflection, sound).

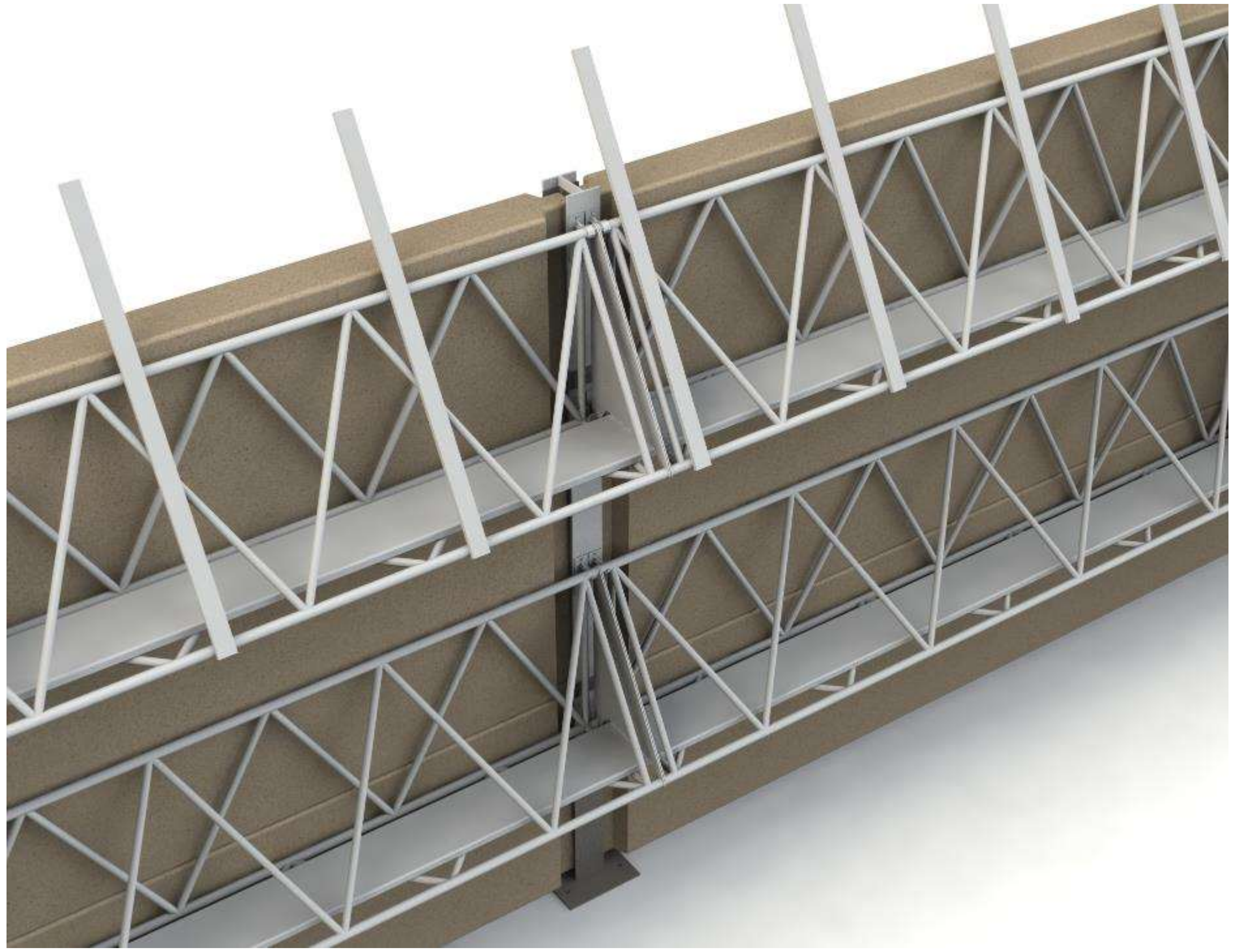
New noise barrier:

H-profile can be prepared on which to attach the solar panel frame

Existing noise barrier:

A clamp can be applied to the H-profile on which to attach the solar panel frame.

