ZERO EMISSION FLEET FOR EUROPEAN ROLLOUT

D4.7 Summary of customer value proposition of FCEV/HRS in the ZEFER project

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Stakeholders identified FCEVs as a solution for decarbonising high mileage applications in transport sector

- Since the advent of personal cars, petrol and particularly diesel vehicles have been viewed as the only option for high-mileage fleet applications such as taxis, private hire and emergency service vehicles. This is a result of the high demands of the use case, requiring **long range vehicles with quick and convenient refuelling processes**.
- However, with growing concerns about the environmental and health damage associated with internal combustion engine (ICE) there is a global consensus, including amongst stakeholders directly impacted such as fleet operators and policy makers, that a **transition is required to cleaner, less polluting vehicles**.
- The transition towards **hybrids and plug-in hybrid fleets began in the late 2000s** with recent trends showing similar evolution for **zero-emission vehicles** including battery-electric or fuel cell electric vehicles (FCEVs). This is illustrated by the ban on sales of new internal combustion cars from 2035 announced by the European Commission[1]. The aim with this restriction is to make the transport sector carbon neutral by 2050.
- Generally, this transition has been driven by 2 key factors:
  - **Policy support** for low and zero emission technologies
  - **Cost effectiveness** of technologies in high-mileage applications
- In recent years **FCEVs, using hydrogen as a transport fuel, have been identified as a sensible alternative for heavy duty and high mileage use cases with hydrogen clearly identified as part of the EC Net-Zero strategy[2]**. FCEVs can provide **similar operational flexibility and experiences** as ICE vehicles with long ranges (over 600km, 3-5 minutes refuels).
- Despite trials evidencing the high performance of the vehicles, **high-cost premiums for purchasing the technology and a lack of sufficient national refuelling infrastructure to support individual drivers still limits the uptake of FCEVs in some countries**. This, in turn, hinders the business case for hydrogen refuelling station (HRS) operators as stations have suffered from low utilization and poor hydrogen sales. A positive trend with increased utilization level and a decrease in the price of hydrogen at the pump has been observed in areas where stakeholders have developed local hydrogen ecosystems.

1 *Update of June 2023*, EU ban on sale of new petrol and diesel cars from 2035 explained | News | European Parliament (europa.eu

2 *Detailed EC proposal*, https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52021PC0559

ZEFER aimed to kick-start scaled roll-out of FCEVs by evidencing an early business case for fleet and HRS operators

Zero Emission Fleet vehicles for European Roll-out (ZEFER)

- The ZEFER project aimed to demonstrate viable business cases for hydrogen mobility in fleet applications, building upon the lessons learnt in the Hydrogen Mobility Europe Initiatives. To achieve this, two approaches were combined:
  - **An early business case for FCEVs** – **180 FCEVs were to be deployed in London, Paris and Copenhagen** (60 per city) in applications that require long ranges and quick refuels (where battery vehicles are not as viable) and where the value of zero emissions can be monetised.
  - **Linking HRS with captive fleets** – **FCEV fleets with predictable driving patterns were linked with specific HRS** to increase station utilization and hence the revenue that can be made by station operators.
- At the time of writing, **180 vehicles were in operation by ZEFER** into taxi, private hire and emergency response services across London, Paris and Copenhagen. Vehicles are operated by:

MPS FCEVs

HYPE FCEVs

- **Green Tomato Cars (GTC):** as planned by the project, 50 Toyota Mirai cars were deployed over a four years period. At the time the lease contract ended, operational challenges related to refuelling and uncertainties over future development led GTC to choose not to renew the vehicle leases.
- **Metropolitan Police Service (MPS)** – 10 Toyota Mirai as general-purpose emergency service vehicles in London have been deployed and are still in operation today.
- **HYPE** – 60 Toyota Mirai in Paris in professional taxi services in operation within the project alongside hundreds of FCEVs in operation in Paris. The company aims to deploy by the end of 2023 around 700 taxis and 7 new stations.
- **DRIVR** – 60 FCEVs were in circulation (as of June 2023), but are currently standing still due to the temporary closure of the HRS in Copenhagen.

ZEFER activities reinforced hydrogen activities by using pre-existing stations mainly owned by ITM Power (London), Air Liquide (Paris) and Everfuel (Copenhagen) and encouraging new stations over time

Deployment for additional HRS and vehicles are planned at all sites

*now out of operation

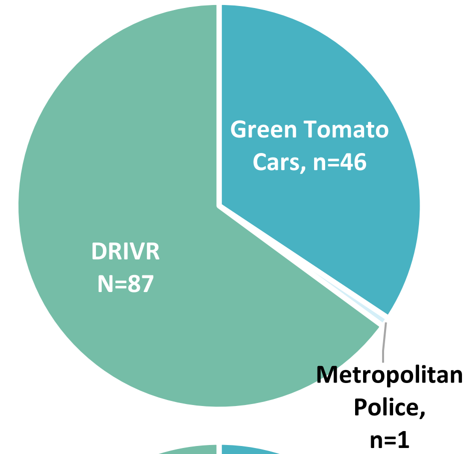
This report aims to analyse the customer value proposition of FCEVs/HRS in fleet operations

- This report aims to analyse the customer value proposition of FCEVs and HRS to investigate whether the hydrogen mobility is feasible, and sustainable, within high mileage fleet applications.
- The report is based on a variety of data including:
  - ✓ **Insights from fleet and HRS operators derived from interviews and ad/hoc discussion** – 5 rounds of interview with all FCEV and HRS operators to understand current issues/challenges of operating FCEVs in fleet applications.
  - ✓ **Surveys of FCEV users and fleet operators** – drivers and fleet managers are requested to answer project surveys both before, and after operating the vehicles to understand attitudes towards FCEVs and HRS and end-user experiences of the technology.
  - ✓ **Workshops with the project consortium** – throughout the ZEFER project a series of workshops have been hosted to discuss the customer value proposition of FCEVs with partners.
  - ✓ **Performance data collected from the FCEVs and HRS** – data on FCEV and HRS performance is collected and analysed by the project and can be used to corroborate sentiments of fleet drivers/operators.
- The report will first analyse **motivations for FCEV uptake and the experiences of the technology** to understand whether the 'value' of FCEVs is being seen in operations**.** The **business case** will then be assessed along with the improvements required to integrate FCEVs into commercial operations. To conclude, the report will draw upon the findings to form **recommendations to improve future experiences.**
- The report represents the **fourth and final iteration** of the customer value proposition and provides an update on the various findings discussed in the previous issues.

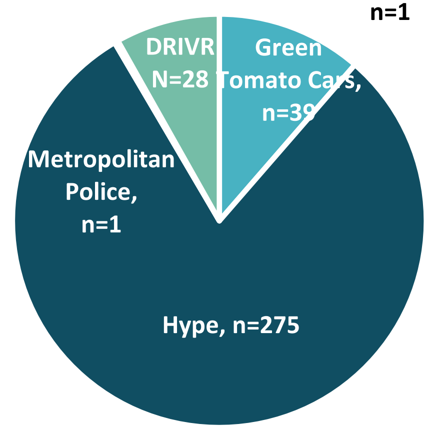
Data was collected over the course of the project from fleet drivers and managers across the ZEFER project

- The fleet drivers and managers included in the ZEFER during operation survey were those from **Green Tomato Cars** (GTC), a London-based taxi company, the **Metropolitan Police Service** (MPS) in London, **Hype**, a taxi operator in Paris, and **DRIVR** a taxi operator in Copenhagen.
- GTC, MPS and DRIVR have provided responses to the pre-operation questionnaire. By the start of the project, HYPE managers and drivers were already familiar with the technology and did therefore not complete the pre-operation questionnaire.
- Responses to the during-operation questionnaire include responses from fleet operators for GTC, MPS, Hype and DRIVR.
- While managers and drivers were asked similar questions, the survey is partitioned to allow responses to be analysed separately.
- A total of **134 responses** were gathered for the **pre-operation questionnaire** and **343 responses** for the **during-operation survey.**

Pre-operation
N = 134*



During operation
N = 343*



**Some respondents did not submit complete answers, that is why the numbers can vary depending on the questions.*

Survey responses on perspectives before and after using the vehicles have been collected since April 2018 and March 2019 respectively

