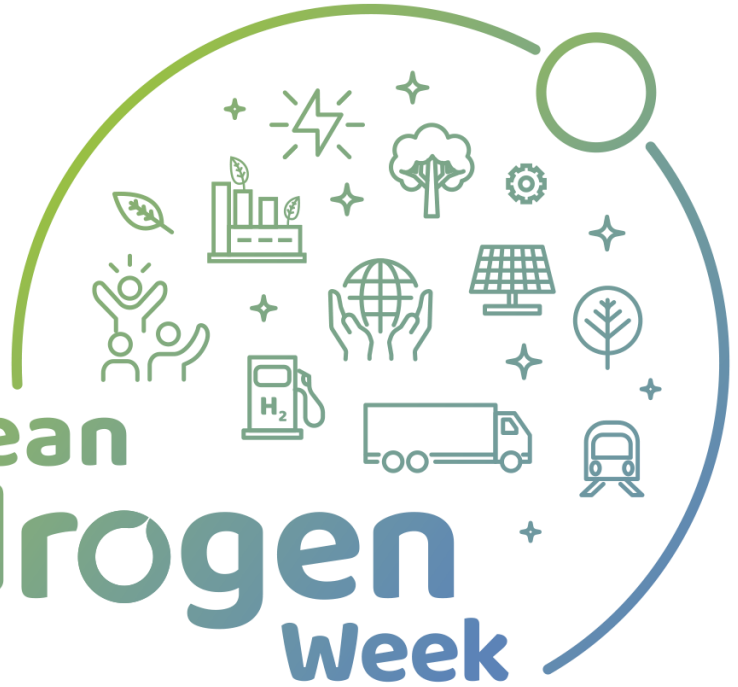
H2ME | Hydrogen Mobility Europe

ZEFER | Zero-Emission Fleet vehicles for European Roll-out

Hydrogen Mobility Europe

ZEFER



http://h2me.eu | https://zefer.eu/

@H2ME_eu | @ZEFER_EU

Coordinator: elementenergy an ERM Group company

Lisa Ruf, Element Energy | Victor Lejona, Cenex

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cenex

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The H2ME and ZEFER projects are part of a family of FCH JU projects

European Hydrogen Week

Light duty vehicle demonstration

Heavy duty vehicle demonstration

FCEV: Fuel Cell Electric Vehicles
HRS: Hydrogen Refuelling Stations
TRL: Technology Readiness Levels

2010 → **2015** → **2022/2025**

Pre-commercial demonstration projects - early TRL	Transition to commercial deployment
SWARM, HYTEC, hyFIVE	Hydrogen Mobility Europe, ZEFER
CHIC, HIGHVLOCITY, HyTransit, NewBusFuel	H2 ZERO EMISSION, H2HAUL, H2BUS, CORRIDOR H2 OCCITANIE
First small scale demo projects for HRS, passenger cars & buses	Pre-commercial deployment with hundreds of HRS, passenger cars & buses First small scale demo projects for trucks

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H2ME Projects Overview

- Call year: 2014 and 2015
- Call topics:

FCH-01.7-2014 & FCH-03.1-2015

- Project dates:

06/15-11/20 & 05/16- 06/23

- % stage of implementation : c. 80%
- Total project budget: €170m
- FCH JU max. contribution: €67m

- Partners:

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European Hydrogen Week

H2ME Projects Summary

- To date the project has deployed another **3 models / generations of FCEVs** and **x3 the number of vehicles on the road in Europe.**
- Added **HRS at key nodes of the EU infrastructure in 8 countries** and **increased the number of equipment OEMs / operators.**

2015 — Hydrogen Mobility Europe — **> 1.400 cars, and vans** — **> 45 HRS** — **2023**

1st commercial generation FCEVs


2nd commercial generation FCEVs


HRS deployment

20 HRS operational with green or low carbon hydrogen delivered for ~ 40% of the stations

13 HRS in France including 7 with on-site electrolysis

6 HRS including 5 with on-site electrolysis

9 HRS with all stations receiving hydrogen from decentralised electrolyzers

Hydrogen Mobility Europe

A MAJOR EUROPEAN ACTIVITY!

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Increased number of suppliers, 3rd generation FCEVs, EU wide HRS network

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H2ME Project Progress
Status of deployment activities

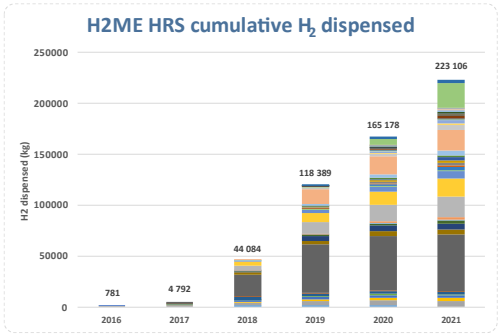
Deployment

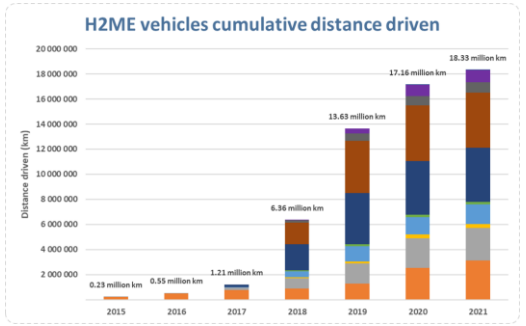
Vehicles: 0%
HRS:0%

Vehicles: 60% HRS: >80%

Vehicles: 100%
HRS: 100%

25% 50% 75%





Since 2015:

- H2ME **vehicles** have reported over **18 million km** driven.
- H2ME **HRS** have dispensed over **223 tonnes** of H_2.
- (Not all H2ME vehicles use H2ME HRS to fuel, and not all H2ME HRS fuel H2ME vehicles).

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ZEFER Project Overview

- Call year: 2017
- Call topic: FCH-01-6-2017: Large scale demonstration of Hydrogen Refuelling Stations and Fuel Cell Electric Vehicle (FCEV) road vehicles operated in fleet(s)
- Project dates: 01/09/2017 – 31/08/2022
- % stage of implementation: c.90%
- Total project budget: €17.56 million
- FCH JU max. contribution: c. €5 million

- Partners:

hype by STEP – Société du taxi électrique parisien
Air Liquide – creative oxygen
DRIVR
TOYOTA
Mairie de Paris
greentomatocars
Metropolitan Police
ITM POWER – Energy Storage | Clean Fuel
cenex
elementenergy
The Linde Group
BMW

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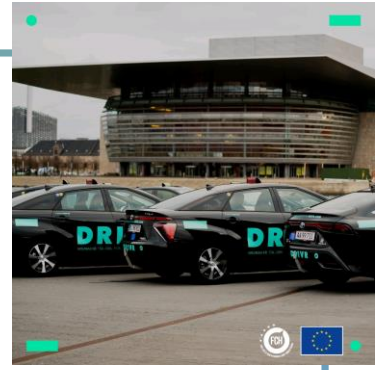
ZEFER Project Progress
Status of deployment activities



