PAINTING THE PICTURE

METRO VANCOUVER'S FUTURE LOW-CARBON HYDROGEN ECOSYSTEM

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FORESIGHT CANADA

Acknowledgments

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.

This report was prepared by Foresight Canada. It was written by Alyssa Kelly and Khushi Nilani with support from David Sanguinetti, Michelle Pavlik, and Kaitie Unwin.

About Foresight

Foresight is Canada's cleantech accelerator. In collaboration with our Helix 5 partners - innovators, industry, investors, government, and academia - Foresight is relentlessly driving cleantech innovation in Canada. Our audacious goal is that Canada be the first G7 country to reach net zero. Our mission is to accelerate the growth and impact of cleantech ecosystems across Canada to achieve deep decarbonization and net-zero climate targets through problem-driven innovation.

Shell Canada Limited (Shell) commissioned Foresight to host a workshop with a diverse group of external parties to explore and create a vision for what a Hydrogen economy/ ecosystem could look like in British Columbia's lower mainland region in 2035. The workshop was held in Vancouver, British Columbia, Canada on September 14, 2022.

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To help reach the goal of being carbon neutral by 2050, government and industry stakeholders in Metro Vancouver are laying the framework for the development of a hydrogen economy.

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These fossil fuels that are used in buildings, transportation, and industry are responsible for 90% of emissions in the region.[1]

Executive Summary

Hydrogen in Metro Vancouver

To help reach the goal of being carbon neutral by 2050, government and industry stakeholders in Metro Vancouver are laying the framework for the development of a hydrogen economy. Currently, 72% of the overall energy sources used in the Metro Vancouver region come from fossil fuels.[1] These fossil fuels that are used in buildings, transportation, and industry are responsible for 90% of emissions in the region.[1] To address these emissions, multiple low-carbon energy sources, technologies, and innovations will be needed to meet regional climate goals. In a number of these situations, hydrogen is an attractive option.

Creating a hydrogen economy is a potentially advantageous opportunity for Metro Vancouver for a variety of reasons:

Renewable Power: BC's hydroelectric dams are a consistent source of renewable power generation, which is advantageous for electrolytic hydrogen production.

Location: Metro Vancouver is strategically located on Canada's southwestern coast. It is also home to the largest port in Canada which facilitates major trade routes to Asia and the west coast of North and South America. If hydrogen was pursued as an export industry, producers in the Lower Mainland or other provinces may ship hydrogen through the Port of Vancouver to reach ports across the Pacific Ocean. With ports being an important facilitator for a variety of transportation modes (i.e., shipping, rail, trucking), Vancouver's location makes it a central, highly interconnected transport hub, which is also an important factor in the development of a successful local hydrogen economy.

Policy Landscape: Local and provincial governments in BC have shown strong political support for hydrogen. The BC Hydrogen Strategy, CleanBC Roadmap, legislation such as the Low Carbon Fuel Standard, and the recent establishment of the BC Energy Regulator to include hydrogen and streamline regulatory oversight have positioned BC as a favourable region to develop a hydrogen economy. Additionally, the federal government's support of hydrogen, including recent efforts in the fall of 2022 to spur the development of clean energy nationwide contributes to a supportive policy landscape at all levels of government.

Hydrogen Cluster: Vancouver is also considered a world-class hub of hydrogen technology. With large industry leaders like Ballard Power Systems, multiple start-ups with innovative technologies, hydrogen-focused academic research, investor knowledge, government support, and technological development, there is already an established hydrogen cluster in the region with promising growth potential.

BC's Hydrogen Economy

The province of BC is laying the groundwork for a future hydrogen economy. This involves developing local use cases — such as transportation fuel — and the creation of a potential export market.

Key Points

- The BC Hydrogen Strategy is guiding the sector's development. Key points from the Strategy that the government is currently acting on include evaluating supply and demand in potential hub regions such as Metro Vancouver. [2]
- The BC government is supporting the development of hydrogen as a transport fuel, with an indicated focus on medium- and heavy-duty vehicles (MDVs and HDVs), shipping and ports, rail, off-road, and aviation applications. [3]
- BC is laying the foundation to develop an export market for hydrogen and hydrogen technology [2]

Notable Policy

- BC Carbon Tax [4]
- BC Hydrogen Strategy [2]
- Clean Industry and Innovation Rate [5]
- CleanBC Industry Fund [6]
- CleanBC Remote Community Energy Strategy (RCES) [7]
- CleanBC Roadmap [3]
- GHG Reduction Regulation [8]
- GHG Reduction Standard (proposed) [3]
- Innovative Clean Energy (ICE) Fund [9]
- Low Carbon Fuel Standard [10]
- Zero-Emission Vehicles (ZEV) Act [11]

Hydrogen Beyond Borders

There are plentiful opportunities for utilization of hydrogen as an energy source in Metro Vancouver and a strong foundation for localized production; however, a future hydrogen economy will not exist in a silo. Understanding the development of policies and strategies related to hydrogen in key jurisdictions and how they may impact Metro Vancouver will help create a future vision for the sector.

"...there is a need to develop an understanding of the supply and demand factors determining the global [hydrogen] hot spots and the significance of trade and transportation corridors for such a hydrogen economy. [12]"

– KPMG

Canada

The Government of Canada has noted the potential for BC to become an export hub for Canadian hydrogen.[13]

Key Points

- The Hydrogen Strategy for Canada outlines a set of recommendations with specific actions for government and industry to guide the development of national and provincial hydrogen economies.[13]
- The Government of Canada has, to date, focused on developing hydrogen applications in transportation, pledging investments in charging and refuelling infrastructure, increasing the availability of ZEVs for consumers, and mandating that ZEVs must account for 35% of medium- and heavy-duty truck sales by 2030.[14,15]
- The Strategy emphasizes that the hub model presents opportunities to scale and improve cost effectiveness, and that ports are ideal locations for hydrogen hubs and fuel cell equipment.[13]

Notable Policy

- Hydrogen Strategy for Canada[13]
- Canada–Germany Hydrogen Alliance[16]
- Clean Electricity Standard[17]
- Clean Fuel Regulations (CFR)[18]
- Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles (iMHZEV) Program[19]
- Regulatory Co-operation on Low Carbon Fuel (LCF) in Transport[20]
- Strategic Innovation Fund[21]
- Zero-Emission Car and Passenger Truck Sales[22]

Alberta

Alberta is currently the top producer of hydrogen in Canada, and is looking to utilize the abundant natural gas found in the province, coupled with carbon capture, utilization, and storage (CCUS), to scale up production and export blue hydrogen starting in 2030. [23,24] Alberta is likely to become a partner in the hydrogen economy to BC and Metro Vancouver, with the province potentially exporting through the Port of Vancouver to Asian markets.

Key Points

- The Alberta Hydrogen Roadmap sets out a path for Alberta to build its hydrogen ecosystem, export markets, international supply chains, and guide future policy development. [23]
- Alberta is exploring both land and sea routes to export hydrogen, which is a key pillar of the Roadmap. The governments of Canada, Alberta, and BC are working to develop port access in a cost-effective manner as sea routes to Asia from Alberta will likely pass through the Port of Vancouver, Prince Rupert, or other United States (US)-based ports. [25, 26]
- Alberta's hydrogen ecosystem is driven by the creation of hydrogen hubs paired with CCUS project development. In 2021, Edmonton announced the development of the first hydrogen hub in Canada. [26]

Notable Policy

- Alberta Hydrogen Roadmap [26]
- Alberta Petrochemicals Incentive Program (APIP) [27]
- Alberta Natural Gas Vision and Strategy [28]
- Emissions Reduction Alberta [29]
- Hydrogen Centre of Excellence [30]
- Technology Innovation and Emissions Reduction (TIER) Regulation [31]

Saskatchewan

Saskatchewan is opening opportunities for industries engaged in the manufacturing of hydrogen, which may lead to the development of a hydrogen supply and demand chain at a commercial scale in the province, aided by existing CCUS infrastructure. [32] Saskatchewan could become a partner region to BC and Metro Vancouver if they intend to begin export activities to target markets in Asia.

Key Points

Saskatchewan has commissioned a study to understand the development of a blue hydrogen hub and ecosystem in the Regina-Moose Jaw region. [33]

Notable Policy

- Saskatchewan Petroleum Innovation Incentive (SPII) [34]

United States

The US is a global leader in hydrogen economy development, with significant public and private funding, existing or planned infrastructure, and programs to spur the development of regional hydrogen hubs across the country. [35] The US could potentially become both a competitive producer to Metro Vancouver and an importing market depending on the level of demand in western states.

Key Points

- The US Hydrogen Strategy focuses on R&D efforts and the roll out of hydrogen-based technologies. [36]
- The Department of Energy (DOE) has established funding under the Bipartisan Infrastructure Law for the development of regional hydrogen hubs. [37] [38]
- The DOE has committed to fund R&D in hydrogen technology via the Hydrogen Shot initiative. [39] This will contribute to 31 projects to significantly reduce the cost of clean hydrogen production. [39]

Notable Policy

- Alternative Fuel Corridor (AFC) Grants [40]
- Bipartisan Infrastructure Deal [41]
- Hydrogen Fueling Infrastructure Development Program (H2USA) [42]
- Hydrogen Demonstration Project Grants [43]
- Inflation Reduction Act [44]
- Low or Zero Emission Ferry Program [45]
- US DOE Hydrogen Strategy [36]

Washington

Washington is planning its future role as a hydrogen hub for the Pacific Northwest region along with the state of Oregon. Washington may become a competitive producer to Metro Vancouver and strategic transportation corridor for export to California if there is sufficient demand and the Pacific Northwest Hub comes to fruition.

Key Points

- Washington's 2021 State Energy Strategy details the blueprint for decarbonization in the state. Transportation is highlighted as the most important sector to decarbonize, and the government is open to exploring all low-carbon transportation fuels and technologies, including hydrogen and use of fuel cell electric vehicles (FCEVs). [46]
- The Pacific Northwest region (Washington and Oregon) is bidding for the federal Hydrogen Hubs initiative. [35]
- Washington intends to become a "Hydrogen Valley," with several major projects in the works, supporting the goal noted in the State Energy Strategy to become a producer of green hydrogen in-state for export to other states and countries. [47]

Notable Policy

- 2021 State Energy Strategy [46]
- Clean Energy Fund [48]
- Clean Energy Transformation Act [49]
- Clean Fuels Program [50]
- Climate Commitment Act [49]
- Green Transportation Grant Program [50]
- HB 1988 [51]
- Medium- and Heavy-Duty ZEV Deployment Support [52]
- Medium- and Heavy-Duty ZEV Requirement [52]
- SB 5910 [53]
- SB 5974 [51]

Oregon

Oregon, with Washington, is developing the local hydrogen economy as a hub region. Similar to Washington, Oregon may become a competitive producer to Metro Vancouver and strategic transportation corridor for export to California if there is sufficient demand and the Pacific Northwest Hub is established.

