



ZERO EMISSION FLEET FOR EUROPEAN ROLLOUT

D3.4: Bi-Annual Technical Report on Vehicle and Refuelling Station Operation

Data: Up to August 2023 (incl.)

Dissemination level: PUBLIC

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This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 779538. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe Research.



Executive Summary (1)



- ❑ ZEFER (<https://zefer.eu/>, 2017-2023) aims to demonstrate that operating fuel cell electric vehicles (FCEVs) in urban vehicle applications can be commercially and operationally viable.
- ❑ This report summarises the results of the operation **to the end of August 2023** of the Toyota Mirai FCEVs and hydrogen refuelling stations (HRS) that have been deployed by ZEFER:
 - **In London**, Green Tomato Cars (GTC) began operating 25 FCEVs as taxis in April 2018 and incorporated 25 more in November 2019. They removed the first 25 taxis from the fleet in April 2022 and the remaining 25 in October 2022 due to the end of their leasing period.
 - **In London**, the Metropolitan Police Service (MPS) operated 10 Toyota Mirais as general purpose police vehicles, joining the existing 11 Mirais in its fleet.
 - **In Paris**, Hype deployed 60 ZEFER-supported Toyota Mirai FCEVs since August 2018.
 - **In Copenhagen**, DRIVR deployed 60 FCEV taxis, a combination of Toyota Mirai generation 1 and 2 vehicles.
- ❑ This report is public and has been updated bi-annually during the whole project.

Executive Summary (2)



- ❑ To the end of August 2023, the ZEFER FCEVs drove **15 017 213 km***.
- ❑ HRS in France, the UK and Denmark dispensed to ZEFER vehicles **149 271 kg of hydrogen**.
- ❑ FCEV taxi driving and refuelling patterns in London and Paris are similar, with vehicles driving **between 195 and 210 km between refuels** and averaging just over 2 kg per hydrogen refuel (the Mirai has a 5 kg tank capacity). The reason for more frequent refuels than a conventional vehicle is that the HRS network is far less developed than the petrol/diesel one.
- ❑ Following technical issues with the hydrogen trailers that were supplying Prags Boulevard station in Copenhagen, the HRS is closed since June 2023. The FCEVs operated by DRIVR and the remaining 28 cars to be deployed could thus not run in the last months of project. In order to reach the objective of 60 vehicles deployed in Copenhagen, it was agreed that 28 cars are switched from the H2ME2 to the ZEFER project.
- ❑ The FCEVs have proven to be reliable (**> 99% availability**), with a small amount of downtime associated with normal taxi use (minor impacts and tyre replacements). The Toyota Mirais are serviced every 10 000 to 15 000 km.
- ❑ The average availability for all H2ME and ZEFER HRS is currently **96.2%**.
- ❑ There were no vehicle or HRS safety issues recorded.

* Last data received from MPS Aug 2019. The MPS distance has been estimated from refuelling records provided by ITM.

Abbreviations



Abbreviation	Definition
FCEV	Fuel Cell Electric Vehicle
GTC	Green Tomato Cars
H ₂	Hydrogen
H2ME	Hydrogen Mobility Europe
HRS	Hydrogen Refuelling Station
MPS	Metropolitan Police Service (London)
NEDC	New European Driving Cycle
NiMH	Nickel Metal Hydride
PEM	Proton Exchange Membrane
WLTP	Worldwide Harmonised Light Vehicle Test Procedure
ZEFER	Zero-Emission Fleet vehicles for European Rollout

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ZERO EMISSION FLEET VEHICLES FOR EUROPEAN ROLLOUT (2017-2023)

Introduction

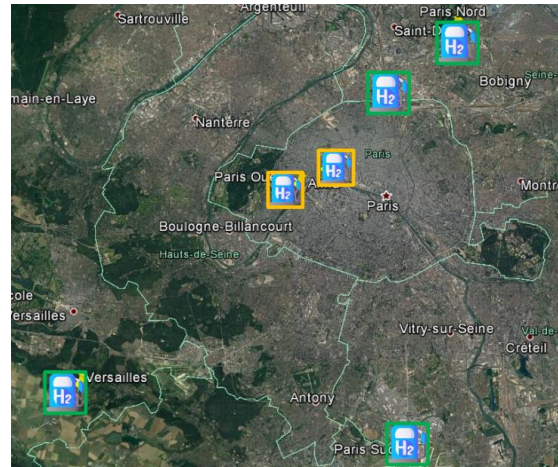
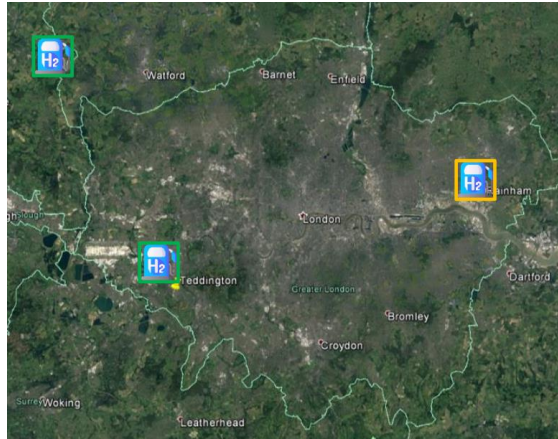


- ❑ ZEFER (<https://zefer.eu/>) aimed to demonstrate that operating fuel cell electric vehicles (FCEVs)* in urban vehicle applications can be commercially viable compared to diesel alternatives. The FCEV use cases that investigated by ZEFER were:
 - As taxis in intensive (up to 24/7) high-distance operation, and
 - In inner-city fleets where their zero-emission characteristics are of particular value.
- ❑ ZEFER's objective was to deploy FCEVs in three locations:

Location	No. of FCEV	Role of FCEV	User of FCEV
Paris	60	Taxi	Hype
Copenhagen	60		DRIVR
London	50		Green Tomato Cars
London	10	Police vehicle	Metropolitan Police

* FCEVs use compressed hydrogen stored on-board to generate electricity in a fuel cell which is used to provide power. The vehicles emit only water.

