Rail Decarbonisation

Mott MacDonald's digital offering for rail decarbonisation planning
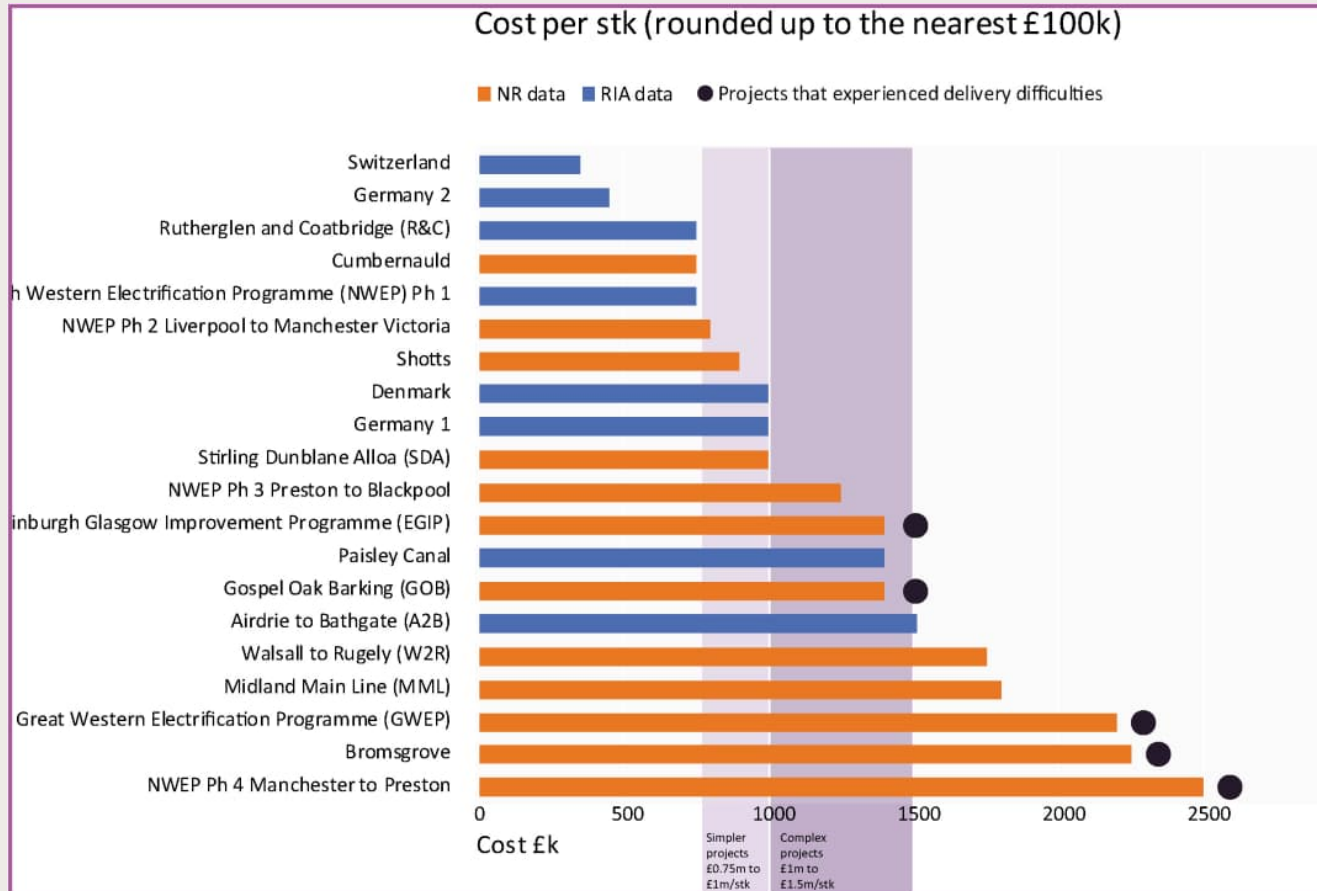
18 May 2023

The challenge of rail decarbonisation

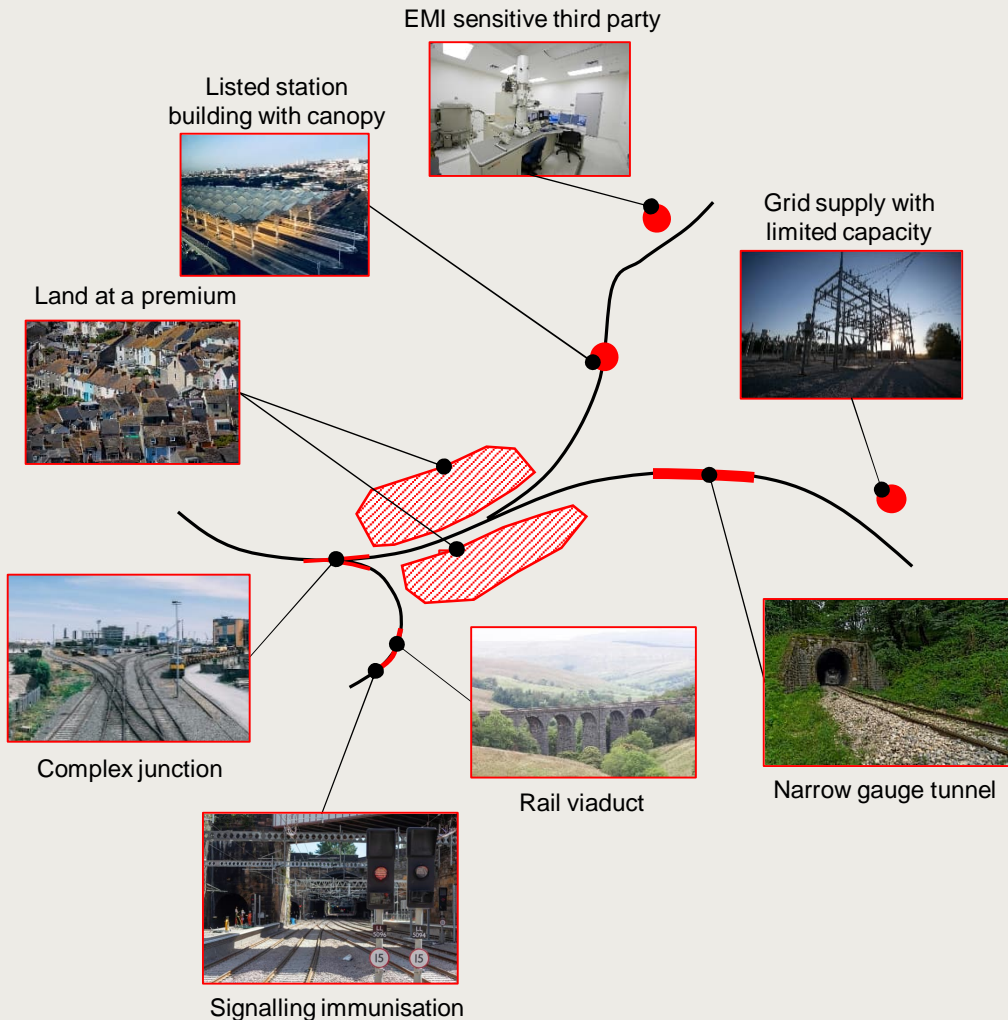Commercial in Confidence

CP5 return of experience

Cost of electrification per single track kilometre (stk) varies by a factor of 3

Cost per stk (rounded up to the nearest £100k)

■ NR data   ■ RIA data   ● Projects that experienced delivery difficulties

Switzerland
Germany 2
Rutherglen and Coatbridge (R&C)
Cumbernauld
h Western Electrification Programme (NWEP) Ph 1
NWEP Ph 2 Liverpool to Manchester Victoria
Shotts
Denmark
Germany 1
Stirling Dunblane Alloa (SDA)
NWEP Ph 3 Preston to Blackpool
inburgh Glasgow Improvement Programme (EGIP)
Paisley Canal
Gospel Oak Barking (GOB)
Airdrie to Bathgate (A2B)
Walsall to Rugely (W2R)
Midland Main Line (MML)
Great Western Electrification Programme (GWEP)
Bromsgrove
NWEP Ph 4 Manchester to Preston

0   500   1000   1500   2000   2500

Cost £k

Simpler projects £0.75m to £1m/stk

Complex projects £1m to £1.5m/stk

Source: RIA, 2019

Do those costs cover more than just electrification?

