INTERNATIONAL UNION
OF RAILWAYS

**Welcome to the best practice workshop**

# HYDROGEN TRAINS

Proposed by the UIC Energy efficiency and $CO_2$ Emissions Sector

**Organised by the Sector's Chairpersons:**


**Bart Van der Spiegel, Infrabel,**
**Gerald Olde Monnikhof, ProRail.**
**Philippe Stefanos, UIC**


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# HYDROGEN TRAINS

- The meeting will be recorded.
- Please remain on **mute** while the speaker is active.
- Please keep your **camera off** while the speaker is active.

# Workshop timeline

10 h **Overview**

- Fuel Cell and Hydrogen – Joint Undertaking, **Bart Biebuyck**
- WaterstofNet, **Isabel François**

11 h **Rail pilot projects and state of art**

- Arup, **Robert Davies**
- ProRail, **Michiel Deerenberg**
- Alstom, **Andreas Frixen**

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# FUEL CELL AND HYDROGEN – JOINT UNDERTAKING


**Bart Biebuyck**
Executive Director

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

# *R&I to boost the development of the EU hydrogen economy with a focus on rail.*


**Bart Biebuyck**

**12 / 05 /2021 Virtual**

# Strong public-private partnership with a focused objective

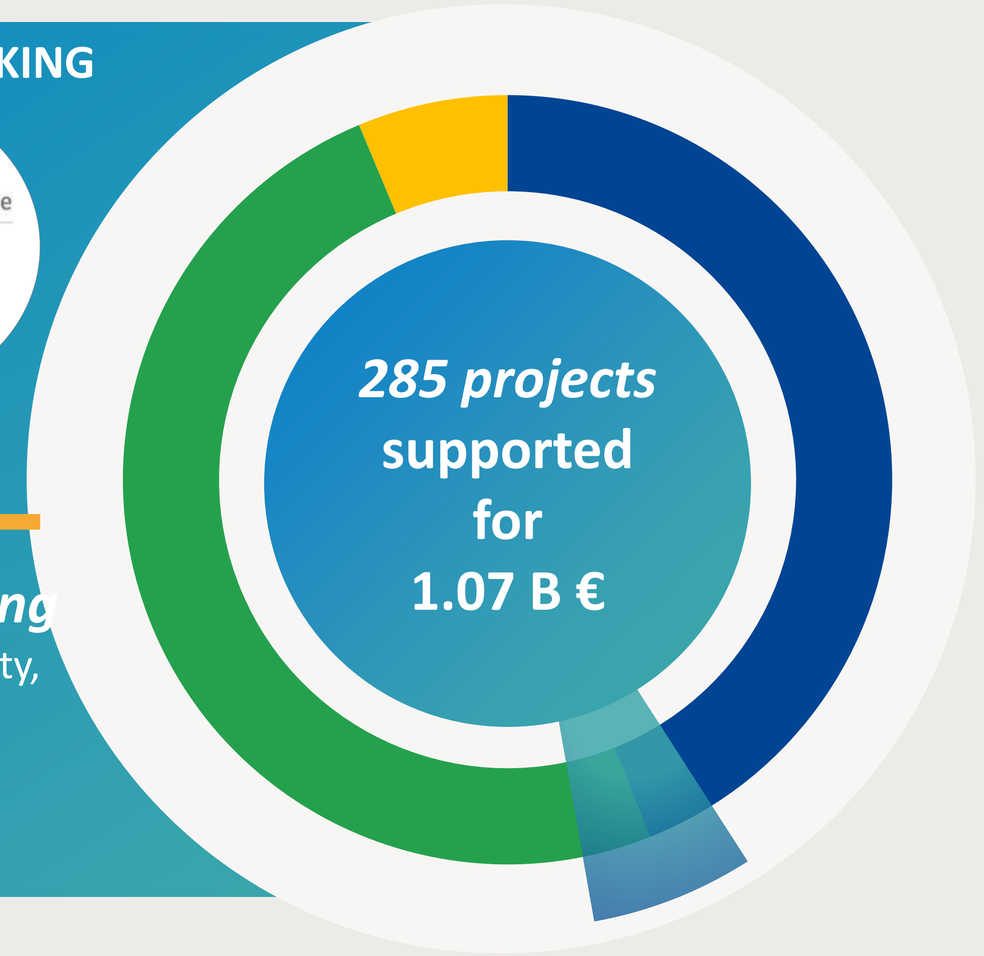
A combined private-public of more than 2 billion Euro has been invested to bring products to market readiness by 2020

## FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Hydrogen Europe
**Industry grouping**
250 members
50% SME

European Commission

Hydrogen Europe Research
**Research grouping**
83 members




### *Energy*
$H_2$ production and distribution
$H_2$ storage
F/C for CHP

### *Transport*
Road vehicles
Non-road vehicles
Refueling infra
Maritime, rail and aviation applications

### *Cross-cutting*
standards, safety, education, consumer awareness, …

**45 %**
481 million euros
153 projects

**41.4 %**
443 million euros
77 projects

**6.3 %**
67 million euros
48 projects

**7.3 %**
79 million euros
7 projects

Similar leverage of other sources of funding: 1.08 B €

# Besides $CO_2$ abatement, deployment of the hydrogen roadmap also cuts local emissions, creates new markets and secures sustainable employment in EU


## 2050 hydrogen vision

**~24%**

of final energy demand[1]

**~560 Mt**

annual $CO_2$ abatement[2]

**~EUR 820bn**

annual revenue (hydrogen and equipment)

**~15%**

reduction of local emissions ($NO_x$) relative to road transport

**~5.4m**

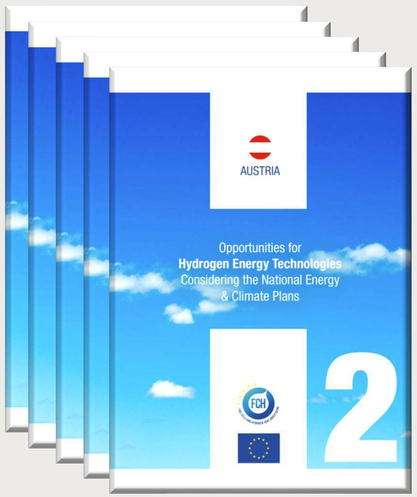
jobs (hydrogen, equipment, supplier industries)[3]

1 Including feedstock 2 Compared to the reference technology scenario 3 Excluding indirect effects

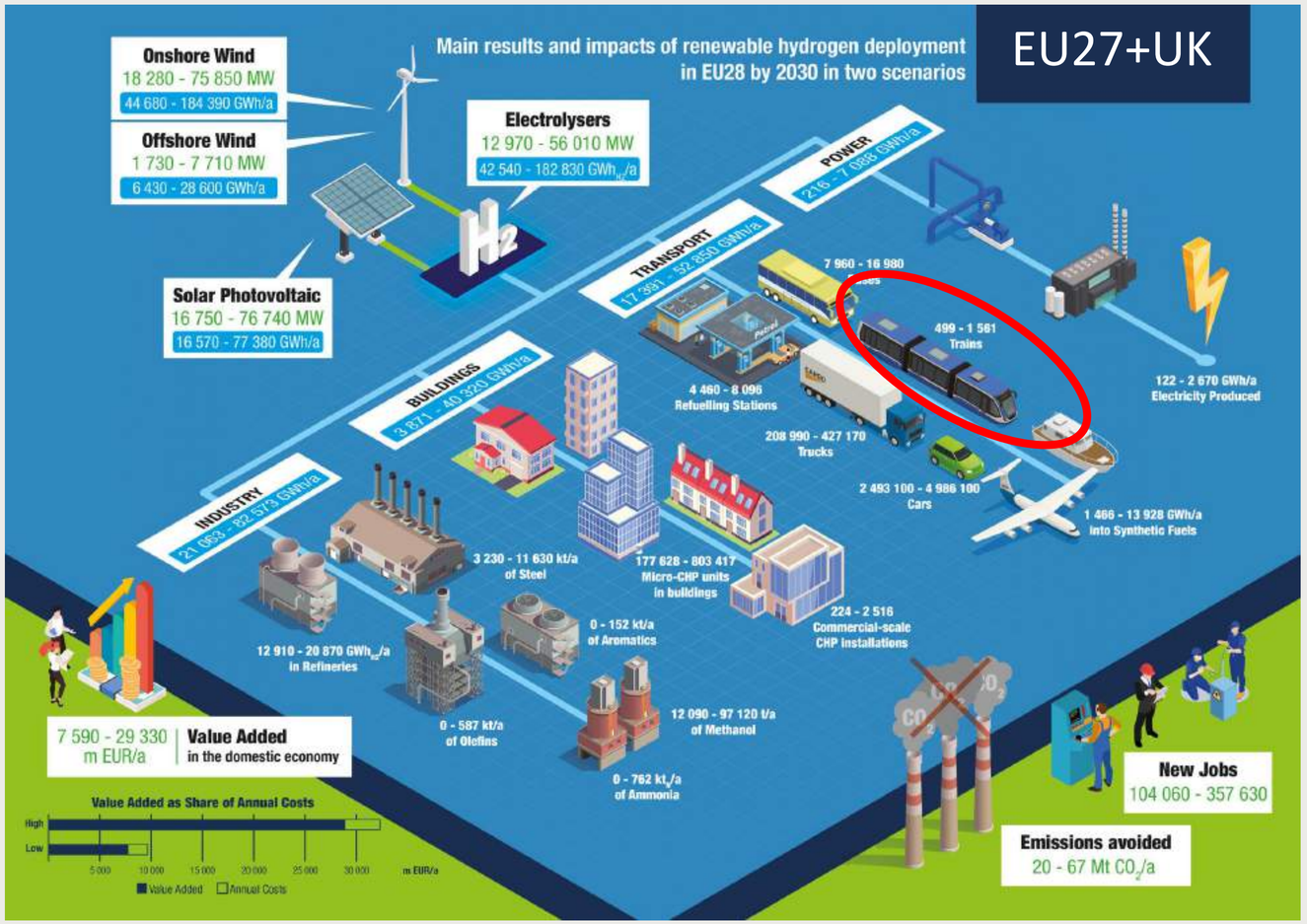
SOURCE: Hydrogen Roadmap Europe team

# Opportunities from the inclusion of Hydrogen in NECPs

EU27+UK NECPs were analyzed on the national opportunities for hydrogen deployment by 2030.




https://www.fch.europa.eu/publications/opportunities-hydrogen-energy-technologies-considering-national-energy-climate-plans




In EU27+UK by 2030 depending on the scenario, 13-56 GW of electrolysers (4800Hrs full load) are needed reducing 20-67MtCO2/a, creating 7.5-29 bn € added value and 104k-358k jobs.

# EU Hydrogen Strategy of 8th July 2020

Objectives in 3 phases with the Hydrogen Alliance to support the investment agenda

## Phase 1: 2020-2024

- **6GW** of renewable $H_2$ electrolysers
- 1 million tonnes renewable $H_2$
- Replace **existing** $H_2$ **production**
- Regulation for liquid $H_2$ markets
- Planning $H_2$ infrastructure

## Phase 2: 2025-2030

- **40GW** renewable $H_2$ electrolyser
- 10 million tonnes renewable $H_2$
- New applications in steel & transport
- H2 for electricity balancing purposes
- Creation of “Hydrogen Valleys”
- Cross-border logistical infrastructure

## Phase 3: 2030-2050

- $H_2$ technologies matured and deployed at large scale in hard to abate sectors.
- Expansion of hydrogen-derived synthetic fuels
- EU-wide infrastructure network
- An open international market

**Clean Hydrogen Alliance to support the EU investment agenda**

European Clean Hydrogen Alliance

https://www.ech2a.eu

# What is it?

- Launch on 8th July 2020
- Mission to create a project pipeline for a massive role-out of EU Clean Hydrogen technology
- Involving all active stakeholders in the clean hydrogen ecosystem, bringing together supply and demand

The blueprint estimates investments of €430 billion by 2030

- **Hydrogen Production**
- **Transmission & Distribution**
- **Mobility Applications**
- **Industrial Applications**
- **Energy Applications**
- **Residential Applications**

# FCH-JU region initiative was key to boost the hydrogen awareness in EU

The regions initiative led to the H2 Valley partnership, PDA and a call topic on H2 Valleys

https://www.fch.europa.eu/page/about-initiative

## Supporting regions and cities in assessing various FCH applications


## European Hydrogen Valleys Partnership

launched May ‘19 at EVS 32 in Lyon

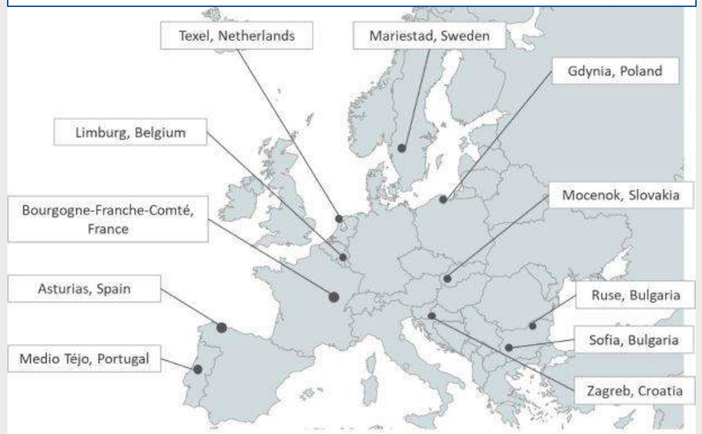

Partnership led by:
North of Netherlands (NL)
Auvergne-Rhône Alpes (FR)
Le Normandy (FR)
Aragon (ES)
**32 regions** joined

http://s3platform.jrc.ec.europa.eu/hydrogen-valleys

***“I want NextGenerationEU to create newEuropean Hydrogen Valleys** to modernise our industries, power our vehicles and bring new life to rural areas.”*

## Project Development Assistance (PDA)

launched Jan ’20 (38 applications / 19 countries)



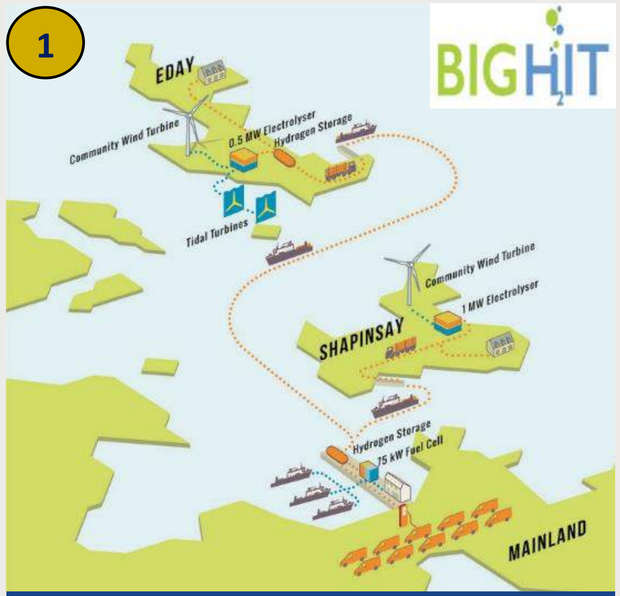

**Great opportunity** to bring on-board and share learnings with ‘less FCH ready’ but higly interested EU13regions

https://www.fch-regions.eu/

# Examples of Hydrogen valleys in Europe today

Its scope is system integration: Production of renewable H2, storage, distribution and end use (transport, stationary & industry)

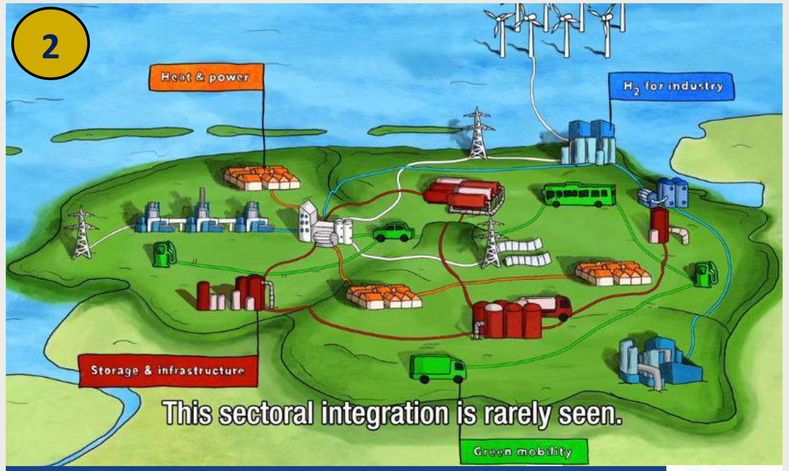
1




**Orkney's Island (Scotland):**

- H2 production by wind on Islands
- Storage and transportation by truck
- Use: heat (school), power (ferries) & mobility (municipality cars)

2




**North Netherlands (Groningen):**

- 31 partners (public + private)
- Electrolysis for green H2 production,
- H2 Mobility: buses, passenger cars and trucks
- H2 Refueling stations
- E-Kerosene for aviation
- H2 for an inland water transport barge
- Domestic Heat applications
- Underground H2 storage (Hystock)

3


**Hydrogen Island (Spain)***

- H2 production from solar
- H2 injection in gas-grid
- Use: heat (hotel, municipality buildings), power (port of Palma), mobility (buses)

