ZERO EMISSION FLEET FOR EUROPEAN ROLLOUT

D3.8 Strategic recommendations for captive fleet business models

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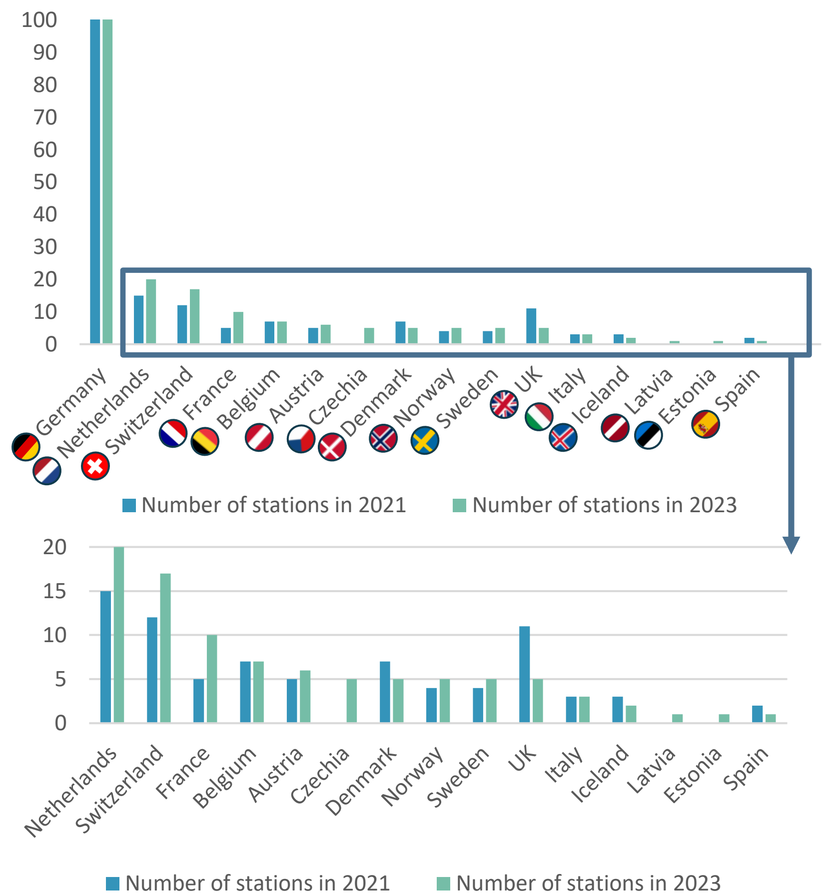
Acronyms

Acronyms:
AFIR - *Alternative Fuels Infrastructure Regulation*
BEV - *Battery Electric Vehicle*
CEF - *Connecting Europe Facility*
FCEV - *Fuel Cell Electric Vehicle*
HDV - *Heavy-Duty Vehicle*
HGV - *Heavy Goods Vehicle*
HRS - *Hydrogen Refuelling Station*
H2ME - *Hydrogen Mobility Europe*
ICE - *Internal Combustion Engine*
LDV - *Light-Duty Vehicle*
OEM - *Original Equipment Manufacturer*
R&D - *Research and Development*
TCO - *Total Cost of Ownership*
ZEFES - *Zero Emissions flexible vehicle platforms with modular powertrains serving the long-haul Freight Eco System*
ZEV - *Zero Emission Vehicle*

Hydrogen mobility has been on the rise as one of the solutions to decarbonise the transport sector by 2050

- **Today, nearly 4,000 FCEVs**[1] **are registered across Europe,** supported by a growing hydrogen refuelling network of **nearly 210 stations in 2023**.[2] 167 of these are operational and 43 are under development, representing an overall increase of nearly 60 stations when compared to the last strategic recommendations report published in 2021, which highlights the desire of European countries to expand the hydrogen network.
- However, **hydrogen mobility is not yet fully commercialized**, with all deployments having to secure significant subsidy support to develop a business case for operation and viable infrastructures.
- While the performance of OEM FCEVs in demonstration projects has been excellent, ensuring reliable supplies of hydrogen has been challenging in some markets. Indeed, some of the HRS deployed in demonstration projects have now closed (e.g. in the UK) and there is a shift to planning larger capacity, better utilised stations.
- Attractive business models for FCEVs have been identified through the H2ME projects in high mileage and heavy-duty applications which utilize a '**captive fleet approach**'. However, **further market improvements are required** before wide-scale commercial roll-out of FCEV fleets can be achieved, with **high costs and limited reliable refuelling infrastructure** still representing significant barriers to uptake.

HRS deployment across Europe

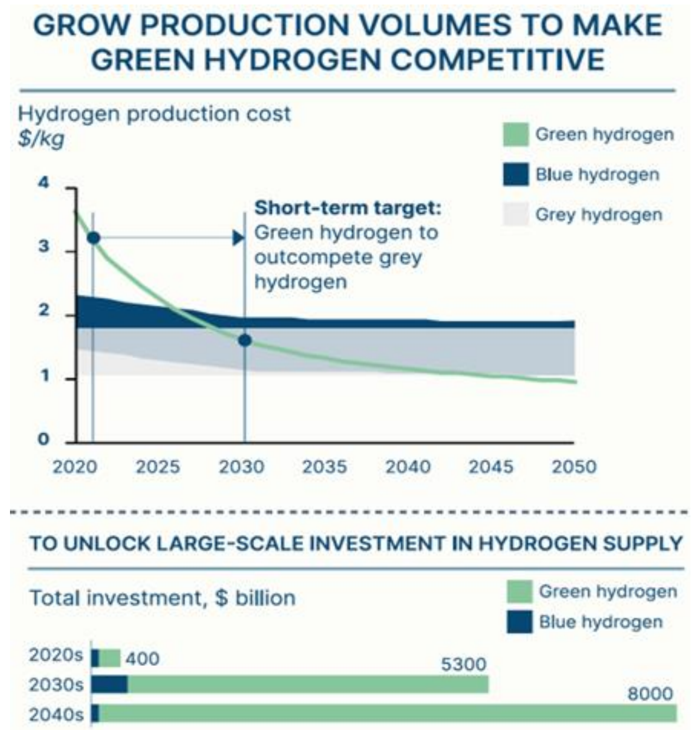


1 https://www.fchobservatory.eu/observatory/technology-and-market/net-number-of-fcev-net
2 H2.LIVE: Hydrogen Stations in Germany & Europe

