ZERO EMISSION FLEET FOR EUROPEAN ROLLOUT

D3.7 Summary and lessons learnt from business cases tested in the project

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Acronyms

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AFIR - *Alternative Fuels Infrastructure Regulation*

BEV - *Battery Electric Vehicle*

FCEV - *Fuel Cell Electric Vehicle*

HRS - *Hydrogen Refuelling Station*

H2ME - *Hydrogen Mobility Europe*

ICE - *Internal Combustion Engine*

OEM - *Original Equipment Manufacturer*

R&D - *Research and Development*

TCO - *Total Cost of Ownership*

ZEV - *Zero Emission Vehicle*

Agenda

ZEFER

Introduction
FCEV business case
HRS business case
Conclusion

Clean Hydrogen Partnership

ERM E4tech elementenergy ERM Group companies

High mileage fleet applications pose a challenge to decarbonising the transport sector

- For many years, petrol and 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 **exceptional technical performance standards** (long ranges, quick refuelling processes, high availability etc) at a **low total cost of ownership.** However, with growing concerns about the environmental damage associated with petrol/diesel vehicles, there is a consensus amongst fleet operators and policy makers that a transition to cleaner, lower emission vehicles is required.
- Recent trends in the fleet market have highlighted a transition towards **hybrids and plug-in hybrid fleets**. This has been driven by **policy support** for low emission technologies, and the **increasing cost effectiveness** of these vehicles as fuel prices and taxes on emissions increase. However, with many cities and countries now presenting 'Net Zero' targets, there is renewed pressure to transition transport fleets to fully zero emission vehicles such as battery-electric or fuel cell electric vehicles.
- There is a **growing consensus across Europe that fuel cell electric vehicles (FCEVs), using hydrogen as a transport fuel, can provide a sensible alternative for heavy duty and high mileage use cases**. This is because FCEVs can provide **similar operational flexibility and experiences** as petrol/diesel vehicles, with long ranges (~600km) and fast refuelling times (3-5 minutes refuels).
- Despite trials evidencing the performance of the vehicles, the **uptake of FCEVs has been limited** in recent years. This has **hindered the business case** for the technology as economies of scale cannot be accessed to reduce the cost of vehicles or to initiate scaled deployment of hydrogen production and distribution infrastructure. This, in turn, has historically led FCEVs to come at a significant cost premium to incumbent petrol/diesel, hybrid and plug-in hybrid vehicles, which has often caused fleet operators to disregard the technology in fleet procurement strategies.

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

ZEFER

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

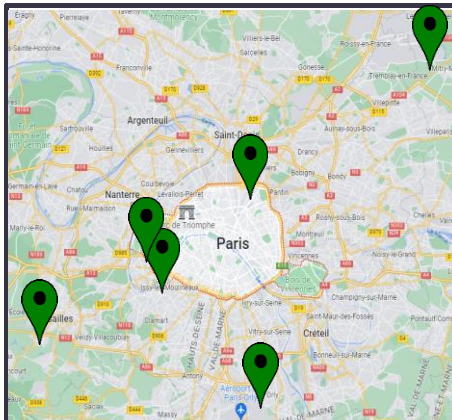
- The ZEFER project aimed to demonstrate viable business cases for hydrogen mobility in fleet applications, building upon the lessons learnt in the Hydrogen Mobility Europe Initiatives. To achieve this, two approaches were combined:
  - An early business case for FCEVs – **180 FCEVs were to be deployed 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 refueling 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.

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



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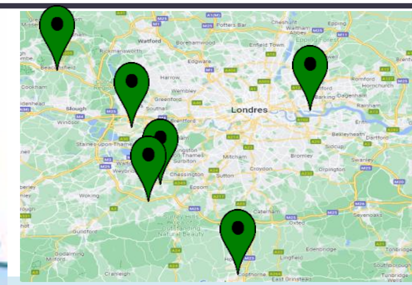
Issy-les-Moulineaux
Paris Porte de Saint Cloud



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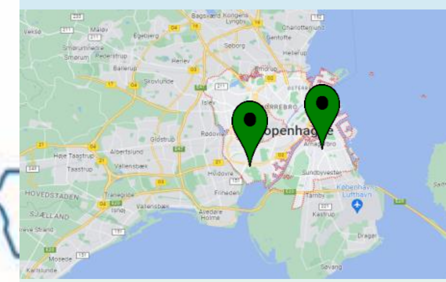


Copenhagen

Deployment for additional HRS and vehicles are planned at all sites

*now out of operation

This report aims to analyse the business case for FCEVs and HRS within the ZEFER project

- This report aims to **analyse the business case for hydrogen mobility** based on fleet applications. To this end, it will address both the business case for fleet and HRS operators and the opportunities that are (or could become) available to reduce costs in the future.
- Due to the rapid evolution of the hydrogen sector, the report will **investigate business cases in a temporal fashion,** dividing analysis into the business case for equipment installed during the ZEFER project, the advancements expected for new equipment installed in 2023 and the outlook for future cost reduction in 2025. This will show both the changes in the market since the initiation of the project, and the further improvements that are required to expand FCEV and HRS roll-out in fleet models across Europe. A few points will also highlight the expected evolutions by 2030.
- To ensure that both qualitative and quantitative factors are taken into account, the report will use a variety of data including:
  - **Vehicle costs derived directly from the project/fleet operators** – project partners have provided exact costs for FCEV operations within ZEFER. Indicative capital and operational costs have also been provided for other vehicle types when operators have experience with the technology. When no information is available, the extensive ERM/Element Energy cost database has been used.
  - **Insights from fleet and HRS operators derived from interviews** – interviews have been held with all FCEV and HRS operators to understand the current issues/challenges they face in making a business case and to gain insights into their business strategy going forward.
  - **Performance data collected from the FCEVs and HRS** – project data has been used to provide real-world inputs into the business case and ensure a rigorous assessment of operations within the ZEFER project.
- This report represents the second and last iteration on the business case for high-mileage fleet applications.

HRS: Hydrogen refuelling Station | **FCEV**: Fuel Cell Electric Vehicle

Agenda

Business case analysis on FCEVs will be separated temporally into 3 key areas

- As noted in the introduction to this report, the business case analysis for FCEVs is divided into three main sections to account for developments and changes in the hydrogen market. A brief description of each section is provided below.
  - **ZEFER business case** – the ZEFER partners finalised their lease contracts and procurement negotiations in 2018 and 2019. The price of the vehicle is therefore outdated in comparison to the time of writing of this report and represents an old market for FCEVs (and other alternative technologies). The ZEFER business case therefore highlights the TCO of vehicles during 2018/2019 to allow fair comparison. This section has not been modified compared to the first iteration of the report.
  - **2023 business case –** the 2023 case analyses the vehicle market at the end of 2022 and beginning of 2023 to show the current status and to highlight the developments that have occurred since the ZEFER leases were signed. In this scenario, FCEVs come at a c. 55-60% premium to current petrol hybrids, c. 30-35% premium over PHEVs and a c. 40-60% premium over BEVs, with some nuances.
  - **2025-2030 business case –** In the 2025-2030 optimistic scenario, the FCEV TCO premium over petrol hybrid reduces to c. 14%, while BEVs enjoy TCO advantages over petrol hybrids of over 20%. Reality for all powertrains for 2025-2030 is likely to lie somewhere between the 2023 business case and the 2025-2030 business case, with the latter presenting the most optimistic scenario and the former representing the worst-case scenario for 2025-2030 (i.e., no improvements beyond the current situation).

- It should be noted that all business case modelling is based on indicative figures and/or speculative forecasts for FCEV uptake and hydrogen market development. The figures may therefore change over time, as and when new information arises.

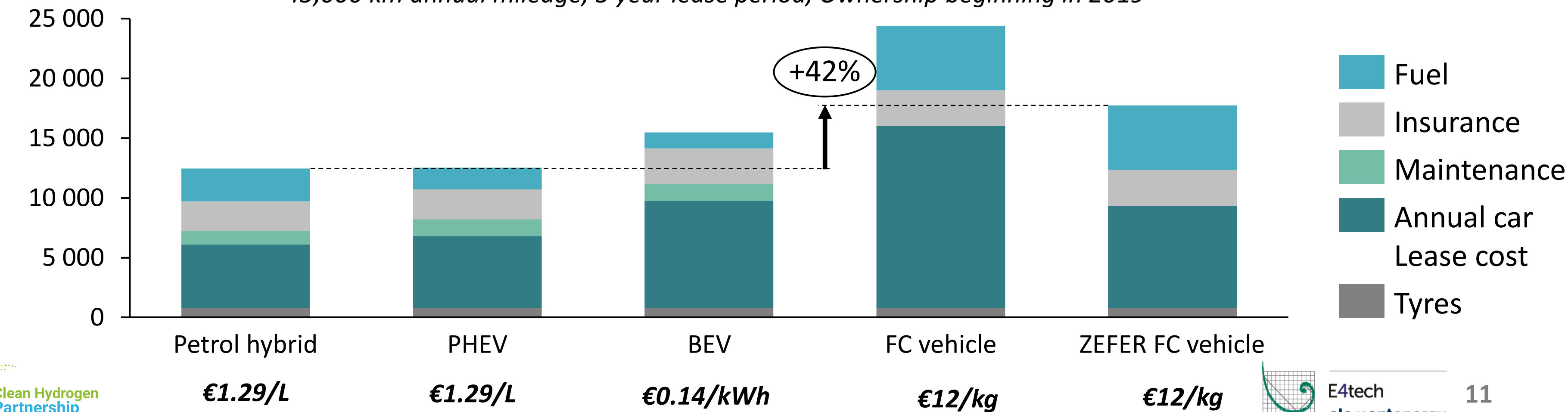
Agenda

At the beginning of the ZEFER project, FCEVs were at a significant premium to petrol hybrid and plug-in hybrid vehicles both with, and without, subsidy

