Technology focus: Fuel cell hydrogen buses

Webinar Series

08th December 2022, 11.00-12.00 CET

Geert Van Hecke

Head of Sales Public Transport at Van Hool

The Clean Bus Europe Platform is financed by the European Union.

Geert Van Hecke
Head of Sales Public Transport, Van Hool

Programme

Technology focus: Battery buses		
11.00 – 11.05	Welcome & Introduction	Flavio Grazian, UITP
11.05 – 11.40	• Introduction to the technology • Vehicle and components • Refueling infrastructure • Main advantages and drawbacks • Examples across Europe • City strategies to deploy this technology	Geert Van Hecke, Van Hool
11.40 – 12.00	Questions & Answers	

Today's goal

- Clear and complete overview of this technology
- What are the main features and main challenges of this technology?
- Which aspects should I consider upfront when considering this technology?
- Insights on safety aspects
- Which sources of information can I refer to, to further learn on a specific technology?

Etiquette for joint discussion

- Participants please mute yourself per default
- You can use the Chat to place your questions, share interesting info or make us aware of any technical issue
- Raise your hand and switch on your camera to ask to have the word
- The session will be recorded.

We count on your valuable contribution for a successful workshop. Thank You!

Transport solutions provided

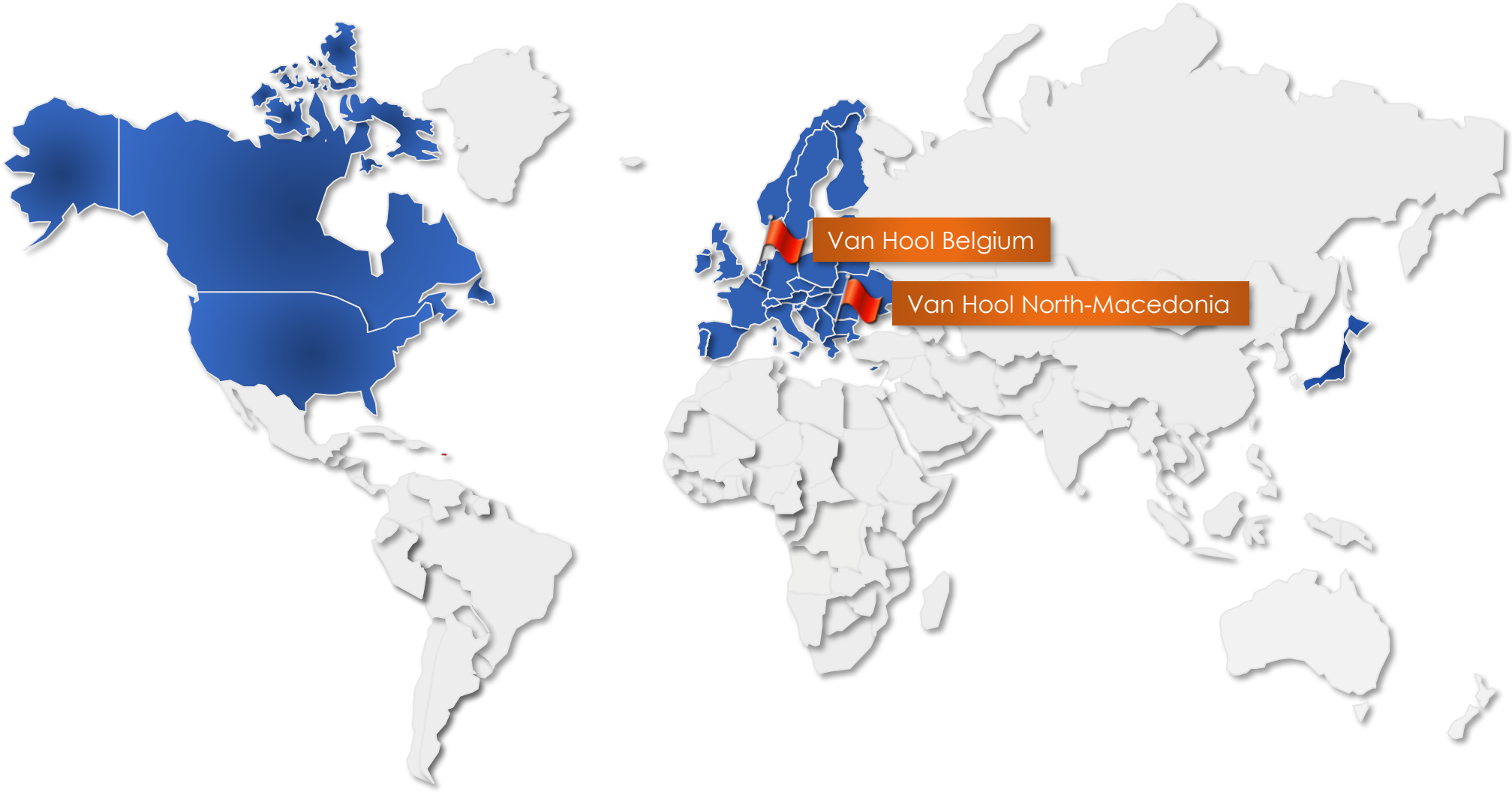
- **Bus and Coach**
- **Industrial Vehicles** : Trailers, semi-trailers and tank containers for road transport & the container sector.