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What increases electrification costs per single track kilometre?

EMI sensitive third party

Listed station building with canopy

Land at a premium

Grid supply with limited capacity

Complex junction

Signalling immunisation

Rail viaduct

Narrow gauge tunnel

1. **Overhead contact & civils clearance issues**
   a) Narrow gauge tunnels and overbridges
   b) Underbridges and viaducts
   c) Retaining walls
   d) Ground conditions
   e) Complex junctions
   f) Heritage assets / aesthetics, historic canopies extending beyond platform edges

2. **Power availability**
   a) Connection to grid

3. **Compliance with existing systems**
   a) Electromagnetic interference (EMI) sensitive third parties
   b) Signalling immunisation requiring in some cases new signalling and/or re-railing

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New kids on the block

Full electrification no longer a must to reduce emissions

Source: Nelso Silva

Class 756
Stadler FLIRT
Tri-mode (AC, batteries, diesel)

Source: Alstom

DART+ BEMU
Alstom X'trapolis
Bi-mode (DC, batteries)

Source: Merseytravel

Class 777 IPEMU
Stadler METRO
Bi-mode (DC, batteries)

Source: Alstom

iLint
Alstom Coradia
Hydrogen and battery hybrid

How to lower electrification costs?

A few pointers…

Discontinuous electrification:

- Catenary free sections

  - Typically several km in length
  - Wired to unwired
  - Pantograph is lowered
  - Use onboard source of energy
  - Beacon / balise controlled

- Permanently earthed sections

  - Typically up to several 100m in length
  - Wired (OCS is earthed at both end of PES)
  - Pantograph is raised
  - Vehicle CB is open
  - Use onboard energy storage
  - Beacon / balise controlled

Voltage controlled clearances (VCC):
- Surge arrestors
- Insulation coating technology

Parapets:
- May be retained as is (no need to raise height)
- Social / economic assessment

"Smart" power supply:
- Static frequency converters (SFC)
  - Allow connections at lower voltages
  - Eliminate power quality issues
  - Faster connections

- Wayside energy storage
  - Trickle charging (no need to upgrade bulk supply point)
  - Quicker battery charging (e.g. DART+)

The problem decision makers are facing

Existing / new / emerging electrification solutions

Existing / new / emerging rolling stock technologies

Department for Transport

Changes in government
Changes in strategies
Changes in policies (inc. taxes, subsidies)
Changes in funding (priority / availability)

Fluid dialogue

Risk management

Great British Railways
TRANSITION TEAM

Economic (NPV)

Optimum rail decarbonisation business case?

Environment (whole life carbon)

Social (journey time)

Ridership and societal changes

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Traditional approach to decision making

Approach:

- Appoint large multi-disciplinary engineering team

- Arbitrarily select 2 to 4 options

- Review each option over the course of several months

Potential issues:

Discipline bias	No true multi-criteria optimisation	Time consuming	Lack of sensitivity analysis	Has the optimum option been missed?

Digital automation & system view

Decarbonisation ecosystem

Mott MacDonald's domain knowledge

Traction power:
- Static frequency converters
- Wayside energy storage
- Energy forecasting

Rolling stock:
- Bi-mode, tri-mode vehicles
- Hydrogen vehicles

Transport planning:
- Journey time optimisation
- Timetabling (RailSys®)

Environmental:
- Carbon assessment
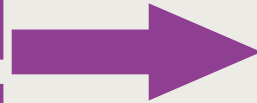
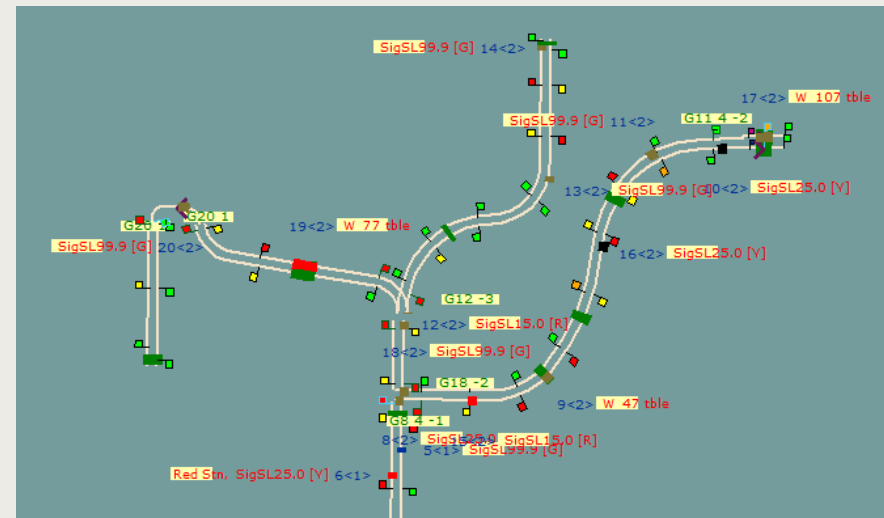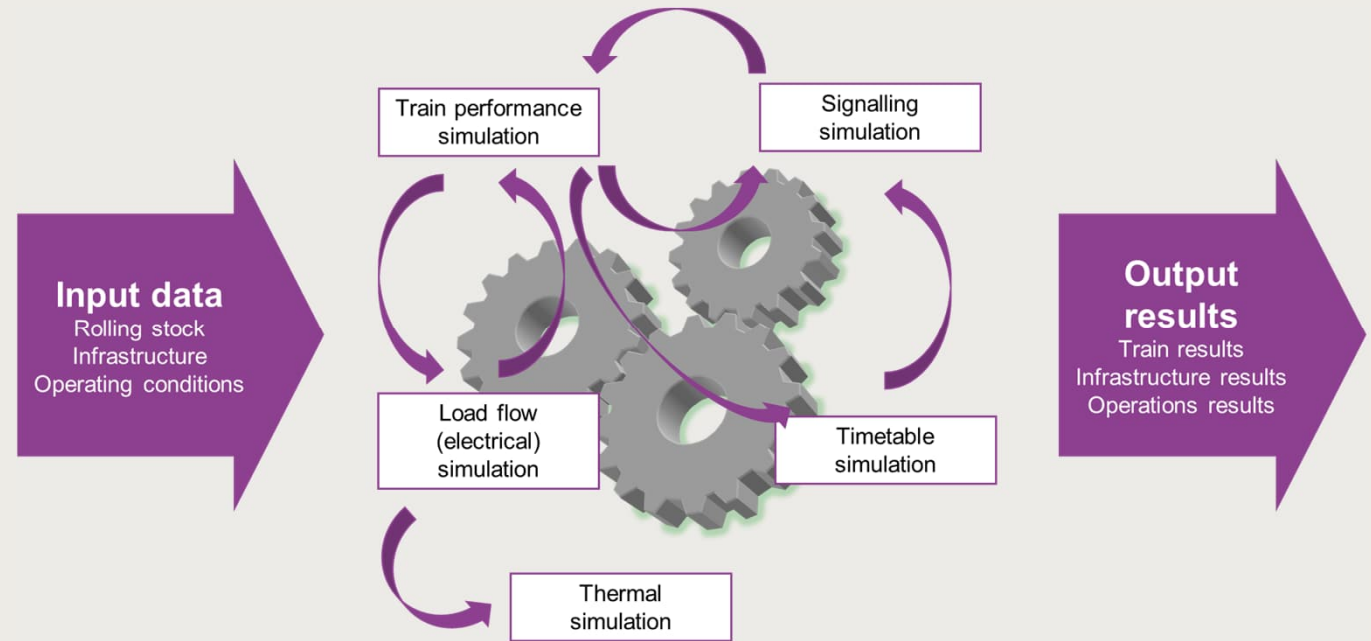**Mott MacDonald's digital toolset**

