3EMOTION

environmentally friendly, efficient, electric motion

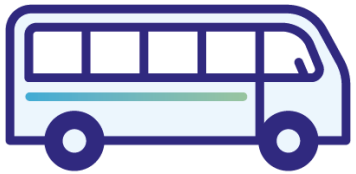
TOWARDS ZERO-EMISSION PUBLIC TRANSPORT WITH FUEL CELL BUSES: EXPERIENCES AND NEXT STEPS

29TH OF NOVEMBER - VÉLIZY (VERSAILLES)

3EMOTION

environmentally friendly, efficient, electric motion

Welcome and coffee



Clean Hydrogen Partnership

Agenda: before noon

09:30	**Welcome and coffee**		
10:00	**Welcome by Be Green**	Philippe Lucas	Be Green
10:05	**Welcome by Van Hool (coordinator of the 3Emotion project)**	Dirk Amerijckx	Van Hool (coordinator)
10:15	**Deployment of fuel Cell Buses in France**	Jan-Erik Stalander	France Hydrogen
10:30	**Deployment of fuel Cell Buses in Europe**	Lionel Boillot	Clean Hydrogen Partnership
11:00	**Fuel Cell buses and development at Van Hool**	Geert Van Hecke	Van Hool
11:30	**Fuel Cell buses and development at Safra**	Vincent Lemaire	Safra
12:00	**Lunch - During Lunch participants have the possibility to drive the buses**		

Clean Hydrogen Partnership

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LONDON 10

Transport for London (TFL)
- 8 existing buses in operation from January 2015 till March 2020 (Wright)
- 2 new buses in operation from January 2018 till March 2020 (afterwards at Metroline) (VanHool)

Aalborg
3

London
10

Rotterdam
6

Versailles
7

Pau
3

AALBORG 3

- 1 bus operated by Keolis – Municipality of Aalborg
- 2 buses operated by Arriva – North Denmark Region

All buses in operation since March 2020

VERSAILLES 7

- 2 buses (SAVAC) in operation since September 2019 (VanHool)
- 5 buses (B.E. green) in operation since August 2020 (Safra)

PAU 3

SMTU/STAP
- 3 Exqui.city buses in operation since December 2019
- *5 other buses are part of the FCH-JU project Jive*

ROTTERDAM 6

- 4 buses Connexxion - Province of South Holland (intercity) in operation since June 2020 (VDL)
- 2 buses RET - City of Rotterdam in operation since September 2017 (VanHool)

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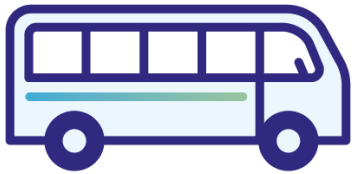
Welcome by Van Hool and B.E. Green

Dirk Amerijckx, Van Hool
Philippe Lucas, B.E. Green



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Deployment of fuel Cell Buses in France

Jan-Erik Stalander, France Hydrogen

Clean Hydrogen Partnership

Deployment of fuel Cell Buses in France

Final Conference 3Emotion

29th November 2022, Vélizy-Villacoublay

Jan-Erik Starlander, France Hydrogène

Head of relations with territories and local authorities

France Hydrogène

Engagée pour la transition écologique

France Hydrogène Mobilité

- ***France Hydrogène Mobilité*** is the group dedicated to the hydrogen powered mobility within ***France Hydrogène***. It brings together energy companies, electrolyser and hydrogen refuelling station providers, fuel cell vehicle manufacturers, components components providers (such as fuel cells and tanks), investment funds, project developers, consultancy firms, as well as institutional and research institutes.
- The **objective** of the group is to enable its members to work in a collective intelligence to **identify the obstacles that players may encounter in the development of projects and to help remove them**.
- *France Hydrogène Mobilité* is a place for sharing and synthesizing information, and its work benefits the entire sector. France Hydrogène Mobilité sets up discussions on all the topics that are relevant to the sector, carries out studies, writes position papers and proposes useful communications for the development of hydrogen mobility in France. **The actions of France Hydrogène Mobilité can be categorized according to four axes:**

1. **Supply and visibility**
2. **Knowledge sharing**
3. **Funding (how to make the TCO more competitive)**
4. **Education and awareness.**

White paper on the deployment of fuel cell buses - October 2020

In October 2022, 33 fuel cell buses are operating in France across 7 cities. These buses have been provided by 3 different OEMs: Safra, Van Hool and CaetanoBus


VANHOOL 2 5 SAFRA Accélérateur de mobilité décarbonée BEMOTION

Commissioning dates: 2019 (2) et 2020 (5)

SAFRA Accélérateur de mobilité décarbonée 1

Commissioning date: 2020
(+ 10 bus articulated buses to come)

CaetanoBus 1

Commissioning date: 2022

VANHOOL JIVE ZERO EMISSION BEMOTION 8

Commissioning date: 2019
(4 standard buses ordered)

Artois

SAFRA Accélérateur de mobilité décarbonée BEMOTION 6

Commissioning date: 2019

Versailles

Le Mans

Auxerre

SAFRA Accélérateur de mobilité décarbonée JIVE ZERO EMISSION 5

Commissioning date: 2021

La Roche sur Yon

Pau

Toulouse

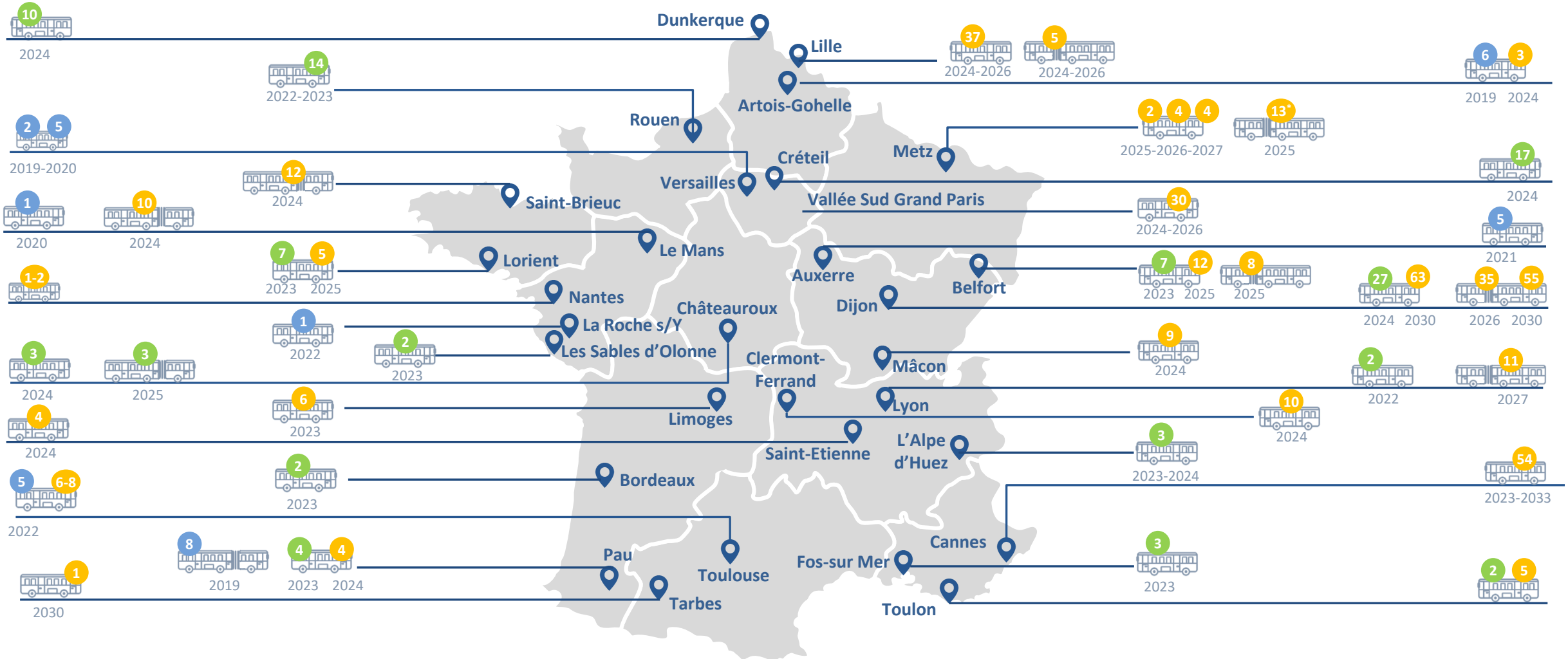
SAFRA Accélérateur de mobilité décarbonée JIVE ZERO EMISSION 5

Commissioning date: 2022


Fuel cell bus deployment projects announced in France:

TOTAL HYDROGEN PROJECTS :
736 (33 + 106 + 409 + 188)
Total (operating + commissioning expected soon + planned publicly + planned confidential)

mobilité France Hydrogène
Engagée pour la transition écologique



A — Number of buses in commercial operation

B — Number of buses under deployment

C — Additional deployments considered

& other confidential projects being defined

Reference : Element Energy for *France Hydrogène Mobilité*

France Hydrogène Mobilité holds discussions with public procurement offices (UGAP and CATP) on a regular basis.

- **UGAP and CATP** offer **simplified** and **accelerated** purchasing procedures to mobility authorities.
- They have added **fuel cell bus offers to their catalogues** in the past few years.
- France Hydrogène Mobilité regularly discusses with UGAP and CATP to obtain **feedback on fuel cell bus orders** and to encourage the acceleration of deployments.

In order to facilitate the upcoming roll-out of fuel cell buses, *France Hydrogène mobilité* has drafted a document gathering the feedback of the 3 first French fuel cell bus deployment projects.

3 interviewed cities: Artois, Versailles and Pau

Document drafted under the coordination of Element Energy

Overview of the specificities of the 3 projects

SUMMARY OF THE MAIN CARACTERISTICS OF THE 3 STUDIED PROJECTS

Localisation	Pau	Artois	Versailles*
Interviewed actors	PAU BÉARN PYRÉNÉES Communauté d'Agglomération	ARTOIS MOBILITÉS	Keolis Versailles / be green / stacars dominique
Number and type of deployed buses	x8 bus articulés	x6 bus standards	x5 bus standards
Bus manufacturer	VANHOOL	SAFRA Accélérateur de mobilité décarbonée	SAFRA Accélérateur de mobilité décarbonée
Delivery date of the 1st bus	Septembre 2019	Juin 2019	Août 2019
Required annual mileage on the bus line	40 000 km/an/bus	70 000 km/an/bus	45 000 km/an/bus
Real total mileage done by the entire FC bus fleet until Summer 2022	~810 000 km en cumulé pour les 8 bus (~100 000 km/bus en moyenne)	Non communiqué	~150 000 km en cumulé pour les 5 bus** (~30 000 km/bus en moyenne)
Station operator	ENGIE Solutions	ENGIE Solutions	Air Liquide
Hydrogen production and/or refuelling equipment provider	ITM POWER ●	McPhy ●	Air Liquide ●
Station capacity	268 kg/jour	200 kg/jour	250 kg/jour

● *Hydrogen production and refuelling station*

● *Hydrogen refuelling station for buses and light vehicles*

* *2 Van Hool standard buses exploited by SAVAC Group until Summer 2022 are also in service in Versailles. They are not included in the scope of the feedback document, but are also being refuellled at the Air Liquide station of Loges-en-Josas.*

** *1st bus entering into service in August 2020*

The document does not aim at comparing directrly the 3 projects with one another, each project having specific characteristics.

Key findings of the feedback of the 3 French pioneer projects

- The feedback of the 3 projects illustrates the **challenges and difficulties that must be overcome** in order to make demonstrators become a **daylife reality**.
- **Some technical reliability issues had to be solved**, both on the FC part and on the conventional bus structure of some models.
- **The expected operational features have been more than met**, and the objective of a zero tailpipe emission meeting all operational advantages of a combustion engine vehicle has been reached.
- The increasing number of running deployment projects and **information sharing on the feedback of these projects should contribute to accelerate the roll-out of FC buses**.
- This should facilitate the uptake of FC buses by French cities, and allow the transition of FC buses **from a niche to a mainstream and mature market**.

Thank you!

jan-erik.starlander@france-hydrogene.org

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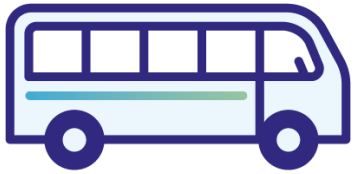
Deployment of fuel Cell Buses in Europe

Lionel Boillot, Clean Hydrogen Partnership



Clean Hydrogen Partnership

Clean Hydrogen Partnership

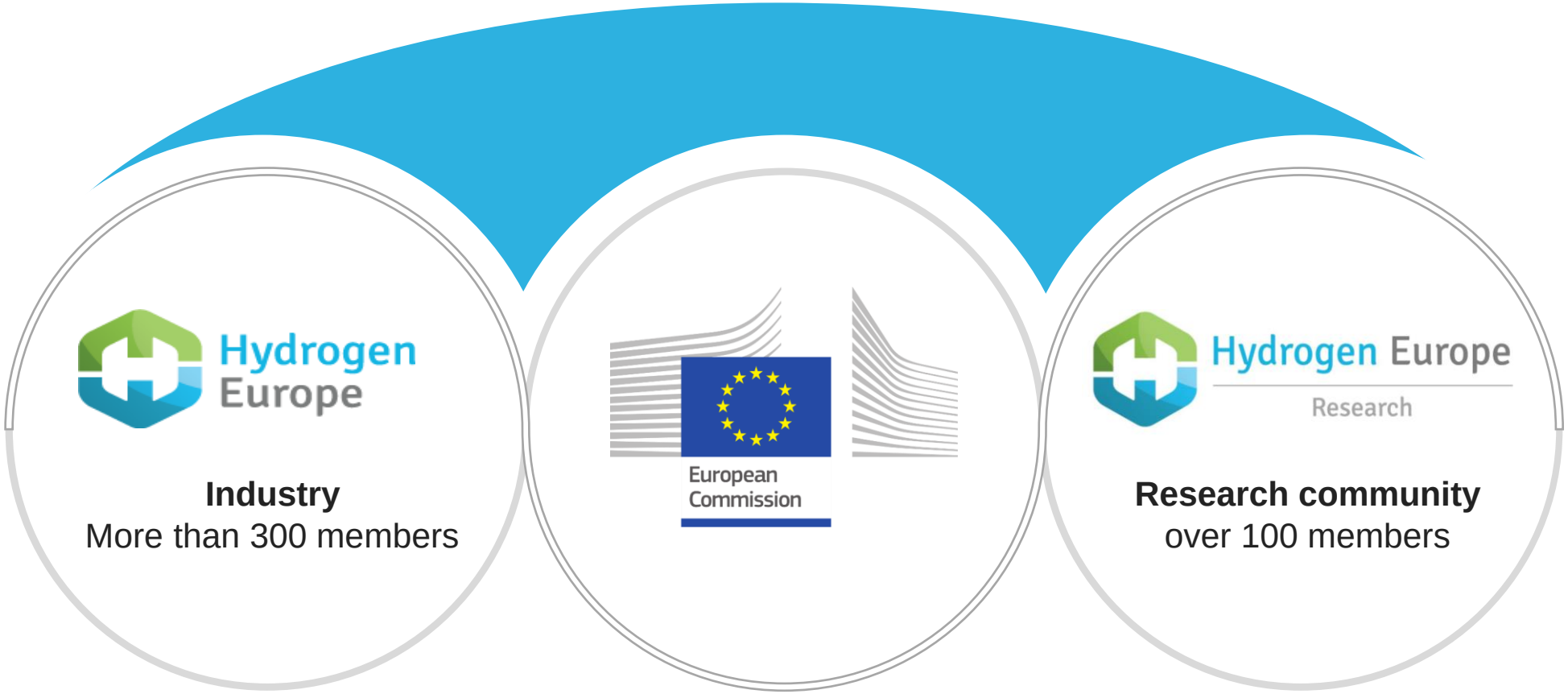
Hydrogen bus deployment in Europe

Lionel Boillot, Project Manager

3EMotion – Final Conference – 29th November 2022

Co-funded by the European Union

Clean Hydrogen Joint Undertaking

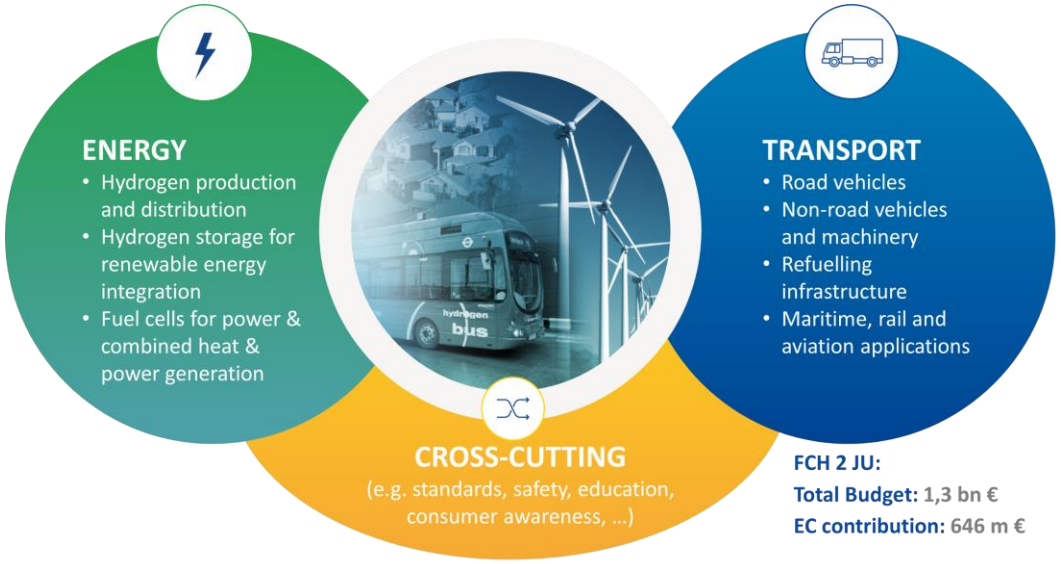


1 billion EURO from Horizon Europe* to implement R&I activities and facilitate the transition to a greener EU society through the development of hydrogen technologies

**** additional 200 million EURO for Hydrogen valleys (under RePowerEU)***

Continuing the work of FCH JU

- A 14 years journey of the JU (FCH JU, FCH 2 JU)
- From research to delivering hydrogen solutions/innovations in the market
- Clean Hydrogen Partnership is the successor of FCH 2 JU, taking over all its activities




Manufacturing


Green H2 production


Buses


ships


Aviation

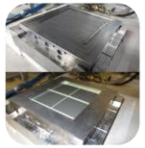

Research PoC


Domestic heat and power


Heat and power for industry


Heavy duty trucks


Logistics machinery


Materials


Gensets


Light duty vehicles


Trains

Co-funded by the European Union

How a hydrogen fuel cell bus work?

As **clean** as an electric bus

As **flexible** as a diesel bus

- Quiet
- Zero emission with green H2
- Refuelling times < 10 min
- Range > 300 km

- Hydrogen tanks on the roof
- Fuel cell at the back

Co-funded by the European Union

Hydrogen fuel cell bus (FCB) and hydrogen refueling station (HRS)

Environmental and societal benefits - case of Aberdeen (UK)

Fuel cell bus

Hydrogen station

Case study – environmental benefits:

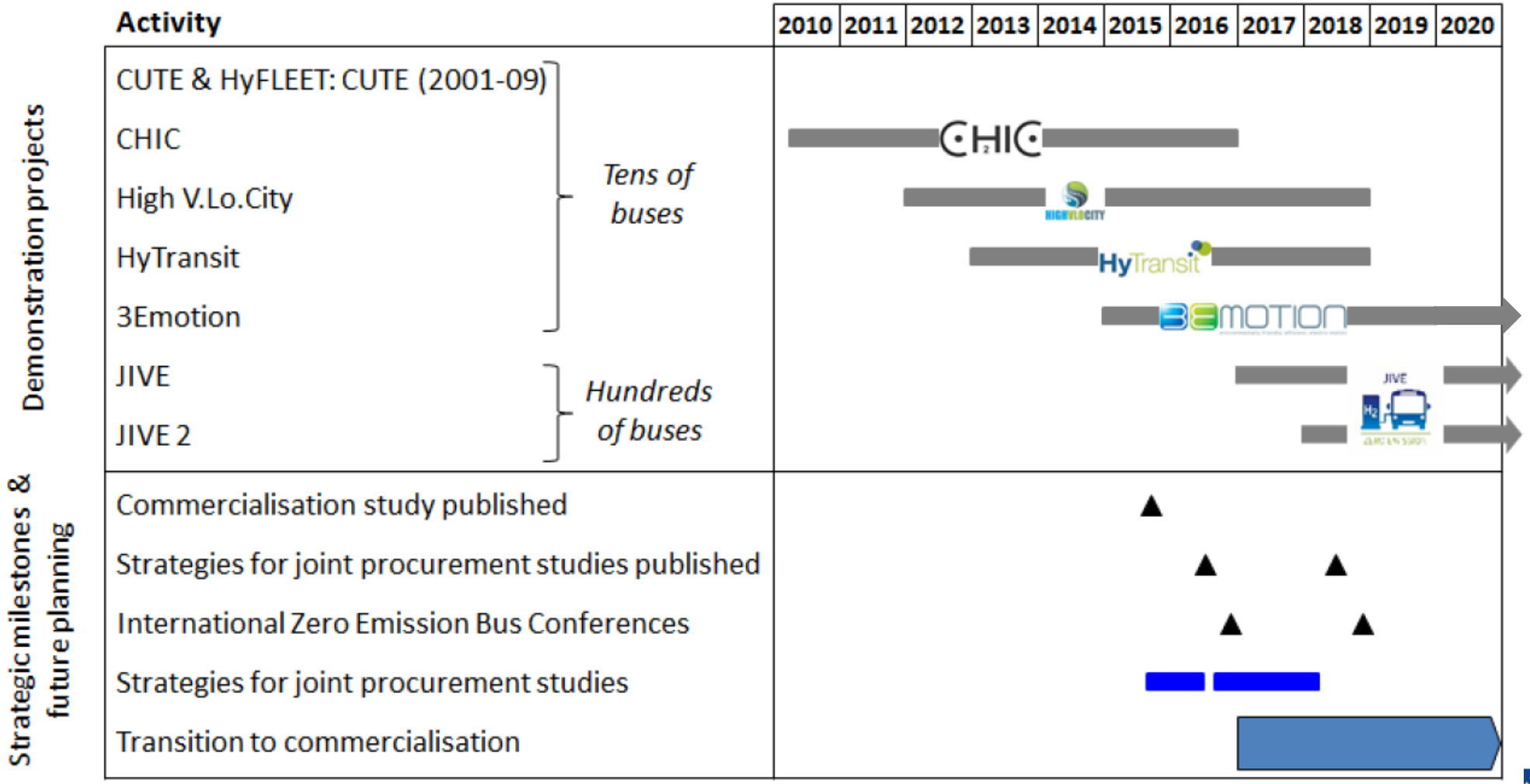
- 6 FCB (out of 10 FCB fleet)
- 1.2 million km travelled between March 2015 and September 2018
- The buses are powered by green H2

1.000 tons of CO2 abated ⇔ 396.000 litres of diesel in comparison with diesel EURO VI buses

-funded by the European Union

JU Funded FCB projects and studies since 2009

8 projects have put in total about 360FCB on the road



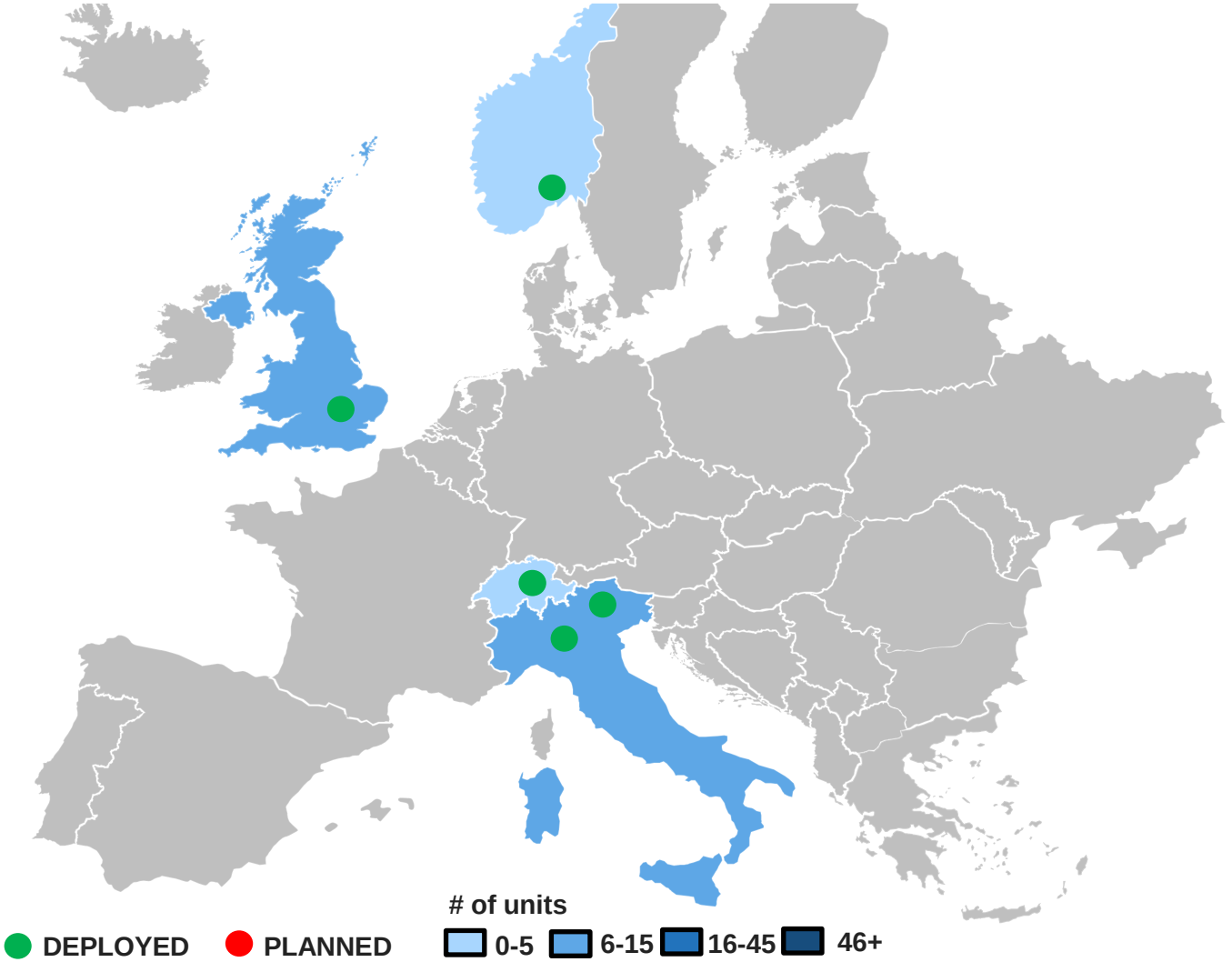
Co-funded by the European Union

FC buses deployment in CleanH2 JU projects

A chronological perspective

2009

#26 BUSES



Co-funded by the European Union

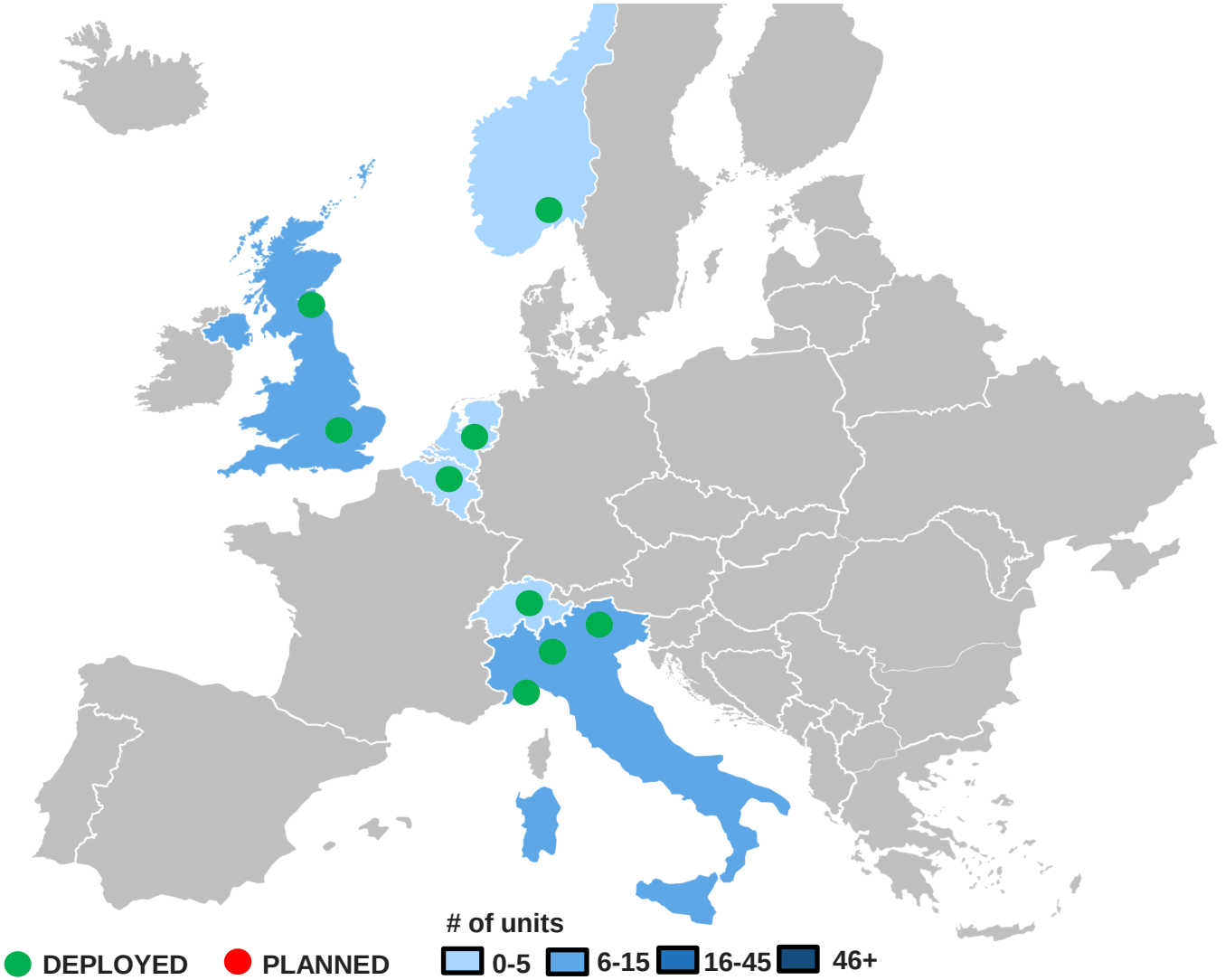
FC buses deployment in CleanH2 JU projects

A chronological perspective

2009
#26 BUSES

2010
#14 BUSES

2011
#6 BUSES



Co-funded by the European Union

FC buses deployment in CleanH2 JU projects

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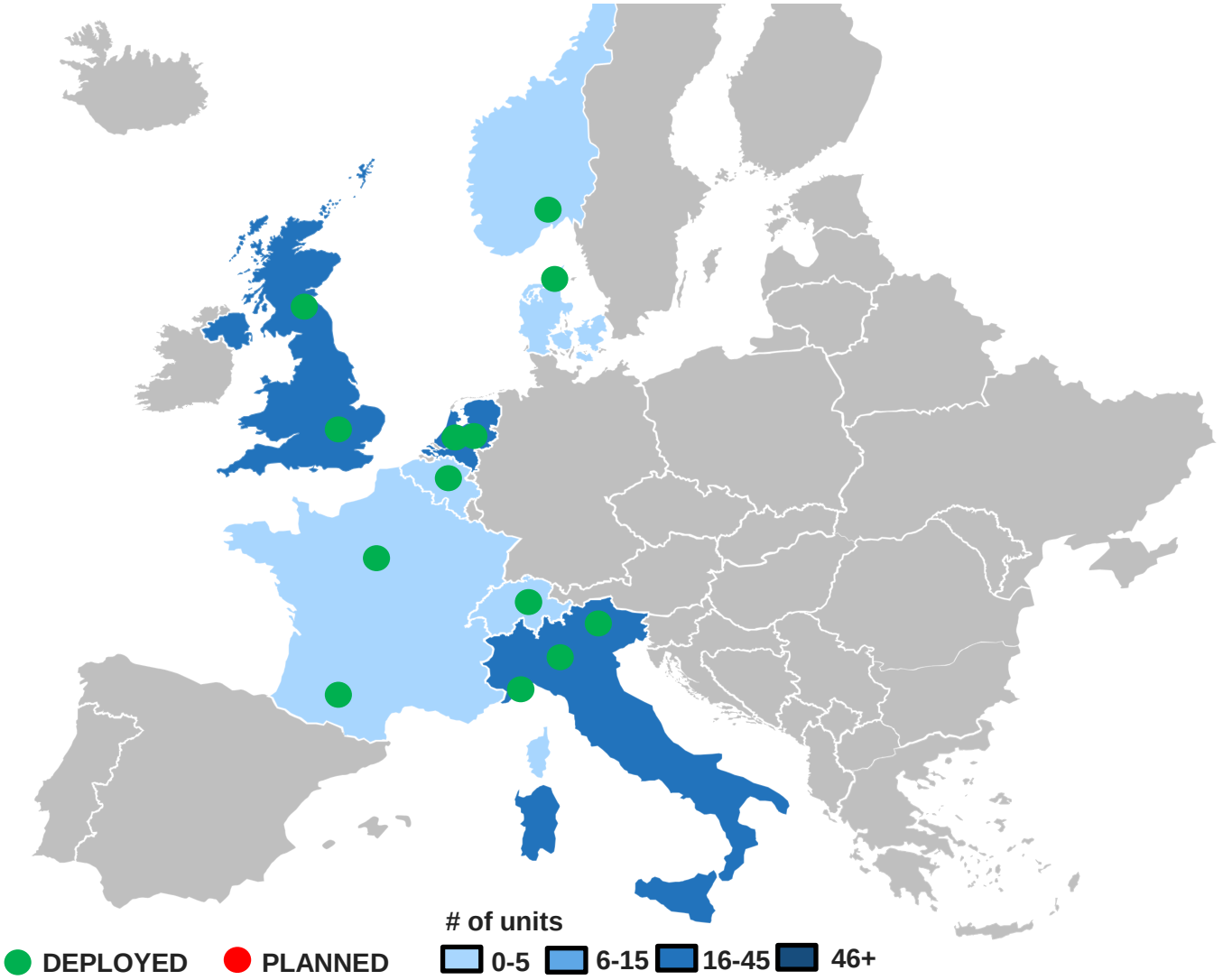


2013
#21 BUSES

Co-funded by the European Union

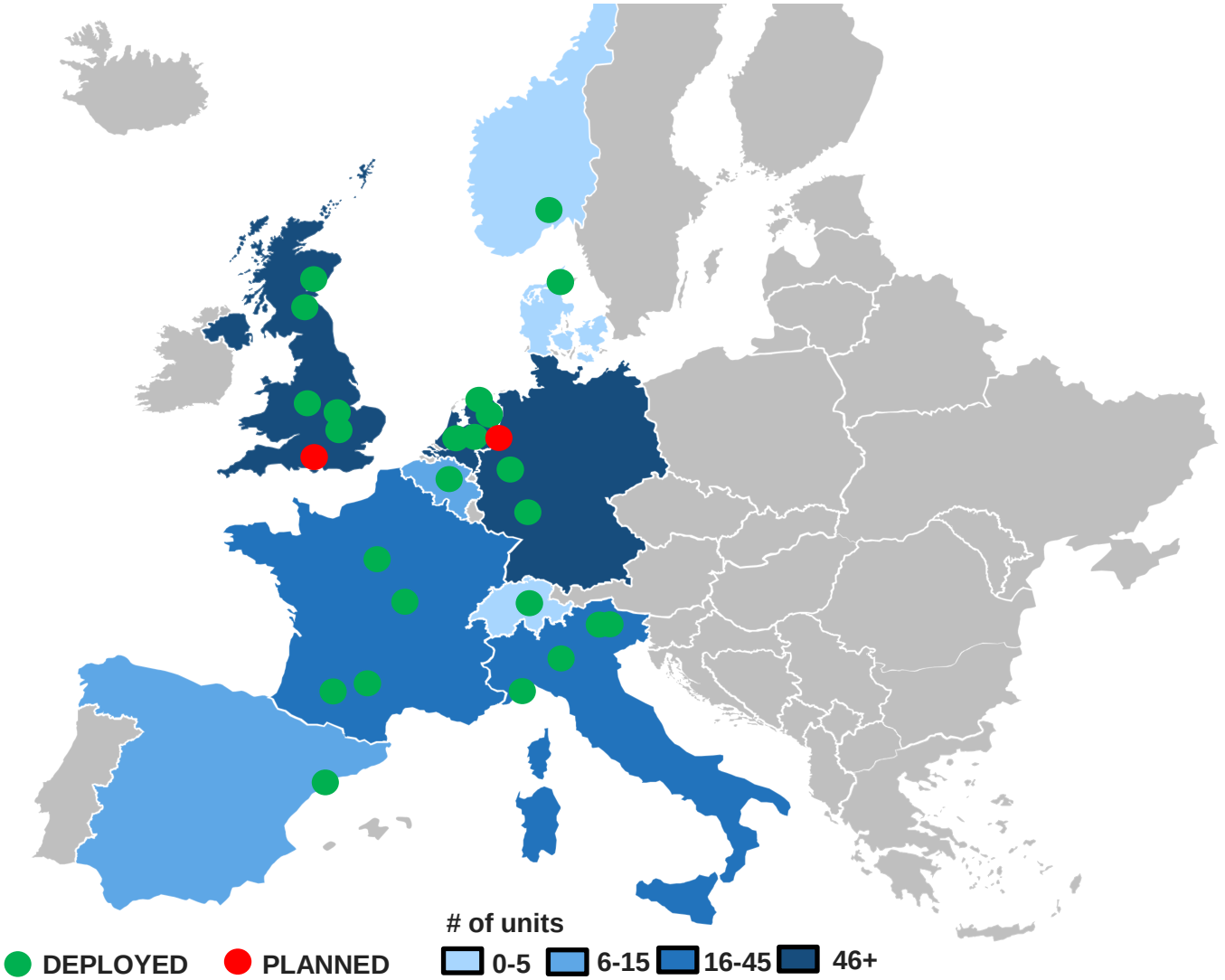
FC buses deployment in CleanH2 JU projects