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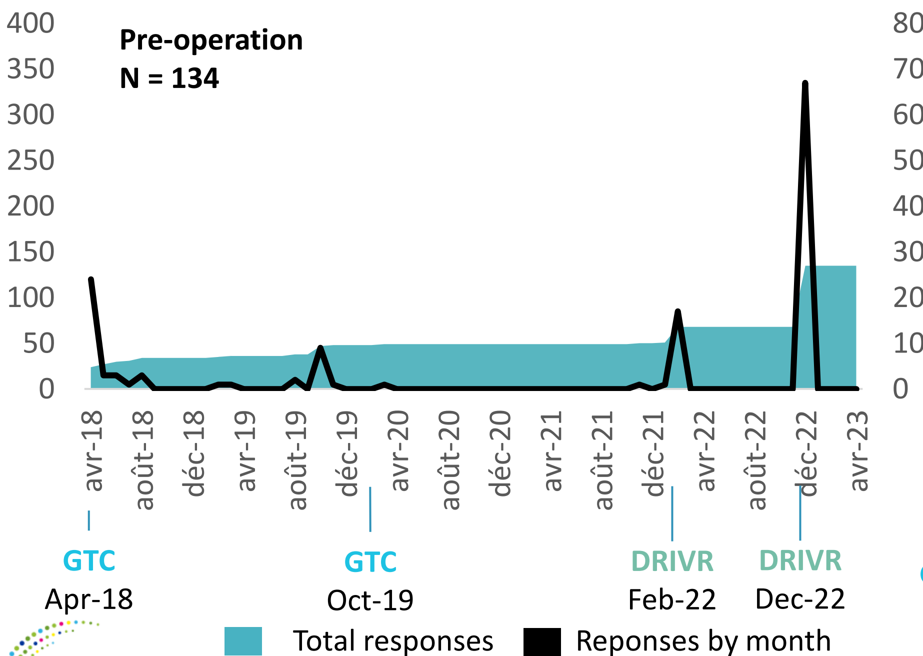
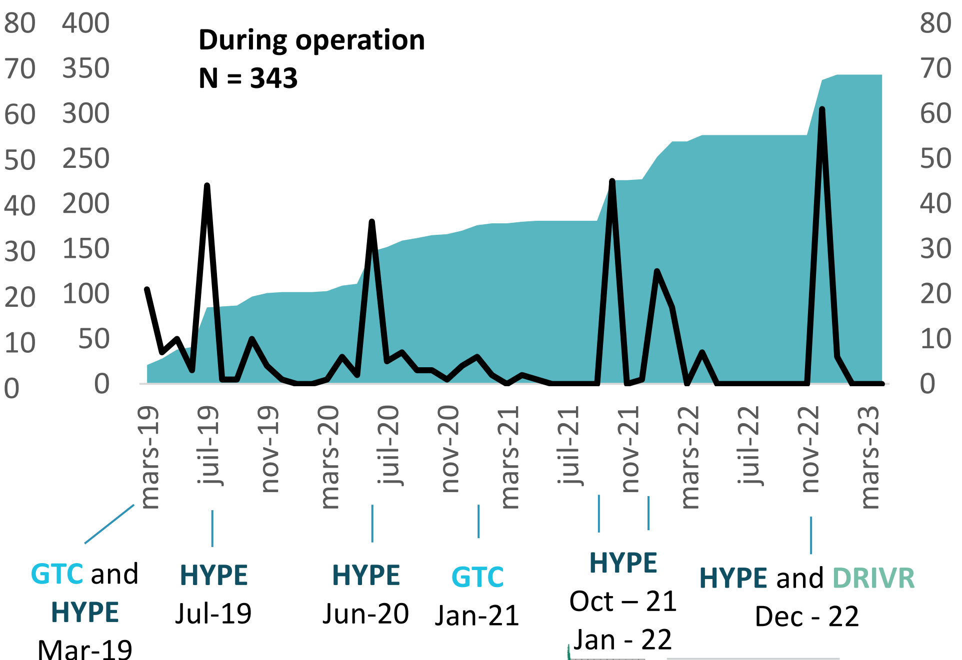
- Responses to the pre-operation questionnaire have been **collected since 2018,** with peaks seen in April 2018, October 2019, and February and December 2022 corresponding to when FCEVs were delivered to GTC and DRIVR.
- Responses to the during-operation questionnaire have been **collected since March 2019**, with DRIVR, Hype and GTC falling into distinct response groups corresponding to when the fleets were reminded to complete the questionnaires. GTC responses were in March 2019, October 2019 and January 2021, while Hype responses were in March 2019, July 2019, June 2020, October 2021 and January 2022. Responses from DRIVR for the during operation questionnaires were gathered in December 2022.
- Note that due to the COVID-19 pandemic there were limited responses to the pre-operation survey **over the course of 2020 and 2021** as few new vehicles were deployed and some were taken out of operation and drivers put on furlough ('partial unemployment').





Clean Hydrogen Partnership

ERM E4tech elementenergy ERM Group companies

Policy and regulations within cities are key drivers to the transition of transport to zero-emission technologies

- Since the Paris Agreement and COP 21, reducing CO_2 emissions has become a priority for national and local authorities in Europe.
- Transport has been identified as a key initial target for policy makers to tackle. This has resulted in a **variety of zero-emission targets and legislations which aim to reduce the number of polluting vehicles** operating in city centres. The table below outlines key policies introduced across the ZEFER cities.
- As restrictions in city centres mount, **increasing value can be attributed to zero-emission vehicles** which allow licensed operation and avoid financial penalties for using vehicles in central areas.

Copenhagen	London	Paris
Low Emission Zone – covers the geographic area of the center of Copenhagen and the municipality of Frederiksberg. The LEZ is applied every day of the week, 24 hours a day. Passenger cars are not yet affected by LEZ, which currently only affects diesel-powered trucks, vans and buses.	**Congestion Charge Zone (CCZ)** – financial fee of up to £15 per day for any petrol/diesel vehicle entering the defined zone between 7am and 6pm. The Cleaner Vehicle Discount, introduced in October 2021 includes battery electric and hydrogen fuel cell vehicles, but will only be in place until December 2025. Hybrid vehicles are excluded from any kind of discount.	**Low Emission Zone (LEZ) and Crit'Air** – limits the vehicles that can enter the city at certain times of the day based on the emission standards of the technology. Since June 2021, Crit'Air 4 & 5 (equivalent to Euro 3 or lower diesel vehicles) are not allowed in the LEZ.
Green parking spaces – Since 2020, a political incentive allows zero-emission taxi (BEV and FCEV) to have a priority access to some public parking spaces (e.g closer to the entrances of buildings) in hospitals, airports, train stations etc.	**Ultra Low Emission Zone (ULEZ)** – covers the same area (but will expand following August 2023) as the CCZ and introduces an additional fee of £12.50 per day for vehicles that don't meet the required standards. As for the congestion charge, BEVs and FCEVs are exempt.	**Taxi licensing** – operating zero-emission vehicles in Paris provides access to a particular category of taxi license (medallions) which allows the operators to conduct multiple shifts per day with one vehicle and one license. This can reduce the effective cost of the vehicle.
Reduction of registration taxes for ZE vehicles - On registration in 2022, zero-emission private cars are subject to a basic deduction of DKK 167,500 from the vehicle registration tax.	**Taxi and private hire licensing** – Transport for London (TfL) have defined licensing for taxi and private hire vehicles operating within London. Today, legislation states all newly licensed vehicles must be 'capable of producing zero emissions to receive official London licenses.	
Reserved zone for FCEVs – there are smaller child life zone which covers zones with day care/schools where only BEVs and FCEVs are authorized to drive into.		

The **Alternative Fuels Infrastructure Regulation (AFIR)** has been adopted in Europe in July 2023, requiring HRS to be **deployed every 200km** along the TEN-T corridor network. These are proposed to be capable of delivering at least **1 tonnes/day of from 2030** onwards.

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For high-mileage applications, FCEVs can provide a positive customer value proposition due to their operational advantages over BEVs

- In the face of increasing regulations on operations in city centres, fleet operators are being driven to find low-emission and now zero-emission alternatives for their operations. Two market options are battery-electric vehicles (BEV) or fuel cell electric vehicles (FCEV).
- For high mileage fleet applications, FCEVs are increasingly being recognized as an appropriate zero-emission alternative as their **long range (up to 650 kms) and quick refueling times (3-5 minutes)** [1] in comparison to BEVs[2] allows them to provide a more like-for-like comparison with petrol and mainly diesel incumbents in operation today. The value ascribed to FCEVs differs between operators in the ZEFER project, largely divided into their use case.
  - **Taxi/private hire operations** – the long ranges and fast refueling times of FCEVs are critical to the taxi/private hire business model as profits rely on the ability of vehicles to drive for many hours with little downtime and to make journeys at short notice.
  - **Emergency services** – motivations for FCEV uptake in the Metropolitan Police Service fleet focused on the availability of FCEVs and their capacity for 24/7 usage.
  - By combining the regulations for zero-emission technology and the operational advantages for FCEVs in fleet applications a **positive value proposition can be made for FCEVs** in fleet applications today. The following slides will explore the extent to which FCEVs are meeting the demands of fleet operators and where the technology provides specific advantages in comparison to its zero-emission alternative.

[1] Fuel Cell Electric Vehicles (FCEVs) | SpringerLink

[2] *can charge a BEV up to 80% in 20 minutes to 1 hour* Charger Types and Speeds | US Department of Transportation

In order to understand the customer value proposition it is important to assess whether FCEVs are meeting the needs of end-users

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- The following section will use data from performance assessments, interviews and questionnaires to understand how well real world FCEVs, and their supporting HRS, are suited to end user demand in fleet applications.
- The data from the questionnaires included in this report are based on responses to the “during operation" questionnaire. Unlike the previous issues of the report, the answers from DRIVR drivers have been included as well, as they have had over a full year of experience with the vehicles.
- The analysis will be broken down into the following sections:

1. Overall experience
2. FCEV experience
3. HRS experience

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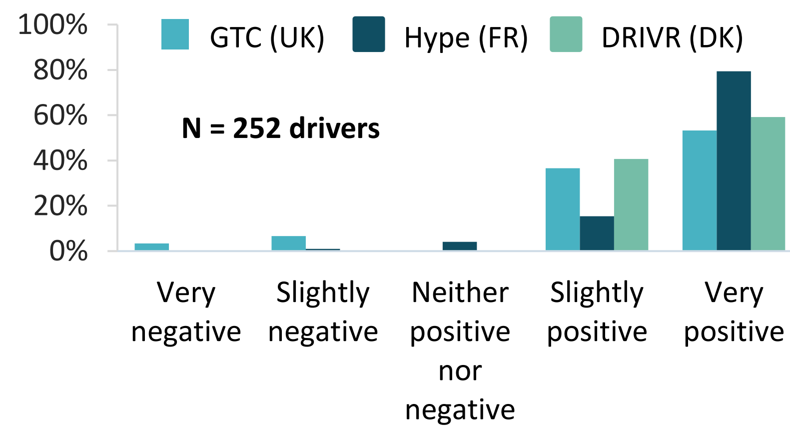
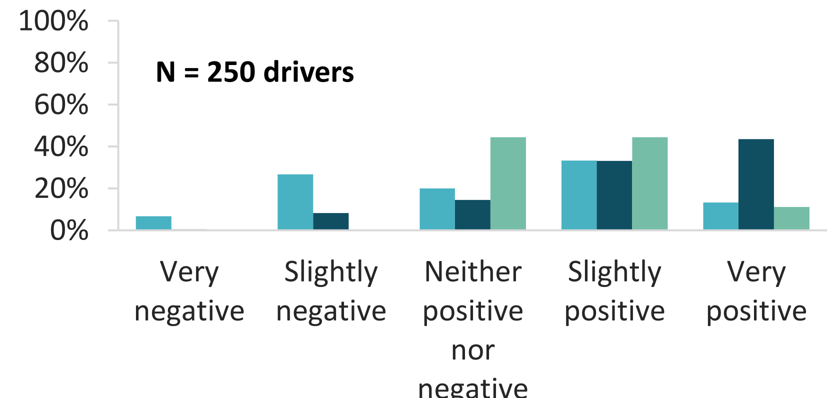
Drivers have noted a very positive experience with FCEVs, but perceptions of HRS are more mixed

- When asked about their overall experience with FCEVs, **nearly all drivers (95%) from GTC and Hype stated that their experience with FCEVs as positive.** DRIVR and GTC drivers are however slightly less enthusiastic with respectively 59% and 53% noting a 'very' positive experience compared to 79% of drivers in Paris.
- This outlook is **heavily supported by fleet operators,** whom noted a 'very positive' experience with FCEVs, describing the technology as a 'bullet-proof' (extremely reliable) alternative to petrol/diesel vehicles in terms of maintenance and operation.
- Perceptions of HRS are however more mixed. Whilst **60% of respondents noted an overall positive experience of the HRS**, 14% of drivers have had an overall negative experience with the infrastructure.
- **Negative perceptions are slightly more skewed towards the UK**, with 33% of GTC respondents noting a bad experience in comparison to 9% from HYPE drivers and 0% for DRIVR.
- **Differences in HRS experiences are reflected in fleet managers' survey responses**, with HYPE noting a 'very positive' experience and GTC and DRIVR noting a 'slightly positive' experience given difficulties faced with the number and reliability of stations in London. Maintaining high availability levels during the COVID pandemic was challenging for HRS operators which could have contributed to more negative perceptions.