ZEFER FCEV Deployments



MAYOR OF LONDON
OFFICE FOR POLICING AND CRIME

London
50 FCEV private hire
10 FCEV police cars



Copenhagen
60 FCEV taxis





Paris
60 FCEV taxis



ZEFER

Vehicle Technical Specification

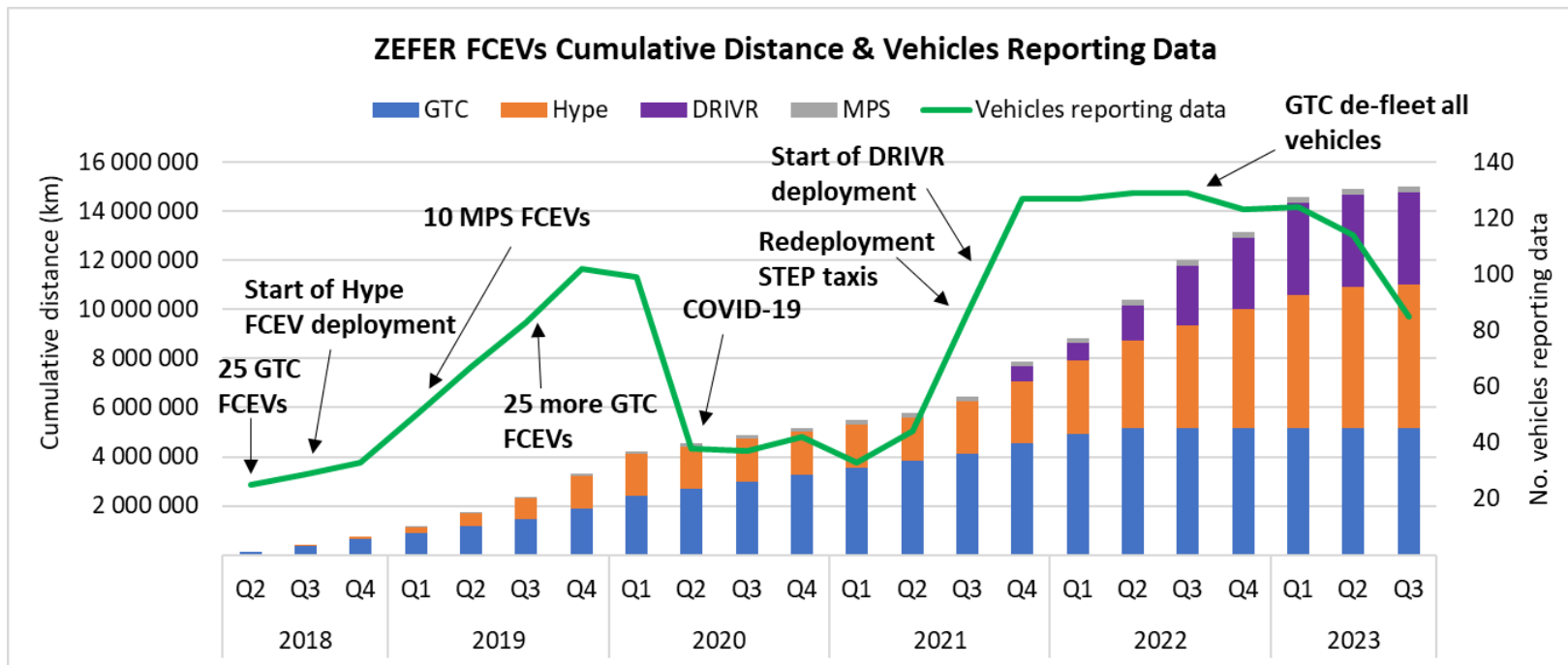


	Toyota Mirai Gen 1	Toyota Mirai Gen 2
Vehicle		
Vehicle architecture	Battery/fuel cell parallel hybrid	Battery/fuel cell parallel hybrid
Top Speed	179 kph	174 kph
Seats	4	5
Acceleration 0 → 100 km/h	9.6s	9s
Range	550 km (NEDC)*	644 km (WLTP)**
Stack Technology	PEM***	PEM***
Stack Power Rating	113 kW	128 kW
Tank Capacity	5 kg H ₂	5.6 kg H ₂
Tank Pressure	700 bar	700 bar
Battery Pack Size	1.6 kWh NiMH****	1.2 kWh Lithium-ion

- * New European Drive Cycle
- ** Worldwide Harmonised Light Vehicle Test Procedure
- *** Proton Exchange Membrane
- **** Nickel Metal Hydride

