Lowering your emissions through innovation in transport and energy infrastructure

PROJECT

REPORT

DfE 10x Economy: Open Call for Research

Transport Energy Research Project 3: Low Carbon Transition for HGVs

July 2023

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Document Revisions

No.	Details	Date
1	Initial release to DfE	19/04/23
2	Revision following feedback	26/06/23
3	Final revised version	21/07/23

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Abbreviations

BEV	Battery Electric Vehicle
BSP	Bulk Supply Point
CCC	Climate Change Committee
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GW, GWh	Gigawatt, Gigawatt Hour
HGV	Heavy Goods Vehicle
HRS	Hydrogen Refuelling Station
kW, kWh	Kilowatt, Kilowatt Hour
LA	Local Authority
LNG	Liquid Natural Gas
PHEV	Plug-in Hybrid Electric Vehicle
RSTN	Regional Strategic Transport Network
ZE	Zero Emission

Executive Summary

This report is produced for the Energy Group in the Department for the Economy and aims to investigate the potential uptake of zero emission Heavy Goods Vehicles (ZE HGVs) and the associated recharging/refuelling/infrastructure requirements to 2040. The investigation uses two scenarios – high and low uptake – for ZE HGV uptake in NI to 2040, based on CCC projections to achieve Net Zero in the UK[1].

Vehicles

- In the High Uptake Scenario, by 2030 ZE HGVs are projected to make up 12% of the HGV parc[2], rising rapidly to 38% by 2035 and 74% by 2040.
- In the Low Uptake Scenario (where ZE HGV uptake is half as rapid as the high scenario), by 2035 ZE HGVs are projected to make up 12% of the HGV parc, rising to 38% by 2040. In this scenario over half the vehicle parc will remain diesel-fuelled in 2040.

Energy demand

The greater energy efficiency of ZE HGVs compared to conventionally fuelled equivalents means that:

- Under the High Uptake Scenario, the overall energy requirements of the NI HGV parc (for public and private refuelling) will fall slightly by 2040 to 15.7 GWh from 16.3 GWh per day.
- However, under the Low Uptake Scenario, the daily energy demand will rise slightly to 16.7 GWh per day.

Infrastructure uptake scenarios

In terms of *publicly accessible refuelling* (i.e., the equivalent of current diesel refuelling stations):

- In the High Uptake Scenario, by 2030 the ZE HGV fleet will require 20 rapid (50 kWh) and 7 ultra-rapid (150 kWh) chargers, rising to 132 and 45 respectively by 2040. Hydrogen refuelling station (HRS) requirements for the hydrogen-fuelled part of the fleet are projected to be 4 in 2030 and 39 by 2040.
- In the Low Uptake Scenario, by 2030 the ZE HGV fleet will require 11 rapid (50 kWh) and 4 ultra-rapid (150 kWh) chargers, rising to 66 and 23 respectively by 2040. HRS requirements for the hydrogen-fuelled part of the fleet are projected to be 2 in 2030 and 20 by 2040.

Electricity supply needs

Mapping the current distribution of HGV overnight parking locations and the currently supply network and demand headroom (the demand headroom is the difference between the rating of the supply and the current demand from consumers) shows that while the substations around the parking locations have headroom, the electrical supply infrastructure currently follows population-driven electrical demand, rather than the potential points where HGV charging infrastructure, and the generation of renewable hydrogen by electrolysis, will require electrical supply in future.

Discussions and caveats of the analysis

The current energy demand numbers produced by this analysis are accurate as they are based on the energy usage of the current vehicle parc.

The number of ZE HGVs in the future vehicle parc is however uncertain, with key variables including the availability, cost, and performance of ZE HGV replacements and the cost and availability of associated refuelling infrastructure. This is particularly true of hydrogen: although the UK

[1] https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf

[2] 'parc' refers to the total number of vehicles on the road at a particular moment of time, originating from the French phrase "parc de vehicules".

Government Hydrogen Strategy[3] cites hydrogen HGVs as potentially playing a significant role in UK decarbonisation, given the lack of current hydrogen HGVs and HRS, and the costs of deployment, there is currently considerable uncertainty about the size of this role.

Next steps

The scenarios presented here have shown the potential scale of national ZE HGV uptake and the associated energy demand and refuelling requirements. Among suggested next steps are:

- Engagement with the NI logistics sector and associated stakeholders to assess the appetite for ZE HGV uptake and assess the barriers to early adoption and trials.
- To map in detail the locations where refuelling infrastructure is needed and where it can feasibly be deployed. This will help identify where "quick wins" for building infrastructure can occur and where business case modelling will be required to justify any grid upgrades to meet future demand of infrastructure.
- To understand how renewable electricity can be provided to key points of demand – whether directly for EVs or, potentially, for hydrogen production. This will ensure that investment in the network is placed appropriately, alongside ensuring that the carbon associated with electricity production is reduced for its application in zero emission vehicles. The role of bi-directional charging and battery storage in mitigating electricity network capability requirements and associated costs should also be examined.

[3] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf

1 Introduction

1.1 Introduction to Cenex

Cenex was established as the UK's first Centre of Excellence for Low Carbon and Fuel Cell technologies in 2005.

Today, Cenex focuses on low emission transport & associated energy infrastructure and operates as an independent, not-for-profit research technology organisation (RTO) and consultancy, specialising in the project delivery, innovation support and market development.

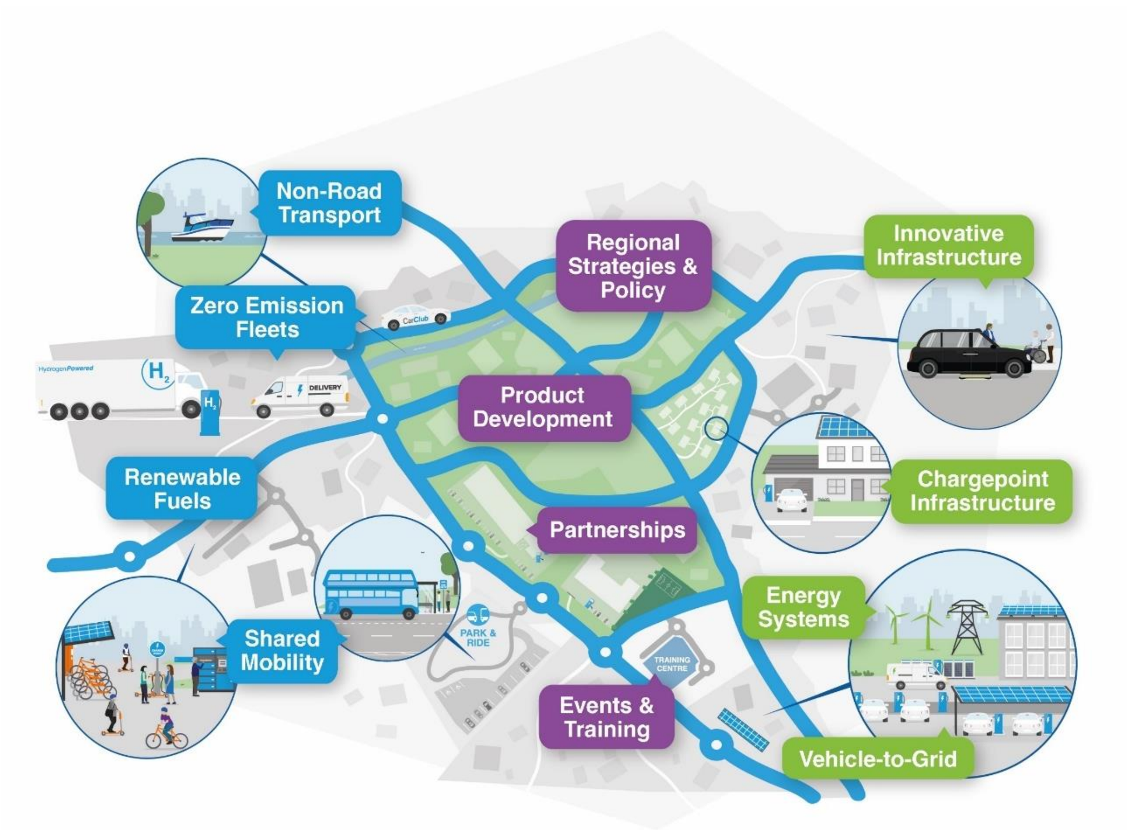
We also organise Cenex-LCV, the UK's premier low carbon vehicle event, to showcase the latest technology and innovation in the industry.

Our independence ensures impartial, trustworthy advice, and, as a not-for-profit, we are driven by the outcomes that are right for you, your industry and your environment, not by the work which pays the most or favours one technology.

Finally, as trusted advisors with expert knowledge, we are the go-to source of guidance and support for public and private sector organisations along their transition to a zero-carbon future and will always provide you with the insights and solutions that reduce pollution, increase efficiency and lower costs.

To find out more about us and the work that we do, visit our website:

www.cenex.co.uk



2 Project Introduction

2.1 Background

The 2021 Department for the Economy (DfE) published *10X Economy - an economic vision for a decade of innovation* (https://www.economy-ni.gov.uk/publications/10x-economy-economic-vision-decade-innovation). In October 2022, the DfE published *A 10X Economy - Research Programme 2022-23 and Beyond* (https://www.economy-ni.gov.uk/publications/10x-economy-open-call-research-proposals) which highlighted the key research areas for the 2022-23 year, and beyond, as the department seeks to deliver on its 10X Economy Vision and the Department for Infrastructure's EV Infrastructure Action Plan (https://www.infrastructure-ni.gov.uk/sites/default/files/publications/infrastructure/ev-infrastructure-action-plan-2022.pdf)..

Queen's University Belfast (QUB) and Cenex were allocated funding from the Department for the Economy (DfE) to research on the decarbonisation of energy used within HGVs, hereafter, Project 3 (light duty vehicles - cars and vans- are addressed in Project 1). The key relevance of this to DfE's policy vires is how decarbonising transport will reduce the current reliance on liquid fossil fuels and grow the demand for alternative low or zero emission fuels such as renewable electricity, green hydrogen or biomethane and their associated refuelling infrastructure.

