HyDrive - Hydrogen Refuelling Initiative

February 2025

COSTAIN

WALES&WEST UTILITIES

Foreword

The decarbonisation of transport has seen significant technological advances. However, while electric vehicles are becoming increasingly common, batteries alone cannot meet the needs of all drivers. Can hydrogen offer a compelling alternative, providing the rapid refuelling and extended range required by heavy-duty vehicles such as trucks, buses, and even vans?

The UK's greenhouse gas emissions have halved since 1990 but transport emissions have remained stubbornly high. That's because improvements in vehicle efficiency have been offset by increasing vehicle usage and mileage. Although battery electric vehicles (BEVs) are gaining popularity for cars, buses, and some vans, hydrogen presents a particularly attractive option for energy-intensive vehicles that are on the road a lot of the time, especially heavy goods vehicles (HGVs).

European and global HGV manufacturers are currently investigating hydrogen options, predominantly as fuel cell electric vehicles (FCEVs) but also via hydrogen internal combustion engines (ICE).

From the Hydrogen Europe consultation, additional hydrogen demand is also anticipated from buses and vans.

Development of infrastructure needed to support hydrogen vehicles will be key.

HyDrive looks to explore this potential, by first establishing a baseline for current demand to inform how further infrastructure could be developed and secondly, to determine how the re-fuelling of hydrogen vehicles could be connected to the gas network.

The Hydrogen Opportunity

Heavy vehicles like bin lorries, gritters, ambulances, vans and HGVs cover long distances every day.

For these vehicles, recharge times and driving range are limited by current battery technology. Additionally, grid capacity and recharging infrastructure are yet to keep up with rising demand.

That's where hydrogen can come in. Hydrogen-powered vehicles offer similar refuelling times and driving range to current diesel vehicles. HyDrive shows how hydrogen refuelling stations (HRS) can be developed in the WWU region, with Swansea emerging as a potential location. HyDrive shows how HRS can be developed by re-purposing sections of WWU's extensive natural gas network.

> "Hydrogen is likely to be fundamental to achieving net zero in transport, potentially complementing electrification across modes of transport such as buses, trains and heavy goods vehicles (HGVs)."
>
> *From the UK Hydrogen Strategy, 2021 [1]:*

The HyDrive project engaged with stakeholders who are actively seeking zero-emission alternatives for transport. Our survey spoke to local authorities, fleet operators, service stations and Wales & West Utilities.

Current HRS typically provide up to 1 tonne per day of hydrogen, capable of supplying 20 HGVs. To meet growing demand, future HRS stations will need higher production levels to support increased demand. The HyDrive study looked at the feasibility of an HRS providing 6 tonnes per day.

Gas distribution network, Cadent, published a report on the Future Role of Gas in Transport, which showed that transport of hydrogen by road above 3 tonnes per day is costly and impractical. **Pipelines offer a more efficient and less costly solution.**

From the HyDrive survey, **94% of respondents considered there to be a place for hydrogen in UK road transport.**

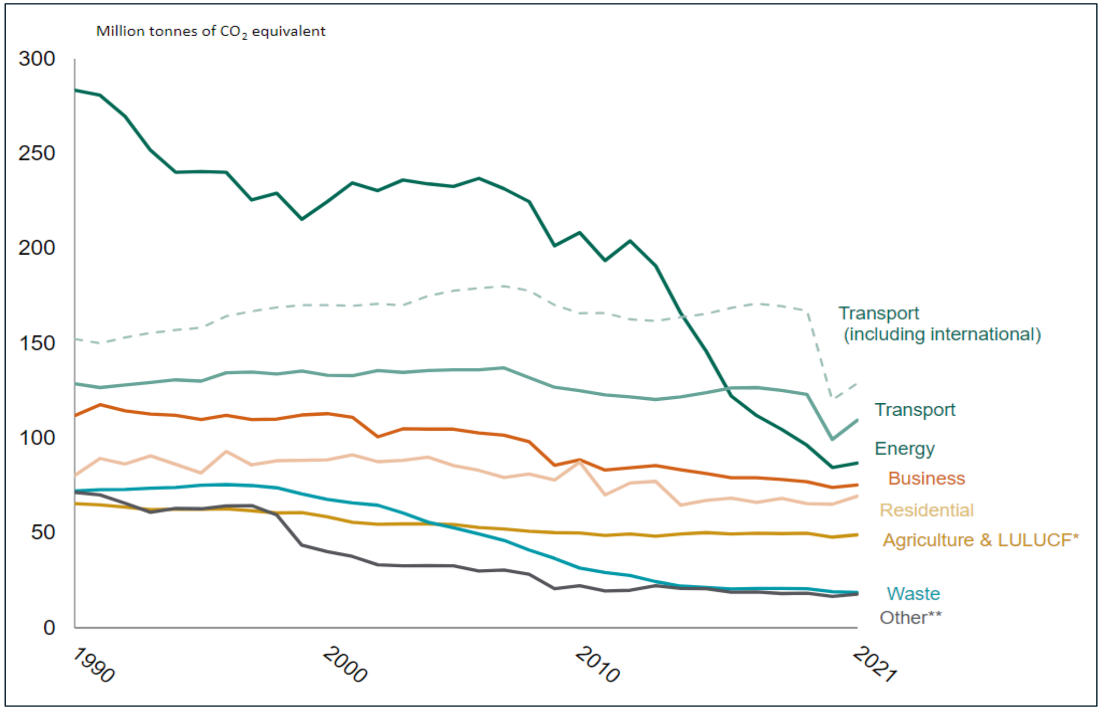
Contents

1 Context

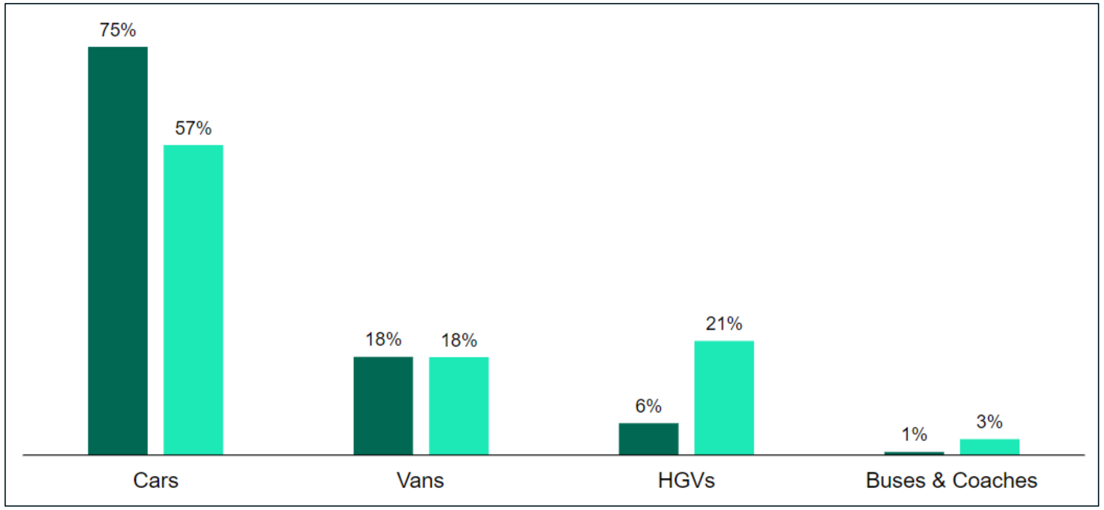
Our Net Zero Challenge

In 2019, UK Government legislated to bring GHG emissions to net zero by 2050 [3]. Progress is already being made: the UK's 2023 emissions (384.2 $MtCO_2e$) were almost half those from 1990 [4]. But whilst electricity generation has seen a major decline in emissions (as we shift from coal to renewables), transport emissions have remained almost static.

Today's vehicles are more efficient than their predecessors but there are more vehicles on the road, covering more miles [5]. Right now, domestic transport (mostly road transport) is the UK's biggest emitter [4]. Within road transport, **HGVs are a significant challenge: these account for 21% of UK road transport emissions.**



Gov.uk,Greenhouse gas emissions by sector, 2021



Gov.uk, Mileage and GHG emissions for cars, vans, HGVs and buses in 2021

The drive towards zero-emission HGVs is already under way.

In the UK, the purchase of new non-zero emissions HGVs under 26t will be phased out by 2035 and those over 26t will be phased out by 2040. In Europe, the EU has amended its Emissions Reduction Target [6]: in addition to a 15% reduction by 2025, Heavy Duty Vehicles (HDVs i.e. 16 t and over) must also achieve further reductions by 2040. Meanwhile, the European Automobile Manufacturers Association (ACEA) has pledged to end the sale of fossil-fuelled HGVs by 2040 [7].