TRAIN
Multi-train power modelling

Bridg-E
Automated OCS clearance

RAIL DECARB

Osiris
Journey time improvements

QTP
Rolling stock performance

Carbon Portal
Carbon data

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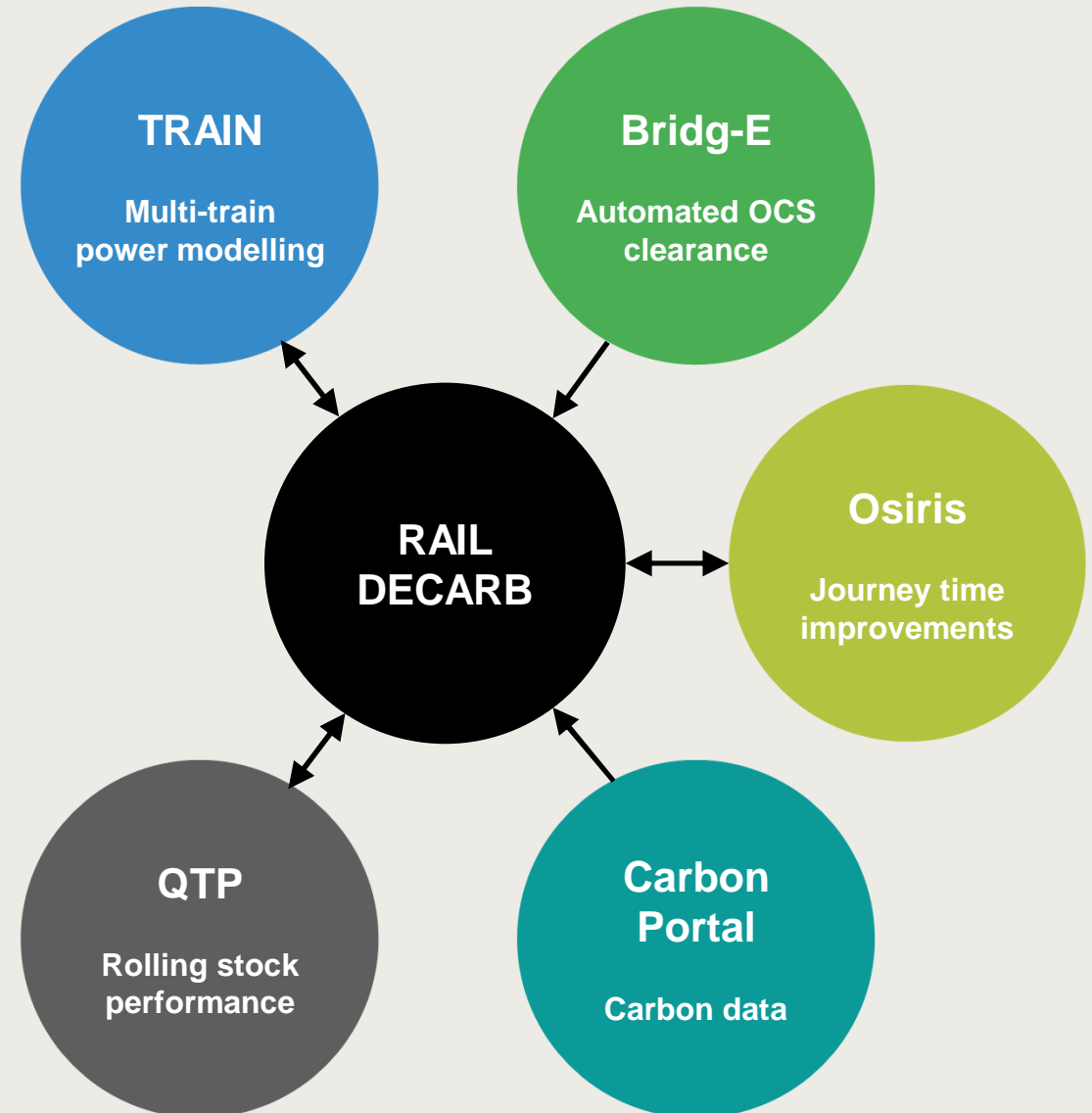
TRAIN +MCE

Rail systems performance simulation

- **Rail system simulator** – multi-train traction power model

- **Diverse applications** – power modelling (inc. SFC), energy forecasting, operational modelling

- **Various vehicle propulsion** – electric, diesel, on-board energy storage

- **Multi-asset model** – traction power, rolling stock, signalling, track etc…

- **Multi-physic simulator** – mechanical, electrical (AC & DC), traffic control, thermal etc…

- **Electromagnetic effects** – multi-conductor transmission line and induced voltage modelling

- **Fully validated against BS EN 50641:2020**

Input data
Rolling stock
Infrastructure
Operating conditions

Train performance simulation

Signalling simulation

Load flow (electrical) simulation

Timetable simulation

Thermal simulation

Output results
Train results
Infrastructure results
Operations results

Bridg-E

Automated bridge clearance assessment tool

- **Automation** – Accelerates a currently manual and time-consuming task

- **Aids project appraisal** – Early cost certainty

- **High-accuracy** – Detailed and consistent asset-by-asset assessment

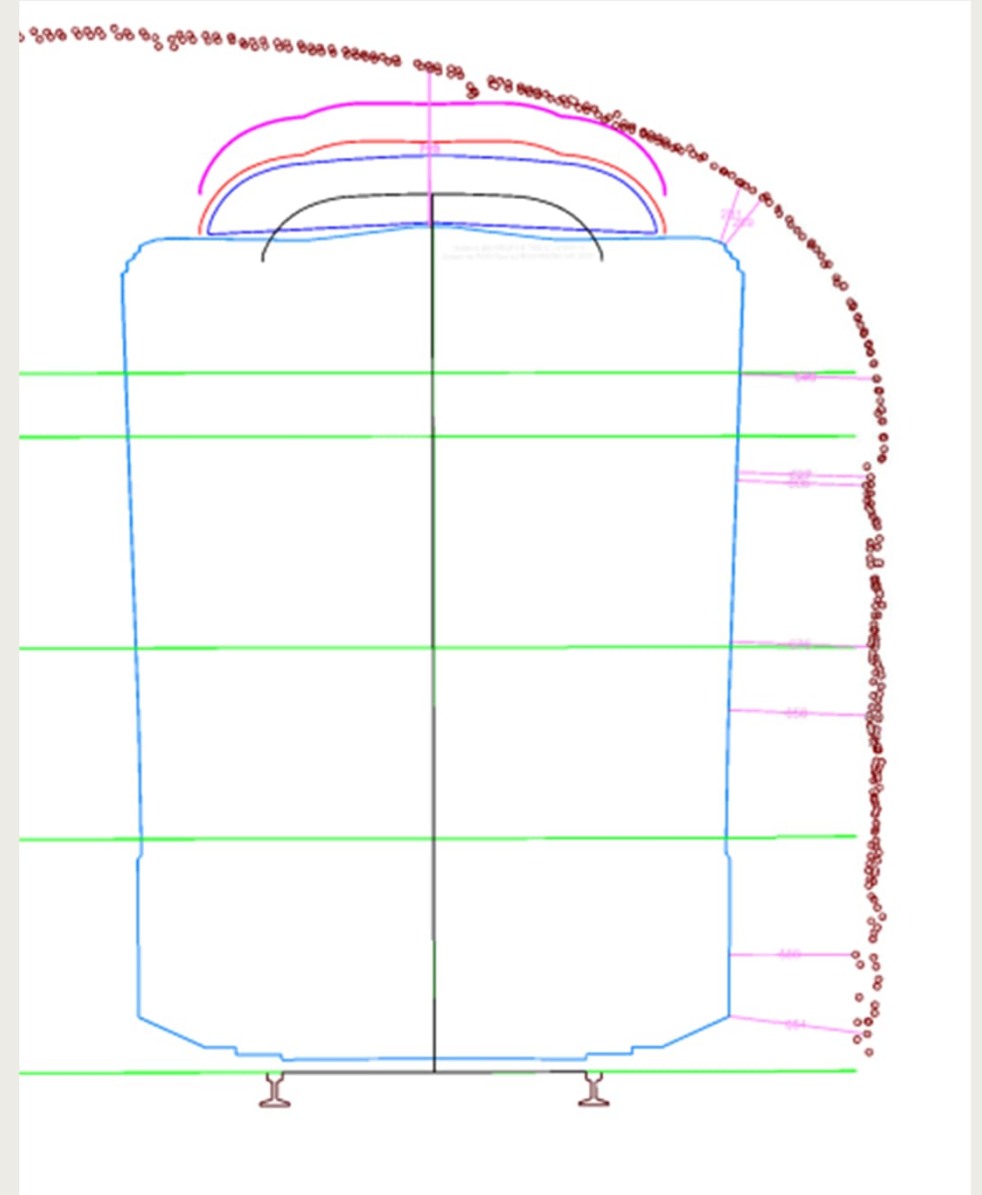## 95+%
Design efficiency
90 days to 90 seconds