2.2 Aim

To identify key HGV fleet locations across NI and assess their suitability for EV and hydrogen refuelling infrastructure.

2.3 Challenges

There is a need for data to inform policy in:

1. Analysis of current HGV fleet in Northern Ireland.
2. Number and location of overnight parking locations.
3. Electrical grid capacity at these locations.
4. Planned and projected grid capacity at these locations.
5. Opportunities for hydrogen and/or LNG storage and distribution at these locations.

2.4 Scope

- HGVs are any vehicle with a total weight over 3,500 kg including their cargo.
- We assume that the UK policy for only zero emission (ZE) HGV sales from 2035 for <26t and 2040 for all other HGVs is the driving factor for transition.
- Given the goal of Net Zero, Compressed Natural Gas (CNG) and Liquid Natural Gas (LNG) are not covered in this report.
- All HGV analysis will be for vehicles registered in NI and not include those registered overseas travelling into the region. It is assumed that HGVs travelling in vs out of the region balance out.

3 Project Methodology

As outlined in the Project 3 proposal, the project has been delivered as five Work Packages as follows:

3.1.1 WP1 – Data Gathering for Fuelling and Grid

Northern Ireland Goods Vehicle Operator's Licence data: https://www.opendatani.gov.uk/@department-for-infrastructure-transport-regulation-unit/northern-ireland-goods-vehicle-operators-licence-records

Rest stops: https://app.truckparkingeurope.com/

Existing fuel locations in Northern Ireland: Cenex dataset obtained from discussions with NIEN that lists supply points of interest including 400+ fuelling locations together with postcode information. This data contains both how much electricity a station can supply and how much actual demand their currently is from consumers. The difference between these two figures is the demand headroom.
Grid connections and capacity: NIEN Network Capacity Map: https://www.nienetworks.co.uk/connections/capacity-map

3.1.2 WP2 – Mapping of existing HGV locations

The data from WP1 was mapped using GIS to show the distribution of HGV overnight parking locations within the wider network for the current year as well as grid capacity at these locations. Data gathered around projected and planned electrical grid capacity expansion from the NIEN Network Capacity Map was also mapped.

3.1.3 WP3 – Analysis of current and future HGV fleet

Current NI HGV parc data was used as a baseline for input into Cenex's model to map the potential uptake of zero emission (BEV and hydrogen) HGVs to 2040. The methodology is presented in Appendix B.

3.1.4 WP4 – Zero emission refuelling requirements

The above HGV uptake scenarios were input into Cenex's models to calculate the total energy demand required to serve the low and zero emission fleet of HGVs and establish the requirements for zero emission (EV & hydrogen) refuelling using the methodology described in Appendix C.

3.1.5 WP5 – Opportunities for hydrogen storage and distribution

A brief high-level overview of advisory conditions and indicative regulations, codes, and standards for sites to be able to store and refuel vehicles with hydrogen.

4 Mapping of HGV Locations and Electricity Grid Capacity

4.1 Introduction

This section provides a visualisation of current HGV usage and locations in NI and selected regions as an indication of where the initial zero emission (ZE) HGV deployments are likely to occur. It then overlays the current electrical supply capacity headroom in these locations. This information is important as the rollout of HGV charging infrastructure, and potentially the generation of renewable hydrogen by electrolysis, is critically depending on the ability to provide electricity at the locations where it is needed.

4.2 Context

From 2022 registration data, the HGV fleet in NI is overwhelmingly diesel-fuelled. There are a small number (circa 250) low carbon biofuel (gas and diesel) HGVs currently in operation, representing 1% of the total fleet of approximately 25,000[4].

The 2022 report *Energy in Northern Ireland*[5] reported that energy use by HGVs in NI increased by almost 7% in the decade between 2009-2019 (latest data available). The chart below breaks down the 2019 HGV energy use at District Council (DC) level, showing that the HGV energy usage is not evenly spread across NI; five of the DCs, led by Armagh City, Banbridge and Craigavon, account for 58% of the national HGV energy use.

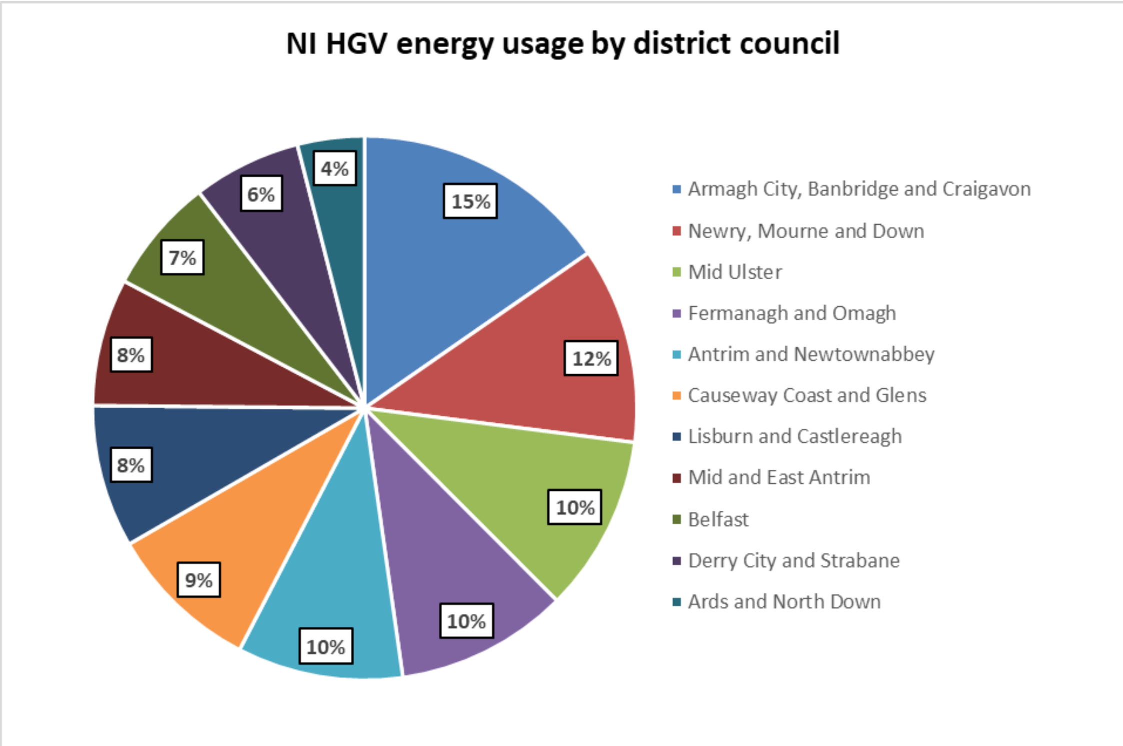


Figure 1: NI HGV Energy Usage by District Council

The report states that more than half (58%) of NI's HGV traffic energy use occurs on A roads, with only 10% on motorways and a third on minor roads; for comparison the UK values are 44%, 46% and 10% respectively. The map below of the Regional Strategic Transport Network (RSTN)[6] illustrates the importance of the NI A road network and Key Transport Corridors.

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[4] Vehicle licensing statistics data tables - GOV.UK (www.gov.uk)

[5] https://www.economy-ni.gov.uk/sites/default/files/publications/economy/Energy-in-Northern-Ireland-2022.pdf

[6] https://www.infrastructure-ni.gov.uk/articles/regional-strategic-transport-network

The next section looks at the distribution of HGV parking locations.

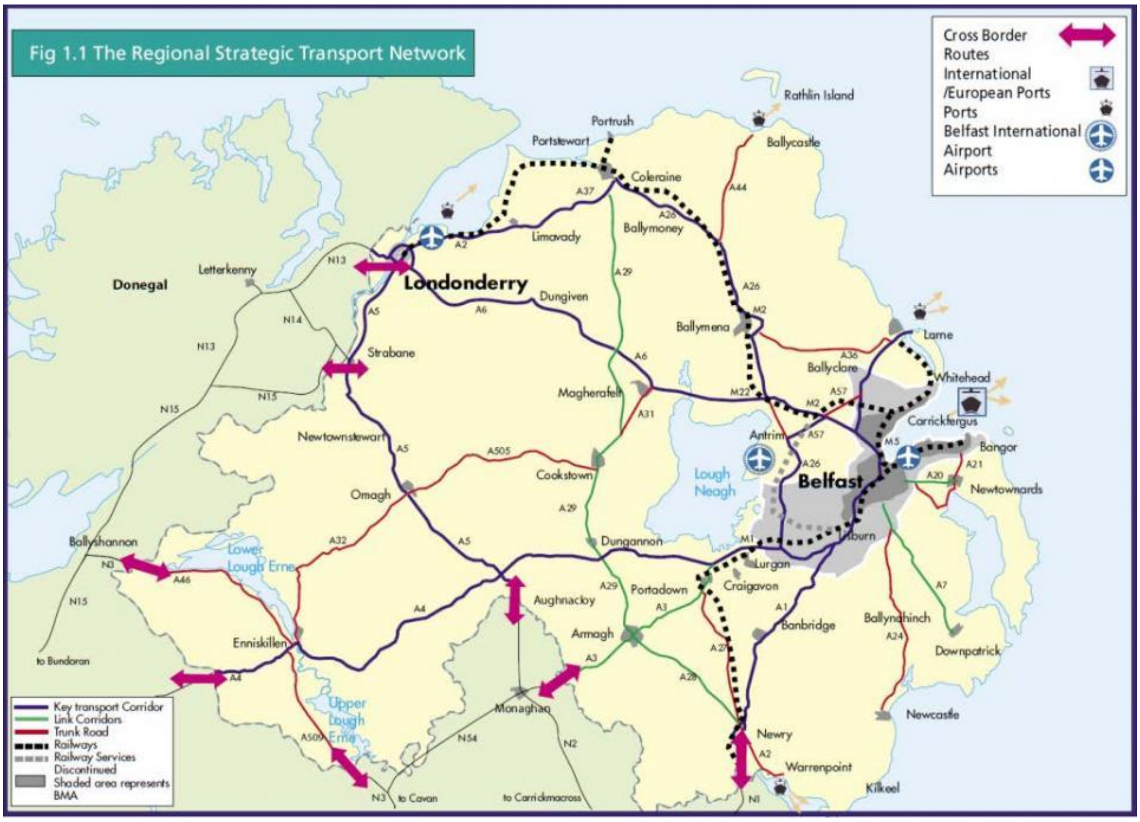

Figure 2: Regional Strategic Transport Network

4.3 NI National

For all maps described in this section, the underlying GIS files have been provided separately to the DfE to allow detailed inspection of individual locations.

