TRANSPORT SCOTLAND
CÒMHDHAIL ALBA

transport.gov.scot

Zero Emission Energy for Transport Project Report

Regional Case Study: Fife

Contents

1. Introduction 3
1.1 Study Area 3
1.2 Overarching Approach 4
2. Methodology 6
2.1 Transport Demand 6
2.1.1 Road Transport Demand 6
2.1.2 Rail Transport Demand 8
2.1.3 Maritime Transport Demand 9
2.2 Hydrogen Transition Scenarios 12
2.2.1 Road Transition 12
2.2.3 Maritime Transition 17
3. Hydrogen Demand Forecasts 21
3.1 Road Results 21
3.1.1 Cars and Vans 21
3.1.2 Buses and Coaches 23
3.1.3 HGVs and HDVs 24
3.3 Maritime Results 25
3.3.1 Shipping 25
3.3.2 Ferries 27
6. Hydrogen Demand Mapping 29
6.1 Roads 29
Cars 29
Vans 31
HGVs 33
7.0 Appendices 35
7.1 Buses and Coaches 35
7.2 Ferries 36

1. Introduction

1.1 Study Area

The Fife Council area in Scotland covers over 1,300 square kilometres and is the third largest local government area in Scotland by population with approximately 370,000 people. A third of its population live in the towns of Dunfermline, Kirkcaldy and Glenrothes. The Fife Council area is a natural peninsular, sharing its western borders with Perthshire.

Almost all road traffic into and out of Fife must pass over one of four bridges: south on the Forth Road Bridge (public transport and cyclists only) and Queensferry Crossing, west on the Kincardine Bridge or north-east via the Tay Road Bridge - the exception being traffic headed north on the M90.

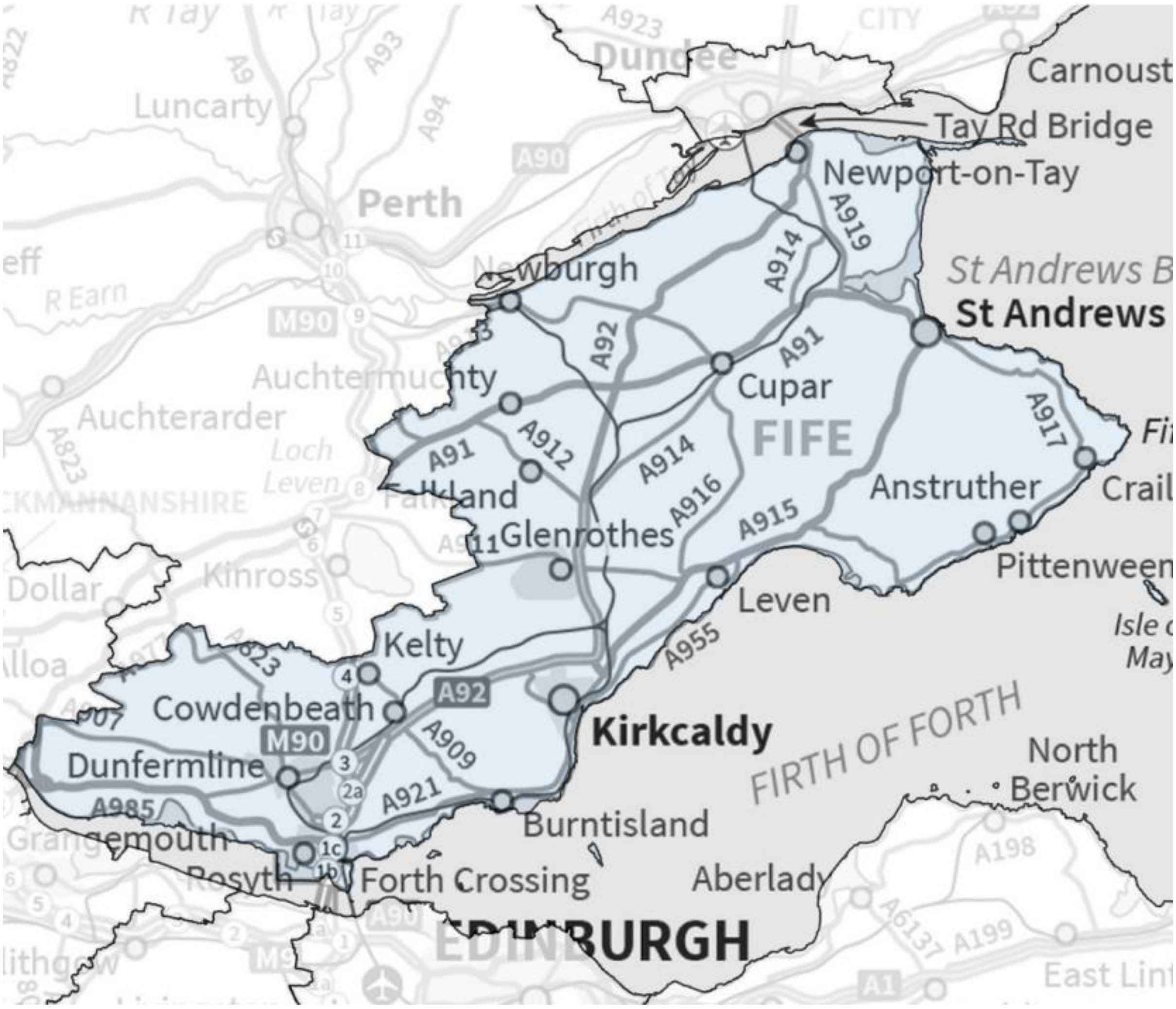


Figure 1 - Map of the Fife Council area, adapted from the Scottish Government 2022.

1.2 Overarching Approach

Transport Scotland commissioned Jacobs to develop regional demand forecasts for the Fife Council area for three potential Low (Scenario A), Medium (Scenario B) and High (Scenario C) hydrogen uptake scenarios across all transport modes as part of its commitment to decarbonise the transport sector. This three-scenario approach was adopted for simplicity and flexibility to compare different scenarios easily.

The details of this study for the Fife Council area are outlined in the following report and estimate annual hydrogen demand for domestic or intra-Scotland transport including road and maritime annually between 2022 and 2030, and for 2035, 2040 and 2045.

In terms of aviation demand, it has been omitted due to the lack of major airports in the Fife region specifically. Additionally, according to the *Rail Decarbonisation Action Plan* (RDAP), it is the Scottish Government's intention to provide overhead electrification for all lines within the Fife Council area by 2035. Consequently, the use of hydrogen for rail traction within Fife is considered unlikely and therefore also omitted.

The three-part approach was adopted for forecasting hydrogen demand for transport in the Fife Council area is as follows:

1. Transport Demand Baseline and Forecasting
2. Hydrogen Transition Scenario Development and Modelling
3. Hydrogen Demand Calculations and Analysis

While the overarching process was consistent across all transport modes (1-3 above), the individual methods for forecasting transport demand varied according to data availability, which is discussed in the following sections.

The study's results are a series of hydrogen demand forecasts for transport in each forecast year for the three scenarios. These results are then broken down into further categories; by transport mode (road and maritime) and individual types of vehicles or vessels (as relevant).

This report is accompanied by a Microsoft Excel Results Tool (Tool) detailing the results for all three regional areas studied: Fife, Highland, as well as Dumfries and Galloway Council area. The Tool enables the exploration and comparison between scenarios in greater detail beyond what is included within this report.

Overall, this study has been designed with the intention to inform the market of three possible hydrogen demand scenarios for transport purposes in the Fife Council area. While supply side considerations such as capacity of the existing infrastructure to produce and distribute hydrogen are critical, they have not constrained the modelling process. This is because a key objective of the study is to indicate potential maximum demand scenarios for transport and thereby stimulate investment infrastructure for supply.

2. Methodology

2.1 Transport Demand

The Fife Council area is multi-modal, being serviced by most transport modes including road, rail and maritime – except for aviation. The following sections describe characteristics of the existing transport demand across the study area (where applicable) and the methods used to quantify transport demand for each mode within the Fife Council area.

2.1.1 Road Transport Demand

Cars and Vans

Car and van use within the Fife Council area, is distributed across the population and employment centres, rather than at specific points of interest. This is due to cars and vans being a fundamental transport mode across all sectors of the population. For this reason, it is necessary to approach and view transport demand, and the potential hydrogen demand for cars and vans as an overall function of the vehicle fleet, rather than a series of discrete geographic areas of demand.

The accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen*** outlines the bottom-up approach adopted to calculate hydrogen demand at a national level using transport demand projections from TMfS18.To establish the demand for the Fife Council area, it was necessary to disaggregate the national demand down to the local authority level.

The disaggregation process utilised the zonal system from the TMfS:18 strategic transport model. The TMfS:18 model follows the standard demand model pattern of assigning origin-destination (OD) pairs to a road network to generate flows of traffic along the network. The origin totals for each zone were used to disaggregate the national demand. This process works under the assumption that most of the demand for hydrogen will be occurring at the point of origin for each journey rather than on route. The equation is as follows:

$$H_2Demand_{Zone1,Y,S} = H_2Demand_{Y,S} \frac{\sum Origin_{Zone1,Y,S}}{\sum_{Zone=All\ Zones} Origin_{Zone,Y,S}}$$

Where H_2Demand is the hydrogen demand for a specific year, Y, and for a specific scenario, S. $Origin_{Zone,Y,S}$ is the origin total for a specific zone, year and scenario.

By utilising this equation and the results of the accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen*** it was therefore possible to disaggregate transport demand for hydrogen a lower level to represent the Fife Council area specifically.

HGVs and HDVs

The same approach to establish transport demand for cars and vans, was also used for HGVs and HDVs. However, HGV demand within the Fife Council area is expected to be distributed across the major employment centres, with some concentration at freight depots. This is because HGV demand characteristically being more heterogenous than for cars or vans. However, demand is still dispersed across many different local areas and for this reason, it is necessary to approach and view demand for HGVs as an overall function of the vehicle fleet, rather than a series of discrete geographic areas.

Buses and Coaches

Bus and coach transport in the Fife Council area consists of a mixture of buses which perform timetabled public services on several routes, as well as coaches largely used for private hire or excursions across the region. Each type of service is dominated by a few large operators, but smaller firms also operate in each category on a much smaller scale.

The largest bus and coach operator in the region is Stagecoach, which has depots in Aberhill, Cowdenbeath, Dunfermline, Glenrothes and St. Andrews. Most vehicles that are owned by Stagecoach are buses which run local scheduled bus services, but there are also a significant number of coaches at most of these depots.

The next largest operator is Moffat and Williamson, based at St. Fort and Glenrothes. The company runs service buses on timetabled routes around Fife as well as hiring out coaches for local hires, school trips, airport transfers, sporting occasions, theatre trips, shopping trips or any type of private hire. Several smaller operators with less than 50 buses and coaches each also operate throughout the region.

In terms of methods to establish transport demand for bus and coach services in the Fife region, this has been established using two complementary approaches:

First national demand figures provided through TMfS:18 data were disaggregated for each of the six national technology transition scenarios for the Fife Council area specifically. Since the TMfS:18 data only included local data for service buses, secondary sources of bus and coach data were located within the local region (such as council information) and cross-checked to establish reliability.

Additionally, bus and coach fleet operators were contacted directly where possible, to understand and verify the details of their specific fleets.

Importantly, the distance travelled buses and coaches in Fife Council area is assumed to be constant through to 2045 aligned with TMfS:18.

This process established the TMfS:18 data only varied slightly from the locally available data in terms of buses, however coaches identified were 50% greater than the model. Figure 2 below shows the difference between the number of buses in the disaggregated national model for the Fife Council area and the number of vehicles identified through the verification process. As shown, 412 buses and coaches were identified, of which 239 are buses and 174 are coaches.

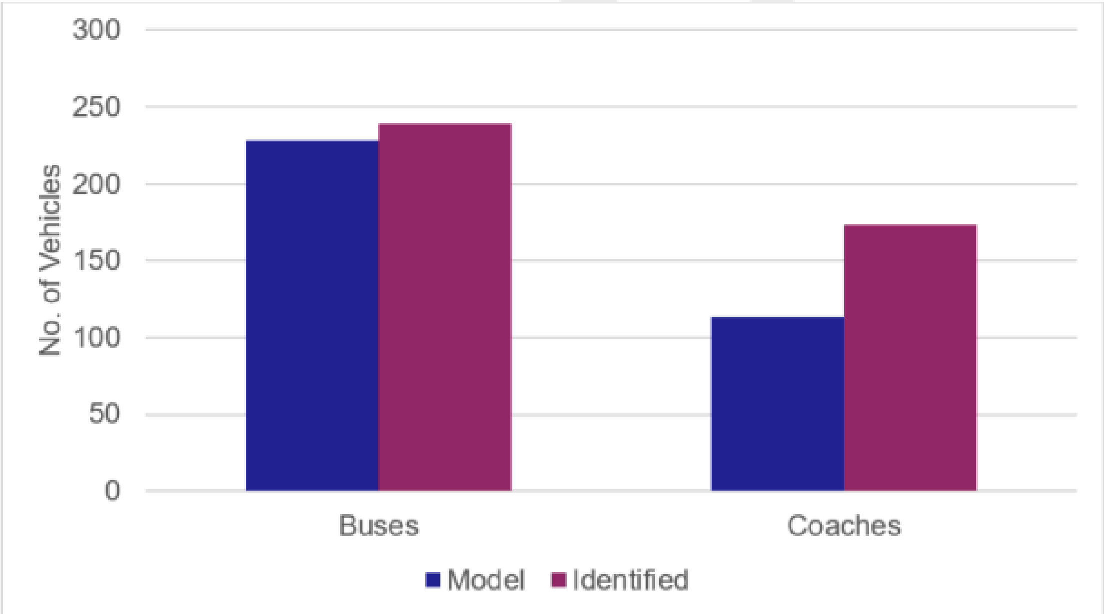


Figure 2 - Numbers of buses and coaches modelled versus identified through verification in the Fife region

Since the bus figures are comparable, the disaggregated national model from TMfS:18 has been used to generate the hydrogen scenarios. However, given the disparity between this model and coach figures, the TMfS:18 datasets were adjusted to account for the verified data. This approach was adopted to ensure accuracy.

2.1.2 Rail Transport Demand

The Rail Services Decarbonisation Action Plan sets out to fully electrify the rail network in Fife and therefore it is assumed that all services in Fife will be operated by either overhead electric multiple units or battery electric units and therefore hydrogen usage for rail transport in Fife is highly unlikely. Consequently, no hydrogen forecasts for rail have been produced and demand is assumed to be zero under all scenarios.

2.1.3 Maritime Transport Demand

Shipping

The UK Department for Transport: Maritime and Shipping provides data on tonnes of cargo handled at each port in Scotland. In total, Fife Council area represented only 0.3% of all tonnes handled at Scottish ports in 2019, as there is no major cargo nor fishing ports in the area. Inverkeithing is the major commercial port within region. The port handled 158,000 tonnes of cargo in 2019, however, as shown in Figure 3 below the port has experienced a shrinking demand between 2015 and 2020. Large proportion of the cargo was handled internationally, mainly for limestones exports.

There are also six other fishing ports within the region with significant volumes of traded cargo: Pittenweem, Anstruther, Crail, Methil & Leven, St Andrews and St Monans.

According to the 2019 Scottish Sea Fisheries Statistics, transport demand from fishing activities within the Fife Council area were responsible for approximately 0.6% of the total fish tonnage handled at Scottish ports. This fishing tonnage has shown an uptrend between 2015 and 2019, with an average growth of 14%.

