CANADIAN GAS ASSOCIATION
ASSOCIATION CANADIENNE DU GAZ

Enabling Higher-Hydrogen Blending in the Natural Gas Distribution System

Global Technology and Market Scan Summary Report for Distributing Hydrogen at >5% into Natural Gas Energy Distribution Systems

Canadian Gas Association **October 2022**

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A SUSTAINABLE FUTURE

As society transitions towards a cleaner and more sustainable future, it is vital to consider all available energy solutions and pathways, particularly those integrating low-carbon and renewable sources. Renewable sources, such as wind and solar, promise the delivery of energy with little or no operational carbon emissions. However, the intermittent nature of these sources requires a resilient and dependable backbone network of distribution and storage to ensure the ongoing health and safety of Canadians.

The ultimate objective of the natural gas industry's hydrogen evaluation work is to increase the industry's understanding and to facilitate the safe, effective blending of hydrogen into natural gas streams. This objective must continue to uphold the industry's overarching commitment to the safety and security of its consumers, the public and its workers.

HYDROGEN AT THE FORE

One of the most significant low-carbon and renewable energy distribution and storage options is the utilization of hydrogen as an energy carrier and storage medium. Globally, hydrogen is emerging as one of the most significant opportunities to decarbonize energy systems. Canada has a competitive advantage in leveraging its abundant renewable and low-carbon resources to economically produce hydrogen at scale. The modern natural gas system offers benefits for hydrogen adoption in terms of bulk energy transportation capacity, long-term energy storage and supply resiliency.

FROM LESS THAN 5% TO GREATER THAN 5%

The natural gas industry is committed to increasing the availability of low-carbon and renewable and alternate energies in North America. In 2017/2018, the American Gas Association's (AGA) Operations Section Managing Committee and the CGA's Standing Committee on Operations and Safety jointly produced an **Information Summary Report** on the **Blending of Hydrogen into Natural Gas Delivery Systems** at less than or equal to 5% (≤5%). This 2022 CGA hydrogen study begins where the previous AGA/CGA study concluded, i.e., the blending of hydrogen into natural gas streams at greater than 5% (>5%).

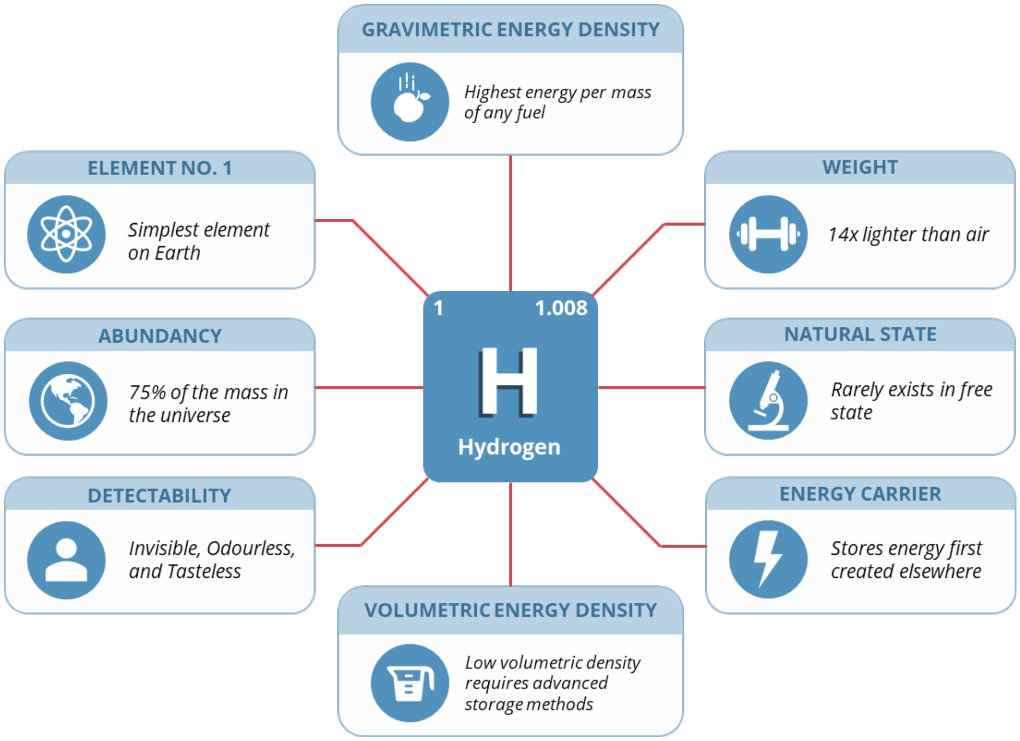
Within this study, the different considerations and the potential impacts of hydrogen use in the natural gas system at between 5% and 20% are assessed in detail. This study is intended as an information source for organizations considering how to build a future where natural networks are a viable low-carbon and renewable energy supply option. This study also contains a scan of the growing development and use of hydrogen in global markets.

LEVERAGING EXISTING NATURAL GAS INFRASTRUCTURE

The integration of low-carbon and renewable hydrogen, along with renewable natural gas (RNG), offers the natural gas pipeline sector the ability to maintain and extend its technical and economic benefits across the economy. The natural gas infrastructure of today can be used to transport, store, and distribute a more complex and variable mix of gases in the near- to medium-term future. The composition of gases in the network will increasingly include RNG (co-produced with hydrogen), and blends of traditional methane natural gas and high volumes of hydrogen. In the future, there is the potential for 100% conversion of pipeline systems to hydrogen.

hydrogen fuel or as part of a fuel blend with natural gas and other renewable gases.