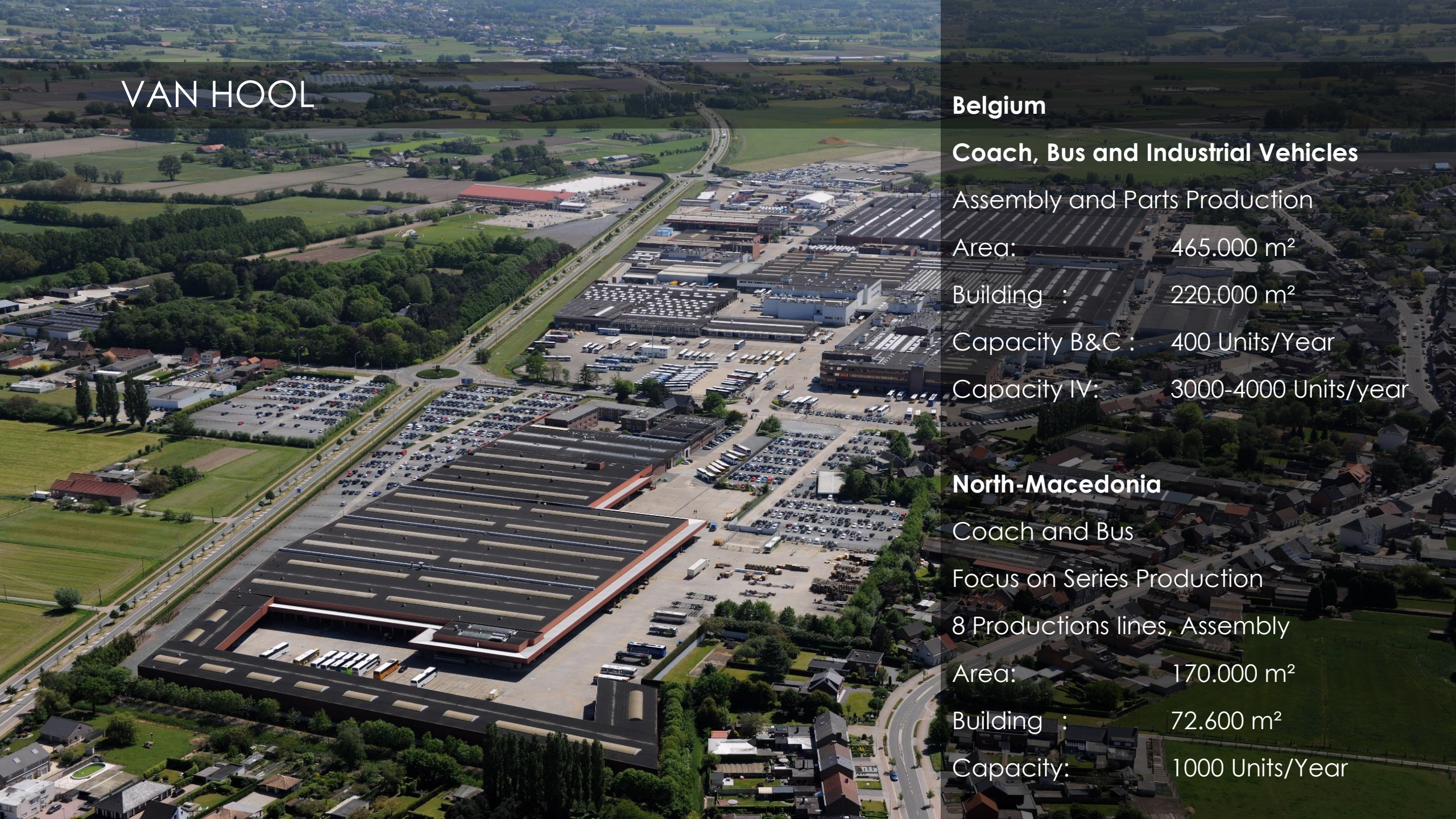
Coaches

Public transport

Industrial Vehicles

Bus & Coach markets and assembly plants





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

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

Van Hool Presentation on fuel cell bus developments

Agenda :

- **Van Hool – New A-line – 100% zero emission**
- **Fuel cell bus technology**
- **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**

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

Solutions provided or in process

	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

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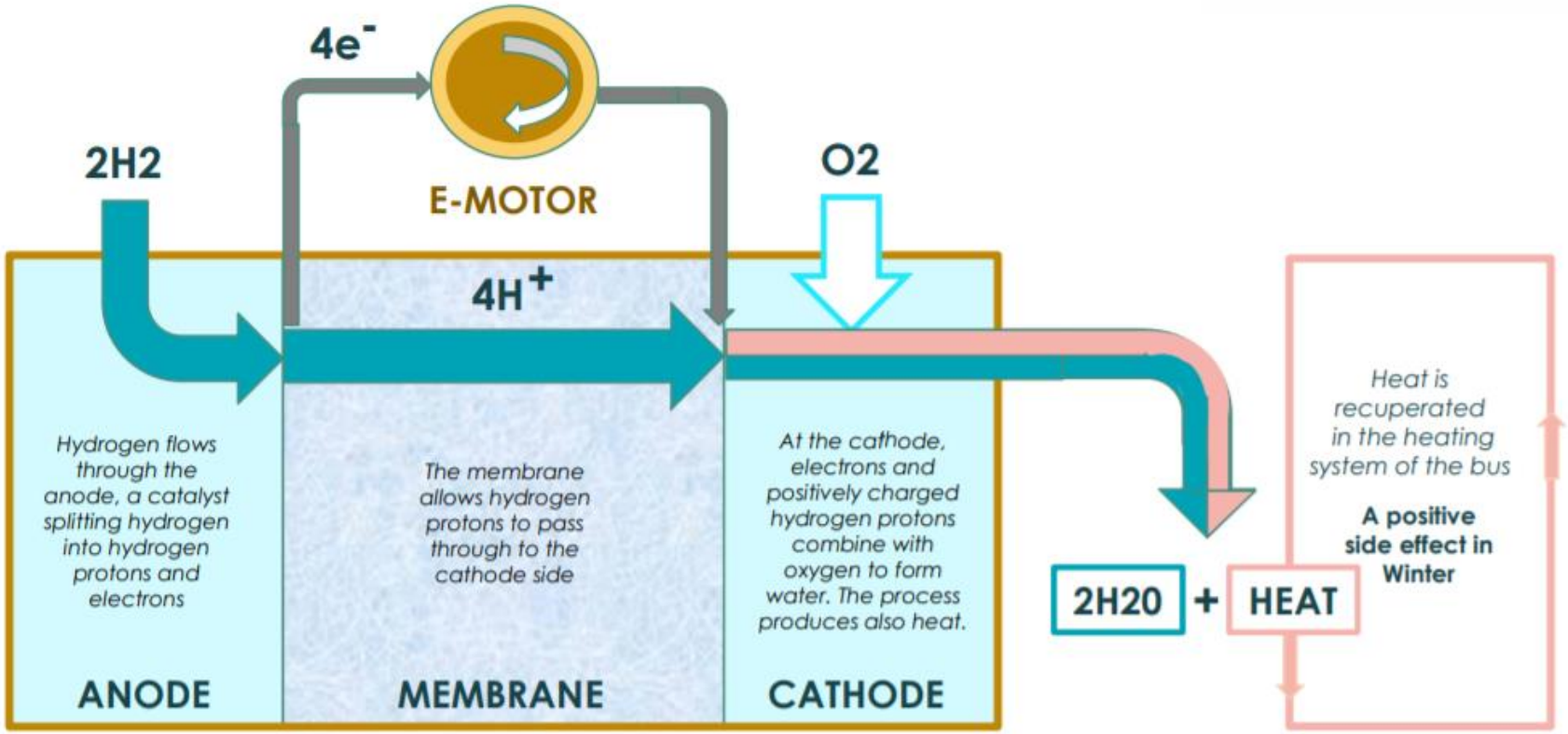
- **Fuel cell bus technology**
- **Fuel cell buses – looking backwards**
- **Fuel cell buses – looking forwards**

Fuel cell bus technology

The Fuel Cell



THE FUEL CELL (the chemical factory inside the bus)

Inside of the fuel cell are no moving or vibrating parts, which makes it a clean and silent generator of energy.