Key Points

- As a result of Senate Bill 333, the September 2022 Oregon Renewable Hydrogen Study will explore supply and demand potential in the state.
- Obsidian Renewables is planning to lead the development of a hydrogen hub tailored around green hydrogen production from wind and solar energy generated at their Oregon facility. [54] The Pacific Northwest Hydrogen Hub is a joint federal proposal for both Oregon and Washington. [55]
- The state is also studying the potential to develop low-cost, offshore wind power used for both green hydrogen generation in-state, and export to California. [56,57]

Notable Policy

- Clean Fuels Program [58]
- House Bill 3055 [59]
- Medium- and Heavy-Duty ZEV Deployment Support [52]
- Medium- and Heavy-Duty ZEV Requirement [52]
- Renewable Hydrogen Study (pending) [60]
- The Heavy-duty Low-NOx Rule [59]

California

With ample potential to generate low-cost renewable energy, California is pursuing a leadership position as a green hydrogen producer. California will likely be a competitive producer to Metro Vancouver's hydrogen export economy, but could potentially be an importer depending on demand in-state.

Key Points

- The California Energy Commission (CEC)'s Green Hydrogen Roadmap and Strategic Plan is currently in development. [61]
- California has indicated its intended focus on green hydrogen production from renewable power, but has projected demand to exceed production and would therefore also look to import depending on cost. [54]
- Hydrogen is expected to play a large role in the road transport sector — especially in public transit and long-haul trucking — marine and ports, aviation, and is being explored in hard-to-decarbonize industrial sectors.
- In May of 2022, California announced an intention to create a renewable hydrogen hub through the federal Hydrogen Hubs initiative. [62]

Notable Policy

- Executive Order N-79-20 [63]
- Green Hydrogen Roadmap and Strategic Plan [61]
- Hydrogen Fueling Station Evaluation [64]
- Integrated Energy Policy Report (IEPR) [65]
- Light-Duty ZEV Requirement [64]
- LCFS ZEV Infrastructure Crediting [66]
- Low Carbon Fuel Standard (LCFS) [67]
- Medium- and Heavy-Duty ZEV Deployment Support [64]
- Medium- and Heavy-Duty ZEV Requirement [64]
- Renewables Portfolio Standard (RPS) Program [68]
- SB 1075 (pending) [69]
- SB 1329 (pending) [70]
- Zero-Emission Transit Bus Requirement [64]

Australia

With abundant wind and solar energy potential and significant fossil fuel resources, Australia is looking to produce both green and blue hydrogen for the creation of a strong export market. Additionally, geographic proximity and longstanding relationships with energy-importing Asian markets strengthens Australia's position as a global export market leader. Australia will likely be a competitive producer to Metro Vancouver's hydrogen exports.

Key Points

- Australia's National Hydrogen Strategy emphasizes the creation of supply and demand chains. They have prioritized the creation of hydrogen hubs close to ports to increase cost effectiveness related to scale, and cater to both domestic and international demand. [71]
- Australia is looking to export hydrogen to countries with established relationships in the energy space such as Japan and Germany.
- Multiple pilot projects are completed or in the works on hydrogen production and supply chains such as the Stanwell Central Queensland Hydrogen Project and the Hydrogen Energy Supply Chain, both regarding export to Japan. [72,73]

Notable Policy

- Australia and Japan Cooperation Agreement on Hydrogen and Fuel Cells [74]
- Bilateral Initiative [75]
- Clean Energy Finance Corporation (CEFC) [76]
- Clean Hydrogen & Carbon Investment [77]
- Clean Hydrogen Industrial Hub Program [78]
- Emission Reduction Fund [79]
- Hydrogen in Mining [80]
- Low Emission Technology Statement (LETS) [81]
- National Hydrogen Strategy [71]

Chile

With abundant potential to generate wind and solar energy, Chile is looking to pursue cost-competitive green hydrogen production as an export commodity. Chile will potentially be a competitive producer to Metro Vancouver for western US export markets; however, geographic distance to Asia may be an impediment for them to access these markets.

Key Points

- The National Green Hydrogen Strategy outlines the intention for the country to become an exporter of low-cost green hydrogen by 2040, sourced from solar and wind energy resources with the world's lowest levelized cost of production. [82]
- Chile has indicated target export markets as Europe, China, Japan, South Korea, the US, and Latin America. [82]
- In 2021, Chile signed an MOU with the Port of Rotterdam to develop a green hydrogen supply chain linking the country to European importers. [83]

Notable Policy

- Chile-Port of Rotterdam Memorandum of Understanding (MOU) [83]
- National Green Hydrogen Strategy [82]

Japan

Japan has been active in the development of international supply chains to ensure a cost-effective, secure supply of low-carbon energy, including hydrogen, as they seek to decarbonize the economy. Japan will likely be an importing market for Metro Vancouver's hydrogen export economy, and a potential competitor for hydrogen technologies.

Key Points

- Japan was one of the first countries to produce a Hydrogen Strategy in 2017. A large focus of Japan in developing the local hydrogen economy is reducing cost, increasing prevalence of FCEVs, and establishing fuel pumps. [84]
- Japan is a global leader in fuel cell technology, with ambitions to lead the export market in this area. Conversely, Japan is looking to import hydrogen to meet projected demand as energy resources and production capacity in the country are limited. [85]
- Japan's trading houses or, sōgō shōsha, are active in developing hydrogen business lines, both inside and outside Japan in technology development, hydrogen production, and building supply chains. The Hydrogen Energy Supply Chain is one such project to establish a supply of Australian-produced hydrogen to Japan via liquefied hydrogen carriers. [86]

Notable Policy

- Australia and Japan Cooperation Agreement on Hydrogen and Fuel Cells [74]
- Green Innovation Fund [87]
- Hydrogen Strategy [84]
- Memorandum of Cooperation (MoC) on Hydrogen between Japan and UAE [88]

South Korea

South Korea is looking to phase out nuclear power, and is thus exploring other low-carbon sources of energy like hydrogen. [89] Though hydrogen is of interest to the government for certain use cases, South Korea's population is averse to hydrogen given a previous explosion, which is a barrier to the sector's development. South Korea may still potentially be an importing market for hydrogen from Metro Vancouver.

Key Points

- Mobility and power generation are two pillars of South Korea's hydrogen economy. The Hydrogen Economy Roadmap focuses on targets for FCEVs, fuel stations, and hydrogen-fuelled power generation in the country. [90]
- The government of South Korea is planning to supply 27.9 million mt/year of clean hydrogen (both green and blue) for domestic use by the year 2050. [91] This will include domestic generation (18%), with the majority imported from international suppliers (82%). [91]
- An agreement among prominent corporations has been made to develop a supply chain of blue ammonia produced in the United Arab Emirates (UAE) to be imported into South Korea for applications in the industrial and power sectors. [92]

Notable Policy

- Hydrogen Economy Promotion and Hydrogen Safety Management Law [89]
- Hydrogen Economy Roadmap [90]
- Hydrogen Shipment Centre Project. [93]
- Korean New Deal [89]

Introduction: Why Hydrogen?

Hydrogen is gaining international attention as a low-carbon energy source as countries around the world look to reduce emissions and prevent the worst effects of climate change. A critical component of transitioning to a decarbonized economy is ensuring a resilient, renewable supply of energy.[1] Resiliency is achieved in part through developing diverse low-carbon energy sources. There is currently no one 'silver bullet' energy source that can realistically be used for all energy needs, therefore, the future energy composition of a particular region will likely come from a combination of complementary low-carbon energy sources, including hydrogen.

Electricity as a low-carbon energy source (where electricity grids are renewable) is currently not practical for all use cases. This is often due to the abundancy of electricity or the refuelling/recharging needs of a particular application. In these cases, low-carbon hydrogen can complement electrification as a source of energy. An example of this is trans-oceanic shipping: long distances, weight and space capacity limit the feasibility of a sufficient battery to support electrification, therefore hydrogen or renewable fuels are attracting interest.

It is impossible to predict the exact future composition of energy we use in a particular region. A lot of factors — both locally and globally — will influence the development of decarbonized energy systems, and consequently, the hydrogen economy.

Low-carbon hydrogen is made via pathways that produce little to no GHG emissions. These pathways are often referred to by colours. Some common pathways referenced in this report include:

- **Green hydrogen,** produced by splitting water into hydrogen and oxygen using clean, renewable electricity through electrolysis.
- **Blue hydrogen,** produced from fossil fuels like natural gas, paired with carbon capture, utilization, and storage (CCUS) to minimize CO_2 emissions.
- **Turquoise hydrogen,** produced from fossil fuels like natural gas through a process called pyrolysis, which produces solid carbon as a byproduct instead of CO_2. Depending on the source of heat, the process may or may not emit GHGs.
- **Grey hydrogen,** produced from fossil fuels without the use of CCUS, and is NOT a form of low-carbon hydrogen.

Why Hydrogen in Metro Vancouver?

To help reach the goal of being carbon neutral by 2050, government and industry stakeholders in Metro Vancouver are laying the framework for the development of a hydrogen economy. Currently, 72% of the overall energy sources used in the Metro Vancouver region come from fossil fuels.[1] These fossil fuels that are used in buildings, transportation, and industry are responsible for 90% of emissions in the region.[1]

In Metro Vancouver, transportation is the largest source of GHG emissions, with 35% coming from on-road transportation sources like heavy-duty vehicles (HDV) and light-duty vehicles (LDV).[94] 26% of emissions are attributed to building sources.[94] Industry, non-road engines, air, marine, rail, agriculture, and waste are also significant sources of GHGs (in descending order).[95] To address these emissions, multiple low-carbon energy sources, technologies, and innovations will be needed to meet regional climate goals. In a number of these situations, hydrogen is an attractive option.

Creating a hydrogen economy is a potentially advantageous opportunity for Metro Vancouver for a variety of reasons:

Renewable power: British Columbia (BC)'s hydroelectric dams are a consistent source of renewable power generation, which is advantageous for electrolytic hydrogen production.

Location: Metro Vancouver is strategically located on Canada's southwestern coast. It is also home to the largest port in Canada which facilitates major trade routes to Asia and the west coast of North and South America. If hydrogen was pursued as an export industry, producers in the Lower Mainland or other provinces may ship hydrogen through the Port of Vancouver to reach ports across the Pacific Ocean. With ports being an important facilitator for a variety of transportation modes (i.e., shipping, rail, trucking), Vancouver's location makes it a central, highly interconnected transport hub, which is also an important factor in the development of a successful local hydrogen economy.

Policy landscape: Local and provincial governments in BC have shown strong political support for hydrogen. The BC Hydrogen Strategy, CleanBC Roadmap, legislation such as the Low Carbon Fuel Standard, and the recent establishment of the BC Energy Regulator to include hydrogen and streamline regulatory oversight have positioned BC as a favourable region to develop a hydrogen economy. Additionally, the federal government's support of hydrogen, including recent efforts in the fall of 2022 to spur the development of clean energy nationwide contributes to a supportive policy landscape at all levels of government.

