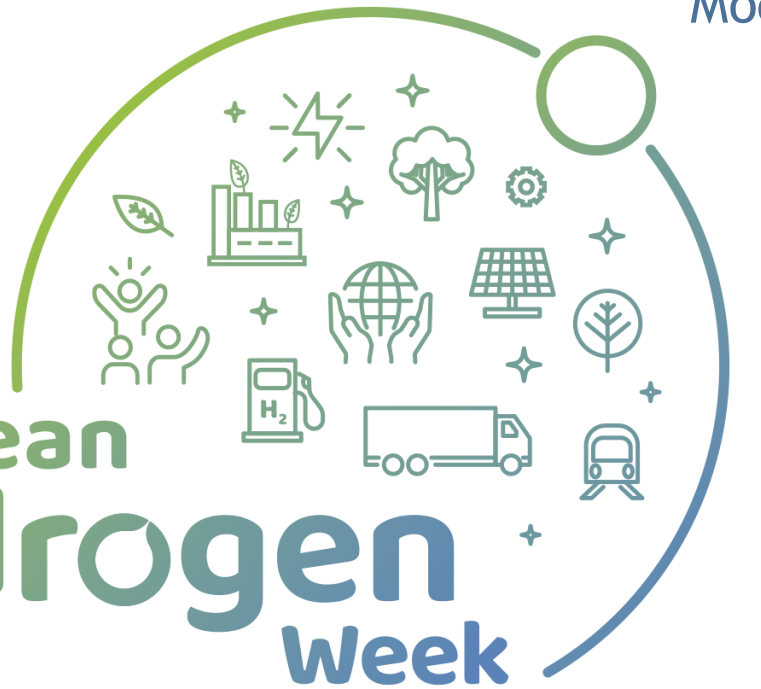
JIVE & JIVE 2

Joint Initiative for hydrogen Vehicles across Europe

MEHRLIN

Models for Economic Hydrogen Refuelling Infrastructure



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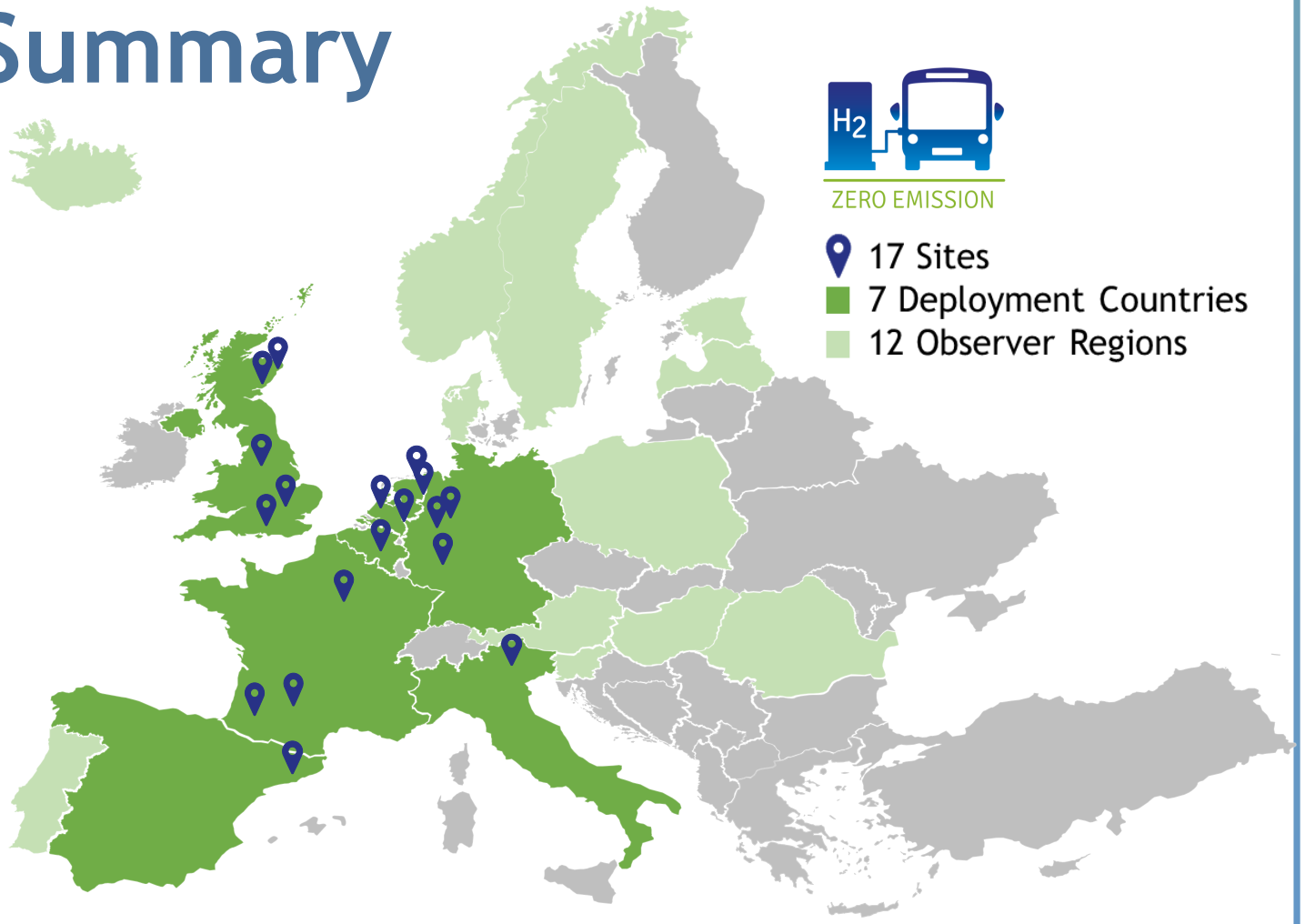
Project Overview