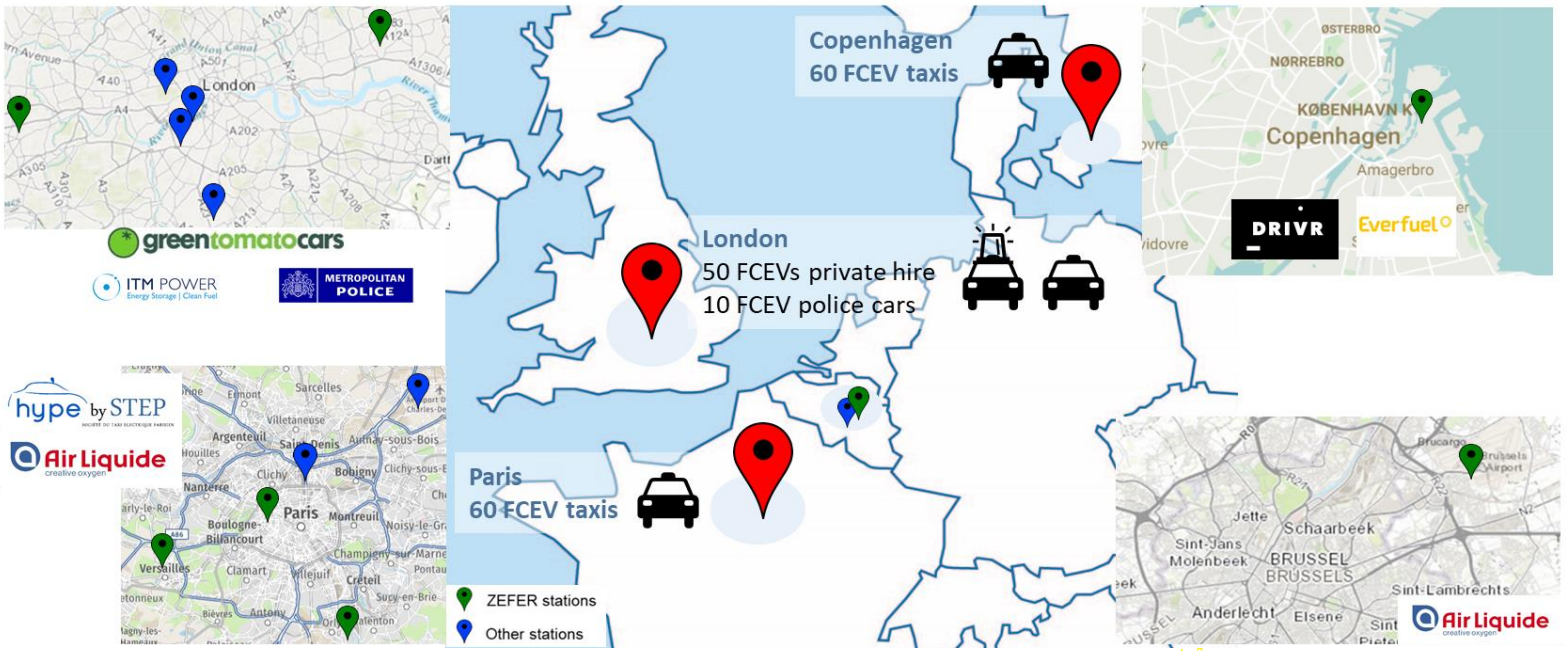
Deployment

0 FCEVs
0 HRS upgrades

180 FCEVs
3 upgrades

180 FCEVs
4 HRS upgrades

25% 50% 75%



- **All project vehicles have been delivered.**
- **Close to 5.8 million kilometres** amassed since April 2018.
- HRS upgrades have been completed in London and Brussels and nearly **51 600 kg H2 of hydrogen has been dispensed** since the beginning of the project*.

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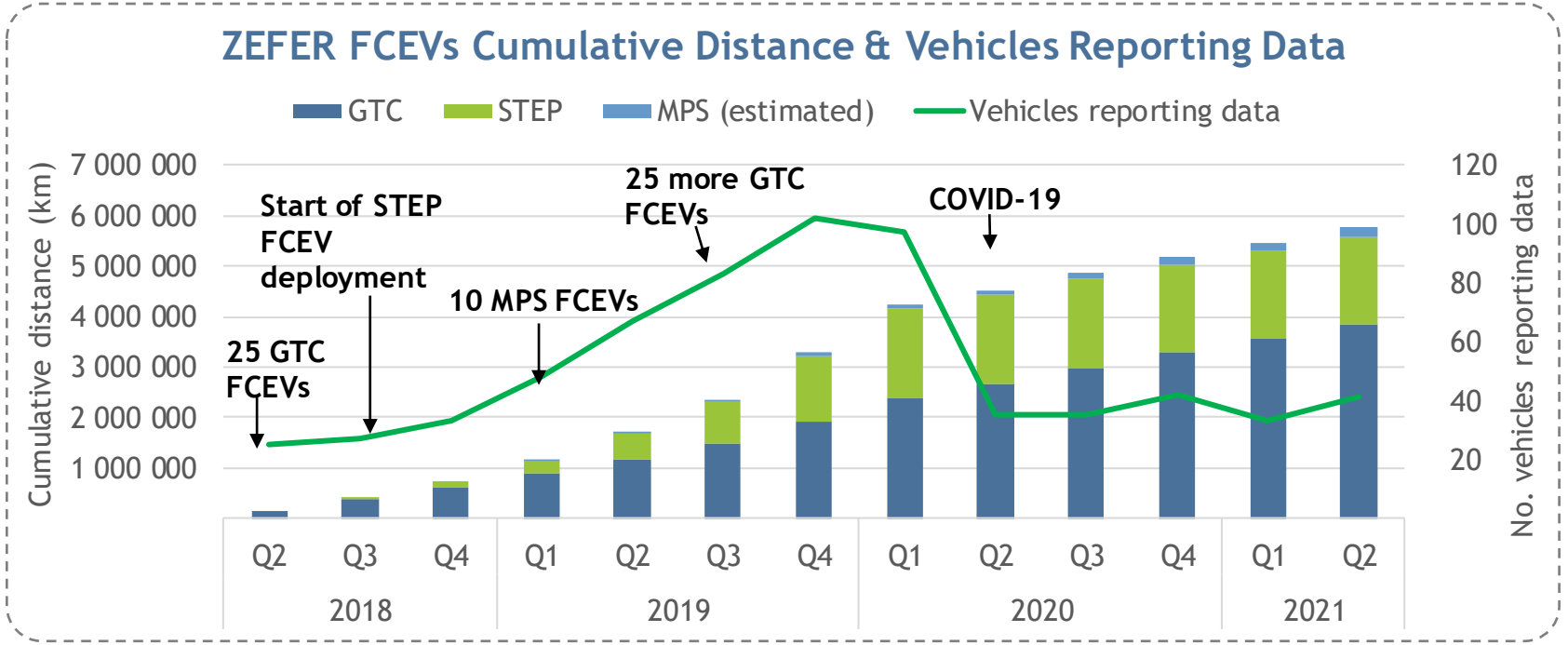
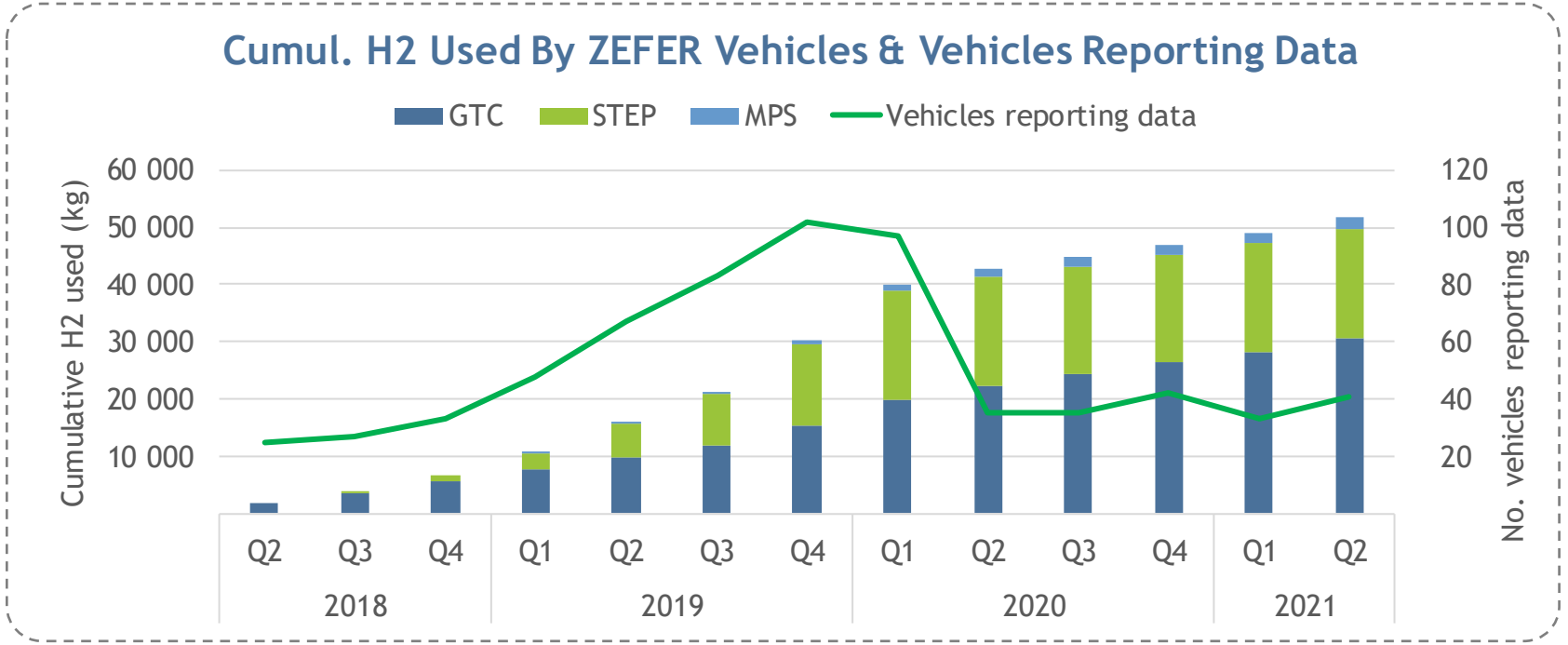
*total volume dispensed by HRS used by ZEFER vehicles since April 2018

