HYDROG(E)NICS

SHIFT **POWER** | **ENERGIZE** YOUR WORLD

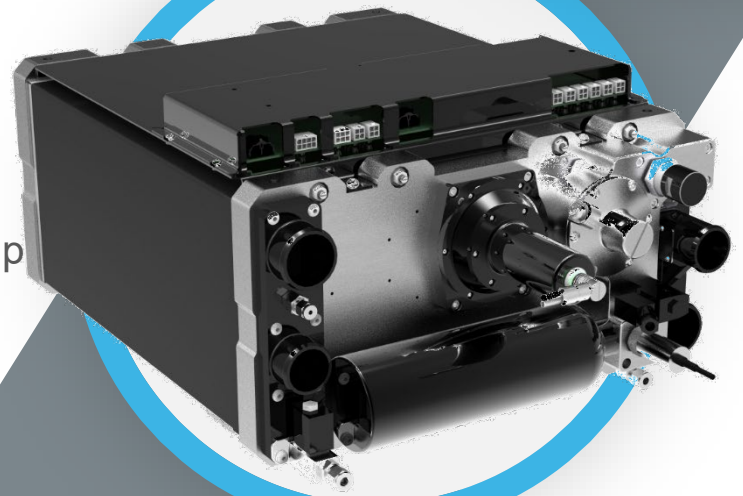
Shift2Rail | FCH | FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Workshop
Fuel Cells and Hydrogen In the Railway Environment

Technology Status prior to railway developments

Hydrogenics HD Power Modules provide a robust and flexible platform for zero-emission heavy mobility applications.

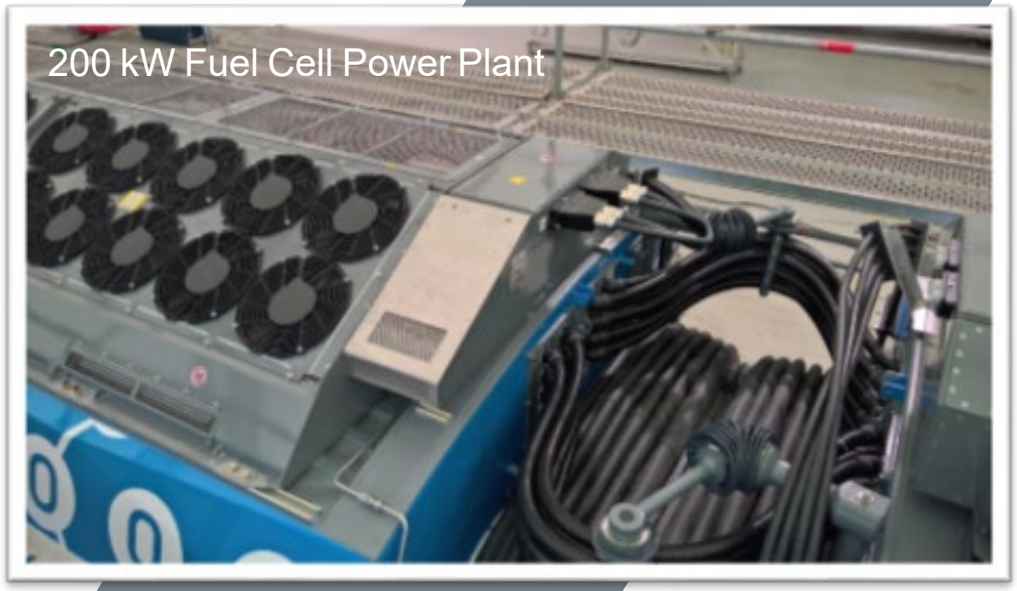
- Proven track record for superior performance, durability and reliability in bus, truck, and other heavy and light mobility since 2002
- Robust stack architecture: low pressure, dry/dry features (no humidifiers since 2009)
- High durability high cycle life components, ruggedized,
- > 10,000+ hour stack lifetime since 2009 with unlimited start/stop cycles since 2005
- Modularity enables wide and flexible kW range



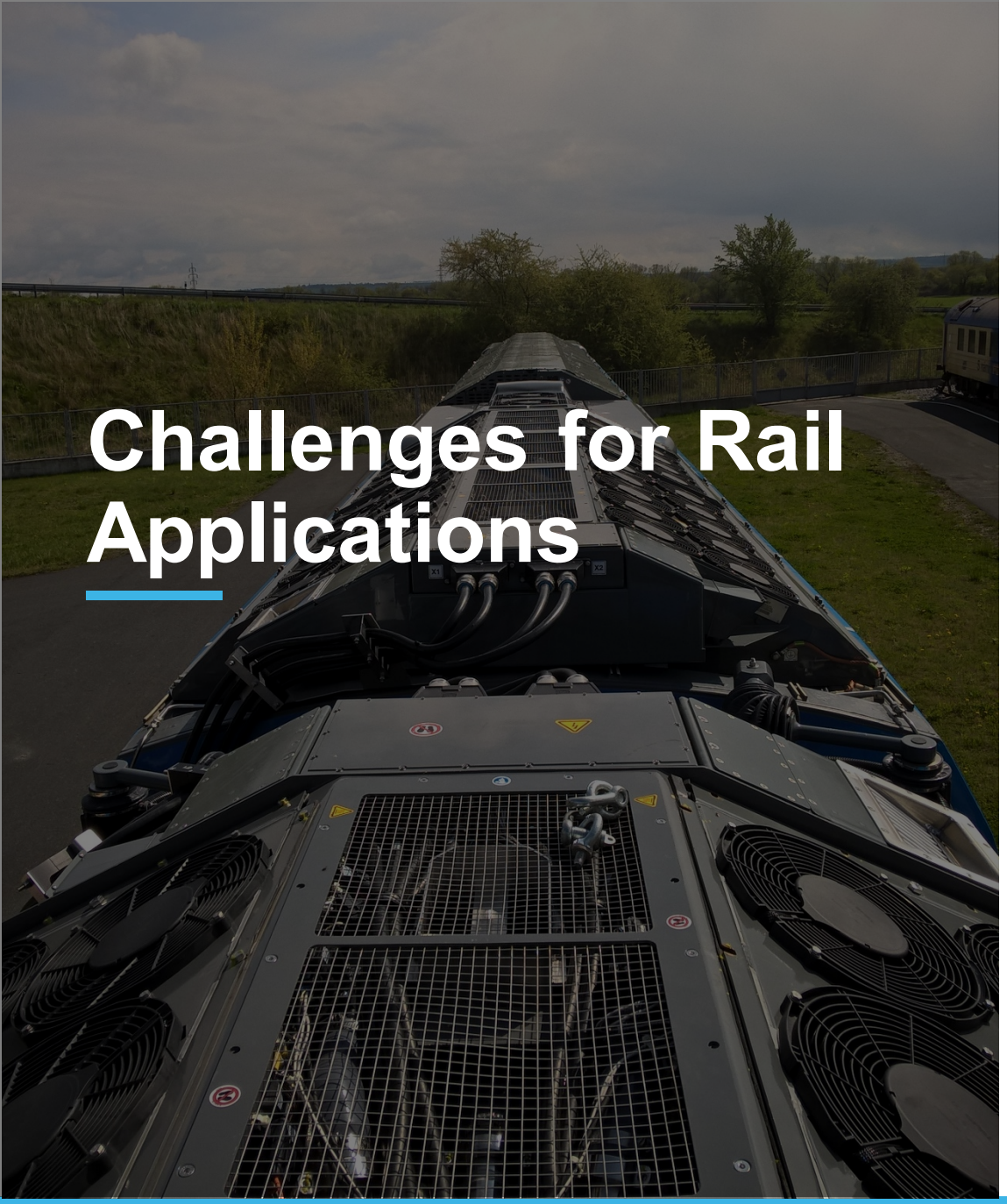
Current Technology Status for Passenger Rail

The Alstom Coradia iLINT has received Certification Approval by the EBA and has started regular Regional Bahn service.

- 2014/2015 Technical Specifications defined
- 2014/2015 Applicable Codes and Standards identified
- 2015/2016 Prototype hybrid system run in the test bench (fuel cell, power electronics, battery, electric drive and controls)
- 2017 Fuel cell systems integrated into two Pre-Series Trains for test track and testing on the public rails
- 2018 Certification by the German Railway Authority (EBA) Awarded ~ TRL Level 8
- Two trains in regular Regional Bahn service – Weser Elbe Netz (RB33: Cuxhafen - Bremerhafen - Bremervörde - Buxtehude)


200 kW Fuel Cell Power Plant

2019 Road Show (© SWR)



Challenges for Rail Applications

- The Rail Application is one of the most demanding in terms of **R**eliability, **A**vailability, **M**aintainability and **S**afety
- Demanding Duty cycle.
  Vehicle operation for 30+ years
- Railway Codes, Standards, etc.,
  extremely demanding
  (EMC, Shock & Vibe, Ingress Protection,
  Welding, QA Requirements …)
- Key Constraints:
  Reliability, **Durability**, **Fuel Efficiency**,
  Weight, **Compactness** and **Noise**

Gen 3.0 Enhancement examples

G2.0
2011

- External coolant strainer no longer required
- Advanced cold start routine
- High isolation resistance
- Long life H2 recirculation unit
- Simplified H2 supply system
- New H2 purge architecture

G3.0
2019

Released 2019-03… HD50

Rated Power: 50 kW

- Increased power in a monolithic stack module
- Increased power density

And for modular combinations:

- reduced weight
- less interconnection
- increased simplicity
- Integration space gains

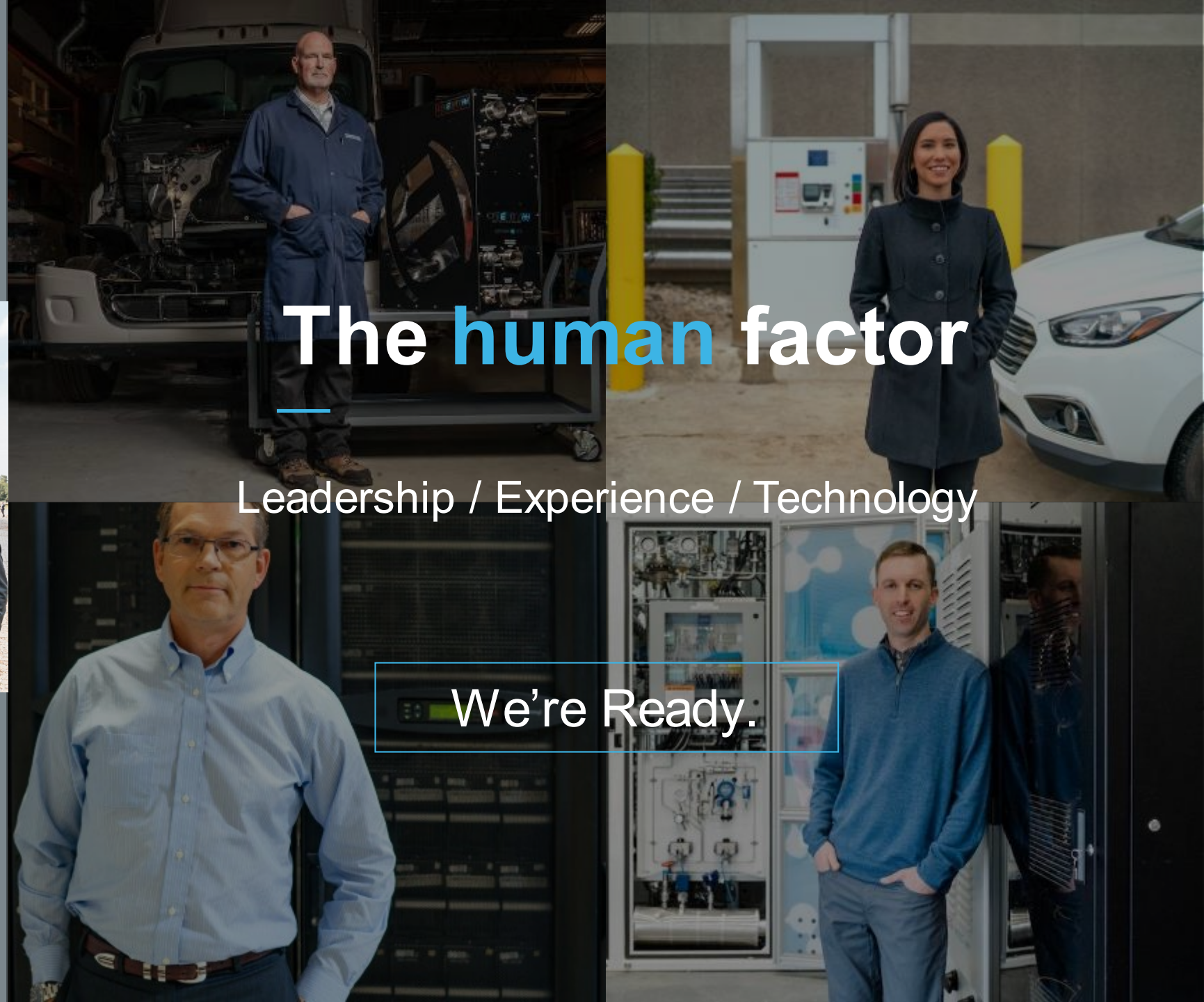
HD50
G 3.0

Ongoing & Future

Continuous improvement:

- Technical
- R A M S
- Production
- Costs
- TRL 9

Thank you for your engagement



The human factor

Leadership / Experience / Technology

We're Ready.

HYDROGENICS

SHIFT **POWER** | **ENERGIZE** YOUR WORLD

Linde Hydrogen FuelTech

Tomorrow's fuel today

Linde Hydrogen FuelTech

Competences, technologies & products

Brussels, May 17th 2019

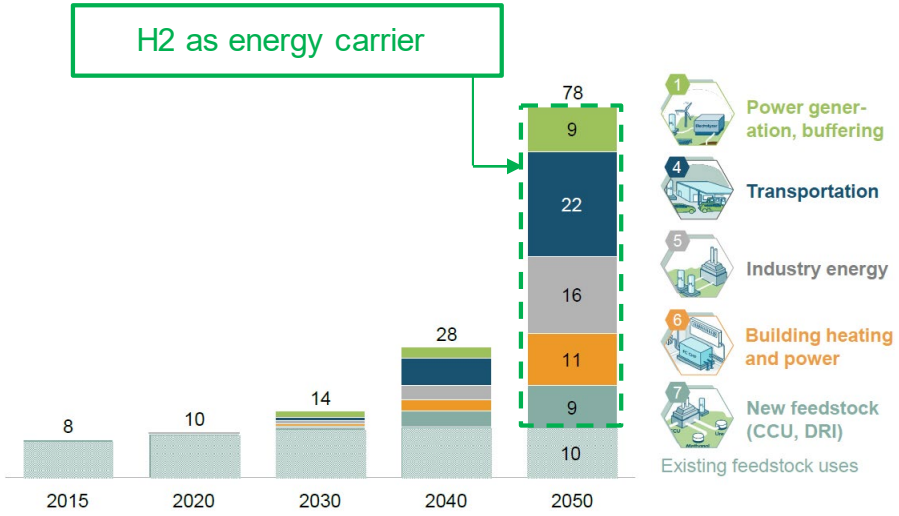
Making our world more productive

Linde

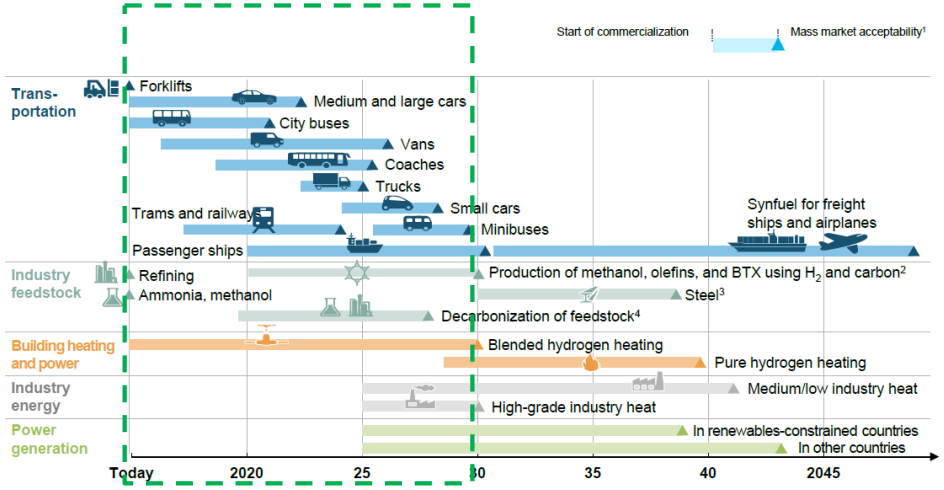
Hydrogen: a game changer in industry

H2 plays a central role as energy carrier

H2 emerging as energy carrier*…



…with mobility applications as first commercial users**



- **De-carbonization** transforms the energy industry; **H2** expected to play an important role **as energy carrier**
- Applications going to transform to H2 at different paces; with **H2 mobility / transportation being the frontrunner**

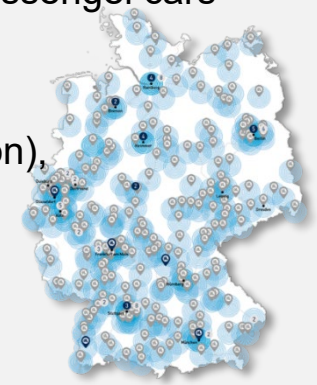
* Source of graph: H2 Council, units: Exa Joule, 1 EJ = 7m tons H2 = 80Bn Nm³ H2 ** Source of graph: H2 Council

Hydrogen: a game changer in mobility

Linde Gas – operational models

Network

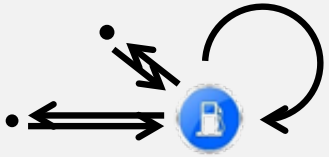
Network of H2 refueling stations for seamless mobility for Fuel Cell Electric Vehicle (FCEV) passenger cars



+ In case of technology break-through (successful customer value proposition), high growth potential
– High upfront investment in infrastructure necessary, with low utilization rates initially (business case challenge)
– Strong & continuous buy-in from multiple players required (OEMs, infrastructure & utility providers, authorities)

Back-to-base

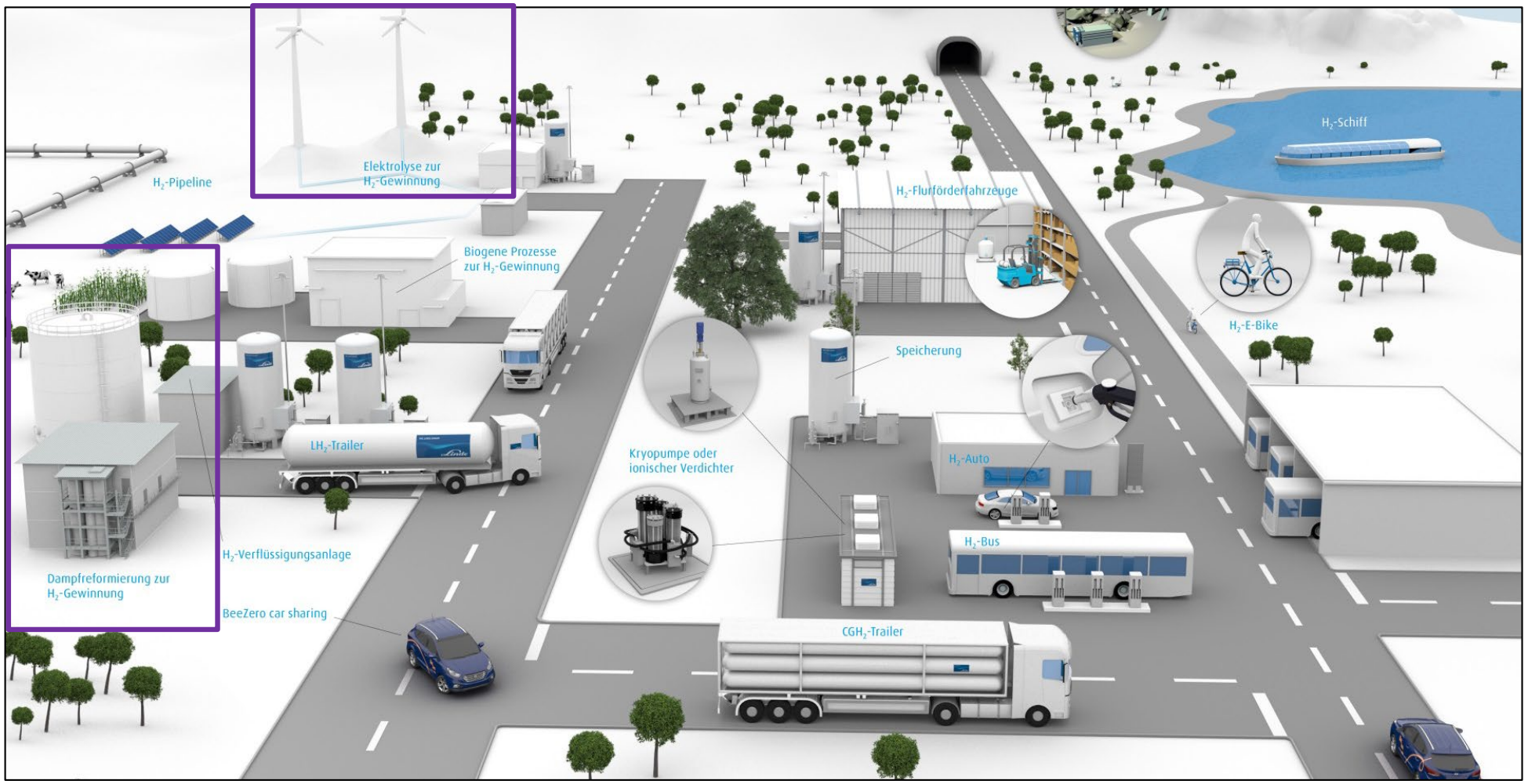
Buses, urban delivery trucks, intralogistics vehicles, taxis, car fleets with regular routes & **H2 refueling at a fix depot** (base)



+ Upfront investment in infrastructure limited to one (few) H2 station(s) at central depot
+ High utilization and predictable H2 demand allowing for economically attractive business cases
+ Strongly positive impact on urban environment (local emission free, noise reduction) already with first project
– Vehicle availability and costs

Linde technology along the hydrogen value chain.

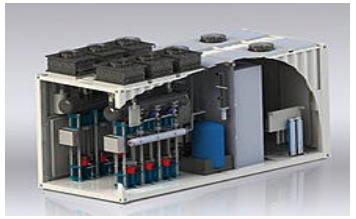
Linde Hydrogen FuelTech is the leader in hydrogen fueling infrastructure.



Production

Steam reformer
(e.g. steam biomethane reformer)

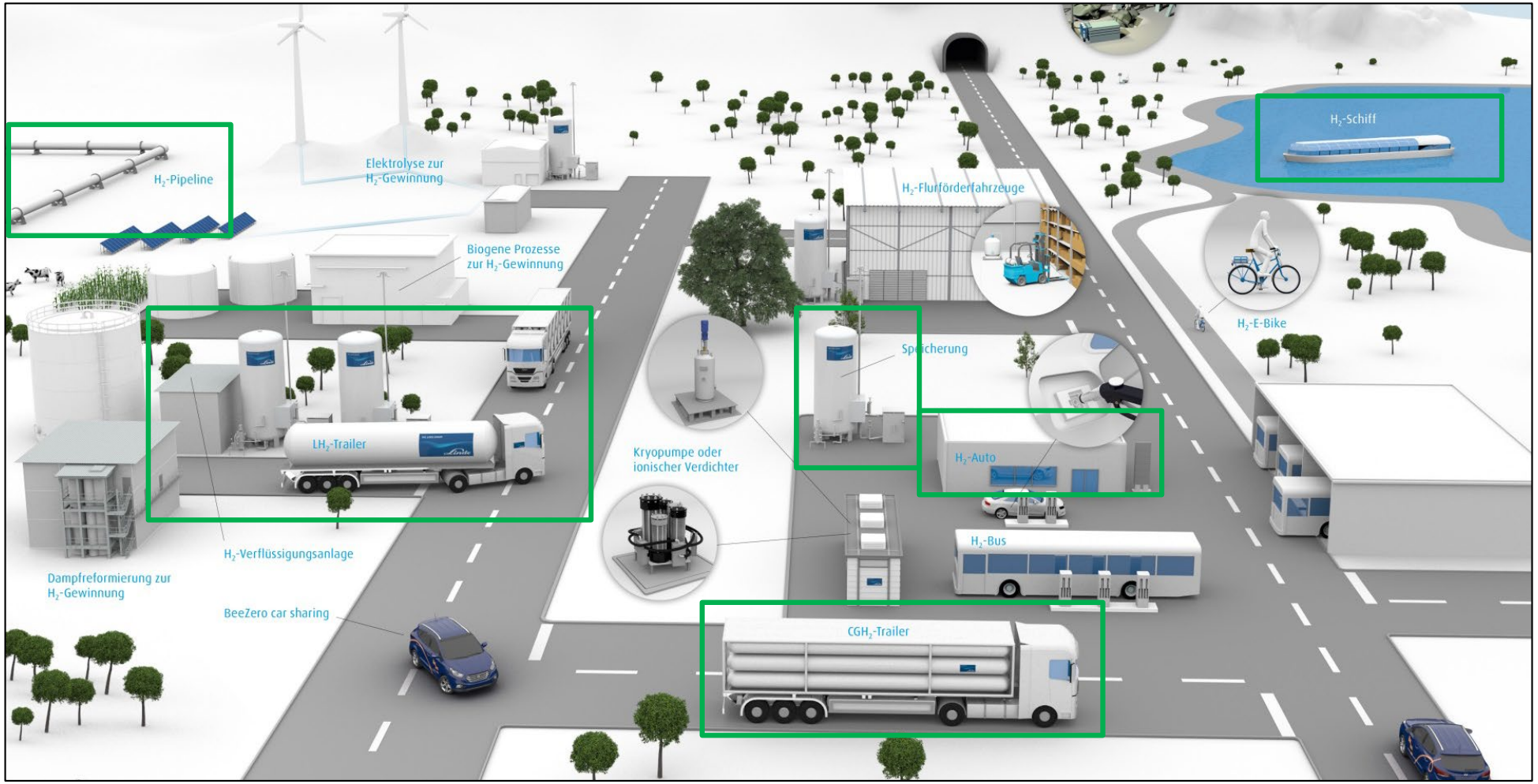
or



Electrolyser
(e.g. PEM or alkaline)

Linde technology along the hydrogen value chain.

Linde Hydrogen FuelTech is the leader in hydrogen fueling infrastructure.