The commercialisation of hydrogen mobility is a vital part of the transition to a net zero Europe by 2050

Context of this report

- Numerous governments across Europe have committed to limiting increases in global temperatures by achieving carbon neutrality by 2050. As part of this, amongst other things, **rapid reductions in transport carbon emissions are needed, representing nearly 25% of the European total greenhouse gas (GHG) emissions.**[1]
- Part of the strategy to achieve this is a switch to **vehicles with zero harmful emissions at the tailpipe**, and very low emissions on a "well-to-wheel" basis – such as battery electric or **hydrogen fuel cell electric vehicles (FCEVs)**.
- FCEVs run solely on **hydrogen which can be produced through various zero or low carbon production methods**, including electrolysis with renewable electricity or even with reformation of methane with carbon capture and storage (CCS).
- Affordable, high-volume green hydrogen is essential to accelerate the adoption of FCEV. A significant capacity in H_2, driven by wider industrial demands and investment (from $ 400 billion to $ 8000 billion), is only possible from 2030 at the earliest.
- The costs of these new technologies remain high but are expected to decrease by 2028, with a **target cost of €1 to €3/kg of hydrogen**.[3]



Source: ETC Global Hydrogen Report 2021

1 CO2 Emissions in 2022 – Analysis – IEA
2 Global average levelised cost of hydrogen production by energy source and technology, 2019 and 2050 - Data & Statistics - IEA
3 Plan_deploiement_hydrogene.pdf (ecologie.gouv.fr)

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. In addition, the company's scope is 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.

This report sets out recommendations for supporting the further commercialisation of the captive fleet model, based on findings from the ZEFER project

Overview of this report

- One of the key aims of the ZEFER project was to **analyse the business case for hydrogen mobility** and ascertain whether a 'captive fleet model' can be used in the near-term to initiate a scaled deployment of passenger car FCEVs and HRS.
- Other deliverables from the project have summarised the customer value proposition and provided detailed business case assessments for FCEVs and HRS which have helped evidence the merits and challenges associated with the technology and its deployment today (link here). This report **focuses on strategic recommendations for the sector, its supply chain and policy makers** to help remove the remaining barriers to uptake and support the commercialisation of the sector.
- The report addresses two key topics:
  - **Progress towards commercialisation** – to provide a brief outline of the current deployment statistics for FCEV and HRS roll-out.
  - **Barriers to commercialisation and targeted recommendations** – the key barriers to passenger car FCEV fleet applications that have been identified in the project by vehicle and HRS operators. This will lead to tailored recommendations for the further development of the captive fleet model for passenger car FCEVs, including sector and policy asks. Moreover, in this last version, an update on emerging market trends and progress will be provided.
- This report represents the **final version** on sector recommendations. As the latest iteration, it explores the conclusions drawn by the project in relation to the above points.

Introduction

Progress towards commercialisation

Barriers and strategic recommendations

Appendix

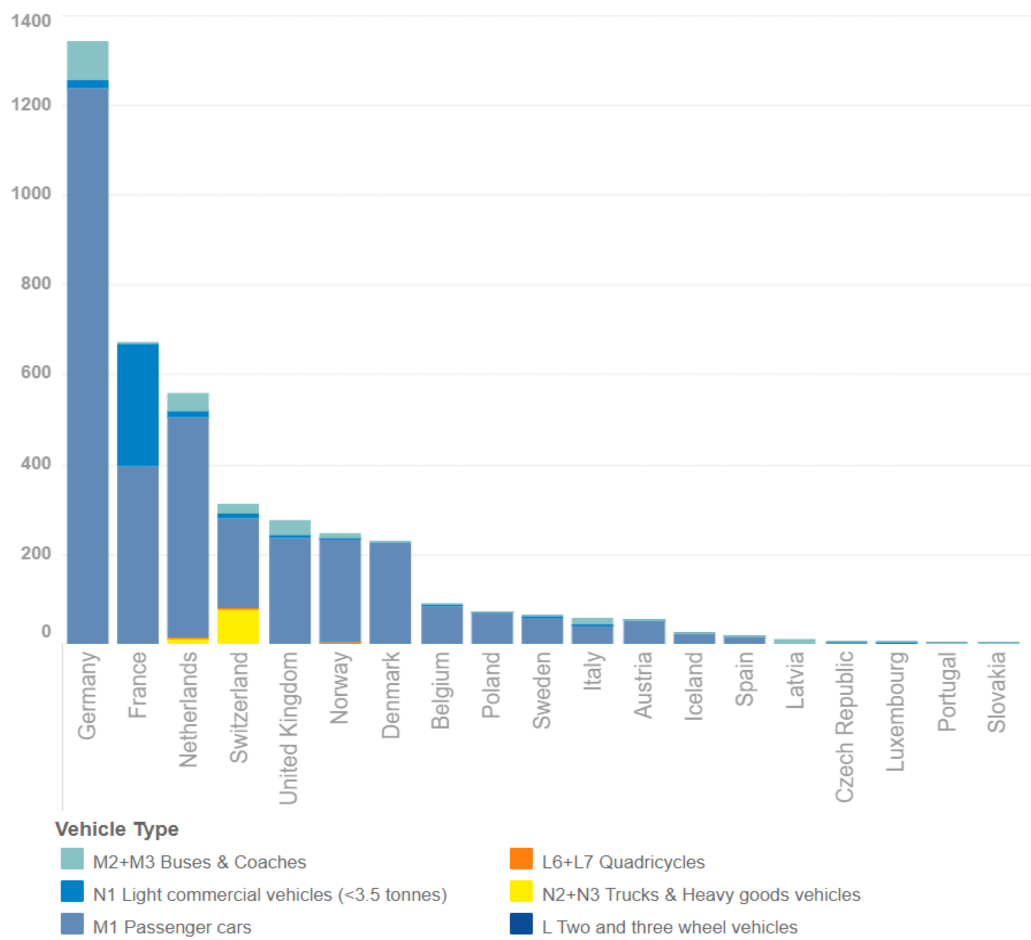
Nearly 4,000 hydrogen vehicles have been deployed in Europe, including cars, vans, buses and trucks

