British Columbia Light-Duty Vehicle Hydrogen Fueling Network Study

Prepared For:
Government of B.C., MEMPR

Submission Date:
March 20, 2020

BRITISH COLUMBIA

ZEN and the art of CLEAN ENERGY SOLUTIONS

Executive Summary

The B.C. Government Hydrogen Network Study provides the estimated locations of a core network of Light-Duty hydrogen vehicle fueling stations across the province in the years 2025, 2030, and 2040. When fully built out, this core network of Hydrogen Refuelling Stations (HRS) will allow safe travel for Fuel Cell Electric Vehicles (FCEVs) throughout B.C.'s primary highways, secondary highways, and major roads.

BC is already a leader in developing and employing HRS infrastructure in North America. There are currently two public stations in operation in the province and five more in the planning stages. These initial stations have been incorporated into the network strategy and support the need for a coordinated and phased approach to station infrastructure investment and development.

The basis for modeling work conducted in this study is the EV Infrastructure Planner Assistant tool previously developed by Kelly Carmichael at BCIT. This modeling tool was developed for a similar study of Direct Current Fast Charging (DCFC) stations for Battery Electric Vehicles (BEVs). The vehicle mileage inputs from this previous study were adjusted for FCEVs based on the performance of the current generation of FCEVs.

This study also provides an overview of the hydrogen fuel supply chain, hydrogen refueling infrastructure technology, and Light-Duty FCEV performance trends. These inputs are used to model how a network of stations could be built out across the province over the next 20 years.

The actual number of stations constructed and their locations will depend on many factors, but the estimated number of stations across the province are 17 in 2025, 55 in 2030, and 141 in 2040.

Table of Contents

List of Figures

List of Tables

Acronyms and Glossary

Bar – A unit of pressure equivalent to 100,000 Pascals or about 1 atm

BEV – Battery Electric Vehicle

Cluster – A group of stations within the same geographic area that FCEVs drivers use interchangeably

Connector – A city or community that links Clusters together, such as along a major highway

CSD – Compression, Storage and Dispenser, equipment used in Hydrogen Refuelling Stations

DCFC – Direct Current Fast Charger, a BEV charging technology

Destination – A city, community or travel hub such as an airport that experiences large non-local traffic

Dispenser – The equipment housing the controls equipment, Point of Sale and connection point for the fueling positions

FCEV – Fuel Cell Electric Vehicle

Fuelling Position – A unique physical location at a station in which an FCEV can fuel from a hose simultaneously with other vehicles fueling from other hoses or dispensers

H2 – Hydrogen gas

HD – Heavy-Duty vehicle, e.g. a bus or Class 8 truck

HRS – Hydrogen Refueling Station

ICE – Internal Combustion Engine

LD – Light-Duty vehicle, e.g. a passenger car or truck

Le/100km – Litres equivalent per 100km, a measure of vehicle fuel economy

LH2 – Liquified hydrogen gas

Market – A local geographic area with a high concentration of current and potential FCEVs drivers such as the Lower Mainland or the Greater Victoria area

MEMPR – The BC Government Ministry of Energy, Mines, and Petroleum Resources

MPGe – Miles per Gallon equivalent, a measure of vehicle fuel economy

OEM – Original Equipment Manufacturer

SMR – Steam Methane Reformation, a method for producing hydrogen gas from natural gas

ZEV – Zero Emissions Vehicle (i.e. a BEV or FCEV)

1 Introduction

The transportation sector makes up approximately 37% of total greenhouse gas (GHG) emissions in B.C. Of that, Light-Duty (LD) vehicles made up 43% or approximately 9.4Mt CO_2e in 2016[1]. Fuel Cell Electric Vehicles (FCEVs) can significantly reduce GHG emissions from LD vehicles as well as complement the performance and application of Battery Electric Vehicles (BEVs). FCEVs use compressed hydrogen gas (H2) stored in tanks on board as their fuel source. The vehicle's fuel cell modules use an electrochemical process to convert the hydrogen directly into electricity which then powers an electric drivetrain. There is no combustion in the process and water vapour as the only tailpipe emission.

This study is intended to inform and guide the development of Hydrogen Refueling Station (HRS) infrastructure throughout the province and provide the general principles for the staged development of these sites. Both BEVs and FCEVs will play a critical role in decarbonizing transportation in the province, with FCEVs particularly suited to longer routes, higher utilization rates, and heavier payloads[2]. The Provincial Government's Light-Duty Vehicle Zero Emission Vehicle (ZEV) mandate will be met using a phased approach, with ZEVs making up 10% of new light-duty vehicle sales by 2025, 30% by 2030 and 100% by 2040[3]. This study can help inform government planning as funding mechanisms are developed to build out the station network in support of the ZEV mandate. It is suggested that funders, governments, utilities, vehicle OEMs, infrastructure developers, and other stakeholders consider the maps of suggested sites when developing their plans for future investment.

This study represents an initial assessment of the requirements of the HRS network and the system is expected to change and evolve as technology improves and the ZEV market in B.C. takes form.

The study is organized into five subsections:

1) The **Modelling Methodology** section outlines the modelling approach and the design principles used for siting HRS infrastructure throughout the province.
2) The **FCEV Performance Characteristics** section details the baseline performance of currently available FCEVs and the likely makeup and performance of the fleet in the future.
3) The **HRS Infrastructure** section covers the most common archetypes of refueling stations and their applicability for different locations.
4) The **Station Capacity and Hydrogen Supply** section provides an outline of how the upstream production and supply of H2 to the stations could be built out.
5) Finally, the **Modelling Results** section provided the resulting estimated station locations maps for the three time horizons and the descriptions of the network.

2 Modeling Methodology

The B.C. LD FCEV Hydrogen fueling network was modeled using the EV Infrastructure Planning Tool developed by Kelly Carmichael at BCIT. The model was previously used to plan the network of DC Fast Chargers (DCFC) for BEVs and was modified to account for the performance characteristics of FCEVs. The

[1] Environment and Climate Change Canada. (2018). National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada, Annex 10. Retrieved from https://open.canada.ca/data/en/dataset/779c7bcf-4982-47eb-af1b-a33618a05e5b

[2] Fuel Cells and Hydrogen Joint Undertaking. (2019). Hydrogen Roadmap Europe. Retrieved from https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf

[3] BC Ministry of Energy, Mines, and Petroleum Resources. (2019). Legislation to Guide Move to Electric Vehicles, Reduce Pollution. Retrieved from https://news.gov.bc.ca/releases/2019EMPR0011-000608

station network design principles are also based on the original DCFC report done by the Province, adapted for FCEVs and HRS infrastructure.

2.1 Network Design Principles

The build-out of the HRS infrastructure network will be constrained by several factors and practical considerations. However, the design seeks to adhere closely to the following guiding design principles[4]:

1) Prioritize initial station clusters in areas with high FCEV adoption potential to align with vehicle Original Equipment Manufacturers (OEMs) deployment plans. OEMs and infrastructure developers have recommended to deploy a minimum of 2 stations per cluster within a 3-month window for redundancy and availability when a new cluster is initiated.
2) Connect clusters through travel corridors across the province, where commuter traffic, cross-jurisdictional travel or tourism is heaviest.
3) Maximize population areas served.
4) Locate stations at existing gas/diesel fueling stations where possible; otherwise, near a source of electricity and/or natural gas with access to service and maintenance parts and labour.
5) Ensure infrastructure deployment allows for safe and convenient travel in the province, whereby stations are planned at a frequency that allows travel under challenging conditions, such as inclement winter weather, for the most limited vehicle models available.

Not all principles will be met at each station location, but HRS infrastructure plans should aim to maximize the number of principles met where possible.

Other factors influencing the location selection, site features, and service standards of HRS infrastructure and the design of the individual stations within an area include:

- Accessible for vehicles travelling in both directions
- Well-lit and safe
- Upgradeable and scalable technology, including for future higher-capacity stations, greater numbers of stations, common standards, payment processes, etc.
- Design to meet or exceed codes and standards

2.2 Model Block Diagram

The block diagram in Figure 1 describes the overall modelling approach. External data sources were used to develop tables for the vehicles, stations and H2 supply inputs. These inputs were then staged and converted into a usable form and fed into individual models to determine vehicle range, station demand, and H2 supply requirements. Finally, outputs from these sub-models were used in the web-based Vehicle Energy-Distance Model (described in the following section) to determine the locations of the HRS sites and generate the network maps for 2025, 2030 and 2040.

[4] BC Ministry of Energy, Mines, and Petroleum Resources. (July 2018). British Columbia Direct Current Fast Charging (DCFC) Network Study: Core Network for Geographic Connectivity. Retrieved from: https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/electricity-alternative-energy/transportation/bc_dcfc_network_study_-_june_12_2018_final.pdf

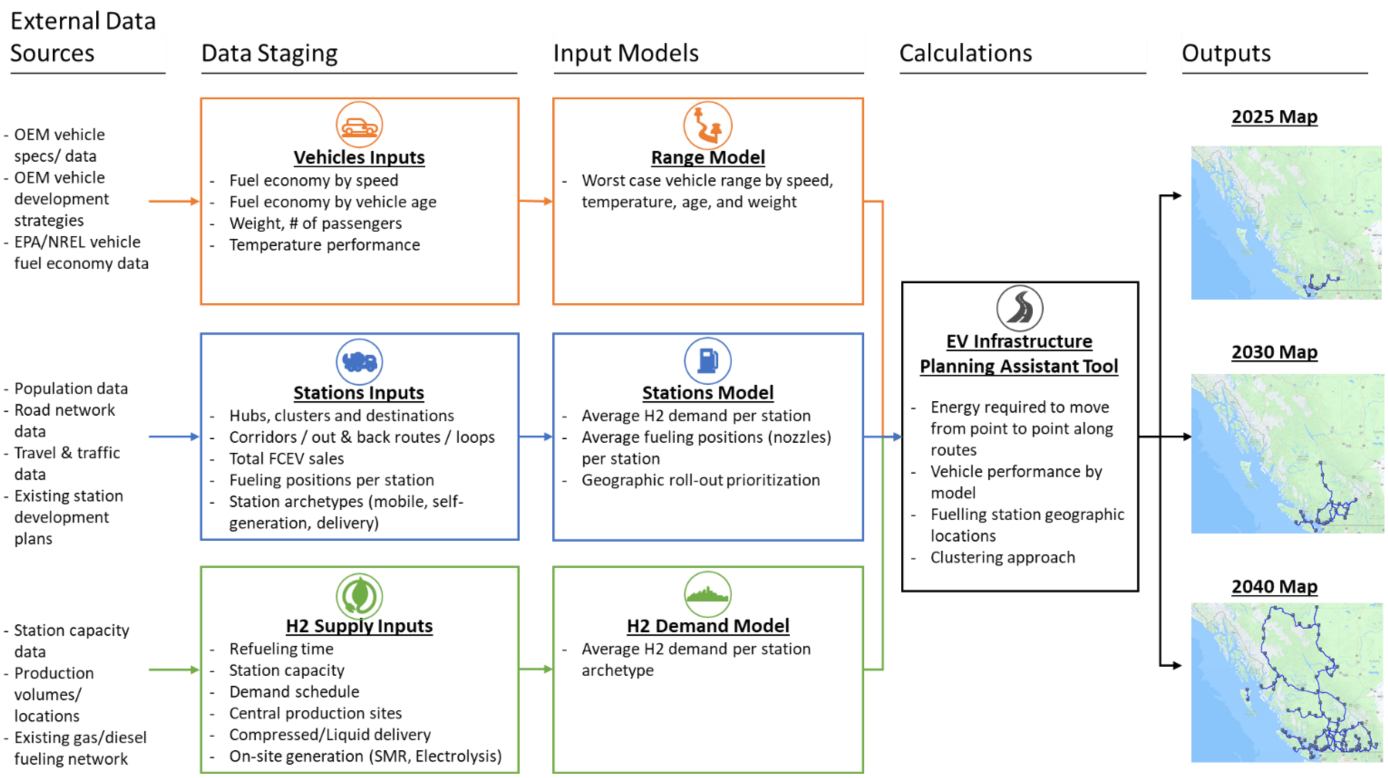


Figure 1. Model Block Diagram

2.3 Vehicle Energy-Distance Model

The H2 HRS Infrastructure Network uses a modified version of the EV Infrastructure Planning tool taking into consideration the performance characteristics of commercially available FCEVs.

Fundamentally, the model works by mapping the maximum range of a vehicle travelling along a route based on energy consumed. In the case of FCEVs, this is measured as the usable energy consumed from the hydrogen gas stored in its onboard fuel tanks. The modelling considers many aspects that could impact EV range, including:

- Efficiency of the vehicle (km per kg of H2 fuel)
- Weight of the vehicle and contents (Number of passengers)
- The terrain the vehicle is travelling on (particularly elevation gain and loss)
- Speed limits of the roads
- Outside air temperature
- The age of the vehicle

The nominal modelling parameters used for this analysis assume conservative values as follows:

- 5kg fuel tank vehicle (the Toyota Mirai's tank size)
- Worse-case baseline vehicle range, in this case, the Toyota Mirai (vs. the Hyundai Nexo)
- 3-year-old vehicle
- 2x65kg passengers in the vehicle

- Temperature of -10°C for Vancouver Island and Lower Mainland; -20°C for the rest of B.C.
- Vehicle is fueled to a 95% state of charge at each HRS and arrives at each station with a minimum 10% state of charge (i.e. vehicle must arrive at station with a minimum of 0.5 kg H2 remaining in the tank)

The EV Planning Tool calculates vehicle range as either round trips radially out and back from an HRS or as one-way trips between stations. Stations are manually placed on the map and a gap analysis is used to indicate the areas along routes where additional stations are required. The full core network of HRS sites is defined as the minimum number of stations required to enable safe travel, under worst-case conditions, throughout B.C.'s primary highways, secondary highways, and major roads.

2.4 Network Formation Priorities

The B.C. Hydrogen Infrastructure Network is expected to be built-out in stages over the next 20 years reaching full coverage by 2040. When staging the development of this network, it will be important to balance the need for greater coverage with the practical limitations of how FCEVs are likely to be adopted and used. Other regions, led by California, have tended to follow an approach that classifies stations as clusters, connectors or destinations[5]. Networks begin with several stations in the same geographic area, which are then linked by connector and destination locations. Additional locations are added as required for gap filling, redundancy, and additional capacity.

Major Clusters

Hydrogen refueling station infrastructure requires upfront investment and oversupply is often required. Vehicle OEMs will only release FCEVs into an area with existing HRS sites and consumers will only buy or lease an FCEV when they have the confidence they can fill up near where they live, work and regularly visit. As such, the build-out of stations benefits from a cluster approach where groups of stations (typically 7-8) are concentrated in one area to provide redundancy before expansion into a neighbouring area[6]. Examples of clusters in the province include the Lower Mainland, the Greater Victoria area, and the Central Okanagan.