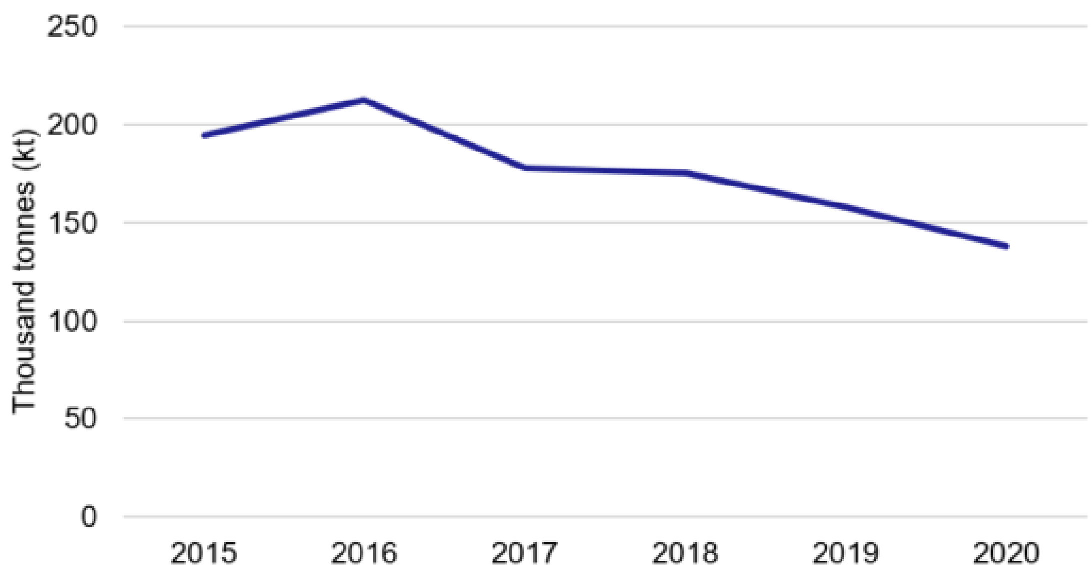


Figure 3 - Thousand tonnes handled at Inverkeithing port within the Fife Council Area (2015-2020)

In terms of methodology to establish transport demand for shipping, the same approach as for the accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen*** with some adjustments of assumptions to make them applicable at a regional level. For example, the national

2019 CO_2e from the maritime sector has been disaggregated down to the percentage of tonnes to represent each port in the Fife Council area proportionally, using the below equation:

$$Port\ A\ CO2e = Total\ CO2e * \frac{Tonnes\ Port\ A}{Tonnes\ all\ Scotland}$$

In addition, the total emissions by port for the region have been split between domestic and international to understand the different categories of potential demand for hydrogen in both domestic and international shipping markets in the future.

Finally, the future growth of transport demand at each port has been forecast based on the specific type of cargo that is being handled at each port within the Fife area. Data sources for these forecasts were obtained from DfT for major ports, while UK Ports and Harbours information was used to ascertain projected demand for minor ports. Inverkeithing port handles mostly dry bulk (i.e., limestones) which, according to the published forecasts, is expected to increase at a rate of circa 1% annually to 2045.

For the fishing ports, the forecast of tonnage has been based on the historical tonnage growth observed during the last 5 years and the same trend has been assumed to continue.

Ferries

For the purposes of this study, it is assumed that a ferry service is only operational if there is sufficient demand for the service and, therefore, transport demand can be inferred based on the existing timetabled ferry services.

The accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen*** report details the methodology Jacobs used to construct a dataset including information on the 150 ferry routes currently operational in Scotland. This dataset included individual journey length, journey times and journey frequency, along with the characteristics of the primary vessel operating the route. This dataset has been relied upon for this regional study of the Fife Council area.

Of the 150 ferry routes identified for the dataset, only one is located in the Fife region. The port is located in the small town of Anstruther to the east of Fife, and the service runs to the Isle of May National Nature Reserve. The operator providing the service on this route is Anstruther Pleasure Cruises, and the vessel currently used is the May Princess, constructed in 2005. The route length is 11 km.

To validate the datasets constructed in the accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen*** report for the local region, the operator in Table 1 was contacted to confirm the publicly sourced information. However, no response was received.

Operator	Number of routes operated	Number of Vessels	Estimated annual distance travelled (km)
Anstruther Pleasure Cruises	1	1	1,908

Table 1 - Characteristics of ferry operators in the Fife area

2.2 Hydrogen Transition Scenarios

Three technology transition scenarios have been developed for the purposes of forecasting future hydrogen energy demand for transport in the Fife Council area specifically, they include:

- A (Low) transition to hydrogen transport
- B (Medium) transition to hydrogen transport
- C (High) transition to hydrogen transport

Although there are plans for hydrogen hubs to become operational in Cromarty Firth (2024), Stornoway (2024), Orkney (2027), Fife as well as Ayrshire the impact of localised hydrogen hubs has not been considered within the hydrogen transition scenarios of this study. This is because the purpose of this study is to model potential demand, rather than consider potential limitations or availability of hydrogen-related infrastructure.

The following sections describe the key assumptions for each of the three scenarios for each transport mode. Unless specified below, the scenarios are consistent with the national technology transition scenarios the accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen*** report:

2.2.1 Road Transition

Cars and Vans

The methodology for cars and vans hydrogen transition assumes no regional specific transition drivers, with instead, the impetus for transition occurring at a national level with the zero emission vehicle requirements pushing an overall change to both electric and hydrogen.

Due to this, the transition to hydrogen and the subsequent demand for hydrogen will be driven in large part by market forces. This will be analogous to the current situation in Electric Vehicle uptake where the general purchase of EVs is not driven by specific regional specific mechanisms of transition, but rather a more global desire to switch to hydrogen.

It should be noted that hydrogen for cars and vans is currently a very uncertain market, with the distinct possibility that the Scenario A (low hydrogen) effectively represents a zero-hydrogen scenario. This is because hydrogen uptake is currently lagging EV uptake by at least a decade, and therefore will face a more challenging market in the future – with few environmental benefits compared to existing EVs.

However, for the purposes of the study, the trajectory of hydrogen vehicle uptake for cars and vans is assumed to follow TMfS:18 demand figures, leading to a peak in the total number of hydrogen vehicles purchased as a proportion of all ULEV vehicles by approximately 2035.

Due to the uncertainties around the use of hydrogen technology for cars and vans, the hydrogen uptake figures in the accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen*** report have been taken as the upper end of potential hydrogen transition scenarios.

- A (Low) transition to hydrogen transport: Cars and vans transition at 1/3 of the national rate of uptake.
- B (Medium) transition to hydrogen transport: Cars and vans transition at 2/3 of the national rate of uptake.
- C (High) transition to hydrogen transport: Cars and vans transition at the national rate of uptake.

Table 2 shows the predicted new vehicle purchase rates for cars based on the TMfS:18 uptake for Scenario A (Low).

Vehicle Type	2022	2025	2030	2035	2040	2045
ICE	76.0%	60.4%	0.0%	0.0%	0.0%	0.0%
BEV	16.1%	34.0%	96.8%	94.8%	95.0%	99.3%
Hydrogen	0.1%	0.1%	1.1%	1.7%	1.7%	0.2%

Table 2 -Predicted new vehicle purchase rates for cars based on the TMfS:18 uptake for Scenario A (Low)

Table 3 shows the predicted new vehicle purchase rates for cars based on the TMfS:18 uptake for Scenario B (Medium).

Vehicle Type	2022	2025	2030	2035	2040	2045
ICE	76.0%	60.4%	0.0%	0.0%	0.0%	0.0%
BEV	11.9%	24.0%	70.2%	94.8%	95.0%	99.3%
Hydrogen	0.1%	0.2%	2.1%	3.4%	3.3%	0.5%

Table 3 -Predicted new vehicle purchase rates for cars based on the TMfS:18 uptake for Scenario A (Medium)

Table 4 shows the predicted new vehicle purchase rates for cars based on the TMfS:18 uptake for Scenario C (High).

Vehicle Type	2022	2025	2030	2035	2040	2045
ICE	76.0%	60.4%	0.0%	0.0%	0.0%	0.0%
BEV	7.6%	14.0%	43.5%	94.8%	95.0%	99.3%
Hydrogen	0.2%	0.3%	3.2%	5.2%	5.0%	0.7%

Table 4 -Predicted new vehicle purchase rates for cars based on the TMfS:18 uptake for Scenario A (High)

Table 5 shows the predicted new vehicle purchase rates for vans based on the TMfS18 uptake for Scenario A (Low).

Vehicle Type	2022	2025	2030	2035	2040	2045
ICE	87.6%	73.3%	0.0%	0.0%	0.0%	0.0%
BEV	3.0%	6.5%	21.8%	99.0%	99.1%	99.7%
Hydrogen	0.1%	0.0%	0.9%	1.0%	0.9%	0.3%

Table 5 - Predicted new vehicle purchase rates for vans based on the TMfS18 uptake for Scenario A (Low).

Table 6 shows the predicted new vehicle purchase rates for vans based on the TMfS18 uptake for Scenario B (Medium).