Overall, how would you describe your experience with FCEVs?



Overall, how would you describe your experience with hydrogen refueling stations?



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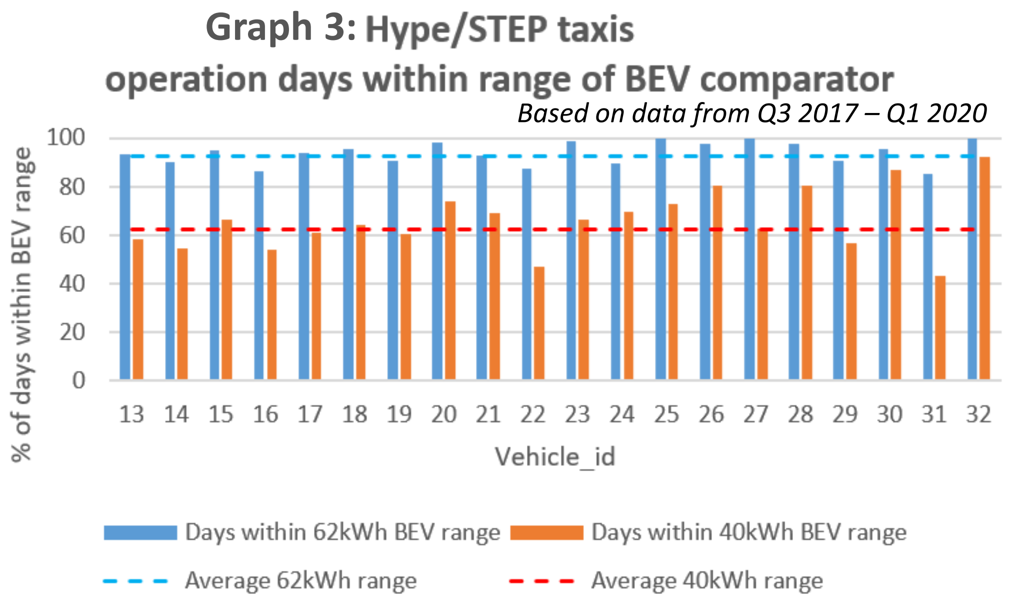
Critical to the value of FCEVs in fleet applications is their range – operator experience to date rates FCEVs highly on this parameter

- All ZEFER vehicles have been deployed into regular services by fleet operators, acting as **direct replacements to petrol/diesel equivalents**. As a result, the vehicles have been highly utilised amassing > 9 million km since April 2018.[1]
- Operators have noted that **distances driven meet their expectations in terms of ranges** for their services. In fact, for GTC the average annual distance driven by FCEVs (~45,500km) compares favorably with equivalent petrol/diesel hybrids and plug-in hybrids (~36,800km). This indicates that GTC see **value in operating the FCEVs more than their incumbent vehicles**, likely due to the ability of FCEVs to avoid financial charges for operating in London's city centre.
- Operators also placed strong value on the daily range of FCEVs. Data from the project has shown that **GTC vehicles operate an average 180 per day** and **HYPE fleets an average of 141km per day** with some ad hoc occurrences of vehicles driving 500km a day. The DRIVR fleets drive an average between 113km and 228km per day.
- Whilst the average daily utilization for the GTC, HYPE and DRIVR fleets falls within the range of most modern BEVs, **operators noted that BEVs would likely struggle to cope with the frequency of events (days) where drivers go well beyond this average**.
- To provide an example **operators stressed 'extreme cases'** in taxi services which have led some vehicles in ZEFER to double their average daily and monthly mileage. In one case, a GTC FCEV was driven 542km in a day and 12,646 km in a single month, over 3 times the usual average for vehicles in the fleet.
- This demonstrates the **need for taxi fleet operators to have vehicles with the ability to deliver high mileages in a single day and to quickly refuel** to maximise operating time. The added value of FCEVs in comparison to BEVs is further explored on the following slide.

[1] Between April 2018 and November 2022. Source: ZEFER Deliverable 3.2 – Quarterly technical performance monitoring reports for HRS and FCEVs.

Based on a case study of HYPE vehicles, no BEV is capable of meeting the range services of FCEVs although large battery BEVs come close

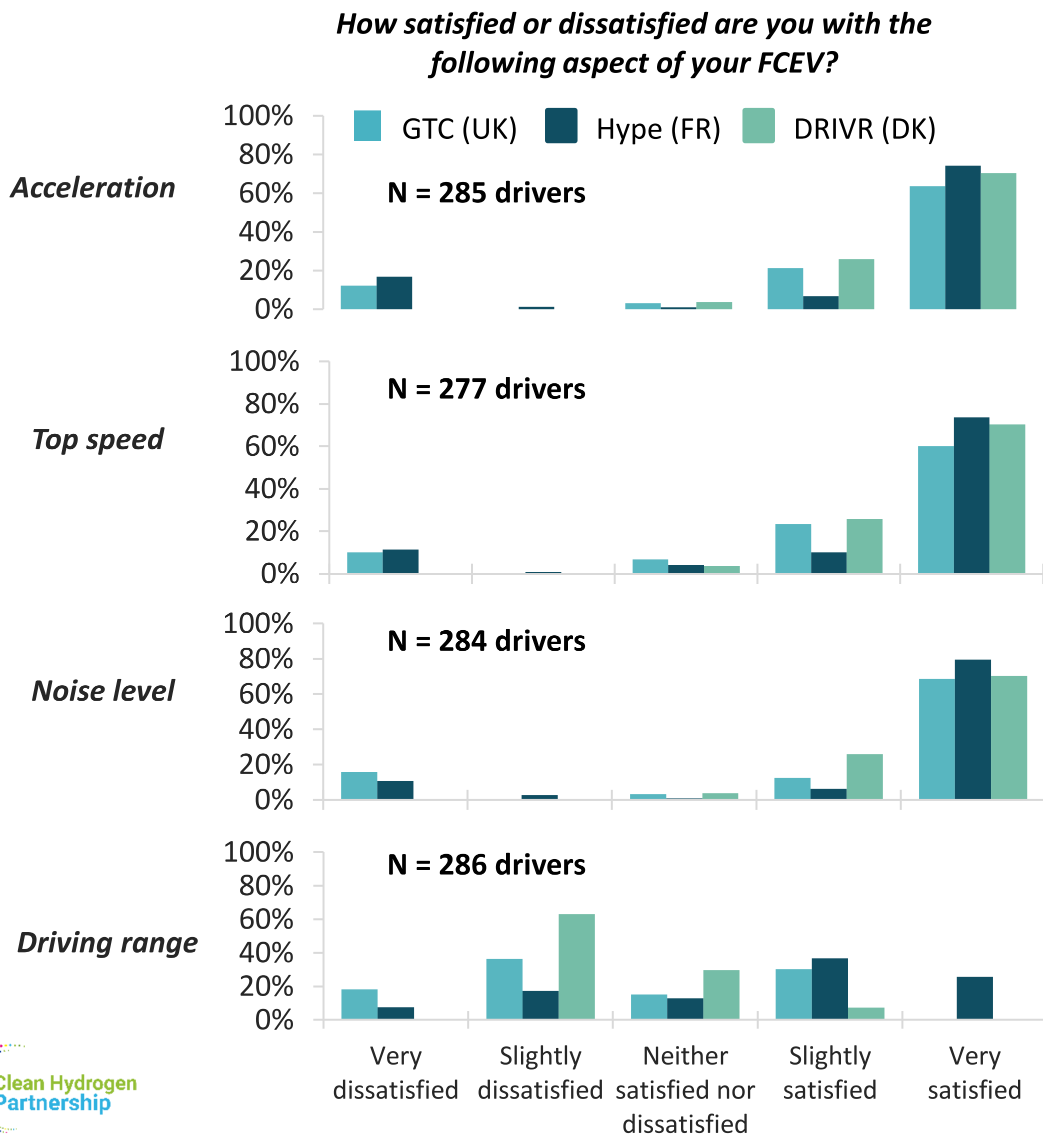
- The graph on the right shows the number of days on a given representative period* that HYPE's taxi operations falls within the range of:
  - ✓ A 62 kWh BEV: **93% overall**, assuming 312 km real-world range on a single charge (based on BEV operational data).
  - ✓ A 40 kWh BEV: **62% overall**, assuming 200 km real-world range.
- ~ 93% of daily operations could, in theory, be covered by a modern large-battery BEV without recharging. This would increase to 99% for a BEV with an 85kWh battery. Longer journeys would require a recharge.