Figure 3 maps the likely overnight parking locations of HGVs (red, deeper red colour means more HGVs registered at the location) and large-scale HGV rest stops (blue).

Figure 4 shows the distribution of electrical substations (red) plus a heatmap showing where the demand headroom (difference between how much electricity a station can supply and how much actual demand there currently is from consumers) is. The heatmap shows green at locations where there is significant demand headroom.

Figure 5 overlays the two figures described above to show NI HGV parking locations and a heatmap of the available electrical demand headroom in NI.

As expected, the HGV parking locations show clustering around areas that are broadly aligned with the RSTN Key Transport Corridors.

The electrical supply maps follow population, with supply points clustered around cities. In terms of demand headroom, the maps show that, in terms of absolute value, the most demand headroom is around Belfast – which again reflects the national population distribution (18% of the NI population live in Belfast)[7].

While there is no simple method to identify exact supply capacity at the identified overnight truck parking locations, the heatmap indicates areas of significant grid capacity that would be needed to provide power to the chargepoints forecast to be needed in the future (section 6.3). The forecasts of chargepoints required in 2030 are modest, which is the period covered by NIEN's RP7 business plan

[7] https://populationdata.org.uk/northern-ireland-population/

through to 2031. It is not until approaching 2040 that more substantial grid planning for BEV HGVs will be required.

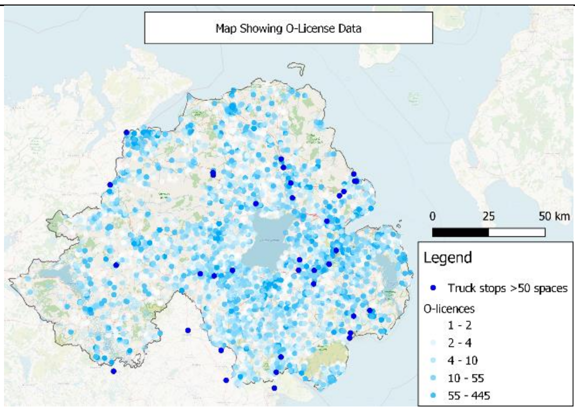

Figure 3: NI HGV Parking Distribution (Deeper Blue = Greater number of HGVs)

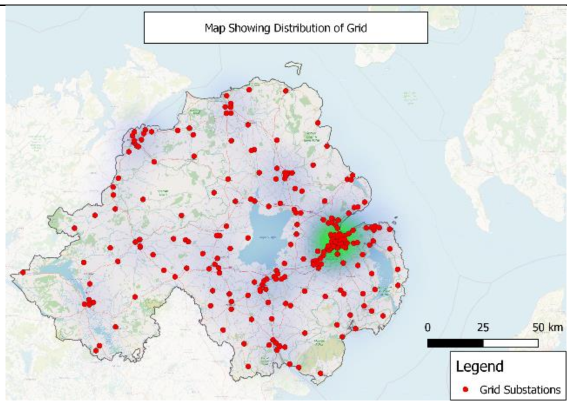

Figure 4: Substations (Red) and Electricity Headroom Heatmap (Green) [8]

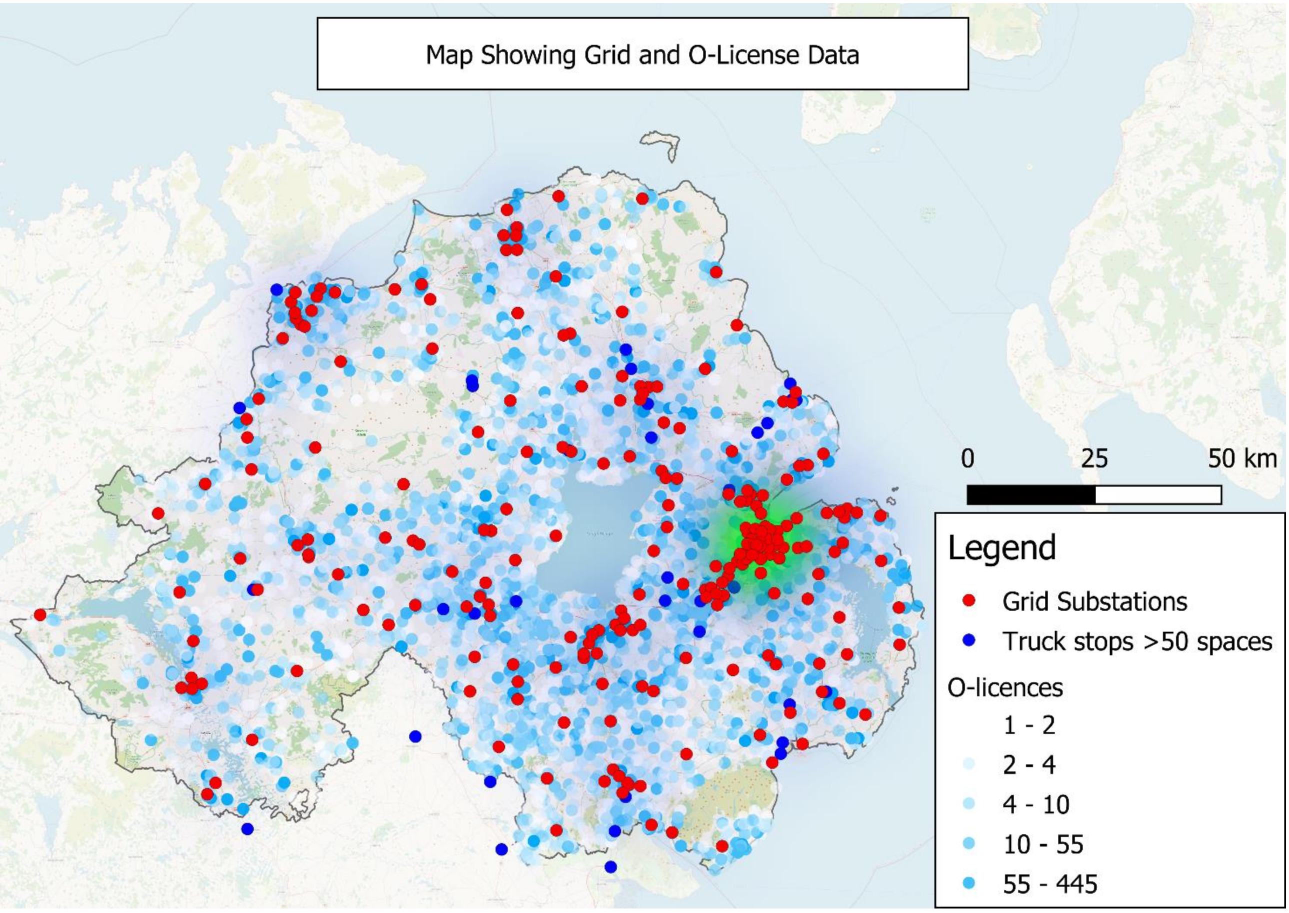

Figure 5: NI HGV Overnight Parking Location (Blue), Electrical Supply Substations (Red) and Demand Headroom Heatmap (Green) Obtained by Superimposing Figures 3 & 4

[8] *Bulk supply points (BSP)* connect the transmission network to the distribution network; power comes in at 132kV and is transformed to 33kV, before being distributed to *primary substations*, where power is transformed from 11kV or 6.6kV. The heatmap shows green at locations where there is significant *demand headroom* (the gap between the rating of the supply and the actual demand)

5 NI Zero Emission HGV Uptake to 2040

5.1 Introduction

The previous chapter looked at the current demand headroom and location of HGV parking overnight throughout Northern Ireland at present. To project what future demand might look like for HGV refuelling, we first need to project the future uptake of ZE HGVs (which will directly affect the future demand on the grid for electricity, and hydrogen demand for FCEVs).

This section uses the methodology described in Appendix B to project the uptake of ZE HGVs across NI and LAs to 2040. Two scenarios – high and low uptake – are given, based on the Climate Change Committee's Sixth Carbon Budget.[9]

5.2 National High Uptake ZE HGV Scenario

The high uptake scenario shows the proportion of diesel HGVs on the road in NI falling relatively slowly to 2030 to 87% of the total parc as the first ZE alternatives are deployed. The rate of uptake then increases significantly, with ZE alternatives making up 12% of the HGV total by 2035 and 74% by 2040 after the 2035 non-ZE sales ban for vehicles under 26t.