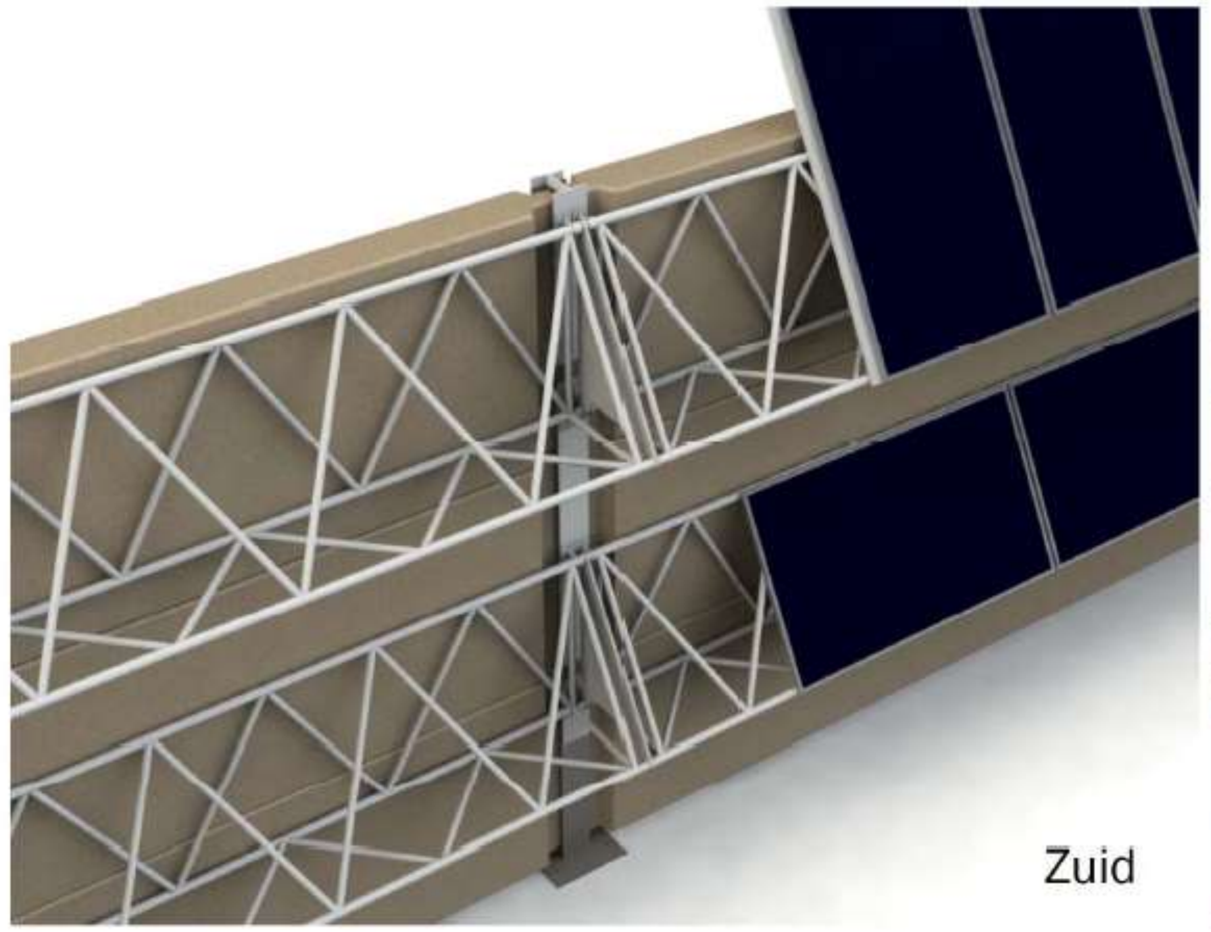
Concept & development: Construction

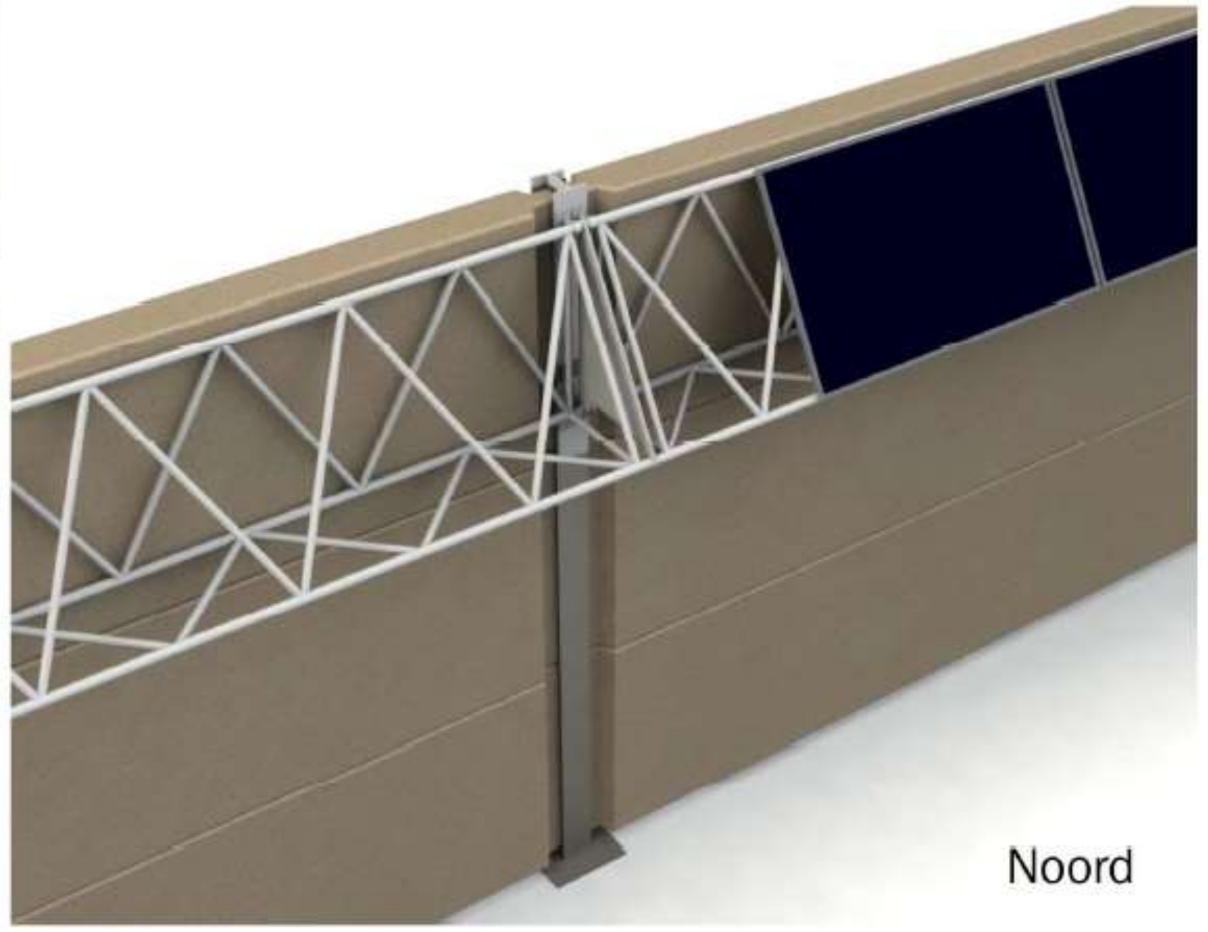


3D space frame
with cable tray
and panel fixation frame

south wall, outside

north wall, inside





Concept & development: Construction requirements

Robustness: wind force and train shockwave (<160 km/h) resistant

→ wind force is normative

→ prevent air inlet at the ends; aperture between panels 10 – 25 mm

Robustness: resistant to vibrations (wind, train)