	MEHRLIN	JIVE	JIVE 2
Funding body:	CINEA	FCH 2JU	FCH 2JU
Call year:	2015	2016	2017
Call topic/Project #:	2015-EU-TM-0316-S	FCH-01-9-2016	FCH-01-5-2017
Project dates:	Jul 16 – Dec 22	Jan 17 – Jun 24	Jan 18 – Dec 24
% stage of implementation:	82%	71%	53%
Total project budget:	€11.2 million	€110.3 million	€106.6 million
Funding contribution:	€5.5 million	€32 million	€25 million

European Hydrogen Week

Projects Summary



Objectives:

- Deploy 310 fuel cell buses
- 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

- Deploy 17 Hydrogen Refueling Stations (7 HRS financed under MEHRLIN)
- Enable new cities & regions to trial hydrogen technologies
- Demonstrate routes to low cost renewable H2
- Stimulate further large-scale uptake of fuel cell vehicles

European funding from the FCH JU for the JIVE & JIVE 2 projects and CEF funding for MEHRLIN **catalyses private and public investment** on the national and regional level.

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Project Progress \1

Status of deployment activities: Buses

Bus Deployment

190/310 Operational
276/310 Ordered

25% 50% 75%

- By the end of 2021, all buses will be ordered and **190 buses across 15 sites will be fully operational**.
- JIVE operators are deploying FCBs from 6 suppliers: Caetano, Optare, SAFRA, Solaris, Van Hool, Wrightbus.
- PTOs are basing deployments on **operational lifetime expectation of 8-15 years**.
- Overall, buses are performing well in the early operation phase, although there are still a few teething issues.

Fuel cell buses operating in Auxerre (SAFRA, top left), Wiesbaden (Caetano, top right) and Aberdeen (Wrightbus, bottom)

Project Progress \2

Status of deployment activities: HRS

HRS Deployment

9/17 Operational
4/17 Commissioning
4/17 Civils Works

25% 50% 75%

- All contracts for HRS/H2 supply will be finalised and **9 HRS will be fully operational December 2021**.
- All HRS will be fully operational by December 2022.
- Several operators will use alternative local HRS / **mobile HRS configurations due to delays in civil works**.
- **Project HRS from 15 suppliers**: Air Liquide, Air Products, BOC, Engie, Everfuel, Elogen, HyPort, Iberdrola, ITM Power, Linde, Maximator, McPhy, Nel, Ryze and Shell.

HRS at the RVK depot in Cologne, Germany (left) and Auxerre, France (right)

