GIVING
DATA
MEANING

Assessing Western Canada's readiness to compete in an emerging hydrogen economy

About GDM Pipelines

GDM Pipelines is the industry leader in providing comprehensive pipeline, facility, midstream and transportation information to the North American Oil and Gas Industry.

Based in Calgary, Alberta, and in operation since 1997, GDM Pipelines offers a broad range of information and services and is the only source for accurate and complete Canadian oil and gas infrastructure data.

For more information about GDM Pipelines, please visit gdm-inc.com.

GIVING DATA MEANING

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Climate change. It is impossible to ignore.

Around the world, countries are looking for ways to reduce carbon emissions to comply with environmental regulations and to strengthen the global response.

In Canada, this includes a commitment to reducing greenhouse gas (GHG) emissions by 30% by 2030, and a further plan by the federal government to achieve net-zero emissions by 2050. As we try to navigate these new regulations and transition to low carbon energy sources, hydrogen is emerging as an equivalent alternative to traditional fossil fuels due to its high energy content and potential for zero carbon emissions when consumed to produce energy.

So, moving further into a hydrogen economy seems like a logical next step for an industry that is in a state of transition, and for a country that is intent on reducing emissions.

As the experts in collecting and maintaining information about Western Canadian oil and gas infrastructure for more than 20 years, GDM Pipelines has begun the process of assessing the potential for current infrastructure to transport hydrogen as we move toward the transition to a hydrogen economy.

Through analysis using our proprietary database, as well as consultation with industry experts and engineering professionals, we have looked at existing infrastructure, processes, technologies, and resources needed to make this happen.

The Transition Equation

For the transition to a hydrogen economy to occur, four elements are required:

Source

A viable resource for hydrogen production

Extraction

Methods of capturing hydrogen with low to no carbon emissions

Transport

Infrastructure that is capable of safe and effective hydrogen transport

Customers

End use infrastructure that can operate using hydrogen

Hydrogen Economy

Use of hydrogen as a replacement for fossil fuels

This paper will examine each of these in more detail.

Source

Sources of hydrogen are varied. At a high level, they could include water, which can be split into hydrogen and oxygen using electrolysis or solar energy, or microorganisms such as bacteria or algae that can produce hydrogen through biological processes.

And, of course, it also includes hydrocarbons. Although it might not be something that we think about often, at the root of hydrocarbons is hydrogen. This means that anywhere there are hydrocarbons, extraction of hydrogen is possible.

In Western Canada, we are fortunate to have an abundant and ideal source beneath our feet…the Western Canadian Sedimentary Basin (WCSB). But, naturally, it's about more than just having a plentiful resource. It's about what you do with that resource.

Extraction

There is a lot of talk about the different “types” or “colours” of hydrogen. These colours largely refer to the methods of extraction and the resulting carbon emissions.

Grey hydrogen is the most abundant source of hydrogen today. It is produced using fossil fuels, but the by-products include CO_2, so it is not considered to be an effective method for reducing greenhouse gases.

Blue and Green hydrogen are viewed as environmentally friendly alternatives. Blue hydrogen still involves extraction from fossil fuels, but it is done in a way that reduces carbon emissions, typically through carbon capture and storage (CCS).

Green hydrogen generally involves production of hydrogen from renewable sources such as wind or solar, although any technique that results in zero emissions would be considered green.

In Western Canada, projects are already underway to develop innovative new technologies to extract hydrogen with low to no carbon emissions. One such technology, Hygienic Earth Energy, designed to release no carbon emissions, is currently being tested inWest Central Saskatchewan by Proton Technologies.

But, even once the hydrogen has been extracted, we need infrastructure that can transport it.

Fortunately, Western Canada has an abundance of this too.

Transport

Over our decades-long history of oil and gas production in Western Canada, we have amassed an infrastructure that includes over 683,000 kilometers of pipelines, 827,000 wells, and 198,000 oil and gas facilities. And, many of these resources can be repurposed to transport hydrogen as we begin to transition to this alternate energy source.

Naturally, though, there are many factors that must be considered before we can embark on this transition.

Safety

On one hand, hydrogen is safer to handle and use than other fuels that are commonly used today. Hydrogen is non-toxic. And, it is lighter than air, meaning it dissipates quickly in the event of a leak.

However, hydrogen also has the potential to ignite more easily than natural gas. Therefore, adequate ventilation and leak detection systems are important elements when it comes to the design of safe hydrogen systems. Additionally, hydrogen has no odor, is difficult to odorize, and it burns with a nearly invisible flame, so special flame detectors are required.

Regulations

According to a National Research Council (NRC) 2017 study, in general, the entire gas grid should tolerate 5% blending anywhere, and up to 20% in distribution or regional transmission pipelines with no critical downstream infrastructure. However, further development of standards and regulations will be required moving forward.

Currently, the five main regulators in Western Canada: the Canadian Energy Regulator (CER), Alberta Energy Regulator (AER), BC Oil and Gas Commission (OGC), the Saskatchewan Ministry of Energy and Resources (MER), and the Manitoba Petroleum Branch (MPB) contain no established limits for hydrogen within their pipeline Acts and regulations.

However, there are inherent limits that exist primarily due to concerns with enduser compatibility, as well as leakage that can occur when systems are not designed to tolerate hydrogen at higher concentrations.

Infrastructure

Some metals can become brittle when exposed to hydrogen. If a material is susceptible to hydrogen cracking, the higher the concentration of hydrogen in a pipeline, and the higher the operating temperature, the higher the potential is for cracking to occur. High strength carbon steels commonly used in larger diameter pipelines are typically more susceptible to cracking, so lower strength steels are required once we introduce higher concentrations of hydrogen into the pipeline.

Because hydrogen is a smaller molecule than natural gas, it is more difficult to compress, requiring changes or retrofits of compression at higher concentrations of hydrogen. In addition, gaskets, seals, valves, and fittings are more susceptible to leakage and may be detrimentally affected by hydrogen service, so they may need to be replaced or retrofitted as concentrations of hydrogen in the system increase.

With these factors in mind, we can now begin to evaluate the current infrastructure and its suitability to transport hydrogen. While it's true that a transition to a pure hydrogen economy is many years in the future due to the upgraded infrastructure requirements, both from a transportation and end use consideration, there are short and mid-term initiatives that can be put in place that repurposes our existing oil and gas infrastructure.