Fuel cell bus technology

Tank Protocol

Standardised H2 receptacle

Standardised charging protocol

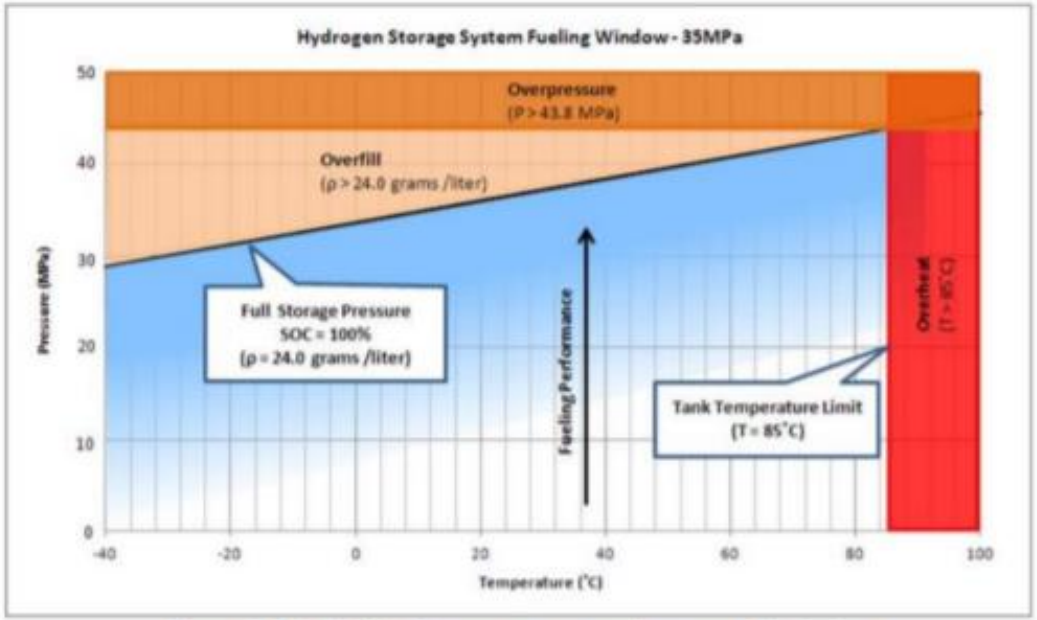


Figure 3 SAE J2601-2 temperature and pressure limitations

While charging the temperature and pressure are controlled simultanously at the bus and at the tankstation. The flow rate of hydrogen is optimised in relation to these parameters (T,P)

Fuel cell bus technology

Hybrid Bus

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.

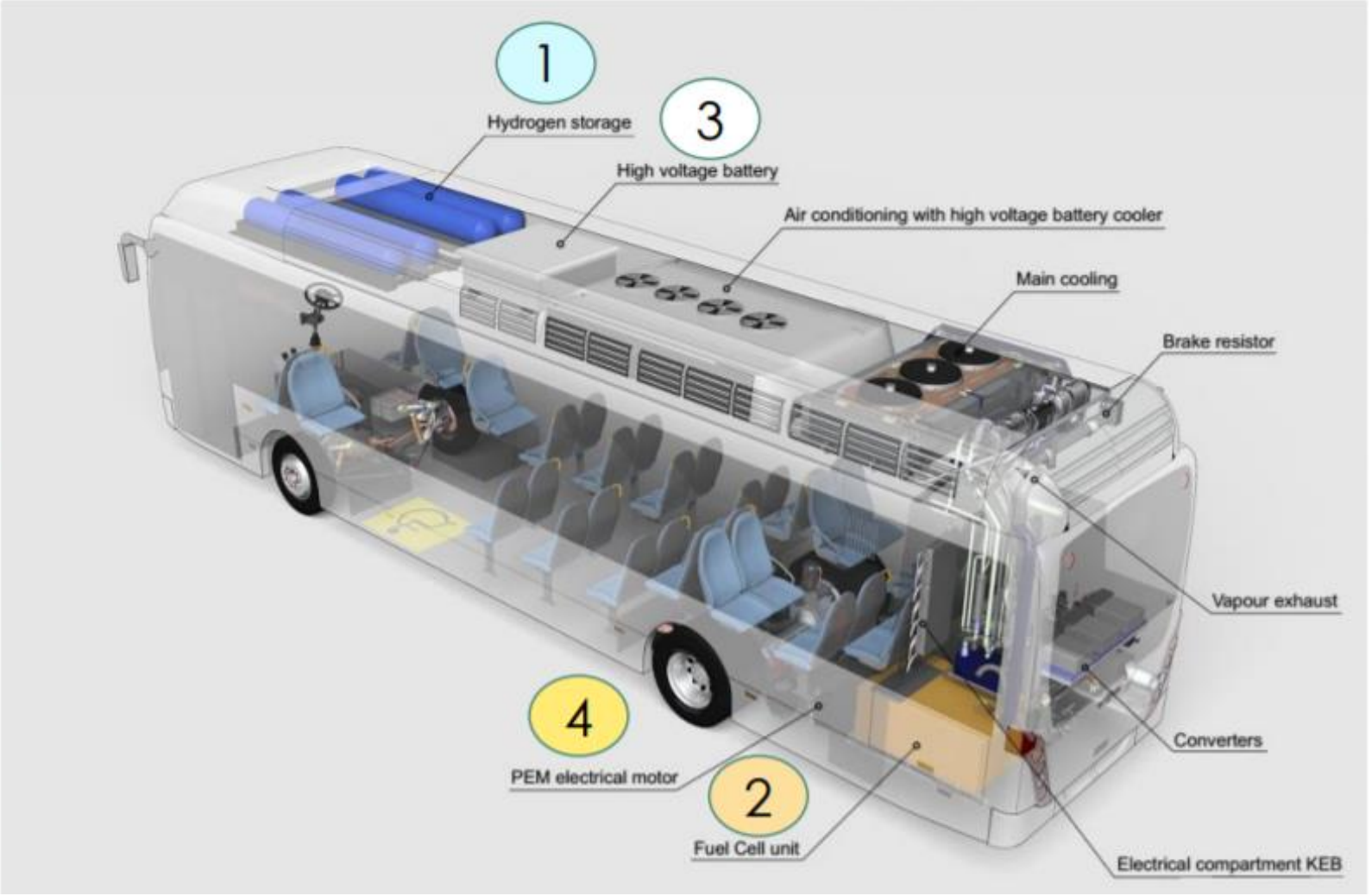
Traction battery 3

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.