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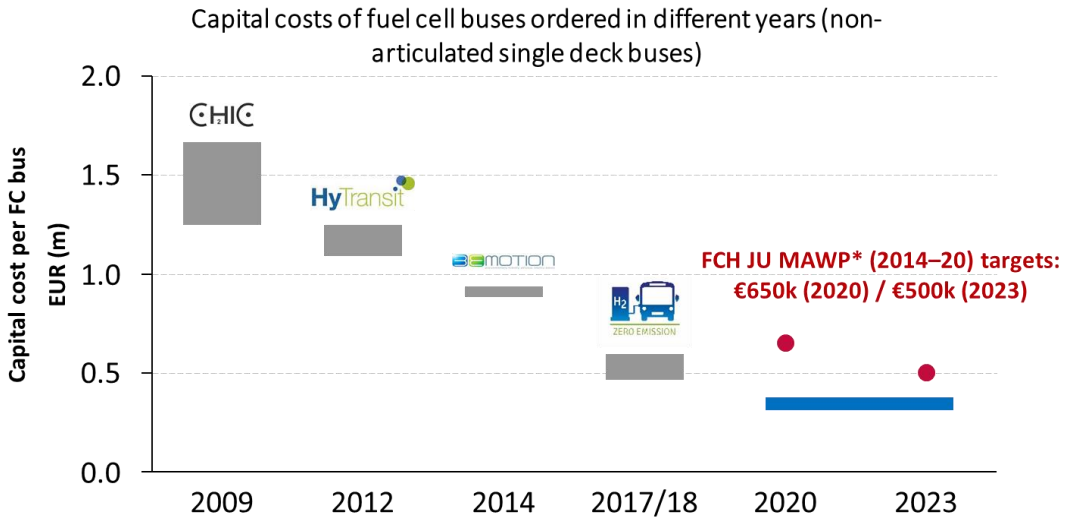
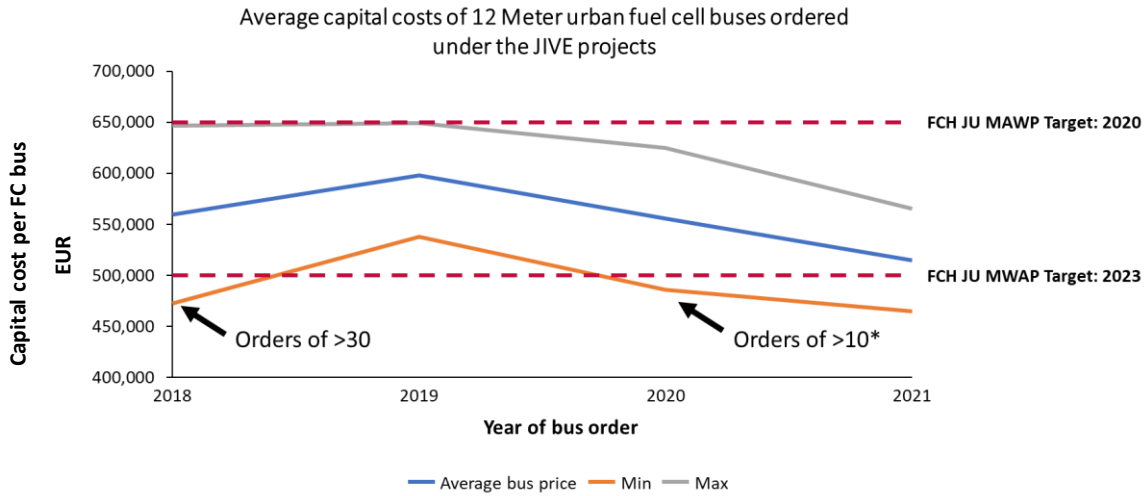
Project Progress \3
Fuel Cell Bus Costs

Actual bus capex – historic FCB projects



Early 2020's: Some OEMs considering commercial rollout indicate capital costs of <€400k/bus are possible, assuming orders of 100 buses per year and continuity of demand. **Average costs per bus are below the FCH JU MAWP targets for 2020** and on track for the 2023 target.

Actual bus capex – JIVE & JIVE 2



Average capital costs of FCBs has decreased substantially since the first orders were made under JIVE in 2018. **Minimum costs are accessible for vehicle orders of >10 buses**. Costs from several suppliers is still >€500,000 per bus; price varies dependent on specifications.

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Key Lessons Learned & Next Steps

Key Lessons Learned

- Multiple sources of funding means EU funding is well leveraged, but this adds complexity and timescale challenges.
- Operators need to **procure HRS & H2 supplies in parallel with buses**.
- **New financing models** are being developed to address the challenge for operators to commit to ordering large fleets without full certainty over lifetime costs ("all-in" offers, leasing, warranty extensions etc).

Next Steps

- Sites beginning to plan for **post-JIVE FCB deployment** across various vehicle types (12m, 18m, coaches) from new suppliers.
- **Collect and analyse data from bus & HRS operations** to validate fuel cell bus deployment for fleets of 10-50 buses.
- Increased **sharing of best practices** & training for new cities & operators.