PRODUCTION OF HYDROGEN



Low-carbon intensity hydrogen is produced through three main pathways: electrolysis of water with low-carbon intensity electricity, autothermal reforming (ATR) and steam methane reforming (SMR) of natural gas with integrated carbon capture, utilization, and storage (CCUS). Additionally, new production methods are emerging like advanced thermal cracking of methane where the carbon is separated from hydrogen as a solid. When produced using low-carbon upstream feedstocks or by managing the by-product carbon dioxide downstream, hydrogen can be used as a scalable, low-carbon, or carbon-free, energy carrier. Just as important, the potential exists for it to be delivered to Canadian consumers via natural gas infrastructure that is already in place for over 7.25 million homes, businesses, hospitals, institutions & industries. It can be delivered to these end users as a dedicated

The use of electrolysis for the production of hydrogen can also be a mechanism that helps balance electric power systems. This occurs where electrolysis provides an interface between the electricity system, which must be balanced in real time, and the pipeline networks, which could offer a variety of ancillary services including long-duration, seasonal energy storage. Using off-peak, or surplus, electricity to produce hydrogen can offset conventional carbon-based fuels directly in appliances. Alternatively, the hydrogen can be stored and then be used to displace conventional fuels that would otherwise have been required such as on-peak dispatch of natural gas power plants. In effect, natural gas infrastructure can facilitate increased growth of solar and wind energy supplies when converted to hydrogen for blending with natural gas. The result is improved feasibility for intermittent energy supplies so they become a more predictable energy supply for consumers where hydrogen can be stored in natural gas infrastructure for seasonal balancing.

HIGHLIGHTS AND KEY CONCLUSIONS

This report indicates there is a justifiable and feasible technical pathway for the blending of hydrogen in the natural gas distribution infrastructure. Hydrogen can serve as means of reducing the carbon intensity of natural gas and reducing the carbon dioxide (CO_2) emissions from end-use appliances. As more information on global best practices is gathered, it is becoming clear that a step-wise approach to gradually increasing the hydrogen composition in natural gas should be considered. Significant work is underway to safely integrate hydrogen, and the next-generation RNG supplies that co-produce hydrogen, into the natural gas transmission and distribution systems and in end-use appliances.

- The consensus from this report's aggregation of the various studies and projects, finds that the industry's metering technologies can support up to 10% hydrogen blends, and confidence is building for measuring 20% blends with existing metering technology.
- Overall, a natural gas distribution system that is 'leak tight' will remain 'leak tight' with hydrogen.
- Additionally, 'selective leaking' of only hydrogen from hydrogen blended systems is not a phenomenon found within natural gas distribution systems.
- Technically, there are no known chemical incompatibility issues of note between hydrogen and the odourising compounds commonly used in natural gas. Hydrogen should therefore have no deleterious interaction with odourants.
- Major gas turbine manufacturers such as GE, Siemens, Solar, etc. are committed to not only having new electricity powerplant turbines 100% hydrogen compatible, but their objective is to provide a technical pathway for the existing legacy turbine fleets to also be upgraded to this capability.
- End-use equipment and appliance manufacturers can also aspire to seamless operation on fuels ranging from 0% to 20% hydrogen by volume with little or no incremental cost to manufacturing. Certification costs for Hydrogen-Ready appliances have some cost-impact today, but these certification costs are insignificant in a market where manufacturers understand that the lack of certification may preclude them from future unit sales.
- The permeability of hydrogen, through plastic (PE) pipe, is still being assessed for improved understanding, but this global scan could not identify any operating, safety or a any operating, safety or any conclusive and meaningful economic/life-cycle concerns with high-hydrogen blends in plastic distribution pipelines.
- Significantly, emerging from this global scan is the identification of a need for national, North American and global cooperation and sharing of best practices for hydrogen blending. The report summarizes the results of several diligence reviews that highlight the global work that has been completed, barriers encountered & dealt with, regulatory experiences, lessons learned, materials & component information, as well as the opportunity for improved or harmonized standards development.
- Several utilities have also suggested that opportunities exist for knowledge transfer, the development of best practices, and in-depth assessment of markets like Hawaii and Hong Kong where hydrogen concentrations of approximately 10%, and higher, are the norm. While these markets may not have extensive

gas transmission networks, their real-life operating and safety standards likely have a high degree of relevance to the distribution system materials, operations, and the performance of modern end-use appliances.

If trends continue, the historical, relatively homogeneous composition of natural gas will have increasing variability with increased RNG and hydrogen injections. The industry therefore is readying itself and signaling to stakeholders that greater flexibility in the typical composition of gas flowing through our pipelines is required.

RECOMMENDATIONS

This report includes specific recommendations across a series of technical topics. A table with key recommendations is also included in the report's conclusions. Some of the recommendations are related to the various research findings on a specific technical topic; however, several overarching recommendations are offered for the industry's consideration.

These overarching recommendations are also summarized, in a single-page, visual snapshot at the end of this document.

Overarching Recommendations Resulting from Global Scan

The preliminary scan of global hydrogen blending offers encouraging examples of projects and research that could be leveraged by utilities to close specific knowledge gaps with respect to hydrogen blending at >5% in the natural gas system. However, the earlier CGA Task Force work on *Blending of Hydrogen into Natural Gas Delivery Systems at 0%-5% by volume* identified some hurdles which become even more pronounced as hydrogen percentages increase. As a result, the following are recommended considerations for utilities to remove technical uncertainty as a means of accommodating higher hydrogen admissibility.

- The United Kingdom (UK) and Australia appear to have projects, and hydrogen strategies, that most closely align with the anticipated technical needs of Canadian utilities. It is recommended that gas utilities explore, through the CGA and other industry networks, how to participate in the technical work scope that is underway in both the UK and Australia.
- Utilities should continue to monitor specific hydrogen projects/market development activities in other nations to assess if their developments have applicability to the Canadian context. Examples include Austria's Sun Storage Project involving hydrogen storage in underground caverns as well as Germany's progress in establishing a 10% hydrogen blending accommodation with no restrictions.
- The industry should consider a specific research initiative to identify how markets like Hawaii and Hong Kong, which already operate with high-hydrogen composition in natural gas, address end-use appliance, material combability, operability and pipeline safety needs for gas containing hydrogen. These markets are too small to justify market-specific end-use appliances, etc., so their technical practices are worthy of review to understand how to support increasing hydrogen concentrations with low operational impact.
- It is recommended that Canada's gas utilities consider establishing expert panels that would

be tasked with tactical evaluations of hydrogen blending expertise occurring in different global markets. This tactical review would be with an eye to co-investing – i.e., a cost share – in the technical learnings that have occurred, or that are underway, in different markets.

