HYDROGEN STRATEGY FOR CANADA

Seizing the Opportunities for Hydrogen

A Call to Action

Draft Executive Summary – July 9, 2020

Hydrogen Strategy for Canada: Draft Executive Summary

Context

The world's energy systems are undergoing radical transformation driven by the need to decarbonize and mitigate climate change. Development of a low carbon hydrogen economy as a strategic priority to drive its use at-scale is a key opportunity to diversify Canada's future energy mix to achieve 2050 net-zero emissions.

Hydrogen is a versatile carbon-free chemical fuel that can be made from feedstocks that are abundant across Canada. Hydrogen can be used:

- directly as a fuel for transportation and power production
- to provide heat for industry and the built environment through burning directly or as a blend with natural gas
- as a feedstock for a range of existing and emerging industrial processes

Canada has played an important role in the development of the growing global hydrogen economy, starting more than a century ago with innovation in hydrogen production technology and four decades ago as pioneers in fuel cell technology.

Canada continues to be an R&D and technology leader in the sector. Canada's expertise and technologies are exported and used in countries around the world, demonstrating the opportunity for growth and deployment on an international scale. Despite this success, there are currently few domestic large-scale hydrogen projects.

Hydrogen can be a used in hard-to-abate sectors to meet Canada's 2030 and 2050 decarbonization objectives. Full scale commercial and demonstration projects in the near term can set us on a path for widespread deployment in the medium and longer term. By applying its world-class expertise at home, Canada can showcase hydrogen's real-world applications and benefits and the role hydrogen can play in transforming our energy system.

Canada is not alone in seeing hydrogen as a critical piece of the puzzle to combat climate change and improve air quality, while driving economic growth in a carbon-constrained world. Countries around the world have developed strategies to inform the optimal supply pathways and end-use applications for hydrogen, as well as to define export strategies. The demand for hydrogen in global energy systems is dramatically increasing, with projections indicating at least a tenfold increase in demand in the coming decades. Studies indicate that hydrogen could provide up to 24%[1] of global energy demand by 2050. The number of countries with polices that directly support investment in hydrogen technologies is increasing, along with the number of sectors they target.

As the world's 4th largest producer of both natural gas and oil, hydrogen serves as a critical opportunity to support a net-zero moon shot for Canada's petroleum sector. By leveraging industry's significant energy expertise and infrastructure, Canada has the opportunity to decarbonize and diversify into a leading global clean fuels exporter.

For three years, NRCan has been working with private sector stakeholders and governments at all levels to inform the

[1] BloombergNET: Hydrogen Economy Outlook, March 20, 2020, https://data.bloomberglp.com/professional/sites/24/BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020.pdf

development of the *Hydrogen Strategy for Canada.* NRCan has also commissioned several key studies that have informed the writing of this strategy, which are publically available.

The Government of Canada has also undertaken significant research, regulatory development activities, pilot deployments and stakeholder engagement, through a variety of *fora*, including workshops, teleconferences, bilateral discussions, and ongoing dialogue through existing working groups

Consultations were held with stakeholders from across the value chain to ensure engagement opportunities were as comprehensive as possible.

Canada's Advantages

Canada has unique competitive and comparative advantages that position it to become a world leading producer, user, and exporter of clean hydrogen, as well as hydrogen technologies and services. A strong hydrogen economy will lead to financial, environmental, and health benefits for Canadians.

The following strategic advantages position Canada for long-term success in developing a strong hydrogen economy:

- Rich in feedstocks to produce hydrogen

  Canada has one of the lowest carbon intensity electricity supply in the world, abundant fossil fuel reserves, potential for growth in variable renewables, (new renewable power generation – solar, wind, offshore wind, hydro, and marine energy resources) and freshwater resources, all of which can be leveraged to produce hydrogen.

- Leading innovation and industry position

  Canada is known for its leading hydrogen and fuel cell technology companies and expertise. As of 2017, there were >100 established companies, employing >2100 people, generating revenues >$200 million.

  Canada also has significant expertise in carbon capture technology, which is fundamental to the production of blue hydrogen from fossil fuels.

