Rail Scotland Conference

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Product Manager

2nd March 2023

ALSTOM

• mobility by nature •

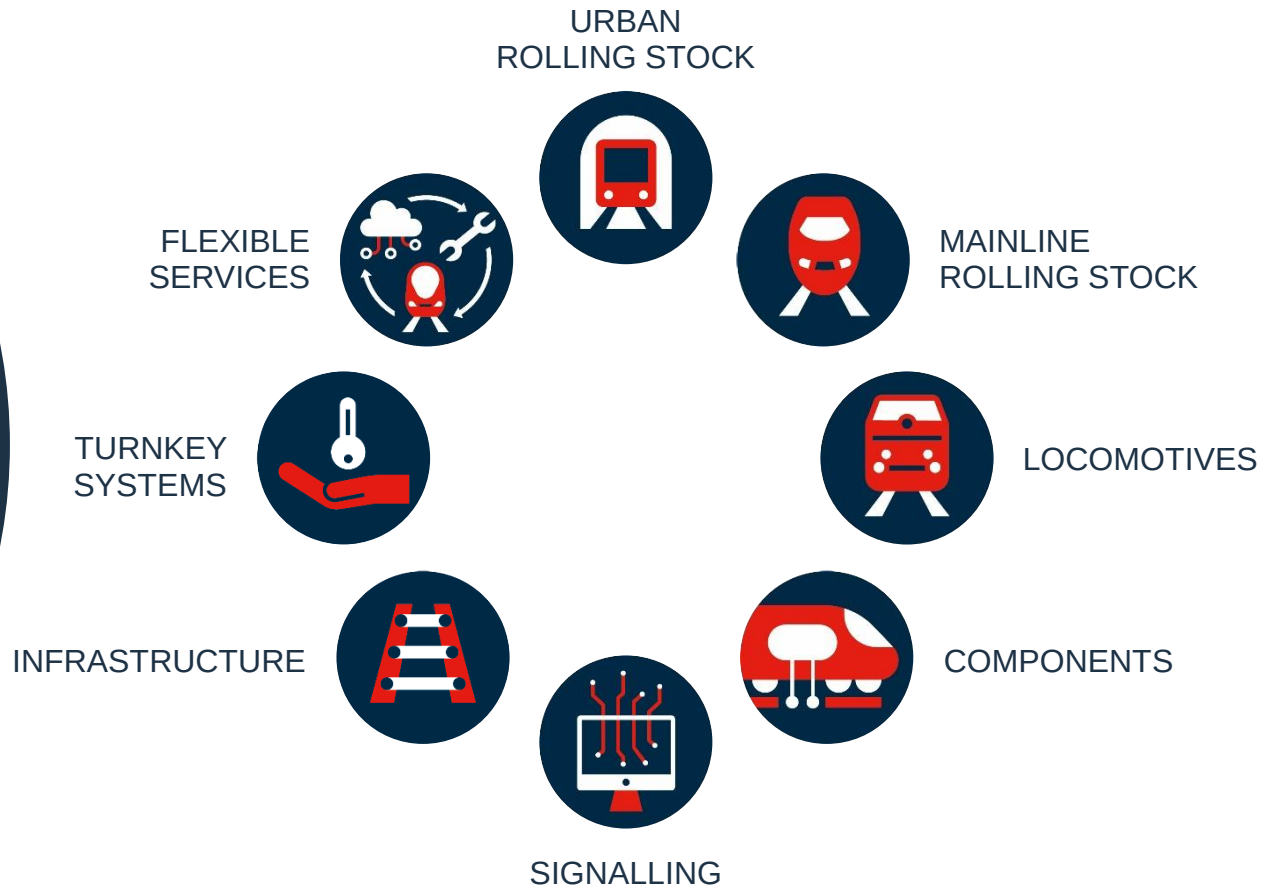
Who are Alstom?

A global leader in the transportation sector in the digital age

Leading societies to a low carbon future

Alstom develops and markets mobility solutions that provide sustainable foundations for the future of transportation.

Our comprehensive product portfolio ranges from high-speed trains, metros, monorail and trams, to turnkey systems, services, infrastructure, signalling and digital mobility solutions.