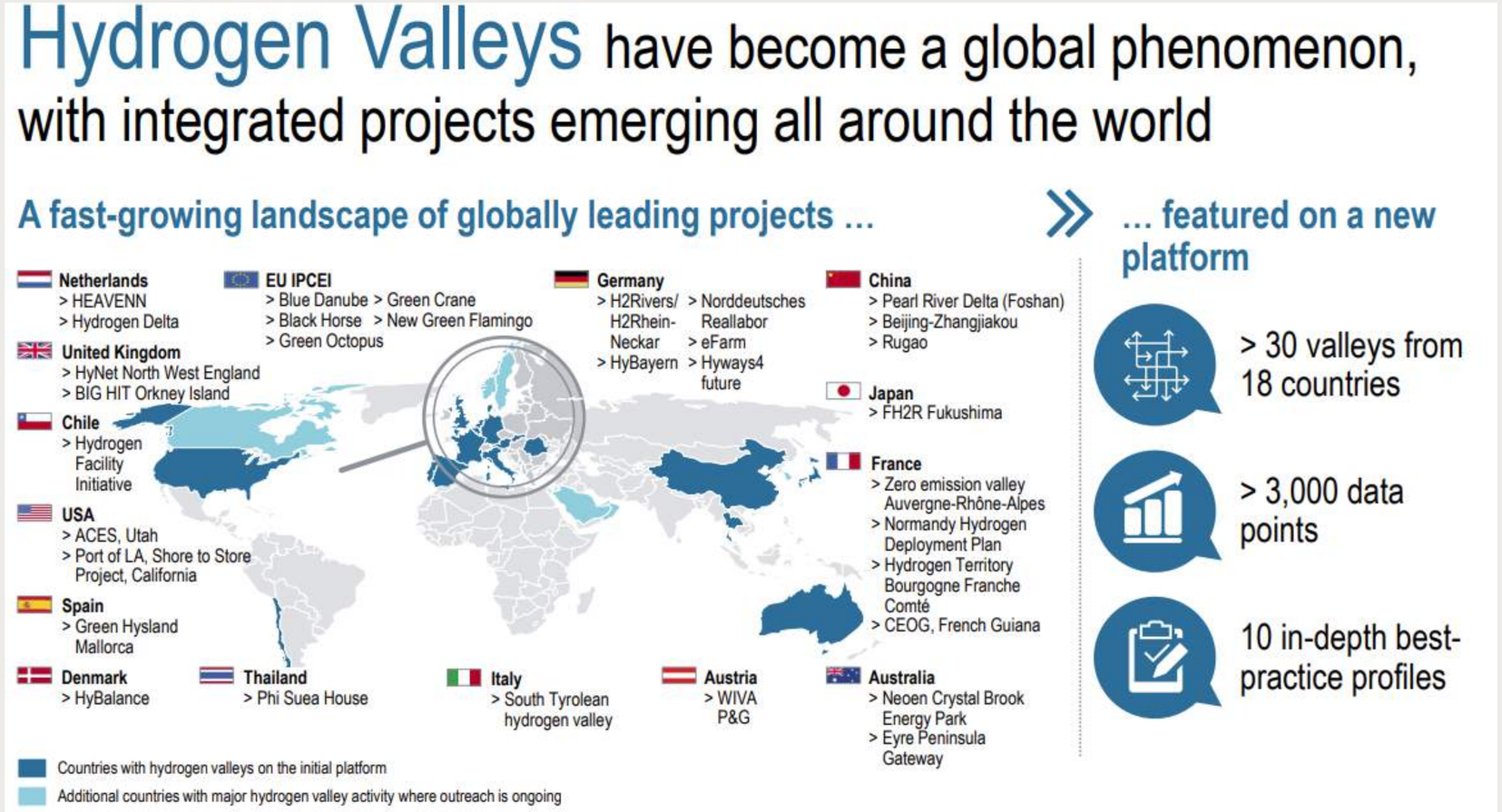
(*) Subject of successful signing the grant by Dec 2020

**Future Possible (cross boarder) H2 valleys:** Ports, Airports, Industrial hubs, Logistical hubs, A H2 city (or area)

# Hydrogen Valleys to accelerate the energy transition

Renewable and Clean Hydrogen Challenge (IC8) under MISSION INNOVATION

## Mission Innovation




- ✓ **Peer-to-peer exchange** among H2 valleys
- ✓ **Raise awareness** among policy makers
- ✓ **Advance clean energy transition**
- ✓ **EU (EC+FCH JU) in the lead also in terms of gathering and sharing lessons learnt**

https://www.h2v.eu/

# Electrolysis projects: increase capacity & lowering cost

Europe is world-leader in electrolysis systems (EU has the most patents and publications vs other parts of the world)

Project: Don Quichot
Place: Belgium
Date: 2011
Electrolyser: Hydrogenics (PEM)
Funding: 5.0 m€

Project: Haeolus
Place: Norway
Date: 2017
Electrolyser: Hydrogenics (PEM)
Funding: 5.0 m€

Project: H2future
Place: Austria
Date: 2016
Electrolyser: Siemens (PEM)
Funding: 12 m€

Project: Djewels
Place: The Netherlands
Date: 2018
Electrolyser: McPhy (ALK)
Funding: 11 m€

Djewels → Scale-up → HYDROGEN VALLEY

**NEXT:**

**~2025: several 100 MW's**

**~2030: GW scale**

**0.15 MW** → **1.2 MW** → **2.5 MW** → **3.4 MW** → **6.0 MW** → **10 MW** → **20 MW → 60MW** → **100 MW**

Project: Hybalance
Place: Denmark
Date: 2014
Electrolyser: Hydrogenics (PEM)
Funding: 8.0 m€

Project: Demo4grid
Place: Austria
Date: 2016
Electrolyser: IHT (ALK)
Funding: 2.9 m€

Project: Refhyne
Place: Germany
Date: 2017
Electrolyser: ITM (PEM)
Funding: 10 m€

The European Green Deal call for proposals includes a topic to install a 100MW Electrolyser.

Call closed:

16 proposals received

# Developing an EU wide Guarantees of Origin (GO) Scheme for Hydrogen

Two definitions: one for Green and one for Low-Carbon Hydrogen – more than 70,000 GOs issued already

## Four production plants included in the pilot scheme which have been already audited

Air Liquide, Port Jerome (SMR +CCS)

Colruyt Group, Halle (Electrolysis +RE)

Air Products, Rotterdam (by product H2 from Chlor-alkali process)

Uniper, Flakenhagen (Electrolysis + RE and methanation


https://cmo.grexel.com/Lists/PublicPages/Statistics.aspx

**On-going actions:**

**(1) Certifhy3: Setup of a platform for piloting a GO scheme for hydrogen across Europe. https://www.certifhy.eu/**

**(2) IPHE taskforce on Hydrogen Production Analysis methodology.**

**=> important to unlock future cross boarder trading.**

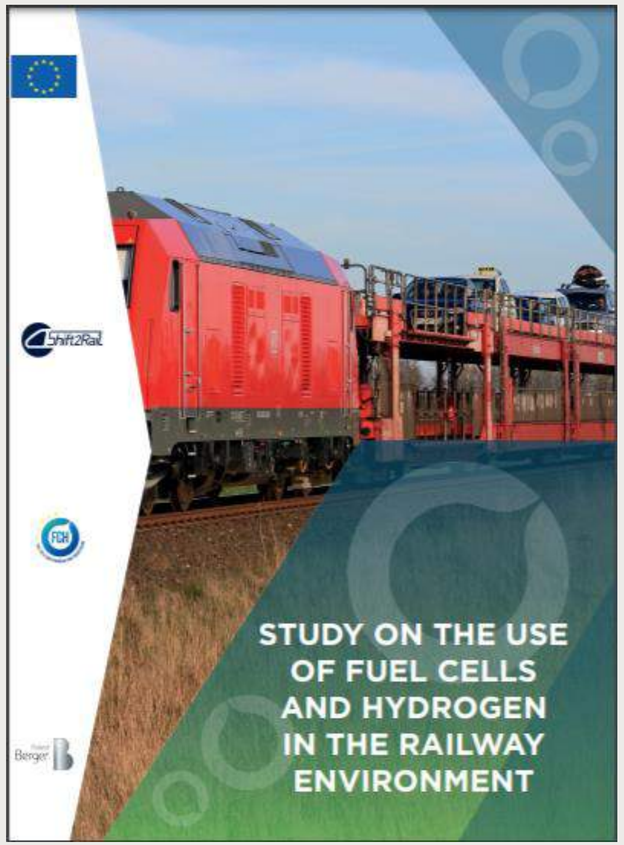
# FCH-JU has projects related to many different modes of transport

Heavy duty  transportation is looking seriously to hydrogen due to the huge performance improvements of fuel cells




# Rail accelerates Hydrogen and Fuel Cells technology

Joint study with great consensus from the stakeholders




## Advisory Board composition

### System integrators / OEMs

ALSTOM

SIEMENS

CAF

BOMBARDIER

### Infrastructure/$H_2$ suppliers

THE LINDE GROUP

TRACTEBEL ENGIE

HEXAGON

PITPOINT CLEAN FUELS

AIR LIQUIDE

ENGIE

nel

### Operators

ALPHA TRAINS

SBB CFF FFS

ProRail

DB BAHN

ÖBB

ZILLERTALBAHN zug · bus · dampf

renfe

SNCF

Stagecoach

### FCH technology providers

HYDROGENICS SHIFT POWER | ENERGIZE YOUR WORLD

BALLARD

POWERCELL

Nedstack

PM PROTON MOTOR

FUEL CELL POWERTRAIN

Intelligent Energy

https://fch.europa.eu/publications/use-fuel-cells-and-hydrogen-railway-environment

# FCH technology can become a viable alternative to replace diesel

## Three main applications explored

> We analysed the potential of fuel cell and hydrogen technology for rail transport for three application areas

> Most activity visible in multiple unit application area (products already being launched)

> First insights suggest attractive use cases and good market potential

| | | |
|---|---|---|
| Multiple units |  | Passenger operation in regional transport |
| | | First FCH trains in operations since September |
| | | up to 1,000 km[1)] |
| | | up to 140 km/h |
| | | 30 years |
| Shunters |  | Shunting and short distance operation |
| | | ? |
| | | 200-1,000 km[1)] |
| | | up to 50 km/h |
| | | 35 years |
| Mainline Loco-motives |  | Med. + long distance freight + passenger service |
| | | ? |
| | | 500-1,100 km[1)] |
| | | up to 120 km/h |
| | | 30 years |

1) Depending e.g. on # cargo/passengers, stops and topography

Application | Maturity of technology | Range | Speed | Lifetime | Market entry

Source: Alstom, ÖBB, Roland Berger

# Hydrogen can be the most economic zero emission solution

Depending on the use and distance, hydrogen can compete with diesel

| | Multiple Unit | Shunter | Mainline Locomotive |
|---|---|---|---|
| Overview | **Aragon, Spain**  | **Riga Node, Latvia**  | **Kalmar – Linköping, Sweden**  |
| Track length | 165 km | 100 km | 230 km |
| Rolling stock | 2x 4 car trains (bi-mode) | 15 Shunters | 5 Locomotives |
| $H_2$ consumption | 0.31 kg/km | 0.49 kg/km | 0.48 kg/km |
| Characteristics | Cross border connectivity and long rout without electrification | Shunting operation between several port terminals | Passenger and freight transport between two cities |
| Diesel | 9.3 | 20.9 | 5.7 |
| FCH | **12.4** | **20.4** | **6.7** |
| Catenary | 22.5 | | 22.0 |
| Battery | 13.7 | 21.8 | |
| $CO_2$ saving potential in one year | **767 t** | **3,350 t** | **4,980 t** |

Source: Expert interviews, Roland Berger

# Market potential study shows Multiple Units will be the first to enter

This entry could be accelerated by policy or incentives

## Overview of FCH train markets outlook for 2030 [standard units[1)]]

| Frontrunner | Low | Base | High |
|---|---|---|---|
| | 150 | 273 | 569 |
| | 12 | 25 | 50 |
| | 10 | 20 | 40 |
| | 951 | 805 | 465 |

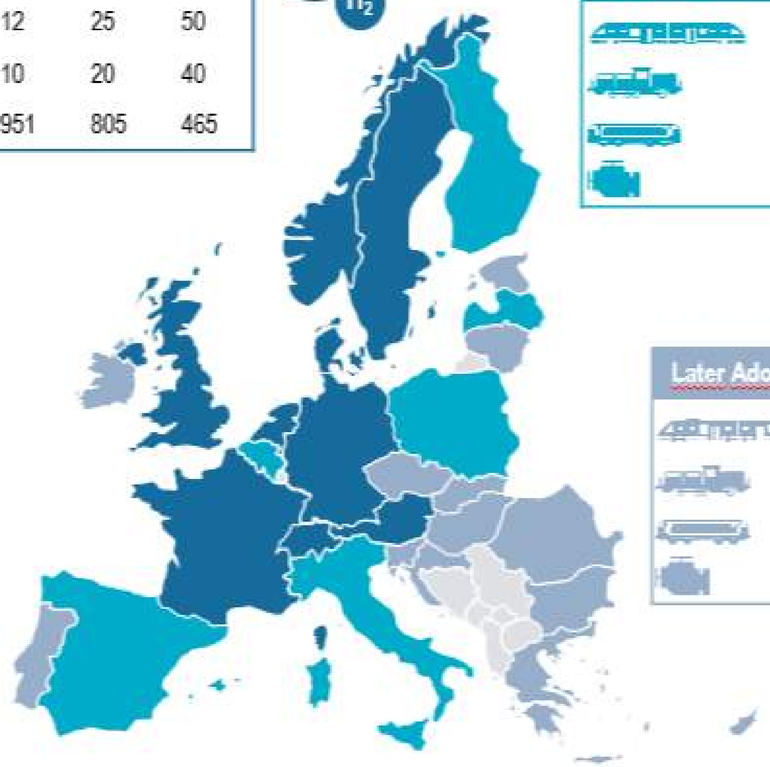
Base 2030 28% $H_2$

| Newcomer | Low | Base | High |
|---|---|---|---|
| | 10 | 21 | 41 |
| | 15 | 29 | 58 |
| | 4 | 8 | 17 |
| | 497 | 467 | 409 |

Base 2030 11% $H_2$

| Later Adopter | Low | Base | High |
|---|---|---|---|
| | 7 | 15 | 30 |
| | 9 | 19 | 37 |
| | 4 | 8 | 15 |
| | 419 | 398 | 357 |

Base 2030 9% $H_2$



X% Market share of FCH in 2030

1) According to definition of UNIFE World Rail Market Report

Source: Market research, Expert interviews, Roland Berger

### Comments

- The Market potential will depend on the projected diesel purchasing volumes
- Substitution of diesel trains is driven by the Multiple Units in the Frontrunner markets
- On the other hand, Shunters drive the substitution in the Newcomer and Later Adopter markets

# No barriers are show-stoppers for FCH rail technology

R&I projects are required to realize a broader commercial potential

## Barriers for FCH trains

> **No** principle **show-stoppers** to the deployment of FCH technology in the rail environment exist

> **High priority barriers** are related to **financing** FCH train deployment, **lack of standard scalable design** and **$H_2$ storage optimisation**

## Suggested Research and Innovation (R&I)

> **R&I projects** can bring FCH technology significantly closer to commercialisation by **addressing high priority barriers**

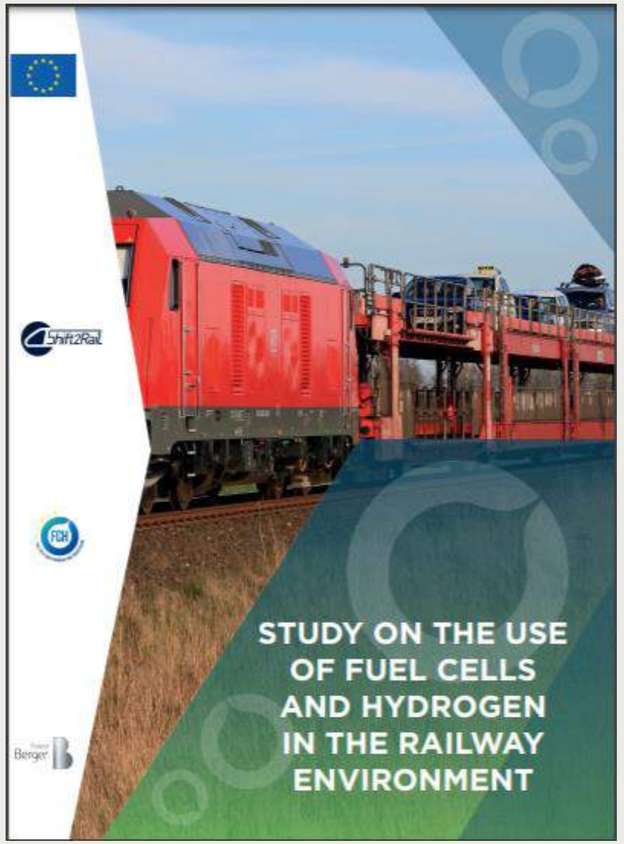
> Three key project topics
  - **Large-scale demonstration** of Multiple Units fleets
  - **Prototype level.** and testing of Shunters or Mainline Locomotives
  - Research and **tech. dev.** of **optimised $H_2$ storage** system

> **Medium**, **low** priority **barriers can integrated** in the same R&I project

# Rail accelerates Hydrogen and Fuel Cells technology

The first business models are appearing

- FCH trains make economic sense above all on longer non-electrified routes >100 km
- FCH trains esp. for last mile delivery & main routes with very low utilisation (<10 trains/day)
- Low electricity costs (<EUR 50 /MWh) & high infra utilisation (HRS…) favour FCH technology;
- FCH trains has downtimes <20 minutes (due to fast refuelling) and withstand long operating hours >18 hours w/o refuelling;
- FCH trains are economically feasible clean alternative to diesel trains in many cases;
- In some cases, battery trains may appear as  more cost-effective option but come with operational constraints resulting from highly route-specific tailored battery configurations.



