Welcome to the best practice workshop

HYDROGEN TRAINS

Proposed by the UIC Energy efficiency and CO₂ Emissions Sector

Organised by the Sector’s Chairpersons:

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

285 projects supported for 1.07 B €

Energy
H₂ production and distribution
H₂ 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, ...

Similar leverage of other sources of funding: 1.08 B €

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
Besides CO₂ 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 demand¹
- ~560 Mt annual CO₂ abatement²
- ~EUR 820bn annual revenue (hydrogen and equipment)
- ~15% reduction of local emissions (NOₓ) 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.


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 H₂ electrolyser
- 1 million tonnes renewable H₂
- Replace existing H₂ production
- Regulation for liquid H₂ markets
- Planning H₂ infrastructure

**Phase 2: 2025-2030**
- 40GW renewable H₂ electrolyser
- 10 million tonnes renewable H₂
- New applications in steel & transport
- H₂ for electricity balancing purposes
- Creation of “Hydrogen Valleys”
- Cross-border logistical infrastructure

**Phase 3: 2030-2050**
- H₂ 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
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

What is it?

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

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

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 highly interested EU13 regions

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

“I want NextGenerationEU to create new European Hydrogen Valleys to modernise our industries, power our vehicles and bring new life to rural areas.”
Examples of Hydrogen valleys in Europe today

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

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

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)

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

Hydrogen Valleys have become a global phenomenon, with integrated projects emerging all around the world

A fast-growing landscape of globally leading projects ...

Countries with hydrogen valleys on the Initial platform

Additional countries with major hydrogen valley activity where outreach is ongoing

✓ 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)

Next:

~2025: several 100 MW’s

~2030: GW scale

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: 2017
Electrolyser: McPhy (ALK)
Funding: 11 m€

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)

On-going actions:

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

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

<table>
<thead>
<tr>
<th>Multiple units</th>
<th>Shunters</th>
<th>Mainline Locomotives</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passenger operation in regional transport</strong></td>
<td></td>
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<tr>
<td>First FCH trains in operations since September</td>
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<tr>
<td>up to 1,000 km(^1)</td>
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<td>up to 140 km/h</td>
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<tr>
<td>30 years</td>
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<tr>
<td><strong>Shunting and short distance operation</strong></td>
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<td>200-1,000 km(^1)</td>
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<td>up to 50 km/h</td>
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<tr>
<td>35 years</td>
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<tr>
<td><strong>Med. + long distance freight + passenger service</strong></td>
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<tr>
<td>500-1,100 km(^1)</td>
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<td>up to 120 km/h</td>
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<tr>
<td>30 years</td>
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</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Multiple Unit</th>
<th>Shunter</th>
<th>Mainline Locomotive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aragon, Spain</td>
<td>Riga Node, Latvia</td>
<td>Kalmar – Linköping, Sweden</td>
</tr>
<tr>
<td>165 km</td>
<td>100 km</td>
<td>230 km</td>
</tr>
<tr>
<td>2x 4 car trains (bi-mode)</td>
<td>15 Shunters</td>
<td>5 Locomotives</td>
</tr>
<tr>
<td>0.31 kg/km</td>
<td>0.49 kg/km</td>
<td>0.48 kg/km</td>
</tr>
<tr>
<td>Cross border connectivity and long route without electrification</td>
<td>Shunting operation between several port terminals</td>
<td>Passenger and freight transport between two cities</td>
</tr>
<tr>
<td>12.4</td>
<td>20.4</td>
<td>6.7</td>
</tr>
<tr>
<td>22.5</td>
<td>21.8</td>
<td>22.0</td>
</tr>
<tr>
<td>767 t</td>
<td>3,350 t</td>
<td>4,980 t</td>
</tr>
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</table>

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
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 H₂ 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 H₂ 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.

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

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 FNIM, 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 FNIM (Fermacar FNM), the main transport and mobility group in the Italian region of Lombardy, for a total amount of approximately €150 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 iLint 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 iLint for FNIM will be equipped with the same fuel cell propulsion technology that was introduced to the world by the Coradia iLint. The hydrogen Coradia iLint will maintain the high standards of comfort already appreciated by passengers of its electric version. This hydrogen version will match the operational performance of diesel trains, including their range.

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

The European Investment Bank (EIB) will lend €1.5 billion 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 €4 billion auto investment package in sustainable mobility. Of this, €1.5 billion euros are spent on sustainable mobility.

