OPPORTUNITY ASSESSMENT

# ENVISIONING A LOWER MAINLAND HYDROGEN HUB IN 2035

FORESIGHT CANADA

JULY 2024


## Acknowledgements

Foresight acknowledges that the lands on which we conducted this work are the traditional, ancestral, and unceded territories of the xʷməθkʷəy̓əm (Musqueam), Sḵwx̱wú7mesh (Squamish), and səlilwətaɬ (Tsleil-Waututh) Nations.

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This report was prepared by Foresight Canada, and led by Colton Martinez Rubio, with the support of Alyssa Kelly.


BRITISH COLUMBIA | Ministry of Energy, Mines and Low Carbon Innovation

## About Foresight

Foresight Canada helps the world do more with less, sustainably. As Canada's largest cleantech innovation and adoption accelerator, we de-risk and simplify public and private sector adoption of the world's best clean technologies to improve productivity, profitability, and economic competitiveness, all while addressing urgent climate challenges. decarbonization and net-zero climate targets through problem-driven innovation.

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# Table of Contents

# Glossary

| Term | Definition |
|---|---|
| **Ammonia** | A colourless, toxic gas with a pungent odour. Chemical formula is $NH_3$. Ammonia is commonly used in fertilizer production and its applications for use as a clean fuel is currently being explored. |
| **Battery electric vehicle (BEV)** | A zero-emissions vehicle that is powered by electricity from a battery. |
| **Blue hydrogen** | Common term used to refer to hydrogen produced from methane through reformation processes, paired with carbon capture, utilization, and storage (see definition of CCUS). The fraction of $CO_2$ that is captured varies depending on the process. |
| **Carbon capture, utilization, and storage (CCUS)** | Refers to a suite of technologies that capture carbon dioxide ($CO_2$) from point sources or directly from the atmosphere, store it in geological formations, or use it in a variety of applications. |
| **Carbon intensity** | A measure of total carbon emissions of something per unit of production or economic activity. Ex: for hydrogen, carbon intensity is measured as the mass of $CO_2$ equivalents emitted per kilogram of hydrogen produced (kg $CO_2$e/kg H2). |
| **Clean energy transition** | The global shift away from fossil fuel-based energy systems to renewable energy systems. |
| **Combustion** | A chemical reaction that produces heat and light in the form of a flame (e.g., burning). |
| **Cryogenic tanker** | A ship designed to store and transport liquefied gases, such as hydrogen, at very low temperatures. |
| **Decarbonization** | The process of reducing the levels of carbon emissions associated with a system or process. |
| **Electrolysis** | A process by which electric current is passed through a substance to create a chemical change. When referring to production of hydrogen, electric current is passed through water to produce hydrogen and oxygen. |

| Term | Definition |
|---|---|
| **Energy carrier** | An energy carrier is a transmitter of energy. Includes electricity and heat as well as solid, liquid and gaseous fuels such as hydrogen. |
| **Fuel cell** | A power generation device that uses hydrogen as fuel to produce electricity, with water and heat as the only by-products. |
| **Fuel cell electric vehicle (FCEV)** | A zero-emissions vehicle that runs on a fuel cell powered by hydrogen. |
| **Green hydrogen** | Common term used to refer to hydrogen produced by electrolysis (see definition of electrolysis) using electricity generated from renewable energy sources. |
| **Greenhouse gas (GHG)** | Any gas in the Earth's atmosphere that absorbs infrared radiation (heat) emitted from the Earth's surface and reradiates it back, creating the greenhouse effect. Include gases such as carbon dioxide ($CO_2$), methane, and water vapour. |
| **Hydrogen** | The chemical element of atomic number 1. A colourless, odourless, highly flammable gas that can be used as a chemical feedstock or energy carrier. |
| **Hydrogen carrier** | A carrier is a molecule containing hydrogen (such as ammonia) that can be easily transported and then broken down to isolate hydrogen for use at its destination. |
| **Low carbon hydrogen** | Common term used to refer to hydrogen produced from methods that produce fewer to no carbon emissions. Includes hydrogen produced by electrolysis, methane reforming with CCUS, and methane pyrolysis (green, blue, and turquoise hydrogen). The Government of Canada categorizes low carbon hydrogen as that which has a carbon intensity that does not exceed 67.8 $gCO_2e/MJ$. |
| **Methane pyrolysis** | A process to produce hydrogen from natural gas/methane that produces solid carbon as a byproduct instead of $CO_2$. |
| **Methane reforming** | Industrial processes used to produce hydrogen from natural gas. Includes methods such as steam methane reforming (SMR) or auto-thermal reforming (ATR). SMR and ATR produce carbon dioxide as well as hydrogen. |

| Term | Definition |
|---|---|
| **Methanol** | A clear, colourless liquid alcohol. Chemical formula is $CH_3OH$. Methanol is commonly used as an industrial substance and its applications for use as a clean fuel is currently being explored. |
| **Molecule** | Two or more atoms bonded together. |
| **Natural gas** | A gaseous, naturally occurring hydrocarbon consisting primarily of methane. |
| **Net zero** | A stage where economies emit no greenhouse gas emissions or offset any emissions. |
| **Renewable energy** | Energy created from natural processes that are replenished at a rate that is equal to or faster than the rate at which they are consumed. Includes energy generated from solar, wind, geothermal, hydropower, and ocean resources, solid biomass, biogas and liquid biofuels, but biomass is considered renewable only if its rate of use does not exceed its rate of regeneration. |
| **Sustainable Aviation Fuel (SAF)** | Sustainable aviation fuel (SAF) is a term that refers to fuels derived from non-fossil sources that have the same approximate composition and energy content but significantly lower life-cycle carbon emissions of conventional jet fuel. |
| **Synthetic fuel** | A term used to describe any manufactured fuel that has the approximate composition and similar energy content of a fuel derived from crude oil sources. |
| **Turquoise hydrogen** | Common term used to refer to hydrogen produced from methane through pyrolysis (see definition of methane pyrolysis). |

# Introduction

Hydrogen is a versatile energy carrier that, when produced sustainably, could play an important role in reducing BC's greenhouse gas (GHG) emissions. It can be utilized in fuel cells to power vehicles, in industrial processes as a heat source, and as a means of storing and transporting energy. However, to realize this potential growth, the sector must overcome a key challenge facing hydrogen development in BC: matching supply and demand. The 2021 BC Hydrogen Strategy highlighted a regional hydrogen hub model as a solution to this challenge.[1] By co-locating hydrogen production and end-use applications, these hubs can ensure a balanced market while accelerating the growth of the local economy. This strategic approach can optimize resource utilization and create synergies among different sectors. As part of the implementation of the BC Hydrogen Strategy, the BC Clean Energy and Major Projects Office (CEMPO) is working with Foresight to examine the potential for hydrogen hub development in the following regions where project development is underway and potential sources of demand exist: The Lower Mainland, Northeast BC, Interior BC (Kootenays and Okanagan), and Vancouver Island. Additionally, the City of Prince George and the City of Prince Rupert are exploring the development of a Northern BC Hydrogen Hub through opportunity assessments in each respective region.

The Lower Mainland, as it is known colloquially, is defined in this report by the economic region of BC Mainland/Southwest. The Lower Mainland is uniquely positioned to become a hydrogen hub for several reasons:

- **Existing infrastructure:** The region has well-developed infrastructure that can be adapted for hydrogen production, storage, and distribution.
- **Existing expertise:** The Lower Mainland is home to a variety of hydrogen experts and leaders, including leading technology companies and academic institutions.
- **Low carbon electricity:** BC's renewable hydroelectric power provides a low carbon pathway for hydrogen production.
- **End-use applications:** There are multiple potential demand-side applications for hydrogen use in the region, including ports, highways and railways.
- **Supportive policy:** Local and provincial commitment to foster sectoral growth through the groundwork of the BC Hydrogen Strategy and complementary programs and policies.

This report is the first in a series of high-level assessments that intend to review regional potential for local supply and demand, and discuss opportunities and challenges associated with hydrogen hub development in the region, over the next decade.

The report is divided into three sections:

1. **Supply:** This section reviews potential sources of supply in the region, including feedstocks, production methods and locations, and transportation and storage.

2. **Demand:** This section explores the potential sources of hydrogen demand within the Lower Mainland, cost trends, and forecasts for demand growth.

3. **Regional Considerations:** This section assesses the competitive landscape and opportunities for collaboration with neighbouring jurisdictions, as well as workforce considerations.

Each section's insights were collected from a literature review, interviews, and an in-depth workshop that was hosted in Vancouver with key hub partners and experts.

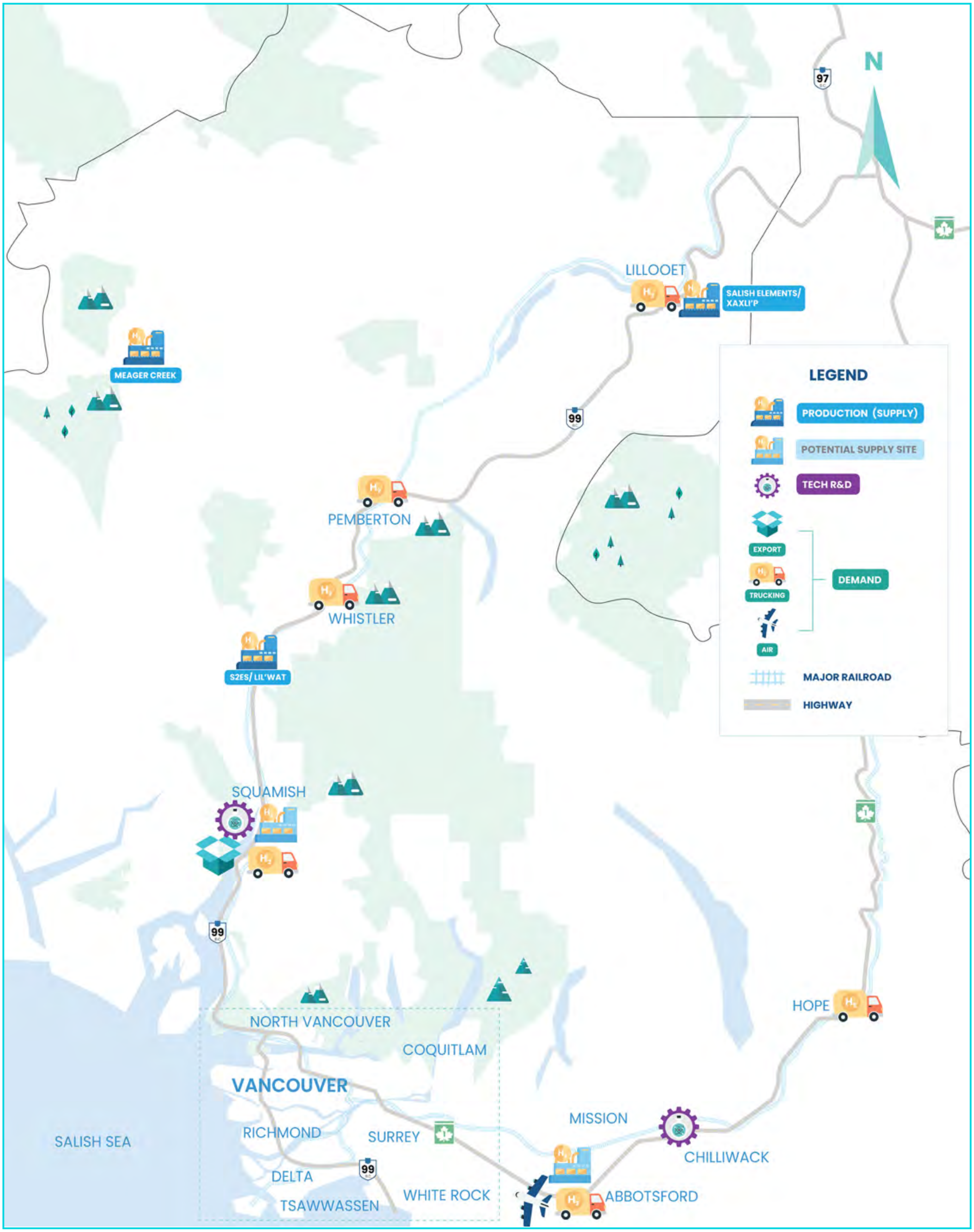
The development of a hydrogen hub in the Lower Mainland by 2035 represents an opportunity for the region to fill the emissions reduction gaps that cannot be addressed by direct electrification, to accelerate the transition to net zero. This report assesses the opportunity to realize this vision.

## Mapping a 2035 Hydrogen Ecosystem

In our in-person workshop, participants engaged in a brainstorming exercise to envision what a hydrogen ecosystem would look like in the Lower Mainland and broader Mainland/Southwest economic region, by 2035. Participants marked areas of future supply, demand, and R&D, as well as key infrastructure.

Using the drafts from the session, Foresight added additional detail and produced the following two maps:

LEGEND
PRODUCTION (SUPPLY)
POTENTIAL SUPPLY SITE
TECH R&D
ACADEMIC R&D
GAS INFRASTRUCTURE
SHIPPING
RAIL
TRUCKING
AIR
INDUSTRIAL
PORT
DEMAND
EXISTING REFUELING STATIONS
MAJOR RAILROAD
HIGHWAY
MAJOR ROAD
WEST VANCOUVER
NORTH VANCOUVER
BURRARD INLET
PORT OF VANCOUVER
ERCO/HTEC
COQUITLAM
PORT COQUITLAM
SFU
SFU H2 HUB
UNDER-UTILIZED GAS INFRASTRUCTURE
PORT MOODY
UBC
UBC SHED
BCIT
BURNABY
HTEC
ANNACIS ISLAND
SALISH SEA
YVR AIRPORT
RICHMOND
FRASER RIVER
DELTA
SURREY
CLOVERDALE
WESTHAM ISLAND
LADNER
BOUNDARY BAY
WHITE ROCK
DELTA PORT
TSAWWASSEN
99
B.C.
N


N
97
LILLOOET
SALISH ELEMENTS/ XAXLI'P
MEAGER CREEK
LEGEND
PRODUCTION (SUPPLY)
POTENTIAL SUPPLY SITE
TECH R&D
EXPORT
TRUCKING
DEMAND
AIR
MAJOR RAILROAD
HIGHWAY
99
PEMBERTON
WHISTLER
S2ES/ LIL'WAT
SQUAMISH
99
HOPE
NORTH VANCOUVER
COQUITLAM
VANCOUVER
MISSION
CHILLIWACK
RICHMOND
SURREY
SALISH SEA
DELTA
99
WHITE ROCK
ABBOTSFORD
TSAWWASSEN

# Supply Side

Bloomberg New Energy Finance (BNEF) modelling estimates that global hydrogen supply will grow thirtyfold by the end of the decade, with the majority of supply coming from non-fossil fuel sources. [2] While this estimate is subject to several uncertainties, these trends indicate that global markets will continue to grow and supply-side technologies will mature further in the next decade. In the Lower Mainland, hydrogen production is emerging but is still in its very early stages. Key supply-side considerations for the development of a regional hydrogen hub include production methods, locations, and transportation and storage. This section will explore each of these considerations further.