- When the ZEFER project was initiated, FCEVs came at a significant premium to alternative technologies without subsidy. Based on figures compiled from partners:
  - FCEVs were expected to come at a **TCO premium of c. 95% above current petrol hybrids and plug-in hybrids** such as a Toyota Prius or the Prius plug-in hybrid.
  - FCEVs were **more competitive with alternative zero-emission technologies** such as battery-electric vehicles, but still remained **more expensive on a TCO basis with a c. 58% premium.**
- The cost premium of FCEVs can largely be attributed to **higher lease costs for the vehicles** (c. 187% premium) and the **higher cost of fuel** (c. 100% premium) in comparison to petrol hybrids.
- **Grant funding from the ZEFER project was therefore vital** in reducing the price of the FCEVs, but further external benefits (e.g. additional funding, avoidance of congestion/pollution charges) were also required to make a business case for fleet operators and to reduce the premium of FCEVs from c. 42% to parity.

Taxi TCO compared to alternatives (€/year)

45,000 km annual mileage, 3 year lease period, Ownership beginning in 2019



An initial business model was created at the beginning of the project based on 2018/2019 data

- The **total cost of ownership model for ZEFER has been based on a 3-year leasing model** as this is the most common procurement strategy amongst ZEFER partners. In order to anonymise figures, an average for the leasing cost of FCEVs has been calculated using data from partners and internal databases at Element Energy. At the time of the development of this business case, with 2018-2019 data, DRIVR was not yet part of the project. Assumptions for hybrid, plug-in hybrids and battery-electric vehicles are based on a number of references including, fleet operator feedback, discussions and quotes received from OEMs and technical brochures for products.

Assumption	Note	Petrol hybrid	Plug-in hybrid (PHEV)	Battery Electric Vehicle (BEV)	FC vehicle	ZEFER FC vehicle
Annual mileage (km)		45,000	45,000	45,000	45,000	45,000
Lease cost (€/vehicle/yr)	Excluding VAT	5,304	6,006	8,931	15,211	10,211*
Car maintenance costs (€/yr)	Excluding VAT	1,123	1,404	1,404	-	-
Insurance costs (€/yr)	Excluding VAT	2,500	2,500	3,000	3,000	3,000
Tyre costs (€/yr)	Excluding VAT	800	800	800	800	800
Fuel consumption (l, kWh or kg per 100 km)		4.71 litres (60 mpg**)	3.14 litres (90 mpg**)	21.45 kWh	1.00kg	1.00kg
Fuel prices (€ per l, kWh or kg)	Including VAT	€1.29/litre	€1.29/litre	€0.14/kWh***	€12/kg	€12/kg

Indicative cost assumptions at the beginning of the ZEFER project in 2018-19

- Two scenarios have been included for FCEVs:
  - **FC vehicle** - shows the cost of FCEVs in 2018/2019 without any subsidy from European or National sources.
  - **ZEFER FC vehicle** - illustrates indicative costs for fleet operators in the ZEFER project, accounting for ~€20,000 funding per vehicle over its lifetime.

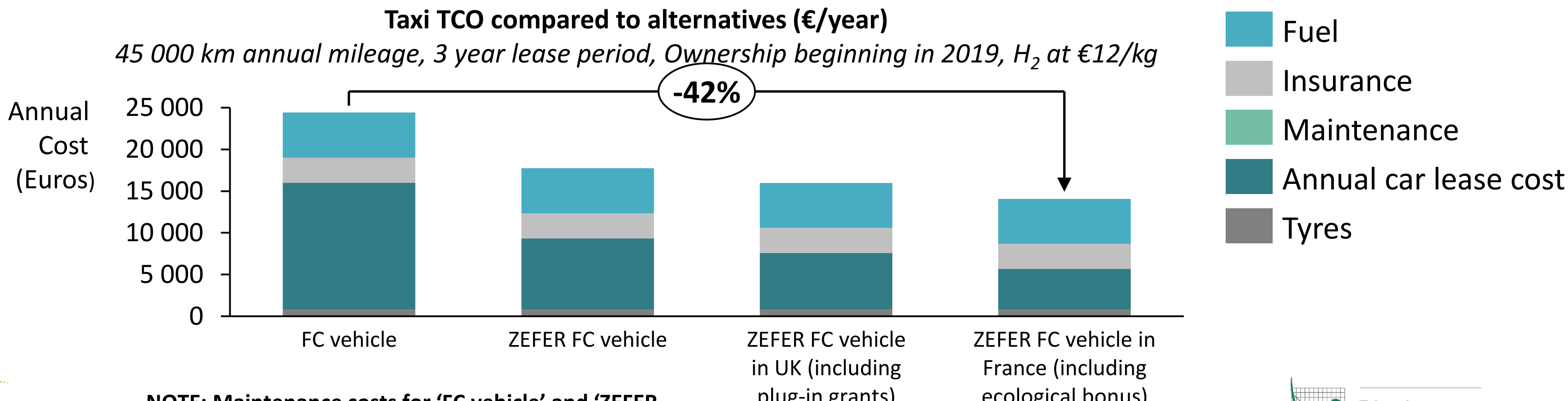
NOTE: Maintenance costs for 'FC vehicle' and 'ZEFER FC vehicle' are included in the overall lease cost.
*including current subsidies from OEMs and maintenance costs.** Consumption figures derived from NEDC test cycle figures. ***Home, slow charge.

Fleet operators had to supplement ZEFER funding with national and regional grants to further reduce the cost premium of the FCEVs

- Fleet operators within ZEFER were able to **complement the ZEFER funding with grant support from national and regional governments**.
  - In the UK, Green Tomato Cars and the Metropolitan Police Service were able to benefit from the **'Plug-in Car Grant'** which provided a discount on the purchase/lease price of new low-emission vehicles. For FCEVs, a subsidy of up to £4,500 (~€5,265*) was made available directly to car manufacturers or dealerships to artificially reduce the sale/lease price to end users.
  - In France, HYPE benefitted from an **'ecological bonus'** which provided up to €5,000 funding to car manufacturers to reduce the purchase/lease price of vehicles. Other ad hoc funding was also made available from **ADEME and Île-de-France** to support zero-emission vehicle uptake (c. €6,000).
- By combining the funding across EU, national and local contexts, the **cost premium of an FCEV could be reduced by c. 34% in the UK and 42% in France,** in comparison to an unsubsidised case. This meant that fleet operators in the UK were then only paying an **additional c. 28% on top of the cost for a hybrid vehicle** for FCEVs, and **French operators were making a 8% saving**.
- The **impact of these subsidies on the competitiveness of FCEVs with BEVs was however limited** as both technologies were eligible for the same amount of national funding.

Taxi TCO compared to alternatives (€/year)

45 000 km annual mileage, 3 year lease period, Ownership beginning in 2019, H_2 at €12/kg



NOTE: Maintenance costs for 'FC vehicle' and 'ZEFER FC vehicle' are included in the overall lease cost.

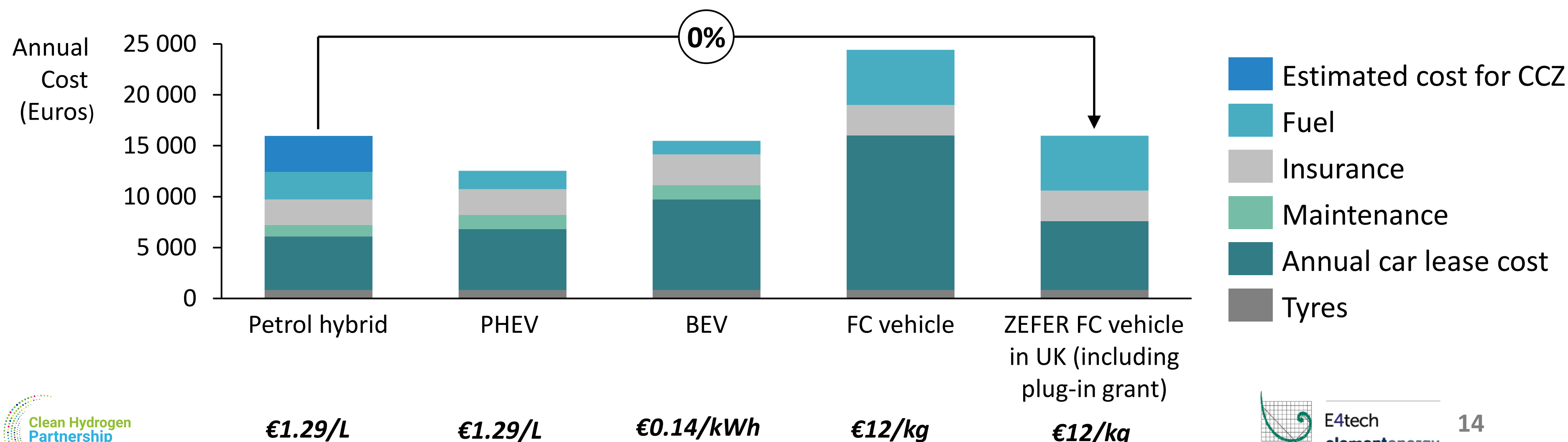
*Based on conversion rate of £1 to €1.17