- However, at present, taxi business models rely on minimal refuelling during operational hours, and when refuelling is necessary, for quick refuelling times. Further, evidence from the project shows that drivers are not willing to run vehicle energy stores down to near its minimum, so it is expected that the practical BEV range would be less. BEV range also decreases more than FCEV range during winter, due to the impact of low temperatures on the battery and cabin heating.
- As such, **FCEVs offer an operational advantage against other zero-emission mobility solutions in high mileage and high availability applications, offering an interesting customer value proposition for fleet operators.**

** The period selected is before the Covid-19 pandemic to provide a representative context*
Ref: H2ME D4.14 Technical Performance Report, Cenex, 2020

Fleet drivers and managers are very satisfied with most aspects of FCEV performance

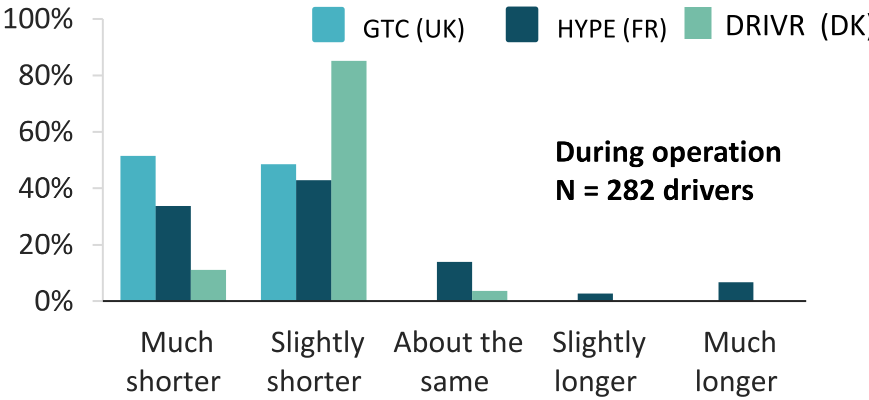


- Findings from surveys largely **support fleet operator views on the performance of the technology** (acceleration, top speed, noise level).
- The **vast majority of drivers** from all fleets **were very satisfied** with various aspects of FCEV vehicle performance.
- The proportion of positive responses has not decreased with time. This supports fleet operator comments that the **vehicles are responding well to high mileage operation** and that performance has not been compromised as the vehicle ages or has amassed mileage.
- It appears that there are less positive sentiments towards driving range in comparison to other performance aspects. This is possibly partly due to a slightly skewed perception due to issues with HRS availability.
- A small number of respondents have consistently noted a 'very negative' experience with the technology. It is suggested that this can be attributed to drivers misunderstanding the question, or a way for them to express a general rejection of the technology.

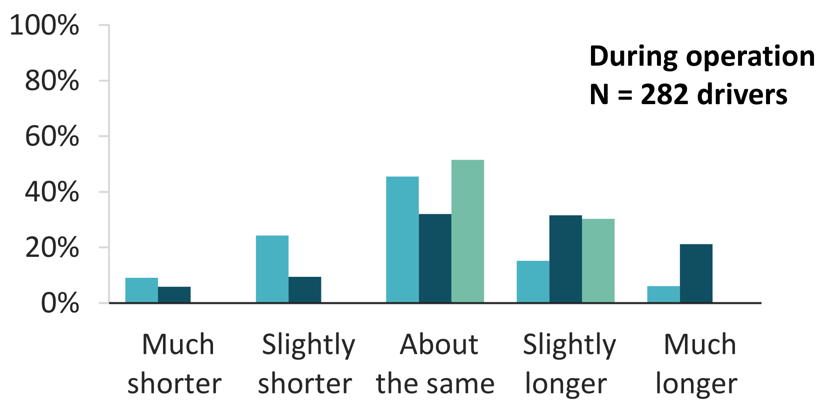
Although FCEVs are not perceived to match the range of conventional petrol/diesel vehicles, the majority of drivers see them as a longer range option than BEVs

- While the **majority of drivers were satisfied with FCEV driving range**, there were a number who requested improvements in performance to match incumbent vehicles in fleet applications.
- When comparing the range of FCEVs with other petrol/diesel incumbents **91% of drivers felt that the driving range is the same or lower.** This is likely due to the vehicles drivers usually operate, with the Toyota Prius commonly used for taxi services throughout Europe (especially within the GTC fleet). This is a hybrid vehicle and has a significantly higher range than current FCEVs models (~1,000km[1]).
- The **perception of FCEVs in comparison to battery-electric equivalents was however more positive,** with the majority of drivers surveyed viewing FCEVs to provide superior ranges than their BEV equivalents. This **reinforces the operational value of FCEVs in fleet applications.**
- However, **perceptions of the technology varied significantly between organisations** with the majority (53%) of HYPE drivers believing that that driving range of FCEVs is greater than BEVs. In comparison, most GTC drivers (45%) viewed the range of vehicles as being the same as BEVs, with 24% considering that they were shorter. DRIVR drivers only noted a similar or slightly longer range when compared to BEVs.

Based on experience, how would you compare the driving range of FCEVs to petrol/diesel vehicles?



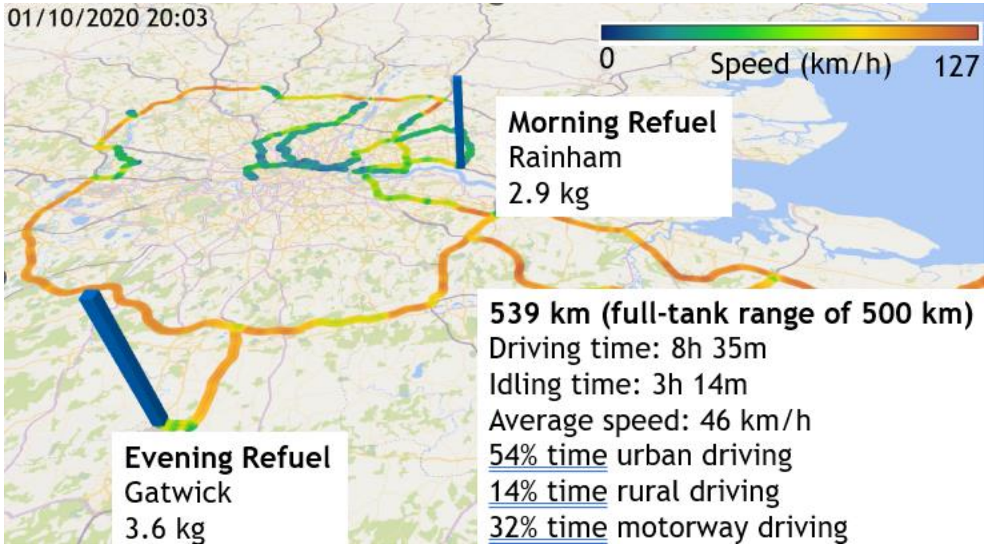
Based on experience, how would you compare the driving range of FCEVs to BEVs?



[1] Driving ranges are derived from WLTC test cycle fuel consumption figures, note that driving ranges are often shorter under real-world conditions

Green Tomato Cars (GTC) case study: FCEV fueling patterns compared to BEV charging times are comparable

- 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.
- Battery Electric Vehicles (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.



Map representing the daily driving trajectory of a Green Tomato Car in the UK.

Negative perceptions are likely to be the result of misconceptions about the maturity of FCEVs and their supporting infrastructure

- As the range of FCEVs are known to be a key benefit and reason, for choosing FCEVs it is important to understand why some GTC drivers (and to a lesser extent some HYPE drivers) did not view them as being competitive with performance standards of BEVs. This trend could be explained by a number of factors, including:
  - **Problems with HRS infrastructure create anxiety over the range of the vehicles** – drivers in ZEFER vehicles refuel more frequently than required as there are concerns about the limited number of stations and the reliability of the refuelling technology. This ‘range anxiety’ will likely have a negative impact on driver’s perceptions of the vehicles.
  - **Limited infrastructure reduces the perceived range of vehicles as significant mileage to access station is taken into account** – many drivers are required to travel significant distances to refuel their vehicles due to the limited number of stations in each city. In some cases, the additional mileage may be taken into account by drivers to produce a ‘serviceable range’ for FCEVs which accounts only for the range of vehicle when they are in service or transporting paying customers (in the case of GTC and HYPE).
  - **FCEVs have historically been advertised as being operationally identical to petrol/diesel vehicles** - This can lead drivers to have higher expectations of the maturity and performance of the technology which cannot be met in real-world applications at this stage.
  - **Advertised FCEV ranges are not always achieved in the real world** – many factors impact the range of an FCEV including seasonal variations and driver patterns (e.g. demanding quick acceleration and high speed journeys etc.). This can reduce the range of vehicles in comparison to the figures advertised which are largely based on factory test cycles. An efficiency of 1 kg / 100 km is often presented for FCEVs whereas fleet operators have reported averages around 1,1 to 1.2kg / 100 km in real world operation. **However, it is important to note that this phenomenon applies to all vehicles (including conventional vehicles and BEVs).**

When considering further uptake of the technology, two major issues emerge, with a series of more minor requests

- **Two major issues can be identified as preventing rapid further uptake of FCEVs:**
  1. **Business case** – Operators' main concerns focussed on improving the business case for FCEVs in fleet applications, noting that cost parity with current hybrid/plug-in hybrid vehicles is required to facilitate commercial uptake. To date, operators are heavily reliant on public funding to cover the cost premium of FCEV purchase/lease and fuel costs in comparison to incumbent technologies. It is expected that public funding will need to continue in the short-term whilst FCEV deployments remain small, but there is confidence that with scale and the introduction of new generation technologies that parity can be reached.
  2. **Number and reliability of HRS to support FCEV fleets -** All operators noted that inefficiencies were encountered in their operating models due to the time taken to travel to HRS and problems encountered with the reliability of the stations. Increasing the number of stations in each city is therefore vital to reduce wasted time/mileage and to provide some redundancy to the network. However, operators recommended a focus on larger scale, more reliable stations in strategic areas to allow easy access for fleet users and other high-demand transport cases (e.g. heavy-duty trucks and buses).
- Operators also suggested some **enhancements would be required to improve the suitability of FCEVs for fleet services**.
  - **More FCEV OEMs and models on the market** – there is still a limited number of FCEVs on the market today with operators largely limited to 2 major OEMs (Toyota and Hyundai). In order for FCEVs to be applicable to all fleet services, operators believed that a wider variety of OEMs and vehicle models (e.g. multi-passenger vehicles) need to be introduced. Different 'standards' of car should also be introduced to allow for a less expensive 'basic' model, and high-end 'luxury' models for executive customers.
  - Following the delivery of the second-generation Toyota Mirai (Mirai 2) in Copenhagen, 37 of the project vehicles now have 5 seats capacity (as opposed to 4 in the first generation Mirai), this allows drivers to service the same trips as their competitors. This was one of the reasons given by drivers for not switching to a FCEV previously, as it could lead them to refuse journeys with more than 3 passengers (though 85% of the taxi rides are individual rides).