To understand how this transition might occur, we must first understand the various scenarios that can be implemented, and what is required at each stage.

<table>
<tr><th></th><th>1
Supplemental Blending
(0-5% H_2 by Volume)</th><th>2
Aggressive Blending
(5-20% H_2 by Volume)</th><th>3
Intensive Hydrogen Infrastructure
(20-50% H_2 by Volume)</th><th>4
Pure Hydrogen Infrastructure
(100% H_2)</th></tr>
<tr><td>Status</td><td>Operating
Non-Operating</td><td>Operating
Non-Operating</td><td>Operating
Non-Operating</td><td rowspan="5">Engineering Assessments would be required for any existing infrastructure.

New infrastructure that is built for purpose would most likely be required.</td></tr>
<tr><td>Material Type</td><td>Any</td><td>Any</td><td>Steel</td></tr>
<tr><td>Material Grade</td><td>Low strength steel</td><td>Low strength steel</td><td>Low strength steel</td></tr>
<tr><td>Age</td><td>Any</td><td>1980 or newer</td><td>1980 or newer</td></tr>
<tr><td>Proven Cracking Resistant Construction Practices and Materials (i.e., Sour Service Compatibility)</td><td>No specific requirements for a pipeline to be built to resist cracking</td><td>Existing systems that transport H_2S will be compatible with H_2 service.

Sweet systems may be suitable if natural gas blends contain no Sulphur</td><td>Existing systems that transport H_2S will be compatible with H_2 service.

Cracking risk makes sweet systems likely unsuitable for this service</td></tr>
</table>

① Supplemental Blending

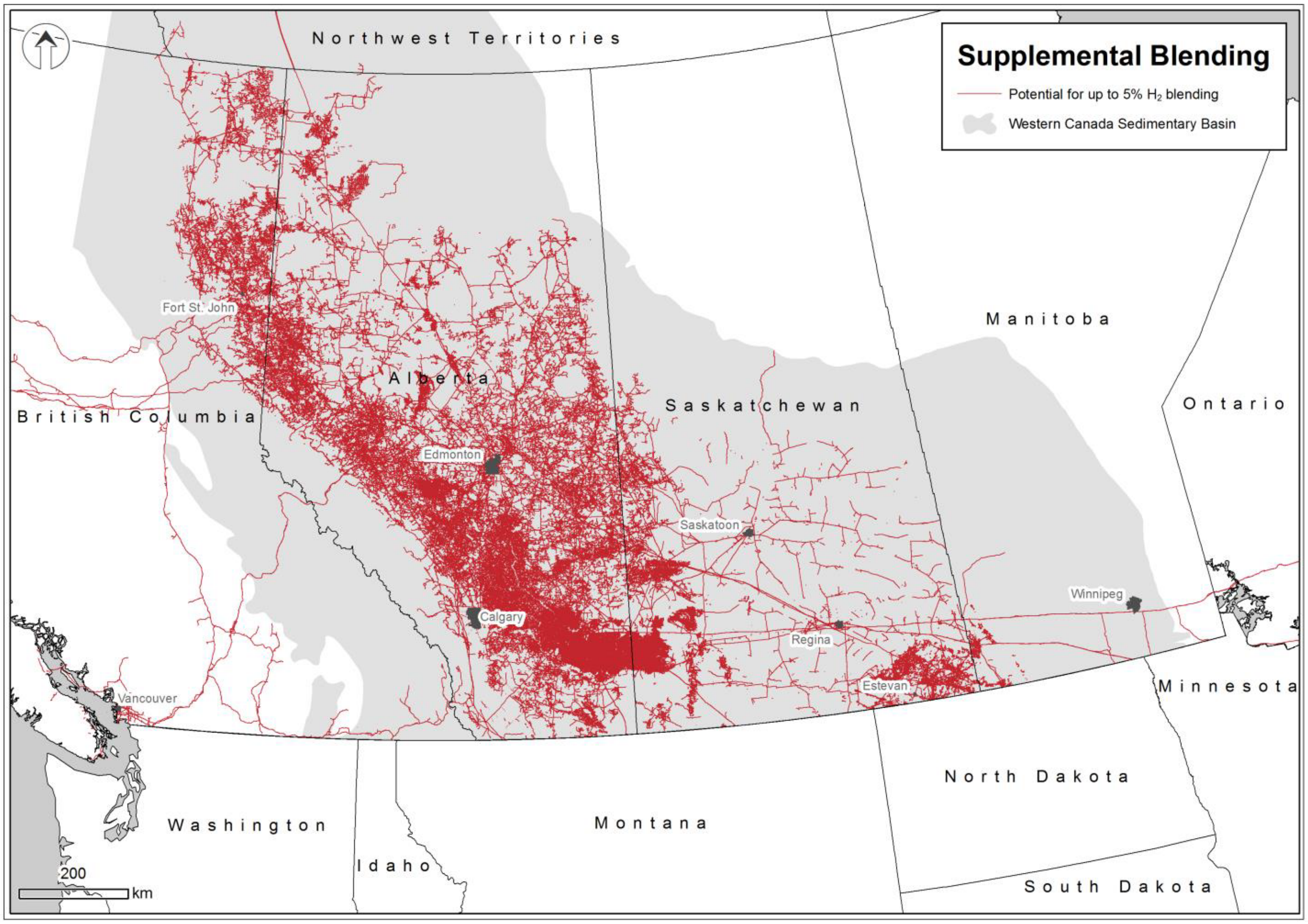


__Figure 1:__ Map of current infrastructure that is capable of transporting up to 5% hydrogen by volume.
Source: GDM Pipelines

With Supplemental Blending, hydrogen is blended into existing natural gas systems in concentrations up to 5%.

Where there is an available hydrogen source, such as in the WCSB, supplemental blending requires very little investment, as current infrastructure can be utilized to transport this blended product with few, if any, modifications…provided the infrastructure is capable of accepting hydrogen based on its operating conditions.