As discussed in Appendix B, the 2022 baseline data is taken from UK Government data (VEH0105). Anecdotal evidence suggests there are a number of HGVs fuelled by bio-methane operational in Northern Ireland, but these are not broken out in the DfT statistics. A separate dataset on plug-in vehicles showed that there was one BEV HGV in NI in 2022 Q4.[10]

Table 1: NI CCC 2020 High Uptake Scenario (ZE HGVs only)

	2022 baseline	2025	2030	2035	2040
Diesel	25,062	22,386	20,046	12,537	3,109
Biodiesel	No data	480	707	1,536	2,394
PHEV	0	710	1,162	1,747	2,361
BEV	1	237	929	3,728	7,083
Hydrogen	0	122	718	4,078	8,996

[9] https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf

[10] VEH0141, https://www.gov.uk/government/statistical-data-sets/vehicle-licensing-statistics-data-tables

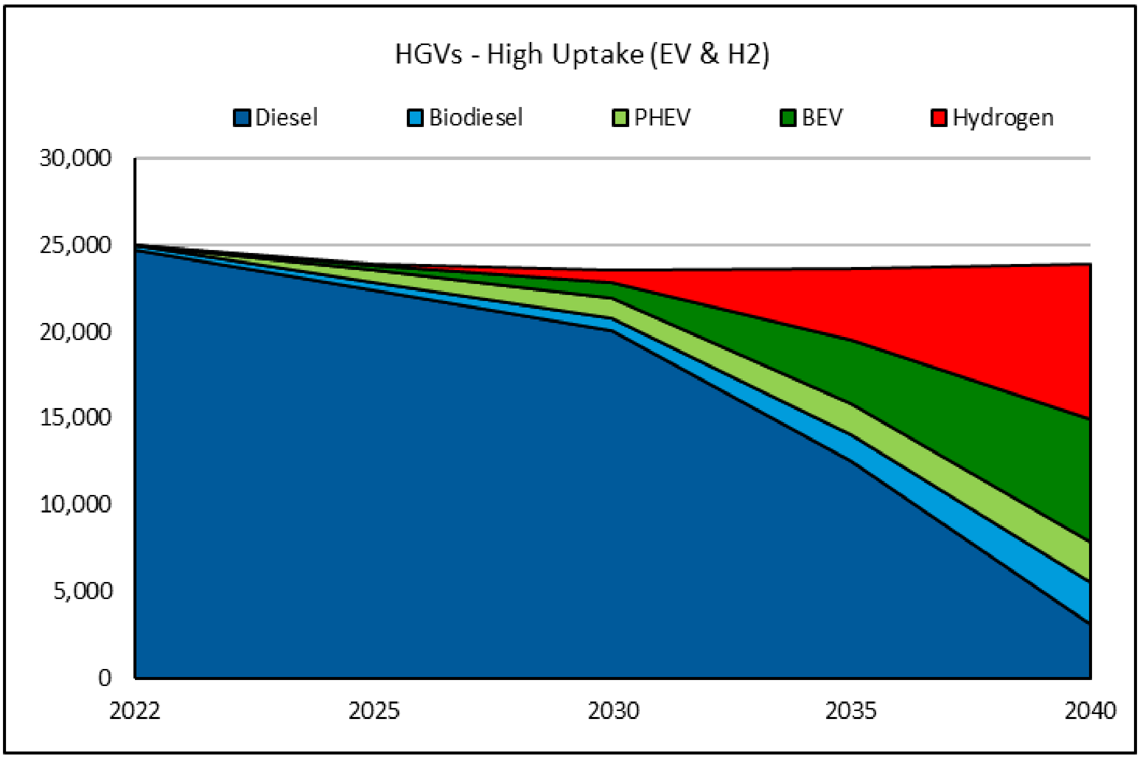

Figure 6: NI High ZE Uptake HGV Scenario

5.3 National Low Uptake ZE HGV Scenario

The low uptake ZE scenario is half that of the high scenario. Consequently, ZE alternatives make up 19% of the HGV total by 2035 and 37% by 2040 after the 2035 non-ZE sales ban. In this scenario 54% of the HGV parc remains diesel fuelled in 2040.

As discussed in Appendix B, the 2022 baseline data is taken from UK Government data (VEH0105). A separate dataset on plug-in vehicles showed that there was one BEV HGV in NI in 2022Q4.[11]

Table 2: NI CCC 2020 Low Uptake Scenario (ZE HGVs only)

	2022 baseline	2025	2030	2035	2040
Diesel	25,062	23,161	21,804	18,081	13,527
Biodiesel	No data	240	353	768	1,197
PHEV	0	355	581	874	1,181
BEV	1	118	465	1,864	3,542
Hydrogen	0	61	359	2,039	4,498

[11] VEH0141, https://www.gov.uk/government/statistical-data-sets/vehicle-licensing-statistics-data-tables,

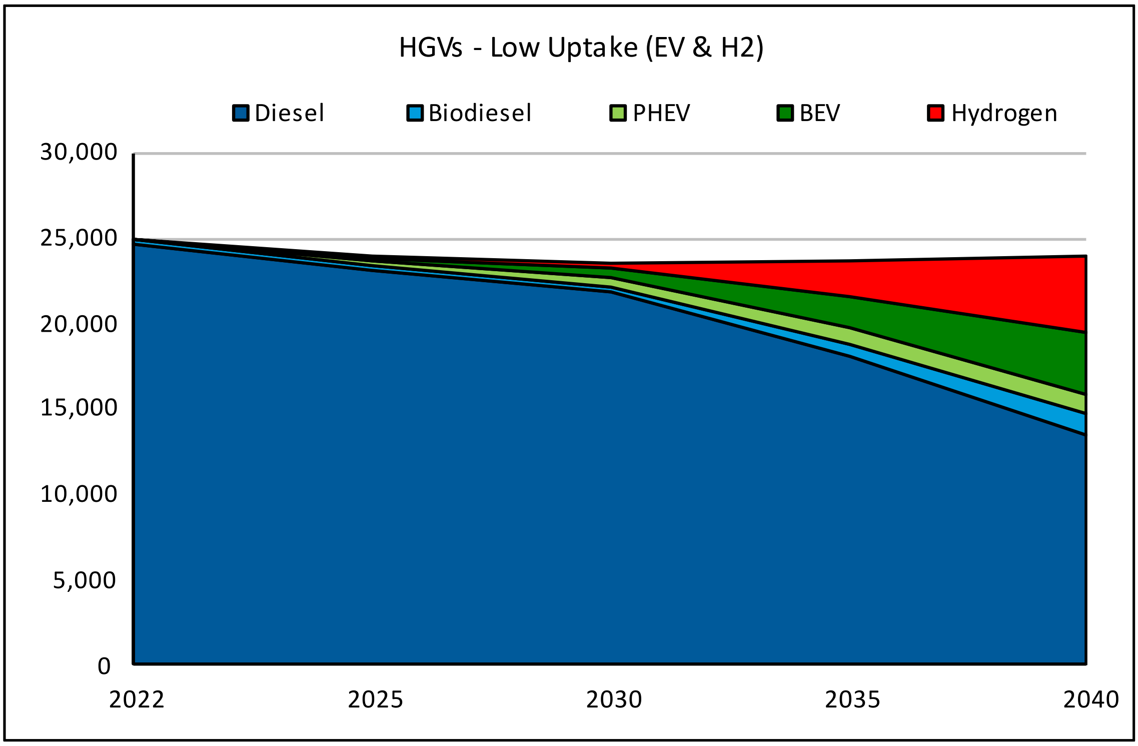

Figure 7: NI Low ZE Uptake HGV Scenario

5.4 Local Authority ZE HGV Scenarios

Tables showing the split of ZE HGV uptake scenarios by council are provided in Appendix D.

6 NI ZE HGV Public Refuelling/Recharging Energy and Infrastructure Requirements to 2040

6.1 Introduction

This section provides the total energy requirement, infrastructure needs, and estimated costs based on today's prices for scenarios of ZE HGV uptake in NI, based on the Climate Change Committee's Sixth Carbon Budget.

The energy demand represents the total for all HGVs across private (i.e., depot) fuelling, plus public refuelling.

As explained in detail in Appendix C, the *infrastructure numbers and costs are for public refuelling infrastructure only*, based on the assumptions that:

- For EVs - 5% of recharging is public with 95% at depot.
- For hydrogen - 70% of refuelling is public and 30% at depot.

6.2 NI HGV Energy Demand Scenarios

The figures below display the total energy demand required per day to service the vehicle uptake scenarios presented in the previous section. It is noteworthy that the total energy demand for the Low Uptake Scenario in 2040 is higher than that of the High Uptake Scenario due to the lower efficiency of ICE vehicles compared to potential ZE replacements.