Strength: barrier should be able to carry the weight of the panels

Deformation: appears due to temperature variation; should be accomodated

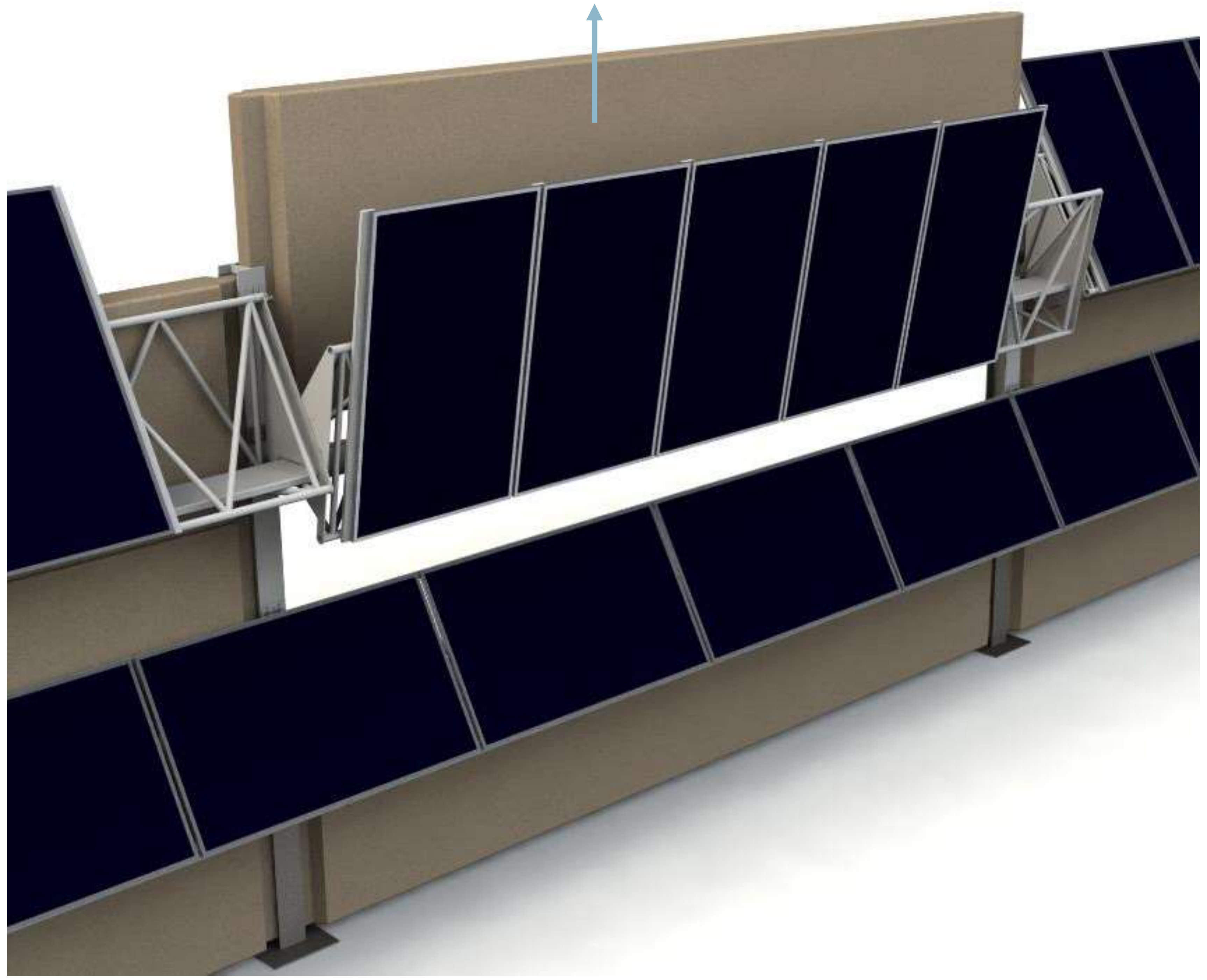
Possibility to approach/replace solar panels and cables from outside

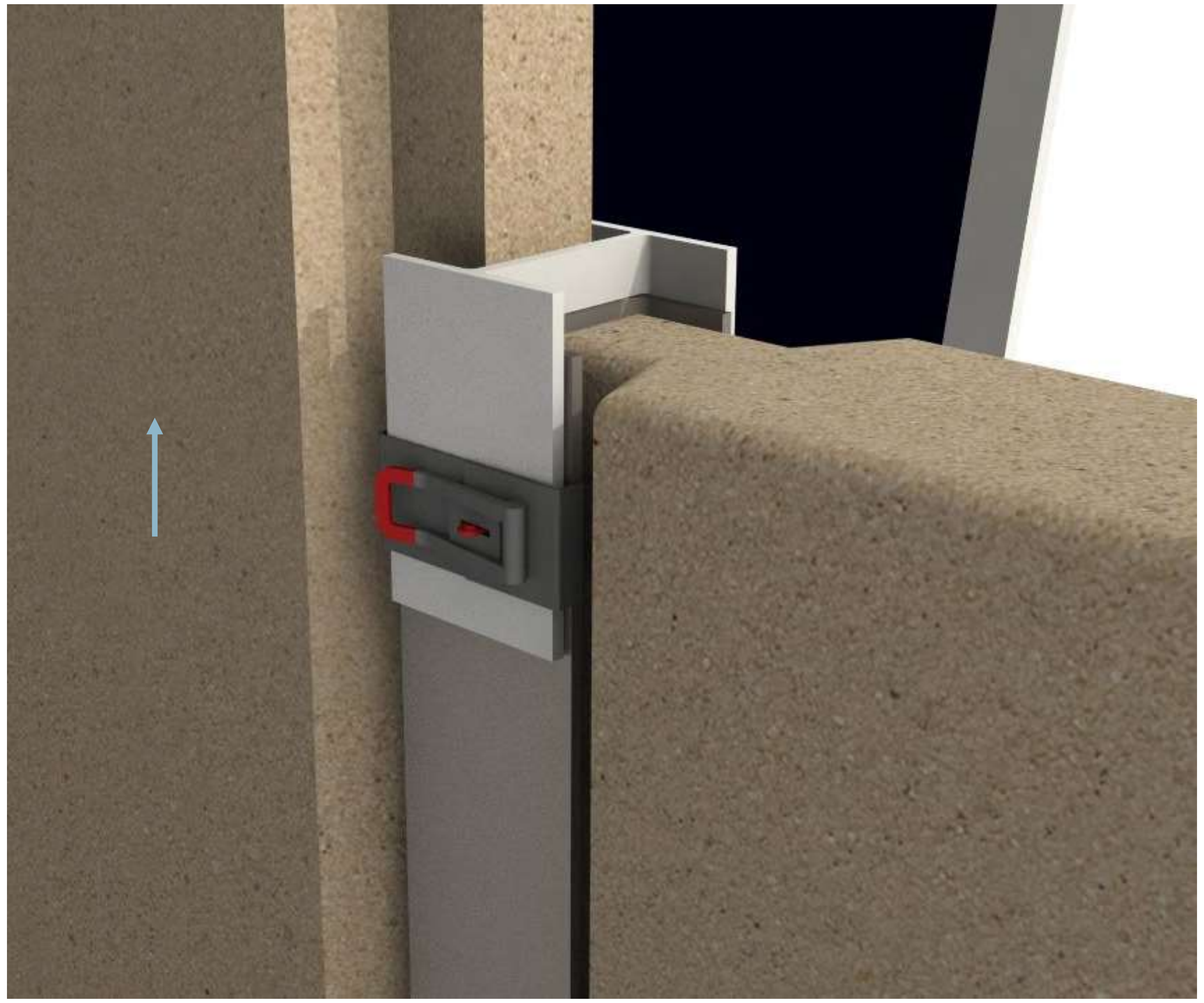
Installation should be done with no/minimal disturbance to train service

Before tender stage: full requirements list has >200 lines about performance, product & materials, product & system, realisation, use, environment, safety, maintenance, monitoring

Concept & development: Maintenance

Possibility to ‘click away‘ the frame, remove a barrier module and approach cables and solar panels for maintenance or replacement.