ZEFER: VEHICLE SUMMARY



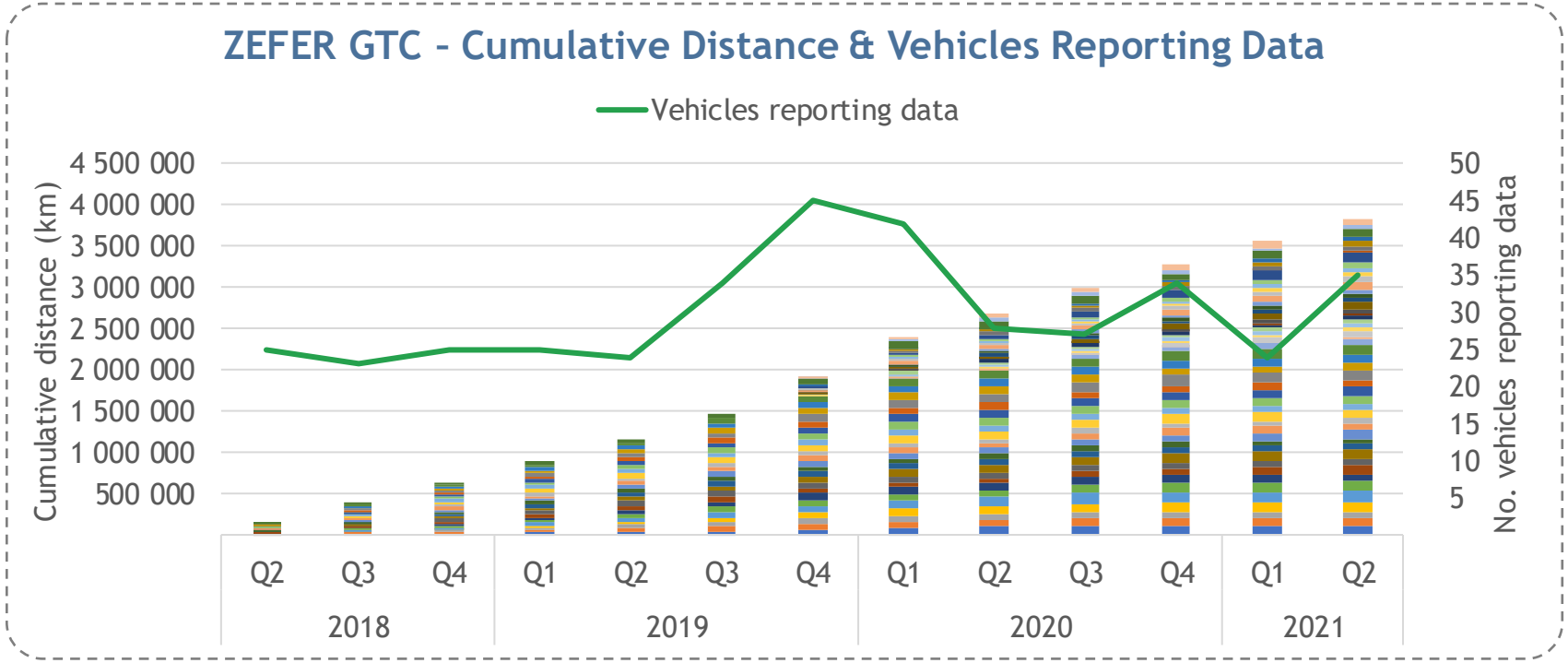
- **ZEFER FCEV taxis in London and Paris, plus the MPS police vehicles in London, have reported 5 763 000 km** driven between April 2018 and June 2021 (both incl.).
- Peak of data-reporting vehicles (102) was reached in Q4 2019. However, the Covid pandemic caused the number of taxis deployed by GTC to reduce by 50% in London, while STEP could not operate any taxis in Paris. The number of vehicles reporting data as of June was around 40.
- Fortunately, GTC are increasingly deploying more vehicles while STEP restarted operations on all 60 taxis in July 2021.

ZEFER: HRS SUMMARY



- **HRS in France and the UK have dispensed 51 600 kg H2** to ZEFER vehicles.
- The two most popular stations are Orly in Paris (10 300 kg) and Teddington in London (12 900 kg), together dispensing 23 200 kg (45% of the total H2 dispensed to ZEFER vehicles).
- Due to the Covid pandemic, only 11 800 kg of hydrogen have been dispensed from Q2 2020 to Q2 2021 (both incl.).

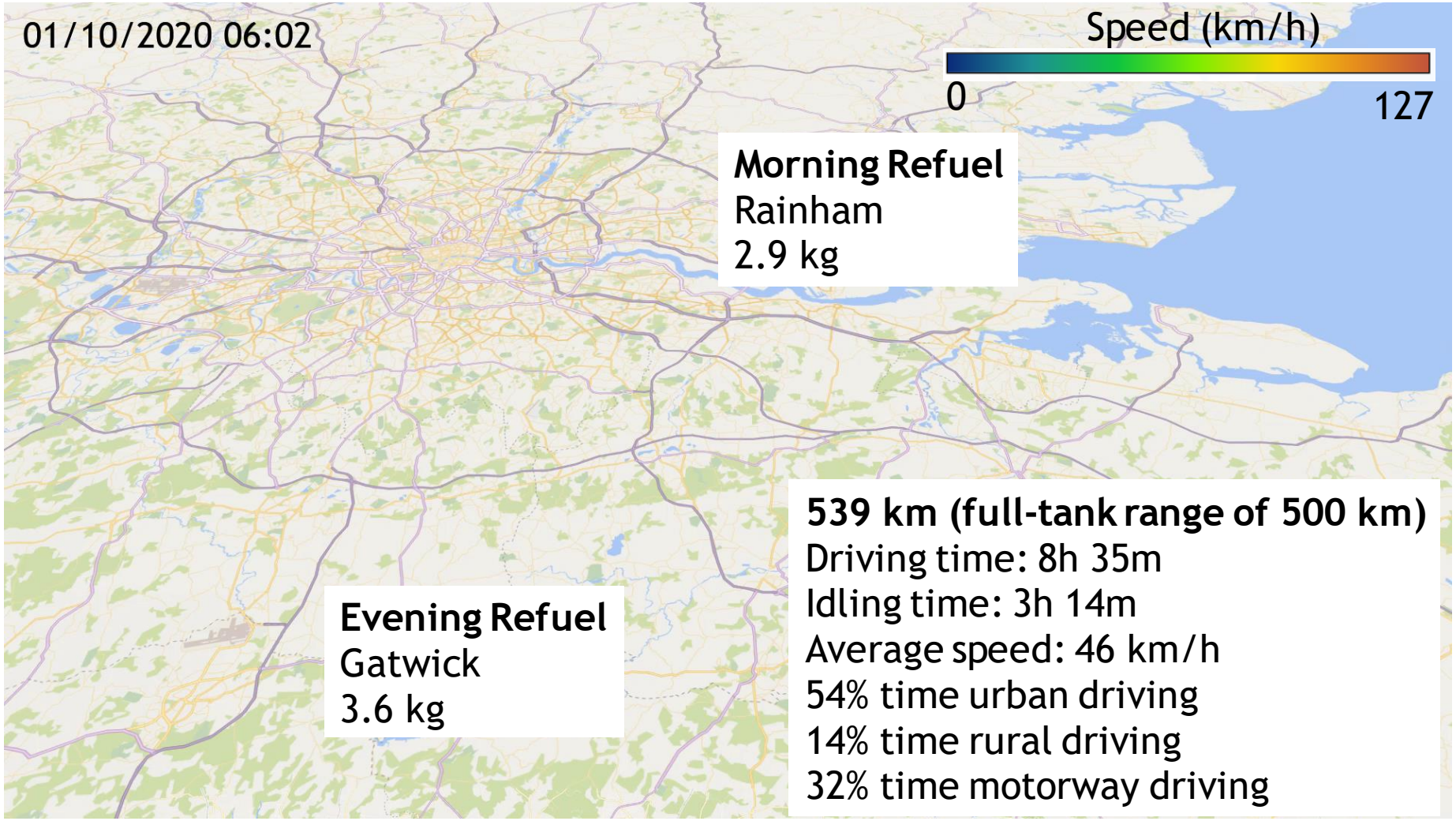
GTC: GENERAL VEHICLE OPERATION



- **GTC's 50 FCEV taxis have driven 3 840 000 km** since April 2018
- The average distance driven by each taxi per month is 3 670 km (~170 km/day).
- The **average annual distance driven by each FCEV taxi is 44 000 km. This compares favourably to the fleet's petrol/diesel and plug-in hybrid vehicles,** which drive 39 000 km/year on average.
- The furthest driven by one of the vehicles in a month was 12 647 km over a busy Christmas month in 2019.