The main infrastructure targets at this stage would be operating pipelines that are either constructed with non-steel materials, or with low strength steel. This includes any pipelines that were built to accommodate sour gas designed to withstand higher concentrations of H_2S, as well as natural gas

lines that have no H_2S content. Non-gas lines that are designed to operate with an H_2S partial pressure of <70 kPa could also be used to transport these lower concentrations of hydrogen with little to no impact.

Pipelines that are currently in a non-operating or discontinued state, but that meet these operating requirements would also be suitable candidates, although an Engineering Assessment (EA) would need to be completed prior to putting them back into service.

As shown in Figure 2, this means that up to 76% of the current infrastructure in Western Canada could be used to transport natural gas with blended hydrogen up to 5%.

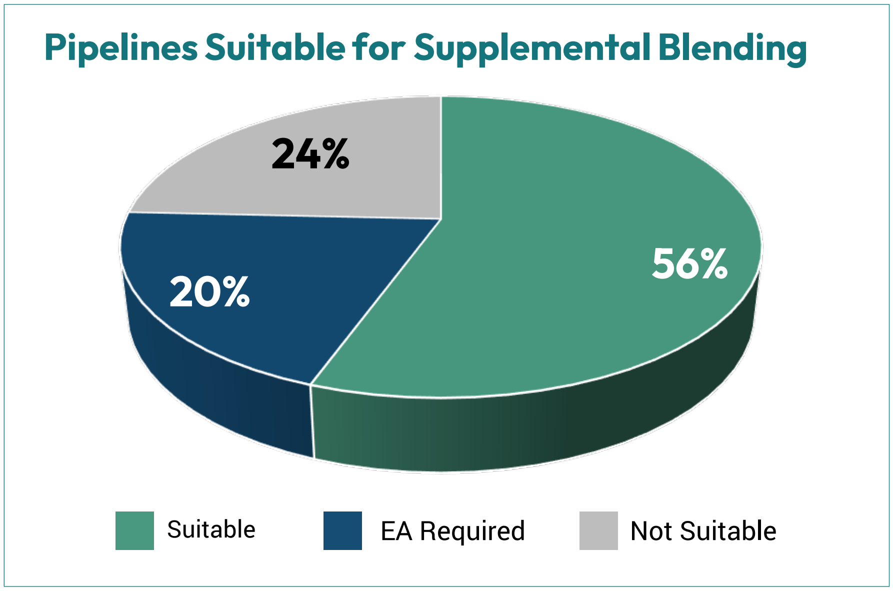


Figure 2: *Up to 76% of current pipeline infrastructure may be suitable for Supplemental Blending, or up to 5%* H_2 *by volume.*
Source: GDM Pipelines

Although it is difficult to predict an exact reduction in emissions that would result with blending 5% hydrogen by volume to all Natural Gas that is sold in Canada, one could expect a reduction of approximately 4-5%, which is 16 billion cubic feet per day, according to Canadian Association of Petroleum Producers (CAPP).

② Aggressive Blending

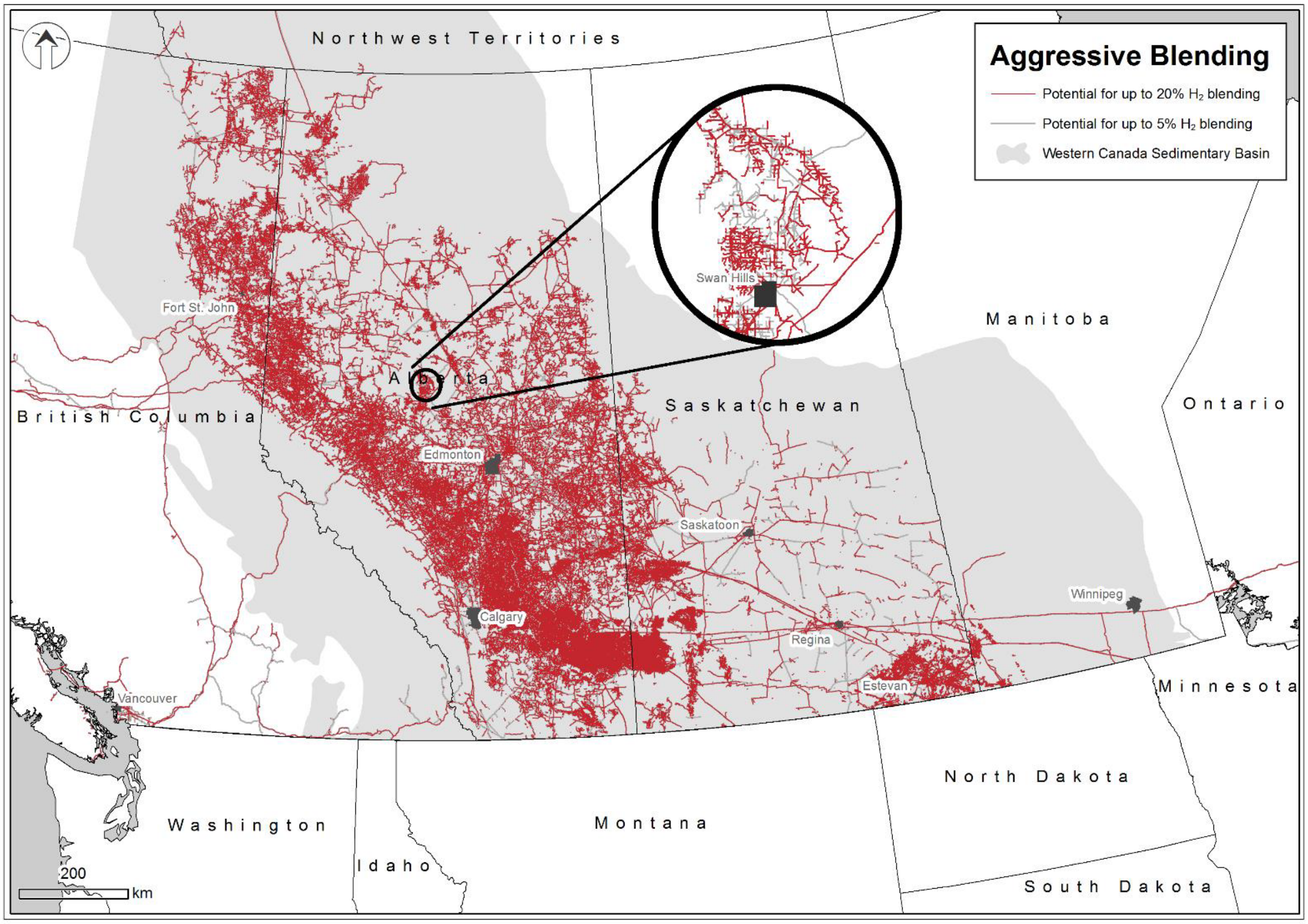


__Figure 3__: Map of current infrastructure that is capable of transporting up to 20% hydrogen by volume.
Source: GDM Pipelines

With Aggressive Blending, hydrogen is blended with natural gas in concentrations between 5 and 20%.

