Government of Yukon

Hydrogen Pilot Project

Final Report

Prepared by High Latitude Energy Consulting

Prepared for the Government of Yukon

Date	Version
Mar 4, 2025	1
Mar 19, 2025	2
Mar 25, 2025	3

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1. Executive Summary

The Government of Yukon aims to implement a hydrogen pilot project as part of its *Our Clean Future*[1] decarbonization strategy. The policy goal is to start construction on a demonstration project by 2027 to be operational by 2029. Navius Research identified transportation as the optimal sector for hydrogen implementation in Yukon.

Initial industry engagement was conducted to explore options for creating a transportation related pilot project. This work resulted in the concept to convert two heavy-duty diesel engines to dual fuel systems that can run on both diesel and hydrogen. One benefit of this pathway is the lower cost compared to fuel cell vehicles. On average an engine conversion to dual fuel costs $100,000 and an average price of a new fuel cell vehicle is $1,500,000. A dual fuel engine can run on 100% diesel if hydrogen is not available. This minimizes the risk of downtime for the asset. The dual fuel vehicles also require less training and tooling to complete the vehicle maintenance.

The proposed pilot would include 6 months of baseline fuel and emissions monitoring before the engines are converted to a dual fuel system. An additional 6 months of data logging would occur post conversion. This would provide direct results on fuel consumption and emissions reduction. It is estimated that 40% of the diesel could be replaced by hydrogen and the pilot would require about 2,160 kg of hydrogen.

This study focused on identifying a temporary supply of hydrogen that would be transported to the Yukon via transport trailers. Currently, hydrogen is limited to grey or blue hydrogen compressed gas from Alberta, with suppliers reluctant to provide small volumes or send assets to Yukon. Preliminary engagement was conducted to get a high-level estimate to explore on-site generation via electrolysis. If hydrogen can be secured for transportation, the pilot would cost approximately $1,000,000. To pursue on-site generation the magnitude of cost is expected to be $10,000,000.

Leaders of other pilot projects were contacted to obtain early-stage lessons learned from their projects. Most of these projects were designed to run for 3-5 years. The other projects were located in the provinces of Canada and significantly closer to the source of hydrogen and still experienced challenges securing small volumes of hydrogen to purchase. The projects that had on-site generation shared that the equipment experienced more down-time than was anticipated. All stakeholders emphasized the importance of working with experienced companies with proven track records in delivering hydrogen projects.

The conclusion of this study found that there is currently no viable option to have hydrogen delivered to the Yukon to support the pilot project as designed. Since the industry is still in early stages of commercialization one recommendation is to pause the development of the pilot project and reassess in

2028. This is the timeline for the completion of the pilot projects that are currently underway. This would enable the lessons learned from existing pilot projects to be applied to the design of the Yukon pilot project. This timeline matches the anticipated completion date of the prioritized codes and standards that are under development to support safe hydrogen projects. Finally, there are new hydrogen generation facilities that are scheduled to come online in Alberta around this time that may make the possibility of transported compressed hydrogen viable. Also, there is a liquefaction plant that is proposed so transporting liquified hydrogen could become a possible solution.

A secondary recommendation is to explore the possibility of on-site generation via electrolysis. Completing detailed industry engagement on this topic could identify how viable this solution is and further refine the pricing to create a solution.

Finally, the Government of Yukon's hydrogen policy goal of starting construction on a demonstration project by 2027 to be operational by 2029 may need to be modified to allow for more industry maturation. It is recommended to revisit the state of the industry in 2028 and start construction in 2030.

2. Background

The Government of Yukon has created a decarbonization strategy that is outlined in *Our Clean Future*[1]. This plan includes an initiative to develop and implement a pilot project to explore the possibility of hydrogen to support decarbonization efforts.

The Government of Canada published the *Hydrogen Strategy for Canada* [2] in 2020. This report communicates the government's position on becoming a world leader in hydrogen production for both domestic use and export. This is a strategic industry being developed in Canada.

Currently, most Canadian hydrogen production is from fossil fuels so the majority of industry development is in regions that have a natural gas supply. In Western Canada, the dominant producer of hydrogen is Alberta. The Yukon does not have a natural gas industry so this production method is not feasible locally. Other options for hydrogen shipment or production would need to be explored.

Hydrogen can be produced using electricity and water. Electricity is used to operate an electrolyzer which splits water molecules into hydrogen gas and oxygen gas. This hydrogen is captured and stored. When electricity from renewable sources is used to produce the hydrogen it is classified as green hydrogen. This production type can support the development of the renewable industry since the electrolyzer can operate during times of excess production and store the energy in the form of hydrogen for later use.

Hydrogen can be used in a variety of applications. It can be used as fuel for transportation in fuel cell vehicles or dual fuel engines. For power generation, hydrogen can be combusted in a turbine or fed into fuel cell power plants. This makes hydrogen a versatile energy source.

The current cost of hydrogen is about $14 - $35/kg[3] when supplied in BC or Alberta. The cost of hydrogen needs to be reduced to about $5.35/kg[3] in order to have a similar Total Cost of Operation compared to diesel trucks. The Government of Canada has estimated that the future cost of hydrogen will be $1.50 - $3.50/kg[2]. In Alaska, they have set a targeted cost of $1(USD)/kg[4].