A chronological perspective

2009 CHIC
#26 BUSES

2010 HIGHVLOCITY
#14 BUSES

2011 HyTransit
#6 BUSES



2013 BEMOTION
#21 BUSES

2016 JIVE
#142 BUSES

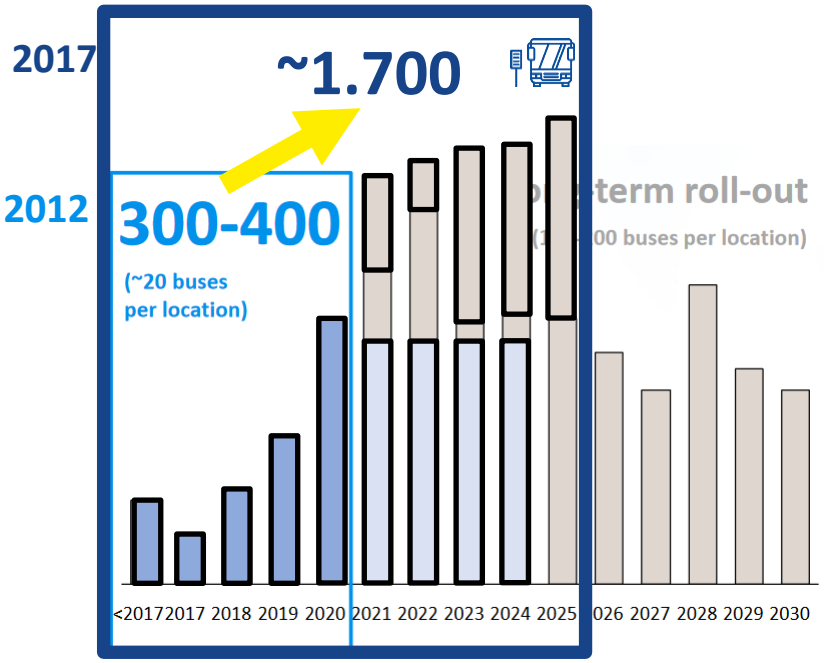
2017 JIVE 2
#152 BUSES

Co-funded by the European Union

Ambition to make FC buses a mainstream choice

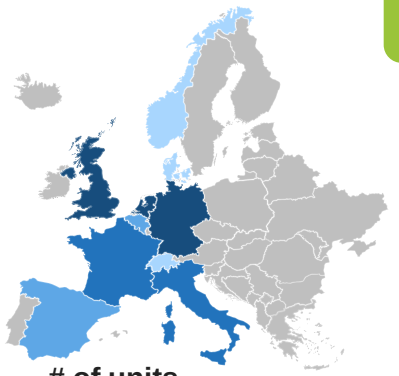
Results of study support since 2012 and strategy forward

Create a stable market for OEMs and Public Transport Operators



Increased European FCB offer

Evolution of FCB in operation in EU



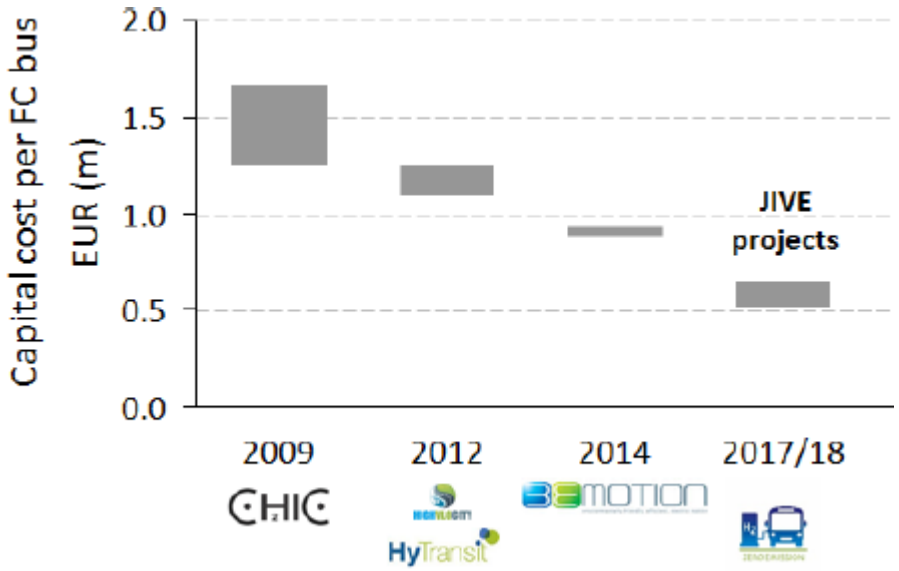
50
2019

115
2020

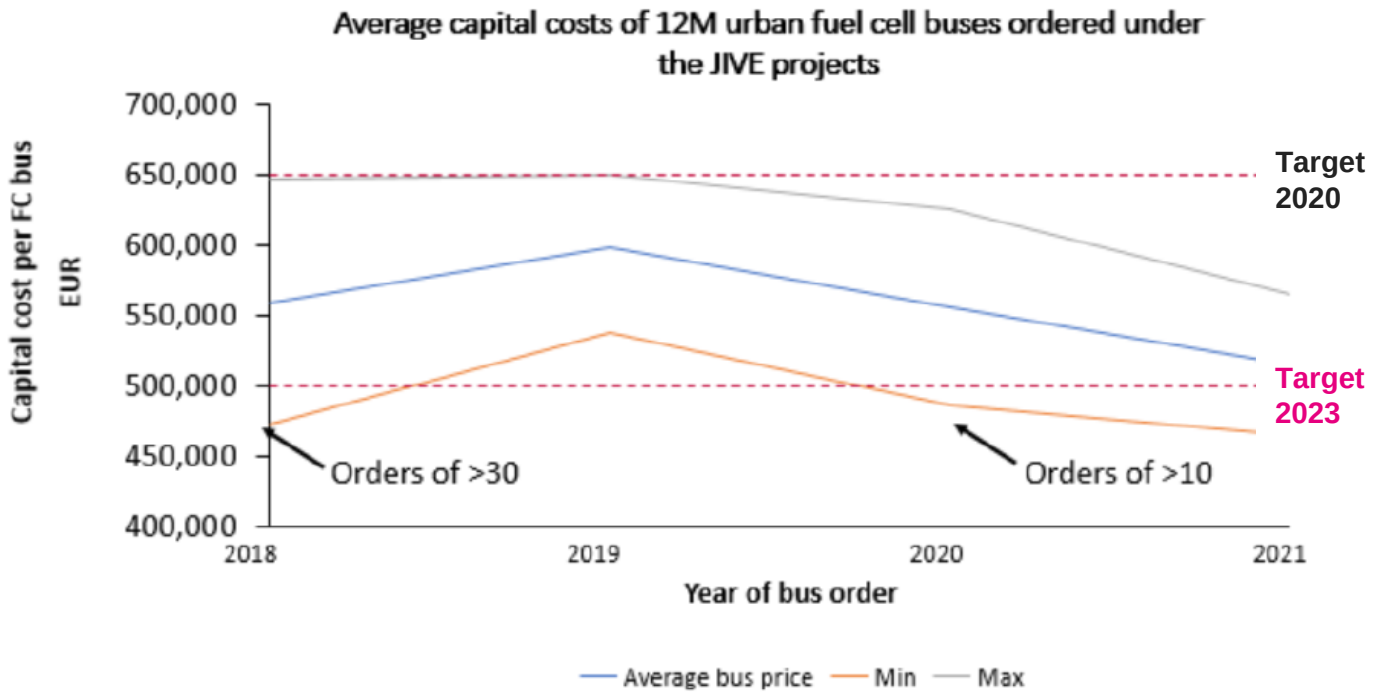
350
2022

Bring the FCB price down

Average FCB price



Ordering FCB fleets reduces CAPEX



Certain OEM considering commercial roll-out for a cost below 350.000 EUR for orders above 100 H2 buses per year and prospects for a continued demand

Co-funded by the European Union

Use smart business and financing models

“Make the purchase easier”

- Joint procurements: 10s + 10s + … ➔ 100s FCB
- Central purchase office: buy the bus from a catalogue
- Special Purpose Vehicle: share the investment risk
- Leasing of FCB: derisk residual value at end of concession
- Pricing per km: predictable TCO
- One stop-shop « turn key solution » with FCB + H2 supply and infrastructure
- To look into: service concession






Co-funded by the European Union

Increasing market and awareness

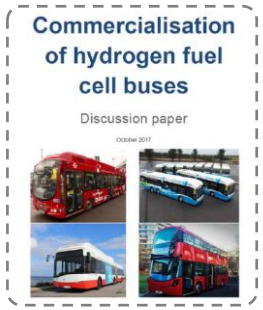
Increasing market

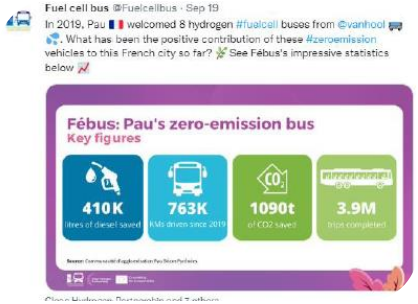
- Expand models range by estimating the demand for coaches and 18m buses
- Aggregation workshops
- Road Show planned in 2022/2023 in Eastern and Central Europe
- Sites planning for post-JIVE FCB deployment
- Policy paper for funding mechanisms

Awareness raising

- Engagement with wider stakeholder – UITP
- Webinars, roundtables, fairs, etc.
- One stop-shop website www.fuelcellbuses.eu
- Data dissemination and social media campaigns

EUROPEAN ZERO EMISSION BUS CONFERENCE 7th - 12th Oct 2023 @ Busworld Europe Brussels





Best practices guides (examples)

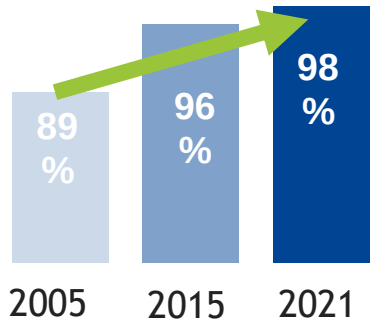
Co-funded by the European Union

Provide reliable operational data

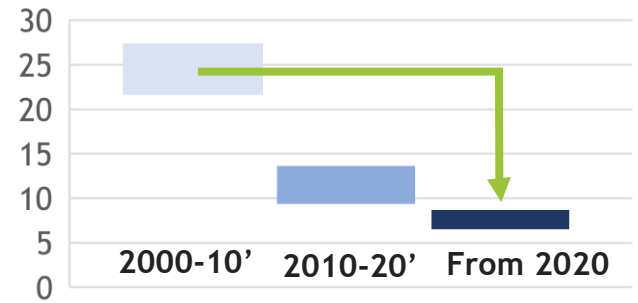
Real operational data

- Range similar to diesel bus (>350km)
- Excellent fuel efficiency 6-7kgH2/100km
- About 6.5 million km driven
- Expected infancy issues cleared
- > 35,000 h FC lifetime reached

Average HRS availability (Bus)



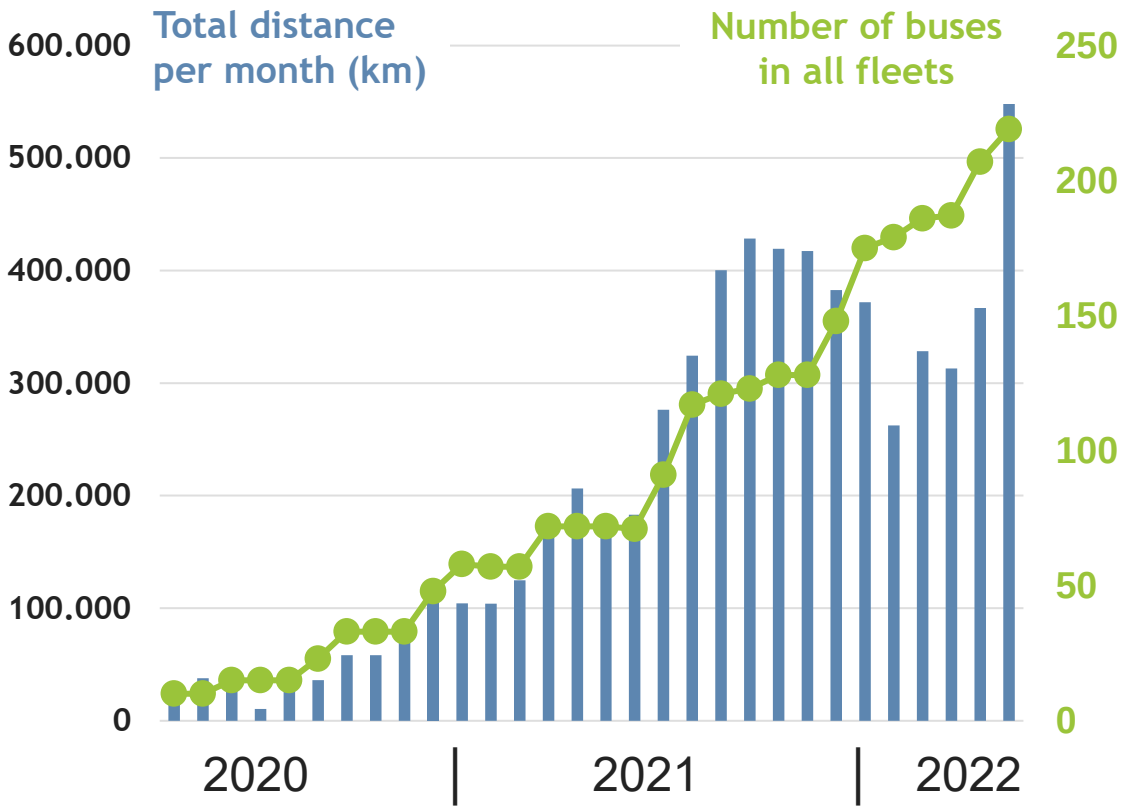
FCB consumption (kgH_2/100km)



68% more efficient buses

JIVE ZERO EMISSION JIVE 2 ZERO EMISSION

Fleet data



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Next steps – hydrogen valleys

HEAVENN

North Netherlands (Groningen):

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

Green Hysland

Hydrogen Island (Spain)*

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

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Clean Hydrogen Partnership

Keep in touch

lionel.boillot@clean-hydrogen.europa.eu

environmentally friendly, efficient, electric motion

Fuel Cell buses and development at Van Hool

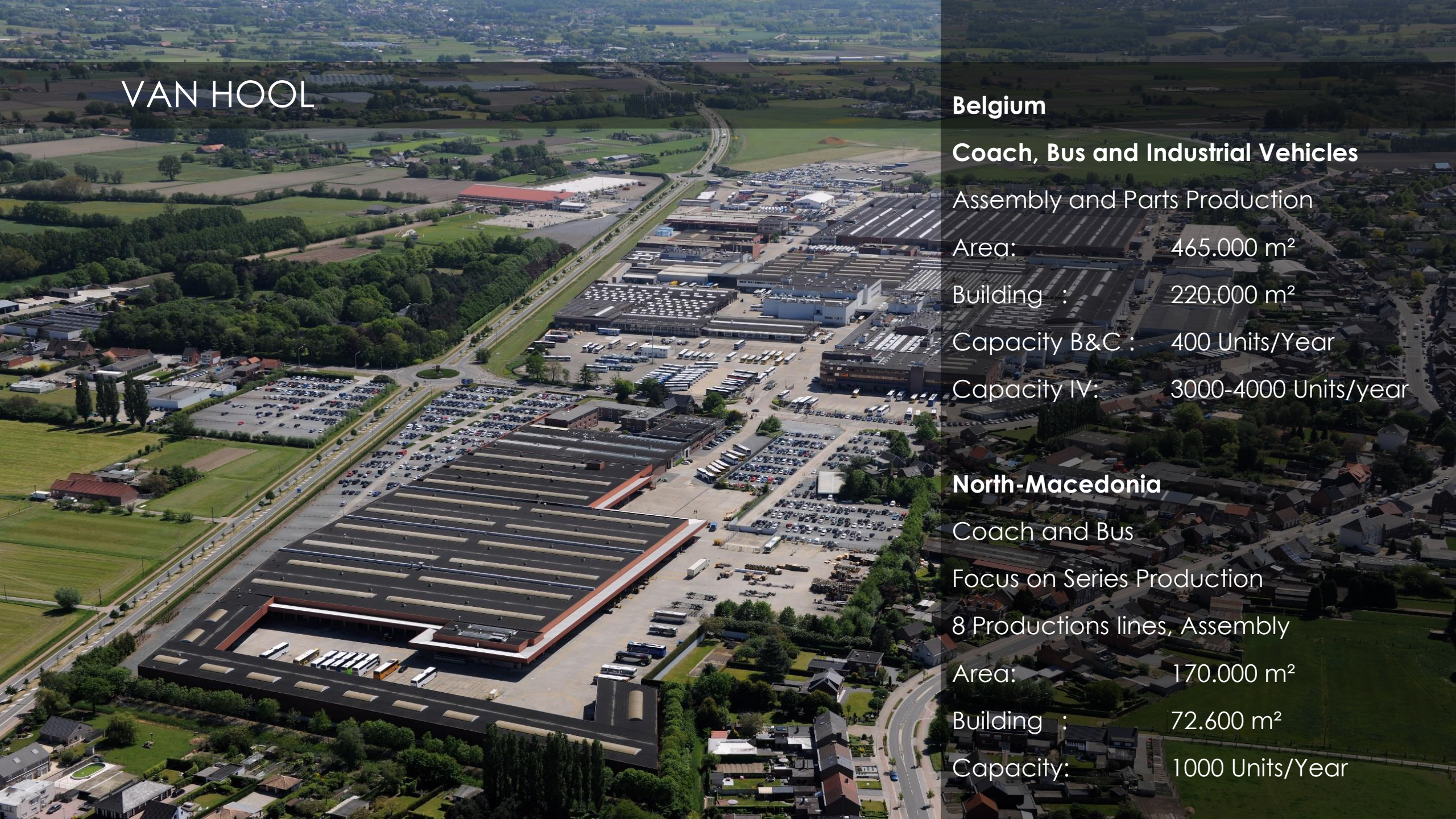
Geert Van Hecke, Van Hool

Clean Hydrogen Partnership

Presentation Van Hool 3EMotion

Closing conference, Versailles
November 29, 2022

Geert Van Hecke
Head of Sales Public Transport



VAN HOOL

Belgium

Coach, Bus and Industrial Vehicles

Assembly and Parts Production

Area:	465.000 m²
Building :	220.000 m²
Capacity B&C :	400 Units/Year
Capacity IV:	3000-4000 Units/year

North-Macedonia

Coach and Bus

Focus on Series Production

8 Productions lines, Assembly

Area:	170.000 m²
Building :	72.600 m²
Capacity:	1000 Units/Year

Van Hool Presentation on fuel cell bus developments

Agenda :

- **Van Hool – New A-line – 100% zero emission**
- **Fuel cell buses – looking backwards**
- **Fuel cell buses – looking forwards**

Development of new A-Line for city buses

- **During Covid period :**
  - **Development of new A-portfolio for city buses**
  - **100% zero emission**
  - **Standardisation and carry-over between different bus types**

Enabling zero-emission bus systems (slide from 2018, but still valid)

- Technology neutral
- Three main solutions are available for zero emission vehicles

TROLLEY-IMC

BATTERY ELECTRIC

FUEL CELL BUSES

New A-Line

Officially launched in june 2022 in Paris ; Berlin - Stockholm - Nice


VANHOOL
A12
VANHOOL


VANHOOL

Van Hool New Range of A-Buses – 100% electrified

Examples of sold projects

	A10	A12	A13	A18 Single Articulated	A24 Double Articulated
ELECTRICAL		 # 36 VVM	 # 67 Tide		
TROLLEY		 # 12 SVE		 # 34 SVE	
FUEL CELL		 # 66 (*)			

(*) several customers in Germany and France

E-Mobility – A13 E AALBORG (67 buses)

Aalborg - Denmark
In Traffic since Aug 2022

E-Mobility – A12 E VVM (36 buses)

VVM - Belgium
Delivery from Dec. 2022

E-Mobility A12 FC

Belfort, Rouen, Pau, Lorient, Dijon
Frankfurt, Eberswalde Berlin, Kerpen – Delivery from Dec 2022

EXQUI.CITY BRT buses – 100% electrification

	XQC18 Single Articulated	XQC24 Double Articulated
ELECTRICAL		
TROLLEY		
FUEL CELL		

E-Mobility – Trolley In-Motion-Charging

Rimini and Pescara
9 + 6 buses 2021-2022

E-Mobility – EXQUI.CITY24-E MALMO plug-in

Malmö - Sweden
21 buses – In traffic since June 12, 2022

E-Mobility – A24-E PARIS – opportunity charging

Paris - 56 buses delivery as of 2024

E-Mobility – FUEL CELL

Pau France
8 buses since 2019

E-Mobility CX45-E & TDX25-E USA

Deliveries ongoing since 2021

Van Hool Presentation on fuel cell bus developments

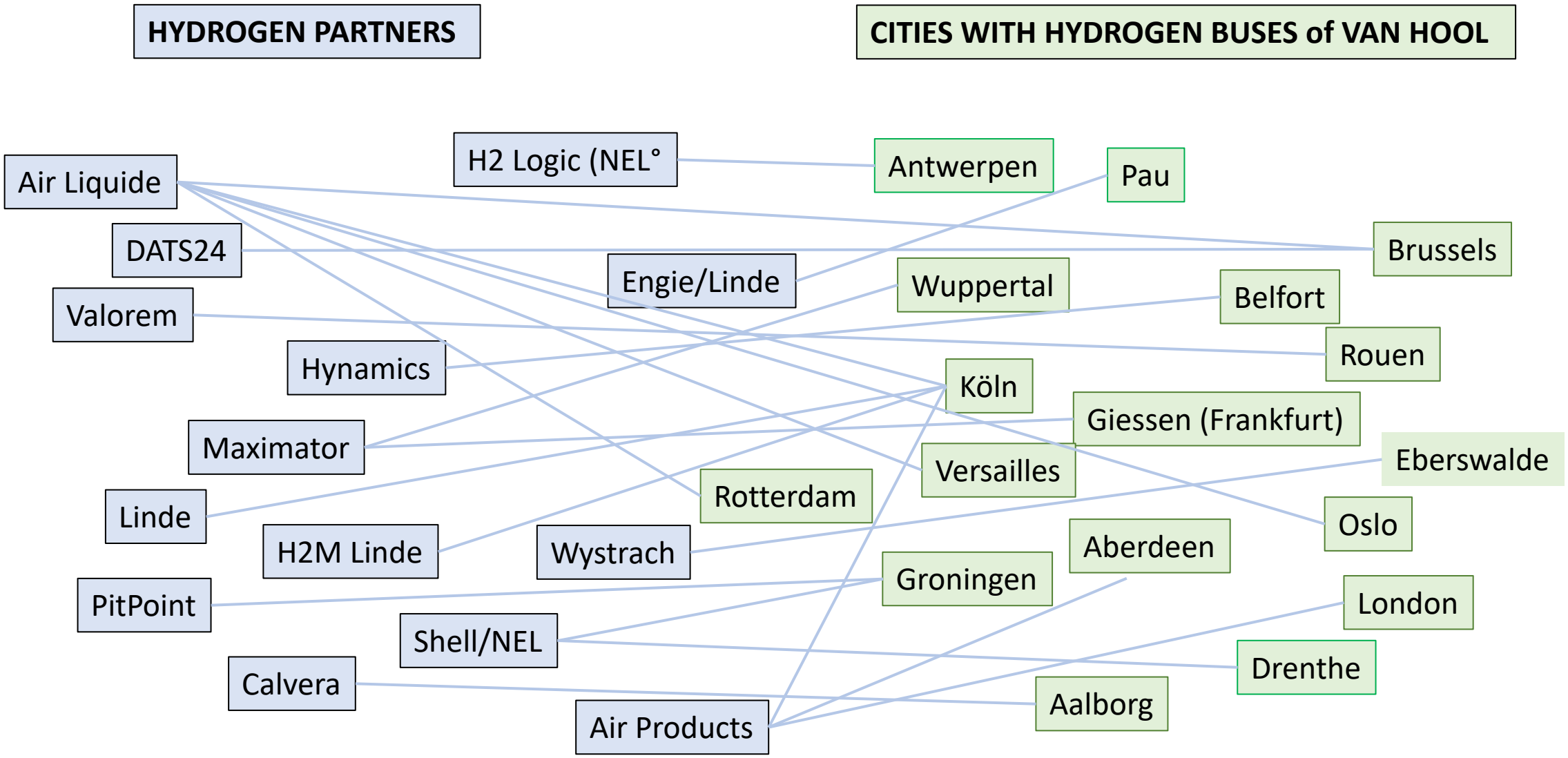
- **Van Hool – New A-line – 100% zero emission**
- **Fuel cell buses – looking backwards**
- **Fuel cell buses – looking forwards**

Fuel Cell Buses – looking backwards

Key facts :

- **208** Fuel Cell buses sold
- **+ 10 million driven kilometers** in several projects
- **Several follow-on orders**
  - ✓ QBuzz Groningen 2 (2017)+ 30 (2020)
  - ✓ RVK Köln 2 (2014)+ 35 (2019)
  - ✓ Pau 8 (2019) + 4 (2021)
- Projects with **several hydrogen providers**

Fuel cell buses – looking backwards



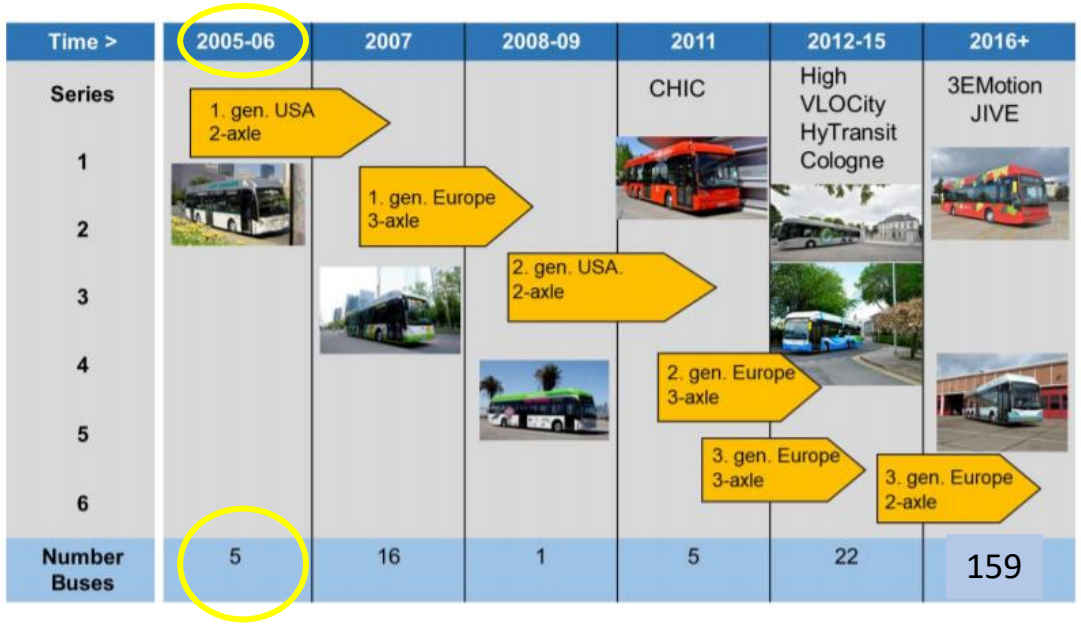
Fuel cell buses – looking backwards

- **The mood towards hydrogen changed**
- **The technology changed**
- **The competitive arena changed**
- **Bus Fleet Data is now available**
- **Introduction of zero emission fleets – changing priorities**

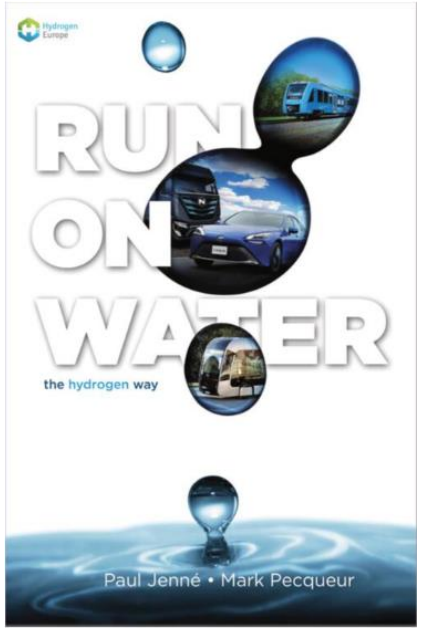
Fuel cell buses – looking backwards

Changing Mood

- **Hydrogen : a solution for an inner crowd of believers …**
  - Mr. Leopold Van Hool took the decision to develop hydrogen buses in 2004 !
  - Paul Jenné (my predecessor) called himself a missionary for hydrogen !



- **Becoming a mainstream solution**
  - Hydrogen the main topic on the last VDV electric bus conference
  - And Paul Jenné wrote a book about Hydrogen



Fuel cell buses – looking backwards

Changing technology

- **Shifting to integrated solutions and component optimalisation**

Hydrogen bus lay-out for 3EMotion

Conventionel airco/heating

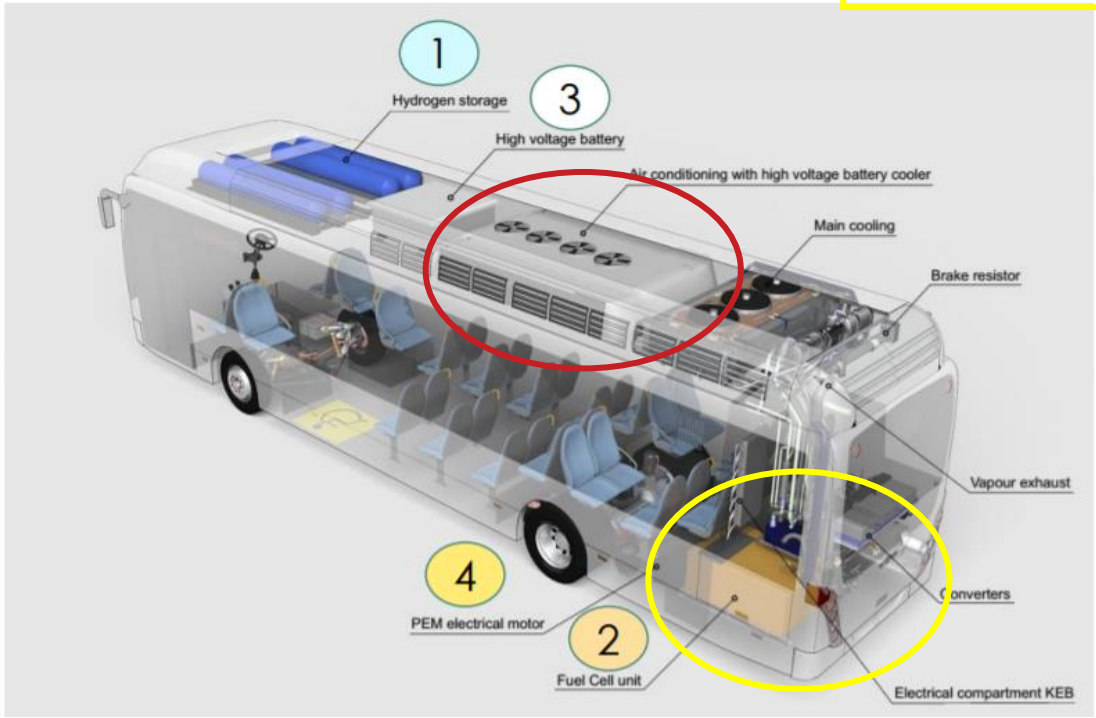
Fuel cell in the back

Hydrogen 1
5 containers with 38 kg of hydrogen at 350 bar.

Fuel cell 2
Fuel cell stack 85 kW.
Electricity produced on board of the bus.

Traction battery 3
Hybrid buffer in the electrical system :
- Providing extra energy while accelerating, climbing,...
- Recuperating energy while braking, driving downhill,..

E-Motor 4
Electric engine powers the bus.



… and tanking protocol via cable, heating of fuel cell needed during cold nights,…

Fuel cell buses – looking backwards

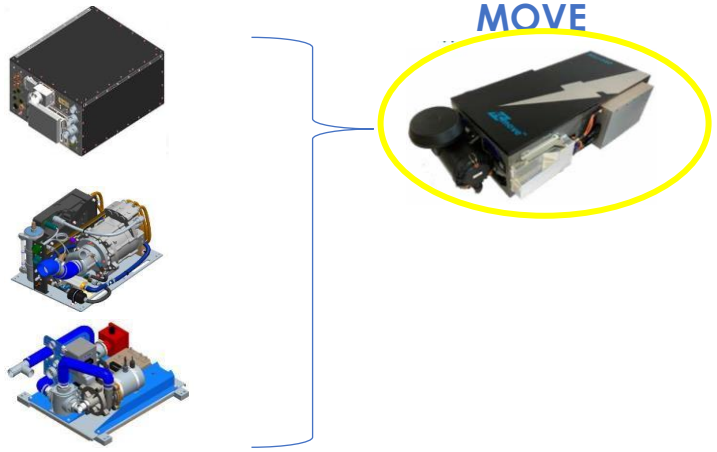
Changing technology

- **Shifting to integrated solutions and component optimalisation**

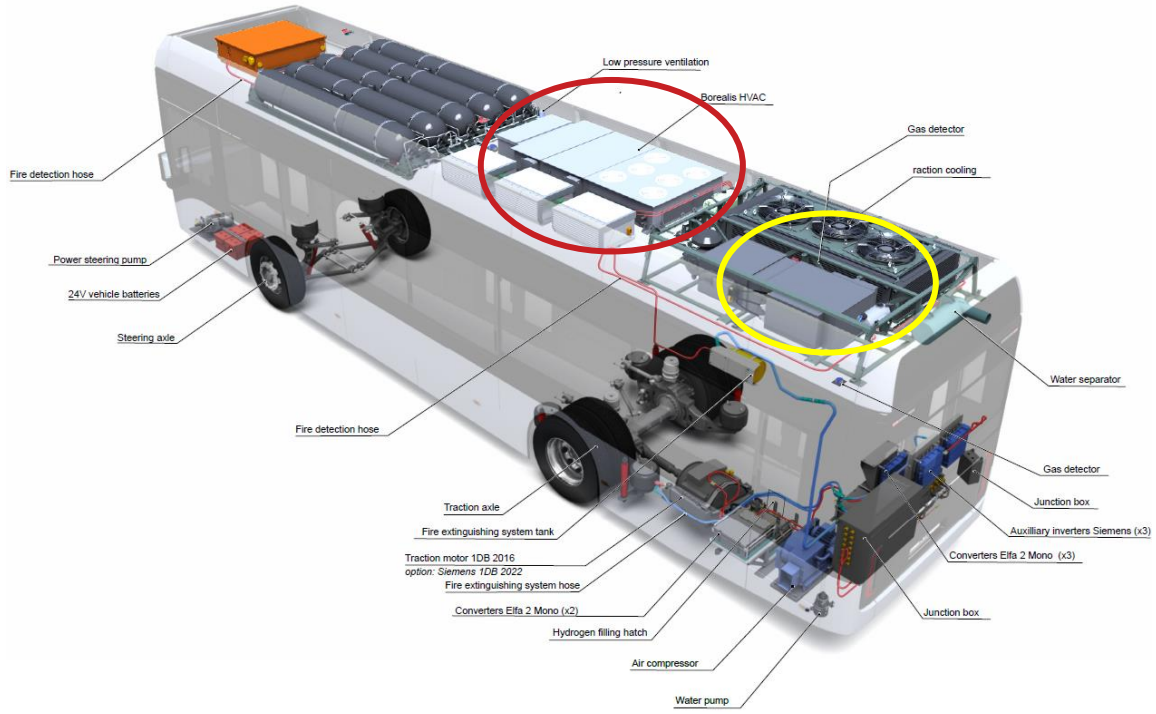
Hydrogen bus lay-out new A-Line

Heatpump

Fuel cell on the roof



Ballard FC MOVE



… and tanking protocol via IR or Bluetooth, self-start function for preconditioning,..