Distribution & storage

Trailer & Tanks

(Trailer: 300 bar GH_2 or LH_2 or 500 bar GH_2, tanks for GH2/LH2, stationary &mobile)

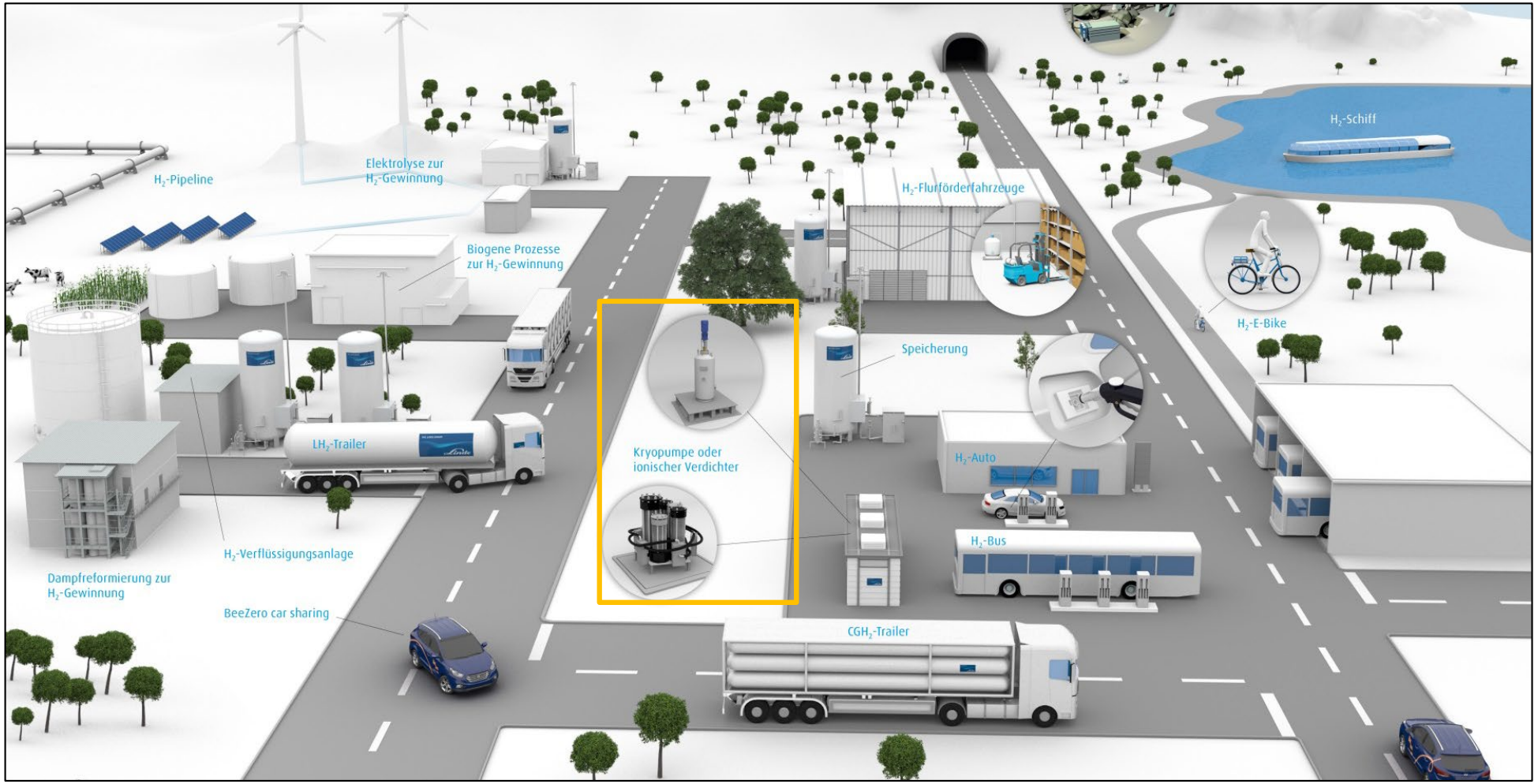
or

Pipeline

(e.g. from producer)

Linde technology along the hydrogen value chain.

Linde Hydrogen FuelTech is the leader in hydrogen fueling infrastructure.



Fueling

Compression
(e.g. ionic compressor station)

or

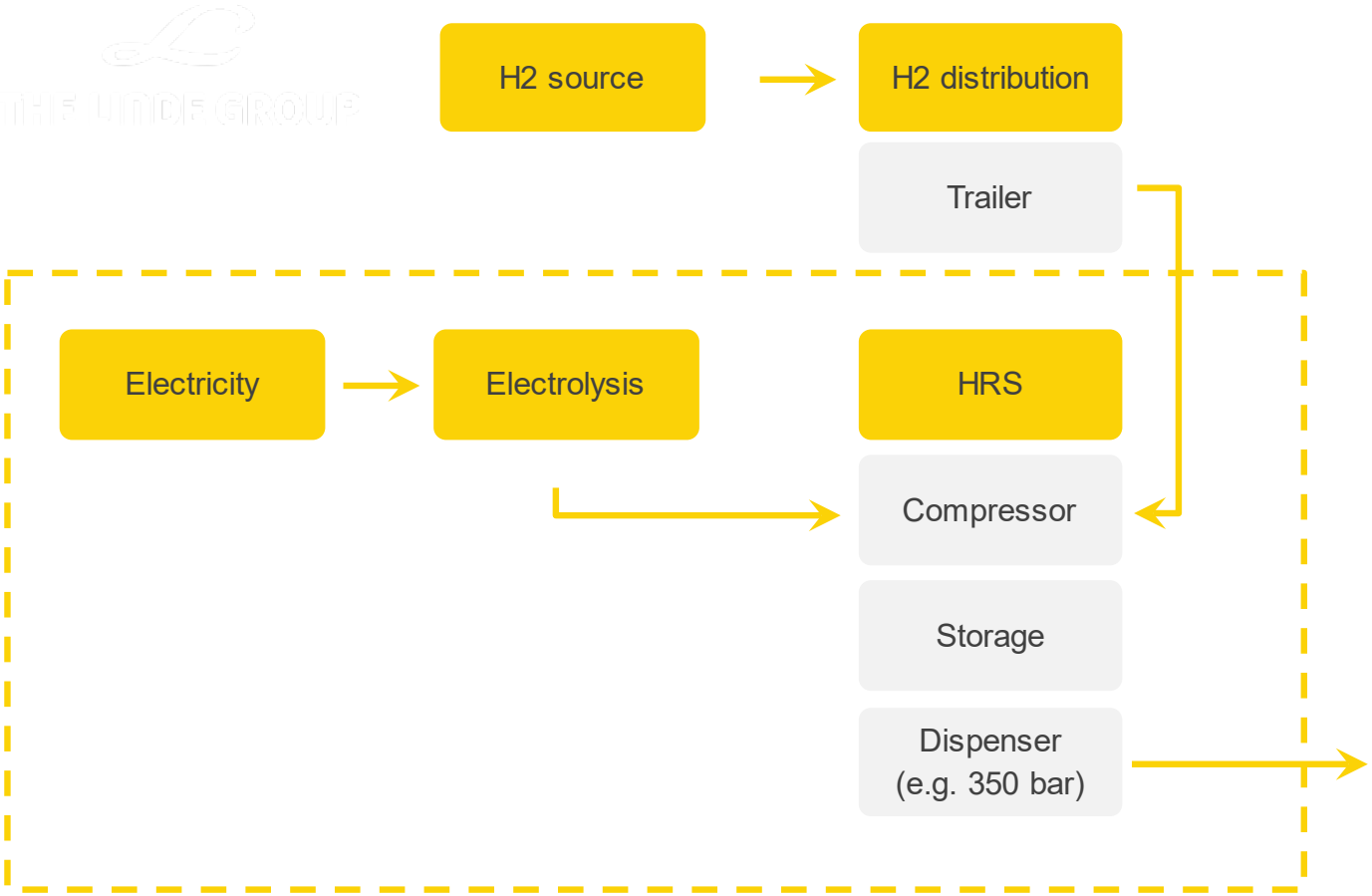
Pumping
(e.g. cryopump station)

Core competence of Linde Hydrogen FuelTech

First to world

Linde Hydrogen FuelTech is building the first station for hydrogen passenger trains

Alstom, Bremervörde/Lower Saxony, Germany



Thank you for your attention.

Linde AG
Dr. Peter Haider
Peter.s.haider@linde.com
www.linde.com

Making our world more productive

Coradia iLint

- Hydrogen train

17-05-2019

ALSTOM
Designing fluidity

Agenda

1. **Coradia iLint**
2. Coradia iLint and the technological challenges
3. Homologation and market introduction
4. Next steps

ALSTOM

Coradia Lint: Diesel platform from which FC train was developed….

LINT 27: 47 trains

LINT 41: 688 trains

LINT 54: 203 trains

LINT 81: 72 trains

… a reliable and service proven base for the first hydrogen FCMU

ALSTOM

Coradia iLint : Design criteria

- Use proven reliable product as base
- Retain the same train dimensions
- No significant changes in weight/center of gravity
- Re-use of architecture and main components
- Maintain performance (acceleration, range, etc)
- Avoid technical equipment in passenger areas
- No adverse impact on passenger experience and comfort
- High energy efficiency

The goal: The FCMU can operate the same services as the DMU

ALSTOM

Fuel Cell Trains: The Technology – transformation from Diesel to FCMU

Removal of diesel propulsion system

Integration of electrical propulsion system

Diesel powerpack

Diesel tank

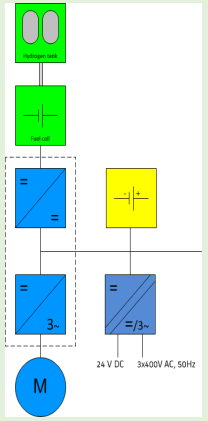
Hydrogen tank

Fuel cell pack

Battery pack

Converter system

Electrical traction motor



ALSTOM

Agenda

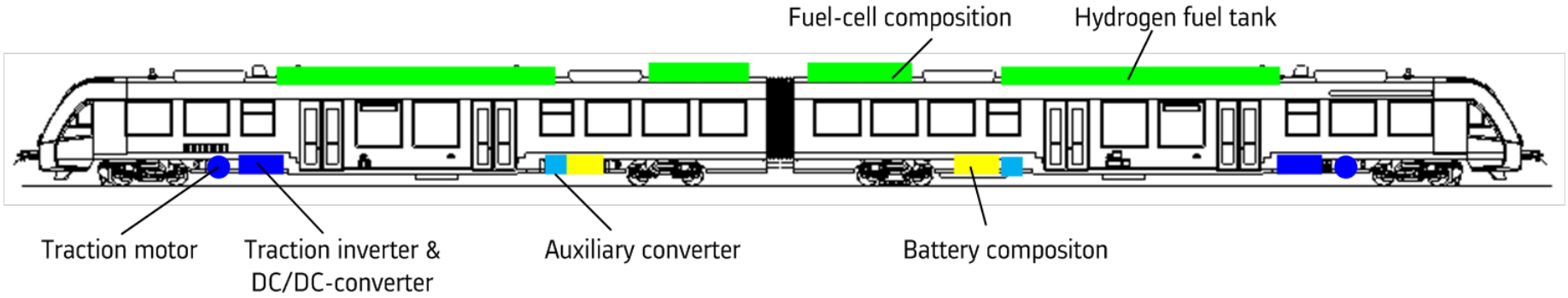
1. Coradia iLint
2. **Coradia iLint and the technological challenges**
3. Homologation and market introduction
4. Next steps

ALSTOM

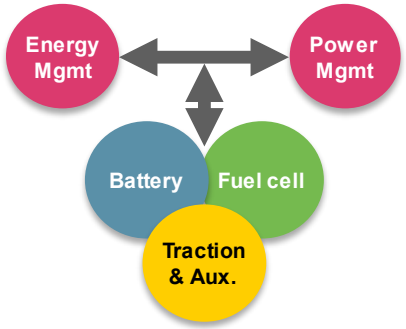
Coradia iLint

ALSTOM

Coradia iLint: Diesel replaced with hydrogen and fuel cell technology



- Replacing diesel traction by electrical traction system
- Primary energy supply by hydrogen fuel cells
- Intermediate energy storage by Li-Ion batteries
  - to boost during acceleration
  - to recover kinetic energy during braking
- All electrical auxiliary supply



Modern energy supply and storage system combined with intelligent energy management

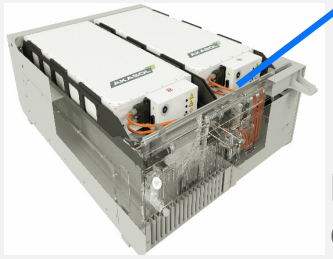
ALSTOM

Coradia iLint - the components: -> fuel cell composition, -> hydrogen storage, -> lithium-Ion battery composition

Fuel cell composition

Hydrogen storage

Storage at 350 bar (@ 15°C)



Lithium-Ion battery composition

ALSTOM

Agenda

1. Coradia iLint
2. Coradia iLint and the technological challenges
3. **Homologation and market introduction**
4. Next steps

ALSTOM

Coradia iLint: Validation and certification process (as completed in Germany)

Eisenbahn-Bundesamt
(EBA)

Eisenbahn-Bundesamt

Core subjects
- Running dynamics
- Crash
- Brake
- Wheelsets
- Train radio / Train protection

European Railway Agency

Safety assessment on Common Safety Methods (CSM)

EBC EISENBAHN-CERT
NOTIFIED BODY INTEROPERABILITY

Technical Specification for Interoperability (TSI)
- LOC & PAS
- SRT
- PRM
- NOI

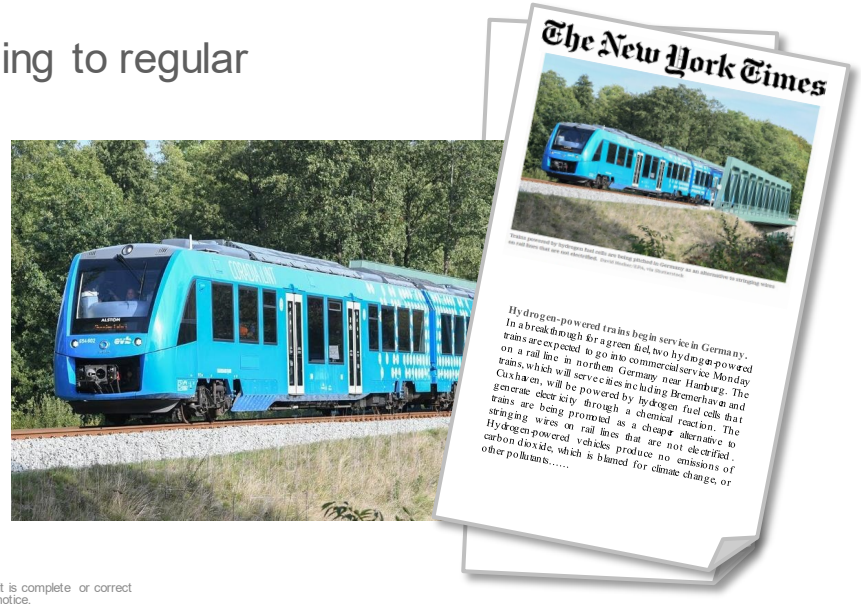
Notified National Technical Rules
- **Running dynamics**
- **Fire Safety**
- **EMC**
- **Functional Safety**
- **Labeling**
- ***and some others***

ALSTOM

Coradia iLint: From certification to regular passenger service

- **Certification** for passenger service in Germany received on **11.07.2018**

- **Daily passenger service** according to regular time table **since 17.09.2018**



ALSTOM

Two pre-series vehicles in passenger service since 17.09.2018

Fahrplan iLint

Montag bis Donnerstag

ab	Bremervörde	16:38 Uhr	an	Bremerhaven Hbf	17:20 Uhr
ab	Bremerhaven Hbf	17:36 Uhr	an	Bremervörde	18:20 Uhr
ab	Bremervörde	18:38 Uhr	an	Buxtehude	19:26 Uhr
ab	Buxtehude	19:53 Uhr	an	Bremervörde	20:36 Uhr
ab	Bremervörde	20:38 Uhr	an	Bremerhaven Hbf	21:20 Uhr
ab	Bremerhaven Hbf	21:36 Uhr	an	Cuxhaven	22:27 Uhr
ab	Cuxhaven	22:39 Uhr	an	Bremerhaven Hbf	23:23 Uhr
ab	Bremerhaven Hbf	23:54 Uhr	an	Bremervörde	00:36 Uhr

Freitag

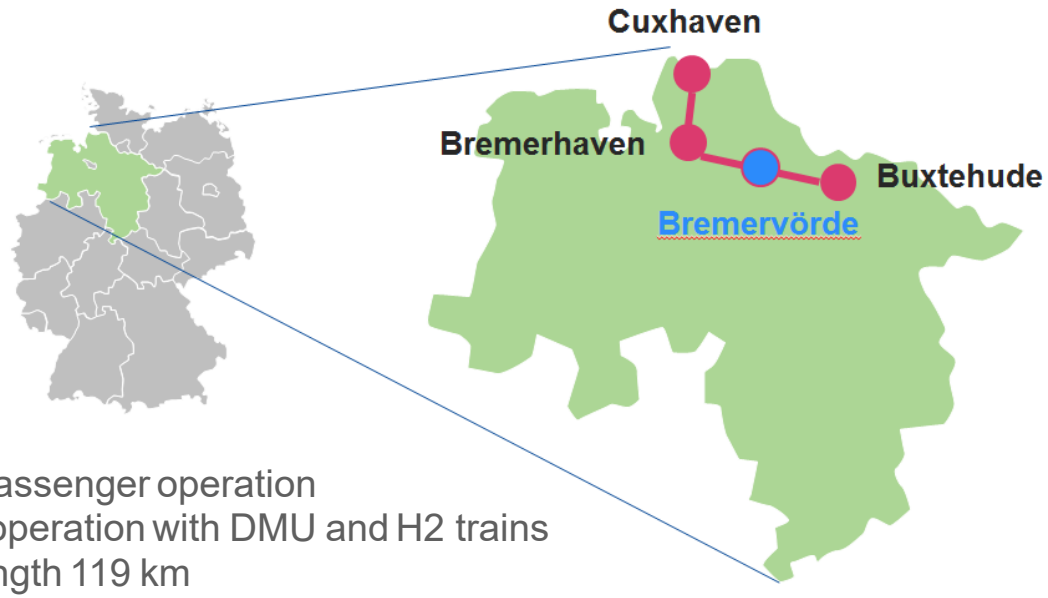
ab	Bremervörde	16:38 Uhr	an	Bremerhaven Hbf	17:20 Uhr
ab	Bremerhaven Hbf	17:36 Uhr	an	Bremervörde	18:20 Uhr
ab	Bremervörde	18:38 Uhr	an	Buxtehude	19:26 Uhr
ab	Buxtehude	19:53 Uhr	an	Bremervörde	20:36 Uhr
ab	Bremervörde	20:38 Uhr	an	Bremerhaven Hbf	21:20 Uhr
ab	Bremerhaven Hbf	21:36 Uhr	an	Bremervörde	22:20 Uhr
ab	Bremervörde	22:32 Uhr	an	Buxtehude	23:16 Uhr
ab	Buxtehude	00:42 Uhr	an	Bremervörde	01:24 Uhr

Samstag

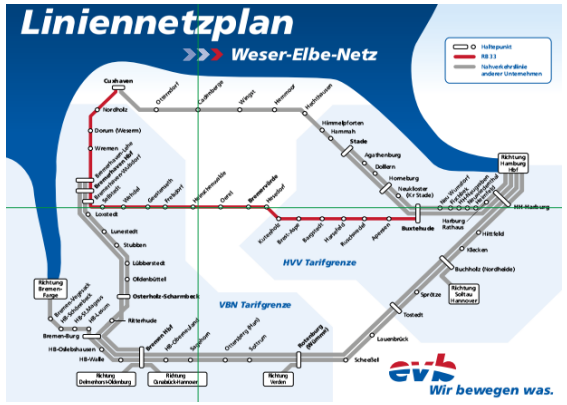
ab	Bremervörde	16:38 Uhr	an	Bremerhaven Hbf	17:20 Uhr
ab	Bremerhaven Hbf	17:36 Uhr	an	Bremervörde	18:20 Uhr
ab	Bremervörde	18:32 Uhr	an	Buxtehude	19:16 Uhr
ab	Buxtehude	19:45 Uhr	an	Bremervörde	20:29 Uhr
ab	Bremervörde	20:38 Uhr	an	Bremerhaven Hbf	21:20 Uhr
an	Bremerhaven Hbf	21:36 Uhr	an	Bremervörde	22:20 Uhr
ab	Bremervörde	22:32 Uhr	an	Buxtehude	23:16 Uhr
ab	Buxtehude	00:42 Uhr	an	Bremervörde	01:24 Uhr

Sonntag

ab	Bremervörde	14:32 Uhr	an	Buxtehude	15:16 Uhr
an	Buxtehude	15:45 Uhr	an	Bremervörde	16:29 Uhr
ab	Bremervörde	16:38 Uhr	an	Bremerhaven Hbf	17:20 Uhr
ab	Bremerhaven Hbf	17:36 Uhr	an	Bremervörde	18:20 Uhr
ab	Bremervörde	18:32 Uhr	an	Buxtehude	19:16 Uhr
ab	Buxtehude	19:45 Uhr	an	Bremervörde	20:29 Uhr
ab	Bremervörde	20:38 Uhr	an	Bremerhaven Hbf	21:20 Uhr
ab	Bremerhaven Hbf	21:36 Uhr	an	Bremervörde	22:20 Uhr



- Daily passenger operation
- Mixed operation with DMU and H2 trains
- Line length 119 km
- One mobile refueling station in Bremervörde



Operated by EVB (local operator)

ALSTOM

Interims H2 fuelling station installed in Bremervörde during operation of the Coradia iLint pre-series trains

Interims solution for train trial operation only

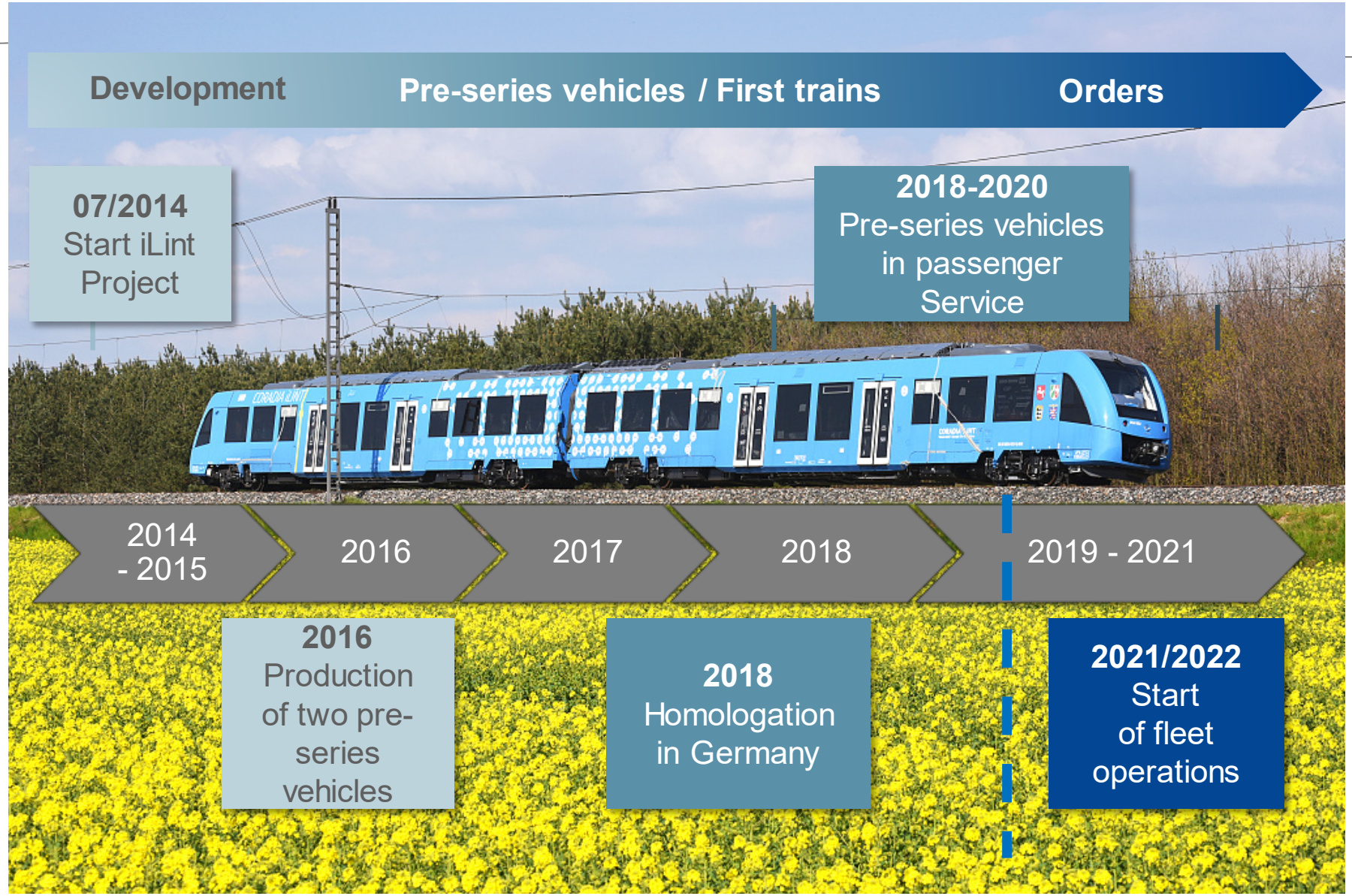
ALSTOM

Agenda

1. Coradia iLint
2. Coradia iLint and the technological challenges
3. Homologation and market introduction
4. **Next steps**

ALSTOM

Coradia iLint - Timetable



ALSTOM

Coradia iLint – next steps

- Passenger service mileage with pre-serial trains
- Development of the hydrogen infrastructure
- 2021/2022 Start of operation of fleet operations
- Homologation in other European countries

ALSTOM

www.alstom.com

ALSTOM
Designing fluidity

Questions?