Hydrogen cluster: Vancouver is also considered a world-class hub of hydrogen technology. With large industry leaders like Ballard Power Systems, multiple start-ups with innovative technologies, hydrogen-focused academic research, investor knowledge, government support, and technological development, there is already an established hydrogen cluster in the region with promising growth potential.

BC's Hydrogen Economy

The province of BC is laying the groundwork for a future hydrogen economy. This involves developing local use cases — such as transportation fuel — and the creation of a potential export market. The BC Hydrogen Strategy acts as a guiding document for all hydrogen-related economic activities. Key points from the Strategy that the government is currently acting on include undertaking a review of regulatory structures to streamline investment and development, conducting planning and engagement with Indigenous and other stakeholder groups, reviewing the feasibility of production pathways and alignment with provincial net zero emissions goals, as well as evaluating supply and demand in potential hub regions, such as Metro Vancouver.

This section highlights hydrogen-focused policies and strategic plans, trends in local use and export market development, and notable research and development (R&D) in BC.

It should be noted that beyond the key policies, strategies, and trends discussed in this section, corporate-level strategies and emission reduction targets may also contribute to hydrogen demand in any given region and should be considered as a complementary driver.

Notable Policy

BC Carbon Tax: Implemented in 2008, the provincial carbon tax currently sits at $50/tonne CO^2e, with an expected increase to $170/tonne CO^2e by 2030. 4 The tax puts a price on carbon emissions from fossil fuel use, which is intended to incentivize investment in low-carbon alternatives.

BC Hydrogen Strategy: Government of BC's core strategy on how low-carbon hydrogen can contribute to decarbonization in the province and support economic growth. [2]
Clean Industry and Innovation Rate: BC Hydro offers discounted electricity rates to producers of renewable or low-carbon fuels, including electrolytic hydrogen. The rate provides a 20% discount on the standard industrial rate for five years, followed by a 13% and 7% discount for the next two years. [5]

CleanBC Industry Fund: Based on revenues from BC's carbon tax, this fund invests in emissions reduction projects concerning large industrial emitters. [6]

CleanBC Remote Community Energy Strategy (RCES): A provincial program involving capacity building in remote communities, funding, and resource support for clean energy generation projects to replace diesel use in remote communities by 80% by 2030. [7]

CleanBC Roadmap: An action-oriented plan from the province of BC that outlines pathways towards reaching a net zero economy. [3]

GHG Reduction Regulation: Allows utilities to reduce emissions by acquiring up to 15% renewable natural gasses. This regulation was amended in 2021 to allow natural gas utilities to produce or purchase hydrogen from various sources, including green hydrogen, to displace fossil fuels in the grid. [8]

GHG Reduction Standard (proposed): A standard based on commitments outlined in the CleanBC Plan that establishes an emissions cap for natural gas utilities for 2030. [3]

Innovative Clean Energy (ICE) Fund: A funding program designed to promote development of BC's clean energy sector and GHG reduction priorities. [9]

Low Carbon Fuel Standard (LCFS): This regulation sets a declining target to reduce the carbon intensity of transportation fuels used in BC. The 2022 reduction target sits at 11.3%, with the province committing to a 20% reduction target by 2030. 96 The government has introduced a proposed change to the LCFS to include aviation and marine fuels. [10]

Zero-Emission Vehicles (ZEV) Act: The ZEV Act mandates LDV manufacturers in the province to offer a percentage of sales/leases as ZEVs — battery electric vehicles (BEVs) or FCEVs — rising to 100% of new cars by 2040. There is a proposed amendment to achieve 100% of new cars by 2035. [11]

Hydrogen Sector Development Trends

Local Use Cases

Aviation: According to their 2022-2024 Strategic Plan, the Vancouver International Airport (YVR) has announced a goal of becoming net zero by 2030. [97] YVR's Carbon Reduction Roadmap notes the intention to develop low-carbon fuel sources and support the development of sustainable aviation fuel (SAF) supply chains to help meet emissions reduction targets. [98] Hydrogen is a key component in some production pathways for renewable fuels and SAFs.

Heating: Natural gas in BC is used extensively for residential heating and hot water. The provincial gas utility, FortisBC, guided by their goal to reduce customer emissions by 30% by 2030 (30BY30), has proposed a 10-year forecast for meeting the 15% renewable gas regulation by 2030, exploring hydrogen as an option from 2025. [99,100] It has been noted by municipalities such as Metro Vancouver that the limited availability of renewable gasses (such as renewable natural gas (RNG), or hydrogen) means it is best used in sectors where electrification is difficult (such as industrial processes requiring high temperatures or combustion), and electricity should be prioritized in sectors where commercially available technology already exists, such as buildings or LDVs. [1] The City of Vancouver has also positioned itself toward building electrification. A zoning amendment in January 2022 requires all new and replacement heating and hot water systems in residential buildings be zero emission. [101] This shortened timeline may result in a shift toward electrification, as a sufficient supply of hydrogen is not yet widely available and the required technologies are not yet implemented.

Remote communities: The BC government has set a target of reducing diesel generation of electricity in remote or Indigenous communities by 80% by 2030. Hydrogen is a potential opportunity being explored in collaboration with various communities. [2]

Road transportation: The BC government has committed to support the development of infrastructure to grow hydrogen as a transport fuel, which includes a long-term refuelling strategy for MDVs and HDVs. [3]

The trucking industry in BC is exploring low-carbon alternatives to diesel fuel, such as BEVs and FCEVs, with hydrogen-diesel co-combustion as a transition technology. According to a recent study, certain hard-to-decarbonize segments of road transportation, such as long-haul routes and about 50% of regional-haul routes are not currently economical to electrify [102], so they may be better suited to hydrogen technologies. In 2022, the BC Trucking Association (BCTA) formally asked for provincial legislation requiring all new sales of HDVs to be low-emission by 2060 - 2050 for MDVs, and has requested government support in transitioning fleets. [103]

BC is also a leading hydrogen technology hub in the transportation space, which is driving the sector's growth. Hydra Energy received funding from the BC Ministry of Energy, Mines and Low Carbon Innovation to build a hydrogen fuelling station in the northeast region of the province and retrofit a fleet of [65] HDVs with their co-combustion technology to use 40% hydrogen as fuel. [104] BC is also a key market for the roll out of fuel cell vehicles. The CleanBC Go Electric Hydrogen Fuelling Infrastructure Program is working with the automotive industry to develop a network of hydrogen fuelling stations in the province, which may support uptake of hydrogen-powered LDVs. [105]

Rail: The BC Hydrogen Strategy notes an intention to develop the use of hydrogen for rail applications in the province. [2] The freight railway system is designed to connect multimodal forms of transportation. The existing linkages from rail to ports and road transport in BC make a solid foundation for developing hydrogen hub infrastructure. Presently, BC's Southern Railway is partnering with Loop Energy and Hydrogen in Motion to convert a diesel locomotive to a hydrogen fuel cell powered system. [106] Canadian Pacific (CP) has also announced an intention to explore the use of hydrogen fuel cell locomotives.

Shipping and ports: Marine applications for hydrogen are also outlined as a priority use case for development in the BC Hydrogen Strategy. [2] The Northwest Ports Clean Air Strategy was developed by the Ports of Vancouver, Seattle, and Tacoma to align decarbonization efforts. The strategy notes that any use of hydrogen as an alternative fuel will require collaboration between the port authorities on infrastructure and protocols, which may impact how operations are decarbonized. [107] The Port of Vancouver's Electrification Roadmap also considers using hydrogen fuel cells for various applications as a potential contributor to decarbonizing operations. [108] Both BEVs and FCEVs are being considered for cargo-handling equipment and trucks, though battery charge longevity was noted as a key constraint. [107] Battery electric and hydrogen options are being considered for both harbour vessels and rail, but both are in early stages of development.[107]

The International Maritime Organization adopted an initial strategy on reduction of GHG emissions from ships in 2018, thus guiding the international shipping industry towards finding low-carbon fuel alternatives. [109] Ocean-going vessels are limited by space and require energy-dense fuels. As such, synthetic fuels, green methanol, green ammonia, and liquid hydrogen are being explored by the sector as fuel options. The Port of Vancouver has implemented mechanisms to incentivize ships that call to reduce emissions, such as leading the International Collaboration on Ship Emission Reductions (ICSER), administering the EcoAction Program, and exploring a green corridor initiative for cruise ships. [110–112]

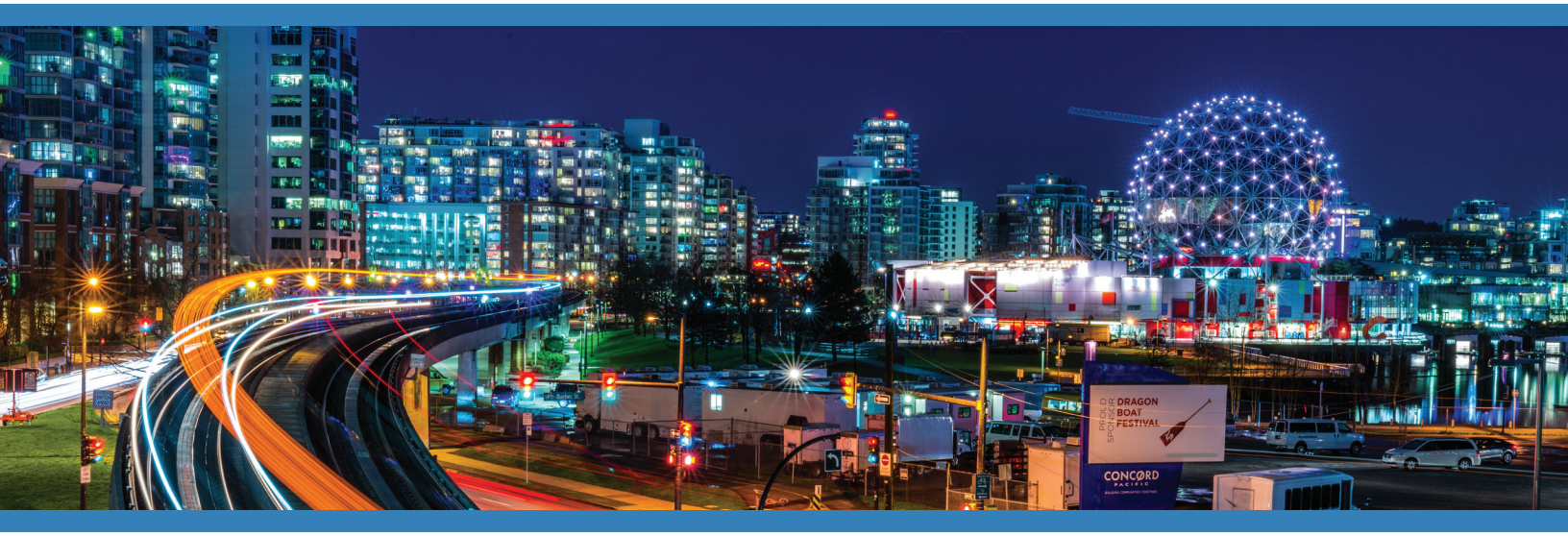
Export and Production

BC is laying the foundation to develop an export market for green, blue or turquoise hydrogen. The Strategy notes the intention to promote investment in BC hydrogen production and position the province as a supplier of both low-carbon hydrogen and hydrogen technology to international markets. [2]