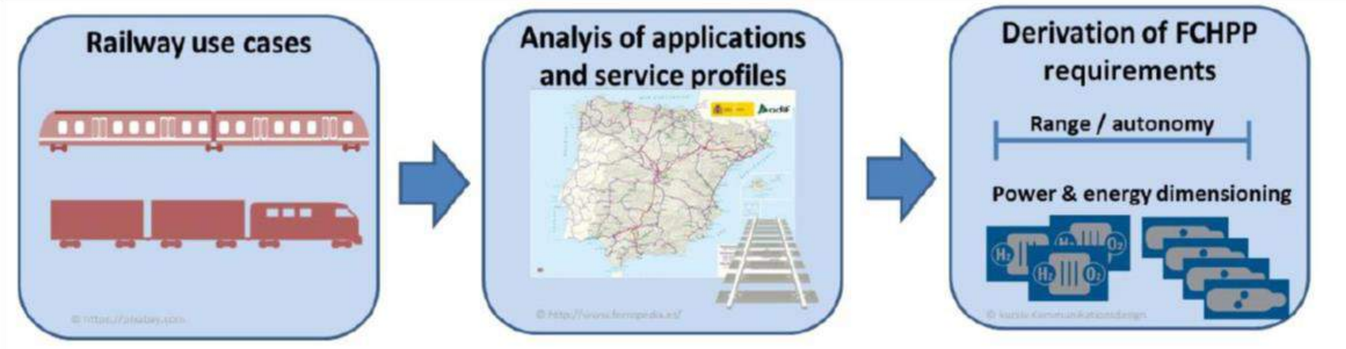

https://fch.europa.eu/publications/use-fuel-cells-and-hydrogen-railway-environment

# Fuel Cell Hybrid PowerPack for Rail Applications

Demonstrate the system in a bi-mode train to be homologated in three MS

- Start date: 01/01/2021
- Total cost: 13,341,609.93 €
- Grant amount: 10,000,000.00 €
- Main Objective:
  - Develop, build, test, demonstrate and homologate a scalable, modular and multi-purpose Fuel Cell Hybrid PowerPack (FCHPP) applicable for different rail applications (multiple unit, mainline and shunting locomotives) also suitable to for retrofit existing electric and diesel trains, to reach TRL7.
  - The train demonstrator tests to be carried out cross-border in Portugal and Spain and homologation to be sought for three EU countries.

Methodology




# What is the current situation in the rest of Europe

## Market is accelerating

Railway-News

Four French regions have signed an order for dual mode electric-hydrogen trains, making this the first order for hydrogen trains Alstom has received in France.


**Alstom to supply Italy's first hydrogen trains**

The board of FNM, Lombardy's leading public transport group, approves major investment in green railway transportation


**26 November 2020** – Alstom will supply six hydrogen fuel cell trains, with the option for eight more, to FNM (Ferrovie Nord Milano), the main transport and mobility group in the Italian region of Lombardy, for a total amount of approximately €160 million. The first train delivery is expected within 36 months of the date of the order.

The new hydrogen trains will be based on Alstom's Coradia Stream regional train platform, which is dedicated to the European market and already being produced for Italy by Alstom's main Italian sites. The hydrogen powered Coradia Stream for FNM, will be equipped with the same fuel cell propulsion technology that was introduced to the world by the Coradia iLint. The hydrogen Coradia Stream will maintain the high standards of comfort already appreciated by passengers of its electric version. The hydrogen version will match the operational performance of diesel trains, including their range.

**Alstom's hydrogen train successfully completes three months of testing in Austria**

The Coradia iLint is fully approved for the Austrian network and has successfully completed passenger operation tests with ÖBB


The first Portuguese hydrogen train will replace Vouguinha

The project for the development of the first Portuguese hydrogen train has already started. The initiative aims to transform the diesel cars that run on the Vouga Line – the train called Vouguinha – by hydrogen fuel cells that produce electricity.


The European Investment Bank (EIB) will fund 25 million euros for the purchase of four hydrogen trains and the construction of a hydrogen filling station in Groningen in the Netherlands. The amount is part of a 3.4 billion euro investment package in sustainable development. Of this, 700 million euros are spent on sustainable mobility.

Scotland's first hydrogen-powered train will run by the end of 2021

LAUREN KEITH *Lonely Planet Writer* 12 JANUARY 2021


Scotland set to launch first train to run on hydro power by the end of the year © JBDesign/Shutterstock


University of Birmingham / Porterbrook

Trials of a hydrogen-powered train are underway in the U.K. with an initial journey successfully completed between the locations of Long Marston and Evesham in the West Midlands region of England.

The HydroFLEX train — which has been developed by a team from the University of Birmingham and Porterbrook, a rolling stock firm — uses a fuel-cell which combines hydrogen and oxygen to generate electricity, heat and water.

Pesa to unveil hydrogen locomotive by year end

The Polish manufacturer has been working on the vehicle since December 2019.

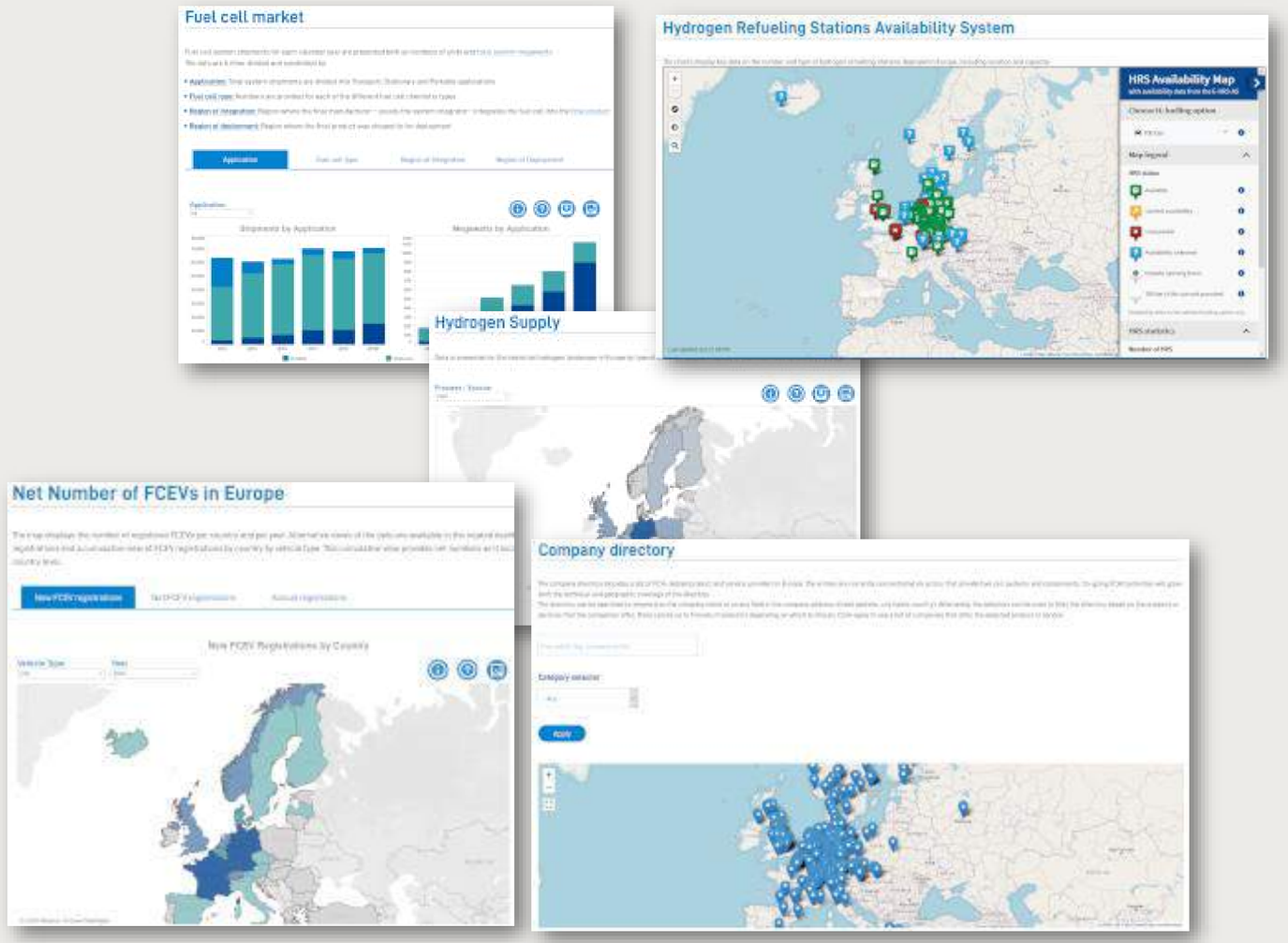
*A Pesa Gama locomotive*

# Fuel Cells and Hydrogen Observatory (Launched 15 Sept ’20)

One stop shop to understand where the FCH sector is at and how it is evolving

- **Go to resource for all things on fuel cells and hydrogen**
- **User friendly and reliable output**
  - charts, graphs and data downloads
  - reports
- **It covers**
  - Technology & Market
  - Policies & regulation
  - Codes & Standards
  - Patents & Publications
  - Funding
  - Education & Training
- **Global resource**
- **www.fchobservatory.eu**

  *info@fchobservatory.eu*




@FCHObservatory

The Fuel Cells and Hydrogen Observatory has been prepared for the FCH 2 JU under a public procurement contract

# European Hydrogen Safety Panel (EHSP) initiative

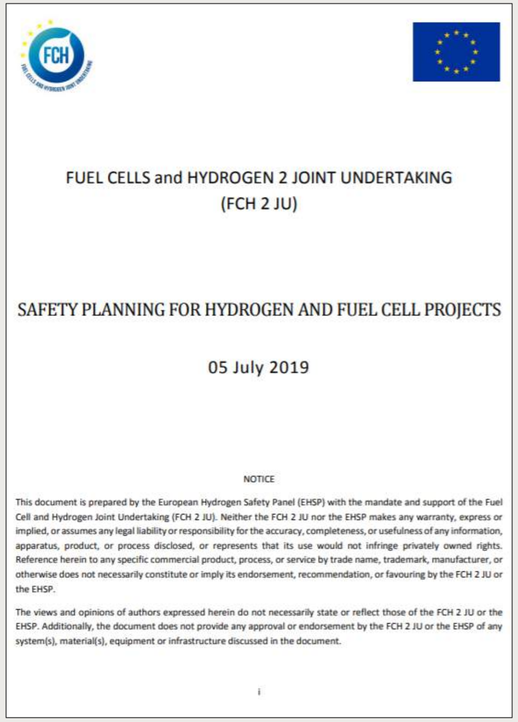
Expert group on hydrogen safety assisting the FCH 2 JU at project and programme level

## EHSP Launched and running!


**16 experts from industry & research**

**Assuring that H2 safety is adequately handled**
**Promoting and disseminating H2 safety culture**

**The EHSP released the first 2 reports on:**
**- Safety planning in FCH projects**
**- Lessons learnt from HIAD**



FUEL CELLS and HYDROGEN 2 JOINT UNDERTAKING
(FCH 2 JU)

SAFETY PLANNING FOR HYDROGEN AND FUEL CELL PROJECTS

05 July 2019

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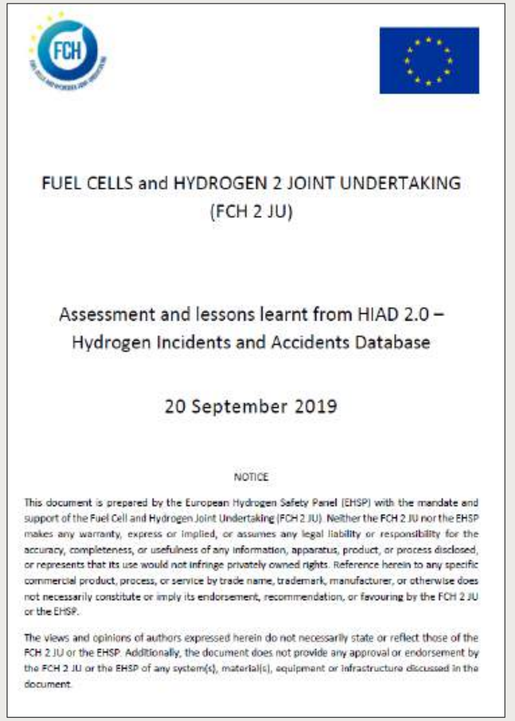

FUEL CELLS and HYDROGEN 2 JOINT UNDERTAKING
(FCH 2 JU)

Assessment and lessons learnt from HIAD 2.0 – Hydrogen Incidents and Accidents Database

20 September 2019

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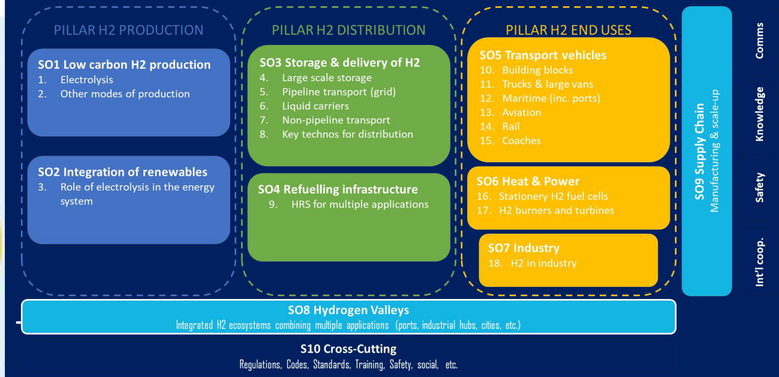
# Funding instruments at EU level

# Future European Funding opportunities for hydrogen

Depending on the project seize and goal, the right funding instrument should be chosen, FCH can help you


## New partnership: CLEAN HYDROGEN



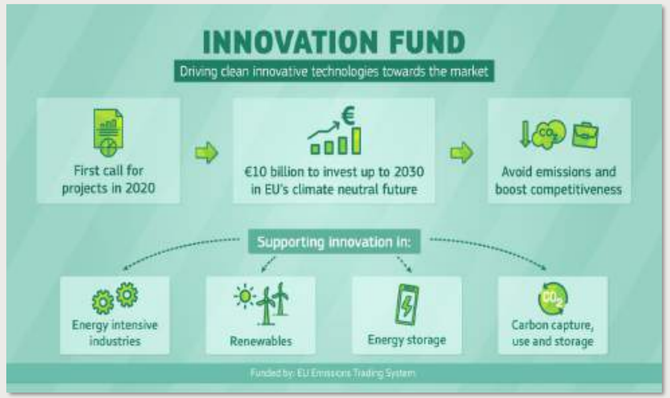

$H_2$ divided in 7 partnerships in EU:

- Clean Hydrogen
- Processes4Planet
- 2ZERO
- Zero Emission Waterborn
- Clean Steel
- Clean Aviation
- Europe's Rail: 600 m EUR

**Start expected end 2021 with an increased budget of 1 billion EUR**

Coordinated calls on:

1. Shunter demonstrators
2. Hydrogen storage
3. Refueling protocols
4. Hydrogen logistics by train

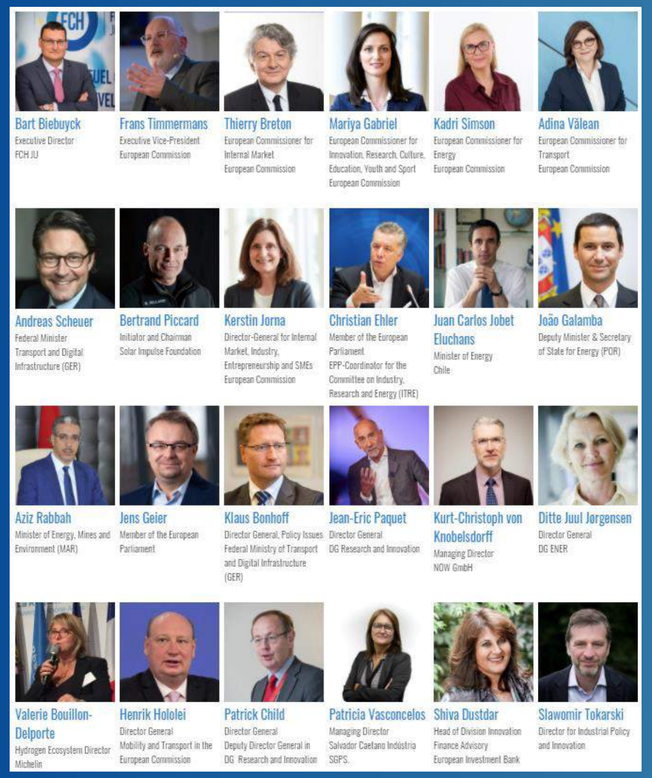





# The 1st European Hydrogen Week

A huge success with many high level speakers

## More than 10.000 people from 63 countries joined





The 2nd European Hydrogen Week + Launch of Clean $H_2$ JU

29th Nov. – 3rd Dec. 2021

Brussels, Belgium

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING


**Bart Biebuyck**
Executive Director
Bart.Biebuyck@fch.europa.eu
@bart.biebuyck
Bart Biebuyck


## For further information

www.fch.europa.eu
www.hydrogeneurope.eu
www.hydrogeneurope.eu/research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Fch-ju@fch.europa.eu

FCH JU

INTERNATIONAL UNION
OF RAILWAYS

# Questions
# Discussion

Bart Biebuyck
Executive Director

**Thank you for your attention.**

INTERNATIONAL UNION
OF RAILWAYS

# HYDROGEN STATUS BELGIUM (BENELUX)

## WaterstofNet


**Isabel François**
Project manager WaterstofNet

May 12, 2021

# Outline

- Introduction WaterstofNet
- Activities in road transport BE/NL
- Planned hydrogen infrastructure – large scale production – import
- Hydrogen trains in our region?