3,500
hours saved on NPR

£240k
saved in design fees on NPR

£30m
CAPEX saving - Fife electrification

Osiris

Speed constraints modelling tool

- **"What-if?"** – testing of infrastructure enhancements against journey time improvements and rolling stock options

- **Distance-speed graph** – overlaid with real train performance curves to aid decision making

- **Real data** – uses track recording train data and other existing NR information

- **Visual & interactive** – live speed profile adjustments

- **Interface** – Use Bridg-E clearance constraints as inputs and feed outputs into TRAIN and QTP models to test detailed traction performance

- **PACE and SPEED** – widely used on Northern Hub, Northwest Electrification, Northern Powerhouse rail, Union Rail Connectivity,…
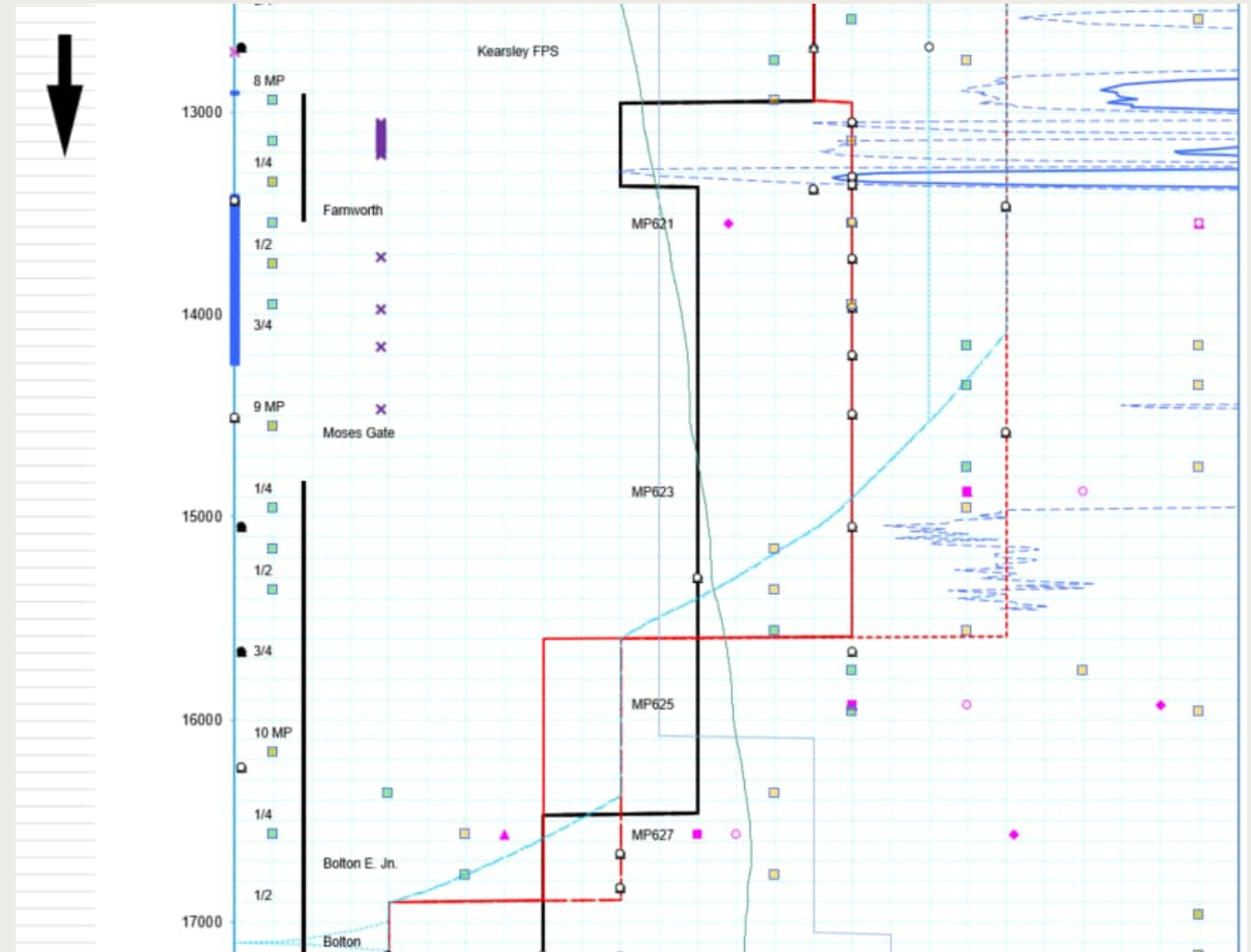
Moata Carbon Portal

Carbon monitoring solution

- **Carbon assessment** – automated modelling the capital and operational carbon of new assets

- **BIM integration** – carbon impacts of design changes can be visualised as they are made

- **Global PAS2080 certification** – compliant with carbon management standard for infrastructure

- **Stay ahead of regulatory changes** – facilitate low-carbon design by calculating carbon quickly and easily.

£450k
saving on disposal costs on the Northern Line extension project.

<90%
Up to 90 % faster carbon footprint calculations, compared to manual methods.

70%
carbon reduction between Stage 1 and 2 on the A417 Missing Link at Air Balloon project.

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Quick Train Performance (QTP)

Single-train performance tool

- **Journey time predictions**

- **Energy consumption** – environmental impact, energy management

- **Alternative traction solutions** – assessment of battery size, partial electrification, feasibility of hydrogen power source

- **Brake specification** – effect of regenerative braking

- **Requirements definition** – to meet specific timetables

QTP BEMU Train Performance Output (Newry - Portadown - GVS)
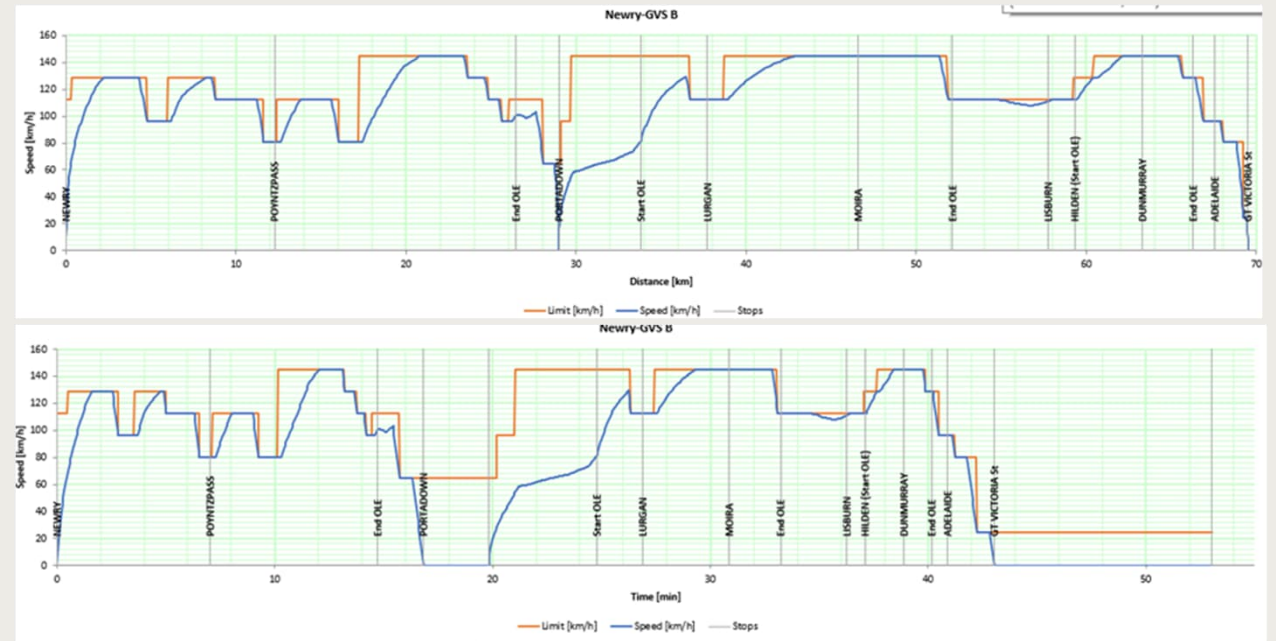
Battery state of charge (Newry - Portadown - GVS)

What is MM Rail Decarb?