The positive externalities of FCEV operation were also maximised to improve the business case for operations – a key example is the Congestion Charge Zone in London

- The business case for FCEVs in ZEFER has benefitted from **increasing air quality policies** across London, Paris and Copenhagen which have helped fleet operators reduce the cost premium of the technology.
- A key example is the **Congestion Charge Zone (CCZ) in London** which has introduced in October 2021 financial penalties for drivers operating polluting vehicles in the city centre. It will only be in place until December 2025 and hybrid vehicles are excluded from any type of discount.
- Petrol/diesel hybrids in taxi and private hire operations were exposed to these fees meaning that **operators have to pay up to £15 per day for operating in the centre.** This increased the TCO of the vehicles to an extent where the FCEVs, supported by ZEFER and the UK plug-in grant, could reach parity with petrol hybrids*.
- **By October 2021, the scope of the Congestion Charge has been widened** to include all but fully zero-emission vehicles. This led to an increase of the TCO of PHEVs in the near-term so that zero-emission vehicles became more cost-competitive with fossil-fuel technology.

Taxi TCO compared to alternatives (€/year)

45,000 km annual mileage, 3 year lease period, Ownership beginning in 2019

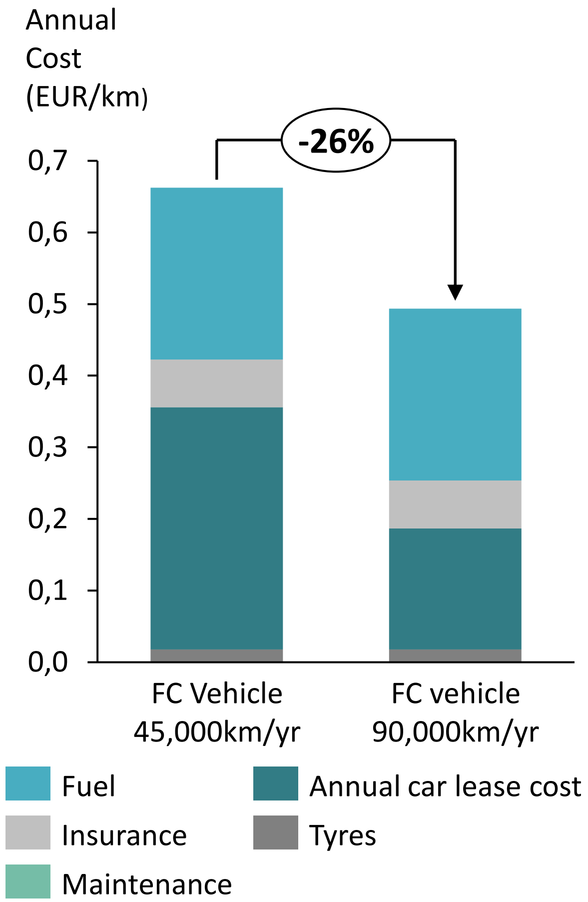


*Based on a conservative estimate that GTC vehicles operate 360 days a year and enter the CCZ 65% of the time.

Qualitative benefits such as greater market share, or access to privileged taxi licenses, also helped justify the cost premium of the technology

- In Paris, HYPE utilised the external benefits of operating a zero-emission vehicle to reduce overall operating costs.
- For example, FCEVs could provide HYPE with **privileged access to 'medallion' licences** which allows the vehicle to be used in double-shift operation*. By operating vehicles in two shifts over a 24-hour period, the number of services one car can complete per day is maximised. This increases the revenue that can be generated from the vehicle and ensures that HYPE – the Parisian operator – can access all areas of the taxi market.
- Although the annual total cost of ownership does not change dramatically (other than an increase in fuel and tyre costs), the **total cost of operating the FCEV on a per kilometre basis is dramatically reduced for fleet operators as the lease cost is spread across higher mileages**.
- This is illustrated in the graph (right) which shows the difference between a standard licence (~45,000km per year) and a medallion licence (~90,000km per year).
- Assuming the lease prices remain the same, the **cost of operating the FCEV reduces by c. 50%** as the mileage over which lease costs can be spread is increased.

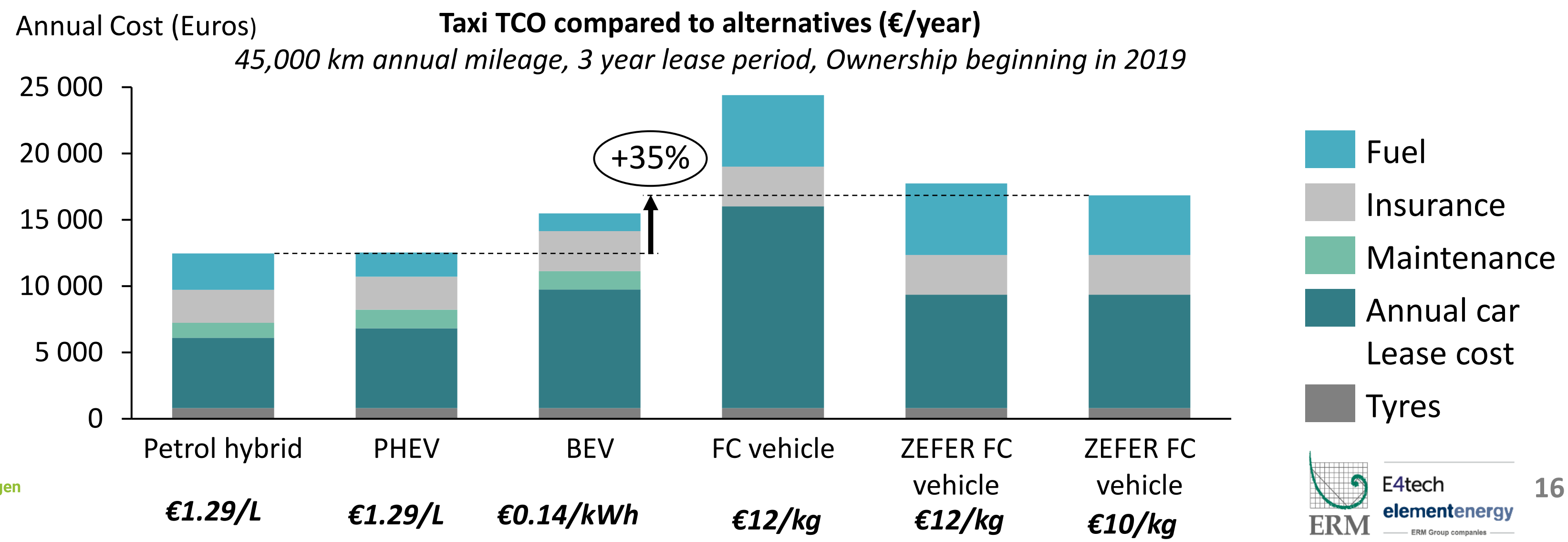
FCEV taxi TCO comparison based on one-shift and two-shift mileages (€/km)



* The car can be used during a day and night shift so long as the driver changes in-between.

High hydrogen prices posed a challenge to all fleet operators but in Paris slightly lower costs allowed HYPE to reduce their annual costs by ~5%

- As shown in all previous TCO models, **fuel costs are a significant component of the overall business case** for FCEVs.
- Current inputs into the model assume prices of €12 per kilogram. However, **costs have been seen to vary in the project between ~€10 to €12 per kilogram** depending on the method used to produce hydrogen (i.e. on-site vs off-site production) and the volume of demand available on a network level. This leads to a **5% difference in the cost premium of operating the vehicles between project partners.**
- The TCO model below shows the impact of different hydrogen prices for fleet operators, starting with €12/kg and reducing to €10/kg.
- **At €10/kg, the premium for the ZEFER FCEV in comparison to a petrol hybrid is reduced to c. 35%.** The **difference between a FCEV and a BEV is also reduced to c. 10% premium** which is increasingly feasible to justify with the qualitative benefits of the technology (e.g. larger market share, more services due to longer range etc).