GTC: INTENSIVE OPERATION

BEVs with specifications comparable to those of the Toyota Mirai have a range of 300 to 500 km and would require 30 to 45 minutes for a full charge on a high-power chargepoint. However, **the vehicle depicted on the map refuelled in only 3 minutes each time**, maintaining uptime at much higher levels than a comparable BEV.



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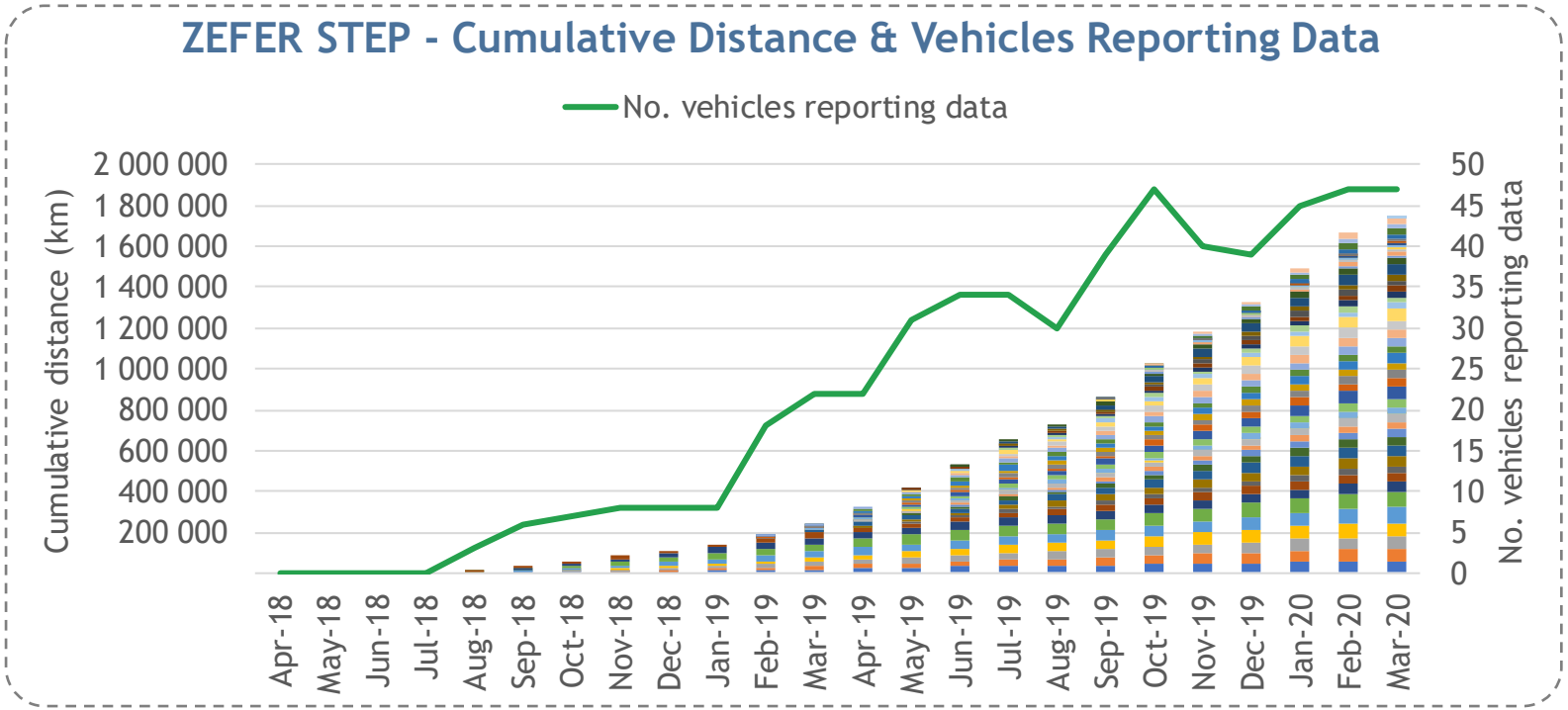
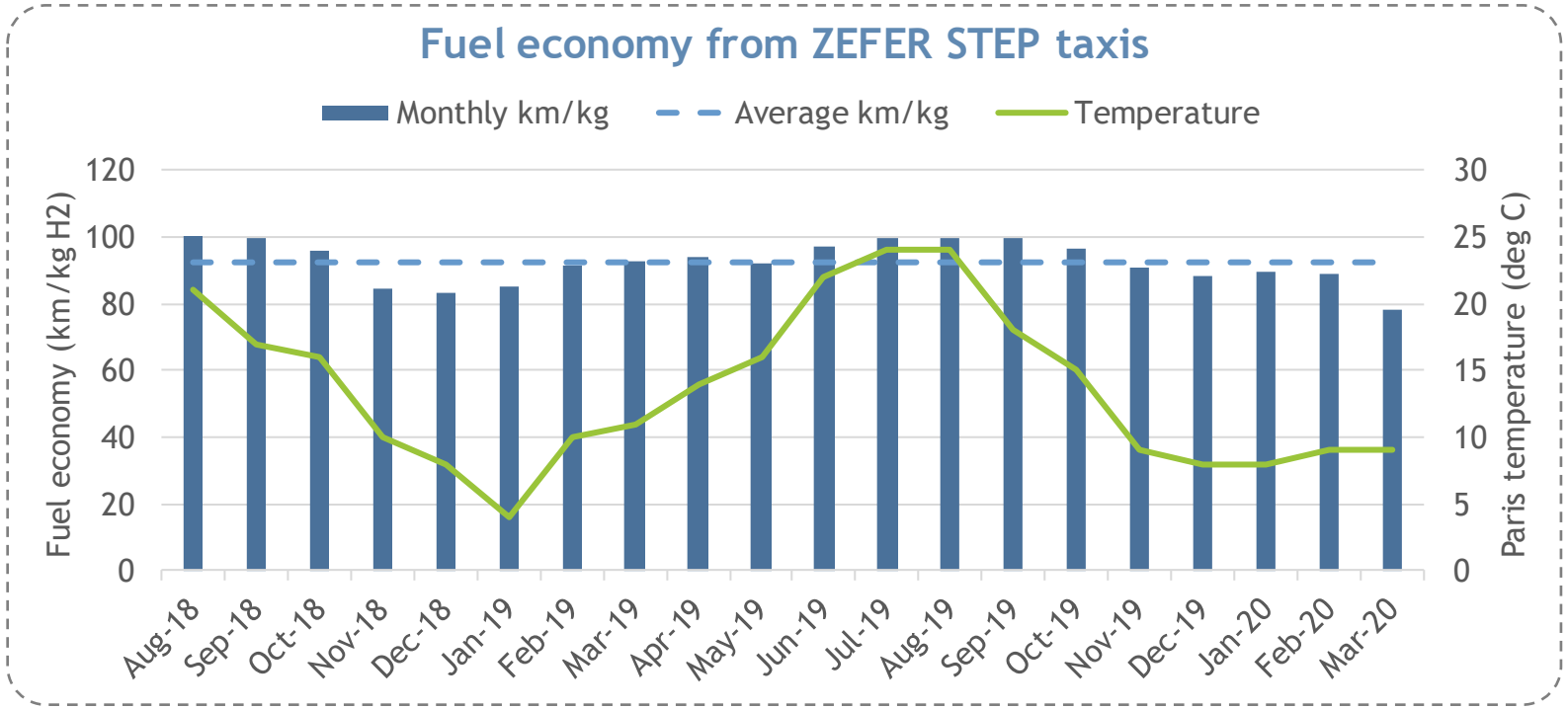
STEP: GENERAL VEHICLE OPERATION



- Unfortunately, STEP stopped operations in Paris in March 2020 due to the pandemic, but all their 60 vehicles restarted operations in July 2021.
- **The ZEFER Hype/STEP FCEVs have reported a total of 1 743 000 km driven.** The ZEFER taxis drive an average of 3 260 km per month (150 km per day and 39 000 km/year).
- The furthest driven by one of the vehicles in a month was 7 470 km.