www.Sli.Do: #HydrogenTrain

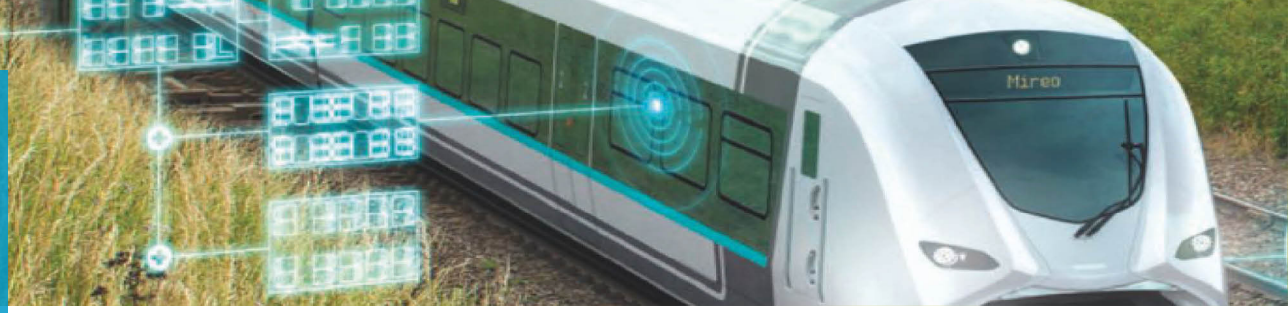
SIEMENS
Ingenuity for life

Mireo Plus H

siemens.com/mireo

The Mireo Plus –

One platform for two hybrid technologies



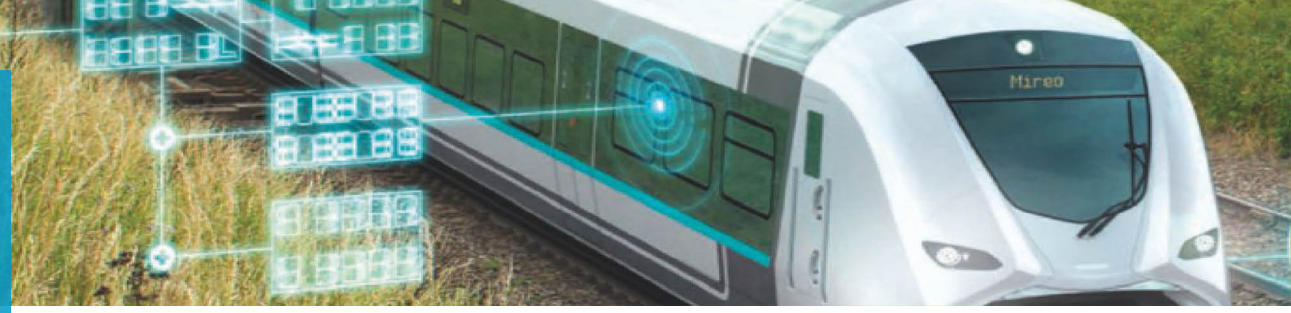
Mireo Plus
All advantages of the Mireo platform

Mireo Plus B
A modular battery drive system

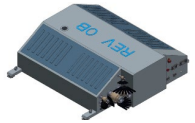
Mireo Plus H
A modular battery and fuel cell drive system

RWTH AACHEN UNIVERSITY
Gefördert durch: Bundesministerium für Verkehr und digitale Infrastruktur
Koordiniert durch: NOW
nip

Our hybrid Traction kit – Overview of innovations

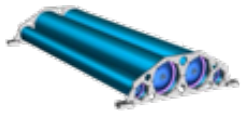


HD8 next gen. fuel cell



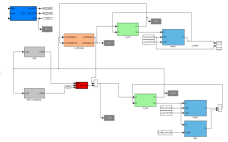
- 50% higher power density
- Higher lifetime
- Low LCCs
- 5% improved efficiency rate

H_2 storage



- Modular concept
- +10% H2 storage capacity

Hybrid control SW



- Optimized operation by predictive E-Management
- ~ 5-15% energy saving

Powerful battery family

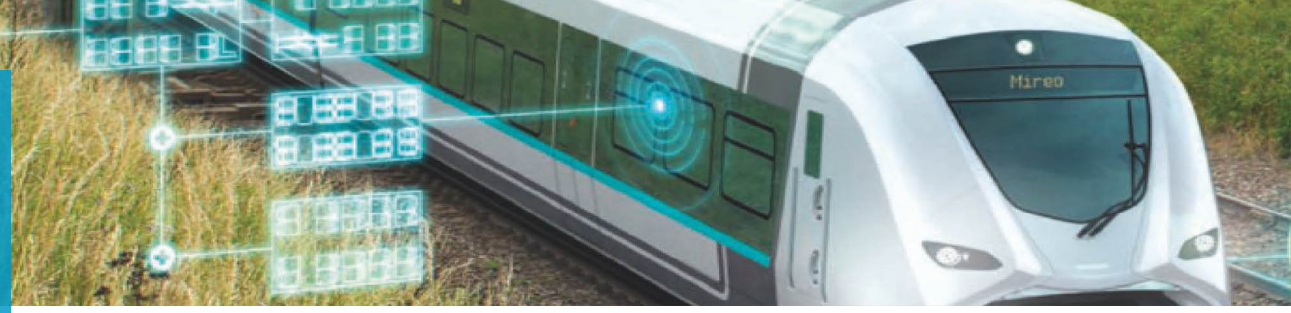
- LTO safe battery cell chemistry
- High-power charging
- 15 years life time

DC – DC chopper

- SiC Technology (compact, light @ low losses)

RWTH AACHEN UNIVERSITY
Gefördert durch: Bundesministerium für Verkehr und digitale Infrastruktur
Koordiniert durch: NOW
nip

Development overview of fuel cell system



Phase 1
Test & system optimization

- Modeling of key components and investigation of vehicle operation strategies
- System behavior investigation on a real system test set up (Co-operation)
- Deep dive view on improvement potentials

Phase 2
Modular traction system

- Definition of a vehicle concept based onto the improvement of the key components
- Development of a FC system of next generation
- Development and detail specification of the sub components

Phase 3
Vehicle integration & safety

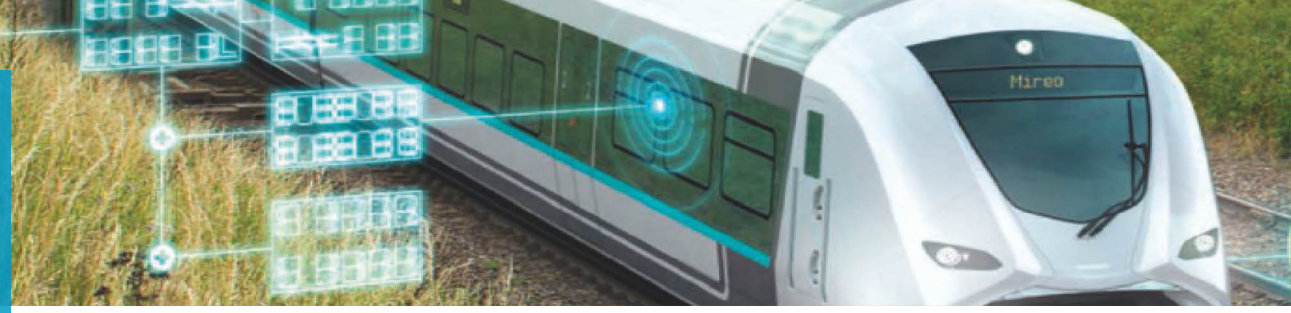
- Development of mechanical designs & interfaces
- Development of a mission management vehicle control system
- Safety management & certification preparation
- Support by ext. studies

2017 → **Funding project** → **2020**

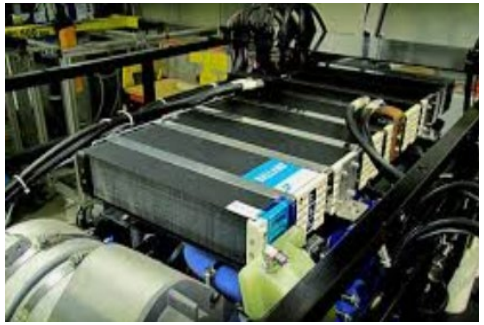
RWTH AACHEN UNIVERSITY
Gefördert durch: Bundesministerium für Verkehr und digitale Infrastruktur
Koordiniert durch: NOW
nip

H2 Traction System Development

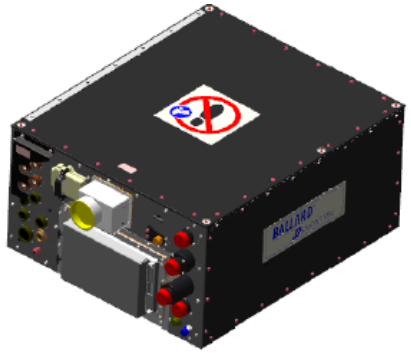
Fuel Cell System Design and Optimization Siemens - Ballard



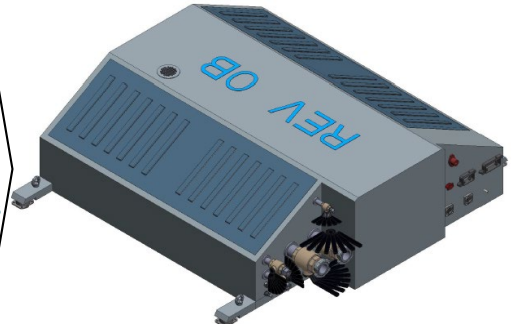
System design and preparation → **Concept design and system test** → **Integration and commissioning**



Transfer of system requirements →



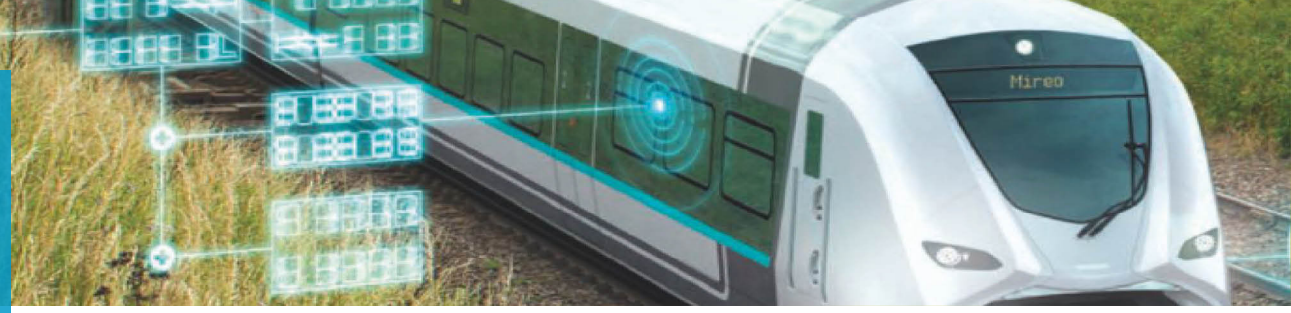
Transfer of train requirements →



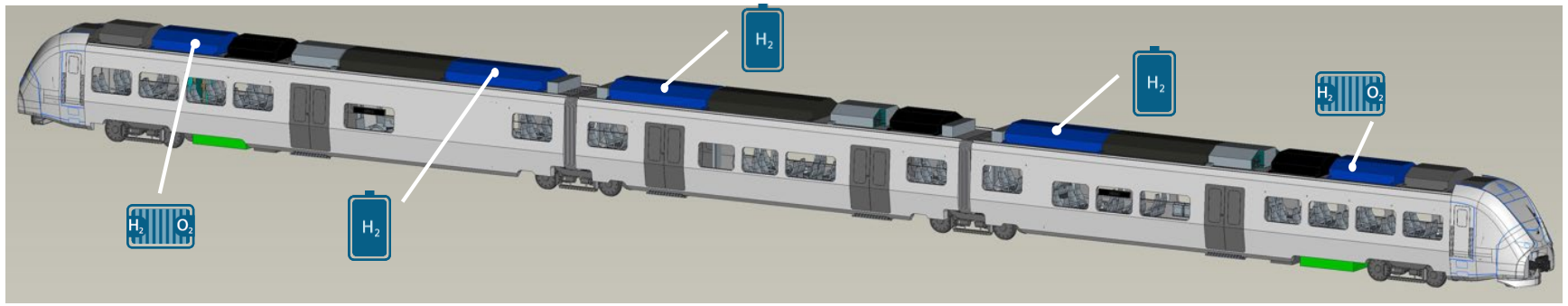
Hardware design | **Concept device for system test** | **Prototype fuel cell for first train**

RWTH AACHEN UNIVERSITY
Gefördert durch: Bundesministerium für Verkehr und digitale Infrastruktur
Koordiniert durch: NOW
nip

Mireo Plus H –
our solution for large scale networks



- H_2 fuel cells HD 8 next gen with storages of Type IV cylinders
- Optimized for large scale networks (> ~120 km) one time refilling per day
- Two configurations for different ranges and applications
  - up to 800 km range : 2-car train with 120 seats
  - 800 up to 1.000 km range: 3-car train with 165 seats



RWTH AACHEN UNIVERSITY
Gefördert durch: Bundesministerium für Verkehr und digitale Infrastruktur
Koordiniert durch: NOW
nip

Contact

SIEMENS
Ingenuity for life

Katrin Seeger
Project manager business development alt. drive systems for regional trains

Werner von Siemens Strasse 67
91052 Erlangen, Germany

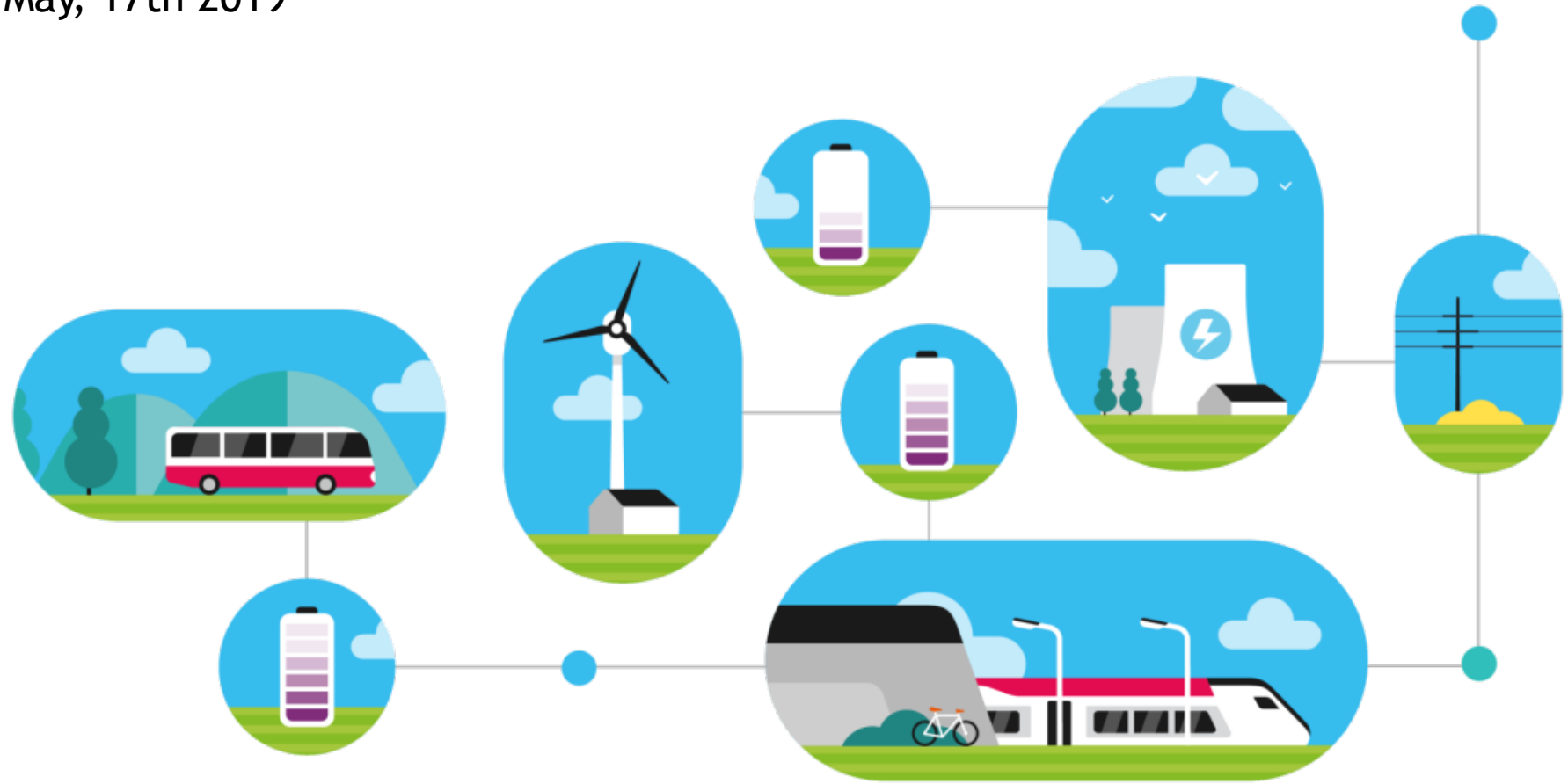
Cell: +49 173 793 5641

E-mail:
katrin.seeger@siemens.com

siemens.com

Hydrogen Train Project

May, 17th 2019



Samuel DESHAYS
samuel.deshays@sncf.fr

France rail network electrification

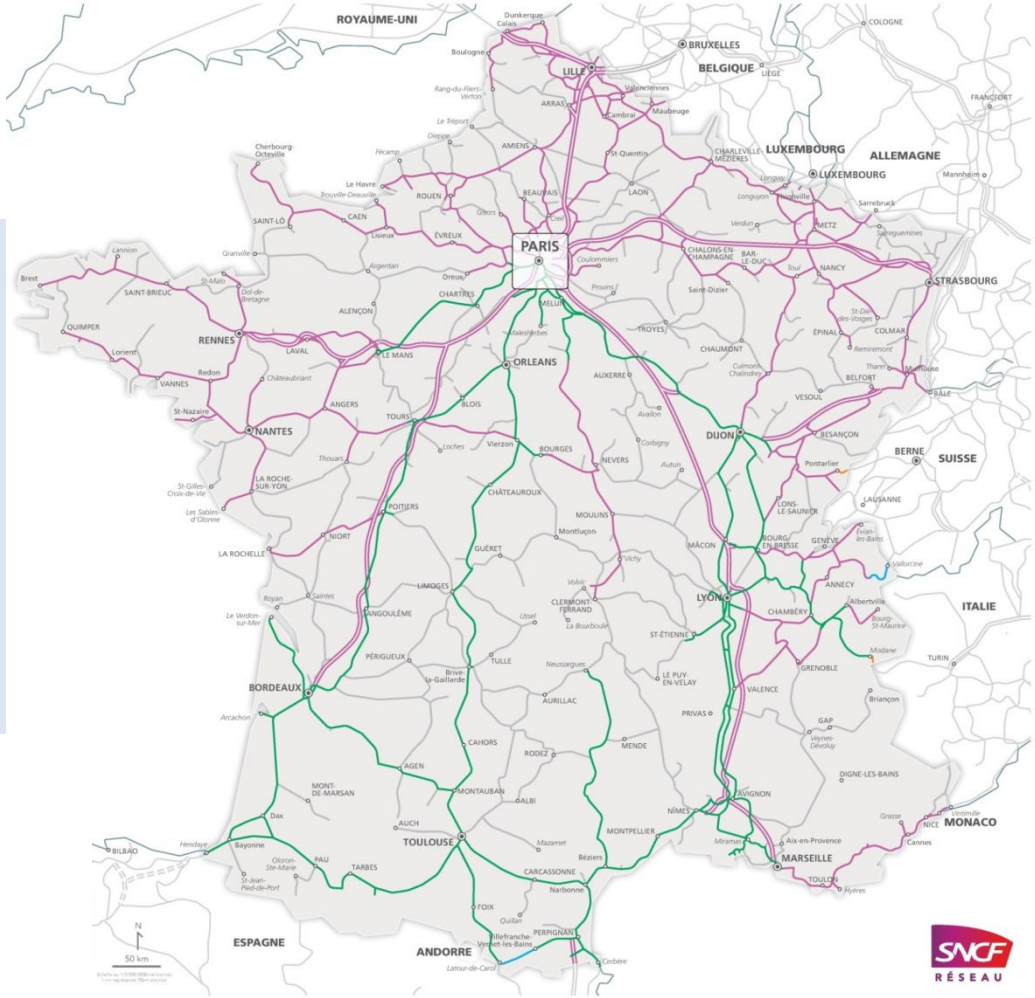
15 500 km

of **electrified lines**

(50% of network)

80 %

of SNCF rail operation is done by electric trains



SNCF Réseau 2017

Improvement potential rolling stock

0,4 % CO_2

of carbon emissions in transport is done through rail

(for shares :11,2% of passenger.km and 10,5% of tons.km)*

20%

Of national traffic is operated by diesel

- **600,000 tons of CO_2** emission per year (2017)

Regional train fleet

2300 trains

- **50 %** of TER train fleet is equipped with **diesel engines**, representing 40% of kilometres operated, mono mode and bi-mode
- Long rolling stock lifetime over **40 years : investment for rail decarbonisation is needed today in order to remain competitive against road transport and be ready large fleet renewal**

*Source : Stratégie Nationale Bas Carbone 2015

SNCF objectives toward decarbonisation

2015 – 2025

Improve energy efficiency by 25%

Improve carbon performance by 20%

2035

End of diesel train operations

Hydrogen part of the solution portfolio

No Electrification	Partial Electrification	Full Electrification

DMU

EMU

Bi-mode diesel - DEMU

Bi-mode Hybrid Diesel Battery – Hy-DEMU

Bi-mode H_2 Train – H-EMU

Bi-mode Battery train B-EMU

Our portfolio is built to value the complementarity of solutions

Operational | Technical | Politic | Societal | Business Model

Innovation in the France H_2 train initiative

Operation flexibility & market size

- Bi-mode train → ability to operate on the whole rail network
- More capacity → suitable for medium traffic

Integration on an existing train platform

The demonstrator project involves the development of a new FCH train on an existing platform with the ability of retrofit in mind

Remaining challenges

- Available volumes → Limited H_2 autonomy
- Regulation/safety of catenary and H_2 in confined spaces
- New partnership model for refueling infrastructure, considering synergies without other usage
- Securing the financial roundtable to kick-off FCH train demo

Hydrogen deployment roadmap

2018	2022 — 2028	2035
French objective **First train in 2022**	**Demonstration and feedback** in several french regions	Potential **Large scale deployment**

- French transport minister to develop a FCH train by 2022
- Specification of the train and conception of infrastructures

- SNCF support the French regions in deploying a first mini fleet
- Generate feedback on operational conditions and economic performance

- Sustainability and replicable business model
- Adapted regulation

#HydrogenTrain

Starting Point: Austrian Climate & Energy Strategy #mission 2030

- ÖBB CO2 Neutrality in the Mobility Sector in 2030
- ÖBB CO2 Neutrality in total in 2050
- Traffic Relocation Road2Rail (Capacity through Innovation&Technology)

Infrastructure

- 4864 km Network (2/3 Electric)
- 10 HydroElectric PowerPlants
- 8+8 Terminals + Shunting Yards
- 80 Single Wagon Hubs

Production

- 6660 Trains daily / 800 Diesel
- 100 Diesel Locos Mainline
- 150 Diesel Shunters (80 E)
- 300 Diesel OTMs

SWOT: From 100% Green Electric to 100% Green Power with H2

S

- Green Power
- Reduced Maintenance
- New Design & Retrofitting
- Packaging & MGU

W

- Change of System
- Increased Complexity (short term)
- Cost level
- Green Hydrogen availability

O

- Innovation Path
- 100% Green Power
- Integrated Hybrid System
- Sector Coupling Enabler
- New Business Models

T

- Stranded Investments
- Legal & Safety hurdles
- Infrastructure restrictions
- Life Cycle
- (Overhead Electrification)

Timeline: From 100% Green Electric to 100% Green Power with H2

2019 2020 2021 2022

15 kW

Development Construction Demonstration Testing

Development Construction Demonstration Testing

300 kW

Development Construction Demonstration Testing

4-6MW

#HydrogenTrain / JU FCH & S2R

Thanks for Your Attention !

BEMU/hydrogen initiative for railways
Workshop FCH JU in Brussels 17 May 2019

Julian Mohr

Initiative on BEMU/hydrogen project for railways

- Motivation DB / SNCF (main promoters)
  - Fossil energy free operation on existing infrastructure (e.g. non or partially electrified)
  - Focus at first on regional traffic
  - With only new trains, it will take more than 30 years until all running diesel trains are substituted by new BEMUs / HMUs.
  - A large portion of the European Diesel fleet (appr. 4.000 Diesel trains) was identified to be suitable for a retrofit
  - Need for a component demonstrator for the use in battery trains, hybrid trains and hydrogen trains

- A separate working group was established, lead by DB / SNCF

- Participating Industry

ALSTOM BOMBARDIER CAF SIEMENS KNORR-BREMSE

The working group identified significant R&D-potential to be investigated

- Additional R&D-potential identified in the following clusters(in **bold**)

R&D-Cluster	Major Topics	Benefit / Effort
Use cases globally	• Market for storage systems • target costs / LCC-reduction • new services / increased availability • Migration strategy for rollout	to improve the knowledge of different solutions and use cases
Infrastructure *	• **Battery charging solutions for different applications** • Standardization of loading and refilling systems	to come to standardized and cost efficient solutions
Rolling Stock *	• **Battery technology for rail application** • weight and energy management • **technical roadmap on batteries and fuel cells**	to make the new technologies cheaper and more available
Operation	• Adoption of time table with recharging requirements • **Performance and system optimization** • safety aspects	to optimize the operational integration of the new technologies
Homologation	• Simplification and standardization of homologation • Scope enlargement to trains and infrastructure	to make the homologation of new technologies faster, cheaper and more flexible

* In coordination with EuroSpec-WG „Alternative traction“

The working group identified significant R&D-potential to be investigated

- Use cases globally
  - Reduction of System LCC expectations
  - Different new services offered by using battery / hydrogen trains
  - New “NEXT generation” battery / hydrogen trains or / and refurbishment of existing trains
  - Business models
  - Benchmarking with other transport modes
  - Adaption of rules for operation / train / infrastructure
- Infrastructure
  - Electricity: catenary and connector/plug; integration into national and European electric network
  - On-site hydrogen production from surplus power (wind or solar) incl. electrical grid stabilization
  - Hydrogen: filling stations integration into hydrogen "network"/supply
  - Ownership of loading facilities / investment / …
  - Standardization of loading and refilling systems/facilities
  - Safety (hydrogen filling)
  - Infrastructure/charging aspects

The working group identified significant R&D-potential to be investigated

- Operation
  - Driver training
  - Timetable optimisation
  - Performance (long distances/high speed/acceleration) vs. Costs (total and in comparison to todays DMU or…?)
  - Recharging time
  - Operation conditions (speed, disruptions, timetable, …)
  - Definition of "range" (under which condition)
  - Safety (passengers, battery hazard, rescue of train)
  - System optimisation (i.e. battery on board or on ground)
- Rolling Stock
  - Train system level (e.g. system architecture, weight management)
  - Battery technology (e.g. increased availability, standardized interfaces)
  - Fuel cell and hydrogen technology (e.g. improvement of hydrogen storage system)
- Homologation
  - Standardisation
  - Reduction of costs and duration
  - Safety (e.g. hydrogen filling)

Possible future collaboration between S2R / FCH – Open to railway stakeholders

- Motivation: Identification and exploitation of possible synergies and avoidance of double-funding by the EC

- Possibility to either make use of existing project results at FCH JU or to define topics for future collaboration involving
  - Technology providers
  - Railway stakeholders
  - Policy makers

- Results of the Roland Berger H2-study (presented today) may path the way for the future collaboration

Many thanks for your attention

GOBIERNO DE ARAGON

Departamento de Economía, Industria y Empleo

GOVERNMENT OF ARAGÓN

Workshop on the use of fuel cells and hydrogen in the railway environment

Brussels, 17th May 2019

D. C. Javier Navarro Espada
Technical Advisor Goverment of Aragón
Board Trustee of the Aragon Hydrogen Foundation

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

WHY HYDROGEN IN ARAGON?