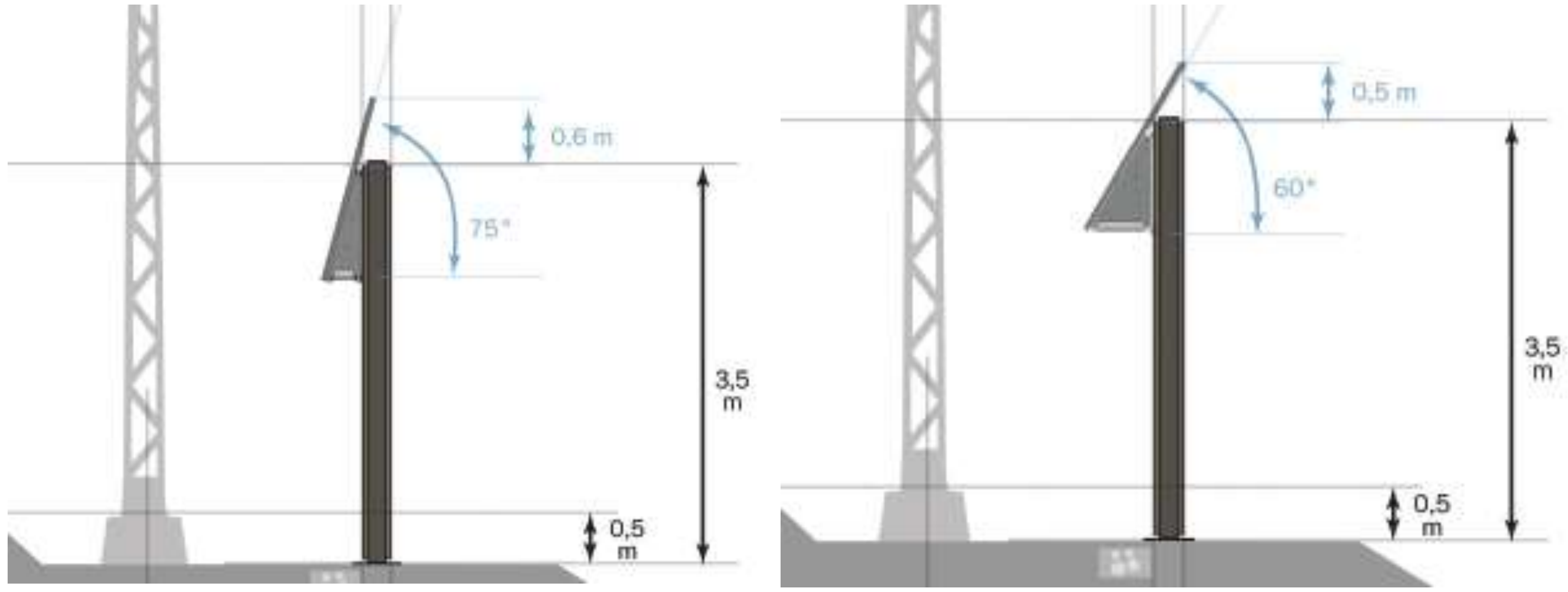
Participation (1)

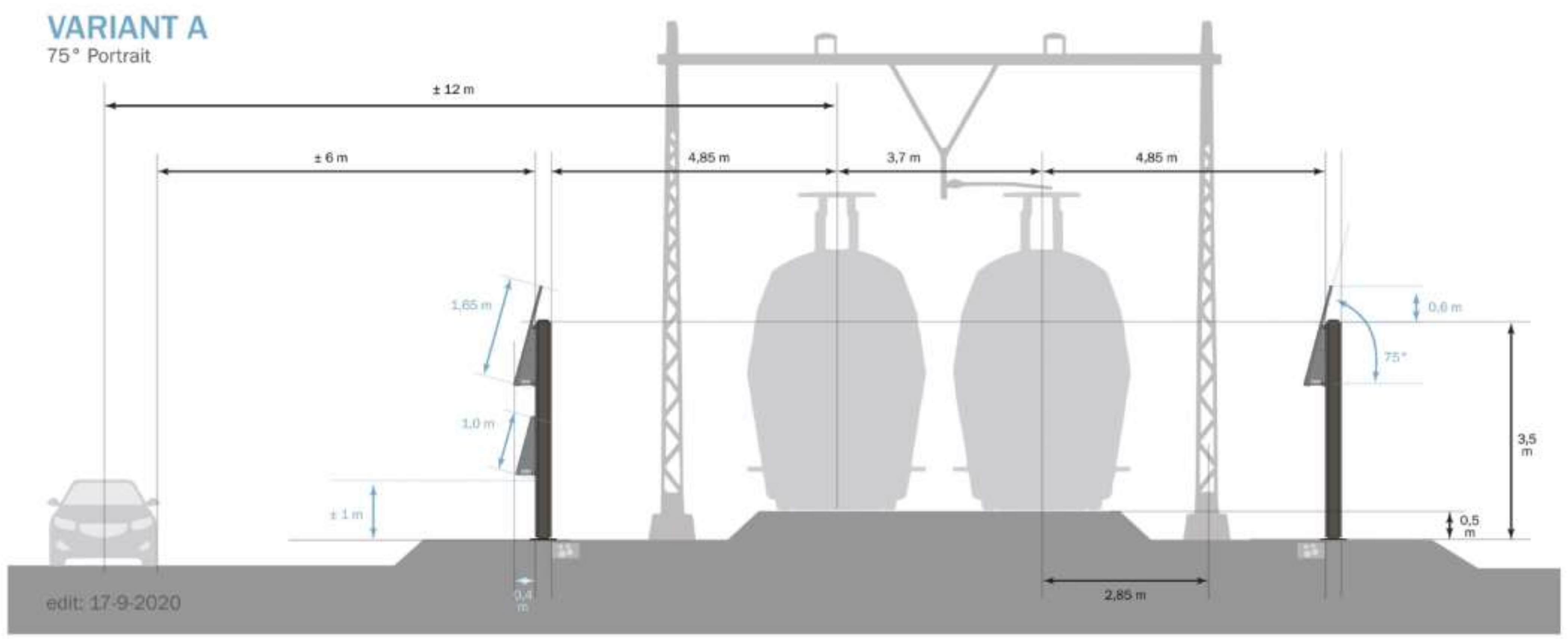
Originally the project was intended to be realized on new 3 m high noise barriers on both sides of the track in America (village in province Limburg).