## Feedstocks & Production Methods for Low Carbon Hydrogen

The most widely discussed projected source of supply for the Lower Mainland Hub is hydrogen produced through a process known as electrolysis, which utilizes electricity to split highly purified water into its constituent elements: hydrogen and oxygen. The process is known colloquially as "green" hydrogen when renewable sources of electricity are used as the feedstock (e.g., wind, solar, or hydro).

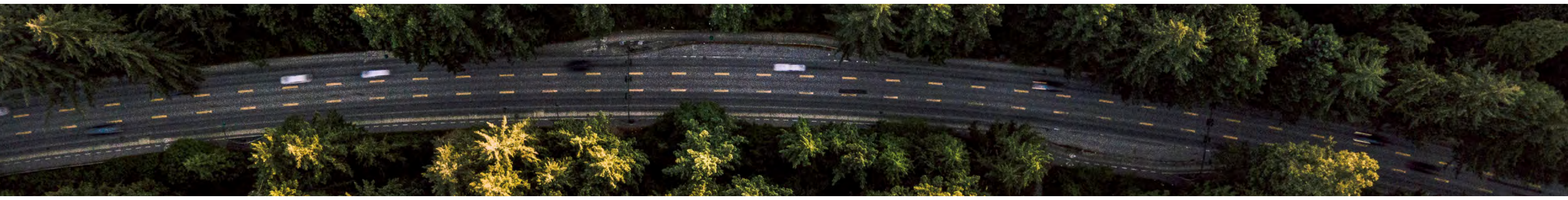
The other is "turquoise" hydrogen, which is produced using natural gas and electricity through a process known as pyrolysis. Pyrolysis technologies, which use high temperatures to break the chemical bonds in methane into hydrogen and solid carbon, have the potential to produce hydrogen with relatively low carbon intensity. The solid carbon byproduct can then be used as a commodity. There are various natural gas pyrolysis technologies available and variants of solid carbon can be used in different industries (e.g., rubber, construction materials, pigment for inks). [3]

**According to the BC-focused Carbon Intensity of Hydrogen Production Methods report:**

- Depending on the technology, to produce 1 GJ of hydrogen, electrolysers can require 282-381 KWh of electricity. [4]
- In contrast to electrolysis, producing 1 GJ of hydrogen, pyrolysis can require 1586-2115 MJ of gas and 18-141 KWh of electricity. [4]

An existing local source of supply is “waste” or “byproduct” hydrogen: hydrogen that is already being commercially produced as a byproduct of chemical processes. Byproduct hydrogen is typically released during industrial activities, such as chlor-alkali production and petrochemical refining, where it is not the primary product. This hydrogen can be captured and utilized, reducing waste and providing a recovered energy resource. Byproduct hydrogen is already playing a role as an early-stage source of supply in the Lower Mainland, and will continue to be the primary source in the short term.[5] However, based on current public projections and feedback collected from experts in our workshop and interviews, it is not anticipated to be a large source of supply in any region of the province over the long term due to its limited ability to scale. [6]

For the purpose of this report, we limit the elaboration on “blue” hydrogen, which extracts hydrogen from the methane ($CH_4$) molecules in natural gas through reformation processes and captures the $CO_2$ for sequestration. While blue hydrogen is projected to be a potential source of supply for BC, the hydrogen hub concept of co-locating supply and demand precludes it from being a likely factor for the Lower Mainland, given upstream oil and gas operations being located in Northern BC and the suitability of Northeast BC for Carbon Capture and Storage (CCS). [4] Blue hydrogen is more likely to play an important role in the supply portfolios of other hubs, such as the Northeast, North Coast and Central regions of BC. The availability of provincial geological formations was not in the scope of this opportunity assessment but is well documented in other literature such as the Northeast BC Geological Carbon Capture and Storage Atlas. [7] Should evidence emerge suggesting that the Lower Mainland is well suited for long-term $CO_2$ storage, there may be reason to reconsider blue hydrogen’s role in the region. [6]

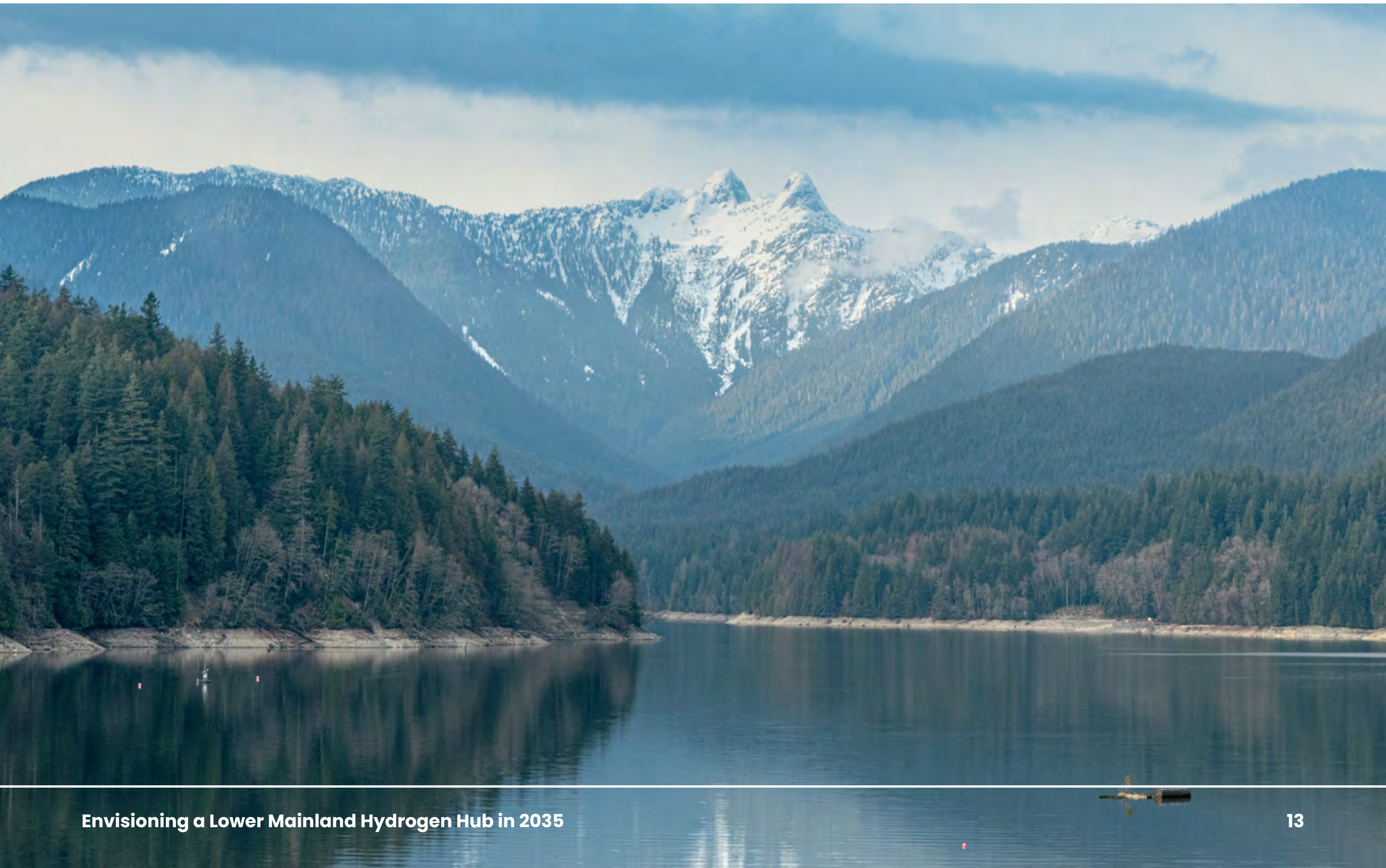


Biomass gasification is another method that we do not examine further in this report. This process converts organic materials, such as agricultural residues, wood waste, or other plant-based materials, into syngas. The syngas can then be processed to separate hydrogen gas from carbon and other components. While some models view this process as having favourable prospects in BC, it may be better suited for other regional hubs in the province that are co-located with greater forestry industry activity.

In the following table, we list the production technologies most likely to scale as part of a Lower Mainland hydrogen hub. The table includes each technology’s approximate Technology Readiness Level (TRL), which measures the maturity of a given technology, from conception to proven commercial stability. It also includes carbon intensity, a measure of the GHG emissions per unit of energy produced, based on analysis from the B.C. Centre for Innovation and Clean Energy (CICE). [4] All the pyrolysis and electrolysis technologies listed have projected carbon intensities below the low carbon threshold of 36.4 gCO2e/MJ adopted in the BC Hydrogen Strategy; the threshold is meant to be a starting point to define low carbon production, and represents a 60 per cent reduction “below the intensity of hydrogen produced from natural gas”. [8]

Table 1. Emerging low carbon hydrogen production pathways for the Lower Mainland (carbon intensities including upstream emissions).

| Feedstock | Technology | TRL (1-11) | Average Liquified & Compressed Carbon Intensity (gCO2e/MJ) in BC [4] |
|---|---|---|---|
| Electricty (On-Grid) | Alkaline electrolyser | 9 | 16.2 |
| | Polymer electrolyte membrane (PEM) electrolyser | 9 | 15.3 |
| | Solid oxide electrolyser | 8 | 12 |
| Methane Gas | Pyrolysis, Thermal | 3-4 | 21.4 |
| | Pyrolysis, Plasma | 8 | 19.9 |
| | Pyrolysis, Catalytic | 6 | 21.3 |



## Electricity Supply

Given that both pyrolysis and electrolysis technologies use varying amounts of electricity in their production process, the availability of electricity is of concern in the timeline we are evaluating. BC Hydro's latest Integrated Resource Plan has an "accelerated electrification" contingency plan that assumes the province meets its CleanBC emissions targets; new electrolysis projects are part of this projection. [10] To fill the large gap between projected supply and demand, the plan also notes that additional resources will need to be procured.

Given its dense population and concentrated economic activity, the Lower Mainland will be the largest source of future electricity demand growth. While specific regional forecasts are limited, the IRP includes projections for capacity needs in the Lower Mainland, in its accelerated electrification contingency plan. After accounting for planned resources, purchase renewals and demand-side management, the IRP estimates 521 MW of new annual capacity resources will be needed in the "South Coast" region over the next decade (South Coast includes the Lower Mainland, the Sunshine Coast, and southern Vancouver Island).

It should also be noted that BC Hydro is facing additional climate-related constraints that will affect future electricity supply, such as:

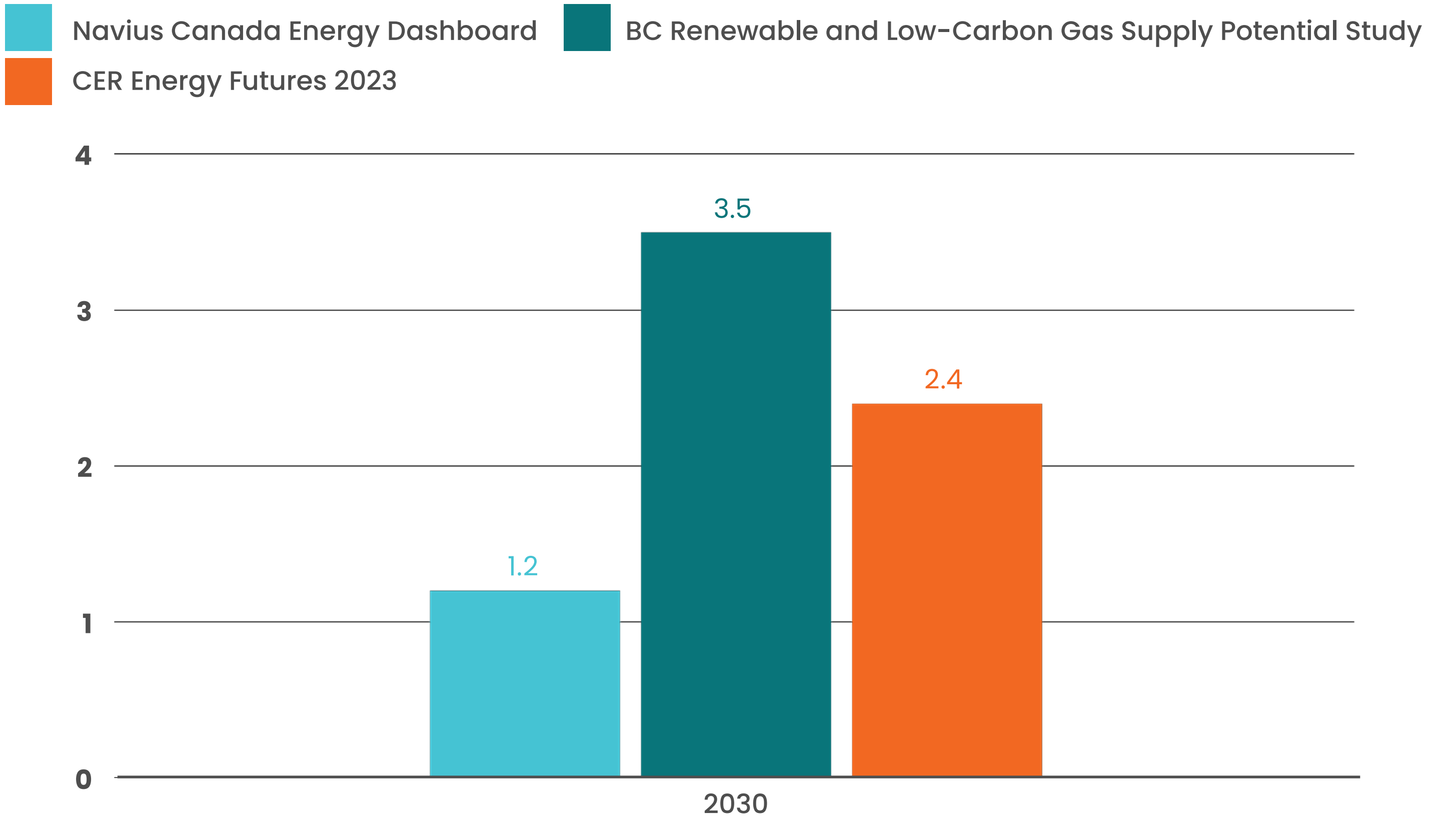
- **Hydrological Changes:** Climate change will alter precipitation patterns, increase temperatures, and change the timing and volume of spring runoff. These changes can impact hydroelectric power generation, which relies on consistent water flows.
- **Drought Conditions:** Extended periods of dry and warm weather, as experienced in recent years, have led to record-low water levels in some reservoirs. This affects the ability to generate hydroelectric power consistently. BC has experienced some of its driest and hottest extended periods on record, impacting water availability for power generation.
- **Extreme weather events:** Wildfires, flooding and droughts can disrupt electricity supply and damage infrastructure.