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Commercial in Confidence
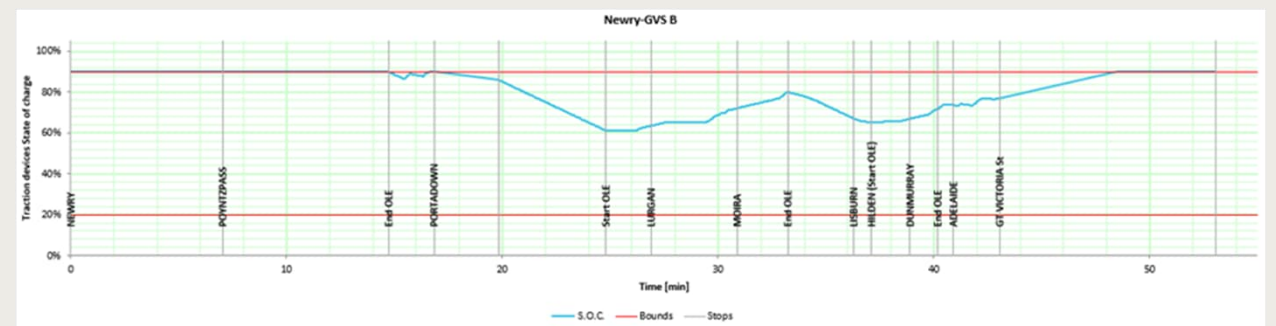
MM Rail Decarb – The problem it solves

"For areas of the network with significant freight flows or long-distance high-speed services, electrification is the only technology currently able to support these service types. Analysis suggests that electrification is also the best whole life cost solution for more intensively used areas of the network. – *TDNS July 2020*"
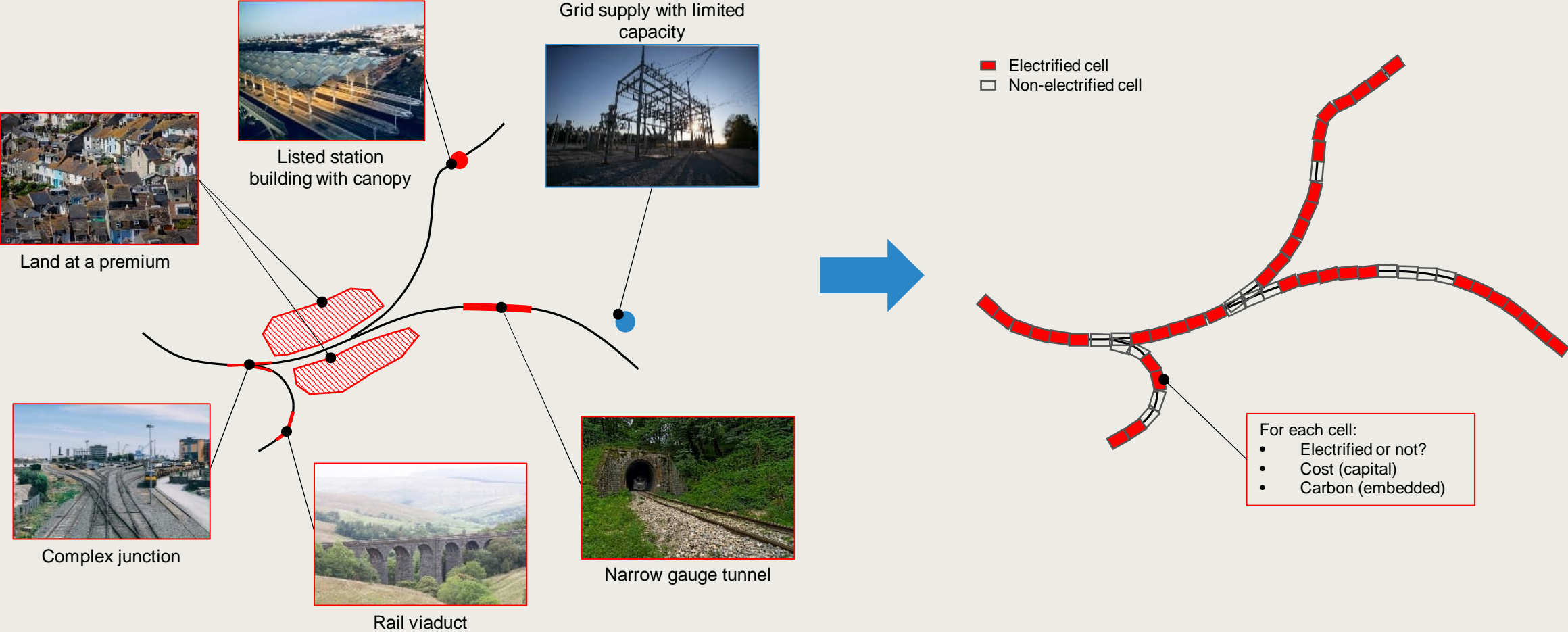
Where
do we electrify?

How
do vehicles bridge gaps?

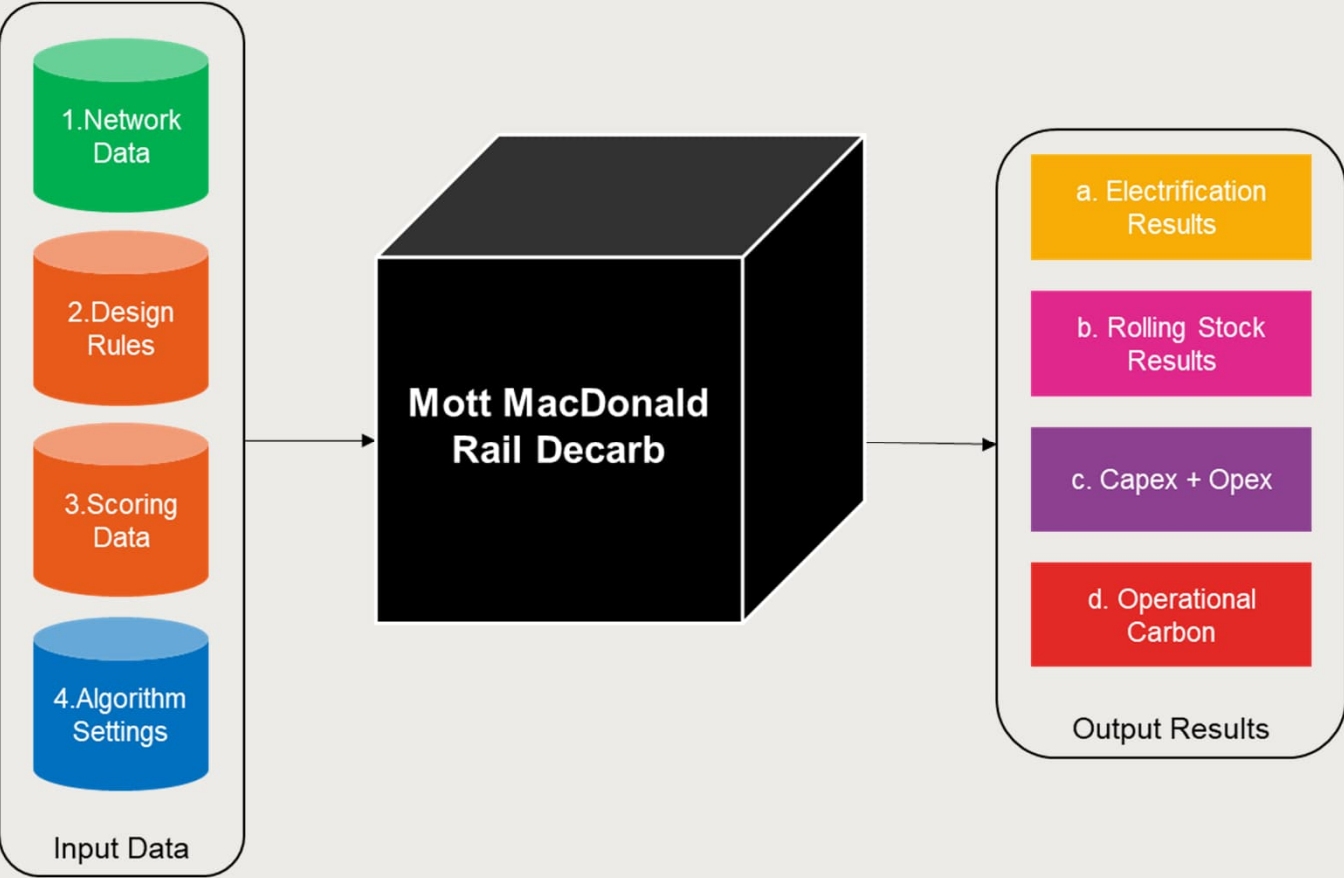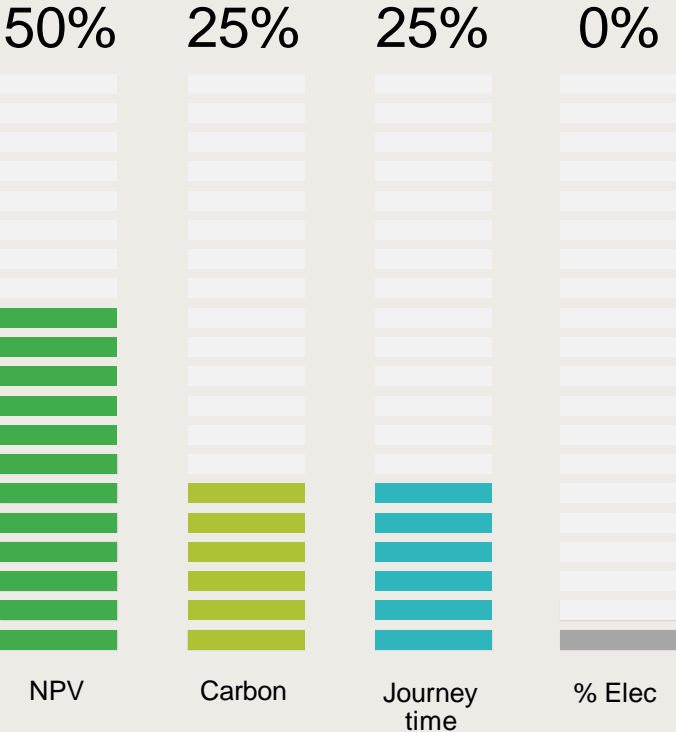# MM Rail Decarb – Concept & purpose