- Strong energy sector

  Canada's energy sector accounted for 900,000 direct and indirect jobs as of 2017, with assets valued at $596 billion[2]. This skilled labour force and strategic infrastructure assets position Canada to rapidly pivot to include hydrogen as an energy currency.

- Established international collaborations

  Canadian government, industry and academia are involved in international collaborations related to hydrogen that position Canada as a leader both from an innovation and commercial perspective.

- Head start

[2] https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/10-Key-Facts-on-Canada_s-Energy-Sector-2018-en%20.pdf

Canada is one of the top 10 hydrogen producers in the world today. An estimated 3 million tonnes are produced per year from natural gas.

- Energy export channels to market

  Canada's proximity to hydrogen import markets including Japan, South Korea, California, and Europe along with export assets such as deep water ports and established pipeline networks as well as natural gas and oil transportation companies, position Canada to be an exporter of hydrogen as the global economy evolves.

By leveraging these advantages to develop a vibrant and robust low carbon hydrogen economy in Canada, benefits will be created for Canadians including:

- Economic growth

  Canada's hydrogen economy will create new green jobs in R&D, manufacturing, and services. Hydrogen will also become a new export currency for the energy sector, including regional energy economies in Western, Central, and Eastern Canada, and will allow Canadian energy companies to move up the value chain as an end-use fuel provider in a zero emission transportation future.

- Energy resilience

  Hydrogen can act as an energy carrier to enable increased penetration of renewables by providing time shifting and energy storage capabilities.

- Moonshot for Canada's petroleum sector

  Hydrogen is critical to achieving a net-zero moon shot for oil and natural gas industries, it provides an opportunity to leverage our valuable energy and infrastructure assets, including fossil fuel reserves and natural gas pipelines, in a way that is carbon-free at the point of use, providing a pathway to avoid underutilizing or stranding these assets in a 2050 carbon neutral future.

- Cleaner air

  Hydrogen does not produce greenhouse gases, black carbon, particulates, SOx, or ground-level ozone. When used in an electrochemical fuel cell, it emits nothing but water. Increased hydrogen adoption for use in fuel cells can lead to cleaner air, and cleaner air means improved health outcomes for Canadians.

- Meeting decarbonization goals

  Hydrogen closes the gap in hard-to-abate, energy intensive applications (such as long-haul freight, mining, industrial processes) and is needed to meet Canada's decarbonization commitments.

Opportunities

Production

Canada's rich feedstock reserves, skilled energy labour force, strategic energy infrastructure assets, and leading position in innovation and industry in the hydrogen and fuel cell sector position us to become one of the top three global producers of clean hydrogen.

Canada is one of the top ten global producers of hydrogen today, producing an estimated 3 million tonnes annually via steam methane reformation (SMR) of natural gas. While steam methane reformation is not considered a clean hydrogen pathway, Canada is well placed to transition to clean pathways going forward.

Colours are often used to represent the different hydrogen production pathways:

- **Grey hydrogen:** produced by SMR without carbon capture and sequestration (CCS). Canada has established production and supply chains, primarily in Alberta for fuel refining and fertilizer production. Over time this will shift to lower carbon intensity pathways.
- **Blue hydrogen**: produced by SMR, with CCS. As the 4th largest global natural gas producer, there exists a significant opportunity to drive this pathway forward. Alberta's Quest project has been in operation since 2015, with >1 million tonnes / year of CO_2 from an SMR plant injected and stored more than 2 km underground. Canadian companies also continue R&D on the production of blue hydrogen from oil reservoirs.
- **Green hydrogen:** produced from water by electrolysis using renewable electricity such as hydroelectricity, wind or solar. Air Liquide is installing a 20 MW electrolyzer plant in Becancour, the largest in the world producing 3,000 tonnes H_2 annually.