Given the uncertainty of these future constraints and where new sources of generation will come from, it appears reasonable to question whether hydrogen will be competing with other end-users (electric vehicles, heat pumps, industrial electrification) for limited clean electricity in the future. Time will tell as new sources of electricity generation are activated and other sources of supply are secured; however, given the requirements of both electrolysis and pyrolysis technologies, the Province will have to carefully consider how new hydrogen projects impact the wider goals of economy-wide emissions reductions across all sectors.

## Modelling Supply

There are differing projections of how much hydrogen will be produced in BC within the next decade and by what means. Using Navius Research's net zero modelling in its Canada Energy Dashboard, we observe a projection of 1.2 PJ of BC hydrogen supply in 2030 and 2.9 PJ in 2035. [11] Navius's model projects all of this supply to come from electrolysis technologies. The BC Renewable and Low-Carbon Gas Supply Potential Study differs slightly, with approximately 3.5 PJ projected in 2030 (0.8 PJ from electrolysis, 1.5 PJ from pyrolysis, 0.9 PJ of waste hydrogen, and 0.3 PJ of biomass gasification). In contrast, the Canada Energy Regulator (CER)'s net zero modelling projects approximately 2.4 PJ of hydrogen production in 2030 and approximately 12 PJ in 2035; but 100 per cent of this supply is from biomass gasification in 2030, and in 2035 electrolysis technologies account for 20 per cent of provincial supply (~2.4 PJ).

Figure 1. Projected BC hydrogen production in 2030.



# Current Regional Projects

Other than Powertech (250 kW electrolyser producing 65 kg/day), no companies are currently producing commercial hydrogen in the Lower Mainland. However, several recent announcements have added to the list of local projects under development.

## In Development

- The University of British Columbia (UBC) launched the "Smart Hydrogen Energy District", an integrated hydrogen facility that includes an electrolyser to produce green hydrogen and local refuelling stations for light- and heavy-duty vehicles. [12]

- Simon Fraser University's new Clean Hydrogen Hub will produce green hydrogen, to be sold to future industrial customers. [13]

- Salish Elements and Xaxli'p First Nation have partnered to develop a new 25 MW green hydrogen plant in Xaxli'p territory. [14]

- Hydrogen Technology and Energy Corporation (HTEC) has a number of active and proposed projects expanding regional supply. There are currently three active fueling stations in the Lower Mainland, in Burnaby, Vancouver, and North Vancouver. There are additional planned stations in Tsawwassen, Surrey, and Vancouver. [15] HTEC's H2 Gateway Project is bringing 18 new fuelling stations online across the province. [16] To support these stations, HTEC has two incoming Lower Mainland hydrogen production facilities: an electrolyser in Burnaby and a liquefaction facility for byproduct hydrogen in North Vancouver. [15]

## Exploratory Stage

There are a number of companies that are currently in the exploratory phase but have not made public announcements. Those that are publicly known include:

- The Meager Creek Development Corporation, in partnership with the Lil'wat Nation, intends to produce green hydrogen using geothermal energy.

- Sea to Sky Energy Solutions and the Lil'wat Nation own the 7.6 MW Brandywine Creek Hydro plant between Whistler and Squamish and are proposing to convert the facility to produce green hydrogen.

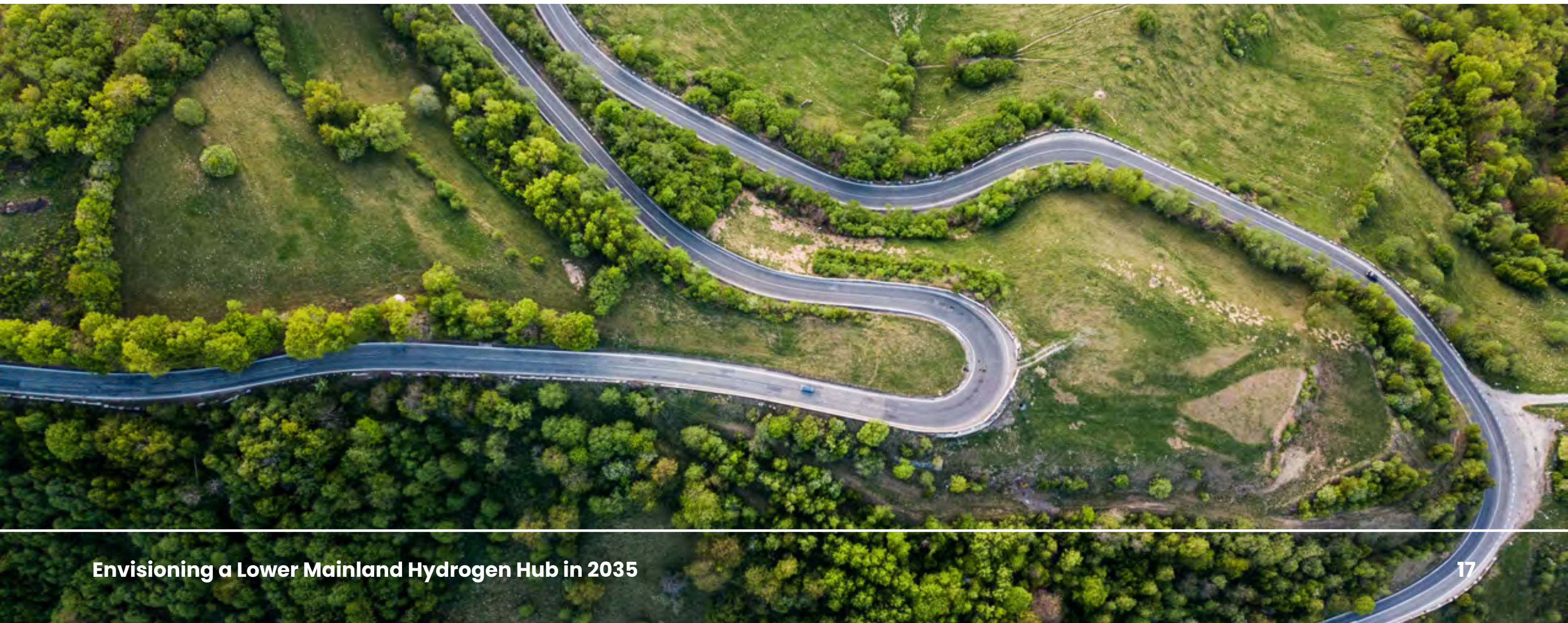
# Transportation & Storage

After production, hydrogen can be transported by truck, rail, or pipeline. It is easier to move as a compressed gas at lower volumes and short distances, while liquefaction is preferred for larger volumes and longer distances. [17] A study titled "Hydrogen transportation: A review of transmission procedures, existing networks, and recent developments," notes that the low volumetric energy density of hydrogen necessitates specialized storage and transportation methods, such as compression, liquefaction, or conversion to alternative carriers like ammonia, methanol or liquid organic hydrogen carriers (LOHCs). Each method has its own technical and economic trade-offs, and the choice depends on factors like distance, volume, and end-user requirements. [18]

Growing hydrogen supply in the Lower Mainland may require a "bulk hydrogen transportation corridor to accommodate large-scale adoption".[17] In response, FortisBC is exploring the repurposing of its gas pipeline infrastructure to enable a "blended hydrogen stream".[17] However, generalizing blending limits is considered "problematic because hydrogen compatibility depends on existing infrastructure component factors". [19] FortisBC and Enbridge have commissioned a comprehensive blending feasibility study, with support from the Province, for their distribution networks. [20,21]

For the purpose of discussing a Lower Mainland hub, we follow the assumptions made in the CICE report "Carbon Intensity of Hydrogen Production Methods", which analyzed the variations in carbon intensity for each production method and transportation mode. Pipeline and truck transportation are the most relevant, while rail is only relevant if blue hydrogen is moved from Northern BC or Alberta to the Lower Mainland. [4]

Transportation by truck within the Lower Mainland would add an average of 2.8 g CO2e per MJ of hydrogen transported (in this case measured over an 80 km distance). [4] Transporting hydrogen also poses significant costs. According to the Transition Accelerator report "The Techno-Economics of Hydrogen Pipelines", transporting hydrogen can account for up to 70 per cent of its total cost. The report highlights that pipelines are the most cost-effective method for transporting large volumes of hydrogen over long distances, but the initial capital costs for new pipeline infrastructure are substantial. [22]



# What We Heard: Expert Feedback on Supply

In our workshop, participants were gathered and asked: "What are the key challenges related to increasing the production, distribution, and transportation of hydrogen in the region?" The following themes represent the summarized feedback collected by facilitators.

## Regulatory and Permitting Constraints

- Regulatory issues were the primary constraints noted. Stable policy environments are needed to encourage investment. The BC Energy Regulator's updated mandate, which consolidates the regulatory framework for hydrogen to one government body, is a step in the right direction.

- Every emerging technology faces the problem of technology moving faster than government policies, creating uncertainty and impacting investor decision-making.

- The lengthy permitting process in the region, involving multiple levels of government, can hinder project progress. Individual municipalities have different processes, all with various timelines to secure. Streamlining and accelerating the permitting process will be critical to avoid delays and reduce costs.

- Regional consistency and educational programs for government officials and stakeholders are necessary. Less regulation and "red tape", along with efficient knowledge transfer, can help speed up project approval and implementation.

## Infrastructure and Resources

- The significant infrastructure and resource requirements for new hydrogen and electricity production are key barriers. Fresh water and renewable electricity are critical for electrolysis, and the future domestic availability of renewable electricity appears limited.

- Electricity and natural gas inputs account for a significant portion of production costs. Efficient resource management is necessary for sustainable hydrogen production.

## Transportation Costs

- Transporting hydrogen is expensive, accounting for the majority of delivered costs. On-site production and the capture of byproduct hydrogen are potential solutions to reduce these costs.

- One company in the region is producing a solid organic transport mechanism that could support export opportunities and overcome some of these transportation-related challenges.

## Economic Viability

- Hydrogen must compete economically with other fuels like diesel and biofuels. Current projects rely heavily on subsidized funding, and costs need to decrease rapidly for broader adoption. Economic reports indicate that fuel cell costs and production are dropping, but this needs to happen more rapidly for the sector to grow.

- High production costs and the lack of competitive pricing are major barriers to the current sectoral outlook. Improving technology efficiency and learning from demonstration projects can help reduce costs.

## Policy Support

- Policies need to reduce production costs and encourage initial investment, phasing out support as the market matures. Federal and provincial programs and mechanisms like investment tax credits (ITCs) and contracts for difference can help bridge the gap between the price of hydrogen and what consumers are willing to pay.

- Government-controlled market dynamics, such as carbon pricing, will also help pull hydrogen into the mainstream as scale is achieved and costs come down. Carbon pricing and carbon credits can drive investment in hydrogen projects. Municipalities with available carbon credits are ahead of those without.

## Proximity to Infrastructure

- Proximity to demand centers and the costs of shipping inputs are crucial considerations. Locating production facilities near demand centers can reduce costs and improve feasibility. New infrastructure for hydrogen and electricity must be co-developed to support large-scale hydrogen production and distribution.

## Supply-Side Recommendations for Hub Partners

- **Focus on pyrolysis and electrolysis technology development.** Based on expert feedback and existing literature, if hydrogen supply were to develop further in the region, electrolysis and pyrolysis technologies appear best suited to fill the role (beyond byproduct projects). Because this is an evolving sector that can experience rapid changes in technology costs and readiness, governments, utilities and industry groups will need to closely monitor the progression of each technology variant. Being responsive to new data and research will be critical to limit the risk of stranded assets. The sector is currently in a exploratory phase, meaning, as new data on carbon intensities, energy consumption and costs of emerging technologies becomes available in the coming decade, project proponents should be prepared to pivot to, and rapidly scale, whichever comes out ahead.
**[Recommendation Lead: All Partners]**

- **Provide further public clarity on electricity supply.** There is concern from many potential hub partners and project proponents about the future availability of clean electricity. The Province should work with the BC Hydro Task Force to disseminate key information and better communicate the challenges ahead. There is a need to clarify BC Hydro's approach to its modelling and transparently share how it is planning for hydrogen production in the next decade. Further clarity will help build the confidence of project developers and investors.
**[Recommendation Lead: Province, Utilities]**

- **Continue support for market-based policies that increase competition between hydrogen and carbon-intensive fuels.** Experts cited economic viability as a key area of concern. For regional hydrogen production to compete with well-established fuels, continued pollution pricing will play an essential role and allow the least carbon-intensive technology to succeed in the market.
**[Recommendation Lead: Province]**

- **Undertake a Lower Mainland permitting case study to help make the municipal permitting process more transparent and understandable for project proponents.** Permitting was consistently raised by proponents as a barrier to project development. Building on the BC Hydrogen Regulatory Mapping Study, the Lower Mainland hub should follow the lead of Prince George and develop a permitting case study.
**[Recommendation Lead: Province, Local Governments]**

# Demand-side

BNEF's net zero modelling expects global clean hydrogen demand to quadruple the current level of fossil-based hydrogen demand by 2050, to 390 million tons per year, with most going towards transportation, steel and methanol decarbonization. They note that this is mainly fulfilled by electrolysis production. [23] Hydrogen appears likely to play a niche but important role in fulfilling global low carbon energy demand in the path to net zero.

In the local context, the Canada Energy Regulator (CER)'s net zero modelling projects approximately 5-6 PJ of economy-wide hydrogen demand in BC in 2030, and 17-20 PJ by 2035. However, virtually all of this demand (over 90 per cent) is projected to be in the transportation sector, with a small portion from industry. [24] BC's climate accountability reporting corroborates this sectoral distribution, through its own modelling conducted by Navius Research. The modelling scenario (only available to 2030) where the province meets its CleanBC climate targets projects 2030 hydrogen demand would be slightly higher, at 8 PJ (approximately 66,667 tonnes of $H_2$), and come almost entirely from "Heavy-Duty Trucks and Rail", along with a small portion from heavy industry. [25] There is no publicly available modelling for the Lower Mainland region alone, therefore assumptions must be made to a certain degree based on provincial-wide forecasts. However, given the emerging production sites in the region that are linked to the transportation sector, we are already seeing these projections begin to be realized.