Vehicle Type	2022	2025	2030	2035	2040	2045
ICE	87.6%	73.3%	0.0%	0.0%	0.0%	0.0%
BEV	6.2%	13.1%	48.6%	97.9%	98.2%	99.5%
Hydrogen	0.1%	0.1%	1.7%	2.1%	1.8%	0.5%

Table 6 - Predicted new vehicle purchase rates for vans based on the TMfS18 uptake for Scenario B (Medium).

Table 7 shows the predicted new vehicle purchase rates for vans based on the TMfS18 uptake for Scenario C (High).

Vehicle Type	2022	2025	2030	2035	2040	2045
ICE	87.6%	73.3%	0.0%	0.0%	0.0%	0.0%
BEV	6.2%	13.1%	48.6%	97.9%	98.2%	99.5%
Hydrogen	0.1%	0.1%	1.7%	2.1%	1.8%	0.5%

Table 7- Predicted new vehicle purchase rates for vans based on the TMfS18 uptake for Scenario C (High).

Buses and Coaches

The accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen*** report developed six technology transition scenarios. However, for the purposes of modelling future hydrogen demand in the Fife Council area only three scenarios for hydrogen technology uptake have been selected for buses and coaches (as outlined in Section 1.1).

The selection of three scenarios for buses and coaches has been informed by the validation exercised conducted as described in Section 2.1.1 which identified current trends in the Fife Council area (allowing more precision than the average national forecast of technology transition scenarios).

Scenario	Description	No. of buses	No. of coaches
Low hydrogen	Moderate take-up of electric vehicles with low take up of hydrogen. Transition	10	12
Medium hydrogen	Moderate take-up of electric vehicles with low take up of hydrogen. Transition	10	12
High hydrogen	Moderate take-up of electric vehicles with low take up of hydrogen. Transition	10	12

Table 8- Hydrogen bus and coach numbers 2023

Based on the same modelling technique as the national model, only one of the scenarios is consistent with the actual number of electric buses expected in Fife by 2023 and with the fact that there are no hydrogen buses planned as yet in Fife. In the national model, the number of vehicles builds gradually, representing the transition of different fleets at different times. The smaller number of vehicles transitioning in Fife will consist of only one or two fleets and so the three scenarios indicate the transition of this small local fleet at different times.

There are large enough fleets of both buses and coaches to meet this level of transition based at Glenrothes, convenient for the planned hydrogen hub at Levenmouth.

HGVs and HDVs

Similar to cars and vans, the hydrogen transition for HGVs assumes no regional specific transition drivers, with instead, the impetus for transition occurring at a national level with the zero emission vehicle requirements pushing an overall change to both electric and hydrogen.

However, unlike the cars and vans transition, it is possible that the transition to hydrogen will be driven by the potential inability of EVs to meet the HGV needs in either an ergonomic or economic sense. This is because EV HGVs would require exceptionally large batteries, as well as infrastructure with greater than 350kW charge points – greater by an order of magnitude than cars and vans.

The predicted uptake rates for HGVs have been specified within the report for the Climate Change Committee: *Analysis to provide costs, efficiencies, and roll-out trajectories for zero emission HGVs, buses and coaches*.

Vehicle Type	2022	2025	2030	2035	2040	2045
ICE	100%	100%	80%	9%	0%	0%
BEV	0%	0%	17%	77%	82%	82%
Hydrogen	0%	0%	3%	14%	18%	18%

Table 9 - Predicted uptake rates for HGVs for Scenario A (Low Hydrogen), adapted from the Climate Change Committee: Analysis to provide costs, efficiencies, and roll-out trajectories for zero emission HGVs, buses and coaches, page

Vehicle Type	2022	2025	2030	2035	2040	2045
ICE	100%	100%	80%	9%	0%	0%
BEV	0%	0%	12%	46%	62%	71%
Hydrogen	0%	0%	7%	46%	38%	29%

Table 10 - Predicted uptake rates for HGVs for Scenario B (Medium Hydrogen), adapted from the Climate Change Committee: Analysis to provide costs, efficiencies, and roll-out trajectories for zero emission HGVs, buses and coaches, page

Vehicle Type	2022	2025	2030	2035	2040	2045
ICE	100%	100%	80%	9%	0%	0%
BEV	0%	0%	13%	47%	57%	54%
Hydrogen	0%	0%	7%	45%	43%	46%

Table 11 - Predicted uptake rates for HGVs for Scenario C (High Hydrogen), adapted from the Climate Change Committee: Analysis to provide costs, efficiencies, and roll-out trajectories for zero emission HGVs, buses and coaches, page

In all scenarios, we can see the rapid drop off in the purchase rates of ICE HGVs from 2030, with the subsequent replacement by either BEV or ICE.

2.2.3 Maritime Transition

Shipping

Currently, Fife Council area has not been earmarked as a major hydrogen hub. This is because the existing hydrogen projects in the area are targeting heat as the main source of hydrogen demand – however there is possibility to expand these projects to include transport in the future.

The hydrogen transition scenarios for the Fife Council area are based on those within the accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen***, which were developed based on current and expected technological readiness, efficiencies and suitability of ammonia or hydrogen fuel compared to other substitute zero emission fuels year by year.

As with the national forecasts, ammonia has been considered preferable over hydrogen due to potential to retrofit existing ship engines to ammonia at a lower cost compared to hydrogen, its higher energy density compared to hydrogen (and therefore requiring less space to store and smaller fuel tanks) and the lower cost of production compared to methanol – an alternative biofuel.

Table 12 below summarises the three hydrogen transition scenarios modelled for Fife Council area. A low, medium and high scenarios were developed to give a range of potential hydrogen demand that would be expected for the Fife region to 2045.

Scenario	Domestic (%) – 2045	International (%) – 2045
Scenario A (Low)	20%	8%
Scenario B (Medium)	40%	32%
Scenario C (High)	76%	52%

Table 12 - Hydrogen penetration rates by 2045 for the high, medium, and low scenarios

Ferries

Although there are no hydrogen ferries currently in service, projects around the world are designing and testing hydrogen vessels including HYSEAS III in Scotland, MF Hydra in Norway, and Sea Change in California. Regardless, it can be assumed the technology is not currently available to many ferry operators in the Fife Council area. By contrast, battery electric ferries have already become operational across the world most notably in Scandinavia where Norway has been growing its electric fleet since 2015. The world's largest electric ferry, the 143 metre-long Bastø Electric, is now commercially operational. However, there are range limitations of battery technology, due to the size and weight of batteries required. As a result, alternative fuels such as hydrogen will need to be used for longer routes.

The hydrogen scenarios developed for the Fife Council area built on the route-based dataset and methodology developed for the accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen*** report. Like these national forecasts, a transition profile was developed for each ferry route in the Fife Council area. This profile estimated the year of vessel replacement and likely replacement fuel-type for each route. The modelled rate of uptake of hydrogen ferries is dependent on the maturity of hydrogen powertrains in the expected year of replacement.

In addition to hydrogen powertrain maturity, the range and performance of the predominant competing technology (battery electric vessels), would also influence future hydrogen ferry uptake. For this reason, and considering the elements above, the replacement fuel type was dependent not only on the route length, but also projected battery energy density, estimated year of replacement, and technological readiness of hydrogen in that year. This is a development from the national scenarios, where only route length was considered when assigning replacement fuel type. Due to the uncertainty around the future maturity of hydrogen powertrains, three possible hydrogen transition scenarios have been modelled, as described in Table 13 below:

Hydrogen Scenario	Lifetime (years)	Year of Hydrogen Readiness	Hybrid	Hydrogen Characteristics
A (Low)	25 + 5	2030	Yes (2022-2029)	Replacements occur up to 30 years after commissioning. Hydrogen is not viable until 2030. Replacements before 2030 are battery electric or hybrid.

Hydrogen Scenario	Lifetime (years)	Year of Hydrogen Readiness	Hybrid	Hydrogen Characteristics
B (Medium)	25	2025	Yes (2022-2025)	Replacements occur 25 years after commissioning. Hydrogen not viable until 2025. Replacements before 2025 will be battery electric or hybrid.
C (High)	25	2022	No	Replacements occur 25 years after commissioning. Hydrogen is ready to be utilised now (no technological readiness or supply side restrictions). No hybrid ferries.