There are also several other pathways for which no colour is clearly defined, but which are fully viable with strong potential in Canada, including:

- **Biomass conversion** – using either gasification or anaerobic digestion to produce hydrogen are considered both renewable and carbon-neutral and is a viable hydrogen production pathways in Canada.
- **Nuclear:** producing hydrogen via electrolysis, using off-peak nuclear electricity, or via high-temperature thermal processes, using waste heat from the nuclear process are viable production pathways in Canada. This leverages Canada's expertise in nuclear technologies (including conventional and the emerging small modular reactor sector) to produce low carbon hydrogen.
- **Industrial by-product** hydrogen in Canada that are currently vented and can be captured, purified, and used directly.

Hydrogen production in Canada is expected to be based on a mix of the various pathways.

The carbon intensity of the hydrogen is a more important factor, than the pathway by which it is produced. To that end, Canada is working with countries around the world to develop a common methodology to determine the carbon intensity of hydrogen, negating the need to define production pathways by colour.

Canada is the world's fourth largest producer and sixth largest exporter of natural gas. Provinces with the highest natural gas production are Alberta, British Columbia, and Saskatchewan, and these are the provinces most suited for production of blue hydrogen. In Alberta, a new Task

Force has been announced[3] to advance the hydrogen economy in Alberta's Industrial Heartland and to seize this transformative opportunity.

The completion of the world's largest carbon capture pipeline – the Alberta Carbon Trunk Line – highlights the opportunity that exists in Alberta to bring clean tech and petroleum together to advance the hydrogen economy.

Six provinces have been identified as having sufficient power capacity for green hydrogen production via industrial scale electrolysis: British Columbia, Manitoba, Ontario, Quebec, New Brunswick and Newfoundland & Labrador. As increasing amounts of wind and solar generation are brought into Canada's energy mix, they offer the potential to expand the production of green hydrogen and to reduce costs. Hydrogen can in turn improve the economics of intermittent renewables by providing large-scale energy storage that optimizes the utilization of these power generation assets.

There are also synergies between hydrogen production and nuclear electricity. Given Canada's position as a tier one nuclear country, we can leverage our experience and expertise in both nuclear technologies (conventional, and the growing small modular reactor sector) and hydrogen production technologies as an additional pathway for domestic low-carbon hydrogen production.

The hydrogen supply network in Canada could include both large-scale centralized plants in Canada's natural-gas rich provinces or in remote regions with high penetration of low-cost renewables, and smaller-scale distributed electrolytic production near demand centers. Delivered hydrogen costs of $1.50-3.50/kg will be achieved as production scale is realized and investment is made in distribution infrastructure.

Industry and provincial governments will play an important role in determining which hydrogen production pathways will come to fruition in Canada, and over what timeframes. Overall, a balanced, regional approach to developing Canada's hydrogen supply is recommended. This diversification of fuel sources enables production volumes to support the development of domestic and export markets, competing against other global producers to diversify Canada's energy export portfolio

End-Use

Domestic deployment of hydrogen is critical to supporting Canada's world-leading hydrogen and fuel cell sector, as well as to meeting climate change objectives. The earlier deployment starts, the sooner infrastructure development and end-user acceptance will come into place, allowing the realization of longer-term projections on uptake and associated benefits.

Adoption of hydrogen can be expected to primarily be focused on energy-intense applications where electrification is challenging or not technically viable, and where economics that today rely on low-cost natural gas are more suited to energy dense fuels. This includes using hydrogen as a fuel for long-range transportation and power generation, to provide heat for industry and buildings, and as a feedstock for industrial processes.

[3] Source: https://mailchi.mp/6726559fb647/new-task-forceto-advance-hydrogen-economy-in-albertas-industrial-heartland?e=7bfdb418c6

Fuel for Transportation

Hydrogen can be used directly as a fuel in fuel cell electric vehicles (FCEVs), which have two times the efficiency of combustion engines and which have zero emissions at the tailpipe. Fuel cell light-duty passenger vehicles and transit buses are commercially available today globally, and in limited numbers in Canada. Fuel cells are also commercially available in off-road equipment, including lift trucks, and power back-up applications.

Heavy-duty trucks and light-rail passenger trains have also been commercially deployed in limited numbers globally. Pilot demonstrations of small marine vessel prototypes are also underway, and show promise. Longer-term, fuel cell applications may expand to include long-haul freight (rail and road), and trans-oceanic marine vessels.