As we move to these higher concentrations, it is necessary to fully assess the state of the infrastructure and in some cases, make modifications to ensure the safe and effective transport of hydrogen.

Infrastructure that would be good candidates to use at this stage are similar to what would be suitable at a supplemental blending stage, but there are additional considerations. Although non-metallic pipelines would be capable of transporting hydrogen, they would not be ideal due to additional product loss that may occur. The smaller hydrogen molecule is capable of escaping pressure containment, even slowly passing through steel pipe walls. More permeable materials, such as the plastics used in hydrocarbon service, may see significant hydrogen losses if used over long distances.

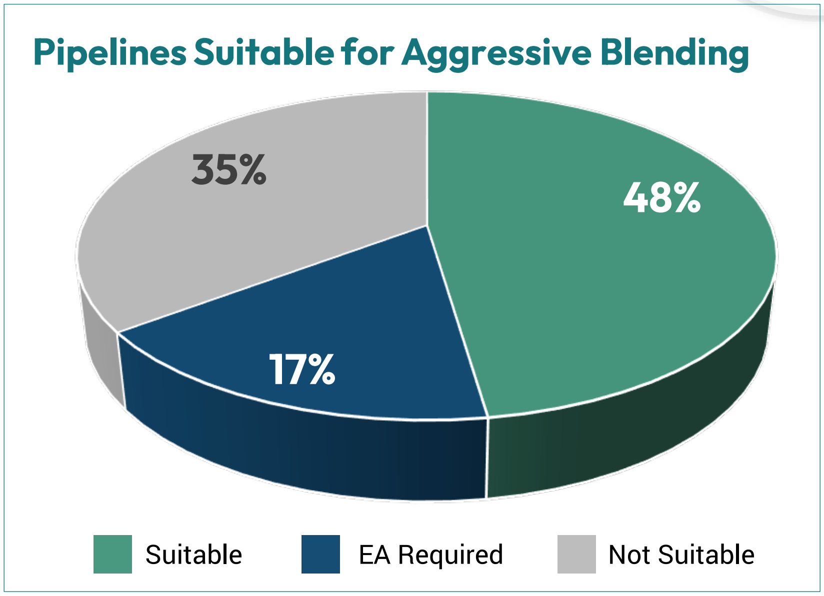


Figure 4: *Approximately 65% of existing infrastructure has potential to be repurposed for Aggressive Blending, or up to 20%* H_2 *by volume.*
Source: GDM Pipelines

Another consideration is the age of the pipeline, as anything constructed prior to 1980 may not be viable due to older fabrication techniques and higher cracking concerns. In addition, any non-gas lines that have an H_2S partial pressure of <70 kPa may be candidates, although an Engineering Assessment would be required before proceeding.

Additional compression infrastructure would likely be necessary, as well as potential retrofits to seals, fittings, valves, and gaskets. Integrity management processes would also need to be reviewed and modified to account for the different safety requirements and best practices. With these requirements, in the short term, aggressive blending would be most suitable for large industrial consumers. For consumer infrastructure to be compatible with these higher concentrations of hydrogen, modifications would be required, so this is something that would need to be put in place over a longer period.