Minor Clusters

In smaller populations centres (i.e. between ~100,000 and ~30,000 people), clusters of 2-4 stations should be developed in parallel. This will ensure there is appropriate capacity to service a smaller proportion of FCEV drivers while providing adequate redundancy. Examples of minor clusters in the province include Nanaimo, Kamloops, Prince George, Vernon, Penticton and Campbell River.

Connectors

Connector stations are the next step in the development of the network and provide the links that allow travel between clusters. These stations will initially have lower local demand but are critical especially given the large distances between cities in most areas of the province. Connector stations can be stand-alone for more remote areas, but multiple stations should be considered for redundancy. Examples of connector locations in the province include Hope, Merritt, and Williams Lake.

---

[5] California Fuel Cell Partnership. (July 2016). A California Road Map: Bringing Hydrogen Fuel Cell Electric Vehicles to the Golden State. Retreived from: https://cafcp.org/sites/default/files/20120814_Roadmapv%28Overview%29.pdf

[6] Various Participants. (October 2019). Interviews with Vehicle OEMs. Interview notes.

Destinations

Destination stations are in popular areas that experience large inflows of traffic from non-residents. These stations may have low local demand but serve the larger population. Examples of destinations in the province would include sites such as Whistler and Tofino and transportation hubs such as ferry terminals and airports.

2.5 Current Network Status

Hydrogen Technology and Energy Corporation (HTEC), is a BC-based company located in North Vancouver that is currently developing the first cluster of HRS infrastructure in the Lower Mainland (Figure 2). HTEC has deployed two stations, one in South Vancouver and another in Burnaby and has two additional stations planned for Vancouver, one in Victoria and one in Kelowna. These first stations will serve as the foundation for network clusters in these three regions.

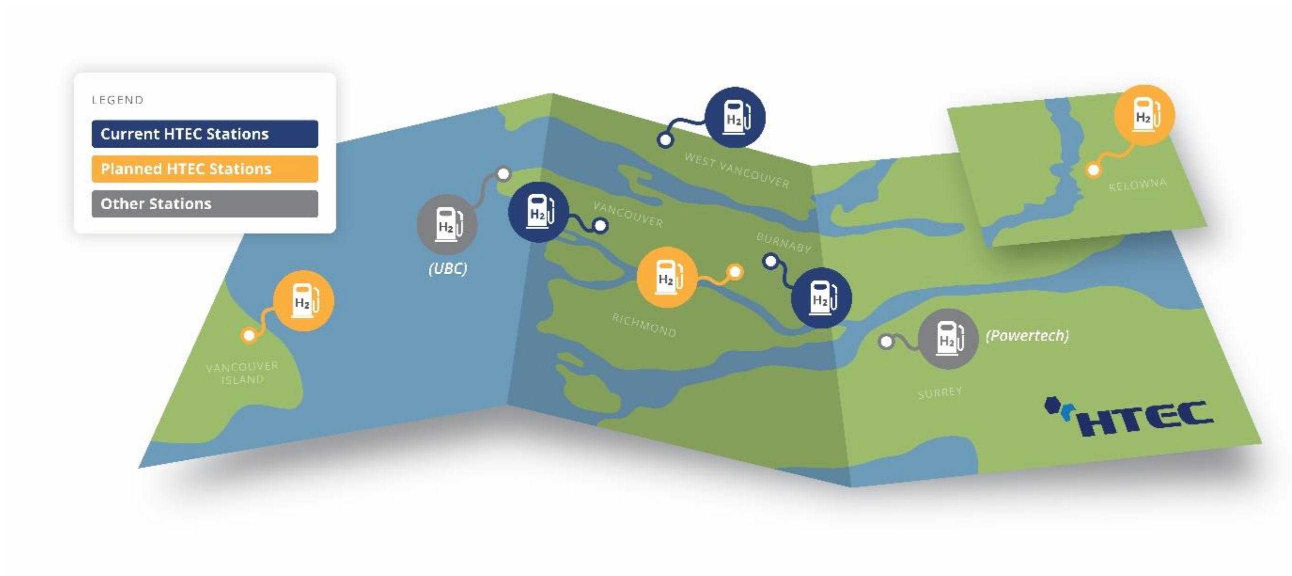


Figure 2. HTEC current HRS deployment plans (Source: HTEC)

3 Fuel Cell Vehicle Performance Characteristics

3.1 Vehicle types and performance

There are currently two models of FCEVs available in B.C. the Toyota Mirai (a mid-size sedan, similar to the Toyota Camry), and the Hyundai Nexo (a crossover SUV, purpose-built as an FCEV). Honda also offers the Clarity FCEV, but this is not expected to be available in Canada until Honda establishes a North American manufacturing facility for FCEVs[7].

[7] Various Participants. (October 2019). Interviews with Vehicle OEMs. Interview notes.

Toyota Mirai

Figure 3. 2019 model Mirai (Source: Toyota Canada[8])

The Toyota Mirai is a mid-size hydrogen fuel cell vehicle with a 2019 EPA-estimated fuel economy of 3.6 Le/100 km and a 502km driving range using a 5kg storage tank. The Mirai Fuel Cell stack has a maximum power output of 114kW (153hp). The curb vehicle weight is 1,850kg with seating for 4[8]

Hyundai Nexo

Figure 4. 2019 model Nexo (Source: Hyundai Canada[9])

The Hyundai Nexo is a hydrogen fuel-powered crossover SUV. The Nexo Blue has an EPA-estimated range of 611km and the Nexo Limited has a slightly lower range of 570km due to tank configuration options. The fuel economy is listed as 4.2 Le/100km. The maximum fuel cell power output is 95kW (127hp) with a maximum speed of 181km/h. The curb vehicle weight is 1,867kg with seating for 5[9].

3.2 Vehicle Fuel Economy Estimates

In the EV Planner Tool, the maximum distance between stations is constrained by the vehicle with the most limited range. The Mirai, with an estimated range of 502km, is therefore used as the limiting vehicle for the network calculations. Specific, real-world fuel economy data was requested from the vehicle OEMs, but as this was not available, they recommended using EPA data. Future iterations of the network plan should refine these estimates using empirical test data from actual vehicle road tests.

The baseline fuel economy values for the 2019 Toyota Mirai (See Appendix, Table 4) were determined by scaling the unadjusted EPA-reported highway fuel economy figures by a correction factor and then varying by speed and temperature as described below.

The EPA conducts multiple tests on vehicles to determine their fuel economy for city and highway driving behavior categorized by the test cycle attributes in Table 1[10]. For both the city and highway tests, the EPA conducts an initial unadjusted fuel economy evaluation for each vehicle under controlled and ideal conditions.

Table 1: EPA fuel economy test conditions for city and highway tests[10].

TEST CYCLE ATTRIBUTES	CITY	HIGHWAY

[8] Toyota Canada. (Feb 2020). 2019 Toyota Mirai: Power to Start Something Bigger (website). Retreived from: https://www.toyota.com/mirai/fcv.html
[9] Hyundai Canada. (Feb 2020). Nexo (website). Retrieved from: https://www.hyundaicanada.com/en/vehicles/2019-nexo
[10] U.S. Department of Energy. (Accessed Feb 2020). Fuel Economy (website). Retrieved from: https://www.fueleconomy.gov/feg/fe_test_schedules.shtml#detailed-comparison

Trip type	Low speeds in stop-and-go urban traffic	Free-flow traffic at highway speeds
Top speed	56 mph	60 mph
Average speed	21.2 mph	48.3 mph
Stops	23	0
Idling time	18%	0
Lab temperature	68 °F – 86 °F	

Additional tests to assess the impact of high speeds, cold temperatures, and auxiliary loads are performed and applied to the unadjusted fuel economy values to reflect realistic national average driving conditions. The EPA accounts for real-world driving conditions (e.g. wind, tire pressure, rough roads, and snow or ice) by applying a reduction factor of 22% and 10% reduction to the highway and city fuel economy values, respectively[11]. Combing the reduction factor and results from the additional condition tests, an adjusted fuel economy value is determined to represent a national average for driving conditions.

The planning tool used for this study does not consider acceleration or traffic and requires that the fuel economy be expressed as a range of temperatures and speeds rather than as an average like the adjusted fuel economy rating. As such, the unadjusted highway fuel economy rating was scaled by the 22% reduction factor and the resulting value of 74.9 MPGe was used as the baseline value for vehicle modeling[12]. The EV Planner tool considers additional factors such as altitude and air density as part of the calculations for the energy demands for each specific route.

Fuel Economy vs. Speed

The general relationship between fuel economy and speed was determined by using a combination of NREL light-duty FCEV-specific experimental data for speeds less than 90 km/h (Figure 5) and EPA industry standard data for speeds greater than 90 km/h (Figure 6)[13,14].

[11] Office of Transportation and Air Quality. (Accessed Feb 2020). Fuel Economy Testing and Labeling Questions and Answers (website). Retrieved from: https://fueleconomy.gov/feg/info.shtml
[12] U.S. Department of Energy. (Accessed Feb 2020). Download Fuel Economy Datay 2020 (website).Retrieved from: https://www.fueleconomy.gov/feg/download.shtml
[13] J. Kurtz, S. Sprik, G. Saur and S. Onorato. (March 2019). Fuel Cell Electric Vehicle Driving and Fueling Behavior. Retrieve from: https://www.nrel.gov/docs/fy19osti/73010.pdf
[14] U.S. Department of Energy. (March 2020). Fuel Economy Guide Model Year 2020. Retrieved from: https://www.fueleconomy.gov/feg/pdfs/guides/FEG2020.pdf

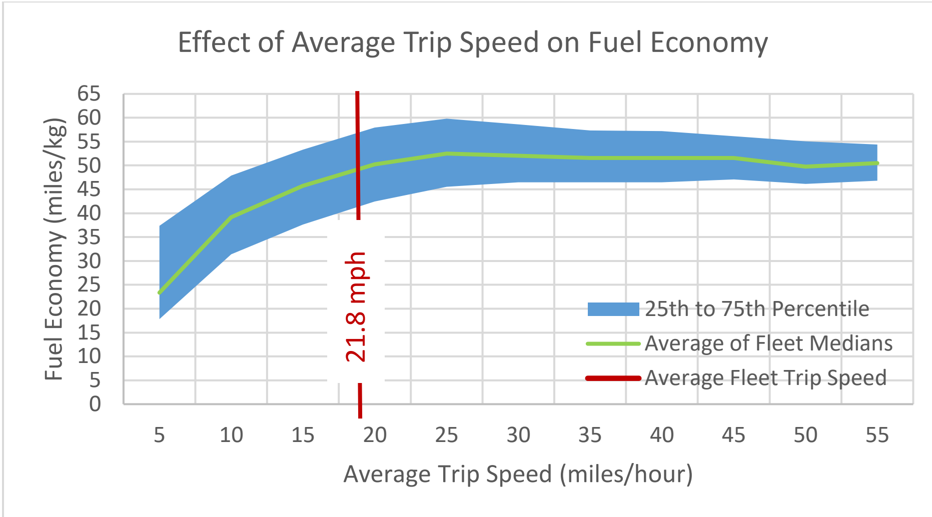


Figure 5. Effect of average trip speed on fuel economy <90km/h (NREL[13])

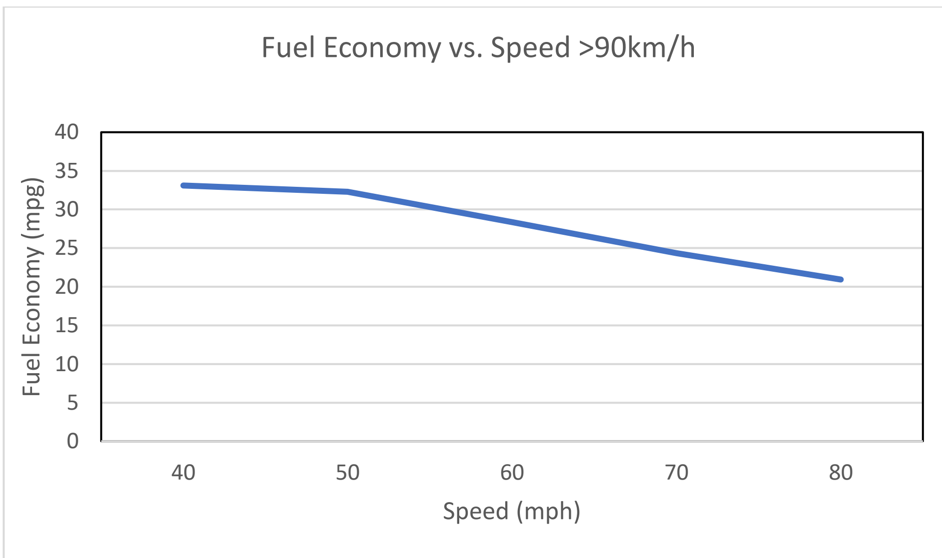


Figure 6. Fuel economy vs. speed >90km/h (EPA[14])

The two trendlines and the baseline fuel economy rating derived from EPA data were combined to generate a speed vs. fuel economy profile for the 2019 Toyota Mirai. Using the average speed of the highway EPA fuel economy test at 78 km/h the two trendlines were scaled and combined to generate a speed and fuel economy profile as displayed in Figure 7.

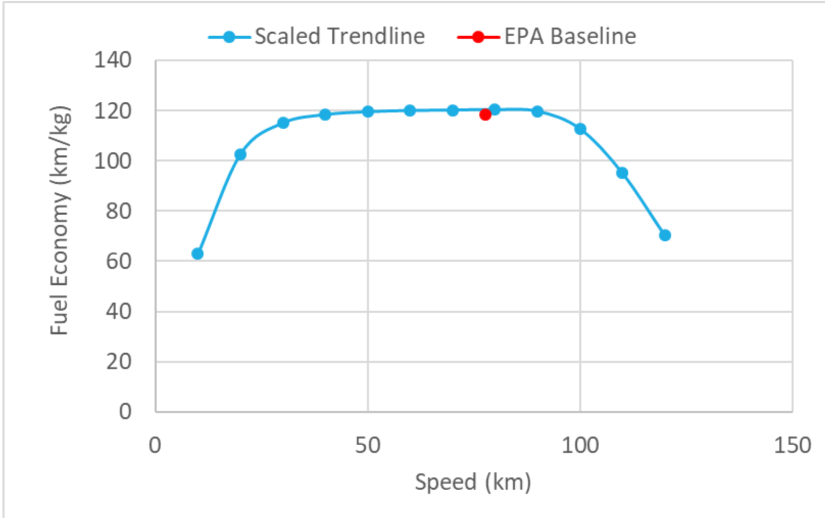


Figure 7. Fuel economy vs. speed with EPA baseline

Fuel Economy vs. Temperature

Existing data or studies on the impact of ambient temperature on the fuel economy of fuel cell vehicles is not currently available. As such, the relationship between battery electric and FCEV at colder temperatures was used to determine a profile.