The Government of Canada has set federal targets for zero-emission vehicles to reach 10% of light-duty vehicles sales per year by 2025, 30% by 2030 and 100% by 2040. Canada considers battery electric vehicles, fuel cell electric vehicles, and plug-in hybrid electric vehicles to qualify as zero emission vehicles. BC and Quebec have led provincially with the adoption of ZEV regulations, and both of these provinces have started to deploy hydrogen fueling infrastructure and fuel cell vehicles.

Electric vehicles are expected to take a significant portion of the market share for light duty applications in Canada, base don these targets. These electrification options include battery electric, and fuel cell electric vehicles. Canadian consumers have shown increasing demand for larger vehicles, with 80% of nationwide spending on new vehicles in 2019 going to trucks, vans, or SUVs.[4] Trends such as autonomous driving and ride sharing may also drive greater demand for hydrogen fuel cell electric vehicles.

Canadian cities need public transportation, and it must be zero emission for Canada to become carbon neutral and to improve air quality in urban centers. Canada has unique potential for a 'made-in-Canada' solution with New Flyer Industries and Ballard Power Systems leading the market with commercial fuel cell electric bus deployments in North America.

The zero emission bus initiative[5] underway in Canada encourages government to support school boards and municipalities in purchasing 5000 zero emission buses over the next 5 years. Canada is home to world leading fuel cell and electric bus manufacturers and can leverage this industry to provide economic value if fuel cell electric buses are a portion of the mix. These buses are well suited to longer routes and cold weather climate that Canadian transit agencies service.

Fuel cells will play a significant role in medium and heavy-duty trucks, rail, and ships where batteries are not likely to be technically feasible. For example, in heavy-duty trucks travelling long distances with heavy payloads, the weight of the batteries to provide the energy needed would result in reduced cargo load carrying capacity that is unacceptable to operators. Long charging times could also impact operations negatively. The improved energy density and fast fill characteristics of fuel cell

[4] Souce: Statistics Canada. Table 20-10-0002-01 New motor vehicle sales, by type of vehicle

[5] https://cutaactu.ca/en/blog-posts/new-federal-government-unveils-its-priorities

electric trucks could make them an optimal choice for certain applications.

There is a similar value proposition for hydrogen use in mining equipment. For the mining industry, hydrogen presents an opportunity to reduce widespread reliance on diesel power for mine production vehicles. Instead of battery technology which may reduce capacity of payloads, hydrogen presents itself as a viable option for heavy transportation due to it`s accessibility and adaptability.

In the near term as costs and availability of fuel cells challenge uptake, hydrogen-diesel co-combustion in truck applications may offer a feasible pathway to create the demand for hydrogen and support infrastructure development.

Fuel for Power Generation

Hydrogen can be used as a fuel for power production through either hydrogen combustion in turbines or use in stationary fuel cell power plants. Hydrogen provides load management, energy storage, and a path to market that enables the growing intermittent renewable power sector.

In the longer term, hydrogen can play a role in greening Canada's electricity grids where there is still a reliance on fossil fuels for power production. Hydrogen can also provide stability for off-grid renewables based power solutions in remote communities and remote industrial sites such as mines.

Mines in northern and remote regions are largely dependent on expensive, highly-emitting diesel power, the mining industry is uniquely-positioned to be an early adopter and major beneficiary of hydrogen fuel cells, to meet energy needs in these regions.

Heat for Industry and Buildings

As a heating fuel, hydrogen is a clean-burning molecule that can be a zero-carbon substitute for fossil fuels in applications where high-grade heat is needed and where electric heating is not technically or economically viable. Hydrogen can be burned directly or blended with natural gas to reduce carbon emissions in hard-to-abate applications like industrial heating, space heating for homes and buildings.

Feedstock for Industry

Hydrogen is used as a feedstock in several industrial processes in Canada today. Most feedstock hydrogen is currently produced via steam methane reforming.