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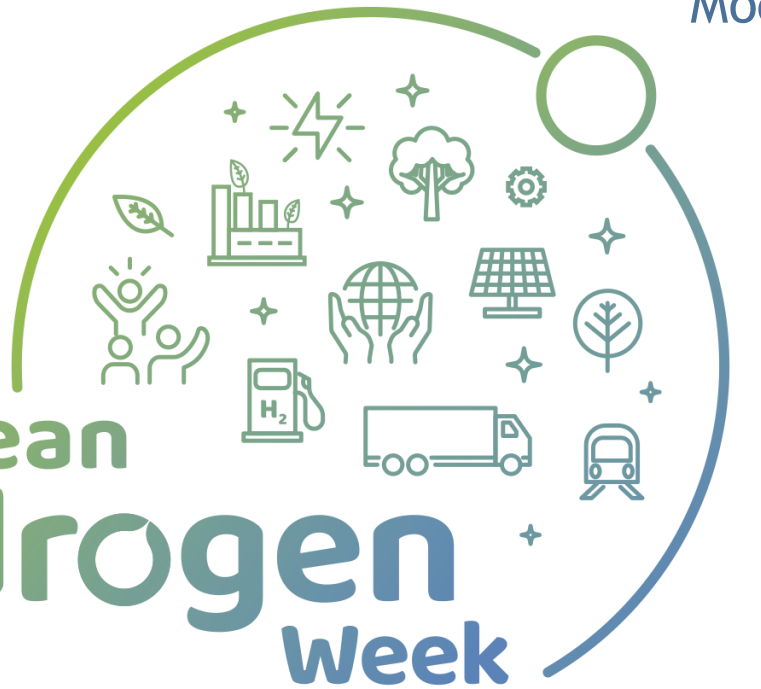

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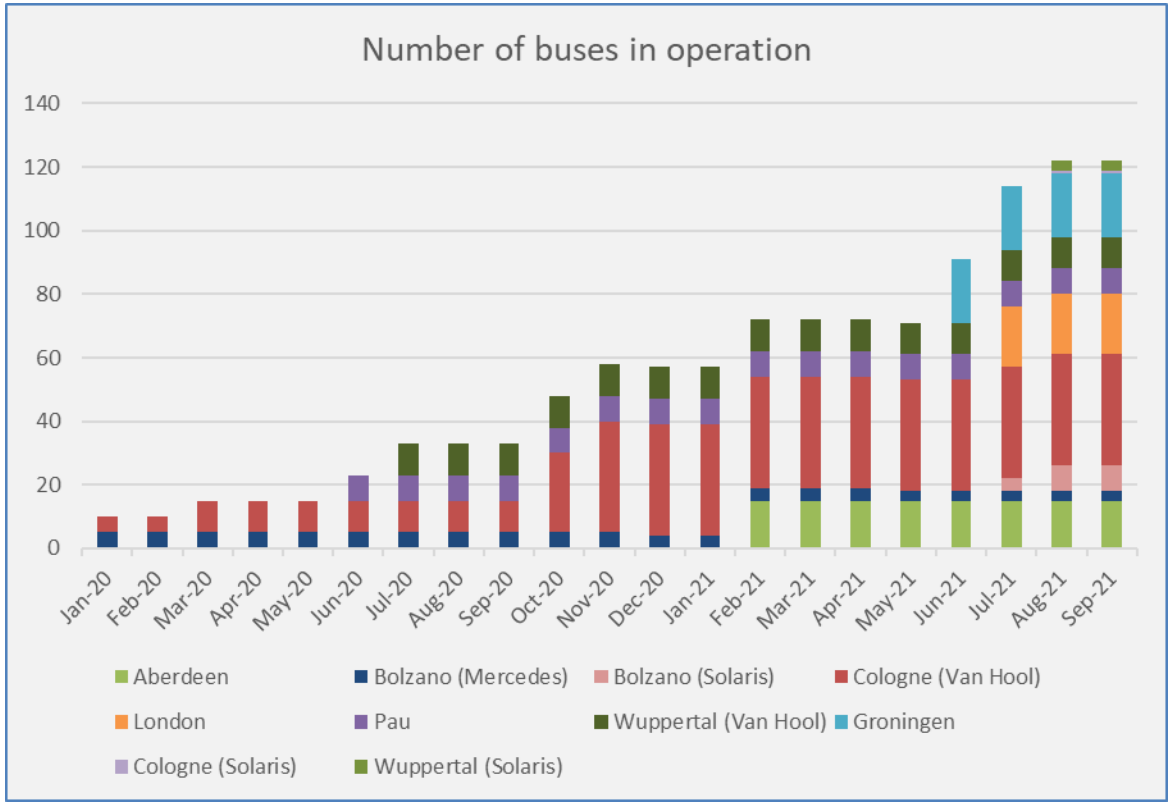
Buses in operation