Fuel cell buses – looking backwards

Changing competitive situation

Competitive situation changed dramatically during the last 10 years

Bus suppliers	Fuel cell suppliers	H2 Tank suppliers
Van Hool	Ballard	Luxfer

2014

Fuel cell buses – looking backwards

Changing competitive situation

Competitive situation changed dramatically during the last 10 years

Bus suppliers	Fuel cell suppliers	H2 Tank suppliers
Van Hool	**Ballard**	**Luxfer**
Safra	Symbio	Worthington
Solaris	Hyundai	Hexagon
Caetano	Toyota	….
Wrightbus	Loop	
…	…	

NOW

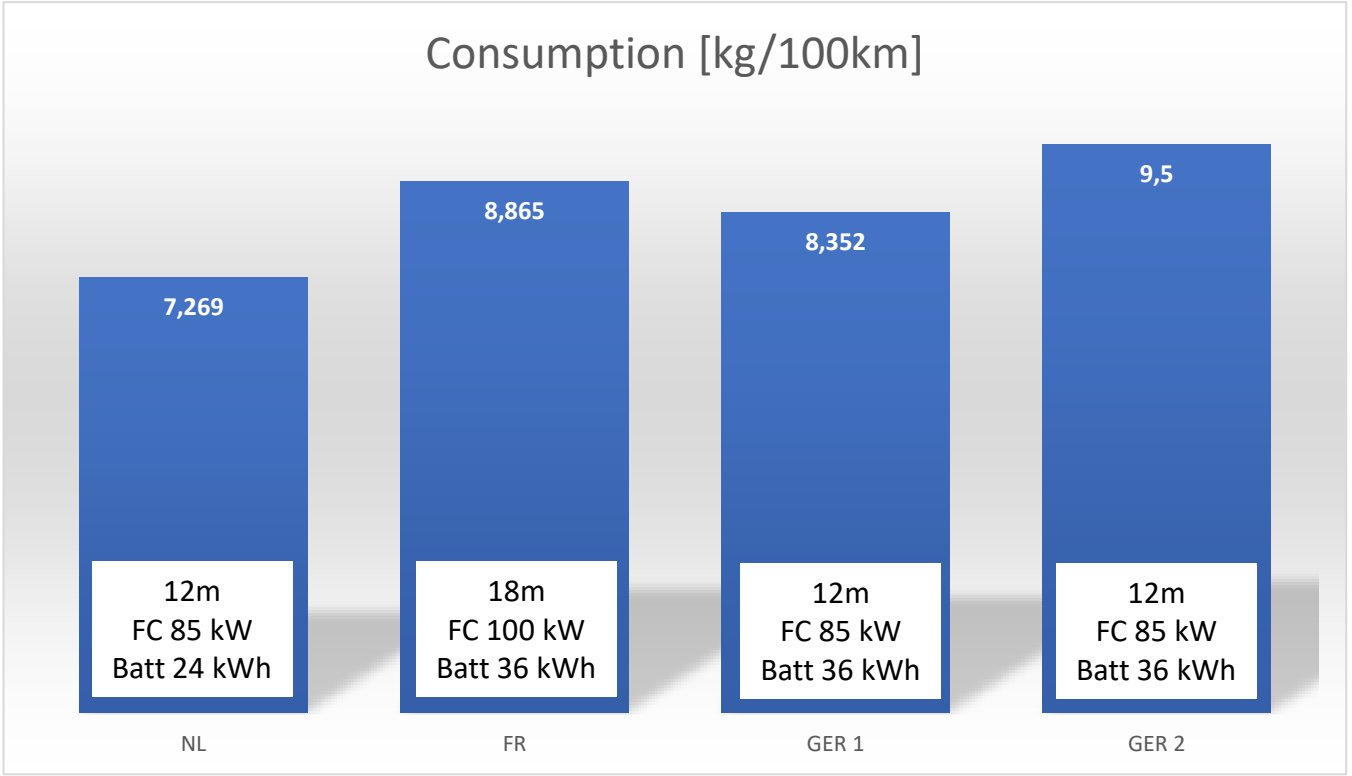
Fuel cell buses – looking backwards

Fleet data is available

Hydrogen data out of the field

- Average consumption based on fleets of minimum 8 and max. 30 buses.
- Average consumption based on +2 years of service for total fleet.

- Understanding differences :
  - Impact of operational speeds
  - Profile of the routes
  - City bus versus articulated bus



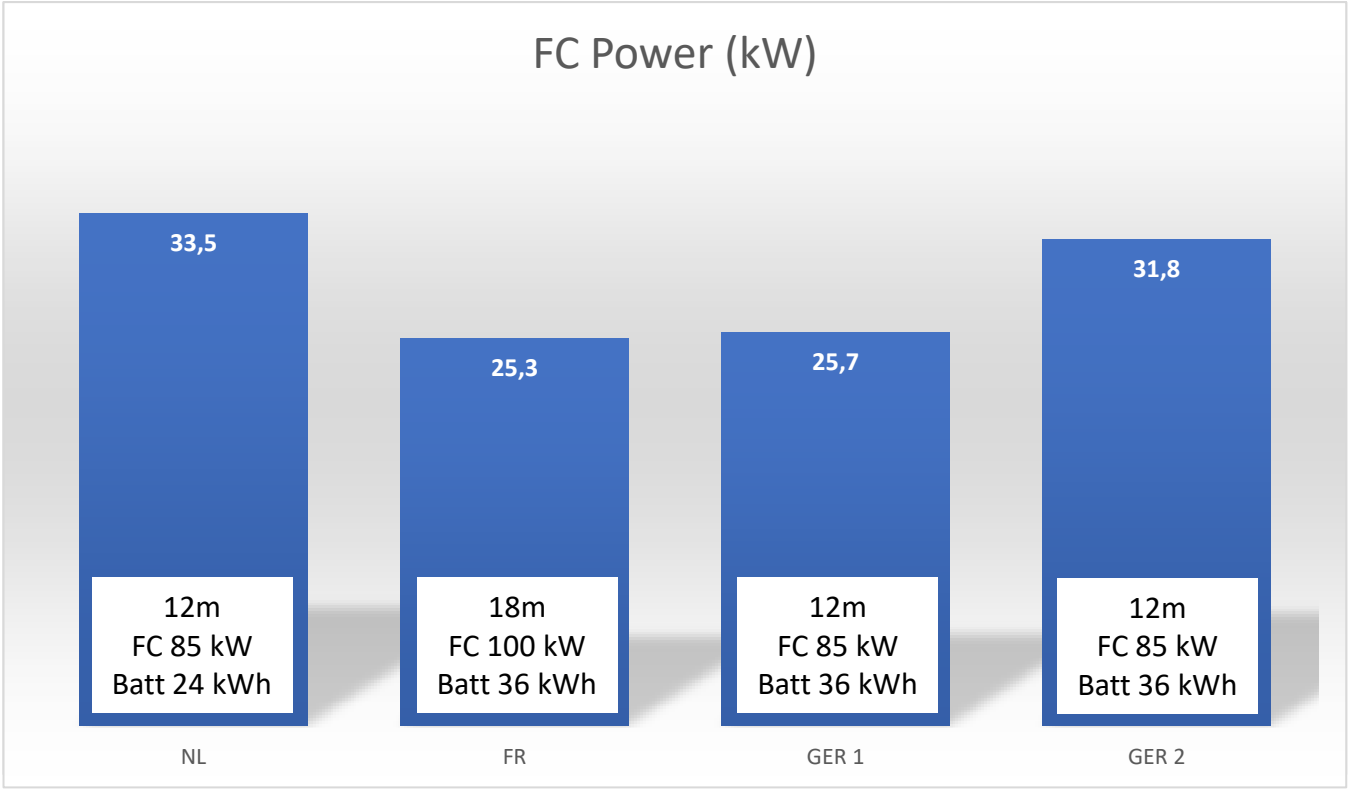
Fuel cell buses – looking backwards

Fleet data is available

Hydrogen data out of the field

- Average fuel cell power based on fleets of minimum 8 and max. 30 buses.
- Data based on +2 years of service for total fleet.

- Understanding differences through :
  - Capacity of traction battery
  - Average speed of the buses
  - Etc…



Fuel cell buses – looking backwards

Big fleets - Changing priorities

Main Reasons to buy fuel cell buses

1. Operational flexibility
   - Depot & charging centralised at one location.
   - Less space needed since no need to connect to the grid.
   - Less CAPEX needed (investment outsourced to H2 supplier)
   - High operational flexibility
   - Growing importance for large scale project.

2. Time to charge
   - Fuel cell bus charges in 8 to10 minutes
   - *Battery Bus 1 hour @400kW (fast charge)*
   - *Battery Bus 5 hours @80kW (depot charge)*

3. Range
   - Fuel cell minimum 600 kWh usable energy (BOL & EOL !)
   - 50% more energy than comparable battery bus
   - Heat recuperation of FC stack (+300 kWh/day)

Picture : fuel cell bus in Versailles

Fuel cell buses – looking backwards

Big fleets - Changing priorities

Main Reasons to buy hydrogen buses

4. Heat recuperation in winter season
   - Additional energy of +300 kWh/day
   - Without noise and vibrations

5. Straigthforward safety concept
   - Detect/evacuate/stop source of fire
   - Easier to organise depots

6. Fast deployment of zero-emission systems (vs Tram)
   - H2 charging infrastructure is prerequisite
   - Urban integration without major adaptations
     - No rails
     - No catenary wiring
     - No charging infrastructure in the city

Van Hool Presentation on fuel cell bus developments

- **Van Hool – New A-line – 100% zero emission**
- **Fuel cell buses – looking backwards**
- **Fuel cell buses – looking forwards**

Fuel cell buses – looking forwards

- **Hydrogen dominant buses**
- **Scaling up (power, passenger capacity, volumes)**
- **Market driven choices (price of H2 ; availability of infrastructure)**
- **Future H2 bus developments**

Fuel cell buses – looking forwards

Hydrogen dominant buses

Hydrogen solutions are the better choice for a zero-emission bus system if :

- **Autonomy** is needed, with its importance increasing with longer distances and higher speeds.
- High **operational constraints** exist (space, management complexity for big fleets, grid stability,…)

Conclusion :

Van Hool's strategy is to develop **hydrogen dominant buses** *as a complement to battery electric buses.*

A choice for mixed charging strategies is counter-productive in the long term.

- Extended autonomies are not compatible with time-consuming electric charging
- Operational constraints get more complex with mixed charging strategies.

Clear choices
Simplify

Fuel cell buses – looking forwards

Scaling up FC power

Supplier Readiness for high power Fuel cells

BALLARD®

Available : FCMove HD : 70 kW
FCMove HD+: **100 kW**
Developping : FCMove XD : **120 & 240 kW**

HYUNDAI MOTOR GROUP

Available : Gen 2C : 80 kW (stackable to **160 kW**)

Developping : Gen 3B : 85 kW (stackable to **170 kW**)

SYMBIO
A FAURECIA MICHELIN HYDROGEN COMPANY

Available : Stackpack 40 : 40 kW

Developping : Stackpack 75/150/300 : 75/**150/300 kW**

LOOP ENERGY

Available : T505 : 50 kW
T600 : 60 kW
Developping : S1200 : **120 kW**

Fuel cell buses – looking forwards

Scaling up volumes

Some conclusions for H2 bus developments

1.	Fuel Cell Stack with 100 to 150 kW	Available as of 2023-2025
2.	Hydrogen containers	Reliable storage systems available for 350 bar. Storage systems for 700 bar and liquid H2 to be developped
3.	Hydrogen infrastructure	Deployment ongoing in timeframe 2022 - 2030 Roll-out embedded in legal frameworks which gives confidence

→ Van Hool will continue to invest in the development of hydrogen buses.
The pace of investment will be function of the availability of the above 3 elements.

→ Van Hool will continue to offer all zero-emission variants (trolley, battery, fuel cell).
All these solutions have their merits in the market.

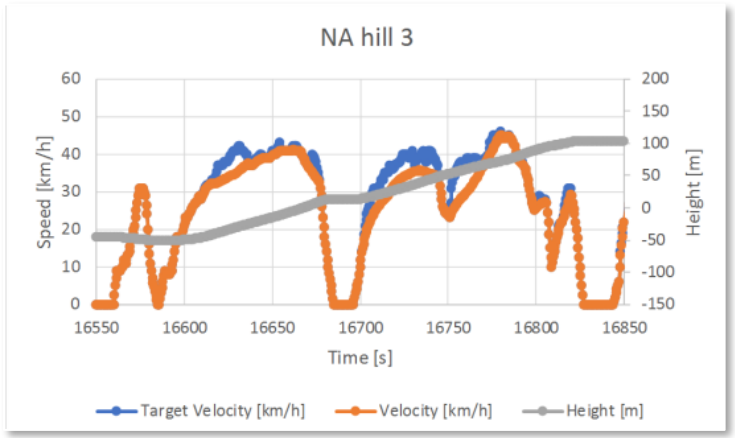
Fuel Cell buses – looking forward

Market driven choices

Technology neutral data-analysis for optimal solutions

Analysis with Geo-Tracker

OSMTracker voor Android™



Routes and profiles

Additional information / Sensitivity analysis
- HVAC (Winter and Summer)
- Pre-conditioning
- Desired top speeds
- Etc..

Optimal choice for the driveline

An analysis of the data leads to the right choice and most optimal definition of the powertrain of the zero-emission bus > data-driven solutions

Fuel Cell buses – looking forward

Market driven choices

In-house charging infrastructure for testing @ high volumes

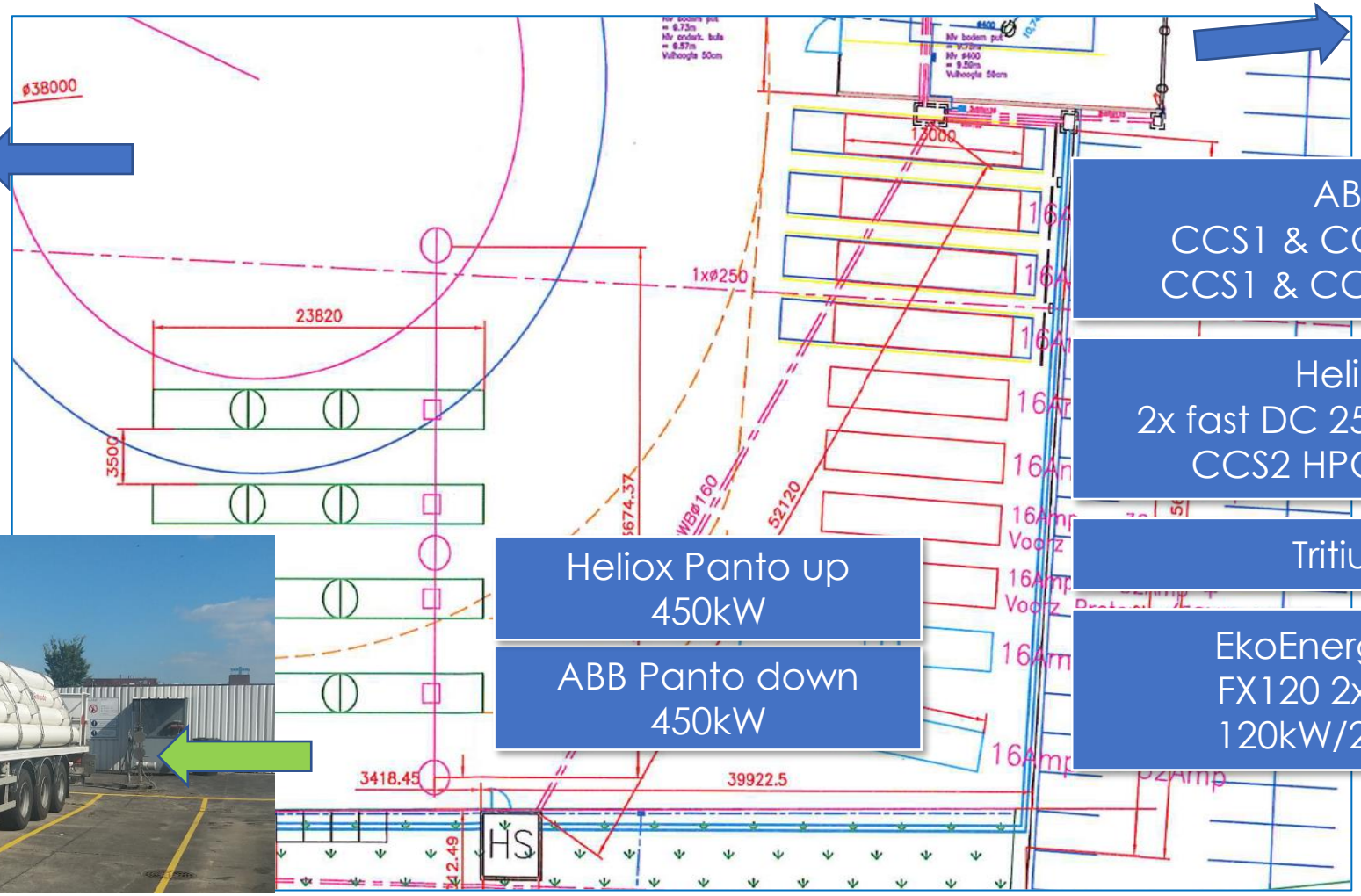


ABB
CCS1 & CCS2 50kW
CCS1 & CCS2 180kW

Heliox
2x fast DC 25kW mobile
CCS2 HPC 150kW

Tritium

EkoEnergetyka
FX120 2x CCS2
120kW/2*60kW

Heliox Panto up
450kW

ABB Panto down
450kW

Fuel Cell buses – looking forward

Future H2 developments

Van Hool will actively continue to develop its H2 portfolio
Market demands will dictate the pace.

XQC18 FC

A18 FC

XQC24 FC ?

E-coach > H2 ?

Thank you for your attention

Q&A

Please contact Van Hool
for more information

geert.van.hecke@vanhool.com

Back-up

References of vehicles with electric powertrain

- Hybrid
- Battery
- Trolley
- Fuel Cell

Aberdeen
Barcelona
Belfast
Keulen
Londen
Luxemburg
Malmö
Martinique
Metz
Monaco
Oslo
Pau
Quebec
Trondheim
US
Versailles
VVM

References of vehicles with electric powertrain

Vehicles with electric powertrain – number of vehicles in service and in production

	Coach	City Bus	Exqui.City	Total
Hybrid (since 2009)		262	185	**447**
Trolley (since 1985)		331	117	**448**
Battery (since 2021)	132	122	77	**331**
Fuel cell (since 2006)		200	8	**208**
Total	**132**	**915**	**387**	**1434**

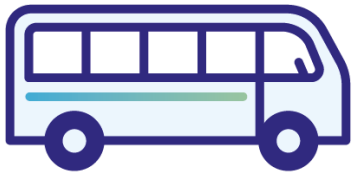
Van Hool is technology neutral with regard to the electrification of its buses.
Three solutions are offered for the choice of powertrain: battery, fuel cell and trolley.

3EMOTION

environmentally friendly, efficient, electric motion

Fuel Cell buses and development at Safra

Vincent Lemaire, Safra



Clean Hydrogen Partnership

FUEL CELL BUSES AND DEVELOPMENT AT SAFRA

Vincent Lemaire
President

SAFRA
Commited to zero emission mobility

SAFRA
THE COMPANY

SAFRA
Commited to zero emission mobility

Our ambition: to provide decarbonised public transport

SINCE

1955

Safra has focused on more eco-friendly mobility, historically through public transport equipment renovation.

SINCE

2011

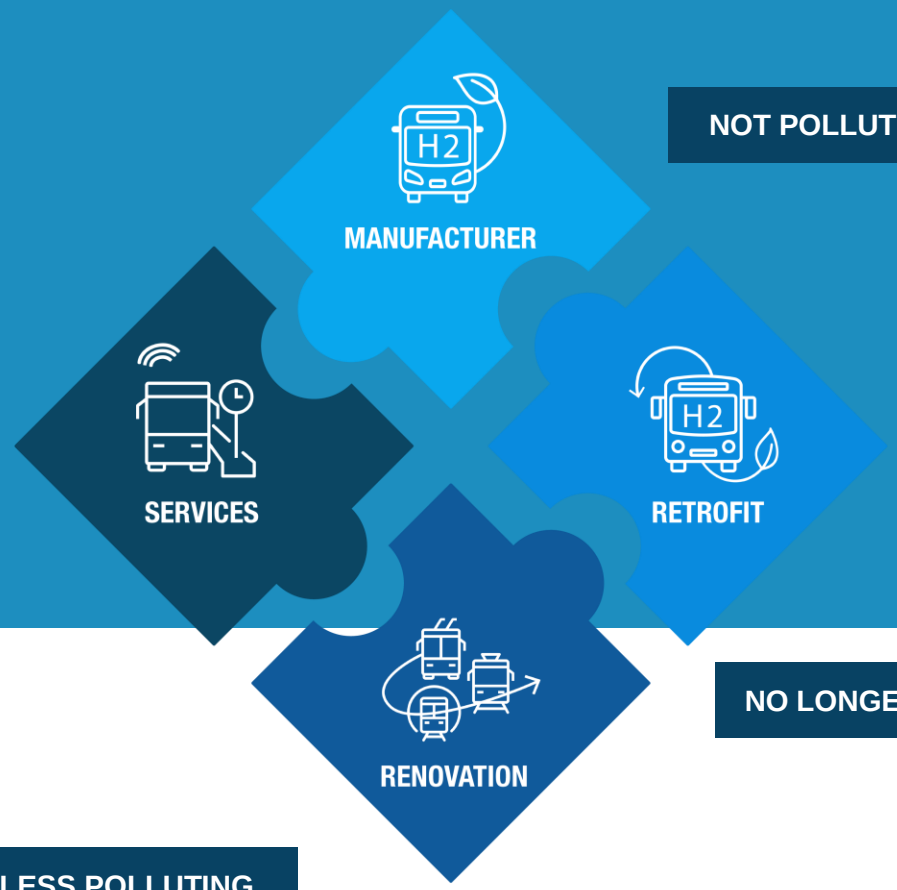
A pioneer in hydrogen, Safra has become the leading hydrogen bus player in France. The Company now designs, manufactures and markets its fully integrated offer to accelerate the decarbonisation of heavy mobility.

SAFRA

European accelerator of carbon-free mobility

Our value proposition: a global player in carbon-neutral mobility

SAFRA's value proposition targets key environmental and social challenges through **4 activities** with shared technical and commercial know how to address a common market segment :



SAFRA
Commited to zero emission mobility

SAFRA
Commited to zero emission mobility

*sur l'utilisation du bus

SAFRA's History

1955 — Creation of the company

1978 — orientation of our activity towards public transport sector

1981 — New industrial site in Albi

2002 — first railway renovation project

2011 — First Businova protoype

2015 — Certification of the first Businova plug-in hybrid

2018 — First sale of Businova hydrogen

2020 — First train renovation project

2021 — Capital opening with Transition Evergreen

2021 — Launch of the Hydrogen Retrofit Coach Project

2022 — Launch of HYCITY, VHYSION et H2-PACK

SAFRA

Safra, committed to sustainable growth

Accelerating the energy transition by sustainably decarbonising public transport[1]

Environmental commitment

- Become a key player in carbon-neutral mobil

Societal commitment

- Champion equal opportunities in the

Economic commitment

- Maintain constant dialogue

SAFRA

BRONZE 2020 ecovadis Sustainability Rating

EthiFinance Double Materiality Agency

France Hydrogène Engagée pour la transition écologique

UN GLOBAL COMPACT

ISO 9001

ISO 14001

THE CONTEXT
OF HYDROGEN BUS

SAFRA
Commited to zero emission mobility

Decarbonising public transport: a twofold challenge for public health and sovereignty...

63%

Nitrous oxide (NOx) emissions from Diesel road transport(1)

1,400 €bn

Economic and financial cost of air po

estimate

~80%

Share of imported natural gas (NGV) out of Europe (3)

~90%

Share of oil (Diesel) importe

out of Europ

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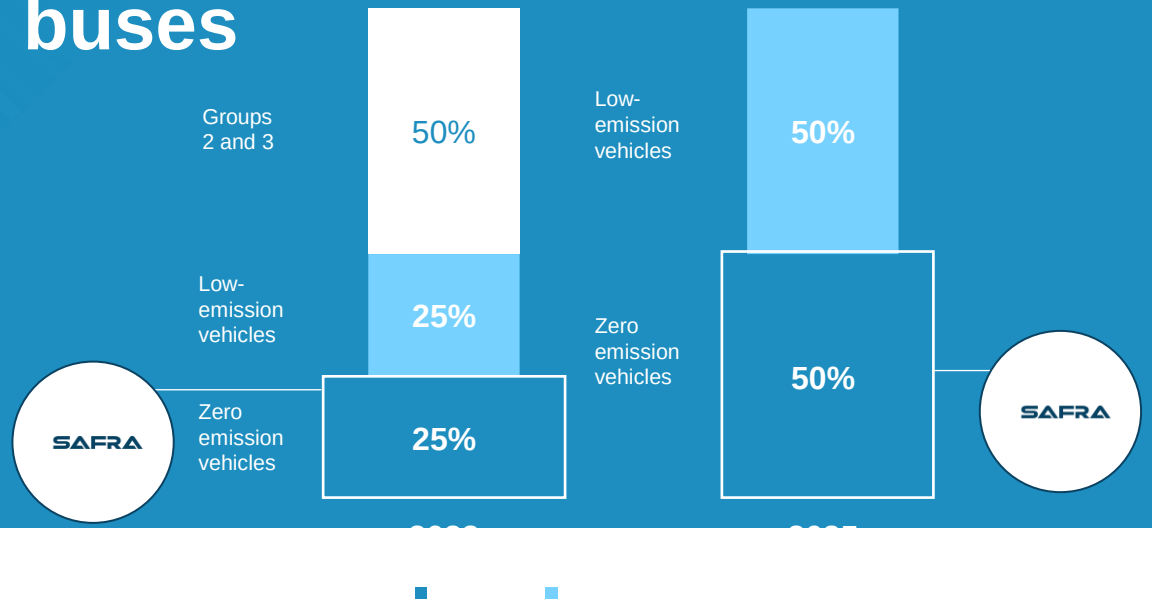
Regulation stipulating minimum levels of zero-emission buses

France's energy transition law (LTECV)

on public transport with the introduction of national minimum quotas for new vehicles(1)



Groups 2 and 3

- Other engine types

Group 1b (Low-emission vehicles)

- NGV with % of renewable gas
- Hybrid Zero emission vehicle

Group 1 (Zero-emission vehicles)

- Hydrogen
- Electric

By 2025, in France, cities with more than 20 buses will have to acquire or use a minimum of 50% of zero-emission vehicles

EU Directive 2019/1161

on the promotion of clean and energy efficient road transport vehicles(2)

20% minimum zero-emission buses since 2021

30% minimum from 2026 onwards

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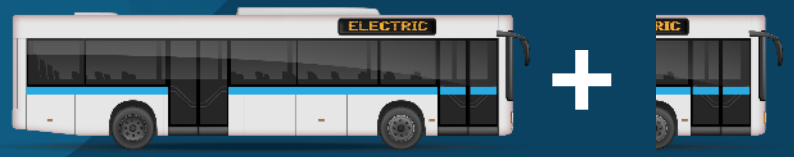
Source: (1) Regulation for cities with 250,000 inhabitants under prefectoral decree (application of LTECV – French Law No. 2015-992 of 17/08/2015); green growth energy transition law.
(2) Based on data from the European Directive 2019/1161 amending Directive 2009/33/EC (23/04/2009) on the promotion of clean and energy-efficient road transport vehicles.

Our product: the hydrogen bus, a key substitute for Diesel

1 Diesel bus

=

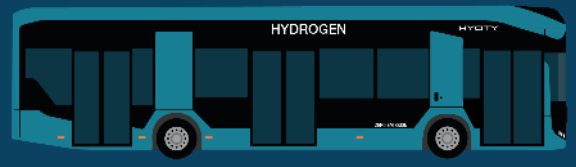


+

1,2 electric buses

+ 20 % d'infrastructures
+20% maintenance costs

OR



1 single H_2 bus

(1) Equivalent use. Safra estimate
(2) Total Cost of Ownership
(3) Report CEA/ Ministry of Ecological and inclusive Transition - "Hydrogen deployment plan for the energy transition" – 2017

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Heavy-duty use

Short refuelling time
(10-15 mins)

High autonomy (350 km / 217 miles):
continuous operation

Use of hydrogen that can be locally produced

4x fewer on-board batteries
vs. electric buses
(less dependency
and less recycling)

Managed and steadily reduced TCO (2)

Decreasing hydrogen prices
(-30% in the past 5 years) (3)

Shared and financed refuelling stops

No additional electric infrastructure or maintenance required

Controlled TCO and 100% electric battery complementary offering (excluding fleet impact)

	CATP[1] scenarios		SAFRA
(€k)	Electric	Hydrogen	Hydrogen
Bus	€554k	€698k	€620k
Energy	€68k	€357k[3]	€357k[3]
Maintenance	€282k	€258k	€258k
Total (CATP scope)	€904k	€1,313k	€1,235k
Subsidies[2]	€100k	€220k	€220k
Infrastructure cost[4]	€100k	-	-
Total with subsidies	€904k	€1,093k	€1,015k
€/km[5]	€1.51	€1.82	€1.70

Sources:
(1) Review conducted by France's Public Transport Central Procurement Service – February 2022
(2) Source – ADEME (France's Agency for the Ecological Transition, 2022)
(3) Estimated cost of electric and hydrogen to date including distribution station infrastructure costs incurred by the energy provider
(4) Including chargers and share of the depot electrical connection
(5) Scenario for 600,000 km travelled (i.e., 15 years – the vehicle's estimated service life)

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Benefits compared to electric:

- Distance/Duration
- Cost of infrastructure
- Refueling speed

Comparative strengths	Electric	Hydrogen
Autonomy	150-200 km	200-350 km
Cost of infrastructure	+	+++
Bus prices	+++	++
Cost of energy to date	+++	+
Refueling speed	+	+++
Line requirements (distance, operating time, slope, etc.)	+	+++
Region requiring thermal comfort	+	+++
Passenger capacity	+	+++
Vehicle size	Favourable ≤12m	Favourable 12m to 18m

EXPERIENCE
FEEDBACK

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OUR FIRST GENERATION OF FUEL CELL BUS : BUSINOVA

Launch in 2015
First sale in 2018

+

Innovative design
Operability
Capacity
Evolutivity

−

Low floor or 3 doors not achievable

SAFRA
Commited to zero emission mobility

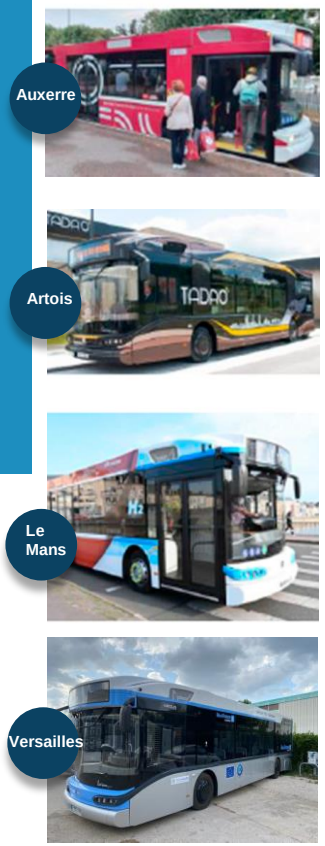
Our position: Leader on the French hydrogen buses market within 3 years

100% designed by Safra

100% assembled in France

100% European key technologies

23 **67%**



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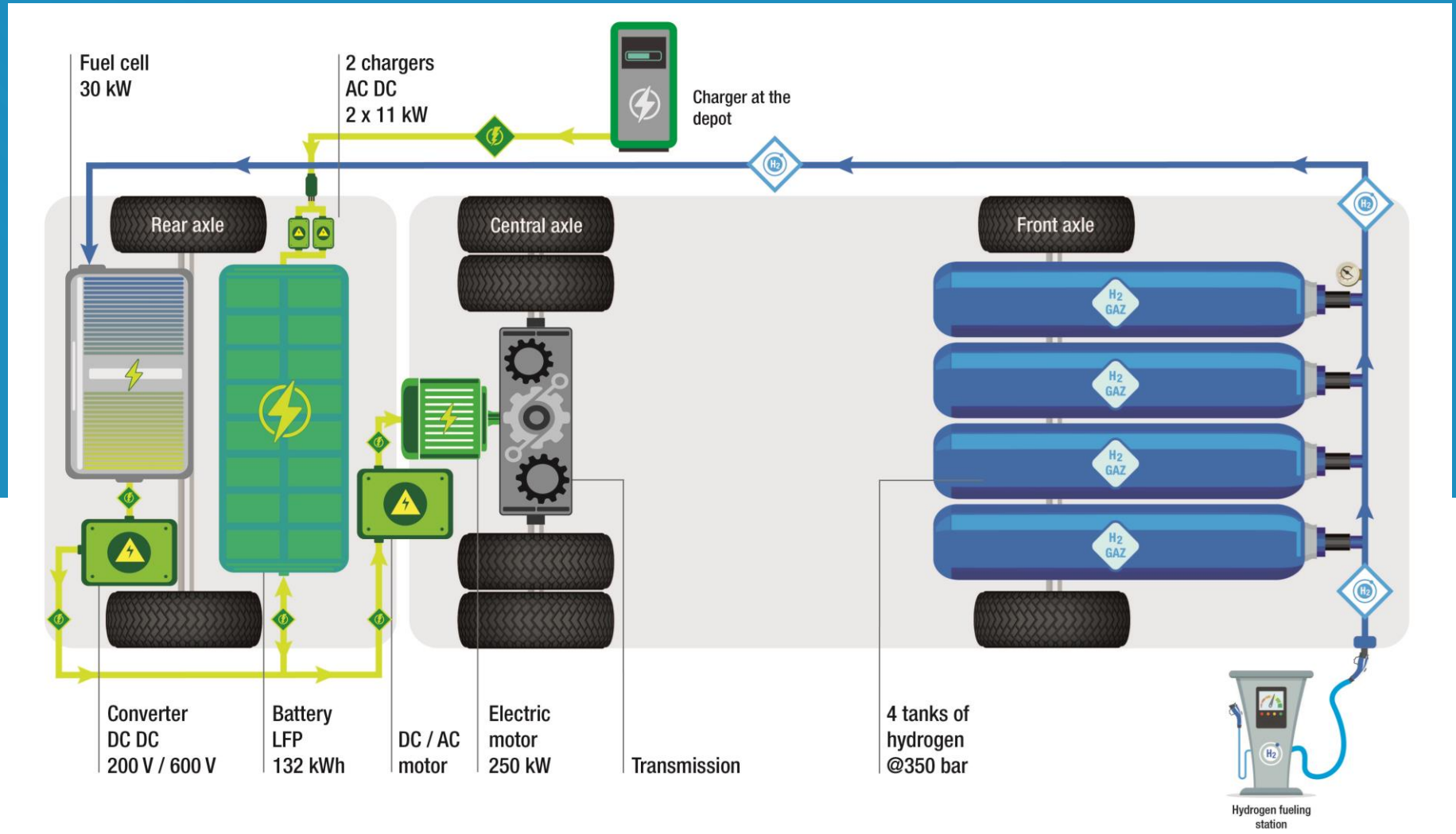
OUR FUEL CELL DRIVE CHAIN

- Hydrogen traction chain controlled
- French Fuel cell
- Full hydrogen system or range extender



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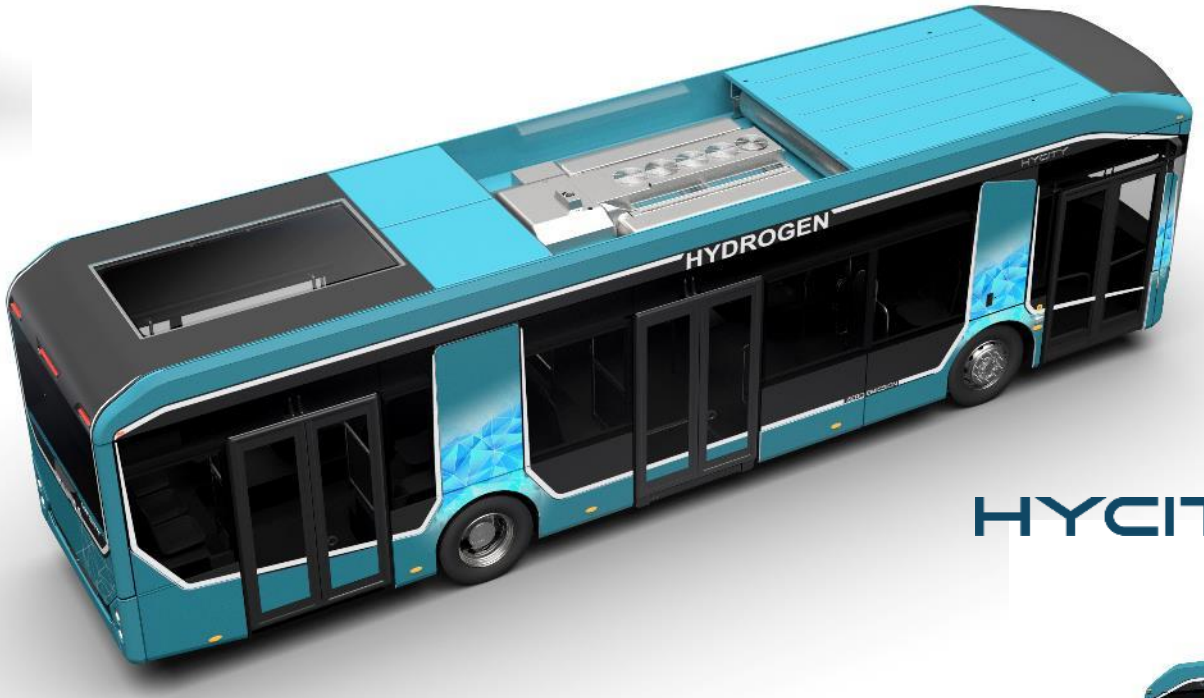
HYCITY
THE NEW GENERATION