BC has the feedstocks to produce green, blue, and turquoise hydrogen. Though renewable electricity is currently abundant in the province, BC Hydro has projected a diminishing electricity surplus by the early 2030s. They have developed an Electrification Plan, investing over $260 million to adapt to increased demand. [1,3] BC Hydro's Clean Industry and Innovation Rate provides lower electricity rates to producers of low-carbon fuels, including electrolytic hydrogen. [5]

Notable Innovation

Vancouver's hydrogen cluster equates to the region being a hot spot of research and development (R&D) in hydrogen technology. Academic research in Metro Vancouver at the University of British Columbia and Simon Fraser University has spurred several technology startups in the hydrogen space. Leading technology companies in the region include Ballard Power Systems, who have put over $1.5 billion in fuel cell R&D, HTEC, and startups like Ionomr Innovations and Hydra Energy. The BC government's Innovative Clean Energy (ICE) Fund and CleanBC Industry Fund have supported the development of the sector. Most recently, the CleanBC Industry Fund has invested in a pilot project in Port Moody, BC with Suncor, FortisBC, and Hazer Group Ltd to produce up to 2500 tonnes of hydrogen annually using a methane pyrolysis technology. [113]



Hydrogen Beyond Borders

There are plentiful opportunities for local use of hydrogen and a strong foundation for localized production in Metro Vancouver; however, the future hydrogen economy will not exist in a silo. As such, understanding what common interprovincial and international trade partners, or key regions focusing on hydrogen, are planning will help create a vision of where the sector can and may go.

The following sections discuss hydrogen-focused policies and strategic plans, trends in local use and export market development, and innovation of note in key regions pursuing a hydrogen economy that could have an impact on Metro Vancouver.

Canada

Globally, the energy demand from hydrogen is expected to be around 18% to 24% by 2050, comprising a $700 billion industry. [14] This is a significant opportunity for Canada — as one of the top 10 global producers of hydrogen — to develop an export market, as renewable energy-deficient nations look for options to decarbonize. [13,14] The presence of renewable energy resources, pre-established trade agreements, and existing, strategic infrastructure like deep water ports and pipelines provide Canada with an edge in this market. The Government of Canada has noted the potential for BC to become an export hub for Canadian hydrogen. [13]

Notable Policy

Hydrogen Strategy for Canada: The federal Strategy outlines a set of recommendations with specific actions for government, industry and various committees, focusing on building strategic partnerships, de-risking investments, supporting innovation, setting standards and regulations, increasing awareness, creating regional blueprints, and developing international markets. [13]

Canada–Germany Hydrogen Alliance: A Joint Declaration of Intent between Canada and Germany to develop supply chains between Germany and the Atlantic coast of Canada to export clean Canadian-produced hydrogen by 2025. [16]

Clean Electricity Standard: The Canadian electricity system has pledged a goal of net zero emissions by 2035. [17] At present, this is at a formative stage and the Government of Canada intends to pass necessary regulations to decarbonize the electricity supply system by 2035. [17] It is noted that BC's electricity is currently generated from 98% renewable energy sources. [114]

Clean Fuel Regulations (CFR): This requires fossil fuel suppliers to reduce the carbon intensity of liquid fuels and promotes adoption of clean fuels, processes and technology by providing incentives. [18]

Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles (iMHZEV) Program: An incentive program for businesses, organizations, provinces, territories, and municipalities to purchase zero-emission MDVs or HDVs. [19]

Regulatory Co-operation on Low Carbon Fuel (LCF) in Transport: Natural Resources Canada and the United States Department of Energy (US DOE) have published a work plan to, "foster greater cross-border natural gas vehicle deployment," which will involve streamlining codes and regulation of low-carbon fuels. [20]

Strategic Innovation Fund: Administered by Innovation, Science, and Economic Development Canada, this fund is intended to support large projects related to the, "knowledge-based economy," long-term industry competitiveness, and clean growth. [21]

Zero-Emission Car and Passenger Truck Sales: The federal government of Canada has set a target for all new sales of light-duty cars and trucks to be zero emission by 2035. [22]

Hydrogen Sector Development Trends

National Trends

The Government of Canada has, to date, focused extensively on developing hydrogen applications in transportation. The Fall Economic Statement pledged $150 million invested in charging and refuelling stations between 2020 and 2023. [14] The government further plans to engage with the US to increase availability of ZEVs for consumers in both markets. [14] The federal government also recently stipulated that ZEVs must account for 35% of medium- and heavy-duty truck sales by 2030. [15] Around $547.5 million has been budgeted for incentives for new truck purchases and $199.6 million to retrofit existing trucks. [15] The Canadian Trucking Association (CTA) has stated that they will work in collaboration with the Government of Canada to achieve the 2030 Emission Reduction Plan and the industry will support adoption of low emission medium- and heavy-duty commercial vehicles in Canada. [115]

There has been some interest from leading steel manufacturers across the country in exploring hydrogen as well. Hamilton, Ontario's ArcelorMittal Dofasco has stated that it plans to utilize hydrogen — eventually replacing natural gas — to power furnaces and decarbonize the smelting process. [116] ArcelorMittal's Contrecoeur, Quebec facility has also successfully piloted green hydrogen usage in the iron ore reduction process. [117]
The Strategy emphasizes that ports are ideal locations for hydrogen hubs and fuel cell equipment. The hub model presents opportunities to scale and improve cost effectiveness. [13] The Strategy notes that mines in interior parts of the country may provide an opportunity to replace reliance on diesel fuel with hydrogen for different mining equipment and extraction processes. [13]

Alberta

Alberta is currently the top producer of hydrogen in Canada. [23] The province has an estimated hydrogen production capacity of about 45 million tonnes per year, which is sufficient to cater to domestic use and a significant portion of international demand. [26] Alberta is looking to utilize the abundant natural gas found in the province, coupled with CCUS to scale up production and export blue hydrogen starting in 2030. [23,24] Alberta is likely to become a partner in the hydrogen economy to BC and Metro Vancouver, with the province potentially exporting through the Port of Vancouver to Asian markets.

Notable Policy

Alberta Hydrogen Roadmap: This key document sets out a path for Alberta to build its hydrogen ecosystem, export markets, and guide future policy development. [26]

Alberta Petrochemicals Incentive Program (APIP): A granting program intended to foster investment into petrochemical industry development, which includes hydrogen. [27]

Alberta Natural Gas Vision and Strategy: The province's plan to develop the natural gas sector to become globally competitive while focusing on responsible sourcing. Hydrogen is noted as a related product. [28]

Emissions Reduction Alberta: Invests in clean technology solutions that align with provincial climate and economic goals. [29]

Hydrogen Centre of Excellence: Led by Alberta Innovates, the Centre distributes funding, provides testing facilities, and supports the advancement of hydrogen technologies and the development of the hydrogen economy more broadly in the province. [30]

Technology Innovation and Emissions Reduction (TIER) Regulation: Functioning as the provincial industrial emissions pricing and trading system since 2020, TIER regulates emissions from large industrial sources to incentivize reduction via credits and offsets. [31]

Hydrogen Sector Development Trends

Local Use Cases

Alberta has identified five market areas to propel the growth of hydrogen. The five target areas include industrial processes, heating, power generation, transport, and export markets. [25] Alberta's hydrogen ecosystem is driven by the creation of hydrogen hubs paired with CCUS project development. In 2021, Edmonton announced the development of the first hydrogen hub in Canada. [26]

Aviation: The Edmonton International Airport has committed to achieving net neutrality by 2040, with hydrogen playing a key role. Air Canada and Edmonton International Airport will explore hydrogen fuel cell technology to decrease emissions. [26]

Heating: ATCO will blend hydrogen into its natural gas network for a demonstration project in Fort Saskatchewan. [118] The gas blend will then be supplied to homes and businesses starting in fall 2022 and will benefit 2,000 customers. 119 The supplied hydrogen will be produced through electrolysis. [119]

Industrial use: Dow is retrofitting and expanding its Fort Saskatchewan facility near Edmonton to decarbonize the chemical manufacturing process. [120] The hydrogen derived from the process of purifying fossil fuels will be used to fuel its petrochemical production.[120]

Transportation: The Alberta Zero Emissions Truck Electrification Collaboration (AZETEC) is exploring the long-range potential of fuel cell electric trucks. The project will test a range distance of over 700 km between Edmonton and Calgary. [121] Participating companies include Ballard Power Systems, Proton Motor, Dana, and Suncor Energy. [121]

Hydrogen powered buses, rail freight, and passenger trains are also being trialed in the province. [26]

Export and Production

Alberta is exploring both land and sea routes to export hydrogen. The governments of Canada, Alberta, and BC are working to develop port access in a cost-effective manner as sea routes to Asia from Alberta will likely pass through the Ports of Vancouver, Prince Rupert, or United States (US)-based ports. The Roadmap notes the potential to export hydrogen via pipeline to California and other American markets in the future, as well as other energy-importing nations such as Japan via ammonia, methanol, or liquid organic compounds to improve cost-effectiveness. [26]

Development of supply chain infrastructure to transport hydrogen from Alberta to the coast is integral to the development of overseas exports. Therefore, various carriers and ships are being explored to meet demand. [26] Japan-based ITOCHU and the Canadian subsidiary of Petronas have mutually agreed to set up a facility in Alberta to produce blue ammonia from natural gas coupled with CCUS and explore the supply chain considerations for export to markets across Asia. [26] Mitsubishi and Shell Canada have also partnered to explore blue hydrogen production in the province for export via ammonia as a carrier to Asia. [122] Existing CCUS projects and infrastructure in Alberta such as Shell's Quest Carbon Capture and Storage are advantageous for blue hydrogen production in the province.

Notable Innovation

A Calgary-based energy company and research team at the University of Alberta are working together on a technology to extract hydrogen from natural gas with reduced energy requirements and produce high-demand carbon byproducts. [123] The later stage of the project will use the extracted hydrogen to fuel the reactor. [123]

Saskatchewan

Saskatchewan is opening opportunities for industries engaged in the manufacturing of hydrogen. [32] This may lead to the development of a hydrogen supply and demand chain at a commercial scale in the province, aided by existing CCUS infrastructure. [32] With ambitions of becoming a hydrogen-producing region, Saskatchewan could become a partner region to BC and Metro Vancouver if they intend to begin export activities to target markets in Asia.