- First Wind Farm in Spain installed near Zaragoza
- 2003: Great energy change approaching
- Reasons to support new hydrogen technologies:
  1. To take advantage of the renewable energy potential
  2. To take advantage of the region's strategic situation
  3. A consolidated industry with sectors that could apply and develop new products
  4. Existence of a high level of involvement in research groups
- 2003: Workshop organized by Government of Aragon
  - Objectives:
    - To learn and to discuss about hydrogen as energy vector
  - Results:
    - **Strategy to develop Hydrogen technologies in Aragon**
    - **Foundation for the Development of New Hydrogen Technologies in Aragon**

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

WHY HYDROGEN IN ARAGON?

- The initiative to develop hydrogen technologies in Aragon was included as key strategic line:
  - 2nd Research, Development and Knowledge Transfer Regional Plan of Aragon 2005-2008
  - Energy Plan of Aragon 2005-2012.
  - Energy Plan of Aragon 2013-2020.
  - **Aragon Research And Innovation Strategies For Smart Specialization (RIS3)**
  - **Aragon spatial planning strategies**

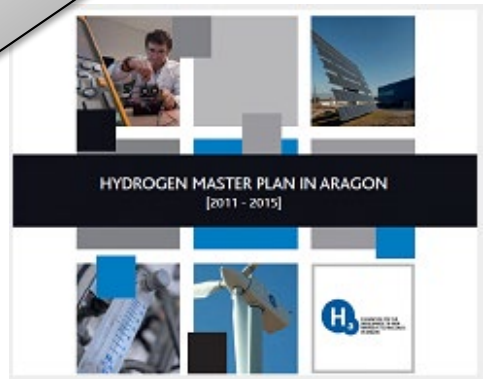
Hydrogen Master Plans in Aragon

TO PREPARE SME's AND PROFESSIONALS FOR THE FUTURE

AIMS OF THE PLAN:

- **GENERALS**
  - To have a tool for the identification of opportuniti technologies
  - To identify strategic lines for the region and t and actions plans
- **SPECIFICS**
  - To review the state of technolog nities.
  - To identify specific projects f
  - To set across-the-boa actions
  - To carry out a su orary horizons 2020-2050, defining the continuity of the strategi

(2007 – 2010)



(2011 – 2015)

(2016 – 2020)

Hydrogen Master Plan in Aragon 2016 - 2020

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

GENERAL AIMS OF THE PLAN

- To have a tool for the identification of opportunities of the new hydrogen technologies detected in Aragon, which will allow decisions to be taken on an institutional, business and academic level.
- To identify the strategic lines for the region and establish a time scale and actions plans for the deployment of these lines.
- To involve the Aragonese economy in the adoption of new technologies as a differentiating competitive positioning factor in the medium and long term

SPECIFIC AIMS OF THE PLAN

- To review the state of the art of technology, current development, projects, reference companies in the sector, potential of the region in the matter, incipient markets and to define opportunities.
- To identify strategic lines of work for the coming years and opportunities for specific development for the Aragonese business sector.
- To set cross-cutting and general support actions: training, awareness-raising, technology transfer, protection and impact needed to guarantee the success of the deployment of the rest of the work lines (production, storage, transportation, distribution and applications.)
- To define actions oriented to achieve specific results through the establishment of monitoring indicators that allow monitoring effectively the objectives proposed.
- To carry out a survey with longer temporary timeframes2020-2050, defining the continuity of the strategic lines drawn and setting the bases to reach these.

http://hidrogenoaragon.org/wp-content/uploads/2016/07/director_plan_english.pdf

Hydrogen Master Plan in Aragon 2016 - 2020

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

A. Production.

B. Storage, transport and distribution.

C. Applications.

D. Transfer of technology, protection and economic impact.

E. Training and awareness.

TRL-0	Idea.
TRL-1	Basic Research.
TRL-2	Technology Concept Formulated.
TRL-3	Applied Research.
TRL-4	Small-scale Prototype.
TRL-5	Large-scale Prototype
TRL-6	Prototype System.
TRL-7	Demo System.
TRL-8	First Commercial-type System.
TRL-9	Complete Commercial Application.

Line of Work: Production

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
1. Electrolysis	Optimization at the technical and cost level, through simulation and improved design of components and subsystems	HIGH	5 to 7	First design made for TRL 6	Systems developed and tested aligned with the European Indicators for 2020 (TRL 7; CAPEX 2M€/ ton/day)

ELYGRID

ELYGRID

Improvements to Integrate High Pressure Alkaline Electrolysers for Electricity/H2 production from Renewable

ELYNTEGRATION

elyntegration

Grid Integrated Multi Megawatt High Pressure Alkaline Electrolysers for Energy Applications

DEMO4GRID

DEMO 4GRID

Demonstration of 4 MW Pressurized Alkaline Electrolyser for Grid Balancing Services

QualyGridS

QualyGridS

Standarized qualifying tests of electrolysers for grid services

ELY4OFF

ely4off

PEM ELECTROLYSERS FOR OPERATION WITH OFFGRID RENEWABLE INSTALLATIONS

PEM ElectroLYsers FOR operation with OFFgrid renewable installations

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

Line of Work: Storage, Transport and Distribution

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
2. Study of development of storage systems for the market standards	Study on high pressure container development	MEDIUM	9	Completed studies and conclusions	To be determined
	Study on development of equipment for the standardised test composite containers	MEDIUM			

BIG HIT

BIG H2IT

Building Innovative Green Hydrogen Systems in Isolated Territories

CALVERA

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

Line of Work: Applications

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
5. Hydrogen integration in isolated grids	Design, development and implementation of projects with hydrogen technologies in isolated networks fed by RES	HIGH	6 to 7	Start of a demonstrator in Aragon	Know-how established in the industrial fabric of Aragon
	Design and optimisation of power electronics and communications and control systems for the production of hydrogen in isolated networks from RES	HIGH			
	Seek opportunities of demonstrators in isolated networks where hydrogen can be somehow integrated, preferably in rural areas. Identification of possible locations /end users	HIGH			

SustainHuts

SustainHuts
Sustainable Huts

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

About the railway

- We believe that the possibilities of application of hydrogen technologies find in the railway one of the niches of application more feasible and closer to the market.

- In Aragon we have a developed sector of bodybuilders.

- In Zaragoza there is an important railway construction company, CAF.

- The industrial subsector of transport equipment is the most important in our region.

- Among the shareholders of the Foundation are several companies from the industrial and services sectors related to the railway.

- The Foundation worked on the planning of mobility concepts for the Zaragoza tramway with the aim of eliminating the catenary at some point. And it already has some experience in the sector.

- The Aragonese logistics sector, due to its geographical location, is one of the strongest in southern Europe.

- We have the technological capacity and the will to promote the application of hydrogen technologies in the railway sector.

Line of Work: Transfers of technology, protection and economic impact

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
4. Impetus to standardisation systems	Participation in AENOR committees	MEDIUM	N/A	N/A	N/A
	Participation in European and international level initiatives(For example: CENELEC)	MEDIUM			

MetroHyVe

METROLOGY for HYDROGEN VEHICLES

Metrology for Hydrogen Vehicles

EMPIR

HYLAW

HyLAW

Identification of legal rules and administrative processes applicable to Fuel Cell and Hydrogen technologies'

HYTECHCYCLING

HyTechCycling

New technologies and strategies for fuel cells and hydrogen technologies in the phase of recycling and

15NRM03 Hydrogen

Hydrogen

Metrology for sustainable hydrogen energy applications

EMPIR

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

Line of Work: Training and awereness

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
1. Studies on social perception and technology dissemination effectiveness	Perception and social acceptance study for companies	HIGH	Degree of acceptance	Hydrogen technologies are known by at least 50% of SMES in the region	Hydrogen technologies are known and accepted by at least 70% of SMES in the region
	Perception and social acceptance studies for society in general	HIGH	Degree of acceptance	Hydrogen technologies are known by at least 20% of the population of the region	Hydrogen technologies are known and accepted by at least 40% of the population of the region

VUELTAH

vueltaH

Estrategias de diVUlgación y concienciación en eL Territorio nAcional en materia de Hidrógeno y pilas de

FECYT

ACTIONS	PROCEEDINGS	PRIORITY	INDICATOR	2018	2020
2. Actions within the WHEC 2016	Competition of ideas on hydrogen and fuel cells technology innovation	MEDIUM	No. of participants	5	NA
	Development of activities in the framework of the "Emprender en la Escuela" Programme	MEDIUM	No. of participants	5	NA
	Demonstration of practical applications close to society presented in the WHEC 2016	MEDIUM	No. of participants	5	NA
	Development of technical visits to projects and entities related with hydrogen in the region	MEDIUM	No. of participants	3	NA

whec 21st 2016 Zaragoza Spain

Med-Term Review 2018

07. CONCLUSIONES

El proceso de evaluación intermedia del Plan Director del Hidrógeno en Aragón 2016-2020 constituye uno de los compromisos adquiridos en su redacción y un elemento de impulso de las actividades previstas en un momento especialmente relevante en el que el sector hidrógeno afronta nuevos retos tecnológicos.

La evaluación realizada se ha divido en tres bloques principales:

- **Resultados por líneas de trabajo, estructurado en las cinco líneas definidas en su redacción.**
- **Resultados en términos globales.**
- **Actualización del Plan Director a mitad de periodo que incluye una propuesta de líneas a trabajar para la fase final del Plan.**

Para ello, el presente informe ha empleado la combinación de un análisis documental de la información disponible y generada en el periodo de vigencia del Plan Director junto con el desarrollo de un intenso proceso de participación a través de mesas de trabajo y entrevistas con responsables de la FHa y organismos representativos en su ejecución.

Las mesas de trabajo contaron con la participación de 30 organismos y empresas que realizaron una labor de análisis de las acciones estratégicas a la vista de los últimos avances tecnológicos y legales. Es destacable por tanto la buena respuesta y alta participación de las empresas y organismos aragoneses que fueron invitados a tomar parte del proceso participativo.

RESULTADOS POR LÍNEAS DE TRABAJO

El análisis y evaluación del desarrollo de las líneas de trabajo, y del cumplimiento de las actuaciones y objetivos establecidos en las mismas, permite extraer las siguientes conclusiones:

- La línea de producción de hidrógeno cuenta con un alto grado de cumplimiento de las actuaciones propuestas. El desarrollo de tecnología de electrólisis y la electrónica de potencia asociada sigue siendo una de las principales líneas de trabajo del FHa y varias empresas de la región. Actualmente existen 8 proyectos en marcha con actuaciones en este campo.
- Otros procesos de producción de hidrógeno, como la producción a partir de residuos, aún con menor actividad en la región, siguen considerándose de interés y se mantienen como acción estratégica.
- La línea de trabajo de almacenamiento transporte y distribución es la que menor grado de actividad y cumplimiento ha tenido en la revisión realizada. Es una línea que engloba acciones de desarrollo de tecnología que han sido modificadas para adecuarse a la realidad del estado de la tecnología en este campo.
- De manera especial, la distribución de hidrógeno sigue considerándose una línea de prioridad alta debido a que Aragón tiene una ventaja competitiva y además se mantiene el interés de lograr el objetivo de quedar incluida en la red de corredores del hidrógeno a nivel europeo. Aunque los objetivos marcados para este periodo no se han cumplido, debido sobre todo al retraso en la puesta en marcha del proyecto más importante al respecto, H2PiyR, se mantiene con toda su vigencia para la fase final del Plan Director.
- En la línea de aplicaciones del hidrógeno destaca el desarrollo de tecnología de pilas de combustible que en Aragón está liderado por el CSIC y la Universidad de Zaragoza. Las acciones y actuaciones propuestas se han cumplido casi en su totalidad en el periodo.

El objetivo a 2020 de una transferencia efectiva de conocimiento que permita tener un know-how establecido en el tejido industrial, aunque se considera ambicioso, se considera interesante de mantener para impulsar las actividades al respecto.

- Otro tipo de aplicaciones del hidrógeno en redes aisladas y aplicaciones nicho como la aeronáutica y los sistemas de Power-to-Gas tienen un grado de desarrollo aceptable a mitad de periodo y se mantienen como acciones estratégicas.
- En general, la línea de aplicaciones del hidrógeno ha sido una de las más dinámicas ya que cuenta con el mayor grado de cumplimiento de todas las líneas estratégicas con un 81 % de acciones iniciadas a mitad de periodo, aunque sólo un 25 % se pueden considerar que han cumplido los objetivos en su totalidad.
- Respecto a la línea de transferencia de tecnología, protección e impacto económico se consideró durante la preparación del Plan Director de importancia estratégica alta y se propusieron acciones muy concretas relativas a acciones de colaboración empresarial, de las cuales se han iniciado más de un 60 % y finalizado el 50 % de las mismas. Los buenos resultados en este ámbito reflejan sobre todo la gran labor de la FHa de cara a la sociedad y tejido empresarial aragonés, como la creación de una nueva empresa y la diversificación de productos/negocio en otras dos.
- Finalmente, la quinta línea de formación y sensibilización se considera de importancia capital y se han realizado muchas actividades durante el periodo con buenos resultados destacando las realizadas en el Congreso Mundial del Hidrógeno 2016, en Zaragoza. No obstante, en el marco de la presente evaluación ha sido redefinida para contener a futuro toda clase de actividades que puedan realizarse. Fruto del desarrollo de las mesas se concluyó que, si bien se había trabajado mucho en este campo, la sensibilización y concienciación de la ciudadanía es de alta importancia, sobre todo ante los cambios de los modelos de transporte y los debates en torno a los nuevos combustibles y nuevas tecnologías. Por ello, en su redefinición continúa teniendo un papel primordial para lograr los objetivos globales del Plan.

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

Med-Term Review 2018

RESULTADOS EN TÉRMINOS GLOBALES

El Plan Director del Hidrógeno 2016-2020 cuenta con un sistema de seguimiento global que ha sido analizado también en la presente evaluación y cuenta con un conjunto de indicadores que permiten valorar su nivel de avance divididos en tres tipologías:

- **Indicadores de seguimiento: globales y por línea de trabajo.**
- **Indicadores de resultado.**
- **Indicadores de gestión.**

El análisis de los indicadores de seguimiento propuestos en el Plan refleja una evaluación intermedia muy positiva del cumplimiento de los objetivos propuestos. Así, durante este período, aunque el número de proyectos financiados ha disminuido levemente ha aumentado considerablemente la inversión global y la financiación recibida en total, siendo resultado este hecho de la participación en proyectos de mayor envergadura y con más participación aragonesa. Además, el número de empresas que tienen en marcha proyectos con tecnologías del hidrógeno es mayor que en periodos anteriores, y la financiación obtenida por las empresas triplica a la obtenida en el periodo total del Plan anterior.

- El hidrógeno constituye un elemento que cada vez suscita un mayor interés. Este factor se refleja en el interés de empresas y organismos aragoneses en el desarrollo de proyectos de hidrógeno, contabilizando además de los integrantes del Patronato de la FHa, 15 organismos que realizan actividades en este campo.
- La composición del Patronato de la FHa ha ido creciendo también paulatinamente, situándose en 70 organismos en el periodo analizado por encima de la media de 66 en el periodo anterior.
- Los profesionales dedicados a las tecnologías del hidrógeno también han crecido de una forma considerable. La plantilla fija de la FHa ha aumentado un 16 % respecto al periodo anterior y la participación en personas/año por parte de las empresas y otros organismos está actualmente en cifras cercanas a los 40.
- Respecto a los indicadores de resultado la cifra de inversión global, cercana a los 10 millones ha superado ampliamente la del periodo anterior, que se encontrada en 8 millones. La financiación recibida en convocatorias públicas se sitúa en casi 7 millones destacando además el éxito obtenido por las empresas con algo más de 2 millones de euros en proyectos de hidrógeno y pilas de combustible.
- Finalmente, respecto a los indicadores de gestión el cumplimiento ha sido muy positivo. El Plan Director cuenta con 21 acciones y 61 actuaciones concretas en las cinco líneas de trabajo establecidas. El porcentaje de actuaciones en marcha en total asciende al 62 % y el de actuaciones que ya han alcanzado los objetivos fijados es del 36 %. Además los indicadores relativos a reuniones de seguimiento, presentación de propuestas y convenios han seguido la senda marcada en su definición.
- En definitiva, los indicadores del sistema de seguimiento globales, así como los de resultado y gestión son adecuados para la correcta monitorización de los objetivos del Plan y por tanto no se han propuesto modificaciones en el mismo en esta etapa intermedia.

ACTUALIZACIÓN DEL PLAN DIRECTOR 2016-2020.

Dentro del proceso de evaluación se ha constatado que el cumplimiento de los objetivos del Plan por línea de trabajo no ha sido uniforme por lo que se ha propuesto en el marco de la presente evaluación una reflexión sobre las causas de esta disparidad y la validez de las acciones y actuaciones propuestas así como de los objetivos fijados.

Para ello además del análisis documental el desarrollo de las mesas de trabajo y entrevistas realizadas ha constituido una valiosa fuente de información para esta revisión.

La realización del proceso de participación a través de las mesas permite concluir que existe un consenso con los participantes para afrontar las modificaciones incluidas en el Plan Director, la replanificación de alguna línea de acción y el mantenimiento o modificación de los objetivos.

Además, aunque algunos objetivos propuestos se consideran exigentes a la vista de las actuaciones ejecutadas, en la mayoría de los casos se ha optado por mantenerlo en respuesta al espíritu positivo de los participantes en continuar con los desarrollos planteados y a la espera de la mejora del marco económico actual.

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

Med-Term Review 2018

Las modificaciones más significativas realizadas sobre la revisión del Plan incluyen las siguientes revisiones:

- En la línea de producción de hidrógeno, se ha incluido una diferenciación de tecnología de electrólisis entre PEM y alcalina.
- Respecto a la línea de almacenamiento, transporte y distribución, se incluye de forma específica el seguimiento de diferentes tipologías de almacenamiento quitando la prioridad al almacenamiento mediante hidruros.
- En cuanto a la línea de aplicaciones del hidrógeno se mantiene las acciones generales propuestas.
- Respecto a la transferencia de tecnología, protección e impacto económico, la revisión se ha dirigido en la línea de seguir fortaleciendo este ámbito incrementando la implicación de empresas aragonesas que puedan aprovechar las oportunidades del hidrógeno. Se mantienen las acciones globales propuestas como objetivo, pero se definen actuaciones de manera más amplia para recoger la enorme diversidad de actuaciones que puedan hacerse en este campo.
- En cuanto a la línea de formación y concienciación al igual que en el caso anterior se mantienen las acciones y se incluyen actuaciones menos concretas para incluir la diversidad de las mismas.

Finalmente, en el marco del presente Plan se establecen algunas recomendaciones operativas surgidas del proceso de evaluación que se considera de interés de aplicación de cara a la fase final de la programación 2016-2020:

- Los cambios normativos constituyen un elemento básico en el ámbito de hidrógeno de cara al futuro. Por ello, resulta de interés el establecimiento de elementos de vigilancia en materia normativa y social para que puedan ser incorporados a la estrategia futura de actuación de cada organismo.
- Las mesas de trabajo han permitido evidenciar líneas futuras de trabajo que si bien puede ser prematura su inclusión en este momento es necesario el establecimiento de un protocolo de seguimiento que permita no perder las oportunidades que ofrece el sector para su inclusión en el próximo Plan. Además esta metodología participativa, que ha resultado muy provechosa por parte de los participantes, puede dar lugar a constituir un foro de encuentro de los organismos más representativos que trabajan o buscan trabajar con el hidrógeno y establecer nuevos mecanismos de trabajo conjunto.
- En materia de seguimiento se considera de interés ampliar el seguimiento de los indicadores de resultado para lograr una verdadera cuantificación del impacto que supone la inversión en hidrógeno así como los resultados de la financiación obtenida en diferentes convocatorias europeas sobre la materia.

International Participation (HyER)

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

HyER

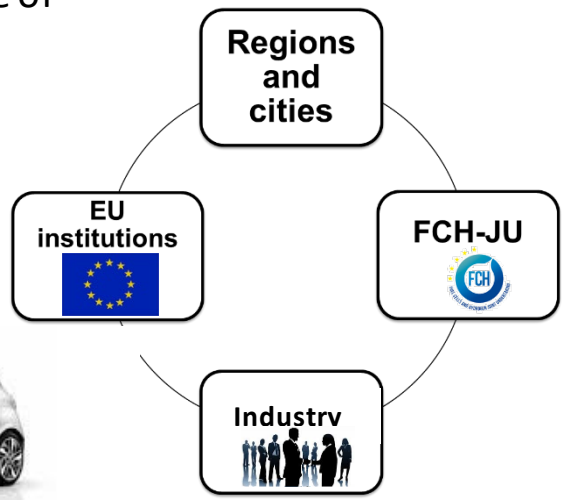
Representing the interests of European regions and cities active in the field of hydrogen, fuel cells and electro mobility

Aberdeen UK	Akershus NO	Aragon ES	Arnhem/Nijmegen NL
Berlin DE	Bolzano IT	Drenthe NL	Groningen NL
Hamburg DE	NRW DE	Occitanie FR	Rogaland NO
Riga LT	Skane SE	Torres Vedras PT	Transp. Scot UK

- Membership based network / political organisation
- 16 members in 10 countries (02.2018)
- **Aim**: help our members to develop their hydrogen and electro-mobility activities

Enabling the share of knowledge

Bridging the gap



FCH JU Cities & Regions Initiative

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

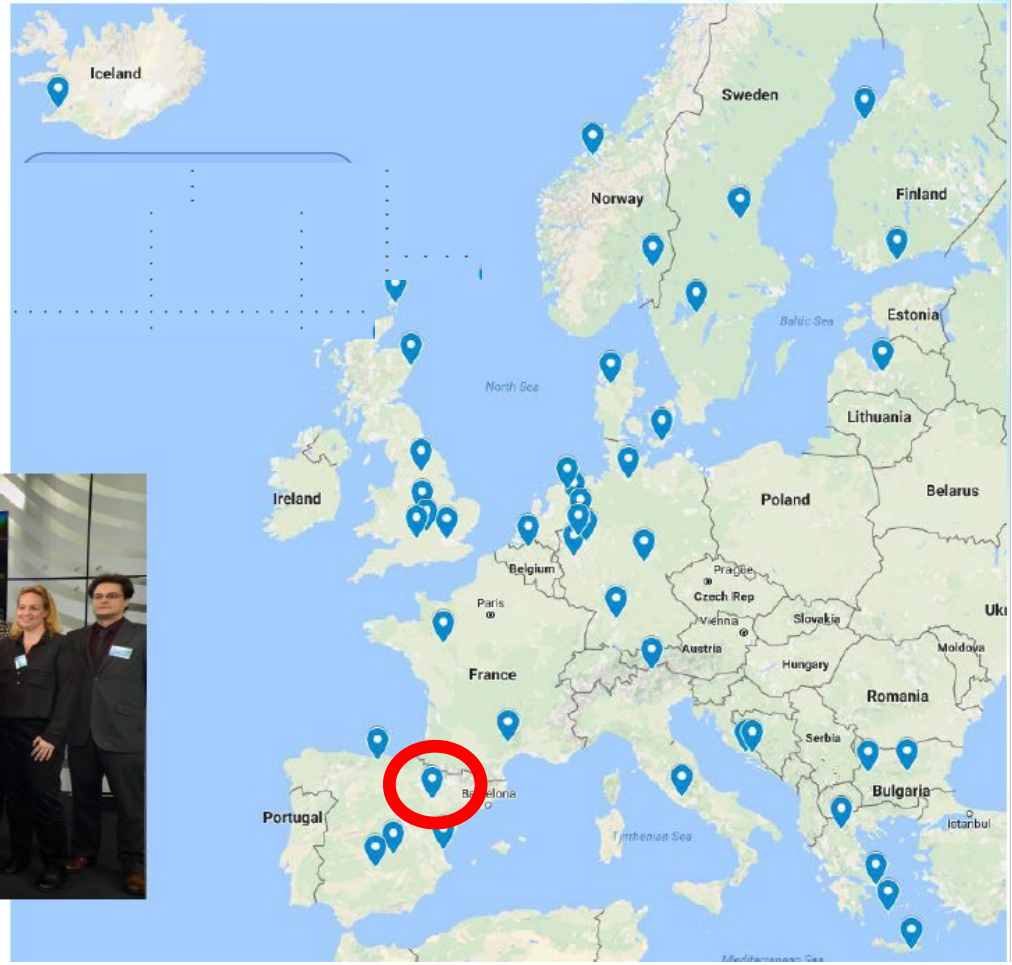
New initiative:
>50 Cities & Regions signed an MOU with the FCH - JU

Opportunity to participate in a large study:

- Defines business cases for Hydrogen & Fuel Cell based products the Cities & Regions are seeking for.
- Put Cities & Regions in direct contact with the Industry
- Help to find best financing schemes

At **no cost to the Cities & Regions**
(other than their own time and travel costs)

Signing ceremony 23rd Nov. 2016



European Hydrogen Initiative

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

Aragon Hydrogen Foundation

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

FUNDACIÓN PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGÍAS DEL HIDRÓGENO EN ARAGÓN

The Foundation for the Development of New Hydrogen Technologies in Aragon is a private, not-for-profit entity, **created to promote the use of hydrogen as an energy vector.**

Key instrument for **the promotion of strategic projects** around the hydrogen, renewable energy, electric vehicles, energy efficiency. With the purpose of generating, storing and transporting hydrogen, for its use in fuel cells, in transport applications or for the generation of distributed energy. In this way it aims to foment research, technological development, cogeneration and industrial adaptation, contributing to industrial modernization and improved competitiveness.