SAFRA
Commited to zero emission mobility

HYCITY®, the new generation of hydrogen bus



HYCITY

ADEME
AGENCE DE LA TRANSITION ÉCOLOGIQUE

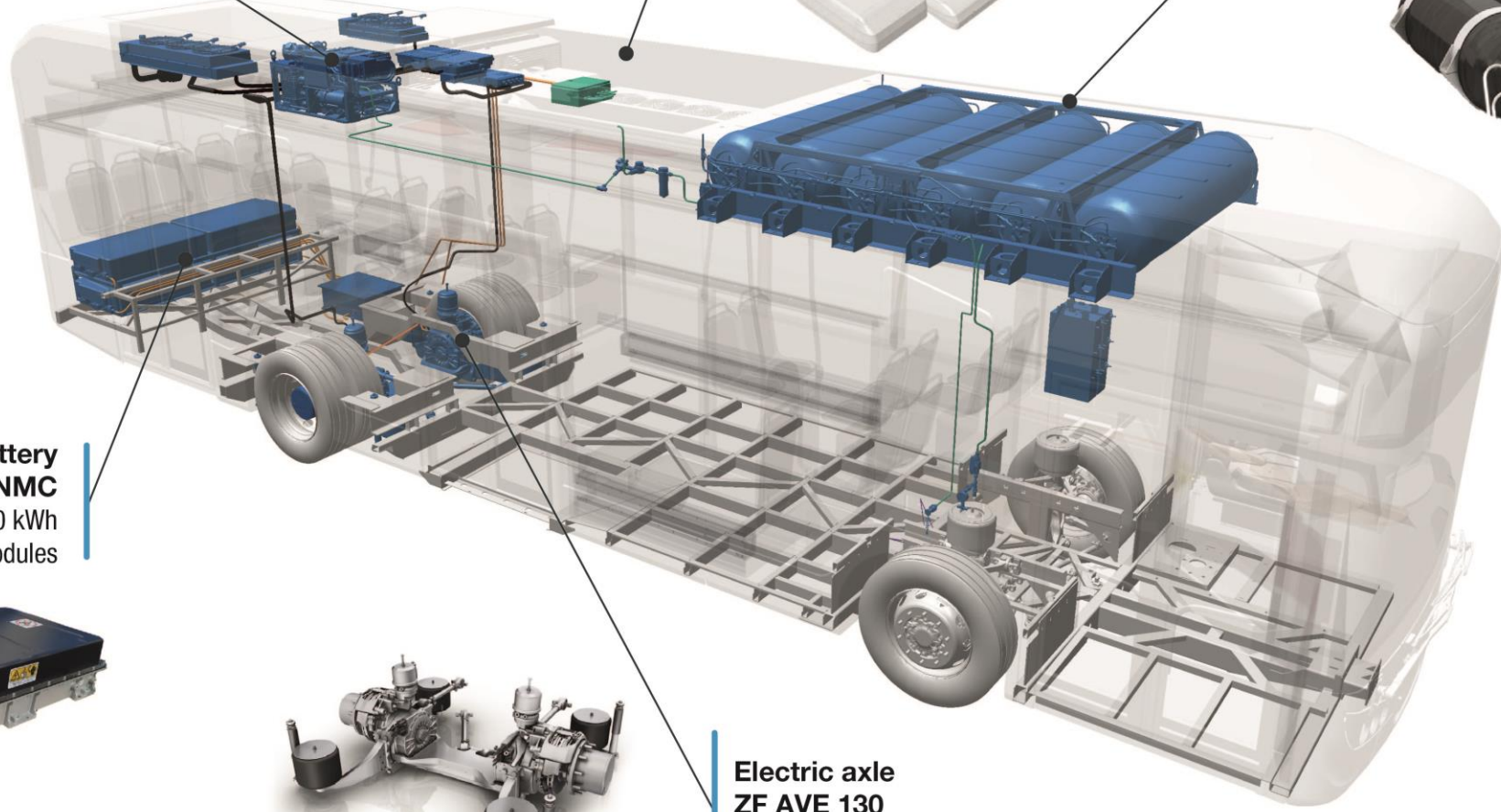
INVESTIR L'AVENIR

Produit sélectionné par UGAP

Thermal confort ThermoKing HVAC
Athenia Mk II – E-960H
38 kW cooling / 47 kW heating
+ Front box driver 7 kW / 18,5 kW

H2 tanks Plastic Omnium
6 tanks @350 bar
Type IV – 34,8 kg
Carbon fiber polymers instead of aluminum

Fuel cell Symbio
45 kW



Microvast battery technology NMC
130 kWh
2 branches of 2 modules

Electric axle
ZF AVE 130
with motor on wheel hub

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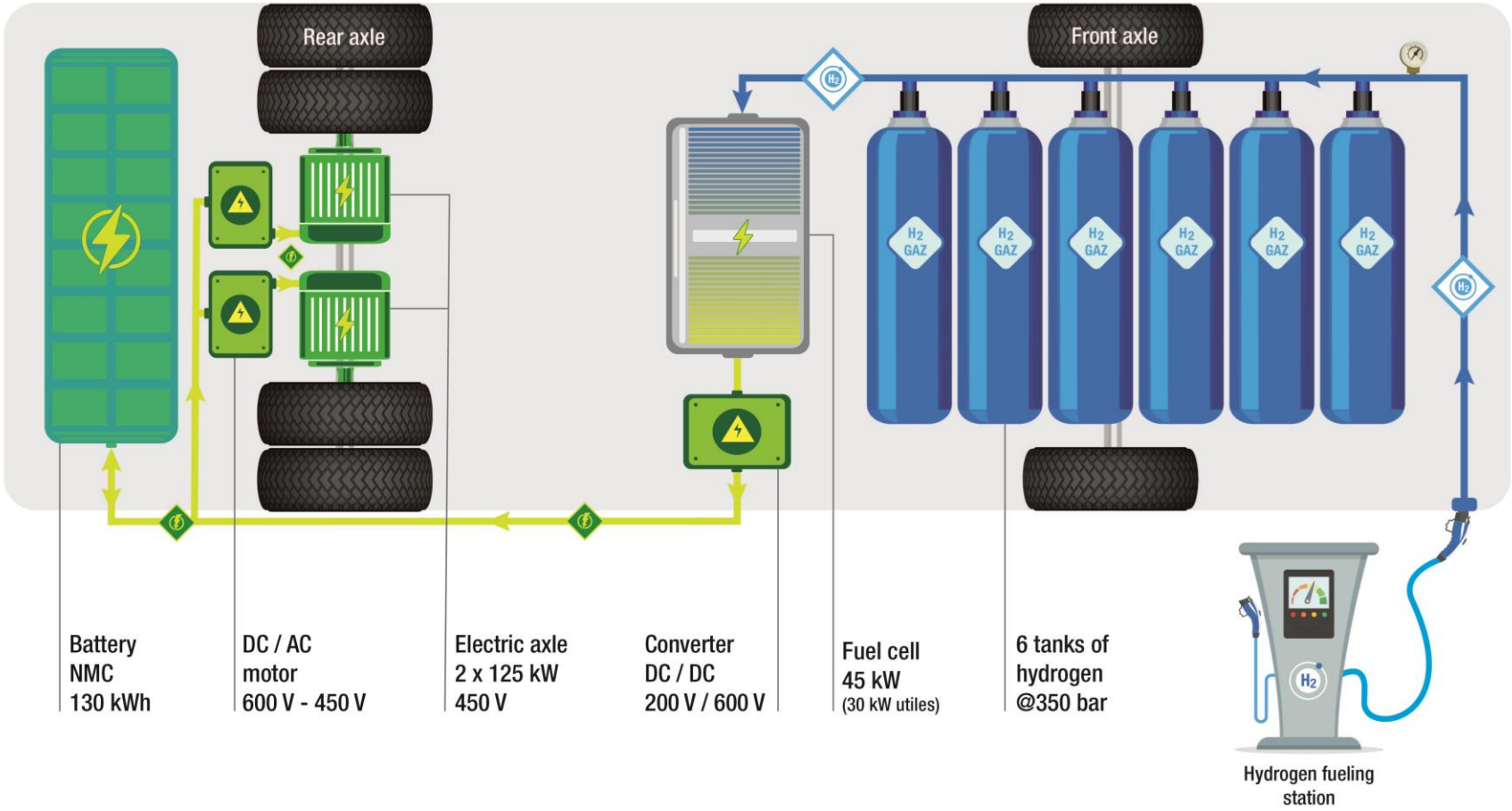
NEW FUEL CELL DRIVE CHAIN

- standardisation of the vehicle
- integration of proven components
- operability
- ergonomy of the driving position
- maintenance
- ADAS and on-board systems integrated



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Our first success: the 100% European hydrogen bus *

Autonomy: **350 km/217 miles**

Charging time: **10/15 mins**

H_2 fuel tank: **30 kg**

Capacity : **>100 passenger**

*100% European key technologies

DESIGN
CAD/3D
Mechanics and electrics
Proprietary on-board systems and software

INTEGRATION
Fuel cell, batteries, components and sub-components

MANUFACTURING
On-site assembly
Road test
Certification

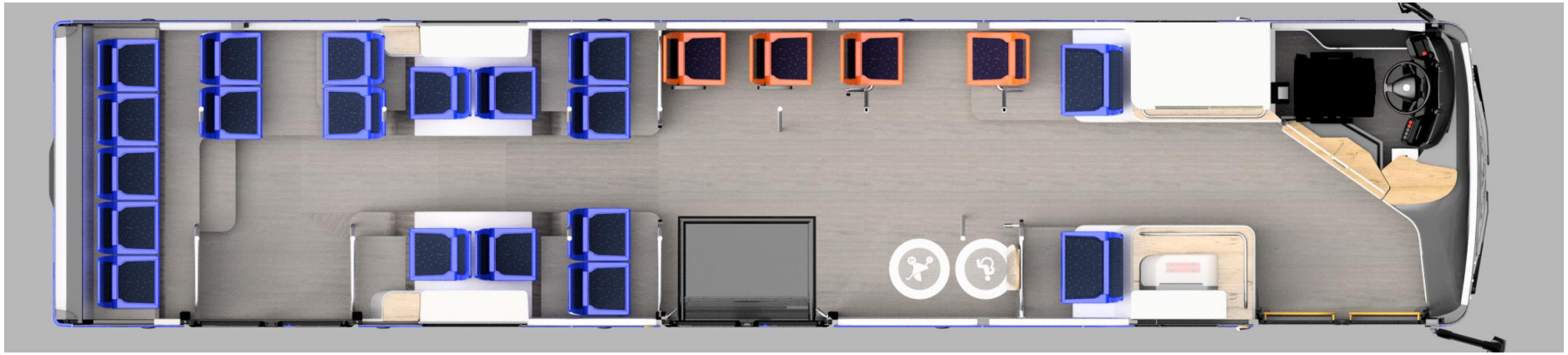
BY SAFRA

100% Safra software on board
(energy, connection to the road, safety, operation, comfort...)

Produits sélectionnés par UGAP

33 seats

23 seats



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A MORE
STANDARDIZED
DESIGN


FOR A
BETTER
CUSTOMER
EXPERIENCE

OUR DEVELOPPEMENT OPPORTUNITIES

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A scalable intracity buses offer

Phase 1 **(2022)**

GEN 2 – 12 meters

Phase 2 **(2023)**

GEN 3 – 12 and 18 meters
Start of industrial ramp up

Develop a **range**
Step up **industrialisation**
Enhance **12 to 18-metre model** (articulated vehicle)
Reduce **cost price**

Phase 3 **(2024)**

GEN 4 - 12 and 18 meters
International version

Special variations to target different foreign markets
Further steps in **industrialisation**

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A multi-activity manufacturing facility

After extension

The site has its own railway linked to the Toulouse-Albi train line.

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Towards a full range in just 3 years

Development on the European market

Generation 1
Businova

2019

Generation 2
Hycity 12 m

2022

Generation 3
12 m and 18 m

2023

Generation 4
12 and 18 m

2024

SAFRA
Commited to zero emission mobility

CONTACT

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President

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v.lemaire@safra.fr

THANK YOU FOR YOUR ATTENTION

www.safra.fr

3EMOTION

environmentally friendly, efficient, electric motion

Lunch 12.00 -14.00h

During Lunch participants have the possibility to drive the buses

Clean Hydrogen Partnership

Agenda: after noon

13:30	**Operating fuel cell buses: experiences, lessons learned and next steps:**		
13:30	• Versailles/Be Green	Philippe Lucas	Be Green/Autocar Dominique
13:40	• Versailles/SAVAC - KEOLIS	Cédric Peyronnet	SAVAC/Keolis
13:50	• Rotterdam	Theo Konijnendijk	RET
14:00	• London	Martin West	LBSL
14:10	• Aalborg	Sandra Bodker	RNJ
14:20	• Province of South-Holland	Wouter Tetteroo	Province of South Holland/Rebel
14:30	• Pau	Mélanie Saudo	SMTU
14:40	**Coffee break**		
15:10	**3Emotion Project : results of data monitoring**	Vincent Phlippoteau	CEA
15:20	**Conclusions of the 3Emotion Project**	Stefan Neis	WaterstofNet
15:30	**Large scale deployment of fuel cell buses (Jive project)**	Magali Senaux	Element energy
16:00	**Reception**		
16:30	**End of Conference**		

Operating fuel cell buses: experiences, lessons learned and next steps

Versailles/B.E. Green

Philippe Lucas, B.E. Green

About the buses

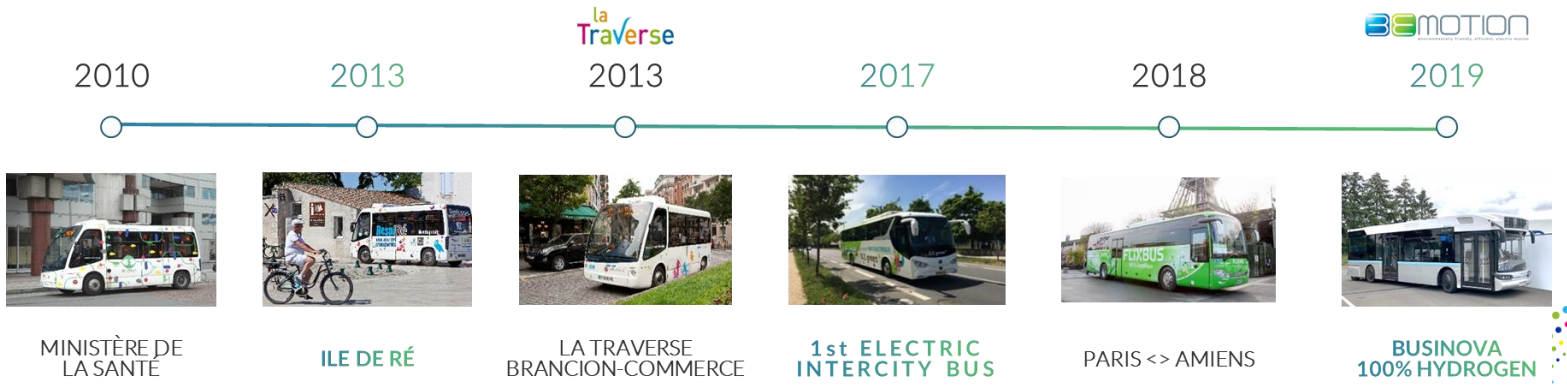
WHY FUEL CELL BUSES :

THE OPPORTUNITUY FOR BEGREEN TO CHOICE FUELL CELL BUS IS REALLY EVIDENT !

Indeed B.E. green decide in 2009 to invest the green mobility, starting with 3 electrics minibus, and continue all other the years to invest in electrics buses and coaches.

We where doing the first outcountry route in full electric coaches between Paris and Amiens wich is more than 180 kms by route, if electrics vehicles are one of the solution to clean the mobilities, the limit of the range is still a problem today.

In 2014, we where thinking about the next step fuel cell buses and coaches, the opportunity for us to join the Consortium 3 Emotion was unexpect ! Our geographic position at less than 1kilometer from the Air Liquid Hydrogene refuelling station .



Clean Hydrogen Partnership

About the buses

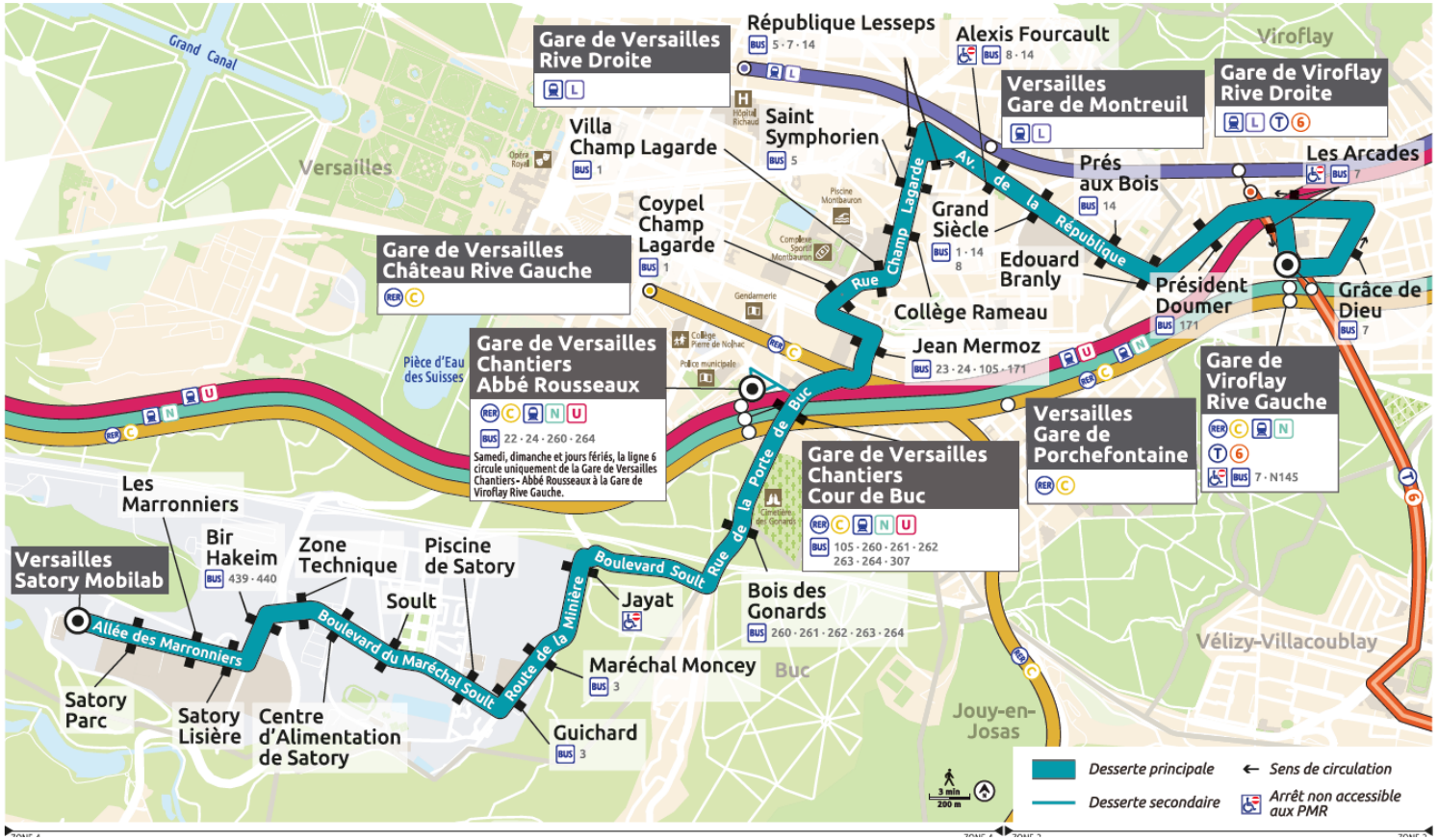
BUSINOVA – SAFRA :

5 SAFRA BUSINOVA ELECTRIC WITH H2 RANGE EXTENDER

- Brand : Safra
- Model : Businova
- Origin : 100% french
- Vehicle Range : 400 km
- Symbio fuel cell
- Charging Time : 15 mns

Clean Hydrogen Partnership

About the buses



ROUTE :

LIGNE 6 FROM VIROFLAY TO VERSAILLES SATORY

- Kilometers : 220 / 250 per day & per bus
- Circulation timing : 16h30 per day & per bus

Clean Hydrogen Partnership

About the buses

KILOMETERS DRIVEN
SINCE AUGUST 2020 :

156 451 KMS

With 5 buses.
It’s really under that what was expected

Clean Hydrogen Partnership

About the buses

MAINTENANCE :

The main problem is that there is no specific training for fuel cell system, for the rest Safra is a new builder, and the Businova is really far from standard vehicles.

However, during this Period we learn a lot of it.

Autocars Dominique works shop is fully equiped :

- 2 H2 detectors under the roof
- Detection unit
- exhaust fans controlled by the detection unit
- Antistatic floor

Clean Hydrogen Partnership

About the buses

	Source	Emission de CO2 phase amont	Emission de CO2 en kg exploitation	Emisson de CO2 en KG du puit a la roue	Unité
Gasoil	Ministere de transition ecologique - info GES transport actualisé 2018	0.66	2.51	3.17	par litre
GNV	Ministere de transition ecologique - info GES transport actualisé 2018	0.555	2.318	2.87	Par Kg
BioGNV	Ministere de transition ecologique - info GES transport actualisé 2018	-1.50	2.318	0.82	Par Kg
ELEC	Ministere de transition ecologique - info GES transport actualisé 2018	0.048	0	0.05	Par KWH
HYDROGENE Vaporeformage STANDARD	Source Bilan - GES - ADEME -2020	12.32	0	12.32	Par Kg
HYDROGENE Vaporeformage Biomethane	Source Bilan - GES - ADEME -2020	3.35	0	3.35	Par Kg
HYDROGENE Electrolyse	Source Bilan - GES - ADEME -2020	2.838	0	2.84	Par Kg

	Consommation moyenne par type/100 kms	Unité
Gasoil	45	litres
GNV	40	Kg
ELEC	120	Kwh
HYDROGENE	8.5	Kg

Fiche de calcul

	Cons(litre-kg-kwh)/km	unité	Emission de Co2 du puit a la roue au en Kg/Km
Gasoil	0.45	litre	1.43
GNV	0.4	Kg	1.15
BioGNV	0.4	Kg	0.33
Moyenne GNV			0.74
ELEC	1.2	Kwh	0.06
HYDROGENE Vaporeformage	0.085	Kg	1.05
HYDROGENE Vaporeformage biomethane	0.085		0.28
HYDROGENE Electrolyse	0.085	Kg	0.24

“

CO_2 SAVED :

178,63 Tons

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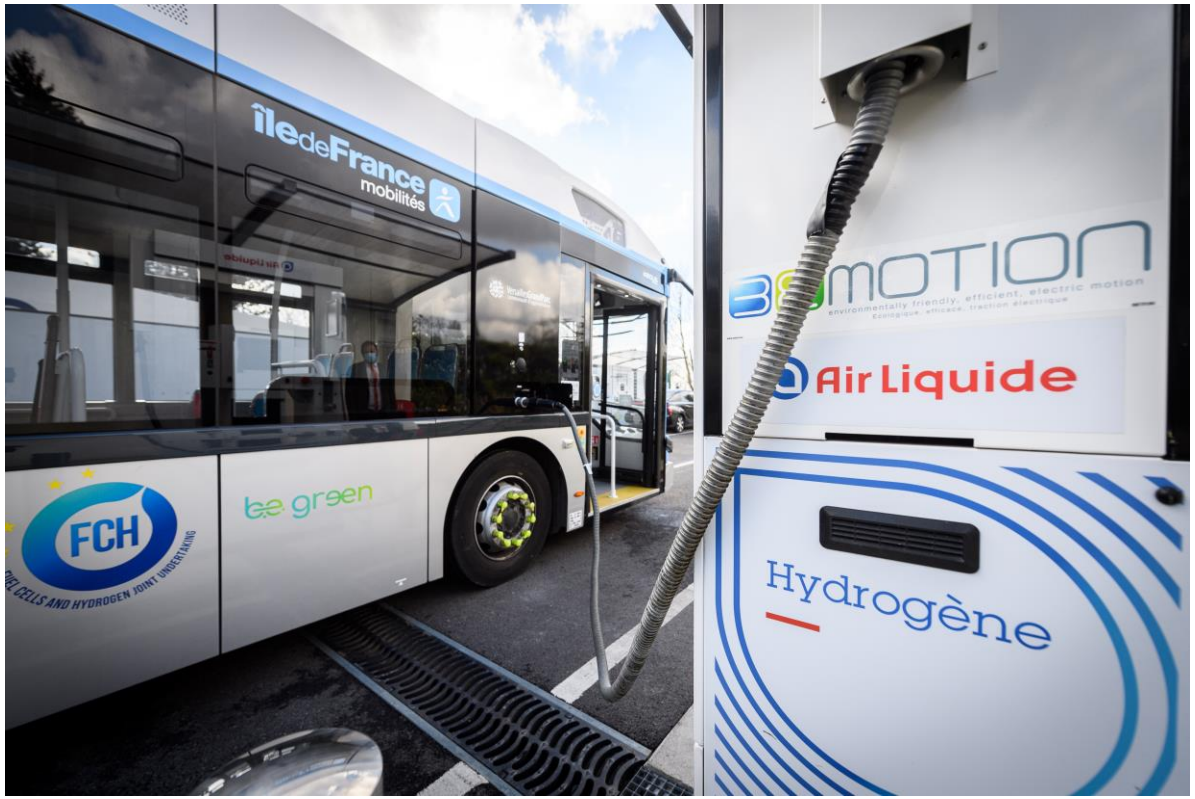
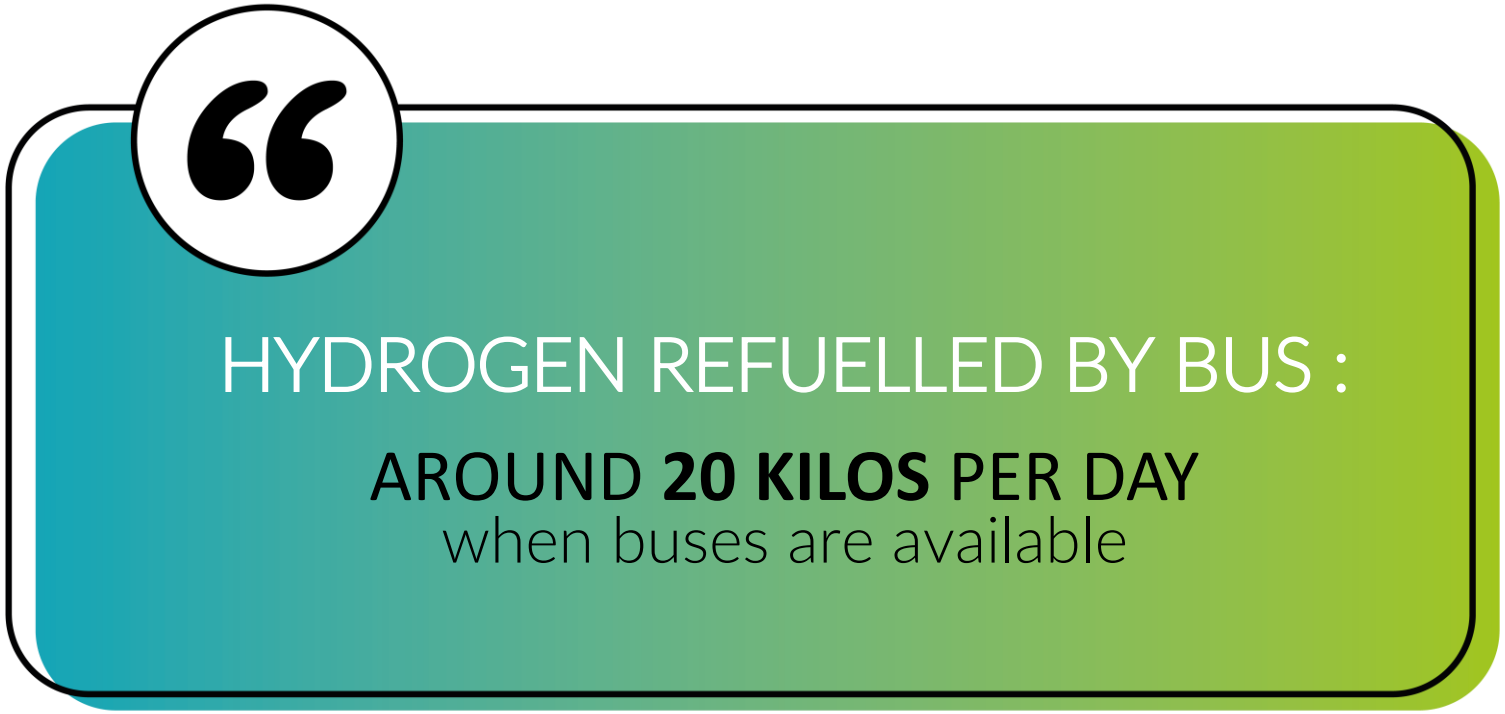
About the refuelling station



- TYPE OF REFUELLING STATION : Public Air liquid refuelling station for both cars and buses
- WHERE : Les Loges-en-Josas

Clean Hydrogen Partnership

About the refuelling station



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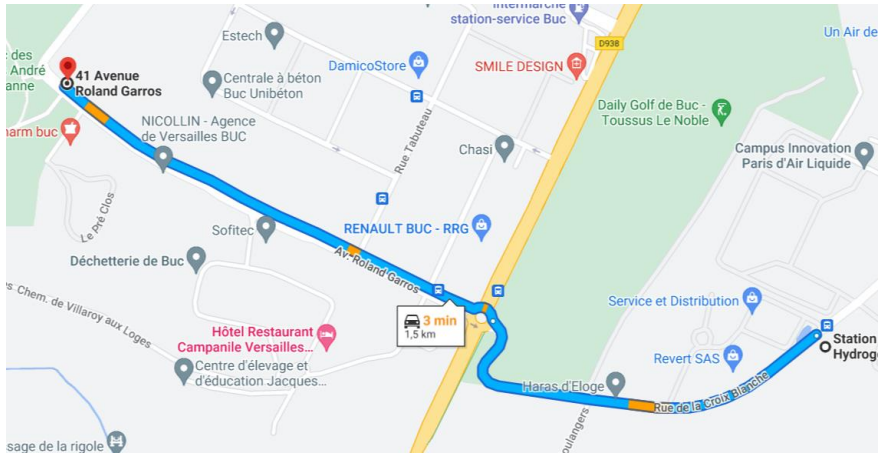
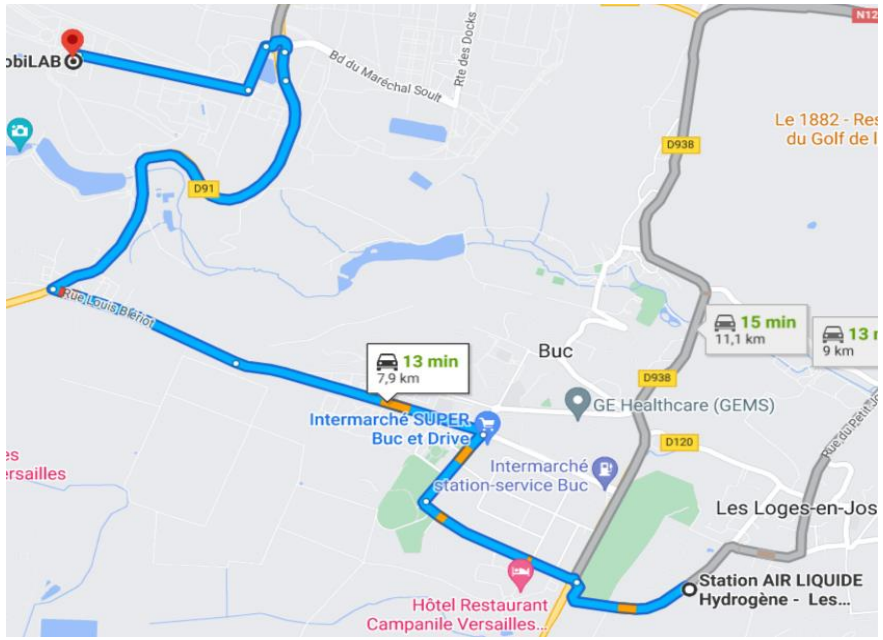
About the refuelling station





STRENGHTS :

Just **1 kilometer** from B.E. green
& **8 kilometers** from the end of the route.

Availibility is correct more than **95%** and an efficient team in the event of a breakdown,

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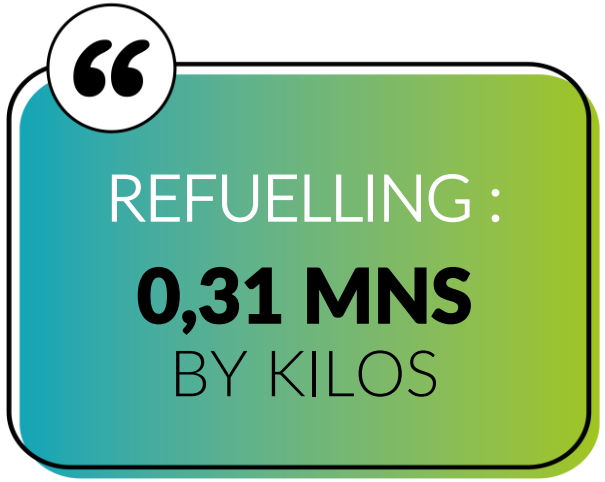
About the refuelling station



CHALLENGES :

REFUELLING IS IN REAL PROGRESS

- More than 1 minute by kilos at the beginning
- Even more than 2 minutes by kilos during summer
- 0,31 minutes by kilos currently

What will be the situation if the HRS should stop for more than 1 day ? All the buses should stay at the depot ! Could imagine an alternative option !

Clean Hydrogen Partnership

Conclusions

- Our experience with electrics buses was a great help to unterstand fuel cell buses.

If we have endured difficulties, we are sure that all these can be corrected shortly.
We strongly beleive in the future of hydrogen mobility, the only downside is “how refuelling“

- Our 5 vehicles should be sold to KEOLIS our IDFM and stay on operation.

- For B.E. green, the next step would be long distance fuel cell coaches.
- We dreamed that we could find available HRS on the road between Paris and Marseille.

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3EMOTION

environmentally friendly, efficient, electric motion

Operating fuel cell buses: experiences, lessons learned and next steps

Versailles/SAVAC - KEOLIS

Cédric Peyronnet, SAVAC/Keolis

Clean Hydrogen Partnership

About the buses

In 2017 IDFM Decide to launch a Fuel cell experimentation

SAVAC join 3Emotion Project

The project was funded

- 60 %
- 30 %
- 10%

About the buses

SAVAC placed an order for
2 VANHOOL A330 FC

- The first FC buses arrived in August 2019
- The second FC Buses arrived in December 2019

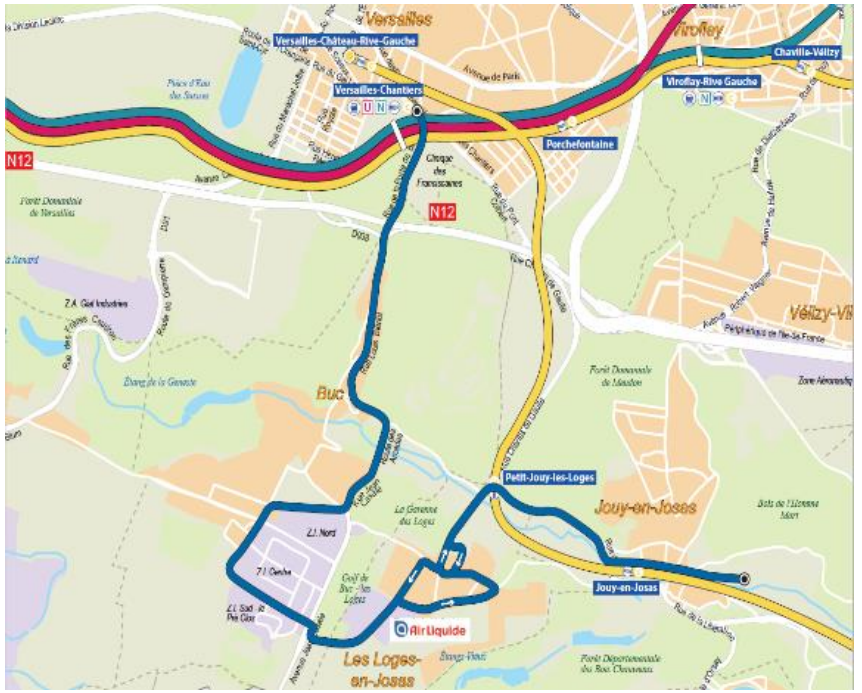
Length	13m
Number of doors	2
Number of passangers	111
Number of seat	35
Size of fuel cell	1610 L 35 Kg
Weight	15.400 Kg
Daily driving range	171 Km
Ballard Fuell Cell	73 Kw

Clean Hydrogen Partnership

About the buses

The 2 FC buses are operated on line 264 which connects the train station Versailles Chantier to Jouy en Josas.