## Potential end-users in 2035

In BC, experts have outlined a variety of potential end-uses for hydrogen, which are listed in the following table. While publicly available modelling does not indicate that all these sources of demand will appear in the next decade, some may be generated in the long term and are therefore worth noting in this assessment.

| Legend | |
|---|---|
| **Hydrogen Suitability Indicator Colour** | **Suitability (2024 - 2035)** |
| H—H (green) | Well Suited for the Region |
| H—H (yellow) | In Development/Further Evidence Needed |
| H—H (red) | Not Suitable for the Region |

Table 3. Potential end-users of hydrogen in the Lower Mainland.

| End-use | Description |
| --- | --- |
| Transportation Fuel | Modelling by the CER found that in the long run in Canada, "hydrogen primarily fuels long-haul transportation in heavy trucks, marine shipping, and hydrogen-based fuels are used to help decarbonize aviation".[26] Navius Research's Canada Energy Dashboard supports the conclusion that hydrogen's main use in BC will be as a transportation fuel.[11]<br><br>**Heavy-Duty Vehicles**<br><br>Fuel cells use hydrogen as a fuel to create electricity, water, and heat. Fuel Cell Electric Vehicles (FCEVs) are being explored as an internal combustion engine replacement for transportation applications that have limited cost-effective decarbonization options. In most cases, Battery Electric Vehicles (BEVs) are projected to be the most energy-efficient and cost-effective method of decarbonizing road transportation over time.[23] This is particularly true, in the case of light-duty vehicles: 23 per cent of light-duty vehicles sold in BC in 2023 were BEVs.[27] This is also true of most medium-duty vehicles, including buses, drayage, short-haul, and urban freight vehicles.[28] However, battery technology does not currently have near-term prospects to meet the demands of the heaviest modes of transportation.<br><br>The Lower Mainland has a large and growing opportunity to build its hydrogen hub around the heavy-duty market, as the region is home to several industry leaders developing fuel cell technologies and fuelling stations, such as Ballard Power Systems and HTEC. The Greater Vancouver region plays a connective role to Asia-Pacific markets for Western Canada, and long-haul trucking transports goods in and out of those ports. According to most experts, FCEVs are the most promising solution to replace heavy diesel class 8 vehicles that need to travel long, mountainous distances and carry large cargo loads. A cost analysis from NREL projected FCEVs to be cost-competitive in the US for these types of long-haul trucks by 2035.[29]<br><br>With support from the provincial government, HTEC is leading the "BCH2 Ports Pilot Project", in collaboration with several local companies, to demonstrate a range of hydrogen fuel cell electric trucks. HTEC is supplying hydrogen from a high-capacity fuelling station on Tsawwassen First Nation land, and using an upgraded maintenance facility in Abbotsford to support the fleet.[30]<br><br>**Rail**<br><br>Rail operators are also piloting hydrogen fuel cell technologies. Hydrogen-powered trains, which emit only water vapor, offer a sustainable alternative to diesel locomotives. CP Rail, which has production locations in Edmonton and Calgary, is piloting hydrogen fuel cell locomotives in Alberta that could be used for cross-border travel to the BC coast. Lower Mainland company Ballard Power Systems has been supplying the fuel cell engines for CP's tests.[31] |

### Shipping

In heavy shipping and other forms of marine transportation, fuel cells are being explored as one decarbonization solution. Other options, such as ammonia (a hydrogen carrier) and battery-electric ships, are also being investigated, though they come with their own set of challenges including toxicity and energy density issues for ammonia and range limitations for batteries. An alternative is methanol, a liquid fuel and hydrogen carrier with industrial applications that shows promise as a source of energy. "Green" or low carbon methanol can be produced using biomass, or by reacting green hydrogen with captured carbon dioxide. [32] Maersk and many of the world's largest shipping companies are leaning heavily into the potential use of methanol, and European leaders such as the Port of Rotterdam have already successfully performed methanol bunkering. [33] Of note locally, the Pacific Northwest to Alaska Green Corridor Project is exploring a low carbon marine corridor between Alaska, British Columbia, and Washington. The Vancouver Fraser Port Authority, among the first to join, is an active collaborator. It has an initial focus on cruise ships with the potential to expand to other marine sectors.

Vancouver is home to the largest port in Canada, however there are no commercial hydrogen fuel cell, ammonia, or solely methanol-powered ships that are currently operating in the Lower Mainland. However, two methanol-fueled tug boats are also expected to enter service in the Vancouver harbour in 2025 and two electric tug boats are already in operation. [34 35] Methanex subsidiary Waterfront Shipping, based in Vancouver, has a global fleet of 19 deep-sea ships with methanol dual-fuel technology. [36] The Lower Mainland hub could explore methanol bunkering further to encourage this type of technology adoption by shipping companies passing through the local ports. One assessment report modelling low carbon fuel uptake at the Port of Vancouver projected that vessels could demand approximately 22 thousand tonnes of methanol annually by 2030, and nearly 10 times that amount by 2040. [37]

### Aviation

Hydrogen can be a key feedstock for the production of low carbon Sustainable Aviation Fuels (SAF). [38] The groundwork for SAF production in Canada is being laid; the Canadian Council for Sustainable Aviation Fuels roadmap sets an ambitious target of producing a billion litres of sustainable aviation fuel by 2030. Hydrogen can also be used in fuel cells or combusted in modified turbine engines. However, technical challenges include the low volumetric energy density of hydrogen, which requires large and heavy storage tanks, and the high costs of hydrogen production. The role of hydrogen as a direct fuel is projected to expand after 2040, but not expected to play a role within the upcoming decade. [38] Alternatives being considered include biofuels and battery-electric aircraft. However the former is limited by feedstock availability and the latter by energy density constraints.

Commercial battery electric aircrafts have been tested successfully by Harbour Air in the Lower Mainland, and ongoing research, development, and piloting of fuel cell technologies is taking place in the region. [39 40] To better understand the local potential for SAF, the Province and YVR invested $250,000 in a "sustainable aviation fuel opportunities study". [41]

## Industrial Decarbonization

In cases where direct electrification technologies do not exist or are not technically or financially feasible, also known as "hard-to-abate" sectors, hydrogen holds potential as a decarbonization solution. While public modelling suggests that hydrogen is not expected to be a major source of emission reductions in the next decade, the Lower Mainland is home to a variety of industries that could leverage hydrogen as a low carbon energy source. For example, hydrogen could be used in the long term in the following ways:

### Hydrogen for Heat

In many industrial processes, fossil fuels are used as energy sources and combusted to produce high temperature heat. Low carbon hydrogen can be combusted directly in boilers, furnaces, and turbines to generate heat without producing $CO_2$ emissions. This can be particularly beneficial in industries such as cement and petrochemical refining, where heat and steam are generated from fuel combustion. In any industry with a demand for high-temperature heat, fossil fuels could be replaced by hydrogen or other renewable fuels.

A few industries stand out for the region, though the most prominent in the next decade is the cement and concrete industry, which is well established in the Lower Mainland. The production of cement involves heating calcium carbonate to high temperatures in kilns to produce clinker, the main component of cement. Hydrogen and other low carbon gases could be used as fuel substitutes to replace the natural gas used for kilns. Electrification technologies (e.g., Electric Arc Furnaces) are also being explored as an alternative.

While there is limited primary steel production in the Lower Mainland, some secondary steel processing and recycling facilities exist. Hydrogen could be integrated into secondary steel processing to replace natural gas in furnaces and reheat processes. For future development, any new primary steel production facilities could be encouraged to utilize hydrogen-based direct reduced iron (DRI) technology. There are also glass manufacturing and recycling plants in the region that could leverage hydrogen to replace gas in their furnaces, providing the high temperatures needed for melting glass.

### Hydrogen for Power Generation

In addition to its use in industrial processes, hydrogen could play a role in power generation. Hydrogen fuel cells can convert hydrogen into electricity with zero point-source emissions. In industrial sites in the Lower Mainland, there is a possibility that hydrogen fuel cells could provide on-site power generation for facilities, complementing grid electricity. This is discussed further in the following Energy Storage section.

### Hydrogen as a Chemical Feedstock

The Lower Mainland has a limited petrochemical industry but there is potential for growth. Hydrogen serves as a crucial feedstock in various chemical manufacturing processes, such as ammonia (one of the largest global consumers of hydrogen, driven by the fertilizer industry), methanol, and other industrial chemicals.

There are a variety of hydrogen end-uses implicated in hydrogen's use as a feedstock. Oil refining is a significant consumer of hydrogen and can use a low carbon alternative to reduce emissions. If prospects in the marine sector see growth in demand for methanol and/or ammonia, there could be greater need to co-locate green methanol production near the Lower Mainland's ports. The Green Shipping Corridors Assessment investigated the requirements and costs of a potential co-located e-methanol plant for the Port of Vancouver: a 200 thousand tonne per year production capacity would require at least $3-4 billion in investment and 370 MW of grid capacity. [37] Similarly, the prospect of decarbonizing the aviation sector in the Lower Mainland hub would likely necessitate co-located SAF plants, which would also seek low carbon hydrogen.

### Built Environment Heating

Some companies are exploring using hydrogen to reduce the carbon intensity of gas supply by blending it with natural gas and injecting it into the pipeline network, for commercial and residential building customers.

There would be logistical and safety challenges with this approach, as blending beyond a roughly 20 per cent volume would require that existing pipelines be retrofitted or new pipelines be constructed to accommodate hydrogen gas requirements. As mentioned in the supply section, FortisBC and Enbridge have commissioned a comprehensive blending feasibility study, to examine these questions further.

Furthermore, a recent analysis by CICE found that "blending hydrogen at approximately 20 per cent by volume" into the provincial gas grid could yield emissions reductions of only 1.7 per cent to four per cent, and should be considered a low-priority use of hydrogen. [4] Research by the Canadian Climate Institute corroborates this; a new report found that building heat will not be a cost-effective use of hydrogen in the long term (buildings account for only a small portion of low carbon gas use in a cost-optimized net zero modelling nationwide). [42] Blending could serve as an initial offtake while regional demand grows, however the latest evidence suggests that it should not be considered a high-priority use of hydrogen in the Lower Mainland.

## Energy Storage

After production, hydrogen can be stored until needed and used as a source of power generation during peak demand or when intermittent resources are unavailable, either through a fuel cell or combustion. Using hydrogen for energy storage could complement renewable electricity deployment in remote communities that are not grid-connected and could help communities transition away from a reliance on diesel power generation. This approach would only be sensible if the cost and carbon intensity of the hydrogen used was lower than diesel, and if it was deployed in climates where battery storage is proved to be prohibitively ineffective. The relative efficiency (energy conversion loss) of hydrogen compared to electrification is low, and community use would require new infrastructure for storage and distribution.

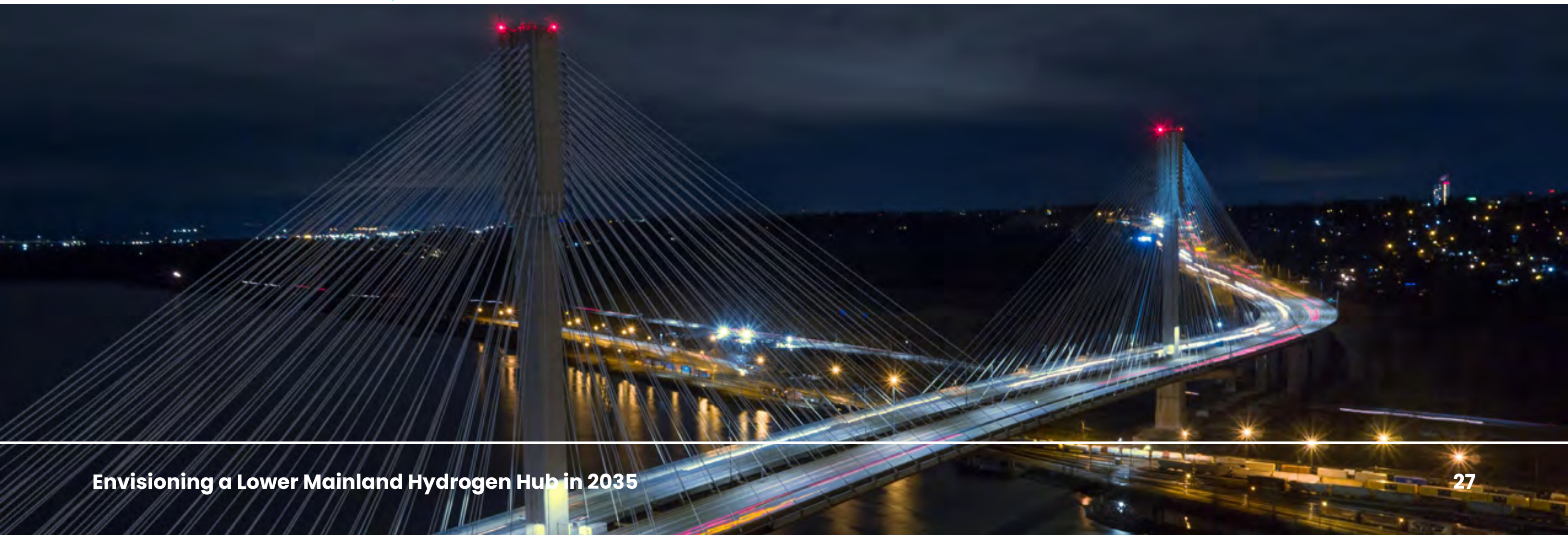
The latest research from CICE suggests that in BC, the likeliest use case for hydrogen as a form of long-term energy storage is on industrial sites that will have already invested in hydrogen infrastructure and co-locate supply and demand; it could be used as a backup to smooth out power demand or provide competitive combined power and heat. [43] Otherwise, its levelized cost is uncompetitive. [43]

In the Lower Mainland, where electric infrastructure is reliable and widespread and project development for industrial use cases has yet to take off, it does not appear that hydrogen will be used meaningfully for energy storage in the next decade.

## Export Commodity

Some consider hydrogen to be a potential export commodity for BC, given the growing global demand for hydrogen as countries set ambitious targets to reduce greenhouse gas emissions. Hydrogen is seen as a key enabler of the transition to a low carbon economy, particularly in sectors where electrification or other renewable energy solutions may be challenging or insufficient. Major economies such as Japan, South Korea, China, the European Union, and the United States have announced hydrogen strategies and initiatives to support the development and deployment of hydrogen technologies.