Here in the UK, the government's Transport Decarbonisation Plan has set out zero-emission target dates for the freight sector [9]. Cities are also beginning to act: London now has an Ultra Low Emission Zone (ULEZ) and urban Clean Air Zones (CAZ) are being rolled out across the country.

CO_2

Existing target for emission reduction for lorries over 16 tonnes

2025 - 15%

New targets for reduction for extended scope of HDVs

2030 - 45%

2035 - 65%

2040 - 90%

Regulation (EU) 2019/1242, Amended HDV Emissions Reduction Targets

Road Transport: electric, hydrogen – or both?

The future of zero-emission transport is not a battle between technologies. Battery electric solutions work well for smaller vehicles, where there is less focus on range and battery weight. Hydrogen has a potential role to play in heavier energy intensive vehicles, especially HGVs, that cover long daily distances.

From a recent UK Government consultation on the phase-out of non-zero emission HGVs [10]:

"...HGVs with a weight of 26 tonnes or less primarily service urban and regional routes, with typically shorter ranges and more predictable journeys. ...As batteries get cheaper and the supply chain scales up, battery electric technology could be a direct swap for diesel in this weight category.

In contrast, HGVs over 26 tonnes are typically used for long-haul applications with longer journeys and heavier loads. Their duty cycles mean these vehicles are more likely to need to refuel away from base, making adequate refuelling and recharging infrastructure essential to support their take up. **There is less certainty around the zero emission technologies for HGVs above 26 tonnes, with battery electric, hydrogen fuel cells and electric road systems all potential solutions to decarbonise heavier HGVs.**"

The Electric Revolution

The electric vehicle revolution is underway: in 2024, one in six new UK cars was a battery electric vehicle (BEV). Buses are even further down the same route: in 2024, 60% of Britain's new buses were BEVs [11] bringing smoother journeys and cleaner air to our cities. We're also seeing a welcome growth of electric vans hitting the roads: their total cost of ownership (TCO) is already starting to beat diesel [12]. But there are challenges including lack of recharging infrastructure.

The Hydrogen Opportunity

For heavier vehicles, such as HGVs, BEV solutions do not currently meet all customer requirements (charging times, driving range). Instead, hydrogen is an option.

Filling up an HGV on hydrogen is similar to filling up on diesel right now - and you can cover a similar driving range on a tankful. Right now, truck manufacturers across the world are developing hydrogen solutions alongside BEV solutions.

We're also starting to see hydrogen-powered buses and bin lorries covering longer distances and hilly terrain that BEVs can't handle. Hydrogen vans are starting to hit the market - these can meet the challenging duties that our emergency services and utility companies deal with every day. Car manufacturers are also exploring hydrogen options. Off-road, construction equipment manufacturers (like Britain's JCB) also see hydrogen as the answer.

And as the electrical network capacity is constrained across most of the WWU Region (especially in rural areas), this can impact EV take-up at depots. Additionally, hydrogen can also relieve some pressure from the electrical grid at peak times when renewable production increases.

Hydrogen Technology

So far, most hydrogen vehicles are fuel-cell electric vehicles (FCEV). In a fuel-cell, hydrogen is converted into electricity which turns the wheels via an electric motor.

Another lower cost concept is also emerging: converting the tried-and-tested internal combustion engine (ICE) design to hydrogen power. Although hydrogen ICE vehicles emit a very small amount of NOX in the exhaust, they are classified as zero emission by the EU. The UK Government is considering a similar approach [10].

From EU Directive 2019/1161 [13]:

> "Zero-emission heavy duty vehicle" means a clean vehicle as defined in point 4(b) of this Article without an internal combustion engine, or with an internal combustion engine that emits less than 1 g CO_2/kWh as measured in accordance with Regulation (EC) No 595/2009 of the European Parliament and of the Council and its implementing measures, or that emits less than 1 g CO_2/km as measured in accordance with Regulation (EC) No 715/2007 of the European Parliament and of the Council and its implementing measures.

From the UK Government consultation on the phase-out of non-zero emission HGVs [10]:

> "We recognise the interest in hydrogen combustion to reduce carbon emissions. At present all internal combustion engines produce harmful exhaust emissions and would therefore be subject to end of sale dates for new, non-zero emission HGVs. However, if technology developments enable renewable hydrogen to be used in combustion engines with zero harmful tailpipe emissions then we would welcome this development."

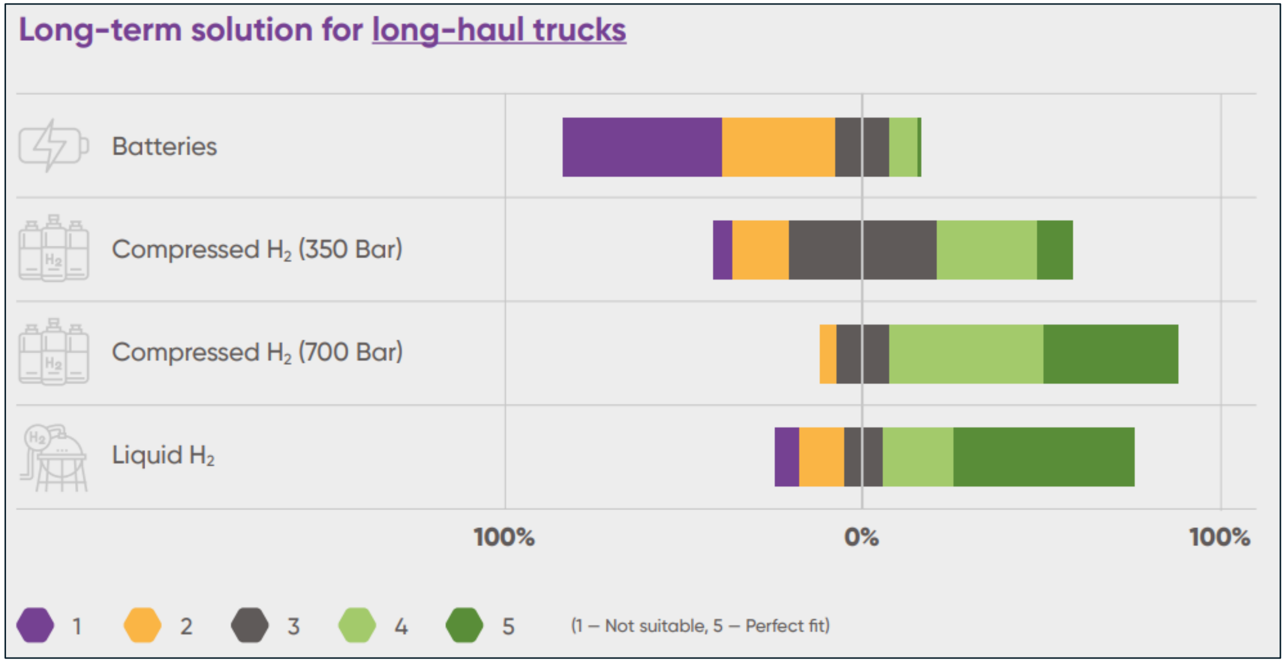
2 Hydrogen Consultations

Hydrogen Europe

Vehicles, especially HGVs, cross daily from the UK to Europe – and vice versa. So, we're likely to see common policies and technologies to deliver zero-emission transport. In the WWU region, the M4 corridor supports the EU's Trans-European Transport Network (TEN-T) [18].

A 2024 survey of members of Hydrogen Europe (HE), including hydrogen producers and end users, was used to generate a long-term outlook on zero-emission mobility [14]. Hydrogen was by far the most popular solution for long-haul trucks. There was also strong support for hydrogen in regional delivery trucks, coaches and vans.

The HE survey [14] also investigated bottlenecks and issues associated with hydrogen HGVs. Areas of most concern included refuelling infrastructure, high costs (CAPEX and OPEX) and the legislative framework.