Created: December 23rd 2003

First meeting of Board: May 25th, 2004

ADMINISTRACIONES PÚBLICAS

- Instituto Aragonés de Fomento
- Gobierno de Aragón
- Ayuntamiento de Sabiñánigo
- Ayuntamiento de Huesca
- Ayuntamiento de Jaca

CORPORACIONES Y ASOCIACIONES

- Ingenieros Industriales
- Cogitiar
- Cámaras Aragón
- CEOE Aragón
- CEOE Zaragoza 40 años

ENERGÍA

- Taimweser
- AEA
- Syder
- IMS Never Stop Heating
- Class management
- CLH
- endesa
- Grupo SAMCA
- Vestas
- Jorge
- Compañía Eólica Aragonesa, S.A.
- innogy
- Redexis gas
- Geolica
- Atlas Copco
- IBERDROLA
- SKY GLOBAL
- SIEMENS Gamesa
- enhol
- ZOILORÍOS
- SAI

INMOBILIARIA Y OBRA CIVIL

- Brial
- HORCONA
- VIDAL

INDUSTRIA QUÍMICA

- Air Liquide
- Ercros
- Linde
- CARBUROS METÁLICOS

AUTOMOCIÓN

- Valeo
- AIRTEX
- OPEL
- TATA

METAL MECÁNICO

- Joarjo
- lapesa
- CALVERA

INVESTIGACIÓN, ENSEÑANZA E INNOVACIÓN

- circe
- ITAINNOVA
- CSIC
- Universidad Zaragoza
- CEEI ARAGÓN
- eupla
- SANVALERO
- walqa Parque Tecnológico

INGENIERÍA Y CONSULTORÍA

- idom
- maetel
- VeaGlobal Ingeniería & Consultoría
- intecsa | inarsa
- tafyesa
- satel

SEGURIDAD Y HOMOLOGACIÓN

- SGS
- GMR
- Grupo itevelesa
- ECA

OCIO Y TURISMO

- aramon

ASOCIADO

- Scottish Hydrogen & Fuel Cell Association

TRANSPORTE

- tradime Aragón
- LeciTrailer
- CAF
- urbanos de zaragoza

FINANZAS

- Going Investment
- Bantierra
- Caja Rural de Teruel

NOMINATIVO

Carlos Javier Navarro

DE HONOR

Jeremy Rifkin

Víctor Manuel Orera

Emilio Domingo

Projects and Colaborations

GOBIERNO DE ARAGON
Departamento de Economía, Industria y Empleo

FUNDACIÓN PARA EL DESARROLLO DE LAS NUEVAS TECNOLOGÍAS DEL HIDRÓGENO EN ARAGÓN

Industrial Development Level

Agreements / Colaborations

FCH – Fuel Cells and Hydrogen Joint Undertaking
Hydrogen Europe Research
HYER
Scottish Hydrogen & Fuel Cell Association
Centro Nacional del Hidrógeno
AeH2 Asociación Española del Hidrógeno
APPICE Asociación Española de Pilas de Combustible
UNE Normalización Española

Projects (Among Others)

EVERYWH2ERE
Making hydrogen affordable to sustainably operate Everywhere in European cities

BIG HIT
Building Innovative Green Hydrogen Systems in Isolated Territories

DEMO4GRID
Demonstration of 4 MW Pressurized Alkaline Electrolyser for Grid Balancing Services

QualyGridS
Standarized qualifying tests of electrolysers for grid services

HYLAW
Identification of legal rules and administrative processes applicable to Fuel Cell and Hydrogen technologies'

HYTECHCYCLING
New technologies and strategies for fuel cells and hydrogen technologies in the phase of recycling and

ELY4OFF
PEM ElectroLYsers FOR operation with OFFgrid renewable installations

ELYNTEGRATION
Grid Integrated Multi Megawatt High Pressure Alkaline Electrolysers for Energy Applications

HYTETRA
Hydrogen Technology Transfer

HYPROFESSIONALS
Training Tomorrow's Hydrogen Professionals

HYUNDER
Assessing the potential, actors and business models of large scale underground hydrogen storage in Europe

KNOWHY
Improving the Knowledge in Hydrogen and Fuel Cell Technology for Technicians and Workers

FLUMABACK
Fluid Management component improvement for Back up fuel cell systems

ELYGRID
Improvements to Integrate High Pressure Alkaline Electrolysers for Electricity/H2 production from Renewable

GOBIERNO DE ARAGON

Departamento de Economía, Industria y Empleo

Thank you very much for your attention

C. Javier Navarro Espada
jnavarro@aragon.es

www.aragon.org www.hidrogenoaragon.org

ENTREE 100

REGION HEIDE

ENTREE100

Project initiative for multi-MW-Applications in Hydrogen und Flexibilities

17.05.2019: Potential of hydrogen by railways in SH - S2R/FCH - Brussels

Development agency Region Heide

City of Heide

REGION HEIDE

Department KLG Heider Umland

Supervisory board

CEO / director

Promotion of economic development

City-surrounding-cooperation

ENERGY

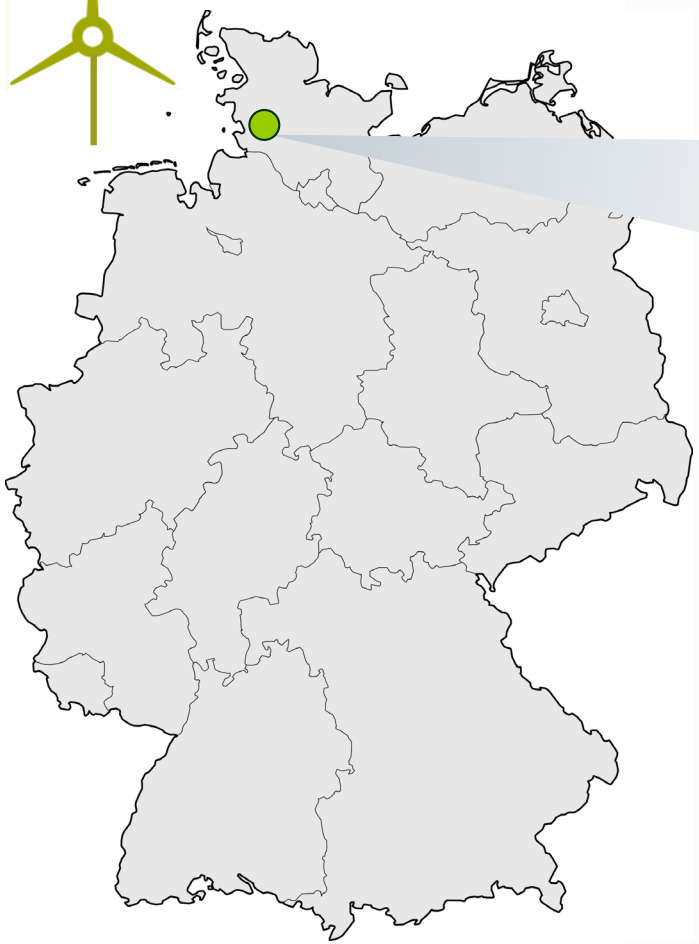
- Real Estate Westküste
- Real Estate Lohe-Rickelshof, Wöhrden, u.a.
- Settlements and Start-ups
- Existing enterprises and expansion
- Networking, R&D-Projects

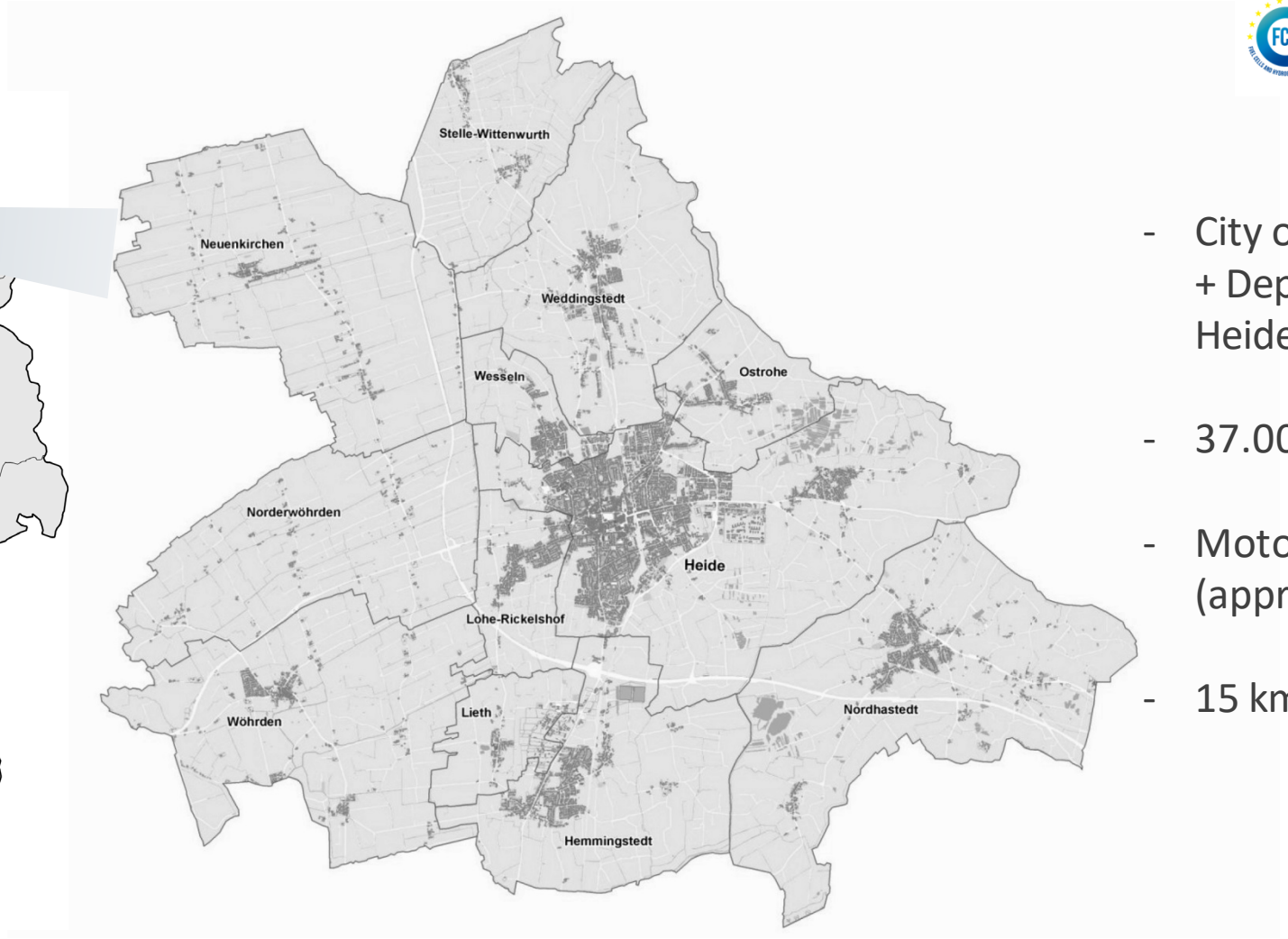
- Living
- Retail and trade
- Schools and social infrastructure
- Traffic & Mobility
- Landscape and Erholung
- Space- and vacancy-management

Funding and project development

Public authority
Non profit
10 employees
Founded 2013

Region Heide - Facts





- City of Heide
  + Department KLG Heider Umland
- 37.000 inhabitants
- Motorway to Hamburg (approx. 45 min)
- 15 km to north sea

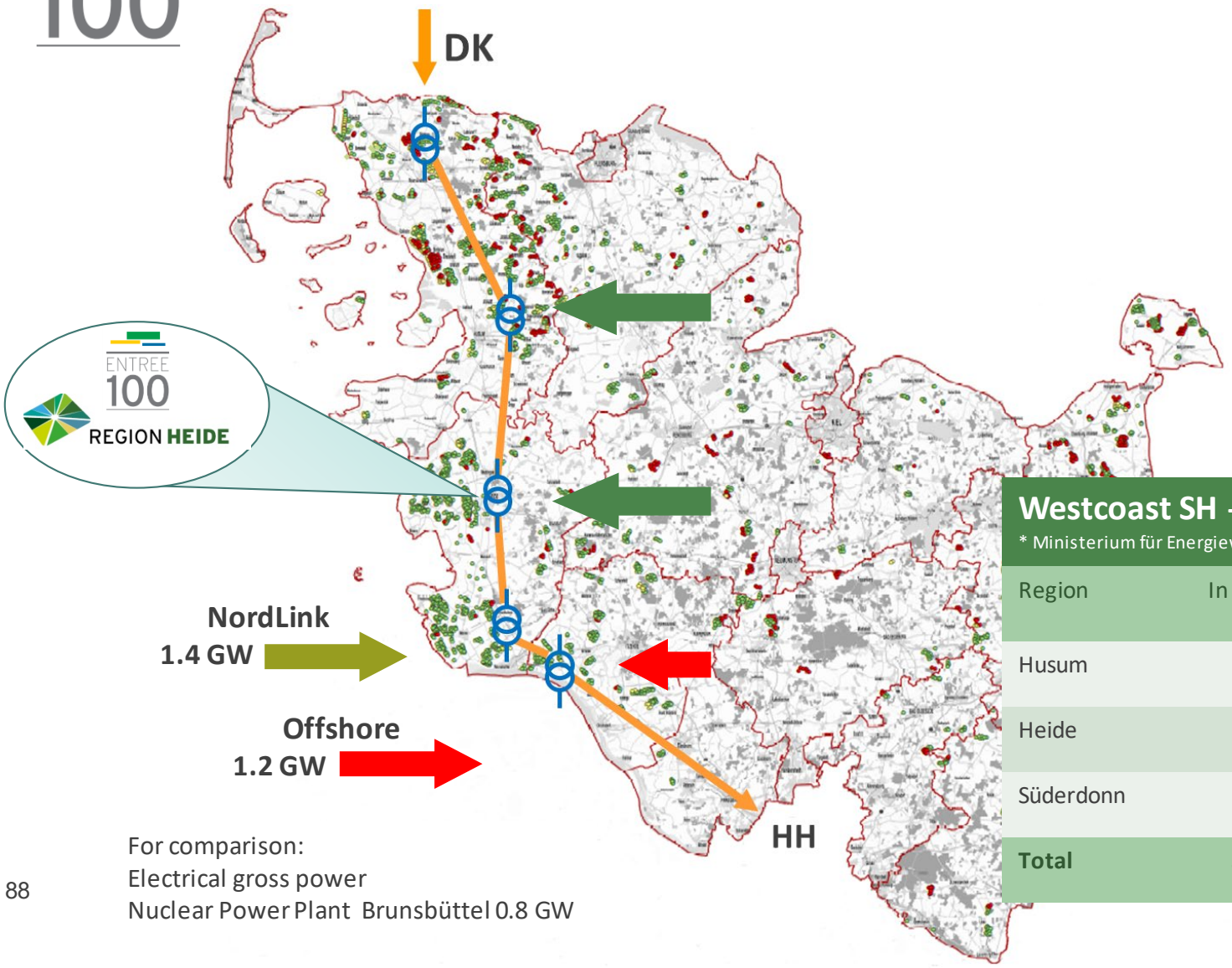
Region Heide - Impressions

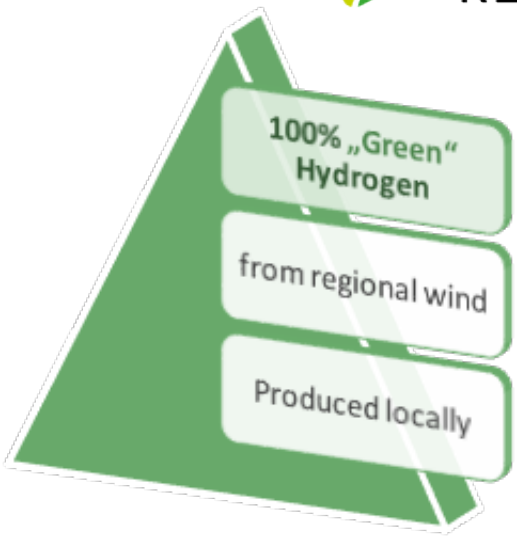
Germany´s largest market place

Europe´s largest region for cabbage

WE‘VE GOT ENERGY!

Our Asset - Energy





Westcoast SH - Windpower Onshore 2016 *

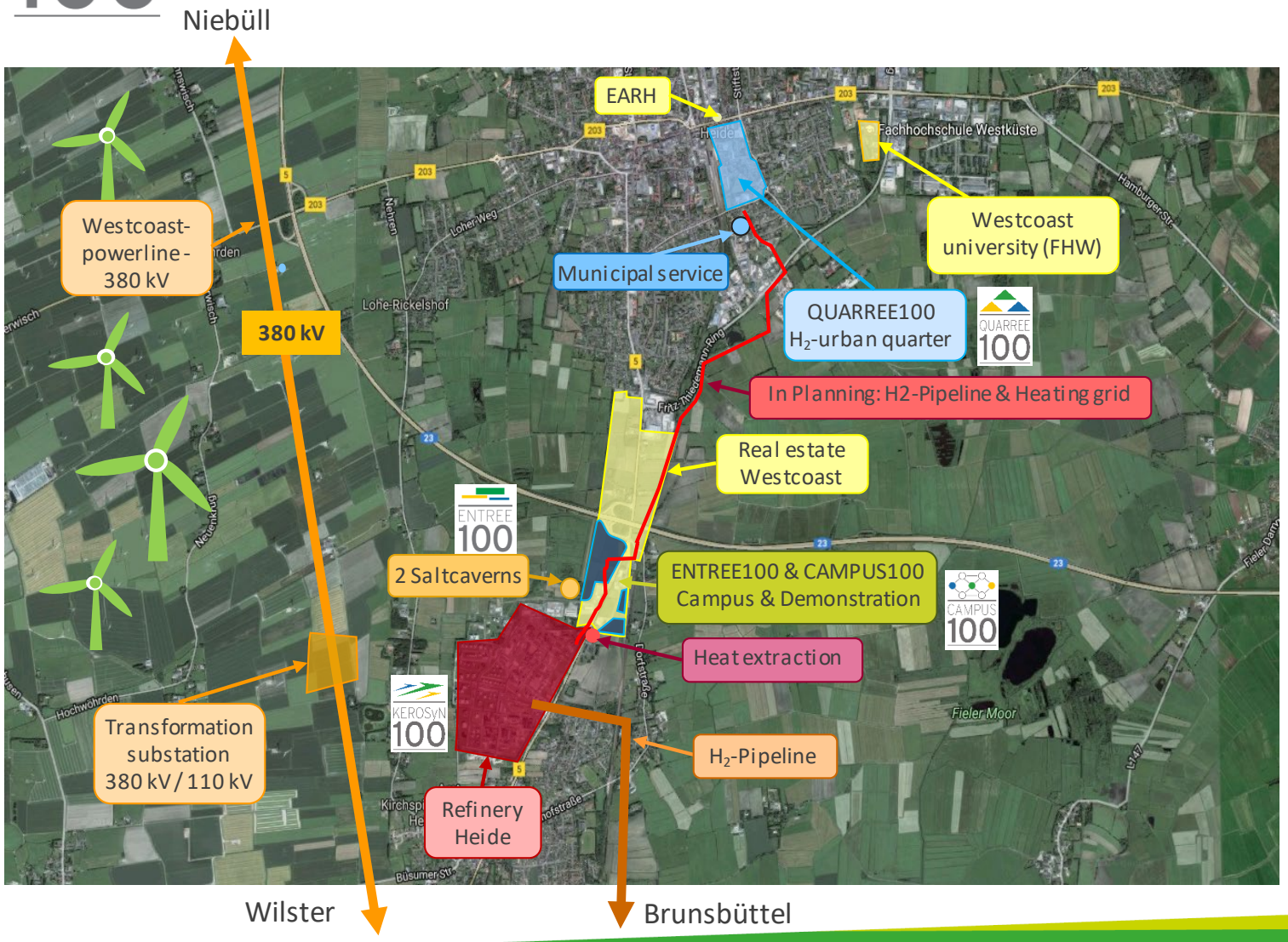
* Ministerium für Energiewende SH

Region	In operation	Under construction	Applied	**Total**
Husum	1,8 GW	0,4 GW	0,8 GW	**3,0 GW**
Heide	0,9 GW	0,1 GW	0,1 GW	**1,1 GW**
Süderdonn	0,8 GW	0,1 GW	0,1 GW	**1,0 GW**
Total	**3,5 GW**	**0,6 GW**	**1,0 GW**	**5,1 GW**

For comparison:
Electrical gross power
Nuclear Power Plant Brunsbüttel 0.8 GW

Prensent project assembly

Region Heide – infrastructure today



Project Initiative
ENergy System **T**ransformation towards **100**% **RE**newable **E**nergy

Project (2017 – 2022)
System-beneficial urban energy supply systems for full integration of renewable energies

Project (2017 – 2021)
R&D to produce green, synthetic jet fuel by hydrogen and CO_2 via methanol

Research
Institute for transformation of the energy system

Current application BMWI

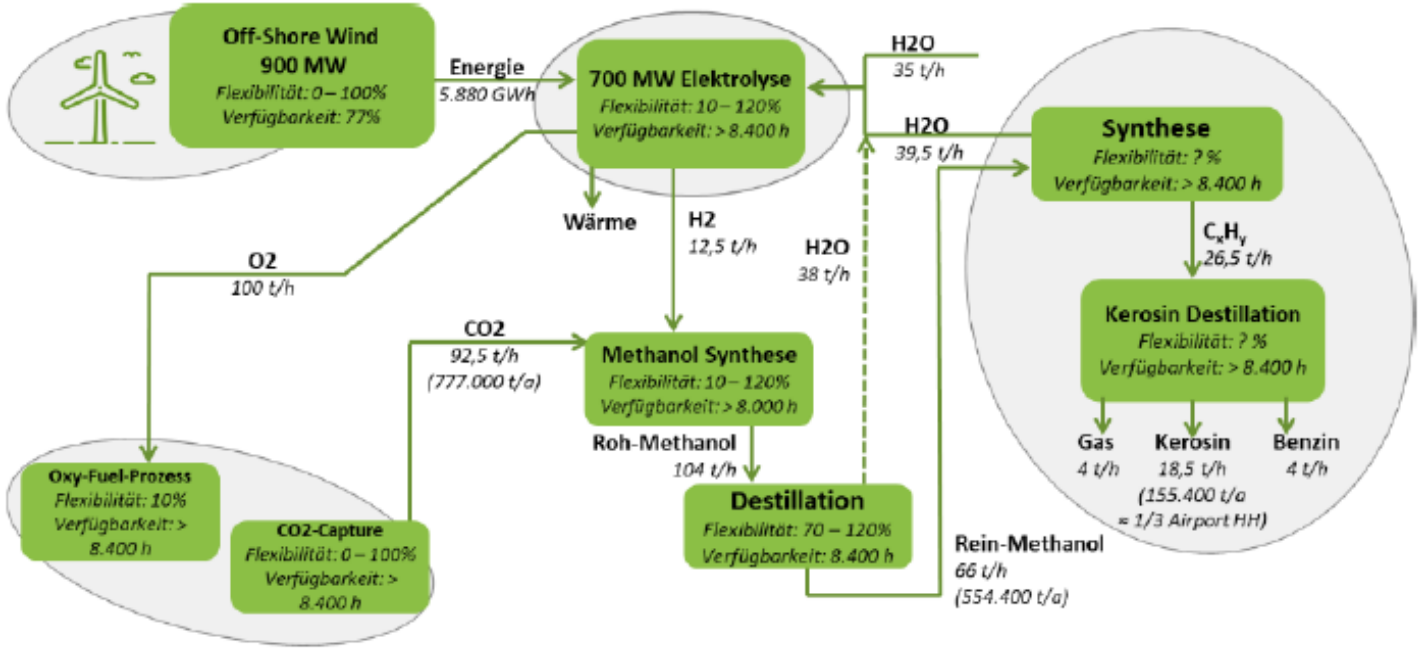
„Reallabor Westküste 100“

Supply-Chain orientierted Energy Transition process meets Decarbonisation of Industry

Application Reallabor
(submitted 05 April 2019, desicion July 2019)

- Application in the call “Reallabore” of the 7th Energy Research Program (BMWI, German Federal Ministry for Economic Affairs and Energy)
- 9 partners (7 enterprises, 1 university, 1 municipal entity)
- 30 MW elektrolyse
- Complete value-added chain from RES to Syn-Fuel
- First integration of the cement industry as unavoidable source of CO2
- Option for scale-up to 700 MW electrolyse

Reallabor Westküste100 – a complete value-added chain



Current application Horizon 2020

H2 Valley Heide-Hamburg-Northern Germany

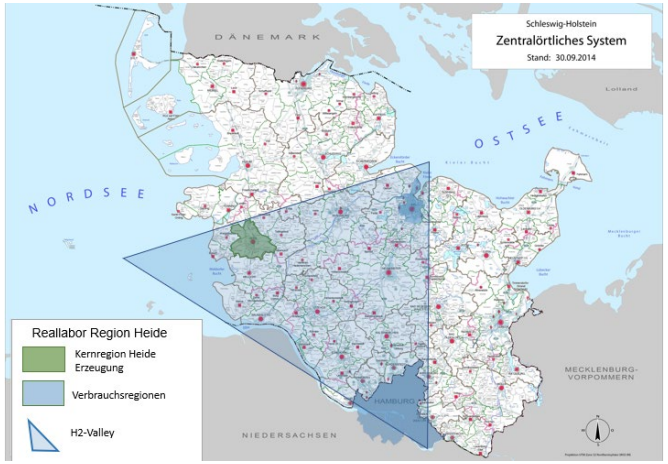
H4Valley - 100% Green Hydrogen for Integrated Economies

H4Valley

PROPOSAL TO THE CALL H2020-FCH-03-1-2019 (Horizon2020)

- H2 integrated hydrogen economy from RES to diverse end-user application portfolio
- H2-Application with 5t/d (1.500 t/a) H2 demand
- H2-Application in transport sector (trucks, busses, cars, garbage trucks)
- H2-Application in energy sector (cooperation with QUARREE100)
- H2-Application in industry sector (Production of synthetic fuels)

H4Valley – core region (Heide – Hamburg)



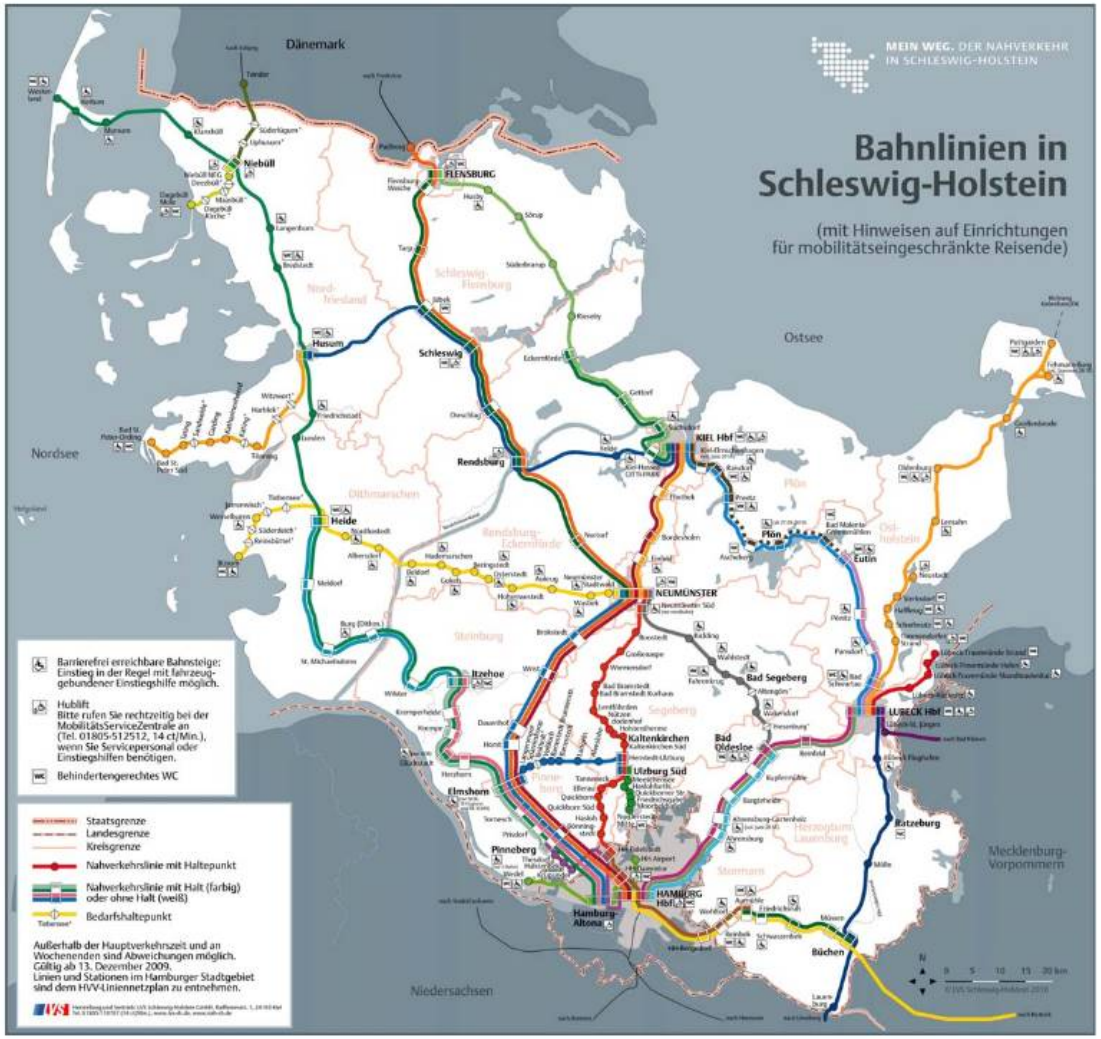
H4Valley – expanded Region (Heide – Hamburg - Kiel)

ENTREE 100

REGION HEIDE

Schleswig-Holstein
fuel cells and hydrogen
in the railway environment

Track overview from NAH.SH



Current Work – H2-to-Rail

Hydrogen train option in Schleswig-Holstein

Schleswig-Holstein

DIENSTAG, 2. OKTOBER 2018

Stiegen in den Wasserstoff-Zug ein (v. l.): Dirk Burmeister (Geschäftsführer Entwicklungsagentur Heide), Wulfgang Seyb (AKN-Geschäftsführer), Verkehrsminister Bernd Buchholz und Jörg Nikuta (Geschäftsführer Alstom Deutschland). FOTO: MANUEL WEBER

Wasserstoff als Alternative

Alstom stellt seinen komplett emissionsfreien Zug vor – und bewirbt sich mit einer Probefahrt bei der AKN

VON BASTIAN MODROW

NEUMÜNSTER/KIEL. Zwischen 250 und 300 Millionen Euro will das Land bis 2022 in 30 neue Regionalzüge investieren. Die Ausschreibung läuft. Die entscheidende Voraussetzung für den Zuschlag Ende des Jahres ist: Die neuen Schienenfahrzeuge sollen innovativ und umweltfreundlich sein. Die AKN Eisenbahn GmbH hat gestern einen der Bewerber geheißt: Zwischen Neumünster und Kiel rollte der Prototyp des wasserstoffbetriebenen Coradia iLint.