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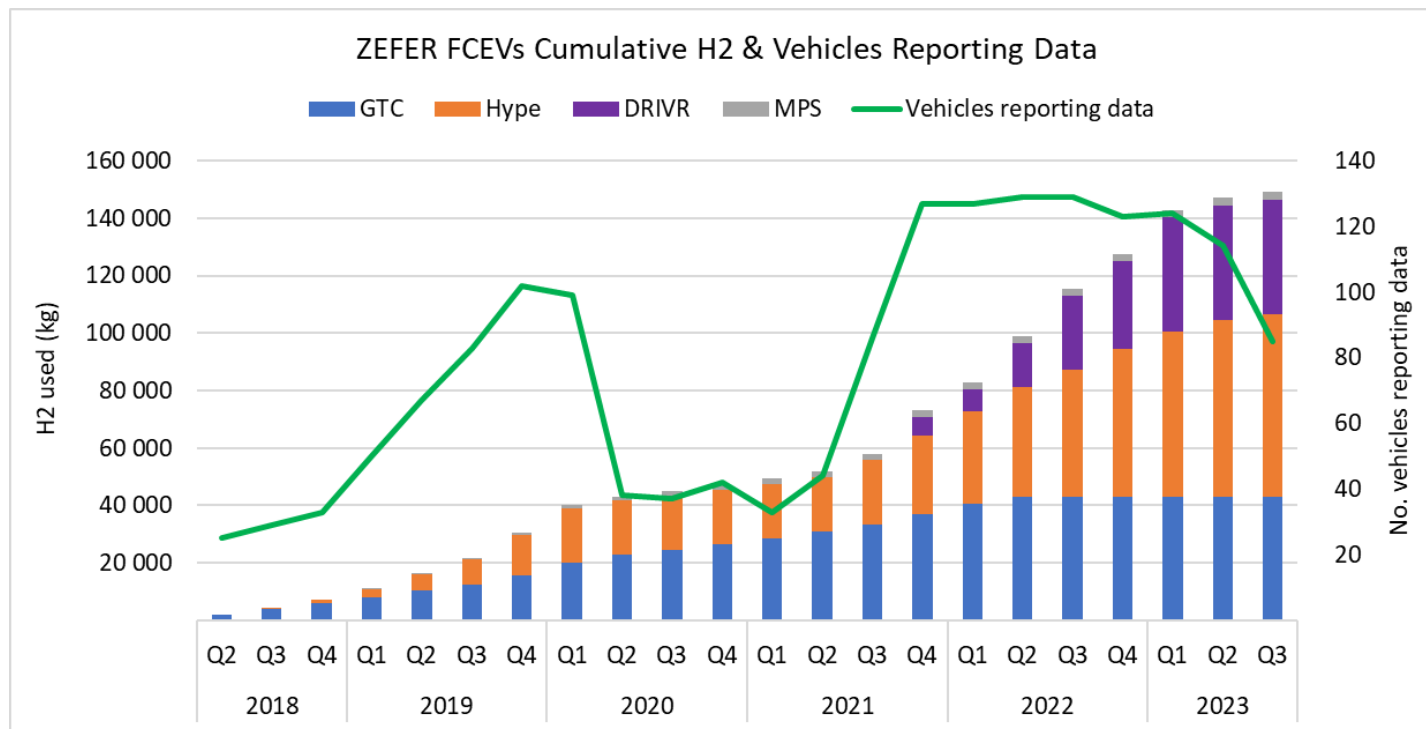


- ❑ ZEFER FCEV taxis in London, Paris and Copenhagen, plus the MPS police vehicles in London, reported **15 017 213 km** driven since April 2018*.
- ❑ Peak of data-reporting vehicles (129) was reached in Q2 and Q3 2022 due to the increase in DRIVR’s deployment in Copenhagen. A larger deployment could not be reached because at this time GTC also de-fleeted all their vehicles due to the end of the leasing period.
- ❑ Following technical issues with the hydrogen trailers that were supplying Prags Boulevard station in Copenhagen, the HRS is closed since June 2023. The FCEVs operated by DRIVR and the remaining 28 cars to be deployed could thus not run in the last months of project. In order to reach the objective of 60 vehicles deployed in Copenhagen, it was agreed that 28 cars are switched from the H2ME2 to the ZEFER project.

* Last data received from MPS Aug 2019. The MPS distance is estimated from refuelling records provided by ITM. MPS vehicles included in ‘vehicles reporting data’.