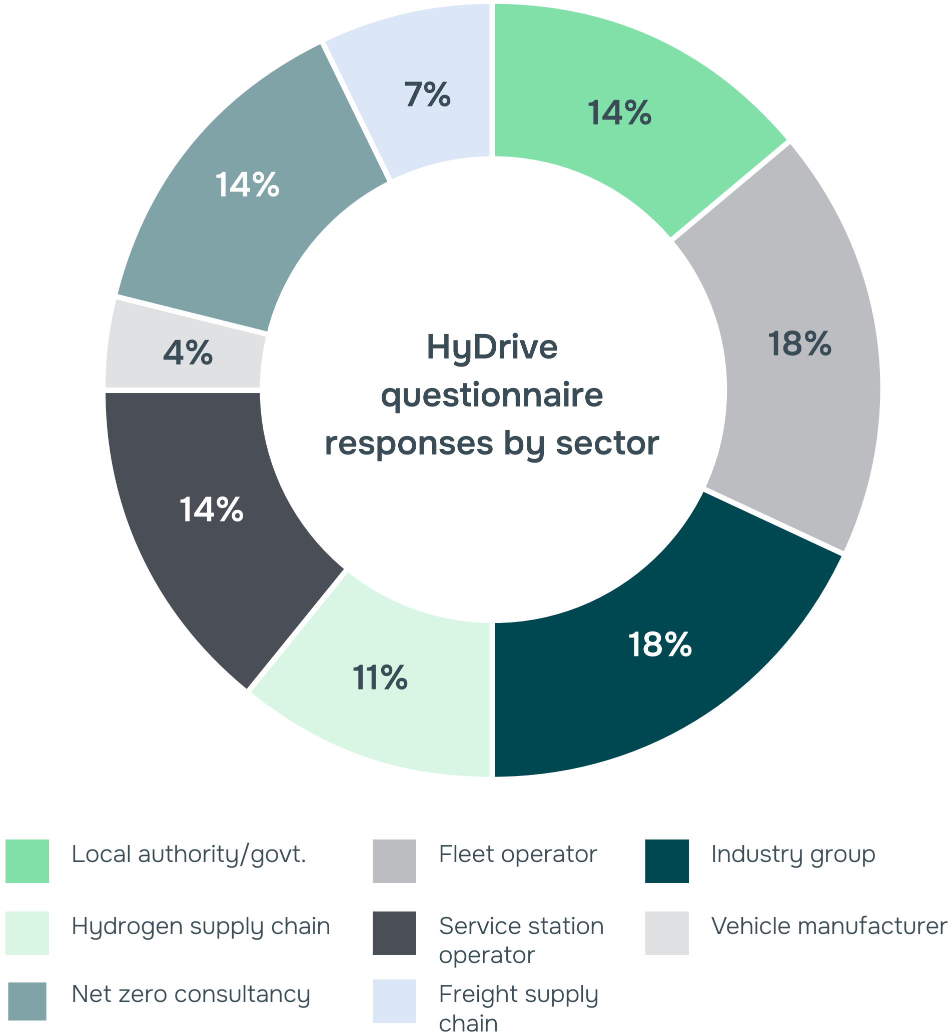
HE Consultation, Long-term solution for long-haul trucks

UK Government

In 2021, the government launched a consultation on its proposal to end sales of all new non-zero emission HGVs: below 26t by 2035 and above 26t by 2040 [10]. Following the consultation, it remains committed to introducing phase-out dates but launched a call for evidence to identify exemptions for sectors needing further time. The UK Government has backed hydrogen HGV initiatives via the Zero Emission Road Freight Demonstration (ZERFD) programme, including the HyHaul demonstrator project on the M4 corridor [15].

Costain: HyDrive Survey

As part of the HyDrive project, Costain conducted a stakeholder survey to road fleet operators (particularly HGVs), service station operators, road vehicle manufacturers, local authorities, companies involved in hydrogen production supply chain, renewable energy providers and WWU.



Key observations:

94% of respondents considered there to be a place for hydrogen in UK road transport

69% of respondents considered that at least a quarter of HGVs will be hydrogen-fuelled by 2040

45% of respondents expect that half of all HGVs will be fuelled by hydrogen in 2040

46% of fleet operators envisaged having hydrogen vehicles by 2030

69% by 2040

84% by 2045

Key fundamental challenges to a hydrogen future were identified as: **Total Cost of Ownership, hydrogen availability and vehicle availability**

Do you think there's a place for hydrogen in UK road transport?

66% Extremely likely	**3%** Somewhat unlikely
28% Somewhat likely	**3%** Extremely unlikely

3 Energy Demand for Road Transport

Current Petrol & Diesel Demand

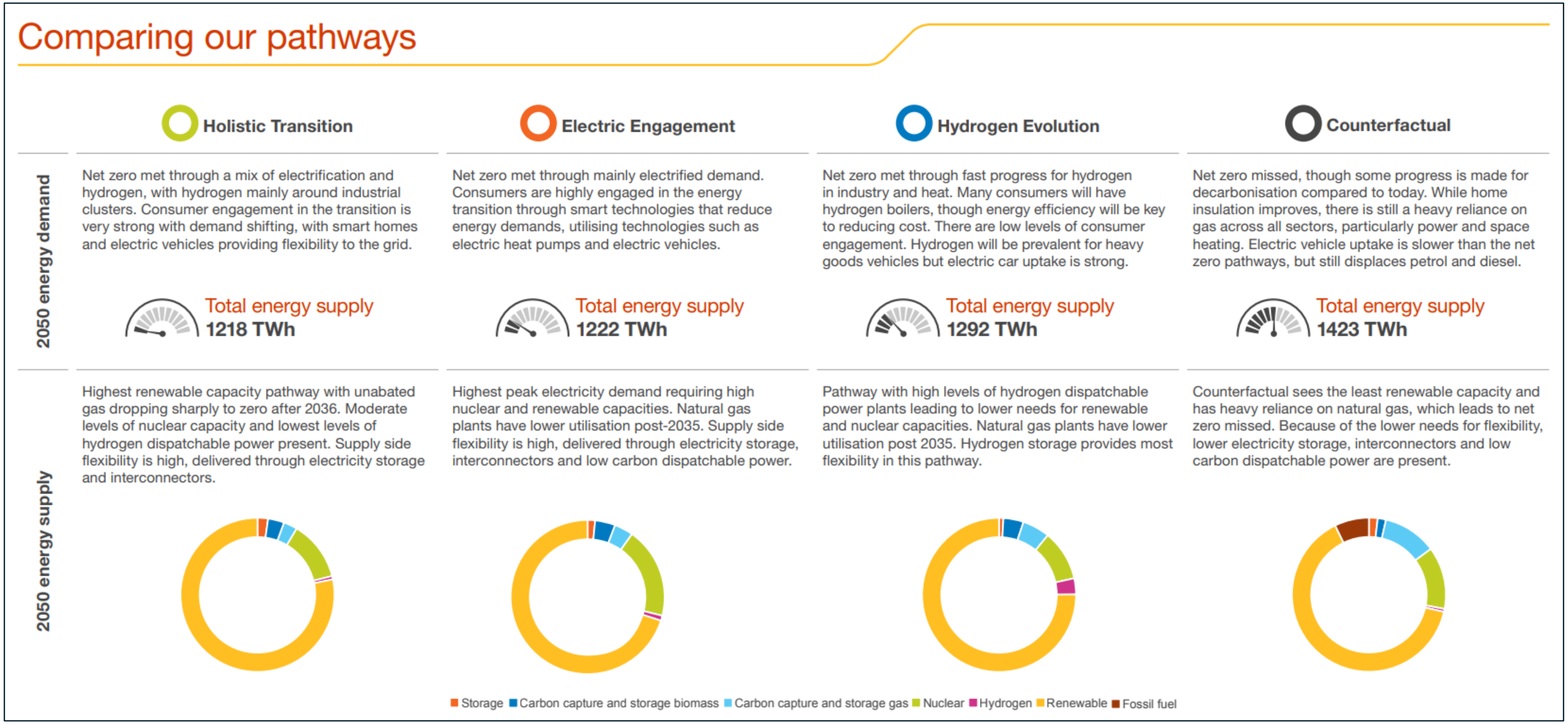
A model of current demand for petrol and diesel in the WWU region was developed using UK Government data and anonymised service station transaction data made available under commercial terms by EdgePetrol.

The model enabled analysis of on an annual, monthly, weekly and hourly basis. This supported definition of the capacity needed for the feed pipeline to the HRS, as well as the potential size of processing and storage equipment.

Future Hydrogen Demand for Road Transport

The National Energy System Operator (NESO) Future Energy Scenarios 2024 (FES) 2024 presents four pathways [16] to net zero. Of these, the only pathway where hydrogen plays a significant role in road transport is called Hydrogen Evolution. In this pathway, “hydrogen will be prevalent for heavy goods vehicles”.

