A Feasibility Study of Hydrogen Production, Storage, Distribution, and Use in the Maritimes

ZEN and the art of CLEAN ENERGY SOLUTIONS

In partnership with:

Dunsky Energy Consulting & Redrock Power Systems

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EXECUTIVE SUMMARY

This study provides an assessment of the role hydrogen can play in the Maritimes' energy transition towards a net-zero-emission future. Opportunities for hydrogen have been identified that support the region's broad energy policy objectives related to climate change, inclusive economic development, and sustainable development of energy resources. Hydrogen opportunities were evaluated through the full value chain from production, storage, distribution and through to end use applications, integrated together into an end-to-end hydrogen ecosystem. Hydrogen shows the potential to be an essential part of the 2050 energy mix, closing gaps in hard-to-abate sectors. However, the region faces challenges that must be addressed for hydrogen to reach its potential and critical policy and infrastructure investments need to be made in the near-term to initiate action in the region.

Hydrogen can become an essential part of the region's energy mix to reach net-zero carbon emissions by 2050 and increase energy independence.

The study was initiated in July 2020, and to date has been focused on the Maritimes region, looking both at unique provincial considerations in New Brunswick, Nova Scotia, and Prince Edward Island (PEI), and at opportunities enabled by a holistic view of the region. It was recognized that it would be beneficial to expand the scope to include Newfoundland and Labrador to encompass opportunities that could be unlocked through looking at the broader Atlantic region. This version of the report covers Maritimes only, and an addendum will be released before the end of 2020 to include Newfoundland and Labrador.

The potential of hydrogen to play a role in decarbonizing the energy system is top of mind for many governments and industries around the world. According to the Hydrogen Council, 18 federal governments representing more than 70% of global GDP have developed national strategies for hydrogen.[1] Within Canada, a hydrogen study for British Columbia was completed in 2019 and the Federal Government is currently finalizing its hydrogen strategy. This Maritimes study builds on these prior reports and considers the potential role of hydrogen within the local context.

Stakeholder Engagement

Stakeholder engagement served as an important tool to gather input from across all three provinces, and across a variety of industry sectors, levels of government, academia, and non-profit associations and environmental non-governmental organizations (NGOs). Through the study timeframe, almost 60 stakeholders representing over 40 organizations were engaged through a series of targeted one-hour virtual interviews, three two-hour virtual workshops, and an online survey. While the level of knowledge and experience on hydrogen varied among stakeholders, they all provided important perspectives on how

[1] Hydrogen Council. (2020). *Path to hydrogen competitiveness: A Cost perspective*. Retrieved from https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf

hydrogen can fit within the Maritimes energy landscape and these perspectives were considered in the opportunity analysis and recommended path forward.

Analysis

The opportunity for hydrogen in the Maritimes was evaluated by forecasting demand under two scenarios meant to represent incremental and transformative change from 2020 to 2050. Neither scenario is intended as a prediction of what will necessarily happen in the region but represent what could happen based on a number of assumptions including technology advancement, policy adoption, and consumer preferences. In both cases, hydrogen is assumed to be one of several key components to a larger decarbonization strategy. Other factors, such as increased low-carbon electrification, energy efficiency improvements, and biofuels are also likely to play large roles in reaching emissions targets in the region. The transformative scenario assumes highly favourable adoption of hydrogen technology and is built around achieving net-zero-emissions in 2050. The incremental scenario incorporates more conservative assumptions relating to the adoption of hydrogen and emissions reduction.

With today's policy framework and lack of strategy or coordinated approach regarding how hydrogen fits into a net-zero future for the Maritimes, the region is more on the path of the incremental scenario. This scenario offers little benefit to the region in terms of decarbonization potential and economic growth and is likely not a scenario that is worth pursuing from a cost benefit perspective. Inaction that allows 'business as usual' to progress will result in crucial time being wasted as other regions recognize the role hydrogen is best suited to play and take necessary actions to create a regulatory and policy framework to maximize the opportunities for hydrogen. A number of recommendation themes are included in the report that could position the region to be on the path of the more compelling transformative scenario, including:

- Developing a holistic **Clean Energy Roadmap for the region** that looks at how hydrogen fits with other low-carbon energy vectors and technology options to achieve a net-zero overall energy mix.
- Working as a region to develop **aligned action plans and policies** related to hydrogen.
- Implementing a **strong regulatory framework complemented with incentives** to drive the transformation and decarbonization of the region's energy systems and encourage end use adoption of alternative fuels.
- Getting started now with high profile **lighthouse projects** that encourage local industry participation.