- As of 2021, in Europe alone, **nearly 4,000 FCEVs**[1] **have been registered** (as shown on the graph on the next slide) across multiple vehicle segments including cars, vans, buses and trucks/heavy goods vehicles. By 2023 the number of FCEVs has continued to grow overall in Europe but at a slower rate.
- The majority of FCEVs deployed to date have been passenger cars, but the focus in recent years has increasingly shifted to heavy vehicles such as buses and trucks.
- However, adoption of the technology has been slower than originally envisaged by national strategies and, as a result, the **business case for investment** remained difficult for both FCEVs and HRS as economies of scale could not be accessed.
- The attractiveness of FCEVs for light duty has diminished due to rapid development in BEVs and charging infrastructure, eroding the range and refuelling-time advantages. As ZEVs dominate the market, the case for H2 in light duty shifts to practicalities (such as grid reinforcement for large depots), addressing battery limitations, raw material availability, and supply chain concerns.
- Also, in recent years, there has been a change in the focus of national deployment strategies to centre **on heavy-duty vehicles (buses, trucks) and the development of hydrogen valleys.**
- Hydrogen valleys create a sustainable hydrogen economy, enabling local production, distribution and storage. They also allow the initiation of a **'captive fleet model'** whereby vehicles with predictable driving patterns are linked to dedicated HRS to increase utilisation and generate larger-scale demands for hydrogen production. However, the key goal of the hydrogen valleys is to combine mobility and industrial applications to rapidly achieve higher-scale hydrogen production. This approach can **facilitate a reduction in the cost of hydrogen available to end users and hence improve the overall business case** for FCEV deployment.

1 https://www.fchobservatory.eu/observatory/technology-and-market/net-number-of-fcev-net

As of 2021, Germany leads Europe in the number of registered hydrogen vehicles, followed by France and the Netherlands

Number of hydrogen vehicles registered in Europe (2021)[1]



Clean Hydrogen Partnership

ERM E4tech elementenergy ERM Group companies

1 https://www.fchobservatory.eu/observatory/technology-and-market/net-number-of-fcev-net

Alternative Fuels Infrastructure Regulation (AFIR) was adopted in July 2023, requiring HRS to be deployed every 200km along the TEN-T core network

- The AFIR was made slightly less ambitious during the agreement process between the European Parliament and the European Council in several aspects relating to road transportation.
- The number of HRS along the **TEN-T core network** was set to **one per 200 km**. These are proposed to be capable of delivering **at least 1 tonne/day of hydrogen from 2030 onwards**, equivalent to 200 cars with 5kg tanks, or 20 trucks with 50kg tanks.
- The EV recharging clusters will be capable of delivering ≥150 kW on main roads (TEN-T core and TEN-T comprehensive*). These must be installed from 2025 onwards.
- Heavy duty vehicle recharging stations have also been agreed to have a minimum output of 350 kW and be deployed every 60 km along the TEN-T core network, and every 100 km on the larger TEN-T comprehensive network from 2025, with complete network coverage to be achieved by 2030.

The European TEN-T network[1]

* **TEN-T comprehensive:** Encompasses the entire EU's long-distance traffic corridors and is about 100,000 km long.
TEN-T core: Comprises the most important long-distance traffic corridors in the EU and is about 40,000 km long.

1 BMDV - The trans-European transport network (TEN-T) (bund.de)
2 European Union Alternative Fuel Infrastructure Regulation (AFIR) (theicct.org)

Driven by AFIR, the hydrogen refuelling network in Europe is growing steadily, with nearly 210 stations installed as of 2023 and more under construction

- Two years ago, there were nearly 150 public HRS in operation in Europe, with a further 39 stations under construction or in the final stages of planning. **As of August 2023, there are 167 public stations in operation** and 43 stations in implementation, which represents a 29% increase on 2021.[1]
- While this represents the start of a pan-European refuelling network, coverage of HRS on a national and regional scale is **not yet sufficient to support wide-scale intra- and inter-city transport** which has hindered vehicle sales.
- In addition, **many of the stations initially deployed (prior to 2021) are small capacity (80 to 200kg/day)**, first-of-a-kind deployments. They were built to evidence the readiness of the technology in parallel with small FCEV deployments (up to 10 vehicles). This approach has however posed a challenge to the performance and business case for HRS operation, with small stations having little (or no) redundancy for failure and high operational and capital costs resulting in high hydrogen prices for users. **Larger stations have since been deployed in accordance with higher demands from heavy-duty vehicles.**
- HRS operators and national governments changed their deployment strategies to focus on installing large-scale, highly-reliable HRS, capable of dispensing at least **200kg of hydrogen per day capable of dispensing 350 and 700 bar hydrogen to address the different needs.**
- In recent years, the capacity of HRS has steadily increased, with Europe's largest light-duty vehicles HRS at Porte St-Cloud in Paris, France.[2] The station is now capable of delivering up to a tonne of hydrogen per day. This development is accompanied by a significant deployment of HRS in clusters, cities and regions, which should, in the long term, lead to a reduction in hydrogen prices and provide a reliable infrastructure network.
- However, a **second phase of investment** will be required to establish a more widespread network of HRS.

Operational public HRS in Europe (August 2023)

Germany is off scale counting the largest number of HRS in Europe by 2023, with 90 stations in operation.

1 H2.LIVE: Hydrogen Stations in Germany & Europe
2 HysetCo Inaugurates Largest Hydrogen Refuelling Station in Europe | Hydrogen Mobility Europe (h2me.eu)

Interest in FCEVs for high mileage applications has remained high across Europe in pursuit of the emission reduction targets announced

FCEV fleet deployment

- In line with the market trends noted on previous slides, increasing interest has been observed for fuel cell passenger cars in fleet services which commonly undertake **high mileage journeys** and **back-to-back services**.
- Whilst ZEFER has so far helped facilitate the deployment of 152 passenger cars into fleet applications, **deployment initiatives led by the private sector are initiating a step-change in market demands**. Recent announcements from taxi fleet operators include:
  - HYPE (a ZEFER partner) aims to deploy 26 HRS by the end of 2025 capable of refueling up to 10,000 hydrogen taxis vehicles. HYPE also aims to deploy its hydrogen mobility platform in 15 cities (excluding Paris) by the end of 2025. HYPE has already announced its next 7 cities to build a European corridor, starting in Brussels, then passing through Le Mans, Bordeaux, Barcelona, Madrid, Lisbon and Porto.
  - In June 2023, at the city hall of Paris, the final event of the ZEFER project took place. During the second roundtable on the role of FCEV fleets in cities' future and their replication potential, the Berlin case was presented. The new partnership "H2 Moves Berlin" between AngloAmerican, Toyota Germany and SafeDriver is working to deploy up to 200 FCEVs in Berlin. This demonstrates the integration and acceptance of this new technology by the population.
- For the captive fleet model to work, the identified barriers to uptake need to be addressed. These are discussed in the following sections.