Agenda

ZEFER

- Introduction
- **FCEV business case**
  - ZEFER business case
  - **2023 business case**
  - 2025 - 2030 business case
- HRS business case
- Conclusion

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

- 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

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

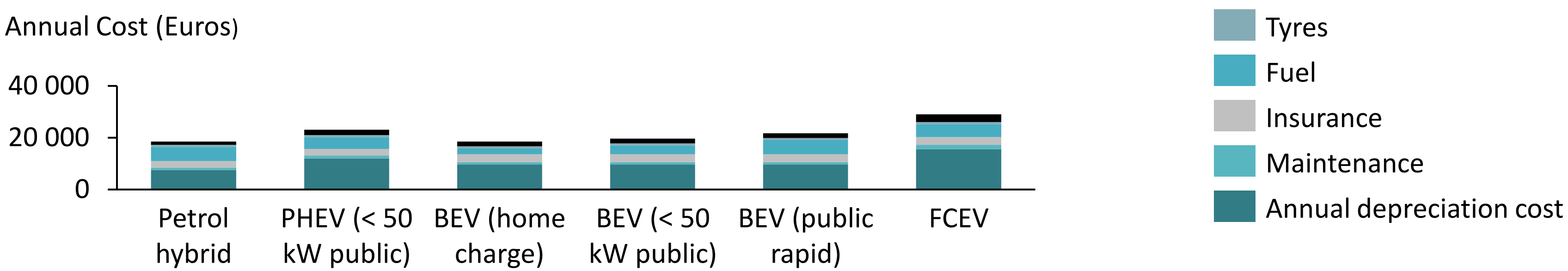
- Vehicle prices were sourced from real-world quotes[1] for the following vehicles available on the French market in September 2023:
  - Petrol hybrid: Renault Arkana
  - PHEV: VW Passat GTE
  - BEV: Tesla Model 3
  - FCEV: Toyota Mirai
- Except for FCEV, segment D[2] saloon cars are considered. For 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

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. Paris taxi drivers derive a disproportionate share of revenue from occasional long trips performed at short notice, for example when public transport is disrupted. For round trips of around 500 km, the ability of a FCEV car to refuel in around 5 minutes and then complete the 500 km trip without any stops for refuelling is advantageous over a BEV, which could require around 30 minutes of charging to complete such a trip (although this could potentially be divided into 2 shorter charges, one before and one after customer drop-off, with the latter having a lower impact on revenue generation). Drivers would need to weigh up the increased ability to capitalise on such exceptional long trip opportunities with the higher costs associated with FCEV operation for the remainder of the year.
  - Infrastructure availability plays a key a role – for drivers without access to overnight charging, fast refuelling is important even for local operations, providing an advantage for FCEV. Conversely, the low availability of hydrogen refuelling infrastructure across Europe compared to BEV rapid charging reduces the FCEV flexibility advantage for routes with a range greater than that which an FCEV can reliably accomplish on one tank.
  - 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.

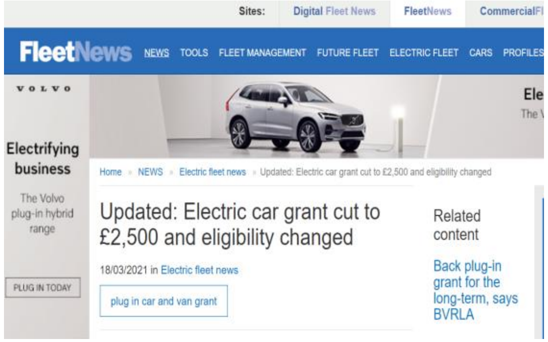
Subsidies and incentives continue to play a critical role in creating a business case for FCEVs in 2023 - increasing restrictions on vehicle eligibility pose a large risk to the commercialisation of the sector

- Fleet operators within the ZEFER project have noted that the cost premium of FCEVs in 2023 still poses a barrier to the uptake of the technology. **Subsidies and incentives which bridge the cost gap therefore remain critical** in creating a positive business case and accelerating deployment numbers.

- However, as the low and zero-emission vehicle markets have developed, **EU and national funds are becoming more strict,** reducing the total funding available per vehicle and placing restrictions on the price/type of vehicles grants can be applied to. For example, in the UK, the plug-in grant available for low or zero-emission cars was reduced several times then closed in June 2022. £300 million in grant funding will now be refocused on specific vehicles including taxis, with no existing funding for light-duty-vehicles [1]**.** The focus is shifting to heavy duty vehicles deployment rather than taxis and light duty commercial vehicles.

- However, subsidy schemes and low emission zones have become widespread in major cities around Europe. In Paris, HYPE is leveraging on funding at the European, national (ADEME) and regional (Ile-de-France); in London, deployments rely on CHP JU and OZEV funding.

- Increasing restrictions on the price of eligible vehicles is for zero emission car funding schemes is necessary to incentive cost reduction and to prevent inadvertently incentivising uptake of large cars over small cars. In some cases, FCEVs are not yet able meet these lower price thresholds set by governments, creating a short-term risk to deployment volumes, with knock-on effects on the growth of the sector.



Extract from Fleet News outlining the new conditions of the UK's Plug-in Grant Scheme before it was closed. Source: https://www.fleetnews.co.uk/news/latest-fleet-news/electric-fleet-news/2021/03/18/electric-car-grant-cut-to-2-500-and-eligibility-changed

1: https://www.gov.uk/plug-in-car-van-grants UK Government website
2: https://easyelectriclife.groupe.renault.com/en/outlook/cities-planning/incentives-for-buying-an-electric-car-in-france-how-do-they-work/

High hydrogen costs continue to be a challenge in the business case for fleet operators, but with higher capacity stations under development in 2023 lower costs could be achievable

- **Increasing scale is key to the business case for HRS operators** as only when large capacity stations are commissioned, with heavy-duty anchor demands, can a steady revenue and profit be made from stations.
- HRS operators both within, and outside, of the ZEFER project are therefore focussing on **scaling-up their infrastructure offer,** with many noting that new stations with 100s of kg demand per day are required.
- This scale-up of HRS capacity has been seen in the recent years, with operators building or commissioning some of Europe's largest stations seen to date:
  - **Birmingham HRS at Tyseley Refuelling Hub** – In 2021, Motive Fuels have commissioned the largest green HRS in the UK that can generate over a tonne of hydrogen per day. The site comprises a car refueller operating at both 350bar and 700bar[1].
  - **Porte de St Cloud in Paris** – HysetCo has built a one tonne per day HRS in West Paris to utilise hydrogen produced on-site via an electrolyser. The station has 4 dispensers to serve the growing taxi fleet HysetCo and HYPE will deploy.
- 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 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.
- Numerous HRS operators are now developing projects for 1 tonne per day stations in line with the requirements of AFIR (Alternative Fuels Infrastructure Regulation), with an entry into service date of 2024-2026. The majority of these stations will be capable of refuelling light- and heavy-duty vehicles.

1: Tyseley Refuelling Station - Tyseley Energy Park
2: Située au coeur de Paris, cette station hydrogène est la plus grande d'Europe (h2-mobile.fr)

Agenda

The 2025 – 2030 business case considers optimistic and pessimistic cases for economics that could materialize during this period (1/2)

- The "2025 – 2030 optimist" scenario is not a prediction. Rather, it is an indication of what could occur if the FCEV and BEV markets reach high levels of maturity (both in terms of infrastructure and vehicles) over this period.
- Reality is likely to lie between the "2025 – 2030 optimist" scenario and the pessimistic scenario, which is that costs remain at 2023 levels. Together, these two scenarios provide book-ends for likely futures.
- The assumptions of the "2025 – 2030 optimist" scenario are set out below.

"2025 – 2030 optimist" scenario narrative

- BEV costs reach petrol hybrid levels, reflecting declining battery prices and economies of scale in production suggested by ERM modelling.
- PHEV costs drop by 5% reduction, based on ERM modelling – small drop owning the small battery size giving reduced potential for cost reduction from declining battery prices.
- FCEV costs fall significantly to reach PHEV levels.
- BEV fuel efficiency improves by 30%, reflecting rapid progress in this space and OEM targets[1] . This improvements are transferred to FCEV. OEMs are very strongly incentivised to improve fuel efficiency as it directly links to the hugely important range / cost trade-off.
- Fuel prices:
  - Hydrogen price at the pump drops to 7.5 €/kg, resulting from improved economics of larger capacity stations, higher utilisation and off-site production, as well falls in electricity price following the recent peaks in 2022-23. This also reflects the pump price needed to provide fuel cost parity with petrol hybrids.
  - Residential electricity price (for home charging) drops back to 2019 levels of 18 cents / kWh including VAT[2] (note that the net effect of taking off VAT and adding on charger price leaves it at 18 cents / kWh for the TCO model).
  - Commercial electricity prices return to 2019 levels of 11.8 cents / kWh including VAT.
  - Improvements in utilisation of chargers from c. 6% to c. 20% result in difference between price at the charger and commercial electricity price (ex VAT) dropping from c. 20 p / kWh to c. 6 p / kWh for slow public charging (9 p / kWh for public slow charging). This results in 16 p / kWh public slow charging and 19 p / kWh public rapid charging prices.
- All other costs remain the same as in the 2023 scenario.

1 - https://www.reuters.com/business/autos-transportation/mercedes-ceo-efficiency-is-new-currency-ev-market-2023-09-01/#:~:text=%22Efficiency%20is%20really%20the%20new,SUV%20model%20Mercedes%20offers%20today 2 - https://en.selectra.info/energy-france/guides/electricity/tariffs

The 2025 – 2030 business case considers best case and worst case for economics that could materialize during this period (2/2)

- The assumptions and narrative for the "2025 – 2030 optimist" scenario are set out on the previous slide. All assumptions not discussed on the previous slide as the same as for the 2023 modelling.
- The total cost of ownership values for the "2025 – 2030 optimist" scenario are set out below.