Fuel economy dependence on ambient temperature was determined using a 2019 study from the Center for Transportation and the Environment (CTE) that compared fuel cell and battery electric bus performance in cold weather. The study estimated a 27.8 % decrease in range for battery electric buses and a 23.1% decrease in range for fuel cell electric buses[15]. Comparing battery electric vehicles and fuel cell vehicles directly, the latter is 39% less impacted by ambient temperature on average. Anecdotal data reported by actual Mirai drivers in BC indicates that this is a conservative estimate that can be used as a “worst-case” cold weather impact for FCEVs.

The impact of temperature on the fuel economy of a battery electric vehicle (2016 Nissan Leaf), validated by the EV Planner Tool’s creator, Kelly Carmichael, was used as a trendline for the 2019 Toyota Mirai. Values from the Nissan were adjusted to reflect the 2019 Toyota Mirai based on a 39% reduction of the percent change between the fuel economy at the EPA baseline temperature of 21°C and a temperature range of -20°C to 32°C for the Nissan Leaf. Table 2 demonstrates how the ambient temperature impacts fuel economy based on the EPA baseline value and generated speed profile.

[15] M. Henning, A. R. Thomas and A. Smyth. (November 2019). An Analysis of the Association between Changes in Ambient Temperature, Fuel Economy, and Vehicle Ranges for Battery Electric and Fuel Cell Electric Buses.

Table 2. Mirai adjusted fuel economy by speed and temperature

Mirai	Fuel Economy @ Varying Speeds (MPGE)												
Temp (°C)	**10 km/h**	**20 km/h**	**30 km/h**	**40 km/h**	**50 km/h**	**60 km/h**	**70 km/h**	**78 km/h**	**80 km/h**	**90 km/h**	**100 km/h**	**110 km/h**	**120 km/h**
-20	36.79	68.63	82.69	89.21	92.22	94.50	96.69		97.80	98.91	94.27	80.72	59.53
-10	37.20	69.99	84.23	90.83	93.88	97.06	99.31		100.62	102.04	96.46	82.80	61.21
0	43.32	80.20	94.26	100.57	102.99	105.57	107.17		108.16	108.31	101.92	86.95	64.59
10	43.73	81.57	96.57	103.01	105.48	108.13	109.79		110.98	111.44	105.20	90.06	66.27
21	62.92	102.67	115.09	118.43	119.57	120.05	120.27	118.30	120.40	119.79	112.85	95.25	70.49
32	44.54	83.61	99.66	107.07	109.62	112.38	114.16		115.69	116.66	109.57	94.21	69.65

The resulting relationship between ambient temperature and fuel economy for the 2019 Toyota Mirai at 80 km/hr is demonstrated in Figure 8.

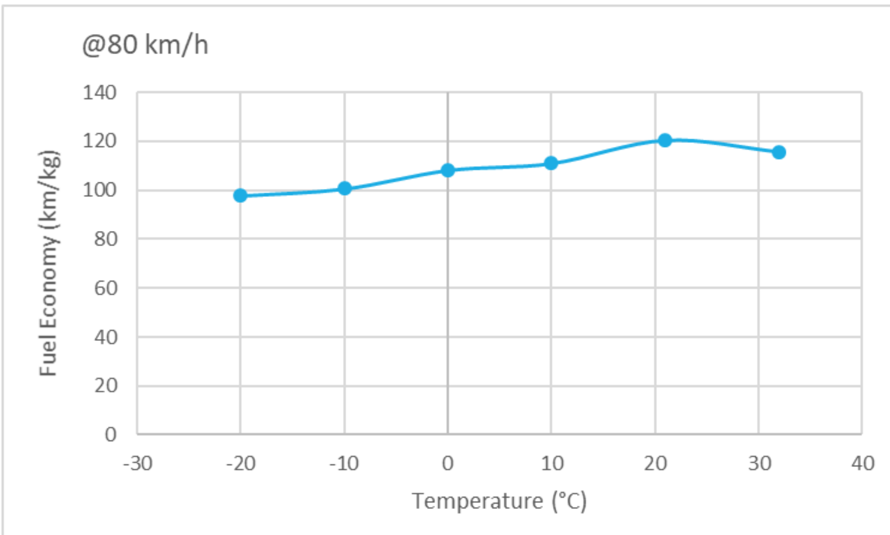


Figure 8. Fuel economy by temperature at 80km/h

These modeled fuel economy values, based on today's Mirai fuel cell technology, were used for the station planning out to the 2040 timeframe. It should be noted that fuel economy is expected to improve as next-generation vehicles incorporate technology advancements. Therefore, this approach for long-term planning should be viewed as conservative to ensure adequate coverage.

3.3 Vehicle OEM FCEV Roll-out Plans & Sales Projections

The adoption of FCEVs, and the locations of the HRS infrastructure to serve them, will be initially driven by the priorities of the Vehicle OEMs and the specific markets being targeted. For example, due to the relative price of FCEVs and the specialized nature of the maintenance and parts, these vehicles will initially be targeted toward consumers in the higher income areas around major urban areas. Vehicle OEMs will also want to see a concentration of fueling stations in one area before scaling deployments from tens to hundreds of vehicles[16].

As part of this study, the three main FCEV OEMs, Toyota, Hyundai, and Honda, were asked to provide feedback on the network deployment maps and their strategies for rolling out and scaling FCEVs across the province. OEM rollout plans are very proprietary so individual plans cannot be shared in this public report. However, all the consulted OEMs agreed with the cluster deployment strategy and indicated 7 to

[16,17] Various Participants. (October 2019). Interviews with Vehicle OEMs. Interview notes.

8 stations are needed in a geographical area before they will consider large-scale (hundreds vs. tens) deployments of vehicles[17].

In addition to feedback on the station deployments, the OEMs were also shown the vehicle deployment projections in BC and asks to comment on their reasonableness. All indicated that the near-term projections of 900-1200 FCEVs by 2023 as an amalgamated total was reasonable. It should be noted that all OEMs are interested in supporting the deployment of HRS infrastructure in the province through various efforts. Infrastructure development must lead vehicle deployments for a successful transition.

3.4 Light-Duty Vehicle Deployment Estimates

The number of fuel cell vehicles sold in B.C. is expected to increase rapidly from nearly 50 FCEVs in 2020 to between 200,000 and 350,000 by 2040 as modeled in the BC Hydrogen Study[17]. These projections are based on (1) the percentage of new vehicles that are expected to be FCEVs from the ZEV mandate, (2) the number of FCEVs produced by the vehicle OEMs, and (3) the historical sales trends to date from the more advance California market. Together these estimates are combined to project the range of FCEVs on the road in B.C. by 2040. After 2040, all new vehicles sold in the province will be required to be ZEVs and the ratio of BEVs to FCEVs is expected to remain relatively constant.

Figure 9 shows the range of estimated FCEVs on the road between 2025 and 2030 with a scaled (based on population) and time-shifted curve of the adoption rate in California for comparison. The right-hand axis shows the expected demand for H2 fuel in tonnes per year based on an average LD vehicle consumption of 0.5kg per day.

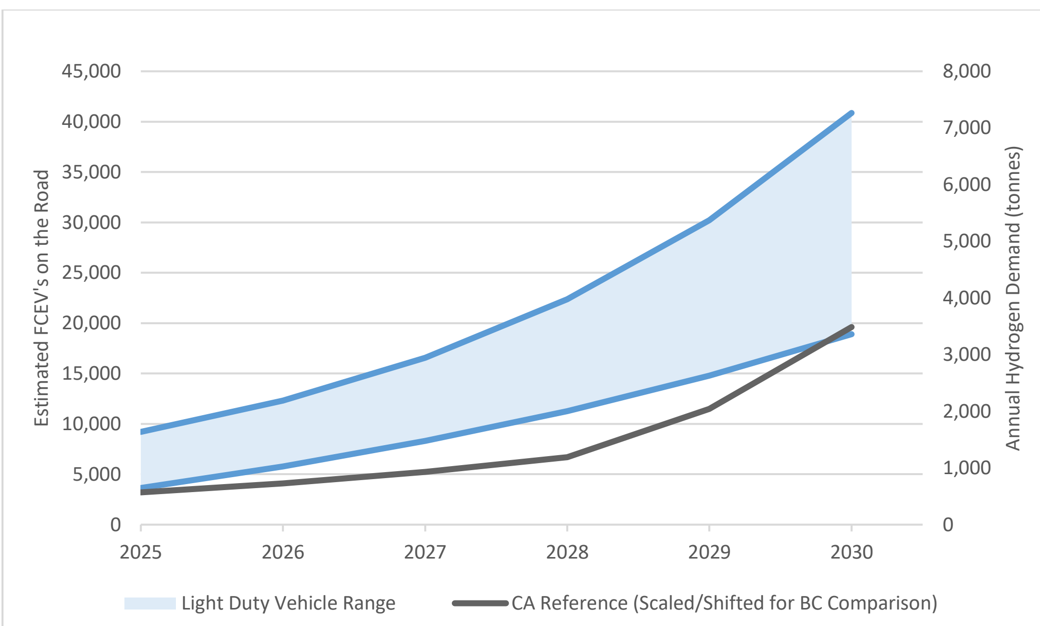


Figure 9. B.C. Light-Duty FCEV fleet estimates by year

[17]Zen Energy Solutions. (2019). British Columbia Hydrogen Study.

Figure 10 shows the 2025 to 2040 view of both the range of LD FCEVs on the road and the number of fueling stations deployed. The number of fueling stations required is calculated based on an assumed average consumption of 200kg/day per fueling position and an average of 6 fueling positions per station. These inputs come from observing the evolution of station designs in California as load grows, and from inputs from station developers.

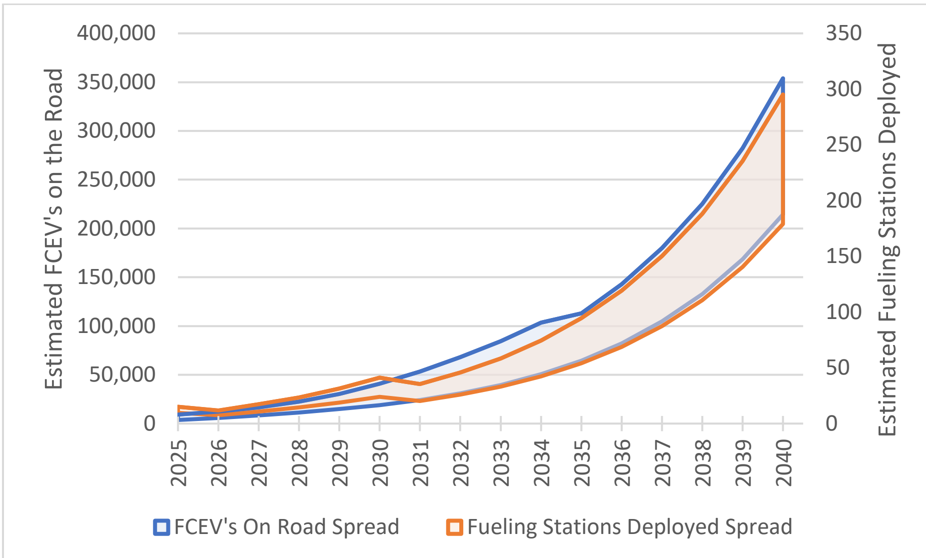


Figure 10. B.C. Light-Duty FCEVs fleet and fueling station estimates by year

3.5 Traffic modeling and Population Density

The final consideration for determining vehicle volumes, and therefore HRS infrastructure demand, is traffic and population density. While the former is available for certain routes, it was found to be generally too infrequent or dated to be a good indication of demand. Population density was instead used as a proxy for future FCEV adoption and distribution.

In Figure 11 below, the main population centres in the provinces are indicated and classified as either a cluster, a connector or a destination for H2 station buildout. These population centres indicate where additional station capacity and redundancy may be required and the connecting routes that are likely to experience the most vehicle traffic. Tofino and Whistler are shown as popular destinations where the incoming traffic volume may be such that additional stations are required.

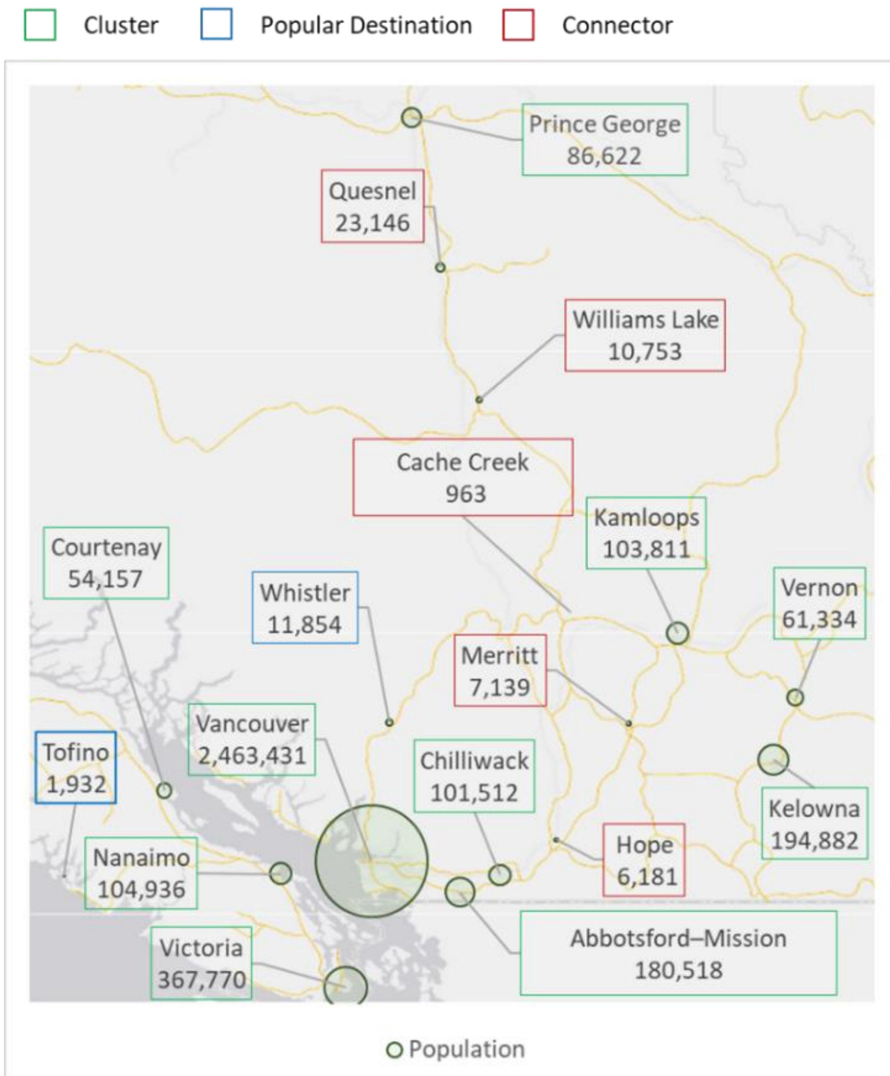


Figure 11. Population clusters, connectors, and destinations (Source: BC Population data[18])

[18] Government of B.C. (March 2020). British Columbia Population Estimates: Municipal and sub-provincial areas population, 2011 to 2019. Retrieved from: https://www2.gov.bc.ca/gov/content/data/statistics/people-population-community/population/population-estimates

4 Hydrogen Refuelling Station Infrastructure

4.1 Station Types

Hydrogen Refuelling Stations are built using standardized and scalable equipment such as Compressors, Storage tanks, and Dispensers, collectively referred to as CSD equipment. It is expected that station design and construction will standardize in a similar way to existing gas and diesel fueling stations[19]. Currently, stations are classified based on the types of vehicles they serve (Heavy-Duty or Light-Duty), their installation type (containerized or permanent), their fuel source (on-site production, gaseous or liquid delivered), and the number of dispensers and daily capacity. By way of example, standard configurations of gaseous delivered and liquid hydrogen delivered stations are shown below (Figures 12 and 13).