Table 13 - Characteristics of the three modelled uptake scenarios

Key notes on the scenarios outlined above:

- All three scenarios assume a ‘medium’ battery electric range. During model development, it became apparent that varying the battery electric range by up to 50% scarcely affected the energy demand forecasts
- The location of specific hydrogen hubs has not been considered for any scenario.
- Vessel replacements are assumed to be either battery electric, hydrogen, or electric-diesel hybrid. Hybrid vessels are assigned in situations where battery electric technology is not viable (e.g. the route length is too great), and the year of hydrogen viability is deemed to be after the necessary replacement year.
- The replacement year of each vessel is based on its year of construction and the assumed operational lifespan of ferries. For scenarios B and C, it is assumed that ferries have a lifespan of 25 years and must be replaced in their 26^{th} year. It is assumed that each vessel is replaced midway through the 26^{th} year, so hydrogen demand is halved for the year of introduction (assuming six-months of operation).
- For Scenario A, it is assumed that a vessels lifespan can be extended for up to an additional 5 years (to 30 years) if it enables a direct transition to hydrogen (rather than the use of a hybrid powertrain). For example, if a vessel is due to be replaced in 2028, but hydrogen technology is not assumed to be viable until 2030, the replacement date can be extended by two years to ensure the vessel can transition to hydrogen rather than the hybrid diesel-electric powertrain that would otherwise be assumed.

- A 25–30 year lifespan is a conservative estimate of the actual operational lifespan of Scottish ferries. Ferries can operate for longer than 40 years. However, a 25–30 year lifespan has been assumed as this rate of replacement will be necessary to achieve the emission targets set by the Scottish Government.

Besides the methodology used to estimate the year of vessel replacement and assign an appropriate low emission replacement fuel type (as described above), the methodology is consistent with the accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen*** report, as described in Section 2.

3. Hydrogen Demand Forecasts

The following section describes the results of modelling of hydrogen demand forecasts for the Fife Council area. The forecasts have been calculated using localised transport demand and the hydrogen transition scenarios described in the preceding sections.

Additionally, the energy demand calculations for each transport mode are consistent with the calculations and assumptions described in the accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen*** report.

3.1 Road Results

3.1.1 Cars and Vans

Across the results for cars and vans, there is expected to be a limited take up of hydrogen technology for cars and vans until 2035. Compared to the national results of accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen*** report – cars represent 11.4% of the regional hydrogen demand, compared to 7.6% of the national hydrogen demand. While for vans, it is 2.3%, compared to 1.4% in the national hydrogen demand, indicating that a greater proportion of the hydrogen demand in the Fife area will be driven by cars. As with most Scottish regions, barring Edinburgh and Glasgow, this is due to a greater proportion of the transport demand being pushed by non-commercial drivers.

Scenario A (Low)

Vehicle Type	2022	2025	2030	2035	2040	2045
Cars	0.3	0.5	1.6	7.0	14.2	17.4
Vans	0.0	0.1	0.3	1.4	2.2	2.7

Table 14 - Hydrogen demand for cars and vans for Scenario A (low hydrogen)

In Scenario A, cars will require 17.4 GWh by 2045, with vans requiring 2.7 GWh.

Scenario B (Medium)

Vehicle Type	2022	2025	2030	2035	2040	2045
Cars	0.4	0.7	3.0	13.7	27.8	34.0
Vans	0.0	0.1	0.7	2.8	4.3	5.3

Table 15 - Hydrogen demand for cars and vans for Scenario B (medium hydrogen)

In Scenario B, cars will require 34.0 GWh by 2045, with vans requiring 5.3 GWh.

Scenario C (High)

Vehicle Type	2022	2025	2030	2035	2040	2045
Cars	0.4	1.0	4.3	20.2	40.9	49.9
Vans	0.0	0.2	1.0	4.2	6.4	7.9

Table 16 - Hydrogen demand for cars and vans for Scenario C (high hydrogen)

In Scenario C, cars will require 49.9 GWh by 2045, with vans requiring 7.9 GWh.

3.1.2 Buses and Coaches

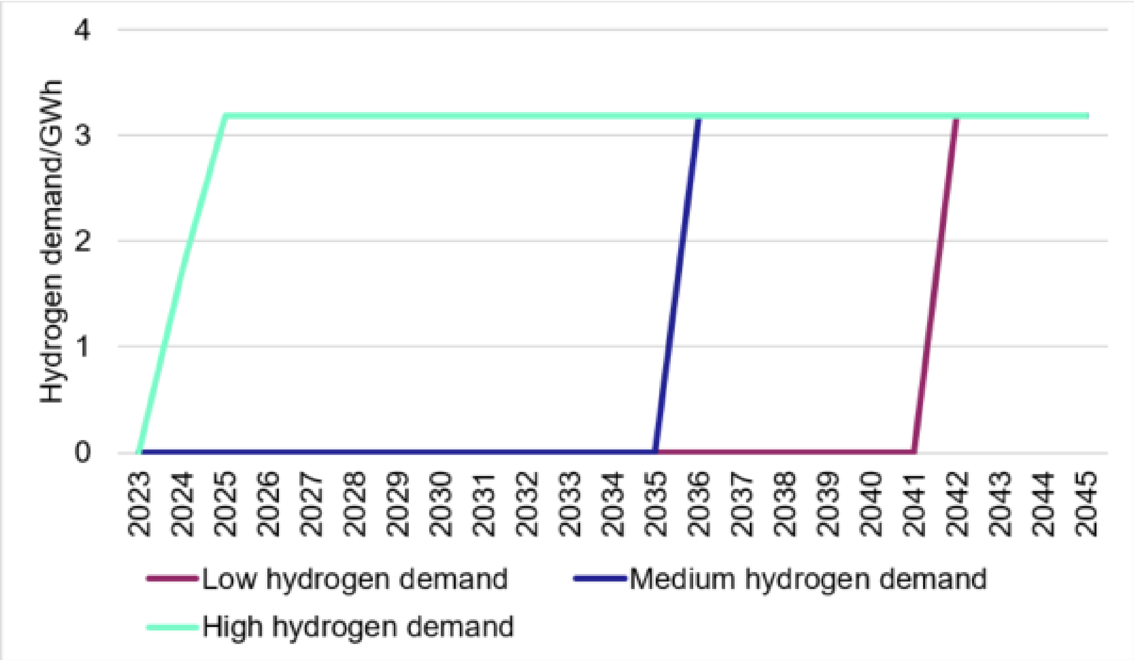


Figure 4 - Forecast hydrogen demand for buses

Figure 4 shows the high, medium and low scenarios for the demand for hydrogen over time. The numbers of buses and coaches making up this demand is presented in Table 21 in the Appendix.

Scenario A (Low)

Moderate take-up of electric vehicles occurs with a low take-up of hydrogen vehicles. The transition of the local fleet is early.

The low scenario indicates 10 buses and 12 coaches at the peak. Coaches are introduced in 2024 and buses in 2025

Scenario B (Medium)

Moderate take-up of electric vehicles occurs with a low take-up of hydrogen vehicles. The transition of the local fleet is at a most likely date.

The medium scenario indicates 10 buses and 12 coaches at the peak, which are all introduced in 2036

Scenario C (High)

Moderate take-up of electric vehicles occurs with a low take-up of hydrogen vehicles.. The transition of the local fleet is late.

The high scenario indicates 10 buses and 12 coaches at the peak, which are all introduced in 2042.

3.1.3 HGVs and HDVs

The Fife forecasts for HGVs are shown in the following tables. Unlike cars and vans, there is no take up of hydrogen at all until 2030. This is a consequence of the technology transition scenarios. However, past 2030 there is an increasingly rapid take up of hydrogen in all scenarios, and particularly in the High and Medium hydrogen scenario. Hydrogen energy demand in these two scenarios is comparable to the total energy demand for electric HGVs.

Scenario A (Low)

Assumed to follow the low uptake rates for hydrogen, as specified within the report for the Climate Change Committee: *Analysis to provide costs, efficiencies, and roll-out trajectories for zero emission HGVs, buses and coaches*.

Scenario	Vehicle Type	2022	2025	2030	2035	2040	2045
Low Hydrogen	HGV	0.0	0.0	8.3	22.8	38.8	54.0

Table 17 - Hydrogen demand for HGVs for Scenario A (low hydrogen)

In Scenario A, HGVs will require 54.0 GWh by 2045.

Scenario B (Medium)

Assumed to follow the medium uptake rates for hydrogen, as specified within the report for the Climate Change Committee: *Analysis to provide costs, efficiencies, and roll-out trajectories for zero emission HGVs, buses and coaches*.