Notable Policy

The province of Saskatchewan has not yet released any specific hydrogen-based policy or regulation. The government has, however, released a number of general policies for, "responsible resource development and technological innovation," including tax credits and incentive programs. [124]

Saskatchewan Petroleum Innovation Incentive (SPII): This program awards transferable tax credits to oil and gas companies at a rate of 25% of eligible project costs. It is applicable to qualified innovative commercialized or pilot scale projects. [34]

Hydrogen Sector Development Trends

Local Use Cases

Mining: The International Minerals Innovation Institute (IMII) is exploring new technologies to reduce emissions in potash and uranium mining operations in Saskatchewan over the coming decades, and hydrogen is noted for further consideration. Hydrogen is of interest to the mining sector as a low-carbon fuel for transportation and mining equipment, power, renewable energy storage, and as a feedstock for certain processes. [125]

Export and Production

Saskatchewan has commissioned a study to understand the development of a hydrogen hub in the Regina-Moose Jaw region. [33] The study is funded by the provincial Ministry of Energy & Resources, Whitecap Resources, and Federated Co-operatives Limited (FCL), and is being conducted by the Transition Accelerator and the Saskatchewan Research Council (SRC). [33] It is intended to provide investors with commercial opportunities to produce hydrogen coupled with CCUS, attract more private firms across the region, and create a blue hydrogen hub and ecosystem in the province. [33,126]

Notable Innovation

The Saskatchewan Petroleum Innovation Incentive (SPII) is intended to support innovation in the oil and gas sector, and has been used to support the development of novel low-carbon hydrogen production technologies. [127]

United States

The US is a global leader in developing a hydrogen economy, with significant public and private funding, existing or planned infrastructure, and programs to spur the development of regional hydrogen hubs across the country. [35] The hydrogen sector's development is active at the state level, with California leading with precedent-setting policy and regulatory mechanisms. The Biden Administration's ambitious goals of net zero emissions by 2050 and a clean electricity grid by 2035 suggest all decarbonization strategies, including hydrogen, will have a critical place in decarbonization across the country. [128] The US could potentially become both a competitive producer to Metro Vancouver or an importing market depending on the level of demand in western states.

Notable Policy

Alternative Fuel Corridor (AFC) Grants: The Department of Transport (DOT) will establish hydrogen fuel stations and electric charging station infrastructure along the department's Federal Highway Administration. [40]

Bipartisan Infrastructure Deal: $66 billion USD ($86 billion CAD) will be invested in public transit infrastructure and, in doing so, will replace fossil fuelled transit vehicles such as buses and rail with ZEVs. [41] Low-emission and zero-emission buses will be provided to schools across the US, as will funding to replace public transit buses. [41] The deal will also contribute $17 billion and $5 billion USD ($22 billion and $6.5 billion CAD) to the modernization of port and airport infrastructure, and $65 billion USD ($85 billion CAD) towards clean energy transmission and electric grids. [41]

Hydrogen Fueling Infrastructure Development Program (H2USA): This public-private collaboration program incentivises refuelling infrastructure before the demand for hydrogen rises. [42]

Hydrogen Demonstration Project Grants: The DOE's Energy Earthshots initiative to bring down the cost of clean hydrogen to $1 USD/kg ($1.3 CAD/kg) in one decade (reduce by 80%). [43]

Inflation Reduction Act: Signed in August 2022, the Act contains strong incentives for clean hydrogen development, including production tax credits and cost-reduction measures. [44] The initial indications are that this act will drive significant development of hydrogen infrastructure, and incentivize other countries including Canada to implement similar measures.

Low- or Zero-Emission Ferry Program: Requires the DOT to invest in new low-emission or electric ferries and retrofit existing ferries to produce low emissions. [45]

US DOE Hydrogen Strategy: The Strategy, released in July 2020, focuses on R&D efforts and roll out of hydrogen-based technologies. It is of note that the Strategy discusses fossil fuel as the primary feedstock to produce hydrogen. [36] Recent policy developments indicate a change in direction.

Hydrogen Sector Development Trends

National Trends

The DOE has established the clean hydrogen initiative stipulated under the Bipartisan Infrastructure Law with total funding of $9.5 billion USD. [37] A key part of this is the Regional Clean Hydrogen Hub initiative, which is intended to connect hydrogen producers to consumers via common infrastructure and close proximity of supply and consumption. Production and export market development discussions are also occurring at the state level.

Also under the Bipartisan Infrastructure Law, the Clean Hydrogen Electrolysis Program helps to improve efficiency and cost effectiveness of electrolyzer-related technology and deployment, and the Clean Hydrogen Manufacturing Recycling initiative provides financial aid to enhance any process involved with hydrogen technology, manufacture, and storage. [129,130] The DOE has conducted Request for Information (RFI) processes to collect stakeholder feedback on program implementation and design. [37]

A grant program entitled, the Hydrogen for Ports Act of 2021, has been issued by the US Secretary of Energy to support the implementation of hydrogen-powered equipment for use in ports. [131] The program will also enable a study on the safety and feasibility of hydrogen-based fuels in shipping by the Secretary of Transportation and Secretary of Homeland Security. [131] The American Association of Port Authorities (AAPA) looks ahead to utilize hydrogen for port related activities and to work with the government. [132] The AAPA is working to test its application with small vessels before venturing into hydrogen as a source of marine fuel. [132]

Notable Innovation

The DOE has committed to providing $52.5 million USD ($69 million CAD) to fund R&D in hydrogen technology via the Hydrogen Shot initiative of the Energy Earthshots program. [39] This will contribute to 31 projects to significantly reduce the cost of clean hydrogen production. [39] The program is projecting a five-fold increase in the demand for clean hydrogen if the initiative is a success. [133]

Washington

Washington is planning its future role as a hydrogen hub for the Pacific Northwest along with the state of Oregon. The region's multiple ports, renewable energy generation potential, and supportive governments have made the region a national leader in moving towards a hydrogen economy. The Ports of Seattle and Tacoma are contributors to the Northwest Ports Clean Air Strategy along with the Port of Vancouver, aligning decarbonization in the marine sector between the two regions. [107] Organizations like the Washington Green Hydrogen Alliance are helping to drive the state's decarbonization efforts via green hydrogen. Washington may become a competitive producer to Metro Vancouver and strategic transportation corridor for export to California if there is sufficient demand and the Pacific Northwest Hub comes to fruition.

Notable Policy

2021 State Energy Strategy: Details the blueprint for decarbonization in the state, and contains a supplementary study on projected hydrogen uses in the state for various scenarios. [46]

Clean Energy Fund: Supports development of clean energy technology development, demonstration, and deployment. [48]

Clean Energy Transformation Act: Mandates a GHG-free electricity grid by 2045. [49]

Clean Fuels Program: Washington's low carbon fuel standard to reduce the carbon intensity of transportation fuels by 20% below 2017 levels by 2035. [50]

Climate Commitment Act: A 'cap-and-invest' program that limits GHG emissions from large emitters and heavy industry, and invests credit proceeds in decarbonization and adaptation initiatives. [49]

Green Transportation Grant Program: From the Washington State Department of Transportation, a grant for carbon intensity reduction of the transportation system, including hydrogen vehicles and fuelling infrastructure. Mandated through the Green Transportation Act, which requires state transportation systems to reduce GHG emissions.[50]

HB 1988: Effective in July 2022, this bill is intended to support development of renewable hydrogen production and refuelling infrastructure in the state by allowing tax deferral on investment. [51]

Medium- and Heavy-Duty ZEV Deployment Support: A memorandum of understanding (MOU) among 17 states (including California, Colorado, Connecticut, District of Columbia, Hawaii, Maine, Maryland, Massachusetts, New Jersey, New York, North Carolina, Oregon, Pennsylvania, Rhode Island, Vermont, Virginia, and Washington) to create a ZEV Task Force and accelerate deployment of MDVs and HDVs to 100% by 2050. [52]

Medium- and Heavy-Duty ZEV Requirement: Based on California's Advanced Clean Trucks Requirements, this mandates car manufacturers to sell zero-emission trucks as a percentage of annual sales on an escalating basis from 2025. [52]

SB 5910: Effective in June 2022, this bill is intended to utilize funding from the federal Infrastructure Investment and Jobs Act to help grow Washington's renewable/green hydrogen sector. It authorizes local governments and utilities to develop and operate hydrogen production and transportation infrastructure, permits public financial support for a federal hydrogen hub application, and includes green hydrogen in sales-and-use and leasehold-excise tax exemptions. [53]

SB 5974: From July 2022, mandates that all passenger vehicles sold in Washington from 2030 must be BEVs or FCEVs. Also requires the state to consider hydrogen fuel cell technology as an application for the ferry system. [51]

Hydrogen Sector Development Trends

Local Use Cases

Road transportation: Transportation is highlighted as the most important sector to decarbonize in Washington, and the government has stated an openness to exploring all low-carbon transportation fuels and technologies, including hydrogen and FCEVs. A project from Fortescue Future Industries is planning to develop and market the green hydrogen it produces as a transportation fuel. Companies supporting the project announcement include Toyota, Kenworth Truck Company, Twin Transit, as well as several government departments, who noted the potential for hydrogen use in transportation applications such as long-haul trucking, shipping, and long-distance aviation. [134] At this time, there are no existing refuelling stations in the state, but Twin Transit and the Port of Chehalis have received funding to build three hydrogen refuelling stations and four fuel cell buses in the Chehalis region. [134]

Shipping and ports: Washington State Ferries (WSF) is mandated by Executive Order 18-01 to meet zero-emission operations by 2040. They are moving towards a hybrid diesel-electric ferry system, but a study by First Mode showed the feasibility of a transition to FCEVs, which would produce one-quarter of the emissions as the hybrid system. [135] The 2022 bill, SB 5974, now requires WSF to explore hydrogen technologies as a method of decarbonization. [135] As previously mentioned, the Washington-based ports of Seattle and Tacoma are contributors to the Northwest Ports Clean Air Strategy with the Port of Vancouver. As noted, any use of hydrogen as an alternative fuel will warrant collaboration between the port authorities to align infrastructure and protocols. [107] The Port of Seattle is currently undertaking a study to determine the feasibility of deploying hydrogen technologies. [136] The Northwest Seaport Alliance (Authority for Ports of Seattle and Tacoma) is also mandated to coordinate a zero-emission truck stakeholder group and demonstration. [50]

Others: The State Energy Strategy notes an interest in green hydrogen as a supplemental source of energy when electricity demand exceeds supply, as well as for a feedstock in synthetic fuel production.

Export and Production

The Pacific Northwest region (Washington and Oregon) is bidding for the federal DOE's Hydrogen Hubs initiative to receive funding under the Bipartisan Infrastructure Law. [35] Washington intends to become a "Hydrogen Valley," with major projects in the works forming the basis of the sector's development. The Douglas County Public Utility District is building a green hydrogen production plant north of Wenatchee, set to be complete in 2023, that will use surplus hydropower generated from high flows in the Columbia River as a renewable energy source. In Centralia, Australia-based Fortescue Future Industries intends to build a green hydrogen production facility.