HYPE fleet

SafeDriver car

Three key barriers have been identified within ZEFER which hinder the commercialisation of captive fleet models

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Overview of barriers

- Within the ZEFER project, three key barriers have been identified which hinder the commercialisation of FCEVs.

1) Business case for FCEV operations

To make a business case for FCEVs in fleet applications the cost of owning and operating vehicles has to **reach parity with incumbent technologies** such as petrol hybrids and plug-in hybrid vehicles on a total cost of ownership (TCO) basis.

2) FCEV market availability

To reach commercialisation, FCEVs need to be **readily available** for the fleet market in large volumes. OEMs also need to be prepared to **cater to all demands of the fleet use case,** providing a variety of vehicle models to cater to all market segments (e.g. executive travel, seven seaters and minibuses).

3) HRS deployment strategies and performance

Sufficient infrastructure needs to be installed to support the hydrogen demands created by fleet use cases. Equipment also needs to **perform to a high standard** to minimize disruption to fleet services and ensure the optimum business case for operations.

- The following slides explore each of these barriers in more detail, providing context on the challenges faced by operators and the issues the sector needs to address to overcome them. Conclusions are based on the experiences and outlook of industry stakeholders participating in the ZEFER project and derived from:
  - **Interviews with fleet and HRS operators** to understand their perceptions and experiences of the technology, as well as their conditions for further scale-up of deployments.
  - **Workshops with the project consortium** and with other stakeholders outside the ZEFER project.
  - **Customer surveys** and **techno-economic analysis of HRS and FCEV business cases** conducted as part of a separate deliverable (see here for more details).

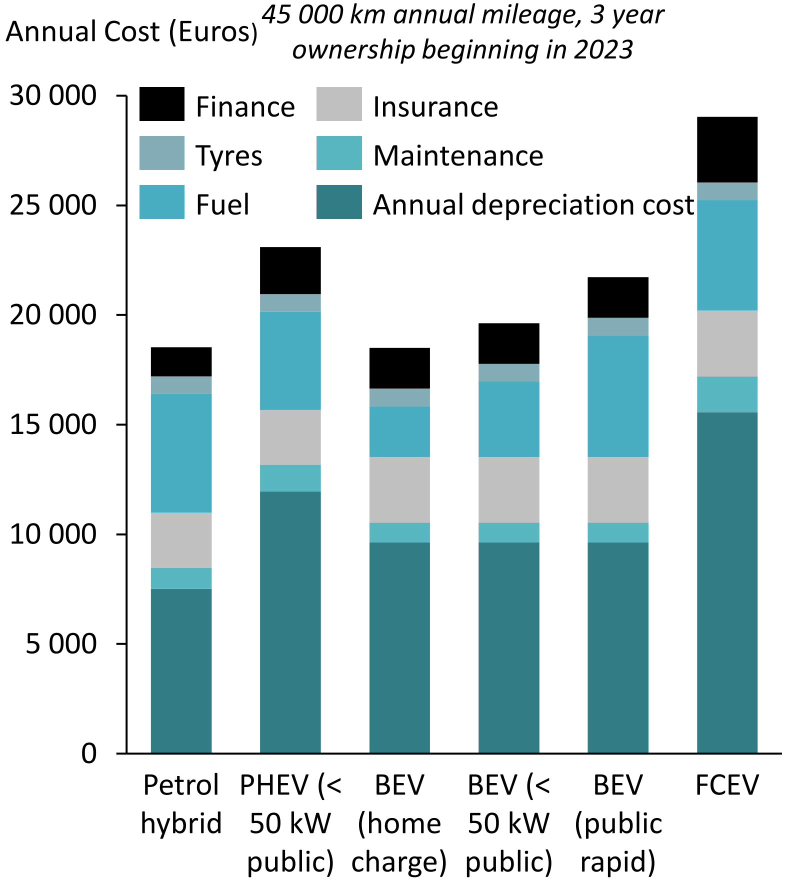
FCEVs today come at a cost premium to alternative drivetrains making their business case difficult

1. Business case – key barriers (1/3)

- In order for FCEVs to be deemed feasible in captive fleet applications, such as taxi or private hire services, the business case for operations **needs to reach parity with the incumbent vehicle used by the fleet operator**.
- Total cost of ownership (TCO) assessments encompass all major costs that are expected to be encountered over the lifetime of the vehicle including: investment costs, fuel costs, insurance, maintenance and tyre replacements. The graph provides an indication of the **annual TCO of different drivetrains** purchased and utilised in current high-mileage fleets. Inputs into the model can be found here and have been updated since this 2021 report.
- Data highlights that **FCEVs are the most expensive drivetrain** in the fleet market costing operators a 57% premium in comparison to hybrids and plug-in hybrids (PHEV) and a 55 - 34% premium in comparison to battery-electric vehicles (BEV).
- Nonetheless, recent trends in the fleet market have highlighted a **transition towards hybrids and plug-in hybrid fleets** driven by policy support for low emission vehicles.
- This poses a significant barrier to uptake as many fleet operators must access the **lowest price of vehicles** for their services to avoid reducing profitability and competitiveness (e.g. for taxi services) or depleting budgets (e.g. public budgets for police services).

Taxi TCO compared to alternatives (€/year)

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



The cost premium for FCEVs is largely the result of high vehicle and hydrogen costs caused by the lack of scale in the market

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1. Business case – key barriers (2/3)

The higher cost of the vehicles (c. €56,000) [1]

- Due to low demand for light duty FCEVs across Europe, OEMs have **not yet been able to access economies of scale to reduce the price of key components** used in the hydrogen drivetrain and **their production costs**. This results in a **>100% premium for the technology in comparison to petrol hybrids and plug-in hybrids** (Renault Arkana and VW Passat GTE respectively) and a 65% premium in comparison to BEVs (based on Tesla Model 3).
- Fleet deployments in operation today have had to use capital funding and subsidies to reduce the cost gap for purchasing an FCEV. In many cases, **additional external benefits** (e.g. avoidance of pollution charges, privileged access to taxi licenses) have been used to supplement subsidies and improve the business case.
- Going forward, further reductions in the cost of FCEVs need to be realised, with the **aim to reach parity with hybrids by 2030**. In the meantime, fleet operators will continue to rely on public funding and policy support to deploy hydrogen vehicles into fleet applications.