Scenario	Vehicle Type	2022	2025	2030	2035	2040	2045
Medium Hydrogen	HGV	0.0	0.0	18.1	66.9	103.3	123.9

Table 18 - Hydrogen demand for HGVs for Scenario B (medium hydrogen)

In Scenario B, HGVs will require 123.9 GWh by 2045.

Scenario C (High)

Assumed to follow the high uptake rates for hydrogen, as specified within the report for the Climate Change Committee: *Analysis to provide costs, efficiencies, and roll-out trajectories for zero emission HGVs, buses and coaches*.

Scenario	Vehicle Type	2022	2025	2030	2035	2040	2045
High Hydrogen	HGV	0.0	0.0	18.3	65.5	105.2	139.5

Table 19 - Hydrogen demand for HGVs for Scenario (high hydrogen)

In Scenario A, HGVs will require 139.5 GWh by 2045.

From comparison to the national forecasts accompanying ***Zero Emission Energy for Transport: National Demand Forecasts for Electricity and Hydrogen*** report, the regional forecasts for hydrogen broadly follow the national forecasts. However, there is a reduction in the percentage of hydrogen being used for HGVs when compared to the national forecasts. This is potentially due to relatively limited large centres of employment or commerce in Fife when compared to other areas in Scotland. It is these employment/commerce centres which drive the HGV origin totals under the TMfS18.

3.3 Maritime Results

3.3.1 Shipping

The Fife forecasts for shipping are shown in Table 20. There is no take up of hydrogen at all until 2030. This is because technology to retrofit existing ship engines to ammonia is not expected to be commercially available until early 2030s.

Scenario (GWh)	2022	2025	2030	2035	2040	2045
Scenario A (Low)	0	0	0.2	1.6	3.2	5.0
Scenario B (Medium)	0	0	0.7	4.3	8.6	13.6

Scenario (GWh)	2022	2025	2030	2035	2040	2045
Scenario C (High)	0	0	1.2	7.6	15.1	23.9

Table 20 - Hydrogen demand for Fife Council area (GWh)

By 2045, the hydrogen demand from Fife shipping sector circa 0.3% of the national hydrogen demand. This low demand is in line with the low proportion of tonnes being handled within the region compared to the total tonnage being handled at national level.

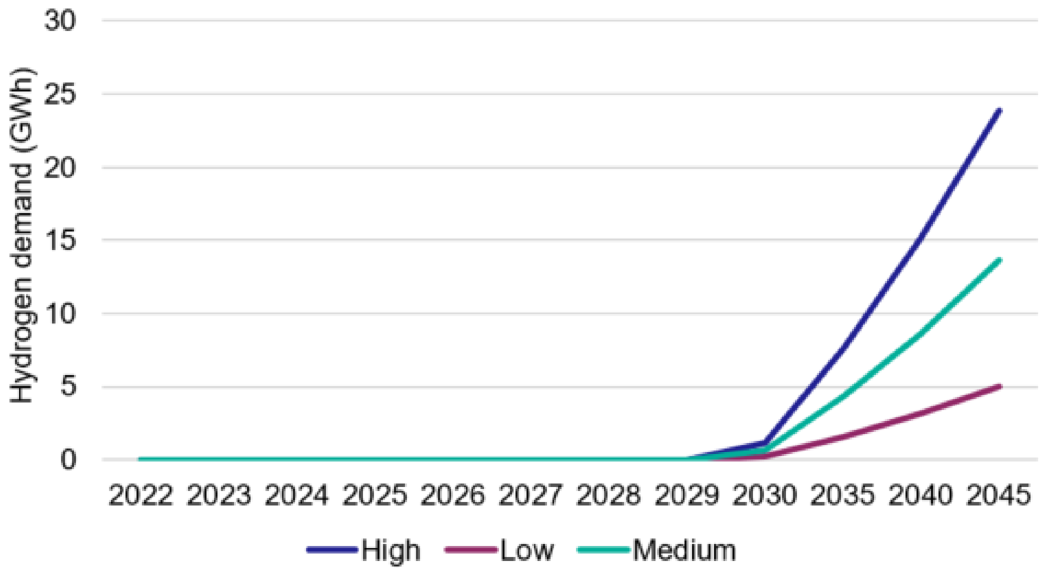


Figure 5 - Forecast hydrogen demand for the Fife Council Area

Hydrogen demand from ferries has been allocated to the Anstruther harbour, as the only ferry terminal within the Fife region is located there. Inverkeithing port accounts for circa 15% of the total hydrogen demand of Fife region while the demand from the fishing ports represents the remaining 85%. This difference is due to some key factors:

- Hydrogen demand is based on the emissions and tonnage from each sector - domestic shipping, international shipping, and fishing - separately. Emissions from international shipping represented 16% of all Scottish emissions in 2019 while emissions from fishing accounted for 12% of all emissions. In terms of tonnage, as described in **Error! Reference source not found.** above, international shipping accounted for 0.3% of the total Scottish tonnage while fishing represented the 0.6%. Based on the figures above, the baseline demand for 2019 is similar between shipping and fishing.

- Additionally, the hydrogen uptake for international activities is not as high as for domestic and finally,
- Fishing shows a stronger growing trend than Inverkeithing port.

3.3.2 Ferries

The hydrogen demand forecasts for the Fife Council area are the same across all scenarios. Figure 6 illustrates the rate of conversion to hydrogen technology for the one route and vessel in the region.