Fuel cell bus technology

Communication Protocol

Fuel cell bus discussion topics :

1. **Choice for Tankprotocol with, IR and Fill'n Drive**

3 Possibilities :

- **With Harting Plug and Cable**
- **With IR-Protocol**
- **With Bluetooth Fill'n Drive-Protocol**

Fuel cell bus technology

Tank Type

Fuel cell bus discussion topics :

1. **Choice for Tankprotocol with, IR and Fill'n Drive**
2. **Choice for Tank Type**

Both Type 3 and Type 4 containers are offered :

Type 3: glas fiber reinforced Alu-Container
Type 4: glas fiber reinforced Composite Container

+/-	Type 3	Type 4
Weight	basis	+ 1 up to 2 Persons passengercapacity
Time to fill	basis	15 to 20% slower fill rate
Price	basis	basis

Fuel cell bus technology

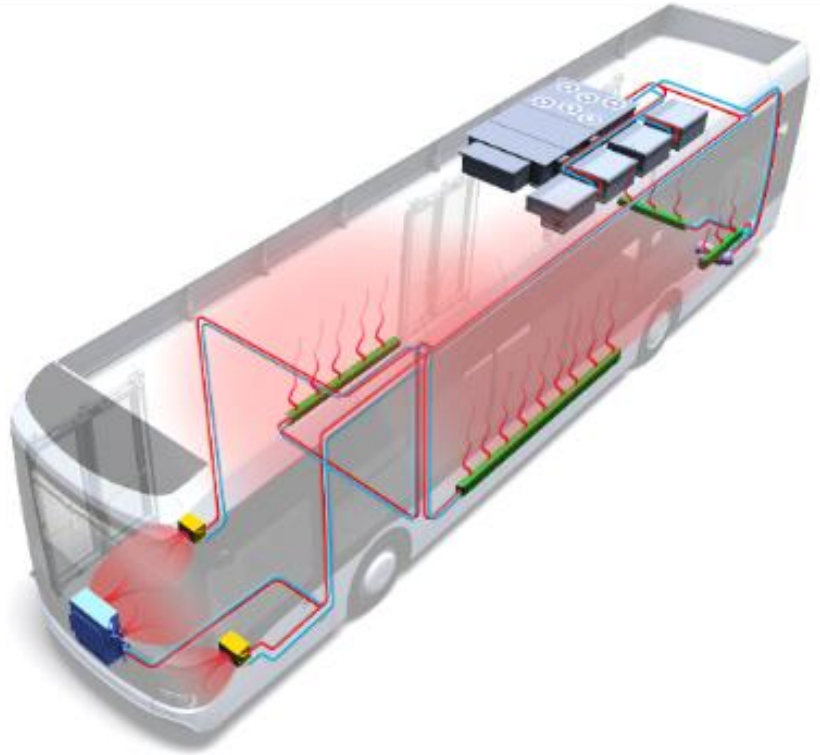
The Fuel Cell

Fuel cell bus discussion topics :

1. Choice for Tankprotocol with, IR and Fill'n Drive
2. Choice for Tank Type
3. Importance of climate strategy for fuel cell buses

Heatpump system
for driver's cab and passenger compartment
(including side wall convectors)

Recovery of waste heat
from the drive train and the fuel cell.

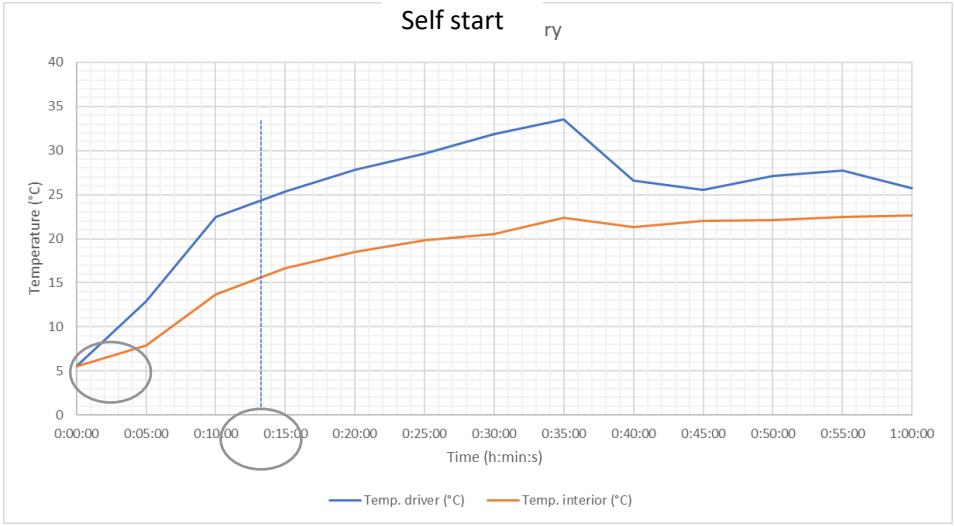


Fuel cell bus technology

Preconditioning

Fuel cell bus discussion topics :

1. Choice for Tankprotocol with, IR and Fill'n Drive
2. Choice for Tank Type
3. Importance of climate strategy for fuel cell buses
4. Strategy for preconditioning



2 Possibilities :

- Self start (no connection tot the grid)
- Combo Charging Plug (1 @ the front right)