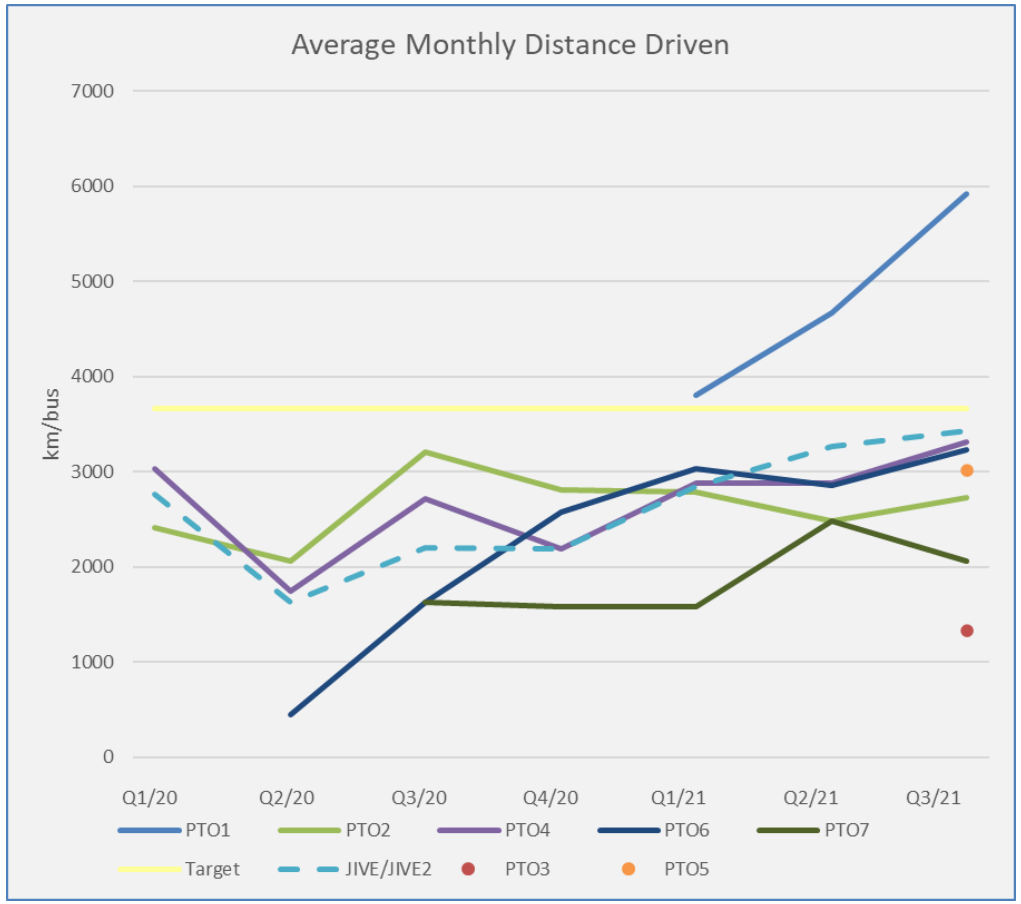


Seven sites in regular operation

- Bolzano: Former CHIC buses (**5, now 3**) and **8** Solaris buses from July onwards
- Cologne: Largest VanHool bus fleet starting with **5** in Jan 20, now **35** vehicles, **1** Solaris bus since Aug 21
- Wuppertal: **10** Van Hool and **3** Solaris buses
- Pau: First JIVE2 site, **5+3** VanHool 18 m buses operational since Dec 2019
- Aberdeen: **15** Wrightbus double deckers
- London: **20** Wrightbus double deckers since Jul 21
- Groningen: **20** buses since Jul 21 (no data yet)

Bus data from latest operational sites still being collected and processed by PTOs (around 70 %)

Average Monthly Distance Driven



- **PTO1**: From the start very high mileage, increasing
- **PTO6**: Continuous ramp up
- **PTO4**: Technical issues with data transmission and flooding resulted in low mileage in summer 2020, after that increasing
- **PTO2, 7**: High fluctuation on rather low level
- **PTO3, 5**: Just started (teething period)

Target >3.667 km/(bus*m): Most sites do not reach target, largely as a result of **continued drop in usage** due to the covid pandemic and **teething problems**