Of the 393 TWh of hydrogen required by 2050 in the Hydrogen Evolution pathway, 51 TWh would be for road transport, 93% of which is for HGVs. This pathway assumes the electrification of most light HGVs (below 26t) with approximately half of all HGVs (some 275,000 vehicles) to be fuelled by hydrogen.



Credit NESO: FES 2024 Pathways

4 Reconfiguring the Gas Network

The FES 2024 Hydrogen Evolution pathway estimates the UK will need a total of 393 TWh of hydrogen by 2050 – of this, 51 TWh would be for road transport. HGVs on the M4 alone would require almost 1 TWh of hydrogen.

Some would be transported from production site by road via tube trailers to an offtaker's destination for storage and use.

But the majority would need to be transported by pipeline – that's either new pipelines or via re-purposed sections of the existing natural gas grid.

Half the hydrogen produced in the Hydrogen Evolution pathway is from the conversion of natural gas. As this pathway has the highest demand profile for natural gas (except for the counterfactual case), the future demand for transporting hydrogen on the gas grid would need to be considered alongside the on-going requirement to transport natural gas.

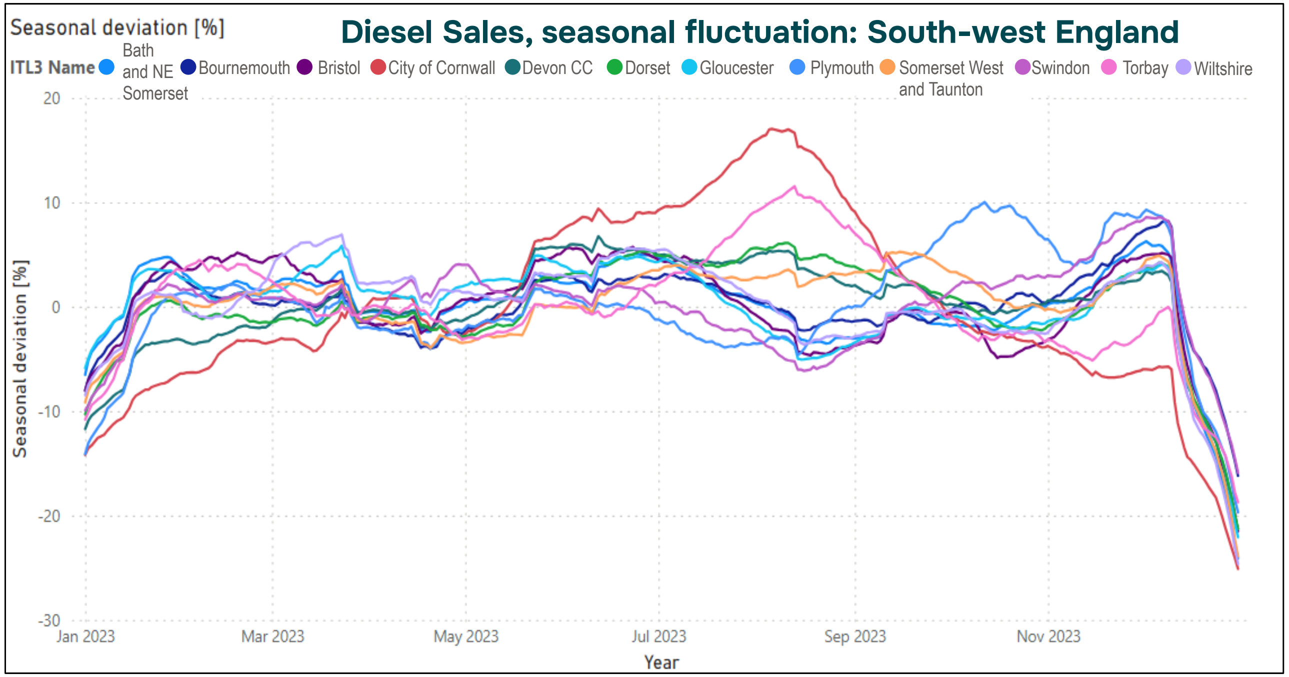
The WWU region could be a location for early development of large-scale hydrogen production, for example, due to the presence of LNG import terminals near Milford Haven (Dragon, South Hook) and their potential to supply natural gas which could be converted to hydrogen.

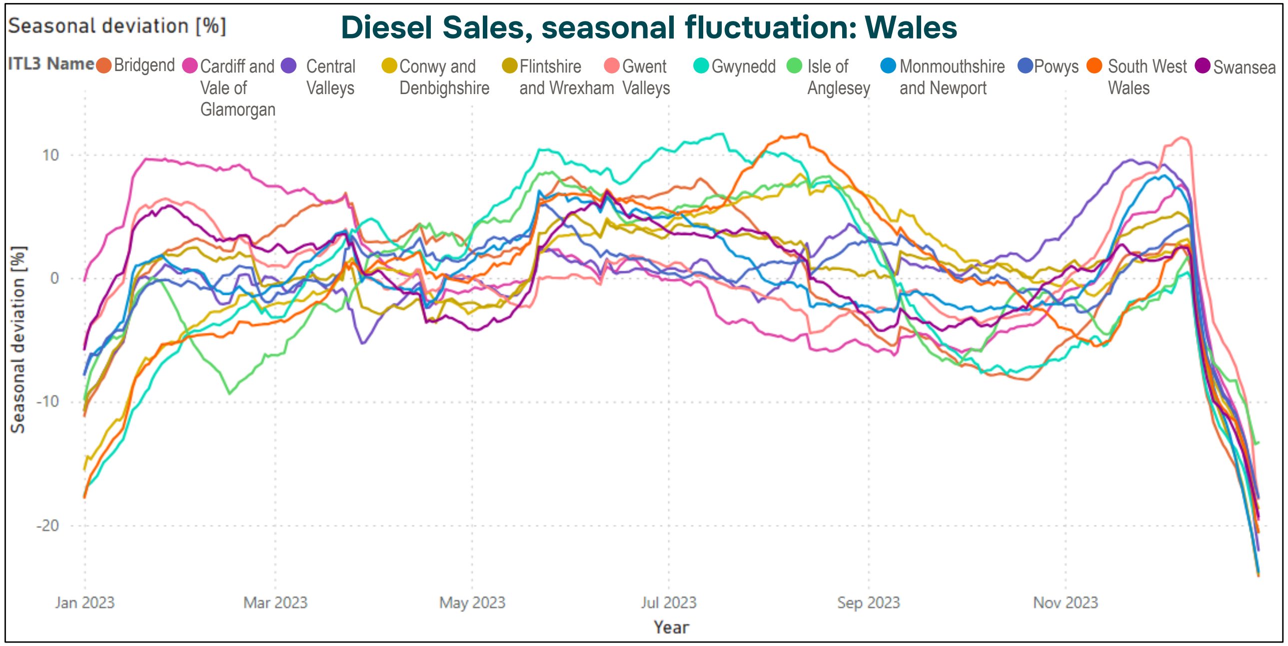
5 HRS Case Study

Current Fuel Demand

Daily weekday fuel sales (petrol and diesel) in 2023 in Wales and south-west England were were analysed down to an hourly level.

In terms of seasonal fluctuation, south-west England exhibits the greater variability, with Cornwall and Torbay showing a 10 to 15% increase during the summer months when tourist numbers are high.