# WaterstofNet: more than 10 years of H2 experience

°2009, 13 persons

Based in Turnhout (BE) en Helmond (NL)

4 pillars

- ✓ Network: Industrial cluster
- ✓ Project organisation
- ✓ Advice to policy makers
- ✓ Knowledge: studies, advice to companies, …

Hands-on experience: HRS Helmond, driving a H2 ca

# Waterstof Industrie Cluster


# Activities in road transport

H2 refuelling stations – buses – heavy duty

# First Hydrogen refueling station Halle –B

Realisation hydrogen station at Colruyt Group (Halle, near Brussels)

Hydrogen regio Flanders - South of the Netherlands

Electrolysis 2012


**Expansion of filling station to Smart Grid environment**

Don Quichote

2012-2017

Expansion hydrogen station to public station 700 bar

Hydrogen region 2.0

2017-2019

Interreg Vlaanderen-Nederland
Europees Fonds voor Regionale Ontwikkeling

# First Hydrogen refueling station in Helmond (NL)

WaterstofNet

**Operation of the hydrogen station at the Automotive Campus in Helmond (Nl)**

Hydrogen region

2013 + expansion in 2018






# Creating a HRS-network…

8 hydrogen stations in the BeNeLux

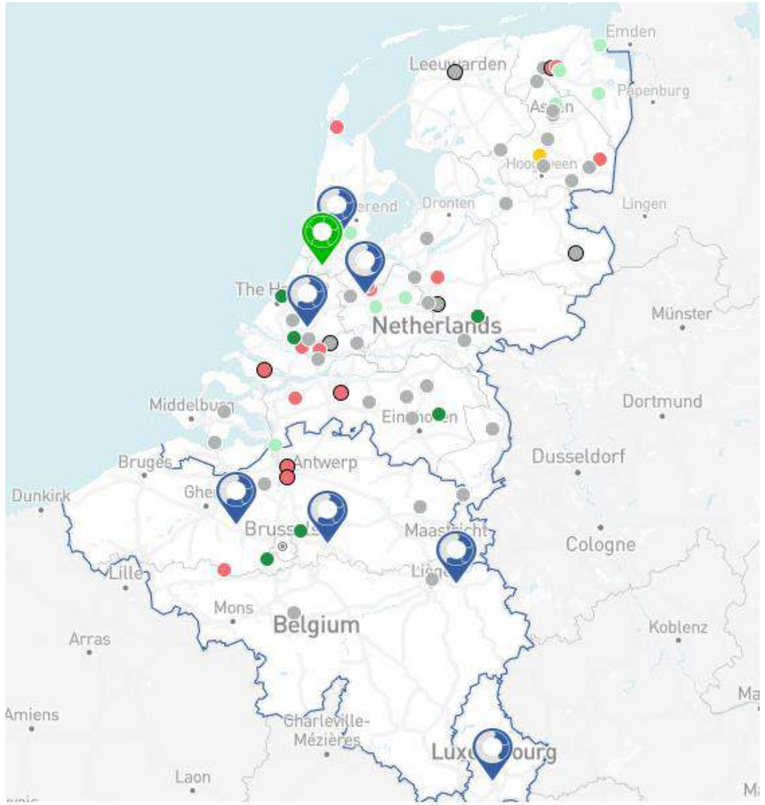
H2Benelux

READ MORE


Development and construction of 2 hydrogen filling stations in Wilrijk and Breda (Nl)

Hydrogen region 2.0

READ MORE


Current status @ https://h2benelux.eu/

Co-financed by the European Union
Connecting Europe Facility

Interreg
EUROPESE UNIE
Vlaanderen-Nederland
Europees Fonds voor Regionale Ontwikkeling

# Hydrogen buses, built (and driving) in our region


5 buses driving in BE: Antwerp
Tram-bus built by Van Hool,

https://www.fuelcellbuses.eu/

# Hydrogen garbage trucks, built & demonstrated in our region



Driving in Groningen, Amsterdam, Best (NL),
Being tested in Breda,
To be demonstrated on short term in Antwerp (BE)

# Hydrogen trucks, built & demonstrated in our region



Being tested by Colruyt (BE),

## Hytrucks project

## Air Liquide and Port of Rotterdam Authority: hydrogen road transport

Air Liquide and the Port of Rotterdam Authority announce the launch of a jointly created initiative, which aims at enabling 1,000 hydrogen-powered zero-emission trucks on the roads connecting the Netherlands, Belgium, and West Germany by 2025. Several partners representing the whole

Port of Rotterdam

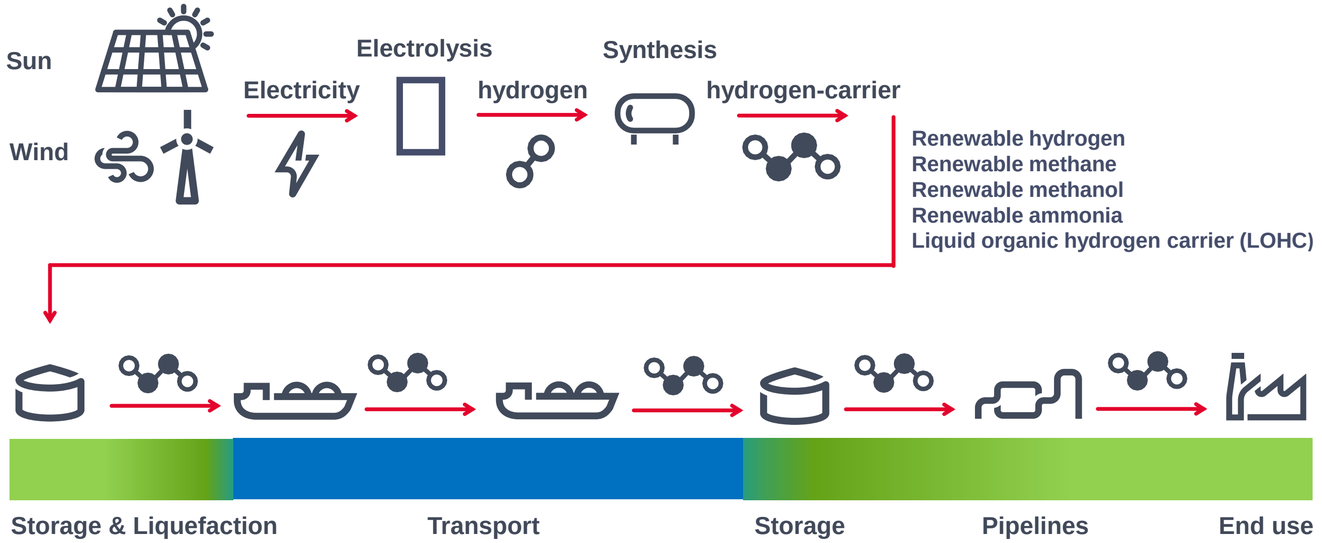
Port of Antwerp

duisport

# Planned H2-infrastructure - large scale production - import

# Will there be sufficient hydrogen in BE/Europe?

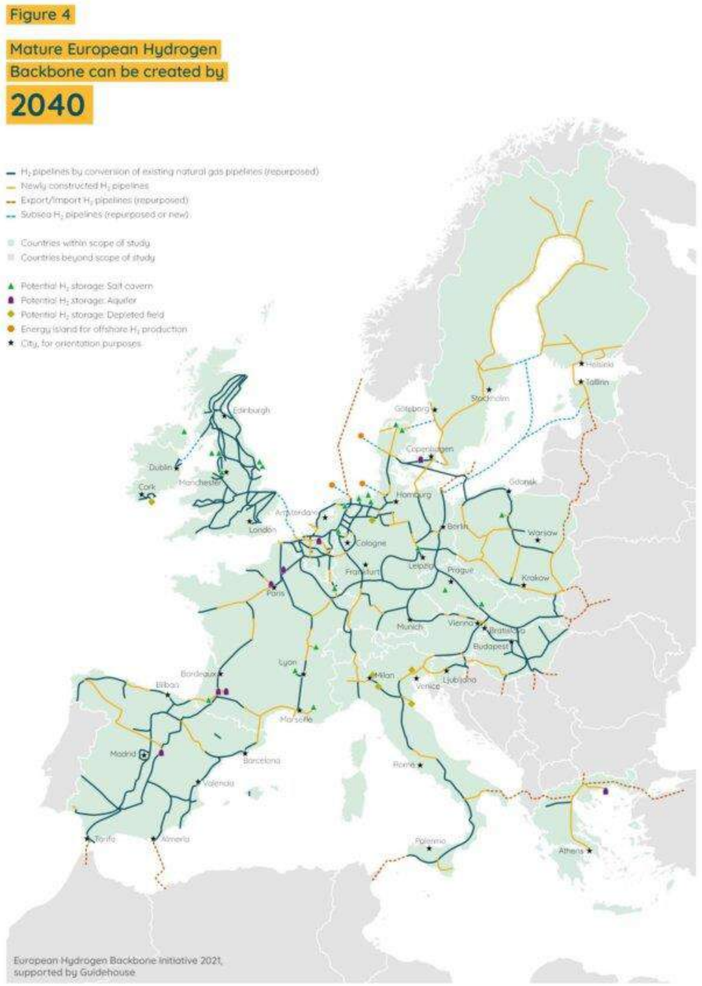
## Domestic production but also large scale import

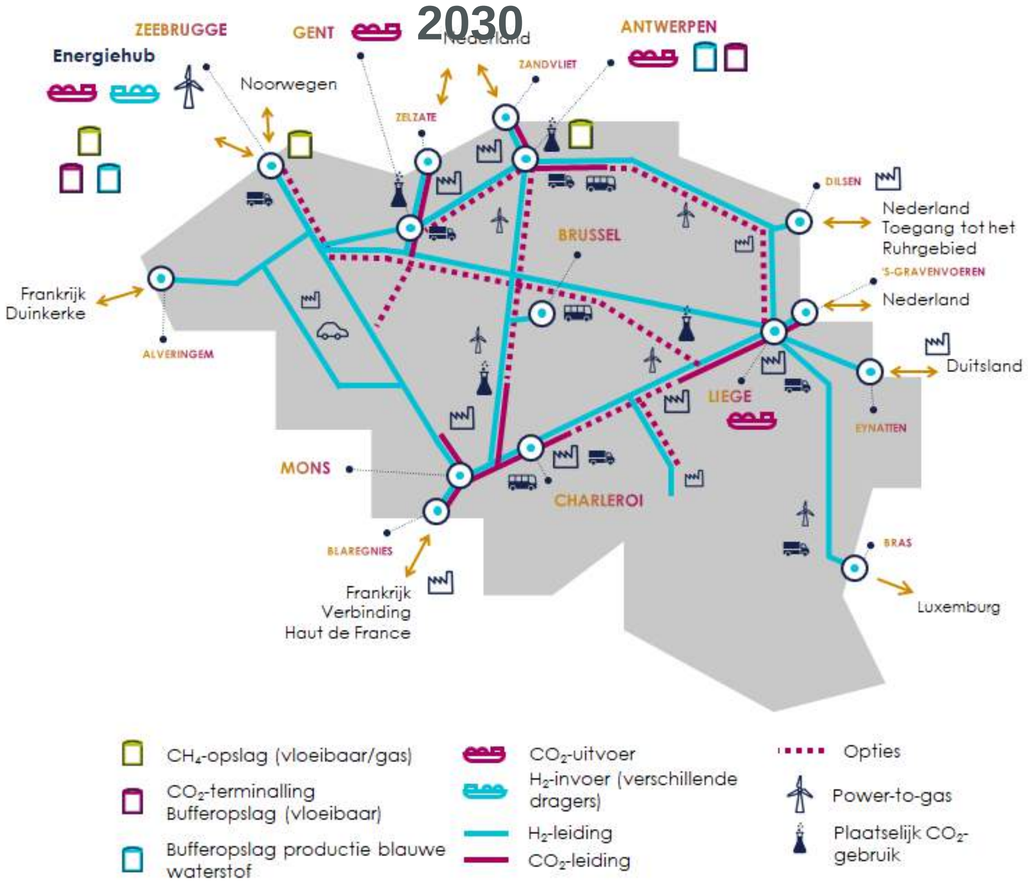




Import technically and economically feasible from 2030

(Hydrogen Import Coalition)

# Transport of hydrogen in EU/BE

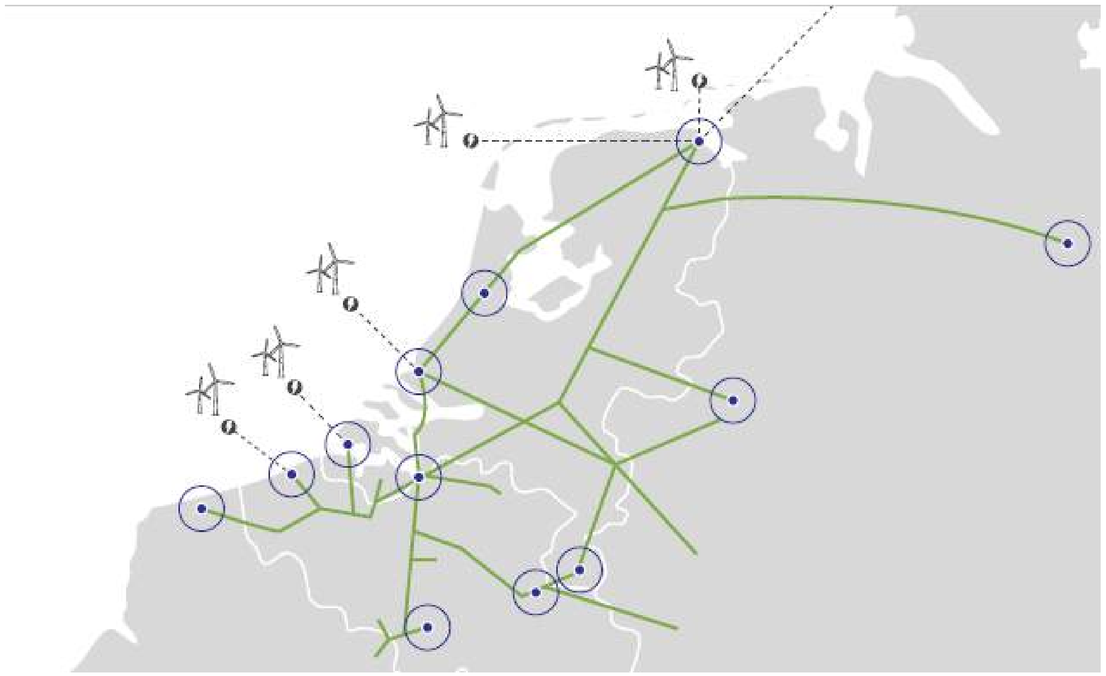



Bron: Fluxys

# Connection with neighbouring countries

## “Green Octopus” initiative



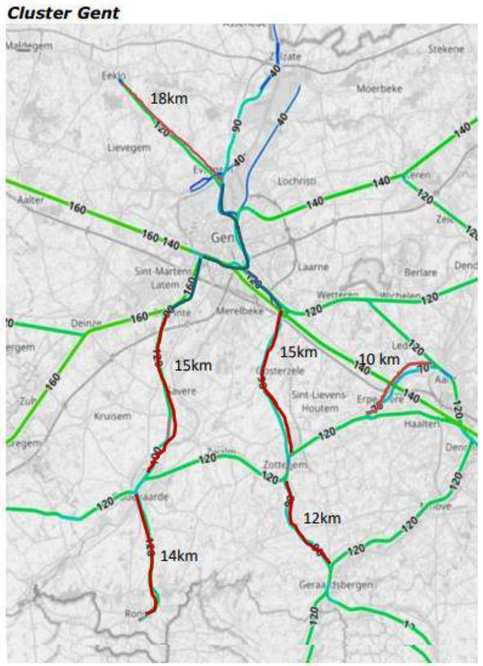
| Project Title | Expected Plant Capacity | | |
|---|---|---|---|
| | 2020 | 2025 | 2030 |
| Djewels, Delfzijl | 20 MW | 100 MW | |
| HyNetherlands, Eemshaven | 100 MW | | 1000 MW |
| PowertoMethanol, Antwerp | 10 MW | | 100 MW |
| Hyoffwind, Zeebrugge | 25 MW | | |
| Zeeland Refinery/Yara, Vlissingen, Sluiskil | 2 *100 MW | 690 MW | 1000 MW |
| VoltH2, Vlissingen | 25 MW | | 100 MW |
| North-C-Methanol, Rodenhuize | 63 MW | | 600 MW |
| H2.50, Rotterdam | | 250 MW | |
| H2 Plant (Shell), Rotterdam | | 200 MW | |
| HyPort, Oostende | 50 MW | | 300 MW |
| H-Vision, Rotterdam | | 750 MW | |
| NortH2, Groningen | | | 3000 MW |
| Hzermes, Ijmuiden | | | 100 MW |
| Green hydrogen production, Emsland | 50 MW | | 500 MW |
| Coal to green hydrogen, Port of Hamburg | | 100 MW | |
| Westküste100, Hemmingstedt | | 30 MW | 700 MW |
| Hybridge, Emsland | 100 MW | | |
| Element Eins, Lower Saxony | | | 100 MW |
| HySynGas, Brunsbüttel | | 50 MW | |
| Power-to-Gas, BW Bürgerwindpark Fehndorf / Lindloh GmbH & Co. KG | 67,2 MW | | |
| HydrOxy Hub, Walsum | | 500 MW | |
| Energiepark, Mainz | 6 MW (started in 2018) | | |
| Energy Park, Bad Lauchstädt | | 30 MW | |

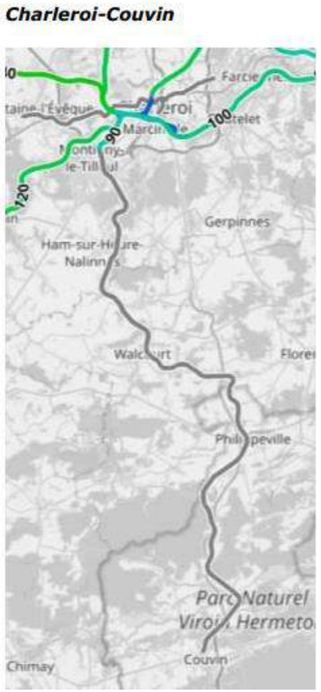
*Figure 4.1. Announced large-scale electrolyser plants in the region[2]*

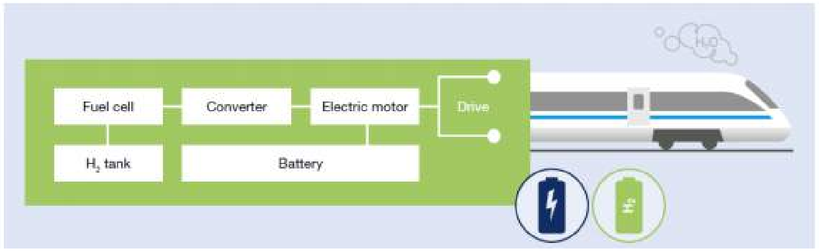
# Hydrogen trains?

