Towards Zero Emission HGV Infrastructure in Scotland

Technical Report

Centre for Sustainable Road Freight
Heriot-Watt University
for
Transport Scotland

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EXECUTIVE SUMMARY

Project Overview

This project, commissioned by Transport Scotland and delivered by the Centre for Sustainable Road Freight (CSRF) at Heriot-Watt University, provides a data-driven approach to identifying critical locations for zero-emission HGV charging and refuelling infrastructure across Scotland. The project utilized real-world data from fleet operators and an in-house modelling and simulation suite developed by CSRF.

A summary report highlighting key messages and findings presented in this technical report is also available at the following URL:

https://www.hw.ac.uk/ebs/research/logistics-sustanability/charging-refuelling-needs-trucks-scotland.htm

Background

- Transport Scotland is the national transport agency of Scotland.
- The Centre for Sustainable Road Freight (CSRF) is a leading research centre specialising in freight transport decarbonisation.

Project Aim

To support a smooth transition to zero-emission freight fleets, the project aims to offer an evidence-based analysis of the most critical locations for shared en-route charging and hydrogen refuelling infrastructure across Scotland.

Project Scope

The project focused on freight transportation by HGVs within Scotland, encompassing journeys ranging from short (2-4 hours) to long-distance operations (over 8 hours).

Project Outcomes

- **Identify locations for shared charging/refuelling infrastructure:** The project identifies potential locations for shared en-route charging stations and hydrogen refuelling facilities to support Battery Electric (BEV) and Fuel Cell (FCEV) HGV operations efficiently, along with estimations of demand at each location.
- **Prioritization and Phasing:** Recommendations are provided on prioritising and phasing the development of these facilities based on anticipated utilisation.

Key Findings

a) Whole fleet BEV HGV operation is possible for current routes, subject to depot and en-route charging infrastructure being developed in key locations across Scotland.
b) Based on data included to date, prioritising shared charging on the A9, A90, and M74 corridors maximises the impact for these BEV operations.
c) Most modelled routes can be completed with no additional stops for charging and, in the worst case, divert an average of 15 km more than the existing diesel HGVs.
d) Even when considering only a small proportion of Scotland's HGV fleet, considerable mitigation for increased peak grid demand, such as reinforcement of grid connections, will likely be required.
e) The mapping of locations for hydrogen refuelling is more uncertain than for charging due to an earlier stage of technology maturity and the potential need to site refuelling alongside hydrogen production. Hydrogen refuelling distributors indicate that hydrogen in individual depots will not be commercially viable and shared fuelling sites are required.

f) Data from more operators will validate the proof of concept, ensuring identified charging or fuelling locations support all operations across Scotland, and creating confidence for investment. Contact the team at cls-info@hw.ac.uk to have your fleet data included in future iterations of the model.

This project provides a valuable foundation for planning and investment decisions related to zero-emission HGV infrastructure in Scotland. By fostering collaboration and data sharing, stakeholders can work together to achieve a smooth transition to a sustainable freight transport sector.

METHODOLOGY

Stakeholder engagement

Stakeholder engagement was crucial to the success of this research for several reasons. Firstly, the model developed in this study aims to replicate real-world HGV operations. Consequently, direct engagement with stakeholders was essential to gather primary data on operational practices and challenges. Secondly, the proposed infrastructure network is anticipated significantly to impact HGV operations. By involving stakeholders early in the process, their insights and perspectives could be integrated into the model, enhancing its relevance and applicability. Finally, fostering a sense of ownership among stakeholders is important for the successful implementation of research findings. Involving stakeholders increases their buy-in and willingness to adopt the model's results and recommendations[1].

Key stakeholders were identified through established networks within the transportation and logistics sector. Primarily, the Zero Emission Truck Task Force (ZETT) network, led by Transport Scotland, served as a foundational source for stakeholder identification. Additionally, the Centre for Sustainable Road Freight (CSRF) and the Centre for Logistics and Sustainability (CLS) networks at Heriot-Watt University provided supplementary stakeholder information. The identified stakeholder groups encompass a broad spectrum of industry representatives, including fleet operators, energy providers (Distribution Network Operators), infrastructure developers, local councils, and truck manufacturers.

A multi-faceted approach was employed to engage stakeholders effectively. Initially, a dedicated webpage was established on the CLS website to provide comprehensive project information[2]. This platform outlined the project's objectives and detailed the specific data requirements. To address potential inquiries and concerns, a comprehensive FAQ section was incorporated, clarifying data sharing procedures, data usage, and security measures.

To facilitate direct interaction and knowledge dissemination, an online workshop was convened on November 29, 2023[3]. This platform served to reiterate the project's potential benefits and encourage stakeholder participation. To gauge interest in data sharing, a questionnaire was distributed among workshop attendees.

Following the stakeholder engagement activities, a structured data collection process was initiated. Stakeholders who during the workshop expressed interest in contributing data were

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[1] Estrada-Magbanua, W.M., Huang, T.T.K., Lounsbury, D.W., Zito, P., Iftikhar, P., El-Bassel, N., Gilbert, L., Wu, E., Lee, B.Y., Mateu-Gelabert, P., 2023. Application of group model building in implementation research: A systematic review of the public health and healthcare literature. PloS one 18(8), e0284765.

[2] https://www.hw.ac.uk/ebs/research/logistics-sustanability/charging-refuelling-needs-trucks-scotland.htm

[3] https://www.youtube.com/watch?v=rKB3WGuG60g

contacted via email for the scheduling of individual online meetings. These meetings served to identify the types of data, formats and composition available within their organisations and to assess their potential value to the project. Through collaborative discussions, agreements were reached regarding the quantity and scope of data that could be shared.

To facilitate secure data transfer, a dedicated SharePoint folder was created. Access to this folder was strictly limited to the research team and designated contact persons from each organisation. This controlled access ensured the confidentiality and integrity of the shared data. Stakeholders were instructed to upload their data directly into the SharePoint folder, streamlining the collection process.

Data collection, cleaning and fusion

The data collected for this research primarily originated from fleet operators within the retail sector and third-party logistics companies. These organisations provided data in CSV or Microsoft Excel formats. Two primary categories of data were acquired from these fleet operators: Telematics Data and Route Scheduling Data.

Telematics Data is a granular dataset capturing individual HGV movements, presented in CSV files. Each row represented an automatically logged "event" during an HGV's journey. Relevant fields included:

- Event Type (e.g., ignition on/off, driver login/logout)
- Vehicle Identifier (unique vehicle identification)
- GPS Coordinates (latitude and longitude)
- Timestamp (date and time)
- Odometer Value (total distance travelled)

The Route Scheduling Data was generated by fleet operators for route planning purposes. However, this data did not contain information on specific routes taken, as these were determined by driver discretion. Relevant fields included:

- Start and End Locations (full address with latitude and longitude)
- Journey Start and End Times (expected arrival and departure times)
- Vehicle Details (unique identifier or truck class)

In addition to these primary sources, a dataset was obtained from one local authority vehicle fleet. However, the nature of this data did not fully align with the specific requirements of the project, necessitating further exploration and potential adaptation.

The data obtained from fleet operators underwent a comprehensive cleaning process to ensure its accuracy and suitability for model processing. We followed best practice in telematic data cleaning and fusion[4,5,6] the process includes:

- ***Event Filtering:*** Events that did not occur at loading or unloading destinations, such as driver breaks or refuelling stops, were identified and removed. This focused the data on

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[4] Ghaffarpasand, O., Burke, M., Osei, L.K., Ursell, H., Chapman, S., Pope, F.D., 2022. Vehicle Telematics for Safer, Cleaner and More Sustainable Urban Transport: A Review, Sustainability.

[5] Grumiau, C., Mostoufi, M., Pavlioglou, S., Verdonck, T., 2020. Address Identification Using Telematics: An Algorithm to Identify Dwell Locations, Risks.