Key Findings

1. Increasing awareness about opportunities for hydrogen is a critical first step

Engagement with stakeholders throughout the study highlighted that many parties in the region are just starting to think about hydrogen and the role it might play. The study started dialogues that should continue for hydrogen opportunities to be realized.

An important step to raise the profile of hydrogen will be to include it as a promising energy vector in the development of a regional Clean Energy Roadmap that looks holistically at the entire energy system in the region, from primary energy supply to end use demand. Hydrogen's role must be understood in the

context of other decarbonizing energy vectors to ensure each is deployed where it can offer the greatest potential benefits technically and economically. Local governments can also support industry in raising general awareness about hydrogen safety and end use applications, through supporting outreach initiatives and the development of educational tools.

A Clean Energy Roadmap for the Maritimes would be an effective tool to plan for the transformation that must take place to achieve the region's decarbonization goals. Hydrogen will be an important piece of the roadmap, but it must consider all potential energy vectors and how they can be used in tandem to reach an overall net-zero mix. It is recommended that the roadmap first look at the current energy baseline and consider economics, technical maturity, and effectiveness of available low-carbon options to determine near-, mid-, and long-term viability to ultimately decarbonize the region. Energy consumption across all economic sectors should be considered including transportation, heating, electricity generation, and industry. The roadmap should be data driven and nonbinary given the range of forecast uncertainties, but can inform a rollout strategy by identifying which low-carbon energy vectors are best suited to specific end use applications under a range of scenarios, to inform policy and infrastructure decisions.

2. Producing hydrogen via electrolysis with renewable wind power is the most promising pathway in the region

The production pathways analysis uncovered both opportunities and challenges for producing hydrogen in the Maritimes. There is global consensus that development of new hydrogen supply must be focused on low carbon intensity (CI) pathways. Hydrogen production via electrolysis powered by renewable wind, often referred to as 'green hydrogen', shows the best overall potential in the Maritimes when looking both at bulk production costs and CI levels. Production of hydrogen via natural gas combined with carbon capture utilization and sequestration (CCUS), referred to as 'blue hydrogen', can also be cost competitive and low CI. It should be noted though that the region currently relies primarily on imported natural gas and delivered commodity prices are high relative to other parts of Canada given the region is at the 'end of the line' on import pathways. Unless more domestic natural gas is produced from local reserves, like the Nova Scotia Offshore, or the McCully Field in New Brunswick, this introduces risk for future pricing and does not provide the added benefit of increasing energy independence. Integrating hydrogen production into wind farms can improve the economics of both energy vectors, and ultimately enable greater development of intermittent renewable resources for both decarbonizing the grid and producing hydrogen as a replacement for carbon emitting transportation and heating fuels.

A challenge in the Maritimes is that electricity grids are still reliant on carbon emitting fossil fuels for a significant portion of the grid electricity generation mix, resulting in higher CI than is viable for producing hydrogen via grid connected electrolysis. Over the longer-term, hydrogen is seen as an energy vector that can help reduce the CI of the grid. The nuclear power plant in New Brunswick offers potential for regional hydrogen production, whereby nuclear power at off peak times when electricity demand is low could be used to produce low CI hydrogen. This warrants further study and is dependent on local opportunities for bulk hydrogen storage and requires a more in-depth analysis of daily and seasonal electricity demand and supply fluctuations in the region.

Import of hydrogen from nearby regions like Quebec with established green hydrogen production and liquefaction assets can be an important bridge for getting early deployments off the ground and should not be discounted as a longer-term option as an alternative to importing refined petroleum products.

3. Hydrogen can play an important role in grid scale energy storage, an important enabler for the region to increase energy independence

Intermittency is a significant problem with renewable energy sources, and hydrogen can provide utility-scale storage solutions. For example, PEI has been adding wind generation capacity; however, the amount produced exceeds demand in the summer, requiring the province to export electricity during these months and import electricity during the winter when production doesn't meet demand due to high electric space heating loads. Hydrogen can be produced via electrolysis during off-peak times and converted back to electricity at peak times. Batteries are a mature alternative technology that are being used globally but cannot currently provide economically viable long-duration storage solutions. Hydrogen, when coupled with bulk storage options such as salt caverns, depleted wells, or gas pipeline systems, provides the most economical utility scale energy storage option available today. Hydrogen offers additional flexibility as an energy storage medium, as it can be both used to generate electricity or can alternatively be stored and transported in pipelines either as pure hydrogen or as a blend with natural gas and used for peak heating demands and / or as a transportation fuel. Energy storage technology is developing quickly, and more analysis is necessary to predict the long-term costs and benefits of competing technologies such as hydrogen and batteries.