STEP: SEASONAL FUEL ECONOMY

- Fuel efficiency is worse in winter due to factors including:
  - reduced battery, fuel cell and mechanical efficiency
  - greater use of cabin heating
  - increased rolling & wind resistance



- There is an evident seasonal variance in fuel economy, with a 22% difference between the worse value (78 km/kg in Mar-20) and the best (100 km/kg in Aug-18). In comparison, BEVs present a 14 to 21% difference in energy use when comparing cold with warm months*. **The FCEVs compare well with BEVs.**
- The average fuel economy across all STEP (ZEFER) vehicles and months is **92 km/kg**, as opposed to GTC's **106 km/kg** in London.

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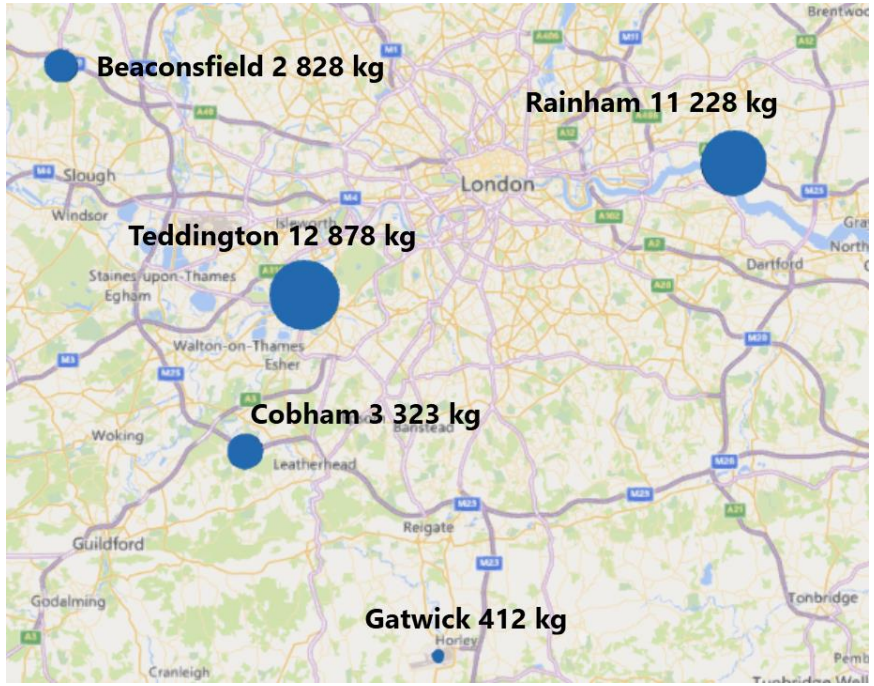
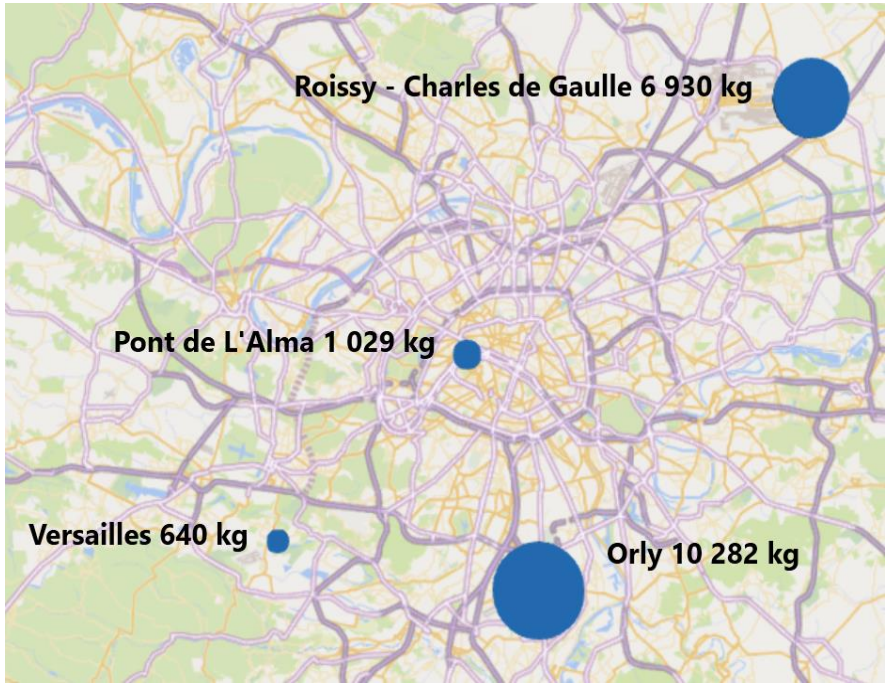
*Data from Geotab's 'EV Temperature Tool'.

LONDON & PARIS HRS NETWORK

H2 used by GTC ZEFER FCEVs in London



H2 used by STEP ZEFER FCEVs in Paris



- In London, **HRS located inside ring road are preferred** by fleets as evidenced by quantities of H2 dispensed.
- In Paris, **HRS placement easier due to smaller size of city and possibility of locating HRS in two airports**. Drivers use these when dropping off or picking up passengers, more convenient locations.

SIMULATION OF HRS HIGH LOAD

EXAMPLE OF TEDDINGTON HRS

Objectives of the simulation

- HRS **back-to-back (B2B) refuelling capability** as the number of vehicles deployed and the station load increases is one of the **key learning aims of FCH JU projects.**
- **If B2B refuelling capability is exceeded regularly, it is likely that issues will being to emerge** i.e lack of sufficient H2 availability for immediate refuelling, leading to increased waiting time for vehicles to refuel.
- The simulation aims to **understand the usage point at which HRS operational issues may become problematic.**

Key findings

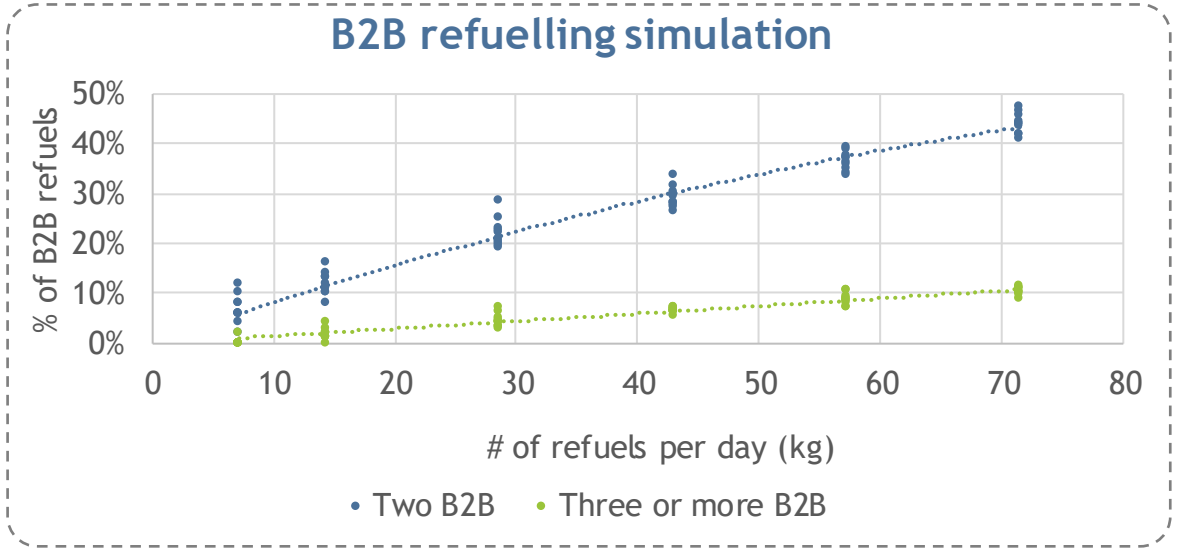
- In line with HRS operators, we define back-to-back (**B2B**) refuelling as a refuelling event that occurs within ***ten minutes*** of a previous event. By this criterion, **9% of refuels at Teddington are B2B.**