[6] Sun, S., Bi, J., Ding, C., 2020. Cleaning and Processing on the Electric Vehicle Telematics Data, in: Yang, H., Qiu, R., Chen, W. (Eds.), Smart Service Systems, Operations Management, and Analytics. Springer International Publishing, Cham, pp. 1-6.

departure and arrival times, enabling accurate representation of trip durations and distances.
- ***Odometer Validation:*** Instances where the odometer value changed between consecutive "ignition off" and "ignition on" events were analysed to identify potential inconsistencies.
- ***Redundant Record Removal:*** GPS blips, where GPS locations changed but the odometer remained unchanged, were addressed. These redundant records were merged or further analysed to determine distinct locations.
- ***Location Granularity Adjustment:*** GPS coordinates were replaced with postcodes to improve efficiency and minimize the impact of imprecise GPS data. This step also aided in identifying missing journeys and stop locations.
- ***Depot Identification:*** The most frequently visited locations by each HGV were identified as depots and verified by fleet operators.
- ***Origin-Destination Extraction:*** When not explicitly provided, journey origin and destination points were derived from the data.

These cleaning steps were executed using Python and resulted in CSV files that served as inputs for the simulation model.

Modelling and analysis

Modelling inputs

The cleaned and fused CSV files served as inputs for the Multimodal Integrated Logistics Environment for Simulation (MILES) model. MILES, a CSRF modelling software package, was employed to simulate the transition of current diesel HGV routes to electric and hydrogen vehicles.

In addition to the route data derived from stakeholder-provided data, the model required input on the charging and refuelling infrastructure network. For this project, a hypothetical network of HGV charging or refuelling locations was created based on existing suitable potential host infrastructure. These locations, such as truck stops, high-traffic service stations, and major ports, offered existing facilities and amenities (e.g., toilets and cafes) that could be leveraged for charging or refuelling purposes.

It's important to note that these potential locations were not influenced by any existing company plans to install electric HGV chargers. A comprehensive list of these potential charging and refuelling station locations within a 5km radius across Scotland is provided in Appendix A, noting that these locations are not the exact boundaries of the truck stop, port, or other site.

For routes that crossed the border with England, given the project's scope limitations, an assumption was made regarding the abundance of charger locations in England, aligning with suggestions from previous studies[7,8]. This implies that trucks could always find a place to charge in England, if necessary, and were modelled as crossing the border into Scotland with their remaining battery level since the last charging event.

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[7] de Saxe, C., Ainalis, D., Miles, J., Greening, P., Gripton, A., Thorne, C., Cebon, D., 2023. An electric road system or big batteries: Implications for UK road freight. Transportation Engineering 14, 100210.

[8] Deshpande, P., de Saxe, C., Ainalis, D., Miles, J., Cebon, D., 2023. A breakeven cost analysis framework for electric road systems. Transportation Research Part D: Transport and Environment 122, 103870.

Simulation Process

The MILES model employed a comprehensive simulation process to evaluate the feasibility of transitioning HGV routes to electric and hydrogen vehicles.

- ***Journey Reconstruction:*** Vehicle movements were chronologically ordered based on time and date. Origin and destination locations were referenced using place coordinate datasets. This process allowed for the reconstruction and analysis of each vehicle's complete journey history.
- ***Route Mapping:*** Existing diesel truck routes were overlaid onto a GIS network, with depots serving as start and end points for each journey. The GraphHopper open-source routing engine, based on Java and OpenStreetMap tiles, was used to calculate the optimal route between each origin and destination. GraphHopper utilizes an A* search algorithm over the UK road network, considering road quality and other factors to determine the likely average speed for each route segment. The network data was sourced from the "Great Britain" entry in the GeoFabrik global repository of OpenStreetMap snapshots[9].
- ***Zero-Emission Journey Simulation:*** The simulation evaluated how battery electric or hydrogen HGVs would complete each route, taking into account potential charging or refuelling stops. Initially, the simulation assumed a fixed battery size or fuel capacity for each vehicle type. For battery electric HGVs, the battery level was constrained within a range of 20% to 80%. This approach avoided exceeding warranty limitations and aligned with previous studies[10].
- ***En route charging:*** The model tracked the battery or hydrogen level at each point along the route to determine if charging or refuelling was necessary. The energy consumption rate per kilometre was factored in to calculate the decrease in battery or hydrogen level. The "critical incursion point" was identified for each route. This point signified where the driver should consider charging or refuelling, based on reaching the unusable energy level (20% for battery electric and 0% for hydrogen) plus a buffer to account for the diversion distance to a charging/refuelling station. For example, a 500kWh battery HGV would require charging when its level reached 150kWh (100kWh unusable + 50kWh remaining charge to reach charging stations). All stations within a 100km radius of the critical incursion point were considered as potential charging/refuelling options. The additional time required to divert from the original route to a charging/refuelling station was incorporated into the overall route completion time calculation. The model identified the charger with the least overall route disruption time, accounting for route diversion, overhead time, and charging duration. The algorithm ran iteratively until a series of charging stops could be identified to complete the route. Battery levels were recalculated after each charging stop addition.

Simulation outputs

The simulation generated a comprehensive dataset of outputs, providing valuable insights into the feasibility and potential impacts of transitioning HGV fleets to electric or hydrogen vehicles.

- ***Aggregated Traffic Flow:*** The simulation allowed for the reconstruction of vehicle routes, enabling the analysis of aggregated traffic flows along different routes.

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[9] http://download.geofabrik.de/europe/great-britain.html

[10] Utomo, D. S., Gripton, A., & Greening, P. (2020, December). Long haul logistics using electric trailers by incorporating an energy consumption meta-model into agent-based model. In 2020 Winter Simulation Conference (WSC) (pp. 147-158). IEEE.

- ***Charging/Refuelling Infrastructure Needs:*** The model identified the locations where charging or refuelling stops were necessary for electric or hydrogen HGVs. This data is crucial for the strategic placement of charging and refuelling infrastructure to support the transition.
- ***Additional Stops:*** The simulation can be used to calculate the number of additional stops required to complete a route when using electric or hydrogen vehicles compared to diesel vehicles. This metric highlights the potential operational challenges associated with zero-emission vehicles.
- ***Charging/Refuelling Station Utilisation:*** The model provided information on the number of visits to each charging or refuelling station and the amount of energy delivered to vehicles. This data is essential for assessing the capacity requirements of charging infrastructure and optimizing its deployment.

A detailed discussion of our findings will be discussed in the findings section.

Validation and Feedback

Validation and Feedback from Fleet Operators

To ensure the model's accuracy and relevance, a series of individual meetings were conducted with stakeholders who had participated in the data-sharing process. These meetings took place during February and March 2024.

The primary objective of these validation meetings was to gather feedback on the preliminary modelling results from relevant stakeholders. This feedback was crucial for assessing the accuracy of the model's outputs and identifying areas for improvement to enhance its practical utility for business decision-making.

During each meeting, the modelling results for a specific company were presented, ensuring the confidentiality of data from other participants. Following the presentation, representatives from each company were asked two key questions:

- ***Route Pattern Correlation:*** Do the route patterns depicted by the model align with the real-world route patterns observed by the fleet operators?
- ***Charging Location Suitability:*** Are the charging locations proposed by the model considered suitable by the fleet operators when contemplating the transition to electric or hydrogen vehicles?

The stakeholders provided valuable feedback based on their real-world experiences, contributing to the validation and refinement of the model and its underlying assumptions. The insights gained from these interactions ensured that the model and its outputs aligned with the actual operational needs of fleet operators.

DNO Interaction

Collaboration with Electricity Distribution Network Operators (DNOs) was essential to understand the potential impact of charging locations on the electricity network. The charging behaviour of battery electric HGVs relies heavily on the capabilities of the network, which is managed by DNOs. In Scotland, the primary DNOs are SP Energy Networks (SPEN) and Scottish and Southern Energy Networks (SSEN).

The project team compared DNO forecasting data with the model outputs to assess the potential strain on the grid. Openly available data from Scotland-based DNOs was obtained as follows:

- ***SPEN:*** Detailed tabular outputs from SPEN's "Network Development Plan (Part 2)" were acquired [11]. The Demand Headroom (MW) values in the High Scenario case for 2025/26 were utilised in the analysis, providing an optimistic estimate of the demand headroom at each substation.
- ***SSEN:*** Detailed tabular outputs from SSEN's "Scenario Headroom Report (2024)" were obtained[12]. Draft values for the Demand Headroom Winter (MVA) in the Winter Scenario case for 2025 were used, providing an optimistic estimate of the demand headroom at each substation. These MVA values were converted to MW by multiplying by a power factor of 0.95[13].