30

Locations across UK&I

#1

UK Rolling Stock & Services

6,000

UK&I Employees

Our Global Products

Rolling stock | Services | Signalling | Systems

22 years in Scotland with Juniper

109 Scottish jobs

Maintenance and train refurbishment at Polmadie

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What’s wrong with Diesel?

Why do we have Diesel in the first place?

The original ‘Business Case’ for Diesel was against Steam Trains

- Less labour to manage the engine
- Lower Maintenance Costs
- Greater Range between fuelling stops
- Introduction of Multiple Units to increase capacity
- Limited impact to existing infrastructure

Due to the financial situation with BR at the time, Diesel was seen as a more cost effective for Regional Routes in the UK vs. Electrification due to the high infrastructure costs.

There were clear benefits in the 20th century to move from steam to diesel traction

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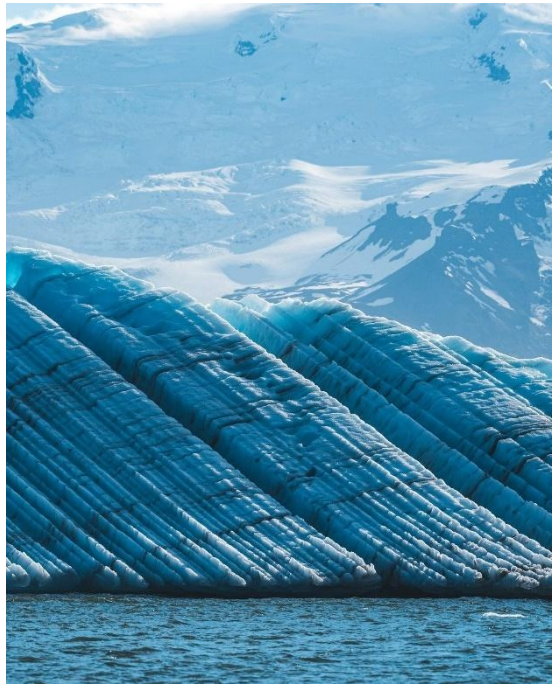
Greener transportation is a prerequisite to a sustainable environment

Limitation of global warming

The 2015 Paris Agreement, set a global objective to reach net zero emissions by 2050, in line with a below +2°C target relative to pre-industrial levels.



Limitation of urban pollution

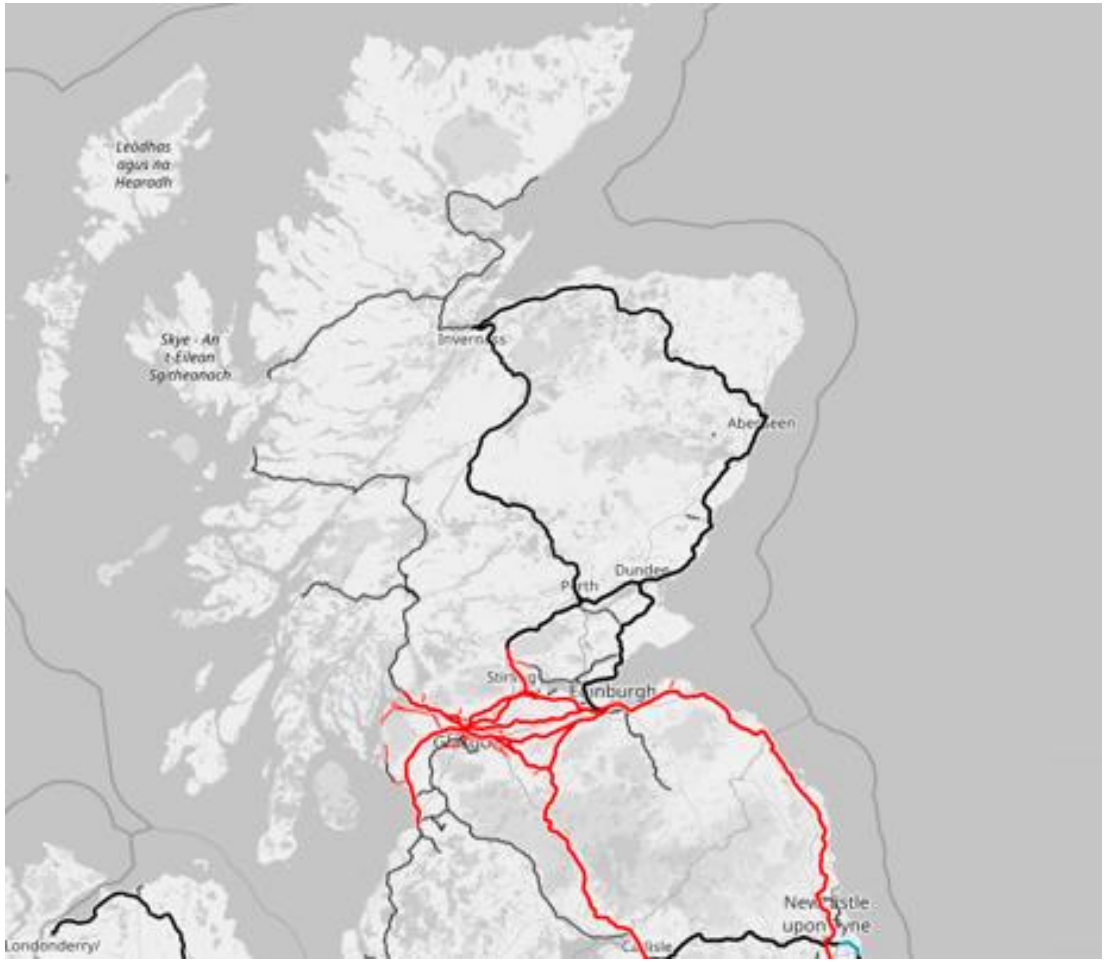
Most countries around the globe have defined limits for particulate matter in the air, multiplicating the “diesel ban” measures by 2040.