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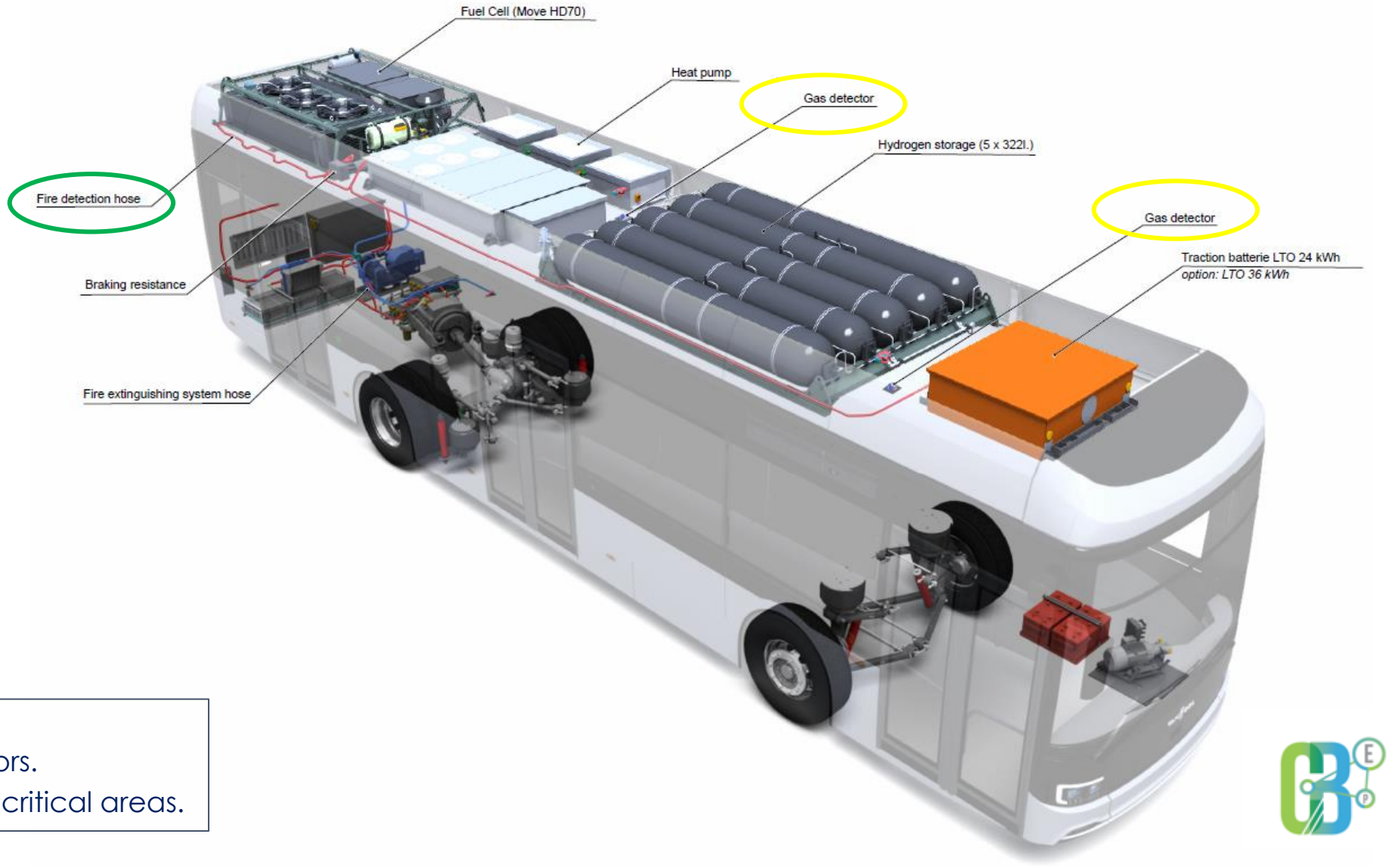
Fuel cell bus technology

Safety



Safety concept

- Several H2 gas detectors.
- Fire detection hoses in critical areas.

Fuel cell bus technology
A consistent approach towards safety

Safety

Safety measures on the bus

DETECT

Hydrogen sensors on the bus

GUIDE/EVACUATE

Bus design to guide potential hydrogen leak outwards towards sensors

STOP POTENTIAL SOURCES OF FIRE

Potential sourse of fire detected and extinguished by automatic Kidde system (motor compartment)

Safety measures in the workshop

DETECT

Hydrogen sensors at the roof of the workshop

GUIDE/EVACUATE

Automatic opening of gates to create air circulation
Automatic opening of roof hatches

STOP POTENTIAL SOURCES OF FIRE

Workshop specific safety drills

Van Hool Presentation on fuel cell bus developments

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- **Fuel cell bus technology**
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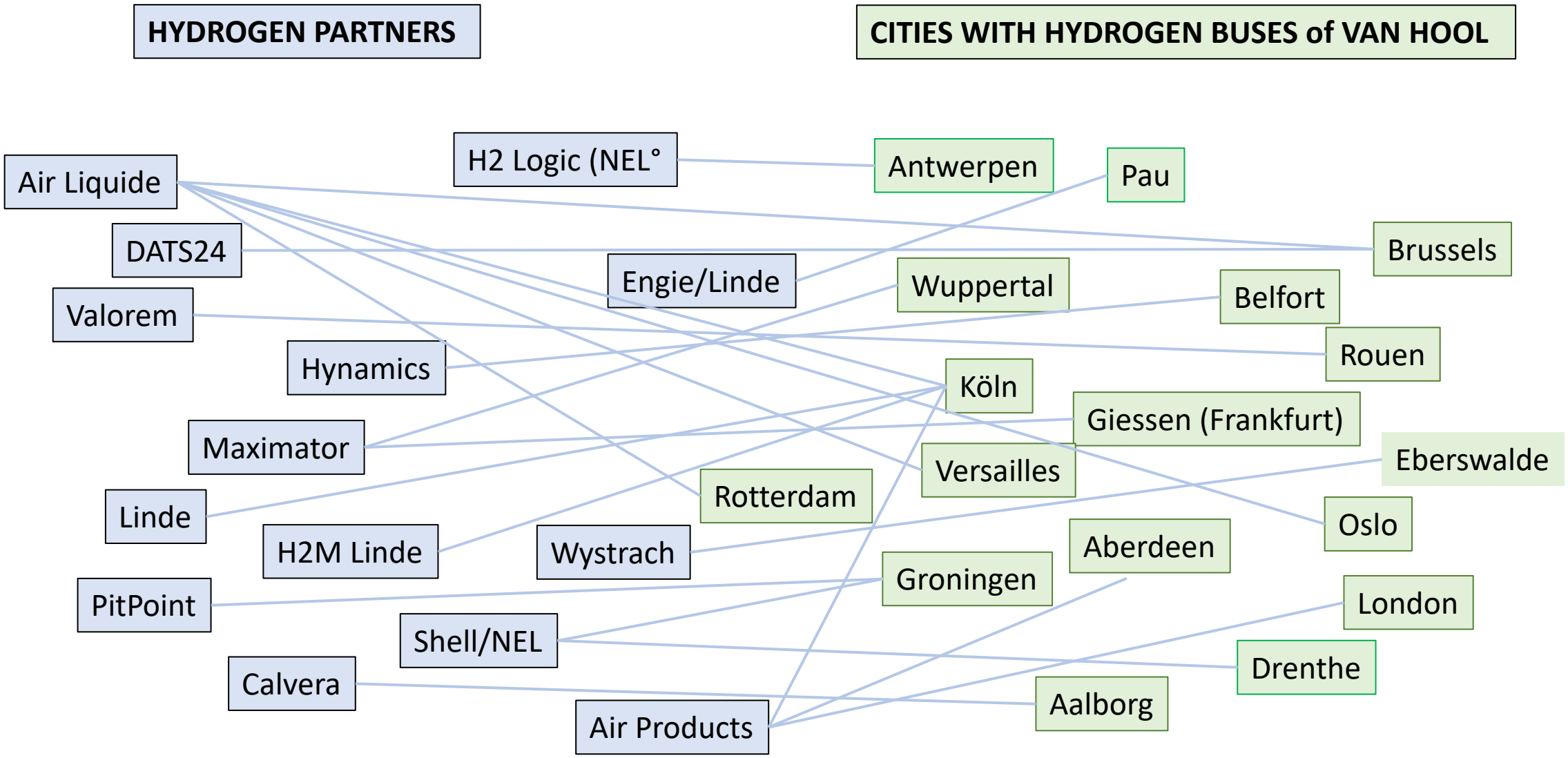
Fuel Cell Buses – looking backwards