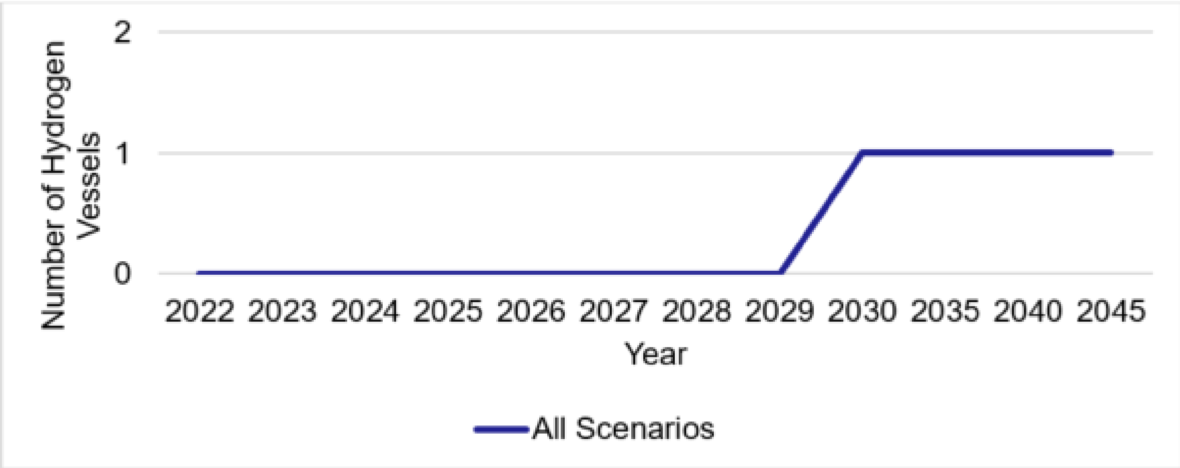


Figure 6 - Number of hydrogen vessels by year and scenario

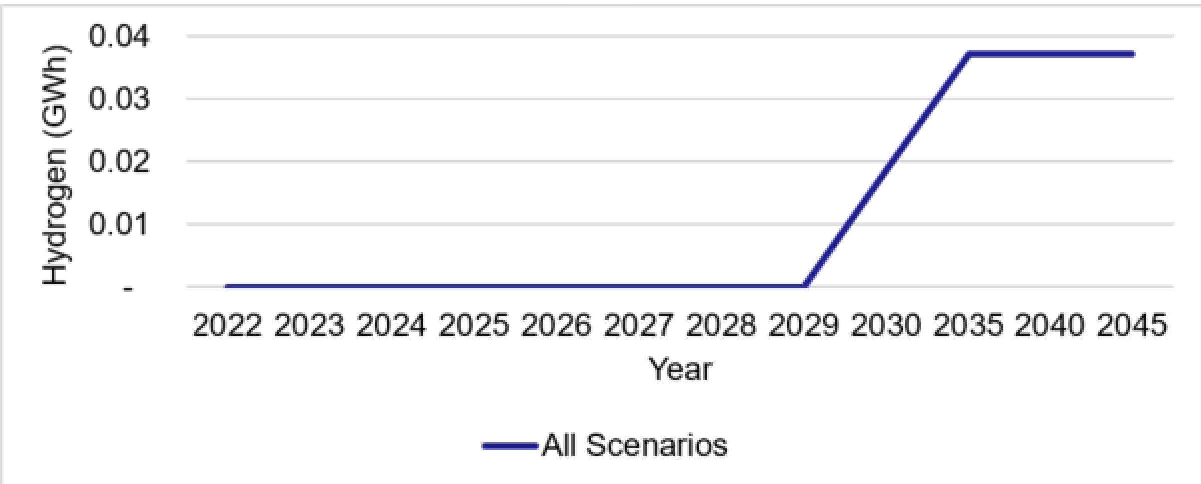


Figure 7 - Forecast hydrogen demand for the Fife Council area

Figure 7 shows the estimated hydrogen demand for each scenario. In all scenarios, the May Princess (operating the route for Anstruther – Isle of May) transitions to hydrogen in 2030, resulting in a hydrogen demand of 0.04 GWh from 2031 (which is shown as the demand by 2035 in Figure 7). This demand remains constant through 2045.

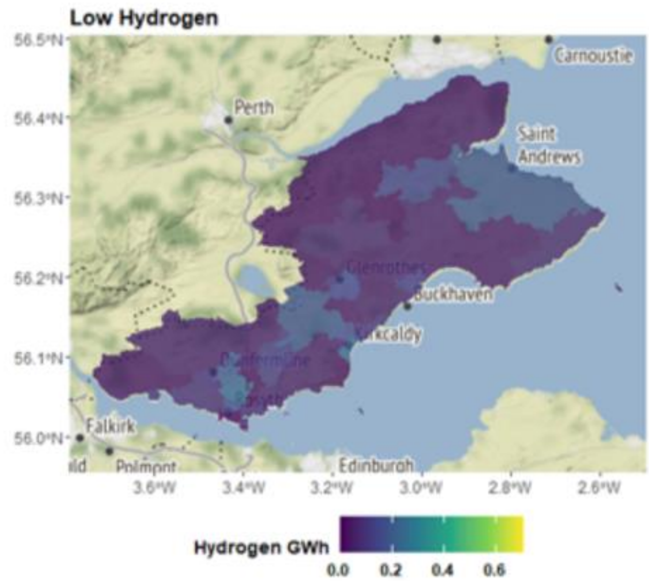
Note that the axis values are provided in GWh to allow comparison with the other two regions. However, due to the significantly smaller values, MWh would be a more appropriate unit of measure. Full data tables are included in the Appendix Table 22 Data for electricity demand (GWh) for each hydrogen transition scenario.

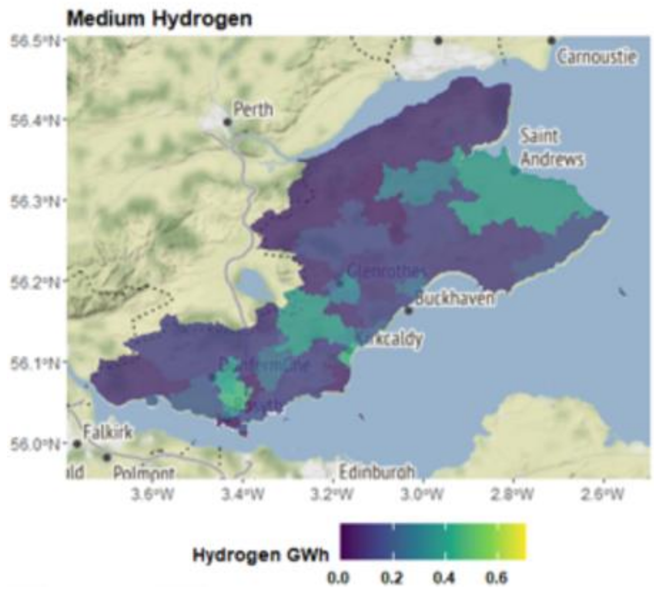
As with all regions in the study, replacement vessels are assumed to be introduced halfway through their introductory year (e.g. July), meaning hydrogen demand during the first year of operation (2030) is only 50%. Hydrogen demand is assumed to be 100% in the second year.

6. Hydrogen Demand Mapping

6.1 Roads

Cars





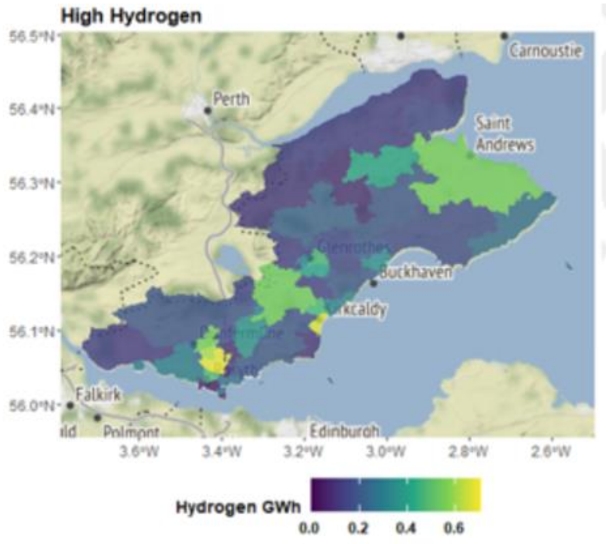
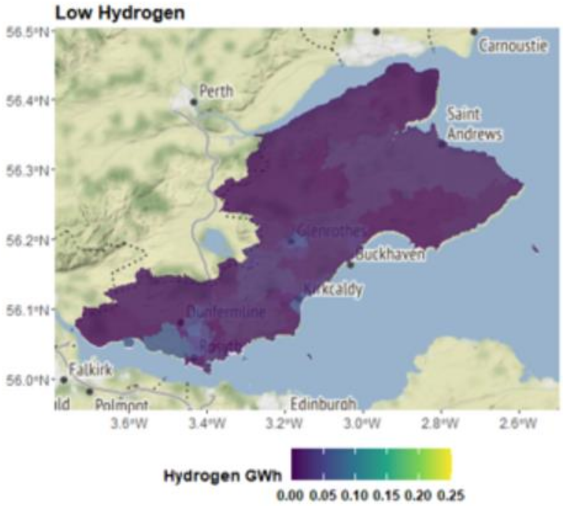
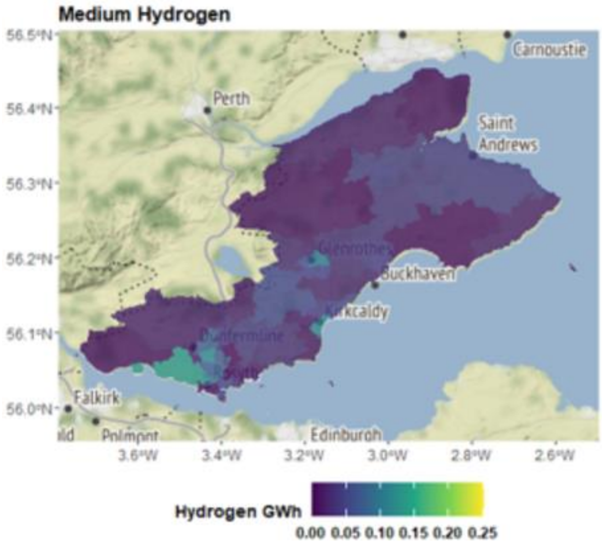


Figure 8 - Hydrogen demand for cars in the Fife region for each scenario

The map shows the total hydrogen GWh demand for cars for all scenarios for 2035 within each separate area in the Fife region. The results shown here are total demand, rather than density of demand, hence the relatively large values shown in the less well populated regions of the Fife. Although there are areas of concentration in demand, specifically Kirkcaldy, the demand is also quite widely distributed across the Fife Council area region.