- It is recommended that the natural gas industry consider how best to signal that future natural gas supplies will have more variability in the gas constituents including the inclusion of hydrogen as well as highlighting the potential benefits for developing a hydrogen-ready appliance certification to support the potential for full conversion of natural gas networks to dedicated hydrogen in the future.

Technical Recommendations Following Review of CSA Z662

CGA is aware that the CSA is undertaking significant efforts across a range of technical areas in exploring the implications of increased use of hydrogen. For example, the CSA Z662 Technical Committee has struck a task force focused on identifying changes to the CSA Z662 Standard for Oil and Gas Pipeline Systems to addressed increased hydrogen blends. Early updates to the standard will be reflected in the 2023 edition with further developments in the 2027 edition. The CGA is monitoring developments in these areas.

The initial scan of the CSA Z662 Standard for Oil and Gas Pipeline Systems has identified a single overarching detail that results in less-than-optimal clarity for engineers assessing the Standard's applicability, and any related interpretation, as it relates to hydrogen blended fuels. ***As a result, a recommendation going forward is:***

- Consider if CSA Z662 requires guidance on the applicable range for hydrogen concentrations in a gaseous service fluid that is denoted as Substitute Natural Gas and Synthetic Natural Gas (SNG). By including such clarity on the relevant range of hydrogen concentrations in SNG, technical designers and chief engineers can confirm they are interpreting the Standard's applicable guidance as it relates to pipelines conveying such service fluids. This guidance could be included in an amendment to the actual Standard.

The above recommendation is the primary finding. The Standard already applies to SNG; however, neither the Standard nor the subsequent Commentary on the Standard provides any guidance on the range of hydrogen that can be in the gas composition and still be classified as SNG. As a result, any future updates that establish this type of guidance are believed to be the most significant contributor to improving clarity for engineers and system operators when interpreting the Standard as well as regulators that apply the Standard to the activities over which they regulate.

In addition to the primary finding, several additional recommendations have been identified to improve the clarity for interpreting the Standard's guidance as it relates to the fuels having hydrogen as one of the constituents in the gas service fluid that is being conveyed by the applicable pipeline. The following are additional items for consideration that may improve the clarity for design engineers, pipeline operators, maintenance experts and regulators when assessing the Standard's requirements as it relates to gas service fluids that include hydrogen.

- Initial technical research suggests that existing odourant management practices are likely applicable for natural gas distribution that includes modest levels (up to 15%-20% H_2 by volume) of hydrogen. It is recommended that the relevant technical subcommittees assess what, if any, changes are required for odourant practices involving both natural gas – hydrogen blends as well as SNG if this is further defined under any updates to the Standard's guidance on SNG.

- Assuming the Standard or Commentary can be updated to include guidance on the applicable range of hydrogen for SNG, it will offer clarity for engineers when assessing when a "change in Service Fluid" requires an engineering assessment. If a specific range for the relevant hydrogen volume in SNG is not available some additional guidance would be appropriate to help assess what incremental hydrogen composition constitutes a change in service fluid compared to natural gas or an existing blend of natural gas and hydrogen.
- Assess and survey the growing body of research and best-practices related to hydrogen blended fuels in natural gas transmission and distribution systems. This could include pipeline applications involving SNG. This body of technical research can be assessed for its relevance to future updates of the Standard and Commentary.
- Consider if the Standard requires the establishment of a separate Subcommittee on Transmission or if other technical groups such as the Petroleum and Natural Gas Industry Systems group could expand the Standard's technical guidance with respect to SNG and higher-hydrogen service fluids in transmission systems.
- Engage the Standard's Subcommittee on Distribution to assess Section 12 of the Standard (Gas Distribution System) so as to confirm the Standard does not impart any downstream impacts or requirements on, i) the B149.1 Installation Code, or ii) impart any requirements for gas quality or consistency (e.g., Wobbe Index, Methane Number, etc.)
- Assess what, if any, requirements related to service fluids that include hydrogen sulphide may have relevance to pipelines conveying SNG (e.g., bake-out procedures)

- The Standard and Commentary include specific references to Carbon Dioxide and LPG pipelines. Consideration should be given to referencing what applicability this standard may have for pure (100%) hydrogen pipelines. At a minimum the Standard, or Appendix, could identify any interdependencies that may exist between this Standard and the Hydrogen Pipeline Code ASME B31.12-2019.
- Survey the Standard's Subcommittees involved in, i) Distribution, ii) Operations & System Integrity, and iii) Materials to identify what, if any, additional undertakings should commence to assess applicable updates to future versions of the Standard, and the Commentary, as it relates to hydrogen-natural gas blends.

Recommendations Following the Review of B149.1 Natural Gas Installation Code

It is recommended that the development of specific codes for renewable gas supplies be avoided wherever possible to ensure technician training, and code conversancy are not strained or compromised. A better approach is to identify where the development and adoption of renewable gas supplies creates a gap, or requirement for clarity, in the existing codes and standards. Then, seek to update the existing code/standard to address these issues.

- Consider how the B149.1 Natural Gas Installation Code could offer improved clarity as to its applicability for both natural gas and synthetic natural gas (SNG). Definitions for SNG could be harmonized with the same SNG definition as CSA Z662 Standard if the Standard is updated to provide a range of applicable hydrogen concentrations under the definition of SNG.

- As part of the regular code review cycle, technical subcommittees for B149.1 could include a review of global best-practices as well as engineering and technical assumptions for end-use equipment operating on hydrogen blended natural gas.
- The code should also establish clear delineation between CAN/BNQ 1784-0000 (Canadian Hydrogen Installation Code) and CSA B149.1. The CSA B149.1 code may benefit from the creation of specific hydrogen section in a similar manner to the structure of International Fuel Gas Code (IFGC).