Key facts :

- **208** Fuel Cell buses
- **+ 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 : from a solution for an inner crowd of believers …**
  - First fuel cell buses delivered in the USA in 2005
  - Then slow development

Time >	2005 - 06	2007	2008-09	2011	2012-15	2016+
Series				CHIC	High VLOCity HyTransit Cologne	3EMotion JIVE
1	1. gen. USA 2 axle					
2		1. gen. EU 3 axle				
3			2. gen USA 2 axle			
4				2. gen EU 3 axle		
5					3. gen EU 3 axle	
6						3. gen EU 2 axle
Nr. Buses	5	16	1	5	22	159

- **To becoming a mainstream solution**
  - Hydrogen one of the main topic on the last VDV electric bus conference

Fuel cell buses – looking backwards

Changing technology

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

Hydrogen bus lay-out for 3EMotion

Conventionel airco/heating

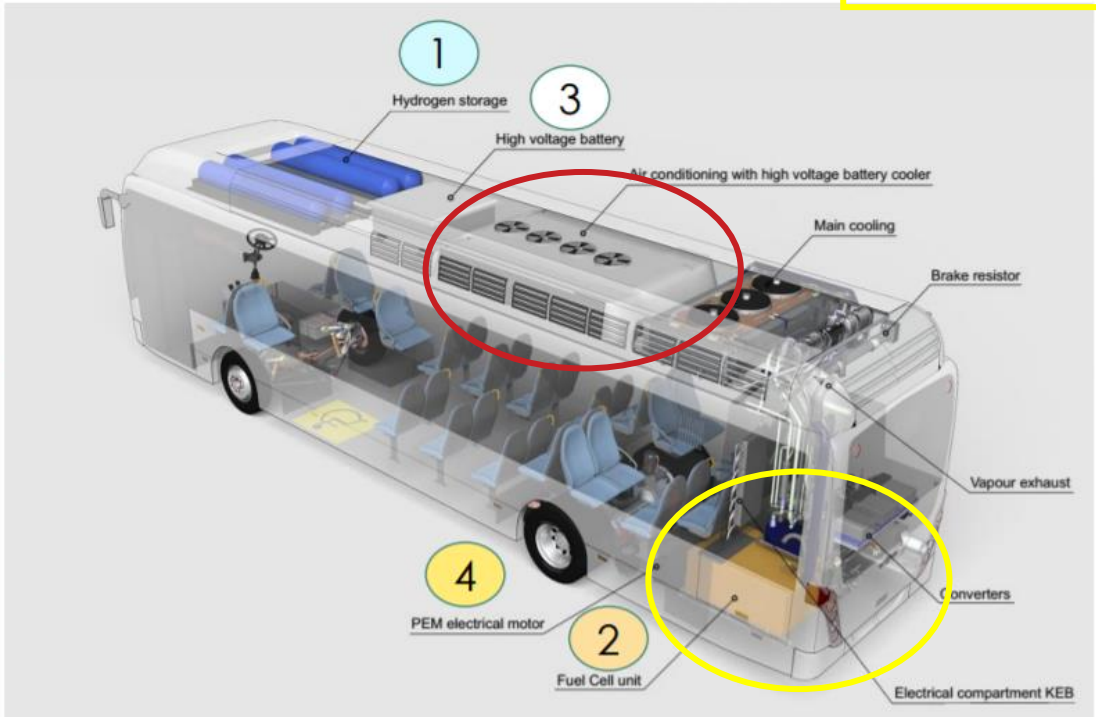
Fuel cell in the back

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

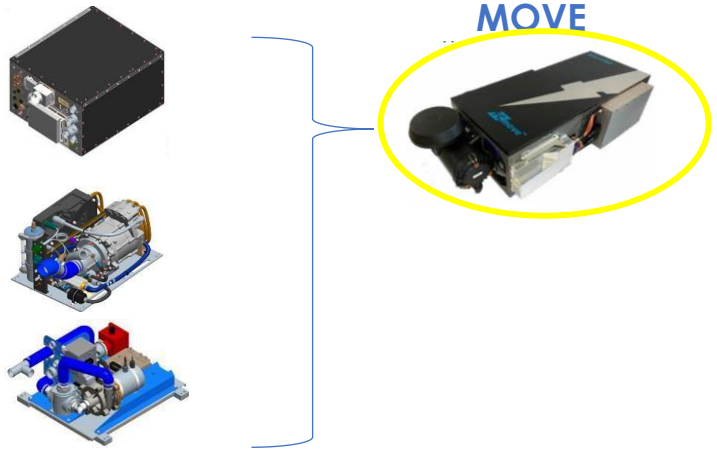
Changing technology

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

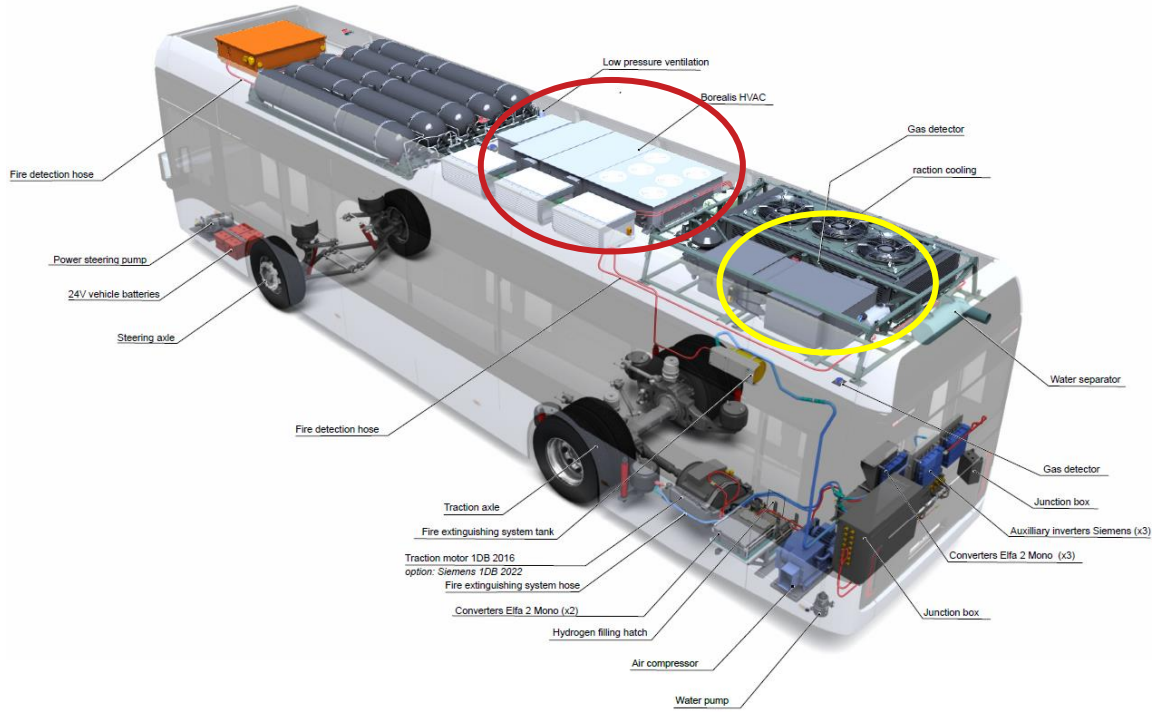
Hydrogen bus lay-out new A-Line

Heatpump

Fuel cell on the roof



Ballard FC MOVE



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

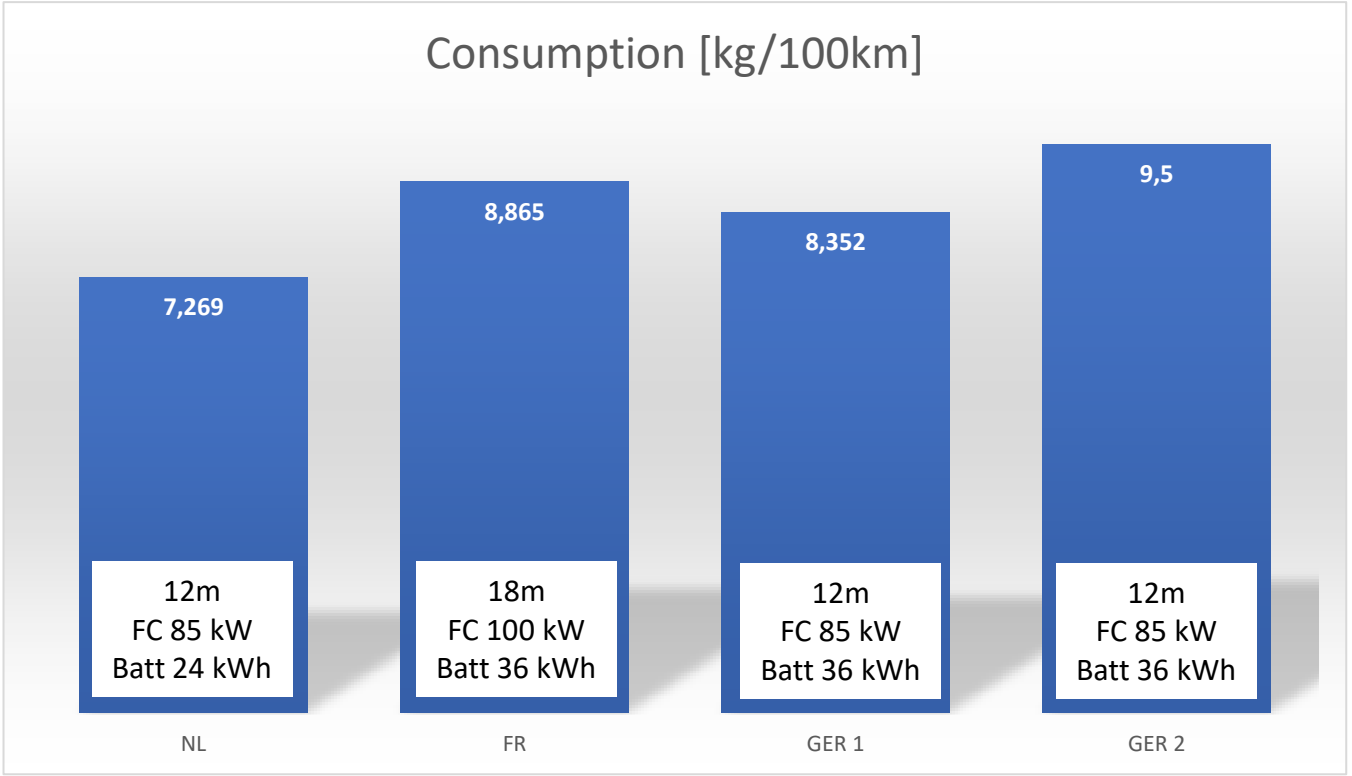
Fuel cell buses – looking backwards

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

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

Agenda :

- **Van Hool – New A-line – 100% zero emission**
- **Fuel cell bus technology**
- **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 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.