The state government has also indicated the potential to explore exporting to other states and countries. [47]

Notable Innovation

The Washington State Department of Commerce manages the Clean Energy Fund grants, which support hydrogen research, development, and deployment (RD&D) in the state. Of the 10 projects selected in 2022, two focused on hydrogen. Modern Electron will demonstrate a pyrolysis technology that uses methane in biogas as a feedstock, and OCOchem will develop green portable electricity generators to produce liquid hydrogen for use at the Port of Tacoma. [137]

Academia in Washington is also actively involved in hydrogen R&D. Researchers at Washington State University (WSU) produced pure compressed hydrogen from ethanol, water, and electricity, which could be a valid solution to the barriers of transporting hydrogen gas if hydrogen could be produced on-site at fuelling stations. [138] WSU's Joint Centre for Deployment and Research in Earth Abundant Materials (JCDREAM) is also leading a Consortium for Hydrogen and Renewable Generated E-Fuels to explore the use of hydrogen in specific applications including heavy-duty transport, aviation, and shipping. [139]

Oregon

Oregon and Washington are developing the local hydrogen economy as a hub region. Green hydrogen projects are more actively being pursued in the region, with advocacy from organizations like the Renewable Hydrogen Alliance in Portland. Oregon's location directly north of California on the I-5 also makes it a strategic transportation corridor. Transportation fuels and natural gas use in buildings are attributed to be approximately 75% of emissions in Oregon. These two areas are thus a large focus of decarbonization and are spurring both electrification and hydrogen use in the state. [140] Oregon may become a competitive producer to Metro Vancouver and strategic transportation corridor for export to California if there is sufficient demand and the Pacific Northwest Hub comes to fruition.

Notable Policy

Clean Fuels Program: Mandates producers and importers of transportation fuels to report the carbon intensity of their fuels in-state and meet a gradual reduction of 10% below 2015 levels by 2025. A credit system also applies under this program. Producers of natural gas, propane, hydrogen, and electricity can voluntarily participate. [58]

House Bill 3055: An omnibus bill containing provisions to allow natural gas utilities to recover investments related to hydrogen-fueled vehicles. [59]

Medium- and Heavy-Duty ZEV Deployment Support: A memorandum of understanding (MOU) among 17 states (including California, Colorado, Connecticut, District of Columbia, Hawaii, Maine, Maryland, Massachusetts, New Jersey, New York, North Carolina, Oregon, Pennsylvania, Rhode Island, Vermont, Virginia, and Washington) to create a ZEV Task Force and accelerate deployment of MDVs and HDVs to 100% by 2050. [52]

Medium- and Heavy-Duty ZEV Requirement: Based on California's Advanced Clean Trucks Requirements, this mandates car manufacturers to sell zero-emission trucks as a percentage of annual sales on an escalating basis from 2025. [52]

Renewable Hydrogen Study (pending): As a result of Senate Bill 333, this planned study will explore supply and demand potential in Oregon and is expected in late 2022. [60]

The Heavy-duty Low-NOx Rule: Mandates a 75% reduction in nitrogen oxide emissions in new HDVs starting in 2024, and a 90% reduction beginning in 2027. [59]

Hydrogen Sector Development Trends

Local Use Cases

Road transportation: In 2022, Oregon's Department of Transportation produced the Hydrogen Pathway Study Transportation Electrification Infrastructure Needs Analysis (TEINA) which explores the potential for hydrogen to complement battery technology in the transportation sector specifically. The study notes a, "supportive policy landscape," for hydrogen in-state, including a growing interest in hydrogen and FCEVs from the transportation sector, particularly in hard-to-decarbonize areas such as continuously operating vehicles, long bus routes, and long-haul trucking. The TEINA study assumes targets of 5% of LDVs, 10% of transit buses, 10% of MDVs, and 25% of HDVs being FCEVs by 2035 in the state. [59]

Though there are no current existing hydrogen retail fuelling stations, or commitments to deploy FCEVs from car manufacturers, there are ongoing projects that indicate an interest from the transportation sector. Portland-based Daimler Trucks North America received $26 million from the DOE to develop and demonstrate two Class 8 hydrogen fuel cell trucks via the SuperTruck 3 program. [59] Portland TriMet, the regional transit operators, have completed a feasibility study for hydrogen fuel cell buses. [59] With a commitment to 100% zero emissions from their fleet by 2040, they are actively exploring and purchasing BEVs, but are considering hydrogen as a complementary technology. [141]

Heating: The Eugene Water and Electric Board has entered into an MOU with NW Natural and the Bonneville Environmental Foundation to study the development of a 2-10 MW green hydrogen production plant. The hydrogen is intended to be blended into existing natural gas lines for building heating and for transportation applications. [142]

Export and Production

Oregon is studying the potential for developing offshore wind power generation through HB 3375. [143] Coos Bay and Brookings in southern Oregon are the two areas of interest, with high potential for low-cost power generation estimated at $53 USD/MWh ($69 CAD/MWh). [56] The HB 3375 study estimates 3 GW of potential power generation, with 1 GW used in-state, in part for green hydrogen generation, and 2 GW shipped via the I-5 corridor to California. [57]

Obsidian Renewables is planning to lead the development of a hydrogen hub tailored around green hydrogen production from wind and solar energy generated at their Oregon facility. [54] The Pacific Northwest Hydrogen Hub is a joint proposal for both Oregon and Washington, and will supply hydrogen to renewable ammonia fertilizer plants through newly developed pipelines. [55]

Notable Innovation

In late 2021, Oregon State University announced promising research into advanced catalysts for electrolytic hydrogen production. The catalysts improve the efficiency of electrolysis, which has potential implications for lowering the cost of green hydrogen production. [144]

California

The state of California is a North American leader in developing a hydrogen ecosystem. Beginning in April 2004 with Executive Order S-7-04 to create a 'Hydrogen Highway' in the state, California has since led North America in the creation and implementation of policy to drive the sector's development. [145] Mobility and transportation is the current focus of hydrogen sector development in the state. With ample potential to generate low-cost renewable energy, California is also pursuing a leadership position as a green hydrogen producer. California will likely be a competitive producer to Metro Vancouver's hydrogen export economy, but could potentially be an importer depending on the level of demand in-state.

Notable Policy

Executive Order N-79-20: A 2021 call to ban sales of new internal combustion passenger vehicles by 2035, and scale up prevalence of ZEVs. [63]

Green Hydrogen Roadmap and Strategic Plan: The California Energy Commission (CEC) plans to invest over $40 million USD ($52 million CAD) in hydrogen research and strategies. This key plan is currently in development. [61]

Hydrogen Fueling Station Evaluation: Requires the California Air Resources Board (CARB) to track and share the expected number of hydrogen vehicles sold or leased in the coming years and determine the need for hydrogen fuelling stations. The California Energy Commission (CEC) will fund up to $20 million USD ($26 million CAD) annually towards building the recommended number of stations. [64]

Integrated Energy Policy Report (IEPR): This annual report from the CEC provides policy recommendations and assesses major trends and issues related to energy in California. The 2020 report focusing on transportation and recommended continued investments in hydrogen infrastructure and FCEV development, particularly for MDVs and HDVs. [65]

Light-Duty ZEV Requirement: Mandates all new sales of LDVs in California to be ZEVs by 2035. [64]

Low Carbon Fuel Standard (LCFS): 2011 regulation mandating a gradual reduction of the carbon intensity of transportation fuels in the state to 2030. A credit program also exists under the LCFS. The CARB is working with Oregon, Washington, and British Columbia to build an integrated market and align policies. [67]

LCFS ZEV Infrastructure Crediting: As an amendment to the LCFS, the ZEV Infrastructure Crediting program includes support for hydrogen refuelling infrastructure, intended to de-risk investment in hydrogen infrastructure before sufficient demand. [66]

Medium- and Heavy-Duty ZEV Deployment Support: A memorandum of understanding (MOU) among 17 states (including California, Colorado, Connecticut, District of Columbia, Hawaii, Maine, Maryland, Massachusetts, New Jersey, New York, North Carolina, Oregon, Pennsylvania, Rhode Island, Vermont, Virginia, and Washington) to create a ZEV Task Force and accelerate deployment of MDVs and HDVs to 100% by 2050. [64]

Medium- and Heavy-Duty ZEV Requirement: Also known as the Advanced Clean Truck Program, this requires all new sales of MDVs and HDVs in California to be ZEVs by 2045. Additionally, all manufacturers must sell an increasing percentage of annual sales as ZEVs from 2024. [64]

Renewables Portfolio Standard (RPS) Program: Requires an escalating percentage of electricity retail sales to be provided as renewable energy. The last amendment in 2018 increases the requirement to 60% by 2030 and 100% carbon-free by 2045. [68]

SB 1075 (pending): Proposes more production and use of clean hydrogen and a role for green hydrogen, including funding and a mandate for development of a roadmap. [69]

SB 1329 (pending): Proposes further support for a hydrogen fuelling network. [70]

Zero-Emission Transit Bus Requirement: Mandates public transit agencies in California to transition to zero-emission buses by 2040. [64]

Hydrogen Sector Development Trends

Local Use Cases

Aviation: In April 2022, ZeroAvia, a hydrogen aviation company, announced a partnership and MOU with ZEV Station, a hydrogen fueling company, to develop an airport-based green hydrogen refuelling system along with pilot demonstrations of hydrogen-electric aircrafts in California airports. The intention is to develop hydrogen hubs focused around airports. [146] Also in April 2022, Air Products announced the development of a commercial SAF production operation in partnership with World Energy. Part of the project includes a new hydrogen plant and an extension of Air Products' hydrogen pipeline network in Southern California, with an intention to transition to green hydrogen in the future. [147]

Shipping and ports: The San Pedro Bay Ports (Ports of Long Beach and Los Angeles) Clean Air Action Plan outlines strategies to reduce emissions in shipping and port operations, including hydrogen applications as a potential option to get there. [148] The "Shore to Store" project is a long-term collaboration to pilot and scale zero-emission technology in the shipping industry. The Port of Los Angeles is partnering with Kenworth Truck Company, Toyota Motors North America, and Shell USA for a pilot and demonstration of 10 hydrogen fuel cell trucks along with two fuelling stations to begin a hydrogen infrastructure network in Southern California. [149]

Road transportation: California's transportation sector (including road, marine, and aviation) is responsible for over half of statewide GHG emissions. [150] Hydrogen is expected to play a large role in the road transportation sector — especially in public transit and long-haul trucking. Currently, 47 of 48 hydrogen fuelling stations in the US are in California, and companies alongside the public sector are investing heavily in developing hydrogen refuelling infrastructure to support adoption of FCEVs. [150,151] California-based Chevron announced a total of $2.5 billion USD ($3.3 billion CAD) invested in developing their low-carbon hydrogen business over the next decade. [152]

The Advanced Clean Trucks Regulation (Medium- and Heavy-Duty ZEV Requirement) will mandate car manufacturers to sell an escalating number of zero-emission trucks. For applications that cannot be electrified, this indicates a future for hydrogen in California's trucking industry. Hyzon Motors, a hydrogen fuel cell truck manufacturer, was recently certified by the CARB as the first fuel cell MDV/HDV able to sell in California. [153]

Export and Production

California has indicated a focus on green hydrogen production from renewable power.[54] Despite California's potential to generate cheap solar and wind energy, the proximity of renewable energy generation sites to the end-user, as well as the current cost of electrolysis are areas of concern in developing the sector. California is also projecting demand to exceed production levels in-state, and would therefore also look to import options depending on cost competitiveness.