1 – see detailed assumptions in appendix
EU Hydrogen Strategy (2020) https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

The cost of H_2 increase because of low HRS capacities and utilisation rates, and cost reduction relies on achieving greater scale through HDV targeting

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1. Business case – key barriers (3/3)

The price of hydrogen as a in mobility applications(c. €8–12/kg)

- As scaled uptake of FCEVs has not yet been achieved, demand for hydrogen in mobility applications is low. **Hydrogen production costs therefore remain high** (between €1.50/kg and €5.50/kg depending on the production route and scale of operations1).
- **Low capacity and utilization of HRS in operation** can dramatically increase the cost of hydrogen (in some cases doubling or tripling its price for the end user). As of 2023, **hydrogen is available at most stations between €8 to €12/kg** (vs. €10 to €12/kg in 2021), accounting for public funding. To achieve commercialisation, hydrogen costs need to be reduced significantly such that parity with petrol/diesel can be achieved (~€5-7/kg).
- Plans for larger HRS to serve HDV like buses and trucks create scaling opportunities for cost reduction in per-kg H2 costs and prices. This cost pathway relies on achieving greater scale, especially with HDV demanding more hydrogen daily (tens of kg) compared to high-mileage cars (1-2 kg).
- Additionally, further funding and subsidies will be required to help scale up FCEV deployments in the coming years.
- The extent of FCEV success, especially compared to BEV is heavily limited by the fuel cost differential which is generally lower for BEVs. However, use cases where BEV charging becomes more expensive, such as through public charging instead of home charging, the FCEV business case is more competitive. Long distance, intensive taxi operations are one such case where public chagrining is inevitable, and hence FCEVs may offer a good solution.

1 EU Hydrogen Strategy (2020) https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

Accessing reductions in FCEV and hydrogen costs will require scale - demand aggregation activities for captive fleets are therefore vital

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1. Business case - Recommendations (1/4)	
Key requirements	**Recommended approaches and market updates since 2021**
FCEV capital cost reductions	• **Aggregate demand orders for fleets** to provide OEMs with investment certainty due to large numbers and access economies of scale in equipment procurement. • **Notify OEMs of interest in the market** from large fleet operators (or a group of smaller operators) via letters of commitment, target deployment numbers or conditional pre-orders. • **Outline requirements for vehicle types** needed in the short- and long-term to allow time for OEMs to develop a solution and create a clear strategy for how production lines could be constructed. • **Governments signal to OEMs** that there will be sustained demand for hydrogen vehicles going forward, including publishing FCEV deployment targets, continued subsidies and incentives for ZEVs. • **Continue OEM R&D** to reduce production costs for FC and hydrogen components for future vehicles. • Market updates since 2021 issue: **More OEMs have announced passenger car FCEV models, although deployment is still slow and in small quantities.**
Reductions in hydrogen price	• For existing stations in operation **focus on maximizing the utilization of the facility** to increase revenues and reduce maintenance issues associated with low demands. • **When establishing new stations, prioritize securing large hydrogen commitments to ensure cost-effective production and combine heavy-duty and light-duty demands requiring higher capacity stations that can accommodate linked hydrogen with dispensers catering to various duty demands*** • **Governments continue to subsidize HRS deployment** to support the capital cost of HRS and potentially introduce additional support on a €/kg basis. More details can be found on the next slide. • Market updates since the 2021 issue: the H_2 price has begun to decrease, although it is still a way away from the expected of €5-7/kg by 2030. Energy prices peaked in 2022, briefly elevating hydrogen prices before reverting to mid-2021 levels (in 2023), however, **issues with HRS deployment and maintenance increase the end-user hydrogen price.**

*e.g. 350bar and 700bar

Financial support for FCEVs needs to remain a key priority for policy makers but other innovative benefits could also improve the business case for fleet operations

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1. Business case - Recommendations (2/4)

Key requirements	Recommended approaches and market updates since 2021
Continuation of subsidy support and incentives – FCEVs	• **Subsidy support for FCEVs will need to continue** in the near-term until the cost premium of the technology can be reduced close to parity with hybrids and plug-in hybrids. Based on the electric vehicle market, the most effective ZEV subsidies are: available close to the point of sale; locked into place for at least several years; relatively simple for consumers/dealers to understand their value, and widely accessible.[1] • Policy makers should investigate whether **further cost exemptions could be accessed** by ZEV operators (low emission zones, congestion charge discounts etc.), as well as restrictions on fossil fuel vehicles. • **National and regional policies could provide more qualitative benefits** for ZEVs which support the business case for vehicles in fleet procurements. This could involve: 1) privileged access to licenses required for fleet applications (e.g. taxi licenses); 2) free parking within cities. • To achieve zero-emission mobility, **governments should consider regulating and incentivizing on a technology-neutral basis**, allowing the market to determine the optimal technology mix. • In cases where a region or country prioritizes FCEVs for specific reasons, there may be a rationale for developing FCEV-specific policies, such as generating new economic opportunities at local or national levels. • However, it's worth noting that the majority of FCEVs deployed in Europe to date have originated from Asian OEMs, making it less likely that region-specific FCEV policies will be applicable. • Market updates since 2021 issue: **Policies to incentivise OEMs to manufacture ZEV models have been announced with stricter timelines** (e.g. UK ban on new ICE vehicles from 2030 on, and 2035 for EU). **Subsidy schemes and low emission zones have become widespread in major cities around Europe.**

[1] ICCT, Principles for effective electric vehicle incentive design, 2016.