# H2-trains as alternative for Diesel trains in BE?

- Two regions in BE without electrification



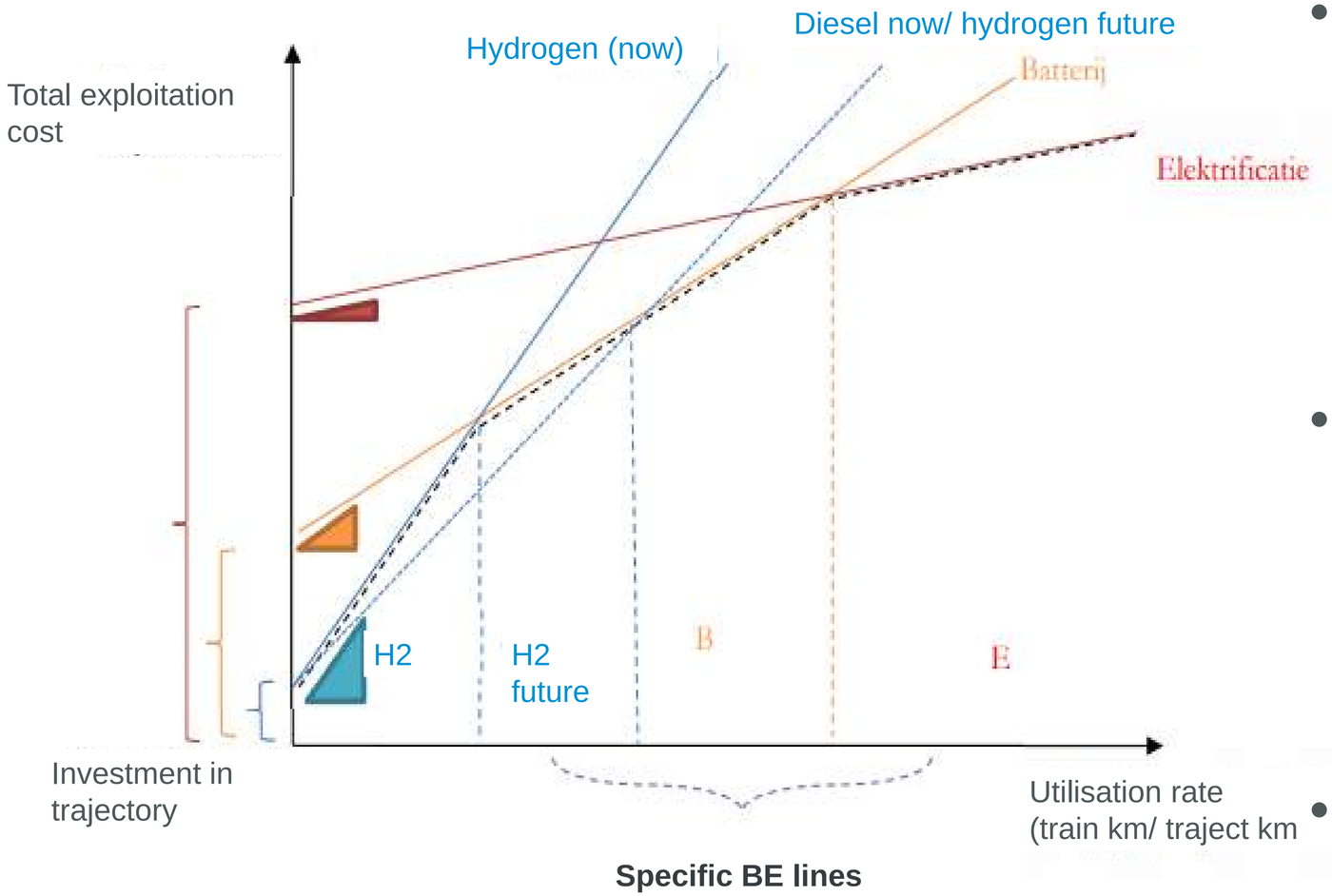




- Study TML for Belgium (commissioned by fed. Gov.)
https://www.railjournal.com/fleet/full-electrification-best-suited-to-replace-diesel-traction-on-belgian-network-study-finds/ (complete study only in Dutch)

- Comparison of
  - Electrification (overhead catenary) - Battery-electric (with partial electrification) - Hydrogen train

# H2-trains as alternative for Diesel trains in BE?(2)



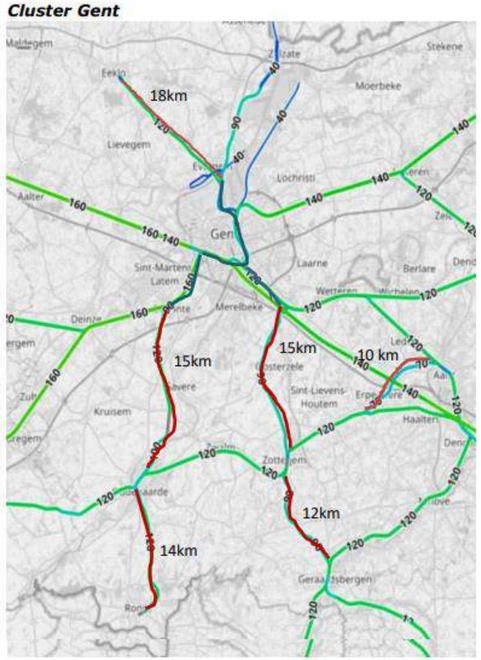



- Balance between
  - Investment costs of the train
  - Investment costs infrastructure
  - Energy cost
  - Maintenance costs

  } utilisation rate!
- Electrification best choice for BE trajectories (cfr TML study) ? =>under discussion (input par.?)
- Synergy with H2 ecosystems for affordable H2 supply

# H2 trains in Gent region?

## Synergy with H2 ambitions in North Sea port


**<u>Available</u>**:
Studies
Examples/test results/BC calculations
DE and NL

**<u>Required:</u>**
Political engagement

**Ørsted North Sea Port to develop one of the world's largest sustainable hydrogen plants for Dutch and Belgian industry**

Published on Thu 1 Apr 2021

On Wednesday 31 March, Ørsted presented 'SeaH2Land', their ambitious vision for a Gigawatt-scale sustainable hydrogen plant. In other words, how a North Sea Port cross-border pipeline will connect the large industrial demand for hydrogen with the sustainable production of hydrogen.

# Technologies

- Fuel cells
- Dual fuel as a transition technology?
  - Retrofit of existing engines


# Conclusions



- Technology for refuelling of road applications available
- Large scale infrastructure & import of hydrogen are planned
- Hydrogen backbone connecting ports & industry clusters
  => Hydrogen will be available in large volumes and reasonable cost
- Different technologies: fuel cells versus combustion (dual fuel)

INTERNATIONAL UNION
OF RAILWAYS

# Questions
# Discussion

Isabel François
Project manager WaterstofNet

**Thank you for your attention.**

INTERNATIONAL UNION
OF RAILWAYS

# BREAK

# Break

## *Restarting at 11h00*

**Online workshops coming up next:**

- 19 May 2021 – 10:00-12:00
  **Battery trains**

*https://uic.org/events/battery-trains*

*Call for speakers on static energy storage, workshop in September 2021, contact stefanos@uic.org*






# Break

*Railways and UIC members are invited to join the*

## UIC project:

## “H2TR - Operating hydrogen powered trains”

*In partnership with the IEC*


*If interested, please reach out to stefanos@uic.org*

*Restarting at 11h09*

INTERNATIONAL UNION
OF RAILWAYS

# ROLLING STOCK

## Is hydrogen the answer?


**Robert DAVIES**
Global Rolling Stock Leader - Arup

# Rolling Stock



| |
|---|
| Welcome to Arup |
| Is hydrogen the answer |
| Why hydrogen |
| Infrastructure |
| Supply network |
| Hydrogen potential |
| Whole life costs |
| Entry into service |
| Future proofing |
| Conclusions |

# Welcome to Arup

Arup is an independent firm of designers, planners, engineers, consultants and technical specialists, working across every aspect of the built environment.

Together we help our clients solve their most complex challenges – turning exciting ideas into tangible reality as we strive to find a better way and shape a better world.

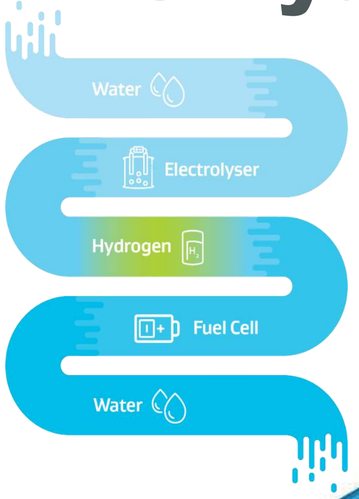
We

- Design quality infrastructure and experiences for people and communities
- Deliver major programmes and develop high performing organisations
- Integrate complex new technologies and systems
- Unlock financial value for investors, asset owners and operators
- Optimise performance and value from existing and new assets

# Rolling Stock – Is Hydrogen the answer

## Why hydrogen

- Sustainable
- Emission neutral
- Autonomous power
- Go anywhere
- Suppliers ready
- Business case



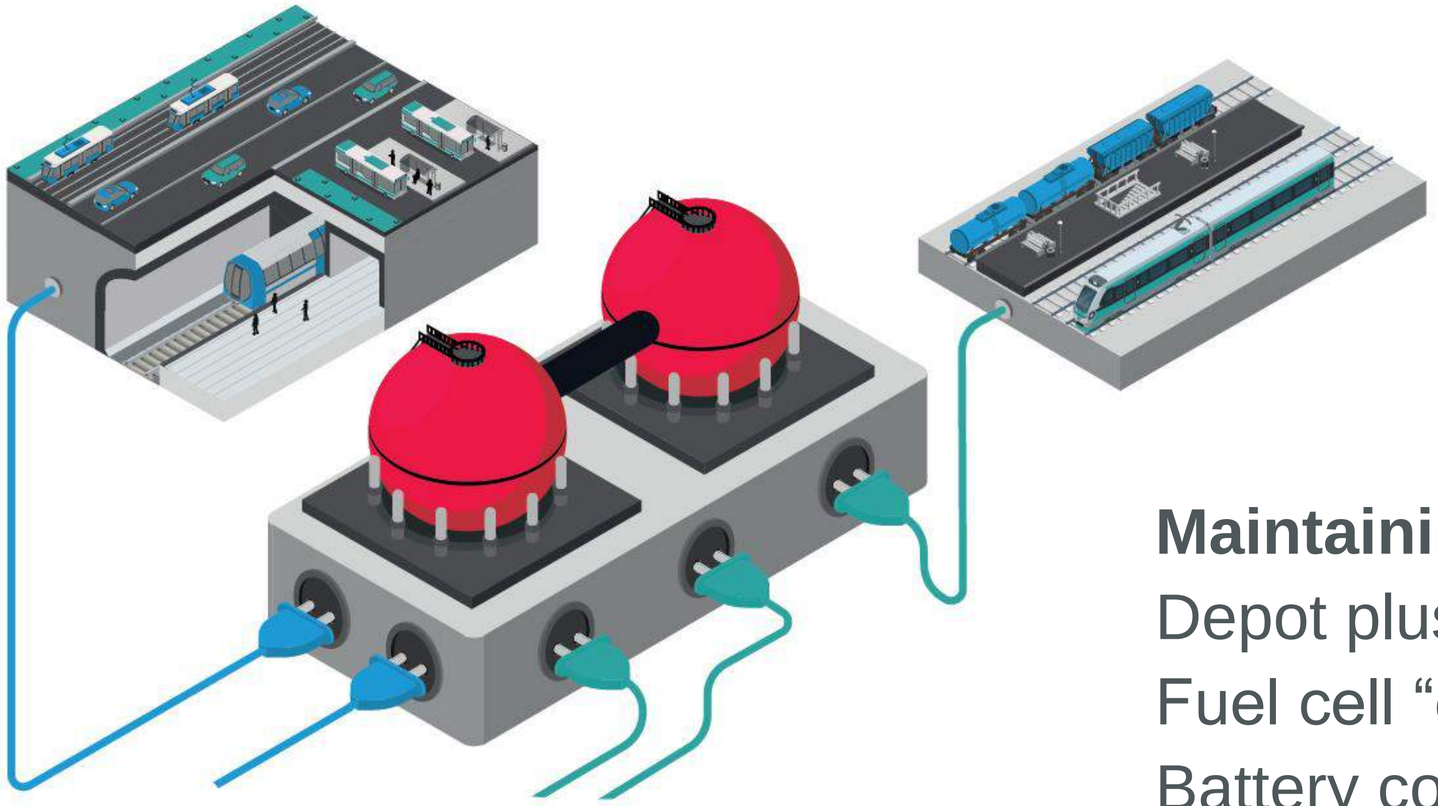



## New Build or Retrofit

## Specification

- Performance
- Range
- Capacity
- Design life
- Future proofing
- Infrastructure
- Whole life cost

# Hydrogen infrastructure – what do we need



**Servicing hydrogen trains**

Network fuel point locations

Dedicated or shared supply

Existing update or renew

**Maintaining hydrogen trains**

Depot plus

Fuel cell “engine”