- 12.5 Km long
- 25 stops
- 30 Rotations H2 / Diesel
- Run from Monday to Friday



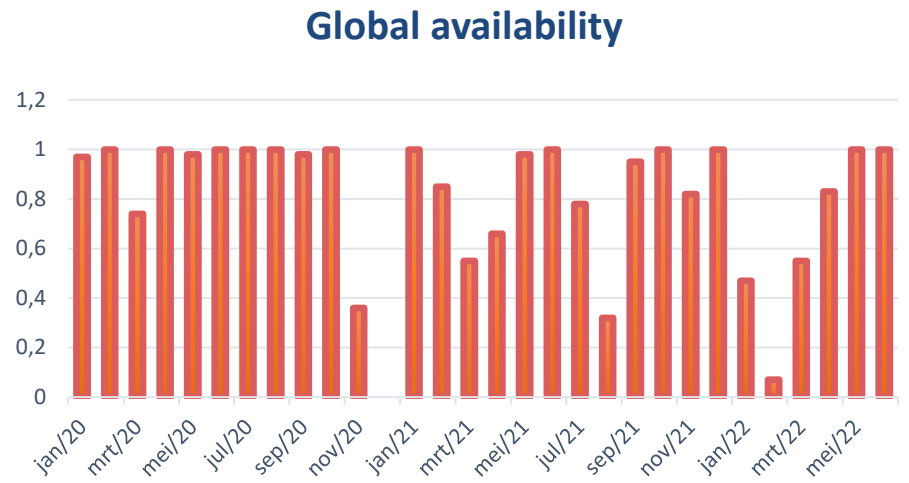
Clean Hydrogen Partnership

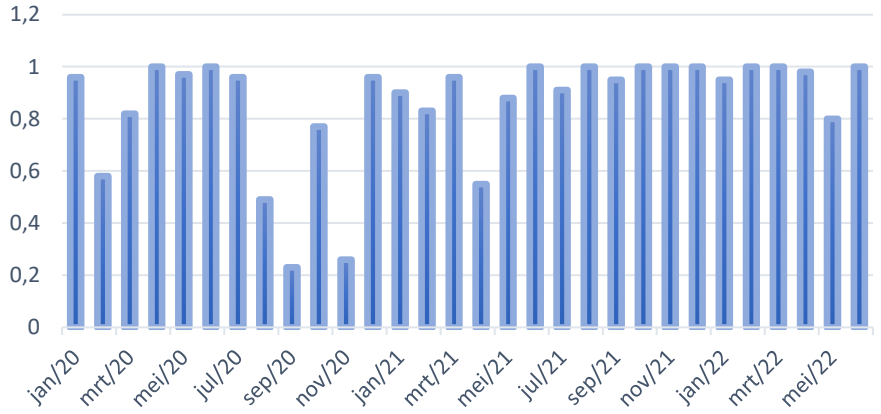
About the buses

During the period the FC buses

- Drived 110 000 Km
- Used 8 045 Kg H2
- 7.4 Kg H2/100 Km

- Full maintenance contract with VanHool
- The workshop had to be adapted for H2 safety





n Hydrogen
tnership

About the refuelling station

H2 Mobility : Versailles station

Versailles (Les Loges)

- Station H2
  - 200 kg/j - 350/700 bg
  - Dual flow - SAEJ2601-2014
- start-up : **12/2017**
- Vehicles :
  - 2 bus H2,
  - 1 BOM (tbc)
  - 20 KangooZEH2,
  - 20 taxis

SAVAC

VersaillesGrandParc
communauté d'agglomération

îledeFrance mobilités

îledeFrance

Clean Hydrogen Partnership

Conclusions

- The FC Buses require more maintenance than the diesel Bus ;
- For two Buses a full maintenance contract has a higher cost than a diesel Bus;
- The drivers and passengers appreciate the silence and the comfort of the FC bus;
- In august 2022 The two FC buses have been transferred to Keolis , they are still in operation

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Operating fuel cell buses: experiences, lessons learned and next steps

Rotterdam

Theo Konijnendijk, RET

Clean Hydrogen Partnership

Site Rotterdam - RET

Clean Hydrogen Partnership

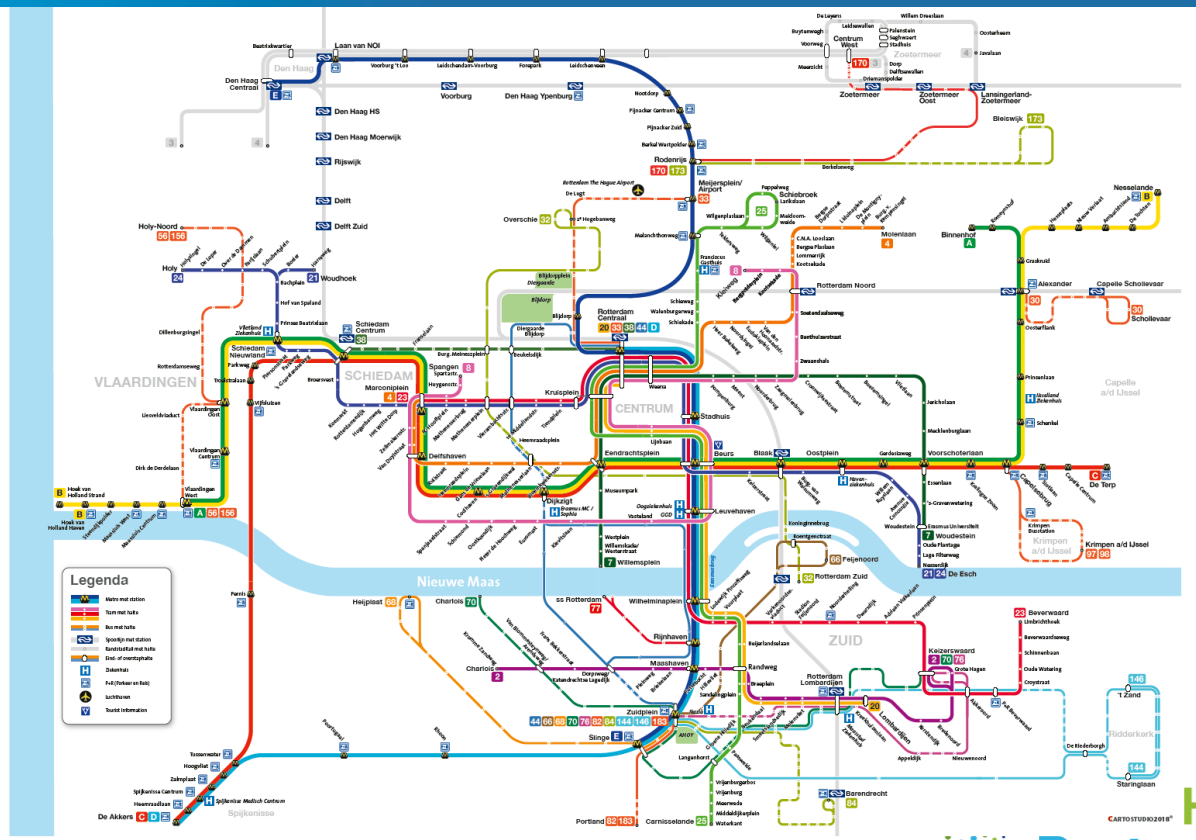
Introduction & key figures

RET is the public transport operator for the greater Rotterdam Region

Key figures RET (2021)	
Established	1878
FTE	2.599
Traveler kilometers	533 mln
Metro’s	166
Metro lines	5
Busses	284
Bus lines	57
Trams	112
Tram lines	9

Key figures Emissions	
CO2 emission Bus	12,8 mln KG
CO2 emission Tram	1,8 mln KG
CO2 emission Metro	6,1 mln KG
Energy consumption Bus	41,7 mln kWh
Energy consumption Tram	24,6 mln kWh
Energy consumption Metro	82,4 mln kWh

RET company movie:
https://www.youtube.com/watch?v=36OZcUWD1rM



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Motivation for introduction FC buses @ RET (back in 2016)

ROTTERDAM.CLIMATE.INITIATIVE

ZERO EMISSIE busvervoer

STADSREGIO ROTTERDAM

Gemeente Rotterdam

Existing fleet (250 vehicles) needed replacement in 2019 and 2021

- Concession until 2019
- New concession until 2034
- FC was experiment with ZE

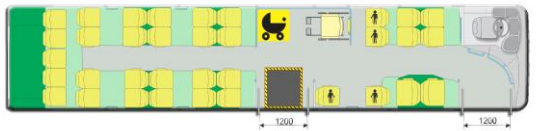
DE PERFECTE REIS — RET — DE PERFECTE REIS

Clean Hydrogen Partnership

RET AARDIG ONDERWEG

FC buses at RET Rotterdam

- 2 vehicles Van Hool A330FC
  - Siemens drive train and Ballard HD85 fuelcell
- Batteries 24 kWh
- 5 Tanks, 40 kg hydrogen
- 32 seats, 62 standing
- Electric heating interior
- Airco for driver and passengers



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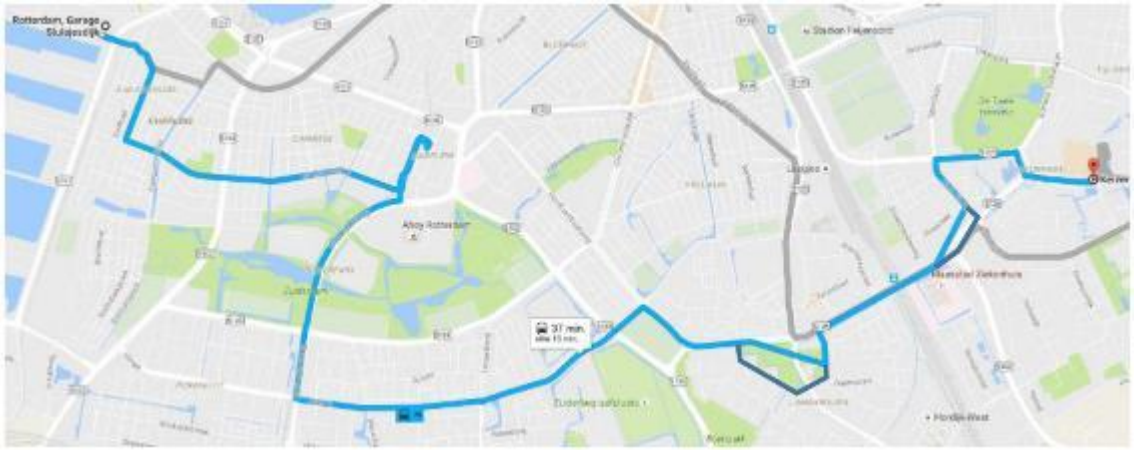
RET AARDIG ONDERWEG

site RET – FC Bus operation

- Buses running on Line 70 (Charlois – Keizerswaard v.v.)



- Line runs every 6’ in peak, 10’ off peak and 20’ at night hours from 5:45 – 0:30
- Use per vehicle on planned shifts is 240 km/day (RET in general 250 km)
- The depot and the maintenance hall are at the beginning of the line in Charlois
    - If necessary, technicians are available every 75’.

- Description of risks on route was made by expert
    - No additional measures to be taken

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site RET – FC Bus operation

Refueling station

- RET: Rhoon, Operated by Air Liquide
- Contract about H2-delivery is finalized
- Station is public accessible
- In 10 minutes drive from main plant RET Bus

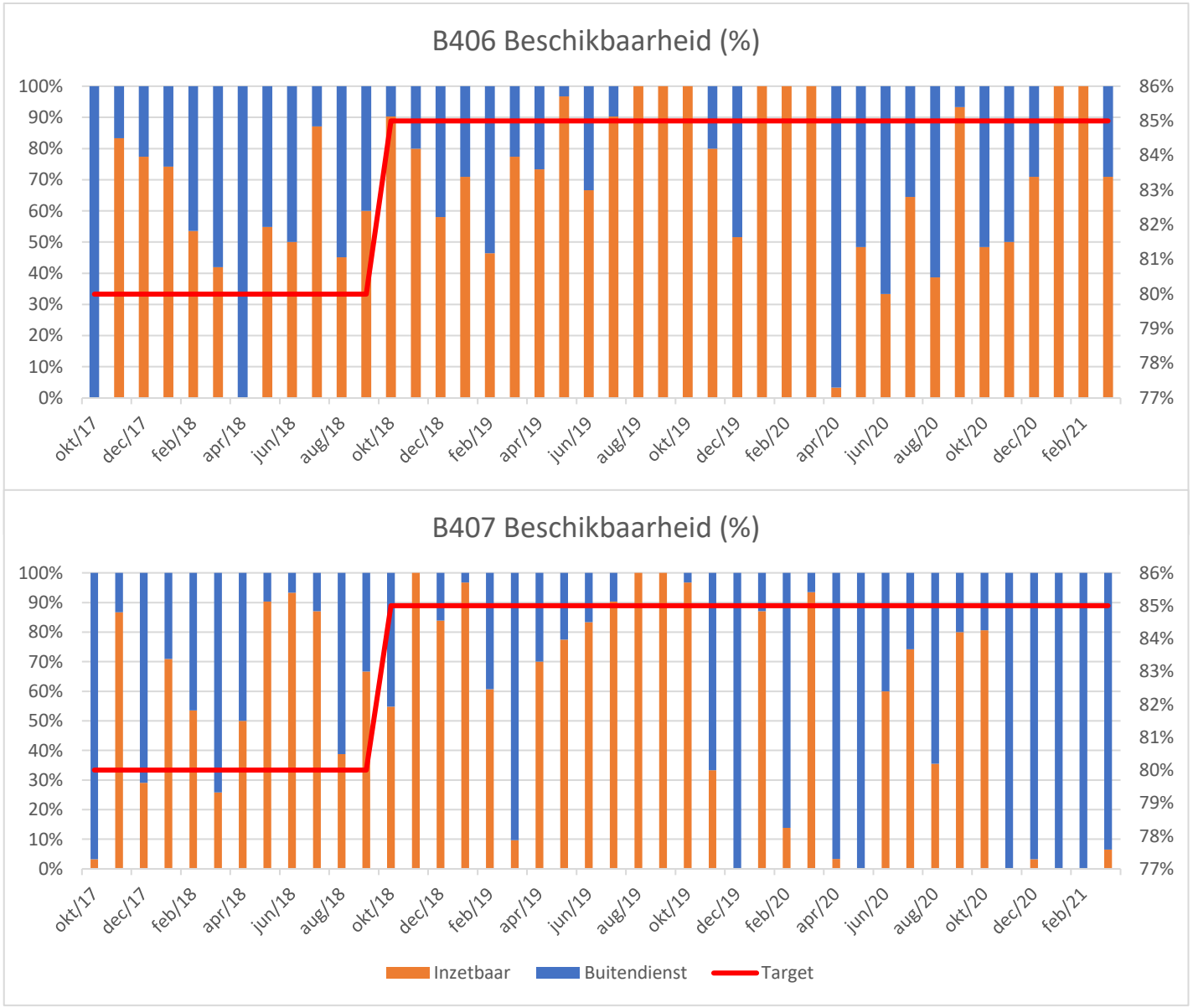
Hydrogen
ership

Current status RET B406-407

Driven > 260.000 km since sept. 2017
Carried > 445.000 passengers
Refuelled > 20.000 kg hydrogen

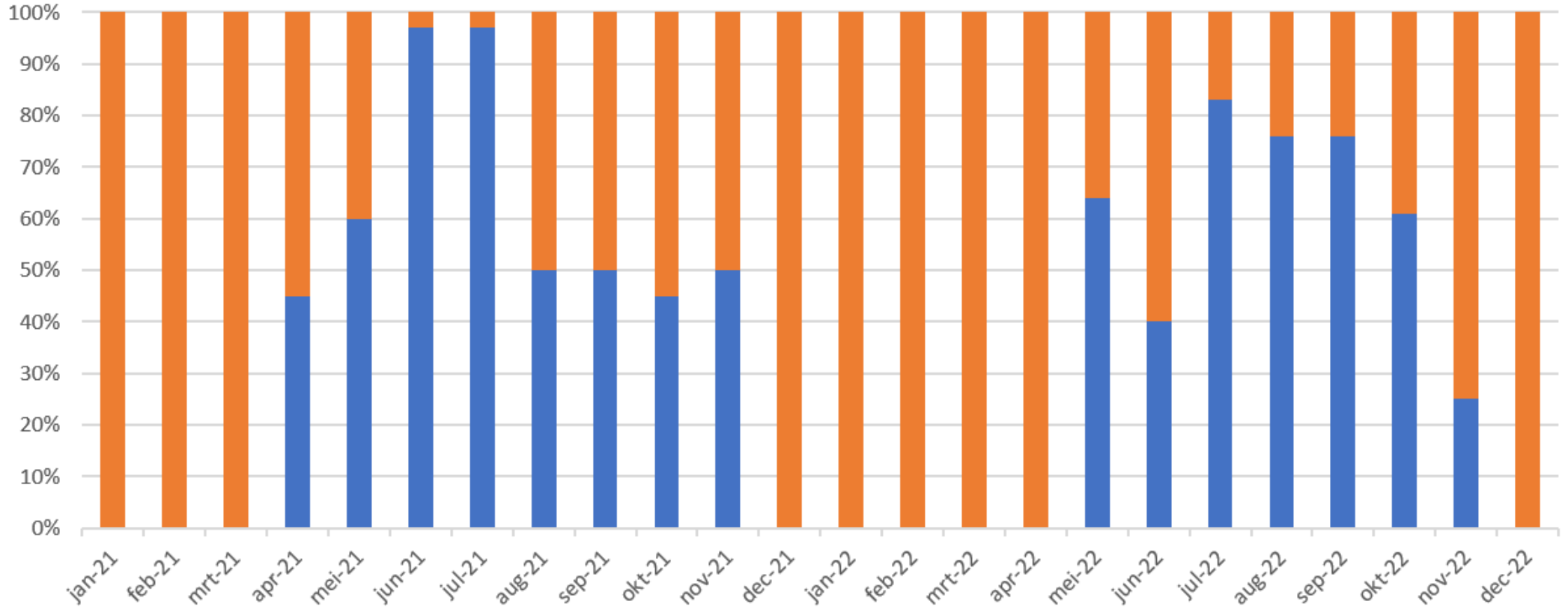
Clean Hydrogen Partnership

status Availability RET 10-2017 / 2-2021



Clean Hydrogen Partnership

status Availability RET 1-2021 – 11-2-22



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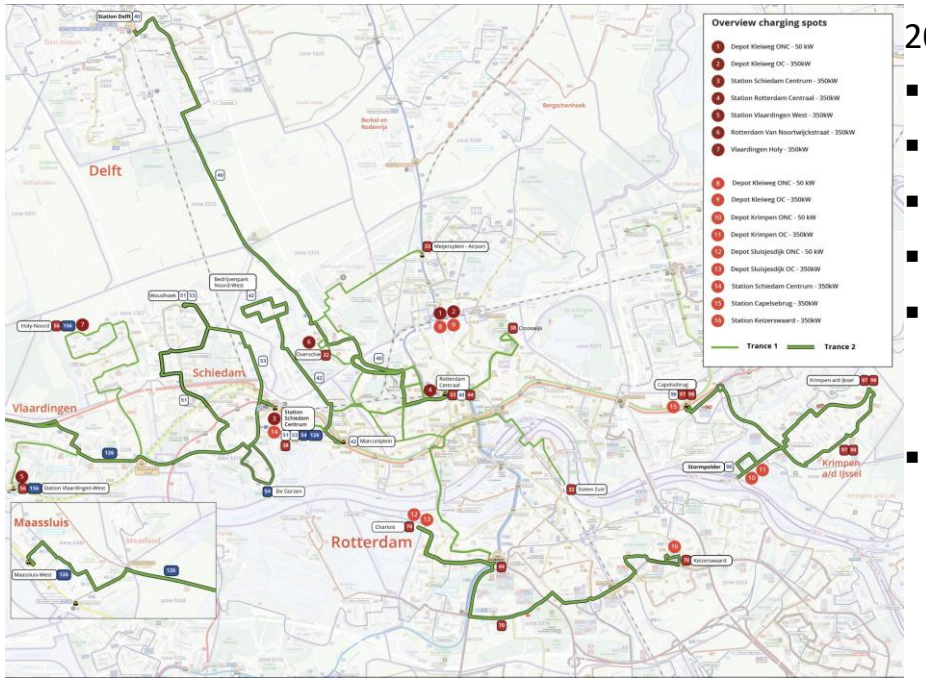
Lessons learned

- ✓ The deployment of **vehicles needs to be aligned** with the **infrastructure** construction
- ✓ Consider new **safety** issues (optimize workshop)
- ✓ Expect Technology **'teething'** issues
- ✓ Make ure there is a good **supply chain** (f.e spare parts at the sites)
- ✓ Make sure **all stakeholders involved** support the project (good internal communication)
  - ✓ Operators have to work closely with manufacturers
- ✓ **Training**
  - ✓ The drivers (ambassadors!)
  - ✓ Technicians but also the management
- ✓ **Inform passengers**!
- ✓ Keep them **rolling**!

Clean Hydrogen Partnership

What have we accomplished so far?

Zero Emission Buses – phase 1 + 2 realized, phase 3 + 4 still to go



2022:

- 97 full electric
- 2 fuel cell
- 103 hybrid electric
- 40 EURO VI
- Infrastructure realized for opportunity and overnight charging
- To be decided phase 3 in 2024 and phase 4 in 2029: BEB or FCEB

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environmentally friendly, efficient, electric motion

Clean Hydrogen Partnership

Focus on a 100% clean bus fleet for RET!

3EMOTION

environmentally friendly, efficient, electric motion

Operating fuel cell buses: experiences, lessons learned and next steps

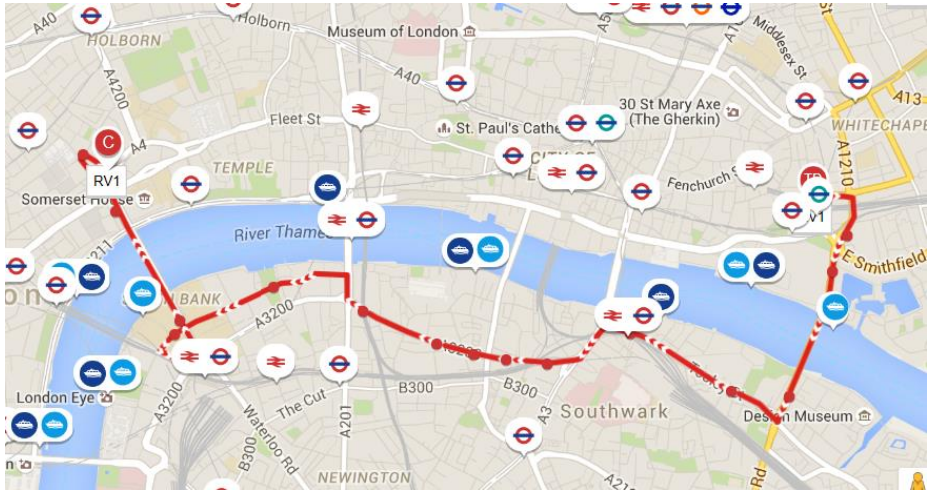
London

Martin West, LBSL

Clean Hydrogen Partnership

Project Overview

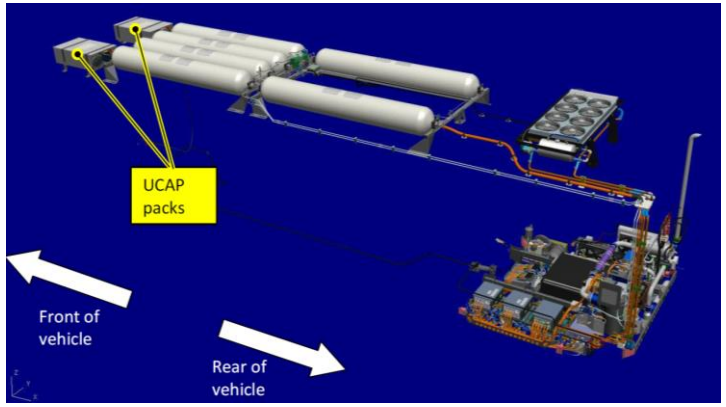
- 8 Wrightbus FC single decks purchased in 2008 within previous Clean Hydrogen Partnership project, CHIC.
  - Operated on route RV1 between 2010 – 2018 and route 444 between 2018 – 2020.
  - 3Emotion funded the refurbishment of the FC modules, extending operational life.
- 3Emotion supported the purchase of two additional VanHool FC buses that went into operation in 2018, enabling the entire route RV1 to be zero emission.



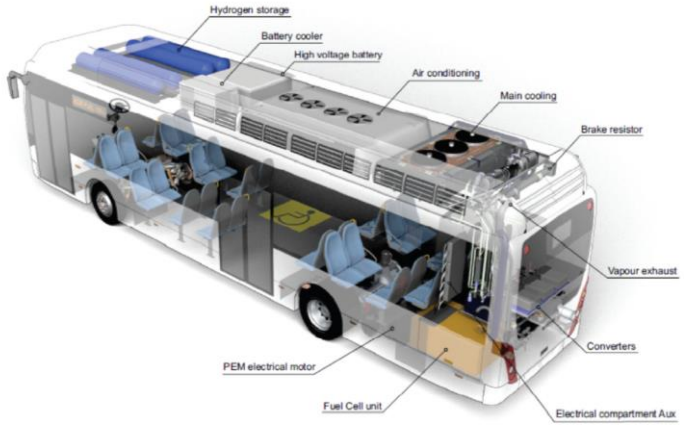
Clean Hydrogen Partnership

About the buses

- Wrightbus/ISE Gemini FC
  - Capacity 49 + driver
  - Fuel cell - Ballard HD6 75 kw
  - Range approx. 350km



- VanHool A330 FC
  - Capcity 63 + driver
  - Fuel cell - Ballard FCVelocity-HD85
  - Range approx. 350km



Clean Hydrogen Partnership

About the buses

- Fleet has travelled over 2.1 million kilometres since 2010
- 300,000 FC module run hours
- All service and maintenance carried out at the depot by operator Tower Transit.
- Dedeciated workshop and technicans
- Specialist training provided by Ballard on FC, other specialist training on high voltage and working with pressurized systems
- The orginal 8 buses became more challenging continue operating due to availablity of parts, being a one off production made in 2010.

Clean Hydrogen Partnership

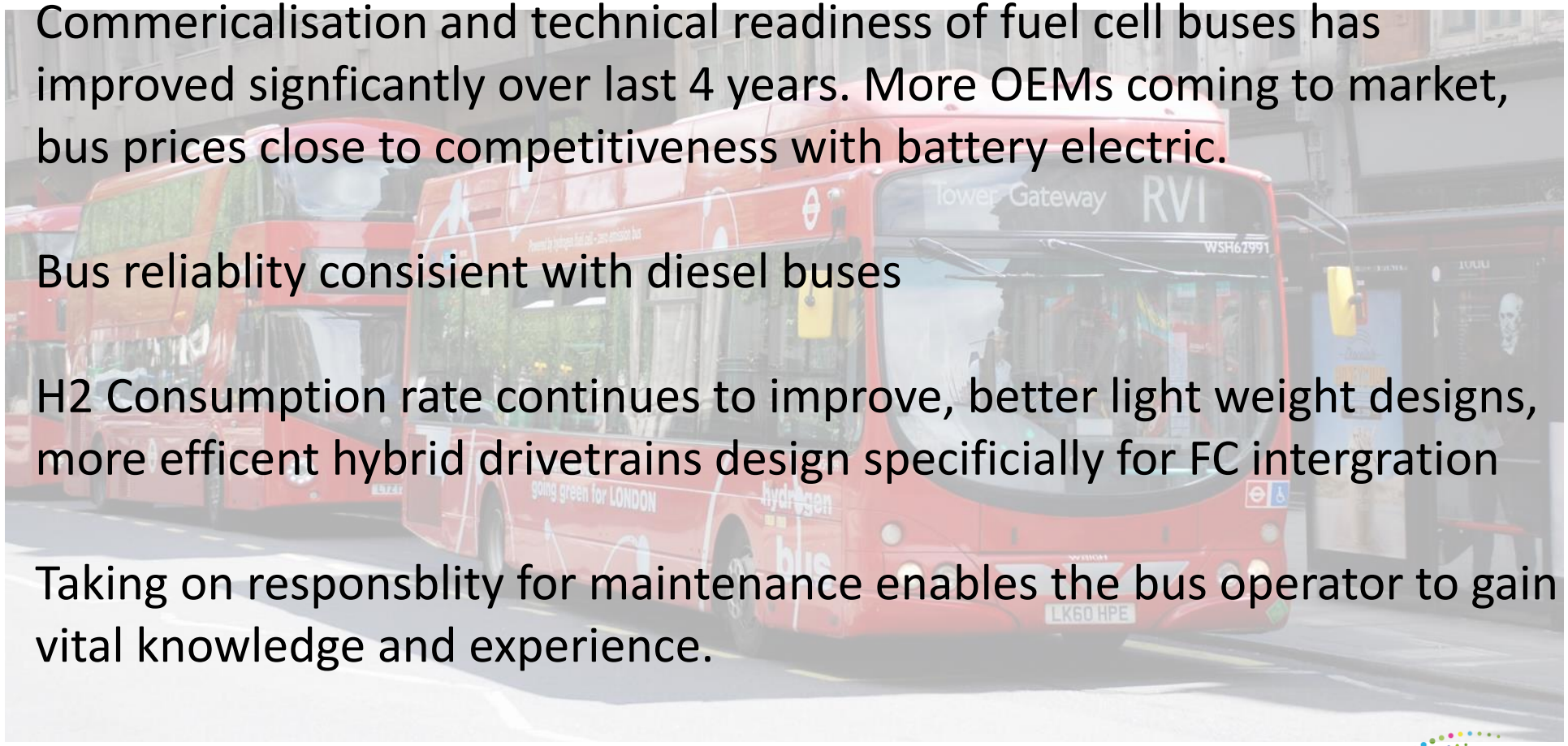
Fuelling

- Delivered gasesous or liquid hydrogen (on board gas vaporizer)
- Fixed storage at 350bar, 500kg
- Gasesous storage trailer 500bar, 900kg
- No onsite compression, production or cooling
- X2 dispensers

- Very high availablity 99.99%
- Only basic maintenance checks required each month

Clean Hydrogen Partnership

Lessons Learnt



- Commericalisation and technical readiness of fuel cell buses has improved signficantly over last 4 years. More OEMs coming to market, bus prices close to competitiveness with battery electric.
- Bus reliablity consisient with diesel buses
- H2 Consumption rate continues to improve, better light weight designs, more efficent hybrid drivetrains design specificially for FC intergration
- Taking on responsblity for maintenance enables the bus operator to gain vital knowledge and experience.
- To achieve best prices for HRS and fuel, long term contracts are essential.

Clean Hydrogen Partnership

Conclusions

Clean Hydrogen Partnership

environmentally friendly, efficient, electric motion

Operating fuel cell buses: experiences, lessons learned and next steps

Aalborg

Sandra Bodker, The North Denmark Region (RNJ)

Clean Hydrogen Partnership

First fuel cell buses in Denmark

Clean Hydrogen Partnership

The North Denmark Region

First '**climate region**' in Denmark with a special focus on being first movers in green transition and solutions

Low population – long distances

Department:

- Regional Development
- Mobility and Infrastructure

Main tasks:

- Create sustainable mobility solutions that interconnect the entire Region
- Responsible for mobility cross the municipalities and in/out of the Region

Clean Hydrogen Partnership

Why fuel cell buses in Aalborg?

- To **generate knowledge and experiences** by accomplishing a project, where green hydrogen, produced from surplus wind-energy is used as an alternative fuel in FC buses. And hereby:

- **Support and strengthen innovation** and industrial development in North Denmark, primarily in the Hydrogen sector, and

- **Promote green transition** in society, by generating the required knowledges for changing heavy transport from fossil fuels to green hydrogen.

Clean Hydrogen Partnership

Project organisation

The North Denmark Region (NDR)
Decides the service level and is financing the regional Public Transport in North Denmark.

Aalborg Municipality (AAK)
Decides the service level and is financing the local Public Transport in the City of Aalborg.

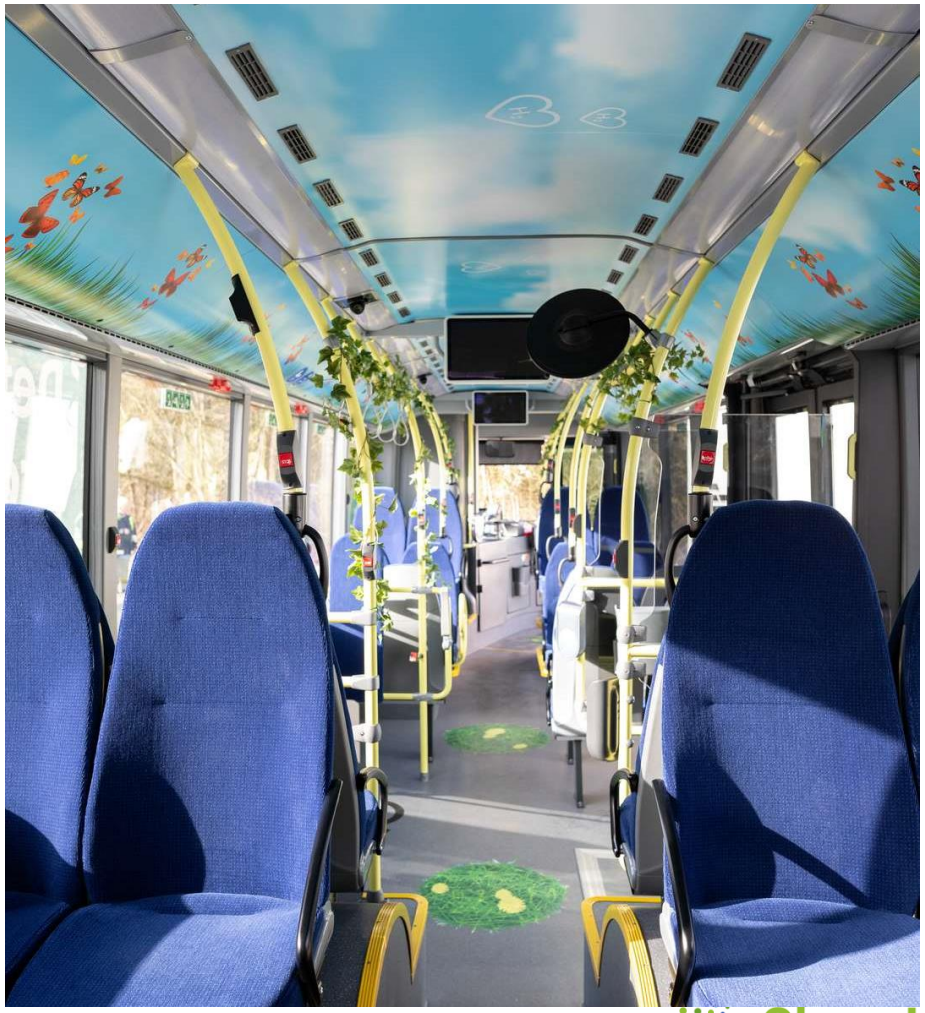
Nordjyllands Trafikselskab (NT)
North Denmark Public Transport Authority. Plans and manages the Public Transport.
Owned in common by NDR, AAK and the other municipalities in North Denmark.

Arriva and Keolis, and now Tidebus
Runs (along with other operators) the buses for NT.