Reduction of dependency on fossil fuels

Finding alternatives to fossil fuels through the development of renewable energies will enable significant improvement of energy security.

Where are we today?

- **~60% of the Scottish network is non-electrified.**
  - Indication is that some lines could remain non-electrified for the next 40 years.
- **Aging Diesel Rolling Stock**
  - (Second Generation Diesels) need urgent replacement
  - Scotland aspires to remove all Diesel Only Trains by 2035, 5 years ahead of England
  - Life extension through retractioning is not commercially viable



Alstom green mobility solutions for non-electrified networks

Reduced emission

Bi-mode (Diesel + Catenary)

- Make use of catenary when operating on **electrified sections**
- Switch to diesel on **non-electrified sections**
- Bio/Synthetic Fuels envisaged to lower overall CO_2 emissions

Illustration with X'trapolis Tren Maya

Emission-free

Battery (BEMU / Battery power car)

- Current range of **80-120 km on batteries**
- Suited for **catenary-free operations** with **recharging** in electrified sections and stations
- Battery autonomy extension with **kinetic energy recovery** during braking

Illustration with X'trapolis Irish Rail BEMU

Hydrogen (FCMU / Hydrogen power car)

- Current range of **600-1,000 km**
- Suited for **catenary-free operations** with requirement of **hydrogen refueling station**
- **Kinectic energy recovery** during braking

Illustration with Coradia iLint FCMU

What are the criteria for deciding the appropriate technology for each use case?

Line length and electrification level

- **Autonomy**: battery (80-120 km) versus hydrogen (600-1,000 km)
- **Range depends on mission profile**
- **“Electrified islands”** can increase the range of BEMU solutions

Hydrogen / battery infrastructure

- **Country hydrogen strategy**
- **Available and affordable infrastructure**
- Hydrogen trains can support the **development of the ecosystem**

Operation, topography and climatography

In particular:

- Acceleration / deceleration & speed
- Ramps length / inclination
- Stops frequency
- Catenary / charging stations
- Tropicalisation / winterisation
- Wind & humidity magnitude

Current fleet age and railway standards

- Electrification
- Retractioning
- Replacement with hybrid traction
- Replacement with green traction

