Ultra Low Emission Vehicle Fleet Gap Analysis

Aberdeenshire Council has assessed that for its vehicle fleet to become zero emission it is not possible to transition to an entire fleet of Battery Electric Vehicles with current technology.
This report collates some evidence to inform the supply of hydrogen required to fill the gap that arises if those vehicles that are not BEV are Fuel Cell powered Hydrogen vehicles.

Report produced as a presentation for the HyTrEc2 Interreg project

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Summary

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Aberdeenshire Council has assessed that for its vehicle fleet to become zero emission it is not possible to transition to an entire fleet of Battery Electric Vehicles with current technology. This report collates some evidence to inform the supply of hydrogen required to fill the gap that arises if those vehicles that are not BEV are Fuel Cell powered Hydrogen vehicles.
This report draws on work in 2021 by Cenex (who provided the graphics) and uses Aberdeenshire Council vehicle tracking data. This edition is produced as a presentation for the HyTrEc2 project. Aberdeenshire Council's work on this was supported by HyTrEc2 a North Sea Programme Interreg project by the European Regional Development Fund of the European Union.
Aberdeenshire have equipped many of the fleet vehicles with telematics and using a years' worth of telematics data an analysis has been done to identify those vehicles which in a zero emissions fleet could be powered by Battery Electric technology and which could not. In this scenario those that cannot are assessed as hydrogen fuel cell powered vehicles (as against hydrogen fuel cell range extended electric vehicles, Internal Combustion Engines, dual fuel vehicles etc)

Of the 854 vehicles in the main fleet (excluding Tractors, small street sweepers, quarry equipment, landscaping machinery etc.) 733 have telematics tracking data for the period March 2019 to February 2020 and the analysis has been done on those vehicles and prorated for "whole fleet" demand.
The assessment made on those 733 vehicles was for 290,000 kg of hydrogen per annum
Which prorated for the whole fleet has a total demand of 325,000 kg
The primary aim of this report is to assess general locations for future hydrogen fuelling stations to supply the Aberdeenshire Council fleet and to illustrate an example scenario and should not be relied upon as a prediction of future demand.

The outcome exceeds the estimate made by Cenex for the North East Scotland Fleet Review (Hydrogen Demand)
https://www.aberdeencity.gov.uk/sites/default/files/2021-04/Fleet%20Review%20Report%20Final.pdf
which was for a total annual hydrogen demand for the Aberdeenshire Fleet of 204,000 kg but only had two fuellers in the Aberdeenshire area which in itself would have required the vehicles to make sometime long (and thought impractical) journeys to refuel. The assumptions also included the availability Hydrogen fuel cell range extended electric vehicles in the vehicle options which would use less hydrogen but more electricity from plug in chargers.

Vehicles assessed as having a Hydrogen demand in this particular future fleet scenario are currently concentrated in 5 areas of Aberdeenshire and on the assumption that all suitable vehicles are converted to a future assumed hydrogen vehicle specification and fuelling stations are made available at all these locations an example hydrogen demand has been assessed for the fleet vehicles stabled at those locations and those that pass nearby

Average estimated demands for the scenario considered ;
Showing the demand from vehicles located at the chosen fuelling location site overnight and vehicles which would fuel while passing.

Location	Annual H2 demand kg vehicles at depot	Daily H2 demand kg	Annual H2 demand kg vehicles passing	Total Annual kg	Total Daily kg	Split at depot vs passing
Macduff	56,000	205	26,000	82,000	296	68% / 32%
Stonehaven	40,000	148	28,000	68,000	250	59% / 41%
Inverurie	31,000	114	51,000	82,000	296	38% / 62%
Banchory	22,000	79	22,000	44,000	171	50% / 50%
Mintlaw	15,000	57	28,000	43,000	159	35% / 65%
Aberdeen City Fuelling Locations			5,000	5,000	20	

This example above also shows the benefits of a relatively fast fuelling hydrogen system when compared to supplying other forms of energy by using overnight replenishment at the over 1000+ overnighting locations used for the entire fleet.

Assumptions

Assumptions are many and not limited to the following aspects :

- The capability of future BEV vehicles
- That where a BEV vehicle can match the duty cycle it would be cheaper and therefore preferred
- That the assumed duty cycle is not adapted to make it compatible with BEV operaton
- That the BEV unsuitability criteria are maintained
- The BEV unsuitability requirements involve battery capacity and chosen criteria about limiting the impact of top up charging opportunities per day/week/year on variable daytime duty cycles
- The availability and specification of future FCEV vehicles
- That there is a requirement on public sector to only purchase new Zero Emissions Vehicles
- Funding is available to purchase new vehicles and any necessary infrastructure
- Hydrogen is available at a comparable price to other energy sources.
- That the current fleet life is not extended beyond a 7 year period for any vehicle
- That the choice is only between BEV and FCEV no dual fuel / diesel efuel / hydrogen injection ICE, hydrogen fuel cell range extended battery electric vehicles are considered.
- The timeline of available of each of the above elements matches with the requirements of the rest of the hydrogen eco-system and that sufficient advance knowledge of these is available to be able to plan the investments
- There is no material change from the fleet composition and duty usage from the base line year March 19 to February 20 (pre-covid)
- The assessment is made on substation of individual vehicles and does not take account of the potential fleet operation benefits of having flexibility if more vehicles at any one location are of common power sources.

The specific assumptions made for each of the above are not included in this document and were made in or prior to 2021
This work is to illustrate an example scenario and should not be relied upon as a prediction of future demand.