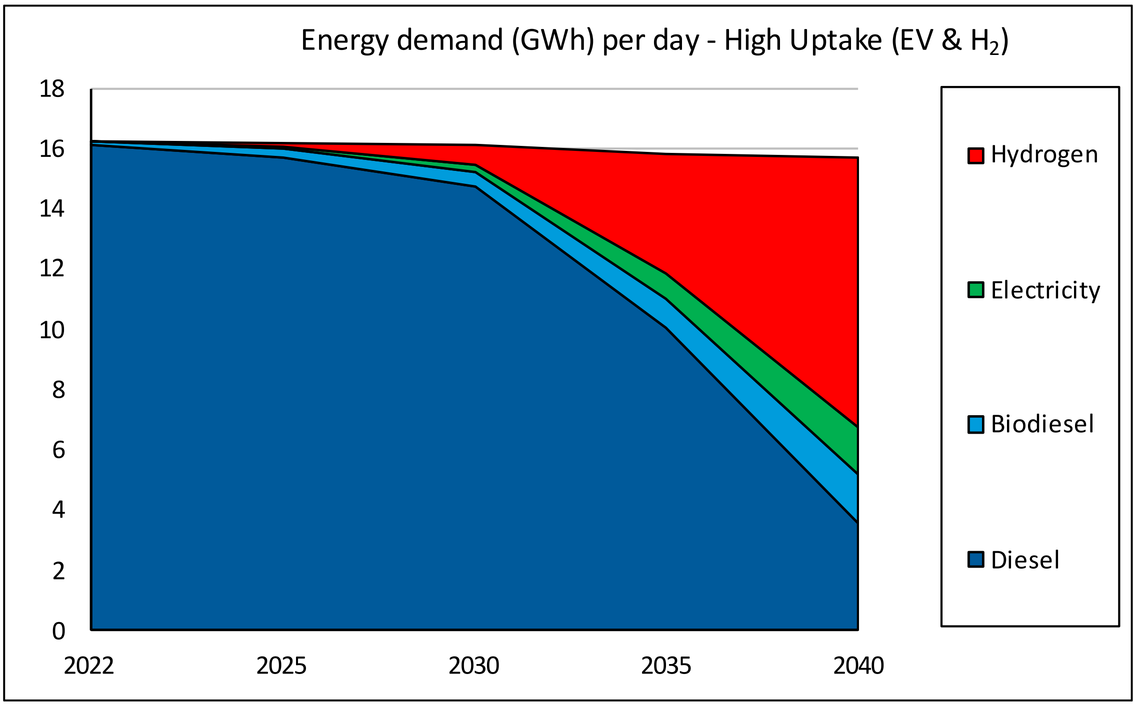

Figure 8: NI High ZE Uptake Scenario HGV Energy Demand

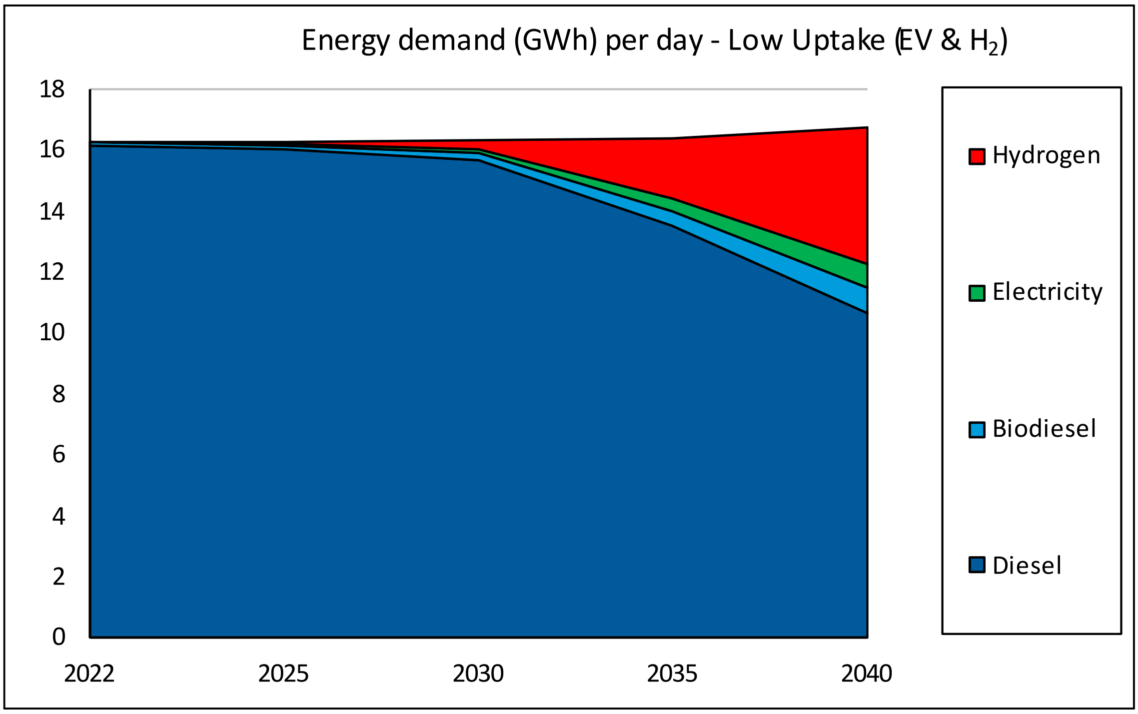

Figure 9: NI Low ZE Uptake Scenario HGV Energy Demand

6.3 NI HGV Recharging/Refuelling Infrastructure Requirements Scenarios

Table 3 and Table 4 show the required publicly accessible infrastructure (equivalent to today's petrol and diesel forecourts) for HGVs in 2030 and 2040 respectively, showing the required growth throughout the next 20 years, for EV chargepoints and hydrogen refuelling stations (HRS). Figures are split between Rigid trucks (fixed cab and trailer up to gross vehicle weight of 26t) and Artics (articulated cab and trailer up to gross vehicle weight of 44t).

Table 3: NI public HGV infrastructure requirements by 2030

	Infrastructure requirements - 2030					
	High uptake (EV & hydrogen)			Low uptake (EV & hydrogen)		
	50 kW	150 kW	HRS	50 kW	150 kW	HRS
Rigids	11	4	1	6	2	1
Artics	9	3	3	5	2	2
Total	***20***	***7***	***4***	***11***	***4***	***3***

Table 4: NI public HGV infrastructure requirements by 2040

	Infrastructure requirements - 2040					
	High uptake (EV & hydrogen)			Low uptake (EV & hydrogen)		
	50 kW	150 kW	HRS	50 kW	150 kW	HRS
Rigids	74	25	10	37	13	5
Artics	58	20	29	29	10	15
Total	***132***	***45***	***39***	***66***	***23***	***20***

The figures below show the estimated costs of the high and low scenario for the electric and hydrogen pathway. Given the UK national requirement to transition the NI vehicle fleet to ZE it is unlikely that either devolved governments or local councils will have to fund publicly accessible infrastructure entirely by themselves. Private industry investment will likely provide a large proportion of these costs as and when economically viable for their business case (as more low and ZE vehicles are deployed, the viability of sites will be realised), but this approach is unlikely to achieve the accelerated uptake demanded by policy. The split of infrastructure between rigid and artic HGVs is indicative as these vehicles do not require different infrastructure. It should be noted that, in general, LGV and HGV access will differ for chargepoint infrastructure and so a distinction is needed between the infrastructure for these vehicles, and so LGVs are covered, along with private vehicles, in our accompanying report.

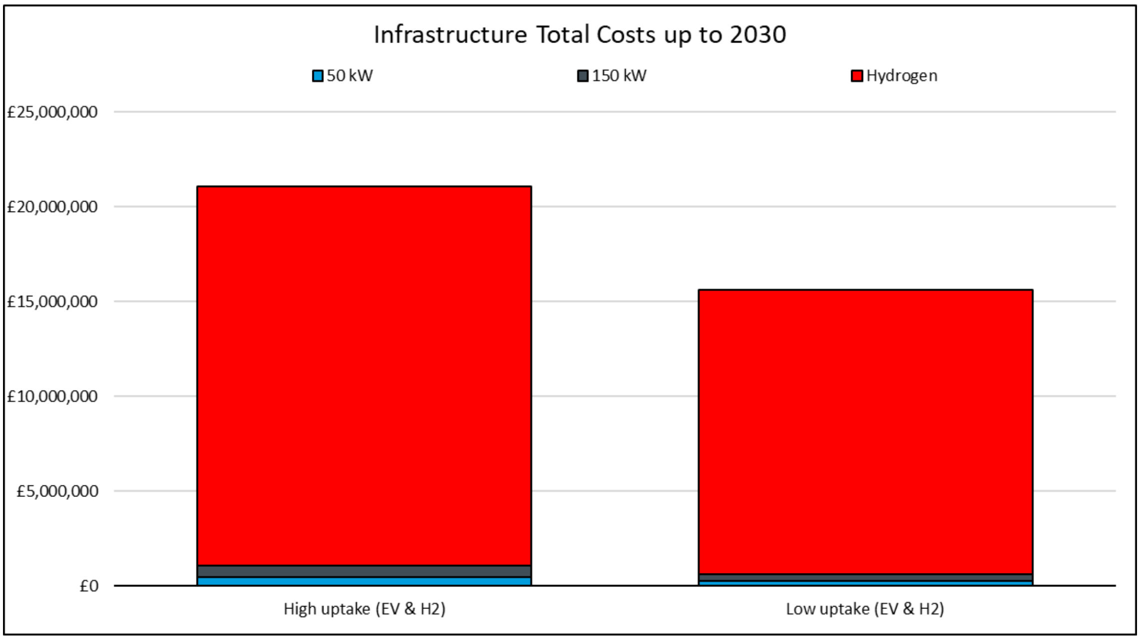

Figure 10: NI public HGV infrastructure costs to 2030

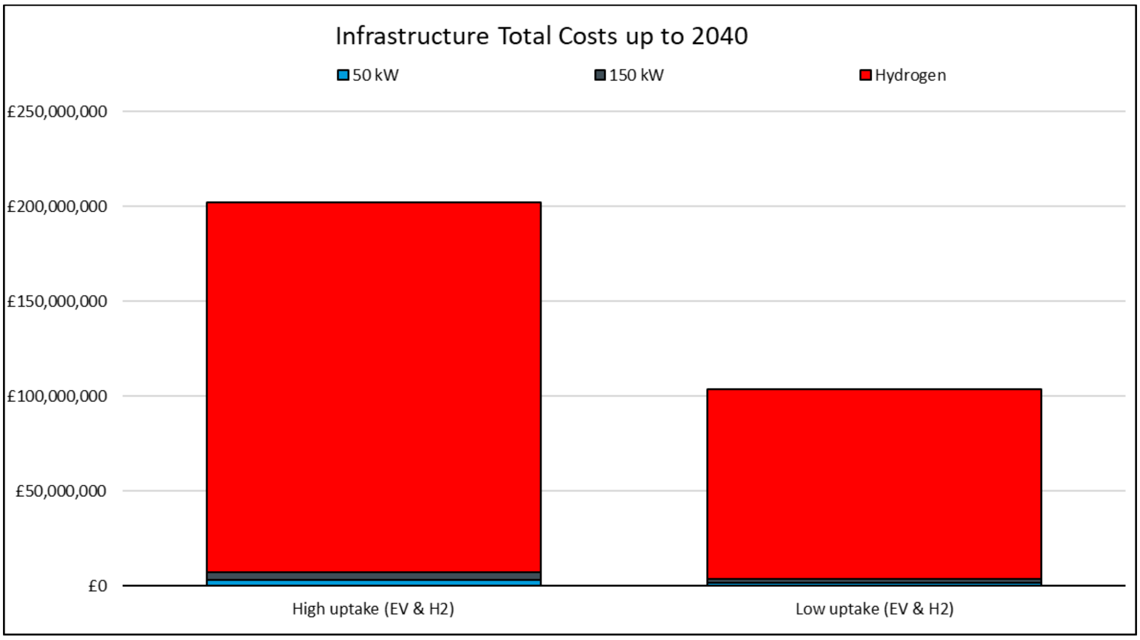

Figure 11: NI public HGV infrastructure costs to 2040

7 Considerations for Hydrogen HGV Refuelling

7.1 Introduction

This section provides a high-level overview of issues to be considered in the rollout of the relatively new and rapidly developing technology of hydrogen HGV refuelling. It is worth noting that this report doesn't identify specific locations for hydrogen refuelling, which would require engagement with HGV fleet operators and physical site inspections. This should be considered as a "next steps" recommendation (page 24).