Our Emissions-Free technologies

Alstom Battery Trains

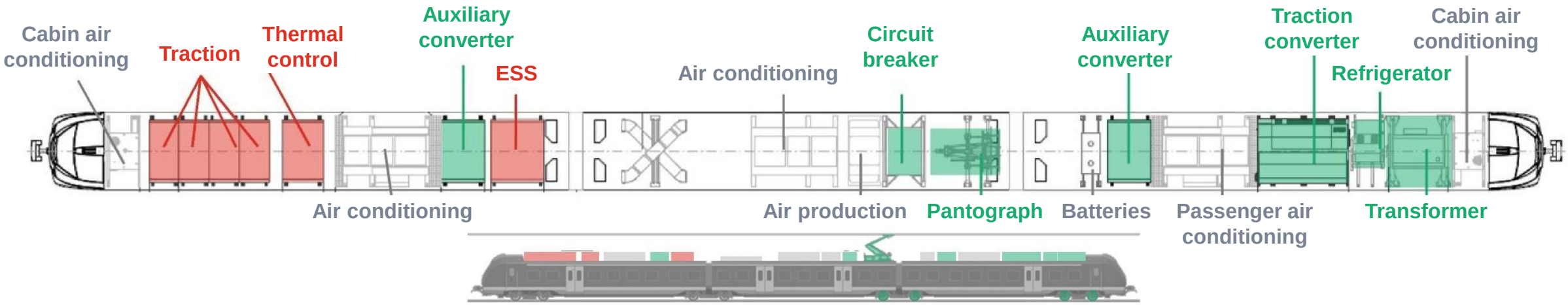
80 **km** of non-electrified line covered in a **single charge**

~30 **min to fully charge** the high-power batteries (depends on mission profile)

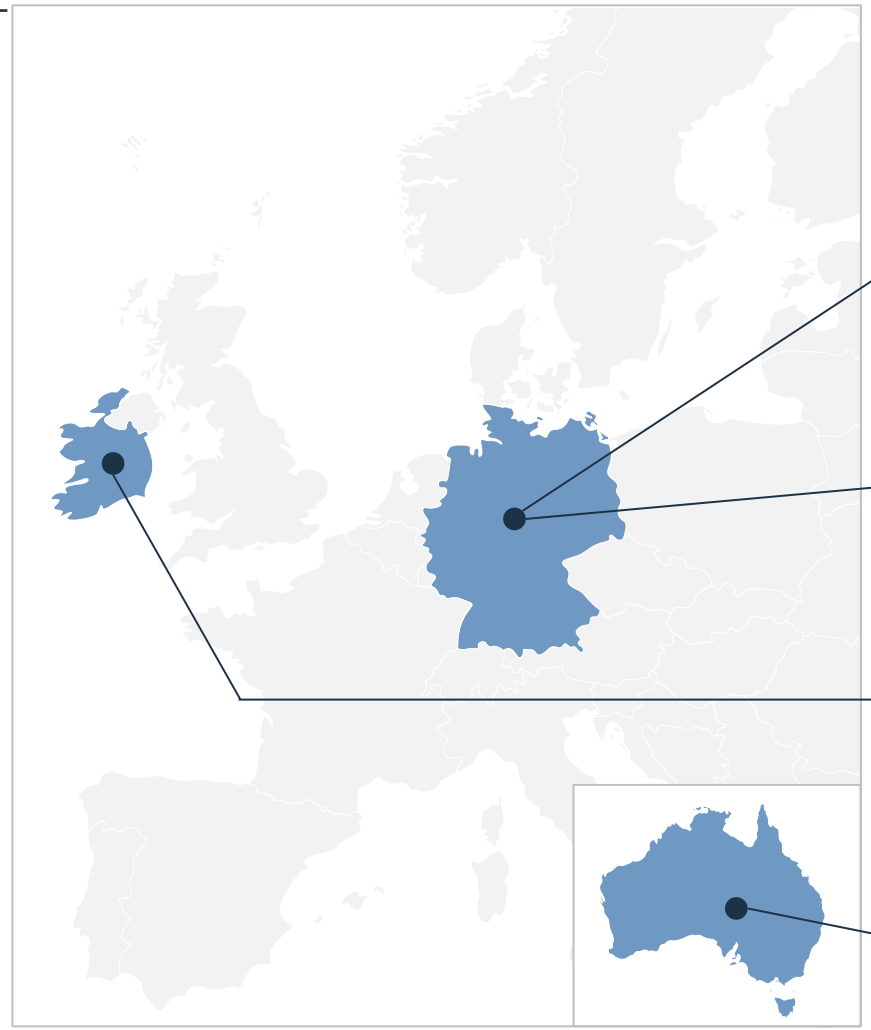
zero **emission** while ensuring **cost-effective** and **comfortable service**

Battery train: how does it work?