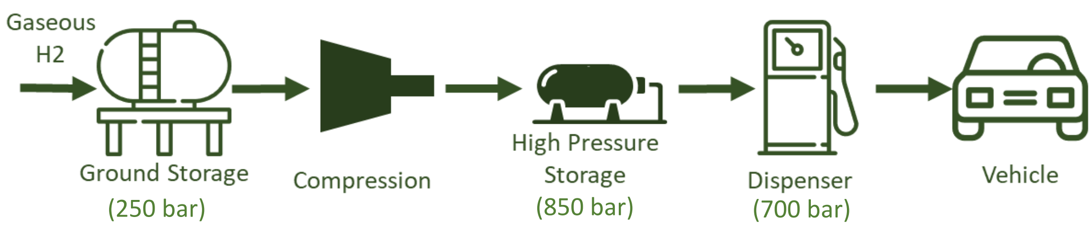


Figure 12. Gaseous H2 Refueling Station Compression, Storage, and Dispensing Equipment Chain

Figure 13. Liquid H2 Refueling Station Compression, Storage, and Dispensing Equipment Chain

Heavy-Duty vs. Light-Duty

While Light- and Heavy-Duty HRS share many of the same components, there are currently two main fueling standards that create important differences. Light-Duty vehicles, due to their smaller size and limited cargo space, required higher compression in their storage tanks, typically 700 bar. While Heavy-Duty vehicles have space for larger storage tanks and therefore tend to favour lower pressures (350 bar) because these tank types are lower cost. HD vehicles may eventually move to 700 bar storage, but most current stations will be designed for one or the other fill pressure depending on the application served.

Containerized vs. Permanent

Containerized fueling stations are designed such that all the required equipment fits into a standard size shipping container. These stations can be rapidly deployed and can be installed temporarily as needed. Fuel is typically delivered in the form of tube trailers or gas cylinders mounted on detachable frames that can be filled remotely and left on site.

[19] Various Participants. (October 2019). Interviews with Vehicle OEMs. Interview notes.

Figure 14. Example of a containerized fueling station in Quebec City

Permanent stations are either purpose-built, green-field sites or modifications and expansions of existing gasoline/diesel fueling stations. These installations have the same general equipment as containerized stations, but they are generally mounted on a concrete pad with various enclosures for the different components. The dispenser units for these stations typically look very similar to well-known gas pumps and feature integrated displays, safety features and point of sales.

Figure 15. Example of a permanent H2 dispenser at an existing fueling station in Vancouver

Volume/Capacity

Like a conventional gas station, a single HRS can consist of multiple dispensers which can each have multiple nozzles that transfer hydrogen to the vehicles. Due to relatively low demand, most stations currently installed around the world are comprised of a single dispenser with a single nozzle.

HRS dispensers are designed to output a maximum amount of fuel per day, which typically ranges from 100 to 200kg/day. The existing and planned stations managed by HTEC in Metro Vancouver, the Capital Regional District and Kelowna are sized for 100-200 kg/day.

Peak station output is determined by the time it takes to position the vehicle, attach the nozzle, fill, pay, and depart. It takes an average of 3.5 minutes to fill a vehicle with hydrogen and an average fill requires 3.1 kg of hydrogen (tank size is typically 5 kg).[20] Assuming it takes an average of 5 minutes to complete all other necessary tasks at the station, the peak output of a single nozzle is 22 kg/hour, which is enough to fill 6 vehicles per hour.

The maximum output of a dispenser is only expected during peak periods. Figure 16 shows the expected daily fueling profile of an HRS based on 465,794 fills measured in California.[21]

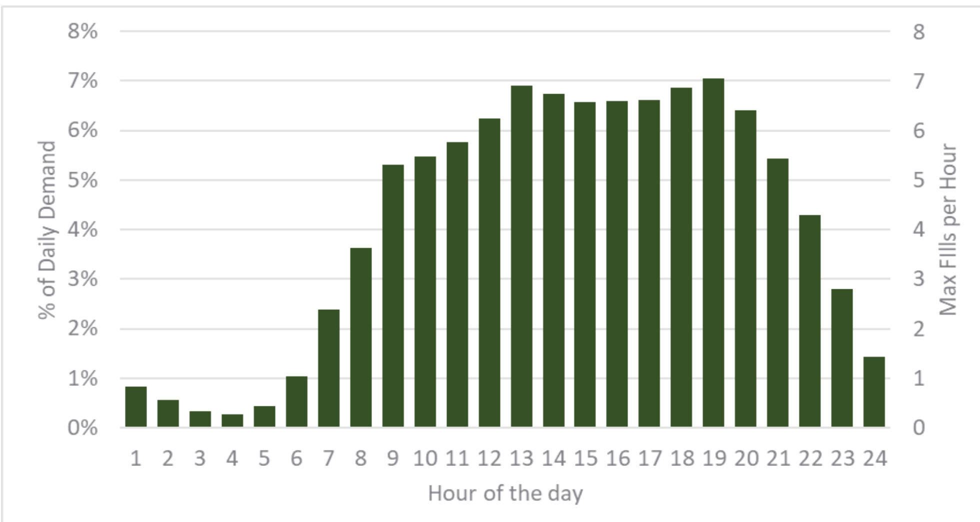


Figure 16. Number of Fueling Events per Time of Day[22]

In California, utilization rate data captured by NREL across 34 stations currently ranges from 5-77%[23] and the average output per station is 54 kg/day.[24] The highest peak fill for the period was 300kg in one day and the station with the highest average was 150kg/day. Station utilization will increase as a greater number of fuel cell electric vehicles are on the road.

---

[20] NREL. (2019). *Next Generation Hydrogen Station Composite Data Products: Retail Stations – Monthly Averages for All Fills*. Retrieved from https://www.nrel.gov/hydrogen/assets/images/cdp-retail-infr-55.20190416.jpg
[21] NREL. (2019). *Next Generation Hydrogen Station Composite Data Products: Retail Stations – Fueling Events per Time of Day*. Retrieved from https://www.nrel.gov/hydrogen/assets/images/cdp-retail-infr-15.20190416.jpg
[22] Ibid.
[23] NREL. (2019). *Next Generation Hydrogen Station Composite Data Products: Retail Stations – Station Capacity Utilization*. Retrieved from https://www.nrel.gov/hydrogen/assets/images/cdp-retail-infr-06.20190416.jpg
[24] NREL. (2019). *Next Generation Hydrogen Station Composite Data Products: Retail Stations – Daily Fueling Amounts*. Retrieved from https://www.nrel.gov/hydrogen/assets/images/cdp-retail-infr-80.20190416.jpg

5 H2 Supply & Delivery

5.1 Production options

The hydrogen supply for refuelling stations must be produced from feedstocks, for example water, natural gas, or biomass, and from energy inputs, such as electricity or natural gas. The two main supply pathways considered in this study are centralized production via large-scale electrolysis or Steam Methane Reformation (SMR), and on-site production via small-scale electrolysis or SMR. Hydrogen can also be sourced from the by-product of industrial processes or through methane pyrolysis, but these methods have limited potential currently.

Large-scale centralized production

A percentage of the hydrogen in the network could be supplied from centralized hydrogen production facilities using electrolysis or SMR with Carbon Capture and Storage (CCS). This centralized production approach can take advantage of sites with existing electrical capacity or access to CCS in the case of SMR. Depending on the scale and the delivery distances, these sites can also be combined with liquefaction plants to produce LH2 to meet higher demand (see Figure 17).

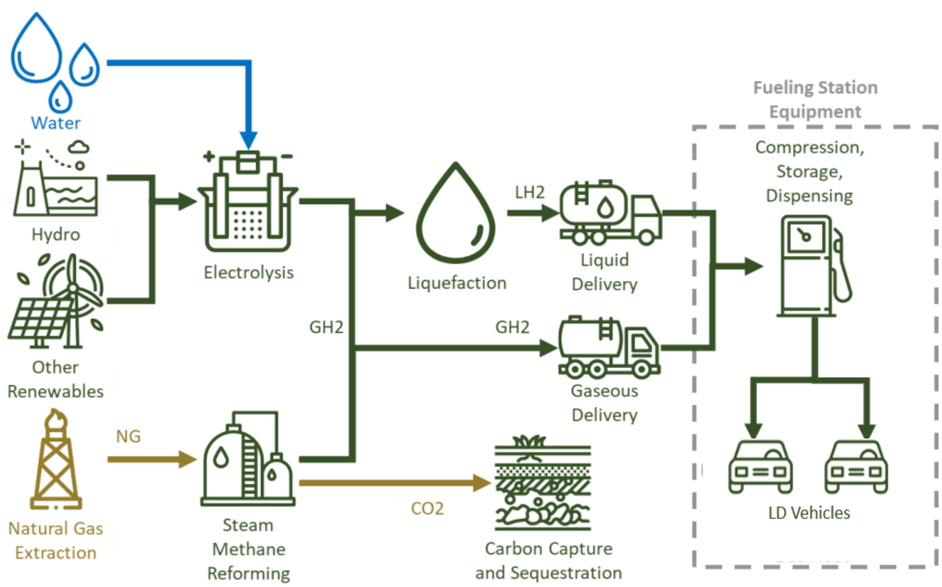


Figure 17.Centralized Hydrogen Production Equipment Diagram

Small-scale on-site production

On-site production via small scale electrolysis is an option for HRS sites located in remote areas that have access to electricity. Depending on the station demand these sites could generate and store H2 in tanks or generate low volumes of H2 fuel on-demand. Due to the cost of electricity, these sites would be ideally suited to locations that have access to the BC Hydro industrial rate (approx. $60/MWh), such as at large industrial sites (see Figure 18).

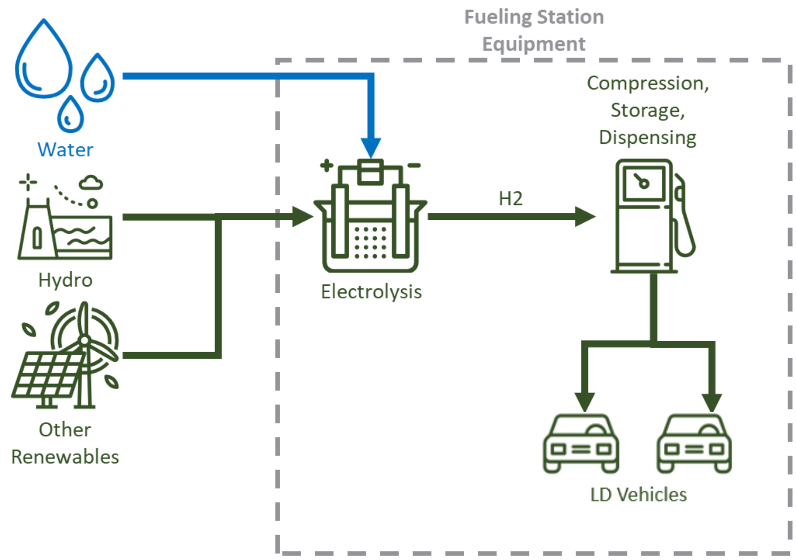


Figure 18. On-Site Electrolysis Hydrogen Production Equipment Diagram

Similarly, on-site production via SMR is suited for HRS sites located near a source of bio-methane or a natural gas pipeline. Small scale SMR has limited commercial deployments currently but may be more cost-effective than electrolysis given the low cost of natural gas in the province (see Figure 18).

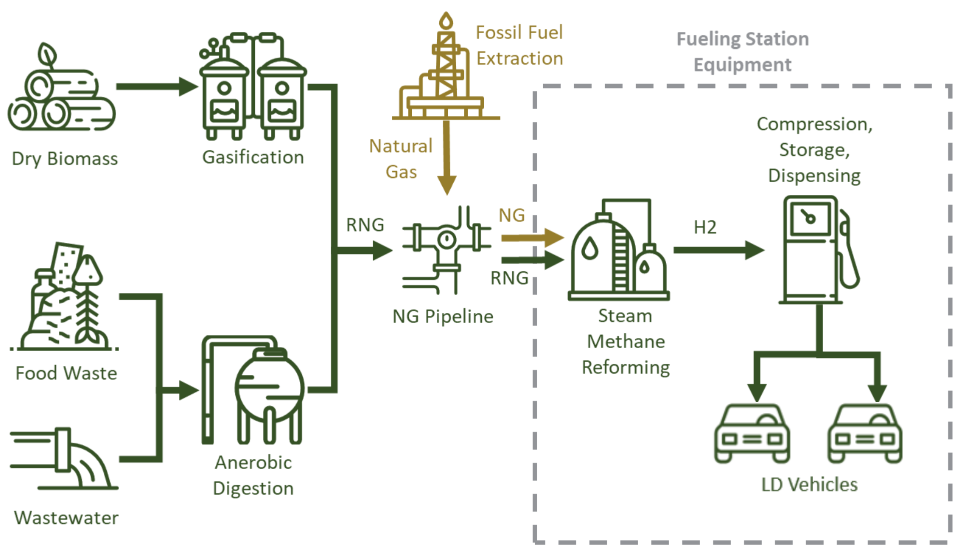


Figure 19. On-Site SMR Hydrogen Production Equipment Diagram

5.2 Distribution considerations

Between 2025 and 2030 most HRS sites will be supplied by either hydrogen generated on-site or by gaseous delivery (see Figure 20). On-site generation is effective for low volume stations far from centralized production facilities such as on islands or along remote highways, assuming there is a source of natural gas and electricity nearby. Gaseous delivery is cost-effective for low volumes and relatively short distances such as within clusters of stations.