③ Intensive Hydrogen Infrastructure

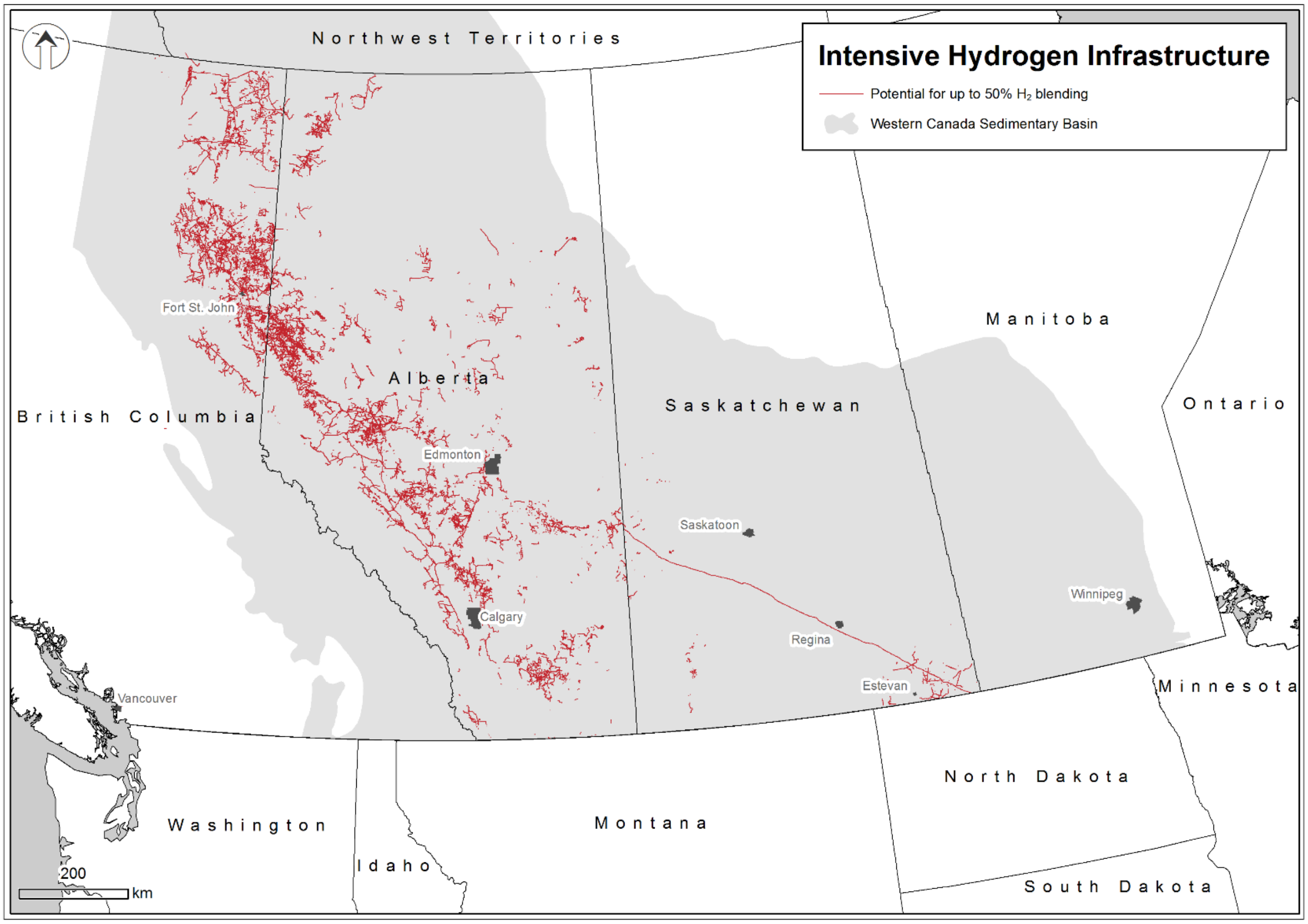


Figure 5: Map of current infrastructure that is capable of transporting up to 50% hydrogen by volume. Source: GDM Pipelines

At hydrogen concentrations above 20%, extensive infrastructure modifications would be required to accommodate hydrogen transport.

Existing infrastructure may be considered, but there are significant restrictions for which infrastructure could even be considered viable options. Any pipelines would need to have been built after 1980 and designed specifically for sour natural gas using low strength steel.

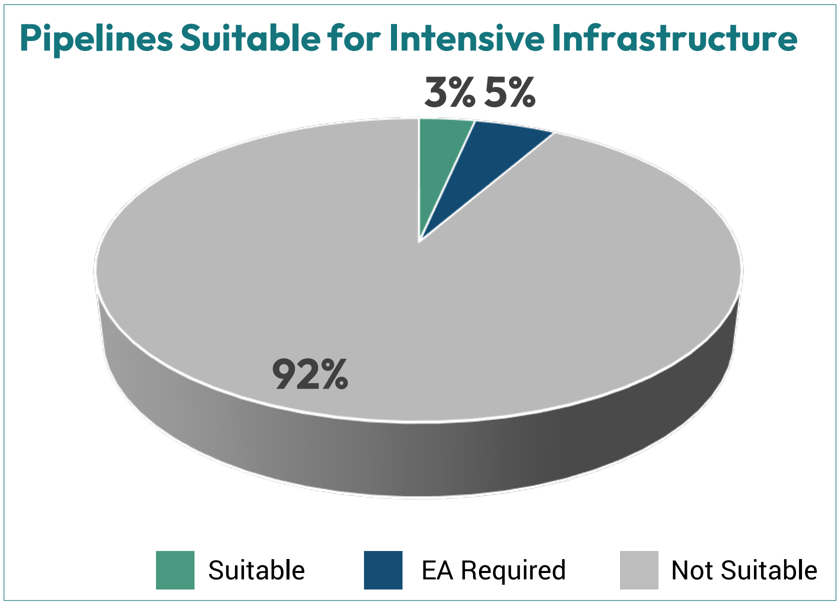


Figure 6: *Approximately 8% of current pipeline infrastructure may be suitable for transporting up to 50% H_2 by volume*
Source: GDM Pipelines

Outside of this, the potential for cracking to occur is likely too great and it could pose significant operating risk.

Therefore, although retrofits including technologies such as inserting liners into existing pipelines or undertaking material assessments of existing infrastructure may be possible in some cases, it is likely that there would need to be significant investment in new infrastructure for this to be viable.

4 Pure Hydrogen Infrastructure

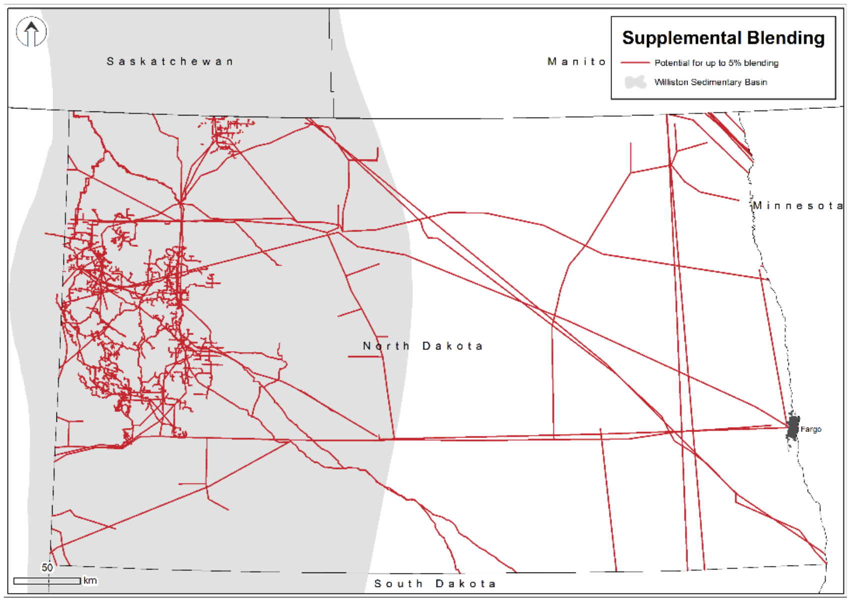
The final step in the transition to a hydrogen economy is the implementation of 100% hydrogen and the adoption of dedicated hydrogen infrastructure.

The implications of this scenario are far-reaching, as it would require a complete retrofit of existing infrastructure, or the construction of purely built-for-purpose hydrogen infrastructure. It would also require modifications for all end use infrastructure.