On average **continuous positive trend** and **target almost met**

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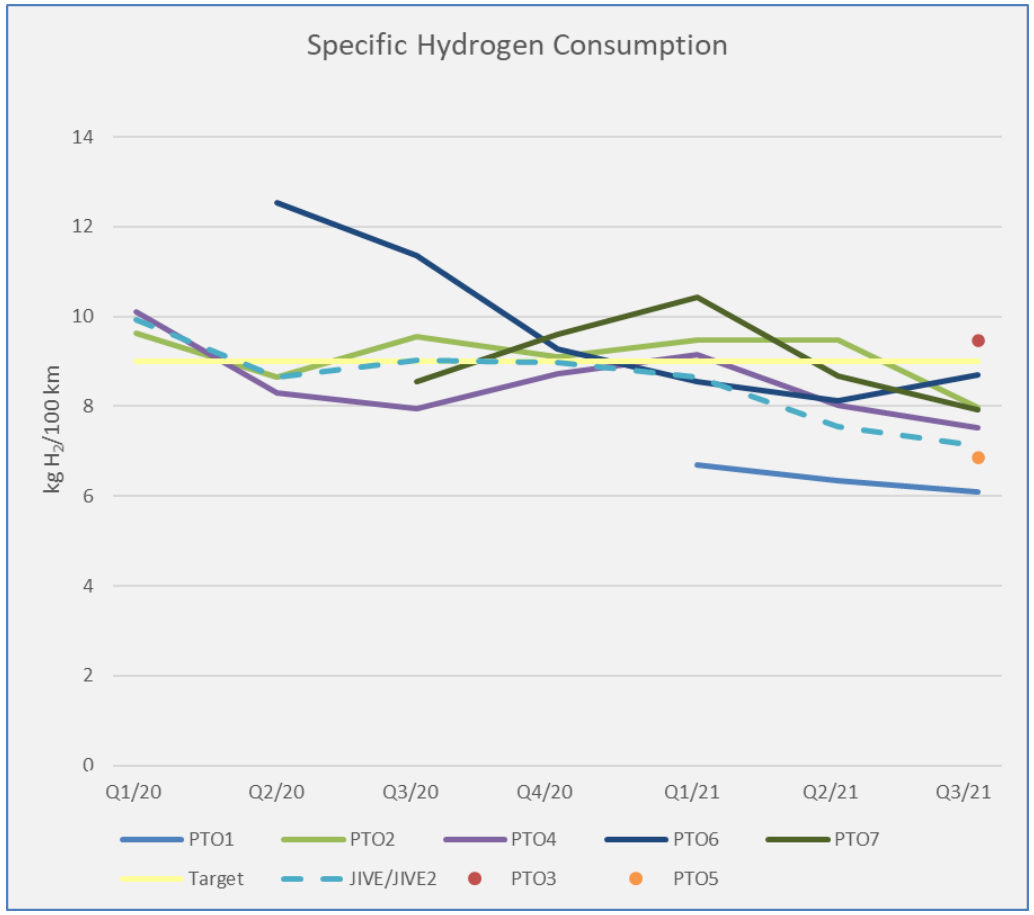
Hydrogen Consumption



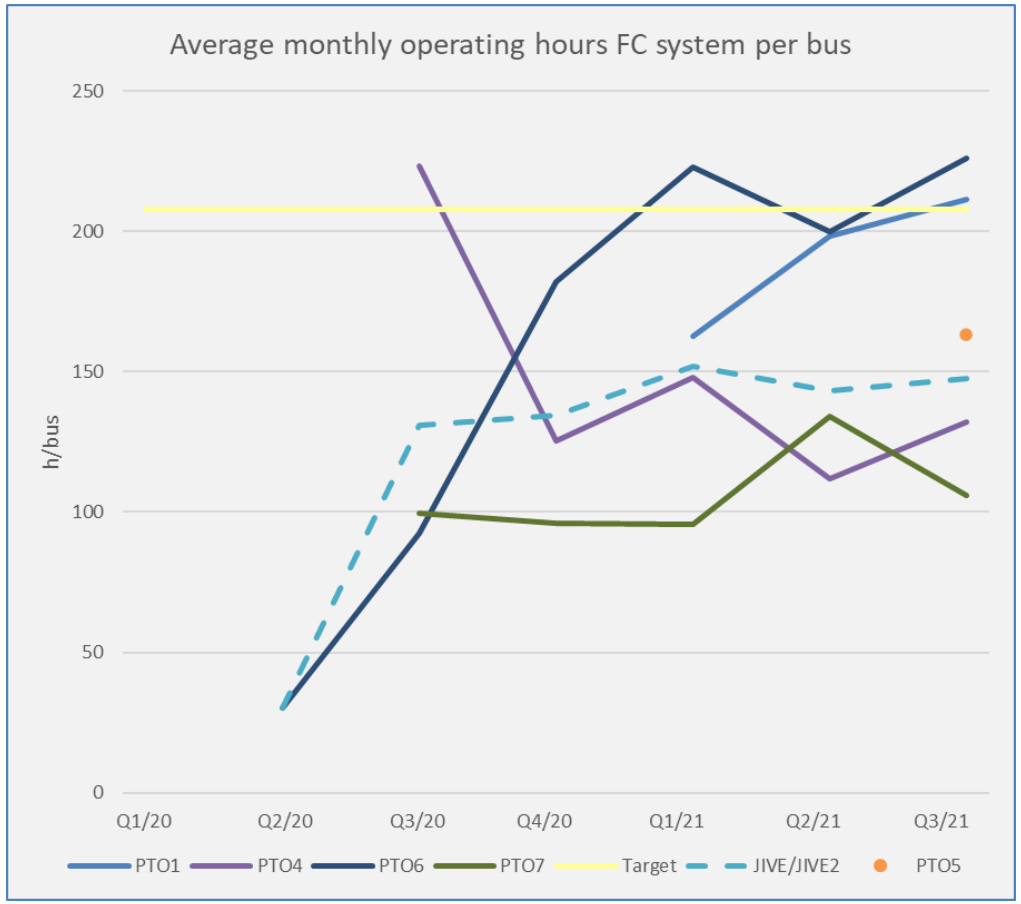
- **PTO1**: Remarkably low consumption from the start with Ø 6.3 kgH_2/100 km
- **PTO6**: Significant decrease over time with Ø 9.0 kgH_2/100 km
- **PTO4,7:** Seasonal fluctuation, increase in winter. Same bus model with Ø 8.4 and Ø 9.0 kgH_2/100 km
- **PTO2**: Consumption derived from HRS data Ø 9.3 kgH_2/100 km