Land at a premium

Listed station building with canopy

Grid supply with limited capacity

Complex junction

Rail viaduct

Narrow gauge tunnel

■ Electrified cell
☐ Non-electrified cell

For each cell:
- Electrified or not?
- Cost (capital)
- Carbon (embedded)

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MM Rail Decarb – Simulation inputs & outputs

Users can change the weighting criteria against net present value (NPV), embedded / operational carbon, % electrification target, and journey time
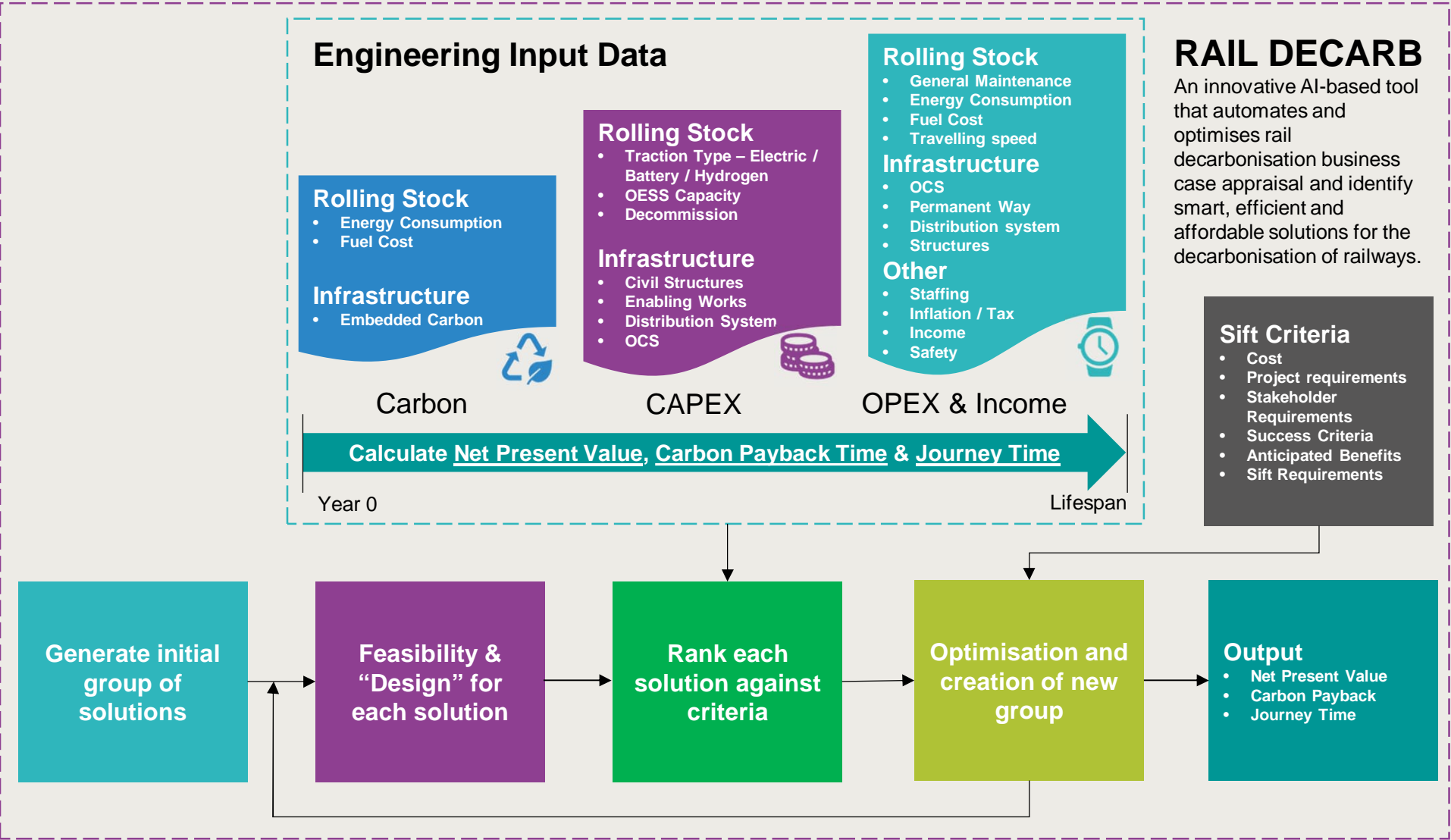
How does it work?

MM Rail Decarb – The algorithm

Engineering Input Data

Rolling Stock
- Energy Consumption
- Fuel Cost

Infrastructure
- Embedded Carbon

Carbon

Rolling Stock
- Traction Type – Electric / Battery / Hydrogen
- OESS Capacity
- Decommission

Infrastructure
- Civil Structures
- Enabling Works
- Distribution System
- OCS

CAPEX

Rolling Stock
- General Maintenance
- Energy Consumption
- Fuel Cost
- Travelling speed

Infrastructure
- OCS
- Permanent Way
- Distribution system
- Structures

Other
- Staffing
- Inflation / Tax
- Income
- Safety

OPEX & Income

RAIL DECARB
An innovative AI-based tool that automates and optimises rail decarbonisation business case appraisal and identify smart, efficient and affordable solutions for the decarbonisation of railways.