Naturally, the investment to move to this pure hydrogen economy would be extensive, so it is long-term strategy, requiring buy-in across many levels of industry and government.

Highlight: North Dakota

While we focus on the potential opportunity in Western Canada, there is also a significant opportunity for hydrogen to be part of the broader North American Energy Network. The connected infrastructure that runs across the border brings potential for opening new markets and expanding the reach of the emerging hydrogen economy.



North Dakota currently has over 14,000 km of pipelines that could be suitable to begin up to 5% hydrogen blending and transportation, and with its proximity to Western Canada, this could present an opportunity for future projects and collaborations.

Assessing Current Readiness

After considering initial suitability to be part of one of the scenarios above, in some cases an Engineering Assessment may be required to further assess any potential issues related to a pipeline's ability to transport hydrogen.

The main objective is to look at a variety of data points that reflect the conditions and characteristics of the pipeline and the area where it is operating. By assessing this information, it's possible to get a more in-depth understanding of whether a pipeline can be used to transport hydrogen in its current state, or whether modifications or retrofits may be required to ensure safe and effective operation of the pipeline.

We need to understand what is happening both within the pipeline, as well as any external factors that could impact the operations.

Some of the points for consideration include:

Operating Attributes

The licensed operating attributes detail the characteristics of the pipeline that must first be assessed to understand its suitability to transport hydrogen.

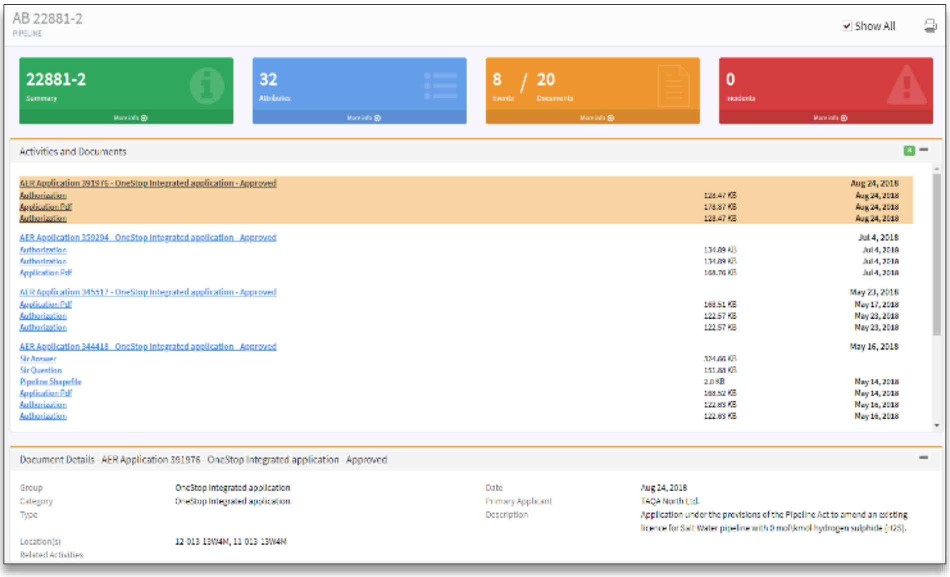


Figure 7: List of historical regulatory filings for a pipeline generated from Converge
Source: GDM Pipelines/Converge

These include factors such as the current Maximum Operating Pressure (MOP), the age of the pipeline and the composition of the materials that it is made of, the wall thickness of the pipeline, Specified Minimum Yield Strength (SMYS), and the H_2S content that the pipeline is capable of transporting.

Each of these attributes, as well as any regulatory or licensing changes that have occurred over the pipeline's lifetime, provide details that need to be factored in as the pipeline is assessed in more detail.

Historical Operations and Maintenance

Understanding a complete operating history of the pipeline provides deep insight into any potential future issues.

This includes any mitigation and monitoring activities such as chemical programs, cathodic protection records, pressure tests, and in-line inspections and pigging programs.

In addition, details of any historical incidents that have occurred, as well as the causes of those incidents also provides valuable information into potential issues that may need to be investigated further.

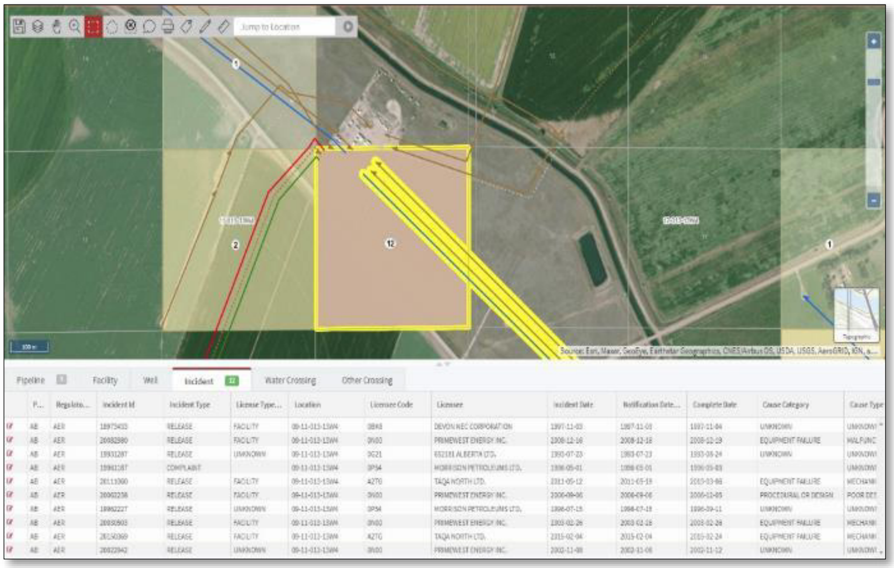


***Figure 8:** List of historical environmental incidents for a selected LSD*
Source: GDM Pipelines/Converge

Operating Conditions

Conditions external to the pipeline construction, including field characteristics such as soil composition and geographic features, pipeline elevation profiles, conditions of adjacent infrastructure, and any pipeline water or transportation crossings, provide context that can be juxtaposed with the pipeline attributes, operations and maintenance records to understand any factors that might adversely affect a pipeline's safety or integrity.