Aberdeenshire Council's main fleet in 2021

This table shows an example composition of the main Aberdeenshire Council vehicle fleet during 2021
(Excluding Tractors, small street sweepers, quarry equipment, landscaping machinery etc)

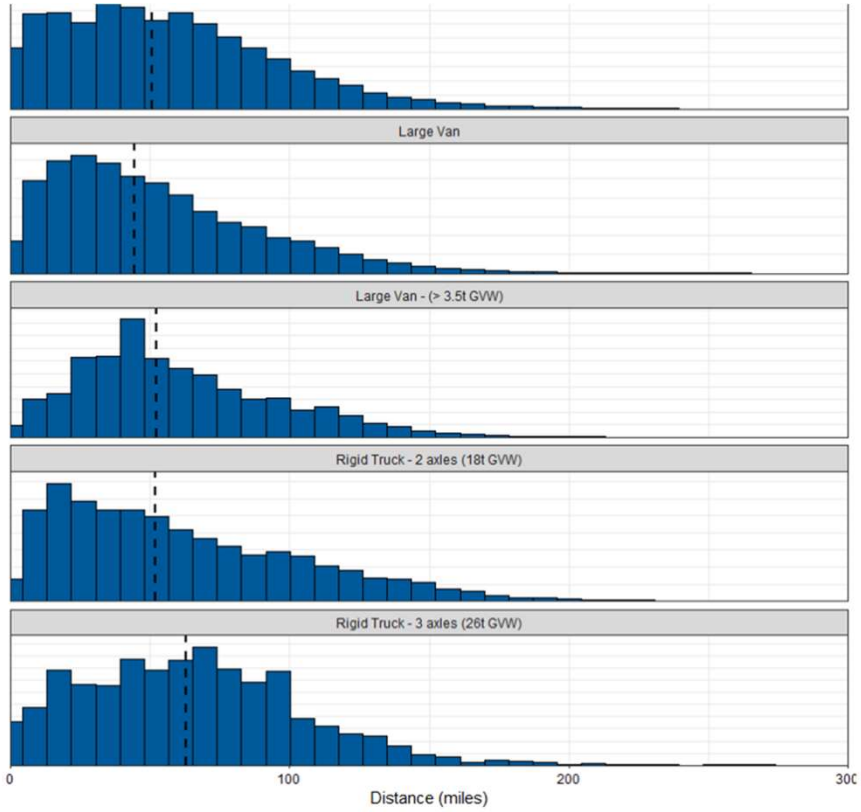
	Average Annual Mileage (miles)	Average Fuel Economy (MPG)	Number of Vehicles	Percentage of Total Fleet
Small Car	8,800	41.5	6	1%
Medium Car	12,200	41.8	5	1%
Large Car	11,400	37.0	4	0%
Medium MPV	4,800	49.0	1	0%
Midsized SUV	9,800	30.3	2	0%
Large Commercial SUV	11,800	26.5	13	2%
Small Van	10,800	44.2	234	27%
Medium Van	12,000	31.7	22	3%
Large Van	10,700	24.5	308	36%
Large Van - (> 3.5t GVW)	10,500	22.0	95	11%
Rigid Truck - 2 axles (7.5t GVW)	11,200	15.3	7	1%
Rigid Truck - 2 axles (18t GVW)	11,400	7.5	46	5%
Rigid Truck - 3 axles (26t GVW)	13,900	5.4	92	11%
Rigid Truck - 4 axles (32t GVW)	20,500	5.7	19	2%
Total	**11,600**	**26.7**	**854**	**100%**

This table shows an example model type for each section the main Aberdeenshire Council vehicle fleet during 2021

(Excluding Tractors, small street sweepers, quarry equipment, landscaping machinery etc)

	Vehicle Type	Most Common Model	Most Common Configuration
Car	Small Car	Vauxhall Corsa-e	Passenger Car
	Medium Car	Nissan Leaf	Passenger Car
	Large Car	Toyota Mirai	Passenger Car
	Medium MPV	Volkswagen Sharan	MPV
	Midsized SUV	Mitsubishi Outlander	Light 4x4
LCV	Large Commercial SUV	Ford Ranger	Pickup Truck
	Small Van	Citroen Berlingo	Panel Van
	Medium Van	Vauxhall Vivaro-e	Panel Van
	Large Van	Ford Transit	Tipper
HGV	Large Van - (> 3.5t GVW)	Iveco Daily	Minibus
	Rigid Truck - 2 axles (7.5t GVW)	FUSO Canter	Refuse Disposal
	Rigid Truck - 2 axles (18t GVW)	DAF LF	Tipper
	Rigid Truck - 3 axles (26t GVW)	Mercedes-Benz Econic	Refuse Disposal
	Rigid Truck - 4 axles (32t GVW)	Mercedes-Benz Arocs	Skip Loader

This table shows example daily distance driven by selected sections of the main Aberdeenshire Council vehicle fleet



This table shows the various overnight stabling locations actually used during the year March 2019- February 2020 by all of the tracked fleet (733 vehicles)
Group 1 main fleet depots
Group 2 minor fleet depots
Group 3 locations have 5 or more vehicles parked overnight during a year and/or more than one vehicle on a night
“Home” locations have fewer than 5 vehicles in the year and are used by the same vehicle more 40 nights per vehicle
Minor locations do not fit any of the above and are used infrequently

Location Type	Number Identified
Group 1 Depot	11
Group 2 Depot	9
Group 3 Depot	128
Home location	187
Minor location	694
Total	**1,029**

This table shows the replacement schedule for the example fleet predicted based typically on 7 year life from vehicles on the fleet in 2021.
Years shown are financial years April to March