Sift Criteria
- Cost
- Project requirements
- Stakeholder Requirements
- Success Criteria
- Anticipated Benefits
- Sift Requirements

Calculate Net Present Value, Carbon Payback Time & Journey Time

Year 0 → Lifespan

Generate initial group of solutions → **Feasibility & "Design" for each solution** → **Rank each solution against criteria** → **Optimisation and creation of new group** → **Output**
- Net Present Value
- Carbon Payback
- Journey Time

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MM Rail Decarb – Automation of feasibility & design

Rolling stock feasibility

- What is the best choice of train for each route on this candidate?
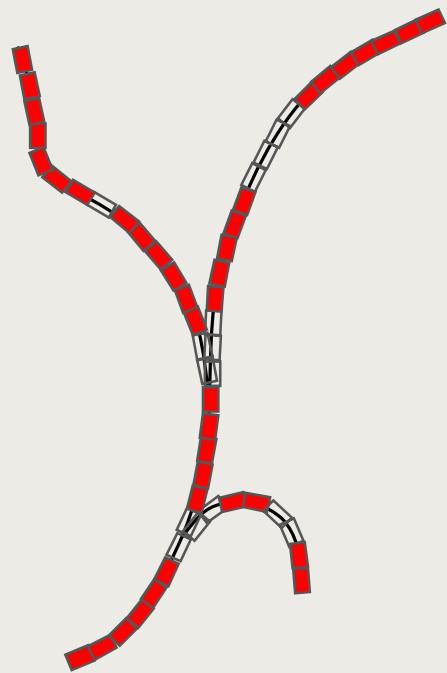
Electric	☒
Battery-Electric	☑
Battery only	☒
Hydrogen-Electric	☑
Hydrogen only	☒
Diesel	☑

Traction power design optimisation (AC)

- Optimise choice of grid supply based on distance and available capacity

- Optimise the placement of feeder stations based on length of feeding section, proximity to grid supply and land availability.

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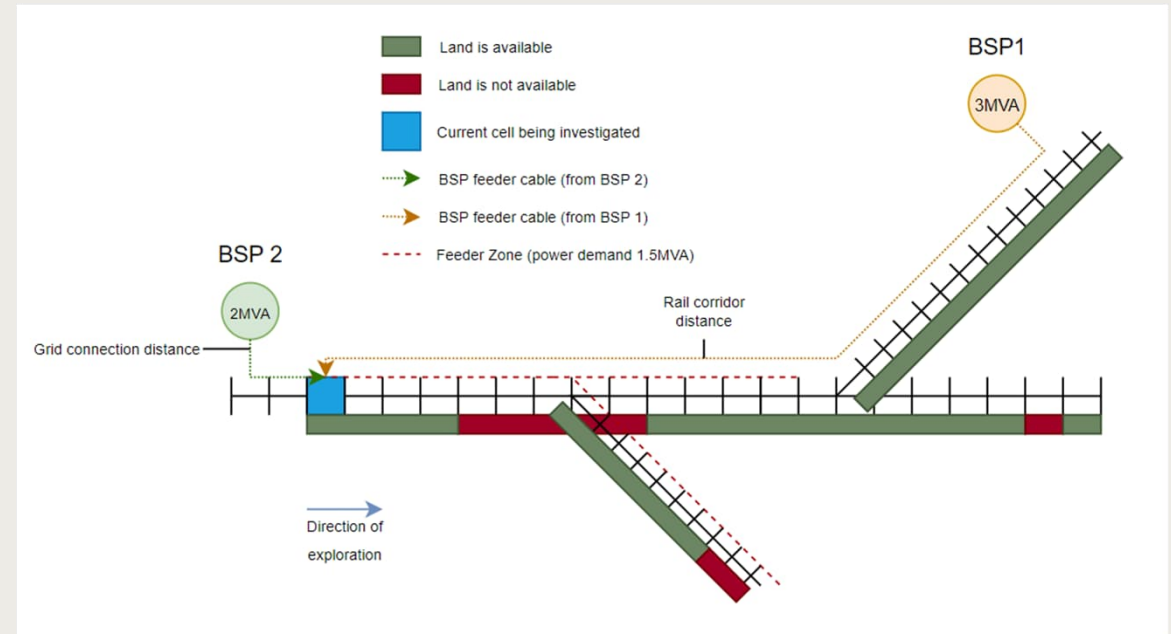
What are its use cases?

MM Rail Decarb – Supporting your business case

Multi-criteria assessment
- Cost (NPV)
- Carbon (embedded & operational)
- Journey time

Design automation
- Proposed traction power infrastructure
- Choice of feasible rolling stock
- Reduced over-engineering at early stages

Early-stage optimisation
- Generally reduced whole-life investment
- Compares 1000's of options in minutes

Risk management
- Run 100's of 'what if' scenarios
- Vary priorities
- Quantify the risk associated with different variables

Decision-making support
- Guide decision-making
- Provide supporting evidence for the validation of the appraisal process

Varied levels of detail

High-level (PACE ES1) ➝ Detailed (PACE ES3)

- Use costing/carbon data from existing libraries
- Consider generic train types
- Estimate rough energy consumption levels

- Use bespoke costing/carbon data relevant to the region
- Include more specific vehicle data
- Input energy profiles from other train performance models

MM Rail Decarb – Supporting your sustainability case
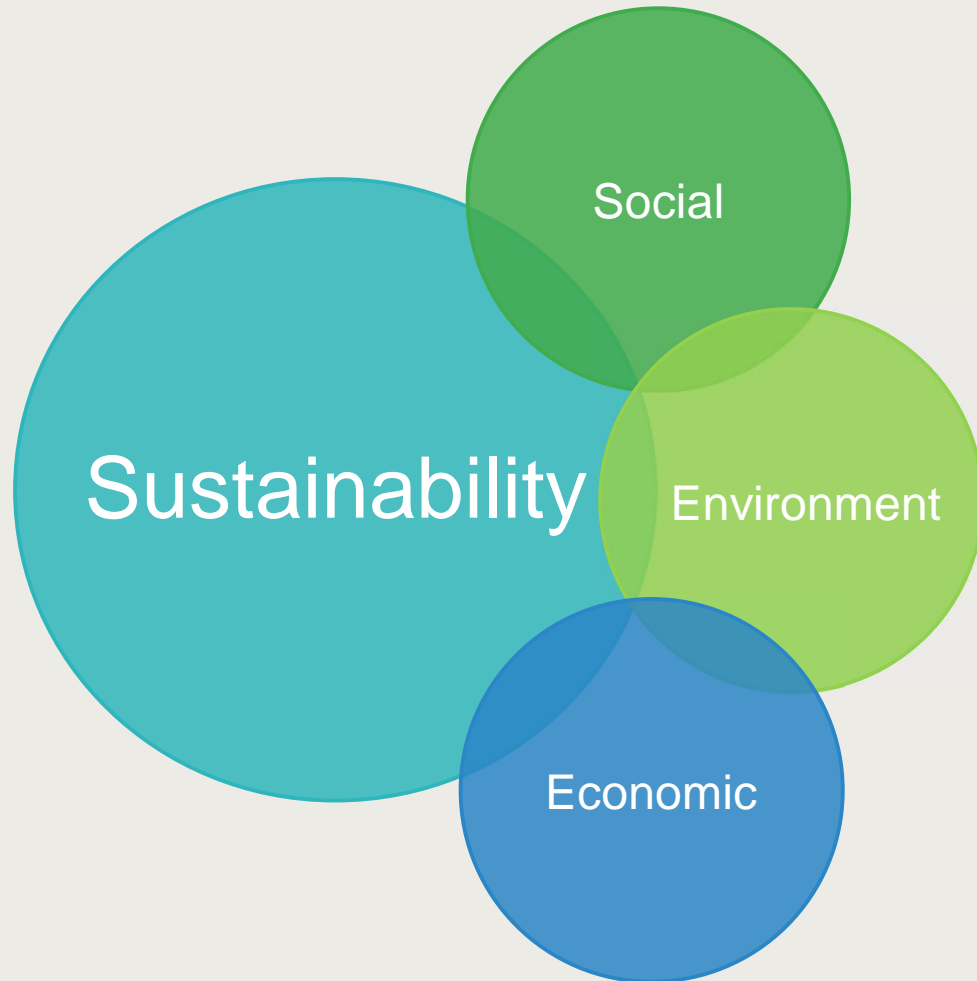
Rail Decarb evaluation criteria & benefits

- Journey time considerations for improved connectivity
- Accelerating appraisal for infrastructure improvements

- Quantified operational and embedded carbon
- Carbon payback period calculations