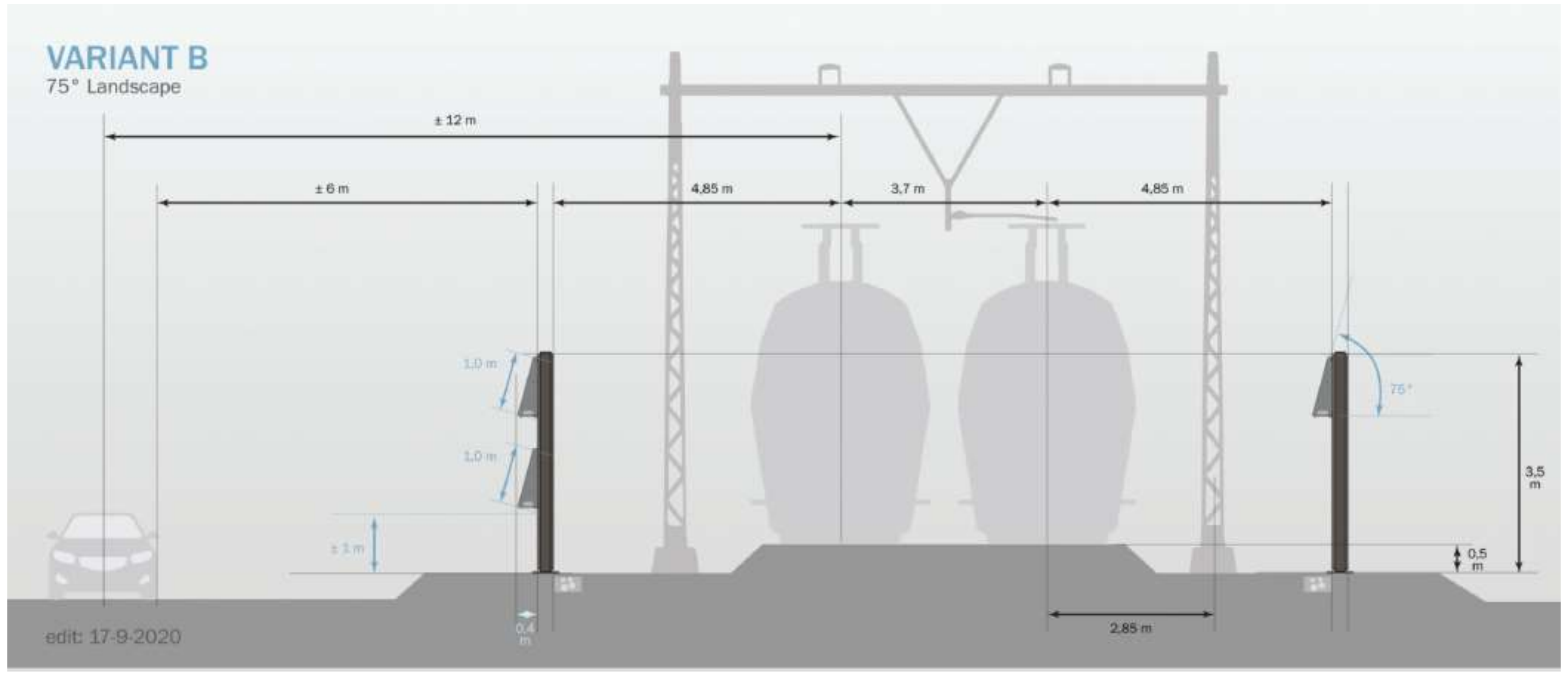
Reindonk Energie & Co. (Energy Cooperation) would exploit the installation for its members in America.

The project aimed to investigate which configuration would be the best. Several options were considered:

- Solar pane size
- 75° or 60°
- Landscape (not above barrier) or portrait (0,5 m above barrier)
- Two rows above each other or not







Participation (2)

Results of the participation process in America:

- An open planning process is essential for successful participation.
- Application of solar panels on the noise barriers on both sides of the track is not enough reason to compensate for the loss of view and the severe impact of high noise barriers. People prefer low barriers in combination with additional measures if this is sufficient. Only if high barriers are necessary, there is added value in applying solar panels.
- At the meeting in the village hall there was:
  - a slight preference for portrait (no impact on the view of the noise barrier);
  - no preference for 75° or 60°.
- There was a modest interest in participation in the energy cooperation.

The resistance at the foreseen 3 m high barriers in America resulted in a new design of the barriers, with 1,5 m high barriers at the south side of the track. This meant that NEWRAIL could not be built in America.