HRS

Cumulative Hydrogen Dispensed



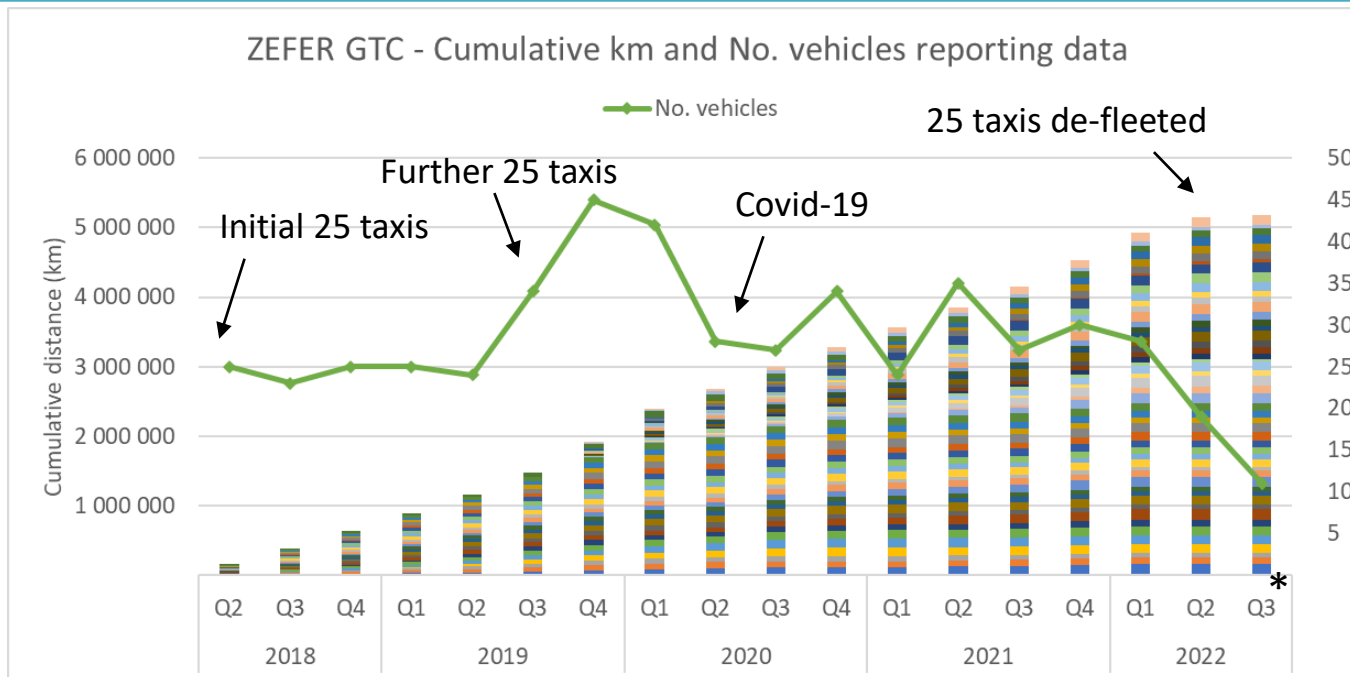
- ❑ HRS in France, Denmark and the UK dispensed **149 271 kg H₂** to ZEFER vehicles.
- ❑ The two most used stations were Orly in Paris, Prags in Copenhagen, and Teddington in London, together dispensing around half of the total hydrogen.
- ❑ As mentioned in previous slides, note the Danish HRS station closure in June 2023 and hence the vehicle swap between ZEFER and H2ME2.



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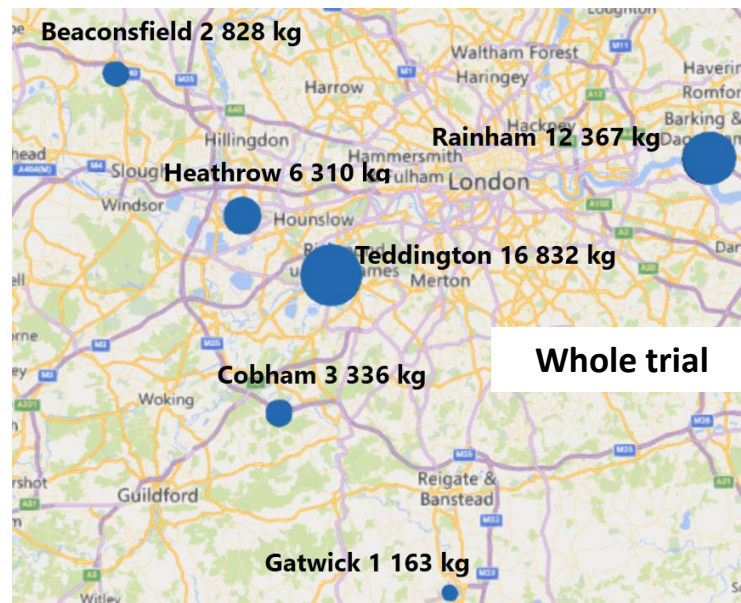
London FCEV Taxi Operation



- ❑ GTC’s 50 FCEV taxis have driven **5 181 143 km** since April 2018 (the different-coloured bars on the graph represent the cumulative distance driven by individual vehicles, while the green line is the no. of vehicles reporting data).
- ❑ **25 taxis were de-fleeted in April 2022 and 25 more in October 2022 due to the end of their leasing period.**
- ❑ The recovery in clients after the pandemic was not translated into all vehicles being redeployed, mainly due to the low reliability or unavailability of HRS.
- ❑ The average distance driven by each taxi per month was 3 848 km (~178 km/day). The furthest driven by one of the vehicles in a month was 12 647 km over a busy Christmas month in 2019.
- ❑ The average annual distance driven by each FCEV taxi was 46 200 km.