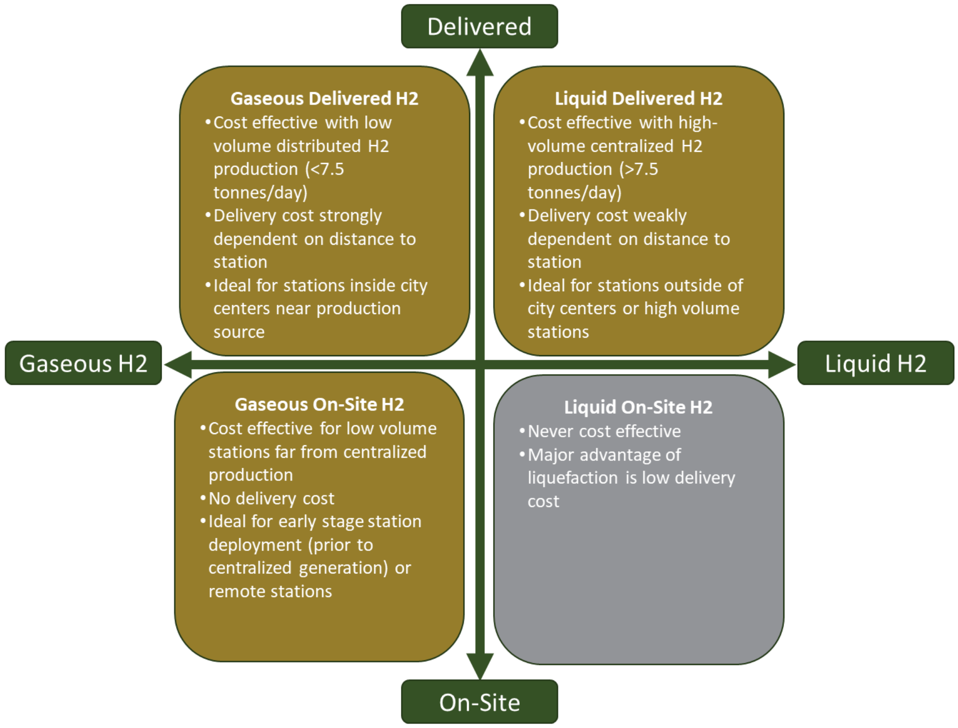


Figure 20. Hydrogen Fueling Station Type Summary

Due to high capital costs, liquifying and delivering liquid H2 becomes cost-competitive only with high volumes, or long distances. Figure 21 shows that for gaseous delivery greater than 100km in distance, delivery costs can become prohibitive. Delivery of LH2, on the other hand, is more insensitive to delivery distance given the high capacity of each delivery. For comparison, a liquid delivery tractor-trailer can carry about 15X as much hydrogen as a gaseous delivery tractor-trailer.

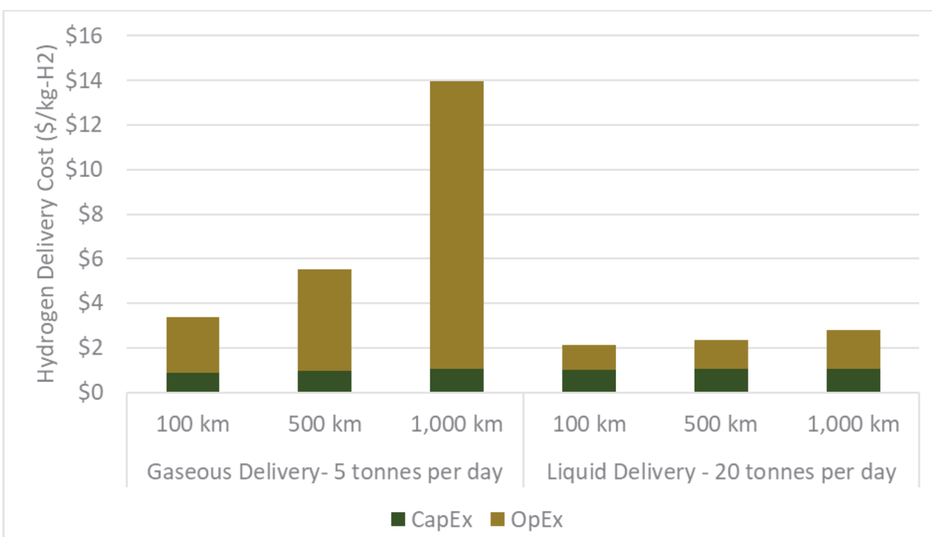


Figure 21. Approximate Delivery Cost for Gaseous and Liquid H2 by Delivery Distance (one-way)

6 Modeling results

Based on the modeling results and the network build-out considerations described above, it is estimated that a total of approximately 82 HRS sites are required to provide a minimum core network connecting all of B.C.'s primary and secondary highway routes by 2040. Due to the clustering approach and the need for additional capacity and redundancy, the actual number of stations deployed will likely be in the range of 150-250.

Table 3 summarizes the build-out of the network by year, station type, and location. By 2025, 10 new stations will be added to those already planned or operational for a total of 17. The initial focus will be to establish a viable network of at least 7 stations in the Lower Mainland and build redundant stations in the three other major cluster locations (Greater Victoria, Fraser Valley, and the Central Okanagan). Connector stations will also be required in Hope and Merritt to bridge from the central interior region to the coast. Finally, a destination station should be added to facilitate travel to Whistler, and a station in Nanaimo to access the east coast of Vancouver Island.

Table 3. Network build-out summary

Type	Name	2025	2030	2040
Major Cluster	Lower Mainland	7	12	15
	Greater Victoria	2	7	10
	Central Okanagan	2	7	10
	Fraser Valley	2	7	10
Minor Clusters	Nanaimo	1	2	4
	Kamloops	0	2	4
	Prince George	0	2	4
	Vernon	0	2	3
	Penticton	0	2	3
	Campbell River	0	2	3
Connector		2	8	67
Destination		1	2	8
Total Stations		**17**	**55**	**141**

In 2030, the network should develop the major clusters around the populations centres of Victoria, Abbotsford, and Kelowna, while adding additional capacity in the Lower Mainland. Minor clusters of 2-3 stations should also be established in the six smaller cities of Nanaimo, Kamloops, Prince George, Vernon, Penticton and Campbell River. Connector stations are required along Hwy 97 to Prince George, Hwy 1 to Revelstoke and Hwy 4 to the west coast of Vancouver Island. Tofino is added as a destination.

By 2040, the network should grow to achieve full coverage of all the primary and secondary highways and major roads in the province. The full build-out of these stations will depend on several factors including hydrogen supply logistics, FCEV uptake in rural areas, vehicle range improvements and connection points in nearby provinces and states. Certain remote areas of the province may require temporary stations to fill gaps while vehicle technology develops or until hydrogen can be generated locally. The remainder of the stations added by 2040 will likely be driven by demand and convenience within the clusters and the need for further redundancy in the connectors and destinations.

Please note that these specific locations are provided for illustrative purposes, based on the mapping tool only, and are provided to give a general sense of the number and high-level distribution of HRS sites across B.C. needed to provide a base level of geographic connectivity for FCEV drivers. These should not be viewed as specific sites.

6.1 2025 Map

In 2025, the first 15-20 HRS sites will be concentrated in the Lower Mainland, Central Okanagan, and South Vancouver Island regions (see Figure 22). FCEVs are not expected to be available in the rest of the province due to targeted OEM roll-out plans and the availability of hydrogen supply.

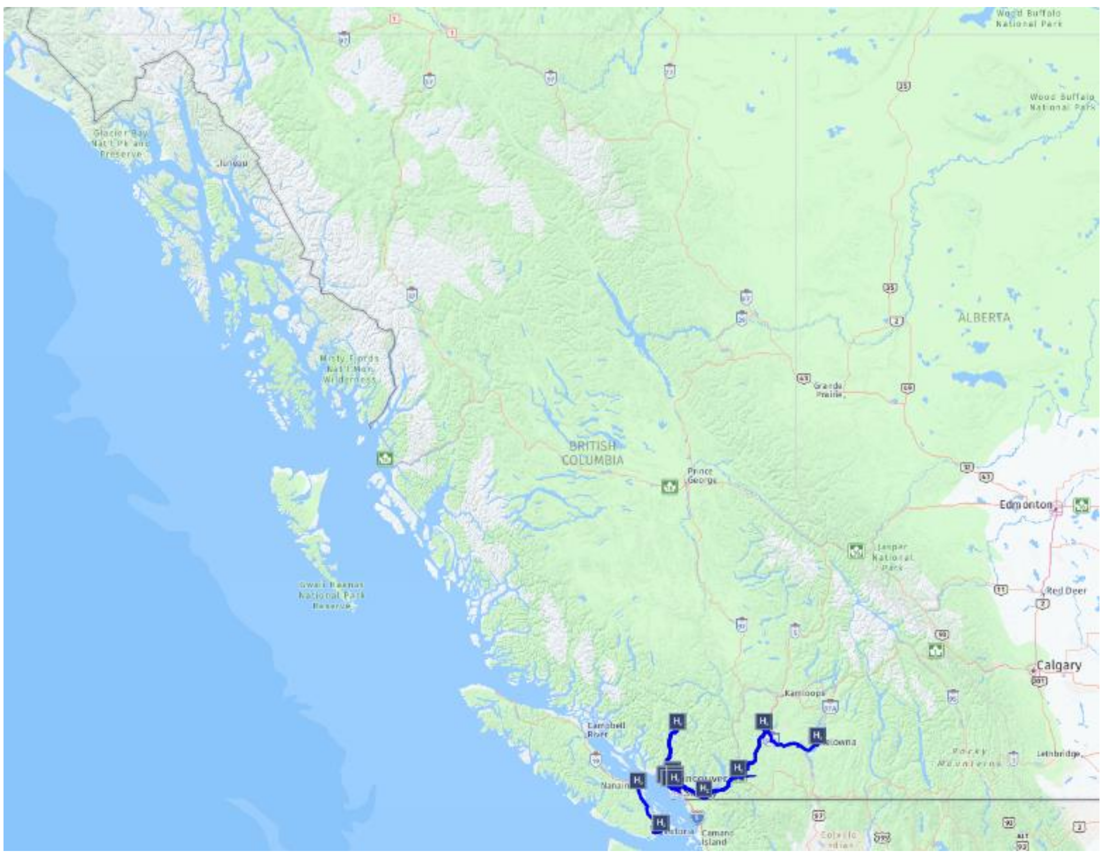


Figure 22. 2025 Provincial Map

Figure 23 shows the build-out of stations, starting from the cluster in the Lower Mainland. Clusters are also established in the Greater Victoria Region and in Kelowna. Connector stations are added in Merritt, Hope, Abbotsford, and Nanaimo. Whistler is a destination station due to high seasonal travel. The blue circles are indicative of a 200km radius trip away from the network edge. For example, a driver in Kelowna should be able to fill up and drive to Vernon and back without running out of fuel.

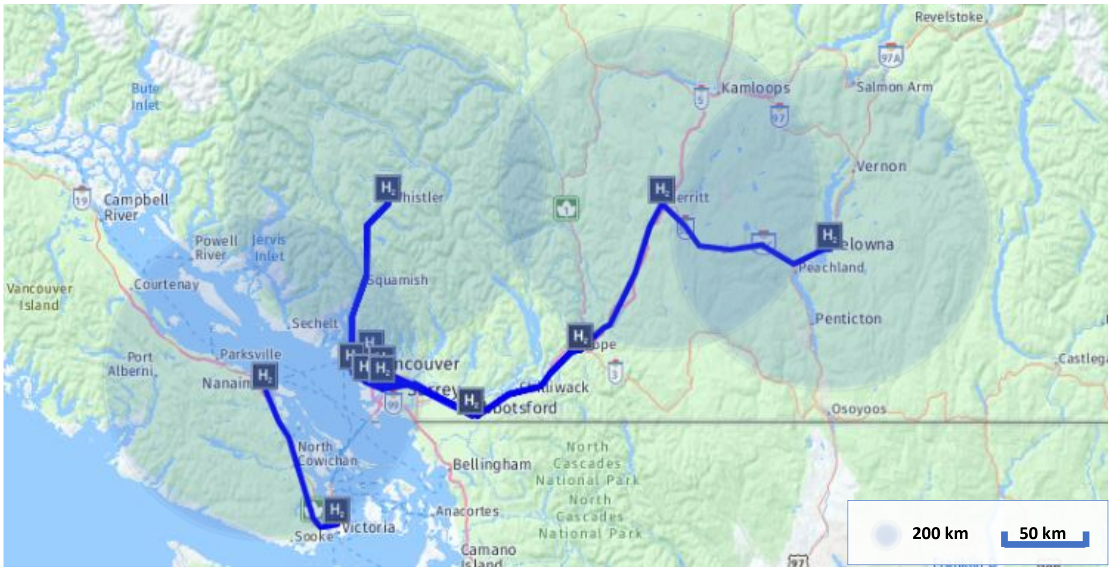


Figure 23. 2025 Southern province map

Figure 24 shows a close-up of the Lower Mainland Cluster. The two existing operational stations in South Vancouver and Central Burnaby are with the stations already in development in North Vancouver, UBC, and South Burnaby. This cluster of 5 stations plus the stations in Abbotsford and Whistler will encourage larger-scale deployments from vehicle OEMs.