***Figure 9**: Map showing locations and priority of pipeline water crossings*
Source: GDM Pipelines/Converge

Production History

One of the key components to understanding a pipeline's condition is to analyze the production that has been flowing through the pipeline over its lifetime. This includes looking at fluid composition and gas analysis records. To do this requires knowing which wells are connected to the pipeline, and the operating history of the connected well(s) to understand how the pipeline may have been impacted.

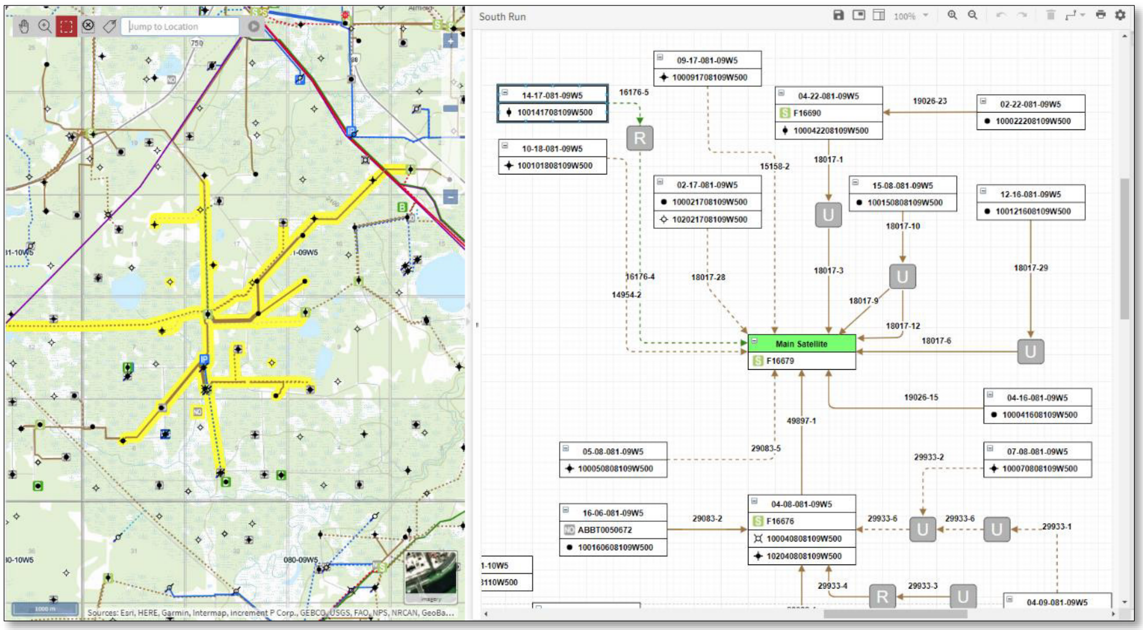
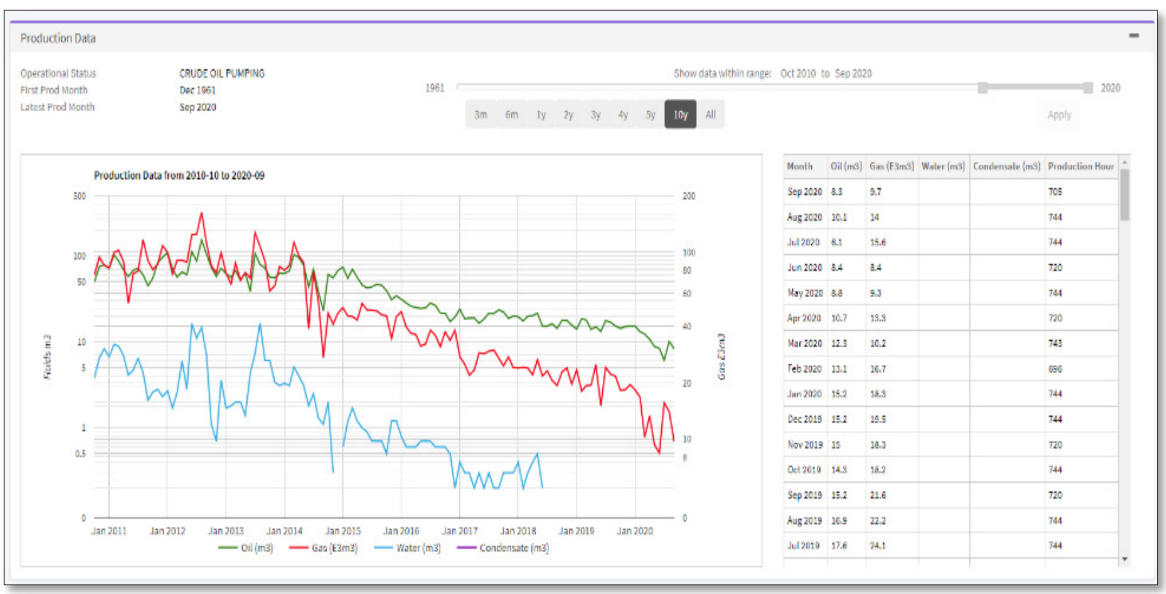


Figure 10: System diagram showing how assets are connected in the field
Source: GDM Pipelines/Converge



Month	Oil (m3)	Gas (E3m3)	Water (m3)	Condensate (m3)	Production Hour
Sep 2020	8.3	9.7			705
Aug 2020	10.1	14			744
Jul 2020	6.1	15.6			744
Jun 2020	8.4	8.4			720
May 2020	8.8	9.3			744
Apr 2020	10.7	13.3			720
Mar 2020	12.3	10.2			743
Feb 2020	13.1	16.7			696
Jan 2020	15.2	18.3			744
Dec 2019	15.2	19.5			744
Nov 2019	15	18.3			720
Oct 2019	14.3	18.2			744
Sep 2019	15.2	21.6			720
Aug 2019	16.9	22.2			744
Jul 2019	17.6	24.1			744

Figure 11: Historical well production chart for an individual well
Source: GDM Pipelines/Converge

Each of these different areas; operating attributes, historical operations and maintenance, operating conditions, and production history contribute to the overall Engineering Assessment that must be completed by a qualified engineer. With the results of this analysis, it will be possible to determine future plans to begin blending hydrogen in greater concentrations within existing systems.