The model predicted the maximum number of daily visits to each charging location based on the available data. This output was combined with the DNO data to assess the potential impact on the grid:

1. For each proposed charging location, the nearest primary substation was identified.
2. The demand headroom for that substation was compared to the maximum total draw on the grid, considering two scenarios:
    a. ***Low Usage:*** 4 peaks of vehicle arrivals (demand headroom - max_daily_visits*0.5/4)
    b. ***High Usage:*** 2 peaks of vehicle arrivals (demand headroom - max_daily_visits*0.5/2)

    A negative value indicated that the demand headroom would be exceeded, while a positive value indicated sufficient capacity. The factor of 0.5 represented a 0.5MW draw for each vehicle being charged.

The results of this analysis, along with a corresponding map (Figure 4), were presented to both SPEN and SSEN.

KEY FINDINGS AND DISCUSSION

This section presents the key findings derived from the simulation analysis. The findings are structured as follows:

1. ***Findings Overview:*** This section provides a general overview of the data collected from stakeholders, popular HGV routes, and the distribution of potential charging and refuelling station locations.
2. ***Battery Electric Vehicle (BEV) HGVs Infrastructure Requirements:*** This section details the simulation results for BEV HGVs, including their impact on the electricity grid.
3. ***Hydrogen Fuel Cell Electric Vehicle (FCEV) HGVs Infrastructure Requirements:*** This section presents the simulation results for hydrogen fuel cell HGVs, highlighting the necessary infrastructure for their operation.

Findings Overview

The data collected from stakeholders encompassed a diverse range of freight sectors, including retail, food, and general logistics. This high-quality dataset, comprising raw telematics and scheduling data, encompassed over 80,000 unique HGV journeys across mainland Scotland

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[11] https://www.spenergynetworks.co.uk/pages/network_development_plan.aspx#tablist1-tab1

[12] https://www.ssen.co.uk/globalassets/about-us/dso/consultation-library/draft-sepd-network-scenario-headroom-report-2024-consultation.xlsx

[13] https://distribution.ssen.co.uk/WorkArea/DownloadAsset.aspx?id=19390

within a one-year period. The average journey distance was 258 kilometres. The descriptive statistics of the journey carried out by the stakeholder's fleet is detailed in Appendix B.

It is important to note that this dataset represents a small portion of Scotland's logistical activity, approximately 1% of all registered trucks in the region. Therefore, the results presented in this study illustrate the model's potential, which can be fully realised with a larger quantity of data.

The analysis of the available data identified several key freight corridors characterised by high HGV traffic volumes. These corridors primarily connect major population centres, industrial zones, and ports across Scotland. Figure 1 highlights these critical corridors for freight movement within Scotland, which are of particular significance for the fleets represented in the dataset.

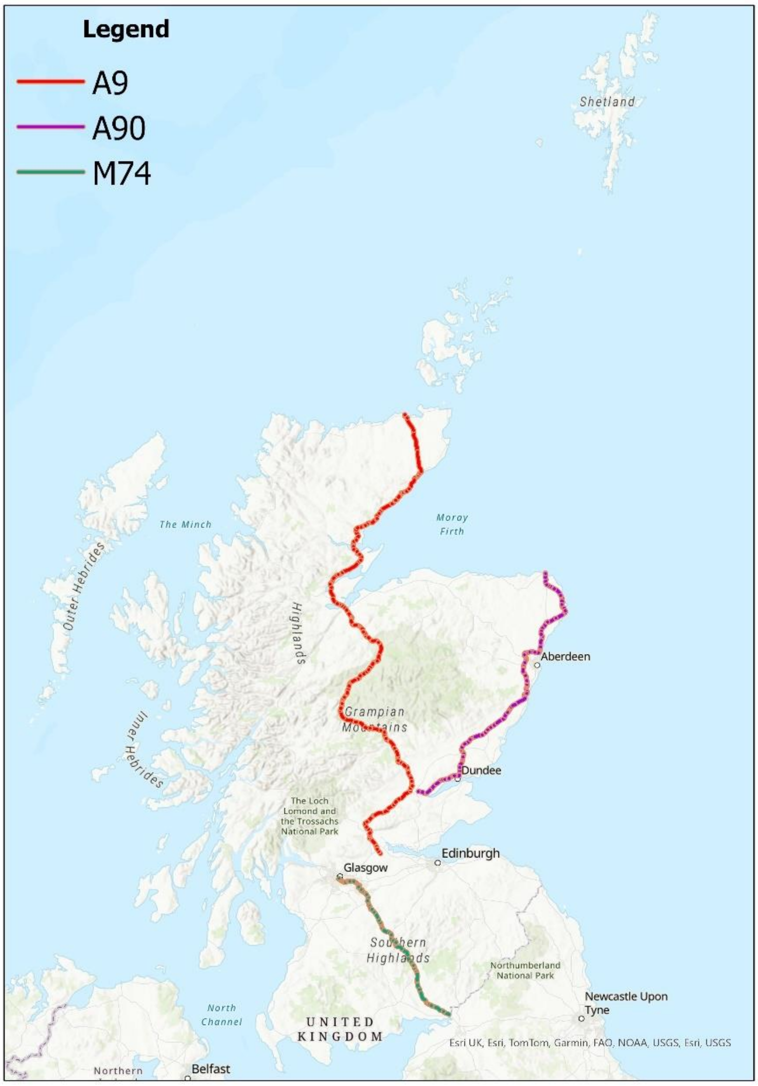

Figure 1 Critical routes for fleets in the data set (1% of HGVs in Scotland)

The model, in conjunction with stakeholder feedback, has suggested specific locations as priorities for en-route chargers, as depicted in Figure 2. These locations are based on existing infrastructure, such as truck stops, lorry parks, intermodal hubs, and ports. Land within or adjacent to these host charger locations will be required to accommodate the installation of rapid chargers and provide parking space for HGVs during charging.

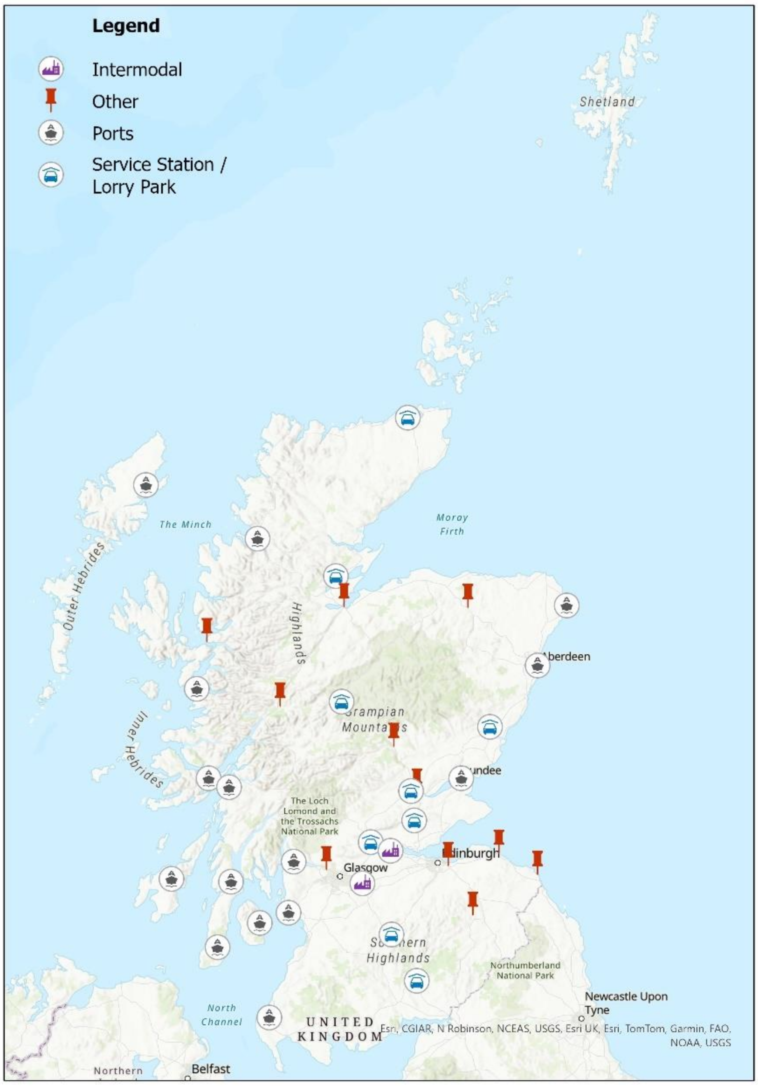

Figure 2 Suggested locations of en-route infrastructure from available data

The strategic locations highlighted in Figure 2 represent potential sites for the addition of new en-route chargers.