4. Hydrogen-powered long-range and heavy-duty transportation can become increasingly important to the region as hydrogen infrastructure matures

Transportation accounts for approximately 32% of greenhouse gas (GHG) emissions in the region and is reliant today primarily on refined petroleum products. To meet long-term decarbonization objectives, the region will ultimately have to make the shift to zero-emission vehicles (ZEVs).

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 (BEVs), fuel cell electric vehicles (FCEVs), and plug-in hybrid electric vehicles (PHEVs) to qualify as zero-emission vehicles. Provinces in the Maritimes have not adopted a ZEV mandate to further catalyze the transition to ZEVs in the region, and currently there is a struggle to attract BEVs given the lack of regulatory incentives. This will likely continue and limit adoption of FCEVs as well. Ultimately both regulations and incentives for vehicle purchases as well as infrastructure development would help to accelerate the transition in the region.

While BEVs are anticipated to dominate the light-duty vehicle market, FCEVs will provide a choice in the light-duty market for consumers looking for larger vehicles such as sport utility vehicles (SUV) and pickup trucks, where the longer range and fast fueling times demonstrate the greatest advantages. Similarly, the biggest differentiation between FCEVs and BEVs will be in the medium- and heavy-duty trucking sector where FCEVs currently provide the only technically viable solution for the most energy intensive applications. Failing a technological breakthrough in battery technology, fuel cells are likely to play a

significant role in heavy-duty trucking applications in the region over time. Hydrogen / diesel co-combustion technology can also provide a transitional technology option in the near term as FCEV commercial rollout is advancing.

5. There is a unique opportunity for Marine applications in the region, but driving change in that sector will be challenging and is not expected to lead hydrogen adoption

The marine sector is of particular interest in the Maritimes due to its cultural and economic importance in the region. While it only represents 4.2% of the overall transportation sector GHG emissions, it presents a bigger challenge in terms of decarbonization compared to land-based transport using other low-carbon energy vectors such as direct electrification with batteries, posing an opportunity for hydrogen to close the gap.

The study looked at potential for ferries, tugs, and fishing vessels, and ferries show the most promise for hydrogen. In comparison to battery electric technology, hydrogen is well suited to vessels that travel longer routes, have high energy requirements, and shorter duration opportunities for refueling that make charging batteries operationally difficult. Ferries also travel on predictable routes which simplifies fueling logistics and infrastructure requirements.

There are no initiatives in the region currently creating pull for zero-emission options. The ferries in the Maritimes are primarily owned by government (Transport Canada, crown corporations, or provincial Departments of Transportation and Infrastructure) but are operated by private industry. The purchasing process for ferries is an important factor to consider, as the procurement process can take years and is largely influenced by government policies. Two ferries (*MV Holiday Island* & *MS Madeleine*) are planned to be replaced over the next few years, and one of these could be targeted for first introduction of hydrogen as a marine propulsion fuel. One of the big challenges for the marine sector is the long lifetime of the vessels – sometimes greater than 50 years. To make significant progress toward Canada's and the International Maritime Organization's (IMO) 2050 emissions reduction goals, pilot projects should be considered as soon as possible in order to demonstrate feasibility as the rest of the sector looks to replace the fleet between 2030 and 2050.

6. Hydrogen as a feedstock for low-carbon fuel production will drive demand and development of supply in the near- and mid-term

Saint John, New Brunswick is home to Canada's largest refinery operated by Irving Oil. Irving already uses significant amounts of hydrogen in upgrading processes in the refinery, and they have started to take steps to reduce the carbon intensity of feedstock hydrogen to lower the carbon intensity of conventional liquid fuels like gasoline and diesel. The federal Clean Fuel Standard (CFS) which is designed to reduce Canada's greenhouse gas emissions through the increased use of lower-carbon fuels, is expected to come into force for liquid fuels in 2022. This anticipated regulation will drive fuel producers like Irving to continue to develop lower CI hydrogen pathways for their refinery feedstock as a compliance pathway. Establishing an increased supply of low CI hydrogen as a feedstock for the refinery can benefit the broader hydrogen sector, through development of lower-cost at-scale production of hydrogen.