Technical Recommendations – Odourization

The prior report on 0% to 5% Hydrogen Blending stated the existing odourant practices were suitable for hydrogen natural gas blends, so long as the fuel was used in a normal combustion process. This report's findings suggest it is unlikely that a circumstance could occur where a leak was creating an unsafe condition due to a hydrogen release without odourant being detected at 1/5th the lower explosive limit (LEL).

- Utility odourization experts should conduct a peer review of the United Kingdom's H21 and H100 hydrogen project developments involving odourization practices. A review of the Australian report "Hydrogen in the Gas Distribution Networks" by these same utility experts is thought to be informative on the subject of odourization practices for hydrogen – natural gas blends.
- Consider further investigation in Germany's real-life operations involving sulphur-free odourants to advance North American utility knowledge in this area. The investigation could better prepare utilities for high-hydrogen blends of fuel distribution and also lessen the environmental impact from current odourant practices. The use of sulphur-free odourants is also expected to support future adoption of non-combustion end-use processes such as fuel cells that operate on pipeline fuels.

Technical Recommendations – Metering

The prior CGA/AGA report on blending (0% to 5% by Vol.) found metering accuracy and suitability for hydrogen blended fuels of up to 50% with an acceptable accuracy (<2%) for the most common bellows or diaphragm meters. Other high pressure metering applications such as CNG fueling can also use mass flow meters (Coriolis type meters). The accuracy of these meters has not been found to be affected by the addition of hydrogen since mass flow is the unit measurement. Key recommendations related to metering in this study include:

- Establish a billing and compliance strategy for managing the anticipated increases in energy content variations within different segments of the natural gas transmission and distribution networks. As the strategy evolves engage Measurement Canada in updating the *Electricity and Gas Inspection Act*. The Canadian Gas Association has initiated exploratory discussions with Measurement Canada to understand what level of knowledge and engagement the government department has on the topic of hydrogen blending and to establish a joint pathway forward.
- Consider the creation of a CGA task force to establish priorities for the next-generation of smart metering and gas analysis systems. Such a task force could evaluate the ongoing technology developments in the gas

chromatography space and the opportunities for adopting smart gas sensors and analyzers to manage the future energy content variations that result from increasing RNG and hydrogen supplies.

- Accuracy requirements (e.g. +/- tolerances established by regulatory mandates like the Electricity and Gas Inspection Regulations) should be evaluated to determine if a wider variation needs to be permitted in mass-market meter applications (e.g., Residential) versus high-volume meters where economies for added metering complexity can be justified. Based on current global studies, hydrogen blends of up to 20% are expected to meet Measurement Canada's accuracy requirements for mass-market meters; however, establishing clear acceptance by Measurement Canada should be a priority.
- Monitor Canadian metering developments related to hydrogen blends. As an example, Fortis has proposed an "Advanced Meter Initiative", that if approved, would establish testing and certification procedures for the gas meters to be hydrogen-ready.
- Through the CGA's Measurement and Regulation committee work, assess the industry's modeling equations, for gas heating value, density, compressibility, speed of sound etc. to verify these equations remain relevant for increasing concentrations of hydrogen.

Technical Recommendations – Materials

Material compatibility is a key area of research for hydrogen blending above 5%. The differences between materials and systems mean this question will require a case-by-case approach; however, several key recommendations include:

- Through the CGA, establish participation within the CSA Z662 Technical Committee Hydrogen Task Force to ensure the Standard's future updates reflect the current body of knowledge on global best practices when assessing material suitability for hydrogen-natural gas blends, as well as RNG. Subcommittee participation would also seek to have the Standard provide more clarity on establishing when an engineering assessment is required because the service fluid is deemed to have changed as a result of specific concentrations of hydrogen in the service fluid.
- Consider establishing industry support for dedicated evaluation of natural gas transmission systems which is separate from any materials and operational system reviews conducted for natural gas distribution systems. The ability to engage transmission system operators in meaningful consideration of transporting blended fuels with hydrogen is believed to better assist in the removal of any technical barriers in a timely manner.
- It is recommended that Canadian utilities explore how they might access the global technical findings from past, and on-going, technical reviews through cost-share and/or research sharing agreements.
- Global research efforts typically employ pure methane as the subject gas, whereas actual gas (line gas) flowing through pipeline systems are not pure methane. They include trace elements such as butane, ethane, O2. The presence of these may inhibit hydrogen embrittlement. Therefore, it is recommended that any future investment in hydrogen embrittlement research should be done on actual line gas, as this may yield markedly different results, which may prove a significant factor for transmission systems.

Technical Recommendations – Underground Cavern Storage

Projects in Europe have demonstrated that existing gas storage reservoirs can tolerate hydrogen blends of up to 10%. Understanding the implications of long-term underground hydrogen storage will help demonstrate the viability of using power-to-gas as an energy storage method.

- Successful projects from Europe and elsewhere should be assessed by engineers familiar with Canada's different storage geology to determine if lessons learned could have applicability to Canada's unique geology.
- Consider if Canadian utilities have any operational storage fields that are sub-optimized and may offer the potential for domestic field trials for underground storage of hydrogen-natural gas blends.
- Consider the potential benefits of a Canadian consortium joining RAG Austria AG's current project which is the Underground Sun Conversion project to advance renewable gas innovation with underground (in-situ) methanation processes.

Recommendations – Improving Flexibility for Gas Turbine Operation on Hydrogen

Manufacturers producing large stationary engines and high-horsepower gas turbines are demonstrating the ability to accommodate higher-hydrogen blending. For mainline transmission compressor plants, the largest issue appears to be the increase in power demand needed to compress pipeline gas containing higher levels of hydrogen.