- **Battery Electric Multiple Unit (BEMU) is an electric train with additional traction batteries on board to operate on partially non-electrified lines**
- Batteries are **charging** when operating under **catenary** or in **stations**
- **Kinetic energy recovery during braking**
- Current range: **80-120 km** for short trains
- **“Electrified islands”** can **increase the range** due to intermediate charging
- Illustration of a possible architecture:



Alstom Battery train references for Commuter & Regional services



Coradia Continental

- 11 BEMU trains for VMS

R&D demonstrator with DB

- Test prototype in passenger operation
- First fully homologated BEMU in Germany

X'trapolis

- 13 BEMU trains for DART (Ireland)

X'trapolis

- Battery power cars for Melbourne (future conversion)

Alstom Hydrogen Trains

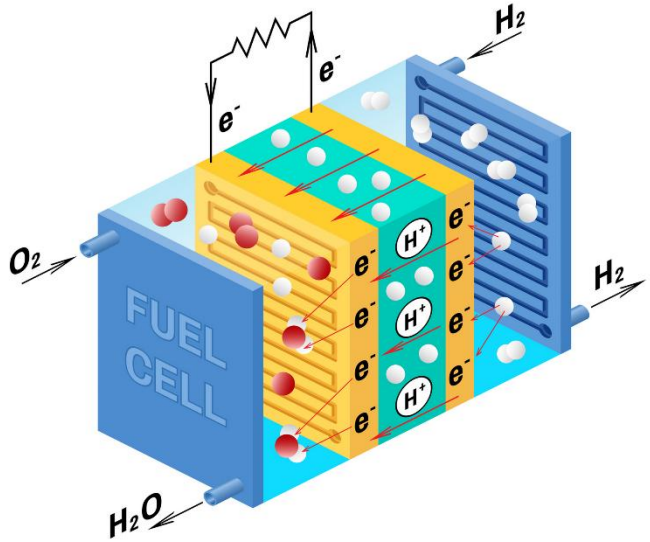
220,000+ **km** already covered in **passenger service** with Alstom hydrogen technology

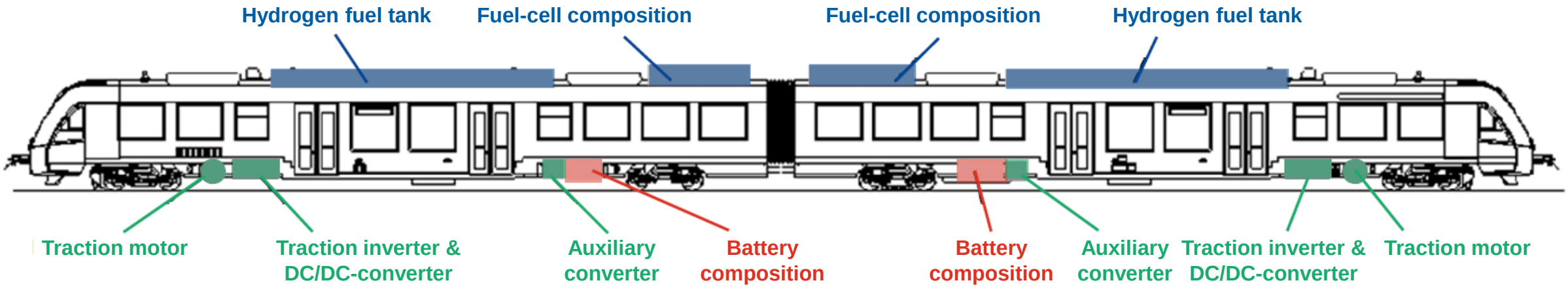
1000 **km of autonomy** with hydrogen fuel cell

zero **emission** while ensuring **economic viability** and **customer satisfaction**

Fuel Cell power pack: how does it work? (example Coradia iLint)

- **Fuel Cell Multiple Unit (FCMU) is an electric train with hydrogen powered fuel cell for onboard electric power generation**
- Fuel cells are composed of two electrodes separated by an electrolyte membrane
- **Oxygen** is taken from the air and combined with **hydrogen** inside the fuel cell to generate electricity through an **electrochemical reaction**
- Traction **Li-Ion batteries** are used for intermediate energy storage
  - to boost during acceleration
  - to recover kinetic energy during braking
  - to provide auxiliary supply





Hydrogen refuelling requires a complete infrastructure

Production

There are different sources to produce H_2: steam/gas reforming, as by-product from chemical industry or electrolysis processes.