Subsidy support for HRS will need to continue – Member States need to act on RED II and ensure that hydrogen is fairly considered and supported in national frameworks

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1. Business case - Recommendations (3/4)

Key requirements	Recommended approaches

Continuation of subsidy support and incentives – HRS	• Implement policy at a national level that **de-risks the business case for HRS operators** to produce low cost, low carbon hydrogen and invest in new HRS. This could involve: 1) Continued availability of **grants or cheap finance** for initial infrastructure investments; 2) In the longer term, a move to **support hydrogen on a "per unit sold" basis**.
	• **Subsidies or certificate schemes to incentivize green hydrogen sales** over a given period can provide some revenue certainty to make investment attractive.
	  ◦ The implementation of the Renewable Energy Directive II (which includes the use of renewable hydrogen for mobility) offers a pathway for the introduction of support schemes for hydrogen at a Member State level. This (or other bespoke hydrogen subsidy schemes) can help unlock the market for hydrogen deployment.
	  ◦ Overly restrictive requirements (e.g. stipulating 100% additional "new" electricity) could limit the potential for such schemes to support hydrogen roll-out. The European-level **definitions of renewable hydrogen should be designed with sufficient flexibility** to enable support for affordable hydrogen production from a range of renewable resources.
	  ◦ National implementation should: a) **guarantee access to support** for early investors for a reasonable period; b) **consider volume caps on renewable hydrogen** to ensure that it does not dominate the RED II targets.
	• Encourage **collaborations between vehicle providers and HRS investors** which can increase the scale of deployment: for example, the taxi initiative in Paris (Hype). Where possible, provide specific incentives aimed at catalyzing the progression to such larger scale initiatives.

HRS policy support has been inconsistent across regions, with some countries benefiting from additional funding while others struggling to make business case

1. Business case - Recommendations (3/4) (*Continued*)

Key requirements	Market updates since 2021

Continuation of subsidy support and incentives – HRS	• Market updates since 2021 issue: **HRS policy support has varied in different regions, with some countries struggling to make the business case for opening new HRS locations due to low utilization.**
	• **However, the market has witnessed some development in the past couple of years, such as:**
	  ◦ Ongoing availability of CEF funding for HRS along the TEN-T corridor.
	  ◦ Introduction of the ZEFES project encompassing cross-border demonstrations involving battery electric and fuel cell electric trucks.[1]
	  ◦ The UK Government's commitment to providing £140 million to showcase hydrogen fuel cell trucks and HRS by 2025.[2]

1 Project - ZEFES
2 Competition overview - Zero emission road freight hydrogen fuel cell truck demonstration - Innovation Funding Service

Third party financiers could play a significant role in reducing the financial risk of adopting FCEVs by providing competitive leasing/package structures

ZEFER

1. Business case - Recommendations (4/4)

Key requirements	Recommended approaches
Financial solutions to reduce fleet operator risk	• **The introduction of private financiers into the market** could help facilitate FCEV uptake in fleet applications by providing competitive financing for larger scale orders. This approach would reduce the large capital risk many end users face when purchasing an FCEV and provide some security over the lifetime of the vehicle via maintenance and servicing contracts. • Financiers could devise **financial 'packages' for the purchase or lease of vehicles to provide an annual cost (€/yr) or a price per kilometer (€/km)**. A key example of this is the "Hype's packaged hydrogen mobility offer" for taxis which includes the vehicle, the fuel, the maintenance and insurance of the vehicle and access to Hype's intermediation app. This aims to reduce the initial investment cost of the vehicles for independent taxi drivers and achieve overall costs closer to parity with equivalent thermal vehicles. • To provide certainty regarding the lifetime of the vehicles and their value after first-use OEMs, or financiers, could develop a **residual price offer** for FCEVs based on their time in operation and the mileage completed by the vehicle. • Based on experience with the vehicles in operation today, OEMs could consider **extending the lifetime of FCEVs** to allow a lower purchase/lease price and to benefit from the second-hand market. • Third parties can **investigate opportunities to upgrade, or modify, vehicles** that have been through several ownerships to create a healthy second or third-hand market for the technology. Demand for used vehicles has already been identified in Europe and across the world.

Limited market availability of FCEVs reduces operator choice and poses a barrier to a full fleet transition to FCEVs

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2. FCEV market availability – key barriers (1/2)

- To date, availability of fuel cell passenger cars on the market is limited, with **only two OEMs providing a commercial offer** and only **two vehicle types available – Toyota Mirai and Hyundai Nexo**. More OEMs since the last issue of this report have started to announce fuel cell passenger cars, however they are not yet available on the market at scale.
- Fleet operators therefore have limited choice which poses a barrier to uptake as:
  - Limited model types **prevent FCEV access to the full taxi market**. A wider variety of vehicles, ranging in size (i.e. small, medium, large and 7-seaters and minibuses) and specification (basic to executive) are required in order to facilitate full fleet transitions to FCEVs.
  - Limited suppliers could mean that **large orders are not achievable for OEMs**, reducing operators' opportunities to achieve economies of scale and hence access low-cost vehicle prices.
  - **Long lead times** between the order and delivery of vehicles prevent fleet operators from responding rapidly to market or policy needs.
  - Hyundai and Toyota may not be listed on **operator's shortlists of approved suppliers**.
- In addition, this poses a risk to the development of the hydrogen mobility sector as restricted supply **prevents access from significant economies of scale** and **reduces competition between OEMs**.

New generation Toyota Mirai (2023).
Source: Toyota Mirai | Explore the Latest Range | Toyota UK

Hyundai Nexo (2023)
Source: 2023 Nexo Fuel Cell | Vehicle Overview | Hyundai USA

OEMs will require clear market signals in order to initiate, or expand, their catalogue of FCEV types and models

2. FCEV market availability – key barriers (2/2)

- Issues in the supply chain are largely due to **OEM's uncertainty surrounding the near- and long-term demands for FCEVs** of all vehicle types.
- It must be remembered that in order for OEMs to develop a new vehicle model, **significant R&D costs are encountered** to develop the drivetrain, design the vehicle, achieve certification and construct production lines. OEMs therefore need significant confidence that they will be able to achieve enough sales to justify the investment and make a profit on the product.
- In addition, **producing vehicles in low volumes is very expensive** for OEMs as scaled orders cannot be placed on key components and dedicated production lines need to be set up to build the vehicles. This means production costs per unit can be exceptionally high and well above expected revenues at market prices.
- To expand market availability, it is therefore expected that **significant demand commitments will be required** from stakeholders to de-risk OEM investment and initiate wider interest from other players.
- A key example of this can be seen in the **Hyundai Hydrogen Mobility Project** whereby a group of transport and logistic fleet operators aggregated their demands for Heavy-Good Vehicles (HGVs) to develop a market request for over 1,600 fuel cell trucks. Although Hyundai had not been a major player in the European truck market prior to this request, the scale of the interest provided Hyundai with certainty to invest in the technology and develop a commercial solution.