Hydrogen is used as a feedstock for:

- Petroleum refining
- Bitumen upgrading
- Ammonia production
- Methanol production
- Steel production

The greatest use of hydrogen globally today is for refining and upgrading crude oil, where hydrogen-based processes remove impurities like sulphur and process heavy hydrocarbon chains into lighter components. The majority of hydrogen required for refining is produced on-site either from dedicated production facilities or as a by-product. Because of this integration of hydrogen production within refining facilities, production is primarily supplied by natural gas reforming methods. The most significant opportunity to reduce emissions associated with hydrogen in the oil and gas industry is retrofitting existing conversion technology with carbon capture and storage. In the Canadian context, this has the special potential to help decarbonize a portion of oil sands operations in Alberta.

Adoption of the Clean Fuel Standard is expected to drive demand for clean hydrogen in these industries. Switching to lower carbon intensity hydrogen offers a compliance pathway.

Availability of low cost, low carbon intensity hydrogen has the potential to create new industry in Canada as well. This includes synthetic liquid fuel production, an innovative process combining renewable hydrogen and carbon captured from the air to produce carbon-neutral, energy dense liquid fuels that are well suited to applications such as aviation and large marine vessels. Renewable fertilizer production also presents an opportunity for new Canadian industry.

Hydrogen also can be a key to reducing emissions from mining. The Canadian Minerals and Metals Plan (CMMP) aims to capitalize on opportunities to strengthen Canada's competitive position within the global mining sector. The CMMP emphasizes the importance of developing and adopting clean technologies and alternative energy sources, such as hydrogen.

Export

It is clear that with worldwide demand for hydrogen increasing, and energy importers actively looking to Canada as a potential supplier, there is a significant opportunity for Canada. The British Columbia Hydrogen Study completed in 2019 shows export potential of $15 billion by 2050 from that Province alone. The growth of this export industry would serve to diversify Canada's energy export portfolio. Canadian oil and natural gas exports alone totalled $122 billion in 2019.

Remaining Challenges

Costs

The main limiting factor for hydrogen use in many applications are economic rather technology-based. The reason that clean hydrogen is not currently used in many potential applications is that it is not yet economically viable compared to other conventional fuel options. This cost barrier can be addressed through strong government capital and production incentives to encourage scale, and through de-risking industry investment as the demand for hydrogen grows. Financial measures for end-use adoption can be effective in de-risking these investments.

Over time, Canada's rich resource base, skill set, and existing energy supply chain provides the opportunity to be cost competitive in global markets

Policy and Regulation

Clean hydrogen projects around the world have primarily been in regions with a combination of supporting policies and regulations. Policies and regulations that encourage the use of hydrogen technologies include low carbon fuel regulations, carbon price, vehicle emissions regulations, zero emission vehicle mandates, creation of emission-free zones, and renewable gas mandates in natural gas networks. Mechanisms to help de-risk investments for end-users to adapt to regulations can be beneficial. A more cohesive national framework could provide a clear signal of the importance of hydrogen and avoid a patch-work of policies and regulations across jurisdictions.

Availability of hydrogen

There is a need to transport and store hydrogen from the site of production to the end-user. This includes refuelling infrastructure for transportation uses.

Over time, as the domestic production and demand grow, there will may be a need for dedicated infrastructure. The cost of these technologies will continue to drop, as advancements are made, and the markets grow.

Codes and Standards

The deployment of hydrogen is in the early stages across many jurisdictions and sectors in Canada, and there are some gaps in existing codes & standards which need to be addressed to enable adoption.

This includes tools that enable and accelerate hydrogen use beyond demonstrations and pilot projects. Harmonizing codes and standards across jurisdictions (provincial and international) will ensure that best practices are applied across the global hydrogen economy to facilitate the growth of trade and export markets.

Canada is also working with countries around the world to develop and align codes and standards, through efforts like the Canada/US Regulatory Cooperation Council, and throughout the UN-ECE. These efforts also include developing and aligning common methodology to determine the carbon intensity of hydrogen production pathways.