7.2 Current Status of Hydrogen Vehicle Refuelling

Hydrogen refuelling stations (HRS) - and the technology and hardware underpinning hydrogen vehicle refuelling - are currently considerably less mature than conventional fuelling stations, EV recharging and natural gas refuelling.

At present in the UK there are eight publicly-accessible HRS as shown in Figure 12, plus several private HRS that are dedicated to bus refuelling. The number of UK public HRS has fallen since 2021 following the closure of several operated by Motive Fuels (formerly ITM Power). Only one public HRS, at Tyseley in the English Midlands, is currently of sufficient size (capable of dispensing 1 tonne of hydrogen per day) to be considered potentially suitable for HGV refuelling.

NI has no public HRS at present. There is one bus HRS at Translink HRS in Newtownabbey built by Logan Energy which was specified to supply up to 2,500 kg of hydrogen per day.[12]

Figure 12: Public HRS in the UK (source: Zap Map, https://www.zap-map.com/)

[12]https://www.h2tec.co.uk/post/scottish-hydrogen-leader-to-supply-one-of-europe-s-largest-refuelling-stations-in-belfast

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7.3 Regulations, Codes and Standards (RCS) for Hydrogen Vehicle Fuelling

The main RCS for light duty vehicle hydrogen refuelling are well established. They are:

- SAE J2601 *Fueling Protocol for Light Duty Hydrogen Surface Vehicles,* is now the standard used by HRS (including all H2ME-2 HRS) to ensure that the vehicle hydrogen storage system stays within operating temperature and pressure limits, and an acceptable refuelling speed and final state of charge (SOC) is achieved.
- EN 17127 *Outdoor Hydrogen Refuelling Points Dispensing Gaseous Hydrogen and Incorporating Filling Protocols* defines the minimum requirements to ensure the interoperability of hydrogen refuelling points, and incorporates SAE J2601.
- ISO 19880-1:2020 *Gaseous hydrogen — Fuelling stations* defines the minimum design, installation, commissioning, operation, inspection and maintenance requirements, for the safety, and, where appropriate, for the performance of public and non-public fuelling stations that dispense gaseous hydrogen to light duty road vehicles.
- In the UK the document used for the permitting of petrol stations in the UK is published by the Energy Institute, and called *Guidance for Design, Construction, Modification, Maintenance and Decommissioning of Filling Stations,* known as the *Blue Book*. This has been supplemented by an addendum *Guidance on hydrogen delivery systems for refuelling of motor vehicles, co-located with petrol fuelling stations.*

7.4 Hydrogen HGV Refuelling

While hydrogen buses (generally considered medium duty vehicles or MDVs) are reasonably well established, hydrogen HGVs and their refuelling remain immature. Key issues that need to be considered in constructing hydrogen HGV refuelling infrastructure include:

- **Cost**: HRS costs are currently high, as each station is essentially a bespoke design. However, costs are falling as more stations are deployed and as manufacturers begin to produce components at larger scale. The cost and timescales of installation vary significantly dependent on various factors which should all be considered when selecting future refuelling sites such as those listed below.
- **Capacity:** The amount of hydrogen the station will be required to provide, which in return is driven by the number and type of vehicles to be refuelled, daily mileage, and forecast future demand. To build a sustainable HRS business case, future stations are likely to have capacities of at least 1,000kg per day.
- **Types of vehicles to be refuelled:**
  - A fuel cell car or van will use around 1 kg of hydrogen per 100 km driven.
  - A hydrogen bus will use around 8 kg of hydrogen per 100 km driven.
  - Data on hydrogen HGVs is limited, but current estimates are that they will use between 8 kg and 12 kg to travel 100 km dependant on the load.
- **Refuelling pressure and number of nozzles:** HRS generally store and dispense hydrogen as a high-pressure compressed gas (CH2). Cars typically refuel at 700 bar, whereas buses and many of the prototype HGVs that are currently available refuel at 350 bar.
- **Liquid hydrogen versus compressed gaseous hydrogen:** To achieve driving ranges comparable to current diesel HGVs, some manufacturers and HRS suppliers are developing liquid hydrogen (LH2) fuelling and on-vehicle storage rather than CH2 storage as LH2 has a much higher (threefold) volumetric energy density than CH2. The practical implementation of this technology however is as yet unproven.
- **Performance:** The ability of an HRS to refuel vehicles back-to-back is dependent on the volume of compressed hydrogen stored. Storing large volumes of hydrogen to facilitate back-

to-back performance adds to HRS costs and the complexity of the planning and permitting process for the station.

- **On-site generation versus external supply:** If on-site generation is used, then power availability and distance to the three phase supply become an important consideration. External supply is the preferred approach due to complex legislation for large capacity on-site generation of hydrogen. It is envisaged that a hub and spoke method of delivering hydrogen is likely in the future: whereby one plant produces large quantities of hydrogen and delivers this to sites within a specified radius.
- **Green versus grey hydrogen:** Hydrogen generated from renewable electrolysis has essentially a zero-carbon footprint and is referred to as 'green hydrogen'. However, around 95% of hydrogen is currently produced by steam methane reforming (SMR) – referred to as 'grey hydrogen'. Vehicles fuelled by grey hydrogen have an overall (well-to-wheel) emission footprint comparable to diesel, even though they have no emission other than water from the tailpipe, due the energy required for grey hydrogen production.

7.5 HRS Planning, Permitting, Installation, and Commissioning Timescales

HRSs, particularly large-scale HRS capable of handling HGVs, are novel pieces of infrastructure and securing planning permission is currently not always straightforward (as discussed further in Cenex H2ME2 reports[13]). Timescales for completing HRS can vary significantly. A large HRS (one tonne per day +) with external H2 supply can take at least two years (on-site generation will take longer to implement). Locating a new HRS on brownfield industrial sites is likely to ease the planning process considerably. A key consideration for large-scale HGV stations is access for the HGVs and the hydrogen supply tube trailers that will likely have to make multiple deliveries per day.

The diagram below taken from a Dutch report indicates the steps necessary in implementation of a new HRS.

[13] Cenex H2ME2 Deliverable for Hydrogen Mobility Europe: https://h2me.eu/wp-content/uploads/2021/11/H2ME2-D5.21-Public-FV-Safety-and-RCS-lessons-learnt-%E2%80%A6.pdf

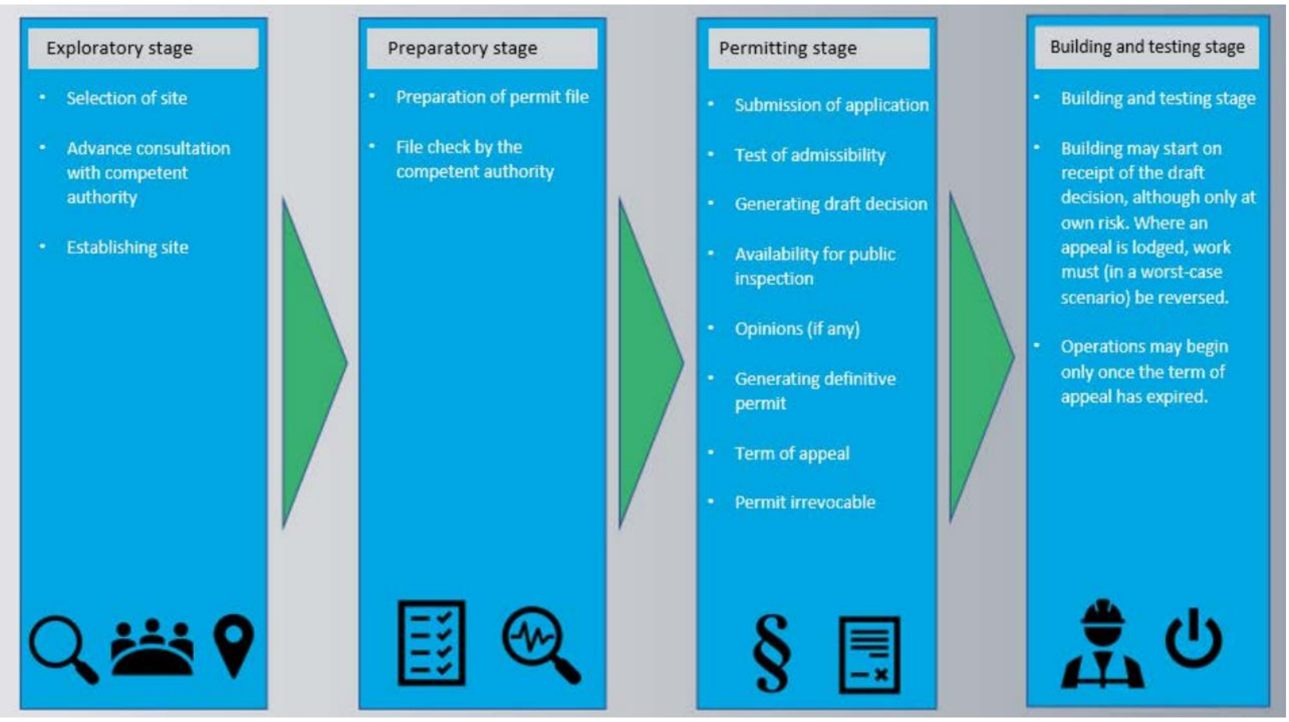

Figure 13. HRS planning, installation, and licensing process in the Netherlands[14]

[14] https://opwegmetwaterstof.nl/wp-content/uploads/2020/06/Summary_Guide-permitting_process_hydrogen_refuelling_stations.pdf

8 Conclusions and Caveats of the ZE HGV Analysis

This study has presented two scenarios – high and low uptake – for ZE HGV uptake in NI to 2040, based on CCC projections to achieve Net Zero in the UK.