Compression

H_2 is compressed to optimize storage space utilization.

Refueling

Trains are refilled at hydrogen refueling stations with 350 bar pressure (at 15°C).

Energy

Electric energy can be obtained from any source (e.g. natural gas, hydrocarbons, renewable).

Transportation and distribution

H_2 is transported and distributed through pipeline, boat or truck

Storage

H_2 is stored in tanks at low or high pressure

734 miles

without refuelling

WORLD RECORD RUN

14

Units already in passenger service and more to come!

0

Carbon emissions produced

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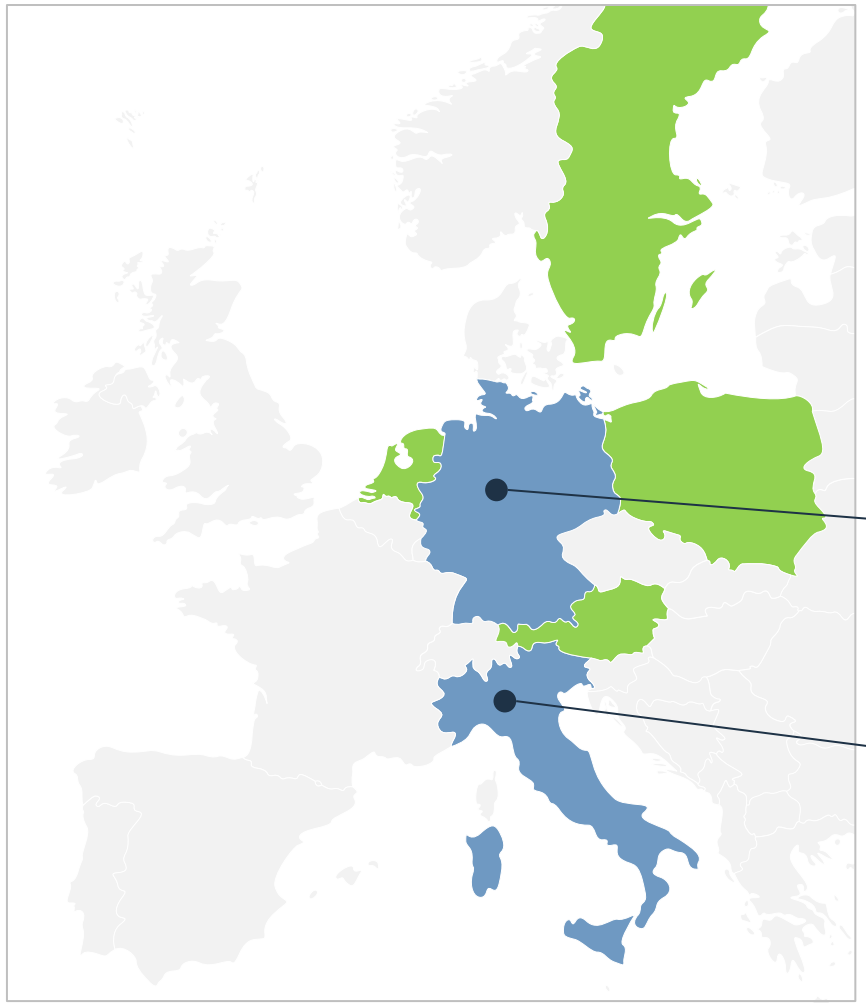
Alstom Fuel Cell train references for Commuter & Regional services