Aalborg Kommune
NT
arriva a DB company
tide
REGION NORDJYLLAND – i gode hænder
KEOLIS
Clean Hydrogen Partnership

About the buses

- EU-tender → Van Hool
- 3 fuel cell buses of the model A330
- Fuel cells delivered by Ballard
- 12 m. and 79 passengers
- 38 kg. hydrogen at 350 bar
- Minimum 350 km. Range
- 8 kg H2/100 km
- Service agreement with Van Hool and operators



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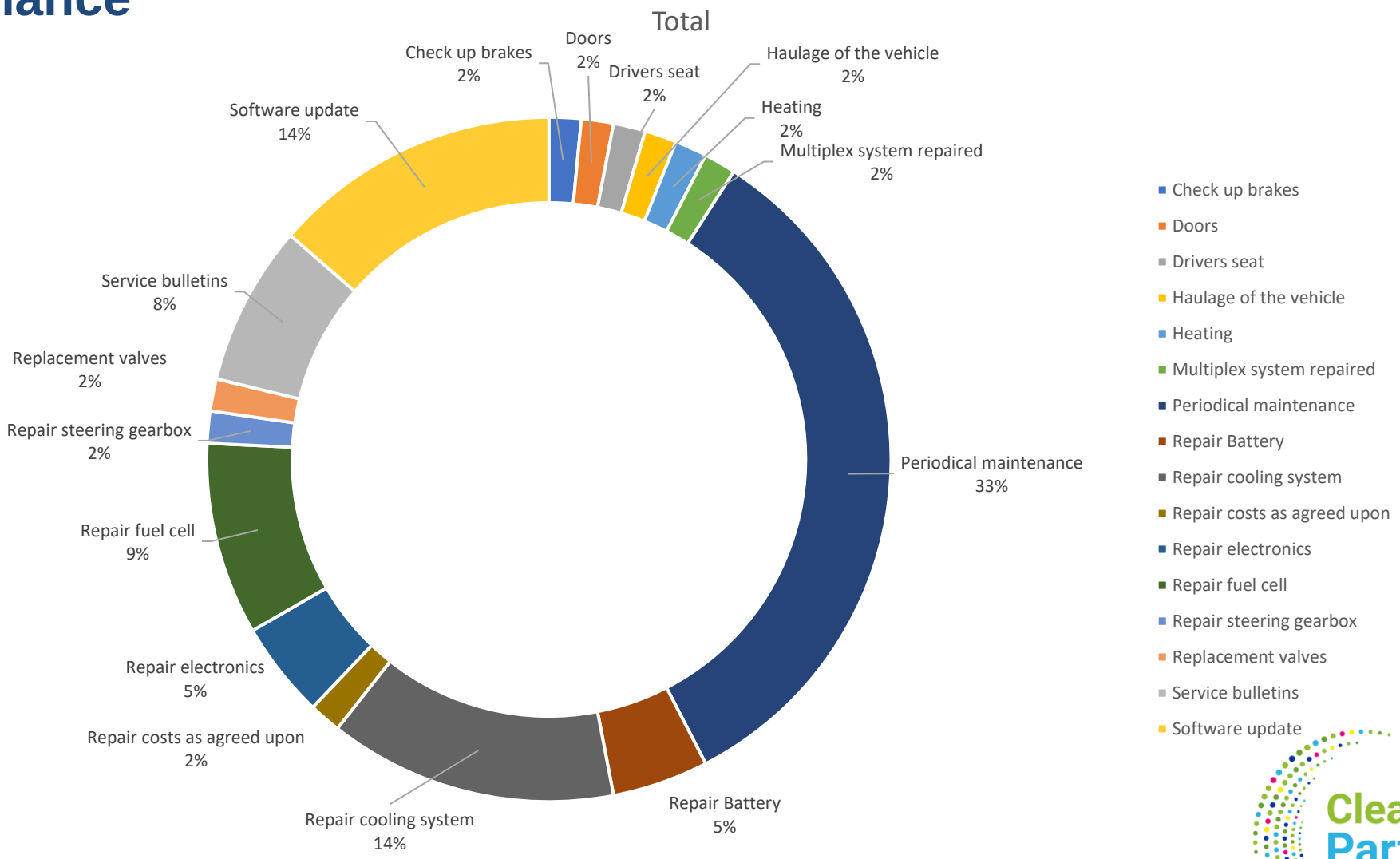
Maintenance



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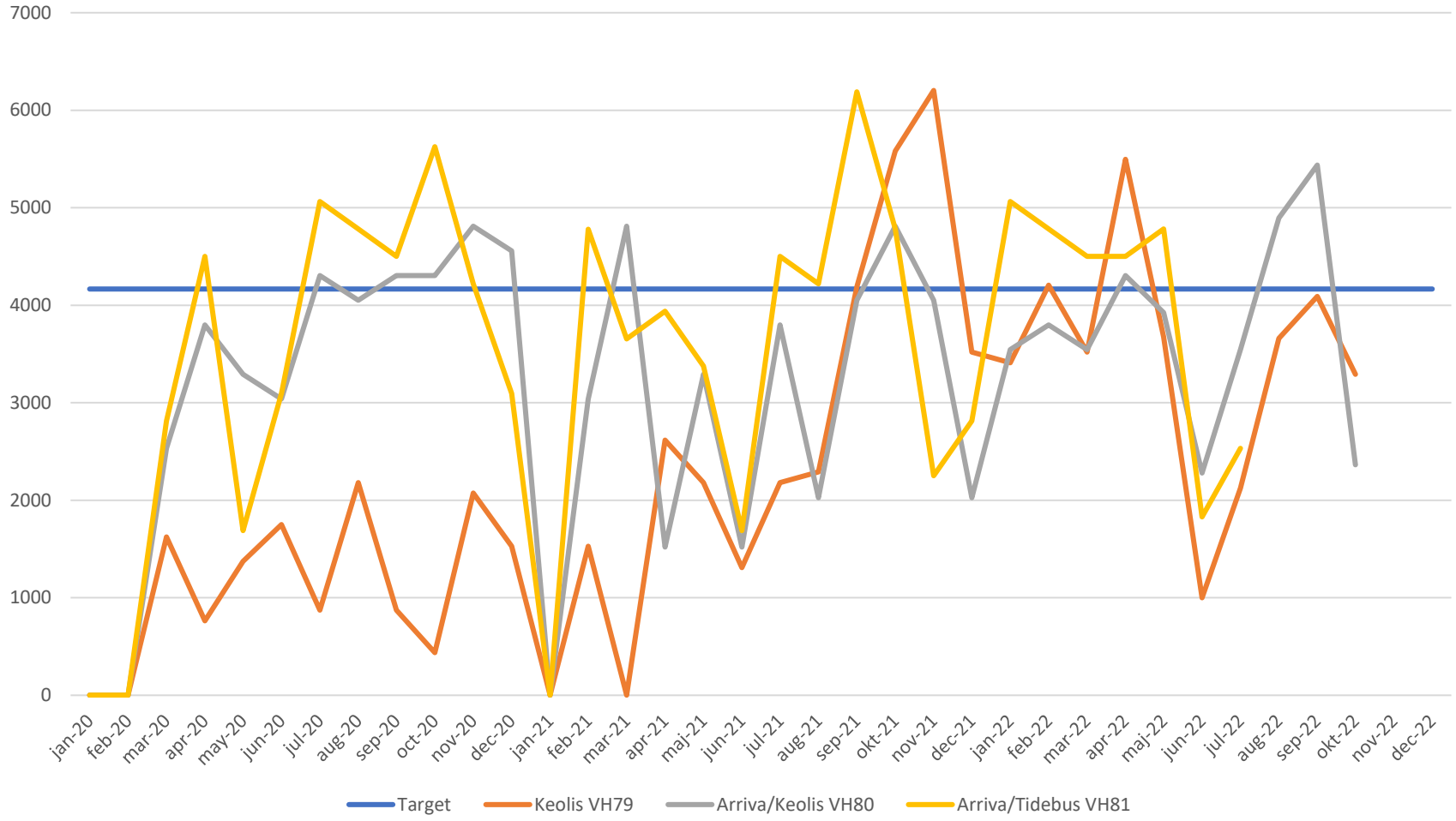
Km driven per month

VH79: 94.997 km. VH80: 117.305 km. VH81: 101.937 km.



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rtnership

Lessons learned with FCB's

- Extremely happy drivers
- Happy passengers
- Less time spend on maintenance
- Same availability as diesel buses
- Longer range than expected
- Workshops are easily ajusted

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Hydrogen refueling station

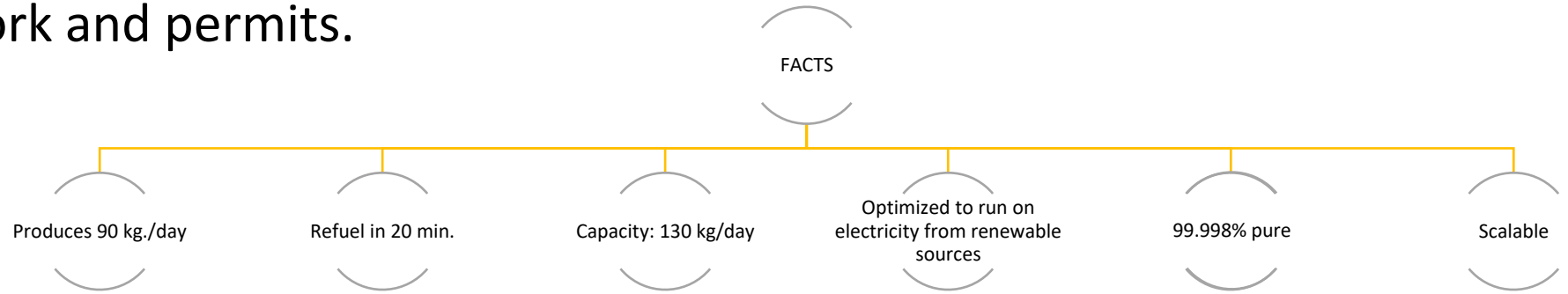
Clean Hydrogen Partnership

Organisation of HRS

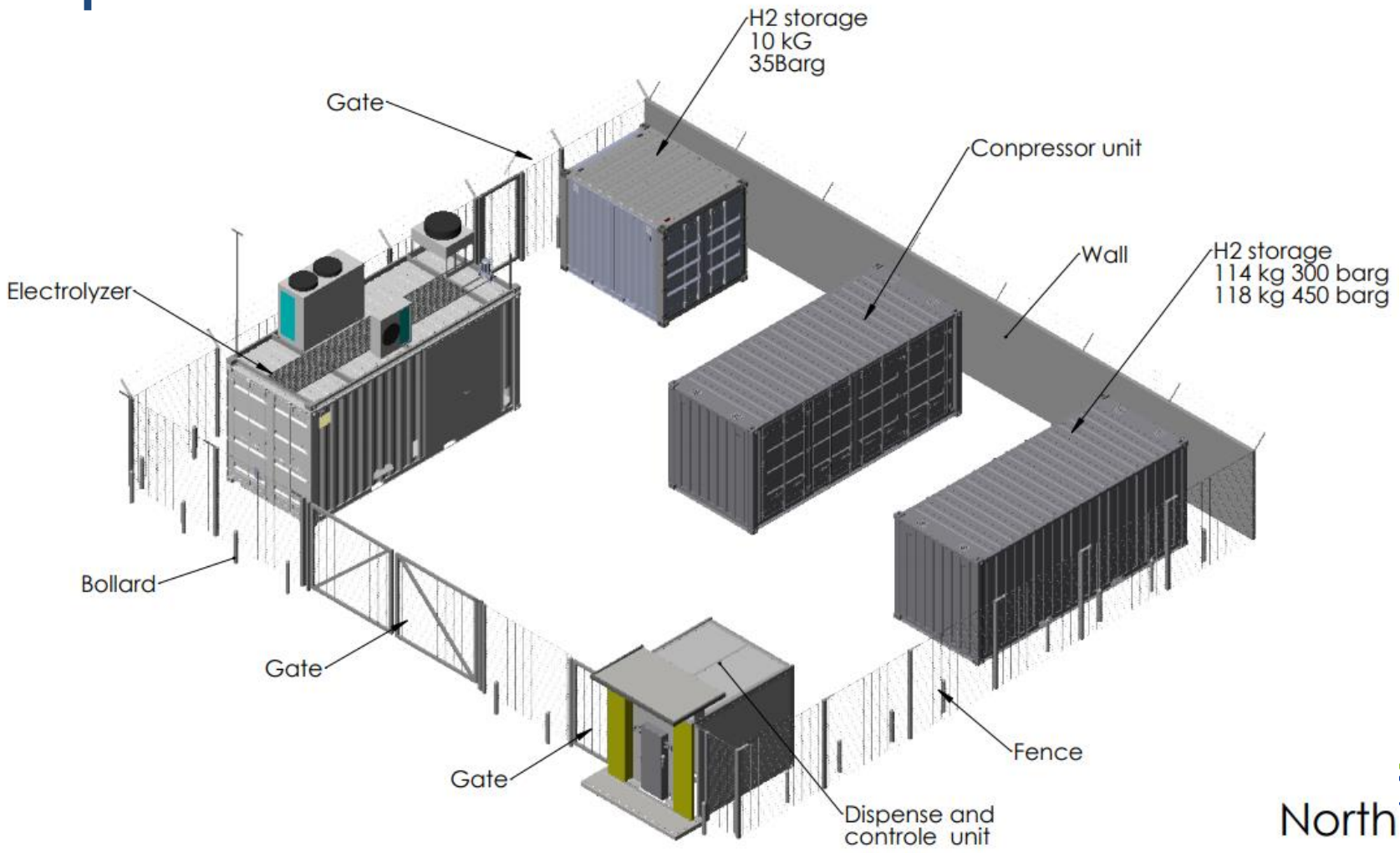
Provider of entire HRS solution:
Green Hydrogen Systems, Denmark.

Provider of facility's storage, compressor and dispenser unit:
Clantech, Spain and Calvera, Spain.

Green Hydrogen delivered the solution, the North Denmark Region delivered the civil work and permits.

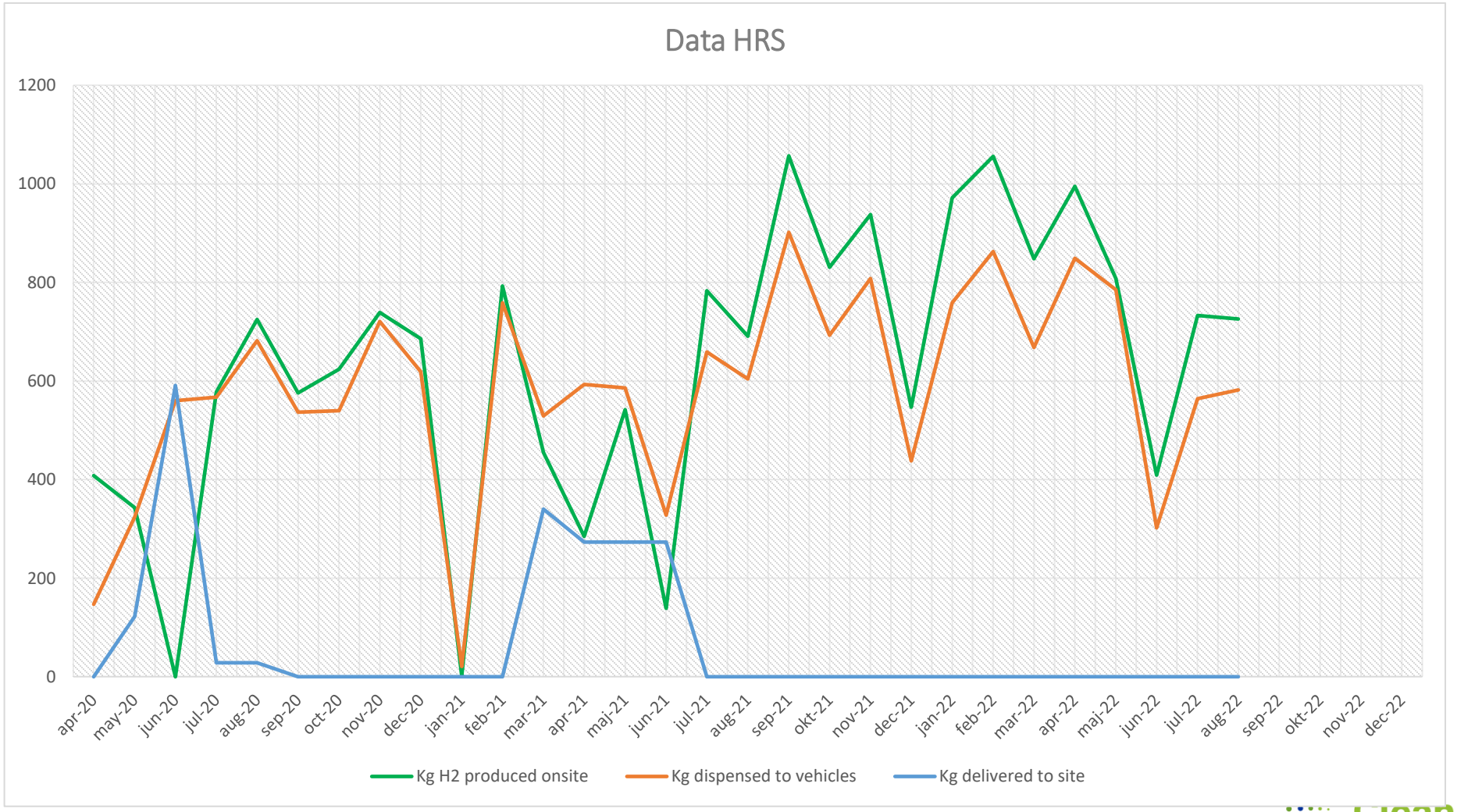


HRS setup



North Clean Hydrogen Partnership

Data HRS



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Lessons learned with HRS

- Extra time for permits
- Communication
- Electricity fee
- Another setup
- Easy for drivers

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Conclusions

- Commitment from all partners and communication
- Challenging with new technology
- Lot of knowledge has been gained
- Buses ready for big scale deployment
- Hydrogen sector in the North Denmark Region is on the way up!

Clean Hydrogen Partnership

Thank you for your attention

Questions?

Sandra Bødker

Project Manager in Regional Development

North Denmark Region

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Clean Hydrogen Partnership

environmentally friendly, efficient, electric motion

Operating fuel cell buses: experiences, lessons learned and next steps

Province of South-Holland

Wouter Tetteroo Province of South Holland/Connexxion

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Why hydrogen buses

- Policy goal: 2025 every new bus ZE, 2030 all buses (5.000+) ZE
- Expected to reach 50% of this goal by 2025
- Support in development of both BEB and FCEB technology
- Goal of 3Emotion project: gain experience for further upscaling

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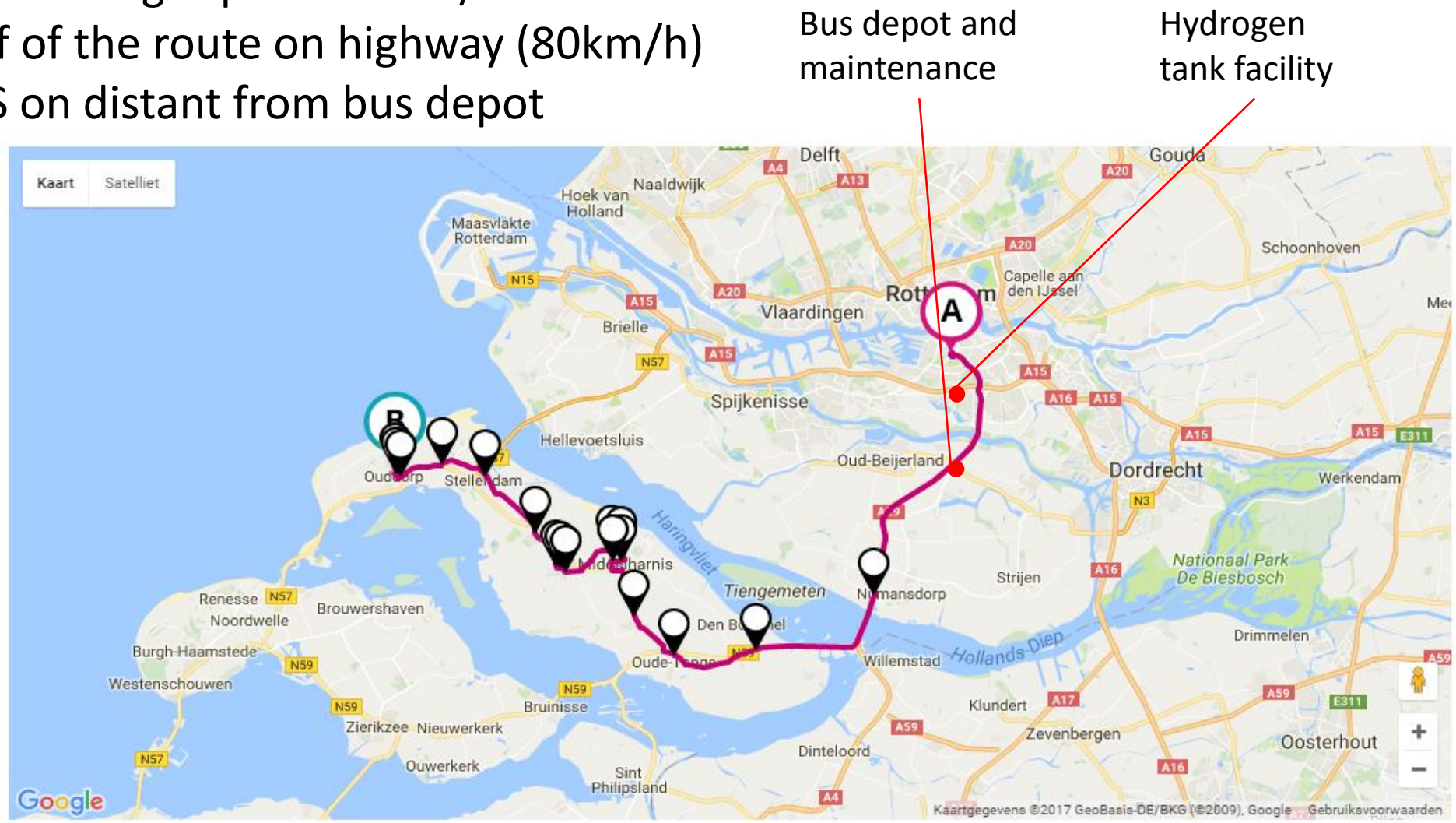
Route

- Dailly mileage per bus: 300 – 375 km
- High average speed: 50km/h
- Half of the route on highway (80km/h)
- HRS on distant from bus depot



Hydrogen ership

Bus concept: innovative try-out of range extender; 4 buses have been part of 3Emotion

Bus concept

- Limited effort in bus development since FC range extender added to standard battery-electric bus
- ‘electric bus’ part operated as expected
- Challenge: bus type approval from Road Authority
  - Delay in start operation (1,5 year)
  - Standstill due to ‘Haringvliet’ bridge repair (4 months)
  - Standstill due to Adjust route to avoid bus lock (2 months)
- Fuel cell power too low to meet operational requirements
  > lower mileage routes have been selected

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Operational performance

	Driven distance (km)	H2 consumed (kg)	Consumption (kg / 100km)
2000	31.062	2.887	9,3
2001	68.909	5.982	8,7
2002	23.835	1.990	8,4
2003	45.387	3.432	7,6
Total	169.193	14.291	-

- Fuel cell worked well; continues operation > better performance
- 3 road incidents, without H2 safety issues
- 1 battery replacement
- Towbar replacement (bankrupt supplier, delay of 5 months)

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Hydrogen refueling station

Hydrogen refueling station

- Upgrade of existing HRS from Air liquide in Rhoon (capacity and extra nozzle)
- Secure hydrogen supply by pipeline
- Initially no pre-cooling, later pre-cooling to -8°C → improvement of refueling time
- Depreciation of the upgrade over just 3,5 year caused high H2 price (€ 15,5/kg) → long contract = better price
- Challenges:
  - Permit
  - Refeuling speed
  - Parallel refueling of vehicles not possible

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Lessons learned

- Stick to a more standardised bus concept
- Passengers and drivers: good experience with the buses (besides lot of standstill)
- For intensive (highway) routes have good alignment with OEM to secure to meet requirements
- Have communication between bus and HRS in place to reach acceptable refueling times
- Procuring buses and HRS in one contract can cause better alignment between OEM and hydrogen supplier
- Continues daily running of buses increases availability

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Conclusions

- Non availability mostly due to range extender concept
- Gained knowledge applied in upscaling
  - Within JIVE2, 20 Solaris buses are now in a 12 year operation
  - New HRS established with over capacity for more vehicles
- New concession starts December 2025, looking for opportunity for full H2 bus fleet (100 buses)
- Next summer possible momentum with national Action Plan Hydrogen in Mobility
- Spin off: hydrogen module is being applied in truck

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Thank you

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Operating fuel cell buses: experiences, lessons learned and next steps

Pau

Mélanie Saudo, SMTU

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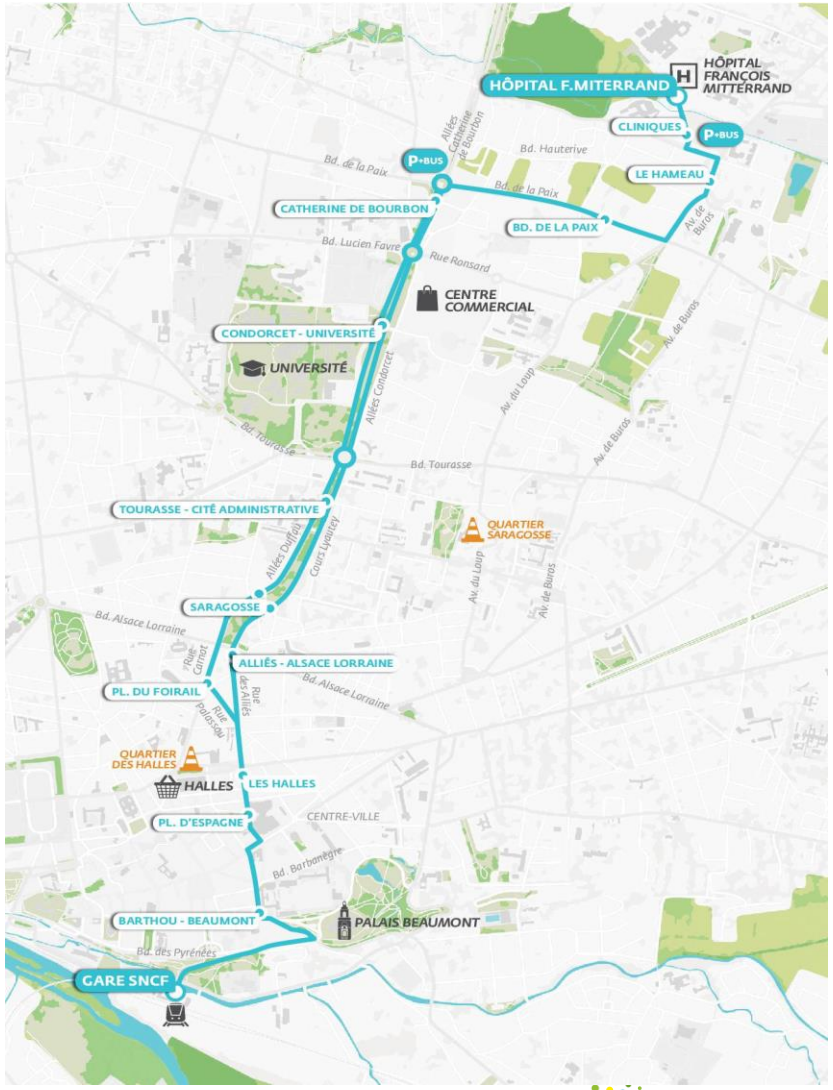
About the buses (1/2)

- Route: 6km, of which 5,1km dedicated. 14 bus stops. 17 min. ~20km/h. 5:30am to 12:00pm.
- Type of buses: 18m articulated Van Hool (145 persons), 200kW Siemens engine, 100kW Ballard FC
- Km driven: ~800.000km. ~4m passagers. 70 t H2 used.



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About the buses (2/2)

- Why Fuel cell buses: because of
  - the range > 250km (in fact near 400km)
  - no need for refuelling points on the line => flexibility of the route.
- Strenghts: “High visibility”. Good availability. ~9kgH2/100km
- Challenges: costs
- Maintenance: dedicated ATEX hall. Specially trained personnel. Contract full maintenance with VanHool (15 years). Good support from Ballard.

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About the refuelling station

- Type of refuelling station: One electrolyser PEM 700kW (ITM). <1 ton H2 storage at 600bars. Green Electricity => green H2
- Where: at our bus depot.
- Hydrogen refuelled by bus: 15 to 20mn (1kg/min)

  Overnight refuelling with 8 dispensers.
- Maintenance: contract full operation & maintenance from Engie's subsidiary – 15 years
- Strenghts: Reliability; back up with Tube Trailers H2 deliveries.
- Challenges: Operationnal costs,

  rising electricity costs

  Permitting (ICPE)

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Lessons learned

- Project development:
  - get external specialist support
  - National, regional and local specific regulations hurdles.
  - Innovative project => delays.
- Costs: high level of subsidies required
- Maintenance:
  - HRS plant is a full-size industrial unit ➔ specialist inspection, operation and maintenance knowledge
  - FC buses maintenance can be managed by the local transport company, but with specialist external support (H2 systems, electric systems)

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Conclusions

- An incredible success:
  - Industrial (it works every day!!)
  - Commercial
- <u>Next steps:</u>
  - 4 new 12m FC buses already ordered (Van Hool) with european subsidies
  - H2 production capacity left for further 4 FCBs…

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3Emotion Project : results of data monitoring WP

Vincent Phlippoteau, CEA

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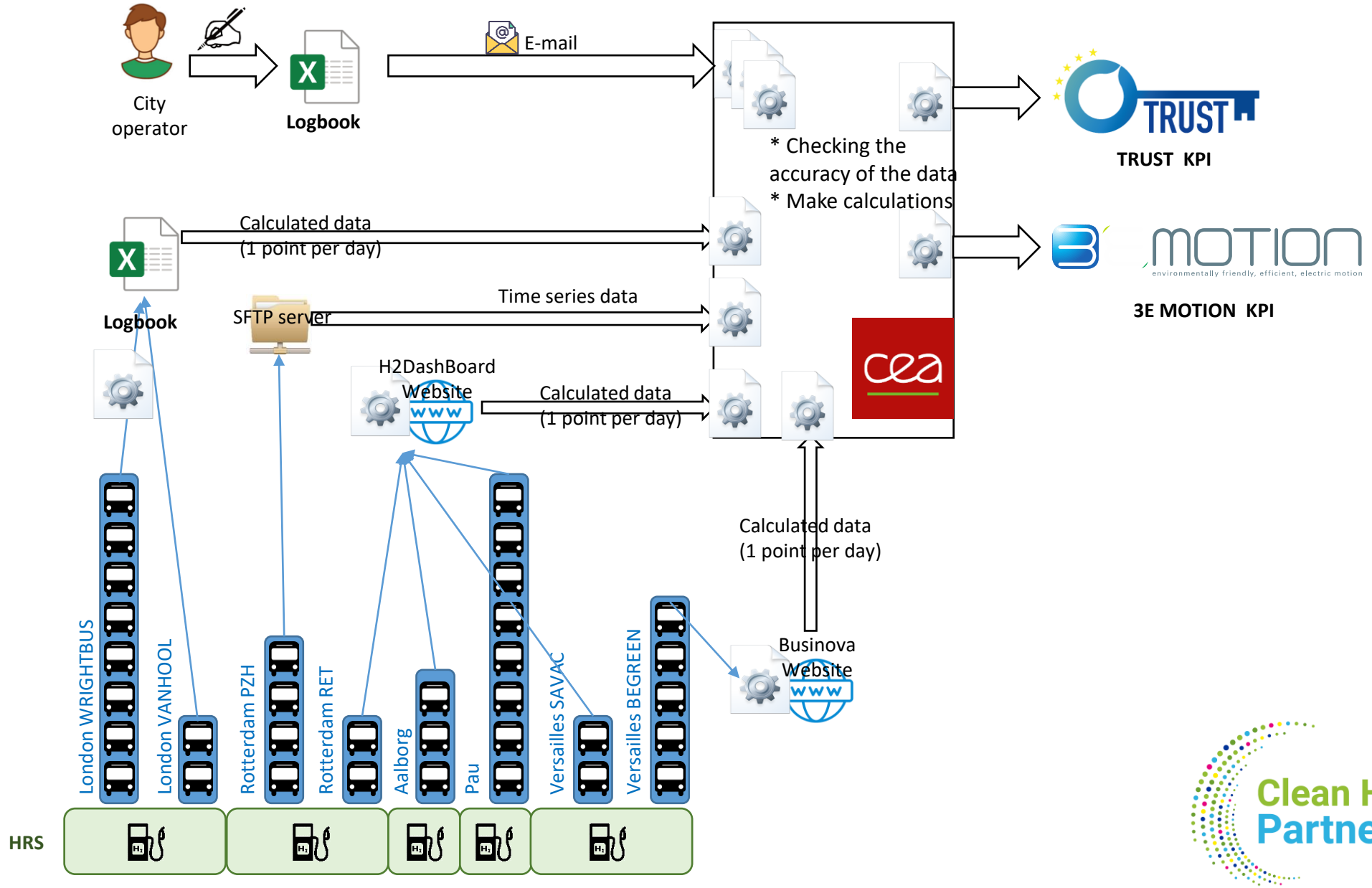
Data collection

Data collection and monitoring is very important to **validate the performance** of FC buses and HRS.

It has been a quite challenging task.

Data collection



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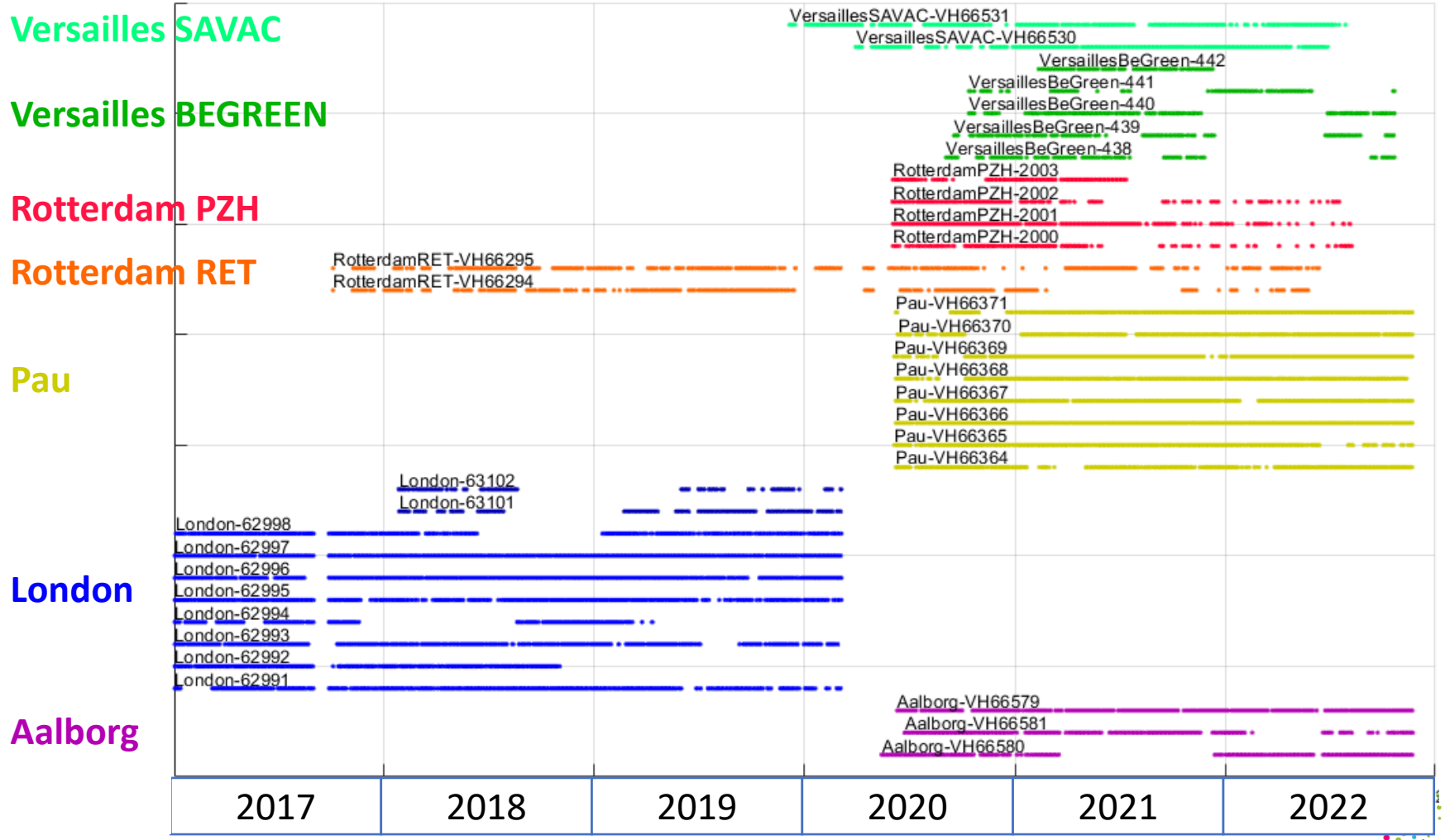
FCB Data collection : days in service

1 dot = 1 day in service with data collection



- not all buses started their mission at the same time
- Holes in the data collection = no service scheduled, failure, … or missing data