Seit 1999 produziert der französische Transportkonzern einen Lint, den „Leichten Innovativen Nahverkehrstriebwagen", der in verschiedenen Bauvorhaben auch auf Schleswig-Holsteins Schienenwegen unterwegs ist. Der entscheidende Unterschied der bekannten Modelle zu dem neuen ist, dass die alten Fahrzeuge klassische Dieselmotoren besitzen. „Das neue Modell, das erst am 11. Juli seiner Zulassung erhalten hat, ist der weltweit erste emissionsfreie Zug", erläuterte Jörg Nikuta, Deutschland-Geschäftsführer von Alstom. Tatsächlich gebe es auch erst zwei Fahrzeuge, die im niedersächsischen Niedersachsen unterwegs seien und die laufend weiterentwickelt würden, bevor man in Serienproduktion gehen werde, versicherte der Manager. Entsprechend groß war das Interesse an der Präsentationsfahrt mit geladenen Gästen aus Wirtschaft und Politik, unter ihnen auch Verkehrsminister Bernd Buchholz (FDP). „Schick ist er ja schon einmal", würdigte er den Coradia, hielt sich mit Urteilen und Eindrücken angesichts des laufenden Ausschreibungsverfahrens ansonsten aber bewusst zurück.

„Moderne Verkehrspolitik heißt, technologische Neuerungen, ökologische Anforderungen und wirtschaftliche Interessen in Einklang zu bringen", formulierte Buchholz das Ziel der Landesregierung. Für Schleswig-Holstein käme allerdings erschwerend die problematische Infrastruktur des Schienennetzes hinzu. „Nur 30 Prozent sind elektrifiziert", betonte der Minister. Auf einen zügigen Ausbau des Oberleitungsnetzes zu warten, sei keine Alternative, „also müssen Schienenfahrzeuge mit innovativen Antrieb her."

Alstom ist einer der Bewerber. Allerdings haben auch andere Unternehmen ihre Entwicklungen und Konzepte im Rennen geschickt. Dazu gehören Fahrzeuge, die mit neuen Akkus auch auf nicht elektrifizierten Trassen per Strom rollen können, aber auch Anbieter neuer kraftstoffbetriebener Zugtypen, deren CO_2-Ausstoß allerdings deutlich geringer ist als bislang. Leicht wird es die Konkurrenz des in Salzgitter entworfenen iLints aber nicht haben, Alstom setzt nämlich auf Kooperationsmodelle mit der Windkraftbranche in Schleswig-Holstein. Dirk Burmeister von der Entwicklungsagentur Region Heide, kündigte bei der Probefahrt an, man freue sich darauf, „grünen Wasserstoff für eine emissionsfreie Mobilität in Schleswig-Holstein" zu liefern.

Ende 2018 läßt die Entscheidung des Landes, welche Fahrzeuge angeschafft werden. In einem zweiten Ausschreibungsverfahren wird dann ein Anbieter gesucht, der die Züge als Leasing-Geber für die Laufzeit von 30 Jahren an Transportunternehmen wie die Deutsche Bahn oder die AKN vergibt.

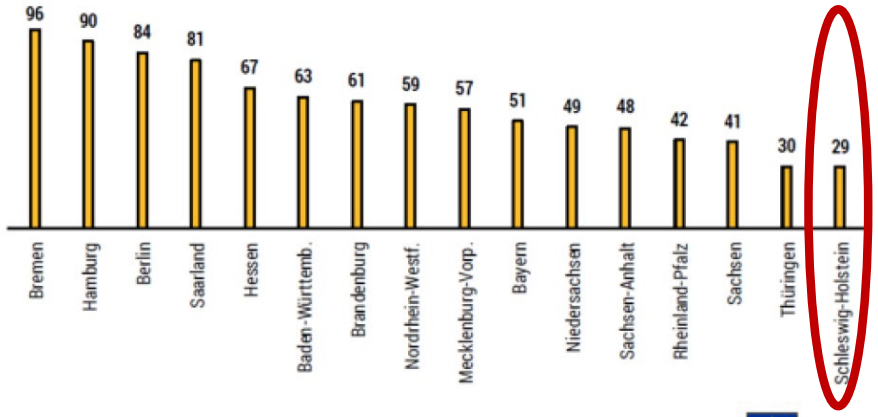
Die Testfahrt von Neumünster nach Kiel und zurück war dann aber noch viel unspektakulärer, als manch einer der Passagiere sich vorher ausgemalt hatte. „Ist halt ein Regionalzug, ich merkte jetzt keinen großen Unterschied", gestand einer. Einen Kommunikationsfehler störte das hochfrequente Pfeifen während der Fahrt, jemand hatte, dass sich die Türen des Zuges nicht mehr per Knopfdruck, sondern per Handvorhalten bedienen lassen. Über eines kann allerdings weder der moderneste Nahverkehrszug nicht hinwegtäuschen: die anfällige Infrastruktur. Und so wurde der iLint auf der Premierenfahrt im Norden unsanft vor Neumünster zehn Minuten lang gestoppt - wegen einer Signalstörung.

So funktioniert der Coradia iLint

Der Coradia iLint wird elektrisch angetrieben. Der Energie wird an Bord des Zuges in einer Brennstoffzelle erzeugt und in Batterien zwischengespeichert. In der Brennstoffzelle wird Wasserstoff, der in Tanks gelagert wird, mit Sauerstoff aus der Umgebungsluft zusammengeführt. Dabei entstehen neben Elektrizität lediglich Wasserdampf und Wasser. Ein erhöhtes Sicherheitsrisiko im Vergleich zu Dieselfahrzeugen gibt es nicht. Der Deutsche Wasserstoff- und Brennstoffzellen-Verband stuft Druckbehälter mit Wasserstoff gegenüber Benzintanks sogar als sicherer ein.

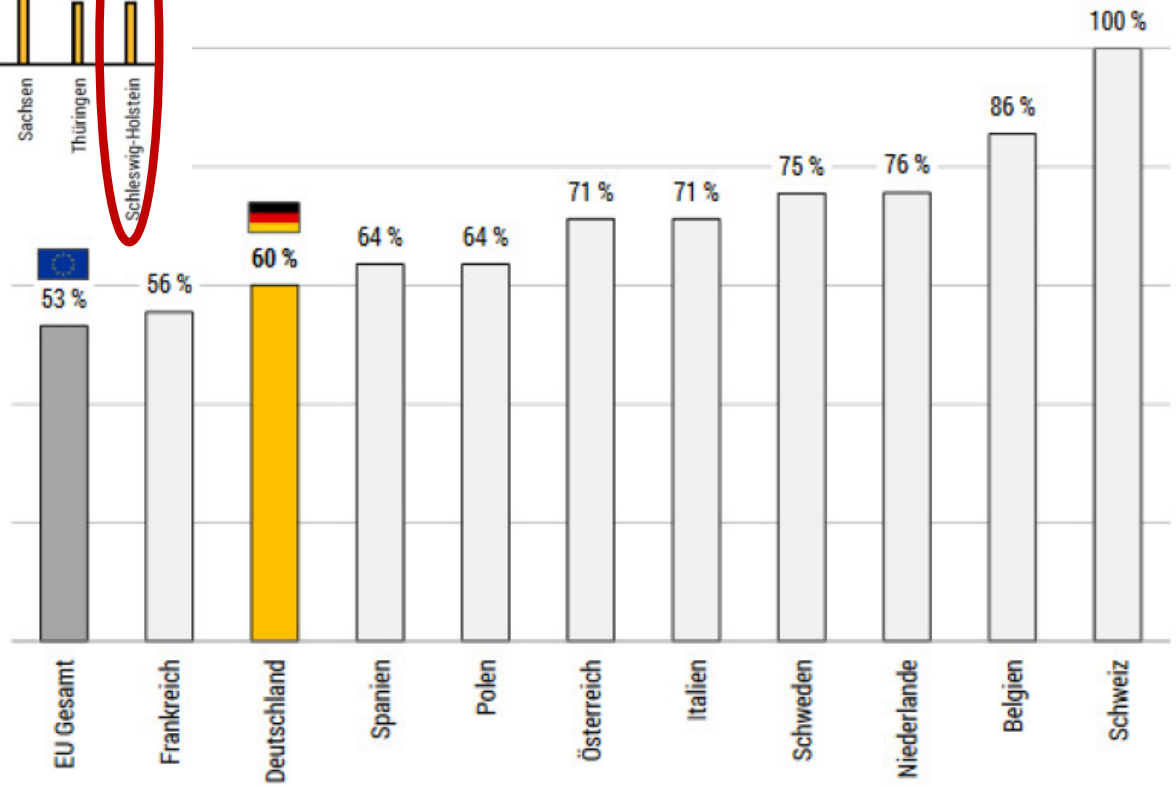
The H2-Consortium Westküste (from left to right): Dr. Uffe Borup (NEL), Frederic Pfeffer (Entwicklungsagentur Region Heide), Jean-Marc Bazenet (EDF Deutschland), Dirk Burmeister (Entwicklungsagentur Region Heide), Harro Possel (IPP Projects); Source: Entwicklungsagentur Region Heide

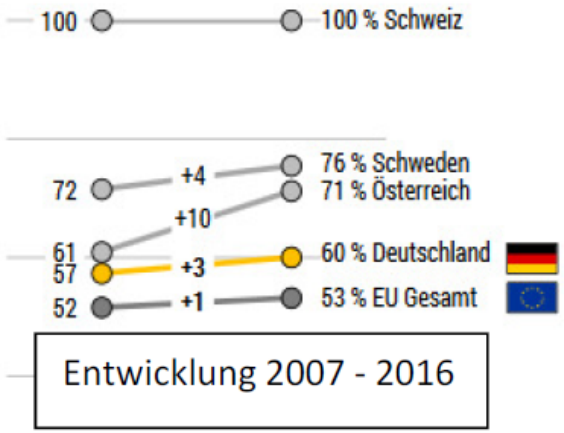
Electrification of tracks



Schleswig-Holstein

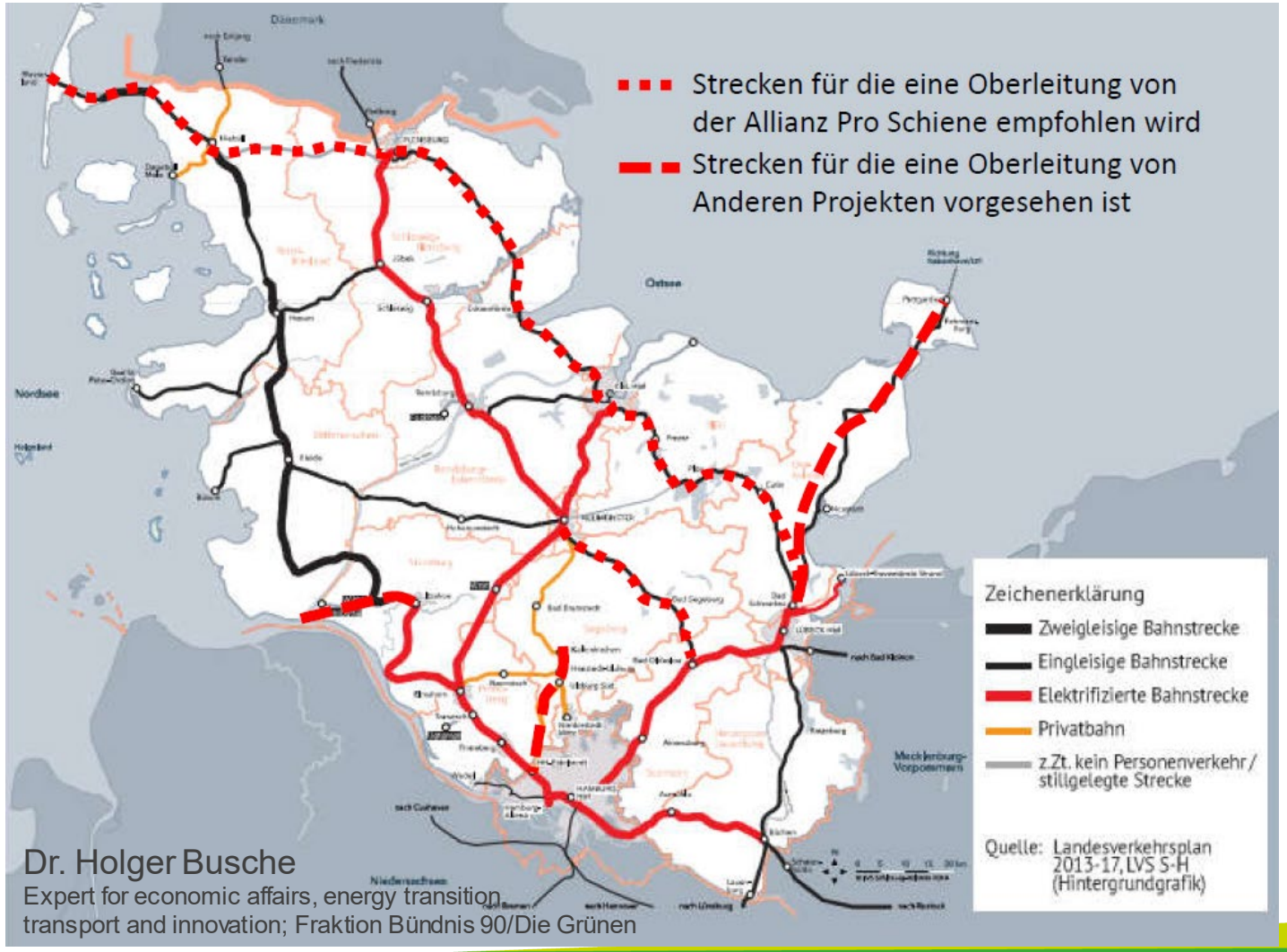
376 km out of 1,275 km electrified (29%)





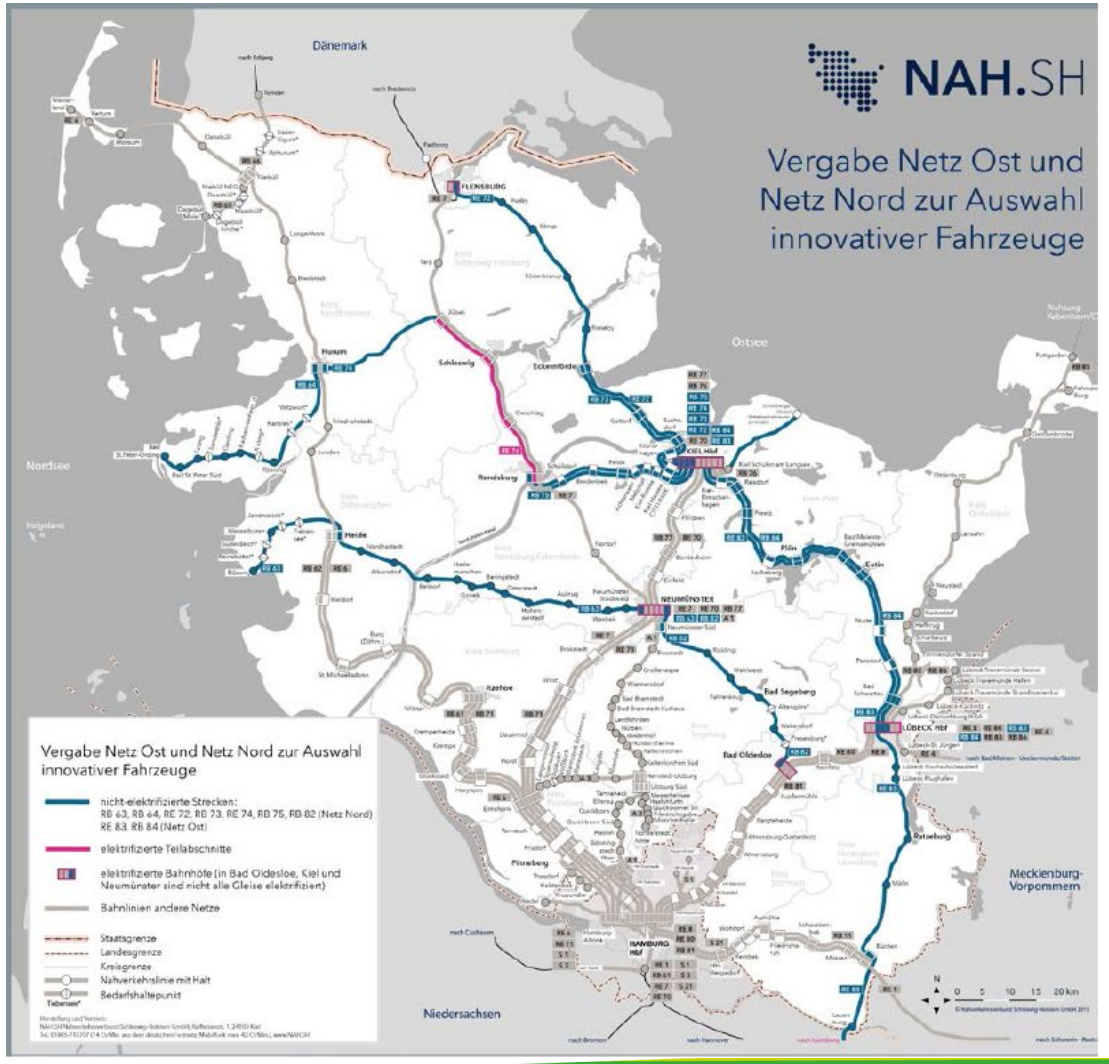
Entwicklung 2007 - 2016

Electrification vs non-electrified tracks (idea)



Dr. Holger Busche
Expert for economic affairs, energy transition, transport and innovation; Fraktion Bündnis 90/Die Grünen

Track lines recently in tender process



Verkehrsleistung

Netz Ost

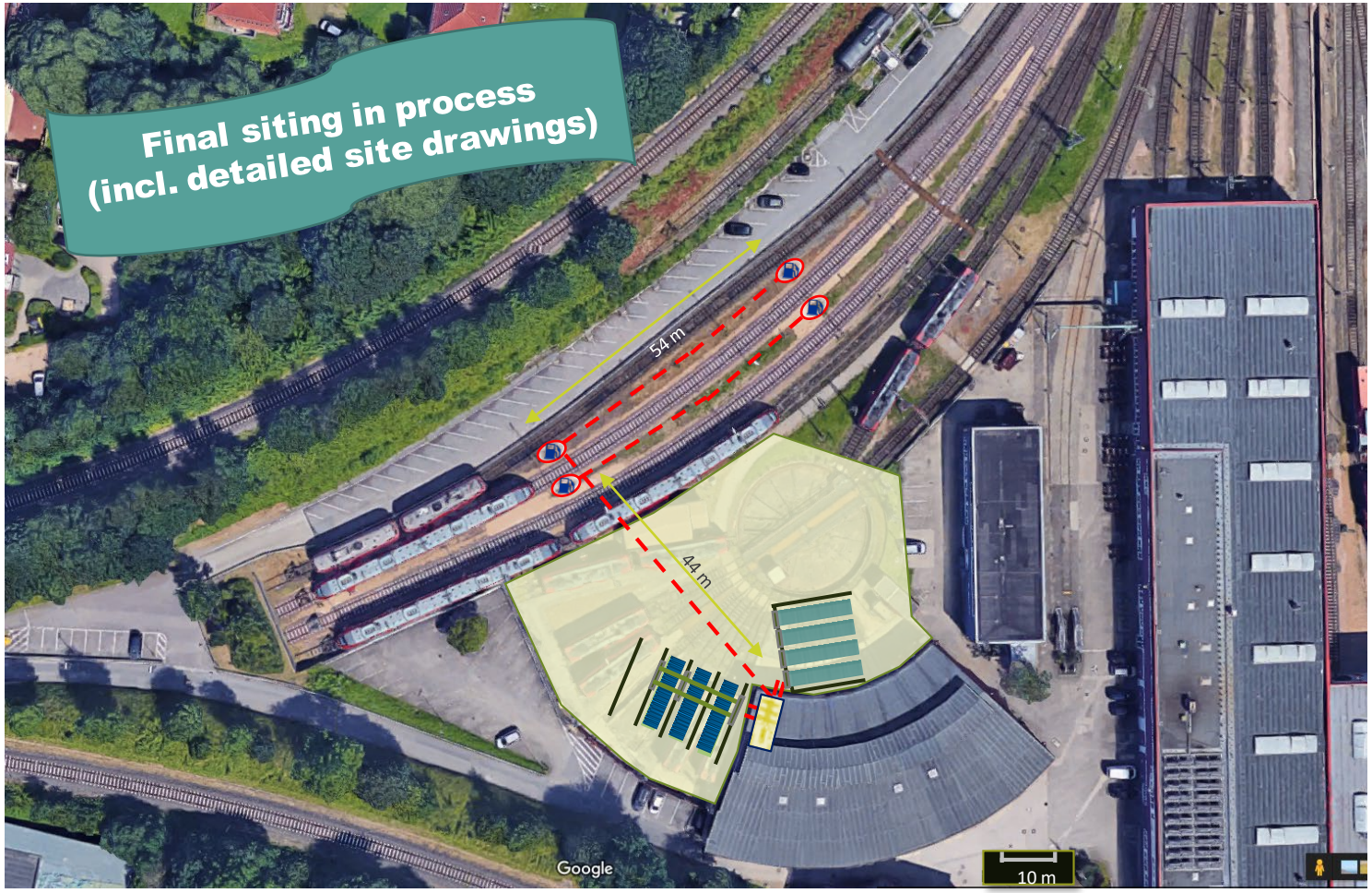
- Größtes Netz in SH: ca. 7,1 von 25,5 Mio. Zug-km
- 2 – 3 Lose denkbar (Betreiber)
- Dieselnetz: 4 Mio. Zug-km, Elektronetz 1,5 Mio. Zug-km, S-Bahnvorlauf 1 Mio. Zug-km
- DB Regio RB SH als Altbetreiber aller Strecken

Netz Nord

- Dieselnetz mit 5,6 Mio. Zug-km
- 2 Lose denkbar (Betreiber)
- Derzeit NBE und DB Regio RB SH als Altbetreiber

Current Work – H2-to-Rail

Preliminary Site Layout (example)



Dispensers planning (35 MPa)
- each dispenser: 0,6x0,6m

mobile swap-storage
- 12,2 x 2,4 m (40ft.)
- 50 MPa

On-site storage
- 12,2 x 2,4 m (40ft.)
- 35 MPa

H2 Station®
- Cooling and controls
- Compressors (redundant)

Current Work – H2-to-Rail

Phases in the associated EU Siting process

Phase	Task	Content	Delivery
Phase 1	**Preliminary Site Layout**	Site visit, lite risk study, pre dialogue with AHJ	1) Site check list/accessories, 2) Site Sketch, 3) Site budget estimate, 4) Draft time schedule, 5) Stakeholder paper & 6) Protocol signing
Phase 2	**Site Quantitative Risk Assessment**	Site Risk Assessment	1) Site risk mitigation list, 2) Input to AHJ & 3) Protocol signing
Phase 3	Site Layout	CAD 3D work, site construction and module placement (Customer to deliver present site drawing in DWG)	1) Draft DWG Site Layout, 2) One review + Adjustment, 3) HRS installation budget, 4) 3D EX Zone drawings, 5) Placement of Grounding, 6) Fundaments Specification, 7) Sign-off Site drawing, 8) Updated time schedule & 9) Protocol signing
Phase 4	Building Application	4a) Nel management of building application 4b) Send documentation on HRS modules – No support included	4a) Subcontracting architect and AHJ. Nel will secure Building and Operation Permit 4b) Hand over HRS Module documentation
Phase 5	Installation Planning	If 4a) ➔ **Tender & Programming management** **If 4b) ➔ Align time schedule and sign Site PO**	1) Site specific Bill of Material from Site Layout & 2) Protocol signing
Phase 6	Installation & Commissioning	Transport, Cranes and Installation	1) Module G certificate, 2) Ready for SAT & 3) Protocol signing
SAT	Site Acceptance Test	SAT test on site with customer	1) Signed SAT document & 2) Protocol closure