HRS Case Study Site Selection

A list of ten potential HRS locations across the WWU distribution network was identified through initial screening. These were scored against key criteria:

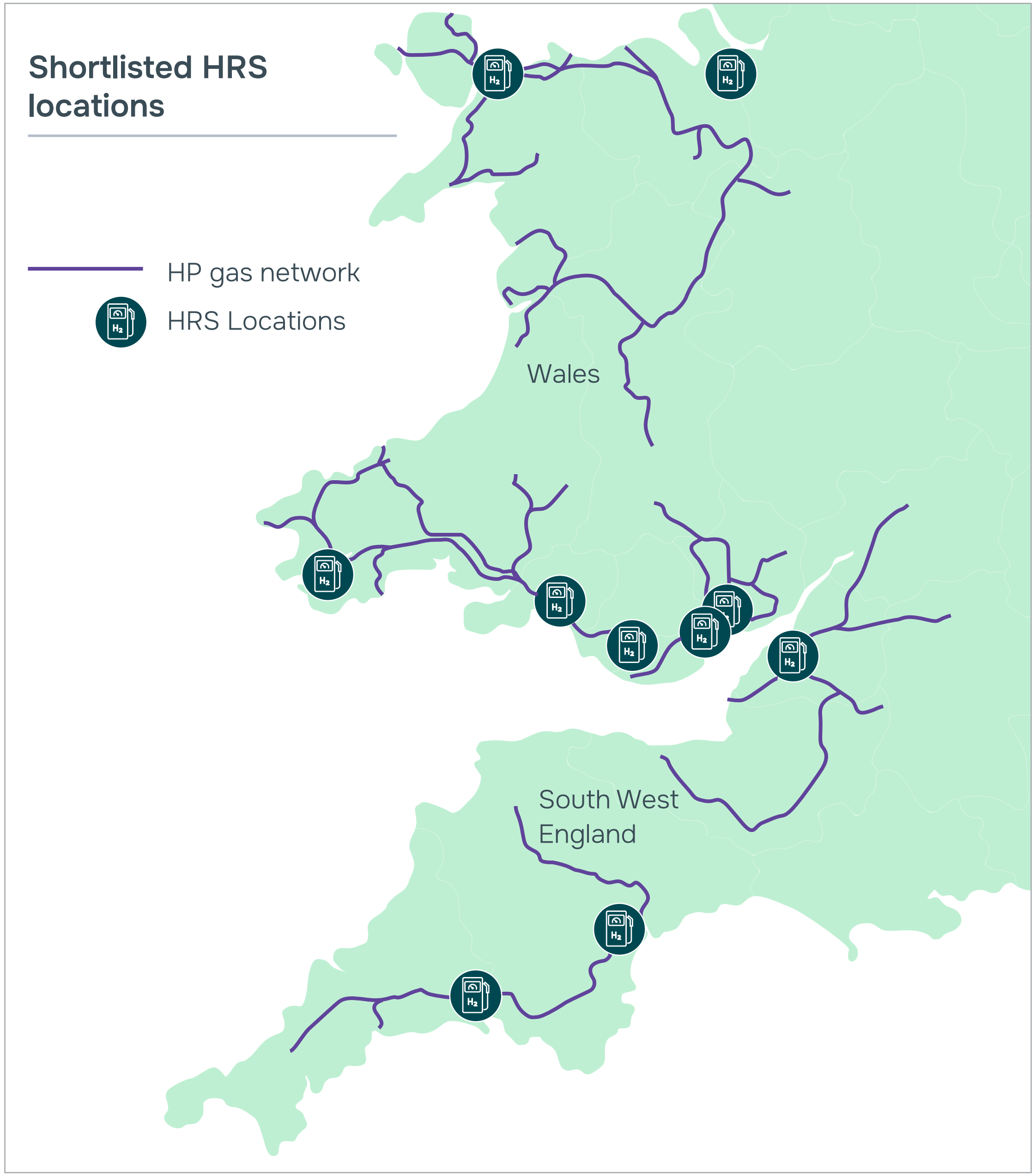
- Proximity to WWU pipeline HP/IP network
- Future hydrogen projects in the WWU region
- Population density
- Current diesel sales

From a short-list of three, the Swansea area was selected.

The M4 corridor in Wales is considered an area of high future HGV demand for hydrogen [17]. It also supports the EU's Trans-European Transport Network (TEN-T) [18]. Most HGV transport to Ireland uses ferry routes via the UK, including those from Fishguard and Pembroke. On the way back, refuelling a hydrogen HGV in Swansea provides enough range to get to Amsterdam or Paris.

EU Regulation 2024/1679 covers the development of the Trans-European Transport Network (TEN-T) [18]. The TEN-T area of most significance to the UK is the North Sea – Rhine – Mediterranean corridor [19]:

> "The corridor connects the Irish capital Dublin and the maritime ports Cork and Foynes and provides a link to Northern Ireland. These ports are connected to the maritime ports of Amsterdam, Rotterdam and Vlissingen in the Netherlands, Antwerp and Zeebrugge in Belgium, Dunkerque, Calais and Le Havre in France, all located along the North Sea and the English Channel."



HRS Capacity

Current HRSs are of low capacity, typically 0.5 to 1 tonne per day (t/d), capable of refuelling just 10 to 20 HGVs daily. Whilst the UK Government has not set out any requirements, it is clear that to meet increased demand, larger capacity HRSs will be required. Based on the ACEA (European Automobile Manufacturers Association) manifesto [21], a capacity of 6 t/d was selected.

From the VDA (German Association of the Automotive Industry) [22]:

> German commercial vehicle manufacturers and suppliers see hydrogen as a medium-to long-term option for making long-distance transportation in particular CO_2 neutral.
>
> The necessary use of green hydrogen and its current lack of availability on the one hand, and the lack of refuelling facilities for trucks/buses along with the cost of fuel cells on the other, are currently limiting factors for the widespread introduction of this technology.

HRS Supply

Currently, small-scale HRSs either produce hydrogen on-site or are supplied by road via tube trailers. But both these options become too expensive at large scale and over long distances: the Cadent HyMotion study [23] found that for 2 t/d of hydrogen delivery, distribution costs are £0.6/kg via tube trailer versus £0.1/kg via pipeline. Furthermore, the Cadent Future Role of Gas in Transport study [24] found safety and operational constraints when supplying more than 3 t/d by tube trailer.

It is therefore anticipated that future, larger-capacity HRSs will be supplied by pipeline. To achieve this, sections of the existing natural gas pipeline grid can be segregated and repurposed for hydrogen duty with new sections added where required. Such concepts are already under consideration across Europe. The European Hydrogen Backbone (EHB) initiative includes 33 European Transmission System Operators (TSO), including National Gas in the UK [25]. For the locations identified in the Swansea area, a 150mm to 200mm diameter piping is required to connect the WWU network to the HRS.

From the International Energy Agency (IEA) 'The Future of Hydrogen' report [26]:

> In many countries there is an extensive existing natural gas pipeline network that could be used to transport and distribute hydrogen.

In the UK, Project Union [27] seeks to:

> Facilitate a low-cost route to net zero and empower a UK hydrogen economy by repurposing existing pipelines to create a hydrogen 'backbone' for the UK by the early 2030s.