London

Where GTC FCEVs are Refuelling

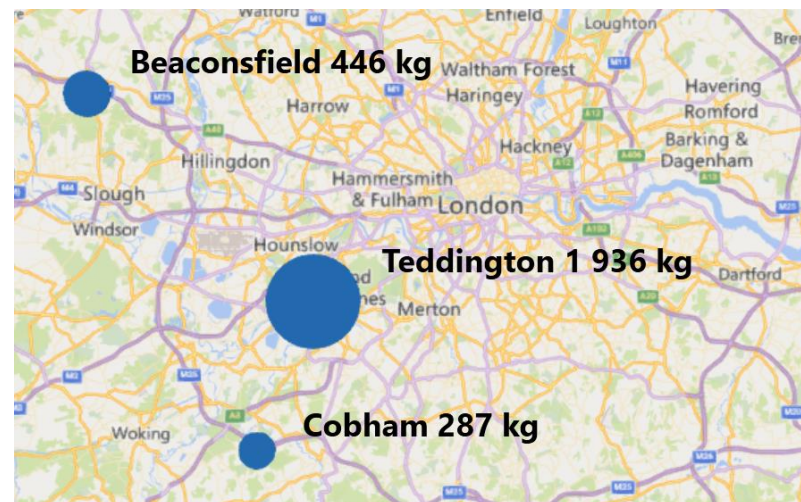
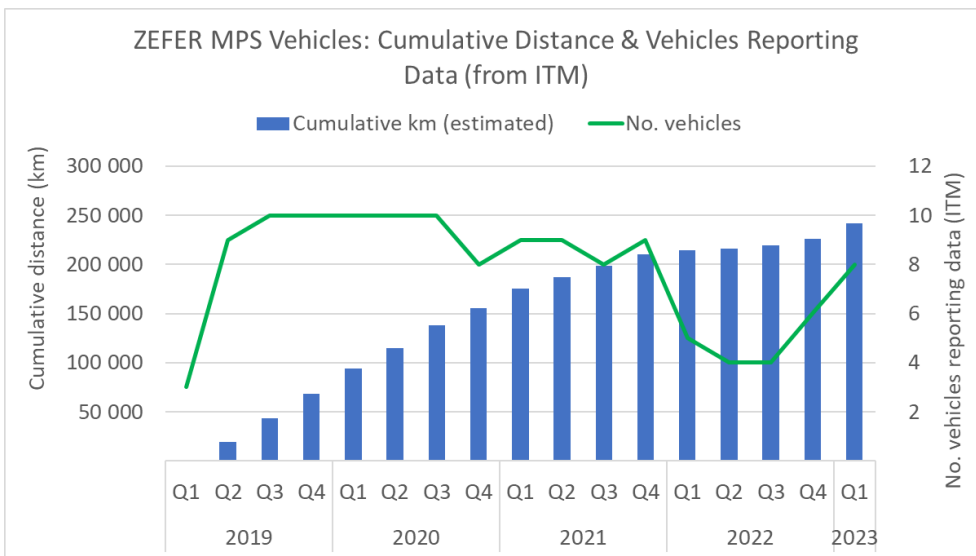


- ❑ The figure above shows the location of ITM Power HRS (except for Heathrow) around London and the number of kg of hydrogen dispensed to GTC FCEVs. During the whole trial, there have been **42 836 kg of hydrogen** dispensed in 20 753 refuelling events, averaging 2.1 kg per refuel (41% of the 5 kg hydrogen tank capacity) and 210 km between refuels.
- ❑ The Beaconsfield HRS is closed since June 2020, and Cobham since July 2021. Therefore, the vehicles relied mostly on Teddington and Heathrow on the West with small quantities being delivered at Gatwick until its closure in July 2022. The hydrogen for the East London operations has been delivered at Rainham which, together with Teddington, closed in May 2023.

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London MPS Distance and Data Status



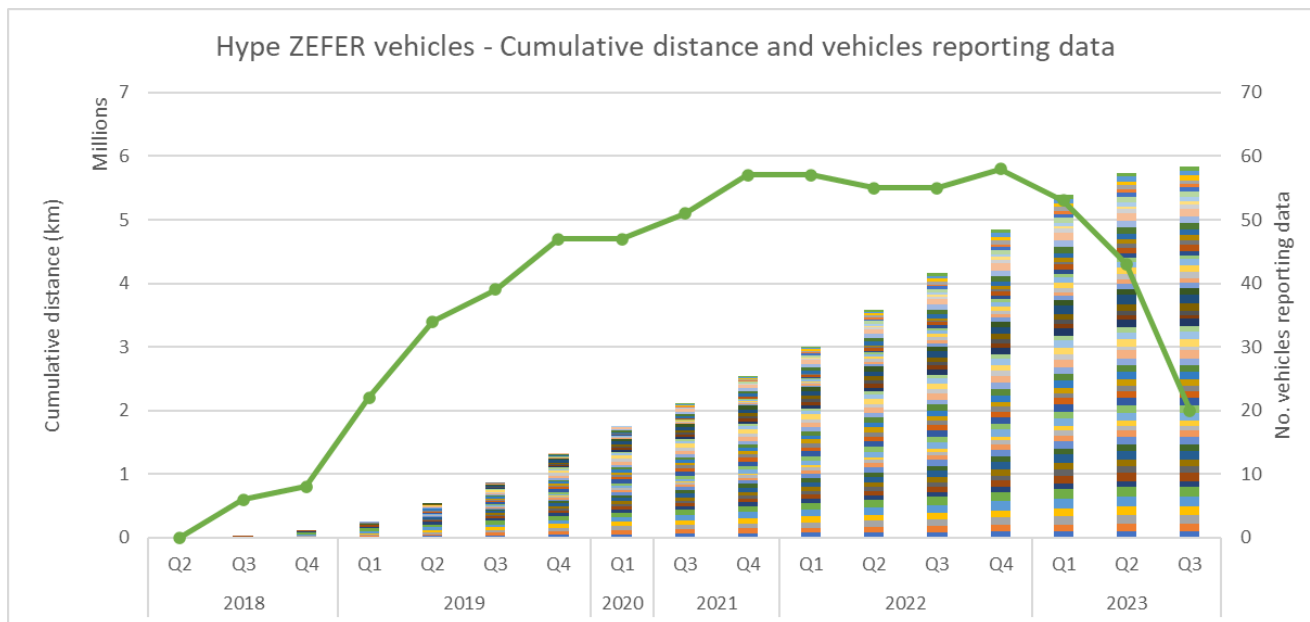
- The graphs above show the cumulative distance from the 10 ZEFER vehicles deployed, and the amount of H2 dispensed to these vehicles. Due to data unavailability from Aug-19, this has been estimated using ITM’s refuelling records and an assumed fuel economy of 90 km/kg (average of other ZEFER and H2ME Toyota Mirais used in non-aggressive driving duties, as these are general purpose vehicles). Total cumulative estimation of **241 741 km** based on a H2 consumption of **2 686 kg**.