Hyundai Xcient Fuel Cell truck at the opening of the AVIA HRS in St Galled
Source: Hyundai Hydrogen Mobility
https://hyundai-hm.com/en/

First fleet of Hyundai trucks being transported to end users.
Source: Hyundai Hydrogen Mobility
https://hyundai-hm.com/en/

Clear market and policy signals are needed to provide OEMs with confidence to scale up production volumes of FCEVs

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2. Market availability - Recommendations

Key requirements	Recommended approaches
Diversify the OEMs supplying FCEVs	▪ Fleet operators to **engage in hydrogen councils and advocacy groups** to ensure that captive fleet models are a priority for the sector and are integrated into the strategic objectives for the EU's hydrogen plans* ▪ **Continue demand aggregation work** and present market requests to OEMs for FCEV deployment of different vehicles, as well as the announcement of deployment targets for FCEVs and large pre-orders. ▪ **Governments could provide clear market signalling** that ZEVs, and specifically FCEVs, will continue to play an increasing role via dedicated targets, policies or subsidies/incentives. In the near-term, this could focus on specific vehicle types (trucks, taxis etc.) which are known to provide an early business case for FCEVs. ▪ The **ZEV credit market**[1] in California has played an important role in the development of ZEV technology amongst numerous car manufacturers; to improve on this approach, future credit markets could **target (or provide extra credits) for ZEV sales within specific market segments** where emissions reductions and new vehicle technology development are most needed (including those well-suited for FCEV use).
Develop new model types and decrease delivery lead times	• OEMs need to **build up their supply chains** to support larger annual production volumes and hence respond to the market with less delay. • More **detailed cooperations or partnership** could be put in place between hydrogen drivetrain component suppliers and OEMs. This could allow for earlier notification of large order volumes and could provide component suppliers with greater confidence to develop their supply chains accordingly. • Market requests could target **maximum lag times** between the order and delivery of vehicles. This would provide an incentive to accelerate production. • Market updates since 2021 issue: **New FCEV models have been announced by European OEMs (e.g. BMW i5), but these are yet to enter the market.**

*In June 2023, Stellantis and Hype have announced a partnership for hydrogen-powered vehicles, beginning with the delivery of 50 zero-emission wheelchair accessible taxis in Paris from 2023

1 RFF, California's evolving zero emission vehicle program, 2019.

Fleet operators within the ZEFER project have noted HRS development as critical to the further uptake of FCEVs in their fleet

3. HRS deployment strategies and performance – key barriers (1/2)

- In order to deploy FCEVs successfully into captive fleet models a **reliable network of hydrogen refuelling infrastructure is required** to ensure that the operational advantages of the technology can be maximized and that a transition to hydrogen does not cause disruption to fleet services.
- The fleet model poses a unique opportunity for the hydrogen sector as vehicles operate in relatively predictable patterns meaning that **fewer stations are required** (compared to supporting FCEVs in general circulation)**,** and that **infrastructure can be clustered in certain areas** to provide redundancy in the network. In addition, the linking of captive fleets with stations can significantly increase utilization (or demand) at HRS, improving the business case for HRS operators.
- Overall, this **approach has been operating well within the ZEFER project**, providing a good foundation to support the initial roll-out of vehicles. However, operators (and drivers) have noted a series of challenges with the infrastructure in operation today which need to be addressed before further FCEV uptake is deemed feasible.
- Key barriers noted include:
  1. **Limited number of HRS and lack of city-wide coverage**
  2. **Low reliability of HRS** (in comparison to expectations)
  3. **Inappropriate HRS specifications** to support high-mileage fleet demands
  4. **End user communication**
- Each of these challenges is discussed in more detail in the following slides and followed with recommendations in this section. The recommendations made have not largely changed since the first issue of this report, as the key barriers remain the same, though an updated overview of the problems experienced by operators has been given.

HRS operators should focus on building larger scale and highly reliable stations in clusters on the main geographical axis of cities

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3. HRS deployment strategies and performance – Recommendations (1/4)	
Key requirements	**Recommended approaches and updates since 2021**
Increase the number and coverage of HRS	(see below)

- Focus on **securing large commitments** to a rapid scale-up of **hydrogen demand at a local scale**. This will involve various **demand aggregation** activities for fleets, light and heavy duty vehicles.
- Secure commitment (e.g. letters of intent, pre-orders etc.) for vehicle deployment and work with key anchor demand users to **ensure station siting is suitable to support fleets and individual users**. Key feedback from operators within the ZEFER project indicates that **HRS are needed on all key axis of the city** (north, east, south, west and central) and in **clusters of at least two stations** to ensure that there is redundancy nearby in the network in case of station downtime.
- Clusters can largely be **focussed on the outskirts of cities**, with one or two in city centres, to allow access to larger sites and avoid issues with planning authorities in built up and residential areas.
- Where appropriate, ensure that **HRS that are built for multiple vehicle types,** considering**:**
  - Suitable refuelling protocols and dispensers
  - Refuelling capacity
  - Interoperability with other public HRS
- <u>HRS updates since 2021 issue</u>:
  - In Paris, the HRS work well and further HRS will be built.
  - In London, the HRS operators have struggled to keep their facilities open due to maintenance issues and lack of demand, and nearly all HRS are now closed in London.
  - In Copenhagen the HRS operators have had maintenance issues that have led to the temporary closure of the stations for several weeks. Before this incident, the stations were working well.

The number, location and performance of HRS have been flagged as the highest priority barriers to address

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3. HRS deployment strategies and performance – key barriers (2/2)	
Number of HRS and city-wide coverage	❖ Fleet operators have noted **significant operational and economic inefficiencies** in FCEV services due to wasted mileage and time encountered travelling to, and from, stations. ❖ Operators continue to call for an increase in the number of HRS, with a focus **on developing clusters of stations in key demand routes over the city.** This aims to both decrease the time wasted accessing stations as well as provide redundancy in the network should one or more stations be closed due to maintenance or unexpected errors.
HRS performance	❖ Many of the HRS deployed today are not designed to cater to high utilisation (due to low hydrogen capacity (onsite or offsite production), low number of dispensers per HRS, and old generation technology) and as a result have struggled to achieve target reliability performance levels. ❖ On multiple occasions, fleet operators have reported drivers arriving at HRS and being unable to refuel due to unexpected failures in equipment (largely attributed to faults with compressors, dispensers and chillers). There are therefore calls to **improve the availability of HRS by introducing redundancy into system processes** (e.g. additional dispensers, additional compressors) **and installing larger volumes of high-pressure hydrogen storage** on-site.
HRS specification	❖ As noted in previous slides, many of the stations installed today are low-capacity, capable of dispensing 80kg to 200kg of hydrogen per day. **There have been reported shortages of fuel** at multiple HRS during peak demand periods. Larger capacity and back-up storage hydrogen are required if the demand is expected to grow. ❖ Operators have also noted an opportunity to **improve the back-to-back refuelling capacities of stations** to reduce the wait time encountered when a station's hydrogen supplies are depleted, and additional compression is required.
End user communication	❖ Due to the limited redundancy in HRS networks currently there needs to be a **high level of communication** between HRS and fleet operators to avoid drivers attending a station which is out of operation. To accomplish that, CH2 JU has launched the EU-HRS-AS* initiative that collects real-time availability data reported by HRS all over Europe and provides the public with real-time availability status as well as various static HRS information ❖ Whilst communication has improved throughout the ZEFER project as a result of live availability apps (e.g. ITM Availability App, Filln'Drive and H2. Live), operators have requested **more transparent feedback**.**