BC is geographically well-positioned to export to major markets in Asia. Its deep-sea ports and robust transportation infrastructure (road and rail networks) facilitate easy access to these markets. However, this is a long-term ambition and unlikely to factor into the Lower Mainland hub in the next decade, particularly given the current state of supply. Large-scale hydrogen export would also need to overcome significant costs and technology challenges. [44 45]



## Cost Trends

The cost of hydrogen can fluctuate significantly, contingent upon the specific technology pathway employed. These costs are influenced by many factors, including the prices of feedstocks (such as natural gas or electricity), the capital investments required, ongoing operational expenditures, and transportation costs. Costs are generally projected to decline as economies of scale are achieved. For example, the CER assumed in its 2023 Energy Futures report that electrolyser capital costs will decline by 80 per cent by 2030. [26] Additional factors that will vary over time include taxes and possible offsetting revenue streams for the producer (e.g., solid carbon).

HTEC's current retail price for hydrogen at its fuelling stations in the Lower Mainland is $14.70 per kg. [46] The BC Hydrogen Strategy estimated that a competitive production cost would need to be no higher than $3/kg by 2030 (approximately $25/GJ based on an assumed hydrogen energy content of 120 MJ/kg). [1]

Table 4. Projected 2030 production cost at a national level (EUR to CAD 1.47; USD to CAD 1.35).

| Source | 2030 Hydrogen Production Cost Projection | Production Method |
|---|---|---|
| Hydrogen Strategy for Canada | $3.20/kg | Electrolysis |
| Transition Accelerator | $3.17/kg | Electrolysis |
| IEA | $3.1/kg (converted from USD) | Electrolysis |
| Canada Energy Regulator | $1.50 - $10.50/kg | All technologies |
| SMIA | $1.71 - $2.03/kg | All technologies |
| PWC | $3.68 - $4.04/kg (converted from EUR) | Electrolysis |
| BNEF | ~$2.7/kg (converted from USD) | Electrolysis |

Three studies over the last five years completed analyses to project cost curves for each major hydrogen production method. The results are available in the following table.

Table 5. Projected 2030 production cost in BC.

| Production Method | Projected 2030 Production Cost in BC | | |
|---|---|---|---|
| | The Potential for Methane Pyrolysis in BC (2024) | B.C. Renewable and Low-Carbon Gas Supply Potential Study (2022) [6w] | BC Hydrogen Study (2019) [48] |
| **Electrolysis** | \$6.07 - \$9.87/kg | ~\$35 - ~\$41/ GJ (\$4.2 - \$4.92/kg) | \$5.13 - \$7.38/kg |
| **Pyrolysis** | \$2.71 - \$6.71/kg | ~\$18/GJ (\$2.16/kg) | \$1.68 - \$2.28/kg |

Unlike the other literature, the CICE report "The Potential for Methane Pyrolysis in BC" went a step further and undertook valuable analysis to present cost projections for delivered hydrogen for each technology. The study found that "hydrogen compression, loading, and transport can add significant costs to the total LCOH, between \$0.2/kg to \$6/kg depending on the transport distances, volumes, and transportation method." The federal Hydrogen Strategy presented a target cost for delivered hydrogen (which includes all production and transportation-related costs) of \$1.5-\$3.5/kg, after 2030. [8]

While the best available public estimates indicate that hydrogen production costs will be near the BC Hydrogen Strategy's target for global competitiveness of \$3/kg, new research signals that, particularly at smaller production quantities, processing and transportation costs are expected to add significantly to the final price. This is particularly important to consider in the context of a co-located hydrogen hub where demand is not expected to reach large quantities in the near term. Pyrolysis technologies do have the advantage of potentially reducing the net cost of hydrogen, with revenues from the sale of solid carbon byproducts; however, these markets are still developing. [3]

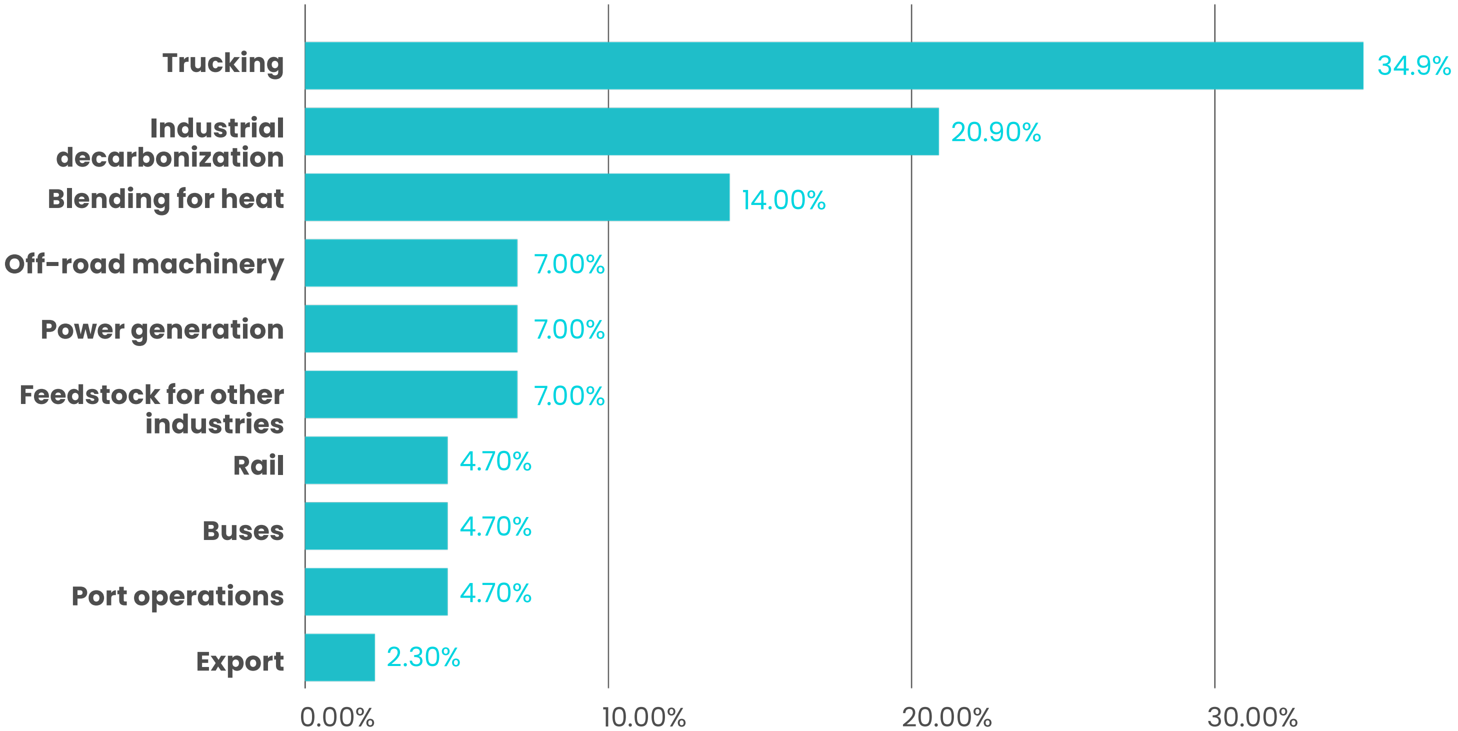
## What We Heard: Expert Feedback on Demand

In our workshop, participants were gathered and asked: "What are the key challenges related to the end-use of hydrogen in the region?" The following themes represent the summarized feedback collected by facilitators.

### Demand Development

- To ensure a balanced market, both supply and demand for hydrogen must be developed concurrently.
- Initial steps to build the market could involve blending hydrogen to transport it to gas heating customers as an initial source of demand; though this is considered a low-priority use in the long term.
- Industry and heavy-duty vehicles, including trucks, buses, and marine applications, are high-priority areas for hydrogen demand.
- Hydrogen has potential to decarbonize aviation, including via fuel cells and SAF production.
- Shipping and port operations were identified as additional areas for hydrogen use, although safety and social license concerns exist.

Figure 2. Expert polling results: Likeliest sources of regional demand.



## Infrastructure Challenges

- Leveraging existing pipeline infrastructure, within its limits, is crucial to expand hydrogen distribution.
- Significant technological and supply issues exist with refuelling infrastructure, which need to be addressed to support hydrogen adoption.
- Hydrogen storage presents challenges, particularly in the Lower Mainland.

## Public Perception

- Overcoming public skepticism about hydrogen is essential. Demonstration projects can help build social license and public trust.
- The public and stakeholders need to be educated about the benefits and potential of hydrogen for decarbonization.

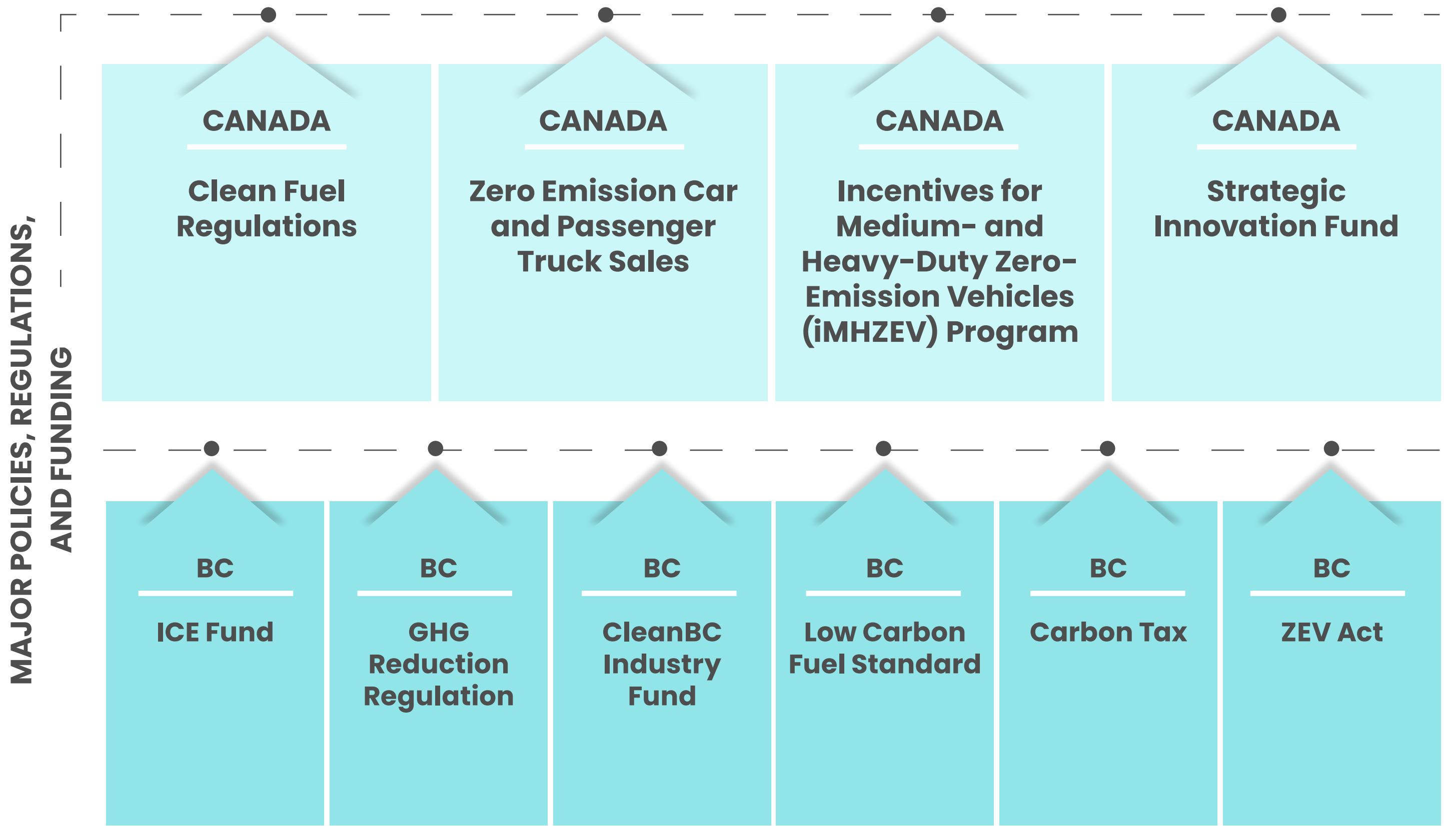
## Challenges in Adoption

- The high cost of hydrogen technology and infrastructure is a major barrier to adoption and there is a limited availability of hydrogen-powered vehicles and core technologies, hindering market growth.

## Government Support

- Clear and consistent regulations are critical to drive investment into end-use technologies in the hydrogen sector. Adopters need confidence the local ecosystem will have the conditions it needs to grow.

- Ongoing financial incentives and subsidies, such as those already available in BC (e.g., Go Electric program, LCFS, CleanBC Industry Fund), can help offset the high costs of demand-side technology adoption.