	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	Total
Small Car	0	0	6	0	0	0	0	0	0	0	6
Medium Car	0	1	4	0	0	0	0	0	0	0	5
Large Car	0	2	2	0	0	0	0	0	0	0	4
Medium MPV	0	1	0	0	0	0	0	0	0	0	1
Midsized SUV	0	0	2	0	0	0	0	0	0	0	2
Large Commercial SUV	1	6	0	0	2	4	0	0	0	0	13
Small Van	41	54	59	21	23	16	19	1	0	0	234
Medium Van	4	7	8	1	1	1	0	0	0	0	22
Large Van	48	63	21	5	48	70	36	17	0	0	308
Large Van - (> 3.5t GVW)	14	27	19	6	17	5	5	2	0	0	95
Rigid Truck - 2 axles (7.5t GVW)	1	2	2	0	1	1	0	0	0	0	7
Rigid Truck - 2 axles (18t GVW)	4	7	12	2	13	7	1	0	0	0	46
Rigid Truck - 3 axles (26t GVW)	18	18	6	7	2	12	15	9	1	4	92
Rigid Truck - 4 axles (32t GVW)	1	11	3	2	2	0	0	0	0	0	19
Total	**132**	**199**	**144**	**44**	**109**	**116**	**76**	**29**	**1**	**4**	**854**

Vehicles identified as potential hydrogen FCEV

This table shows those of the 733 tracked vehicles that passed the Battery Electric Vehicle suitability test and those that failed Those that failed are deemed to be candidates for fuel cell hydrogen vehicle consideration

	Vehicles assessed	Vehicles meeting BEV criteria	Vehicles failing BEV criteria
Large Commercial SUV	12	12	0
Small Van	213	167	46
Medium Van	14	12	2
Large Van	272	204	68
Large Van - (> 3.5t GVW)	85	50	35
Rigid Truck - 2 axles (7.5t GVW)	7	1	6
Rigid Truck - 2 axles (18t GVW)	44	32	12
Rigid Truck - 3 axles (26t GVW)	68	22	46
Rigid Truck - 4 axles (32t GVW)	18	11	7
Total	**733**	**511**	**222**

Identification of fuelling sites and demand

From the 733 vehicles tracked five depot location were identified as having concentrations of vehicles being considered for hydrogen fuel

These five are at
Group 1 locations : Macduff, Stonehaven, Inverurie,
Group 2 locations : Banchory
and an assumption based on the potential for an imminent new depot location for Mintlaw

For 733 vehicles the scenario examined gives hydrogen demand of:

Location	Annual H2 demand kg	Daily H2 demand kg
Macduff	49,000	180
Stonehaven	35,000	130
Inverurie	27,000	100
Banchory	20,000	70
Mintlaw	13,000	50

These are for vehicle know as normally stabled overnight at these locations in the period.

If the total fleet vehicles of 854 were assumed to be proportionally the same as the 733 analysed (in terms of vehicle model, mileages, duty cycle, overnight stabling location, terrain operated over etc) the uplift for the 121 not analysed would be + 16.5%
However 18 vehicles of the 121 not analysed are cars or MVP which would both be expected to have a higher possibility of being BEV compatible and a smaller than average hydrogen consumption where not BEV compatible. Therefore the assumed uplift is reduced to + 14%

On this assumption
For 854 vehicles an estimated scenario with the above assumptions gives hydrogen demand as approx:

Location	Annual H2 demand kg	Daily H2 demand kg
Macduff	55,000	205
Stonehaven	40,000	150
Inverurie	30,000	115
Banchory	22,000	80
Mintlaw	15,000	55

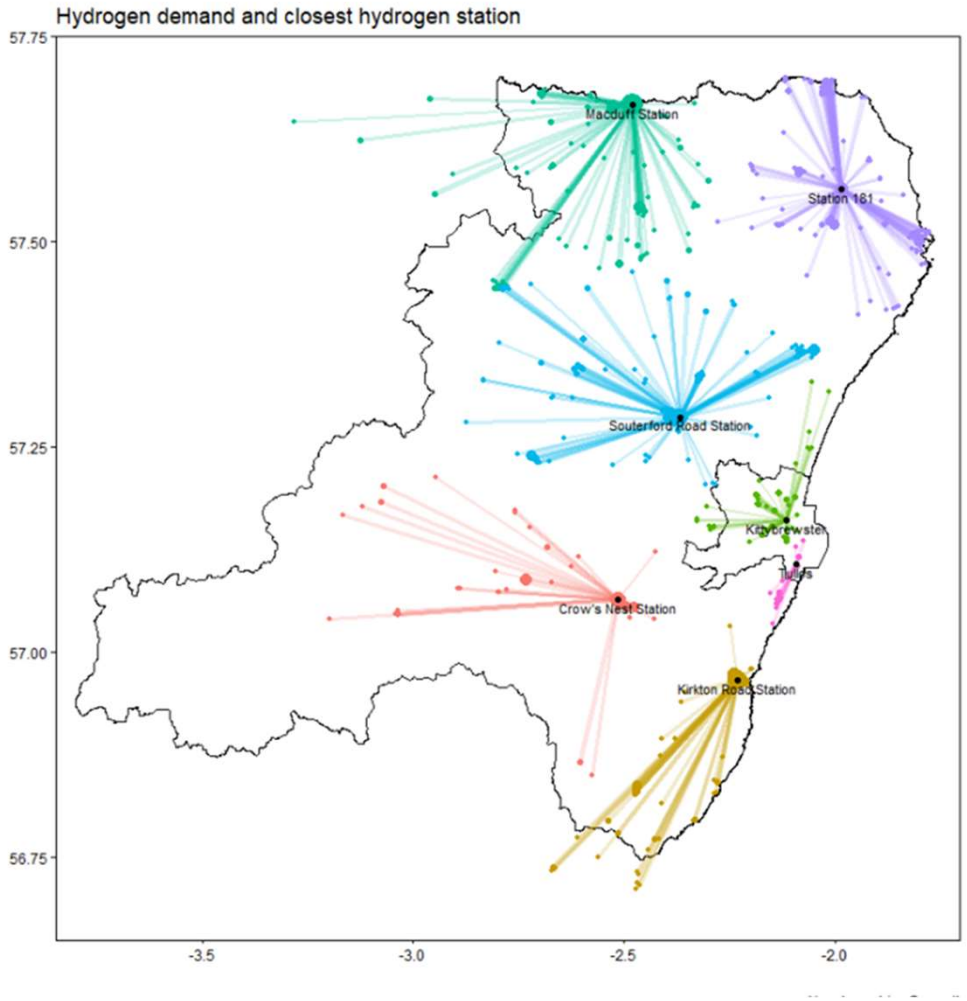
These are for vehicle know as normally stabled overnight at these precise locations in the period plus an allowance for vehicles which had not been located but are assumed to be stabled overnight at these locations.