All routes were similarly modelled for hydrogen vehicles. However, these findings should be considered in the context of evidence in the supply chain that battery electric HGVs are dominating due to better maturity and lower cost than hydrogen HGVs. The cost differential between electricity and hydrogen is likely to remain in the future for zero emission HGVs as the production of green hydrogen is less energy efficient than the production of electricity[14,15,16, 17].

Battery Electric Vehicle (BEV) HGVs Infrastructure Requirements

Simulation Scenarios

This section details the key findings for Battery Electric HGV Vehicles (BEVs), assuming a complete transition of HGV fleets to electric power. Given the lack of clear evidence regarding future fleet intentions, a fixed ratio was not used.

Three scenarios were explored to assess the viability of routes under different charging infrastructure configurations:

a) ***Home Depot Charging Only (Scenario A):*** This scenario assumes that battery charging occurs exclusively at the operator's depot.
b) ***En Route Charging Only (Scenario B):*** This scenario considers battery charging exclusively along the journey of HGVs.
c) ***Home Depot and En Route Charging (Scenario C):*** This scenario incorporates battery charging stations at both the operator's depot and along the routes taken by HGVs.

By a Home Depot, we mean a depot which is run by the operator of the truck. Regarding the charging behaviour, the following assumptions were made:

- **Depot Usage:** Vehicles were assumed to charge at operator-run depots. In Scenarios A and C, vehicles were considered 100% charged at the start of a day. In Scenario B, vehicles left the depot with their existing charge level and could only charge en-route.
- **Charging Infrastructure:** Charging points were assumed to be 500 kW for ultra-rapid charging. HGV batteries were assumed to have a usable capacity of 350 kW. Vehicles were modelled as fully loaded 44-tonne trucks and with conservative energy consumption estimates of 2kWh/km. Range assumptions were based on previous CSRF publications[18].
- **Destination Charging:** Charging at destinations was assumed to be infeasible due to infrastructure and space limitations.

Simulation Results

The results from each scenario, including any additional stops compared to current diesel HGV journeys, are summarized in Table 1. Scenario C, with both depot and en route charging, emerges as the most favourable option, allowing all routes to be completed with potential additional stops.

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[14] Zixian Wang, S. Acha, Max H. Bird, Nixon Sunny, M. Stettler, Billy Wu, Nilay Shah (2023). A total cost of ownership analysis of zero emission powertrain solutions for the heavy goods vehicle sector. Journal of Cleaner Production

[15] Howey, D., Contestabile, M., Clague, R. D., & Brandon, N. P. (2009). Comparative analysis of battery electric, hydrogen fuel cell and hybrid vehicles in a future sustainable road transport system. Energy Policy

[16] Gray, N., O'Shea, R., Wall, D., Smyth, B., Lens, P., & Murphy, J. (2022). Batteries, fuel cells, or engines? A probabilistic economic and environmental assessment of electricity and electrofuels for heavy goods vehicles. Advances in Applied Energy

[17] Cunanan, C., Tran, M. K., Lee, Y., Kwok, S., Leung, V., & Fowler, M. (2021). A Review of Heavy-Duty Vehicle Powertrain Technologies: Diesel Engine Vehicles, Battery Electric Vehicles, and Hydrogen Fuel Cell Electric Vehicles. Clean Technology

[18] de Saxe, C., Ainalis, D., Miles, J., Greening, P., Gripton, A., Thorne, C., & Cebon, D. (2023). An electric road system or big batteries: Implications for UK road freight. Transportation Engineering, 14, 100210.

However, some remote routes may require further analysis as outlined in the Future Works section.

Table 1 Complete or incomplete routes and additional stops under each scenario

	Scenario A (depot charging only)	Scenario B (en route charging only)	Scenario C (both)
% routes unable to complete	33%	2%	~0%
% complete with no extra stop	65%*	59%	61%
% complete with +1 stop	2%	12%	12%
% complete with +2-3 stops	0%	20%	20%
% complete with 4+ stops	0%	7%	7%

In Scenario A (depot charging only), 33% of routes experienced flat battery events due to insufficient charging opportunities. Even in the 65% of routes that were successfully completed, some dipped below the 20% minimum battery charge threshold, indicating a need for further investigation in future model developments.

Scenario B (en-route charging only) supported almost all routes, with a minimal increase in stops for longer routes compared to Scenario C. However, shorter routes faced a 2% non-completion rate, which could become significant over a larger sample of journeys.

Combining en-route and depot charging (Scenario C) proved to be the optimal option for all operations included in the dataset.

In Scenario C, 61% of modelled journeys could be completed without any charging stops between the depot, destination, and return. Only 12% required one en-route stop, and 27% needed more than one stop. Charging diversions for BEV trucks averaged 15 km compared to diesel equivalents.

Charging hotspots

The analysis identified high usage on specific routes, such as A9, A90, and M74, emphasising the need for strategically placed en-route charging stations along these critical corridors.

Figure 3 and Table 2 present the high utilisation hotspots, with the longest distance between potential charging locations being 106 km to Cairnryan. The median distance between charge points is 43 km. Further investigation is required to ensure sufficient coverage for remote and critical routes.

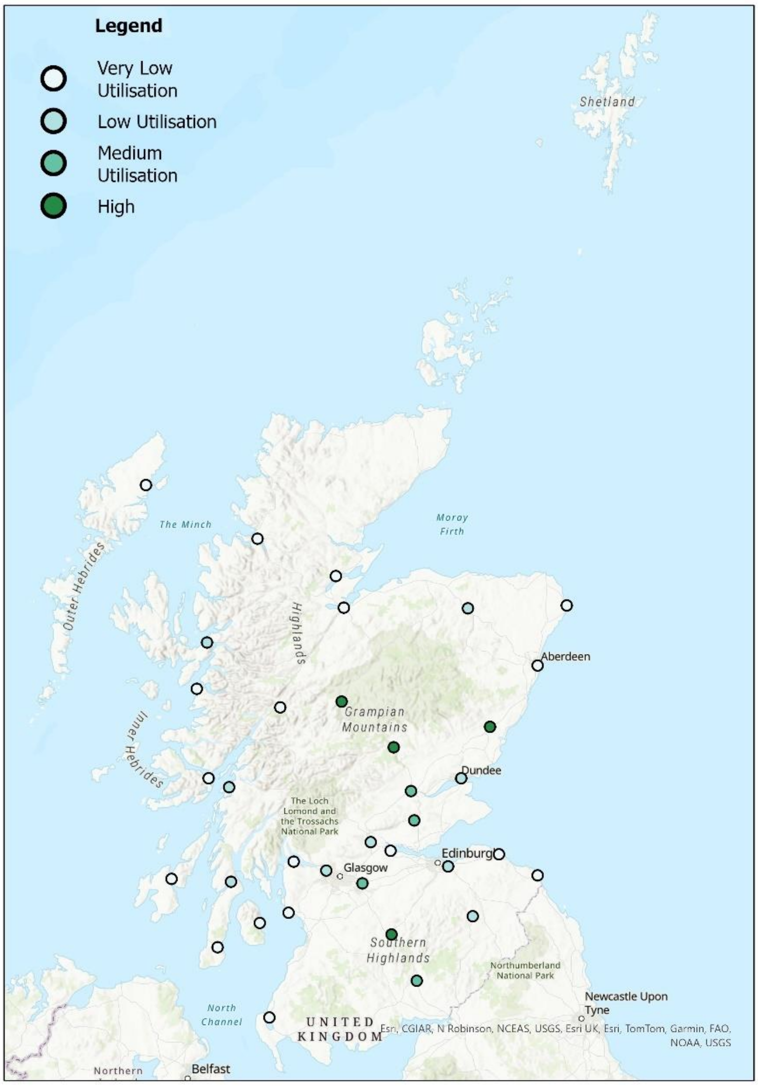

Figure 3 Medium to high utilisation en route charging locations for fleets in the dataset (dark = more visits)