Path Forward

Vision for 2050

If Canada seizes the opportunities for hydrogen, by 2050 we could realize the following:

- >5 million fuel cell electric vehicles
- Nationwide hydrogen fueling network
- >50% of energy supplied today by natural gas is supplied by hydrogen through blending in existing pipelines and new dedicated pipelines
- Established supply base of low carbon intensity hydrogen with delivered prices of $1.50 - $3.50/kg
- New industries enabled by low-cost hydrogen supply network
- Established export market
- Diversification of Canada's petroleum sector – with hydrogen established as major energy export for Canada
- >100,000 hydrogen sector jobs
- >$5 billion in hydrogen sector revenue
- >100 Mt CO_2e annual GHG reduction
- Canada is one of top 3 global clean hydrogen producers

Near Term: Laying the Foundation

The focus of the next 5-years will be on laying the foundation for the hydrogen economy in Canada. This includes developing new hydrogen supply and distribution infrastructure to support early clusters of deployments in mature applications while supporting Canadian demonstrations in emerging applications, such as long haul trucking, light-rail and small marine vessels. Early actions are fundamental to driving investment in the sector.

Canada's petroleum sector is a major driver of investment, with $52 billion in 2019. Despite the oil price downturn and uncertainty over the COVID-19 recovery, an opportunity exists for government to partner with industry to drive commercial blue hydrogen projects as part of the sector's net-zero agenda.

Hydrogen use in the near-term will be dominated by mature market applications at or near the commercial market Technology Readiness Level (TRL) including fuel cell electric vehicles and fuel cell electric buses for transit operation. Pre-commercial applications such as heavy-duty trucks, seaport goods movement equipment, power generation, heat for the built environment, and industrial feedstock applications will be introduced as pilot projects in regional clusters.

These regional clusters will be strongly influenced by:

- Regulatory approvals for blending hydrogen and natural gas to decarbonize the utility distribution system.
- Availability of technical evidence from pilots to inform the safe integration of fuel cells into domestic regulatory regimes, i.e. Railway Safety Act, Motor Vehicle Safety Act.
- Increased production of RNG and biogas due to favorable policies will drive low carbon hydrogen production.
- Zero-Emission Vehicle mandates for passenger vehicles such as the existing legislation in Quebec and British Columbia.
- There will be variances in CFS compliance plans that will drive low carbon hydrogen generation for industrial applications including the upgrading of transportation fuel products.
- Existing hydrogen generation, distribution and dispensing infrastructure that can be leveraged e.g. liquefaction capacity in Quebec, or steam methane reforming with carbon sequestration in Alberta.

Mid Term: Growth and Diversification

Activities to ignite the sector in the next 5 years will be followed by growth and diversification of the sector in the 2025 – 2030 timeframe.

As the technology matures and the full suite of end-use applications is at or near commercial technology readiness levels, hydrogen use in the mid-term will be focused on applications that provide the best value proposition relative to other zero-emission technologies. For example, fuel cell electric vehicles and transit buses will enter the rapid expansion phase as the market for fuel cell and battery technology becomes more defined. For example, fuel cells will gain traction where charging times, energy requirements, range, grade ability, and operation in extreme climates make battery technology technically challenging for specific market segments

Class 8 heavy-duty trucking in corridors that require heavy payloads and drayage equipment in regions with regulated air sheds will move into the commercial phase of deployment. New, larger scale hydrogen production in the mid-term will allow H2/NG blending for industry, the built environment and as a feedstock for chemical production and hydrocarbon upgrading to be commercialized in regional clusters during this period.

Pre-commercial applications like Class 5-7 delivery trucks, operating in urban zero-emission zones, passenger and freight rail where gantry infrastructure need to electrify

the line is prohibitively expensive, mining vehicles and smaller domestics marine vessels

A regulatory framework, and market ready technologies enable early deployment of hydrogen in mining operations, toward the later part of this timeframe.

Long Term: Rapid Market Expansion

In the 2030-2050 timeframe, Canada will start to realize the full benefits of a hydrogen economy as the scale of deployments increase and number of new commercial applications grows, supported by Canada's foundational backbone supply and distribution infrastructure.