When to act

/ local specifics

/ regional added value

/ more than providing transportation

AND in SH

/ 100% green and regional energy for H2-to-Rail

Martin Eckhard
Dr. Stefan Rehm

www.region-heide.de

ENTWICKLUNGSAGENTUR REGION HEIDE • Hamburger Hof 3 • 25746 Heide
tel.: 0481 123 703 0 • fax: 0481 123 703 33 • info@region-heide.de

Stefan Bergander

Perspective on Fuel Cell Trains in East Germany

FCH JU, „Fuel cells and hydrogen in the railway environment", 17 May 2019

SPONSORED BY THE
Federal Ministry of Education and Research
zwanzig20
PARTNERSCHAFT FÜR INNOVATION

H Y P O S HYDROGEN POWER STORAGE & SOLUTIONS EAST GERMANY

Hydrogen in East Germany

Middle Germany: Saxony, Saxony-Anhalt, Thuringia

- hydrogen-related:
  - Middle German Chemical Triangle with large hydrogen demand: 3.6 bn m^3/a
  - dedicated hydrogen Pipeline: 200 km
  - large-scale storage in salt cavern
  - **Green Hydrogen activities since 2013!**
- train-related:
  - several regional commissioner
  - remaining nonelectric routes
  - first test drive of FC-train in February

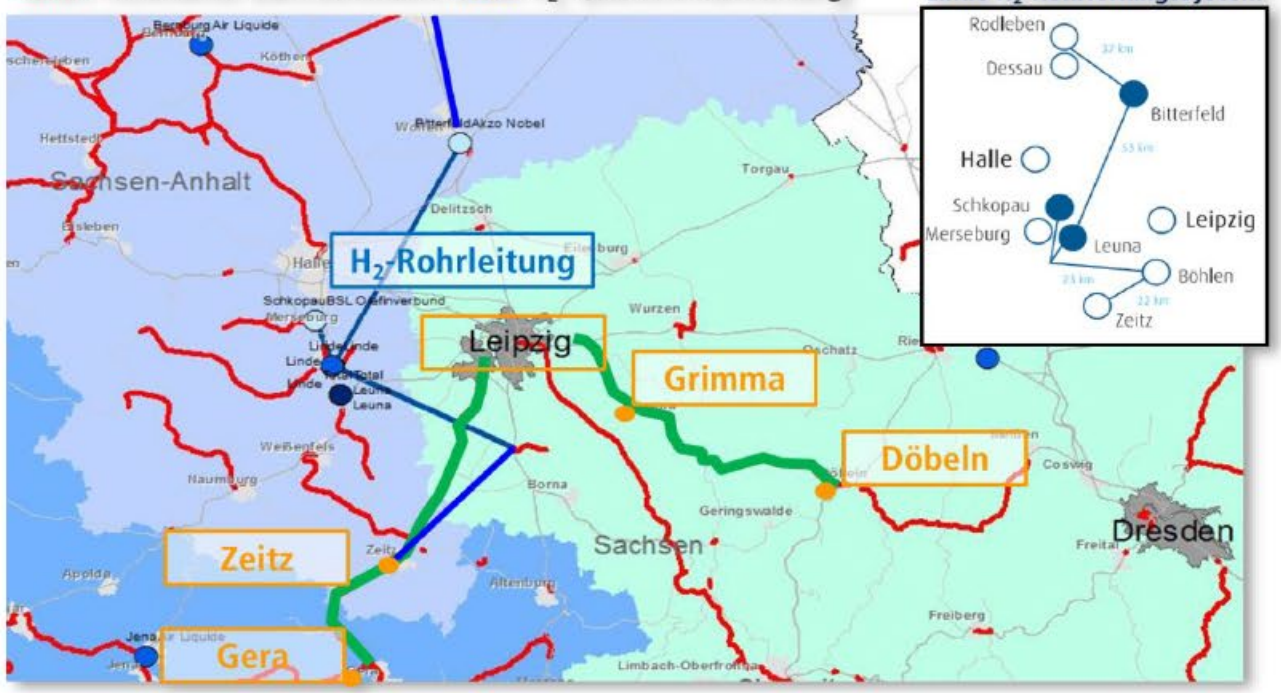
HYPOS

Feasibility Study on FC-Trains in Middle Germany

Background & Target

- future tender with new modalities concerning technology and infrastructure
- possible routes:
  - Leipzig – Grimma – Döbeln
  - Leipzig – Zeitz – Gera
- evaluation concerning:
  - technology in context
  - refuelling infrastructure
  - drive through Citytunnel Leipzig
  - railway installations

Grau: Bahnstrecken; Rot: nicht elektrifizierte Bahnstrecken;
Grün: Relevante Bahnstrecken; Blau: H_2-Quellen/Rohrleitung



Source: HYPOS 2017

Commissioner:

ZVNL
metropolregion mitteldeutschland

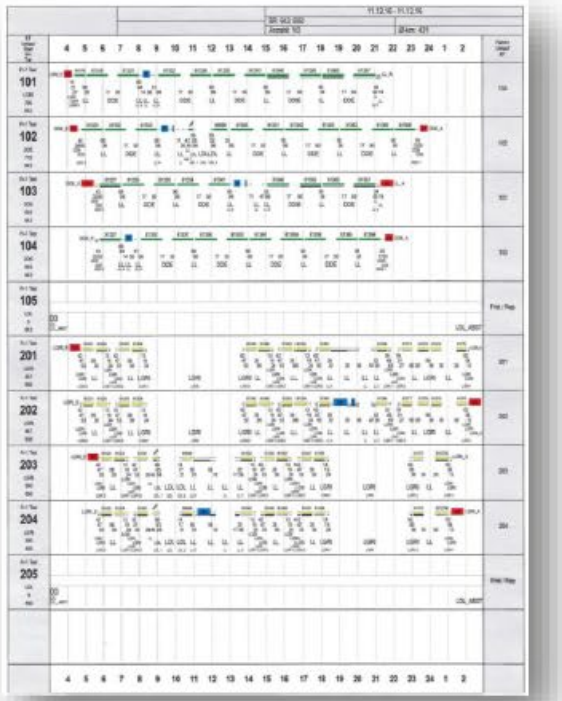
Contractor:

TÜV SÜD
ludwig bölkow systemtechnik
ALSTOM
HYPOS

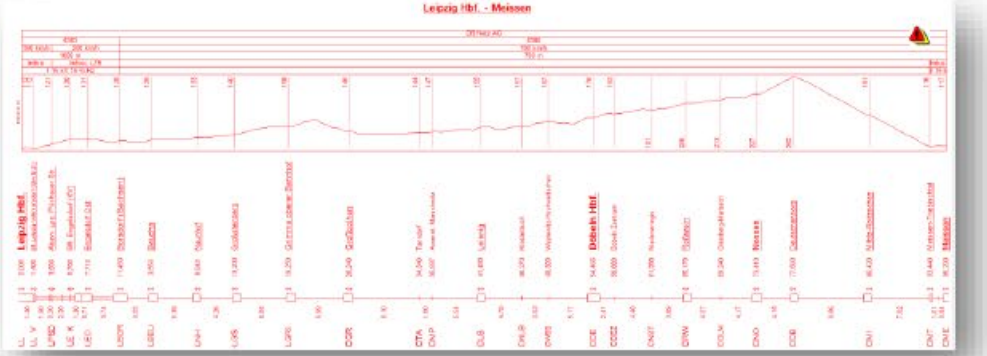
Feasibility Study on FC-Trains in Middle Germany

Approach

- determination of possible rotation schedules
- consideration of route profile
- determination of fuel demand



Quelle: HYPOS 2017



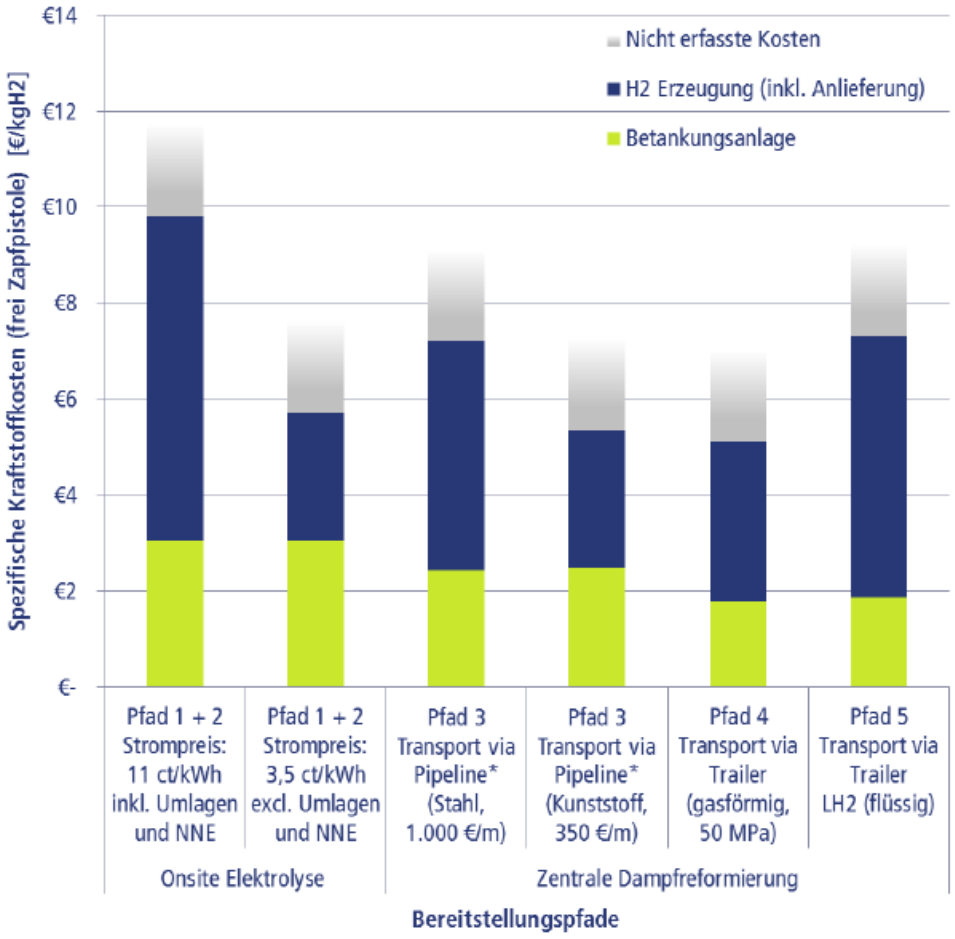
- Leipzig – Döbeln: 725 kg H2/d
- Leipzig – Gera: 580 kg H2/d

➢ **1300 kg H_2/d**

Commissioner:

Contractor:

Feasibility Study on FC-Trains in Middle Germany



*zum gemeinsamen Tankstellenstandort beider Strecken in Leipzig; Ergebnis nicht auf die Tankstellenstandorte Grimma und Gera übertragbar

Quelle: HYPOS 2017

Specific Fuel Costs, €/kg H_2

- largest expense are hydrogen production cost
- path 1+2:
  - possible hydrogen cost of 5-6 €/kg H2
  - via onsite electrolysis, pipelines, compressed transportation
- cheapest opportunity remains: SMR+pipeline (path 3), SMR+trailer (path 4)

Commissioner:

ZVNL metropolregion mitteldeutschland

Contractor:

TÜV SÜD ludwig bölkow systemtechnik ALSTOM

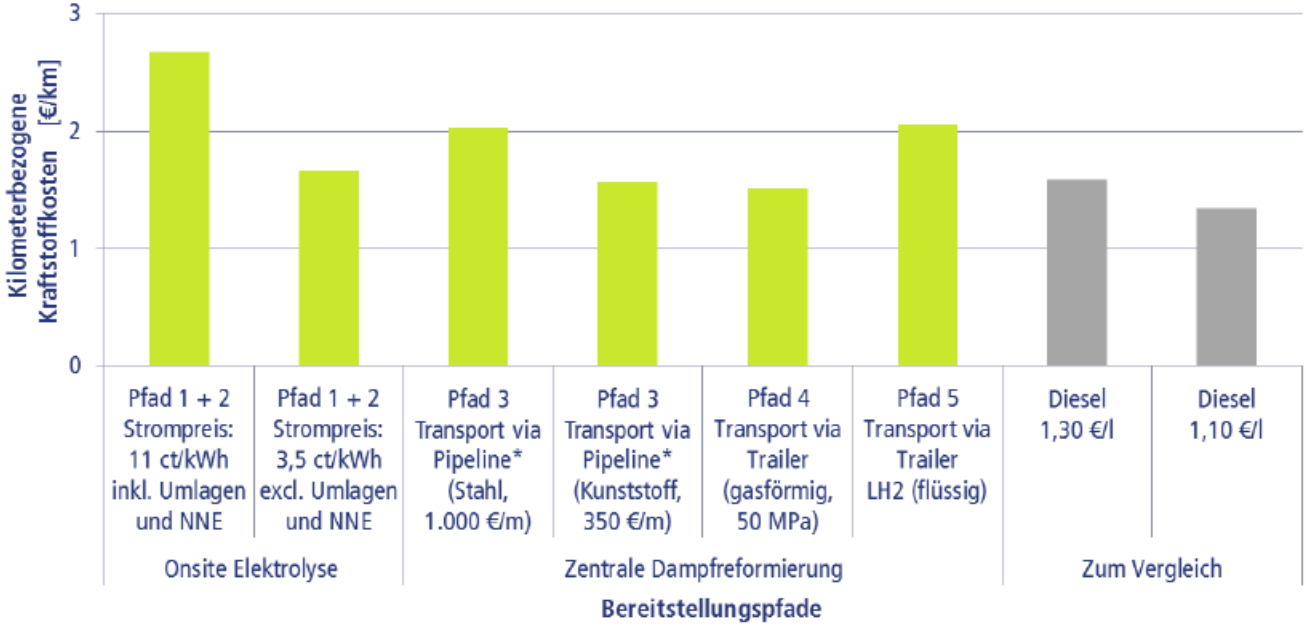
HYPOS

Feasibility Study on FC-Trains in Middle Germany

Cost per Kilometre, €/km

- Diesel:
  - 1,3–1,6 €/km
  - at diesel cost of 1,1–1,3 €/l
- **hydrogen cost:**
  - 1,5–2,7 €/km
  - competitive at high diesel price of 1,3 €/l

➢ consumption optimisation, technology progress, carbon pricing



*zum gemeinsamen Tankstellenstandort beider Strecken in Leipzig; Ergebnis nicht auf die Tankstellenstandorte Grimma und Gera übertragbar

Quelle: HYPOS 2017

Commissioner:

Contractor:

Funding Opportunities

Middle Germany is facing a structural transformation!

- phase-out of lignite mining
- phase-in of new technologies and value chains
- participation process including basically all local/regional parties

- **in this context hydrogen is one of the major topics in Middle Germany**
  - supplier: large electrolyser projects
  - storage: salt cavern to be realised as large-scale hydrogen storage
  - distributor: utilisation of hydrogen grid and gas grid
  - consumer: refinery, chemical industry, households and mobility

- opportunity to fund FC-trains projects with structural transformation

HYPOS

Future Projects

Targets of Local Commissioner ZVNL

- several routes are in consideration:
  - Leipzig – Grimma – Döbeln: gradual implementation of FC-trains, regular operation planned with tender in 2025, implementation in local-traffic grid
  - Leipzig – Zeitz – Gera: consideration of freight traffic, tender in 2024
  - Glauchau – Rochlitz – Colditz – Großbothen: reactivation of decommissioned route, restoration of all infrastructure

- year 2019: in-depth study on future routes, hydrogen supply chain, legal aspects
- year 2020-2021: building of refueling infrastructure
- year > 2021: procurement of trains

HYPOS

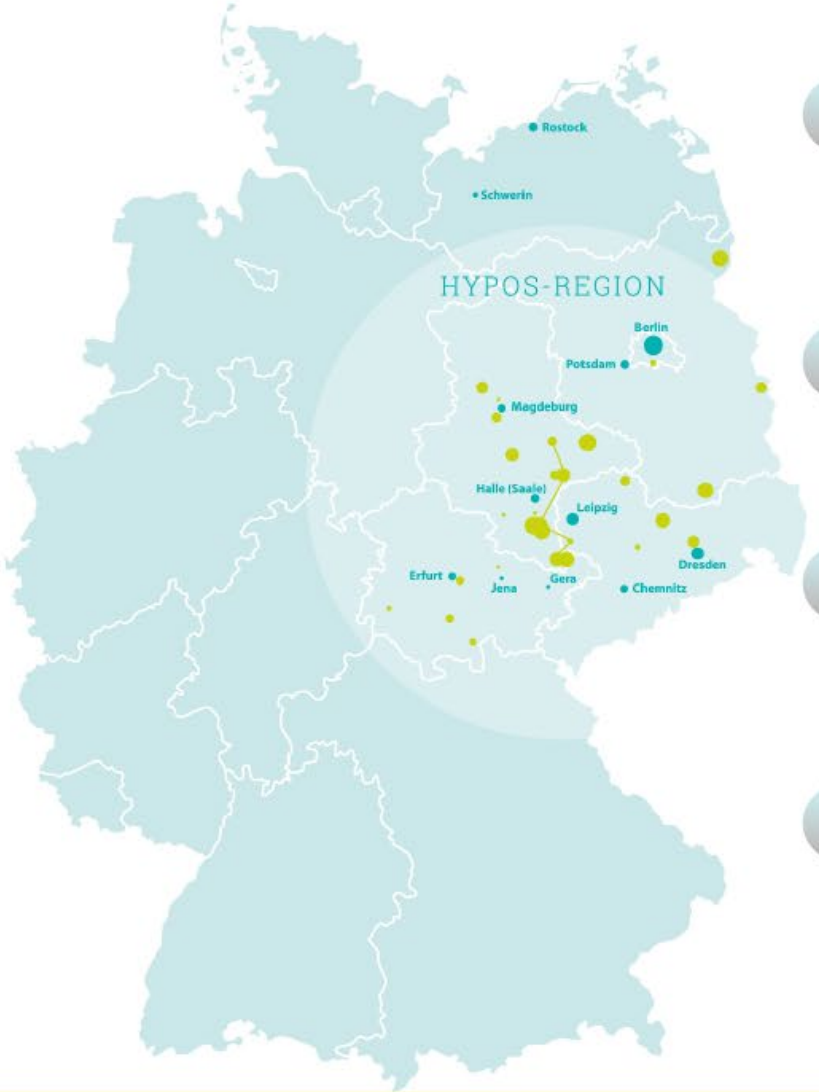
THANK YOU FOR YOUR ATTENTION

SPONSORED BY THE
Federal Ministry of Education and Research

zwanzig20
PARTNERSCHAFT FÜR INNOVATION

H Y P O S HYDROGEN POWER STORAGE & SOLUTIONS EAST GERMANY

HYPOS – The Region



Second longest H2 pipeline in Germany

- 150 km, spreading between Zeitz and Bitterfeld
- connecting H2 production with consumption

Salt Caverns for large-scale storage

- high storage potential in underground storage units
- caverns just 20 km away from H2 pipeline

Existing high hydrogen demand

- 3,6 bn. m³/a in the Middle German Chemical Triangle
- 1,25 bn. m³/a substitutable

High potential for Renewables

- 105 TWh/a onshore wind power
- 33 TWh/a photovoltaic

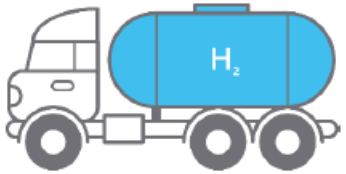
Utilization of existing infrastructure

HYPOS

HYPOS – The Idea

Vision
Constitution of a widespread **Green Hydrogen Economy.**

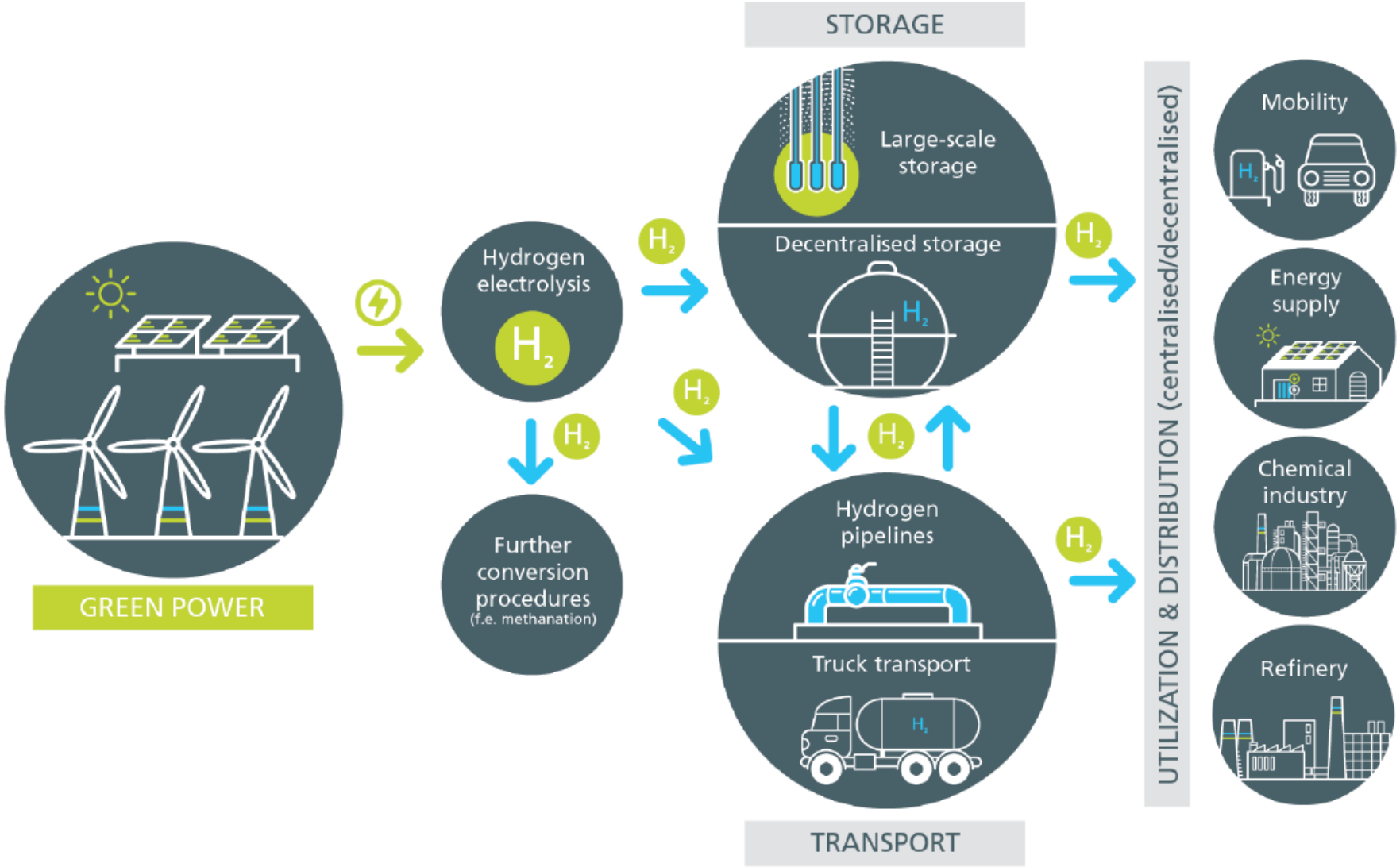
Mission
HYPOS is connecting the power, natural gas and chemical grid in East Germany via Green Hydrogen. Through systemic innovation and research Green Hydrogen applications will reach **economic efficiency.**



Mission statement
HYPOS is a **long-term network** of small, medium and major sized companies as well as research institutions working on the entire hydrogen supply chain of **production, transportation, storage and utilisation.**

H Y P O S

HYPOS – The Value Chain



HYPOS

HYPOS – The Projects

strategic projects - strategy concept, roadmap study, H2-Index, ImplaN, Chancendialog

Chemical Conversion

PEM-Elektrolysis

Mega-Lyseur: Development of 2 MW Stacks

ElyKon: Assessment of degradation in dynamic operation

Alkaline Electrolysis

LocalHy: Development of a decentral high pressure electrolysis

ELKE: continuous process of coating for electrodes

Reversible Electrolysis

rSOC: Demonstration of reversible high temperature electrolysis

REVAL: Development of reversible alkaline electrolysis

Other Systems

COLYSSY: Process development of CO-electrolysis

H2-Flex: Flexibilisation of chloralkali process

RW-Trockner: Drying of hydrogen based on radio waves

Transport & Storage

Grid

H2-PIMS: Conversion of natural gas infrastructure for hydrogen

H2-MEM: Development of a carbon based membrane to seperate natural gas and hydrogen

H2-Netz: Demonstration of hydrogen distribution grid based on synthetic materials

HyProS: Development of sensor technology for hydrogen in natural gas grids

Storage

H2-UGS: Standardisation for assessment of cavern storage units

H2-Forschungskaverne: Construction and demonstration of hydrogen storage within a salt cavern

Storage Technology

MMH2P: Mobile storage solution including energy management system

H2-HD: Development of 1000 bar storage as a trailer

Utilization & Distribution

Energy Supply

H2-Home: Development of a FC-cogeneration unit based on PEM

LocalHy: Development of hydrogen combustion engine

Mobility

LocalHy: Development of decentral hydrogen tank station concept

ImplaN: Design of an optimal extension schedule for hydrogen tank stations in Germany

Chemicals and Refinery

FRAGRANCES: decentral production of CO with reverse water-gas shift reaction

COOMet: Development of an one step process for methanol production

HYTHANOL: Development of a double membrane reactor for methanol production

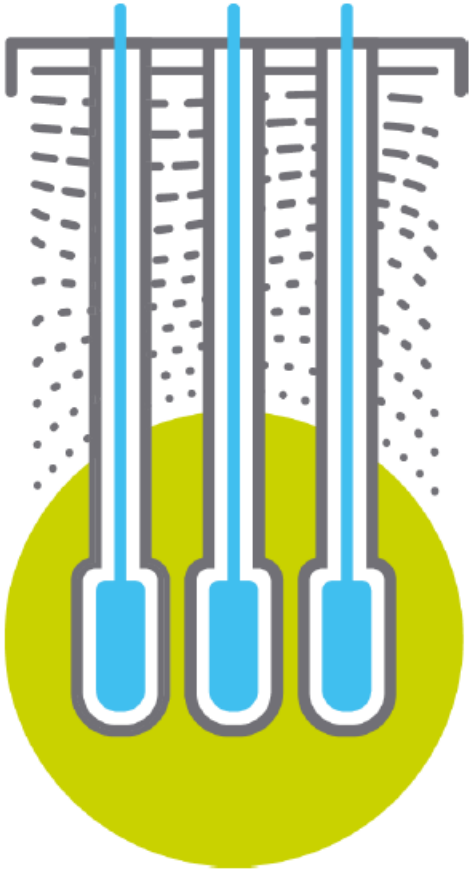
eKeroSyn: Conceptual study on renewable kerosine production