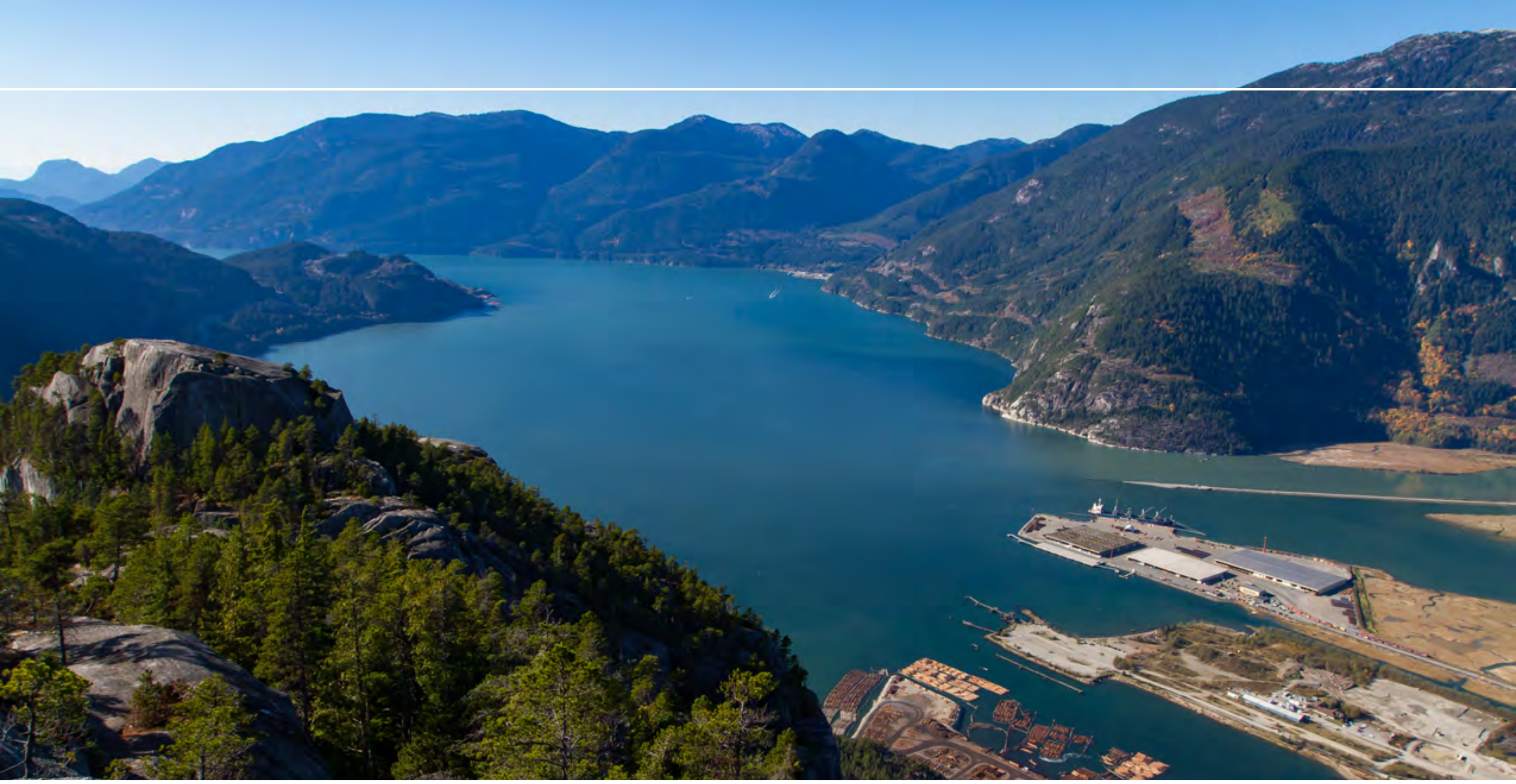



## Hub for Demand

- Identifying anchor tenants (e.g., BC Rail) can help secure demand in production zones and catalyze investment in the hub.

- Co-locating hydrogen production and consumption can overcome some logistical challenges and create synergistic ecosystems.

- The hub model can help de-risk investments by providing a stable supply and demand environment, and encouraging companies to adopt new technologies.



## Demand-Side Recommendations for Hub Partners

1. **Focus the Lower Mainland hub's development around heavy transportation and industrial decarbonization use cases for hydrogen.** The latest evidence and expert consensus suggest that these will be the primary sources of hydrogen demand in the region. In the next decade, on-road class 8 vehicles will be a target with supportive infrastructure (e.g., refuelling stations) already being built. Policy-makers should work with utilities to plan infrastructure development and incentives accordingly, and closely monitor how the costs of hydrogen end-use technologies compare to electrification counterparts over time. Rapid cost declines are not off the table for new and evolving technologies (e.g., BEVs, FCEVs) and could change the consensus. **[Recommendation Lead: All Partners]**

2. **Limit consideration of blended hydrogen for heat as a pathway to reduce emissions in the Lower Mainland.** Consider blended hydrogen for heat as a short term anchor tenant, if supply outpaces demand-side technology adoption. Beyond that, government should not consider additional support for an end-use that evidence suggests will not make a meaningful difference in meeting our emission reduction goals.
**[Recommendation Lead: Province, Utilities]**

3. **Continue government funding and support for demonstration projects.** Canada has an adoption problem across all cleantech sectors. Continued government support for pilot and demonstration projects is critical to build confidence in potentially key end-use technologies and pave the way for commercialization. Existing BC support for new projects is helping lay the foundation for sectoral growth. **[Recommendation Lead: Province]**

# Regional Considerations

The Lower Mainland holds a strategic position, with access to renewable energy, supportive policy, and robust infrastructure. In addition, the hub is already developing and home to several national industry and academic leaders. This section will discuss the opportunities for the Lower Mainland to stand out from its regional counterparts and leverage synergies where possible.

## Competitive Advantages

The Lower Mainland holds significant competitive advantages for hydrogen hub development. Its strategic location offers major ports and well-developed transportation infrastructure, including highways, railways, and ports, which support efficient distribution and logistics; all crucial components of a hydrogen supply chain.

By comparison, Northeast BC and Interior BC also present significant opportunities for hydrogen hub development and share the advantage of local renewable electricity that provides a pathway to produce low carbon hydrogen. As discussed in the supply section of this report, the Northeast in particular has vast natural gas reserves and geological storage suitability, which can be utilized for blue hydrogen production. Nonetheless, the Lower Mainland's proximity to major urban centers and ports gives it a logistical advantage over these more remote regions. Its established industrial base and greater access to skilled labour and research institutions also bolster its investment attractiveness.

The government commitment to reducing emissions and promoting clean technologies also creates a favourable environment in the Lower Mainland. Incentives, grants, and supportive regulations encourage investment and innovation in the sector. At the provincial level, CleanBC programs and policies including the Low Carbon Fuel Standard, Zero Emission Vehicle Act, Go Electric program and others advance adoption of hydrogen technologies and its competitiveness with other energy sources. At the local level, many municipal governments in the Lower Mainland have strong decarbonization ambitions and voter mandates to support clean energy development; the Metro Vancouver Climate 2050 Roadmap includes hydrogen as a key area of focus and is committed to developing a hydrogen hub in the Metro Vancouver region.

The region is a major source of innovation, research and development, and is expected to continue to be so in the future. Several trail-blazing companies, including HTEC and Ballard Power Systems, as well as BC's largest post-secondary institutions such as UBC, SFU, and the BC Institute of Technology (BCIT), each with their own hydrogen initiatives, also reside in the Lower Mainland. [49] BC is home to over half of Canadian hydrogen and fuel cell companies and the majority of sector R&D investment; most of which is happening in the region. [13]

## Opportunities for Collaboration

Alberta is a key player in the hydrogen industry due to its extensive energy infrastructure and expertise in oil and gas. Alberta's expertise in hydrogen production and use, with its existing sources of supply and demand, is complemented by significant investments in CCUS technologies, making it a competitive region for development. The majority of this activity is centered around the Alberta Industrial Heartland and the Edmonton Hydrogen Hub. The strong local industrial base, investments in hydrogen production, and storage position the region as a formidable competitor to the Lower Mainland.

Collaboration with Alberta can enhance the overall hydrogen supply chain in Western Canada and leverage each province's strengths. For example, Alberta's expertise in blue hydrogen and CCS can complement BC's focus on green hydrogen and pyrolysis. Joint ventures and shared infrastructure projects, such as pipelines and storage facilities, could optimize resource utilization and reduce costs. Partnerships can facilitate knowledge sharing, technology transfer, and coordinated policy efforts. Establishing a cohesive regional hydrogen market can attract larger investments to Canada and improve market stability.

The US federal government invested USD $7 billion to establish the "Regional Clean Hydrogen Hubs Program".[50] In late 2023, the Pacific Northwest Hydrogen Hub (Washington, Oregon and Montana) was one of seven selected to receive funding (though the funds have not yet been delivered).[51] While there is a competitive factor, the opportunities for collaboration are endless given the region's similar focus on green hydrogen and the decarbonization of heavy transportation and industry.

Both Alberta and the Pacific Northwest Hydrogen Hub offer immense potential for technology, skills, and knowledge transfer. The local cluster of Lower Mainland technology companies has the potential to export technology to buyers in the US to support further growth, while post-secondary institutions will see greater opportunities for research and development, and collaboration and skill training demand.

## Potential Barriers to Overcome

One of the main barriers to interprovincial collaboration is the regulatory and policy differences between provinces. Aligning regulations related to hydrogen production, storage, and distribution is important for cooperation. Standardized safety protocols and environmental regulations can mitigate these challenges. CSA Group is working to address these barriers to promote safety and harmonize requirements across North America.

Alignment in infrastructure development is also critical. Building the necessary infrastructure for a hydrogen economy in the Lower Mainland requires significant investment and coordination between regions. Differences in infrastructure readiness between regions can create bottlenecks. Collaborative planning and investment in shared infrastructure projects can address these issues.

Ensuring sufficient market demand for hydrogen production centres in the Lower Mainland will be crucial for the long term economic viability of the hub. Collaborative efforts to stimulate demand, such as joint public-private partnerships and incentives for hydrogen adoption in various sectors, can enhance market attractiveness.

Lastly, the cost of living and commercial real estate in the Lower Mainland cannot be overlooked when considering hub development. Higher capital and operational costs, along with potential difficulties in attracting and retaining talent due to housing affordability (among other costs), weigh against the region's strengths.

## Workforce Development Needs

The development of a hydrogen hub in the Lower Mainland has the potential to create numerous multi-sectoral opportunities, necessitating a highly skilled workforce. This transition presents both challenges (e.g., retraining) and opportunities (e.g., job creation, economic diversification). Broadly, the hydrogen industry will require diverse talent in a wide range of professions in order to grow, including but not limited to:

- **Engineering:** Professionals skilled in chemical, mechanical, electrical and process engineering.
- **Renewable Energy:** Expertise in integrating hydrogen production with renewable energy sources, such as wind, solar, and hydroelectric power.
- **Safety and Compliance:** Specialized training in safety protocols, hazardous materials handling, and compressed gas to ensure safe operations and adherence to industry standards.
- **Operations and Maintenance:** Skilled technicians and plant operators to manage the day-to-day operations of hydrogen production plants, storage facilities, and distribution networks.

- **Digital Transformation:** Professionals with digital skills and expertise in generative AI, design, data analytics, and automation.
- **Automotive:** Skilled trades & technicians to maintain and service FCEVs and refueling stations.
- **Business and Policy:** Professionals with project management, sales and commercial skills to support the growth of the hydrogen economy, and experts who understand the regulatory and compliance requirements specific to the hydrogen industry.
- **Innovation and Research:** Continued advancements in hydrogen technologies will rely on researchers and scientists who can innovate and improve production methods, storage solutions, and application technologies.

To meet these needs, specialized training and education programs must be developed. At the early stages of a sector's growth, there is often a disconnect between what industry needs and what post-secondary institutions are offering. At a high-level, this means a hydrogen hub would require:

- **Vocational Training:** Programs focused on specific technical skills related to hydrogen production, safety, and maintenance, as well as end-use technologies such as refueling stations, vehicle and fuel cell maintenance, and more.
- **Higher education programs:** Universities and colleges will need to offer courses and degrees in hydrogen technology, renewable energy systems, and engineering.
- **Continuing education and upskilling opportunties:** For the existing workforce, upskilling opportunities through workshops, certifications, and on-the-job training will be vital to transition current skill sets. BCIT's Hydrogen Symposium identified three elements for an upskilling package: "1) certification for working with materials at extreme high pressure, 2) training in cryogenics for extreme low-temperature materials, and 3) hydrogen safety training." [52]

With these considerations in mind,  hydrogen companies in the Lower Mainland have identified the following priorities with respect to workforce development:

- **In-Demand Skills:** Companies in the region value a blend of scientific expertise and practical business knowledge. There is high demand for mechanical and electrical engineers, particularly those with expertise in high-pressure gas piping, process controls, and system integration. Data management and data science skills are increasingly important, alongside software engineering, power electronics, product design, and R&D in electrochemistry and catalysts. Proficiency in integrating big data and AI, as well as leadership in technical groups, are also sought after. Given the nature of the industry, remote work proficiency and international business skills are essential, especially in a sector reliant on B2B interactions and premium disruptive technology. Basic knowledge of cleantech, sustainability principles and climate change is also considered essential for both technical and non-technical roles.

- **Certifications & Skills for Employment:** Certifications and skills that make candidates highly attractive include the gas fitter certification for technicians, Project Management Professional (PMP) certifications for project work, and mechatronics for system-level engineering. Business-oriented qualifications such as an MBA or certificates in strategic planning and software are also considered valuable. Transferable skills from existing jobs and sectors include mechanical engineers, professionals with high-pressure gas knowledge, and data analysis experts. Skills from the oil and gas industry, particularly in sales and maintenance, also offer significant cross-training opportunities.

- **Roles Requiring Upskilling:** Certain roles require significant upskilling. Maintenance personnel need retraining for advanced manufacturing and automation, while engineers and technicians must adapt to advanced robotics and quality control processes. The future workforce shows no shortage in basic engineering principles, and there is strong interest among young workers in clean energy. However, there is a notable gap in middle-level experienced engineers, often due to competition from sectors like software development.

- **Barriers to Recruitment:** Reported barriers include traditionally lower wages and sector instability. Financial challenges persist due to the market’s infancy, and attracting and retaining talent is challenging compared to higher-paying sectors such as software development. However, values alignment in sectors with a social and environmental impact, helps in attracting talent. Recruitment strategies involve using co-op hires, social media, executive recruiters, and international hiring to access a diverse talent pool, with a strong focus on maintaining a good ecosystem for retention, especially in cities like Vancouver.

# What We Heard: Expert Feedback on Regional Considerations

In our workshop, participants were gathered and asked: "What are the competitive advantages associated with hydrogen hub development in the region (compared to other prominent hubs in development) and what are the opportunities to collaborate with neighbouring jurisdictions?" The following themes represent the summarized feedback collected by facilitators.

## Competitive Advantages

- **Geography:** The Lower Mainland's access to low-cost electricity, water, key infrastructure (e.g., ports, pipelines) and the US border makes it a strategic location for hydrogen production and distribution. The robust local economy and demand for clean technologies provide a strong market base for hydrogen.

- **Skilled Workforce and Innovation:** The Lower Mainland has a high concentration of trained and experienced workers, making it an innovation hub for hydrogen technologies. The presence of supportive post-secondary institutions and a cluster of hydrogen tech companies enhances the region's competitive edge.

- **Policy Environment:** The BC Hydrogen Strategy and policies such as the Low Carbon Fuel Standard support local hydrogen development. The local population also typically prioritizes climate action, providing social support for hydrogen projects as long as they are low carbon.

## Opportunities for Collaboration

- There are opportunities to work with neighbouring jurisdictions, including Washington State and other provinces, to share technology and infrastructure. For example, developing transportation infrastructure, such as hydrogen refuelling stations, to link hydrogen demand across regions. We can also look beyond our borders to consider the lessons learned from regulatory and implementation strategies in Europe. Creating standardized transportation and distribution networks between regional partners is also essential to ensure supply and demand consistency.