- Utilities may want to consider signalling that future natural gas compositions could include higher hydrogen compositions so that engineering firms and turbine suppliers can consider this at the early project planning stages.
- Survey the gas turbine industry to arrive at consistent feedback on existing and future technical capabilities for the North American gas turbine fleet operating on natural gas with hydrogen blends. This could be modeled after the "EU Turbine Stakeholder Group".
- Continue to expand manufacturer-specific surveys of hydrogen co-firing capabilities beyond GE and Siemens, particularly for the existing North American pipeline compressor fleets. Additional gas turbine suppliers active in North America include Solar Turbines (Caterpillar), OPRA Turbines, etc.
- Fast rates of change for the hydrogen composition in a gas turbine have not been found to be a concern to turbine suppliers during this initial survey. Future industry surveys should continue to gather confirmation from other turbine suppliers to confirm that rate of change on fuel composition is not a concern for any anticipated future ranges in hydrogen blending. Based on this research scan, it is suggested that rate of change in hydrogen composition should not be a high area of concern for gas utilities contemplating higher-hydrogen blends (as it relates to gas turbines).

Technical Recommendations – CNG Vehicle and Refueling Systems

CNG vehicles require several important considerations with regards to hydrogen blending. Both existing storage cylinder designs and engine designs may be affected by different hydrogen blending levels, but there are ways to mitigate these risks.

- Consider leveraging any program funding, that may be part of a National Hydrogen Strategy, to support a phased-in, Type-1 tank retirement program for CNG systems as part of natural gas grid and equipment end-use modernization. Such a retirement program may be able to be incorporated into allowable utility rate base. Regardless, the removal of these legacy assets from the gas infrastructure removes one of the most restrictive pinch points on a natural gas utility having the future flexibility to respond to market, government or regulatory requirements that seek increased renewable content in the natural gas networks.

- Monitor the SoCal / University of California (UCR) emission research using the CWI engine in applications with high-hydrogen blends. The CGA or CNGVA may want to co-fund the study if the results also provide insights into the engine maintenance impacts, if any, for operations on high-hydrogen blends. Regardless, the CWI restriction on hydrogen is an example of an OEM having limited fuel-flexibility for hydrogen blends. The limitations on fuel flexibility to accommodate hydrogen blends appears to be related to a perceived lack of market need and limited testing on hydrogen blends. If utilities provided market signals that their future natural gas composition is expected to include more gas constituent variability, including hydrogen, then end-use OEMs would consider this when establishing operational, service and warranty programs for their customers. As it stands, these OEMs are shifting responsibility to utilities for any gas composition changes that may be required to comply with future clean fuel standards, etc.

Technical Recommendations – Appliance Operations on Higher-Hydrogen Blends

Home appliances appear to be largely compatible with lower blending amounts. Significant technical due-diligence and appliance testing has been completed in various markets and by Canadian utilities. This has also included physical appliance testing on high-hydrogen blends up to 30%. Additional considerations include:

- Consider proposals to have the industry and policy makers establish a hydrogen-ready appliance certification that could be structured in a manner similar to the Energy Star certification for electrical appliances. Establishment of such a program would provide a carrot to the pro-active, natural gas appliance OEMs to differentiate their appliances. Furthermore, it would start the shift of costs and the responsibility for establishing operational performance for high-hydrogen blending. The outcome would be that utilities are not the only stakeholder tasked with the implementation burden related to establishing fit-for-purpose operations of end-use appliances on hydrogen blends that are required to support the reduced carbon intensity for pipeline fuels.
- Look for market catalysts, like the introduction of next-generation natural gas heat pumps, to also advance consumer awareness of the benefits of purchasing next-generation natural gas equipment that could also incorporate hydrogen-ready operations. A survey of the natural gas heat pump OEMs suggests these appliance manufacturers are already considering how hydrogen-ready branding could differentiate their products, and their embracing of this certification would put pressure on legacy natural gas appliance OEMs to follow.
- It is recommended that future technical diligence reviews for hydrogen blending be streamed into two categories. The first, and most realistic early adopter opportunity, is for higher-hydrogen blending (5% to 20%) in the natural gas distribution grid including end-use appliances. The second category would validate the medium-term opportunity to accommodate higher-hydrogen blends in Canada's natural gas transmission network and the unique end-use operations linked to the country's transmission networks. This focused review of different asset classes (transmission and distribution) is also being practiced in Australia based on the country's National Hydrogen Strategy.

CONCLUSIONS - CGA STRATEGIC OVERVIEW FOR HYDROGEN BLENDING ACTIONS & RECOMMENDATIONS

To enable higher hydrogen blends in our natural gas networks, eleven different priority areas have been identified for the natural gas industry's consideration with various proposed timeframes from immediate to longer term.

The **primary recommendation** is to build-out a hydrogen admissibility plan, and for progress to be made in nine specific areas during the 2022 through 2025 timeframe.

The **second recommendation** is to seek government and regulatory policy support for Grid Modernization Programs. In the electricity industry, past smart grid programs have evolved into Grid Modernization Programs to enable the higher penetration of renewable energy within the nation's electricity grids. The programs addressed a variety of infrastructure developments to support new capabilities. These included the accommodation of more distributed resources, improve metering capabilities, new technology deployments and support for the utilities and standards organizations to embrace new processes that support the growth of renewable energy while maintaining or improving system reliability. The same Grid Modernization Program thinking can be leveraged to support the natural gas industry's growth, which also includes integrating similarly distributed resources, to accommodate higher hydrogen levels in the natural gas networks and by extension grow the renewable energy mix in the nation's pipeline networks.

Nine additional priority areas are identified including - standards and code updates, gas metering improvements and strategies for utilities to engage the industry's material suppliers, equipment manufactures, regulators and customers in preparing for a future where hydrogen is increasingly included as a component of natural gas supplies.

These priority areas are depicted in Table 1 – Key Recommendations and Actions and are elaborated upon throughout this report.