Vehicles

- In the High Uptake Scenario, by 2030 ZE HGVs are projected to make up 12% of the HGV parc, rising rapidly to 38% by 2035 and 74% by 2040.
- In the Low Uptake Scenario (where ZE HGV uptake is half as rapid as the high scenario), by 2035 ZE HGVs are projected to make up 12% of the HGV parc, rising to 38% by 2040. In this scenario over half the vehicle parc will remain diesel-fuelled in 2040.

Energy demand

The greater energy efficiency of ZE HGVs compared to conventionally fuelled equivalents means that:

- Under the High Uptake Scenario, the overall energy requirements of the NI HGV parc (for public and private refuelling) will fall slightly by 2040 to 15.7 GWh from 16.3 GWh per day.
- However, under the Low Uptake Scenario, the daily energy demand will rise slightly to 16.7 GWh per day.

Infrastructure uptake scenarios

In terms of *publicly accessible refuelling* (i.e., the equivalent of current diesel refuelling stations):

- In the High Uptake Scenario, by 2030 the ZE HGV fleet will require 20 rapid (50 kWh) and 7 ultra-rapid (150 kWh) chargers, rising to 132 and 45 respectively by 2040. Hydrogen refuelling station requirements for the hydrogen-fuelled part of the fleet are projected to be 4 in 2030 and 39 by 2040.
- In the Low Uptake Scenario, by 2030 the ZE HGV fleet will require 11 rapid (50 kWh) and 4 ultra-rapid (150 kWh) chargers, rising to 66 and 23 respectively by 2040. Hydrogen refuelling station requirements for the hydrogen-fuelled part of the fleet are projected to be 2 in 2030 and 20 by 2040.

Electricity supply needs

Mapping the current distribution of likely HGV overnight parking locations and the currently supply network and demand headroom (difference between the rating of the supply and the demand) shows that while the substations around the parking locations have headroom, the electrical supply infrastructure currently follows population-driven electrical demand, rather than the potential points where HGV charging infrastructure, and the generation of renewable hydrogen by electrolysis, will require electrical supply in future.

Discussions and caveats of the analysis

The current energy demand numbers produced by this analysis are accurate as they are based on the energy usage of the current vehicle parc.

The number of ZE HGVs in the future vehicle parc is however uncertain, with key variables including the availability, cost, and performance of ZE HGV replacements and the cost and availability of associated refuelling infrastructure. This is particularly true of hydrogen: although the UK Government Hydrogen Strategy[15] cites hydrogen HGVs as potentially playing a significant role in UK decarbonisation, given the lack of current hydrogen HGVs and HRS, and the costs of deployment, there is currently considerable uncertainty about the size of this role.

[15] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf

Next steps

The scenarios presented here have shown the potential scale of national ZE HGV uptake and the associated energy demand and refuelling requirements. Among suggested next steps are:

- Engagement with the NI logistics sector and associated stakeholders to assess the appetite for ZE HGV uptake and assess the barriers to early adoption and trials.
- To map in detail the locations where both electric and H2 refuelling infrastructure is needed and where it can feasibly be deployed. This will help identify where "quick wins" for building infrastructure can occur and where business case modelling will be required to justify any grid upgrades to meet future demand of infrastructure.
- To understand how renewable electricity can be provided to key points of demand – whether directly for EVs or, potentially, for hydrogen production. This will ensure that investment in the network is placed appropriately, alongside ensuring that the carbon associated with electricity production is reduced for its application in zero emission vehicles. The role of bi-directional charging and battery storage in mitigating electricity network capability requirements and associated costs should also be examined.

Appendix A, Proposal of Work as Originally Submitted

Transport Energy Research Project 3: Low Carbon Transition for HGVs

Project Background

The Transport Energy branch in the Department for the Economy (DfE) on policies and support relating to the decarbonisation of energy used within the Transport Sector. The key relevance of this to DfE's policy vires is how decarbonising transport will reduce the current reliance on liquid fossil fuels and grow the demand for alternative low or zero emission fuels such as renewable electricity, green hydrogen or bio-methane. This transition will have associated impacts on the vehicle refuelling infrastructure, the electricity grid's capacity and resilience, demand for green electricity and hydrogen and ultimately on the mode and cost of transport for both private drivers and businesses in Northern Ireland. A clear example of this is covered in the first action of the government's recently released EV Infrastructure Plan, which identifies DfE as responsible for future proofing electrical capacity at key strategic sites along key transport corridors.

QUB and Cenex are very clear that this research project, along with the other two projects being currently tendered, are interconnected and will provide informative evidence to support the role of DfE, while also recognising the roles of other key actors in Northern Ireland's transport stakeholder landscape such as the Department for Infrastructure, councils, Northern Ireland Electricity Networks (NIEN), the Utility Regulator, the EV owners association of NI (EVANI) and the CBI.

Understanding the Brief

The Transport Energy branch has stated that the Data required would be:

1. Analysis of current HGV fleet in Northern Ireland.
2. Number and location of overnight parking facilitates.
3. Electrical grid capacity at these locations.
4. Planned and projected grid capacity at these locations.
5. Opportunities for hydrogen and/or LNG storage and distribution at these locations.

For the purposes of this proposal, QUB and Cenex have assumed that HGVs are any vehicle with a total weight over 3,500 kg including their cargo. We also assume that the UK policy for only zero emission sales from 2035 for <26t and 2040 for all other HGVs is the driving factor for transition. All HGV analysis will be for those vehicles registered in NI and not include those registered overseas travelling into the region. It is assumed that HGVs travelling in vs out of the region balance out. The overall aim of this project is to identify key HGV fleet depot locations across NI and assess their suitability for either EV charging or Hydrogen refuelling infrastructure.

Methodology

QUB and Cenex propose a top-down analysis for this project based on publicly available data about vehicle and operator licensing combined with our extensive knowledge of HGV operation in NI, based on previous project experience.

1. **WP1 – Data Gathering for Fuelling and Grid:** We will utilise publicly available data through the O-license database of where HGVs are registered within NI, giving a strong indication of where these vehicles are typically parked overnight. This will include number and body type of vehicle. Grid capacity data at each of the major sites identified will be obtained subject to working with the DNO.

2. **WP2 – Mapping of existing fuelling:** The data from WP1 will be mapped using GIS to show the distribution of HGV overnight parking locations within the wider network for the current year as well as grid capacity at these locations. Where relevant, data gathered around projected and planned electrical grid capacity expansion will also be mapped, however this will be subject to data provided by the DNO as due to the size of the project we will not be able to contact each facility individually.

3. **WP3 – Analysis of current HGV fleet:** Through DfT and DfI data we will establish the current baseline of EVs within NI, broken down into fuel type, GVW and chassis type. Inputting this data into Cenex's own proprietary model we will map the potential uptake of low and zero emission HGVs.

This model has been used with England's Strategic Transport Bodies to map HGV decarbonisation with an oversite from DfT.

4. **WP4 – Zero emission refuelling requirements:** Using the above forecasts we will calculate the total energy demand required to serve the low and zero emission fleet of HGVs and establish the opportunities for low and zero emission refuelling (EV, Hydrogen, and LNG).

5. **WP5 – Opportunities for hydrogen and LNG storage and distribution:** Building on WP4 we will establish the conditions required for hydrogen and LNG storage. This will be a set of advisory conditions and requirements for sites to be able to store and refuel vehicles and will not look at individual sites. Satellite data may be utilised in this work package.

6. **Reporting:** We will produce a Report detailing the above 5 work packages as well as provide GIS mapping of vehicle overnight parking facilities and electrical grid capacity.

Appendix B. ZE HGV Uptake Scenarios

Cenex's ZE HGV uptake module model applies the following methodology:

1. Establish the total number of HGVs currently registered (all fuel types) in the NI[16].
2. Baseline the number of ZE HGVs in NI.
3. Use the scenarios[17] supporting the Climate Change Committee's 2019 Net Zero report for the total number of HGVs (all fuel types) expected in the UK from now to 2040. This is the most recent and widely accepted view of how the vehicle parc will grow in the UK.
4. Develop scenarios for uptake of ZE HGVs to 2040: Zero emission technology pathway—a mix of hydrogen and electric vehicles—with a high and low uptake scenario. This is in-line with the planned phase out of ICE vehicles in the HGV sector (proposed sales ban date of 2035 for vehicle under 26 tonnes, and 2040 for vehicles over 26 tonnes[18]).

   The table below shows the assumptions for each scenario:

Table 5: Scenario development for LGVs and HGVs

	HGVs	
Scenario	**Assumption**	**Source**
High uptake (electric & hydrogen)	96% of new sales of HGVs by 2035 are ZEV (42% EV, 54% FCEV) 33% of total fleet ZEV by 2035, 67% by 2040 Biodiesel to meet 10% of HGV demand by 2040	6th Carbon Budget report by CCC[19] in-line with UK ban on internal combustion engine HGV sale
Low uptake (electric & hydrogen)	Slow uptake of alternative fuels, electric and hydrogen	Half the CCC forecast rate of uptake

[16] VEH0105 from Vehicle licensing statistics data tables - GOV.UK (www.gov.uk)

[17] Climate Change Committee Report: Zero Emission HGV Infrastructure Requirements. 2019, Ricardo Energy and Environment. Available at:https://www.theccc.org.uk/publication/zero-emission-hgv-infrastructure-requirements/

[18] https://www.gov.uk/government/news/uk-confirms-pledge-for-zero-emission-hgvs-by-2040-and-unveils-new-chargepoint-design

[19] https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf

Appendix C. Recharging/Refuelling Infrastructure Scenarios

The Cenex infrastructure uptake model applies the following methodology:

1. Project vehicle mileages in NI up to 2040 using the most up-to-date UK Government Road Traffic Forecasts (2018)[20].
2. Convert vehicle mileage for each fuel type into quantity of fuel required. Cenex used its proprietary Fleet Advice Tool data for fuel consumption rates for each fuel and vehicle type.
3. Convert fuel quantities into energy demand using Defra's fuel energy density figures[21].
4. Construct scenarios for the infrastructure requirements for each fuel type for the years 2030 and 2040. This is for predicted **publicly accessible infrastructure only** (equivalent to today's petrol and diesel forecourts)[22] and does not include depot and home refuelling. The below section explains in detail the assumptions for each fuel and vehicle type:

Hydrogen for HGVs

Cenex made the following assumptions:

- Based on discussions with H2 station operators, 30% of refuelling performed at depot and 70% at publicly accessible stations. This is half the rate of the current ratio of depot refuelling for diesel and gas vehicles, reflecting the fact that hydrogen is a lower maturity technology with more complex building, operational, and safety requirements, and so the roll-out of depot infrastructure is likely to be slower with specialist organisations operating the stations.
- Hydrogen refuelling station (HRS) capacity will be 10,000 kg per day[23]. This is the upper end of capacity for stations available now but is likely to become standard if more hydrogen vehicles were on the road.
- Daily station utilisation is 50% of total capacity, as per typical gas station utilisation.