Project developers and sponsoring government agencies should work with local Indigenous communities to advance Indigenous leadership and ownership in regional hydrogen projects. The Lil'wat First Nation's collaboration with Sea to Sky Energy Solutions and support for the Meager Creek Geothermal Project, as well as the partnership between Salish Elements and the Xaxli'p First Nation, are examples of projects already underway.

## Barriers to Overcome

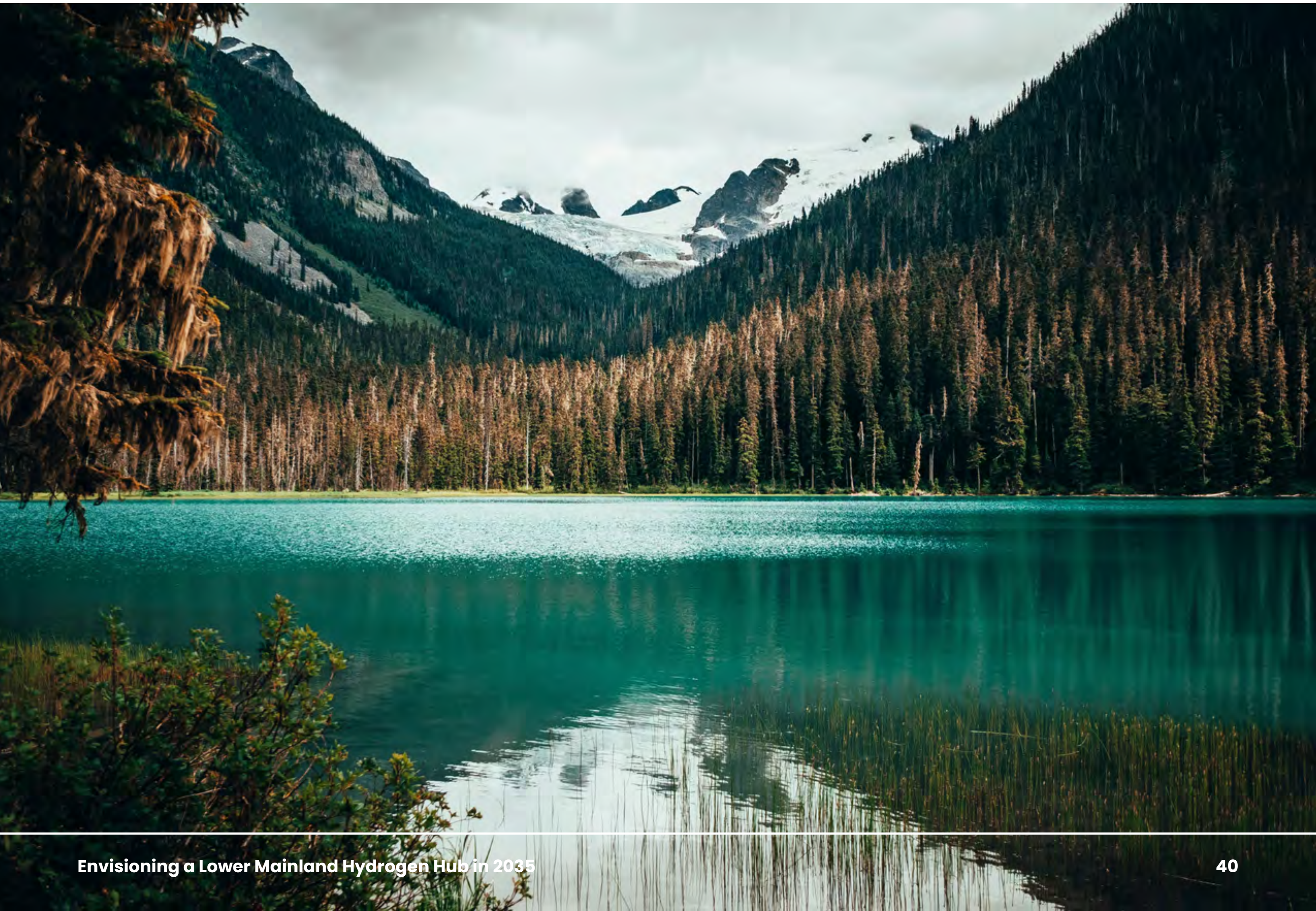
- **Public Awareness and Trust:** More work needs to be done to build public awareness and trust in hydrogen technologies (e.g., educational campaigns). This includes addressing safety concerns and change management to further improve social license.

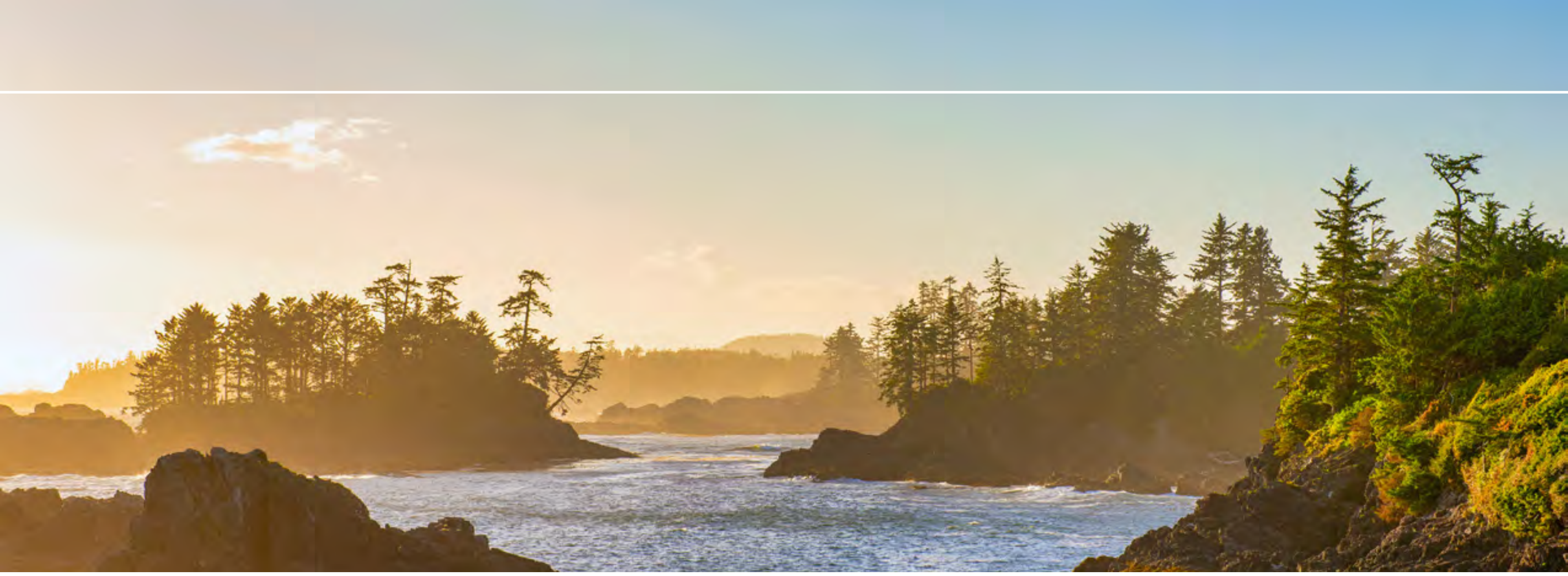
- **Regulatory Hurdles:** There is a need for governments to work with industry to streamline regulatory processes to reduce delays and uncertainty.

- **Resource Management:** Some of BC's competitive advantages require careful management. Monitoring resource constraints, particularly water and electricity, is essential to ensure sustainable hydrogen production.

- **Ongoing Policy Support:** Consistent government policies are needed in the region to support long-term investment.

- **Workforce Development:** The Lower Mainland has a number of advantages in this respect, however further improvements to training and knowledge transfer are needed to support the growth of the hub.





## Regional Recommendations for Hub Partners

1. **Explore new ways to enhance knowledge transfer between the region and nearby hubs.** Consultations suggested that the Lower Mainland Hub should find more opportunities to collaborate with its neighbours. Regional partnerships and collaboration already occur through existing bodies and forums such as the Pacific NorthWest Economic Region, Pacific Coast Collaborative, and the Canadian Hydrogen Association. Regular regional roundtables (or other means of organizing facilitated discussions) between partners that leverage existing channels and networks could be productive to respond to the unique needs of the Lower Mainland Hub. This approach could be replicated for partners with assets and commercial interests in multiple BC hubs.
**[Recommendation Lead: All Partners]**

2. **Explore the creation of a regulatory task force.** Experts consistently suggested that there was a need to streamline regulatory and permitting barriers to project development. There may be a role for CEMPO to play in facilitating regular collaboration between industry, utilities, First Nations and municipalities, to identify the barriers facing project developers and overcome them promptly. This recommendation aligns closely with the policy action in the BC Hydrogen Strategy to: "Establish a working group made up of representatives from the hydrogen industry, regulatory agencies, and government to implement B.C. Hydrogen Strategy actions".
**[Recommendation Lead: Province, Utilities, BCER]**

3. **Increase collaboration to discuss how to prepare the hub to successfully develop and retain talent.** The Lower Mainland is a hub for academic research and skilled labour training, such that existing institutions have the built-in reputational advantage to attract the next generation of industry leaders. However, for that advantage to make a meaningful difference in the region's growth, policymakers must consider how systemic challenges such as housing affordability and the broader cost of living crisis affect labour retention. The region's built-in advantages can attract people, but retention will be limited if these systemic challenges are not addressed by a whole-of-government approach.
**[Recommendation Lead: All Partners]**

4. **Create a hydrogen workforce development strategy.** Part of the collaborative approach to develop and retain talent should include setting measurable, actionable targets to develop the hub's labour force. BC does not currently have a dedicated labour strategy for the clean economy. A dedicated hydrogen workforce strategy should build on the existing consultations to avoid duplication, and partner with Lower Mainland post-secondary institutions and municipalities. There is a need for ongoing collaboration between academia and industry to ensure that the strategy or any future planning that occurs ensures the skills needed by industry are being taught, and that they are marketed as a tangible career path for workers of all ages looking to join the low carbon workforce. The Province is working with Fraser Basin Council to complete a gap analysis to identify resources for hydrogen labour and skills development in BC; this could lay the groundwork for the strategy.
   **[Recommendation Lead: Province, Industry, Post-Secondary Institutions]**

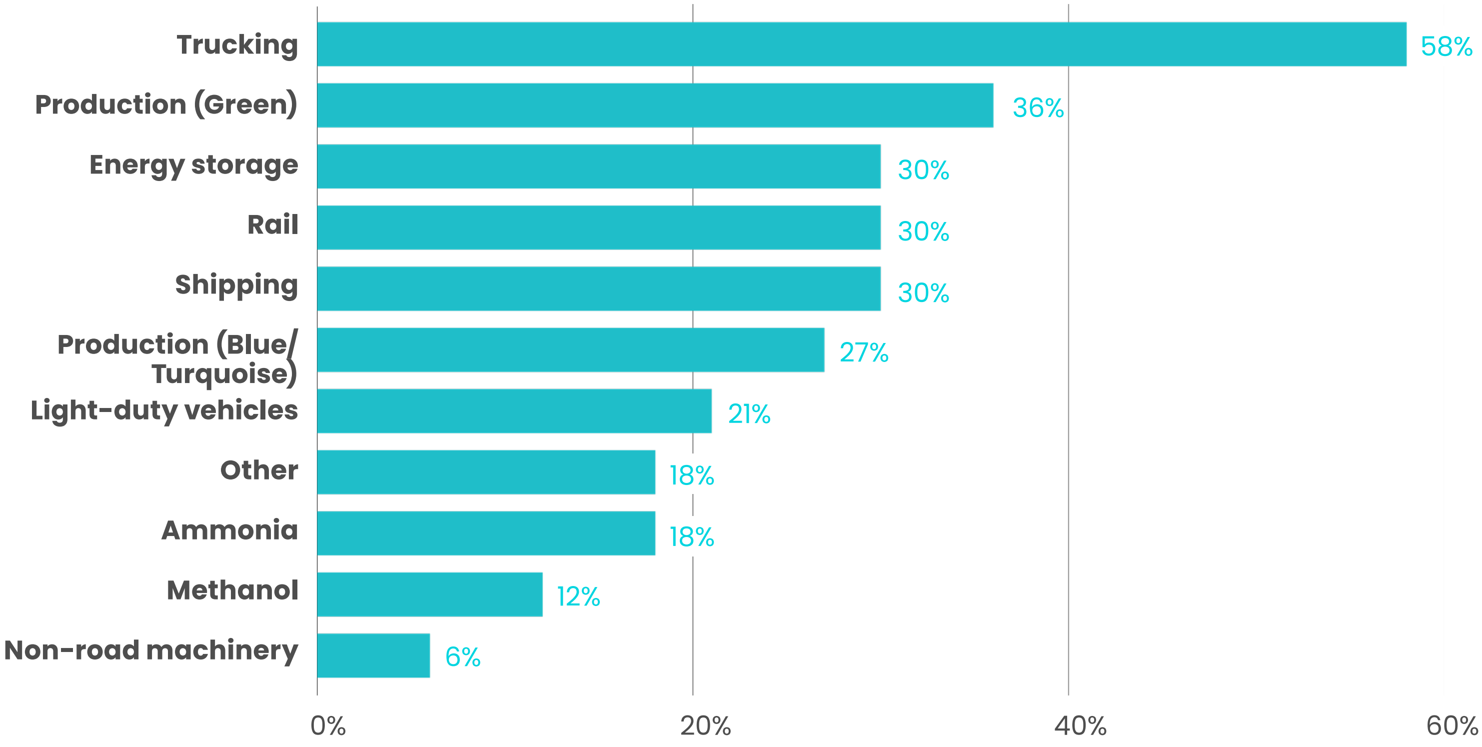
5. **Continue support for public education and awareness activities.** Based on consultations held for the Lower Mainland hub, there is still a limited public understanding of hydrogen. Further efforts are needed to disseminate the latest evidence surrounding hydrogen's role in the local economy, from carbon intensity to safety, best end-uses and more. Accessible, summarized resources and "101" content can help dispel myths and increase public awareness of the role hydrogen can play in the decarbonization of local communities, thereby building buy-in. The Province is currently working with Fraser Basin Council to develop new hydrogen education and safety materials to inform the public. This is a good first step and should be a building block for ongoing public-private-nonprofit sector collaborations to advance awareness and education.
   **[Recommendation Lead: Province, Local Governments]**

# What We Heard: Public Engagement

In addition to the research completed to develop this report and an in-person workshop, Foresight conducted a public "Hydrogen 101" workshop on May 29, 2024 and had 45 attendees. The workshop gave members of the public and organizations in BC's Mainland/Southwest region an opportunity to learn about the potential roles of hydrogen in BC and share perspectives on the future of a Lower Mainland Hydrogen Hub. The session began with a "Hydrogen 101" presentation, where presenters shared educational information on hydrogen, including some of the potential sources of demand and supply. This was complemented by interactive poll questions and a word cloud to gather feedback.