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Existing HRS have provided a good foundation for initial FCEV deployments in London, Paris and Copenhagen

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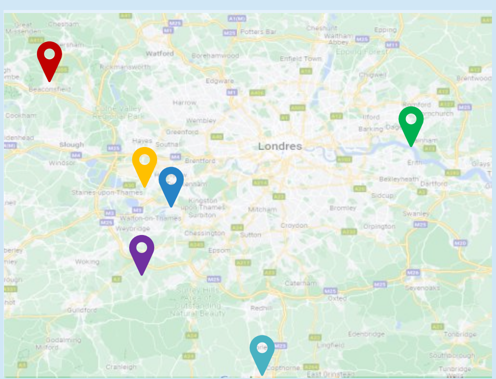
- Before analysing the HRS experience and in order to understand operators' perspectives, it is important to describe the number of HRS in each deployment location differs, as well as the operators of the stations:
  - In London, six HRS were commissioned (see the map below). As of the date of this report, five HRS are out of operation (Teddington, Rainham, Cobham, Beaconsfield and Gatwick).
  - ITM Motive operated all of the stations that are now out of operation. The last two HRS (Rainham and Teddington) were closed in May 2023 following a review of station performance; according to the operator, there was not sufficient demand to support the investment needed to continue the station operation.
  - The next slide will outline the challenges encountered by ITM Power, which ultimately led to the closure of the five operational hydrogen refuelling stations.
  - The London metropolitan area is spread over 1,583 sq km (Greater London).

Map and details of HRS in London



	Station	Operator	Capacity
	Hatton Cross	Air Products	80 kg/day
Out of operation	Teddington	ITM Power	80 kg/day
Out of operation	Rainham	ITM Power	80 kg/day
Out of operation	Cobham	ITM Power	80 kg/day
Out of operation	Beaconsfield	ITM Power	80 kg/day
Out of operation	Gatwick	ITM Power	80 kg/day

ITM Power faced various challenges, including supply chain disruptions, technical problems, and extended repair times, ultimately resulting in station closures

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Challenges faced by ITM Power:

1. **Faulty Refrigeration Pipeline in Beaconsfield**: ITM Power encountered difficulties in repairing a faulty refrigeration pipeline, as it required a station redesign and approval from the landlord for civil works. This slow process initially led to the station being out of operation for several months before its eventual closure.
2. **Supply Chain Issues for Key Component**: Another station in the London network encountered issues with a key component. Delays in the supply chain, exacerbated by COVID-19 and Brexit, extended the downtime of the station. This key component is now considered "high-risk" and is stored on-site or nearby in an ITM facility.
3. **Technical Problems with Motive Fuels Equipment**: In the past years, availability has been challenging due to ongoing technical problems identified with compressors, dispensers, and electrolysers used by Motive fuels*.
4. **Increased Operational Pressure on Opened Stations**: The decreased number of stations directed more customers to the operational ones, putting these stations under greater pressure. This increased demand made customers more vulnerable to unforeseen station downtime.
5. **Extended Repair Turnaround Times**: Longer turnaround times for repairs were experienced, partly due to supply chain disruptions. Stocking more spare parts to reduce downtime was challenging due to parts expiring before use.

* In June 2020, ITM Power established ITM Motive as a subsidiary company responsible for building, owning and operating the hydrogen refuelling stations (HRS) in England. Motive owns all the UK HRS constructed by ITM Power. ITM Motive became Motive Fuels in March 2022.

Inefficiencies in the HRS positioning in London and the lack of infrastructure meant that GTC has been unable to renew their lease for new vehicles

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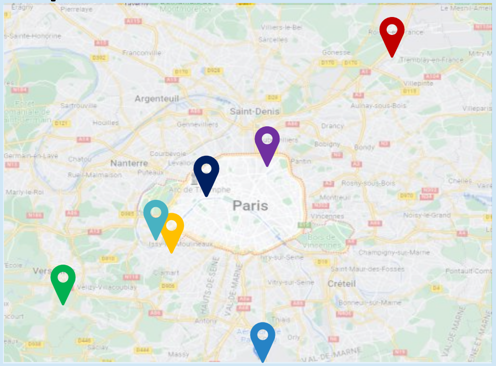
- The 50 FCEVs operated by GTC utilise 6 HRS which are located across London.
- Although GTC tried to locate drivers in West London around the cluster of HRS in Teddington, Beaconsfield and Cobham, the vehicles operate across the city of London with many jobs in, or around, central London.
- A previous analysis of the system in London showed two main issues in the operation:
  - Through an analysis of 5 GTC taxis fitted with telemetry devices, it was estimated that drivers **travel on average 24km to refuel their vehicles and take nearly 30 minutes out of their shift to reach the HRS*.** This poses a large obstacle to GTC's business case as a significant period of driver's shifts are spent refuelling rather than completing paid passenger services. The 'dead mileage' and wasted fuel to the HRS also adds an additional operational cost for the driver/operator to consider in their business case.
  - Concerns about the reliability of the infrastructure have also led drivers to **refuel their vehicles more frequently than required, with the average refuel across the fleet amounting to ~44% of the tank capacity** on the Mirai. This leads to inefficiencies in GTC's operation as drivers take additional time out of their shifts to top up their vehicles. To avoid this in the future, the **HRS network needs to be improved in terms of reliability** and drivers need to be reassured that they will be able to refuel successfully.
- In order to re-structure the system to be efficient, the number of HRS needs to be increased, with a larger geographical coverage over the city's area. Due to a lack of plans to make this happen, and due to a number of HRS closing down, GTC found themselves unable to renew their lease and continue deploying new vehicles.

calculation is based on evidence from 5 GTC vehicles and is based on the assumption that trips ending at an HRS represent dedicated trips. Source: ZEFER Deliverable 3.4 – Bi-annual Technical Report on Vehicle and Refuelling Station Operation

In Paris, seven HRS are available with an expansion to the system planned by 2025

- In Paris (The Paris metropolitan area is spread over 814 sq km), seven HRS are currently available. Most of them are operated by HysetCo and Air Liquide. HYPE started in 2023 to deploy public HRS to supply hydrogen, including to taxi operators.
- With demand for hydrogen in Paris growing, HRS operators are planning to roll out new stations over the next few years with higher capacity. For instance, HYPE has the objective to deploy 26 publicly-accessible stations in Paris/Ile-de-France region by the end of 2025. These will include at least 20 large-capacity stations, each with a capacity of around 1t/day, supplied with locally-produced green hydrogen.
- The hydrogen vehicle and HRS system in Paris has had the most success out of the three cities in the scope of this project, and its expected expansion in the coming years will support the business case for future fleet and HRS operators to invest in the city.

Map and details of HRS in Paris



Station	Operator	Capacity
Issy-les-Moulineaux	HYPE	200 kg/day
Orly	HysetCo	150 kg/day
Versailles	Air Liquide	200 kg/day
Porte de la Chapelle	HysetCo	250 kg/day
Charles de Gaulle	HysetCo	250kg/day
Porte de Saint Cloud	HysetCo	1T/day
Alma	Air Liquide	40 kg/day

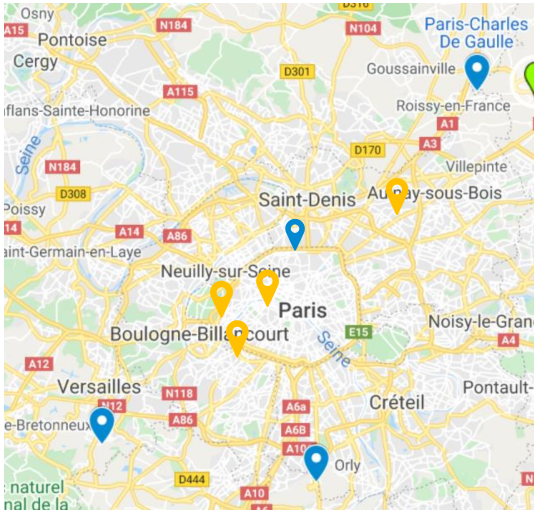
In Paris, the HRS network has been operating well with HYPE noting limited concerns about the performance of the stations and expects a scale up

- HYPE's **overall perception of hydrogen refuelling infrastructure** (through the HYPE project) **is positive**, with few concerns noted about the reliability of the stations in operation.
- Although the number of stations was flagged as a concern, the **limited infrastructure has not been viewed as a major barrier** to operations to date. This is due to the **strategic location of stations**, close to major airports (Orly and Charles de Gaulle) or close to the centre (Porte de la Chapelle), at a site owned by the operator where vehicles park between shifts. The construction of several additional HRS since the start of the project, and the announcement of many others by 2025 will contribute to increasing the density of the network.
- In Paris, the majority of refuels have been undertaken at the Orly station at the airport (21,101 kg dispensed overall). This represents a key area of business for HYPE, with airport transfers starting/ending in this location accounting for a large proportion of HYPE's daily business. The **Pont de l'Alma** was closed at the beginning of the project but is expected to reopen in Q4 of 2023. , the recently built **Porte de la Chapelle HRS,** is highly utilised as it is the closest one to the Paris city centre. The Issy-Les-Moulineaux and the Porte de St Cloud HRS which have been opened during the project both have on-site electrolysers.
- The positive outlook on the stations could also reflect:
    - **Important hydrogen demand from HYPE fleet –** The current HYPE fleet includes more than 300 vehicles which refuel regularly. This allows the stations to have a good level of utilisation. Moreover and despite the change of ownership for Roissy and Orly, Air Liquide, the station manufacturer, still remain involved in the maintenance of the HRS.
    - **The HRS archetype -** Air Liquide produce hydrogen off-site via steam-methane reforming (with carbon capture and storage) and deliver it to stations via high-pressure gas tube trailers. As a result, the stations are less complicated and therefore have less opportunity for technical failure compared to sites with on-site production. Additionally, Air Liquide can provide back-up hydrogen supply should one production site close, improving the reliability of hydrogen supply to the station.