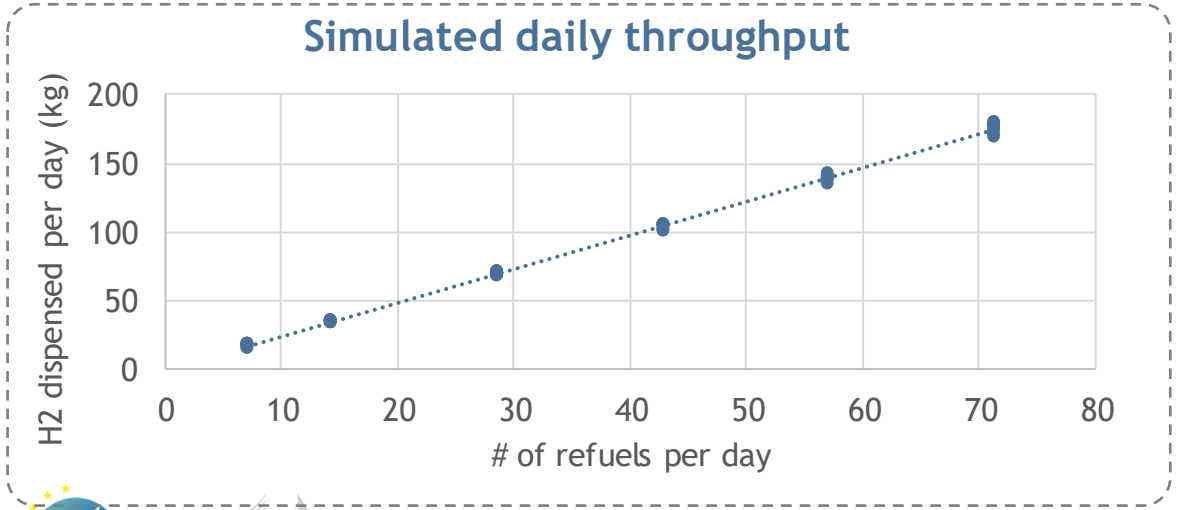
- When comparing this to stations with lower load (% of HRS capacity in kg/day that is actually dispensed), **the lower the station load, the lower the B2B refuelling probability.**

SIMULATION OF HRS HIGH LOAD

OUTPUTS

- The top graph shows a limited run (10 weeks) **simulation of 100 Mirai B2B refuelling behaviour** for varying number of refuels, showing:
  - Proportion of 2 B2B refuels
  - Proportion of 3 or more B2B refuels
- As the usage reaches ~70 refuellings per day:
  - The chance of **B2B** refuelling exceeds **40%**
  - The chance of **3 or more B2B** approaches **10%**
  - The HRS average daily load approaches 180kg, near the 200 kg/day limit of many H2ME2 HRS





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Conclusions : Further efforts needed to prepare for the commercial roll-out of FCEVs

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Technology performances

- FCEVs **exceed drivers and operators' expectations** in terms of reliability & performance.
- **Long ranges** and **quick refuelling times** are essential to elevating the value of FCEVs above zero-emission alternatives.
- HRS have provided a good foundation for the deployments but **limited infrastructure networks** and challenges with **reliability** can prevent the full operational advantages of FCEVs being realised.

Costs reduction

- At low levels of demand (<200kg/day) the cost of supplying H2 can be high. **Network planning** is key to ensuring **economies of scale** and **adequate proposition to customers.**
- FCEVs still have a significant cost premium compared to diesel vehicles but can reach parity in 2025.
- An unsubsidised business case could be just **one generation away.**

Public support

- **Success stories** are linked to **financial incentives/tax exemptions** for zero emission vehicles, as well as **support from local authorities** and **restrictions placed on diesel vehicles.**

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* https://www.fch.europa.eu/sites/default/files/4.%20Eynon_ZEFER.pdf | https://www.fch.europa.eu/sites/default/files/3.%20Speers%20%26%20Jodecke_H2MEs.pdf

Thank you for your attention

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Coordinator: elementenergy an ERM Group company

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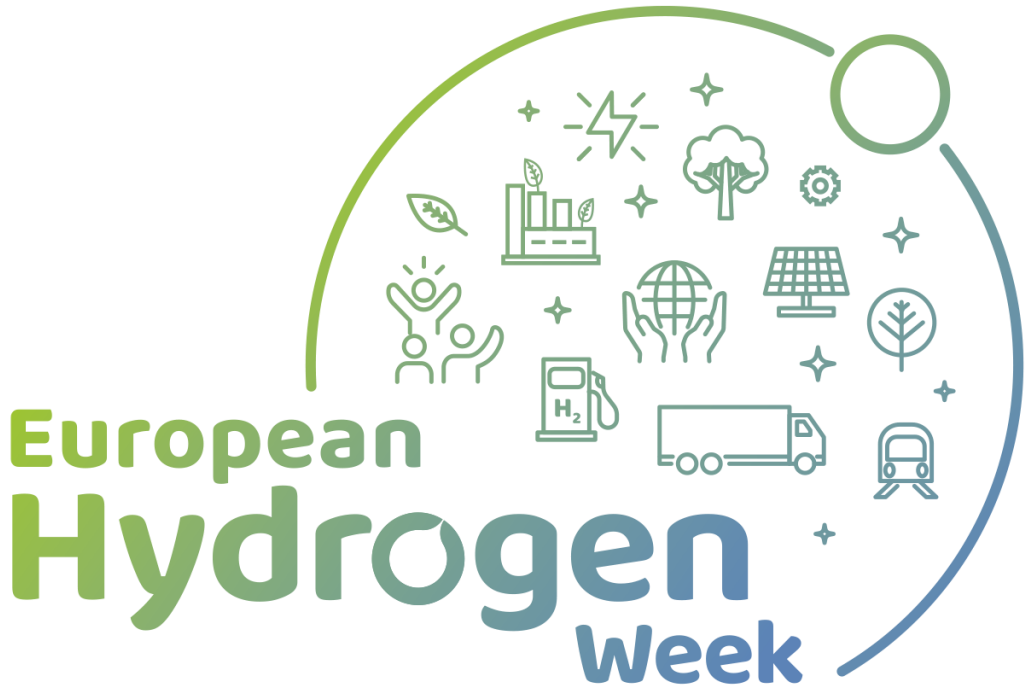

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SIMULATION OF HRS HIGH LOAD

EXAMPLE OF TEDDINGTON HRS

- In line with HRS operators, we define back-to-back (**B2B**) refuelling as a refuelling event that occurs within ***ten minutes*** of a previous event. By this criterion, **9%** of refuels at Teddington are B2B.
- When comparing this to stations with lower load (% of HRS capacity in kg/day that is actually dispensed), the lower the station load, the lower the B2B refuelling probability.
- HRS B2B refuelling capability as the number of vehicles deployed and the station load increases is one of the key learning aims of FCH JU projects.
- If B2B refuelling capability is exceeded regularly, it is likely that issues will being to emerge. For example, lack of sufficient hydrogen availability at the HRS for immediate refuelling, and therefore increased waiting time for vehicles to refuel.
- Given the current relatively low levels of usage at HRS, we have simulated increasing Teddington HRS usage to understand the usage point at which HRS operational issues may become problematic.