This figure shows the location of the 5 depots with concentrations of Hydrogen in Aberdeenshire plus the two current station in Aberdeen City
Points also show the main overnight stabling location of those vehicles from the 733 analysed that are contributing towards the hydrogen demand totals and identifies the closest station for those vehicles.

Note : vehicles are assumed to fuel at the nearest location irrespective of duty route

Aberdeenshire locations are named as
Macduff: Key depot
Stonehaven: Kirkton Road depot
Inverurie: Souterford Road depot
Banchory: Crow's nest Household Waste Recycling Centre
A new depot at Mintlaw (denoted location 181)

Aberdeen City Locations are named as
Kittybrewster
Tullos – ACHES

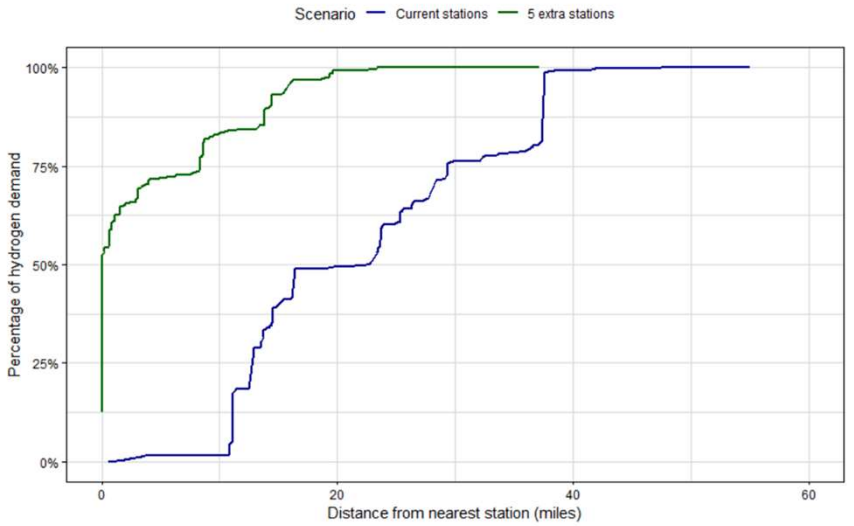


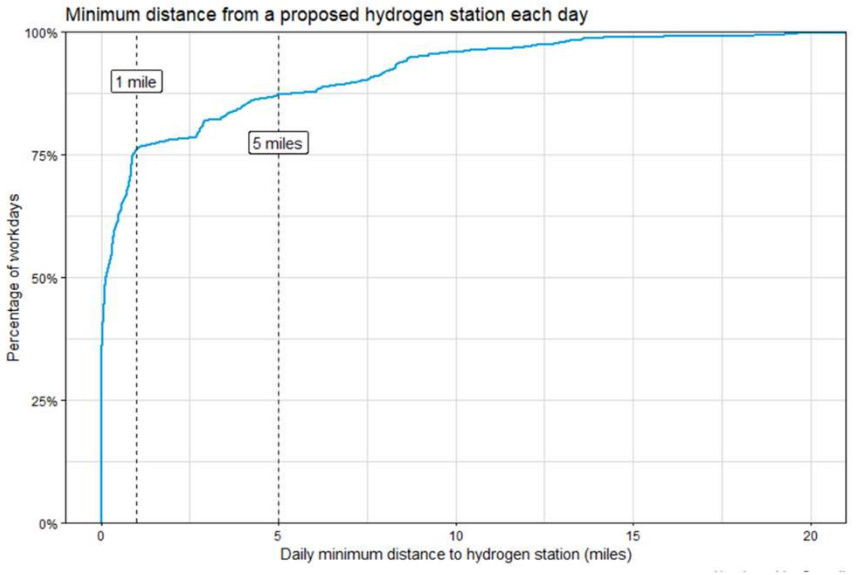
Passing vehicles and demand

The top figure shows the percentage of hydrogen demand against the distance from a fuelling station in the two scenarios
A base scenario of the existing two stations in Aberdeen City and
A new scenario which places an addition five stations at the depots with concentrations of Hydrogen in Aberdeenshire.
50% demand is overnight at the station
25% is overnight within 10 miles
25% is overnight between 10 and 20 miles from a station

The bottom figure is the result of an assessment of the minimum distance the 733 tracked vehicles get to one of the fuelling stations in their normal operations when five additional Aberdeenshire stations are added to the two existing in Aberdeen City.
It shows 75% get within 1 mile and 87.5% get within 5 miles which might be considered a reasonable distance to deviate in order to refuel.

Note : the fueller sites are chosen for where the most vehicles are stabled overnight and then assessed as to how many other vehicles will pass close by – this may not be optimal





In the scenario on the previous page assessed whether the 733 tracked vehicles get near to one of the fuelling stations in their normal operations when five additional Aberdeenshire stations are added to the two existing in Aberdeen City.