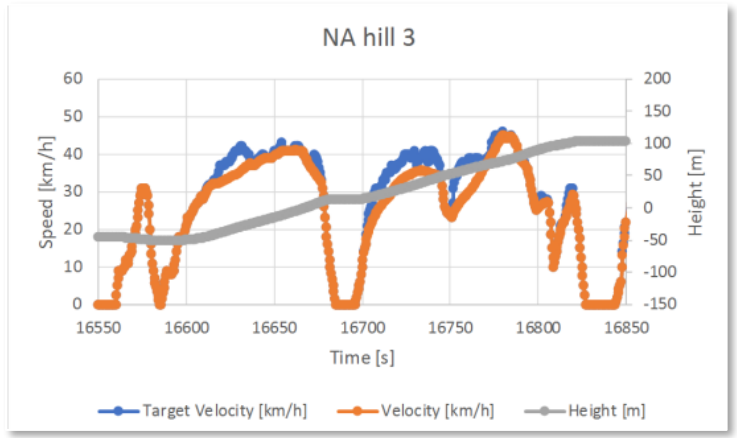
Fuel Cell buses – looking forward

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

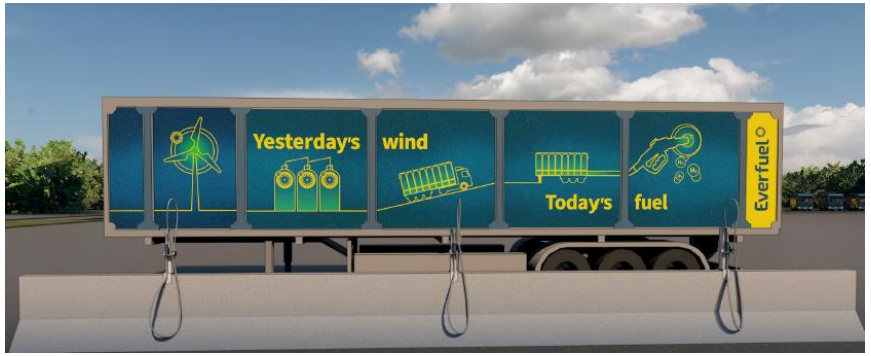
Fuel Cell buses – looking forward

Market driven choices

Technology neutral analysis of your specific situation

Every specific situation is different :

- Availability of H2 tank stations, H2 pipeline,…
- Availability of green hydrogen via flexible tank containers…
- Availabitity of space for the depot, and evaluation of market prices for space
- Availability of E-Grid ; evaluation of the E-Grid stability
- Etc…



Picture of Everfuel H2 Flexible Solution – hydrogen delivery via Milkrun

Fuel Cell buses – looking forward

Market driven choices

In-house charging infrastructure for testing @ high volumes

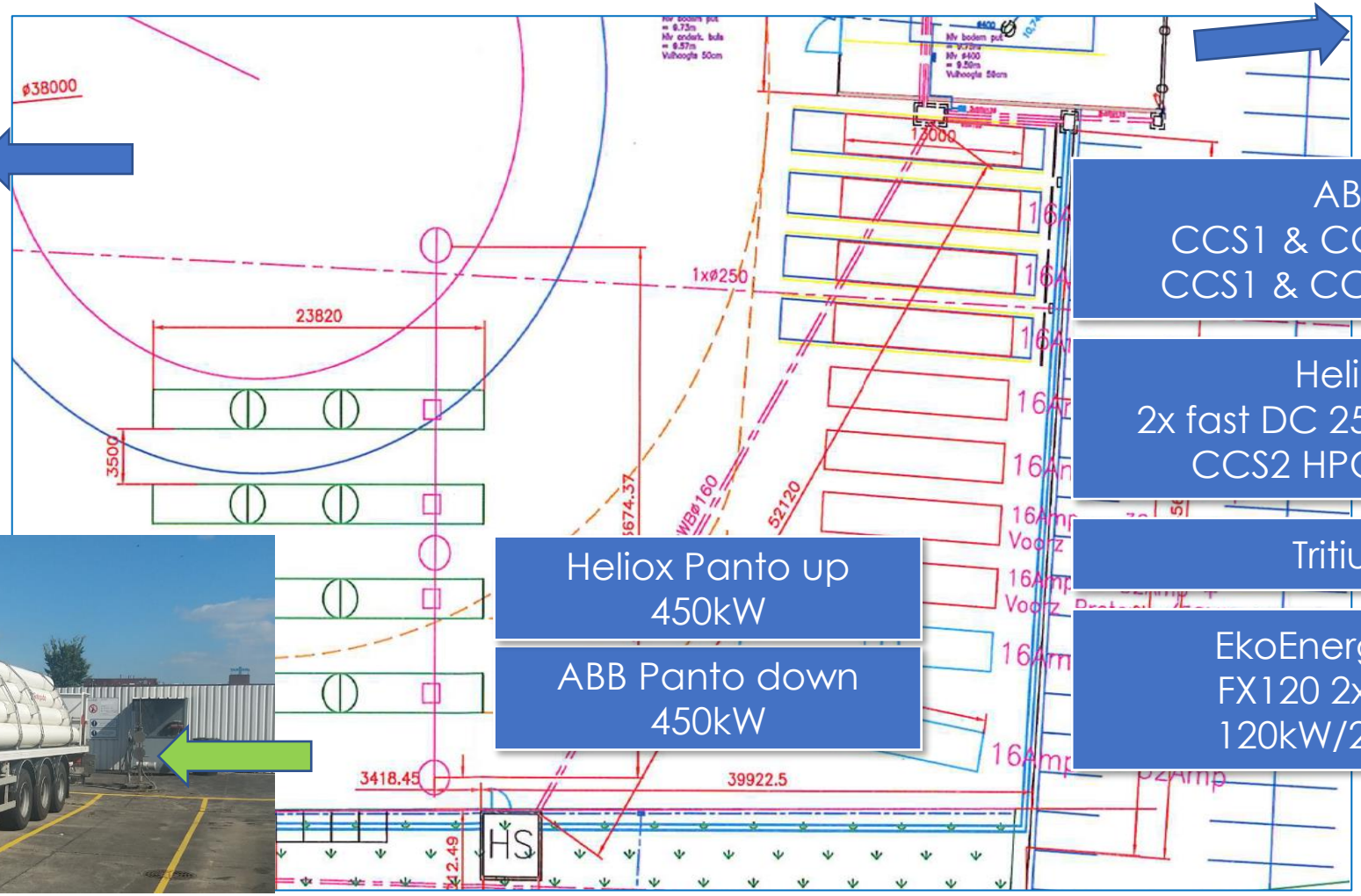


ABB
CCS1 & CCS2 50kW
CCS1 & CCS2 180kW

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!

The recording and slides will be available soon at

www.cleanbusplatform.eu

Questions & Answers