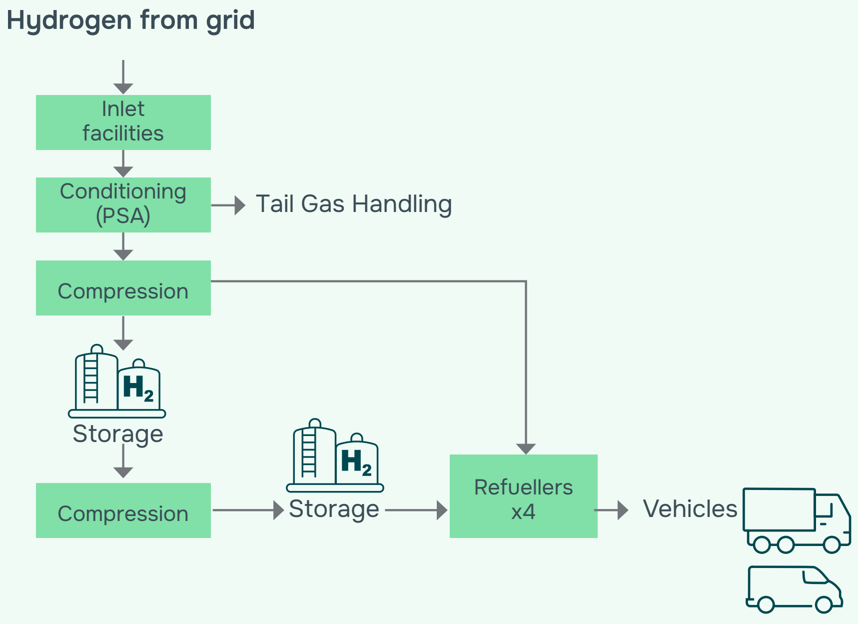
HRS Facilities

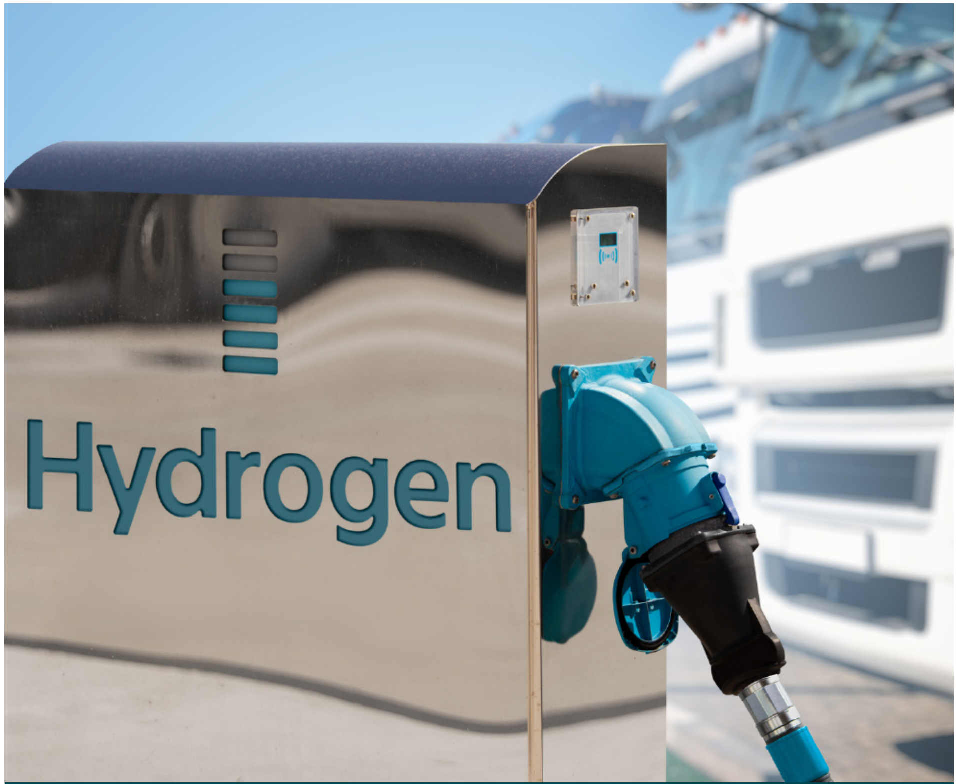
Hydrogen that is used for heating needs to be purified before it can be used in fuel-cell vehicles. HRS facilities convert the hydrogen supplied by pipeline into fuel-cell grade hydrogen. The hydrogen is then compressed and stored ahead of refuelling vehicles.

To meet current HGV fuelling patterns, four refuellers are specified, capable of delivering a peak rate of 18t/d. More in-depth analysis is available in the technical report for HyDrive.

A preliminary layout has been designed taking into account safety requirements and the customer experience. Whilst most users are likely to be HGVs, the site is also useable by other vehicles e.g. vans and cars.

HRS schematic



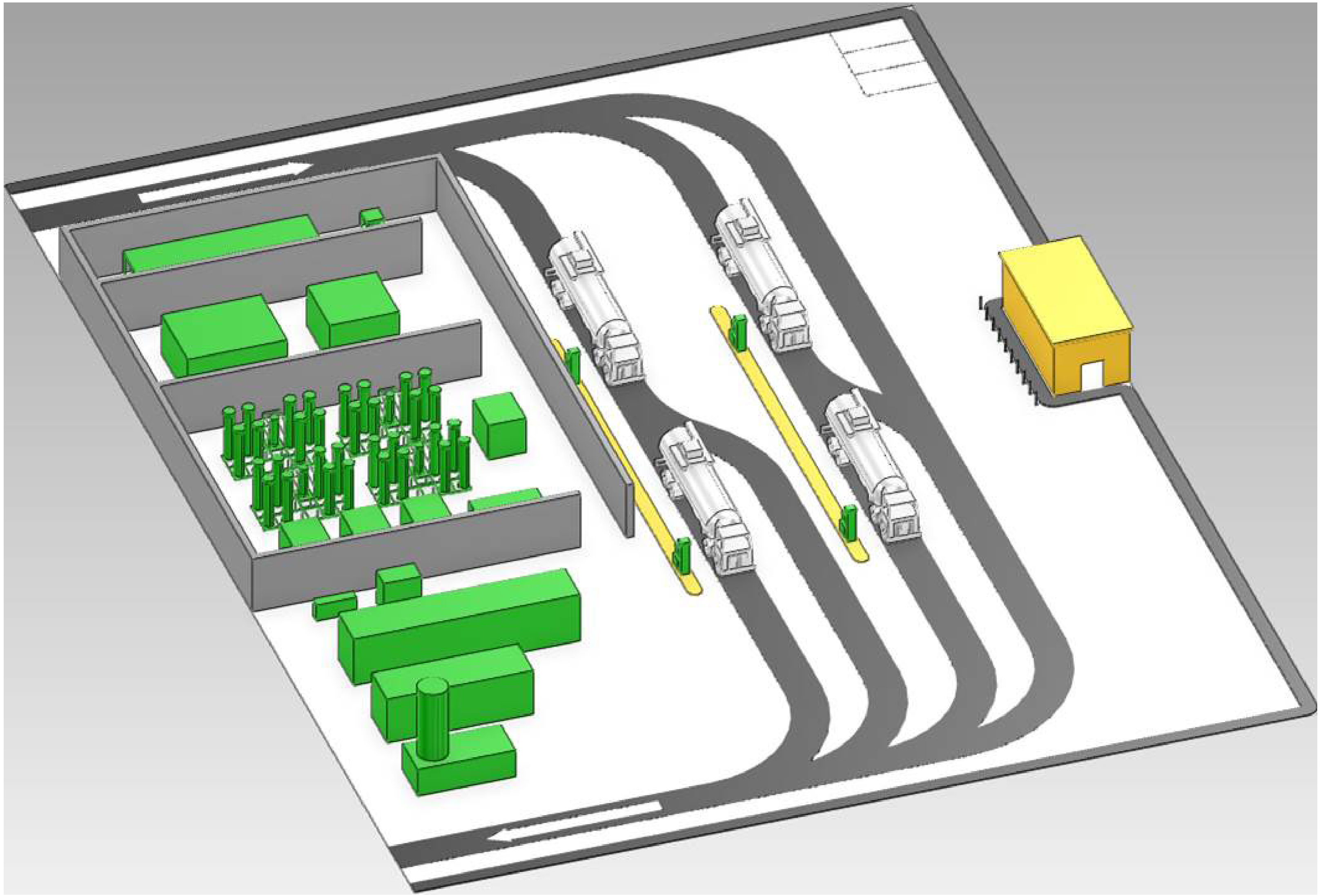


The following HRS facilities are required to provide fuel-cell grade hydrogen for road transport:

- **Inlet facilities:** filter, coalescer, analyser, metering
- **Conditioning:** to convert heat-grade hydrogen to fuel-cell grade hydrogen. Includes tail gas recovery for re-use.
- **Compression:** to achieve the pressure required for storage and vehicle refuelling
- **Storage:** to ensure sufficient inventory is available to meet demand and to provide a break between the network and compression and also between compression and refuelling
- **Dispensing:** to refuel road vehicles.

HRS Layout

The HRS is located a distance from other service station facilities. The HRS site itself is segregated: hydrogen inlet facilities, conditioning, compression and storage are not accessible to the public.



Hydrogen Refuelling Station

HRS Location

As the HRS is predominantly for use by HGVs, three locations along the M4 motorway were considered:

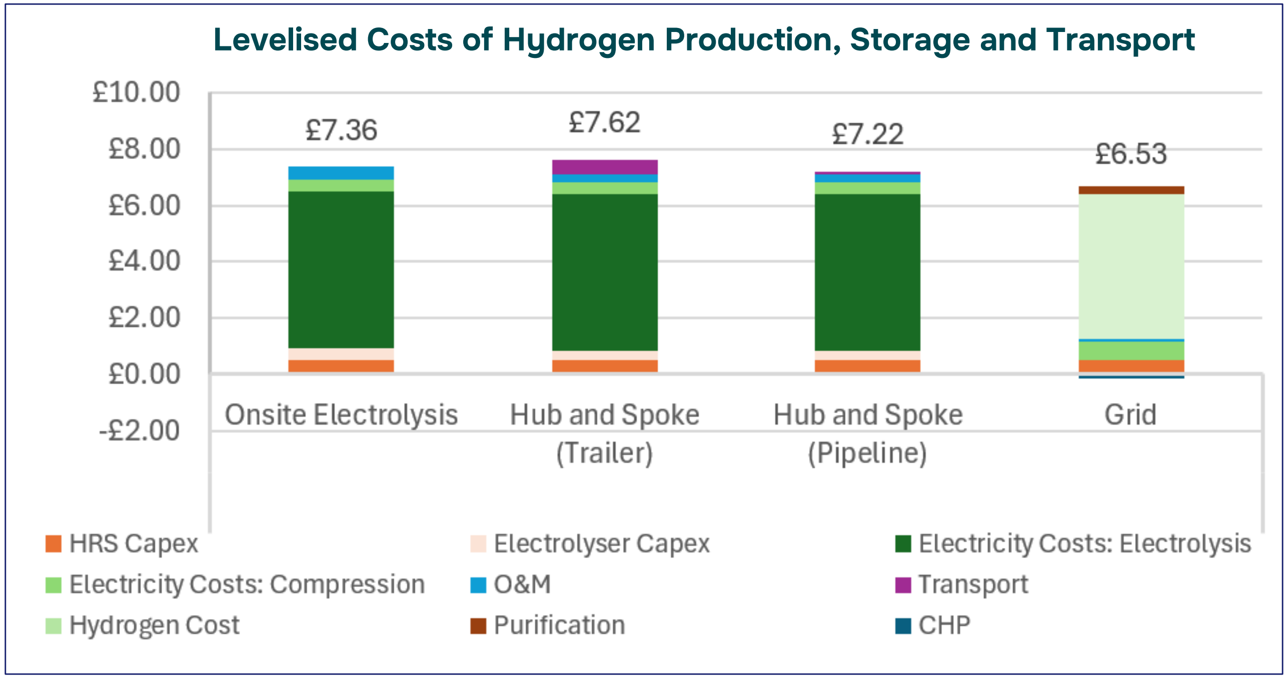
- **Junction 36:** Sarn Park Services (existing M4 service station)
- **Off Junction 42:** Former Ford factory site adjacent to Amazon Logistics Hub in Swansea
- **Junction 47:** Moto Swansea Services (existing M4 service station).

6 Costing

Economics

As part of HyDrive, an economic assessment was undertaken by Gemserv. This considered a range of hydrogen production and supply routes: on-site electrolysis, hub-and-spoke (hydrogen produced at centralised site and transported to HRS by pipeline or through tube trailers) and pipeline grid supply.

Levelized costs of hydrogen production, storage and transport ($LCOH_{PST}$) were generated for 2030, 2035 and 2040. Until the year 2035, the hub-and-spoke scenario is the lowest cost option with an $LCOH_{PST}$ of £7.82/kg of hydrogen. By 2040, the pipeline grid supply becomes the most financially viable with an $LCOH_{PST}$ of £6.53/kg. These were calculated on a 2024 basis: these are likely to come down as the hydrogen economy develops.

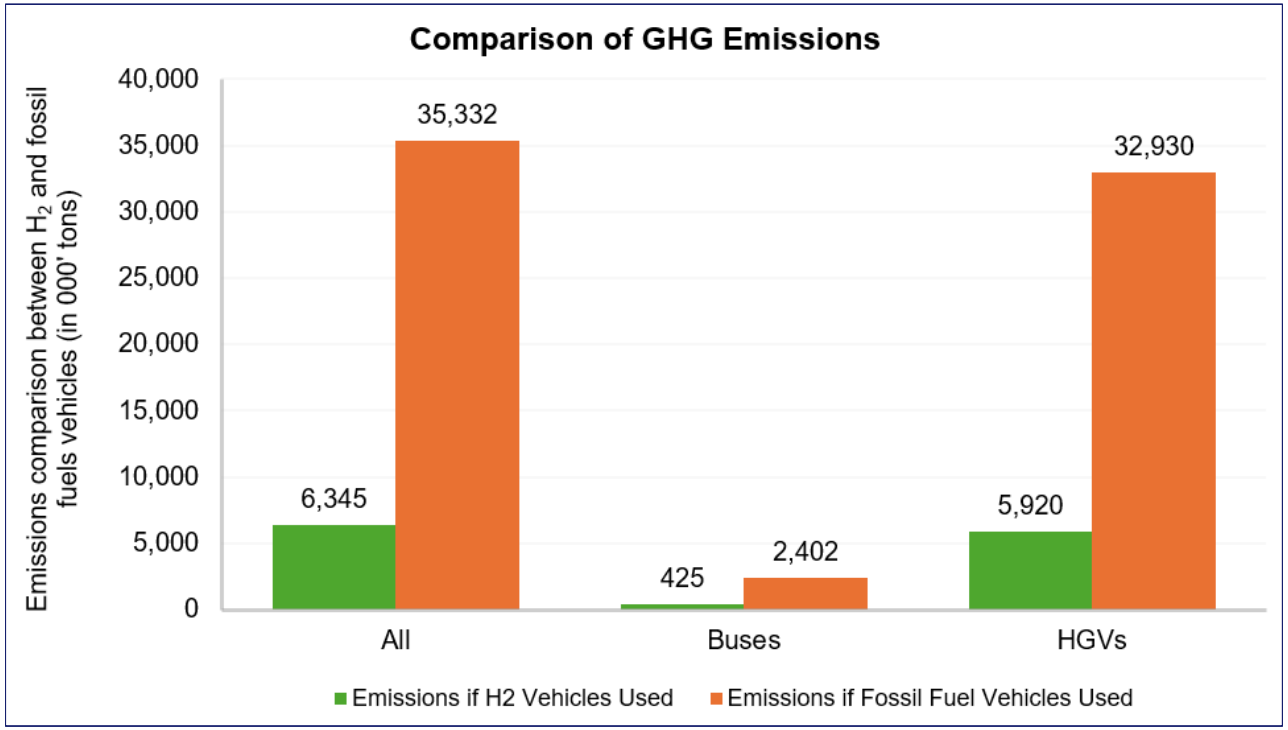


Alternative revenue pathways associated with hydrogen production can add revenue. By selling waste heat, an HRS could earn £300 per ton of hydrogen. Potential revenue from waste oxygen could be £600 per ton of hydrogen.

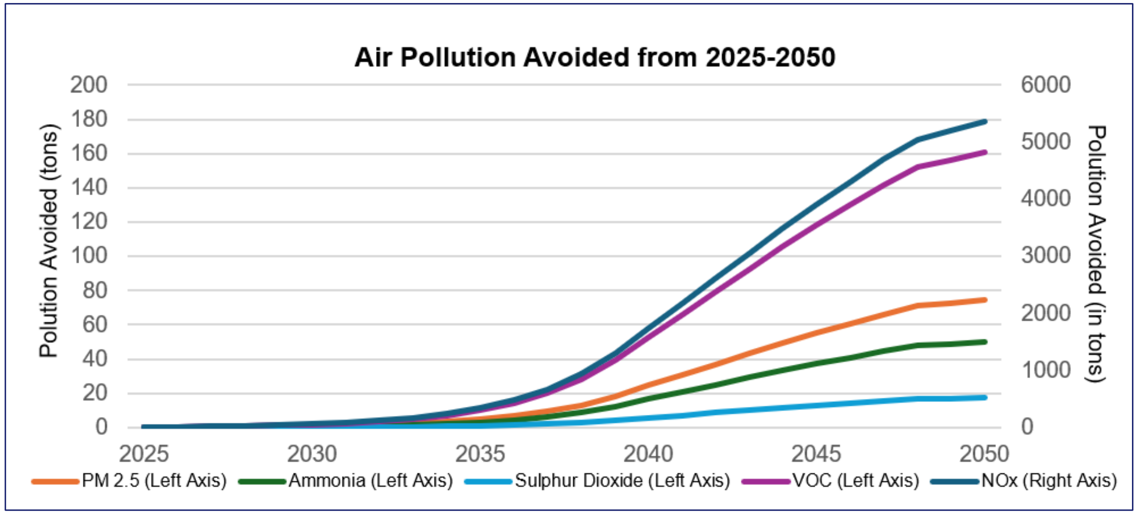
Additionally, a 'low-regret' infrastructure assessment was conducted to ascertain the minimum number of HRS required in a low demand scenario. From the FES 2024 Electric Engagement pathway, the WWU Region would require 86 HRS (each of 0.5 t/d capacity) operating at a 50% utilisation rate. These would be distributed across the WWU Region to ensure access for all users.

The report also explored the cost distribution associated with the required infrastructure development both initially and as government policy schemes develop. Policies analysed included the Hydrogen Production Business Model (HPBM), Hydrogen Storage Business Model (HSBM) and the Hydrogen Funding Mechanism. Most costs will be borne initially by developers with some potential for small-scale government support. Final costs are likely to fall between hydrogen users, government and potentially energy bill payers through the hydrogen funding mechanism.

The report further analysed the wider environmental benefits of deploying hydrogen vehicles in the WWU region by quantifying the reduction in greenhouse gas (GHG) emissions and air pollution.