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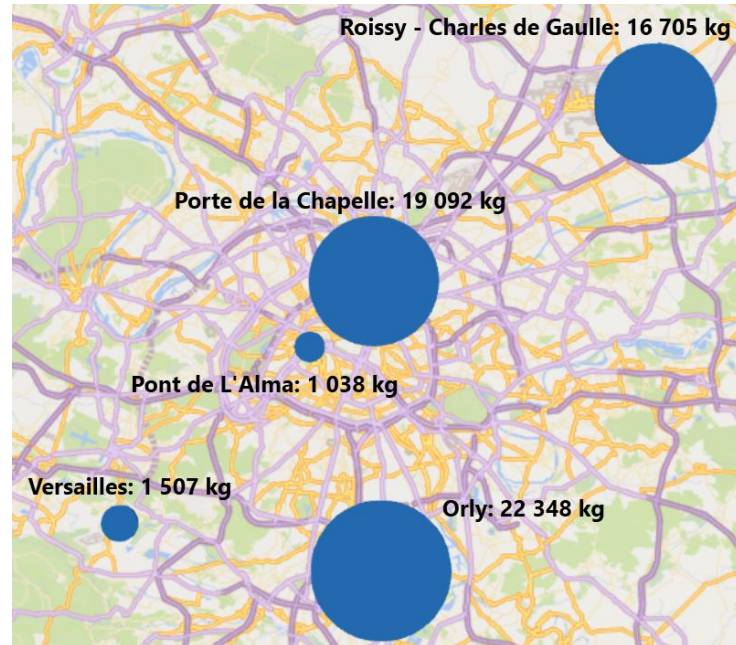
Paris FCEV Taxi Operation



- ❑ The bars show cumulative distance per vehicle (one colour per vehicle), while the green line shows the no. of vehicles reporting data. Notice the gap in the horizontal axis due to the pandemic, which caused Hype's activity to stop between April 2020 and June 2021. In Q3 2021, however, the taxis restarted operations strongly. The decrease in Q3 2023 is due to new telemetry being installed in all vehicles, and also due to some vehicles reaching their end of ownership.
- ❑ The ZEFER Hype/Hype FCEVs reported a total of **5 837 710 km** driven. The ZEFER taxis drove an average of 3 274 km per month (151 km per day and 39 289 km/year).
- ❑ The furthest driven by one of the vehicles in a month was 11 443 km.

Paris

Where ZEFER FCEVs Refuelled



- ❑ The figure above shows the location of Air Liquide HRS around Paris and the number of kg of H₂ dispensed to ZEFER Hype FCEVs. During the whole trial, there were **62 463 kg of hydrogen** dispensed in 29 205 refuelling events, averaging 2.1 kg per refuel (41% of the 5 kg hydrogen tank capacity). The mean distance between refuels for the ZEFER Hype taxi fleet was 197 km. Please note that this data comes from vehicle telemetry and has been produced using Cenex geofencing algorithms.
- ❑ The FCEVs used all the Paris HRS, but the most popular stations were Orly and Porte de la Chapelle. Orly was popular because the taxis refuel at the airport when they leave and pick up passengers and they did not need to detour to refuel, like it often happened in London. Porte de la Chapelle became the most popular HRS since taxis began to use it in Q3 2021, because many taxis have their depot/base close by, and also because of its central location.