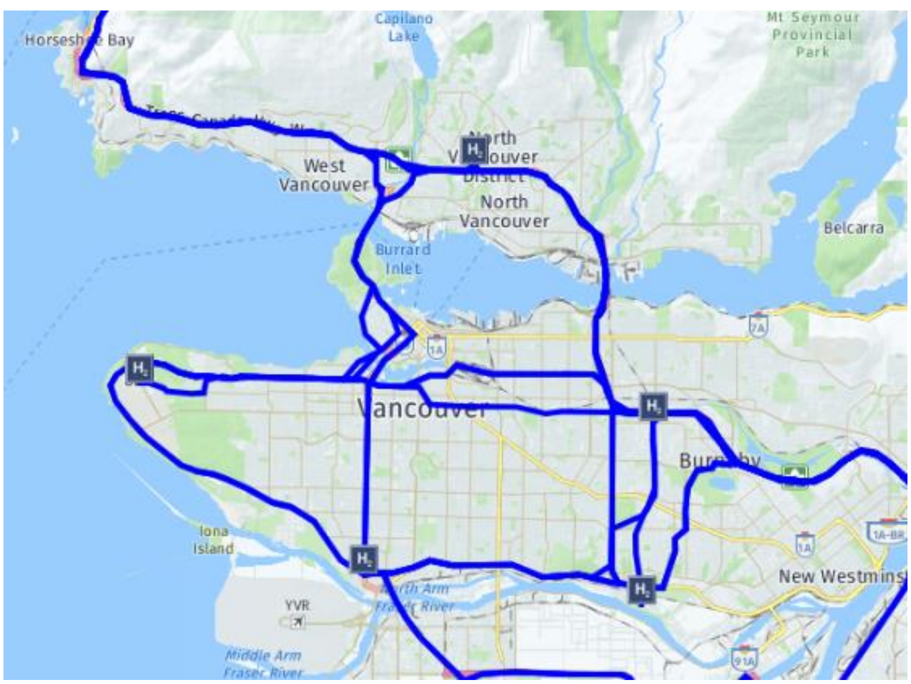


Figure 24. 2025 Greater Vancouver cluster map

6.2 2030 Map

By 2030, the station network will connect the Lower Mainland, Central and North Okanagan, East Vancouver Island and Caribou Central Interior regions of the province as far as Prince George (see Figure 25).

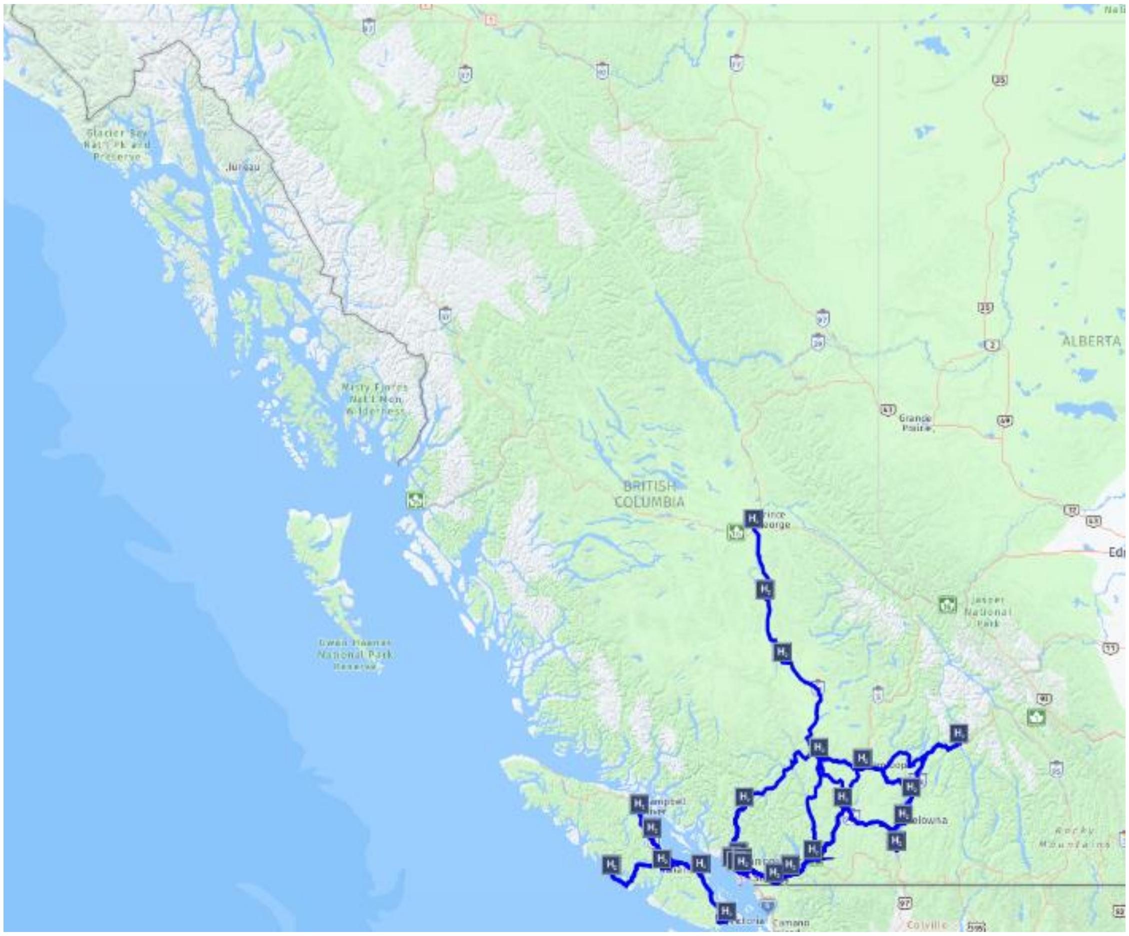


Figure 25. 2030 Provincial map

Stations are added to the clusters in the Lower Mainland, Victoria and the Central Okanagan. Additional stations are added in Courtney and Campbell River to allow travel up the east coast of Vancouver Island. A destination station is added in Tofino, as early adopters of BEVs indicated this was a high priority for charging build-out and likely will be for FCEV adopters as well. Further connector stations are added in the Fraser Valley (Chilliwack), North Okanagan/Central Interior (Vernon, Kamloops), Central Vancouver Island (Port Alberni), and along Hwy 97 as far as Prince George (Cache Creek, Williams Lake, and Quesnel).

Figure 26 shows the extended range of the network for out and back trips from Campbell River, Prince George, Penticton, and Revelstoke. Note, there may be potential for adding additional stations along routes into Alberta if stations are installed in destinations such as Banff or Calgary by this time.

Figure 26. 2030 Extended range map

6.3 2040 Map

The majority of new stations added in 2040 will be connectors to allow for travel throughout the North of the province and the Kootenays (See Figure 27). North of Prince Rupert and Fort St. John, stations should be sited in towns and villages where possible or near existing gasoline/diesel fueling stations. Additional stations added to existing clusters are not visible on the map but can be found in the table of stations in the appendix. Adding 59 new connector stations between 2030 and 2040 may prove to be very logistically challenging, as many of these stations would be in remote locations with little load. An approach to consider would be to prioritize coverage to south of Prince George, which would enable a reduction of 26 connector stations in remote northern regions of the province, without significantly impacting the market that would practically be served by FCEVs.

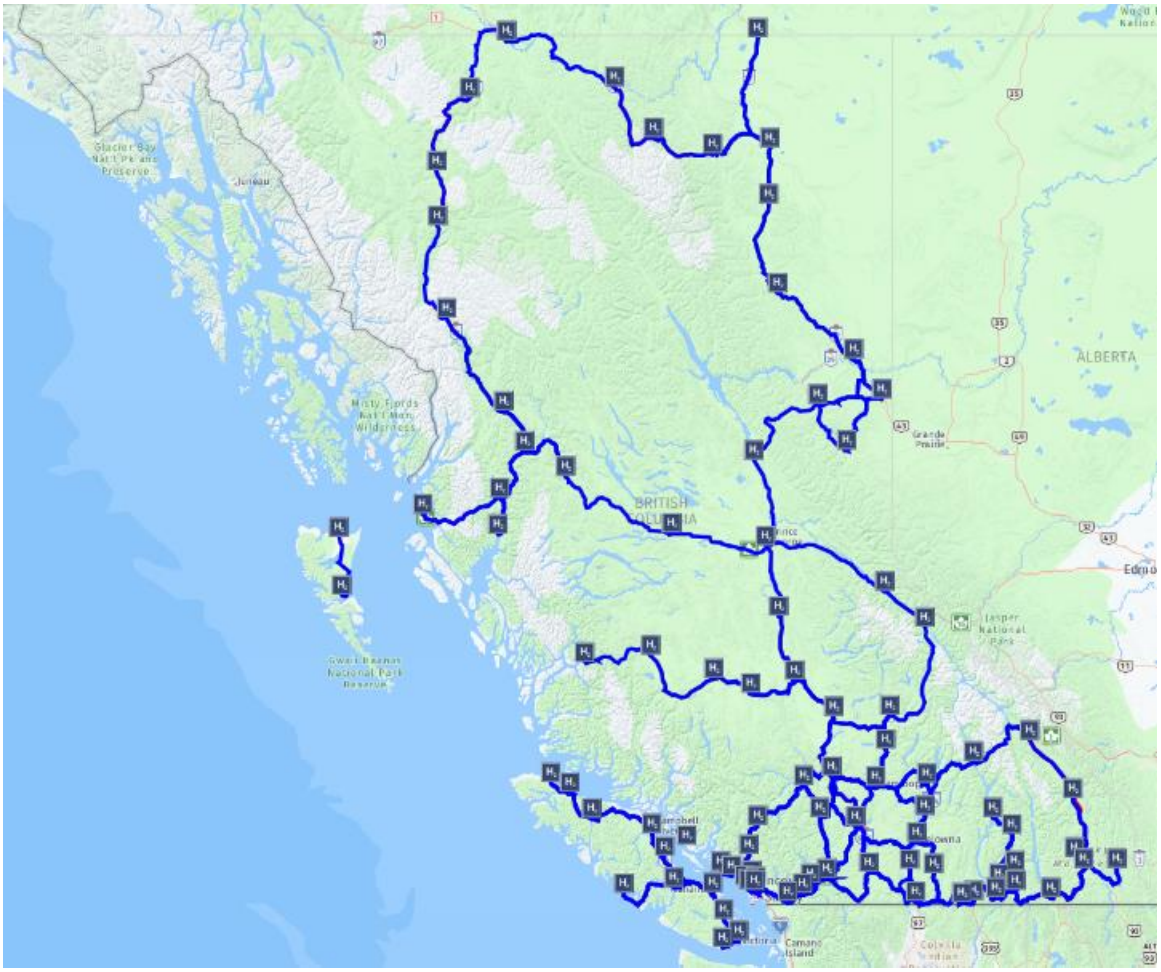


Figure 27. 2040 Provincial map

7 Next steps and recommendations

This study will be used to inform the priorities and direction of HRS infrastructure funding and planning across the province. The following recommendations are provided to guide this process:

- Stations should be developed in clusters to promote vehicle deployments, provide redundancy and capacity, and concentrate supply logistics. When a new cluster is initiated, at least two stations should be opened in the region within a short timeframe in order for OEMs to be able to deploy vehicles while ensuring availability of fuel supply to retail customers.
- For minor clusters, connectors, and destinations, stations should be deployed in pairs where feasible and where demand exists.
- Mobile (containerized) stations should be used to help fill temporary gaps in the network and provide redundancy. These mobile containerized stations can be rapidly redeployed within the network as it develops and as demand evolves. Mobile stations can also be effectively used to build out the 'fringes' of the network as it grows.
- Station build-out must proceed vehicle deployments and decisions should be made in close collaboration with vehicle OEMs, infrastructure suppliers and with a view to other hydrogen

economy projects being developed in the province such as production facilities and Heavy-Duty stations.

- Stations should be prioritized in areas to support larger economic development and social program goals such as employment and trade where possible.
- Further testing of the actual fuel economy performance of the Toyota Mirai and Hyundai Nexo FCEVs on B.C. routes is recommended to improve the accuracy of the study and serve to validate the station locations.
- Hydrogen production and transport infrastructure development depend on reaching economies of scale and trigger points, such as the switch from gaseous to liquid delivery, should be factored into planning.
- Technology advancements in both vehicle performance and station design are expected to evolve rapidly in the coming years and should be monitored as inputs to future study updates.
- The market dynamics and players in the hydrogen sector are expected to evolve as demand for hydrogen as a transportation fuel grows in B.C. For example, major energy and industrial gas players (e.g. Shell, Air Liquide) and/or the province’s major utilities (e.g. BC Hydro, FortisBC) may become more engaged in supplying or developing the H2 infrastructure. Regular stakeholder engagement with existing and new industry players is recommended for future updates.
- As the FCEV market in BC evolves and both vehicle and station technology and performance improve, these maps should be refined and recalculated to remain up to date.

References

BC Ministry of Energy, Mines, and Petroleum Resources. (2018). *British Columbia Direct Current Fast Charging (DCFC) Network Study: Core Network for Geographic Connectivity.* Victoria: BC EMPR.

California Hydrogen Fuel Cell Partnership. (2009). *Hydrogen fuel cell vehicle and station deployment plan: a strategy for meeting the challenge ahead.*

OEMs, V. V. (2019, October). Interviews with Vehicle OEMs.

Zen and the art of Clean Energy Solutions. (2019). *British Columbia Hydrogen Study.* Vancouver: BC Bioenergy Network.

Crisostomo, Noel. (2018). *CEC Charging Infrastructure Resources Supporting Fleet Electrification.*

California Energy Commission. (2018). *CEC Joint Agency Staff Report on Assembly Bill 8: 2018 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California*

Natarajan, S.K. et al. (2019). *Hydrogen Infrastructure in Quebec*. Institut de Recherche sur l'Hydrogene & Universite du Quebec a Trois-Rivieres.