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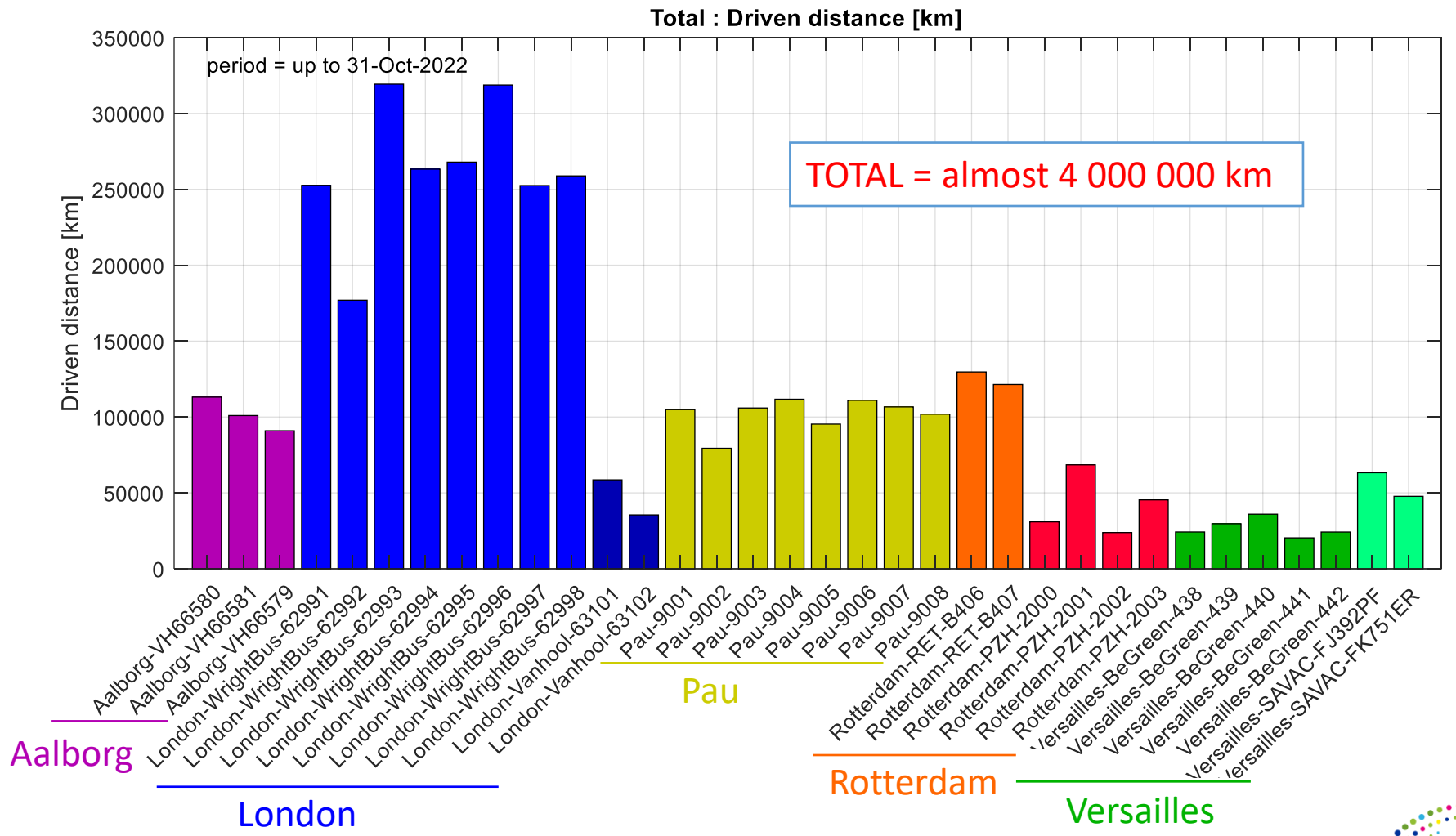
FCB Data collection : Driven distance



- London buses began their operation before the start of the project => high mileage

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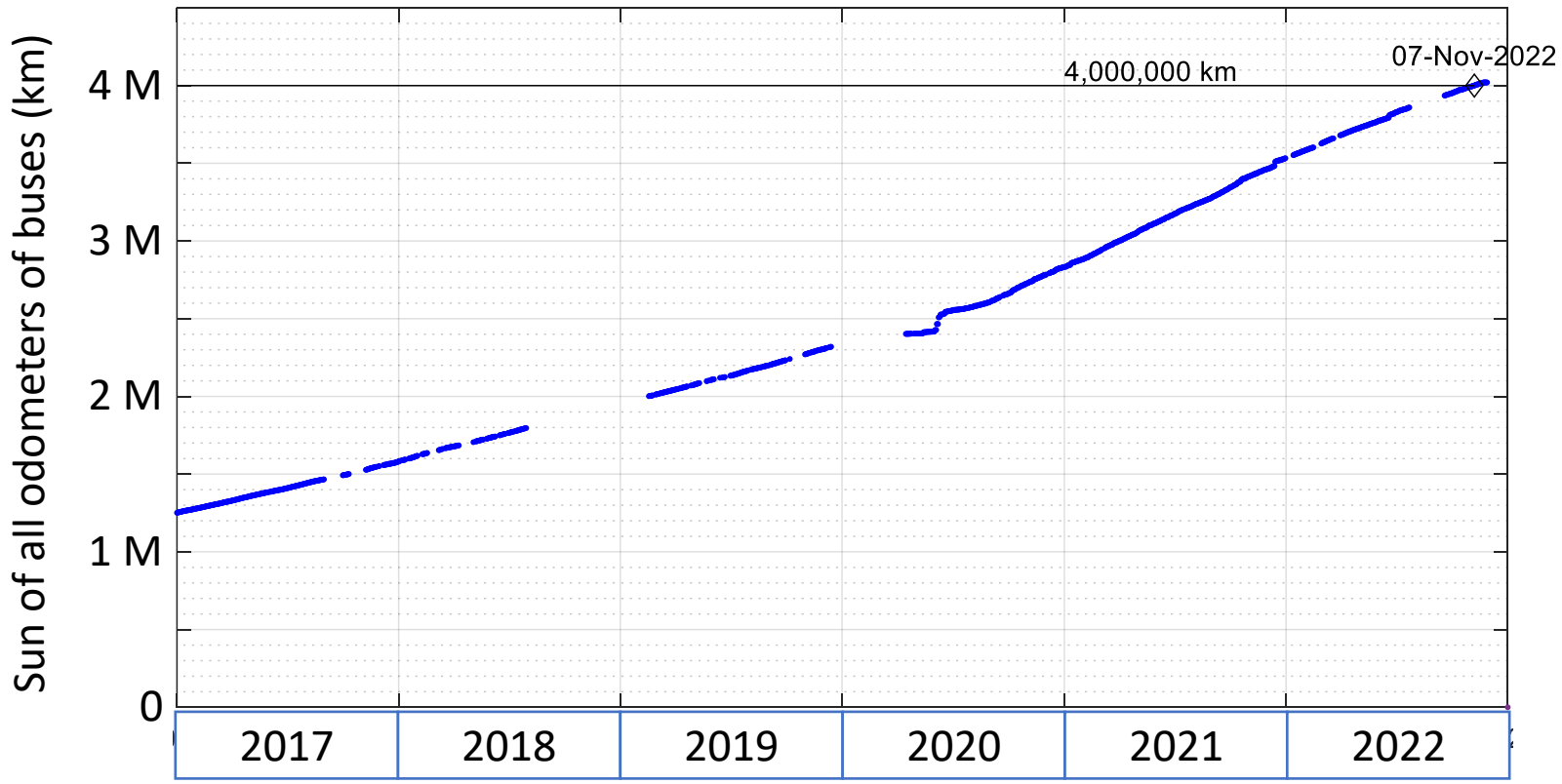
FCB Data collection : Driven distance

4 000 000 km were achieved beginning of Nov 2022 !



Note : in this graph, if 1 bus has missing data for 1 day, we calculate the sum of all buses as also missing data

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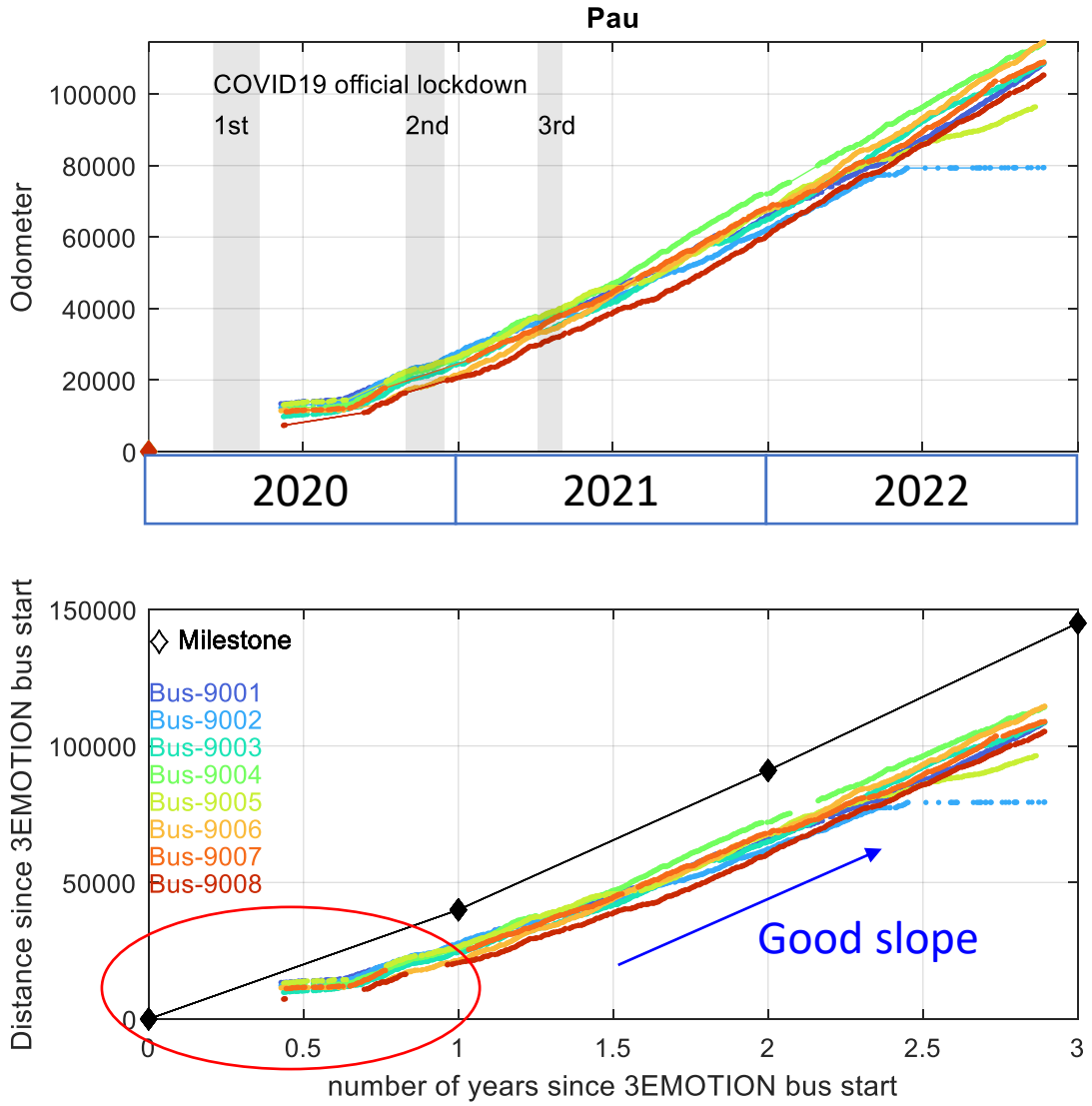
FCB Data collection : Exemple of Pau



Difficulties at the beginning

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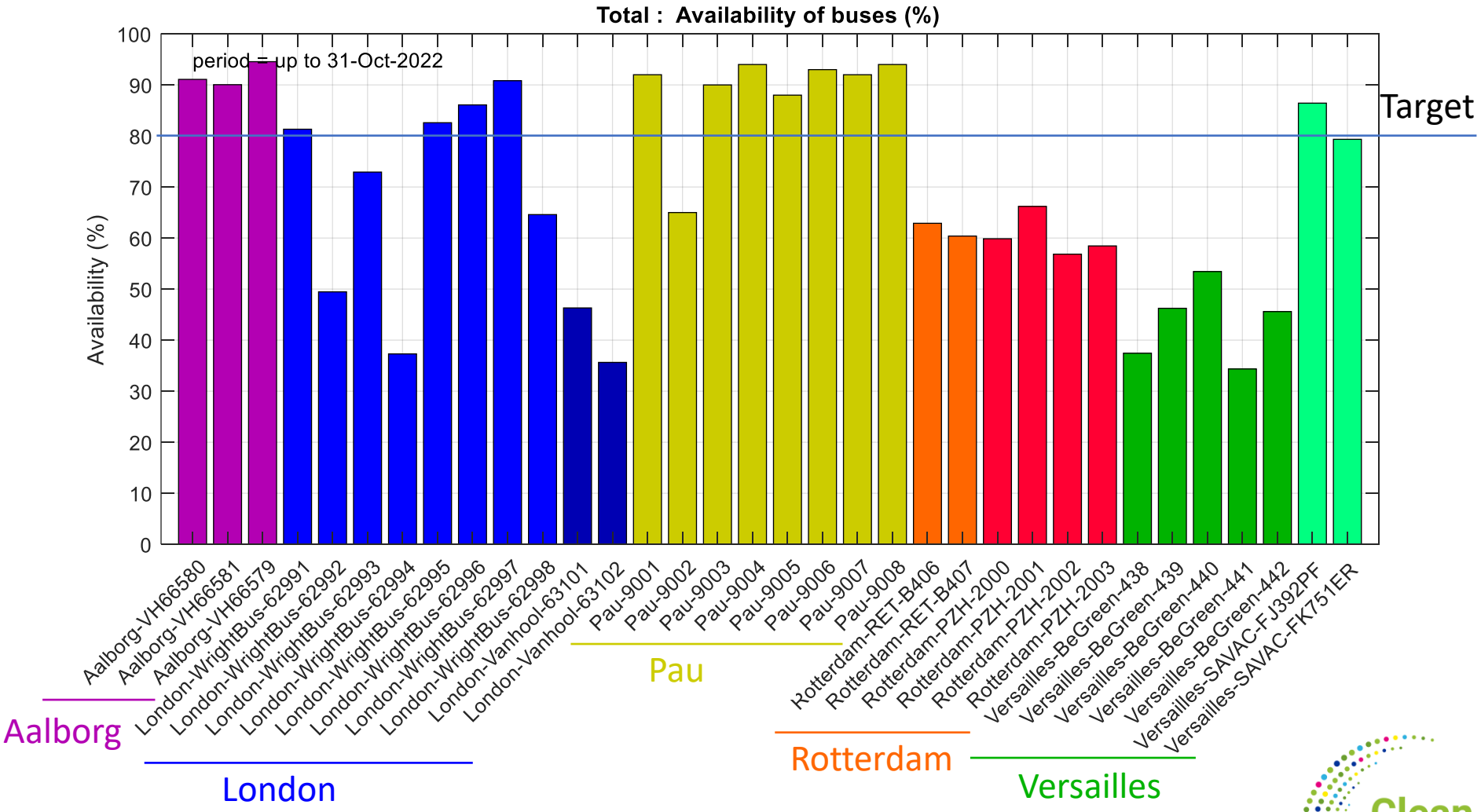
FCB Data collection : availability



Target : more than 80%

Note : Pau : only 2021 + 2022; Rotterdam RET : only 2017… 2021

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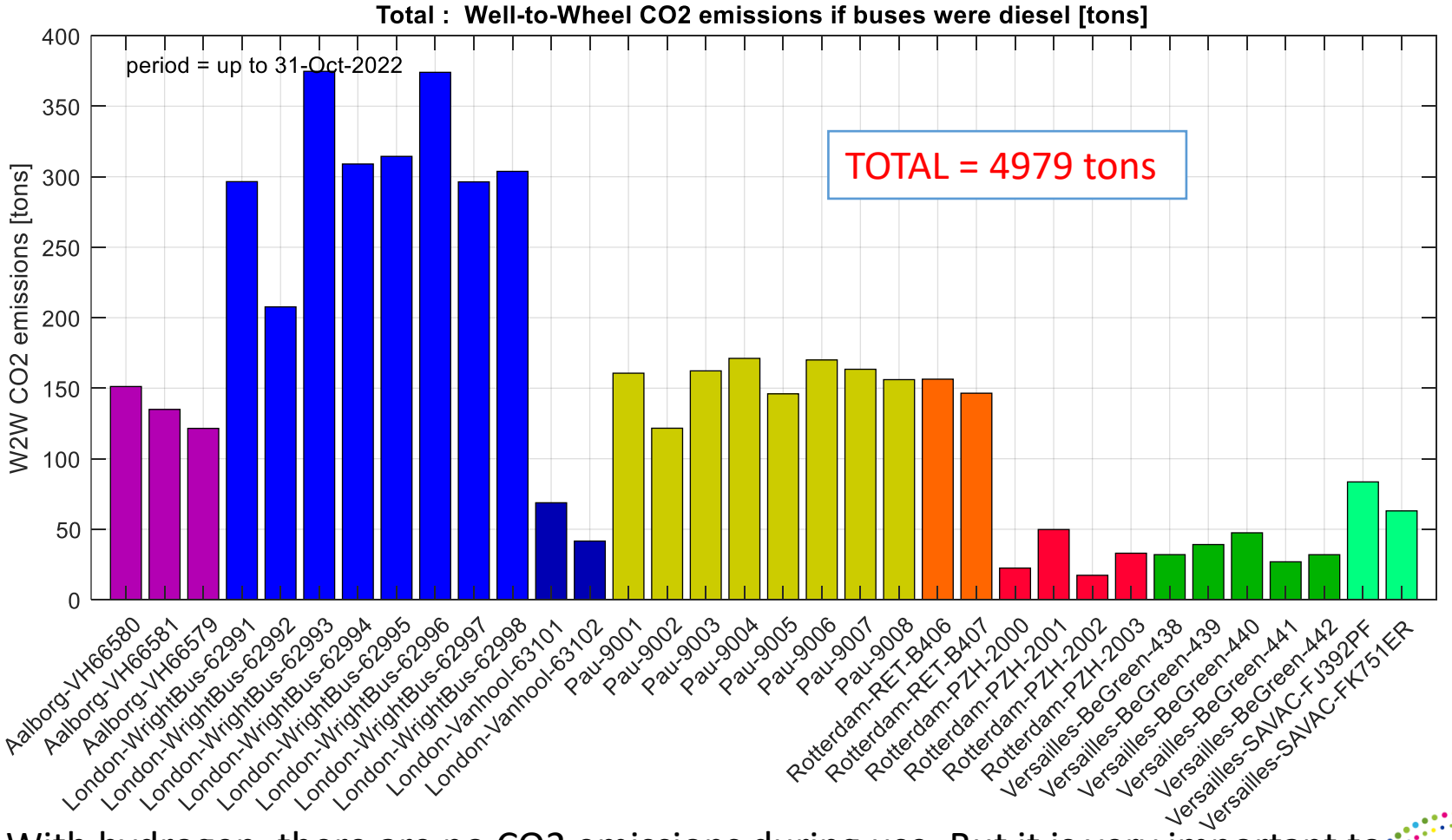
FCB Data collection : CO2 emissions



- With hydrogen, there are no CO2 emissions during use. But it is very important to produce H2 in a clean way (“green H2”)
- During the project, most cities had “green H2”, but some buses were supplied with "grey H2": this scenario is temporary and will have to be replaced in the future.

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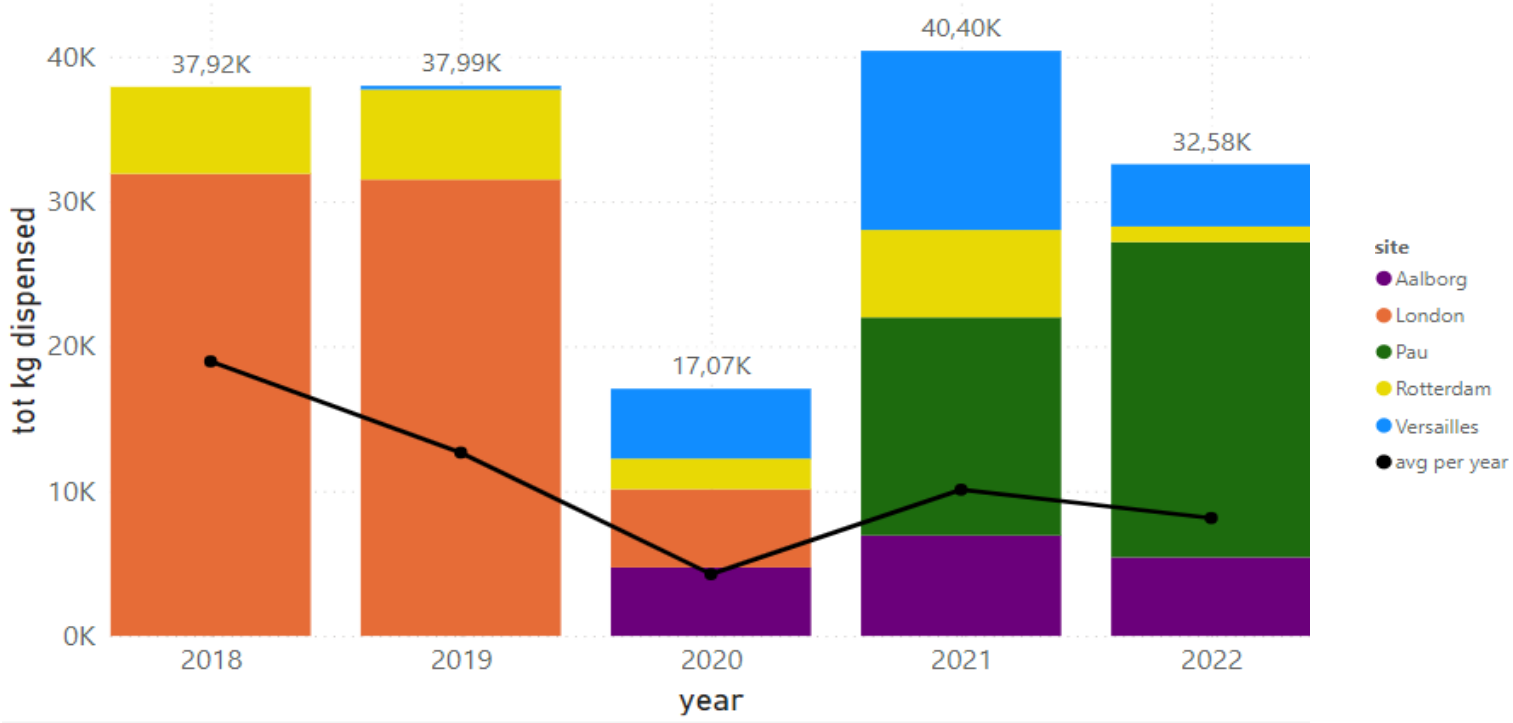
HRS Data collection

- **Total H2 dispensed from 2018 to 2022 in each site**



- Cumulative H2 dispensed = 165,952.15 kg (≃166 ton)
- Avg H2 dispensed per station = 4,287 kg (Rhoon)-22,984 kg (London)
- Cumulative fuelings = 9056

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HRS Data collection

1. Succesfull five years operation with more than **116 tons H2 (11 tons/year)** dispensed and **9056 completed refuelings (2084 fills/year).**

2. The average **refueling duration** for each site is **10-20 minutes**. The average **mass dispensed** per bus is between **15-20 kgH2**.

3. All PTO are fully engaged towards zero-emission mobility, but towards low-cost green H2 requires improvements in **technology efficiency, reliability, clear regulation, and low electricity price.**

4. A **reduction of the LCOH** is possible when large fleets are deployed, especially in **on-site facilities**. The decentralized HRS are impacted by the retail hydrogen price and transport delivery distance.

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Lessons learnt and conclusion

- On data collection :
  - if possible, avoid manually filled files as much as possible: it is source of errors, sometimes partially filled, and above all **it takes time for the operator**.
  - The automatic data collection takes time initially to set up, but afterwards, the results are very decent.
  - The more data we have, the best

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Lessons learnt and conclusion

- About the data :
  - For most cities, we saw problems at the beginning (because of new HRS, new Buses, new workshop, new maintenance, etc.)
  - Without a support of all actors, problem solving can take a lot of time

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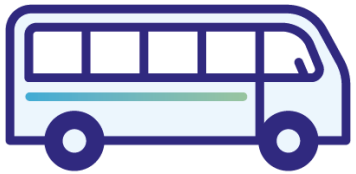
Conclusions of the 3Emotion Project

Stefan Neis, WaterstofNet



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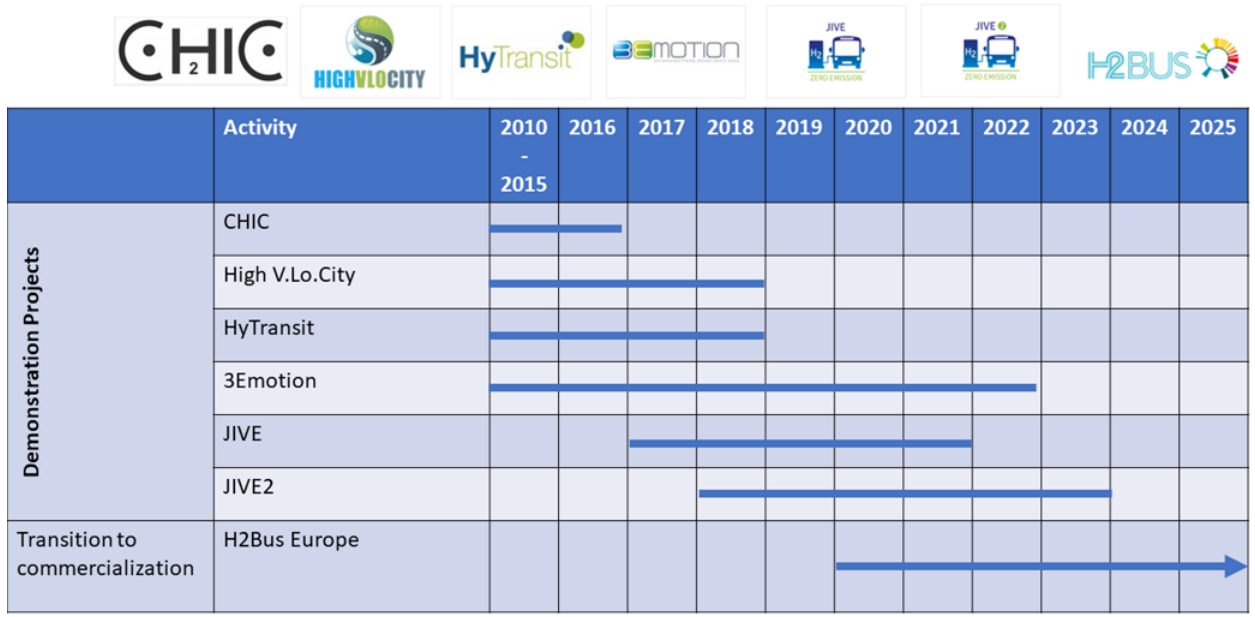
Project objectives

- Bridge the gap between current (2014) demonstration projects - deploying small numbers of FCB- towards larger scale deployment
- Demonstrate to decision makers and other stakeholders across Europe, the potential value of the H2 technology for their bus fleets. (Both 12 & 18m) fleets.



	Activity	2010 - 2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Demonstration Projects	CHIC											
	High V.Lo.City											
	HyTransit											
	3Emotion											
	JIVE											
	JIVE2											
Transition to commercialization	H2Bus Europe											

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Specific Objectives

- Moving towards cost effective integration of **FCB in local bus fleets**
- To ensure widespread visibility of FC buses **across Europe**
- To enhance the **technical availability** of the buses
- To demonstration of the **10-year life of fuel cell buses**

- To demonstrate the potential for **full** decarbonization of hydrogen dispensed from refueling stations
- To develop common technical **specifications of HRS**

- To consolidate and enhance the European Clean Hydrogen Bus Centers of Excellence (ECHBCE) – **www.fuelcellbuses.eu**

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Project Targets and main output

BUS Targets and Outputs	Units	SP1-JTI-FCH.2013 call Targets	3EMOTION Targets	3EMOTION results pr 30.06.2022
Bus Fleets	**n°**	5 buses for each site (minimum 15 FCB in two sites)	29 FCB in 5 sites	29 FCB in 5 sites
Bus Availability	**%**	>85% with maintenance	>90%	<=90%
Fuel cell warranty of buses	**hours**	6000 h	> 15000 h warranty	> 15000 h warranty
Bus costs	**euro**	reduction of 25% with respect of running buses (1.300.000)	850.000 euro (1.250.000 euro for articulated bus)	850.000 euro (1.250.000 euro for articulated bus)
Fuel Consumption*	**kg/km**	< 11 - 13 kg H2/100 km	8-10kg H2/100 km	8-10kg H2/100 km
Gas pressure	**bar**	350 bar CGH2	350 bar CGH2	350 bar CGH2

HRS costs	**euro**	not applicable	1.900.000
Refuelling station capacity	**kg/day**	200 kg H2/day	200-350 kg H2/day
Availability of the station	**%**	98%	<=98%
Station hydrogen production efficiency	**%**	50 – 70%	> 70%
Hydrogen cost (selling price)	**€/kg**	10	8-10 (range)
Gas pressure	**bar**	350 bar CGH2	350 bar CGH2

Impact by COVID 19 & Energy crisis

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Overall results

All sites are/ have been demonstrating fuel cell buses and hydrogen refueling infrastructure

29/29 buses by 4 OEMs and 2 FC suppliers are/were* in operation:

- TFL London
  - 8 Wright buses of London (UK) have been retired (>10y operation)
  - 2 VanHool buses have driven > 2 years and are now again being put into operation together with the new generation JIVE buses
- RET Rotterdam (NL) 2 VanHool buses have been in operations since 30/06/2017
- Connexxion PZH (NL) 4 VDL buses have been driving since
- Aalborg (DK) 3 VanHool buses are in operation since
- Pau (F) 3 VanHool articulated buses haven been operating since
- Versailles
  - SAVAC/Keolis Versailles (F) 2 VanHool buses have been in operation since
  - BeGreen Versailles 5 Safra buses are operated since

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Overall results

All HRSs of the project have been build or haven been upgraded that provide fuel for the FC-buses in the project. Some stations fulfill their duty only for 3EMotion, some also fuel the buses in the JIVE project:

- 3 HRS upgrades were completed (lessons learned implemented by AL stations)
  - Rhoon (Rotterdam)
  - Les Loges en Josas (Versailles) also H2ME station
  - London
- 2 New HRS stations with onsite-electrolysis are built and completed
  - Pau (F)
  - Aalborg (DK)

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What makes 3EMotion “special”?

Succesfull execution of the project enabling first scale up of hydrogen fuel cell electric hybrid buses throughout europe

The project delivered on the call requirements and expectations set in 2014 and showedreal life exploitation of different hydrogen buses and types during a long period.

OVERVIEW

- 4 bus OEMs
  - VanHool
  - VDL
  - SAFRA bus
  - Wright bus
- 4-5 bus types
  - 12m
  - 13m
  - Articulated 18m
  - Integrated Range extender
  - Range EXtender (REX) Trailer
- 2 FuelCell supplier
  - Ballard
  - Michelin-Symbio

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kms driven => **4.000.000** total and still counting

CO2 avoided(compared to diesel) => **5.000 Tons**

FCH

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Take aways of the project

- Several bus-concepts have been trialed, not all bus concepts are equal successful and some are suitable for upscaling.
- Data-monitoring exercise remains a challenge in the project.
- HRS availability still needs to improve.

- Competition from BEV, cheaper buses, infrastructure is clear.
- New businessmodels for ZE are emerging, service providers are well known power solution providers/ electricity suppliers.
- At large deployment, the large charging infrastructure, grid connections and real estate come into play, that favour for Hydrogen. As well as heavy usage (kms and slopes)
- Hydrogen showed to be a viable option in full operational service over the full lifetime of the buses. (EOL reached)

- ***"A true zero emmission transport system will require for BEVs and FCEBs to go hand in hand"***

- All are going to ZE public transport. Therefore important to keep developing and operating FCEBs.

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Barriers for commercialisation

- Small fleet projects are too expensive.
  - Costs for small scale operation higher, therefore less favourable, both for bus maintenance as well as small scale electrolyses and bus fueling.
- HRS load utilisation impacts availability and efficiency (critical succes factor)
- To commercialy scale without subsidies the following is needed:
  - Price gap Renewable hydrogen and diesel needs to shrink.
  - Bus price needs to go down
- Transfer early experiences and learnings to new sites for:
  - training of staff, workshopadaptations, permitting etc.
- Local regulations compared to EU/ national = not alligned
  - Respect european norms and try to accept these timely to prevent delays
- Bus as a service or full contract for service & maintenance most effective

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Essence:

"Transporting people is at our essence, moving people from A to B, (without emissions at "acceptable" cost)"

The buses driven by happy drivers, rated by happy customers as very comfortable!

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This project is supported by the EU through the Fuel Cells and Hydrogen 2 Joint Undertaking (Now Clean Hydrogen Partnership) under grant agreement 633174 and by a series of local and national authorities.

Co-funded by
the European Union

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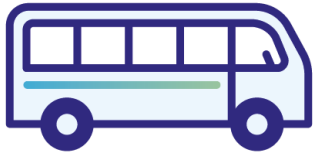
Large scale deployment of fuel cell buses (Jive project)

Magali Senaux, Element energy



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JIVE/JIVE2/MEHRLIN

Towards clean public transportation with fuel cell buses

3Emotion Final Conference – 29th November 2022 – Vélizy, FR

Presentation by Element Energy, an ERM Group company
Magali Senaux

ZERO EMISSION

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Co-funded by the European Union

High daily range

- **350+ km without refuelling**
- Operating temperature does not affect range

Increased passenger capacity

- **~10% more capacity** than BEBs

Enhance European competitiveness

- Due to the European manufacturing base and the supply chain

A concrete answer to ambitious **policy targets** set for **transport decarbonisation**

Operational flexibility

- Similar user experience to diesel refuelling (**5-10 min. refuelling time**)

Zero tailpipe emissions

- Only water emitted: no air pollutants or CO_2 emissions

Scalability

- The refuelling infrastructure can be scaled up to accommodate growing fleets

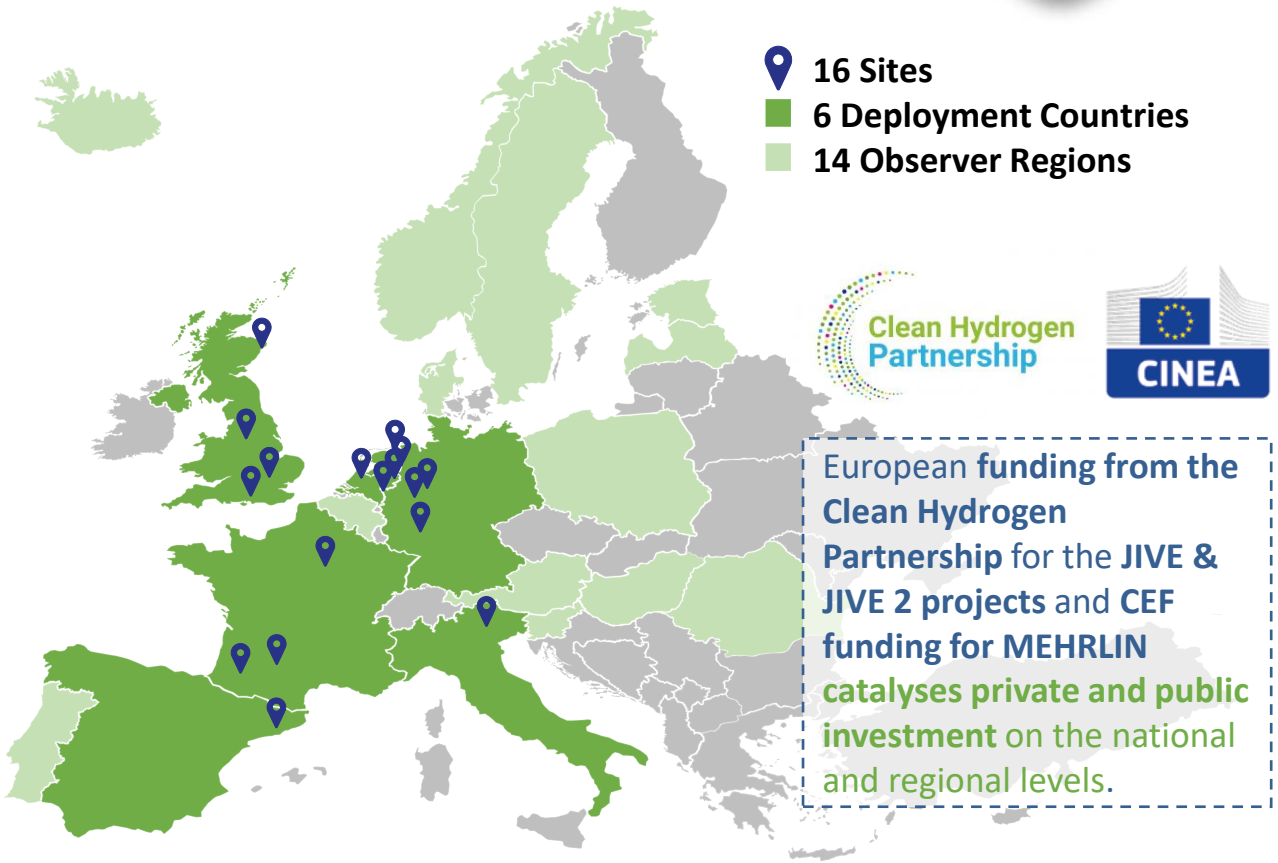
The JIVE projects are the flagship fuel cell bus projects in Europe aiming to deploy around 300 buses by the end of 2022

ZERO EMISSION

Objectives:

- ❑ **Deploy 298 buses** across 16 European cities and regions in **6 countries** – the **largest deployment attempted to date**
- ☑ Validate large scale fleets in operation
- ☑ Stimulate the FCB market
- ☑ **Achieve a maximum price of €650k (JIVE) and €625k (JIVE 2)** for a standard fuel cell bus
- ☑ Trial joint procurement methods to **access economies of scale**

- ❑ Deploy 18 Hydrogen Refuelling Stations
- ☑ **Enable new cities and regions to trial hydrogen technologies**
- ❑ Demonstrate routes to **low cost renewable H2**
- ☑ Stimulate further large-scale uptake of fuel cell vehicles



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CINEA

European **funding from the Clean Hydrogen Partnership** for the **JIVE & JIVE 2 projects** and **CEF funding for MEHRLIN catalyses private and public investment** on the national and regional levels.