Change in ownership and plans for new HRS are expected to lead to increased redundancy with a dense network of HRS from 2024 in Paris

- **HYPE acquired the taxi company SLOTA,** taking over taxi licences and parking sites. **One semi-temporary HRS was built in Porte de la Chapelle (north of Paris)** in the premises of SLOTA. The HRS, owned by HysetCo, is situated close to the city center, at a site owned by the SLOTA where vehicles park between shifts, increasing the convenience of refuelling for drivers.
- HysetCo took over the ownership and operation of the Paris North (Roissy) and Paris South (Orly) HRS and operate the HRS at SLOTA (Porte de la Chapelle). **In June 2023 they opened Europe's largest HRS, producing and serving up to 1 tonne of hydrogen per day in Porte de St Cloud[1]**. This HRS, manufactured by NEL, is equipped with an electrolyser and can allow up to 400 cars fill-ups per day. The HRS has 4 dispensers with 1 dual dispenser 700-350 low volume fills*, 1 twin dispenser 700-700 (2 simultaneous refuelling possible) and 1 dual dispenser 700-350 high volume fills*.
- Beyond this, **HysetCo has announced 6 new HRS to be built in 'Ile de France' region** after being granted 13,5 million by l'ADEME (French agency in charge of the energy transition). **By 2024, HysetCo plans to operate 15 HRS in the Paris region.**
- **Hype Assets was created by HYPE in 2021 to acquire and finance the assets necessary for the development of hydrogen mobility (HRS and production facilities)** in France and Europe. Hype Assets is 100% owned by HYPE and will remain controlled by HYPE. The company is dedicated to deploying hydrogen mobility infrastructure including HRS and production assets. **HYPE aims to deploy 26 HRS, including 20 HRS of large-capacity (1 t/day), in the Ile-de-France region by the end of 2025**, capable of refueling up to 10,000 hydrogen-powered taxi vehicles. HYPE concluded strategic partnerships to meet this agenda with two leading French suppliers of hydrogen equipment HRS and McPhy.[2]

HRS network in Paris by 2025



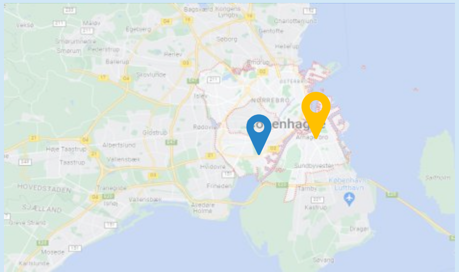
Legend:
- HRS in currently in operation
- HRS under commissioning (to be opened by Q1 2023)
- Number of HRS in operation by 2024/2025 >**35**

[1] HysetCo Inaugurates Largest Hydrogen Refuelling Station in Europe | Hydrogen Mobility Europe (h2me.eu)
[2] https://zefer.eu/uncategorised/hype-raises-e20-million-in-strategic-industrial-partnerships-with-hrs-and-mcphy/

Recent deployment of HRS in Copenhagen support the ZEFER vehicles, although there have been some complications with the service

- In Copenhagen, Everfuel is the operator of the two HRS that have been deployed*. One of the HRS is a larger unit, known as a dual station (with two dispensers).
- Recently, there have been issues with the HRS units in the city, and they have been temporarily been put out of service whilst maintenance is taking place. It is not yet fully clear when the HRS are expected to open again.
- The Copenhagen metropolitan area is spread over 1,767 sq km (but the urban area of Copenhagen is spread over 292 sq km).

Map and details of HRS in Copenhagen



Station	Operator	Capacity
Prags Bld	Everfuel	376 kg/day
Energiporten	Everfuel	>100 kg/day

*At the time of the present report, Copenhagen HRS are temporarily out of service.

In Copenhagen a limited number of HRS and continues maintenance and availability issues have resulted in a negative HRS experience

- **DRIVR, Toyota and Everfuel established a partnership** in January 2022 aiming for a **symbiotic development of the market for fuel cell vehicles in Copenhagen** by the vehicle manufacturer Toyota, the taxi operator DRIVR and the hydrogen provider Everfuel.
- The collaboration was initiated with the **deployment of an initial 100 taxis and one HRS in Copenhagen in Q3 2021.** The three companies have announced a **joint ambition to reach more than 200 by the end of 2022 and 500 Mirais in Copenhagen by the end of 2025.** [1]
- **Previous deployments have shown that access to a reliable hydrogen refuelling station is vital** for a new site with relatively limited refuelling options to ensure it can cater for the need of FCEVs in fleet applications.
- Drivers surveyed in the ZEFER project have reported **concerns about the limited number of stations available and the reliability of the infrastructure network** to provide consistent, and 'full' refuels to vehicles.
- The two HRS that have been built (see previous slide) have however not fully solved the concerns and problems experienced by drivers. In fact, due to extensive maintenance issues the HRS kept being closed, and have been temporarily been put out of service. It is still unclear when these will be re-opened.
- Future plans to extend the network are needed, if a successful infrastructure system of HRS serving the expected demand in the city is to be built.

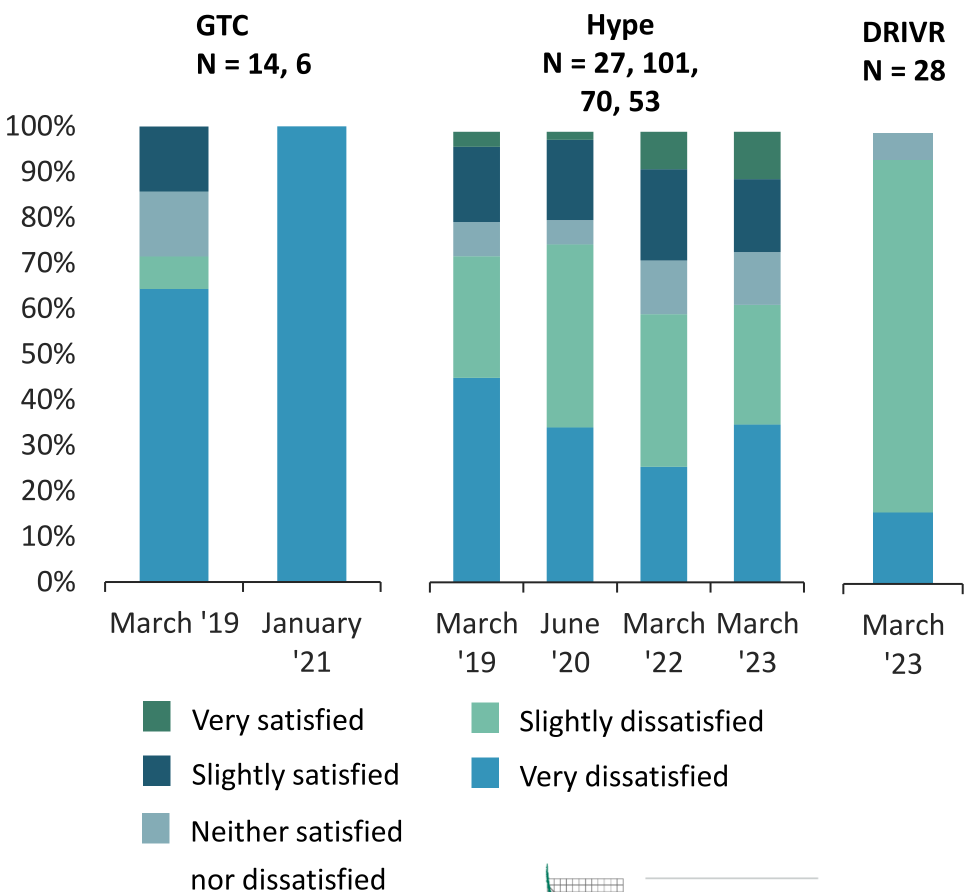
DRIVR taxis in front of the HRS in Prags Boulevard - © Everfuel

[1] https://news.cision.com/everfuel-a-s/r/toyota--everfuel-and-drivr-signs-agreement-on-scaling-up-hydrogen-taxis,c3482371

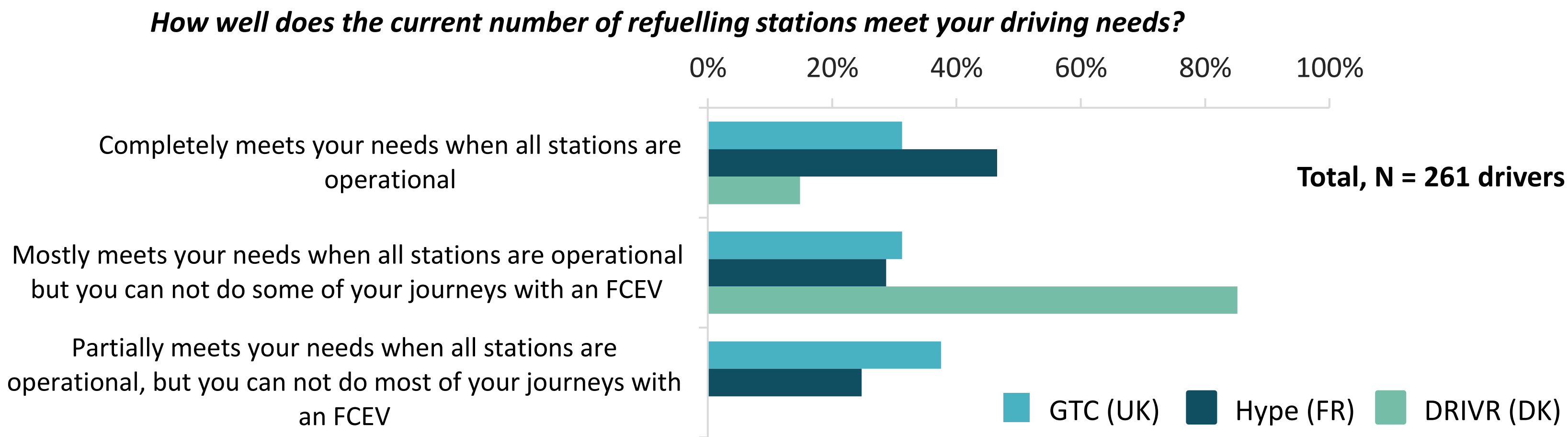
In London and Copenhagen, driver satisfaction with the number of HRS remains low, whereas Paris satisfaction levels have increased