Assumptions and results: 2025-2030 total cost of ownership model

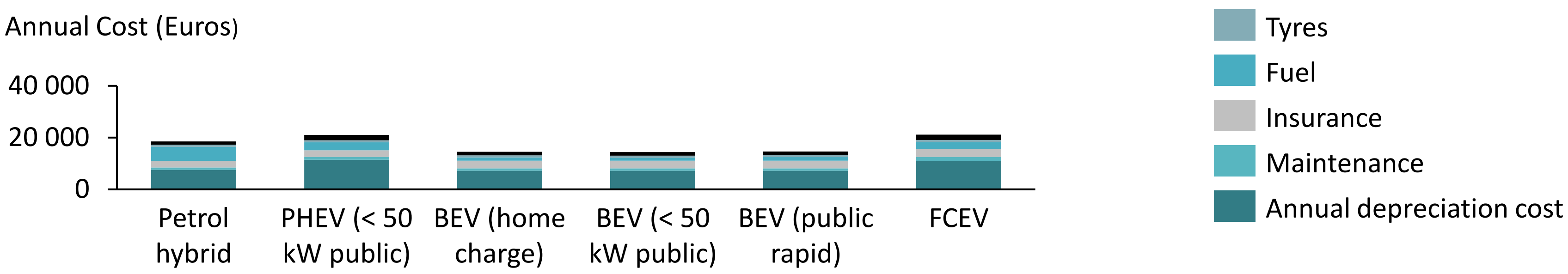
	Assumption	Petrol hybrid	PHEV	BEV (home charge)	BEV (public slow charge)	BEV (public rapid charge)	FC vehicle
	Annual mileage (km)	45,000	45,000	45,000	45,000	45,000	45,000
Lease	Vehicle purchase price (€)	26,000	39,742	26,000	26,000	26,000	39,742
	Residual value (€)	3,472	5,688	4,533	4,533	4,533	6,929
	Depreciation (€/yr)	**7,509**	**11,351**	**7,156**	**7,156**	**7,156**	**10,937**
	Finance (€/yr)	**1,326**	**2,044**	**1,374**	**1,374**	**1,374**	**2,100**
Fuel	Fuel consumption (l, kWh, kg per 100 km)	7.42	2.65/16.56*	15,67	15.67	15,67	0.78
	Fuel price (€ per l, kWh or kg)	1.62	1.62/0.16	0.18	0.16	0.19	7.5
	Fuel opex (€/yr)	**5,423**	**3,129**	**1,269**	**1,127**	**1,339**	**2,646**
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**	**21,045**	**14,499**	**14,358**	**14,569**	**21,120**
	% DELTA VS PETROL HYBRID	**N/A**	**+14%**	**-22%**	**-23%**	**-21%**	**+14%**

*Petrol / electricity

In the 2025-2030 optimistic scenario, the FCEV TCO premium over petrol hybrid reduces to c. 14%, while BEVs enjoy TCO advantages over petrol hybrids of over 20%

Taxi TCO compared to alternatives (€/year) – 2025-230 optimistic scenario

45 000 km annual mileage, 3-year ownership beginning in 2025-2030



- In the 2025-2030 optimist scenario, zero emission powertrains achieve full economies of scale, resulting in BEVs with all charging behaviours achieving significant economic advantages of petrol incumbents, and FCEV reaching TCO parity with PHEV.
- This is not a prediction. Reality is likely to lie in between the "worst case" scenario (costs remain the same as 2023) and the "best case" scenario presented above.
- By 2030 competition between ZE and non-ZE powertrains will be of decreasing importance as policies phase out polluting vehicles (for example, the expected Paris 2030 ban on non-ZE vehicles). However, the competition between FCEV and BEV will remain: at the current rate, the embedded costs of the electrical charging infrastructure are decreasing at a faster rate than those of HRS, and batteries are also improving in performance (lifetime, energy content, charge rate).
- The Alternative Fuels Infrastructure Regulation (AFIR) was adopted in July 2023, requiring HRS to be deployed every 200km along the TEN-T core network. These are proposed to be capable of delivering **at least 2 tonnes/day of hydrogen from 2030 onwards.** This would encourage the demand and production of more vehicles, which in turn could bring down fuel cell costs through mass production.

Agenda

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Clean Hydrogen Partnership

ERM

E4tech

elementenergy

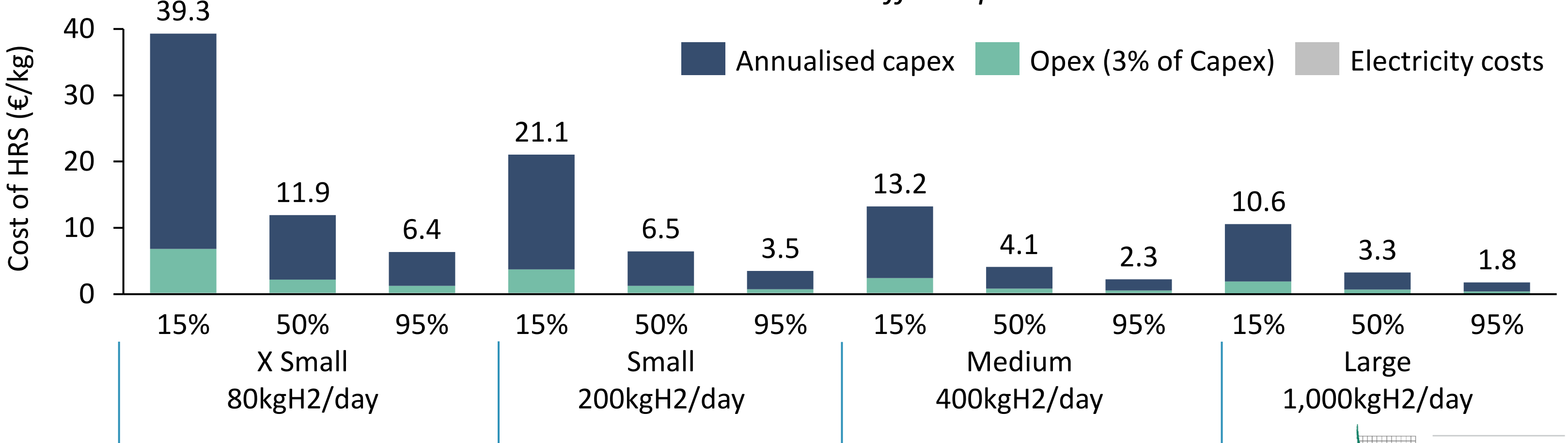
ERM Group companies

In order to create a business case for HRS operators, stations and their supply chains require scale and high utilisations

- In order for hydrogen refuelling stations to operate profitably and reliably, two key factors need to be considered:
  - **Scale** – HRS operators with larger capacity stations are able to spread the cost of the station parts, and maintenance, over larger volumes. This results in a lower cost per kilogram of hydrogen dispensed.
  - **Utilisation** – the business case for HRS is optimised when utilisation of the station is high as revenues from hydrogen sales can be maximised. This allows for a quicker return on investment for the HRS operator.
- The impact of these factors are outlined in a high-level TCO below which highlights that **with increasing scale and utilisation the cost of a hydrogen refuelling station on a per kilogram of hydrogen basis reduces**.
- However, to date, the **majority of stations in operation across Europe are small, or very small,** which makes a business case challenging and heavily reliant on public funding. This is the case for the ZEFER stations which will be analysed in the following chapter.

Cost of HRS per kilogram hydrogen dispensed (€/kg)

Based on an HRS with off-site production

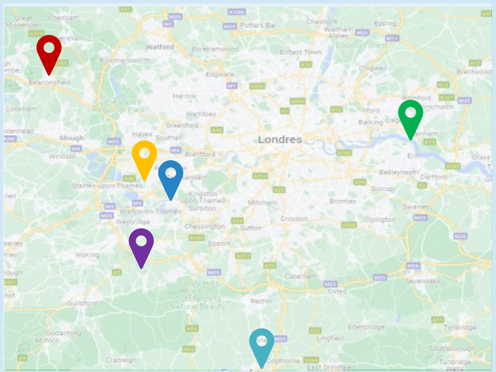


Agenda

ZEFER vehicles utilise first generation, ‘proof-of-concept’ stations installed in London and Paris and new stations in Paris

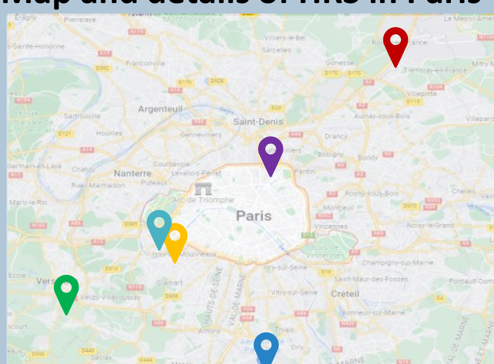
- The ZEFER project relies on existing hydrogen refuelling stations in London and Paris to supply the fleet vehicles. Since the beginning of the project, new HRS have been deployed in France (outside of ZEFER) and are also used (Porte de Saint Cloud and Issy-les-Moulineaux). **Most stations to date have been low capacity** (<200kg/day) except the new Porte de Saint Cloud, and supplied largely by **ITM Power and Air Liquide**.