INES: multidisciplinary safety analysis

H2-Index: multidisciplinary economic efficiency analysis

HYPOS

HYPOS – H2-Forschungskaverne



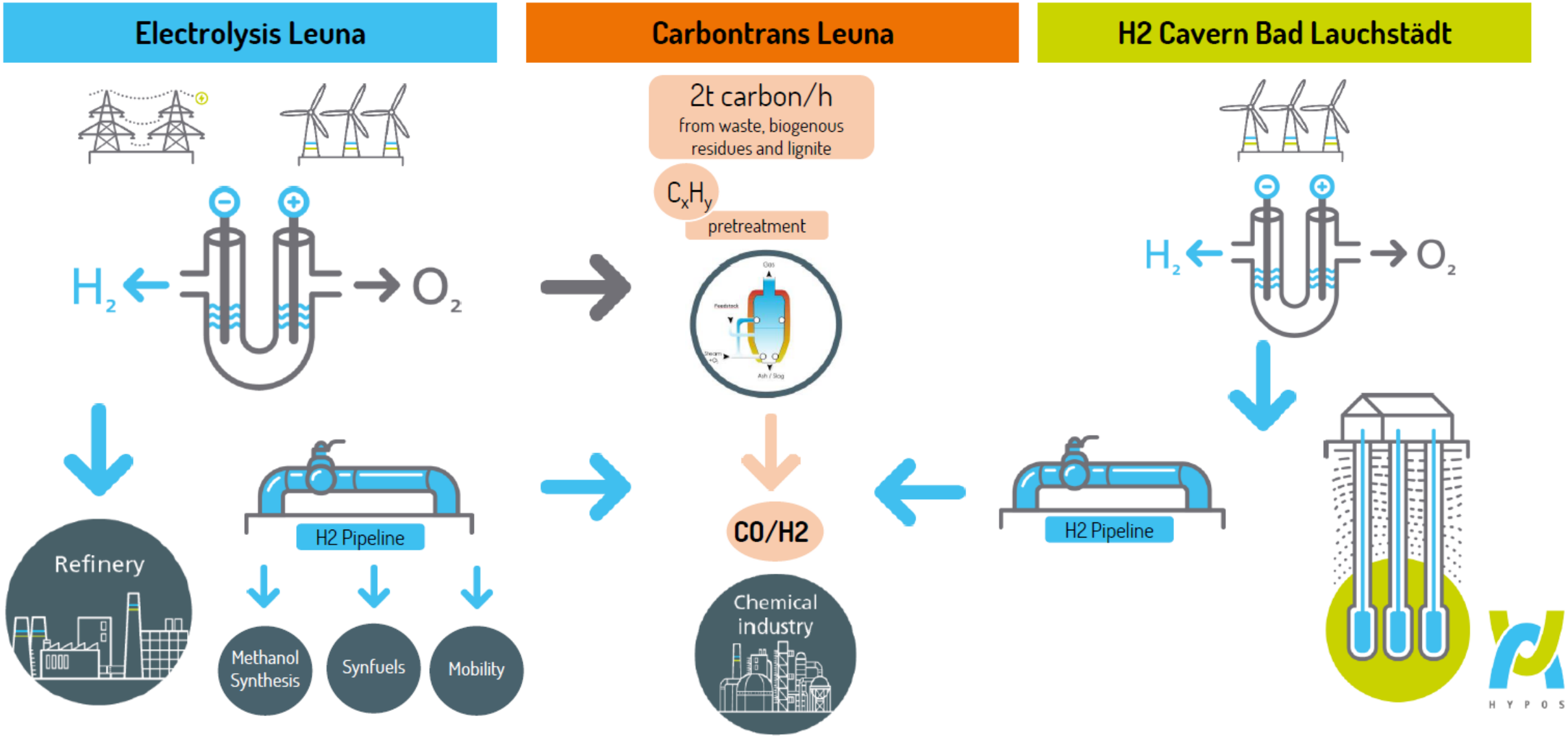
Development and construction of a large-scale underground storage for Green Hydrogen

- Conversion of a salt-cavern in Bad Lauchstädt/Saxony Anhalt
- Conjunction with on-shore wind farm and multi-MW electrolysis
- Connection to natural gas grid and hydrogen grid

- Realisation within three project phases
- First filling scheduled for 2023/24

DBI GTI Gastechnologisches Institut · Fraunhofer IMWS · VNG Gasspeicher · ontras Gastransport GmbH · IfG · THE LINDE GROUP · HYPOS

Living Lab – GreenHydroChem



HYPOS – The Roadmap

SHORT TERM (2017 – 2021)

HYPOS PROJECTS

- H2-UGS, HyProS, H2-PIMS, H2-MEM
- Mega-Lyseur, REVAL, ELKE, rSOC
- INES, H2-Safety-Re-Design
- RWTrockner
- ...

- Efficient green hydrogen applications (decentralized / niche markets)
- Initial substitution of grey hydrogen in the chemical industry
- Preparation of infrastructures (networks and storage)

MEDIUM TERM (2022 – 2030)

CONTINUATION OF THE HYPOS RESULTS

- Conversion of the natural gas infrastructure
  >> H2-Forschungskaverne
- Implemantation of various electrolysis technologies according to the field of application

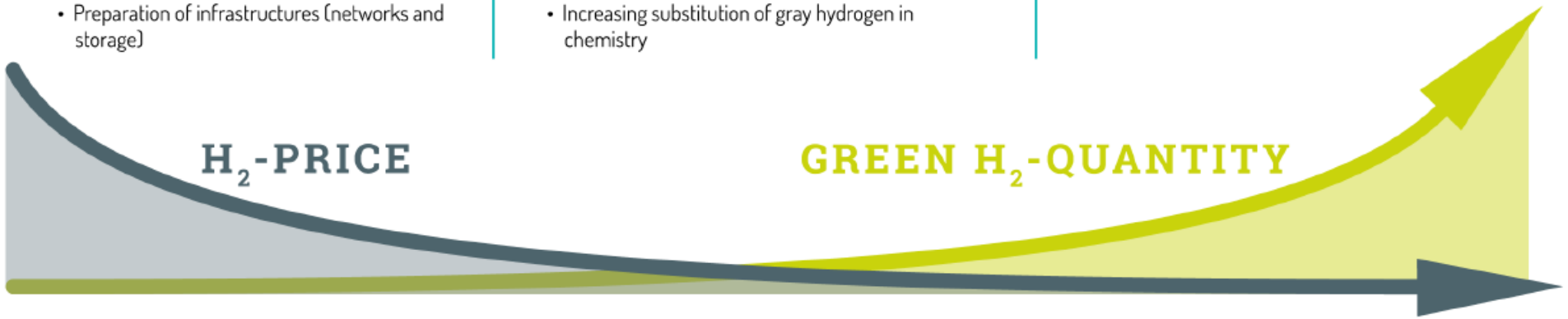
- Implementation of green hydrogen value chains in energy supply using natural gas networks as well as in the mobility sector
- Entry into the refinery market and fuel production
- Increasing substitution of gray hydrogen in chemistry

LONG TERM (FROM 2030)

WIDESPREAD USE OF HYPOS AND OTHER TECHNOLOGIES ALONG THE HYPOS VALUE CHAIN

- Hydrogen production
- Transport and storage
- Utilization and distribution

- Widespread use of electricity-based H_2-technologies in the sectors of chemistry, refinery, mobility and urban energy supply



HYPOS

HYPOS – The Services

Services

- Extensive networking for hydrogen activities
- Increasing Visibility for model region Middle Germany
- Presence at fairs, events and conferences
- Support for search of project partners
- Presentation of research results
- Monitoring of relevant research and funding programs
- Contributions and publication in journals and periodicals
- Regular newsletters and press releases

Website

- HYPOS-Blog with news, dates, calls and studies
- English version available
- scheduled H2-project-, stakeholder- and expert catalogue with integrated search and filter functionality

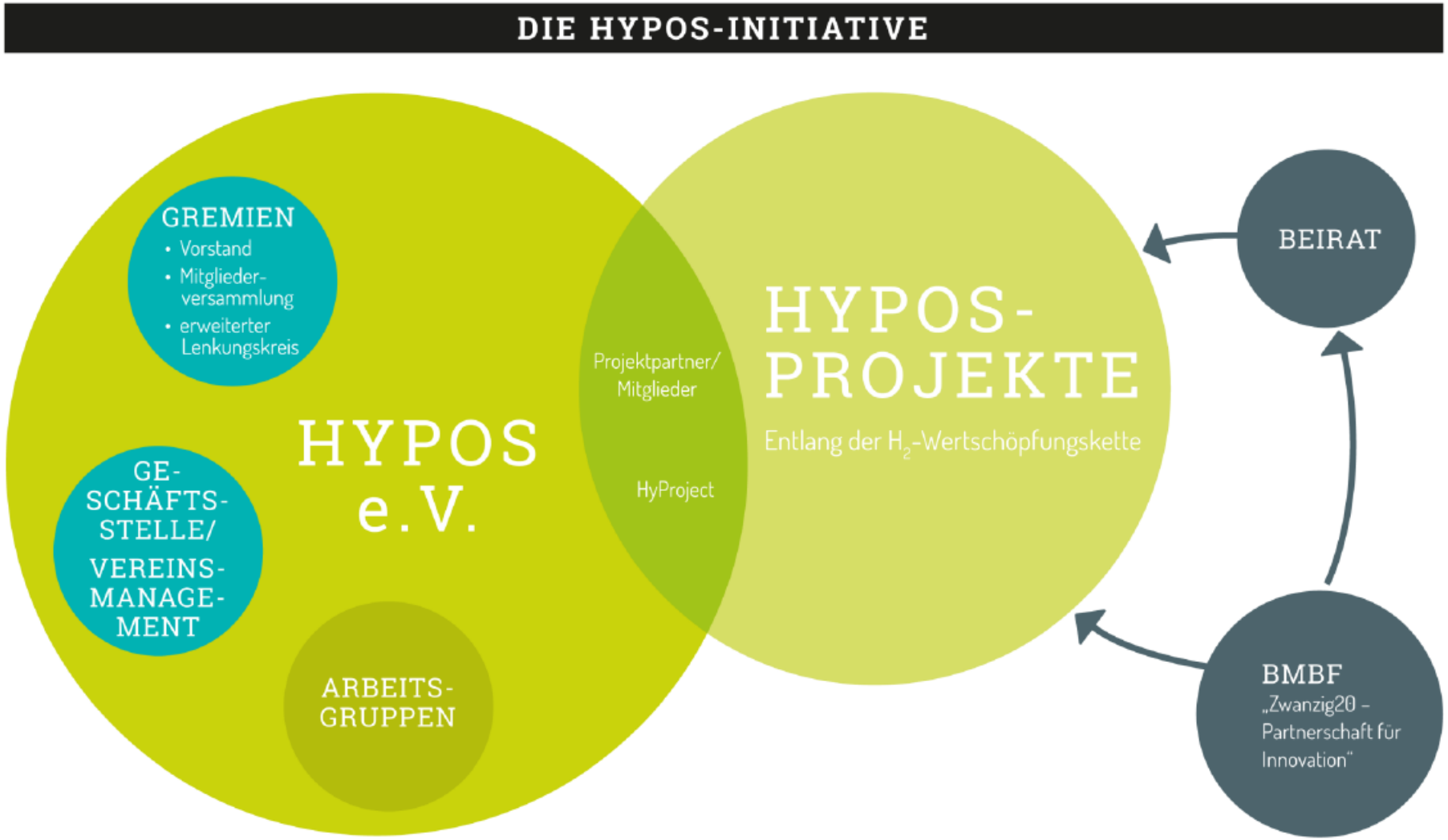
Events

HYPOS DIALOG

HYPOS FORUM

HYPOS

HYPOS – The Structure



HYPOS

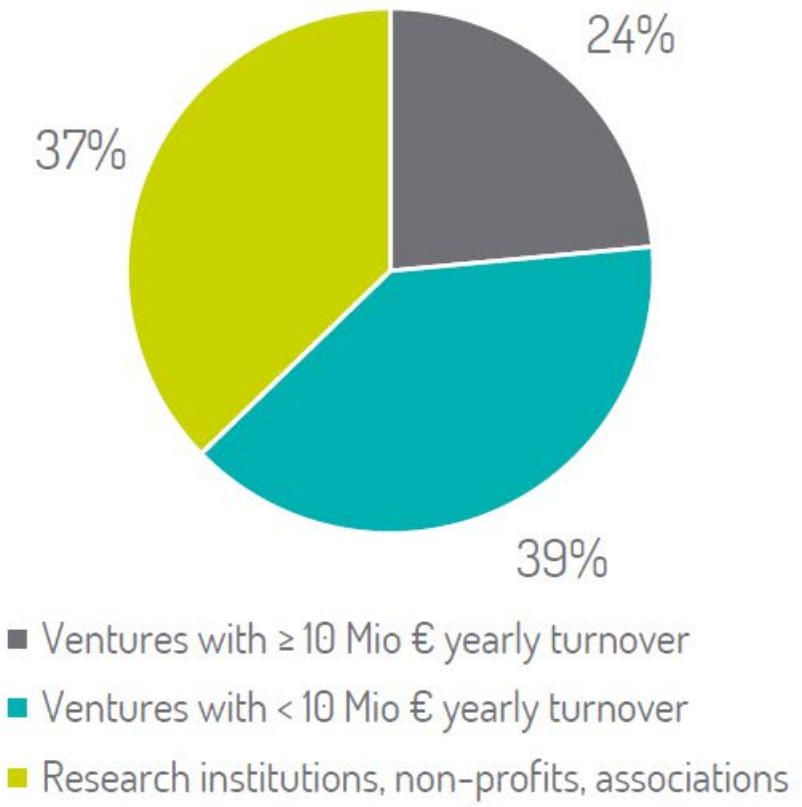
HYPOS – The Members

102 Members

- 24 major enterprises
- 40 SME
- 38 research institutions, non-profit organisations and associations

- 78 members from East Germany
- 24 members from West Germany

- 3 honourary member



HYPOS

HYPOS – The Board

Dr. Joachim Wicke

Siemens AG
Chairman

Prof. Dr. Ralf Wehrspohn

Fraunhofer IMWS
1st Deputy Chairman

Axel Klug

Ehrenmitglied
2nd Deputy Chairman

Dr. Christoph Mühlhaus

Cluster Chemie
Honorary Member

Dr. Kathrin Goldammer

Reiner Lemoine Institut

Thomas von der Heide

Terrawatt
Planungsgesellschaft mbH

Stefan Kauerauf

Nouryon
Akzo Nobel Industrial
Chemicals Bitterfeld

Kay Okon

VNG Gasspeicher GmbH
Co-opted Boardmember

HYPOS

HYPOS – The Office

Juliane Renno

Association and Network Management

Stefan Bergander

Project and Knowledge Management

Florian Thamm

Marketing and Public Relations

HYPOS

NOW-GMBH.DE

Elena Hof | Brussels | 17th May 2019

Germanys Perspective on Hydrogen Trains

- Political Perspective & Policy Landscape -

FCH JU Workshop on the use of hydrogen in the railway environment

Photo: Ernst & Young

SHAPING SUSTAINABLE MOBILITY

Integrated implementation of German national funding programms

NOW
NOW-GMBH.DE

Battery Electric Mobility

Research and develpment, market activation, concepts

Charging Infrastructure

Nationwide buildup, normal and fast charging

Mobility and Fuels Strategy

Pilot projects, alternative fuels, LNG as a marine fuel

Export Inititative Environmental Technology

German-Japanese cooperation for PtG, development cooperation for H2/FC technologies, cooperation with the GIZ

NIP*

Research and development, market activation

Coordination
Implementation
Networking
Acceptance
Visibility

* National Innovation Programme Hydrogen and Fuel Cell Technology

R&D PROJECTS

Fuel cell and battery electric trains

X-EMU

Siemens, RWTH Aachen – Fuel cell drive for hybrid EMU trains

TALENT 3

Bombardier, TU Berlin, NVBW, SWEG – development of a battery electric train

iLint

Alstom, DLR – development & validation of a fuel cell electric train

EcoTrain

DB RegioNetz, TU Chemnitz, TU Dresden – modular battery drive and storage technology

NIP – VEHICLE AND INFRASTRUCTURE ACQUISITION

5 calls

241 Mio. € requested funding of which

191 Mio. € are requested funding for trains

85 Mio. € granted

Cars	563
LDV	500

Busses	84
HRS	3
Ely	1

Trains	164
HRS	13
Ely	7

Ships	1

HRS	47
Ely	11

ACQUISITION OF HYDROGEN TRAINS IN GERMANY

Defined projects

LNVG, LOWER SAXONY

Cuxhaven – Bremerhaven – Bremervörde – Buxtehude

14 trains + HRS in Bremervörde, acquisition until the end of 2021, operation starting in early 2022

RMV/FAHMA, HESSE

RMV lines 11, 12, 15 & 16

28 trains + HRS in Frankfurt-Höchst, acquisition and start of operation in 2022

„FOR RAIL TRANSPORT WE INTEND TO ESTABLISH A COMPREHENSIVE FUNDING PROGRAM, WHICH COVERS BOTH THE ELECTRIFICATION OF TRACKS AND THE ACQUISITION OF VEHICLES AND THE RESPECTIVE CHARGING/REFUELING INFRASTRUCTURE. FURTHERMORE, REGIONAL RAIL TRANSPORT IS INTENDED TO BE SUPPORTED THROUGH INVESTMENT GRANTS FOR FUEL-CELL-HYBRID-RAILCARS INCLUDING FACILITIES & DEPOT MODIFICATIONS AS WELL AS THE CONSTRUCTION AND OPERATION OF HYDROGEN REFUELING STATIONS.“

– TRANSLATED FROM THE COALITION AGREEMENT BETWEEN CDU, CSU & SPD, 2018

NEW FUNDING GUIDELINE

NOW
NOW-GMBH.DE

→ Applications for 164 fuel cell trains, 11 HRS and 4 onsite electrolyzers

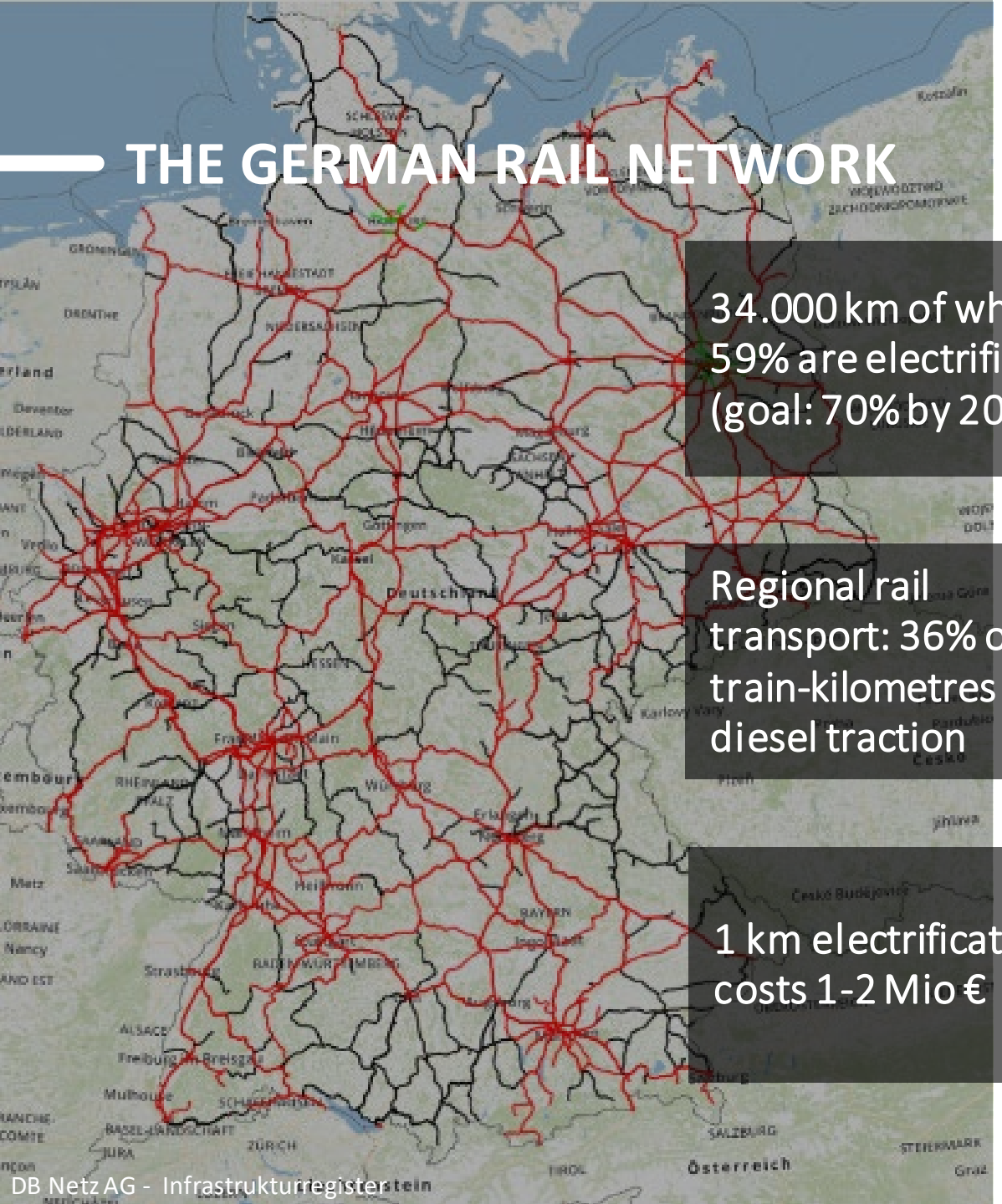
→ Expressions of interest for more than 300 battery and fuel cell electric trains until 2024

New funding programm for the acquisition of trains with alternative drives

→ Announced budget 2019: 13.9 Mio € + 38.8 Mio € until 2024

→ Funding guideline in preparation

THE GERMAN RAIL NETWORK



34.000 km of which 59% are electrified (goal: 70% by 2025)

Regional rail transport: 36% of train-kilometres with diesel traction

1 km electrification costs 1-2 Mio €

DB Netz AG - Infrastrukturregister

NOW
NOW-GMBH.DE

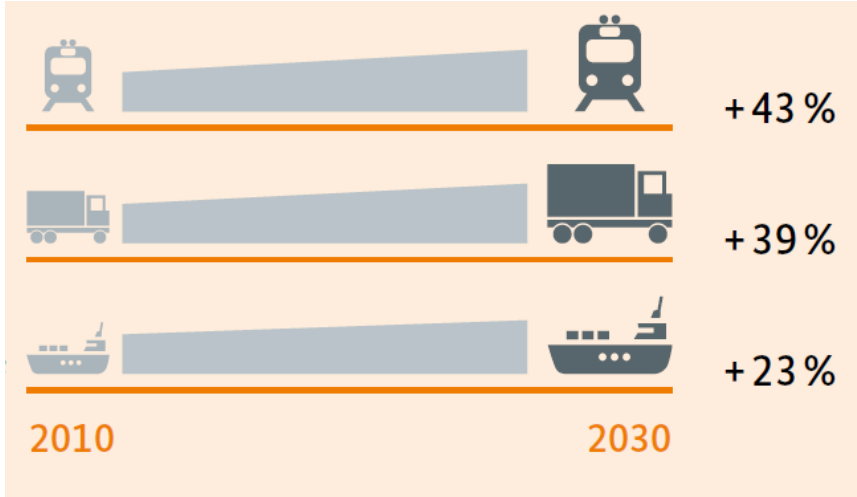
- Electrification through catenaries
  → feasible for tracks with a high level of traffic
- Battery electric trains
  → lucrative for tracks with already existing catenaries in some parts
- Fuel cell electric trains
  → lucrative for longer tracks (up to 1.000 km range) without catenaries and with availability of inexpensive hydrogen sources

Conclusion: SIGNIFICANT POTENTIAL FOR BOTH BATTERY AND FUEL CELL ELECTRIC TRAINS IN GERMANY

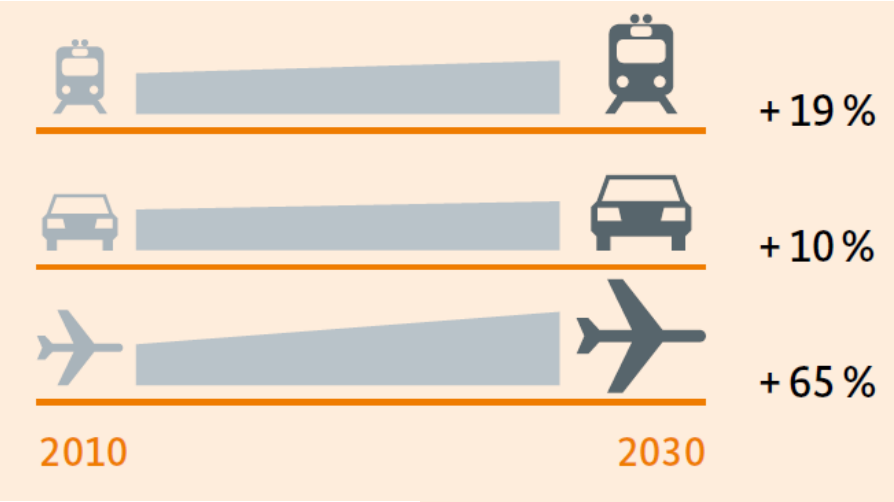
TRAFFIC FORECAST GERMANY 2030

NOW-GMBH.DE

Freight transport



Passenger transport



Source: https://www.bmvi.de/SharedDocs/DE/Anlage/MKS/energie-auf-neuen-wegen.pdf?__blob=publicationFile

Great potential for fuel cells in rail & heavy duty!

MARKET ANALYSIS

ALTERNATIVE DRIVES IN REGIONAL RAIL TRANSPORT

NOW-GMBH.DE

1 Comparison of European countries

2 Technology comparison

3 Status-quo of the German rail network

4 Detailed analysis of specific tracks

5 Market potential for battery and fuel cell

6 Derivations concerning funding

CHALLENGES

- **CAPEX & financing** (e.g. risk surcharges)
- Usually high costs for „green“ hydrogen production through electrolysis due to **levies**
- **Responsibility** for infrastructure (costs, risks)
- **Access to infrastructure** owned by the „DB Netz AG“
- **Legal aspects** of tendering procedures
- Lengthly **approval procedures**

POTENTIALS

- Raising hydrogen demand significantly
  → **economies of scale**
  → strengthening hydrogen as **sector coupling enabler**
- Raising **awareness**
- Proving **market maturity**
- Reducing overall **rail grid electrification costs**

NOW-GMBH.DE

Elena Hof
Programme Manager NIP
elena.hof@now-gmbh.de
Phone: +49 30 311 61 16-39
Mobile: +49 173 23 20 906

Fasanenstr. 5
10623 Berlin
Germany

Photo: Ernst & Young