- OPEX and CAPEX calculations
- Optimised traction power design
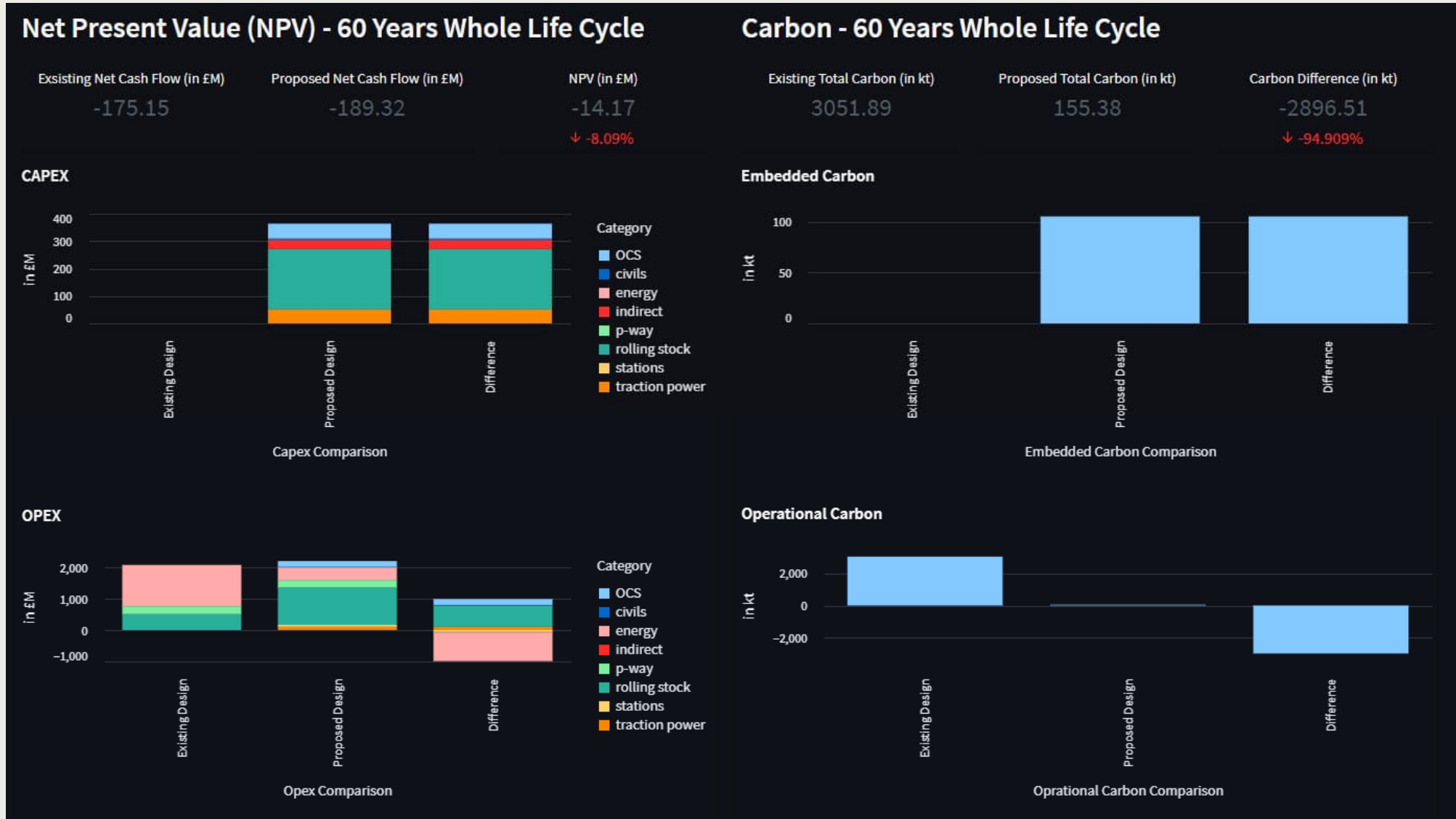- Ticketing / operational income

Demonstration of outputs
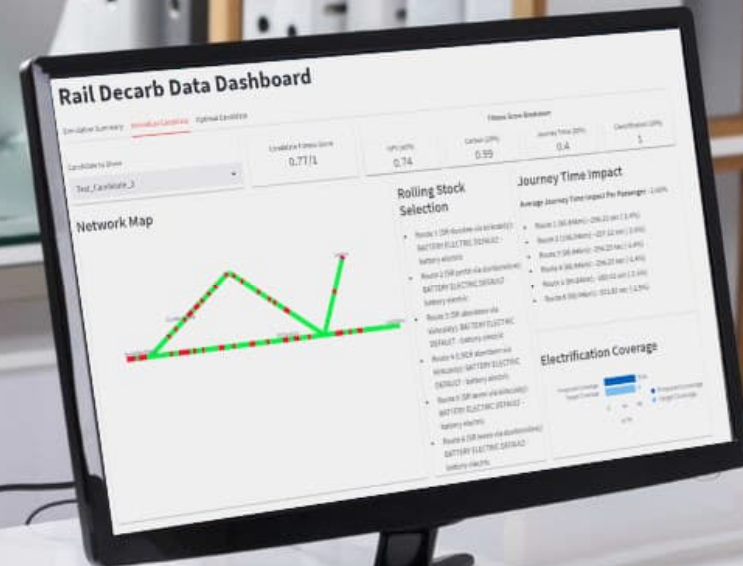
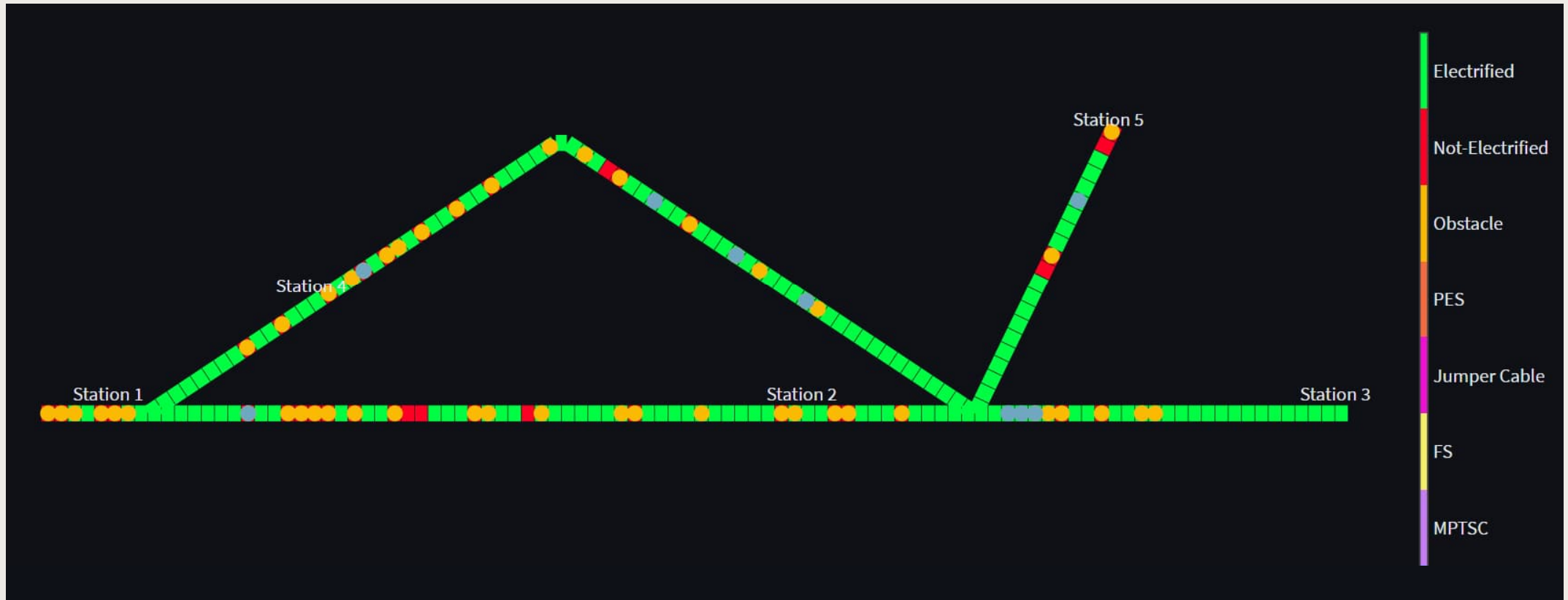# MM Rail Decarb – Simulation summary page

MM Rail Decarb – Candidate data

MM Rail Decarb – Candidate data

MM Rail Decarb – Map visualisation tool

Thank you

For more details, please contact:

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