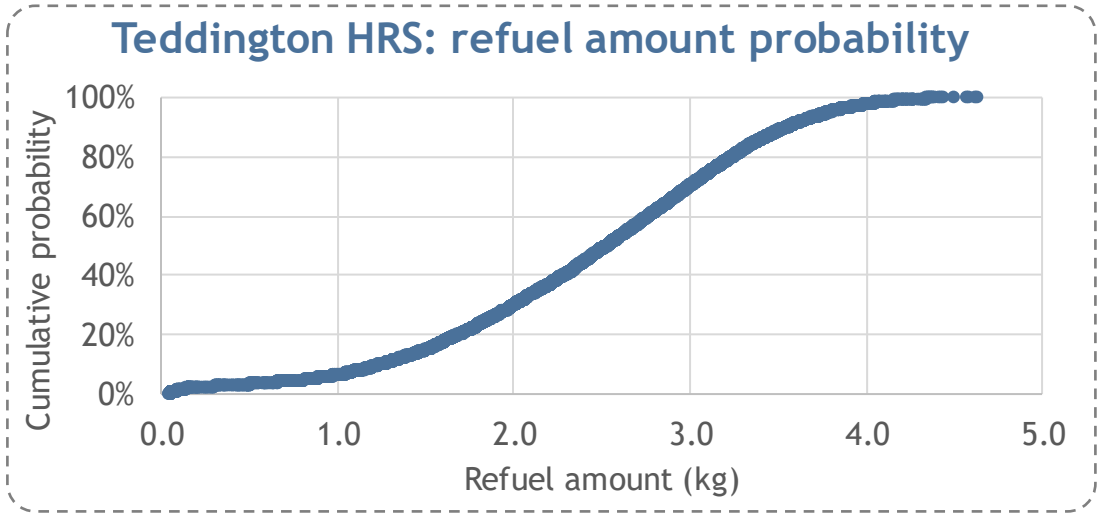
SIMULATION OF HRS HIGH LOAD

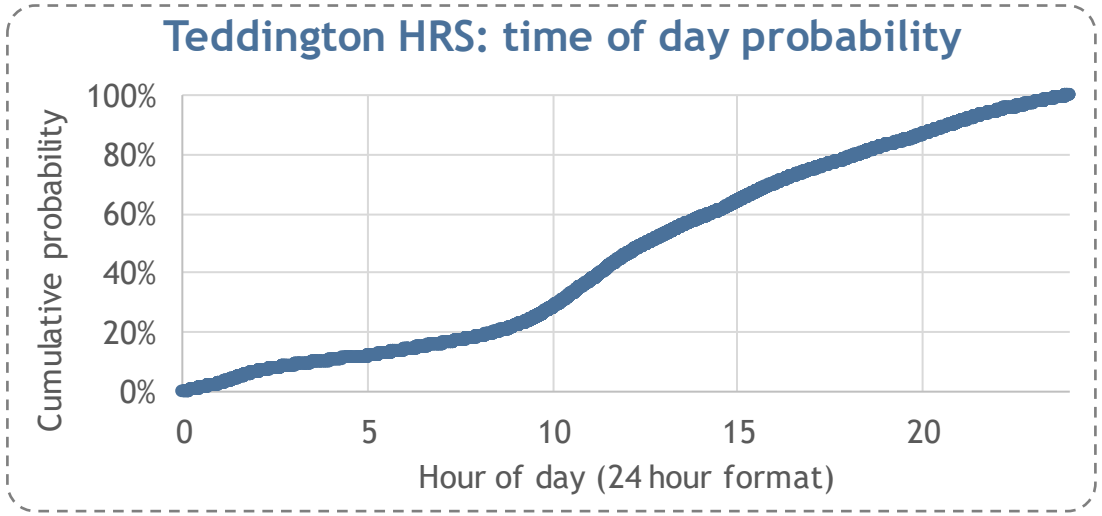
INPUTS

Monte Carlo (MC) simulation recreates a chance process, runs it many times, and observes the results.

Procedure

1. Generate weighted inputs (scenarios) according to the distribution of refuelling observed in reality. For these refuelling simulations, there are three input variables:
   I. Day of week (16% weekdays, 9% weekends)
   II. Time of Day
   III. Amount of hydrogen refuelled
2. Simulate a week's refuelling based on the inputs.
3. Run the simulation multiple times to ensure statistical validity.





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Project Progress
HRS availability: good progress ….

PRD 2020
H2ME

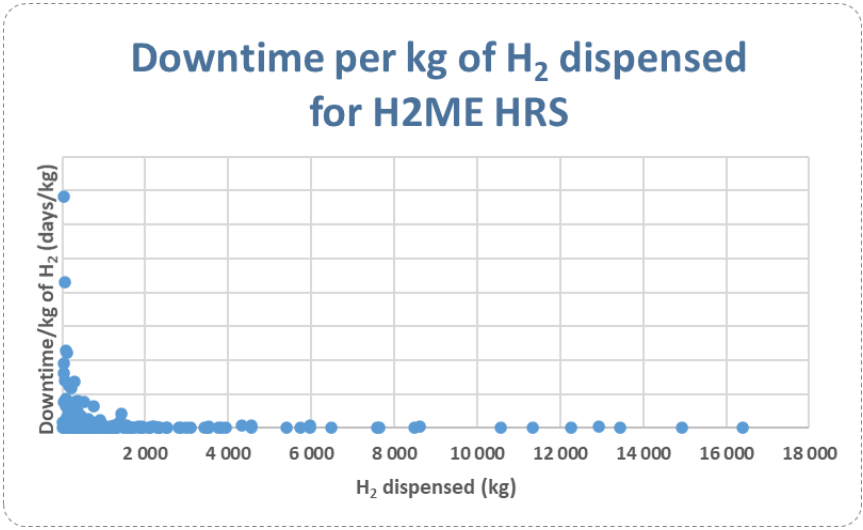
HRS: 95.4% FCEV: >98%

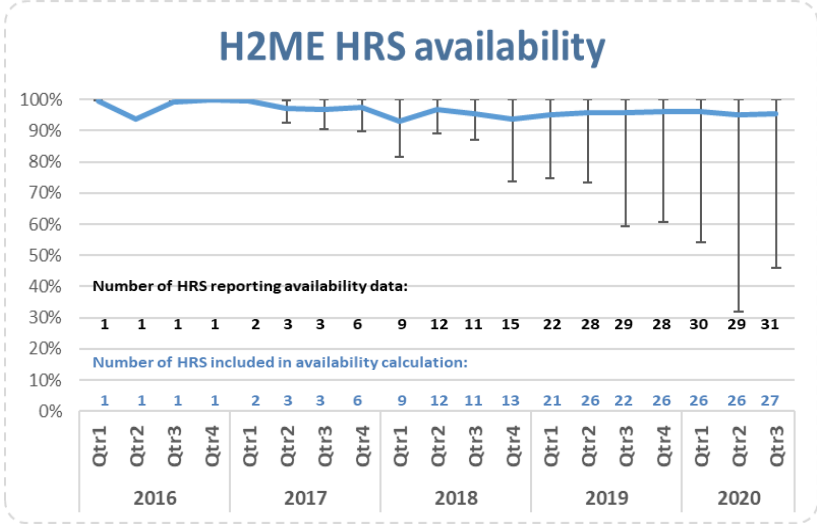
Availability

FCEV: 99%
HRS:98%

FCEV: >98%
HRS: >98%

25% 50% 75%





- Station availability improves after initial teething problems as more H_2 is dispensed (**bathtub curve**).
- Project-average availability is currently **95.4%**.
- (Average availability excludes stations with low availability in one quarter).

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Project Progress
HRS availability: … but challenges remain

PRD 2020
H2ME

Availability

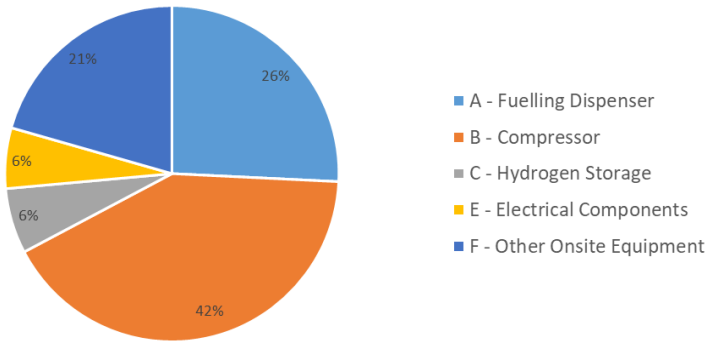
FCEV: 99%
HRS:98%

HRS: 95.4% FCEV: >98%

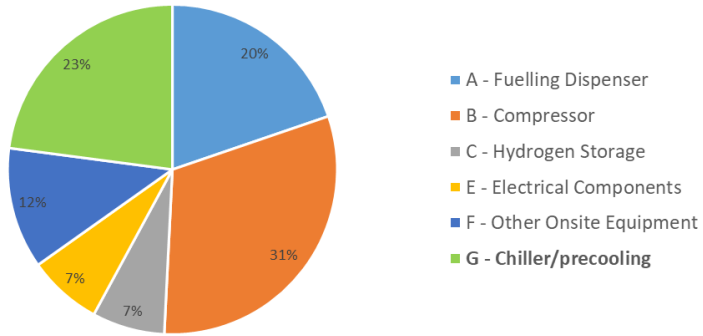
FCEV: >98%
HRS: >98%

25% 50% 75%

H2ME HRS downtime by category (HyLights)



H2ME HRS downtime by category (new chiller faults category G)



- "What gets measured gets improved".
- (Chart on left) HyLights MAF (2011) did not consider precooling.
- (Chart on right) Including chiller faults allows more focus on main areas for improvement.
- Compressors, dispensers and precooling main sources of downtime.