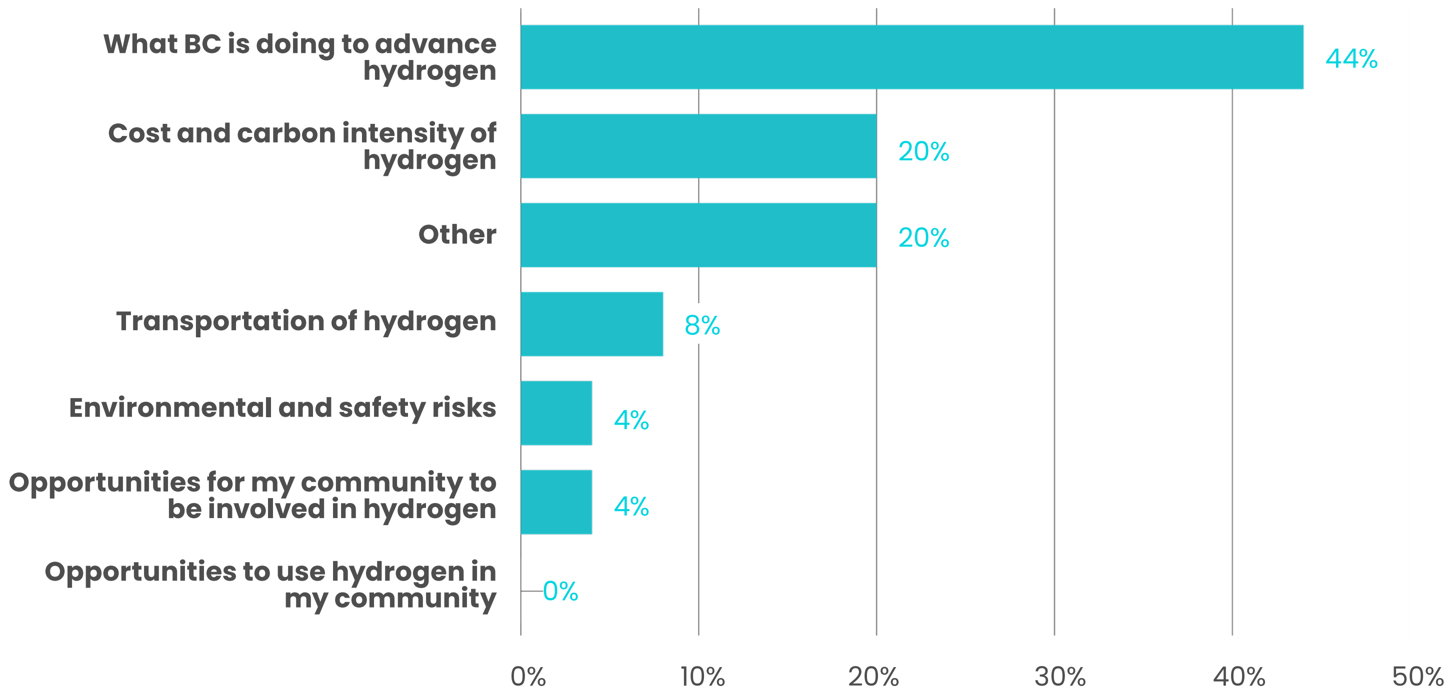
The results from the polls and word cloud exercise are included in this report as an example of how people in the region are currently thinking about the future of hydrogen.

Figure 3. Poll 1: Where do you see opportunities for hydrogen in your community?




The results of the polls and word cloud indicate several key areas of interest and concern regarding the future of a Lower Mainland Hydrogen Hub. Poll 1 results provide insight into where the community sees the most promising opportunities for hydrogen. The top interest, with 58 per cent of responses, is in long-distance trucking, highlighting its potential for heavy-duty transport. This is followed by production using electrolysis (36 per cent) and shipping (30 per cent), indicating support for local low carbon hydrogen and the transportation sector. Renewable energy storage and rail also garnered significant interest (30 per cent each). Personal vehicles (21 per cent), production through reformation/pyrolysis (27 per cent), and other unspecified opportunities (18 per cent) were also noted, reflecting a broad range of potential uses for hydrogen in the community. Methanol, ammonia, and non-road mobile machinery had the least interest, indicating they might be seen as less viable or immediate options for hydrogen application.

Figure 4. Poll 2: What would you like to learn more about when it comes to hydrogen?




According to Poll 2, the most interest (44 per cent) is in learning more about what BC is doing to advance hydrogen development. This highlights the need to further amplify CEMPO's undertakings and share regular updates with the public on projects and regulatory changes that are underway. This is followed by interest in the cost and carbon intensity of hydrogen (20 per cent), and equal interest in other unspecified topics (20 per cent). Other areas of interest include the transportation of hydrogen (8 per cent), environmental and safety risks (4 per cent), and opportunities for community involvement in hydrogen production (4 per cent).

GLOBAL
ENERGY TRANSITION
OPPORTUNITIES WITH RISKS SOURCE
ENERGY ROI + INFRASTRUCTURE CLEAN ENERGY
INDUSTRIAL USE GHG REDUCTION
EXPENSIVE COST
EFFICIENCY CONCERNS
LONG TERM USE CASE? USEFUL IN SOME CASES
POTENTIAL DANGERS OPPORTUNITY FOR BC
ENABLER CHALLENGING METHANOL
COMPLEXITY BETTER FUEL
SPECIFIC USE CASES

Figure 5. Word cloud: Tell us what words come to mind when you think of hydrogen.

The word cloud highlights the primary associations people have with hydrogen. The most prominent term is “expensive,” indicating a significant concern about the cost of hydrogen. Other notable terms include “cost,” “clean energy,” “opportunity,” “global energy transition,” and “GHG reduction,” suggesting there is broad recognition of both the potential benefits and challenges associated with hydrogen. The word cloud also reflects concerns about “potential dangers,” and “efficiency concerns,” pointing to safety and practicality issues. Overall, the feedback collected shows a mix of optimism about hydrogen’s role in clean energy and apprehension with regard to its costs and safety.

# Conclusion

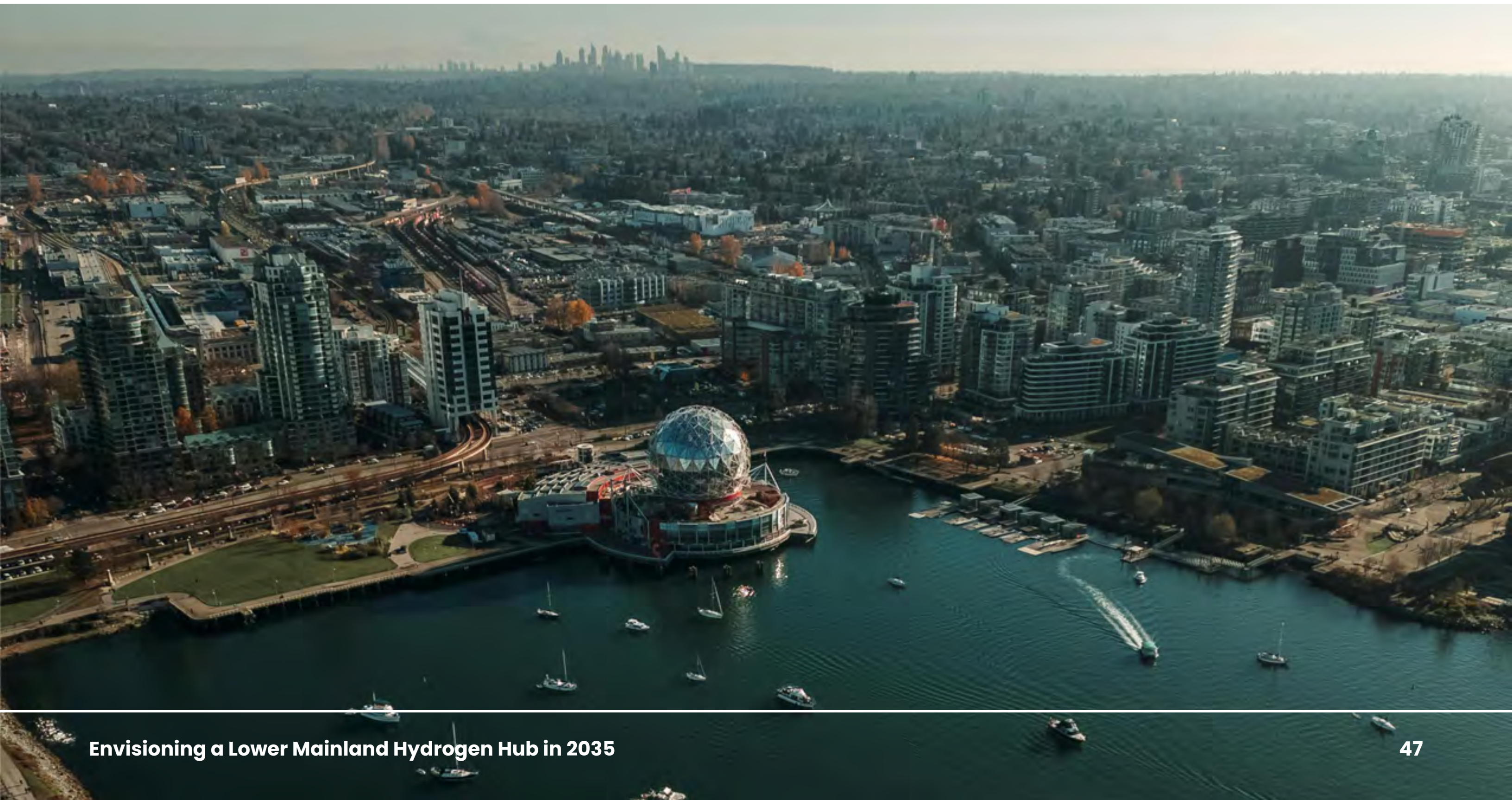
Based on the findings of this work, a hydrogen hub is already growing in the Lower Mainland and continued development presents an opportunity to support the reduction of provincial emissions in the next decade, to a limited extent. The feedback gathered through engagement sessions with key stakeholders, experts, and the public highlights a strong regional interest in hydrogen as a decarbonization tool and a desire to see more public work on the economic and environmental impacts of its production and use. In the literature and among the local community, there is a consensus on hydrogen's role as a decarbonization solution for heavy transportation, and a desire to see local production of low carbon hydrogen collaboratively grow to address this need. This interest provides a solid foundation upon which to foster a hub.

However, the discussions and literature also raised important barriers that need to be overcome. High hydrogen costs and uncertain availability of supply, which remain key considerations, will need to be tackled through ongoing public-private collaboration, technological advancements, and economies of scale. While cost declines and technology improvements are occurring, there is no clarity that hydrogen will emerge as a definitively cost-effective fuel within the decade. The findings of existing cost analyses and projections should be amplified to improve public awareness of current data and illustrate the economic viability of hydrogen projects over time, and future studies should continue to be supported as new data emerges.

Stakeholders emphasized that the region's next steps should focus on continued collaboration between key stakeholders, including government agencies, private sector partners, and research institutions, to leverage regional strengths, reduce silos, address competition and identify opportunities to reduce regulatory hurdles on an ongoing basis. This collaboration should also extend to developing shared infrastructure and supply chains to reduce costs and increase efficiency. Regional opportunities for collaboration might include partnerships with neighbouring provinces and cross-border initiatives with US states to create a North American hydrogen corridor. Engaging with industry experts around the world and adopting best practices from established projects worldwide will further enhance the potential of the hub.

Investing in training and education programs to build a skilled workforce capable of supporting the regional hydrogen economy is essential. This includes not only technical training for hydrogen production and handling but also educational initiatives to raise awareness about hydrogen technologies and their benefits. Partnerships with local educational institutions, trade schools, and universities can help create specialized curricula and certification programs tailored to the hydrogen industry.

Overall, the path forward involves a combination of strategic planning, stakeholder engagement, and targeted investments to realize the full potential of a hydrogen hub in the Lower Mainland. By addressing the identified issues and building on the local wealth of expertise and knowledge, the region can grow the regional hydrogen ecosystem in a targeted manner that complements other viable decarbonization technologies to drive down emissions as rapidly as possible. Continuous monitoring, evaluation, and adaptation will be necessary to ensure the hub evolves in response to technological advancements and market dynamics.



## All Recommendations for Lower Mainland Hub Partners

| Category | Recommendation | Lead Partner(s) | Timeline |
| --- | --- | --- | --- |
| **Supply-side** | **1.** Focus on pyrolysis and electrolysis technology development | All Partners | 2025-2030 |
| | **2.** Provide further public clarity on electricity supply | Province, Utilities | 2025-2030 |
| | **3.** Continue support for market-based policies that increase competition between hydrogen and carbon-intensive fuels | Province | Ongoing |
| | **4.** Undertake a Lower Mainland permitting case study to help make the municipal permitting process more transparent and understandable for project proponents | Province, Local Governments | <1 year |
| **Demand-side** | **1.** Focus the Lower Mainland hub's development around heavy transportation and industrial decarbonization use cases for hydrogen | All Partners | 2025-2030 |
| | **2.** Limit consideration of blended hydrogen for heat as a pathway to reduce emissions in the Lower Mainland | Province, Utilities | 2025-2030 |
| | **3.** Continue government funding and support for demonstration projects | Province | 2025-2030 |
| **Regional Considerations** | **1.** Explore new ways to enhance knowledge transfer between the region and nearby hubs | All Partners | 2025-2030 |
| | **2.** Explore the creation of a regulatory task force | Province, Utilities, BCER | <1 year |
| | **3.** Increase collaboration to discuss how to prepare the hub to successfully develop and retain talent | All Partners | <1 year |
| | **4.** Develop a hydrogen workforce development strategy | Province, Industry, Post-Secondary Institutions | 2025-2030 |
| | **5.** Continue support for public education and awareness activities | Province, Local Governments | 2025-2030 |

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