Chargepoints for HGVs

Cenex made the following assumptions:

- 95% of recharging performed at depot and 5% at publicly accessible sites. Adapted from the Climate Change Committee (CCC) forecast that 100% of HGV charging will be at depot as we expect some non-depot charging to take place. During the Innovate funded project H2GVMids which Cenex participated in, and through operator surveys, we found that 10% of HGVs travelled over 350 miles in a single day. We have assumed that battery sizes in the future will not allow a range of over 350 miles, due to the economics of installing large batteries and weight constraints. Of the 10% of vehicles travelling over 350 miles a day we have assumed that half of their daily charging requirements comes from publicly accessible chargepoints, equating to 5% of all charging requirements for the full UK fleet.
- HGVs will use a 50:50 split for the energy delivered by 50 kW and 150 kW chargepoints. While at present there are a lack of 150 kW chargepoints available in comparison to 50 kW, it is expected that, as the HGV BEV market grows, there will be an increasing demand for higher capacity chargepoints - due to large battery sizes and operators wanting to limit vehicle downtime - and their availability and use will increase.
- Each chargepoint will provide an average of 6 hours of charging, assuming each chargepoint is operational for 12 hours per day and is utilised 50% of the time. There is a lack of data available showing likely chargepoint utilisation rates for HGVs; this assumption is Cenex's

[20] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/873929/road-traffic-forecasts-2018-document.pdf

[21] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021

[22] Publicly accessible infrastructure is equivalent to fuel forecourts which are set up and managed by the private sector, and are open access for use by fleets and drivers

[23] Climate Change Committee Report: Zero Emission HGV Infrastructure Requirements. 2019, Ricardo Energy and Environment. Available at: https://www.theccc.org.uk/publication/zero-emission-hgv-infrastructure-requirements/

estimate of future network usage patterns based on current utilisation of chargepoints by cars.

Infrastructure Costs

Cenex undertook a high level estimate of the **publicly accessible infrastructure costs only** (equivalent to today's petrol and diesel forecourts) for each scenario—this is in addition to any depot based refuelling which has not been included in this analysis. Public agencies will not have to fund publicly accessible infrastructure entirely by themselves and so these costs should not be read as required investment. Private industry investment will likely provide a large proportion of these costs as and when economically viable for their business case (as more low and zero emission vehicles are deployed, the viability of sites will be realised). Costs are based on today's prices with no adjustments made for inflation or falling costs as more infrastructure is deployed. Estimates use the following data and assumptions:

- **Hydrogen:** The total cost of installing a large capacity hydrogen station is estimated to be £5m, as presented in "Zero Emission HGV Infrastructure Requirements" (Ricardo Energy and Environment)[24].
- **EV Chargepoints:** Cenex has estimated total capital costs for chargepoints from an average of three quotations provided by industry contacts. Costs include equipment, electrical connection costs, enabling works and miscellaneous installation costs. Table 6 shows a cost summary. Potential grid or connection upgrades are not included in the calculations, which are more likely for large installations, however Table 7 shows indicative costs based on the size of installation.

Table 6: Capital cost and enabling works for chargepoints

	22 kW Fast Charger	50 kW Rapid Charger	150 kW Ultra-Rapid Charger
Capital cost of chargepoint	£2,000	£20,000	£80,000
Enabling works and electrical connection[25]	£4,000	£4,000	£4,000
Total	£6,000	£24,000	£84,000

Table 7: Indicative costs for major connection upgrades

	Medium (200 kVA – 1 MVA)	Large (>1 MVA)
Number of charge points	Up to 15 rapids	Above 15 rapids
Connection time	8-12 weeks	6 months+
Connection cost	£4,500 - £75,000	£75,000 - £2 million
Other considerations that may affect cost	Street work costs, legal costs for easement & wayleaves.	Street work costs, legal costs for easement and wayleaves. Planning permission & space for a substation.

[24] Zero Emission HGV Infrastructure Requirements (Ricardo Energy and Environment). Available at: https://www.theccc.org.uk/publication/zero-emission-hgv-infrastructure-requirements/

[25] Costs quoted here include an electrical connection (feeder pillar, Residual Circuit Breaker with Over-current device (RCBO), RCBO housing, RCBO protection, Miniature Circuit Breaker (MCB) installation, fixings and an assumed 5m electrical cable run), enabling works (foundations, 5m of ducting & surface reinstatement, guard raid/crash protection, bay markings, signage, and branding) and warranty.

Appendix D. ZE HGV Uptake Scenarios by LA

Antrim and Newtownabbey

	2025	2030	2035	2040
Diesel	2,210	1,979	1,238	307
Biodiesel	47	70	152	236
PHEV	70	115	172	233
BEV	23	92	368	699
Hydrogen	12	71	403	888

	2025	2030	2035	2040
Diesel	2,286	2,152	1,785	1,335
Biodiesel	24	35	76	118
PHEV	35	57	86	117
BEV	12	46	184	350
Hydrogen	6	35	201	444

Ards and North Down

	2025	2030	2035	2040
Diesel	803	719	450	112
Biodiesel	17	25	55	86
PHEV	25	42	63	85
BEV	8	33	134	254
Hydrogen	4	26	146	323

	2025	2030	2035	2040
Diesel	831	782	649	485
Biodiesel	9	13	28	43
PHEV	13	21	31	42
BEV	4	17	67	127
Hydrogen	2	13	73	161

Armagh City, Banbridge and Craigavon

	2025	2030	2035	2040
Diesel	3,820	3,421	2,139	531
Biodiesel	82	121	262	409
PHEV	121	198	298	403
BEV	40	159	636	1,209
Hydrogen	21	122	696	1,535

	2025	2030	2035	2040
Diesel	3,952	3,721	3,086	2,308
Biodiesel	41	60	131	204
PHEV	61	99	149	201
BEV	20	79	318	604
Hydrogen	10	61	348	768

Belfast

	2025	2030	2035	2040
Diesel	1,503	1,346	842	209
Biodiesel	32	47	103	161
PHEV	48	78	117	159
BEV	16	62	250	476
Hydrogen	8	48	274	604

	2025	2030	2035	2040
Diesel	1,555	1,464	1,214	908
Biodiesel	16	24	52	80
PHEV	24	39	59	79
BEV	8	31	125	238
Hydrogen	4	24	137	302

Causeway Coast and Glens

	2025	2030	2035	2040
Diesel	1,564	1,401	876	217
Biodiesel	34	49	107	167
PHEV	50	81	122	165
BEV	17	65	260	495
Hydrogen	9	50	285	628

	2025	2030	2035	2040
Diesel	1,618	1,523	1,263	945
Biodiesel	17	25	54	84
PHEV	25	41	61	82
BEV	8	32	130	247
Hydrogen	4	25	142	314

Derry City and Strabane

	2025	2030	2035	2040
Diesel	1,525	1,365	854	212
Biodiesel	33	48	105	163
PHEV	48	79	119	161

BEV	16	63	254	482
Hydrogen	8	49	278	613

	2025	2030	2035	2040
Diesel	1,577	1,485	1,231	921
Biodiesel	16	24	52	82
PHEV	24	40	60	80
BEV	8	32	127	241
Hydrogen	4	24	139	306

Fermanagh and Omagh

	2025	2030	2035	2040
Diesel	2,151	1,926	1,205	299
Biodiesel	46	68	148	230
PHEV	68	112	168	227
BEV	23	89	358	681
Hydrogen	12	69	392	864

	2025	2030	2035	2040
Diesel	2,225	2,095	1,737	1,300
Biodiesel	23	34	74	115
PHEV	34	56	84	113
BEV	11	45	179	340
Hydrogen	6	34	196	432

Lisburn and Castlereagh

	2025	2030	2035	2040
Diesel	1,627	1,457	911	226
Biodiesel	35	51	112	174
PHEV	52	84	127	172
BEV	17	68	271	515
Hydrogen	9	52	296	654

	2025	2030	2035	2040
Diesel	1,684	1,585	1,314	983
Biodiesel	17	26	56	87
PHEV	26	42	64	86
BEV	9	34	135	257
Hydrogen	4	26	148	327

Mid Ulster

	2025	2030	2035	2040
Diesel	2,946	2,638	1,650	409
Biodiesel	63	93	202	315
PHEV	93	153	230	311
BEV	31	122	490	932
Hydrogen	16	94	537	1,184

	2025	2030	2035	2040
Diesel	3,048	2,869	2,379	1,780
Biodiesel	32	47	101	158
PHEV	47	76	115	155
BEV	16	61	245	466
Hydrogen	8	47	268	592

Newry, Mourne and Down

	2025	2030	2035	2040
Diesel	2,603	2,331	1,458	362
Biodiesel	56	82	179	278
PHEV	83	135	203	275
BEV	28	108	433	824
Hydrogen	14	83	474	1,046

	2025	2030	2035	2040
Diesel	2,693	2,535	2,102	1,573
Biodiesel	28	41	89	139
PHEV	41	68	102	137
BEV	14	54	217	412
Hydrogen	7	42	237	523

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