Vans


Low Hydrogen
56.5°N
56.4°N
56.3°N
56.2°N
56.1°N
56.0°N
Carnoustie
Perth
Saint Andrews
Glenrothes
Buckhaven
Kirkcaldy
Dunfermline
Falkirk
Polmont
Edinburgh
3.6°W
3.4°W
3.2°W
3.0°W
2.8°W
2.6°W
Hydrogen GWh
0.00 0.05 0.10 0.15 0.20 0.25


Medium Hydrogen
56.5°N
56.4°N
56.3°N
56.2°N
56.1°N
56.0°N
Carnoustie
Perth
Saint Andrews
Glenrothes
Buckhaven
Kirkcaldy
Dunfermline
Falkirk
Polmont
Edinburgh
3.6°W
3.4°W
3.2°W
3.0°W
2.8°W
2.6°W
Hydrogen GWh
0.00 0.05 0.10 0.15 0.20 0.25

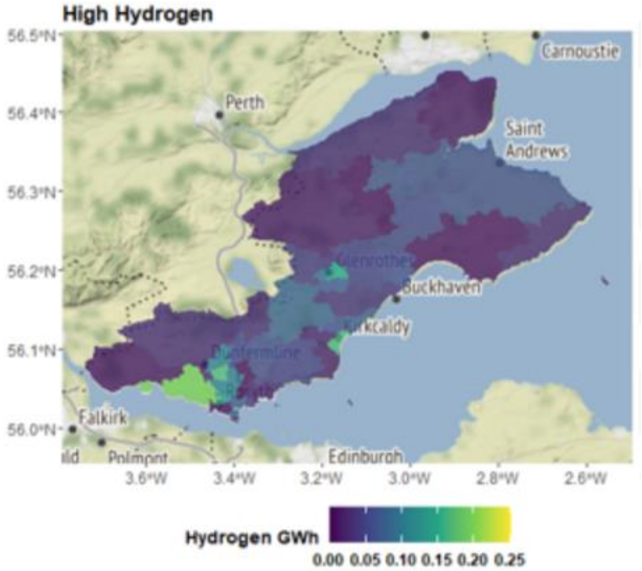
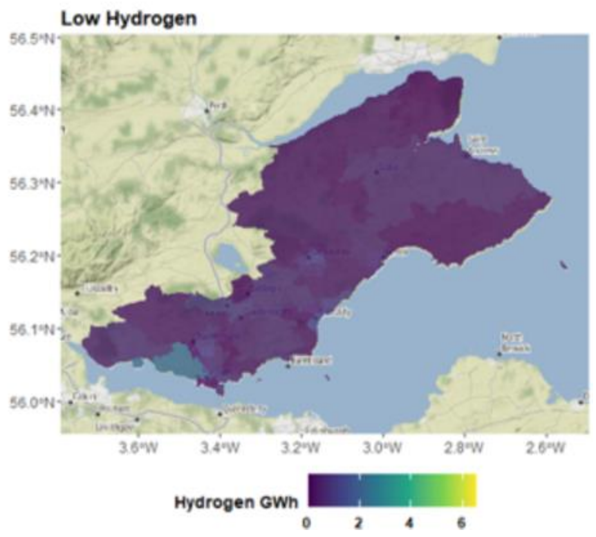
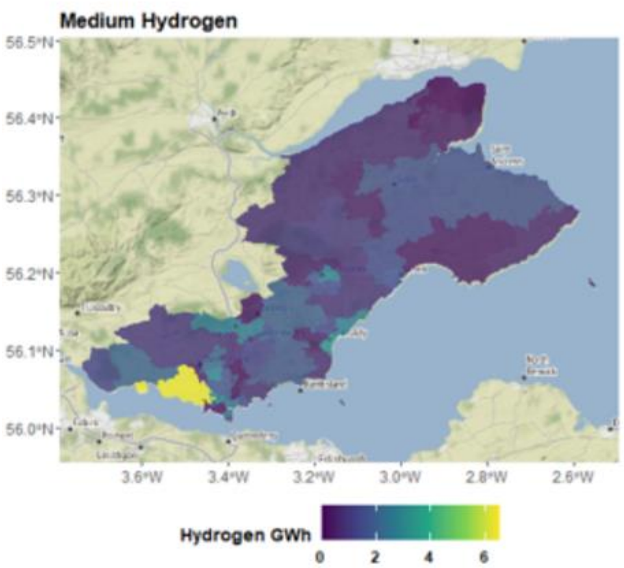


Figure 9 - Hydrogen demand for vans in the Fife region for each scenario

The map shows the total hydrogen GWh demand for vans for all scenarios for 2035 within each separate area in the Fife region. A major difference between car and van demand can be seen in the concentration of hydrogen demand around the Kirkcaldy and Dunfermline. The area, with little to no demand in the more rural zones. This indicates that the demand for hydrogen refuelling for light commercial fleet is likely to be concentrated around urban areas.

HGVs


Low Hydrogen
56.5°N
56.4°N
56.3°N
56.2°N
56.1°N
56.0°N
3.6°W
3.4°W
3.2°W
3.0°W
2.8°W
2.6°W
Hydrogen GWh
0
2
4
6


Medium Hydrogen
56.5°N
56.4°N
56.3°N
56.2°N
56.1°N
56.0°N
3.6°W
3.4°W
3.2°W
3.0°W
2.8°W
2.6°W
Hydrogen GWh
0
2
4
6

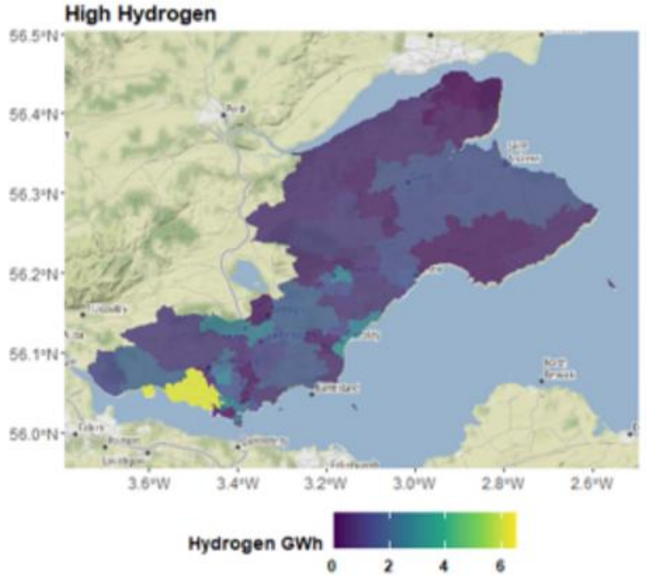


Figure 10 - Hydrogen demand for HGVs in the Fife region for each scenario

The maps show the HGV hydrogen demand for the Fife region. The spatial distribution follows the can demand but the total demand within the individual areas is much higher than for car or van, indicating that, as would be inferred from the technology transition forecasts, it is HGV which will be the dominant hydrogen demand. In addition, for 2035, there is relatively little difference between the medium and high scenario.

7.0 Appendices

7.1 Buses and Coaches

Year	High hydrogen Demand in GWh	High hydrogen fleet	Medium hydrogen Demand in GWh	Medium hydrogen fleet	Low hydrogen Demand in GWh	Low hydrogen fleet
2023	0	No H2FC vehicles	0	No H2FC vehicles	0	No H2FC vehicles
2024	2	12 coaches	0	No H2FC vehicles	0	No H2FC vehicles
2025	3	10 buses, 12 coaches	0	No H2FC vehicles	0	No H2FC vehicles
2036	3	10 buses, 12 coaches	3	10 buses, 12 coaches	0	No H2FC vehicles
2042	3	10 buses, 12 coaches	3	10 buses, 12 coaches	3	10 buses, 12 coaches
2045	3	10 buses, 12 coaches	3	10 buses, 12 coaches	3	10 buses, 12 coaches

Table 21 - Hydrogen Demand for Buses and Coaches

7.2 Ferries

Year	Scenario A (Low)	Scenario B (Medium)	Scenario C (High)
2022	0	0	0
2023	0	0	0
2024	0	0	0
2025	0	0	0
2026	0	0	0
2027	0	0	0
2028	0	0	0
2029	0	0	0
2030	19	19	19
2035	37	37	37
2040	37	37	37
2045	37	37	37

Table 22 - Data for Hydrogen Demand (GWh) for each Transition Scenario

Further copies of this document are available, on request, in audio and visual formats and in community languages. Any enquiries regarding this document / publication should be sent to us at info@transport.gov.scot

This document is also available on the Transport Scotland website: www.transport.gov.scot

Published by Transport Scotland, May 2022

Follow us:

transcotland

@transcotland

transport.gov.scot