The tracker analysis is robust for that vehicles are based at main depots with fuellers and operate out and back with a daily cycle which can be encompassed with one fueling but some errors might occur with vehicles that move around a lot or drive very large distances but return to base

There are 25 vehicles that are considered under the then existing duty cycle do not get close enough to a station without either making a material deviation and/or adjusting the duty.
However these vehicles are identified on the table to the right and these are found not to be big users of fuel. Thus whether the duty cycle is amended or they are not replaced by hydrogen at this time it is not considered to have the biggest impact on the demand levels

Vehicle Type	Department	Average minimum daily HRS distance (miles)	Average days a week within 5 miles of HRS
Small Van	HOME CARERS	13.1	0.2
Small Van	ROAD INSP SOUTH	9.7	1.4
Large Van	HWAYS MARR SOUTH	11.9	0.9
Large Van	HWAYS FORMARTINE	7.6	1.8
Large Van	HWAYS FORMARTINE	7.1	2.0
Large Van	HWAYS MARR NORTH	10.9	0.7
Large Van	HWAYS MARR NORTH	10.2	1.4
Large Van	HWAYS MARR NORTH	13.1	1.2
Large Van	BUILD MAINT B&B	7.3	1.6
Large Van	BUILD MAINT B&B	7.2	1.8
Large Van	STREET CLEANSING	9.2	0.8
Large Van	HWAYS FORMARTINE	7.4	1.5
Large Van	HWAYS FORMARTINE	6.1	2.3
Large Van	HWAYS FORMARTINE	6.1	1.8
Large Van - (> 3.5t GVW)	HWAYS MARR NORTH	10.2	1.4
Large Van - (> 3.5t GVW)	PTU SOCIAL WORK	6.4	2.1
Large Van - (> 3.5t GVW)	EDUCATION CENTRAL	11.7	0.8
Large Van - (> 3.5t GVW)	PTU SCHOOL TRANSPORT	6.2	1.1
Large Van - (> 3.5t GVW)	HWAYS MARR NORTH	10.2	1.3
Large Van - (> 3.5t GVW)	PTU SOCIAL WORK	6.1	1.2
Large Van - (> 3.5t GVW)	PTU SOCIAL WORK	7.9	1.3
Large Van - (> 3.5t GVW)	PTU SOCIAL WORK	7.5	0.7
Large Van - (> 3.5t GVW)	PTU SCHOOL TRANSPORT	7.4	1.9
Rigid Truck - 2 axles (7.5t GVW)	REFUSE COLLECTION	8.3	1.3
Rigid Truck - 3 axles (26t GVW)	REFUSE COLLECTION	7.1	1.6

Whilst all of the 733 vehicles that failed the BEV test were considered for hydrogen fuel cell operation
4% of those vehicles have power or range requirements that would exceed what had been assumed as the capacity of the hydrogen fuel tanks to service without refilling.
There are 29 vehicles in this category whose performance is shown in this table

These vehicles are kept in the hydrogen demand on the basis that the Zero Emission Vehicle solution is selected from one or more of the following:

- Additional hydrogen fuelling events
- Additional hydrogen tanks on the vehicles concerned
- Reallocation of duty between vehicles
- Improved performance of the relevant hydrogen vehicle when it is actually available.

no assessment has been made of whether these vehicles also pass more than one fueller at a suitable time in the day.

Vehicle Type	Department	Average daily mileage (miles)	Fuel use (MPG)	Days over FCEV range	Refill days in worst week	Refills on worst day
Small Van	HOME CARERS	75	26.1	12%	4	1.2
Small Van	HOME CARERS	117	30.7	52%	7	2.1
Medium Van	VMS INVERURIE	35	27.8	1%	1	1.9
Large Van	PTU SOCIAL WORK	48	22.8	5%	3	1.1
Large Van	HWAYS MARR SOUTH	53	19.6	4%	3	1.3
Large Van	BUILD MAINT G&F	100	24.1	25%	4	1.3
Large Van	REFUSE COLLECTION	146	26.9	35%	3	1.4
Large Van	OCCUPATIONAL THERAPY	97	19.3	19%	3	1.2
Large Van	BUILD MAINTK/M & M	85	17.4	26%	2	1.3
Large Van - (> 3.5t GVW)	PTU SOCIAL WORK	42	23.3	1%	1	1.8
Large Van - (> 3.5t GVW)	HWAYS BANFF & BUCHAN	22	9.8	11%	3	1.7
Large Van - (> 3.5t GVW)	PTU SOCIAL WORK	77	17.3	16%	2	1.2
Large Van - (> 3.5t GVW)	PTU SOCIAL WORK	65	16.6	6%	3	1.2
Large Van - (> 3.5t GVW)	PTU SCHOOL TRANSPORT	89	16.4	57%	5	1.5
Large Van - (> 3.5t GVW)	HWAYS FORMARTINE	54	9.2	26%	4	1.5
Rigid Truck - 2 axles (7.5t GVW)	REFUSE COLLECTION	52	8.3	29%	2	1.5
Rigid Truck - 2 axles (18t GVW)	REFUSE COLLECTION	65	4.3	16%	2	1.1
Rigid Truck - 2 axles (18t GVW)	HWAYS K & M	78	6.5	3%	3	1.1
Rigid Truck - 2 axles (18t GVW)	HWAYS K & M	101	7.3	3%	3	1.2
Rigid Truck - 2 axles (18t GVW)	HWAYS K & M	66	3.8	35%	4	2.0
Rigid Truck - 3 axles (26t GVW)	WASTE DISPOSAL	76	4.7	40%	3	1.6
Rigid Truck - 3 axles (26t GVW)	REFUSE COLLECTION	65	3.6	22%	2	1.1
Rigid Truck - 3 axles (26t GVW)	REFUSE COLLECTION	54	3.1	52%	4	1.6
Rigid Truck - 3 axles (26t GVW)	REFUSE COLLECTION	95	4.2	29%	3	1.0
Rigid Truck - 4 axles (32t GVW)	WASTE DISPOSAL	57	5.1	16%	2	1.4
Rigid Truck - 4 axles (32t GVW)	WASTE DISPOSAL	70	3.9	65%	6	1.9
Rigid Truck - 4 axles (32t GVW)	WASTE DISPOSAL	117	5.5	66%	5	1.3
Rigid Truck - 4 axles (32t GVW)	WASTE DISPOSAL	108	4.9	37%	4	1.7
Rigid Truck - 4 axles (32t GVW)	WASTE DISPOSAL	99	3.6	82%	5	2.3