Tendering

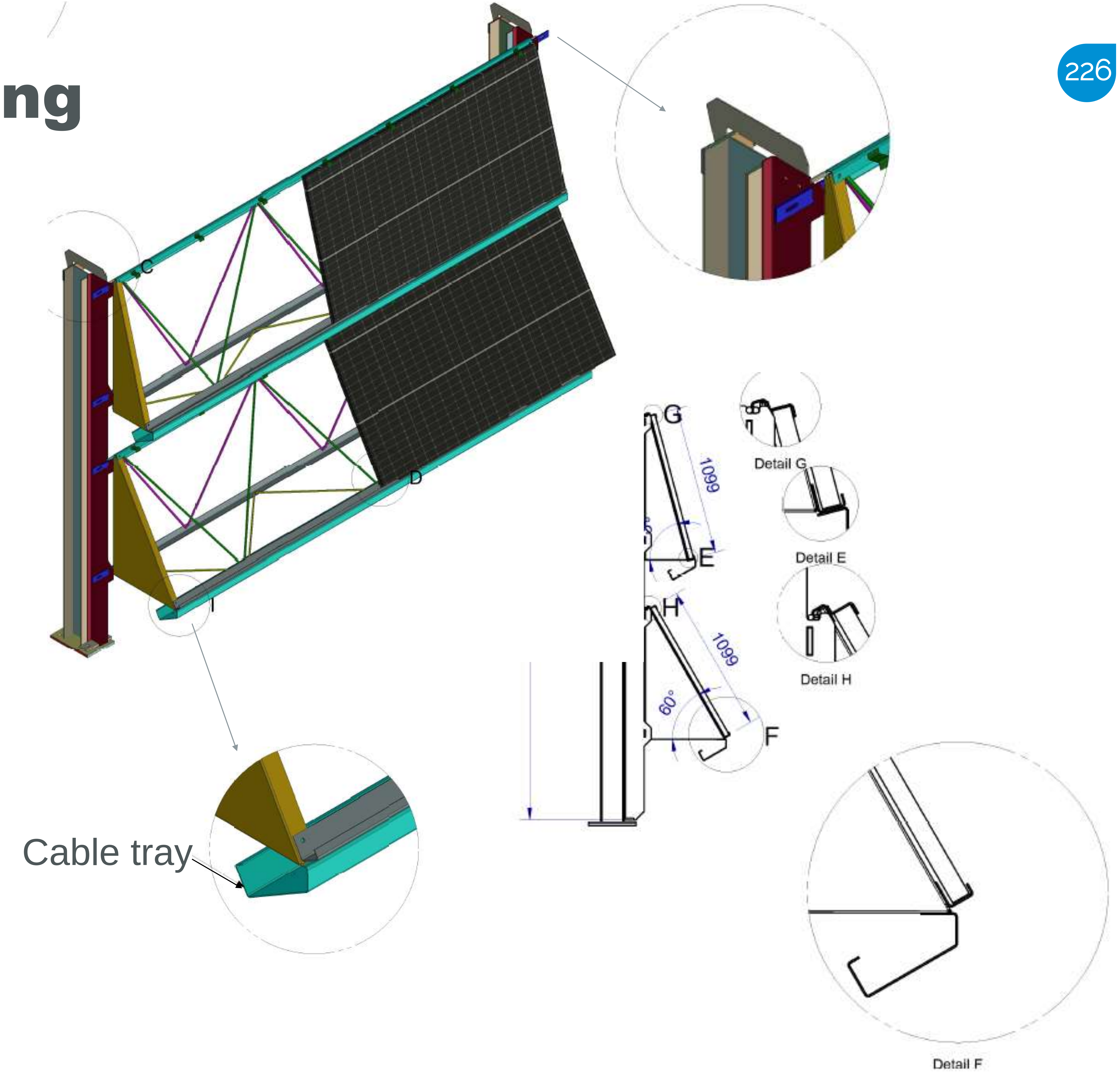
- Design, construction and maintenance contract;
- Based on concept developed by TNO;
- 75 m inside of noise barrier (single row PV-panels);
- 445 m outside noise barrier (double row PV-panels; 3 different settings);
- In total 200 kWp panels; 150 kWp inverters.
- Delivery was planned in July 2022.

Legend:
S1: Segment rail side; 1 row 75 m; 75°
B1: Segment non-rail side; 2 rows 65 m. Upper row 75°, lower 60°.
B2: Segment non-rail side; 2 rows 190 m. Upper and lower row 60°.
B3: Segment non-rail side; 190 m. Upper and lower row 75°
ASP: AC cable towards tunnel

Engineering & building

Sunprojects won the contract.
Some findings:

- Bid was more expensive than ProRail expected.
- Sunprojects proposed some optimalisations to the original design of TNO. The design is modular and easy to assemble and disassemble.
- Meeting all requirements for a company that's not used to work in a rail environment proved to be hard, which resulted in a considerable delay.



Test prototype by Sunprojects

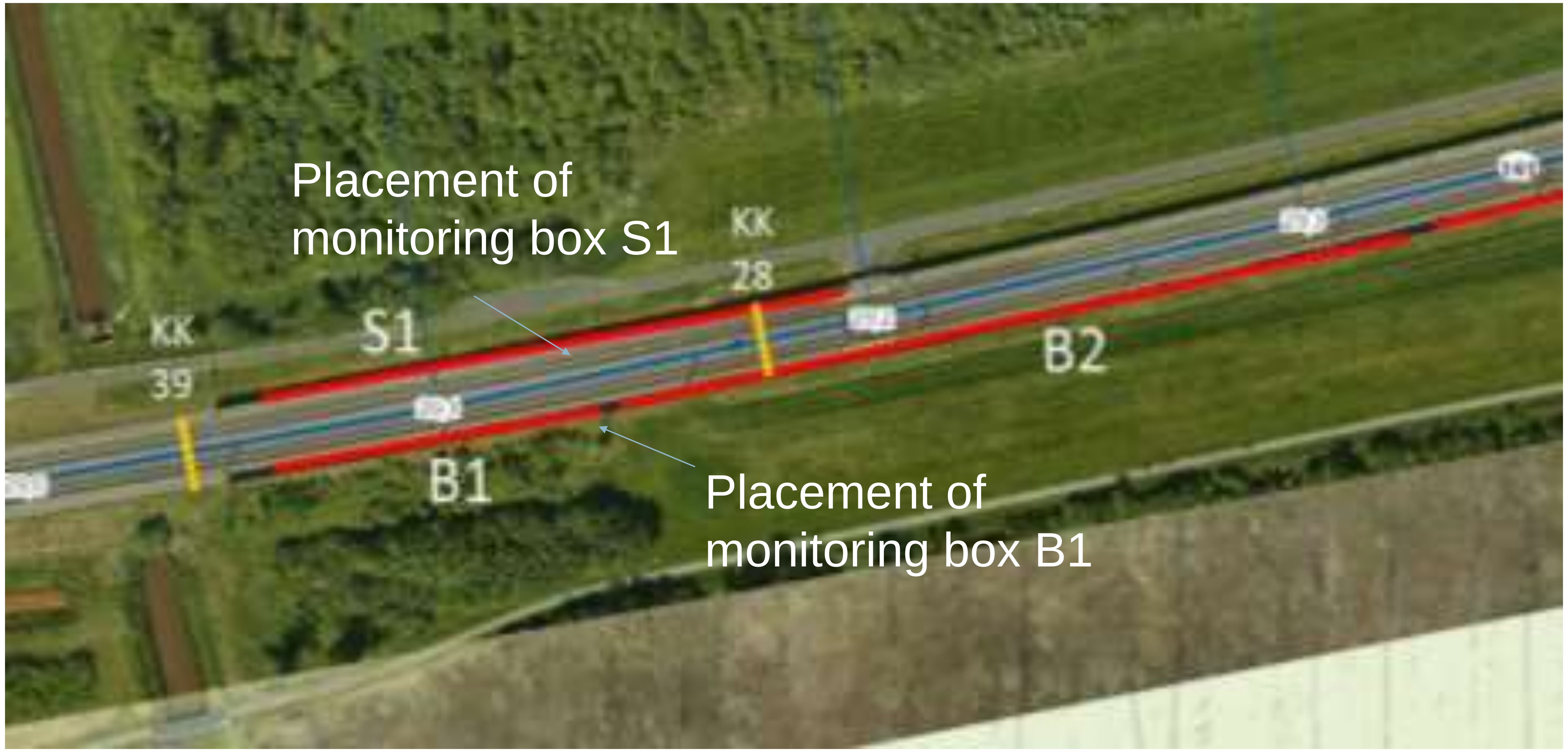
Monitoring (1)