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Project Progress
The customer value proposition

PRD 2020
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Availability

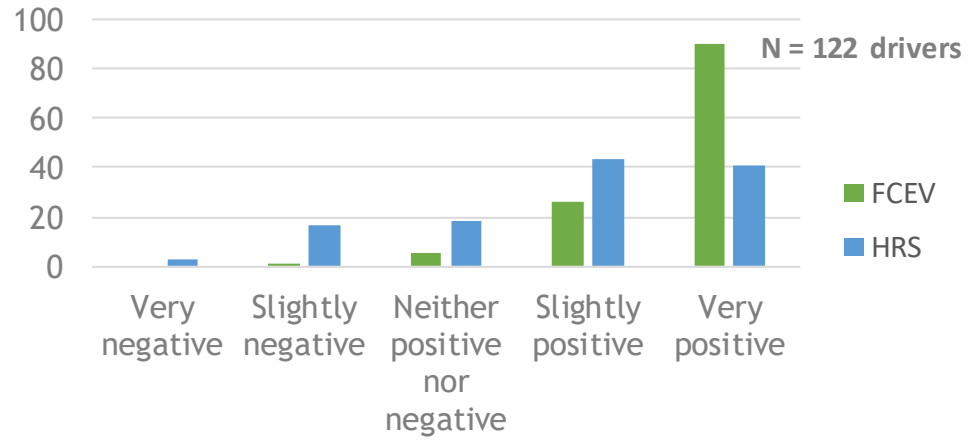
FCEV: 99%
HRS:98%

HRS: 96.5%* FCEV: >99%

FCEV: >98%
HRS: >98%

25% 50% 75%

Experiences with FCEV and HRS within the ZEFER project



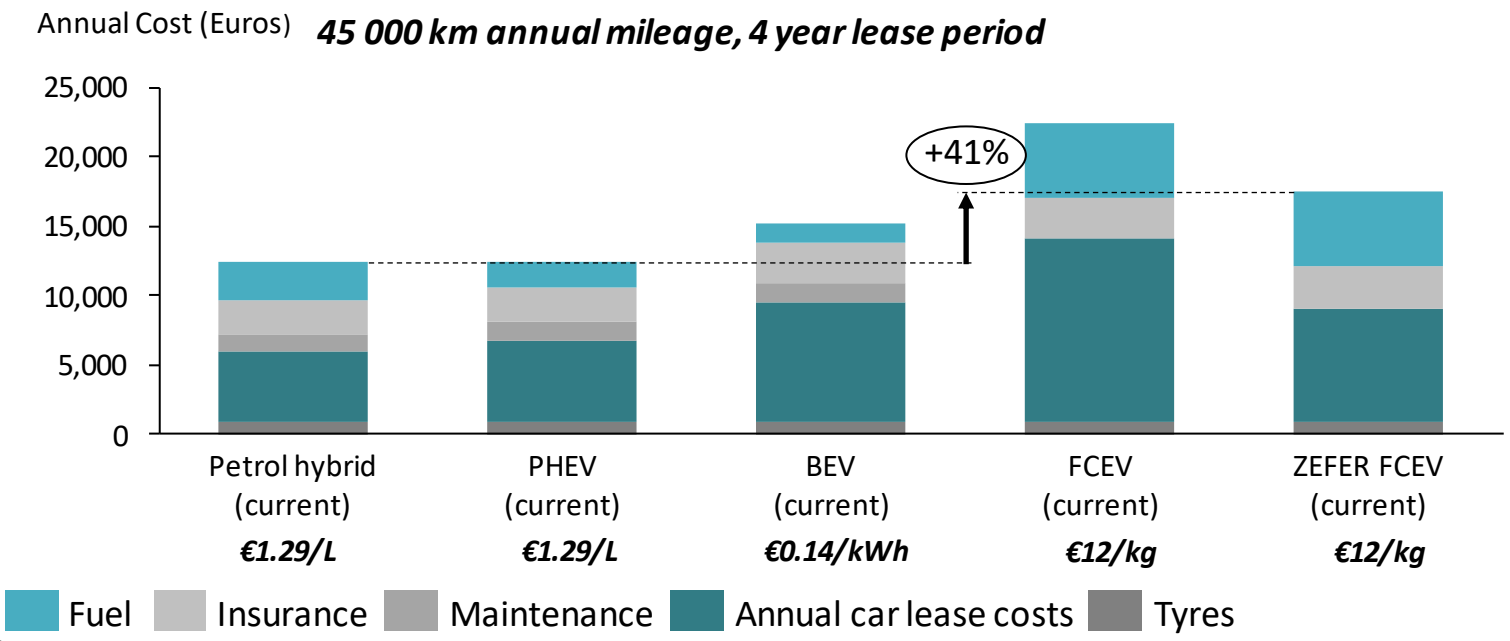
- FCEVs have **exceeded driver and operator expectations** in terms of reliability and performance.
- **Long ranges** and **quick refuelling times** are essential to elevating the value of FCEVs above zero-emission alternatives.
- HRS have provided a good foundation for the ZEFER deployments but **limited infrastructure networks** and challenges with **reliability** have prevented the full operational advantages of FCEVs being realised.

24 Average availability of H2ME and ZEFER HRS since 2016

Project Progress
Today's business case

PRD 2020
ZEFER

Taxi TCO compared to alternatives (€/yr)



- To make a commercial case for fleet operators the TCO of an FCEV is required to reach parity with current petrol hybrids.
- ZEFER funding has been vital in reducing the TCO premium of FCEVs from c. 80% to c. 40% above petrol hybrids.
- Although prices still remain above parity, the operational advantages of FCEVs lead to positive externalities for operators which can be monetised.

Maintenance for FCEVs (current) is included in lease costs

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Project Progress
The 2025 business case

PRD 2020
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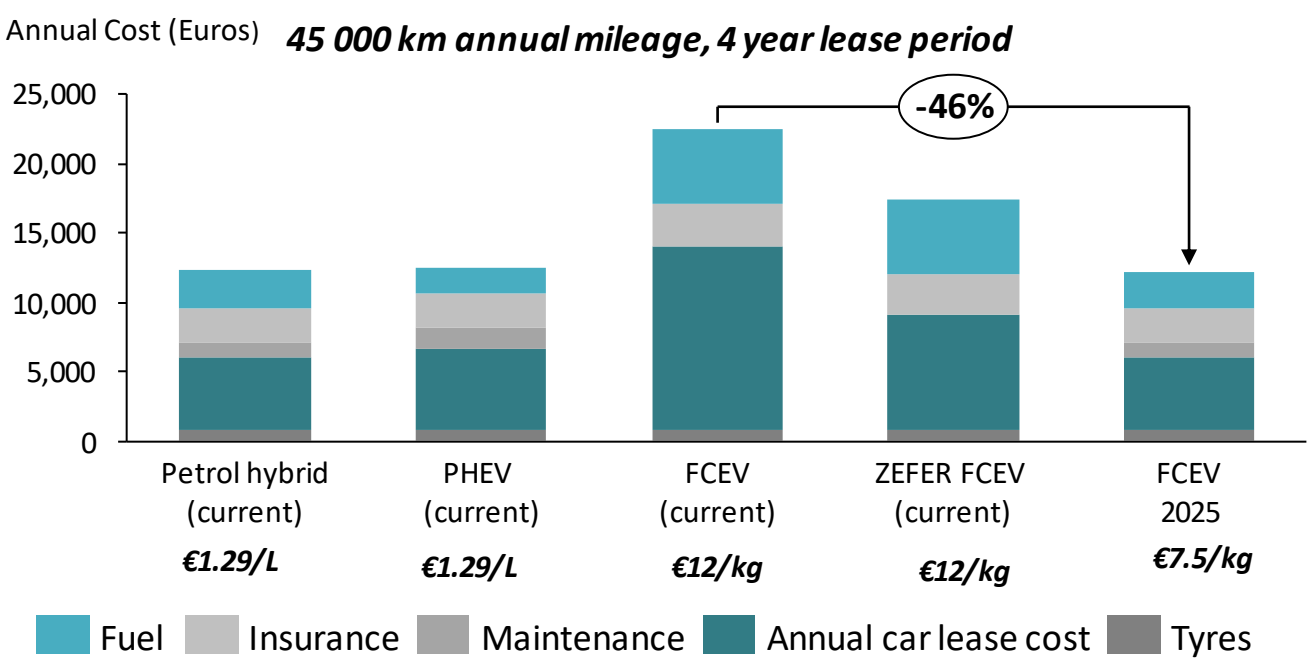
Taxi TCO compared to alternatives (€/yr)



*Maintenance for FCEVs (current) is included in lease costs

1 Price target in OEM roadmaps

- By 2025 it is widely expected that **FCEVs can reach parity with petrol/diesel hybrids**[1] and that hydrogen costs can be reduced to **€7.50/kg or below** as a result of scaled demand.
- 2025 prices will bring the TCO of FCEVs **below parity with current incumbents** and into competition with modern battery-electric equivalents.
- An unsubsidised business case is just **one generation away** and there is appetite for scaled uptake from ZEFER partners.