In the long-term, it is anticipated that with advances in battery and charging technology there will be a more defined division between battery and fuel cell utilization in Canada for transportation purposes. This will result in the higher power demand applications (utility biased) predisposed toward hydrogen energy storage and the lower power demand applications (efficiency biased) using batteries for energy storage. New transportation applications will move into the commercial and rapid expansion phases during this period.

In parallel, economies of scale in the production of hydrogen, coupled with regulatory pressures, will lead to accelerating growth in the blending of hydrogen in the natural gas distribution system and construction of new dedicated hydrogen pipelines supplying fuel to full hydrogen-based communities. Power generation applications will continue to grow, complementing increased penetration of intermittent renewable power sources in Canada's energy systems.

As low carbon intensity hydrogen is more widely available throughout Canada, new industries are expected to emerge including production of liquid synthetic fuels, ammonia and renewable fertilizer.

Time to Act

The time to act is now. Governments around the world are releasing and executing hydrogen strategies that are building global momentum. In 2019 Canada seized this momentum by developing and launching a new Hydrogen Initiative under the Clean Energy Ministerial, designed to be the cornerstone for global hydrogen deployment.

Now, one year later, Canada is poised to again leverage this momentum, to grow the domestic opportunity for hydrogen production and end-use, while also benefiting from growth in global demand, via this Strategy. Although the COVID-19 pandemic has shaken all sectors of the economy, the recovery can also present a unique opportunity for change.

Recommendations

The next five years will determine Canada's trajectory for achieving the 2050 vision and associated benefits. Eight pillars of actions have been identified, as follows:

Pillar 1: Strategic Partnerships

Themes include enabling and encouraging collaboration between private sector stakeholders, governments at all levels, and academia to coordinate actions and activities.

Pillar 2: De-Risking of Investments

Themes include driving investment to establish supply and distribution infrastructure, support regional deployment clusters, and establish manufacturing capabilities in Canada.

Pillar 3: Innovation

Themes include a strategy for sustained support for research, development and demonstration, that includes domestic industry, academia, and government collaboration, as well as international collaborations. Support for demonstrations and early deployments that include the full value chain from supply, to distribution, to end use can serve as a living lab to support Canada's innovators in the sector and ensure these technologies can be integrated in a safe and timely manner.

Pillar 4: Regulations, Codes and Standards

Themes include developing codes, standards, and regulations that enable and accelerate the production, distribution and use of hydrogen within domestic and international regulated energy markets. These regulatory instruments can range from national codes and standards, to industry specific established practices, technical requirements, safety assessments, and terminologies for products, services, and systems.

Pillar 5: Enabling Policies

Themes include developing a Canadian policy framework that is technology-neutral and accelerates hydrogen adoption and levels the playing field between low-carbon hydrogen and other fuels. Approaches to developing tools that are flexible enough to meet the changing demands associated with new, emerging technologies will be explored.

Pillar 6: Awareness

Themes include communicating the hydrogen sector as a priority sector and raising public awareness and confidence in hydrogen systems and fuel cell technologies through a combination of outreach campaigns and highly visible flagship projects.

Pillar 7: Regional Blueprints

Themes include developing regional specific blueprints to focus on unique considerations that may differ from region to region. Blueprints will provide recommendations for actions and roles/ responsibilities for all levels of government and the private sector to ensure each region is well positioned to seize their specific opportunities.

Pillar 8: International Markets

Themes include developing an export strategy and action plan to complement the Hydrogen Strategy for Canada.

Roles and Responsibilities

Development of a strong Canadian hydrogen economy requires a coordinated and collaborative effort between industry, governments, academia, and non-government associations driven by a common vision and strategy.

Implementation Plan

Following the release of this *Hydrogen Strategy for Canada*, there will be ongoing engagement with public, private and Indigenous stakeholders, to continue the momentum, initiate and track activities related to the recommendations, follow progress, and identify new priority areas as

the market evolves. It is proposed, that this engagement will be formalized through an Implementation and Steering Committee and Working Groups.