Monitoring in 2023 and 2024:

- Instantaneous and cumulative energy yield of solar panels
  (sampling rate 1 Hz = determined by train length & speed → shadow)
- Effect of passing trains on yield, electrical interference, physical damage
- Micro cracks (due to vibrations) through electroluminescence photos
- Impact of PV-panels at the inside of the barrier on noise reduction (modelling)
- Visual effect of different mountings and perception of the public
- Confirmation that reflection of solar panels do not hinder the train drivers
- Measuring the impact of the panels at the inside of the barrier at the way it’s transferring noise (the model suggests no significant effect).

Monitoring (2)

Monitoring boxes for voltage, power and irradiance, north and south strings



Which lessons we've already learned

- It's expensive compared to solar parks and solar on roof ➔ we need to find out if a positive business case is possible if it's being procured at a larger scale and at current energy prices.
- A lightweight spaceframe can be mounted on a noise barrier, offering a very simple and modular system.
- The weight of the panels and spaceframes are not a problem for the construction of the barriers. Wind pressure is the limiting factor. This must be taken into consideration.
- Wind shear of passing trains at this location is not problem (not a high speed line), compared to the high potential natural wind pressure.
- There is not a standard to calculate the construction, since it is not a normal building.
- Designing and working in a rail environment is a challenge for companies in solar business, since most of these companies are not familiar with the regulations and culture of rail infra managers.
- Participation of neighbours in the solar installation does not increase the acceptance of (high) noise barriers.

NEWRAIL

Thank you for your attention

Questions?

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Break

until Technical visit / presentation

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INTERNATIONAL UNION OF RAILWAYS

TU DELFT

Hyperloop tests

DELFT HYPERLOOP

TU Delft

DELFT HYPERLOOP

DELFT
HYPERLOOP

INTRODUCTION

Maaike Krap
Public Relations Manager

Teije Nolen
Partnership Manager

Oscar van Baar
Lead Business

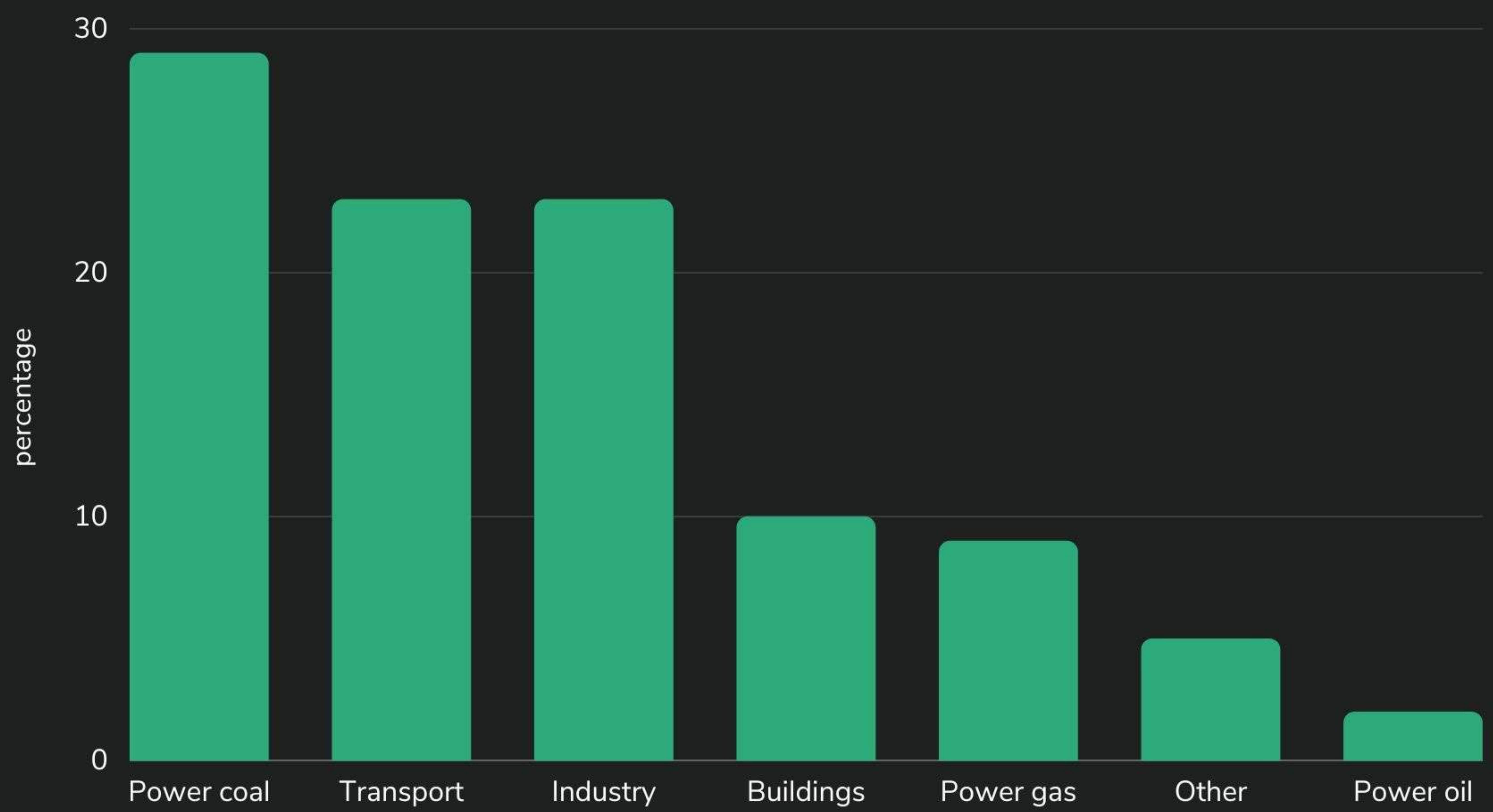
DELFT HYPERLOOP

WHY HYPERLOOP?