Customers

The final step in the equation is to have a market that is capable of consuming hydrogen. This means ensuring that any appliances or end-use equipment can operate using hydrogen.

With supplemental blending, there would be little to no impact on end users. For consumers, a 5% concentration of hydrogen works within existing natural gas appliances with no modifications required. Likewise, commercial applications would not see any adverse impact at this lower concentration.

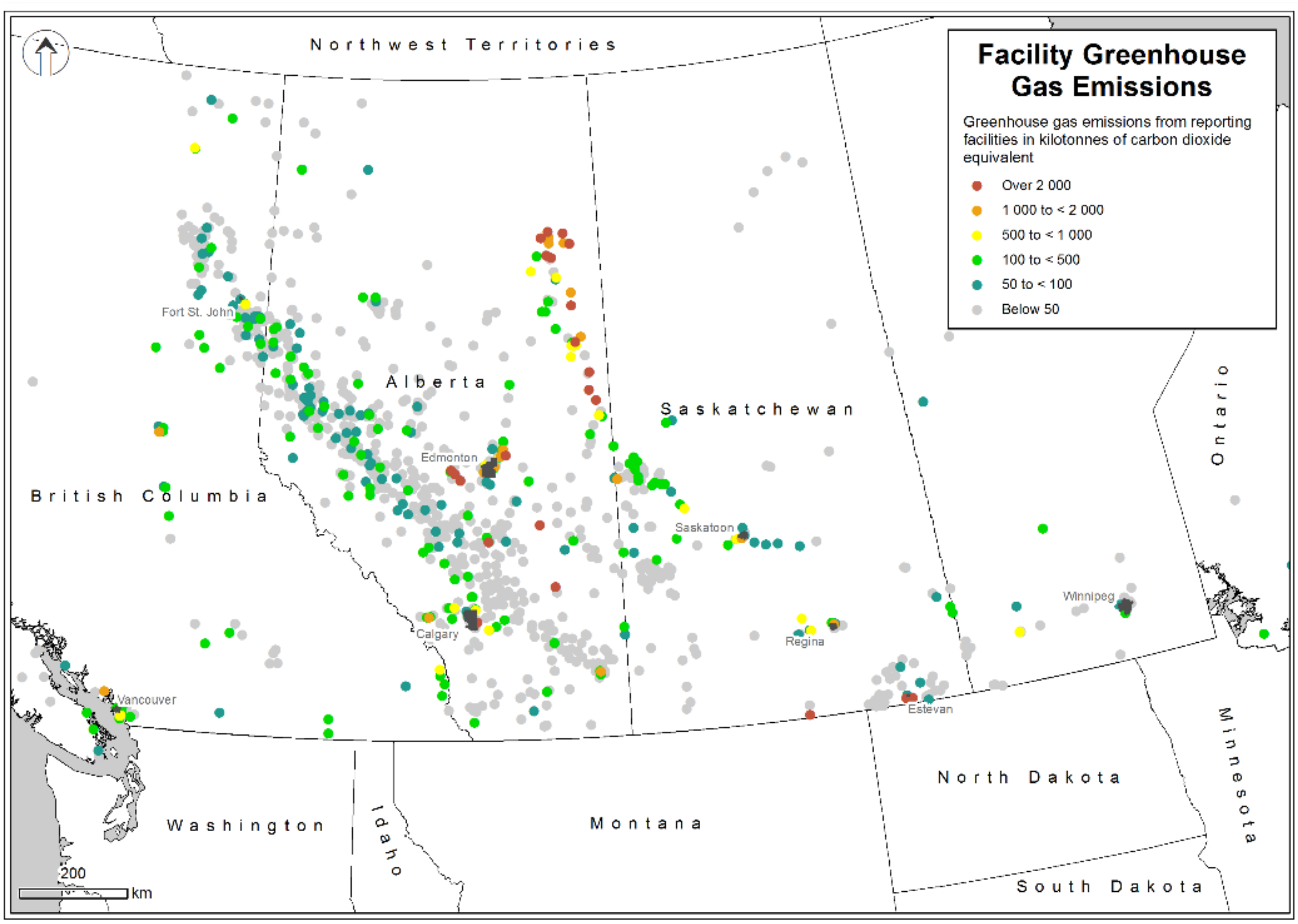


Figure 12: *Greenhouse gas emissions from facilities in Western Canada*
Source: Government of Canada Greenhouse Gas Reporting Program

As we move into aggressive blending, the higher concentrations of hydrogen may not be fit for purpose for many consumer appliances without upgrades or retrofits. The costs associated with this for consumers is not likely to be embraced in the short term. However, aggressive blending does offer great potential for large industrial customers who are looking for ways to reduce greenhouse gas emissions.

As shown in Figure 12, many of the largest commercial producers of CO_2 are in direct proximity to the WCSB and the vast infrastructure that already exists. This may present opportunities for oil and gas producers and customers to work together on projects to retrofit facilities to accommodate higher percentages of hydrogen, leading to significant emissions reductions.

At the intensive and pure hydrogen infrastructure stages, existing end use equipment, both for commercial and consumer applications, may not be capable of handling the higher concentrations. Therefore, the markets for these options are yet to be defined, and it is likely to be many years into the future before this is viable. Significant investment will be required to approach commercial use of intensive and pure hydrogen use cases. But with this investment, the full power of hydrogen would be released.

Summary

The transition to a hydrogen economy is under way.

The good news is that in Western Canada, we have an opportunity to not only be part of this transition, but to be global leaders as we leverage our vast hydrocarbon reserves, our extensive network of oil and gas infrastructure, widereaching expertise for hydrocarbon extraction, and our history of innovative technology implementation to bring products to market.

Fortunately, embarking on this transition does not mean abandoning our current fossil fuel economy. It simply presents us with an opportunity to pivot with the goal of positioning Canada as a leader in a world that is demanding change.

The key is understanding how to take advantage of the resources we have at our disposal.And, this begins by having a detailed understanding of every aspect that is required to reach the end goal.

GDM Pipelines has been collecting, managing, and analyzing data related to Western Canadian oil and gas infrastructure for over 23 years. We are excited to share our expertise to help the industry understand everything they need to know about their assets as we embark on Western Canada's transition to a hydrogen economy.