In May of 2022, California announced an intention to create a renewable hydrogen hub through the federal Bipartisan Infrastructure Law's hubs initiative. [62]

Notable Innovation

From 2008, the CEC has poured $242 million USD ($317 million CAD) into hydrogen RD&D. [61] In June 2022, SoCalGas received a grant from the CEC to develop an innovative blue hydrogen production pathway via biogas without combustion, at a low estimated cost, and with carbon capture and utilization. [154] SoCalGas has also partnered with GKN Hydrogen and the federal DOE for R&D into a hydrogen storage project without the need for compression via the HY2MEGA system in Colorado. [155]

Academic research in California is also focusing on hydrogen, with world-leading universities in the state like the California Institute of Technology (Caltech). Caltech's Hydrogen Research Group, under the DOE's HydroGEN project, is working on advanced electrolysis and water-splitting technologies. [156]

Australia

With abundant wind and solar energy potential and significant fossil fuel resources, Australia is looking to produce both green and blue hydrogen for the creation of a strong export market. To encourage local use, Australia is focused on bringing down costs associated with hydrogen to a reasonable range to be competitive with all fuels in a given sector. For example, hydrogen can easily replace high-cost diesel consumed by trucks in remote, off-grid mining and power supply sectors.

Australia also aims to increase public acceptance of hydrogen by publicizing successful projects to demonstrate safety through trusted, unbiased institutions such as universities and organizations like CSIRO (Commonwealth Scientific and Industrial Research Organization). [71] Australia will likely be a competitive producer to Metro Vancouver's hydrogen exports. With abundant resources and geographic proximity and longstanding relationships with energy-importing Asian markets, Australia is likely to be a global export market leader.

Notable Policy

Australia and Japan Cooperation Agreement on Hydrogen and Fuel Cells: Australia and Japan have a mutual agreement to develop an international hydrogen and fuel cell supply chain. [74]

Bilateral Initiative: The Australian Renewable Energy Agency (ARENA) and the German Federal Ministry of Education and Research will invest $50 million AUD and €50 million EUR ($45 million and $66 million CAD) in HyGATE, a hydrogen innovation and technology incubator. [75]

Clean Energy Finance Corporation (CEFC): Provides financing for projects in, "renewable energy, low emission technology, and energy efficiency," of approximately $9 billion AUD ($8 billion CAD) over the course of five years from 2012. [76]

Clean Hydrogen & Carbon Investment: The Government of Australia has committed to investing $539.2 million AUD ($484.5 million CAD) in clean energy and CCUS technology as a part of the 2021-22 Budget. [77]

Clean Hydrogen Industrial Hub Program: Under this program, $464 million AUD ($416.3 million CAD) is being sanctioned to establish clean hydrogen hubs around the country. [78]

Emission Reduction Fund: A voluntary initiative wherein companies and individuals can receive Australian Carbon Credit Units (ACCU) for reducing or storing carbon emissions in the form of CCUS. [79] The earned ACCUs can be purchased by the government or by anyone in the market. [79]

Hydrogen in Mining: The Government of Australia is investing up to $579,786 AUD ($521,000 CAD) in a research study to understand the efficacy of replacing natural gas with renewable hydrogen in processing alumina. [80]

Low Emission Technology Statement (LETS): In 2020, the Low Emission Technology Statement (LETS) set a target of reducing the cost of hydrogen to less than $2 AUD ($1.80 CAD) per kilogram. [81]

National Hydrogen Strategy: The Strategy emphasizes coordination at all levels of government, creation of supply and demand chains, good governance and regulatory environments, collaboration with international counterparts, developing a competent workforce, increasing public awareness, and R&D. [71]

Hydrogen Sector Development Trends

Local Use Cases

Australia's strategy is based on the expectation that hydrogen is going to be a part of the larger decarbonization system alongside other renewables, as no one source can fulfill energy demands. They are exploring utilization of hydrogen in sectors such as iron, steel, and aluminum manufacturing that are challenging to decarbonize. Energy companies are focusing largely on production of hydrogen for both domestic and international use.

Export and Production

Australia is heavily focusing on the development of a hydrogen production economy, and multiple projects are in the works. The Australian Gas Infrastructure Group (AGIG) has set up the Hydrogen Park SA (HyP SA) demonstration plant to produce green hydrogen for residential and commercial use through blending with natural gas. [71] ATCO Australia's Clean Energy Innovation Hub is also producing green hydrogen for blending with the established gas network. [118] CS Energy is constructing a hydrogen demonstration production plant in Queensland, partially funded by the Queensland Renewable Energy and Hydrogen Jobs Fund to produce 50 tonnes of green hydrogen per year for use in the mobility and power generation sector. [157] Stanwell Central Queensland Hydrogen Project is studying the technical and commercial feasibility of a project to produce 800 tonnes per day of renewable hydrogen to be exported to Japan. [72]

Australia has prioritized the creation of hydrogen hubs close to ports to increase cost effectiveness related to scale and to cater to both domestic and international demand. [71] Significant funding has been allocated to the creation of regional export hubs under the Clean Hydrogen Industrial Hub Program and the 2020-21 Budget. [78] The Australian Renewable Energy Agency (ARENA) has also set out funding exclusively for hydrogen ecosystem development. [78]

Australia is looking to export hydrogen to countries with established relationships in the energy space such as Japan and Germany. Australia's relationship with North American countries is defined more by collaboration given the presence of similar resources. In preparation for developing the export market, Australia has established the Hydrogen Technologies Technical Committee to harmonize domestic standards with international hydrogen standards associated with trade. [71] Australia plans to ramp up supply of hydrogen in the latter half of the decade once the direction of the global market and investment trends are clear. They are also looking to collaborate with the US, UK, Germany, Japan, Singapore, and South Korea for low-emission technology partnerships. [78]

Notable Innovation

Australia has invested in hydrogen related R&D for the last 50 years. Over the years, capability has been developed in fuel cell and electrolyzer technology. In the last five years, research has focused on production cost reduction, scaling exports and global value chains, and the logistics of hydrogen carriers such as ammonia. Universities are carrying out research on solid state storage and systems integration. Australia is further looking to explore sector coupling to establish links between areas such as heavy industry, agriculture, and waste.. An MOU was entered between the Canadian Hydrogen and Fuel Cell Association (CHFCA) and the Australian Hydrogen Council (AHC) to plan and deploy zero-emission hydrogen and fuel cell technology projects as well as mining applications. [13]

Chile

For what is currently a net energy-importing country, Chile is facing a reversal of fortune.[158] With abundant potential to generate wind and solar energy, they are looking to pursue highly cost-competitive green hydrogen production as an export commodity. Chile is home to the most powerful solar radiation on Earth, as well as strong on- and off-shore wind generation potential. [82] Chile will face a few challenges, including maintaining competitiveness with the cost and logistics of transporting exported hydrogen, and the federal government, which has had a politically turbulent past few years. [158] Chile will potentially be a competitive producer to Metro Vancouver for western US export markets, however, geographic distance to Asia may be an impediment for them to access these markets.

Notable Policy

Chile-Port of Rotterdam Memorandum of Understanding (MOU): 2021 MOU between Chile and the Port of Rotterdam to develop a green hydrogen supply chain linking the country to European importers. [83]

National Green Hydrogen Strategy: A key focus of the 2020 Strategy is the intention for the country to become an exporter of low-cost green hydrogen by 2040. It also discusses the intent to develop a regulatory framework which would address standards gaps in safety, establishing a task force to support project developers, and conduct a review of natural gas regulation and infrastructure to support hydrogen blending. [82] The Strategy also indicates the creation of a public-private roundtable to discuss future implementation of a carbon tax. [82]

Hydrogen Sector Development Trends

Local Use Cases

The Strategy notes three waves of development of the hydrogen economy, beginning with domestic use, scaling local production of ammonia, replacing grey hydrogen with green, and use in heavy and long-haul transportation. The second phase will see the start of exporting hydrogen and green ammonia, and increase local green hydrogen use, including in land transportation and blending. The final phase will involve a massive scale-up of production, new export markets, and expansion into shipping and aviation sectors. [82]

The Strategy prioritizes six applications for developing a local market for hydrogen, including heavy-duty trucking, mining haul trucks, long-range buses, ammonia, blending into gas grids, and oil refineries in descending order of projected size. [82]

Mining: Chile's prominent mining sector is exploring hydrogen technologies for mining trucks and other vehicles. In 2019, CORFO released a call for feasibility studies on hydrogen co-combustion engines for mining trucks and fuel cell mining trucks and support vehicles. The former was given to a consortium including Anglo American, Engie, and BHP Chile, and the latter to another consortium including Siemens, Linde, and Engie. Both were largely financed by the consortiums. [159] Anglo American's Chilean copper mining operation has also developed the country's first green hydrogen station that feeds a fuel cell-powered forklift, as well as a stationary fuel cell for electricity generation. [160]

Export and Production

The National Green Hydrogen Strategy outlines the intention for Chile to become an exporter of low-cost green hydrogen by 2040. It estimates the potential for 160 megatons of green hydrogen produced annually, sourced from solar and wind energy resources in the Atacama Desert and Magallanes Region, via the world's lowest levelized cost of production. [82]

Though Chile's geographic location on the southwest of South America is quite remote from potential hydrogen markets, they have indicated export market targets as Europe, China, Japan, South Korea, the US, and Latin America for both green hydrogen and green ammonia. [82] In 2021, Chile signed an MOU with the Port of Rotterdam to develop a green hydrogen supply chain linking the country to European importers. [83] A feasibility study

dubbed, Project TANGO, was recently concluded between GASCO, HyNewGen, Linde, Vopak, and the Port of Rotterdam to develop a green hydrogen project in Chile. Next steps are in development to study production and logistics in exporting this hydrogen to Europe.[161]

In developing the hydrogen economy, the Chilean government has indicated an emphasis on public-private collaboration, intending the market to be largely financed by the private sector. [162] To date, government support consists of a $50 million USD ($65.5 million CAD) grant program to support six green hydrogen projects led by industry giants Air Liquide, CAP, GNL Quintero, Linde, Enel, and Engie, respectively. [158,162] CORFO has since signed agreements with CAP, GNL Quintero, and Air Liquide; the first two for electrolyzer construction projects, and the latter for green methanol production. [163]

Notable Innovation

Based on commitments in the National Green Hydrogen Strategy, the Chilean government is promoting innovation in the country to help advance the sector's development. In 2021, Chile's Energy Sustainability Agency (AgenciaSE) launched the H2V Accelerator, which will offer scaling support and co-financing to green hydrogen projects focused on production and exports. [164] The federal ministry of science and technology also launched a call for technologies to optimize green hydrogen production, specifically relating to the efficiency of pairing off-grid solar photovoltaic plants with electrolyzers. [165] Chile is also committed to the creation of a new cleantech research centre. A consortium of universities has been awarded the development of Chile's Institute of Clean Technologies (ITL), which will focus in part on green hydrogen innovation. [166]

Japan

Japan is a net energy importing country. They have been active in the development of international supply chains to ensure a cost-effective, secure supply of low-carbon energy as they seek to decarbonize the economy. With significant technology expertise in fuel cell development, importing hydrogen for local use is of great interest to the country. Japan's strict safety protocols and standards are noted as a potential barrier to the sector's development, as is cost competitiveness. Japan will likely be an importing market for Metro Vancouver's hydrogen export economy, and a potential competitor for hydrogen technologies.