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

Map and details of HRS in Paris

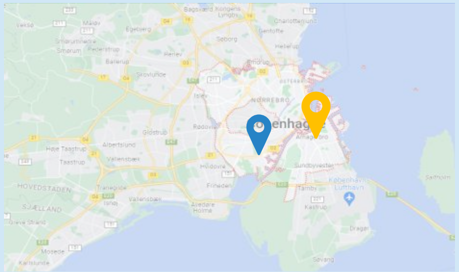


Station	Operator	Capacity
Issy-les-Moulineaux	HYPE	200 kg/day
Orly	HysetCo	200 kg/day
Versailles	Air Liquide	200 kg/day
Porte de la Chapelle	HysetCo	250-350 kg/day
Roissy	HysetCo	200kg/day
Porte de Saint Cloud	HysetCo	1T/day

ZEFER vehicles also utilise more recent HRS deployed in Copenhagen

- The ZEFER project initially planned to deploy vehicles in Brussels, but the funding were reallocated to deployments in Copenhagen, where two HRS were commissioned end of 2021 in the heart of the city of Copenhagen, and the deployment of vehicles started shortly after that.
- Everfuel is the operator of the two HRS currently in operation, and hydrogen is dispensed via tube trailers.

Map and details of HRS in Copenhagen



Station	Operator	Capacity
Prags Bld (yellow marker)	Everfuel	376 kg/day
Energiporten (blue marker)	Everfuel	>100 kg/day

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

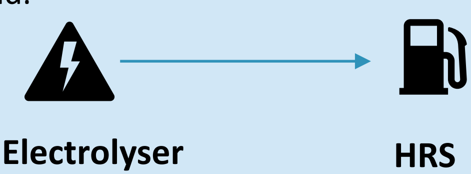
Two station archetypes and production pathways are demonstrated in the project

ZEFER

- Stations within the ZEFER project can be divided into two types:

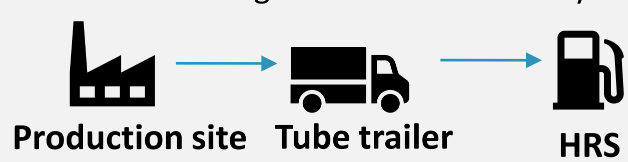
HRS with on-site production

- Hydrogen is **produced on-site at the refuelling site via electrolysis**.
- These stations are **often more costly to install and operate today** due to the additional equipment required (e.g. electrolysers, extra compressors etc), the small scale of production for some of them (~80kg/day for ITM Power's HRS) and difficulty in securing a low-cost (and renewable) electricity tariff to supply the electrolyser.
- **ITM Power operated 5 stations** of this type in London to supply passenger car and small van FCEV drivers in the city with 'green' hydrogen*.
- One advantage is that the **hydrogen produced is fully green**. This is likely to support getting buy-in from political stakeholders. This was the case in Paris for Porte de St Cloud.



HRS with off-site production

- Hydrogen is **produced off-site and transported** to the HRS, often by road tube trailers. This is the case in London and Copenhagen.
- Hydrogen can be produced by a variety of methods. However, **in Paris, the Air Liquide HRS are supplied with blue hydrogen produced via steam methane-reforming (SMR) with carbon capture and storage (CCS) or as a by-product of the chloro-alkaline process.**
- At the point of production, hydrogen is relatively cheap due to the scale of the industrial processes from which it is derived. However, once **transportation and preparation costs** have been taken into account for small-scale demands, the end price of hydrogen is often only slightly less expensive than that which is achievable utilising a small-scale electrolyser.



*currently only one remaining in operation

Figures in the ZEFER business model (2018-19) have been based on the following assumptions

- Hydrogen costs can be divided into three main components which together form the final price of hydrogen available to the end user:
  - **Production cost –** the cost of hydrogen at the point of production, excluding any compression or purification.
  - **Preparation / transportation cost** – the cost to purify (if necessary), compress and transport hydrogen from the production site to the HRS.
  - **Fuelling station cost –** the cost to be added onto the price of hydrogen after it is delivered to site to compress, store and dispense it to vehicles.
- The table (right) provides the key inputs used for the ZEFER business case. The base case assumes a **100kg/day station,** with **utilisation increasing by ~4% each year** to reflect new vehicles being deployed on the road (~15 vehicles/year).
- The business case will model the first **10 years of operation** for the stations. After this, HRS operators would be expected to undertake minor upgrades of old parts or decommission the station.

Parameter	Unit	Input
HRS specifications		
Capacity	Kg/day	100
Utilisation	%	18% & increasing
Fuelling station cost (CAPEX)		
HRS without on-site production	€	1,200,000
HRS with on-site production	€	1,620,000
Fuelling station cost (OPEX)		
Electricity cost for on-site production	€/MW	100
Maintenance as % of CAPEX	%	3%
Cost of FTE	€/yr	50,000
Average land rent	€/yr	10,000
Production cost		
SMR w/CCS	€/kg	2.00
Electrolysis	€/kg	5.50
Transportation / Preparation cost		
Trucked off-site production	€/kg	1.50[1]
On-site production	€/kg	0.66[1]
Other financing assumptions		
Hydrogen revenue	€/kg	12
Discount factor	%	7.5%
Loan as % of CAPEX	%	10%
Ownership period	years	10 years

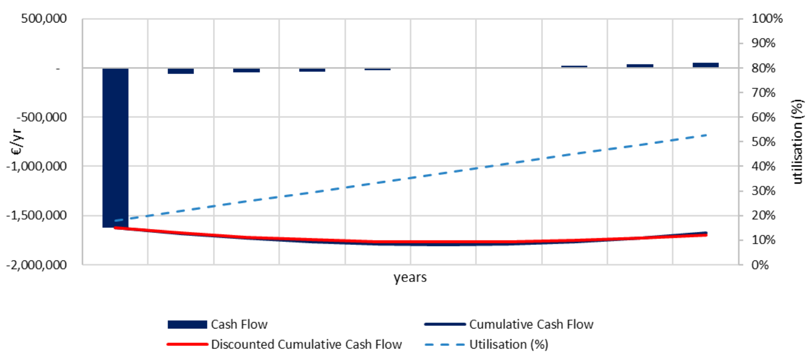
1: Hydrogen Council (2020) – Path to Hydrogen competitiveness

To date, with limited hydrogen demands and low capacity stations, there is not yet a profitable business model for operators

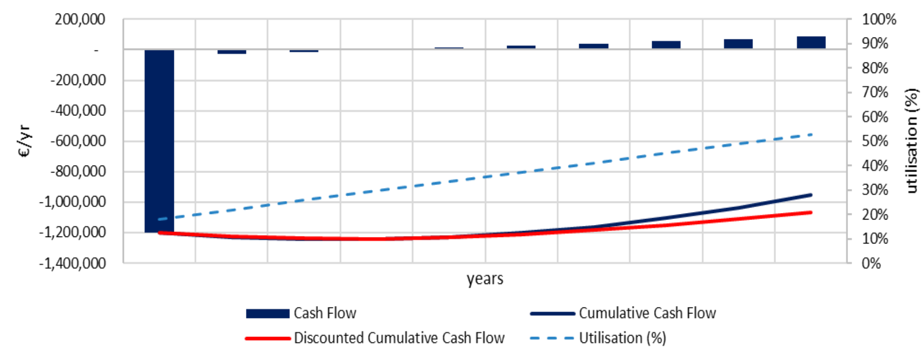
ZEFER

- To date, with low capacity stations (80kg/day to 200kg/day) and low utilisation (~18-55%), the business case for HRS operation in the ZEFER project is challenging.
- The graphs below illustrate an **indicative cash flow** for HRS at capacities of **100kg/day,** assuming utilisation increases over time (15 vehicles added onto the road each year*) and a constant price of €12/kg.

H2 produced on-site via electrolyser (green h2)



H2 trucked in, produced via SMR + CCUS (blue h2)



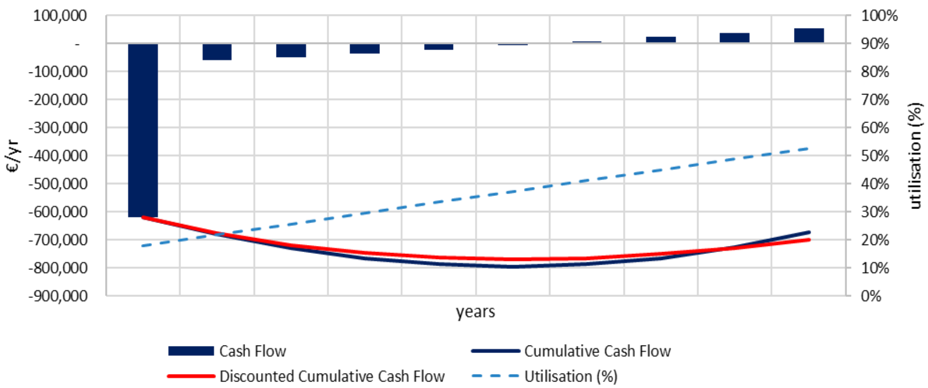
- **Both cash flow models show a negative business case for HRS operators,** with most of the investment on the capital of the station never being retrieved. This is despite a high hydrogen cost of €12/kg which adversely affects the business case for FCEV operation (as described in slide 16).
- These stations were deemed as '**proof-of-concept' projects to demonstrate the feasibility of hydrogen refuelling** and investments were justified as a critical HYPE in kick-starting the wider-scale rollout of the technology. However, a pathway to profitable large-scale HRS will be needed to attract the substantial investments needed to build out a Europe-wide network.