- Despite new stations being commissioned over the course of the project (Gatwick in October 2020 and Charles de Gaulle in December 2018, etc.), the **level of driver satisfaction with the number of places to refuel remained relatively low.**
- The graph (right) show the evolution in drivers' opinion between March 2019 and March 2023, when many drivers first answered the survey, to the latest batch of responses.
- Fewer batches of responses for GTC (2) compared to Hype (4) means that the data is less up to date for drivers in London with possible evolutions not captured.
- Negative responses from GTC drivers reflect the **difficulties that have been noted on the London HRS network** since 2021 as a result of the COVID pandemic and difficulties encountered in getting maintenance personnel and spare parts to site.
- An important strategy for maintaining good level of availability at the city level is to ensure redundancy in the number of HRS in the event of failure or maintenance at a site. However, it is less straightforward to rely on this strategy in London due to the distance between the HRS sites, aggravated by heavy traffic.
- In Copenhagen drivers have relied on one main station for everyday use, supported by a smaller one put in operation to mitigate downtimes of the main one. This enables to guarantee a satisfactory reliability of the HRS, but both fleet operators and drivers indicate the need for more options to refuel.

Level of satisfaction with number of places to refuel



If stations are operating with high availability, driver concerns about the number of HRS decreases



- When the performance of hydrogen refuelling stations is taken into account, driver satisfaction with the number of hydrogen refuelling stations in their area changes. This indicates that drivers are **slightly less concerned about the number of stations** in their area **when HRS are performing extremely well**, and that consequently, less sites may be necessary to meet the operational need of customers when high performance can be ensured.
- If all stations are operational, **almost 80% of drivers believe that pre-existing stations can completely or mostly satisfy their driving needs,** but they are not able to complete some journeys with the current HRS network available at their site**.** This indicates that HRS operator should in priority focus on ensuring maximum levels of reliability for their HRS, but on the long term a more complete territorial coverage by the HRS network is necessary.
- Unsurprisingly there are significant differences between the sites due to different HRS network contexts. GTC drivers remained more pessimistic than DRIVR and HYPE drivers about the number of stations available in their area, with **40% of drivers noting that they could not satisfy most of their journeys** with the existing network of stations. This could again highlight the difficulty GTC have encountered with the location of the stations outside of the city centre, but also different coverage needs depending on the topography of the city and its drivers' habits.

Contents

Assumptions for business case analysis, and changes since last iteration

- A critical aspect of the customer value proposition is whether the technology **meets expectations in terms of purchase and operational costs.** This allows an assessment into whether a sustainable business case can be devised for fleet applications.
- To analyse this, the project has collated indicative figures from partners and literature to model the **total cost of ownership (TCO)** for leasing and operating FCEVs in high-mileage applications. In order to anonymise figures, an average for the leasing cost of the vehicles has been calculated using data from partners and internal databases at Element Energy.
- Assumptions for hybrid, plug-in hybrids and battery-electric vehicles are based upon a number of references: fleet operator feedback, discussions and quotes received from OEMs and technical brochures for products.
- For the comparison with BEV, it was decided **to include the price for using a rapid charger instead of home charging** (as done in previous version), the price of which has been estimated at €0.34/KWh today (vs. €0.4/KWh in previous version).
- **Other updates compared to previous iterations include** (see full assumptions on the next two slides):
  - Hydrogen price at the pump has decreased on average across europe from €12/kg to €10/kg.
  - Fuel prices included for BEV is based on an average electricity price for rapid chargers which is expected to play a large role in high-mileage fleet applications as drivers try to minimise vehicle downtime.
  - Car maintenance, insurance costs and car mileage have been updated accordingly, following conversations with partners

Key assumptions have been gathered from extensive market research undertaken by ERM, and validated with ZEFER partners (1/2)

Overview of sources for assumptions: 2023 total cost of ownership model

- Vehicle prices were sourced from real-world quotes[1] for the following vehicles available on the French market in September 2023:
  - Petrol hybrid: Renault Arkana
  - PHEV: VW Passat GTE
  - BEV: Tesla Model 3
  - FCEV: Toyota Mirai
- Except for FCEV, segment D[2] saloon cars are considered. For FCEV, there is no segment D vehicle available on the market in France, so the Toyota Mirai was taken as the closest available model. The Toyota Mirai is a segment E saloon.
- Residual values, fuel consumption maintenance costs were obtained from ERM analysis of a large sample of real-world data, except for FCEV fuel consumption which was obtained directly from the FCEV trials.
- Fuel prices were obtained from the following sources:
  - Petrol: 2023 average pump prices in France[3]
  - Electricity: slow and rapid public charging – ERM survey of 2023 electric vehicle charge point costs in France
  - Electricity: home charging – ERM experience of 2023 home electricity price, with VAT taken off and an additional 3 p/kWh to cover a €1,000 home charger spread over 3 years.
  - Hydrogen: see HRS business case section

1 - Actualité et infos voitures électriques et hybrides - Automobile Propre (automobile-propre.com) 2 – as defined by the UK Society of Motor Manufacturers and Traders (SMMT) 3 - https://plein-moins-cher.fr/en/index.html

Key assumptions have been gathered from extensive market research undertaken by ERM and validated with ZEFER partners (2/2)

- The table below shows the new input figures for the 2023 business model. Sources are discussed on the following slide.
- The base case scenario for all vehicle costs assumes:
  - Vehicles are **bought from new today** are **operated for 3-years** and then sold on to another user. **VAT is excluded.**
  - Vehicles are operated in high mileage applications, averaging **45,000km per year**.

Assumptions and results: 2023 total cost of ownership model

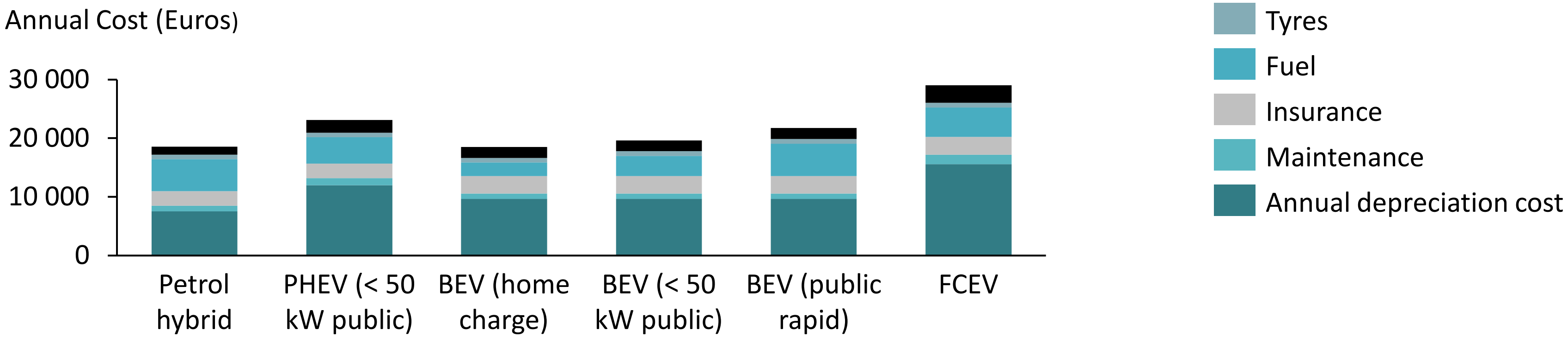
	Assumption	Petrol hybrid	PHEV	BEV (home charge)	BEV (public slow charge)	BEV (public rapid charge)	FC vehicle
	Annual mileage (km)	45,000	45,000	45,000	45,000	45,000	45,000
Lease	Vehicle purchase price (€)	26,000	41,833	34,922	34,922	34,922	56,583
	Residual value (€)	3,472	5,987	6,101	6,101	6,101	9,866
	Depreciation (€/yr)	**7,509**	**11,949**	**9,630**	**9,630**	**9,630**	**15,572**
	Finance (€/yr)	**1,326**	**2,152**	**1,849**	**1,849**	**1,849**	**2,990**
Fuel	Fuel consumption (l, kWh, kg per 100 km)	7.42	2.65/16.56*	22.38	22.38	22.38	1.12
	Fuel price (€ per l, kWh or kg)	1.62	1.62/0.34	0.23	0.34	0.55	10
	Fuel opex (€/yr)	**5,423**	**4,482**	**2,316**	**3,440**	**5,539**	**5,040**
Other	**Insurance costs (€/yr)**	**2,500**	**2,500**	**3,000**	**3,000**	**3,000**	**3,000**
	Maintenance (€/yr)	**973**	**1220**	**900**	**900**	**900**	**1,636**
	Tyres (€/yr)	**800**	**800**	**800**	**800**	**800**	**800**
OUTPUTS	**TOTAL COST OF OWNERSHIP (€/yr)**	**18,532**	**23,104**	**18,496**	**19,621**	**21,719**	**29,039**
	% DELTA VS PETROL HYBRID	**N/A**	**+25%**	**0%**	**+6%**	**+17%**	**+57%**

*Petrol / electricity

2023 figures still show FCEVs as the most expensive drivetrain for operators; however the premium over BEVs is lower when the latter rely fully on public rapid charging

Taxi TCO compared to alternatives (€/year)

45 000 km annual mileage, 3-year ownership beginning in 2023



- Using updated figures (see previous slides), **FCEVs come at a c. 55-60% premium to current petrol hybrids, c. 30-35% premium over PHEVs and c. 40-60% premium over BEVs**.
  - However, this analysis does not factor differences in revenue generating potential between powertrains, which is influenced by refuelling times, range and infrastructure provision. Drivers would need to weigh up the increased ability to capitalise on exceptional long trip opportunities with the higher costs associated with FCEV operation for the remainder of the year.
- Subsidy schemes can allow FCEV to become nearer to cost parity with the alternatives, however the premium is currently too high even with a subsidy to make the business case valid on a pure cost basis.
- Continuing improvements in battery technology will reduce some of the range and refuelling time benefits of FCEVs, though FCEVs are expected continue to outperform most BEVs in these metrics in the long term.