Notable Policy

Australia and Japan Cooperation Agreement on Hydrogen and Fuel Cells: Australia and Japan have a mutual agreement to develop an international hydrogen and fuel cell supply chain. [74]

Green Innovation Fund: A ¥300 billion JPY ($2.8 billion CAD) fund was created by the Ministry of Economy, Trade and Industry (METI) in 2021 to import hydrogen, develop a supply chain and transport pathways, and support technology development related to liquefaction, hydrogen-powered turbines, and electrolyzer projects. [87] Japan has enforced the hydrogen strategy since 2019, as Japan's long term goal is to transition into a hydrogen-based economy.

Hydrogen Strategy: Japan was one of the first countries to produce a hydrogen strategy in 2017. [84] It has been enforced since 2019, as Japan's long term goal is to transition into a hydrogen-based economy.

Memorandum of Cooperation (MoC) on Hydrogen between Japan and UAE: A 2021 agreement between Japan and the UAE to cooperate on establishing a hydrogen supply chain involving production (UAE), transport (to Japan), setting standards, and aligning policy. [88]

Hydrogen Sector Development Trends

Local Use Cases

A large focus of Japan in developing the local economy is reducing the cost of hydrogen, increasing the prevalence of FCEVs, and establishing fuelling infrastructure. The country has a target of 200,000 FCEVs in the market by 2025 at a similar price range as EVs, and making hydrogen cost-competitive with fossil fuels. Japan has taken the initiative to propose new international technical and safety standards on hydrogen such as hydrogen technologies, fuel cell technologies, and fuel cell vehicles. [84] This will eventually lead to standardization at the international level. [84]

Japan's trading houses or, sōgō shōsha, are unique entities to the country. Given their involvement in multiple areas of the global economy, many are active in developing hydrogen business lines both inside and outside Japan in both technology and production. Mitsubishi, a ubiquitous brand and one of Japan's trading houses, is investing ¥2 trillion JPY ($18.8 billion CAD) in decarbonization industries by 2030. [167] In Japan, Mitsubishi's power solutions arm is developing the Takasago Hydrogen Park, a testing and demonstration center to advance commercialization of hydrogen technologies.[168] Mitsubishi is also investing in global hydrogen projects including green hydrogen production in Europe and blue hydrogen production in Alberta. [122,167] Sojitz, another trading house, is developing a green hydrogen production project in Australia for fuel cell-powered electricity generation in Palau, as a model for other Pacific Island nations.[169] Itochu is partnering with Air Liquide on a liquid hydrogen production plant in Japan, using natural gas as a feedstock and capturing generated CO_2 for industrial use. [170]

Japan is a global leader in fuel cell technology, with ambitions to lead the export market in this area.

Import

Japan is looking to import hydrogen to meet projected demand as energy resources and production capacity in the country are limited. [85]

The Hydrogen Energy Supply Chain (HESC) pilot project is intended to create an integrated supply chain, comprising manufacturing of hydrogen from the Latrobe Valley in Australia and shipping its liquified form to Japan. [86] The project is supported by Japanese and Australian entities including Kawasaki Heavy Industries, J Power, Iwatani Corporation, Marubeni Corporation, AGL, and Sumitomo Corporation. [86] The pilot project successfully ended in early 2022 and the decision to move the project towards commercialization is under consideration. [171]

Multiple Japanese companies have also formed the Japan Hydrogen Association, which has the goal of developing international hydrogen supply chains. Industry players including Mitsui and Co., Iwatani, Kawasaki Heavy Industries, Sumitomo Mitsui Financial Group, ENEOS, Kobe Steel, Toshiba, Toyota, Kansai Electric Power, and K Line are involved. [172]

Notable Innovation

The National Institute of Advanced Industrial Science and Technology has set up the Global Zero Emission Research Centre (GZR). [173] The GZR will conduct research with other G20 countries on innovative energy technologies in areas such as hydrogen, battery storage, and renewable energy. [173]

South Korea

In the late twentieth century, South Korea showed political interest in developing hydrogen as a source of fuel, but the subsequent political regime steered the country toward nuclear power. [89] They are now looking to phase out nuclear power and explore other low-carbon sources of energy as they decarbonize the economy. [89] Though hydrogen is of interest to the government for certain use cases, South Korea's population is averse to hydrogen given an explosion a few years ago, which is a barrier to the sector's development. South Korea may still potentially be an importing market for hydrogen exports from Metro Vancouver.

Notable Policy

Hydrogen Economy Promotion and Hydrogen Safety Management Act: Streamlines government efforts to promote hydrogen as a fuel and to provide subsidies. [89]

Hydrogen Economy Roadmap: This key strategy focuses on targets for FCEVs, fuel stations, and hydrogen-fuelled power generation in the country. [90]

Hydrogen Shipment Centre Project: The Government of South Korea will sanction ₩6.3 billion KRW ($6.1 million CAD) towards hydrogen supply infrastructure and fuel stations to supply about 2000 tonnes of hydrogen annually. [93]

Korean New Deal: The Korean New Deal is further split into the Digital New Deal and Green New Deal. Under the Green New Deal South Korea is stipulated to spend ₩42.7 trillion KRW ($41.4 billion CAD) to aid in the transition to a low-carbon economy until 2025. [89] One of the goals under the Deal is to achieve 200,000 active hydrogen-powered vehicles by 2025. [89]

Hydrogen Sector Development Trends

Local Use Cases

Road transportation: The Hydrogen Economy Roadmap notes the intention of South Korea to intensify the use of FCEVs, particularly as the country is a leading global auto manufacturer and fuel cell developer. They intend to be producing 6.2 million FCEVs (2.9 million for domestic markets and 3.3 million for international markets) by 2040.[174] Simultaneously, South Korea is looking to ramp up the number of hydrogen fuelling stations in the country to 1200 by 2040 to further grow FCEV use. [174]

The South Korean government has formed a special-purpose conglomerate named HyNet to establish 100 hydrogen fuel stations by 2022 and run it until 2028. [89] Heavyweight manufacturer Hyundai, as a part of HyNet, has sought to invest ₩7.2 trillion KRW ($7 billion CAD) to build 100 fuel stations by 2022. [89] Hyundai has sold about 100,000 FCEVs globally and believes that the price of FCEVs may be competitive with BEVs and internal combustion engines with more advanced regulations. [89] The US DOE and South Korea have entered into an agreement to study the feasibility of FCEV applications. [89] Hyundai has also set a 'FCEV Vision 2030' to produce 700,000 FCEVs by 2030. [175] Hyundai is a global leader in the hydrogen car segment with the FCEV NEXO – the first hydrogen-powered SUV to be commercially available in Canada – winning multiple awards. [175]

Power generation: The Roadmap also discusses the use of fuel cells for the purpose of generating power in the country. There is a goal to generate 15 GW of power by 2040, with 7 GW exported. [174] 2 GW of electricity is estimated for residential units and buildings. [174]

Import

Currently, about 80% of hydrogen in the country is emissions-intensive grey hydrogen, which has received public backlash. The government of South Korea is planning to supply 27.9 million mt/year of clean hydrogen (both green and blue) for domestic use by the year 2050. [91] This will be partially domestic generation (3 million mt/year of green hydrogen, and 2 million mt/year of blue hydrogen), with the majority imported from international suppliers (22.9 million mt/year). [91] Australia, Saudi Arabia, Canada, and Chile are all favourable options. South Korea has also initiated the launch of the Global Hydrogen Industrial Association Alliance, an international effort — including participation from the US, Canada, Australia, Germany, France, the United Kingdom, China, Spain, Singapore, and Colombia — which will set uniform standards between domestic and foreign companies to simplify trade. [176]

The United Arab Emirates (UAE) will produce 1 million tonnes of blue hydrogen per year on the basis of an agreement entered between South Korea's GS Energy, the UAE's Abu Dhabi National Oil Company (ADNOC), and Japan's Mitsui. [92] Although the facility will be situated in the UAE, this project will develop a supply chain with blue ammonia imported into South Korea through GS Energy for use in the industrial and power sectors. [92]

Notable Innovation

About 4.5% of South Korea's GDP is spent on R&D, including hydrogen energy, technology and infrastructure. [175]

Conclusion

Understanding the hydrogen-focused policies, strategies, and industry plans currently in place within Metro Vancouver and BC, and in key international regions and how they are moving sector development is intended to help stakeholders visualize a clear path forward.

This report demonstrates that:

- The hydrogen policy framework in BC is more robust than in many other geographies, indicating strong government support for developing a local economy.
- The majority of existing policies in BC are driving use cases for hydrogen in the transportation sector.
- Australia, Chile, Washington, and Oregon are potential competitive producers to Metro Vancouver in hydrogen exports. Japan, South Korea, and California are potential hydrogen importing countries. California may also be a competitive producer. Alberta and Saskatchewan are likely to be partner producing regions to BC and Metro Vancouver, utilizing BC ports for export.

Though policy mechanisms are supporting the growth of Metro Vancouver's hydrogen sector, there are still barriers to its widespread establishment. A core prohibitive factor in hydrogen is cost. Cost will reduce as industrial-scale production of hydrogen intensifies, but developing demand at a synchronized pace will be a challenge in the region. A provincial Energy Strategy would help clarify the future distribution of low-carbon energy sources and where hydrogen is best used. Having this Strategy would serve as a framework for development of additional mechanisms to support industrial-scale hydrogen production, which could lower costs and incentivize adoption in those targeted use cases.

Decarbonization is a complex undertaking, and the distribution and proportion of low-carbon energy that will become prevalent in the Metro Vancouver region is hard to predict. Continuing to paint the picture of the future hydrogen ecosystem and its many potential iterations lays the foundation to get us to an ideal hydrogen economy.

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