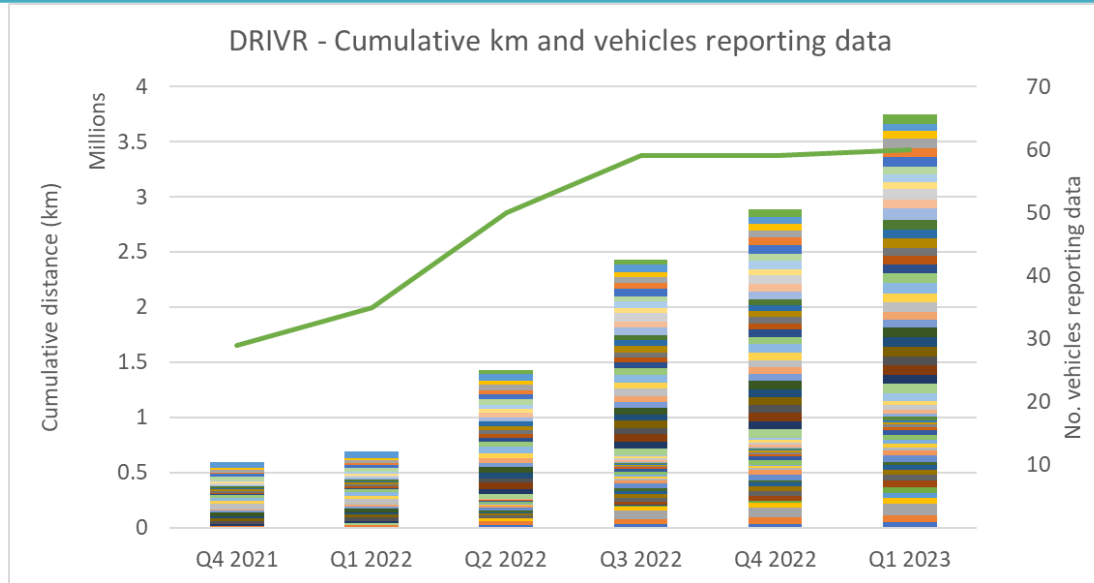


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Denmark

FCEV Taxi Operation



- ❑ Following technical issues with the hydrogen trailers that were supplying Prags Boulevard station in Copenhagen, the HRS is closed since June 2023. The FCEVs operated by DRIVR and the remaining 28 cars to be deployed could thus not run in the last months of project. In order to reach the objective of 60 vehicles deployed in Copenhagen, it was agreed that 28 cars are switched from the H2ME2 to the ZEFER project. This explains the difference in distance and no. of vehicles between this and previous reports.
- ❑ The bars show cumulative distance per vehicle (one colour per vehicle), while the green line shows the no. of vehicles reporting data.
- ❑ Data is available from 60 taxis, that covered a total distance of **3 745 000 km**.
- ❑ Data loggers capturing GPS granular data every 1 to 5 seconds were installed in 29 DRIVR vehicles, enabling a more detailed analysis (see final technical report D3.5).



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- ❑ Toyota Mirais are serviced every 10 000 to 15 000 km (or 10 000 miles in the UK)*:
 - 10 000 km/mile service comprises general check plus H₂ leak test.
 - Deionising filter changed every 30 000 km/miles.
 - Battery and fuel cell coolant is topped up at 100 000 km.

- ❑ Regular maintenance usually takes between 2 and 4 hours, depending on type of servicing as described above. This time is comparable to other types of vehicles.

- ❑ Vehicles have in practice proven to be very reliable (> 99% availability).