Energy companies like Irving can play a financing role with project developers, as CFS credit deficits from conventional fuel production can be offset through purchasing credits generated through hydrogen projects where it is used as a transportation fuel. This has been an effective mechanism in British Columbia where the provincial Low-Carbon Fuel Standard (BC-LCFS) has been instrumental in establishing the network of hydrogen fueling retail stations for light duty vehicles. Energy companies can also generate credits via hydrogen themselves should they choose to produce low CI hydrogen as an alternative fuel.

Longer-term, liquid synthetic fuels will complement pure hydrogen as a fuel where energy density shows preference for liquid fuels or where conversion from lower efficiency internal combustion engines (ICE) to higher efficiency fuel cells is not practical or economically competitive.

7. The largest potential demand for hydrogen by 2050 is expected to be for heating, and natural gas distribution networks and new hydrogen pipelines can be the most effective delivery option

Hydrogen and renewable natural gas (RNG) can be used as a substitute for natural gas in the grid. However, the supply of RNG is limited by feedstock availability, thus limiting the potential to incorporate a large amount into the grid. The Maritimes are a particularly attractive region for hydrogen blending in the natural gas grid because the infrastructure is relatively new and primarily based on polyethylene piping that is compatible with hydrogen, so implementation is easier. Moreover, the gas distribution system is relatively small compared to other provinces; incorporating even a small amount of hydrogen will move the needle toward reaching GHG emission reduction targets, and there is potential to future proof to enable pure hydrogen regions as the grid grows.

With electricity delivered in the region being relatively high carbon emitting, there is strong potential for electricity and natural gas utilities to work collaboratively to develop regionally optimized integrated energy systems with hydrogen as the carbon free energy vector connecting the two. Utilities of the future may have blurred lines with a focus on energy rather than a single commodity.

8. Successful adoption of hydrogen will depend on a regionally coordinated effort

The Maritimes is a small yet diverse region. Hydrogen presents an opportunity for the Atlantic Provinces to coordinate efforts and align policy when planning for a net-zero future, and the success of hydrogen adoption depends on it. Coordination is needed to align policies and regulation, as well as develop common codes and standards to facilitate deployments and trade across provincial boundaries. Including hydrogen for consideration in the Clean Energy Roadmap for individual provinces as well as in a common integrated roadmap for the region would be a concrete step to align actions and policies.

A joint interprovincial hydrogen working group that is tied into the federal Strategic Steering Committee for hydrogen to be led by Natural Resources Canada (NRCan) would be an effective way to work together on a go-forward basis. Through joint development and sharing lessons learned, as well as hard infrastructure assets where appropriate, a more cost-effective introduction of hydrogen can be achieved. This will provide benefit for the region which has invested so heavily in renewables on a per capita basis and continues to struggle with regional energy poverty.

9. Enabling policies and regulations are needed to drive action

Successful deployments of hydrogen have been in regions with a combination of supporting policies and regulations. The Maritimes currently lacks concrete regulations and complementary incentives needed to de-risk industry investment and drive activity in the sector. A number of specific potential policies and actions have been identified for consideration, including those that support the use of hydrogen and other low-carbon technologies, such as ZEV and renewable gas mandates combined with incentives for related infrastructure development. Policies to disincentivize the use of incumbent technologies are also encouraged, such as road taxes or creation of local emission free or combustion free zones. Policy and regulation at the federal level will help guide the way but will likely be slower than what is needed to position for successfully reaching decarbonization goals. Provincial leadership is needed, and municipalities can also play an important role.

10. Regional deployment hubs driving use at scale are needed

There is very limited rollout of hydrogen in the Maritimes region today. To realize the long-term potential benefits, regional deployments must start in the near-term. Development of the full value chain spanning from production, to distribution and storage, through to end use will need to be developed in regional hubs that can facilitate supply and demand growing concurrently at scale. Provincial and Municipal governments will play an important role in supporting local developments and contributing to end use demand, for example by being an anchor tenant with adoption of fleet vehicles or other end use applications that provide financeable demand certainty.

One of the best opportunities to drive awareness is to deploy hydrogen domestically in projects that are high profile. The Port of Saint John, which is located close to the Irving Oil Refinery and hosts multiple end use equipment types that could be converted to hydrogen, and the City of Halifax, have been identified as two promising locations worthy of further study.

11. Established industry and utilities will play an important role

Utilities in the Maritimes are already leading the way in exploring opportunities for hydrogen and understanding the role it can play in solving problems and growing market share in a carbon constrained future. Both natural gas and electric utilities are anticipated to be champions for early demonstration projects, and longer-term broader adoption. Regulated utilities will face some unique challenges and must invite regulatory bodies to the table early to avoid barriers to entry. Energy companies including Irving Oil and Repsol are also well positioned to play an important role but are risk adverse and may be more focused on hydrogen's role in lowering CI of conventional fuels in the near-term.