Table 2 High-demand locations for battery charging

Location	Number of uses (annual)	Total charge delivered (MWh)
Dalwhinnie	11,180	2,357
Ballinluig	8,801	1,409
Stracathro	8,490	2,045
Abington	6,950	1,571
Kinross	4,662	945
Annandale Water	3,835	937
Broxden	3,625	822
Mossend	2,890	658
Clydebank	2,538	576
Dundee	2,152	476

The study demonstrated the feasibility of switching to BEVs, with over half of the journeys in the dataset requiring no additional charging stops. However, real-world trials are essential to validate assumptions and address unforeseen challenges, as this preliminary work considered a limited segment of existing HGV operations. Ongoing and planned trials focus on both soft (behavioural, opinion) and hard (technology-related) challenges associated with BEV implementation. These trials will also help understand ways to mitigate the impact of additional stops.

Battery electric HGVs are already in use on UK roads, and the HGV Decarbonisation Pathway for Scotland[19] states that where the technology is proven and commercially viable, haulage, energy and finance businesses should begin transitioning to low-carbon emissions technologies without delay.

Implications for the electricity grid infrastructure

As explained in the methodology section, the model was used to predict the maximum instantaneous draw on the electricity network for each charging location for the current small dataset under two scenarios, with the results compared to the available demand capacity headroom (unutilised grid capacity) predicted by DNOs. The first scenario considers high intensity charging activities where trucks arrive at charging stations in two concentrated peak periods, and the second scenario considers low intensity charging activities where truck arrivals are spread out across three charging periods over the day.

The results of this analysis are summarised in Figure 4, where the identified primary substations are colour-coded based on their current headroom availability:

- Yellow: Sufficient headroom to handle even the high intensity scenario (68% of all substations based on available data).
- Amber: Headroom is sufficient only for the low intensity scenario. Upgrades might be necessary depending on future demand projections (5.2% of all substations based on available data).
- Red: Insufficient headroom to handle even the low intensity scenario. Upgrades are likely required (26.4% of all substations based on available data).

The identified primary substations are the most likely to require upgrades / reinforcement; many more substations may require upgrades once the full logistics industry fleet data is included in the model.

The primary substations that were identified as critical include: Milnathort, Inchbare, Symington, Kirkwall, Burghmuir, Ullapool, Lochdonhead, Dalwhinnie, and Pitlochry. Precise locations are given in the Appendix.

There may be situations in which the DNO can still provide for rapid charging, e.g., using flexibility services, whilst minimising reinforcement, despite low capacity.

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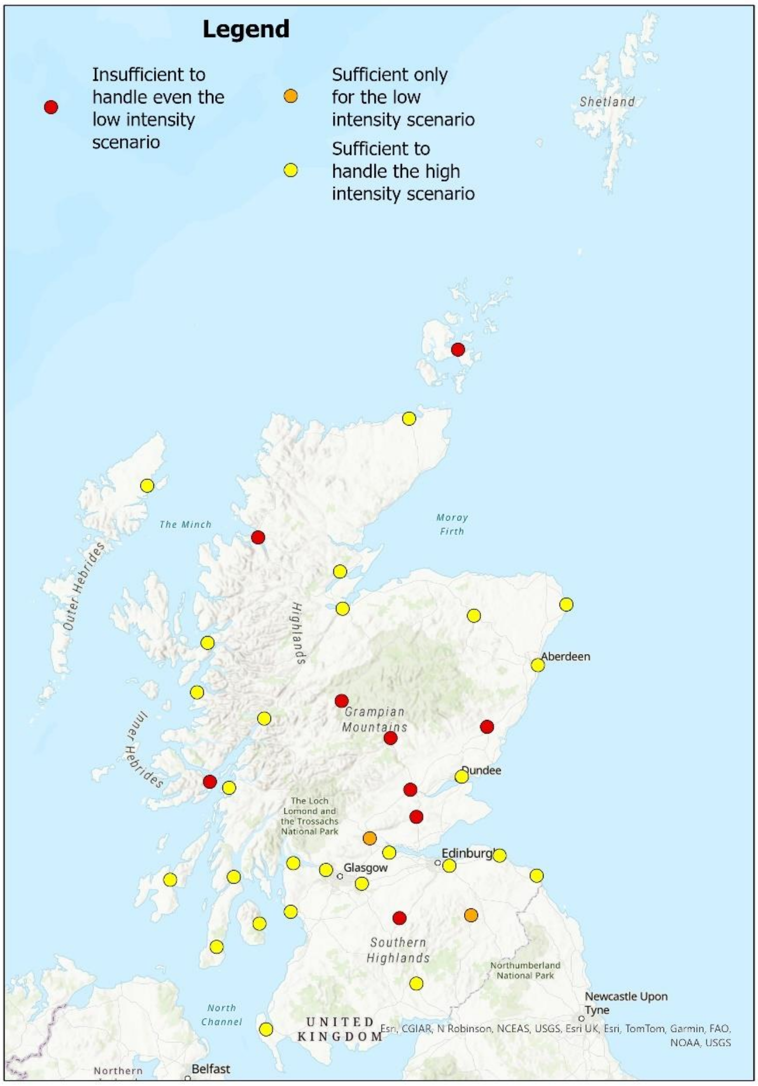
[19] Transport Scotland. (2022). HGV Decarbonisation Pathway for Scotland: Zero Emission Truck Taskforce. Available: https://www.transport.gov.scot/media/z0ofzfbs/hgv-decarbonisation-pathway-for-scotland-zero-emission-truck-taskforce.pdf



Esri, CGIAR, N Robinson, NCEAS, USGS, Esri UK, Esri, TomTom, Garmin, FAO, NOAA, USGS

Figure 4 Charging locations coloured to highlight insufficient demand capacity headroom at primary substations for serving BEV routes included in the current dataset

Hydrogen Fuel Cell Electric Vehicle (FCEV) HGVs Infrastructure Requirements

Using the same dataset as for BEVs, all routes were modelled assuming that all fleet vehicles were hydrogen FCEV-based HGVs to identify the required hydrogen refuelling station locations. However, the model only considered en route refuelling stations, as depot-based refuelling was not assumed due to the complexities associated with hydrogen infrastructure.

Given the current dominance of BEVs in the UK market, the volume of low-carbon hydrogen supply requirements is likely to be lower than reflected in Table 3.

Table 3 High demand locations for hydrogen refuelling

Location	Number of uses (annual)	Total hydrogen delivered (kg)
Dalwhinnie	6205	140,722
Annandale Water	6166	290,291
Kinross	1675	46,780
Clydebank	631	18,651
Broxden	197	9,034
Ballinluig	155	8,502
Abington	133	5,658
Stirling	98	2,972
Stracathro	79	2,504
Dundee Port	64	2,040

Hydrogen Refuelling Hotspots:

- ***A90 and M74:*** The model identified significant hydrogen refuelling demand along the A90 (Perth-Aberdeen) and M74 (Glasgow-Carlisle) corridors, which serve as major freight routes. Prioritising these corridors is essential to ensure sufficient refuelling capacity.
- ***Central Belt:*** The model also indicated potential for hydrogen refuelling stations within the central belt, although to a lesser extent compared to the A90 and M74 corridors.
- ***A9:*** While the A9 corridor is expected to have lower hydrogen refuelling demand compared to the A90 and M74, it is still a significant route. This variation might be attributed to the specific operations of the fleets included in the dataset and could change with the inclusion of additional data.