*Utilisation begins at 18% and rises 4% each year based on the assumption that ~15 vehicles are added onto the road annually

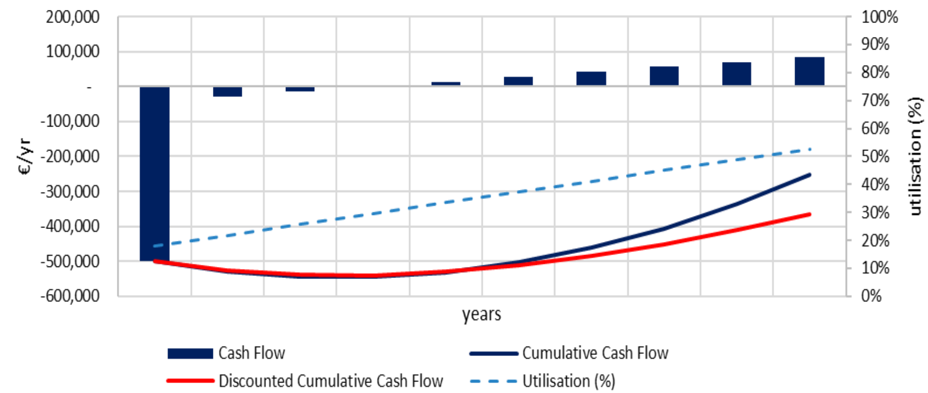
HRS operators have relied heavily on capital grants to support the investment, and continued operation, of the ZEFER stations

- In order to make the current business case acceptable to HRS operators, a **significant subsidy** has been required to support their investment in the station.
- Both operators have **benefitted from capital funding from the Fuel Cell and Hydrogen Joint Undertaking** via the Hydrogen Mobility Europe initiative*. This has allowed operators to account for much lower capital expenditures in their business models and hence create a more positive business case.

H2 produced on-site via electrolyser, including EU funding (green h2)



H2 trucked in, produced via SMR with CCUS, including EU funding (blue h2)



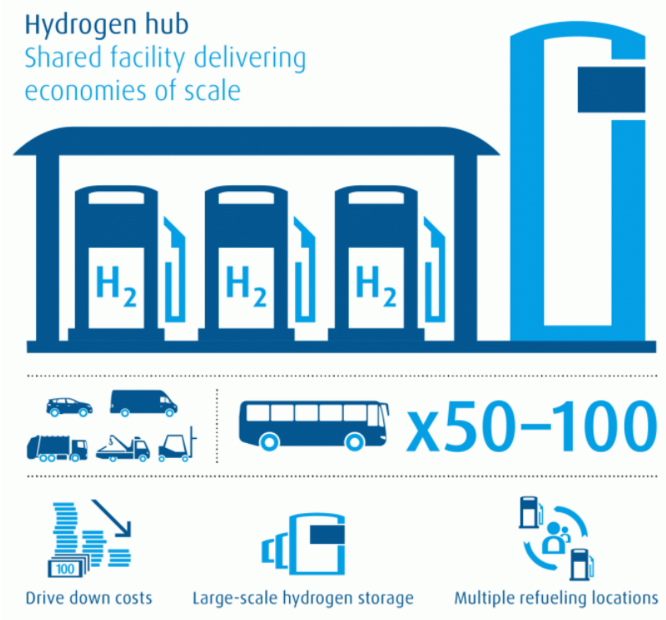
- Despite capital funding, **both HRS archetypes are not profit-making over 10 years**, although losses are significantly reduced.
- In order to improve this, **each station will require a higher level of utilisation** in order to improve the revenues from the station and support on-going maintenance costs.
- This case also proves that operators could benefit from **more targeted support for the operational costs** of the station.

*Funding within H2ME is estimated to be ~€1,000,000 for HRS with electrolyser and €700,000 for HRS utilising off-site production

Agenda

Going forward, HRS operators will focus on larger capacity stations with concrete demands

- As shown in the previous slides, HRS operators within the ZEFER project are not making positive returns on the current generation of HRS.
- In Denmark, no upgrades of the stations is planned.
- In the UK, upgrades of the stations were planned to replace the existing 100kg/day LEP electrolyser of Teddington then Beaconsfield with a new 270kg/day MEP electrolyser, and to upgrade Rainham to a 1MEP electrolyser system which would have increased daily hydrogen production capacity from 80kg/day to 270kg/day . However, this did not occur due to the closure of the stations and challenges with the site owner of one site.
- In France, HYPE announced its ambition to deploy 26 HRS in Ile-de-France region capable of refuelling up to 10,000 hydrogen taxi vehicles by the end of 2025.
- In recent years, the capacity of hydrogen refuelling stations has steadily increased, with Europe's largest light-duty vehicles HRS at Porte St-Cloud in Paris, France, capable of delivering up to a tonne of hydrogen per day.
- Globally, going forward, it is forecasted that HRS operators will focus on **increasing the capacity of stations** and **ensuring large anchor demands are available** to provide certainty over the utilisation (and revenues) of the station.
- The 2023 business case examines the rationale behind this approach and the opportunities for cost reductions that could be accessed by operators.



Concept illustration for a dual-purpose hydrogen hub (Credit: BOC, Linde)

Based on interviews with HRS operators, analysis focusses on large capacity 1,000kg/day stations

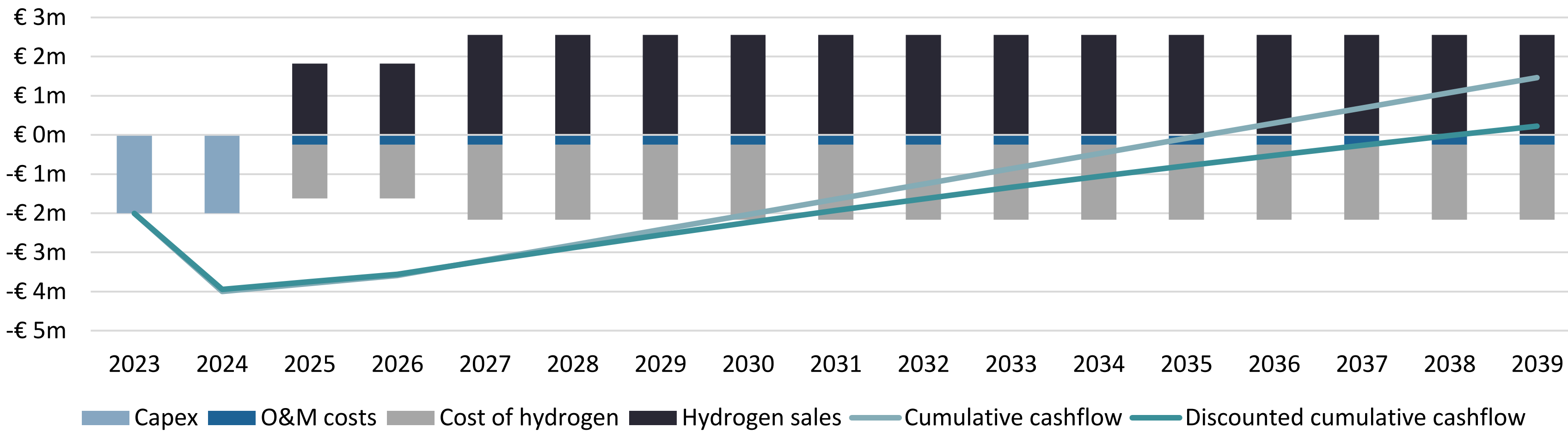
- In order to cater to dual-purpose demands and form a commercial case for HRS operation, HRS operators have indicated that **new stations will require a dispensing capacity of at least 1,000kg/day** to generate suitable profits.
- The table (right) provides the inputs which have been used to model the 2023 case.
- The base case assumes a transition to **1,000kg/day stations** and models a utilisation scenario with a utilisation rate estimated to 50% in 2023 and 2024 then 70% onwards, due to the fleet considered being captive.
- Due to the challenge of modelling the HRS business case at a time where the energy prices are increasing, two scenarios have been considered:
  - One with a constant selling price of 10€/kg and a constant hydrogen cost of 7.5€/kg
  - A more optimistic one with a constant selling price of 7.5€/kg and a constant hydrogen cost of 5€/kg
- The following slides show HRS operators' cash flow for HRS with on-site production and **analyse what hydrogen price could be feasible for end users** given scale price reductions in HRS CAPEX costs.