Advanced Power & Energy Program UC Irvine. (2011). *UC Irvine STREET Model: Determining hydrogen fueling station needs in targeted communities*

California Fuel Cell Partnership. (2012). *A California Road Map Bringing Hydrogen Fuel Cell Electric Vehicles to the Golden State*

APPENDIX

Table 4. 2019 Mirai baseline fuel economy estimates

2019 Mirai	Fuel Economy @ Varying Speeds (km/kg)											
Temp (°C)	**10 km/h**	**20 km/h**	**30 km/h**	**40 km/h**	**50 km/h**	**60 km/h**	**70 km/h**	**80 km/h**	**90 km/h**	**100 km/h**	**110 km/h**	**120 km/h**
-20	36.79	68.63	82.69	89.21	92.22	94.50	96.69	97.80	98.91	94.27	80.72	59.53
-10	37.20	69.99	84.23	90.83	93.88	97.06	99.31	100.62	102.04	96.46	82.80	61.21
0	43.32	80.20	94.26	100.57	102.99	105.57	107.17	108.16	108.31	101.92	86.95	64.59
10	43.73	81.57	96.57	103.01	105.48	108.13	109.79	110.98	111.44	105.20	90.06	66.27
21	62.92	102.67	115.09	118.43	119.57	120.05	120.27	120.40	119.79	112.85	95.25	70.49
32	44.54	83.61	99.66	107.07	109.62	112.38	114.16	115.69	116.66	109.57	94.21	69.65

Table 5. List of Stations

Station #	Station Name	Station Address (Approx)	Station Type	Cluster Name	Year Operational
1	South Vancouver*	71st and Granville	Cluster	Lower Mainland	2025
2	Central Burnaby*	Willingdon & Canada Way	Cluster	Lower Mainland	2025
3	South Burnaby*	TBD	Cluster	Lower Mainland	2025
4	UBC*	University Blvd & Wesbrook Mall	Cluster	Lower Mainland	2025
5	North Vancouver*	Westview	Cluster	Lower Mainland	2025
6	Kelowna*	City of Kelowna	Cluster	Central Okanagan	2025
7	North Saanich*	North Saanich/Airport	Cluster	Greater Victoria	2025
8	Abbotsford 1	City Centre	Cluster	Fraser Valley	2025
9	Hope	City Centre	Connector	-	2025
10	Merritt	City Centre	Connector	-	2025
11	Delta/Tsawwassen	Deltaport	Cluster	Lower Mainland	2025
12	Victoria 1	City Centre	Cluster	Greater Victoria	2025
13	West Kelowna 1	Westbank City Centre	Cluster	Central Okanagan	2025
14	Mission 1	City Centre	Cluster	Fraser Valley	2025
15	Richmond	YVR	Cluster	Lower Mainland	2025
16	Nanaimo 1	City Centre	Cluster	Nanaimo	2025
17	Whistler	City Centre	Destination	-	2025
18	Langford	Langford	Cluster	Greater Victoria	2030
19	Esquimalt	Esquimalt	Cluster	Greater Victoria	2030
20	Central Saanich	Central Saanich	Cluster	Greater Victoria	2030
21	Oak Bay	Oaklands/UVic	Cluster	Greater Victoria	2030
22	Surrey Guildford	Guilford	Cluster	Lower Mainland	2030
23	Kelowna 2	Hwy 97 (Airport)	Cluster	Central Okanagan	2030
24	Chilliwack 1	City Centre	Cluster	Fraser Valley	2030
25	Kamloops 1	City Centre	Cluster	Kamloops	2030
26	Port Coquitlam	City Centre	Cluster	Lower Mainland	2030
27	Penticton 1	Hwy 97	Cluster	Penticton	2030
28	Prince George 1	City Centre	Cluster	Prince George	2030
29	Vernon 1	City Centre	Cluster	Vernon	2030
30	Campbell River 1	Hwy 19	Cluster	Campbell River	2030
31	Tofino	Hwy 4	Destination	-	2030
32	Revelstoke	Hwy 1	Connector	-	2030
33	Kelowna 3	Mission	Cluster	Central Okanagan	2030

34	West Kelowna 2	City Centre	Cluster	Central Okanagan	2030
35	Abbotsford 2	Airport	Cluster	Fraser Valley	2030
36	Chilliwack 2	Hwy 1	Cluster	Fraser Valley	2030
37	Kamloops 2	Hwy 97	Cluster	Kamloops	2030
38	Kitsilano	Burrard	Cluster	Lower Mainland	2030
39	Nanaimo 2	Hwy 1/Hwy 19	Cluster	Nanaimo	2030
40	Penticton 2	Hwy 97	Cluster	Penticton	2030
41	Prince George 2	Hwy 16	Cluster	Prince George	2030
42	Vernon 2	Hwy 6	Cluster	Vernon	2030
43	Williams Lake	City Centre	Connector	-	2030
44	Courtney	City Centre	Connector	-	2030
45	Campbell River 2	Hwy 19	Cluster	Campbell River	2030
46	Peachland	City Centre	Cluster	Central Okanagan	2030
47	Aldergrove	Aldergrove	Cluster	Fraser Valley	2030
48	Mission 2	Hwy 7	Cluster	Fraser Valley	2030
49	Swartz Bay	Swartz Bay	Cluster	Greater Victoria	2030
50	Cache Creek	City Centre	Connector	-	2030
51	Quesnel	Hwy 97	Connector	-	2030
52	Port Alberni	Hwy 4	Connector	-	2030
53	Pitt Meadows	City Centre	Cluster	Lower Mainland	2030
54	Langley	City Centre	Cluster	Lower Mainland	2030
55	Lake Country	City Centre	Cluster	Central Okanagan	2030
56	Kelowna 4	Rutland	Cluster	Central Okanagan	2040
57	Golden	Hwy 95	Connector	-	2040
58	Woss	Hwy 19	Connector	-	2040
59	Port McNeil	Hwy 19	Connector	-	2040
60	Port Hardy	Hwy 19	Destination	-	2040
61	Squamish	City Centre	Connector	-	2040
62	Harrison Hot Springs	Hwy 7	Destination	-	2040
63	Princeton	Hwy 3	Connector	-	2040
64	Osoyoos	Hwy 97	Connector	-	2040
65	Grand Forks	Hwy 3	Connector	-	2040
66	Christina Lake	Hwy 3	Connector	-	2040
67	Trail	Hwy 38	Connector	-	2040
68	Castlegar	Hwy 3	Connector	-	2040
69	Salmo	Hwy 6	Connector	-	2040
70	Creston	Hwy 3	Connector	-	2040
71	Cranbrook	Hwy 95	Connector	-	2040
72	Fernie	Hwy 3	Destination	-	2040
73	Kimberley	Hwy 95A	Connector	-	2040
74	Invermere	Hwy 95	Connector	-	2040

75	Salmon Arm	Hwy 1	Connector	-	2040
76	Barriere	Hwy 5	Connector	-	2040
77	100 Mile House	Hwy 97	Connector	-	2040
78	Clearwater	Hwy 5	Connector	-	2040
79	Valemount	Hwy 5	Connector	-	2040
80	Mcbride	Hwy 16	Connector	-	2040
81	Fraser Lake	Hwy 16	Connector	-	2040
82	Smithers	Hwy 16	Connector	-	2040
83	Terrace	Hwy 16	Connector	-	2040
84	Kitimat	Hwy 37	Connector	-	2040
85	Prince Rupert	Hwy 16	Connector	-	2040
86	Dawson Creek	Hwy 49	Connector	-	2040
87	Fort St. John	Hwy 97	Connector	-	2040
88	Prophet River	Hwy 97	Connector	-	2040
89	Anahim Lake	Hwy 20	Connector	-	2040
90	Beaverdell	Hwy 33	Connector	-	2040
91	Bell II	Hwy 37	Connector	-	2040
92	Bella Coola	Hwy 20	Connector	-	2040
93	Cranberry Junction	Hwy 37	Connector	-	2040
94	Chetwynd	Hwy 97/Hwy 29	Connector	-	2040
95	Dease Lake	Hwy 37	Connector	-	2040
96	Duncan	Hwy 1	Connector	-	2040
97	Fort Nelson	Hwy 97	Connector	-	2040
98	Gibsons	Sunshine Coast Hwy	Destination	-	2040
99	Good Hope Lake	Hwy 37	Connector	-	2040
100	Hanceville	Hwy 20	Connector	-	2040
101	Iskut	Hwy 37	Connector	-	2040
102	Kitwanga	Hwy 37	Connector	-	2040
103	Liard River Provincial Park	Hwy 97	Connector	-	2040
104	Lillooet	Hwy 99	Connector	-	2040
105	Lower Post	Hwy 97	Connector	-	2040
106	Lytton	Hwy 1	Connector	-	2040
107	Massett	Hwy 16	Connector	-	2040
108	McLeod Lake	Hwy 97	Connector	-	2040
109	Mill Creek	Hwy 97	Connector	-	2040
110	Nakusp	Hwy 6	Connector	-	2040
111	Nelson	Hwy 6	Connector	-	2040
112	New Denver	Hwy 6	Connector	-	2040
113	Pink Mountain	Hwy 97	Connector	-	2040
114	Powell River	Sunshine Coast Hwy	Connector	-	2040
115	Queen Charlotte	Hwy 16	Destination	-	2040
116	Redstone	Hwy 20	Connector	-	2040
117	Sechelt	Sunshine Coast Hwy	Destination	-	2040
118	Soma Road	Hwy 16	Connector	-	2040
119	Sooke	Hwy 14	Connector	-	2040

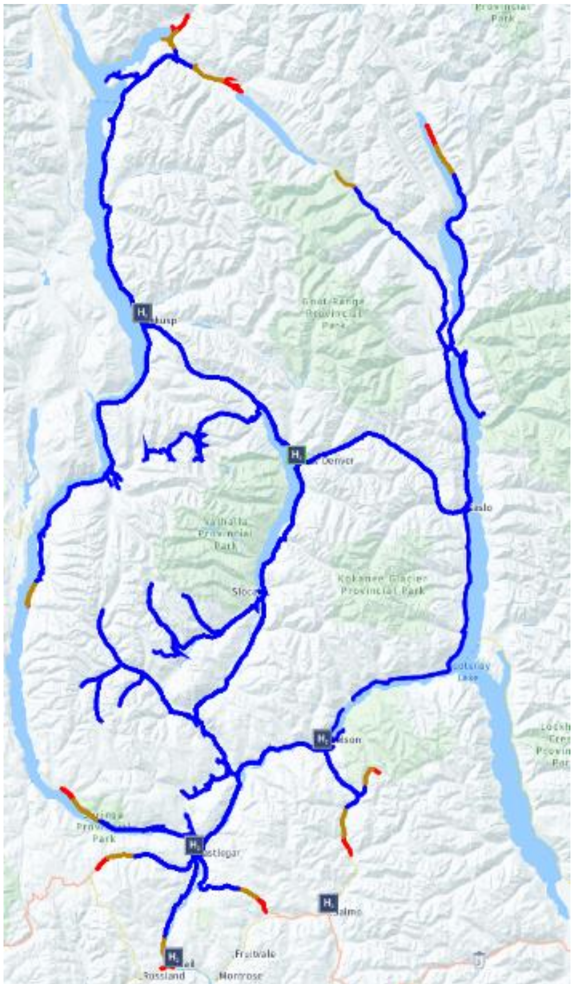
120	Toad River	Hwy 97	Connector	-	2040
121	Tumbler Ridge	Hwy 29	Connector	-	2040
122	West Vancouver	City Centre	Cluster	Lower Mainland	2040
123	Coquitlam	City Centre	Cluster	Lower Mainland	2040
124	White Rock	City Centre	Cluster	Lower Mainland	2040
125	West Kelowna 3	City Centre	Cluster	Central Okanagan	2040
126	Kelowna 4	Glenmore	Cluster	Central Okanagan	2040
127	View Royal	View Royal	Cluster	Greater Victoria	2040
128	Sooke	Sooke	Cluster	Greater Victoria	2040
129	Metchosin	Metchosin	Cluster	Greater Victoria	2040
130	Nanaimo 3	Hwy 19	Cluster	Nanaimo	2040
131	Vernon 3	City Centre	Cluster	Vernon	2040
132	Penticton 3	Hwy 97	Cluster	Penticton	2040
133	Kamloops 3	Hwy 97	Cluster	Kamloops	2040
134	Kamloops 4	Hwy 97	Cluster	Kamloops	2040
135	Campbell River 3	Hwy 19	Cluster	Campbell River	2040
136	Prince George 3	Hwy 16	Cluster	Prince George	2040
137	Prince George 4	Hwy 16	Cluster	Prince George	2040
138	Nanaimo 4	Hwy 19	Cluster	Nanaimo	2040
139	Abbotsford 3	Hwy 1	Cluster	Fraser Valley	2040
140	Mission 3	Hwy 7	Cluster	Fraser Valley	2040
141	Chilliwack 3	Hwy 1	Cluster	Fraser Valley	2040

*Planned or in operation as of March 2020.

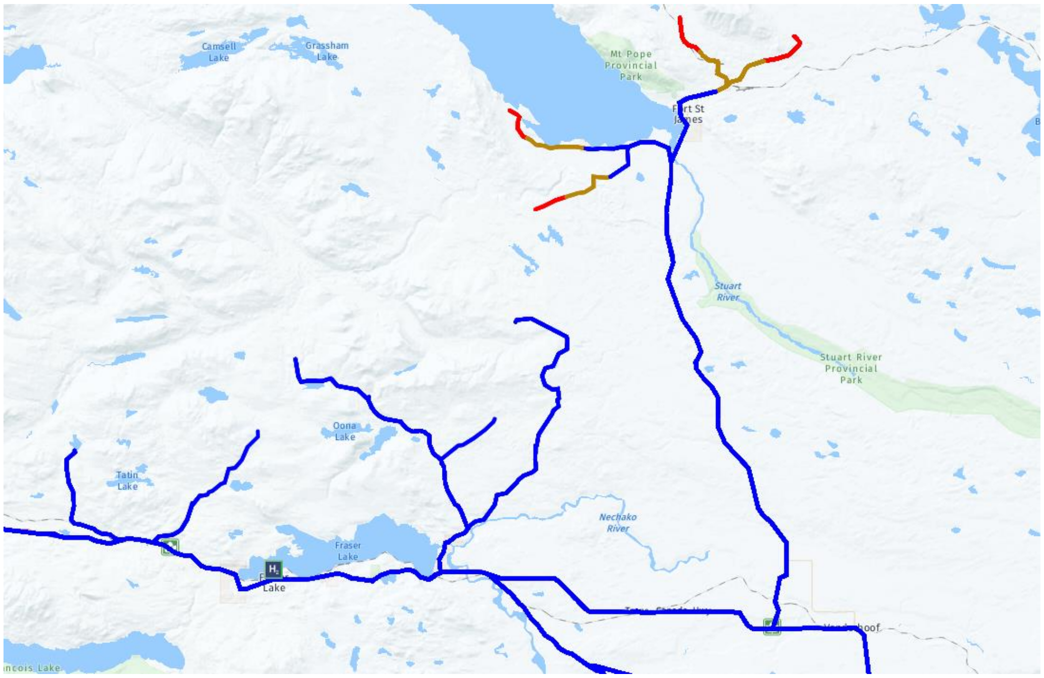
Out and back (round-trip) detail maps:

These maps show the round trips possible from stations to demonstrate coverage for certain routes. Blue lines indicate trip can be completed with no fuel warnings, brown lines indicate a Low Fuel Warning is likely, and Red Lines indicate the trip may be possible, but risks encountering a Very Low Fuel Warning.