*Sources: Toyota UK and Toyota Denmark

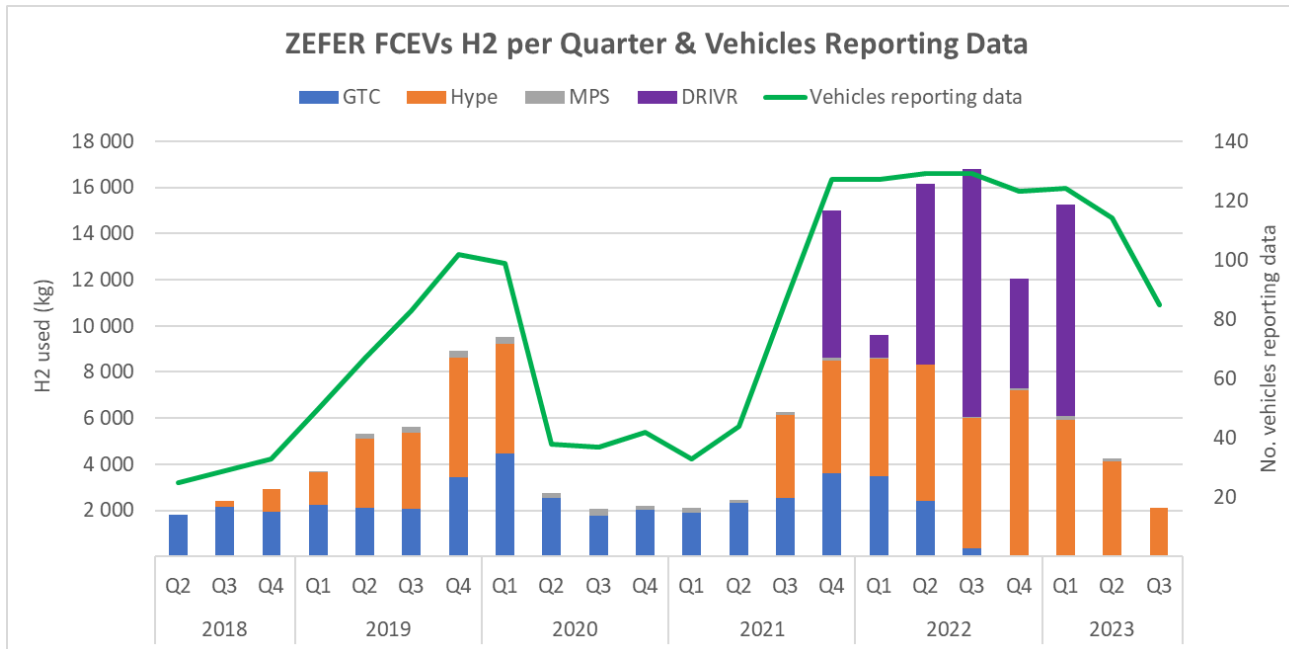


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HRS Operational Monitoring

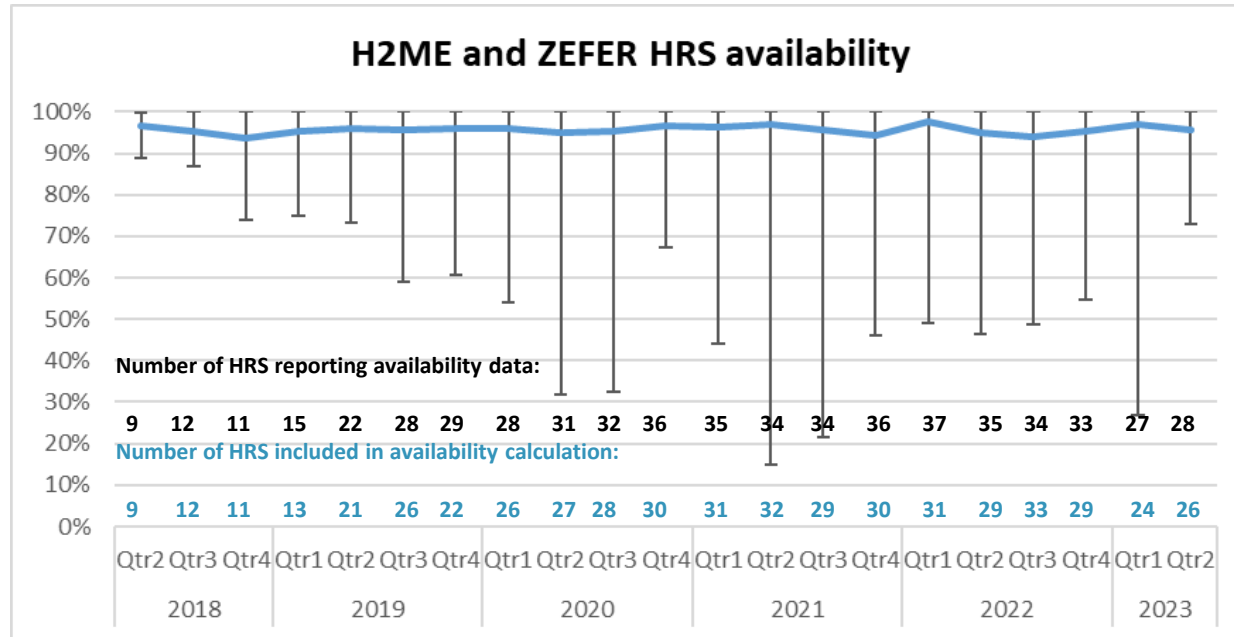
Usage of the Paris, London & Copenhagen HRS



- ❑ The graph above shows that the increase in usage and load of the London, Paris and Copenhagen HRS network closely follows the increase of FCEV deployment as part of ZEFER, but it also follows the decrease due to the GTC de-fleeting.
- ❑ The taxis in Paris stopped their operation in March 2020 due to the Covid pandemic, but restarted operations strongly in July 2021 drawing a significant amount of hydrogen demand.
- ❑ The GTC fleet reduced operations in March 2020 by approximately 50%, causing a decrease in hydrogen dispensed in London.
- ❑ As mentioned in previous slides, note the Danish HRS station closure in June 2023 and hence the vehicle swap between ZEFER and H2ME2.

HRS Operational Monitoring – All Stations

Station Availability



- ❑ The graph above shows data to the end of March 2023 from H2ME and ZEFER (no Q2 data available at the time of writing). The data from these projects has been combined to:
 - provide a more complete dataset and
 - maintain anonymisation for the ZEFER HRS providers.
- ❑ The black bars show the lowest and highest HRS availability in the quarter (a presentation format recommended by the CH2 JU). The project-average station availability is currently **96.2%**. As new HRS are deployed, the minimum availability drops, but the average remains stable.
- ❑ The reported average excludes HRS which have exhibited unusually-low availability in a given quarter (less than 80%) as these are generally down to one-off issues or, more recently, COVID-19 related problems (e.g., lack of parts and available maintenance staff). The number of HRS included in this reported average is indicated in turquoise on the graph.

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- ❑ Toyota Mirai fuel cell electric vehicles operated effectively as zero tailpipe-emission taxis and police vehicles in London, Paris and Copenhagen.
- ❑ Taxis are an excellent use-case to test the high utilisations of FCEVs, and placing number of taxis in a network of multiple HRS increases station usage, which helps the business case for the stations.
- ❑ Since 2018, ZEFER FCEVs have driven **over 15 million km**.
- ❑ Using FCEVs as taxis requires some operational adjustments to keep journeys within reasonable range of refuelling stations.
- ❑ The FCEVs have proven to be reliable (> 99% availability). They are serviced every 10 000 to 15 000 km. The vehicles have been involved in several accidents and collisions. **None of the incidents involved the release of hydrogen or problems with the fuel cell system.**
- ❑ The average HRS availability for all H2ME and ZEFER stations is currently 96.2%. **There have been no project HRS safety incidents reported.**
- ❑ Quantitative analysis during this project, feedback from drivers and partnership working with vehicle and station providers is being used to improve the operational efficiency of the vehicles and refuelling infrastructure.

Acknowledgement



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