Using the 733 vehicles analysed as a base
And assuming that all 5 stations in Aberdeenshire are provided and that all vehicles failing the BEV test can access a fuelling station

Location	Annual H2 demand kg vehicles at depot	Daily H2 demand kg	Annual H2 demand kg vehicles passing	Total H2 demand annual	Total kg Daily
Macduff	49,000	180	23,000	72,000	260
Stonehaven	35,000	130	25,000	60,000	220
Inverurie	27,000	100	45,000	72,000	260
Banchory	20,000	70	20,000	40,000	150
Mintlaw	13,000	50	25,000	38,000	140
Aberdeen City Fuelling Locations			5,000	5,000	20

Aggregated demand

Using the 733 vehicles analysed as a base and assuming that all 5 stations in Aberdeenshire are provided and that all vehicles failing the BEV test can access a station
The following assumptions and adjustments are made and proposed to make an assessment of the demand for the 854 vehicle main fleet.
Add a proportion as +14% on hydrogen demand for the 103 vehicles not analysed

- Do not add a material amount of hydrogen for the 18 cars not analysed
- Do not reduce for the 25 vehicles (of the 733) found not to pass close to a hydrogen station
- Do not reduce for the 4% - 29 vehicles (of the 733) vehicles found to exceed the initial fuel requirement from hydrogen

Location	Annual H2 demand kg vehicles at depot	Daily H2 demand kg	Annual H2 demand kg vehicles passing	Total H2 demand annual	Total kg Daily
Macduff	56,000	205	26,000	82,000	296
Stonehaven	40,000	148	28,000	68,000	250
Inverurie	31,000	114	51,000	82,000	296
Banchory	22,000	79	22,000	44,000	171
Mintlaw	15,000	57	28,000	43,000	159
Aberdeen City Fuelling Locations			5,000	5,000	20

Variations in demand

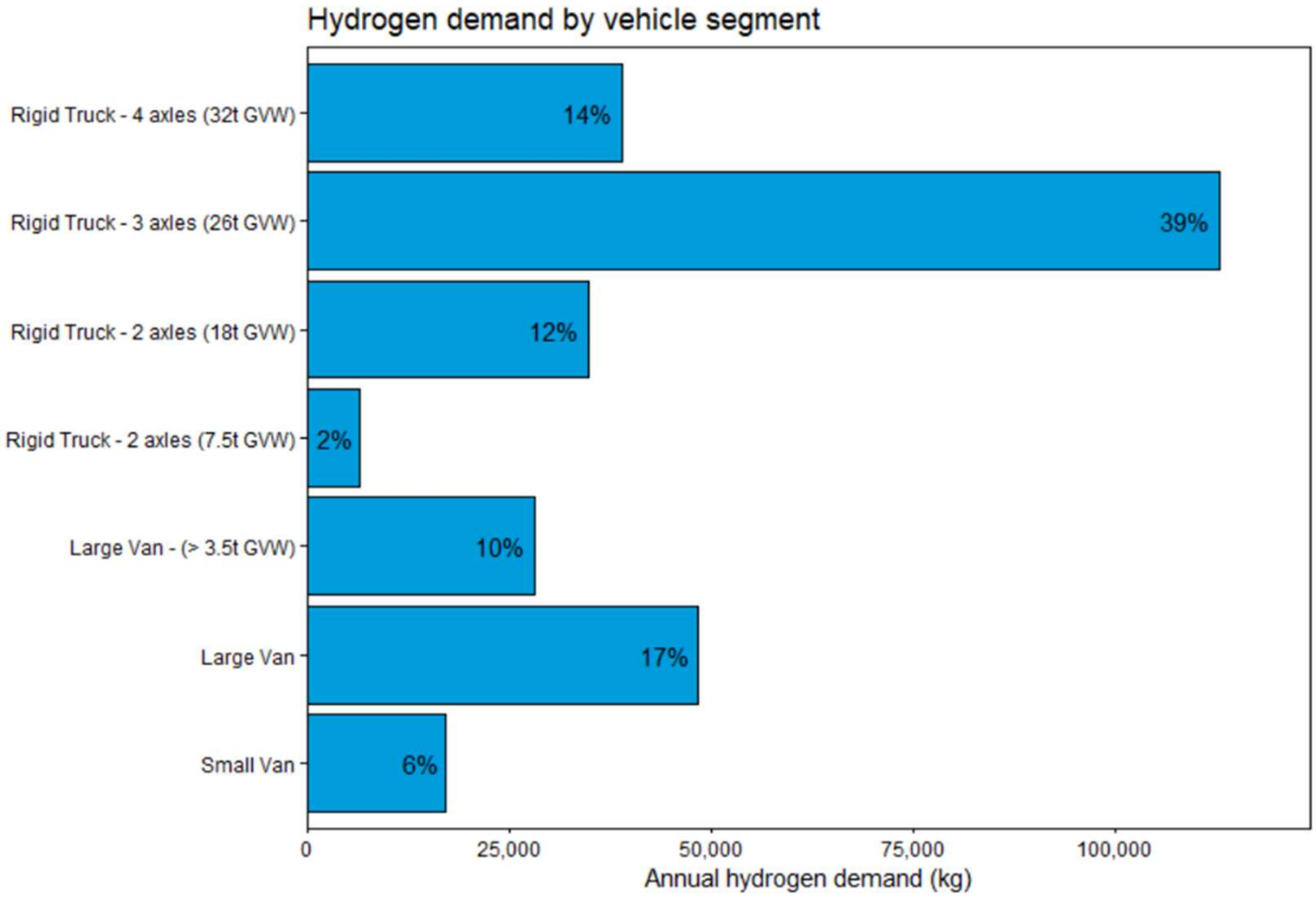
This table shows the demand from the 733 tracked vehicles split by vehicle type