12. Economic growth and job creation can be realized through fostering a hydrogen cluster approach, Innovation Hub, and supporting local deployments

The supply chain for hydrogen in the Maritimes will evolve as the sector grows and as competition enters the industry and as more services and differentiated production pathways are added. At the same time, the global supply chain will be evolving at an accelerated pace and certain roles and functions will be

integrated, consolidated, and commodified by large outside players. It will be important for the Maritime Provinces to build out the supply chain for hydrogen in a deliberate and integrated way to form a critical mass of companies, academic institutions, talent pools, and related services. The cluster approach to industrial development has been successful in many regions around the world including Northern Italy for the textile industry, South Korea for steel production, and South-western Germany for precision manufacturing and may work well for the Maritimes as a new hydrogen economy is developed.

The Maritimes have a long history of resource extraction and other heavy industry, road/rail/marine transport, shipbuilding, and international trade. There are also many opportunities for organizations, skilled technicians, academic institutions, and other local services to pivot and/or participate in the hydrogen supply chain. There are several gaps in the supply chain where local players currently do not operate or are not well suited to transition to hydrogen. These areas will be filled by local product and service providers if they can find innovative ways to operate and stay competitive.

There are a number of innovative start-ups in the region with a focus on hydrogen production technologies. There are also activities in adjacent sectors like nuclear small modular reactors (SMR) that are complementary to hydrogen. Creating a cluster approach to encourage collaboration and consortium-based projects in the region will position the sector for long-term success.

13. The next 10 years should be focused on domestic use rather than export due to supply limitations

While the Maritimes region is strategically located close to several large potential demand markets for hydrogen, it is unclear at this time whether there will be sufficient production capacity for low-carbon hydrogen to satisfy both domestic requirements and export markets.

The region currently relies on imports to meet energy needs, and acts as a gateway for liquid natural gas (LNG) imports converted to natural gas and exported to the Eastern US market. Ultimately there could be potential to transition this export channel to provision of low CI hydrogen rather than natural gas, continuing to use imported LNG as the feedstock and leveraging the region's CCUS potential, or by leveraging other local pathways for producing low CI hydrogen, or most likely some combination of the two. With Europe looking to import large quantities of hydrogen as they move to net zero, the Maritimes could also act as Canada's export gateway to that region. This approach would require infrastructure to transport hydrogen from high capacity, low cost production regions to a port hub, and would also require liquefaction or hydrogenation processing capability as well as bunkering capacity. This is a concept that warrants further study and discussion with European counterparts.

It is recommended that potential for export be considered secondary to first establishing a domestic market for hydrogen that can benefit the region in meeting decarbonization goals, and longer-term position for export.

14. Challenge of being a small region can be turned into an advantage

The Maritimes is a small region in the context of national energy use and economics. This can be both a challenge and advantage in embarking on transformation of energy systems. The federal government will

be looking to support lighthouse projects and regional deployment hubs as the *Hydrogen Strategy for Canada* moves into the execution phase. Being a small region, the size of deployments needed to make a significant impact are more manageable. As a small region, industry players are well acquainted and used to collaboration. Certain aspects of the energy system, such as the fact that the natural gas network is reasonably new and positioned for growth, position the region to lead in bold strategies to adopt hydrogen. The key will be finding local champions to develop integrated projects.

15. In a transformative scenario, hydrogen can make up 22% of delivered energy in the Maritimes by 2050, contributing to 6.5 Mt-CO2e emissions reduction or 21% of the region's overall GHG challenge.

In a transformative scenario in which the Maritimes is successful in transitioning to a net-zero carbon energy system by 2050 and adoption of hydrogen technology is aggressively driven by a strong policy and regulatory environment, hydrogen's decarbonization potential shows the greatest opportunity in the following areas:

- As a fuel for electricity production, contributing to decarbonization of the electricity grid through displacing power generation that is today reliant on natural gas and coal
- By providing heat for buildings/industry and replacing natural gas as a feedstock for industry through displacing combustion of carbon emitting natural gas or fuel oil with non-carbon emitting hydrogen
- As a transportation fuel in fuel cell electric vehicles, that are zero-emission at the tailpipe and are double the efficiency of internal combustion engine vehicles