Battery conditioning

High pressure storage vessels

Fuel connections

# Hydrogen network – how do we feed

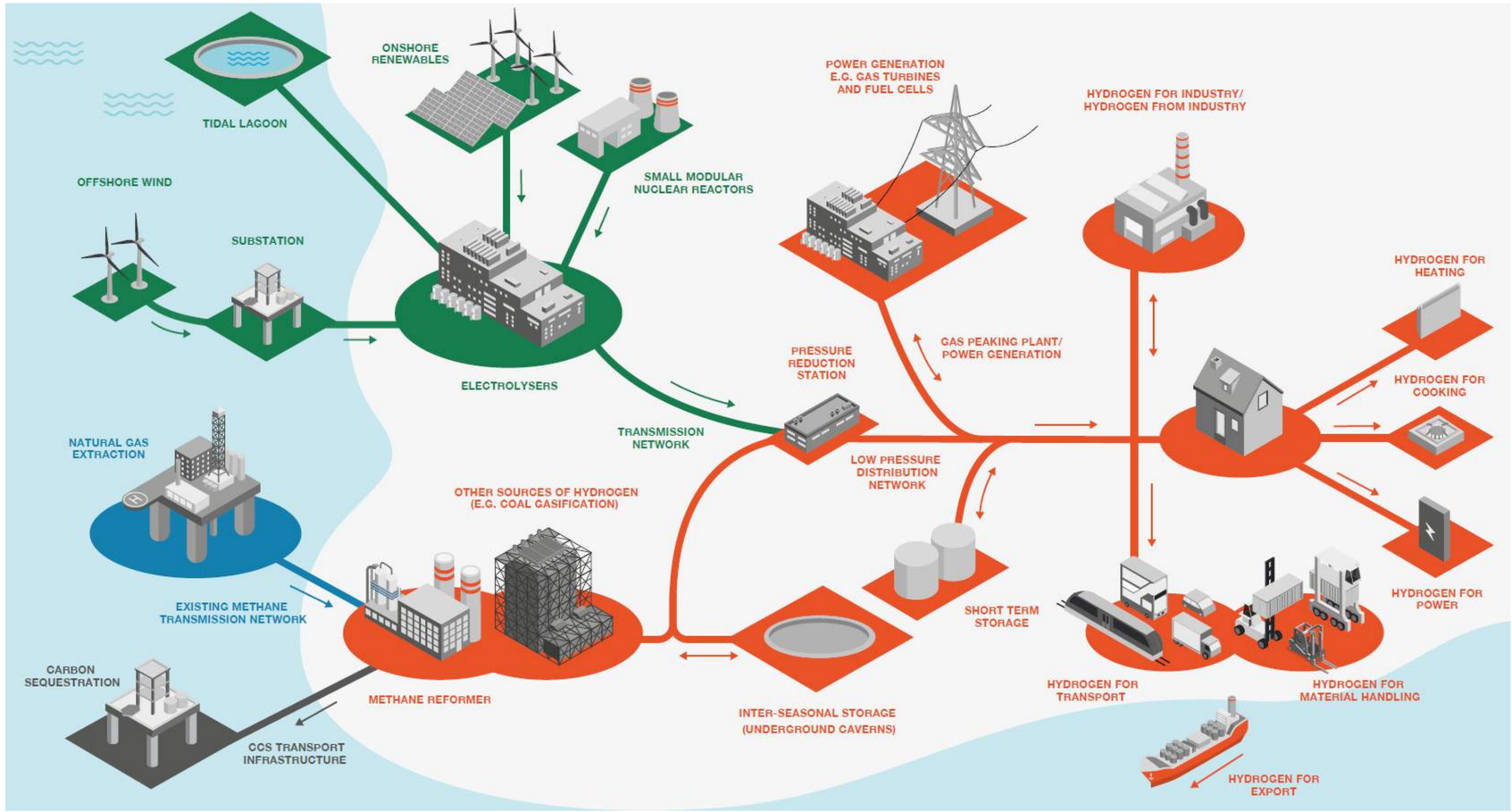
**Network supply**

Green, Blue or Grey

Surge capacity

Grid

Local distribution

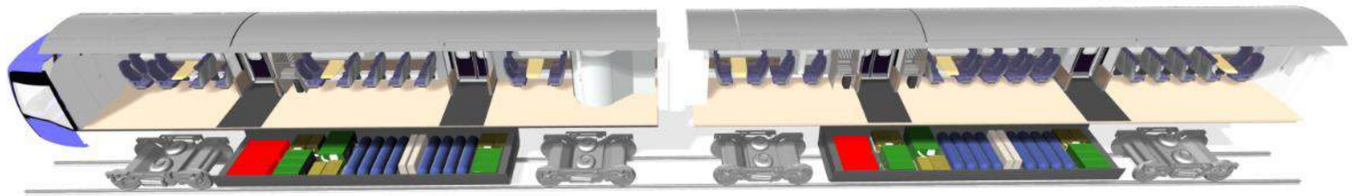



**Sustainability**

Driven by supply credentials

# Hydrogen potential – what can we achieve

## Fuel cell performance today



New build or retrofit packaging

120 to 140 km/h passenger trains with 500-800km

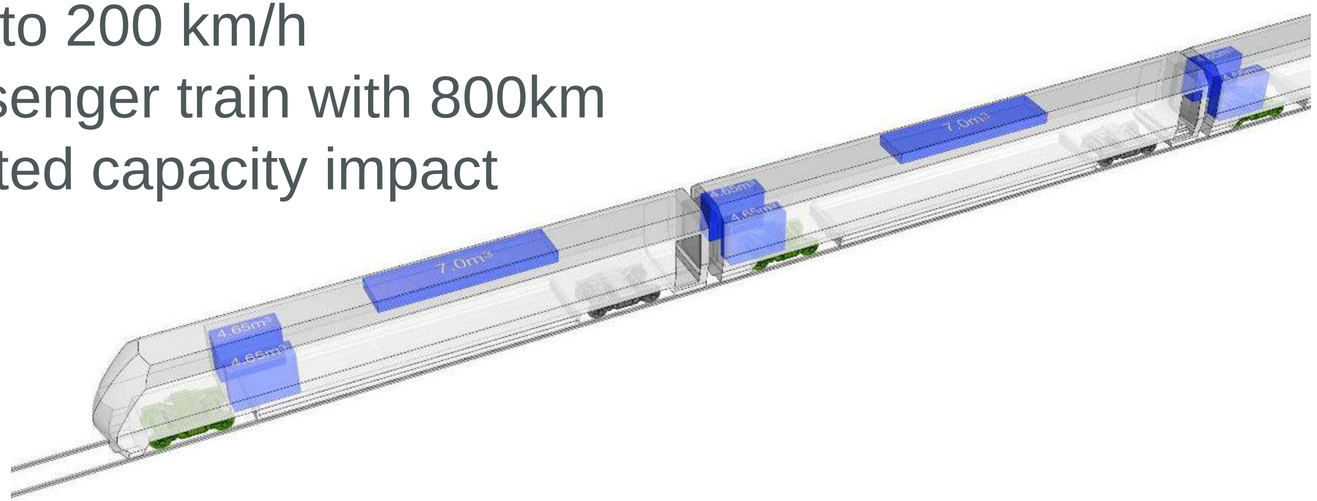
100 to 120 km/h heavy haul with 200-300km

## Fuel cell potential

160 to 200 km/h

passenger train with 800km

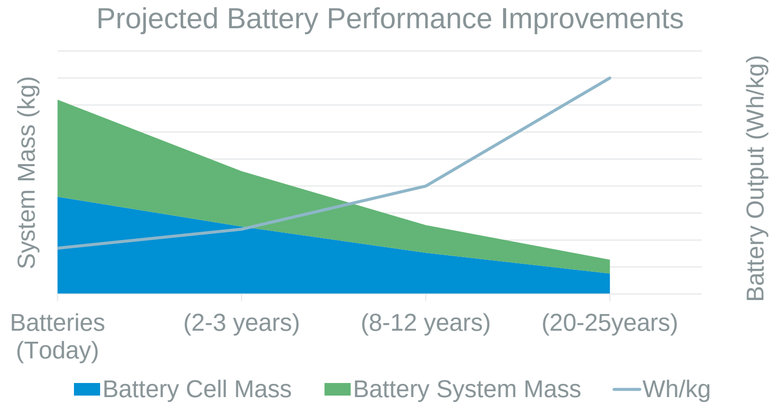
Limited capacity impact




## Technology watch

Fuel cell sub-system

Energy density



# Hydrogen costs – whole life view

Comparison with a diesel service

## Direct costs

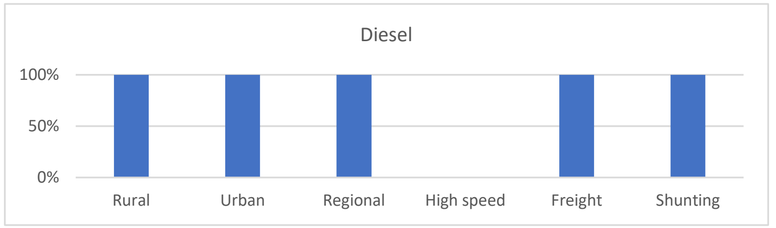
Capital investment
Maintenance
Energy consumption
Operations

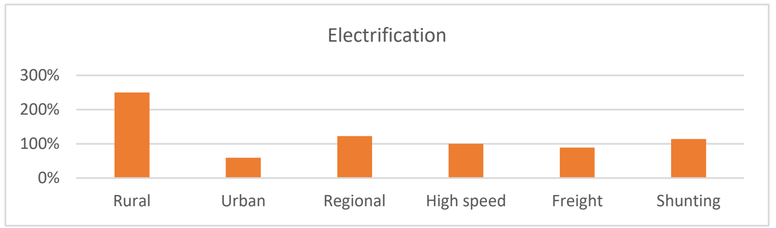
## Indirect costs

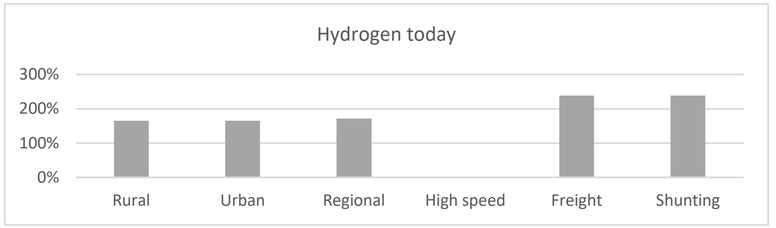
Carbon emissions
Air quality
Potential incentivisation

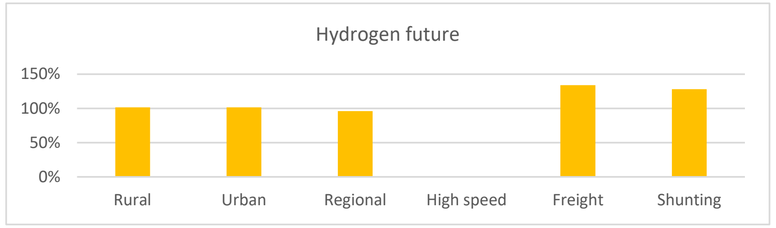
**Key**
Rural = low frequency
Urban = mass transit
Regional = intercity
High speed = very fast
Freight = heavy haul
Shunting = local haul

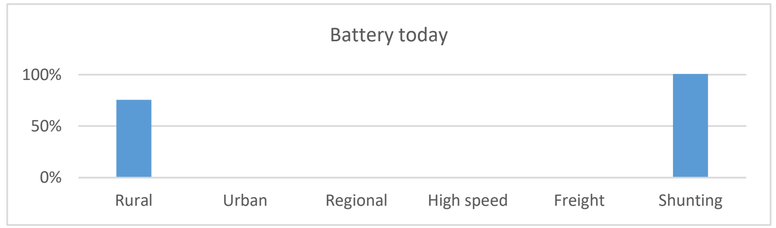
*High sensitivity to train utilisation*




**Direct cost example**

# Hydrogen – entry into service

## Emerging regulatory approach

Interoperability

Component regulation

Common safety method

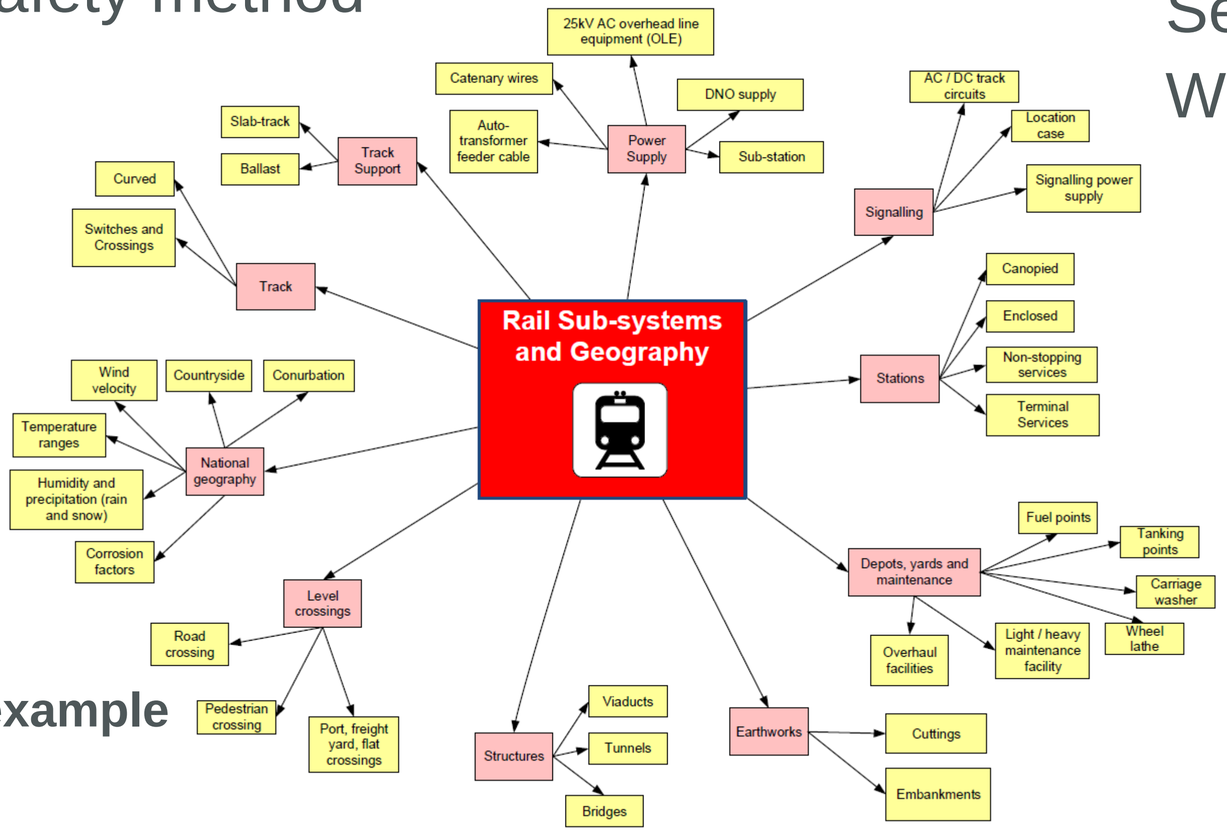
## Commercial investment

Technical

Performance

Service agreements

Whole life costs




## V&V

Fuel cell sub-system

Rolling stock system

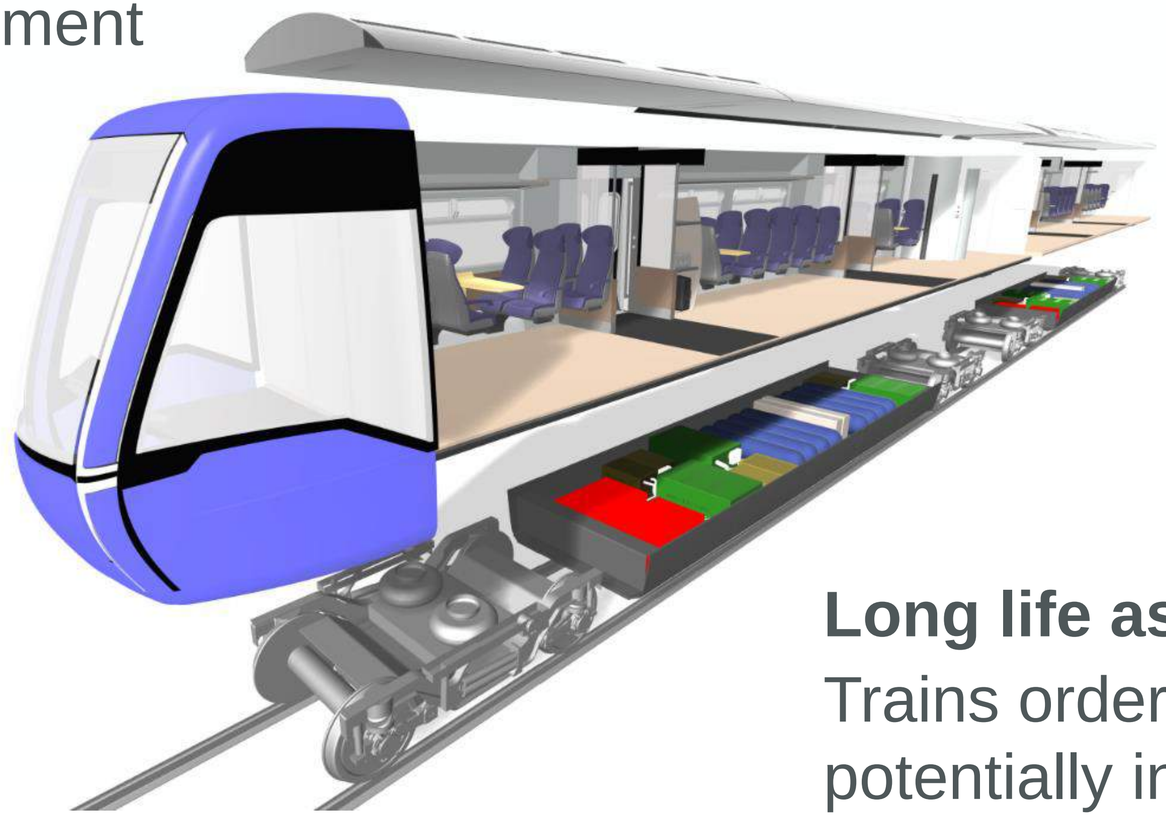
Rail systems integration

**Integration matrix example**

# Future proofing – investment risks

**Life cycle**
Technical maintenance maturity
Obsolescence management

**Modular design**
Can sub-systems be replaced by emerging technology



**Mode**
Single or hybrid

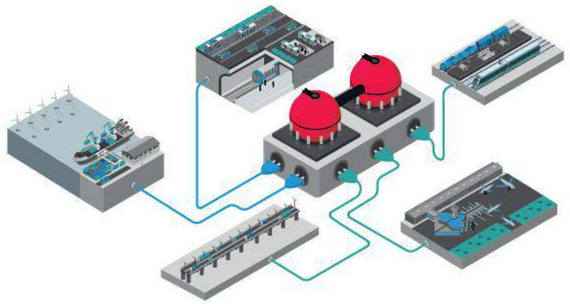
**Long life asset**
Trains ordered today potentially in service to 2060

# Thank you from the Arup team

ARUP

Hydrogen Transport -
Fuelling The Future

The Future of Energy



Arup University

**Research on hydrogen trains and possible applications**

Research Report

079000-79 Report

Final | 26 March 2021



Job number 079000-79

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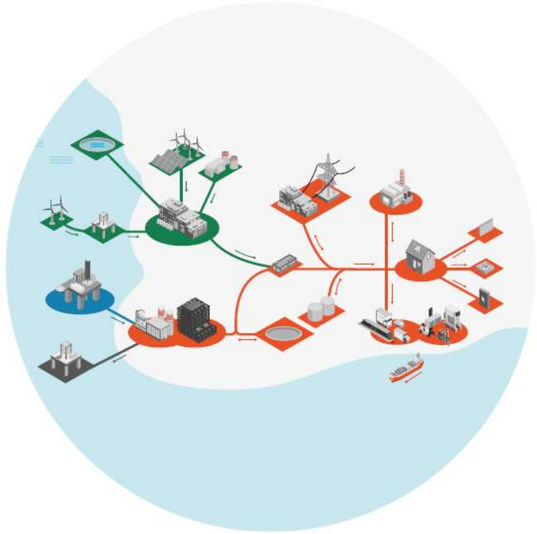
WE SHAPE A BETTER WORLD