Target <9 kgH_2/100 km (solo) / <14 kgH_2/100 km (articulated): **All PTOs have met the target** except PTO3 (teething period)

Total average consumption **Ø 8.05 kgH_2/100 km**

Consumption of articulated and double decker buses at or even below the level of solo buses

Fuell Cell Hours



- **PTO1, 6**: Continuous increase in line with mileage, target reached
- **PTO7**: Correlation with rather low mileage
- **PTO4**: Data points impacted by transmission problems, to be examinated
- **PTO5**: Teething period

Measurement of data point challenging, not yet available for all sites

Incomplete data could be circumvented by **extrapolation**

Target >208 h/(bus*m): Two sites meet target, on average stagnation/**slightly positive trend** around **150 h/(bus*m)**.

Correlates with limited distance driven.

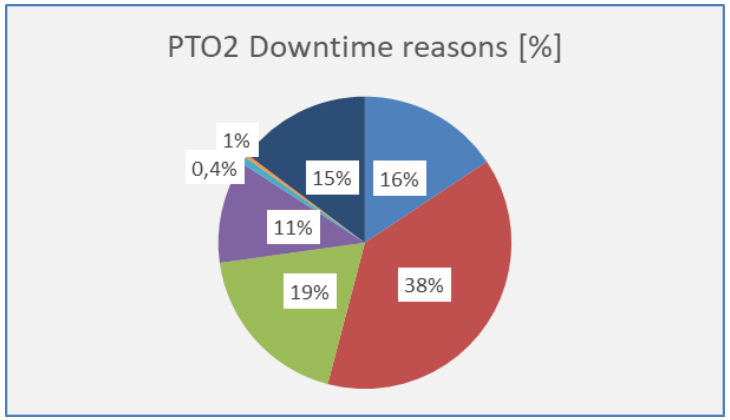
Mean Distance between Failures (MDBF)

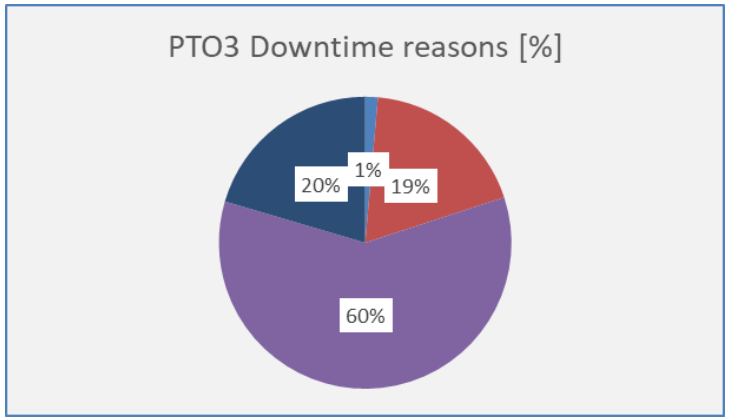
Recording of downtime **(duration of downtime) varies significantly between sites.** Various sites face difficulties to report downtime according to TRUST criteria.