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Table 1 - Key Recommendations and Actions

#	Area	Recommendation	Timeframe and Notes
1.	**Build out CGA's Hydrogen Admissibility Plan**	Establish guidance for enabling wide-scale hydrogen blending in small (≤5% by Vol) but increasing concentrations (>5% by Vol). The objective is to establish well-researched, engineered and step-wise methodologies to enable hydrogen blending while minimizing the requirement for network-specific engineering assessments at each injection node. Such an action plan could then be used to highlight the benefits for governments and regulatory bodies in supporting pipeline system modernization for improved flexibility in transmitting, distributing and storing renewable pipeline fuels.	**Medium-Term** **(2022-2025)** Note that some utilities suggested that such admissibility plans may benefit by focusing on large gas users (e.g., power plants) where high hydrogen concentrations could be engineered as "fit-for-purpose end-use" while still supporting a wider market transformation strategy
2.	**Grid Modernization[1] to Support Higher-Hydrogen Blending**	Establish consensus amongst CGA members in identifying global collaborators for modernizing the pipeline networks. This would include a review of peer-utilities to establish best practices in the area of high-hydrogen blending. The objective is to lessen the individual utility member costs involved in increasing the operational capabilities to deliver natural gas with higher-hydrogen concentrations. By establishing cost-share agreements and sharing of best practices with peer utilities and government funders, the capabilities of CGA members can be accelerated with less budget impact. Energy regulators should be educated on the benefits of supporting utility investments in this area.	**Short -Term** **(2022-2023)** Note that utility feedback also identified an interest in expanding the Grid Modernization activities to include modernization of end-use appliances and applications (e.g., NGV infrastructure) so as to achieve more flexibility on accommodating renewable gas compositions.
3.	**CSA Z662-19 Standard for Oil and Gas Pipeline Systems**	Assess how the Standard's Technical Committees could establish range guidance on the applicable hydrogen concentrations in a gaseous service fluid that is denoted as Substitute Natural Gas and / or Synthetic Natural Gas (SNG). By including such clarity on the relevant range of hydrogen concentrations in SNG, technical designers and senior engineering staff can confirm they are interpreting the Standard's applicable guidance as it relates to	**Short-Term** **(2022-2023)** Range Guidance as a % by Vol. is likely suitable for Distribution Systems with lower material stresses. For Transmission systems, it was suggested

[1] Over the last two decades governments have extended significant "Grid Modernization Funding" to the electricity sector to accommodate increased supplies of renewable energy and increasing the pipeline network capabilities for higher-hydrogen blends is a similar infrastructure modernization program to accommodate fuels with lower carbon intensities. Early findings within this global scan suggest both the United Kingdom and Australia are likely market collaborators with Canadian utilities.

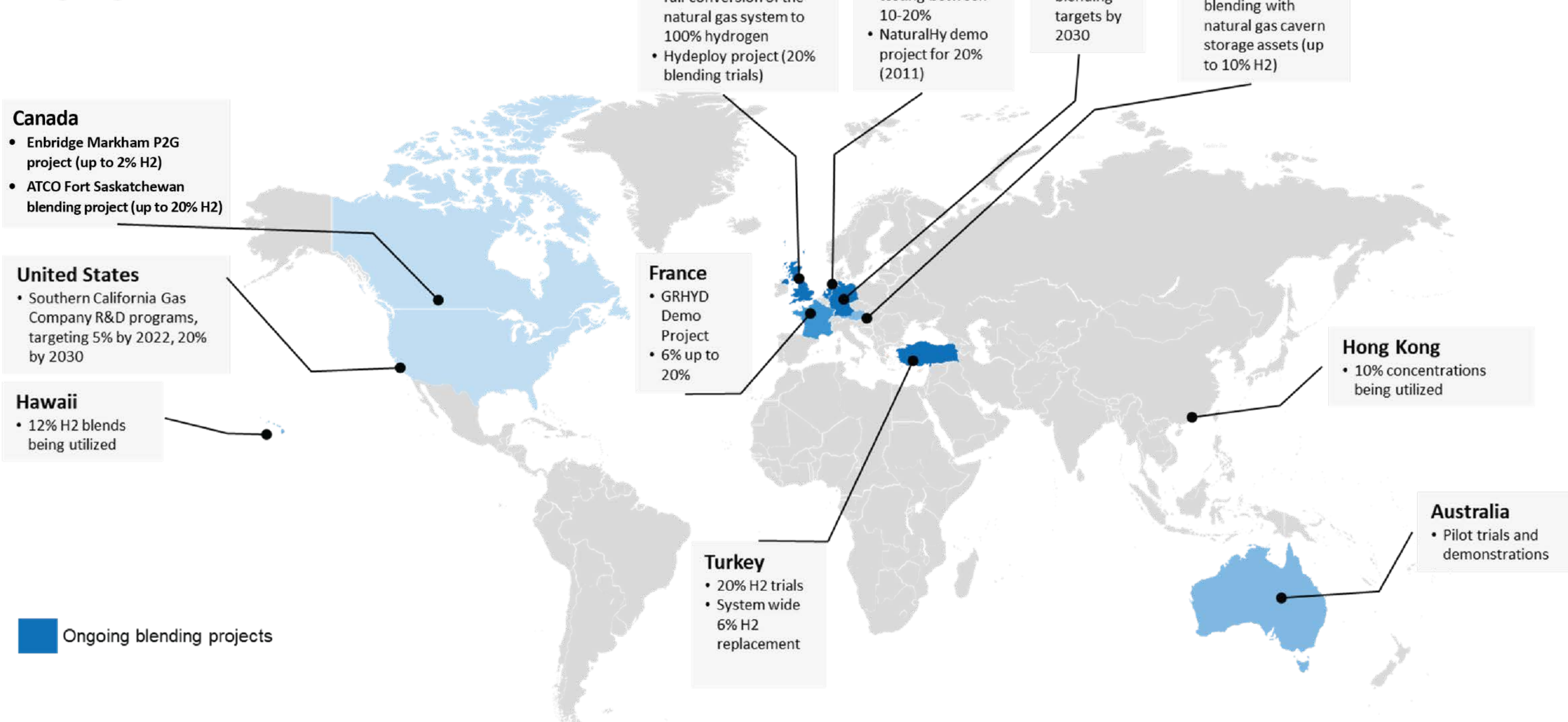
		pipelines conveying such service fluids. Input into this process could be via the current CSA Taskforce activities that seek to identify the necessary updates to the CSA Z662 Standard for 2023. Recommended guidance could exist in the form of a clause note, or use of non-mandatory language, directly in the standard.	that guidance around the allowable "Partial Pressure of Hydrogen" may improve design criteria
4.	**Provide Market Signals for Increasing Hydrogen Content in Natural Gas**	Using range guidance on blend levels, establish a timeline for the growth of hydrogen as a constituent in natural gas (e.g., hydrogen content if defined in CSA Z662 definitions for SNG). This could have progressive milestone dates such as 2025, 2030 and 2040 where the natural gas industry would seek to support operational capabilities "up to" specific concentrations of hydrogen with no restrictions.	**Medium-Term** **(2022-2025)**
5.	**Harmonize the B149.1, 2020 Installation Code with Clarity on Hydrogen-Natural Gas Blends**	Prior to the next code update cycle, work with the technical subcommittee members to ensure that the upcoming code revisions establish clarity on the B149.1 Installation Code's applicability to SNG (as defined in CSA Z662, etc.). Establishing such clarity will assist subcommittee members, installers and appliance manufacturers in accounting for hydrogen as a constituent in natural gas when assessing code applicability and future evaluations of global best practices. This subcommittee work could run in parallel with the taskforce review of the CSA Z662 Standard, or a separate technical working group could be established for the B149.1 Installation Code.	**Short-Term** **(2022-2023)**
6.	**CGA participation on the Materials Technical Subcommittee for CSA Z662**	Through the CGA, establish participation within the CSA Z662 Materials Subcommittee to ensure future updates to the Standard reflect the current body of knowledge on global best practices when assessing material suitability for hydrogen-natural gas blends. Consider if the Standard may provide additional clarity on establishing when a service fluid in a pipeline is deemed to have been changed through the addition of hydrogen or an increase in concentration. A change in service fluid would necessitate an engineering assessment.	**Immediate** Additionally, the industry may benefit by establishing a process to support "Management of Change" with respect to evolving hydrogen competencies
7.	**Develop a Strategy for High-Pressure Pipeline Systems;** **Identify Unique Technical Considerations that are**	Consider establishing a separate stream of work, or Technical Working Group for natural gas transmission systems is required due to the unique material use, operating pressures, system cycling, etc. This work scope would be differentiated, where required, from the engineering and safety assessment work that is	**Immediate** Note that CSA Z662 has formed a single hydrogen and renewable gas taskforce to assess what changes are needed in the Standard. As an alternative to creating