Establishing a Hydrogen Economy

*The Future of Energy 2035*



www.arup.com/energy

INTERNATIONAL UNION
OF RAILWAYS

# Questions
# Discussion

Robert DAVIES
Global Rolling Stock Leader - Arup

**Thank you for your attention.**

INTERNATIONAL UNION OF RAILWAYS

# INTRODUCTION OF HYDROGEN TRAINS IN THE NORTHERN NETHERLANDS

## In the context of Emission Free Rail transport


**Michiel Deerenberg**
ProRail Innovation

*UIC Webinar Hydrogen Train, May 12th, 2021*

# Introduction

Michiel Deerenberg
michiel.deerenberg@prorail.nl
+31619132311

ProRail - Project Manager Innovation

- Test Hydrogen Passenger Train
- Test Pantograph-Battery Passenger Train
- Pilot Pantograph-Battery Freight Locomotive

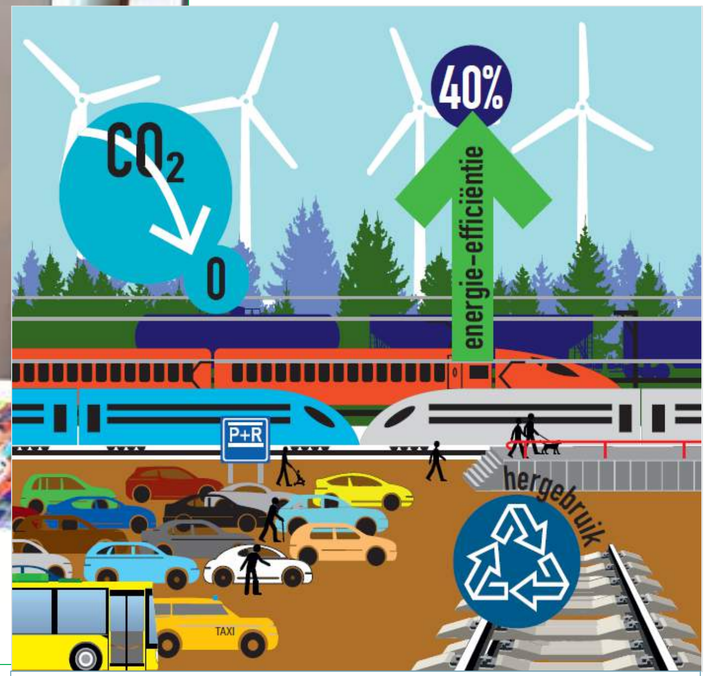
Experience

- Working in the Dutch railway sector for almost 30 years

# Main message for this webinar

- To demonstrate that it is possible to run a hydrogen train in the Netherlands we could suffice with a temporary test dispensation.
- We didn’t need a full admission of a homologated hydrogen train.
- Applicable in your country?

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11




**Together we achieve a Dutch carbon free rail sector**

*Vision 2050*

# Dutch rail infrastructure: 20% is not electrified

Total length of the rail network : 3434km

**Electrification (80%)**

- Large part 1,5kV DC (red lines);
- Non-mixed part High Speed Line and Freight Line Betuweroute is 25kV AC (blue lines).

**Not electrified (20%)**

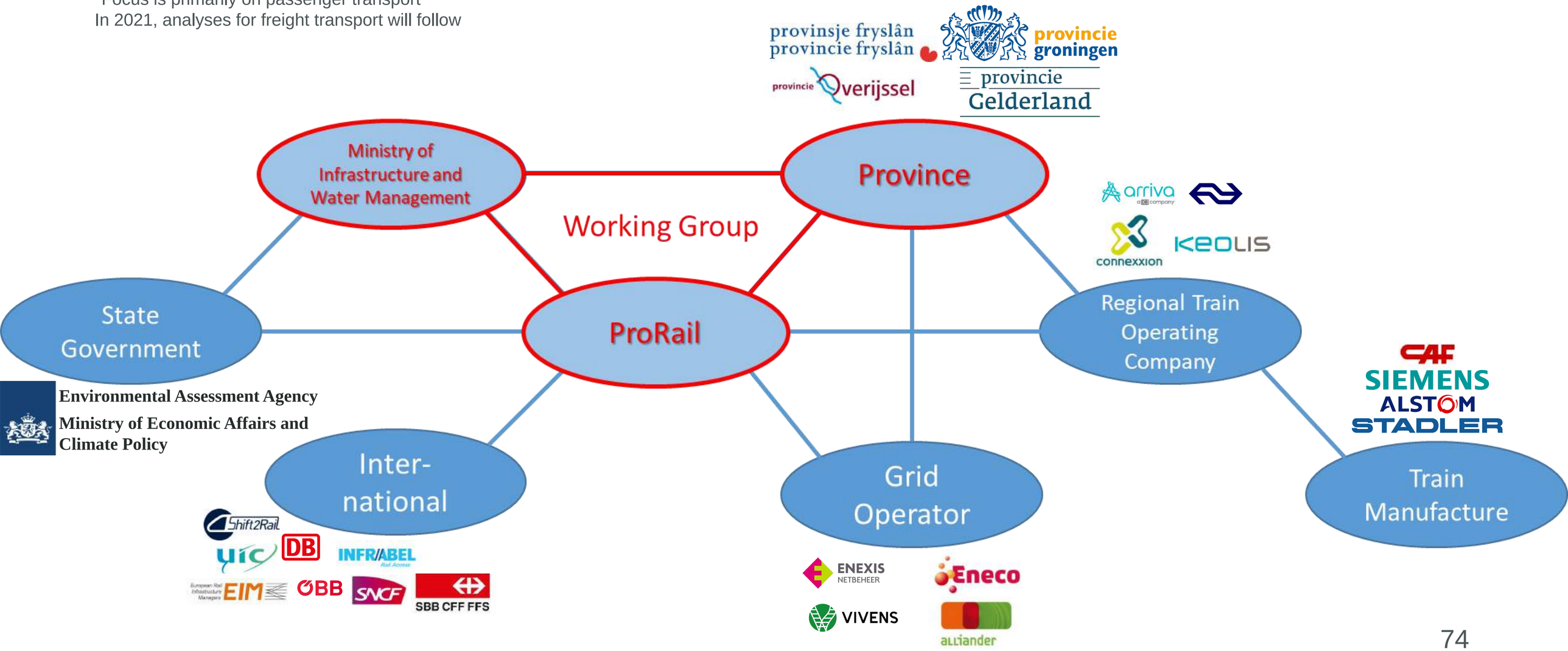
- In the North, East and South of the Netherlands, 572km of track is not electrified (black lines);
- Port areas of Amsterdam, Rotterdam, Moerdijk and Sloe are not electrified;

**$CO_2$ emissions**

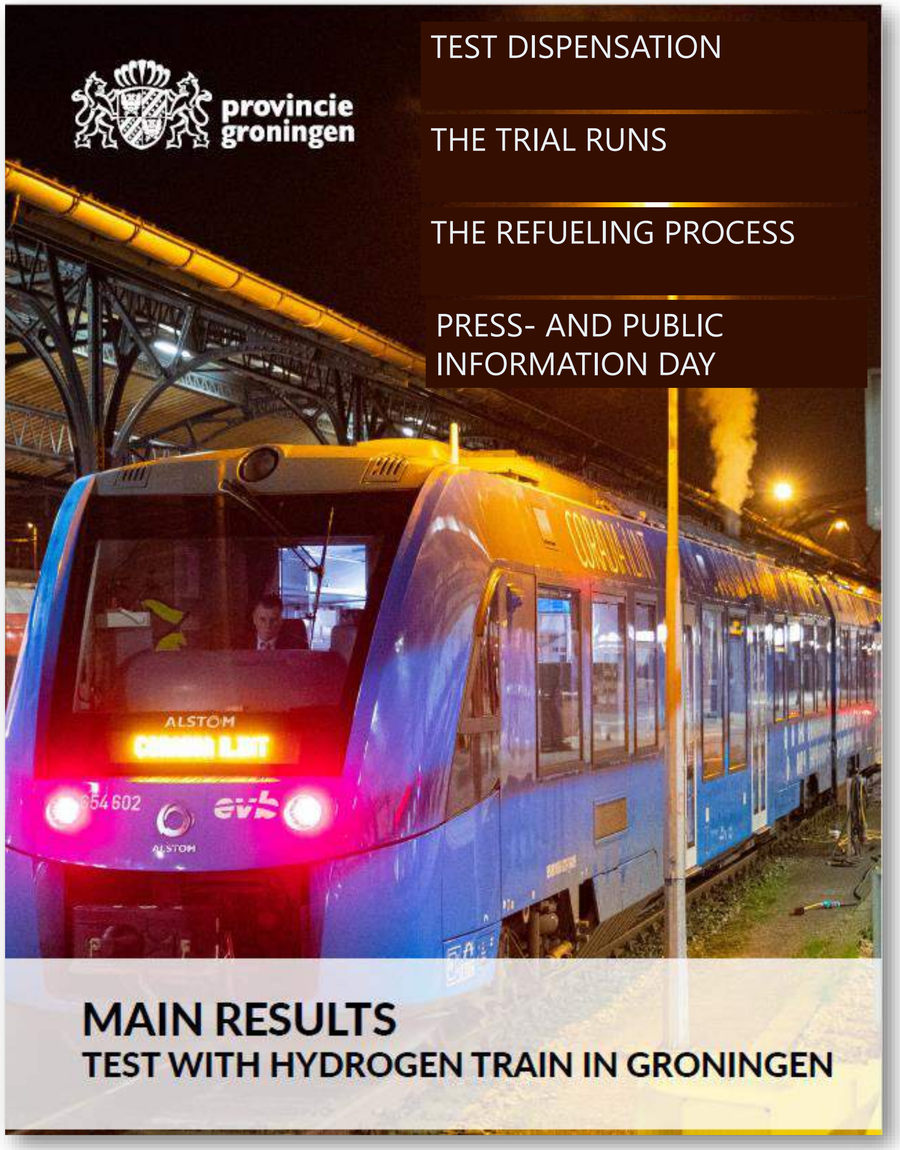
- Since 2017 all electrical trains run on renewable wind energy
- Annually about 85 ktons of $CO_2$ eq. (≈ 4.2 Million trees);
- About 2/3 by passenger and 1/3 by freight transport;
- Roughly 30% of the $CO_2$ emissions of the rail sector.

# From vision to action plan* through building a knowledge (network) and cooperation

*Focus is primarily on passenger transport
In 2021, analyses for freight transport will follow



# First concrete cooperation: Proof of Concept $H_2$ train




Excellent cooperation with our partners

- Each with its own responsibility and role

provincie groningen, arriva a DB company, ALSTOM, ENGIE, DEKRA, ProRail

Various business units ProRail involved, each with its own responsibility and role

- Traffic control
- Incident management
- Asset management
- Capacity management
- Environmental Management
- Projects
- Relationship management/Communication
- Innovation

Mindset: ‘How can it be done?’

Approach: Learning by doing

Keys: Cross Acceptance and Temporary Local Test Permit

# Original plan (July 2018)

- In the context of European Capital of Culture 2018
- Borrow a hydrogen train (Coradia iLint) from Alstom
- Make use of the German admission of the train
- Get temporary Dutch admission for driving and refuelling
- Install Dutch Automated Train Control System in the train
- Install a temporary mobile refuelling station
- Run the hydrogen train, **with passengers**, during two ‘emission free’ weeks



**Obstacles**

- German admission not ready
- Installation Automated Dutch Train Control System → German admission invalid → German re-admission

# Reboot: New plan (March 2020)

- Borrow a hydrogen train (Coradia iLint) from Alstom
- Make use of the German admission of the train
- *Describe and implement safety measures and procedures (like ‘Non Detecting Rolling Stock’ and ‘Railway Crossing Failure’)*
- *Obtain a temporary testing permit (instead of admission)*
- Get a temporary admission for refuelling
- Install a temporary mobile refuelling station
- *Run the hydrogen train, **without passengers**, during night times for a period of two weeks*
  - *In train free periods (nights)*
  - *With strict shunting procedures*
  - *With second driver that replaces Dutch Automated Train Control System*

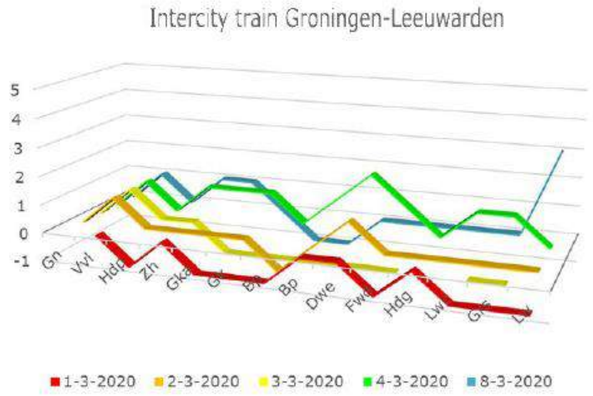
# Testplan

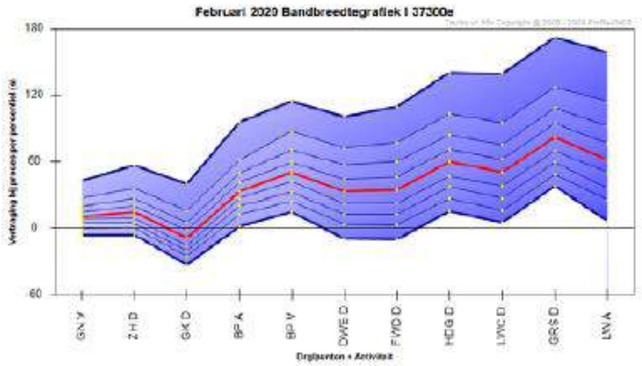
- ✓ Towing Coradia iLint – GTW DMU
- ✓ Correct detection
- ✓ Vehicle stability in relation to rail-installation inclination (risk of derailment)
- ✓ Feasibility of current timetables
- ✓ Ambient noise in a comparative measurement study Coradia iLint – GTW DMU.

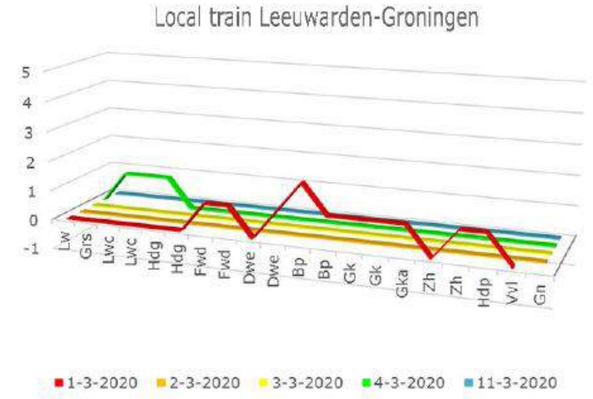


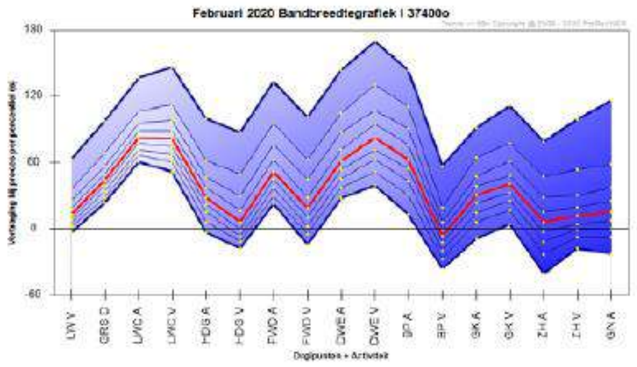
# Feasibility of current timetables

Local- and intercity train services were tested multiple times



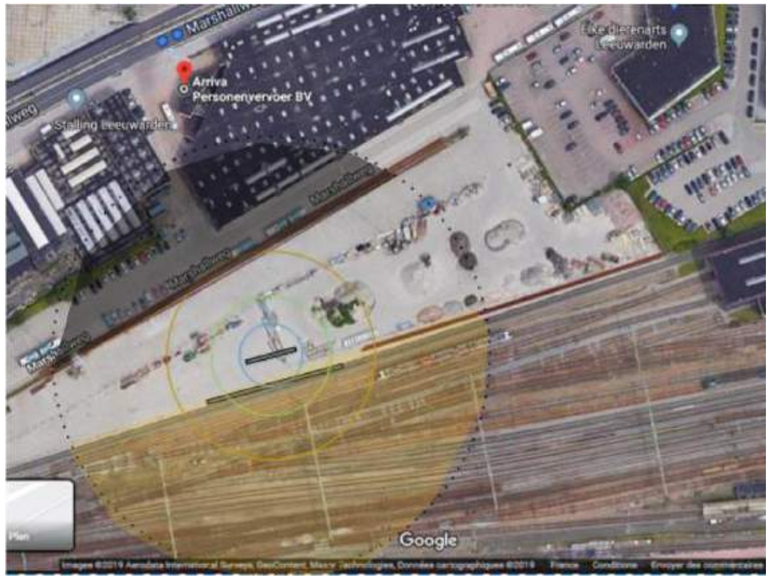




**Conclusion**: the hydrogen train is capable of operating according to the planned timetable of the GTW DMU.

# Mobile refuelling

Safety measures (like earthening the rail, concrete blocks, 24x7 security) and procedures (like ‘No tresspassing while refuelling’)





# Press and Public Information Day


# Press and Public Information Day

# Next steps

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## Hydrogen trains will replace diesel units in Groningen

Published on 01-10-2020 at 09:10

The Dutch province of Groningen will deploy hydrogen trains on its tracks in the year 2024. The Wunderline to Germany is one of the tracks on which the train can be deployed. A feasibility study showed that a hydrogen train is a viable alternative for the current diesel train. It will be the first time in the Netherlands that a hydrogen train will be used in passenger service.