Infrastructure Constraints:

- **Hydrogen Transportation:** Currently, there is limited infrastructure for large-scale hydrogen transportation, such as pipelines, which could influence refuelling station locations.
- **Hydrogen Production:** While many hydrogen production projects are proposed, most are not yet under construction. Therefore, the identified refuelling locations should be considered as speculative (Figure 5).
- **Site Selection:** Identifying suitable sites for hydrogen refuelling stations can be complex due to potential requirements for proximity to hydrogen production facilities.

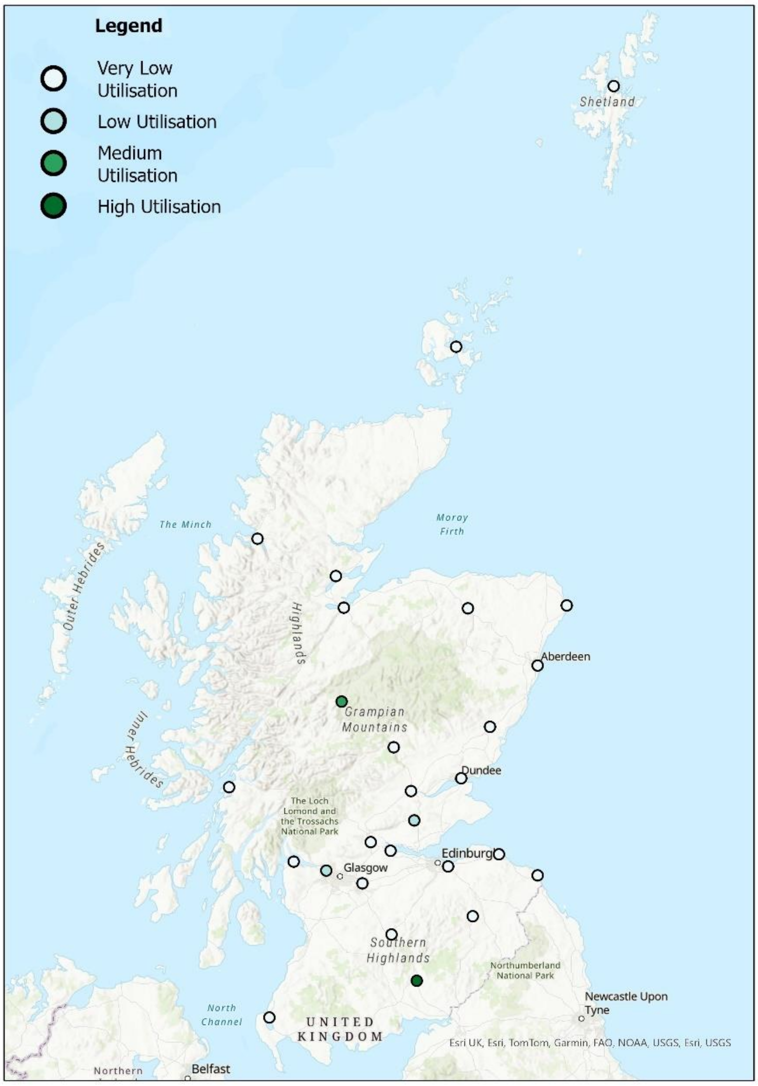


Figure 5 Locations for hydrogen refuelling locations

CONCLUSION AND FUTURE WORKS

This study has investigated the feasibility of transitioning HGV fleets in Scotland to zero-emission electric vehicles (EVs) and explored the associated infrastructure requirements for both battery electric (BEV) and hydrogen fuel cell electric (FCEV) options. The simulation results and analysis provide valuable insights for future planning and investment decisions.

Data Updates

Expanding the dataset with additional HGV journey data is crucial for a more accurate understanding of infrastructure needs and building a robust evidence base for investment in HGV charging and refuelling stations.

Integrating aggregated data sources, such as forestry data and traffic count data, could potentially enhance the model's relevance to all heavy vehicle operations in Scotland, even though this data may have limitations in quality.

Access to more comprehensive data will allow for a deeper analysis of low, medium, and high charging demand scenarios. Distribution Network Operators (DNOs) emphasise the importance of detailed scenarios combined with charging timeframes for planning future energy infrastructure.

Remote locations with insufficient existing host infrastructure (e.g., service stations, truck stops) for charging were identified, including the A9 north of Invergordon, Shetland, and potentially the A82, A83, A77, and ferry routes to the islands. The need for further modelling in these areas will be re-evaluated as additional data becomes available.

The final Network Development Plan for 2024 from SSEN will be used in future iterations of the report[20] for a more accurate grid impact assessment.

Report Updates

An updated version of this report is planned for publication later in 2025.

Contributions of additional journey data from HGV fleets are highly encouraged. Details regarding the required telematics data format, storage practices, and anonymization procedures can be obtained by contacting cls-info@hw.ac.uk.

Transport Scotland is developing a forum for stakeholders including HGV fleet operators, chargepoint operators, financiers, and others interested in zero-emission HGV infrastructure development. To join this forum and potentially express interest in specific charging locations, please email FleetsandInfrastructure@transport.gov.scot. This forum aims to foster collaboration and potentially secure the necessary investment for infrastructure projects. Early engagement with DNOs is also recommended for those considering the installation of charging infrastructure in the future. Contacting your DNO can help in understanding the information required to secure the electricity needed for charging stations.

By fostering collaboration, data sharing, and continued research, stakeholders can work together to make the transition to zero-emission HGVs in Scotland a reality.

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[20] https://www.ssen.co.uk/globalassets/our-services/network-capacity/network-development-plan-consultation-documents/2024/sepd-network-scenario-headroom-report-2024.xlsx

APPENDIX A POTENTIAL LOCATIONS FOR CHARGING HUBS AND REFUELLLING STATIONS

Table 4 Proposed charging hubs and refuelling stations

* Charging or refuelling stations can be located within a 5 km radius of the locations in this table.

PlaceID	PlaceName	Latitude	Longitude
2345	M90	56.37715	-3.416235
4713	Stirling Services	56.07575	-3.92248
4714	Kinross Services	56.20874	-3.444
4715	Abington Services	55.5064	-3.69442
4716	Stracathro Services	56.77769	-2.61558
4717	Thurso Overnight Lorry Park	58.59409	-3.51688
4718	Skiach Services	57.67578	-4.30427
4719	Ashgrove Filling Station and Restaurant	57.48425	-2.85587
4720	Dalwhinnie Service Station	56.92856	-4.24181
4721	Ballinluig Motorgrill	56.65419	-3.66884
4722	Broxden Services	56.38799	-3.48168
4723	Loch Ryan Port	54.98555	-5.03513
4724	Annandale Water Services	55.21588	-3.41607
4727	Peterhead Port	57.50258	-1.77417
4728	Port of Aberdeen	57.14632	-2.09344
4729	Grangemouth Docks	56.02327	-3.70504
4730	Dundee Port	56.46625	-2.9288
4731	Greenock Port	55.95605	-4.766
4732	Ullapool Ferry Port	57.89441	-5.16306
4733	Ardrossan Ferry Port	55.64068	-4.8233
4734	Brodick Ferry Port	55.5766	-5.13907
4735	Campbeltown Ferry Port	55.42501	-5.60263
4736	Craignure Mull Ferry Port	56.46594	-5.69872
4737	Kennacraig Ferry Port	55.83303	-5.45331
4738	Mallaig Ferry Port	57.00634	-5.82848
4739	Oban Ferry Port	56.41219	-5.47596
4740	Port Askaig Ferry Port	55.85013	-6.10661
4741	Stornoway Ferry Port	58.20688	-6.38656
4743	Spean Bridge	56.89569	-4.91513
4744	Clydebank Railway Station	55.90125	-4.40796
4745	Inverness Seafield	57.48875	-4.21516
4746	Edinburgh East	55.92628	-3.07274
4747	Kyle of Lochalsh	57.28143	-5.71856
4748	Galashiels	55.6194	-2.8033
4749	Dunbar	56.00272	-2.5169
4750	Eyemouth	55.871	-2.093
4751	Mossend Intl Railfreight Park	55.82227	-4.01341

APPENDIX B DESCRIPTIVE STATISTICS OF THE STAKEHOLDER'S JOURNEY

This appendix provides an overview of the routes in the original dataset, including the distribution of the number of stops, route length (in kilometres), and route duration (in minutes). It also presents the distributions of the feasible routes for each of Scenarios A, B, and C. Additionally, the appendix compares each new route with its original counterpart, showing both the difference ("new – original") and the ratio ("new/original").