Parameter	Unit	Input
Capacity	Kg/day	1 000
Station life	Years	15
Hydrogen production	-	On-site **via electrolysis**
Utilisation	%	50% in 2023 and 2024, then 70%
Starting year (Year 1)	Year	2024
Years to plan and build	Years	2
HRS Capex	Million €	4
Capex reduction in starting year X vs 2024 reference year	%	100% in 2024, 99% in 2025, 98% in 2026, 97% in 2027, 94% in 2030
Fixed Opex – maintenance + overhead	Million €	0,25
Discount rate	%	3%
Selling price of H2 at the pump	€/kg	Constant at 10€/kg In the first scenario Constant at 7.5€/kg In the second scenario
Hydrogen cost (paid by HRS operators)	€/kg	Constant at 7.5€/kg in the first scenario Constant at 5€/kg in the second scenario

First scenario: a constant selling price of 10€/kg and a constant hydrogen cost of 7.5€/kg

- Modelling the economics of HRS in 2023 has proven challenging, due to the increase of the energy prices. Therefore, the below modelling is indicative and based on the assumptions of a current selling price of 10€/kg and a constant hydrogen cost of 7.5€/kg.

HRS cashflows:



Reminder of the assumptions used:

Utilisation - per year of operation	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Utilisation used (fraction of peak capacity)	50%	50%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%

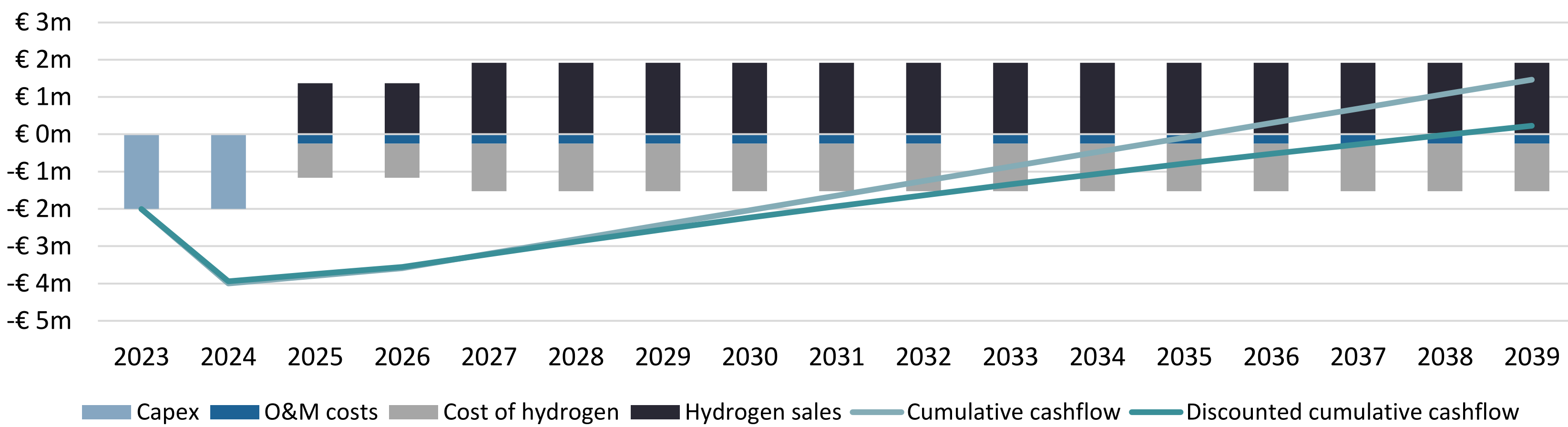
Selling-price of hydrogen (at the pump)		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2042
Price for end-users	€/kg	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €	10,0 €

Hydrogen cost (paid by HRS operators)		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2042
Hydrogen cost - delivered to the station	€/kg	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €

Second scenario: a constant selling price of 7.5€/kg and a constant hydrogen cost of 5€/kg

- A second scenario has been modelled, with a constant selling price of 7.5€/kg and a constant hydrogen cost of 5€/kg, aligned with the 7.5 €/kg of the vehicles TCO analysis in the previous slides. To be reached, this scenario would imply a significant fall in the energy price and/or support mechanisms to decrease the cost of hydrogen.

HRS cashflows:



Reminder of the assumptions used:

Utilisation - per year of operation	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Utilisation used (fraction of peak capacity)	50%	50%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%

Selling-price of hydrogen (at the pump)		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2042
Price for end-users	€/kg	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €	7,5 €

Hydrogen cost (paid by HRS operators)		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2042
Hydrogen cost - delivered to the station	€/kg	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €	5,0 €

Agenda

The business case for FCEVs has improved significantly since the initiation of ZEFER but subsidy support is still required in 2023

ZEFER

Development of the FCEV business case

ZEFER Business case

- **Lease (and capital) costs for FCEVs were at a significant premium** to all other drivetrains on the market and vehicles were assumed to have no residual value after first use.
- **Hydrogen fuel costs were significantly above parity** with petrol/diesel (€12/kg) due to the small scale of production and the lower-than-expected utilisation of the station.
- ZEFER partners have been able to make a business case feasible due to **significant subsidy support** and the avoidance of **financial penalties** for operating polluting vehicles.
- **Once grants and incentives are taken into account,** the technology is still expected to come at a premium to alternative drivetrains (e.g. hybrid, PHEVs and even BEVs). However, the operational advantages of the technology (e.g. longer range) can be used to justify additional expenditure.

Reduction in CAPEX costs

Inclusion of residual value

Continuation of subsidy support

2023 FCEV Business case

- **CAPEX costs for FCEVs bought in 2023 have reduced by ~20%** due to technology development (2nd gen Mirai).
- Hydrogen fuel costs still pose a significant challenge to the business case for FCEVs but as large-scale stations are deployed, **lower purchase prices (per kg) become available.**
- In this scenario, FCEVs still come at a premium. However, there are ‘fixes’ to improve the business case:
  - **Policy support/subsidy** for FCEVs.
  - **Near-term reductions in hydrogen prices** are within reach with increases in station capacities
- **A business case for FCEVs can therefore be made in 2023** but is still heavily reliant on subsidy support and the exploitation of operational benefits.
- **Stakeholders should lobby for more nuanced subsidy support for FCEVs** to ensure that the technology is not left behind due to its lesser market maturity.

The long-term business case for FCEVs will depend on strong cost reductions as well as the targeting of uses cases where their operational flexibility is most valuable

- In 2023, FCEV taxi TCO is at a c. 55-60% premium to current petrol hybrids, c. 30-35% premium over PHEVs and c. 40-60% premium over BEVs.
- In the optimistic scenario for 2025-2030, FCEVs reach TCO parity with PHEVs (remaining c. 14% more expensive on a TCO basis than petrol hybrids), but this scenario represents the highest level of optimism, and reality will lie between this scenario and the current situation presented for 2023. By comparison, in this optimistic scenario, BEVs achieve TCO savings of more than 20% over petrol hybrids.
- FCEVs bring certain operational advantages over BEVs for niche applications – particularly if very fast refuelling is required to perform a long trip at short notice (this can happen in Paris for example, when trains are not running). Drivers would need to weigh up the increased ability to capitalise on such exceptional long trip opportunities with the higher costs associated with FCEV operation for the remainder of the year. This advantage of FCEVs will continue to be eroded as BEV range, recharging time and infrastructure continues to improve.
- By 2030 competition between ZE and non-ZE powertrains will be of decreasing importance as policies phase out polluting vehicles (for example, the expected Paris 2030 ban on non-ZE vehicles). However, the competition between FCEV and BEV will remain: at the current rate, the embedded costs of the electrical charging infrastructure are decreasing at a faster rate than those of HRS, and batteries are also improving in performance (lifetime, energy content, charge rate). Both FCEVs and hydrogen refuelling infrastructure will have to deliver similar improvements to remain competitive, while continuing to offer operational flexibility in the most challenging duty cycles.

Only with an increase in scale and utilisation can HRS operators begin to make a business case for their refuelling stations

- Despite high hydrogen costs, the **business case for HRS within the ZEFER project is unfeasible** without significant public subsidy and investment by operators, given the small scale of the stations and low utilisation.
- The small capacity stations installed by EU demonstration projects have been a successful proof-of-concept, illustrating the technical feasibility of the technology. However, there is now a **need to move towards a more commercial business case** for the installation and operation of stations to ensure that infrastructure does not delay or prevent FCEV deployment.
- This has led to a strategic move from HRS operators to focus on **larger capacity HRS** with **defined anchor demands** (generally from heavy duty vehicles) in order to spread capital costs over larger volumes of hydrogen and provide a certainty of revenue to aid an investment decision. This approach is already being seen in 2023 and **lower hydrogen prices are already being announced** by industry players.
- However, in order to create a business case for HRS operators and to ensure the healthy uptake of FCEVs, **further reductions in hydrogen prices are needed**. This will require an **increase in the scale of the supply chain**, such that production and transport costs are reduced for HRS with off-site production and **electrolyser costs are minimised** to access cheap, green hydrogen on-site. Considerations should be given to perceptions on green and blue hydrogen to ensure buy-in of political stakeholders.
- In the near-term this will **require subsidy support from governments.** Mechanisms are beginning to be discussed via the Renewable Energy Directive II and initial examples are being implemented in the UK via the Renewable Transport Fuel Obligation (RTFO). It is hoped that this support can kick-start the scale-up of the market and, over time, transition the supply chain to cleaner origin energy (e.g. green or ultra-low hydrogen only).
- More reliable and numerous HRS are also necessary to facilitate the roll-out of vehicles.

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