RailTech.com

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## Europe funds hydrogen train in the Netherlands with 25 million

Published on 26-04-2021 at 10:38

The European Investment Bank (EIB) will fund 25 million euros for the purchase of four hydrogen trains and the construction of a hydrogen filling station in Groningen in the Netherlands. The amount is part of a 3.4 billion euro investment package in sustainable development. Of this, 700 million euros are spent on sustainable mobility.

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OF RAILWAYS

# Questions
# Discussion

Michiel Deerenberg
ProRail Innovation

**Thank you for your attention.**

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# ALSTOM

## Coradia iLint


**Andreas Frixen**


# Coradia iLint

# UIC Hydrogen Trains

Andreas Frixen

May 12, 2021

ALSTOM
• mobility by nature •

# Alstom’s Coradia iLint – Accomplishments so far

**2014** **2015** **09 / 2016**

Prestudies → Production & Commissioning → Testing & Validation

**First Train @ Innotrans**

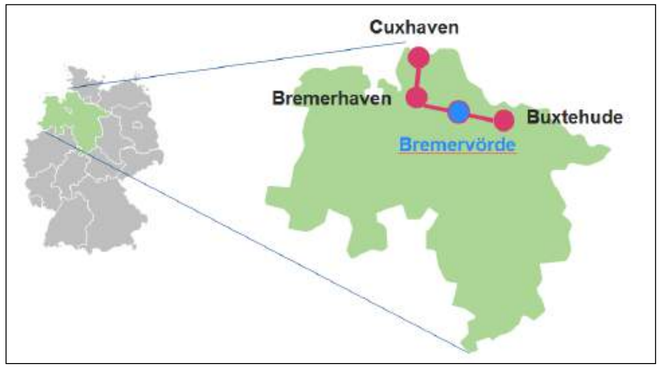
**Homologation by EBA July 2018**

**Passenger Service Ger Sep 18 – Feb 20**

**Test Operation NL 27.02.20 – 11.03.20**

**Passenger Service Austria Sep - Nov 20**

# Coradia iLint Operational Experience – Passenger operation in Germany




## Summary and conclusion

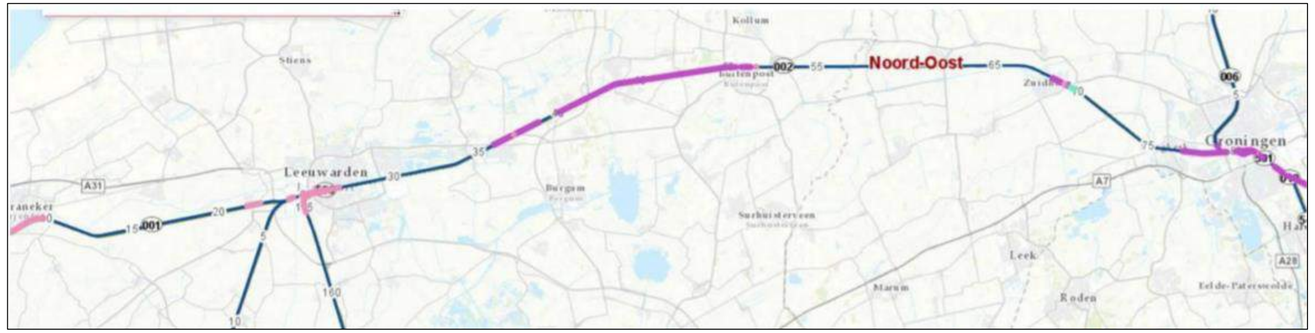
- 2 Coradia iLint in daily regular revenue service
- Drivers from local operator evb
- Validation of train and system performance in all kinds of operation in passenger service
- Adjustments and improvements of hydrogen storage, fuel cell composition and energy management system
- Validation and improvement of the hydrogen consumption
- Reliable and safe supply of hydrogen via mobile refuelling station

**Coradia iLint has proven to be reliable and fit for purpose**

# Coradia iLint Operational Experience – Test operation in the Netherlands

## Summary and conclusion

- Infra compatibility confirmed
- Timetable perfectly adhered to
- Drivers very satisfied:
  “comfortable and easy to drive”
- Coradia iLint range fits the needs of NL
- Coradia iLint perfectly fit for operation instead of the current Diesel Fleet
- Lower noise emissions in operation and at platforms





**Coradia iLint has proven its capability for operation in the Netherlands**

# Coradia iLint Operational Experience – Passenger service in Austria

## Summary and conclusion

- Passenger Service 09-11/20
- Coradia iLint operated on all lines without limitation (slopes up to 4.4%)
- Timetable was perfectly adhered to
- Drivers very happy with easy operation and accoustic comfort
- Easy refueling very similar to Diesel trains

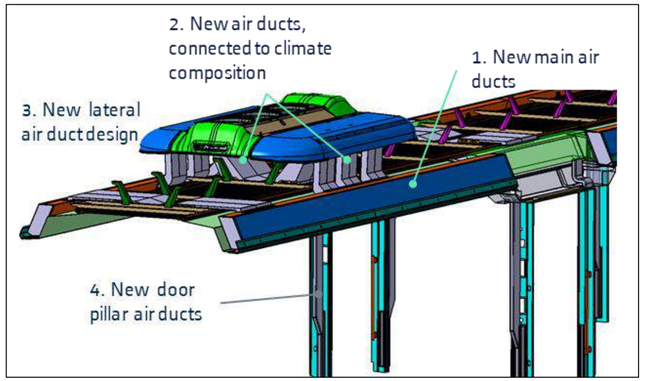


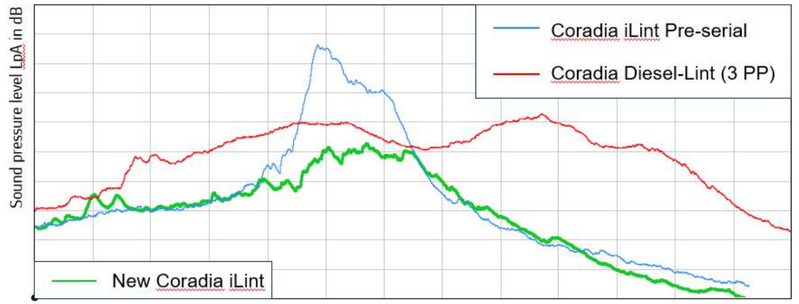
**Coradia iLint - Reliable and comfortable operation in challenging topography**

# The New Coradia iLint

## Passenger Experience

- Lighter and more spacious interior design
- Upgraded LED lighting concept
- Improved thermal and acoustic insulation
- Optimised air distribution for increased climatic comfort
  - Additional air ducts in door pillars
  - New air ducts
  - Increased air volume with reduced air speed
- Latest developments for better connectivity
- Significantly reduced interior and exterior noise level



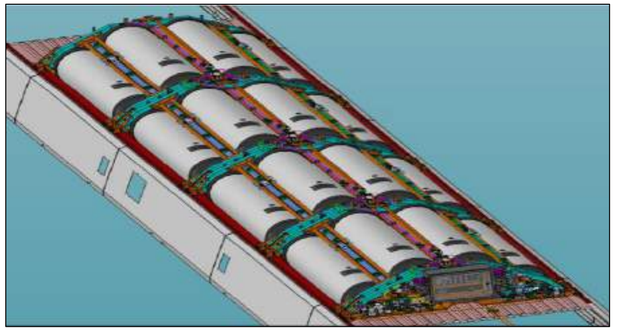




**The New Coradia iLint – Increased comfort with zero emission**

# The New Coradia iLint

## Operational Range

- Optimised hydrogen tank arrangement on the roof
- 4x4 cylinders per car for maximum $H_2$ capacity
- Range of Coradia iLint increased to ≥1.000km*
- Maximum flexibility in operation
- Reduced hydrogen consumption



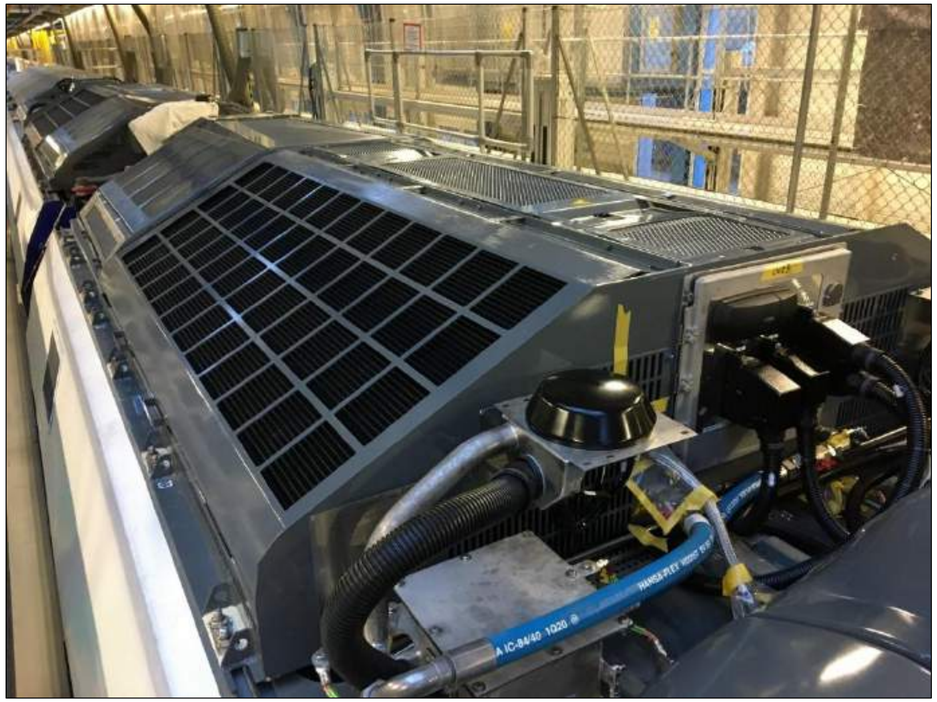
*) Under challenging conditions: demanding topography + time-table; high load for air-conditioning or heating

**Operational range increased by 25%**

# The New Coradia iLint

## Efficiency & Reliability

- Simplified architecture of fuel cell composition
  - 30% reduction of active components
  - Optimised arrangement of components
  - Next generation Membrane Electrode Assembly (MEA)
- Improved operational strategy of fuel cells
- Higher system efficiency
- Reduction of maintenance needs



**The New Coradia iLint – Increased Efficiency & Reduced Costs**

# The New Coradia iLint

## Benefits for the Operator

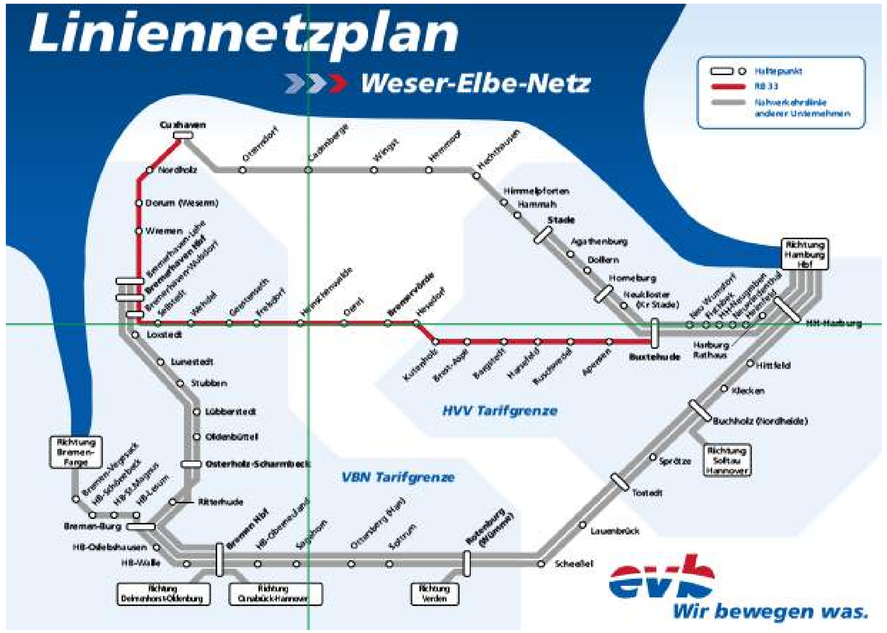
- Service-proven product and technology
- Unrivalled range of 1000 km
- High availability and reliability proven over more than 2 years in passenger service
- Higher acceleration for operational flexibility
- Reduced maintenance and cleaning costs
- Zero emissions
- Air conditioning unit using refrigerant with extremely low $GWP_{100}$

**The New Coradia iLint – Making the difference**

# Next steps – The New Coradia iLint in Germany

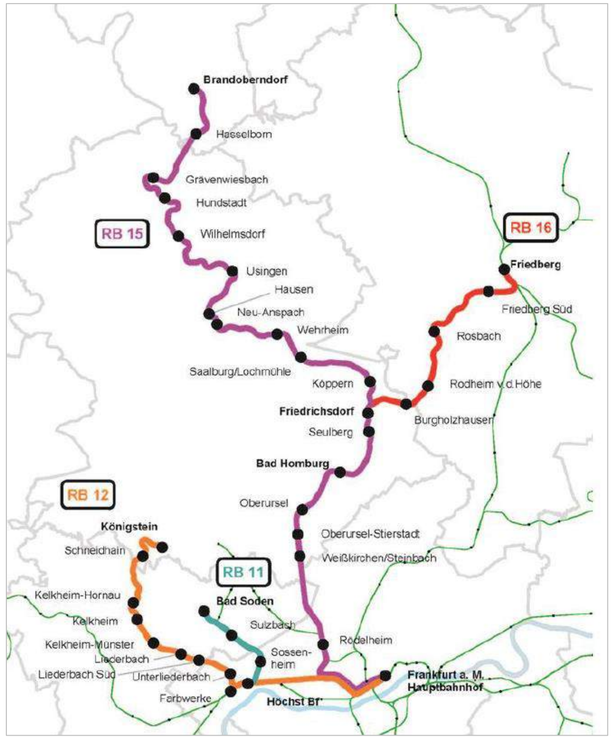
## LNVG

- 14 Coradia iLint
- Start of operation 2022
- 30 years of maintenance and hydrogen supply




## Taunusnetz (rmv)

- 27 Coradia iLint
- Start of operation 2022/23
- 29 years of maintenance and hydrogen supply



# HRS: Components and preparation on-site in Bremervörde

LNVG Landesnahverkehrsgesellschaft Niedersachsen mbH

Dispensers

compressors


High pressure storage

Aerial view of construction site BRV (04/21)

# Next steps - Alstom’s Coradia Stream in Italy

Coradia Stream **EMU**

Coradia Stream **FCMU**

‹ Press releases and news 26 Nov 2020

## Alstom to supply Italy’s first hydrogen trains

**26 November 2020** – Alstom will supply six hydrogen fuel cell trains, with the option for eight more, to FNM (Ferrovie Nord Milano), the main transport and mobility group in the Italian region of Lombardy. The first train delivery is expected within 36 months of the date of the order.

**Coradia Stream: the family expands**

# Coradia Polyvalent FCEMU for SNCF

## Main Characteristics

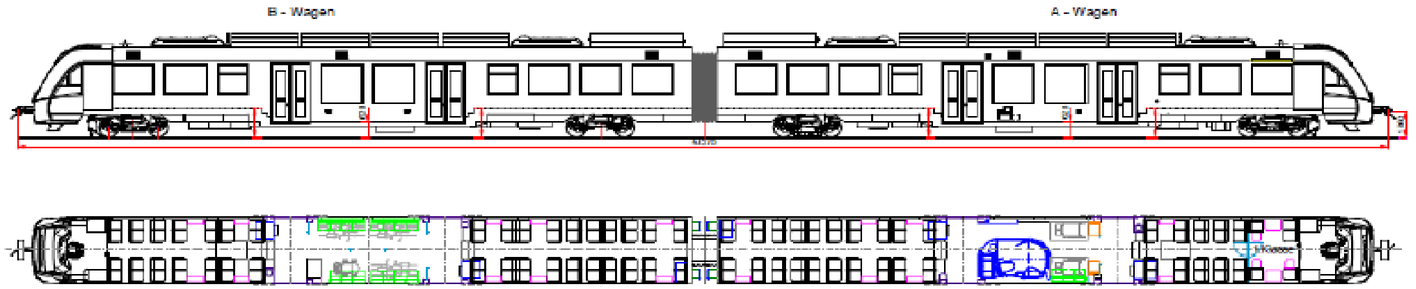
- Bi-mode train (Hydrogen + Pantograph)
- Max Speed: 160 km/h
- Range (only $H_2$): 600 km
- Capacity: 218 seats

## First Contract

- 12 trains
- Train Validation  2023
- Start of operation 2025

# Alstom’s Coradia iLint – General Overview

- Based on successful Coradia Lint 54 DMU
- Lowfloor entrance (620 or 810 mm)
- Max. speed 140 km/h
- 1000 km range
- No technical components in the passenger area
- 150 seats / 1 toilet / Flex Area
- Zero emissions

THANK YOU!

www.alstom.com

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# Questions
# Discussion

Andreas Frixen

**Thank you for your attention.**


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## #UICrail

**Online workshops coming up next:**

- 19 May 2021 – 10:00-12:00
  **Battery trains**

*https://uic.org/events/battery-trains*

*Call for speakers is open for a workshop on stationary energy storage systems, please contact stefanos@uic.org*

**Thank you for your attention.**