Coradia iLint – Testing & Demonstrations

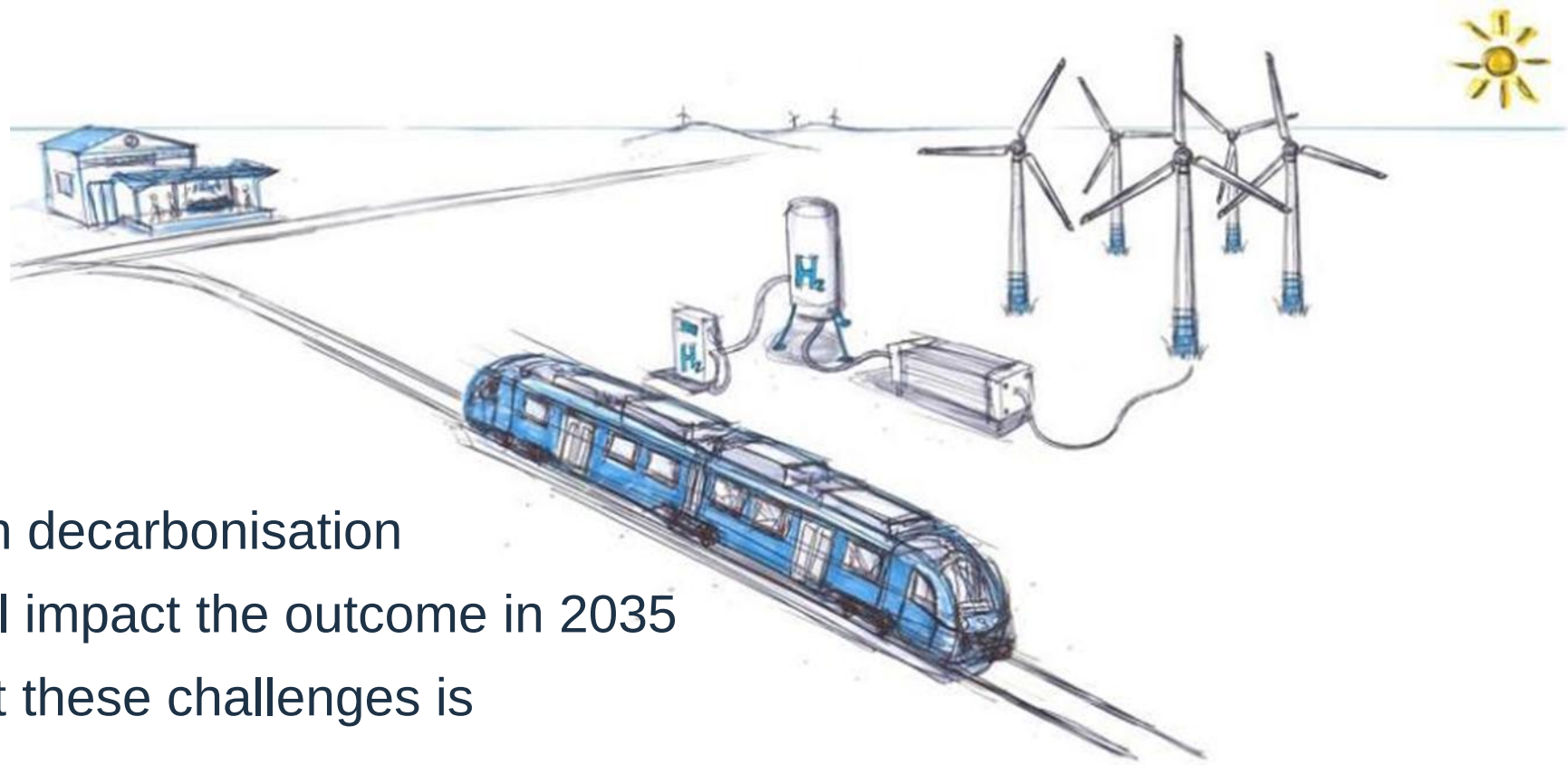
Coradia iLint

- 14 FCMU trains for LNVG
- 27 FCMU trains for RMV

Coradia Stream

- 6 FCMU trains for FNM

Summary



- Rail can lead the way in decarbonisation
- Our decisions today will impact the outcome in 2035
- The technology to meet these challenges is available today
- Modern products can help incentivise passengers back to the railway
- Alstom can help find the best technology to fit your operation

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