For each distribution, we provide the mean, standard deviation, and key quantiles (50%, 75%, and 90%). These quantiles represent the smallest values that exceed 50%, 75%, and 90% of the data, respectively. The total number of feasible routes is also included.

Table 5 Distribution of the number of stops on routes. Units: Stops.

	Original routes	**Scenario A** (depot charging only)	**Scenario B** (en route charging only)	**Scenario C** (both)
Mean	2.74	3.2	3.81	3.89
Standard Deviation	5.2	5.98	6.49	7.04
50% (median)	2	2	3	3
75%	3	3	5	5
90%	4	5	6	6
Count	84,190	54,655	81,973	84,190

Table 6 Distribution of the number of additional stops on routes (from the formula "new-original"). Units: Stops.

	Scenario A (depot charging only)	**Scenario B** (en route charging only)	**Scenario C** (both)
Mean	0.03	1.08	1.15
Standard Deviation	0.19	3.51	4.1
50% (median)	0	0	0
75%	0	2	2
90%	0	3	3
Count	54,655	81,973	84,190

Table 7 Distribution of route length. Units: km.

	Original routes	**Scenario A** (depot charging only)	**Scenario B** (en route charging only)	**Scenario C** (both)
Mean	227.69	107.12	238.72	242.69
Standard Deviation	242.04	81.21	306.59	341.4
50% (median)	148.28	103.43	148.42	148.28
75%	360.54	151.14	387.87	388.54
90%	550.43	206.94	556.02	552.24
Count	84,190	54,655	81,973	84,190

Table 8 Distribution of additional route length (from the formula "new-original"). Units: km.

	Scenario A (depot charging only)	**Scenario B** (en route charging only)	**Scenario C** (both)
Mean	1.39	12.44	15.01
Standard Deviation	9.77	147.79	176.97
50% (median)	0	0	0
75%	0	5.58	2.71
90%	0	30.23	30.23
Count	54,655	81,973	84,190

Table 9 Distribution of route length (ratio, from formula "new/original").

	Scenario A (depot charging only)	**Scenario B** (en route charging only)	**Scenario C** (both)
Mean	1.01	1.04	1.04
Standard Deviation	0.04	1.5	1.51
50% (median)	1	1	1
75%	1	1.01	1.01
90%	1	1.07	1.07
Count	54,655	81,973	84,190

Table 10 Distribution of route time. Units: minutes.

	Original routes	**Scenario A** (depot charging only)	**Scenario B** (en route charging only)	**Scenario C** (both)
Mean	162.03	84.53	173.76	176.32
Standard Deviation	161.41	67.18	223.79	250.43
50% (median)	109.25	78.93	109.52	109.25
75%	273.78	111.17	290.33	292.42
90%	376.98	157.07	384.78	381.48
Count	84,190	54,655	81,973	84,190

Table 11 Distribution of additional route time (from formula "new-original"). Units: minutes.

	Scenario A (depot charging only)	**Scenario B** (en route charging only)	**Scenario C** (both)
Mean	1	12.38	14.3
Standard Deviation	6.93	121.81	145.43
50% (median)	0	0	0
75%	0	7.8	4.65
90%	0	33.52	32.37
Count	54,655	81,973	84,190

Table 12 Distribution of route time (ratio, from formula "new/original").

	Scenario A (depot charging only)	**Scenario B** (en route charging only)	**Scenario C** (both)
Mean	1.01	1.04	1.05
Standard Deviation	0.04	0.69	0.77
50% (median)	1	1	1
75%	1	1.02	1.03
90%	1	1.1	1.11
Count	54,655	81,973	84,190

APPENDIX C CHARGE AND REFUELLING LOCATIONS, WITH ANNUAL USAGE

This appendix gives the charging and refuelling locations, along with annual usage. Table 2 and Table 3 are the first few rows of these tables. More locations were utilised for electric recharging compared to hydrogen refuelling; the unused locations in the hydrogen scenario are not listed in the table.

Table 13 Locations for hydrogen refuelling (with tolerance of ± 5km radius), with annual demand.

Location	Longitude	Latitude	Number of uses (annual)	Total Hydrogen Delivered (kg)
Dalwhinnie Service Station	-4.24181	56.92856	6205	140721.9
Annandale Water Services	-3.41607	55.21588	6166	290291.3
Kinross Services	-3.444	56.20874	1675	46779.92
Clydebank Railway Station	-4.40796	55.90125	631	18650.7
Broxden Services	-3.48168	56.38799	197	9033.739
Ballinluig Motorgrill	-3.66884	56.65419	155	8501.654
Abington Services	-3.69442	55.5064	133	5657.966
Stirling Services	-3.92248	56.07575	98	2971.868
Stracathro Services	-2.61558	56.77769	79	2504.101
Dundee Port	-2.9288	56.46625	64	2040.058
Mossend Intl Railfreight Park	-4.01341	55.82227	61	4323.49
Grangemouth Docks	-3.70504	56.02327	36	1098.109
Ashgrove Filling Station and Restaurant	-2.85587	57.48425	18	873.277
Orkney Port	-2.98533	58.99816	10	749.92
Port of Aberdeen	-2.09344	57.14632	10	978.501
Inverness Seafield	-4.21516	57.48875	10	605.118
Skiach Services	-4.30427	57.67578	6	156.074
Dunbar	-2.5169	56.00272	6	190.894
Sullom Voe Port	-1.25824	60.44283	5	103.447
Galashiels	-2.8033	55.6194	4	137.299
Peterhead Port	-1.77417	57.50258	3	262.777
Oban Ferry Port	-5.47596	56.41219	3	75.956
Edinburgh East	-3.07274	55.92628	3	86.964
Eyemouth	-2.093	55.871	3	131.791
Greenock Port	-4.766	55.95605	2	94.447
Ullapool Ferry Port	-5.16306	57.89441	2	119.351
Loch Ryan Port	-5.03513	54.98555	1	25.759

Table 14 Locations for battery charging (with tolerance of ± 5km radius), with annual demand

Location	Longitude	Latitude	Number of uses (annual)	Total Charge Delivered (MWh)
Dalwhinnie Service Station	-4.24181	56.92856	11180	2356808
Ballinluig Motorgrill	-3.66884	56.65419	8801	1408604
Stracathro Services	-2.61558	56.77769	8490	2045237
Abington Services	-3.69442	55.5064	6950	1570971
Kinross Services	-3.444	56.20874	4662	944957.2
Annandale Water Services	-3.41607	55.21588	3835	937305.8
Broxden Services	-3.48168	56.38799	3625	821768.8
Mossend Intl Railfreight Park	-4.01341	55.82227	2890	657539.3
Clydebank Railway Station	-4.40796	55.90125	2538	576111.2
Dundee Port	-2.9288	56.46625	2152	475706.9
Ashgrove Filling Station and Restaurant	-2.85587	57.48425	2050	397628.7
Galashiels	-2.8033	55.6194	1895	309862
Kyle of Lochalsh	-5.71856	57.28143	1820	362733.1
M90	-3.41624	56.37715	1696	135081.2
Stirling Services	-3.92248	56.07575	1567	290300.3
Edinburgh East	-3.07274	55.92628	1531	251828.9
Oban Ferry Port	-5.47596	56.41219	1515	324201.9
Kennacraig Ferry Port	-5.45331	55.83303	1043	264320.5
Grangemouth Docks	-3.70504	56.02327	944	108940.6
Brodick Ferry Port	-5.13907	55.5766	698	121281.6
Loch Ryan Port	-5.03513	54.98555	679	158393.3
Peterhead Port	-1.77417	57.50258	559	129506.8
Dunbar	-2.5169	56.00272	559	129688.7
Skiach Services	-4.30427	57.67578	548	158930.7
Thurso Overnight Lorry Park	-3.51688	58.59409	520	70524.22
Spean Bridge	-4.91513	56.89569	482	75606.52
Craignure Mull Ferry Port	-5.69872	56.46594	468	127583.4
Port of Aberdeen	-2.09344	57.14632	452	23505.48
Inverness Seafield	-4.21516	57.48875	314	83528.98
Greenock Port	-4.766	55.95605	312	86789.17
Mallaig Ferry Port	-5.82848	57.00634	312	86663.3
Eyemouth	-2.093	55.871	306	59406.2
Ardrossan Ferry Port	-4.8233	55.64068	246	45507.47
Campbeltown Ferry Port	-5.60263	55.42501	55	10918.44
Port Askaig Ferry Port	-6.10661	55.85013	55	9763.548
Ullapool Ferry Port	-5.16306	57.89441	4	740.392
Stornoway Ferry Port	-6.38656	58.20688	2	344.084

APPENDIX D CHARGER AND SUBSTATION LOCATIONS

This appendix presents the charger locations used in the model, along with details of the nearest electricity network primary substations. The table is ordered by the maximum number of visitors on a single day; this gives a slightly different ordering from Table 13 and Table 14, which are about total use of each charging station across the year.