	Specific to Transmission & High-Pressure Distribution System Suitability for Hydrogen-Natural Gas Blends	focused on natural gas distribution systems. As an example, British Columbia is establishing the BC Hydrogen Feasibility Study, where the Transmission, Distribution and behind-the-meter assets classes will be assessed separately but with a common end-state vision. Opportunities to share best practices learned from this type of activity should be explored to lessen the industry's cost of attaining proficiency across the operational and safety-related objectives.	separate Technical Work Groups for transmission and distribution systems, consider creating an industry backed project to compare the existing requirements of CSA Z662 against other references such as ASME B31.12 Hydrogen Pipeline Code.
8.	**Gas Metering, System Monitoring of Hydrogen Levels and Gas Detection Devices**	Through the CGA, engage Measurement Canada in establishing a smart gas measurement framework (or other suitable regulatory/rate constructs) to account for increasing variability in the energy content of natural gas due to the increasing levels of RNG and hydrogen that are expected in the future natural gas networks. This may require updates to the Electricity and Gas Inspection Act. It will also require the CGA to engage with its members to prioritize the development of specific technologies and/or system procedures to understand real-time changes in the energy content for gas distribution nodes and large customer / custody transfer locations. Verification of the performance for gas detection technologies used with hydrogen-natural gas blends will also be needed to ensure operational procedures remain safe when purging networks, etc. for gas that contains higher levels of non-carbon constituents.	**Short-Term** **(2022-2023)**
9.	**Expanded Regulatory Framework**	As part of the sustainability objectives, emission compliance measures and regulatory obligations that are being imposed on natural gas utilities, seek an expanded regulatory framework for hydrogen asset ownership and operation by natural gas utilities. Current legal and regulatory frameworks may limit the ability for natural gas utilities to own / operate assets involving hydrogen. Ensure CGA members have the optionality to expand their service models to include a wider range of gas supplies and leverage the process/operational safety benefits the utilities have to secure support for an expand the regulatory framework.	**Medium-Term** **(2022-2025)**
10.	**Assessing Feedstock Customers**	A technical and market assessment should be completed to understand the locations, supply infrastructure (transmission / distribution pipeline connections), and volumes of natural gas, that align with feedstock customers. The majority of feedstock customers are assumed to be transmission-connected, but this needs to be confirmed and the distinctions need to be understood. Transmission networks will invariably have a longer timeline for the	**Medium Term** **(2022 to 2025)** CGA member feedback suggested the nearest-term opportunity to assess feedstock customer solutions may be LNG facilities in BC, and it is noted that