DELFT HYPERLOOP

CLIMATE CHANGE

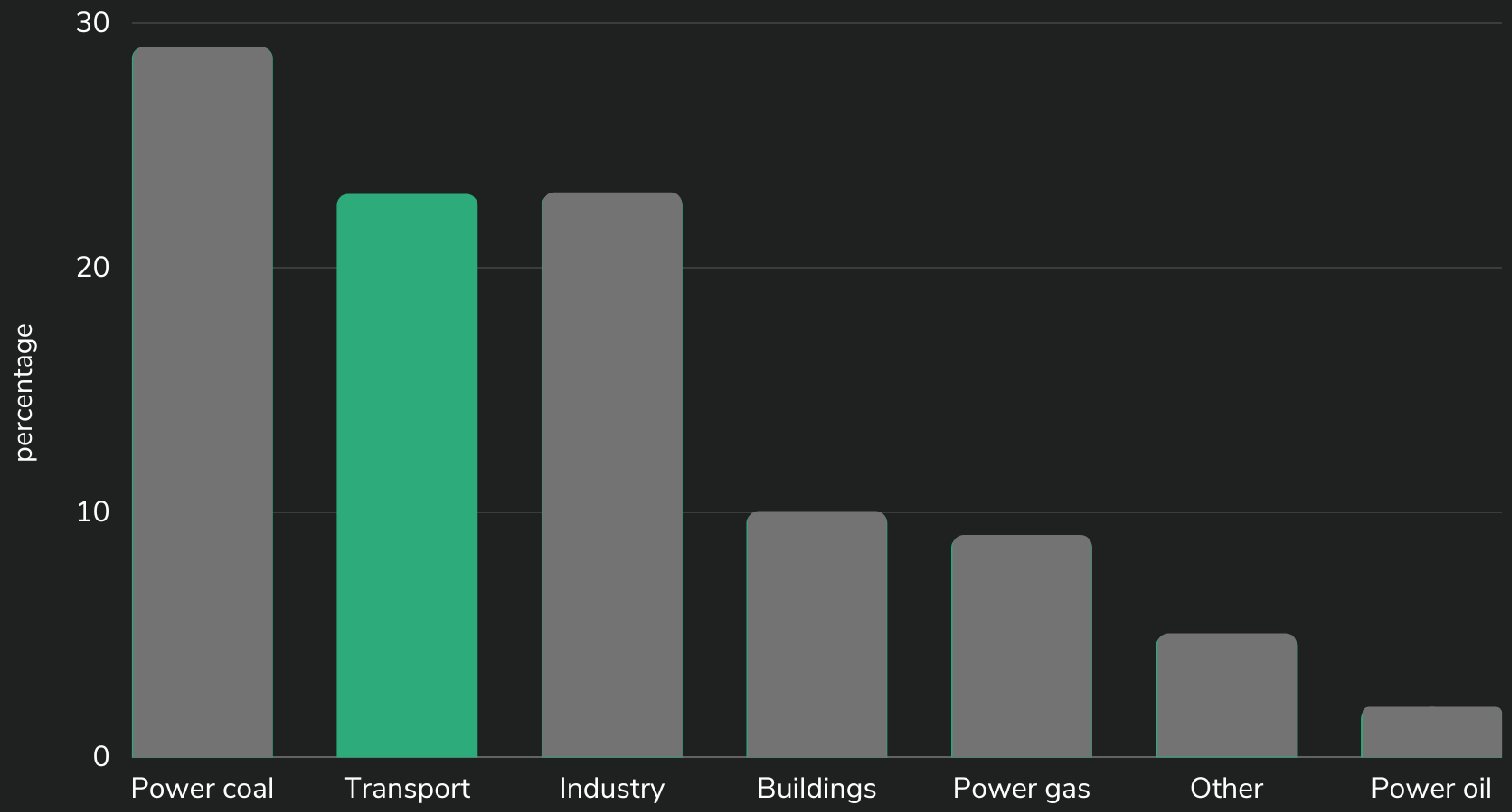
CO2 EMISSION PER SECTOR 2020



Bron: *Global energy-related CO2 emissions by sector - Charts - Data & Statistics*. IEA

DELFT HYPERLOOP

CO2 EMISSION PER SECTOR 2020



Bron: *Global energy-related CO2 emissions by sector - Charts - Data & Statistics*. IEA

CURRENT TRANSPORT SECTOR

1950 – 2:13

2022 – 2:14

DELFT
HYPERLOOP

AIR RESISTANCE

ROLLING RESISTANCE


TIME FOR INNOVATION


Magnetic Levitation
Magnetic Propulsion
Near vacuum environment

Speed
kilometers / hour
Energy use
Wh / kilometer / passenger
50
Boat
250
130
Car
450
250
HS train
116
850
Airplane
515

Speed
kilometers / hour
Energy use
Wh / kilometer / passenger
50
Boat
250
130
Car
450
250
HS train
116
850
Airplane
515
1000
Hyperloop
40


0
km/h
AMSTERDAM
PARIS
0
min

DH01- DH06

DH05: founders EHW

DH01: winner Space X competition

DH04: speedrecord attempt 360 km/h

DH06
- First step levitating: Vertical levitation
- Hanging pod

DELFT HYPERLOOP


DELFT
HYPERLOOP
HELIOS I

DH01- DH07

DH05: founders EHW

DH07

DH01: winner Space X competition

DH04: record speed attempt 360 km/h

DH06
- First step levitating: Vertical levitation
- Hanging pod

DELFT HYPERLOOP VII

MISSION OF DELFT HYPERLOOP

”Our mission is to catalyze the implementation of the hyperloop system by demomstrating its full-scale potential”

DELFT HYPERLOOP


EHW
EUROPEAN
HYPERLOOP
WEEK

DELFT
HYPERLOOP

Questions

Discussion

Thank you for your attention.

Tour de table

Questions

Discussion

Wrap up

Thank you for your attention.

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Medias to be made available on the event page
https://uic.org/events/energy-and-co2-renewable-energy-integration-in-railways-workshop-and-sector-meeting

Thank you for your attention.