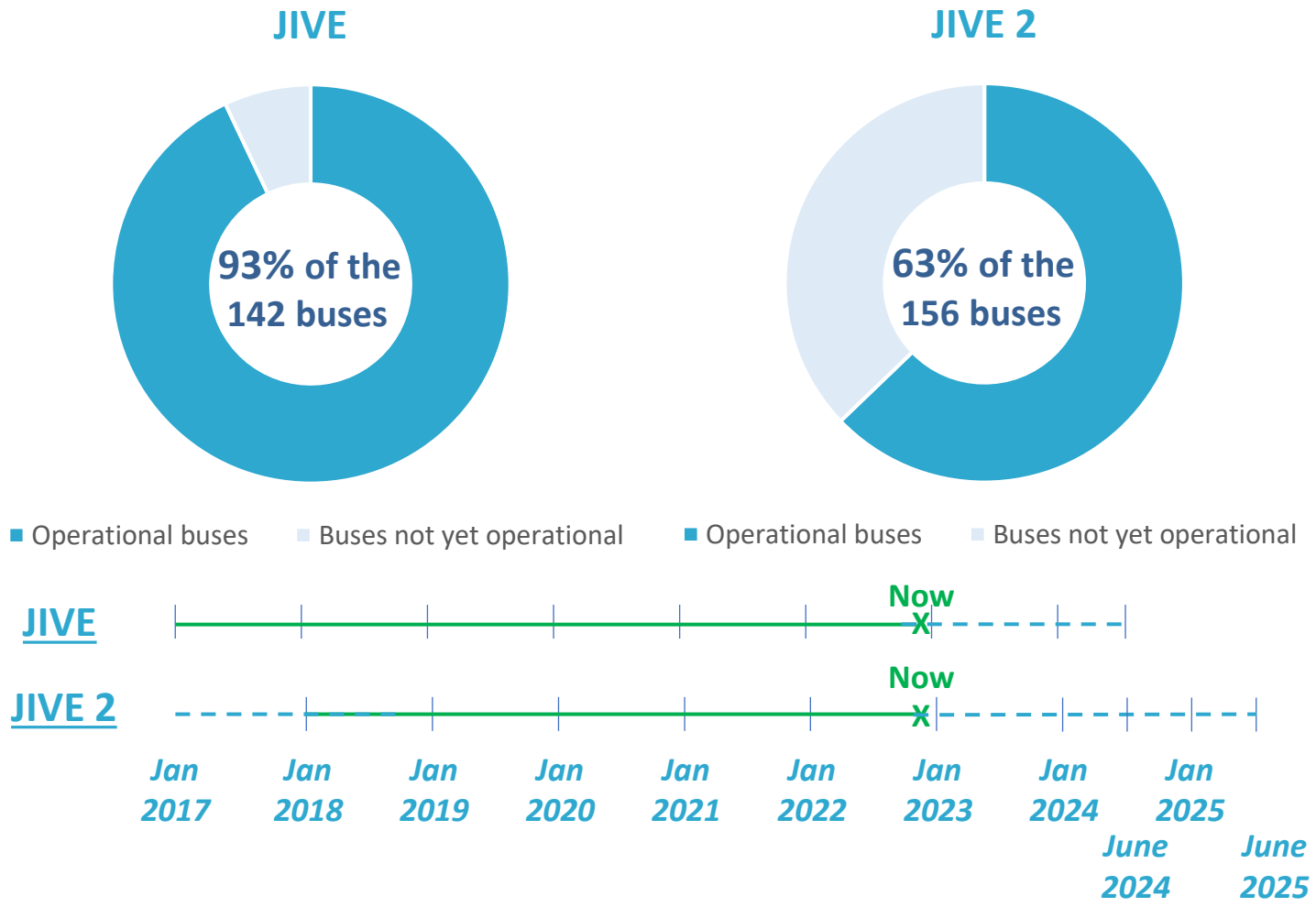






Current Status: Fuel Cell Buses

As of November 2022, **~77% of the buses are operational*** (i.e., 230 buses), and **6.5M km** have been driven cumulatively as of June 2022.



- 5 European OEMs

CaetanoBus VANHOOL SOLARIS WRIGHTBUS SAFRA Accélérateur de mobilité décarbonée

- Single deck (~67%) and double deck (~33%) buses
- Fleets from 5 to 50+ buses







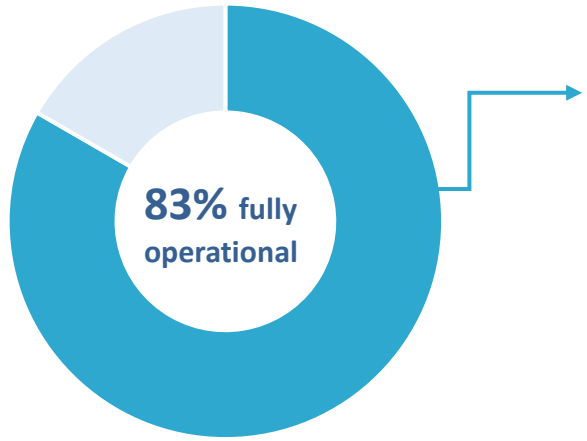

Several sites are still at the beginning of their operational phase and therefore are experiencing issues (bus or hydrogen related) which can lead to longer downtimes for their buses.

Current Status: Hydrogen Refuelling Stations

There are 15 HRS fully operational, most delivering green hydrogen to the vehicles.

- **Seven** hydrogen refuelling stations used by the JIVE and JIVE 2 buses are financed through the MEHRLIN project (CINEA).
- Several operators use, or plan to use, other existing local HRS / **mobile HRS configurations** to allow buses to start operating before HRS commissioning.

Hydrogen refuelling stations (JIVE/JIVE2/MEHRLIN)



- **13** of the 15 operational HRS dispensing **green hydrogen** – Once all stations will be online, ~90% of them will be dispensing green hydrogen.
- Sites with currently blue or by-product hydrogen have plans to move to green hydrogen.
- Across the project, **~60%** of the hydrogen will be produced **on-site with electrolysers**.








The projects objectives in terms of Key Performance Indicators

Bus Performance

Distance travelled

JIVE: min. 100,000km/bus in 3 years
JIVE 2: min. 150,000km/bus in 3 years

Availability of Buses

>90%

Specific Fuel Consumption

>9kg/100km (standard buses)
>14kg/100km (articulated buses)

HRS Performance

Availability of Station Unit

>98%

Speed of Dispensing

JIVE: >3kg/min

Amount of Hydrogen Dispensed

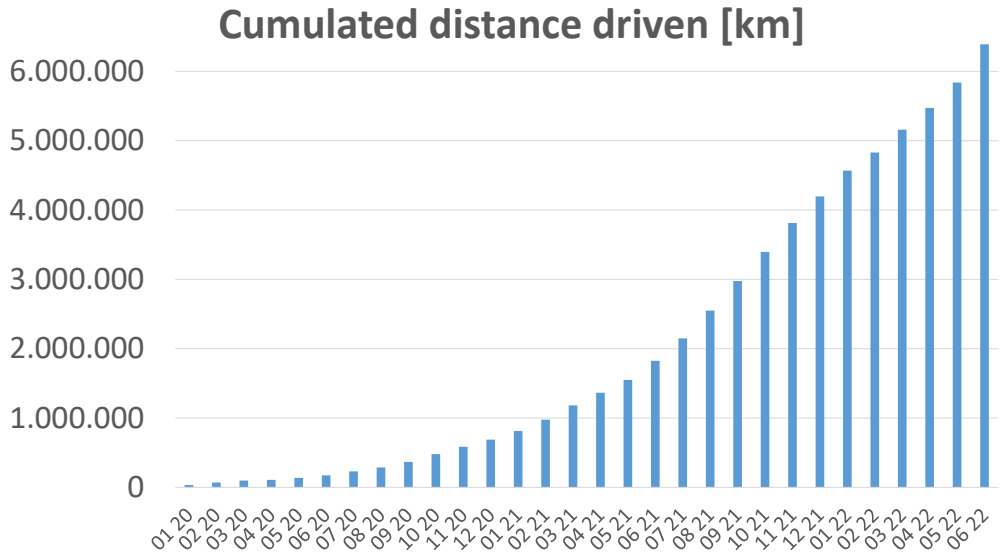
JIVE: >4,500kg/bus/year

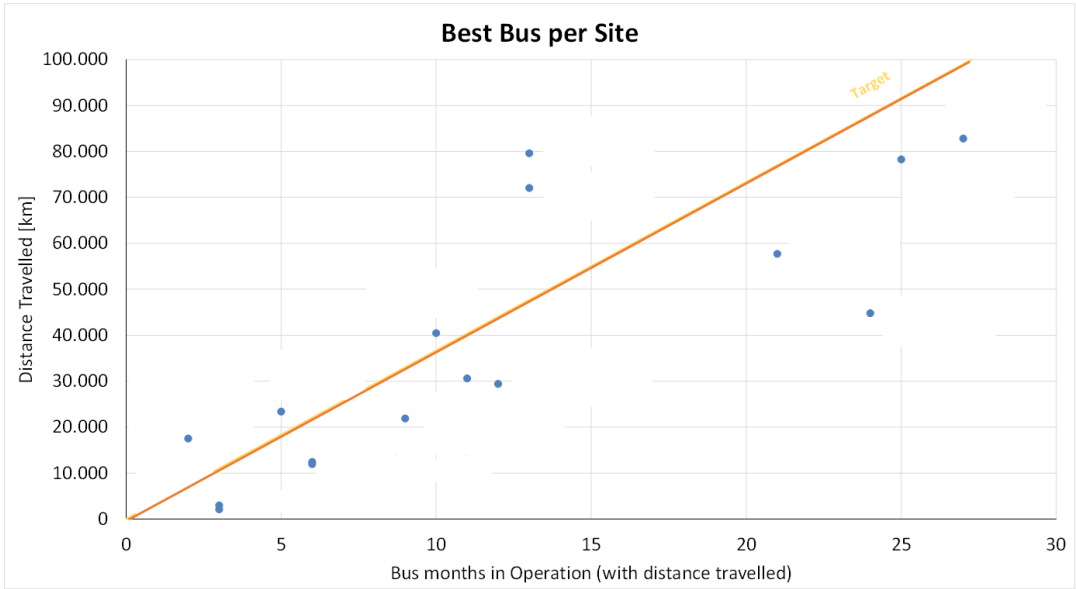
Performance of the Buses (Distance Travelled) – Significant increase in monthly distance can be

Distance Travelled

- **~6.5M km** have been driven cumulatively as of June 2022. **Monthly distance driven up to 550,000km**.
- **Slowdowns** are caused by **operational issues** linked to technical bus or HRS issues, Covid-19 crisis, unfavourable operating procedures, and currently high hydrogen prices.
- To be noted, there are still minimum 1.5 and 2.5 years before the JIVE and JIVE 2 projects end respectively. Several sites only started operations in 2022 and others are not yet operational.

- Five sites have their best performing bus already above target; several others are very close.
- The **maximum cumulated distance for a site as of today is ~1,790,000 km** (in CHIC it was ~4,000,000 km).





NB: Data from various sites is still missing. The data is as of Q2 2022.

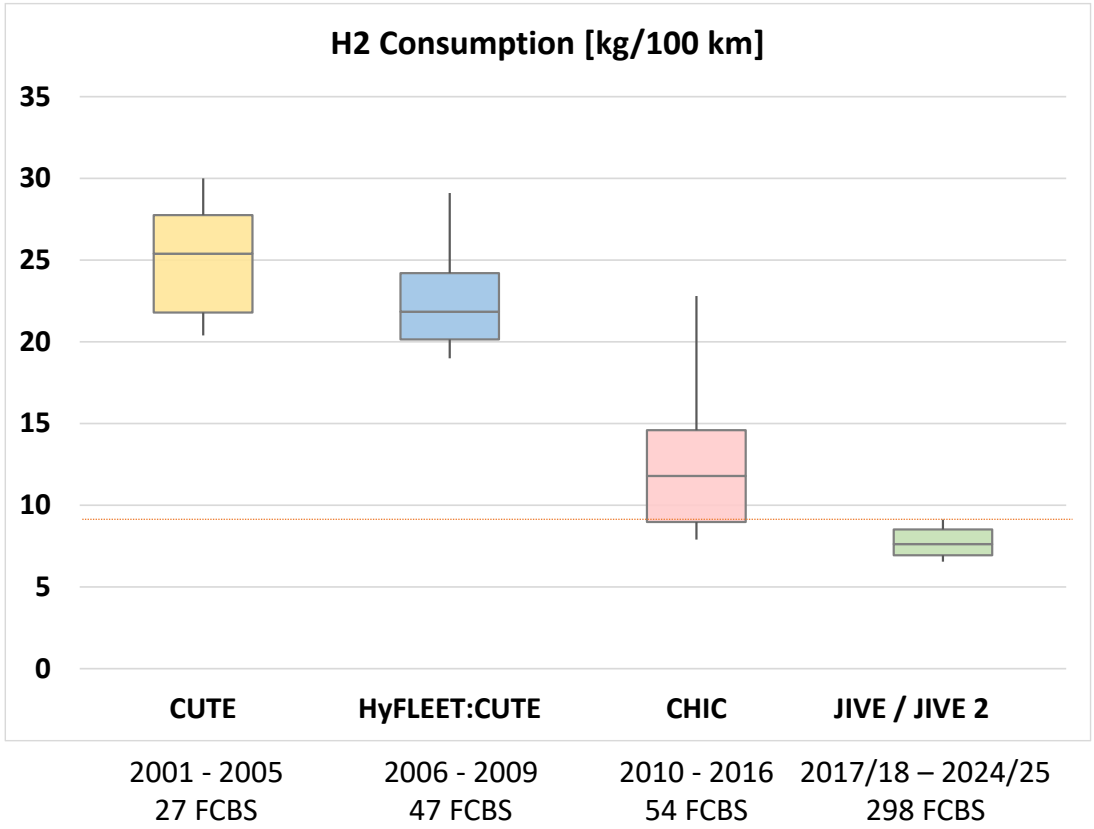
Performance of the Buses (Fuel Consumption) – Buses are outperforming the project

Specific Fuel Consumption

- Excellent fuel efficiency with the majority of consumptions currently between **7 and 8.7kg of hydrogen per 100km for 12m and double decker buses** and **less than 9kg per 100km for 18m articulated buses.**
  - Project objective: 9kg/100km (standard buses) and 14kg/100km (articulated buses).
    - **Buses are outperforming the objectives**.

- **Significant reduction in fuel consumption over the projects** (incl. for the 18m FCBs) with values **as low as 6.5kg/100km** achieved.

- Average values could lower even more as, by experience, consumption still decreases after the teething period.

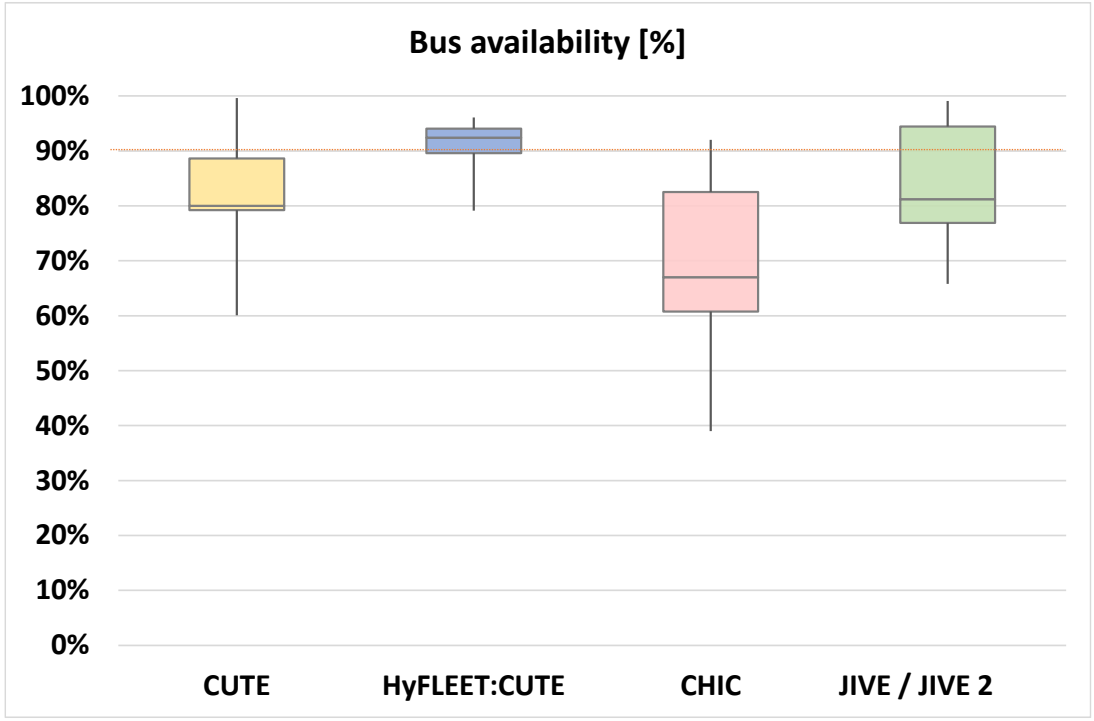


NB: Data from various sites is still missing. The data is as of Q2 2022.

Performance of the Buses (Availability) – Good performance in general

Availability

- **Single sites have reached 99% availability**.
- **Average availability** across all JIVE sites **~85 % in Q2 2022**.
- Several sites have just started operations and are therefore in their **teething phase** where lower availability levels are expected and common.

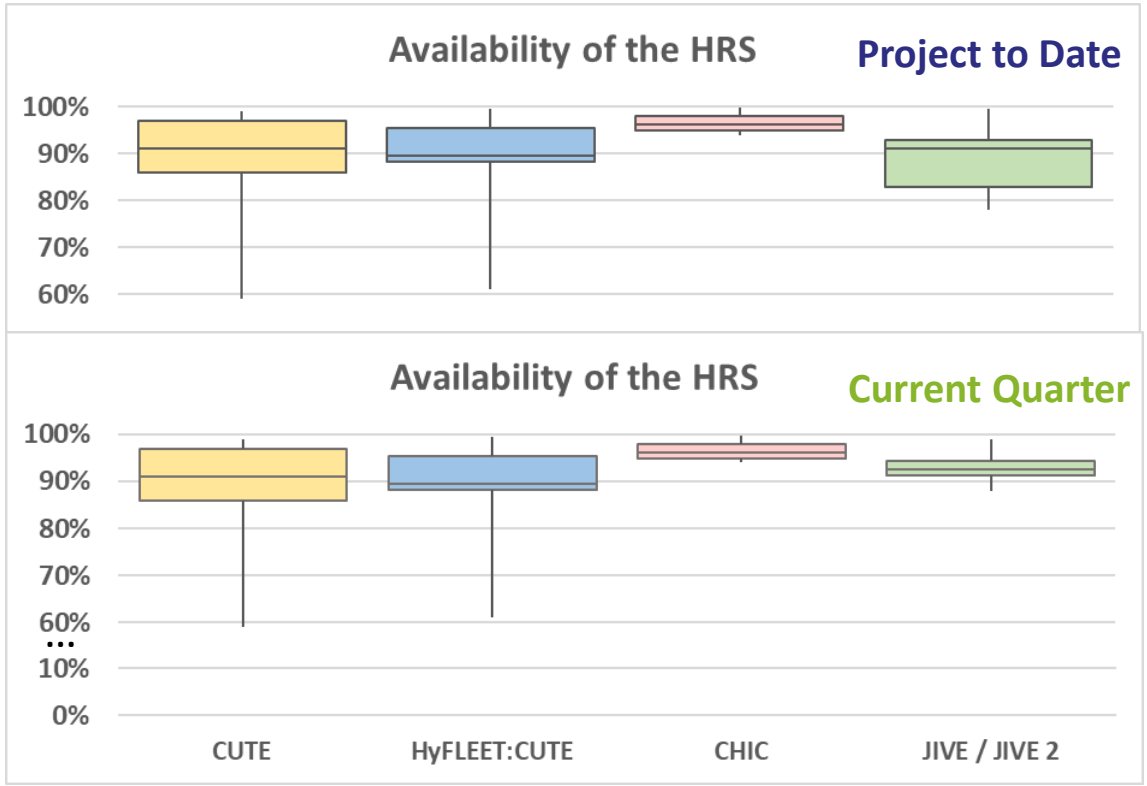


NB: Data from various sites is still missing and goes up to Q2 2022.

Performance of the Hydrogen Refuelling Stations

Availability of Station Unit

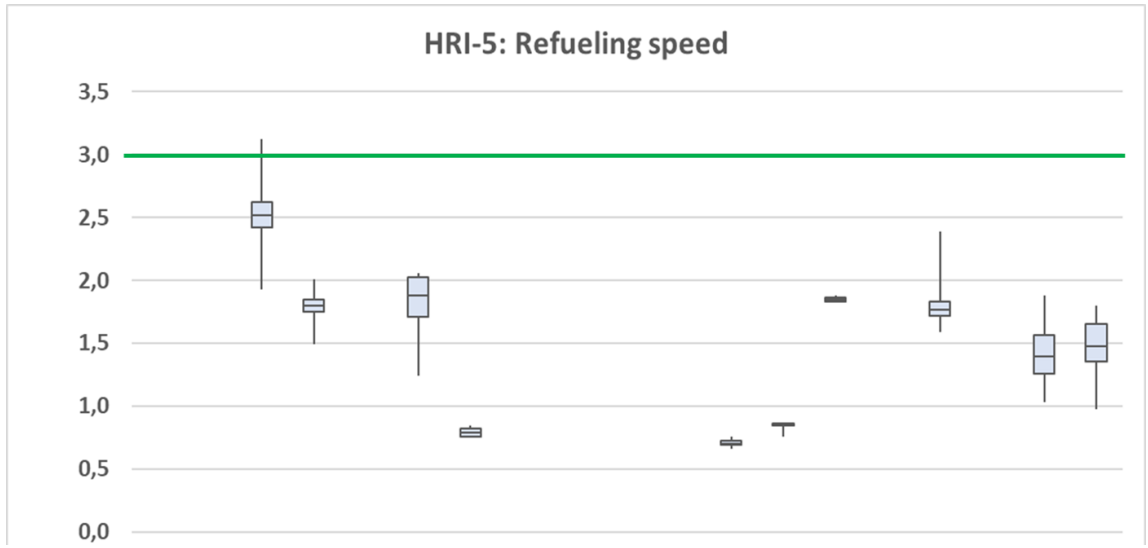
- **Performance in general is good**; however, some major issues have led to longer downtimes at some sites.
- There is **room for improvement**; however, the **trend is very positive.**



NB: Data from various sites is still missing. The data is as of Q2 2022.

Speed of Dispensing

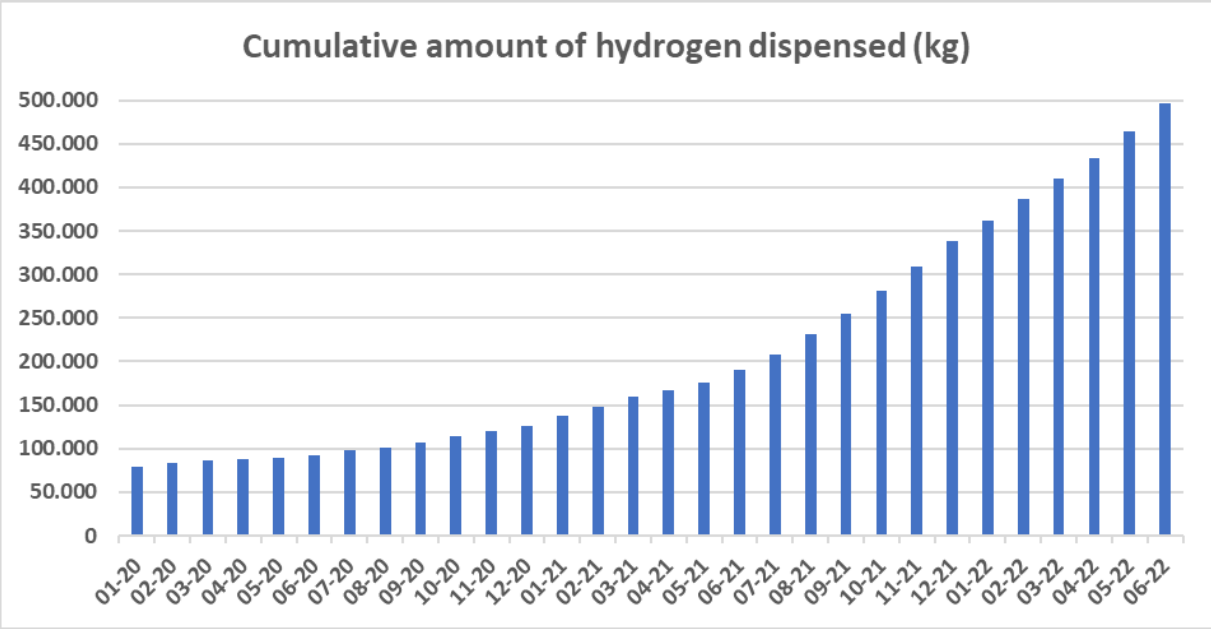
- Currently, **levels are not reached** by the JIVE / JIVE 2 sites
- Some site specificities, modifications in the tank types, and HRS/bus communication issues can, in parts, explain these gaps.

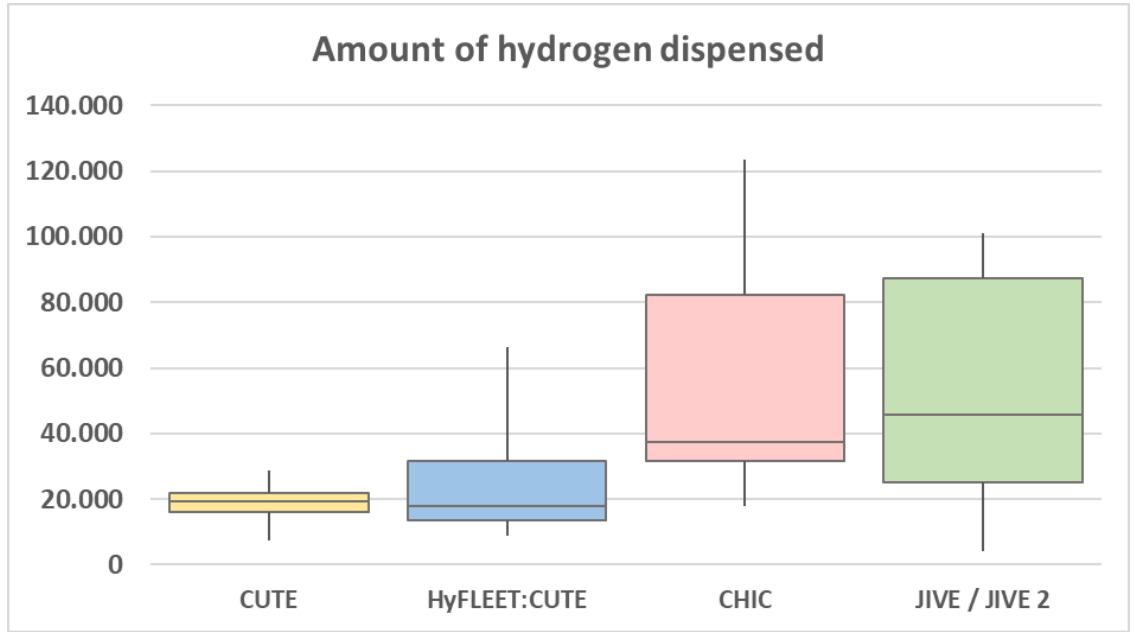


Performance of the Hydrogen Refuelling Stations (Amount of Hydrogen Dispensed)

Amount of Hydrogen Dispensed

- The amount of hydrogen dispensed has **gradually increased as the number of buses operating grew** (mid-2021). By end of June 2022, **more than 0.5 million kg of hydrogen dispensed to JIVE/JIVE 2 buses**.
- However, the **project target (JIVE) of 375kg of H2 dispensed/bus/month is not yet reached**. This is sometimes due to limited bus operations but also due to the good fuel efficiency of the buses.
- Given the larger bus fleet deployed, the **amount of hydrogen dispensed in higher than previous projects** (to be noted, that 1.5 and 2.5 years are left for JIVE and JIVE 2 respectively.



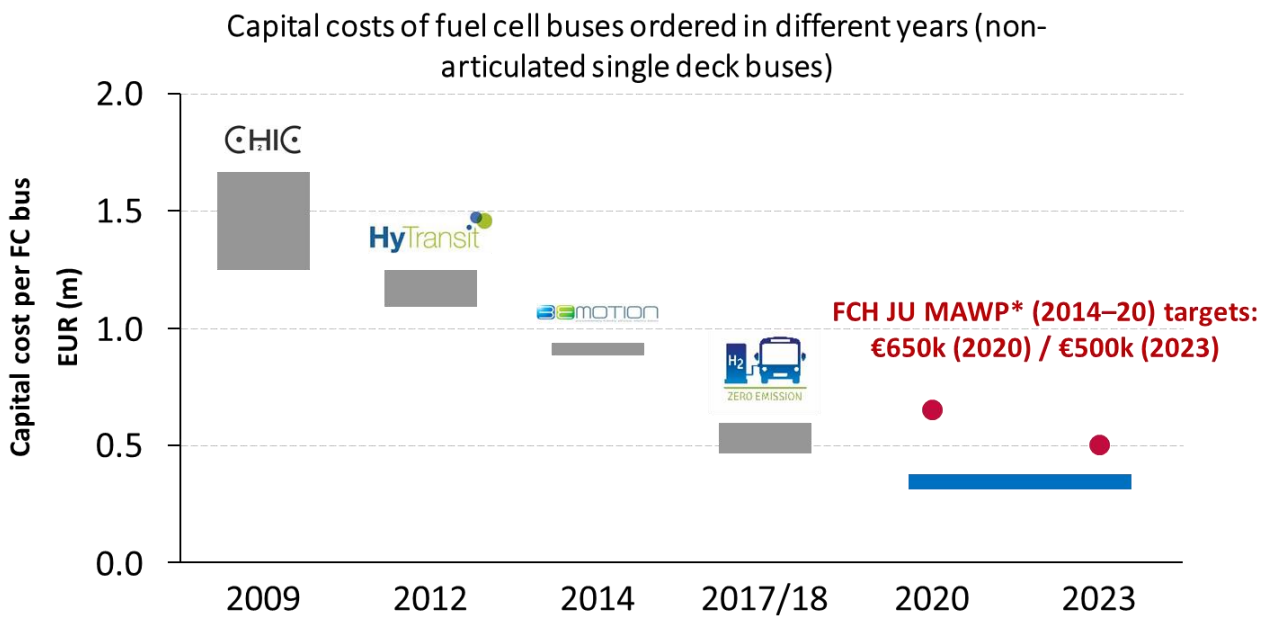


NB: Data from various sites is still missing. The data is as of Q2 2022.

Drop in bus prices compared to previous FCB projects

The prices of the buses purchased under JIVE and JIVE 2 have significantly decreased compared to previous projects.

Actual bus capex – historic FCB projects



- Prices have significantly decreased since the first funded FCB projects.
- **The JIVE and JIVE 2 targets in terms of prices have been achieved** (below €650,000 and €625,000 respectively).
- **Minimum costs are accessible for vehicle orders of >10 buses**. Price varies depending on specifications.

Major achievements within the project up to date

- FCB prices: The targets of having bus order prices below €650,000 and €625,000 for JIVE and JIVE 2 respectively has been achieved.

- +50 FCB cities: Cologne, through JIVE 2, is Europe's first +50 FCB city.

- First-of-a-kind deployment: Barcelona, under JIVE 2, was the first city in Spain to deploy FCBs; Pau was the first city to deploy 18m FCBs; etc.

Ingredients for success and key lessons learned

Keys to successful deployments within the JIVE Projects

- Fuel cell bus projects that have been established as part of a **broad energy system** (e.g., Pau and Groningen).
- Fuel cell bus projects that **establish and communicate realistic project expectations**.
- Fuel cell bus projects with **the 'right' people** – champions for the technology, expert planners, etc.

Other key lessons learned

- **Funding:** Multiple sources of funding means the EU funding is well leveraged. However, this adds complexity and timescale challenges.
- **Procurement:** The HRS and hydrogen supply should be procured parallel to the buses. If not, the risk is that the buses stay idle, which can lead to component damage. If no interim hydrogen supply solutions were anticipated, it would be difficult to test the vehicles.
- **Hydrogen supply:** Diversifying and securing backup hydrogen supply is key.
- **Financing models:** New financing models are being developed to address the challenges to commit to large orders without having full certainty of the lifetime costs (e.g., 'all-in offers').

Challenges remaining for Fuel Cell Buses and recommendations

For suppliers (Buses and HRS)

- **Standardising components and supply chain maturation** to decrease investment costs and provide certainty of TCO for purchasers.
- **Decreasing the timeframe for production** – increased involvement from major bus suppliers.

Note: There appears to be an **increasing desire to purchase buses and their refuelling infrastructure from a single supplier** –need for partnerships between Bus OEMs and HRS OEMs / Gas suppliers.

For operators

- Understanding this is a **major step change from running diesel buses** and that securing support and a team of experts is essential.
- Being prepared to **ask and learn from others.**
- **Working collaboratively with suppliers and the government** to make the FCB system viable for a commercial enterprise.

For governments (Local, National & Supra-National)

- Providing certainty for operators by **providing the right frameworks**: regulation and permitting.
- Providing commercial certainty for operators by **de-risking their investment** (e.g., guaranteed demand for H2; providing expertise; financial investment, etc.).
- Leveraging the fuel cell bus deployment to integrate hydrogen into the regional energy system.

ZEB 2023: 9th – 12th October 2023 alongside Busworld

Next ZEB conference (5th edition) in collaboration with Busworld **(9th – 12th October 2023)**

- Conference which brings together operators, policy makers, manufacturers, and industry to discuss decarbonisation of public and private transportation.
- **Considerable mutual benefits to both events**: the conferences and the exhibition. All ZEB attendees will have free entrance to the Busworld Europe exhibition.
- **Content** – focus on deploying **Zero Emission fleet at scale**. New in this edition will be the **special attention for zero emission long distance and tourism coaches** whilst maintaining attention on battery electric technologies and hydrogen-fuelled buses.
- Stay tuned for more information → **https://zebconference.eu/**

What to expect from this edition?

- A content-driven conference bringing together **battery and fuel cell electric stakeholders**
- **400 attendees** from the zero-emission bus sector
- **500 exhibitors,** amongst which the 80 biggest bus manufacturers
- Speakers providing **lessons learned, best practices** and **experts' insights**

@EUZebConference

EU Zeb Conference

The JIVE 2 project is organizing 3 CEE (Central Eastern Europe) roadshows – 1st one started mid-Jenia

The JIVE 2 project is organising a bus tour of cities in Eastern and Central European countries who are interested in the adoption of hydrogen technology for public transportation. The aim is for relevant local actors to test a demonstration bus to build regional capacity to deploy fuel cell bus technology and expand the sector in the short/medium term.

JIVE 2 project partners involved in the JIVE 2 CEE Bus Roadshow:

elementenergy an ERM Group company

Hydrogen Europe

UITP ADVANCING PUBLIC TRANSPORT

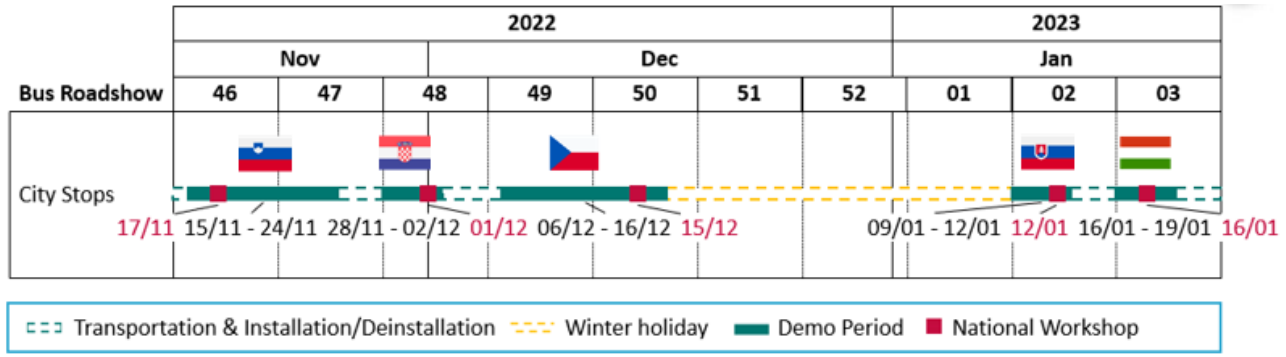
Infrastructure providers:

CaetanoBus

MESSER Gases for Life

1st CEE Bus Roadshow (Central Europe)

1st National Workshop took place in Tolmin (jointly with NAHV – North Adriatic Hydrogen Valley)



Next steps

The **last buses and HRS are expected to go live** in the next couple of months – all should be operational by end Q2 2023. Some challenges are still expected along the way.

Data will continue to be gathered to **provide further knowledge and insights on the performance** of the buses and HRS (vs. the targets set out in the project).

Dissemination and communication activities will be pursued.

Continue discussions with partners and the industry on the **post-JIVE FCB sector**.

QUESTIONS?

For further information, please don't hesitate to contact:
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https://www.fuelcellbuses.eu/ @fuelcellbus @fuelcellbus @fuelcellbus

Project coordination

elementenergy

an ERM Group company

Project dissemination

Hydrogen Europe

The JIVE and JIVE2 projects have received funding from the Clean Hydrogen Partnership under Grant Agreements No 735582 and 779563.

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The MEHRLIN project is co-financed by the European Union's Connecting Europe Facility.

If you have any questions, please don't hesitate to contact:
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Clean Hydrogen Partnership

Co-funded by the European Union

3EMOTION

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Reception

Clean Hydrogen Partnership