Pesa to unveil hydrogen locomotive by year end

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

The Fuel Cells and Hydrogen Observatory has been created with the support of the European Union’s Horizon 2020 research and innovation programme.
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

The views and opinions of authors expressed herein do not necessarily state or reflect those of the FCH 2 JU or the EAC. This document is prepared by the European Hydrogen Safety Panel (EHSP) with the mandate and support of the FCH 2 JU and the FCH-2-JU-Addressing-H2-Infrastructures (HIAD) project of the FCH 2 JU. The EHSP makes every effort to ensure that its views and opinions are based on reasonable data and assumptions but no warranty is given as to the accuracy, completeness or reliability of any information, specification, product, or process disclosed, or representation that its use will not infringe any patent or commercial product or process. Any such use is at the risk of the user. This report is not to be construed as an endorsement, recommendation or promotion for the FCH 2 JU or the HIAD.
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

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

Clean Hydrogen
Processes4Planet
2ZERO
Zero Emission Waterborn
Clean Steel
Clean Aviation
Europe’s Rail: 600 m EUR
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 H₂ JU
29th Nov. – 3rd Dec. 2021
Brussels, Belgium
Questions

Discussion

Bart Biebuyck
Executive Director

Thank you for your attention.
HYDROGEN STATUS
BELGIUM (BENELUX)

WaterstofNet
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 car
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
First Hydrogen refueling station in Helmond (NL)

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

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

Hydrogen region 2.0

Current status @ https://h2benelux.eu/
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...
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
"Green Octopus" initiative

Figure 4.1: Announced large scale electrolyser plants in the region²
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

- 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

Available:
Studies
Examples/test results/BC calculations
DE and NL

Required:
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)
Questions
Discussion

Isabel François
Project manager WaterstofNet

Thank you for your attention.
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
ROLLING STOCK

Is hydrogen the answer?

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

<table>
<thead>
<tr>
<th>Welcome to Arup</th>
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<tbody>
<tr>
<td>Is hydrogen the answer</td>
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<tr>
<td>Why hydrogen</td>
</tr>
<tr>
<td>Infrastructure</td>
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<td>Supply network</td>
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<td>Hydrogen potential</td>
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<tr>
<td>Whole life costs</td>
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<tr>
<td>Entry into service</td>
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<tr>
<td>Future proofing</td>
</tr>
<tr>
<td>Conclusions</td>
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</table>
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

Specification
• Performance
• Range
• Capacity
• Design life
• Future proofing
• Infrastructure
• Whole life cost

New Build or Retrofit
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

Projected Battery Performance Improvements

<table>
<thead>
<tr>
<th>Batteries (Today)</th>
<th>(2-3 years)</th>
<th>(8-12 years)</th>
<th>(20-25 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Cell Mass</td>
<td>Battery System Mass</td>
<td>Wh/kg</td>
<td></td>
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</tbody>
</table>
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
Questions

Discussion

Robert DAVIES
Global Rolling Stock Leader - Arup

Thank you for your attention.
INTRODUCTION OF HYDROGEN TRAINS IN THE NORTHERN NETHERLANDS

In the context of Emission Free Rail transport
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?
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;

CO₂ emissions
- Since 2017 all electrical trains run on renewable wind energy
- Annually about 85 ktons of CO₂ eq. (≈ 4.2 Million trees);
- About 2/3 by passenger and 1/3 by freight transport;
- Roughly 30% of the CO₂ 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 H₂ train

Excellent cooperation with our partners
- Each with its own responsibility and role

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’)

[Images of mobile refuelling operations and safety equipment]
Press and Public Information Day
Press and Public Information Day
Next steps

Hydrogen trains will replace diesel units in Groningen

Published on 11-10-2020 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.

Europe funds hydrogen train in the Netherlands with 25 million

Published on 26-04-2021 at 10:36

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.
Questions

Discussion

Michiel Deerenberg
ProRail Innovation

Thank you for your attention.
ALSTOM

Coradia iLint
Coradia iLint

UIC Hydrogen Trains

Andreas Frixen

May 12, 2021
Alstom’s Coradia iLint – Accomplishments so far

2014

Prestudies

2015

Production & Commissioning

09 / 2016

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 acoustic 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 $\text{H}_2$ capacity
- Range of Coradia iLint increased to $\geq 1,000\text{km}^*$
- 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

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$_{100}$
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

Dispensers

compressors

High pressure storage

Aerial view of construction site BRV (04/21)
Next steps - Alstom’s Coradia Stream in Italy

Coradia Stream: the family expands

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 Polyvalent FCEMU for SNCF

Main Characteristics
- Bi-mode train (Hydrogen + Pantograph)
- Max Speed: 160 km/h
- Range (only H₂): 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
Questions

Discussion

Andreas Frixen

Thank you for your attention.
Stay in touch with UIC:
www.uic.org

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.