Greenhouse gases emissions avoided from 2025-2050, WWU Region [Gemserv]



Air pollution avoided from 2025-2050, WWU Region

7 WWU Fleet Case Study

WWU's Ford Transit vans are among some of Britain's hardest-working fleet vehicles. They respond to emergency call-outs 24 hours a day, 7 days a week, 365 days a year. The team operate daily at their 3.5t GVW (Gross Vehicle Weight) limit, sometimes even at 6.5t GTW (Gross Train Weight) when hauling heavy equipment such as mini-diggers and portable compressors for power. Once on site, they operate as a stationary power source supplying on-board generators and air compressors to ensure WWU can improve, maintain and repair their gas network.

The HyDrive case study examined over 60 WWU Transits in the Bristol (urban) and Swansea (rural) areas, studying their driving and refuelling patterns over a whole year. Although daily distances are relatively low (usually under 50 miles), vehicle weight is at the maximum limit, the terrain can be challenging. A static operations (digging the road) consume a substantial amount of fuel.

Currently WWU, diesel Transits refuel every three to four working days. For an equivalent FCEV van with a 10 kg hydrogen tank, 60% of refuelling events would be covered by current intervals.

Refuelling on hydrogen every two days increases this to over 97%, and daily refuelling would cover 99.9% of the fleet operations.

8 The Hydrogen Opportunity

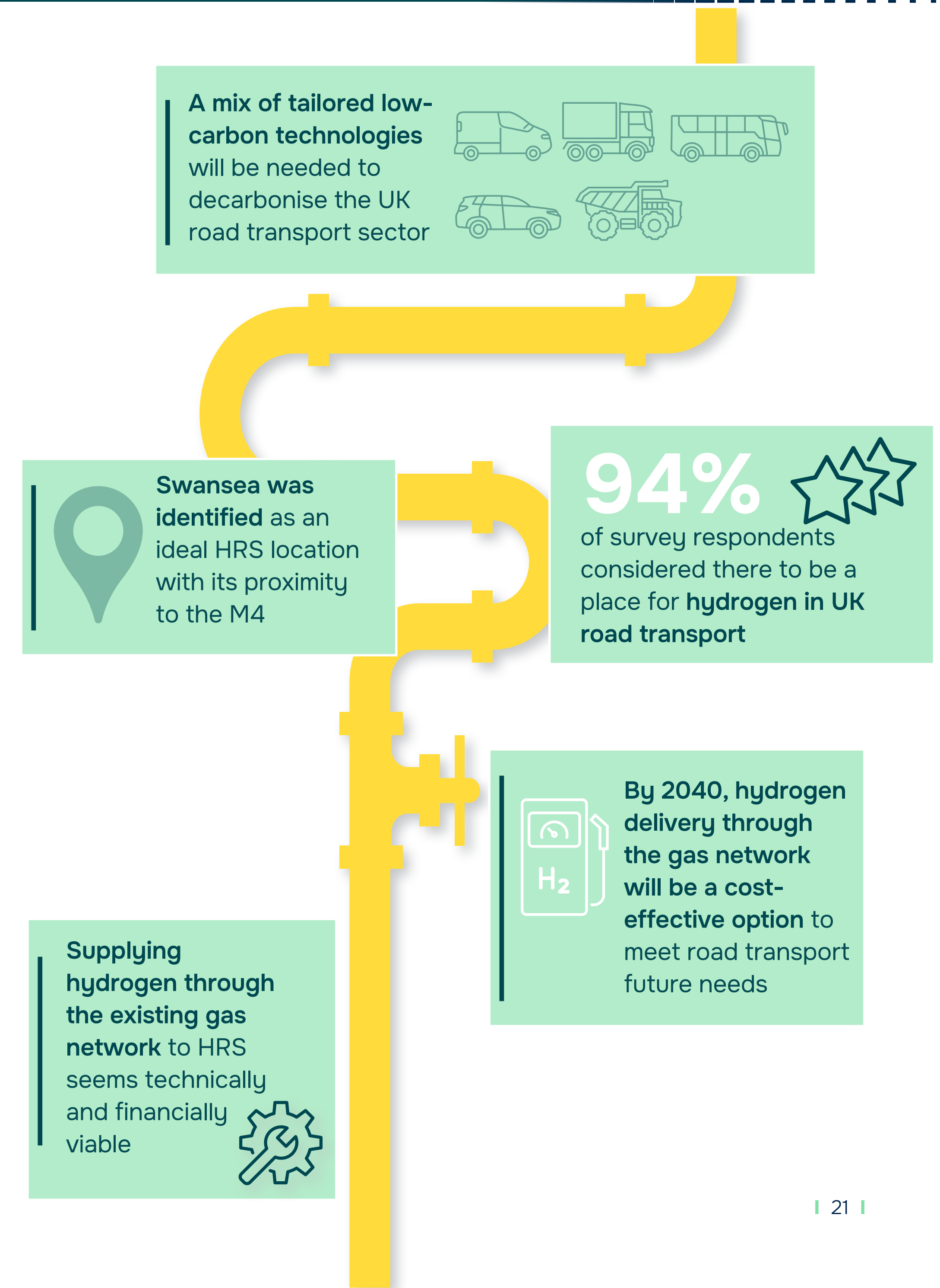
- Battery electric vehicles don’t meet everyone’s needs for charging times and driving range.
- Hydrogen is a zero-emission alternative that works for larger vehicles that cover long distances every day.
- A smart way to supply future hydrogen refuelling stations is to re-use the WWU pipeline network.

Conclusion

With such a diverse range of vehicles forming the UK's road transport sector, it's clear that a mix of tailored low-carbon technologies will be needed to efficiently decarbonise. Hydrogen must be considered a supporting technology, alongside battery electric solutions, backed by robust distribution and refuelling infrastructure.

- Stakeholders showed strong support for the role of hydrogen in UK road transport. An impressive 94% of survey respondents considered there to be a place for hydrogen, with 69% predicting that at least a quarter of HGVs will be hydrogen-fuelled by 2040.
- HyDrive identified Swansea as an ideal HRS case study location, thanks in part to its proximity to the M4 motorway. Connecting to WWU's gas pipeline, a 6t/d station could help meet future needs for road transport in the area.
- The study also explored the feasibility of replacing diesel transit vans in the WWU fleet with hydrogen alternatives. This highlighted hydrogen as a suitable alternative, acknowledging that more frequent refuelling would be needed.

Economic analysis shows that by 2040, hydrogen delivery through the gas network will be the most cost-effective option. These results amplify hydrogen's emerging role in decarbonising transport, when supported by strategic infrastructure and informed by projections for hydrogen demand.



Abbreviations

ACEA	Association des Constructeurs Européens d'Automobiles (Fr.) European Automobile Manufacturers Association
bar	bar
barg	bar gauge
BEV	Battery Electric Vehicle
BSI	British Standards Institution
CAPEX	Capital Expenditure
CAZ	Clean Air Zone
CO_2	Carbon Dioxide
d	day
EHB	European Hydrogen Backbone
ESO	Electricity System Operator
EV	Electric Vehicle
FCEV	Fuel-Cell Electric Vehicle
FES	Future Energy Scenarios
g	gramme
GHG	Greenhouse Gas
GVW	Gross Vehicle Weight
HDV	Heavy Duty Vehicle
HE	Hydrogen Europe
HGV	Heavy Goods Vehicle
HPBM	Hydrogen Production Business Model
HRS	Hydrogen Refuelling Station
HSBM	Hydrogen Storage Business Model
H2	Hydrogen
ICE	Internal Combustion Engine
IEA	International Energy Agency
IP	Intermediate Pressure
ISO	International Organization for Standardization
kg	kilogramme
km	kilometre
kW	kilowatt
kWh	kilowatt hour
LCV	Light Commercial Vehicle
LNG	Liquefied Natural Gas
mbarg	millibar gauge
mm	millimetre
MP	Medium Pressure
$MtCO_2e$	Million tonnes of Carbon Dioxide equivalent
NESO	National Energy System Operator
NOX	Nitrous Oxide
OPEX	Operating Expenditure
PSV	Public Service Vehicles
TEN-T	Trans-European Transport Network
TSO	Transmission System Operator
TWh	Terawatt hour
UK	United Kingdom
ULEZ	Ultra Low Emission Zone
USA	United States of America
VDA	Verband der Automobilindustrie (De.) German Association of the Automotive Industry
WWU	Wales & West Utilities
yr	year
ZERFD	Zero Emission Road Freight Demonstration
£	Pound Sterling

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