While each bar contains different numbers of vehicles it shows the impact on demand that the availability of various fuel cell vehicles has on demand.

To note the splits:

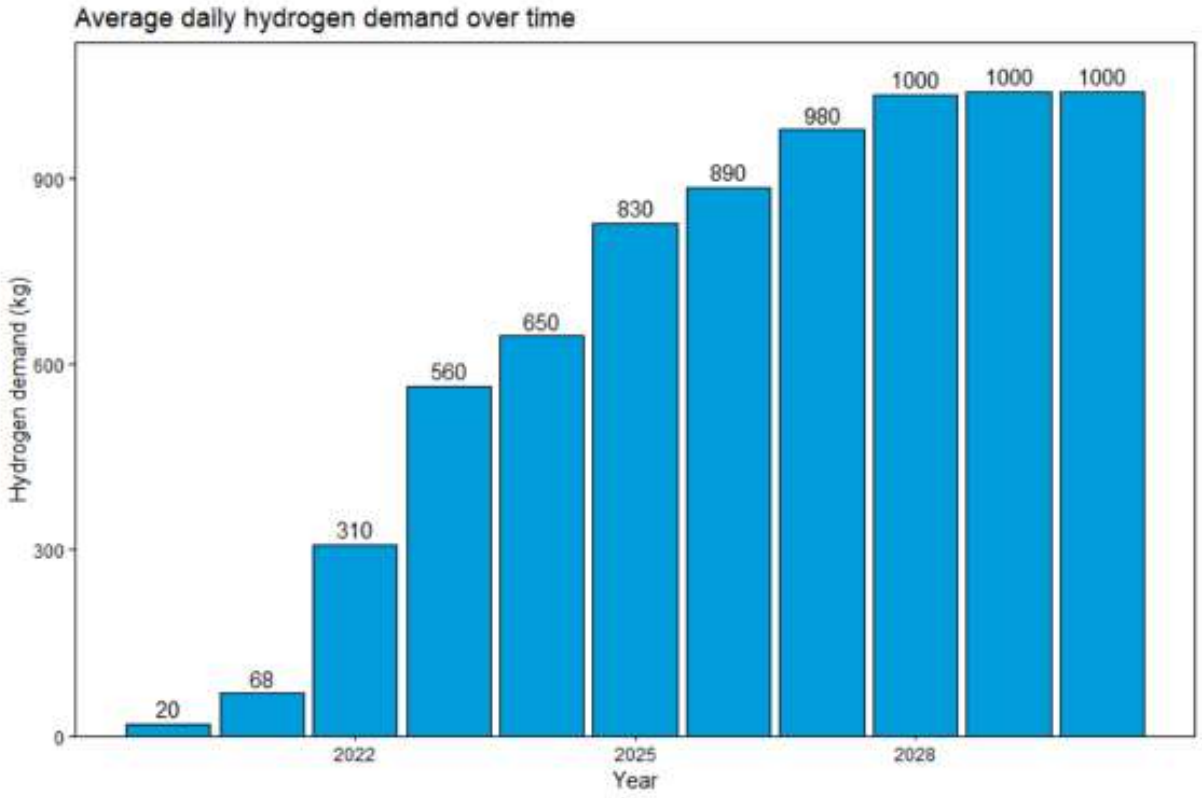
77% HGV – 23% LCV

Of the 77% that are HGV half of the consumption is for 26t Refuse Collection Vehicles at 110,000 kg per year



This graph shows how the demand for hydrogen rises over time as vehicles are brought onto the fleet