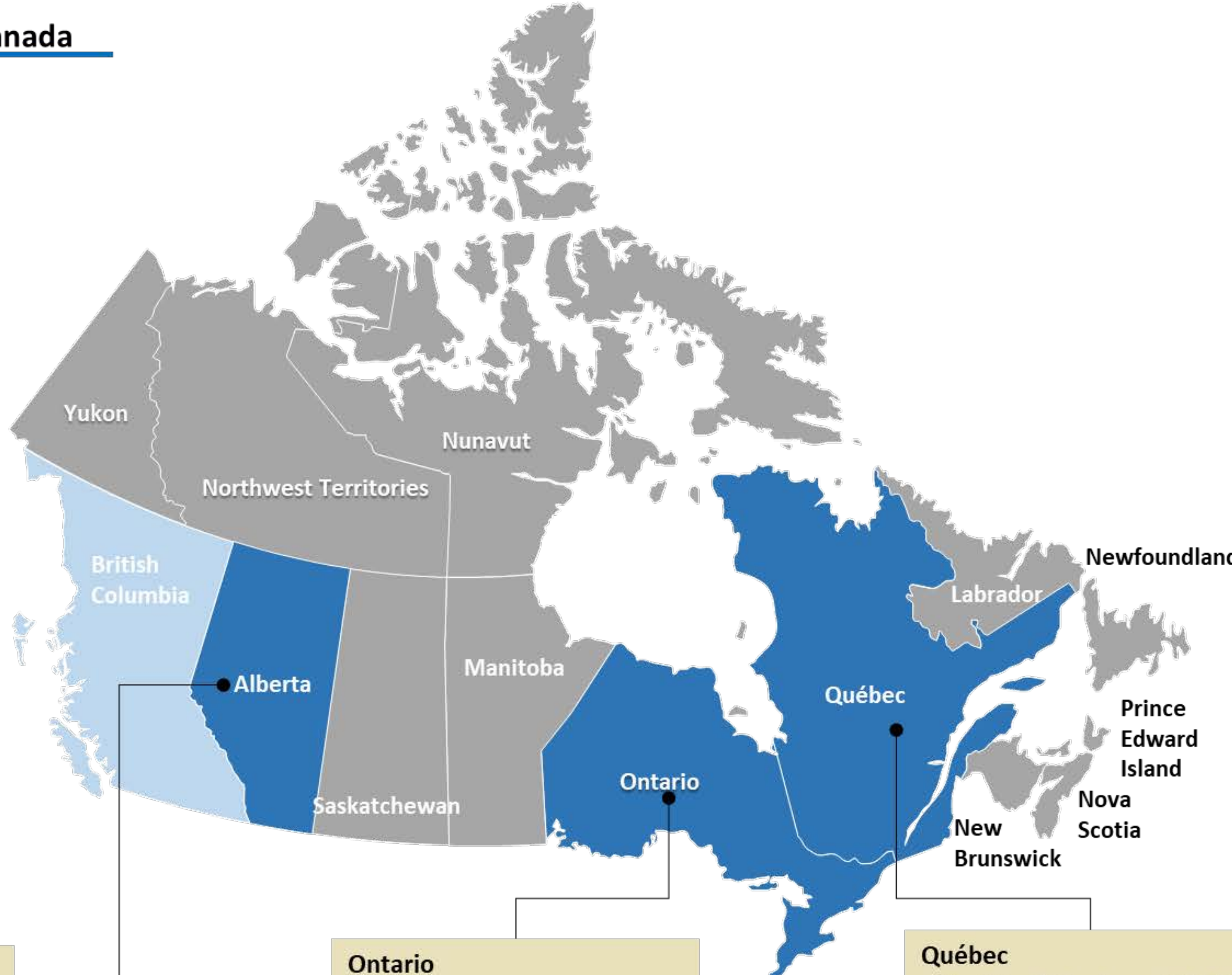
		adoption of higher-hydrogen blends; however, work should start soon so as to understand if utilities might economically integrate hydrogen removal systems as part of the large-volume, customer metering station as a rate-base investment.	the CGA has also fielded extensive interest in this topic from the chemical and fertilizer associations in Canada.
11.	**Dedicated Hydrogen Transmission, Distribution and End-Use**	Consider establishing a CGA member task force to identify priority areas (technical, operational, legal, regulatory, etc.) that improve the utility's operational capabilities and eligibility to provide dedicated hydrogen services with respect to the production, transmission, storage, distribution and end-use adoption. Examples would be hydrogen metering capabilities, dedicated hydrogen micro-grids for community energy systems and next-generation pipeline design for transporting hydrogen (e.g., repurposing existing pipelines for hydrogen service, evaluating role of composite materials, etc.). Task force priorities would also include establishing a pathway for adaptive end-use technologies where hydrogen-ready certification of natural gas appliances could be established.	**Medium to Long Term (Beyond 2025)** CGA Member Feedback suggest that Legal and Regulatory relief, to pursue hydrogen related activities, should be the first priority starting as early as 2022

IMMEDIATE	NEAR – TERM (2022 – 2023)	MID – TERM (2023 – 2025)	LONG – TERM (2025 & BEYOND)	Notes
		Establish a Hydrogen Admissibility Action Plan		Guidance for enabling wide-scale hydrogen blending in small (≤5% by Vol) but increasing concentrations Establish well-researched step-wise methodologies to enable blending
	Grid Modernization Programs to Support Higher H2 Blending			Establish consensus amongst CGA members in identifying global collaborators for modernizing pipeline networks
		Signal to Market Increasing H2 Content in Natural Gas		Establish timeline for the growth of hydrogen as a constituent in natural gas
		Assessing Feedstock Customers Needs		Understand customers process sensitivity
Support the CSA Z662 Materials Subcommittee				Through the CGA, establish participation within the subcommittee to To ensure adoption of global best practices for H2 blend material suitability
	CSA Z662-19 Standard for Oil & Gas Pipeline Systems			Technical Committees establish range guidance on the applicable hydrogen concentrations
	Harmonize B149.1 Installation Code			Establish clarity on codes applicability to H2 Blends
	Gas Metering & System Monitoring of Hydrogen Levels (Smart Gas Metering Framework)			Engage Measurement Canada to establish a smart gas meter framework 1. New systems for energy-content billing 2. Improve energy literacy
		Expanded Regulatory Framework		Future-proof utility model for H2 blends & 100% H2 services to consumers
Develop Strategy for High Pressure Systems				Gap analysis for H2 blends in transmission
			Dedicated Hydrogen Transmission, Distribution & End use	

Highlights of the Global Scan



Hydrogen Blending Activity in Canada



- Ongoing Blending Projects
- Established Blending Policies

Alberta
- ATCO Fort Saskatchewan Blending Pilot

Ontario
- Enbridge Markham P2G project

Québec
- Gazifére & Evolugen 20 MW electrolyzer blending project

Natural Gas Distribution System:
Highlight of Key Areas Impacted by Hydrogen Blending