* The European Hydrogen Refuelling Station Availability System
** When, why and for how long stations are expected to be out of operation.

Including redundancy into station process lines will be key to ensuring high availability at captive fleet HRS

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3. HRS deployment strategies and performance – Recommendations (2/4)

Key requirements	Recommended approaches
Improve HRS performance – design and technical improvements	• HRS operators should focus on **high-capacity stations which include redundancy** to allow isolated failures to occur without the HRS experiencing downtime. • Sufficient **high-pressure hydrogen storage should be installed on site to account for at least one full day of hydrogen demand from the fleets using the station** should there be disruption to hydrogen supply (e.g. electrolyser failure or transport disruption). As the scale of demand increases at HRS sites, many HRS operators are increasing storage capacities to account for 2 to 3 days of hydrogen demand. • A **back-up hydrogen supply chain** should be secured for HRS clusters with large demands. This can be through tube trailer delivery from a production plant or from pipeline distribution as this infrastructure starts to be more widespread. • **Standardised, modular designs for HRS** could lead to improved availability as best practices can be employed for installing and operating the station. Efficiencies can also be achieved in the management of stations as spare parts could be easily sourced and technicians could be trained to maintain a network of HRS to reduce response times. • Establish an independent **regulatory body** for HRS at the national level to **test and certify new refuelling stations** for safety and performance, and to maximise the interoperability of the growing networks of public HRS. This may require support from vehicle suppliers & existing HRS operators and is likely to require funding either from government, and/or from within the sector. • The industry should seek funding for projects to bring **improvements to the quality and supply of specific HRS components** that frequently need repairing or replacing. Ease of use should also be considered in aspects such as nozzle design to reduce periods of downtime caused by user error.

Management improvements can help reduce the instances of major equipment failure and minimise downtime when failures do occur

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3. HRS deployment strategies and performance – Recommendations (3/4)

Key requirements	Recommended approaches
Improve HRS performance – management improvements	• Ensure local (in-country) **availability of replacement parts** for 'high-risk' components and **train local technicians** to address a range of issues at the HRS. • Conduct **rigorous testing of stations** off-site and on-site. This could entail operators being certified to do their own testing or include third party testing of the HRS before commissioning. • Ensure **robust, centralised, and constant, data monitoring systems** are in place with dedicated employees for analysis of data. • Provide **training to ensure that common technical issues can be addressed remotely or by local maintenance staff**. • Establish **formalized maintenance procedures and contracts** with clearly defined responsibilities and timescales which reflect targeted availability (>98%). • Use data (cross-checking downtime with video surveillance) and/or customer feedback to **improve user-friendliness of stations** to help decrease user error as a cause of downtime. • Ensure that end users can **access the live availability status of stations** and that **24/7 customer helplines are available** at HRS (this can help ensure that any technical issues are identified quickly). • Fleet operators **request performance contracts/guarantees** from HRS operators to ensure that minimizing downtime is a high business priority. This can also help improve fleet operator (and driver) confidence in the technology.

HRS should be designed specifically to cater to high utilisation to ensure the technology meets fleet expectations

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3. HRS deployment strategies and performance – Recommendations (4/4)

Key requirements	Recommended approaches

Design stations for high utilisation	• New HRS should be **modularly designed** to ensure that the technology is built to cater to current demand/refuelling patterns and future-proofed for high utilisation. Fleet operators and station providers should work together to plan an optimized refuelling profile and station design.
	• If high demands are identified, station design should take into account:
	  • **Daily demand profiles** – the ability of a HRS to meet daily demand fluctuations will depend on the installed compressor capacity on-site and the volume of high-pressure storage available. The approach taken by HRS operators will depend on the size of the site and careful consideration of the costs of each upgrading equipment.
	  • **Hourly demand profiles** – meeting hourly demand variations will depend on the back-to-back refuelling specification of the station and the waiting time required to refill high-pressure buffer storage. Increasing compressor capacity allows for an increase in back-to-back refuelling events and would facilitate shorter wait times in comparison to upgrades in high-pressure storage.
	  • **Actions to reduce downtime** – three key strategies have been recommended by HRS operators including: increasing high-pressure storage on site, introducing redundancy into process lines at stations and ensuring a back-up supply of hydrogen is in place in case of production failures.

Develop end user communication	▪ Continue to **improve the customer experience of existing HRS** by ensuring **live data is available** on the status of the station. This data should also be provided to third party mapping. ▪ **HRS operators need to provide transparent feedback** to key demand fleets or users as to why the station is out of operation and how long it will take to re-enter operation. This can boost technology confidence and enable focused mitigation for reduced driver disruption.

Introduction

Progress towards commercialisation

Barriers and strategic recommendations

Appendix

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

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- 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
Lease	Residual value (€)	3,472	5,987	6,101	6,101	6,101	9,866
Lease	**Depreciation (€/yr)**	**7,509**	**11,949**	**9,630**	**9,630**	**9,630**	**15,572**
Lease	**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	Fuel price (€ per l, kWh or kg)	1.62	1.62/0.34	0.23	0.34	0.55	10
Fuel	**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**
Other	**Maintenance (€/yr)**	**973**	**1220**	**900**	**900**	**900**	**1,636**
Other	**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**
OUTPUTS	**% DELTA VS PETROL HYBRID**	**N/A**	**+25%**	**0%**	**+6%**	**+17%**	**+57%**

*Petrol / electricity

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

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

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