The FCEV TCO model is broken down into three key scenarios for FCEV leasing

The graphs displayed in the following slides will show up to three TCOs for FCEVs:

- **Current FC vehicle[1] –** shows the current cost of FCEVs without any subsidy from European or National sources.
- **ZEFER FC vehicle[2] –** illustrates indicative costs for fleet operators in the ZEFER project, accounting for ~€20,000 funding per vehicle over its lifetime
- **Optimist FC vehicle 2025 (see D3.7)** – accounts for a reduction in many key costs, including:
  - **Capital cost of FCEVs** – cost of FCEVs are expected to come down as the technology develops and becomes more widespread. Through internal modelling and outreach with OEMs we have assumed that in this best case scenarios, FCEV costs in 2025-2030 will decrease to reach parity with PHEV costs.
  - **Maintenance cost of FCEVs** – assumes no change in maintenance cost although certain OEMs are already more aggressive in their assumed maintenance costs with some quotes indicating yearly costs lower than petrol vehicles.
  - **Fuel costs** – Fuel costs are expected to reduce due to improved consumption figures (up to 25% improvement) and a reduction in fuel costs to ~€7.5/kg as a result of increased demand at stations. It is estimated that public funding will still be needed to reach this target.
  - **Insurance costs** - forecast to reduce to parity with current vehicles as the capital costs of the vehicle reduces and insurance companies become more familiar with the technology and its safety.

Summary of assumptions for FC vehicles

Assumption	Current FC vehicle	Current ZEFER FC vehicle	Optimist FC vehicle 2025
Annual mileage (km)	45,000	45,000	45,000
Vehicle purchase price (€)	56,583	36,583	39,742
Car maintenance costs (€/yr)	1,636	1,636	1,636
Insurance costs (€/yr)	3,000	3,000	2,500
Fuel consumption (l, kWh or kg per 100 km)	1.0kg	1.0kg	0.75kg
Fuel prices (€ per l, kWh or km)	€10/kg	€10/kg	€7.5/kg

[1] *Based on data provided by ZEFER partners and information gathered in internal databases at Element Energy*
[2] *Anonymized data calculated based an average between real estimates given by fleet operators*

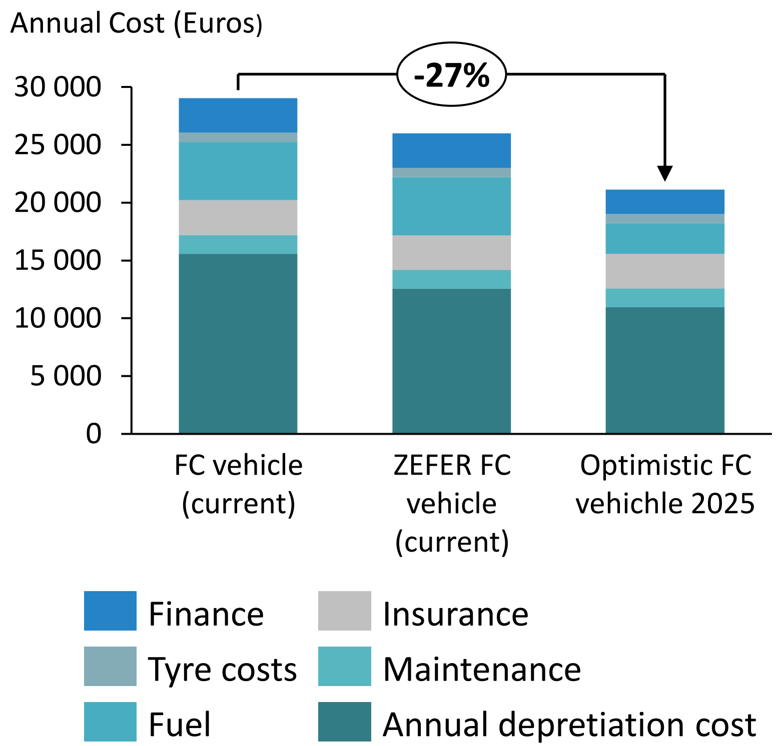
Contents

With projected cost reductions for vehicle and fuel, the FCEV can start to compete without subsidy by 2025

FCEV cost development to 2025

- Fuel costs are a significant component of the FCEVs overall business case and pose a key obstacle to commercialisation.
- Prices to date rest around €10/kg hydrogen which is expected to equate to ~100km/kg in real-world range of a vehicle. Accessing a lower price for hydrogen has a large impact on the TCO of vehicles, **reducing cost premiums by up to 27%.**
- It is **widely expected that FCEVs can reach near capital cost parity with BEVs by 2025 and that hydrogen costs can be reduced to €7.50/kg or below as a result of increased scale of demand**. This will bring the TCO of FCEVs close to parity with petrol hybrids or plug-in hybrids and into competition with modern battery-electric equivalents.
- A **full and unsubsidised business case is therefore expected to be a few generations away.** However, This is fully reliant on hydrogen production costs decreasing to reduce fuel cost.

45 000 km annual mileage, 3 year lease period



Drivers have been overwhelmingly pleased with FCEV performance across the ZEFER project

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Conclusions and recommendations – FCEV experience

Performance and Motivation

- FCEVs meet/exceed operator expectations.
- High satisfaction with range, acceleration, and speed.
- Satisfy fleet application demands effectively.
- Taxi drivers and fleet operators are increasingly feeling the necessity do decarbonise their activities, **however, only 35% of drivers did not consider petrol vehicles as a suitable choice for their organisation in the next 5 years.**

No Major Improvement Required:

- Positive operator response (95% of drivers defined their experience with the FCEV as an overall positive experience) ; no major improvement requests.
- Throughout interviews, operators maintained that FCEVs offer unique advantages over zero-emission alternatives.

Reliability and Availability

- **99% availability during the project.**
- Comparable or better reliability than hybrid vehicles.
- Long ranges meet service needs safely and effectively.

Efficient Refuelling

- Quick refuel times similar to petrol/diesel vehicles.
- Enhances availability for unpredictable service calls.

Outlook

- Confidence in a sustainable business case with scale and technology.
- Desire for more OEMs and vehicle models for FCEVs.

HRS have provided a good basis for ZEFER deployments, but limited infrastructure networks and reliability have limited the full operational advantages of FCEVs from being realised

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Conclusions and recommendations – HRS experience

Challenges with Refuelling Infrastructure:

- **60% of drivers** have defined their experience with the HRS network as overall positive.
- Satisfaction with the HRS networks has differed significantly between sites.
- Operators adapted to FCEVs' operational patterns.
- Challenges with refuelling infrastructure during deployments.
- Key obstacles: Limited stations per city, off-route travel to find a station, and reliability issues.

Location Insights:

- **Paris:** Highest satisfaction due to more HRS and strategic locations.
  - Reported queues and station unavailability at times.
- **London:** Scarce HRS, extended travel, low driver satisfaction.
  - Common unavailability and maintenance issues.
- **Copenhagen:** Lack of infrastructure, high maintenance, very dissatisfactory user experience.

Recommendations for Infrastructure Improvement:

- Build large-scale, redundant HRS to minimise closures by allowing certain parts to fail without the full station being shut down.
- Introduce multiple lines for dispensing to separate failures.
- Address upstream hydrogen supply chain issues.
- Encourage multiple operators at a site for better redundancy.

Conclusions and recommendations

Business case

- **Compared to the latest report, the cost of ownership of FCEVs in fleet operations has declined but remains higher than that of existing hybrid vehicles. However, it is anticipated that with increased scale and the introduction of new-generation technology, FCEVs can achieve cost competitiveness by 2025.**
- When considering fleet applications with heavy duty cycles, FCEV's operational advantages can lead to financial benefits. For example, in taxi services the ability of FCEVs to drive long distances means that they can be deployed on the same number of jobs as a petrol equivalent vehicle. Additionally, due to the fast refuelling of the technology, operators do not lose time (or money) associated with drivers refuelling/recharging on their shifts.
  - FCEVs are already competitive today with battery-electric equivalents when high daily ranges and rapid recharging are taken into account. This highlights the value of FCEVs in high-mileage fleet applications.
  - However, it is important to note that the business case for ZEFER vehicles today is sustained by local legislation and public funding which reduces the cost premium from c. 60% above a petrol hybrid, which is prohibitive to further uptake, to c. 40%.
- **Key elements required to improve this are:**

1) **Reduced capital cost and leasing of FCEVs** to a level at which it is competitive with petrol hybrids or plug-in hybrids (higher capital cost when compared to petrol hybrid). FCEVs could be available at a capital cost of ~€40,000[1] and then would make hydrogen taxis competitive with hybrid and BEV especially if it requires rapid public charging access which commands a higher price for electricity.
2) **Reduction in hydrogen price.** Hydrogen is a significant contributor to the cost premium of FCEVs in comparison to equivalent technologies. It is expected that costs need to reduce to below €8/kg to be competitive with petrol/diesel prices today.
3) **Continuation of funding and policy support.** Funding is required to support the business case going forward until vehicle prices can be reduced and low hydrogen costs can be sustained. Government and local authorities should continue to support FCEVs even when BEVs start to become competitive†.
4) **Network redundancy:**, this has been an issue on London and Copenhagen while fleet operators will expect high reliability and good redundancy . Deployment of HRS should include redundancy either at a site e.g "dual HRS" or by redundancy of sites to support first deployment, ideally both to ensure operators can plan their day around maintenance, if needed.

1 – Based on OEM announcements for 2025 production *volumes* (expected to be 100,000 per year)
† Increased regulations on polluting vehicles can also help the business case for FCEVs as shown by the London case.

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