Kooteney (Highway 31A/Highway31/Highway 23) Round Trip Range Map

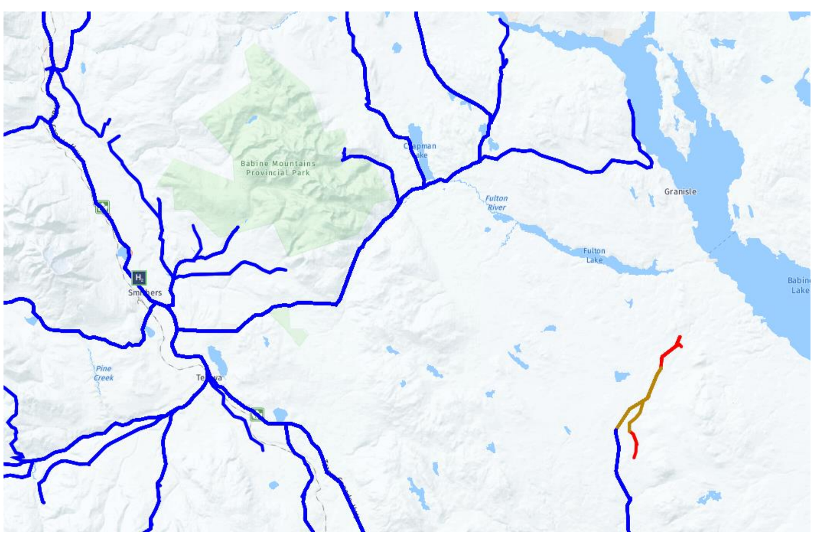


Fort St. James from Fraser Lake Round Trip Range Map



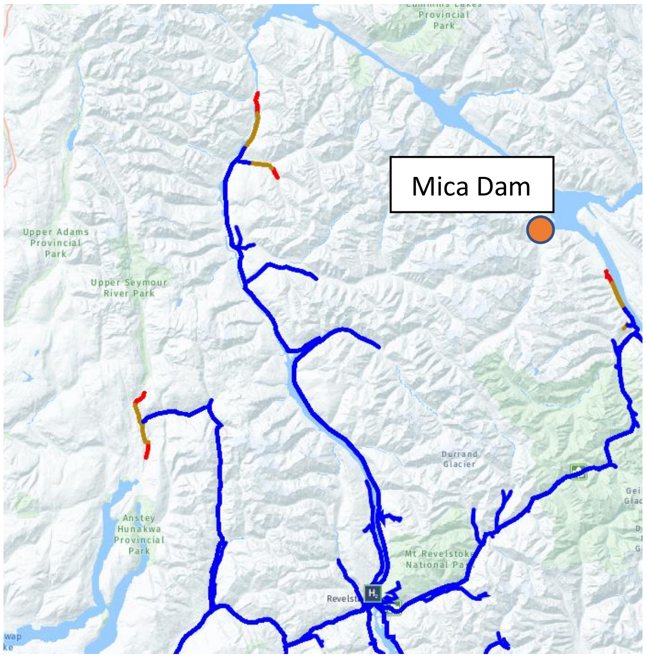
Granisle from Smithers Round Trip Range Map

Note: Map does not go along that road but indicates that it should reach that far because no brown/red/black coloured routes are in that area (meaning that the simulation stopped because of a dead-end).

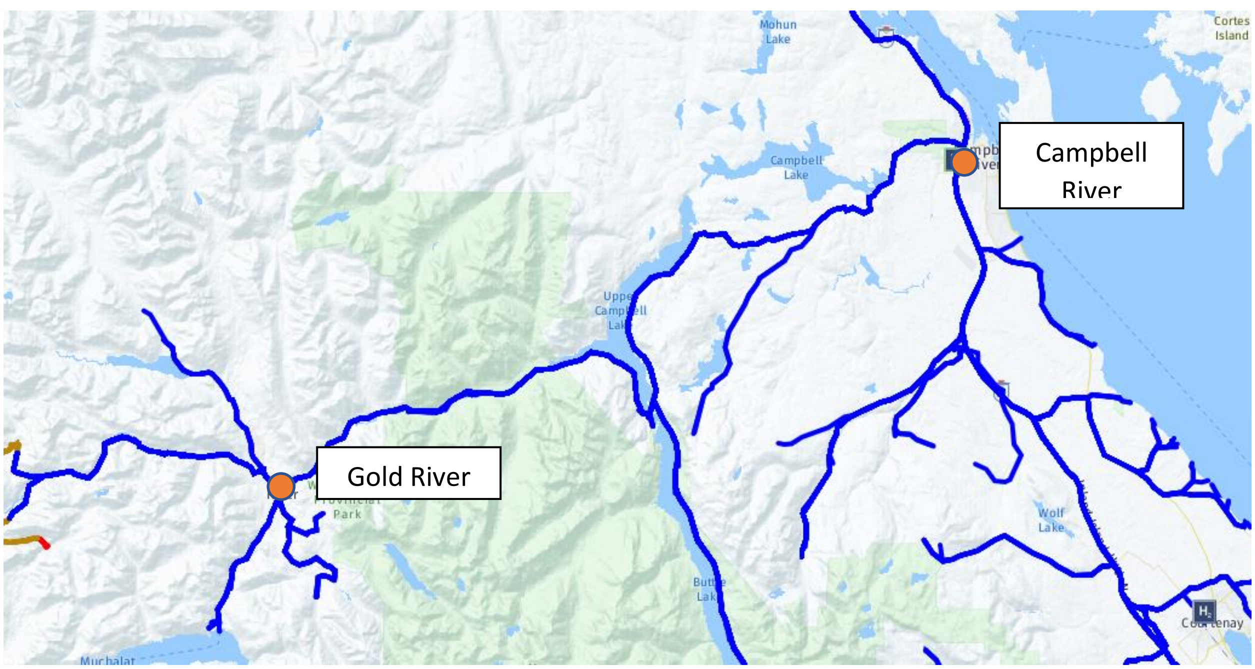


Hwy 23 Mica Dam from Revelstoke Round Trip Range Map

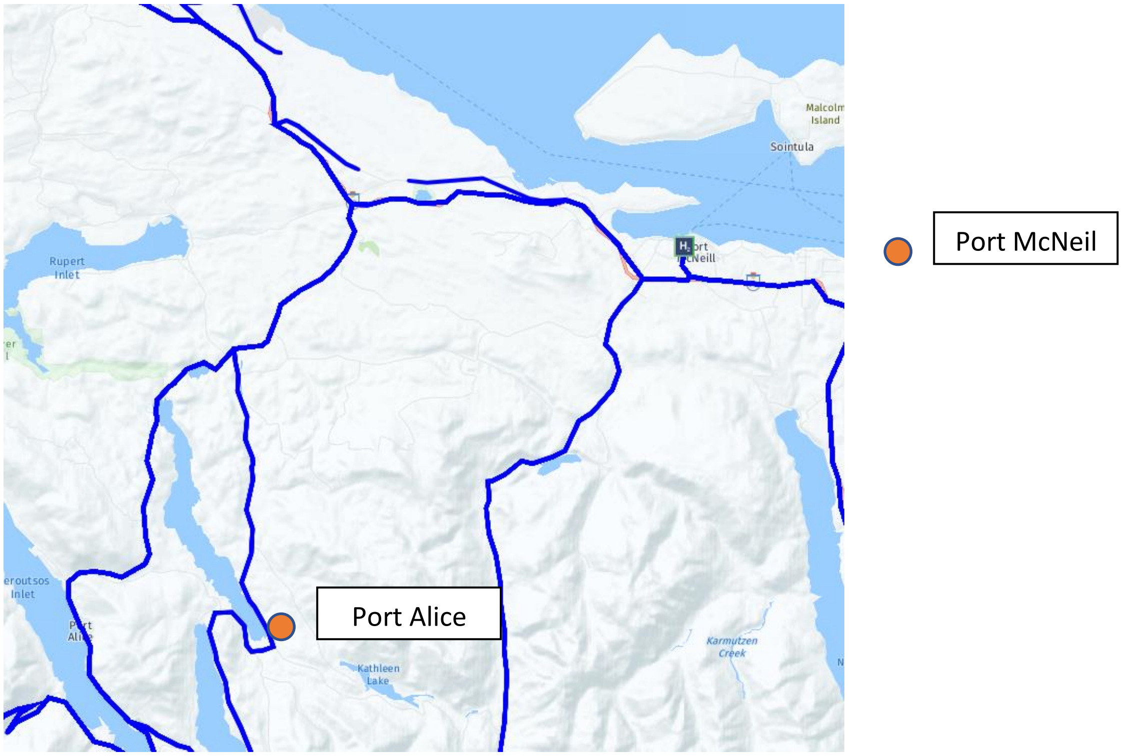
Note: Does not quite make it to Mica Dam or Mica Creek, but this will likely be feasible in the future with improvements in vehicle range.



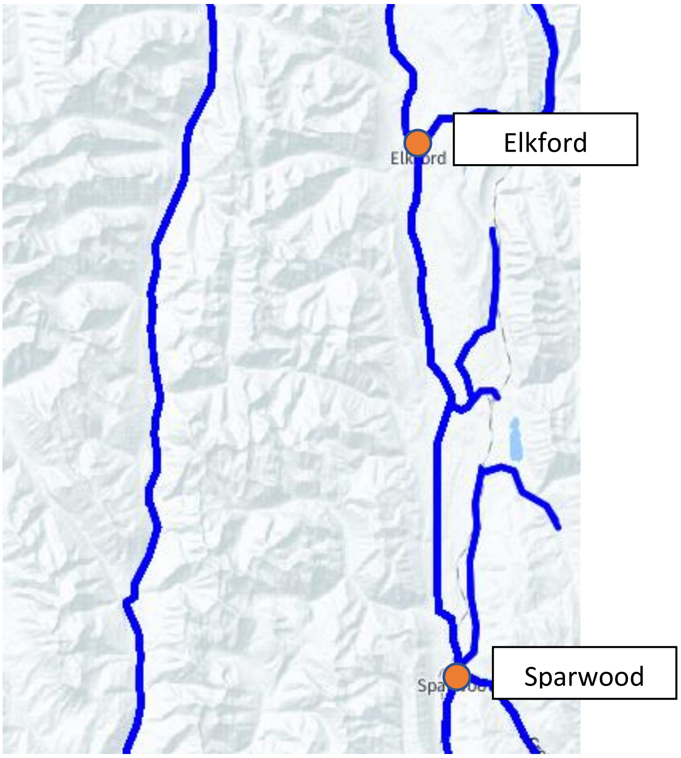
Hwy 28 Campbell River to Gold River Round Trip Range Map



Hwy 30 Port McNeil to Port Alice

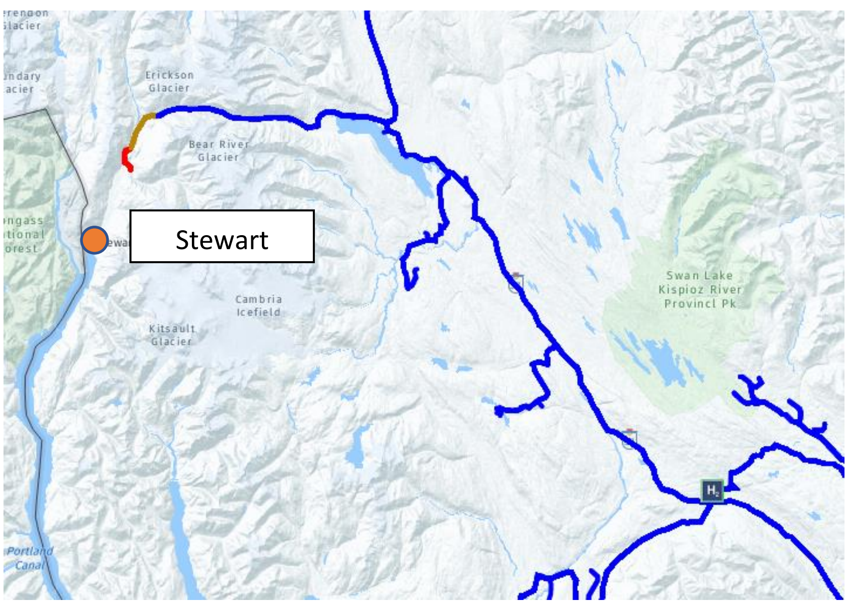


Highway 43 Sparwood – Elkford

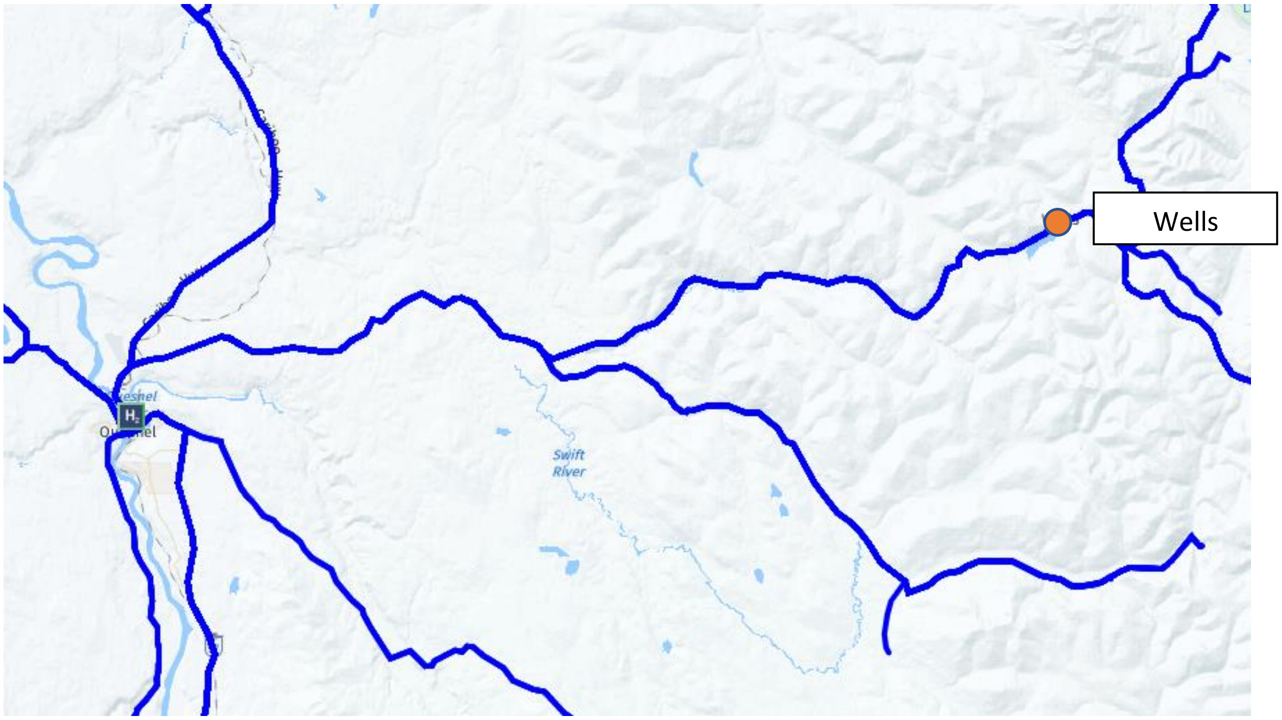


Hwy 37A Stewart

Not covered with the current model vehicle range but will likely be feasible in the future.



Hwy 26 – Quesnel to Wells


Wells
Swift River