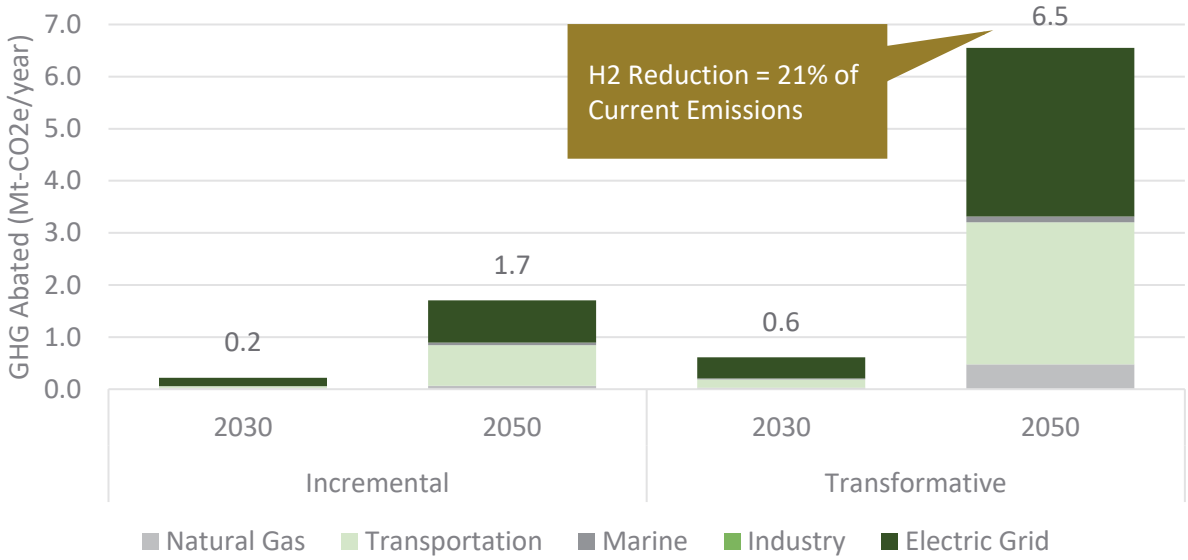

Figure 1 – GHG emissions reduction potential from hydrogen 2030 and 2050

The size of the opportunity is significant, and hydrogen is seen as an essential carbon-free energy vector in the Maritimes future 2050 energy mix.

Recommendations

A number of detailed recommendations are provided throughout the study to drive adoption of hydrogen in the region. Broader recommendations focused on closing near-term knowledge gaps relating to economic and technical challenges, as well as provide actionable next steps to move into the deployment phase, are broken into seven theme areas. These generally align with recommendation pillars in the federal Hydrogen Strategy for Canada that is under development, as ultimately coordination and alignment with national efforts is an important lever for success. The recommendation themes are as follows:

Theme 1: Strategic Partnerships
1. Develop regional working group to align provincial approaches to developing hydrogen sector.
2. Encourage leading industry players to participate in national strategy working groups in relevant sector – e.g. utilities, low-carbon fuel producers, emerging transportation.
Theme 2: Hydrogen Awareness
1. Include hydrogen in provincial and regional integrated Clean Energy Roadmap.
2. Support hydrogen outreach initiatives.
Theme 3: Infrastructure and De-Risking of Investments
1. Initiate studies to determine options and magnitude of investment for hydrogen infrastructure build out, both in individual provinces and as a regional approach.
2. Implement policies that support demand for zero emission and low carbon alternatives, as a mechanism to de-risk private sector investments.
Theme 4: Innovation and Hydrogen Cluster Development
1. Foster collaborative efforts between industry and academia by supporting consortium-based projects for fundamental research priority areas important to the region.
2. Form Maritimes chapter of Canadian Hydrogen and Fuel Cell Association or like industry association to encourage regional cluster development.
Theme 5: Codes and Standards
1. Adopt Canadian Hydrogen Installation Code and like standards to facilitate new technology and infrastructure adoption in early markets.
2. Develop and adopt common standards and practices across the region to facilitate inter-provincial trade.
Theme 6: Policy and Regulation
1. Ensure regional policy framework developed to meet decarbonization targets does not unintentionally preclude hydrogen as a pathway for compliance through narrow definitions.
2. Establish policy frameworks that provide long-term certainty for the sector and that are technology-neutral, performance-based, and non-prescriptive.
Theme 7: Regional Deployment Hubs
1. Identify champions and hosts for regional deployment hubs.
2. Provide support for feasibility studies to advance projects from conceptual to implementation phase.