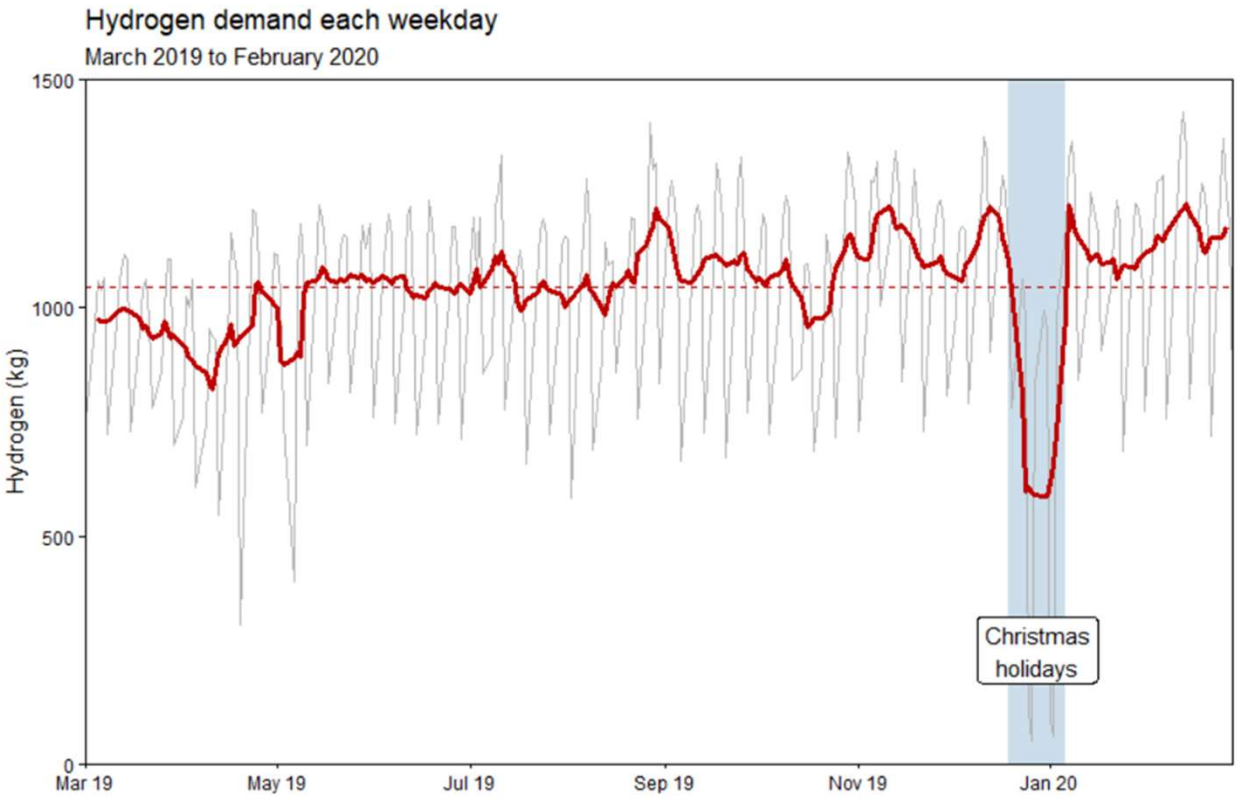
IMPORTANT
This is from the baseline of the study in 2021 assuming that vehicles were purchased as the existing fleet became life expired at 7 years old. Some of these vehicles will by now already be replaced with new diesel vehicles.
The replacement profile is not constant as is shown in the table on page 10.
Vehicles might not be replaced in the future after 7 years as assumed.
There is an assumption that suitable hydrogen FCEV vehicles will come to market within this timescale.



For fuel station operation design the daily variation is important
The graph to the left shows the variation arising from those vehicle selected from the 733 analysed

- Red dashed line is the average
- Grey line is the daily
- Red line is the rolling 5 day average

Note: any impact of temperature variation thoughout the year is not assessed

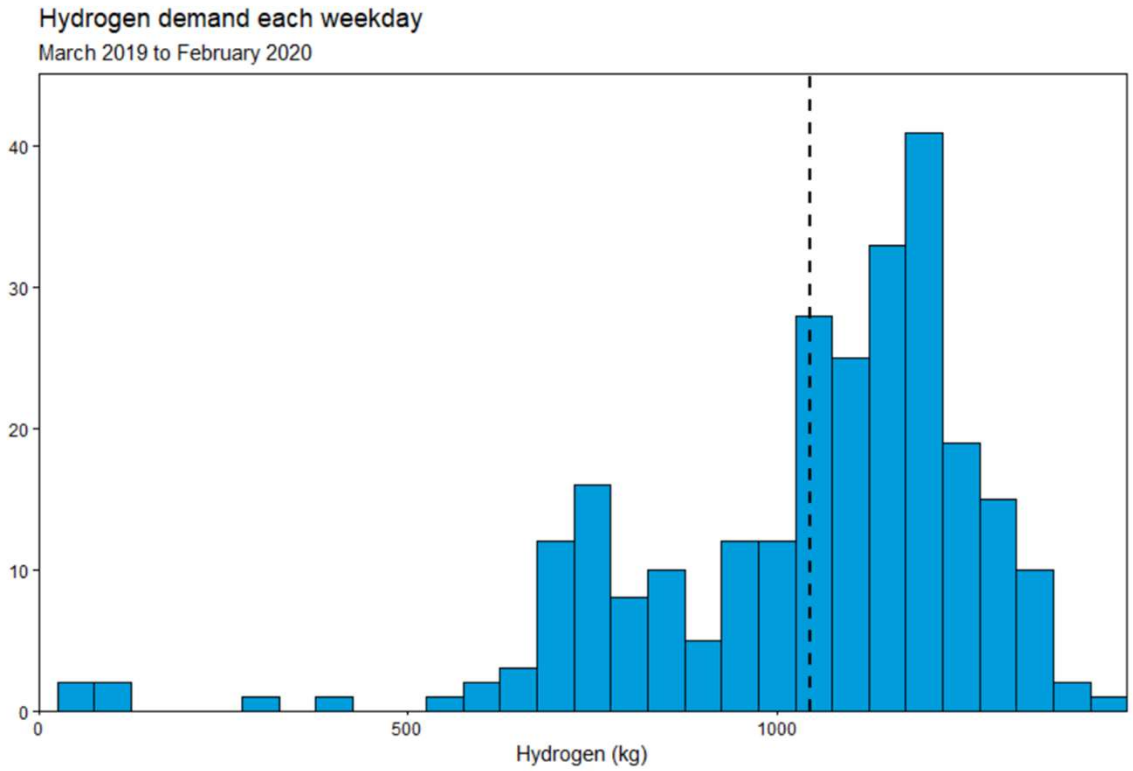


A histogram of the hydrogen demand variation by weekday from selection of the 733 vehicles analysed is shown on the right.

Of the demand from this segment the statistical averages are

Daily total demand on a weekday

Mean	1050 kg
Median	1100 kg
Mode	1200kg
Maximum	1450 kg

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HyTrEc2
Hydrogen Transport Economy
for the North Sea Region