Table 15 Charger locations (with tolerance of ± 5km radius) and the nearest primary substation locations – an analysis of demand capacity headroom (abbreviated as H'room).

Charger Details			Nearest Primary Substation					High Usage		Low Usage	
Charger Location	**Charger Longitude**	**Charger Latitude**	**Substation Name**	**Longitude**	**Latitude**	**DNO**	**H'room (MW)**	**H'room (MW)**	**Valid**	**H'room (MW)**	**Valid**
Dalwhinnie Service Station	-4.24181	56.92856	Dalwhinnie	-4.2413	56.9332	SSEN	0.261138	-8.73886	FALSE	-4.23886	FALSE
Ballinluig Motorgrill	-3.66884	56.65419	Pitlochry	-3.70449	56.71093	SSEN	2.58732	-5.41268	FALSE	-1.41268	FALSE
Stracathro Services	-2.61558	56.77769	Inchbare	-2.64498	56.77831	SSEN	1.576156	-5.92384	FALSE	-2.42384	FALSE
Abington Services	-3.69442	55.5064	Symington	-3.60761	55.60616	SPEN	3.38757	-4.11243	FALSE	-0.61243	FALSE
Kinross Services	-3.444	56.20874	Milnathort	-3.42264	56.23002	SSEN	0.084175	-5.91583	FALSE	-2.91583	FALSE
Broxden Services	-3.48168	56.38799	Burghmuir	-3.48789	56.39664	SSEN	1.161767	-3.83823	FALSE	-1.33823	FALSE
Annandale Water Services	-3.41607	55.21588	Kirkbank	-3.42226	55.19831	SPEN	5.522487	1.022487	TRUE	3.022487	TRUE
Grangemouth Docks	-3.70504	56.02327	Zetland Park	-3.71981	56.0113	SPEN	18.23533	13.73533	TRUE	15.73533	TRUE
Dundee Port	-2.9288	56.46625	Milton Of Craigie	-2.92469	56.47538	SSEN	11.91308	8.413076	TRUE	9.913076	TRUE
Clydebank Railway Station	-4.40796	55.90125	Clydebank Business Park	-4.41213	55.90476	SPEN	9.619889	6.119889	TRUE	7.619889	TRUE
Mossend Intl Railfreight Park	-4.01341	55.82227	Bellshill (Primary)	-4.02159	55.82148	SPEN	9.955986	6.455986	TRUE	7.955986	TRUE
Ashgrove Filling Station and Restaurant	-2.85587	57.48425	Huntly	-2.78857	57.44081	SSEN	7.481566	4.481566	TRUE	5.981566	TRUE
Stirling Services	-3.92248	56.07575	St. Ninians	-3.93173	56.09982	SPEN	2.45816	-0.04184	FALSE	0.95816	TRUE
Edinburgh East	-3.07274	55.92628	Monktonhall	-3.05896	55.9317	SPEN	2.781627	0.281627	TRUE	1.281627	TRUE
Oban Ferry Port	-5.47596	56.41219	Oban	-5.47594	56.40748	SSEN	7.809499	5.809499	TRUE	6.809499	TRUE
Galashiels	-2.8033	55.6194	Glendinning Terrace	-2.82136	55.62496	SPEN	1.502028	-0.49797	FALSE	0.502028	TRUE
Kyle of Lochalsh	-5.71856	57.28143	Kyle	-5.70975	57.28101	SSEN	5.880384	4.380384	TRUE	4.880384	TRUE

Table 15 Conti…

Charger Details			Nearest Primary Substation					High Usage		Low Usage	
Charger Location	**Charger Longitude**	**Charger Latitude**	**Substation Name**	**Longitude**	**Latitude**	**DNO**	**H'room (MW)**	**H'room (MW)**	**Valid**	**H'room (MW)**	**Valid**
Brodick Ferry Port	-5.13907	55.5766	Brodick	-5.14255	55.57244	SSEN	5.722444	4.222444	TRUE	4.722444	TRUE
Kennacraig Ferry Port	-5.45331	55.83303	Tarbert Loch Fyne	-5.42125	55.86185	SSEN	1.553197	0.053197	TRUE	0.553197	TRUE
Peterhead Port	-1.77417	57.50258	Peterhead North Street	-1.77685	57.50805	SSEN	9.043945	7.543945	TRUE	8.043945	TRUE
Inverness Seafield	-4.21516	57.48875	Waterloo Place	-4.23166	57.48266	SSEN	7.692644	6.692644	TRUE	7.192644	TRUE
Port of Aberdeen	-2.09344	57.14632	Commerce Street	-2.08731	57.14739	SSEN	8.78039	7.78039	TRUE	8.28039	TRUE
Spean Bridge	-4.91513	56.89569	Inverlochy	-5.08838	56.82808	SSEN	5.085474	4.085474	TRUE	4.585474	TRUE
Ardrossan Ferry Port	-4.8233	55.64068	Saltcoats Main	-4.79728	55.64573	SPEN	20.7034	19.7034	TRUE	20.2034	TRUE
Greenock Port	-4.766	55.95605	Caddlehill	-4.77191	55.9475	SPEN	11.27893	10.27893	TRUE	10.77893	TRUE
Skiach Services	-4.30427	57.67578	Crosshills	-4.25902	57.70102	SSEN	5.731175	4.731175	TRUE	5.231175	TRUE
Eyemouth	-2.093	55.871	Eyemouth	-2.10196	55.86939	SPEN	4.975515	3.975515	TRUE	4.475515	TRUE
Loch Ryan Port	-5.03513	54.98555	Auchneel	-5.06881	54.9106	SPEN	3.253249	2.253249	TRUE	2.753249	TRUE
Dunbar	-2.5169	56.00272	Spott Road	-2.50893	55.99397	SPEN	5.415706	4.415706	TRUE	4.915706	TRUE
Thurso Overnight Lorry Park	-3.51688	58.59409	Mount Pleasant	-3.50334	58.58967	SSEN	3.640604	2.640604	TRUE	3.140604	TRUE
Ullapool Ferry Port	-5.16306	57.89441	Ullapool	-5.15694	57.90139	SSEN	-1.33116	-1.83116	FALSE	-1.83116	FALSE
Craignure Mull Ferry Port	-5.69872	56.46594	Lochdonhead	-5.68614	56.44453	SSEN	0.113509	-0.38649	FALSE	-0.38649	FALSE
Campbeltown Ferry Port	-5.60263	55.42501	Campbeltown	-5.61268	55.42717	SSEN	6.574363	6.074363	TRUE	6.074363	TRUE
Orkney Port	-2.98533	58.99816	Kirkwall	-2.96431	58.98243	SSEN	-6.02418	-6.52418	FALSE	-6.52418	FALSE
Port Askaig Ferry Port	-6.10661	55.85013	Port Askaig	-6.12156	55.84341	SSEN	1.597719	1.097719	TRUE	1.097719	TRUE
Mallaig Ferry Port	-5.82848	57.00634	Mallaig	-5.82626	56.98587	SSEN	7.202778	6.702778	TRUE	6.702778	TRUE
Stornoway Ferry Port	-6.38656	58.20688	Battery Point	-6.37365	58.20335	SSEN	3.931943	3.431943	TRUE	3.431943	TRUE