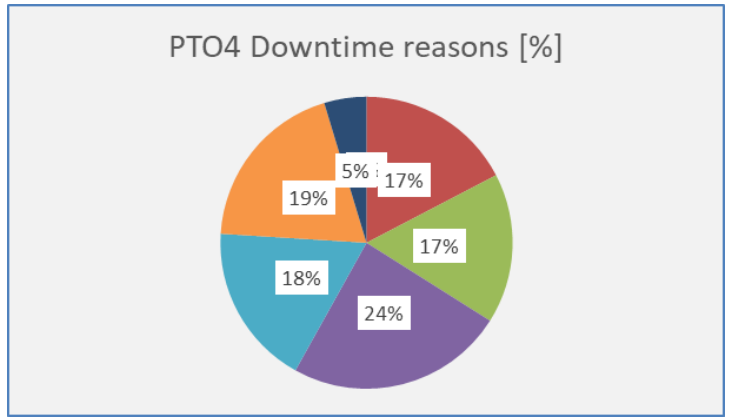
Target >2.500 km. Rather low current values are attributed to **former CHIC buses** still in service and numerous **teething issues** in the beginning.

KPI may be affected by a low number of buses: (Long) failure of one bus has significant impact, leading to extreme fluctuations

Fuell Cell Hours







- **PTO2**: longest monitoring of downtimes, **FC stack** issues as main cause
- **PTO3**: Main cause **electrical components** (2 months of monitoring)
- **PTO4**: Downtime reasons quite equally distributed, main cause **electrical components**

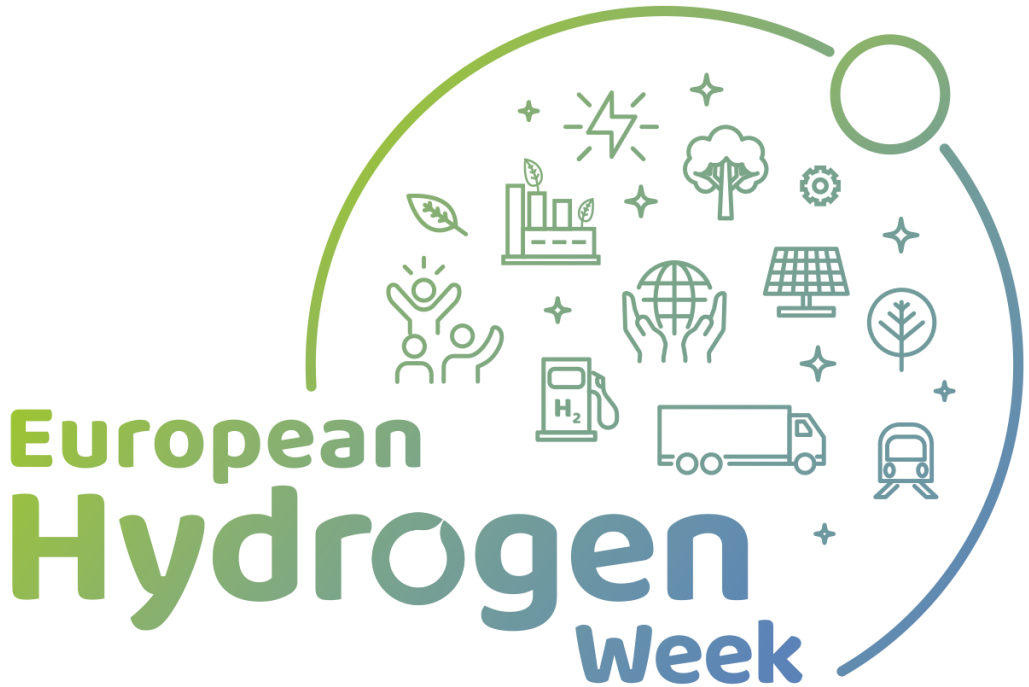
Not all bus operators report all downtime categories, and reasons for downtime and associated downtime duration may differ between sites.

Comparison of downtime duration and distribution should be taken with care.

Summary

FC Bus Operation

- More and more sites become operational. **High increase of new sites and data** expected in the next months.
- Increasingly more sites start operation with buses from **different OEMs**
- Current performance data highly impacted by teething phase and additionally the covid pandemic. Generally **positive trend**.
- **Data availability and harmonization** is ongoing task
- **Long-term evaluation** and data from **more sites** will allow **further insights**



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