There are some key challenges to the development of the hydrogen industry. While the industry is operating below critical scale, the projects have high capital costs, and the cost of the fuel is higher compared to alternatives. The funding programs that have been developed to support the creation of hydrogen projects are intended to help the industry grow to this critical point.

There are barriers in codes and standards that need to be updated to create a smooth pathway for hydrogen project success. Developing codes, standards and policies is an essential step in the development of a hydrogen industry in any region. Natural Resources Canada established a Codes and Standards Working Group in April 2021 to identify gaps and priorities. They released their report, *Canadian Hydrogen Codes and Standards Roadmap*[5] in 2025 summarizing where there are no gaps, partial gaps or full gaps in the various parts of the hydrogen value chain. All use cases had gaps identified in codes and standards. The report suggests that the major gaps could be addressed on a prioritized basis over a timeframe of 18 months - 6 years with the most critical gaps being addressed within 3 years.

Energy, Mines and Resources commissioned the report *Potential of hydrogen to help decarbonize the Yukon*[6] by Navius Research. The findings suggest that the best use-case for hydrogen is in the transportation sector. This pilot project design is intended to build off this recommendation and identify a viable pathway for hydrogen to be introduced as a transportation fuel in the Yukon.

2.1 Alternatives Considered

Hydrogen Fuel Cell Vehicles are a zero-emission solution while maintaining a large driving range and fast refuelling time. These projects have a high upfront cost, requiring the purchase of a new asset for prices between $1.2M - $1.8M each. These assets are dependent on the availability of hydrogen. Without reliable refueling infrastructure, it puts the asset and related operations at risk. The hydrogen used in these vehicles needs to be high purity (99.97%) which further limits the availability of the fuel. These vehicle types are also substantially different for maintenance and repair compared to diesel engines. This requires significant staff training and new tools to keep the vehicles maintained and operational.

It is also possible to have Hydrogen Internal Combustion Engines which operate by burning hydrogen directly. There are groups in early stages of development of these engines and none are currently commercially available. Some engines have been converted from traditional fuels to hydrogen combustion. These conversions require a large amount of modification, so it is primarily hobbyists who do this; no commercially viable options are available.

2.2 Proposed Pilot

The recommended pilot project is to convert two heavy-duty diesel engines to dual fuel systems that run on both diesel and hydrogen.

The selection of the dual fuel engine opportunity was informed by exploring other pilot project designs and an initial round of engagement with 5 stakeholders in the hydrogen industry who have developed hydrogen projects in North America and Australia. Open-ended questions were asked to explore if there was another concept that could be a better fit for a Yukon pilot project. All conversations supported the idea of the pilot project proposed.

The project was planned to run for 12 months after the engine conversions have been completed. This would include 6 months of performance monitoring of the engines prior to conversions to establish baseline diesel consumption and GHG emission information. After the conversion, the pilot will run for 6 months to capture the resulting diesel usage and GHG emissions on the converted engines.

Hydrogen will be produced in Alberta and transported to the Yukon as a compressed gas in transport trailers. These trailers will be used as the temporary refueling station.

Hydrogen has been produced in Alberta for over 50 years for use as an industrial gas. Other pilot projects have sourced hydrogen from Alberta and used transport trailers as temporary fueling infrastructure. This pilot will explore the highest capacity trailer options to reduce the number of shipments required to complete the pilot. The short duration of the project was selected because of the hydrogen shipment logistics. This is not a long-term solution for having hydrogen available in the Yukon and is only being considered as a short-term solution to demonstrate the use case technology.

Some benefits of the proposed pilot compared to other alternatives are:

- **Lower upfront capital costs.** The ability to convert existing engines minimizes the cost of purchasing new assets. The conversion of a single engine costs between $55k - $120k. The dual fuel engines can run on 100% diesel if hydrogen is unavailable. This fuel flexibility minimizes the risk associated with introducing a new fuel type and the availability of hydrogen refueling infrastructure. This also enables the asset to return to regular diesel operation at the end of the pilot project if hydrogen use proves not to be viable.

- **Reduced complexity for technicians.** The maintenance and repair protocols require less technician training compared to fuel cell vehicle maintenance. This reduces the total complexity of the project since fewer changes to tooling, shop space and technician skills will be required.
- **Incremental innovation.** This project creates a path to demonstrate if hydrogen technology works in the Yukon while minimizing other risks
- **Leverage learnings from other pilot projects.** A mid-sized Canadian city has a similar pilot project underway with expected completion in 2028. Transportation companies also have dual fuel pilot projects underway. There is an opportunity to learn from the experiences of these projects to refine the pilot project in the Yukon to reduce friction and increase the likelihood of success.

3. Industry Engagement

The intention of industry engagement was to identify a viable pilot project including potential distributors of the key components to complete the project.

Three primary pathways were used to generate leads for stakeholder engagement. First, engineering colleagues who work in the hydrogen industry were contacted. Second, the names of companies and individuals identified in hydrogen industry reports and news articles about hydrogen projects were contacted through LinkedIn. Finally, an internet search was conducted to identify companies that could potentially provide products or services. These businesses were then contacted through website forms, phone calls and emails.

Each communication opportunity was used to gather information to develop the pilot project and request additional contacts. For each product or service provider a discovery conversation was had to understand what the inputs and outputs were for their offering. A detailed discussion was conducted to determine how the elements would work together to create a complete solution. In some cases, the stakeholders would be contacted multiple times as new information was available to confirm if the different solutions would work together. Finally, in all of the conversations additional contacts and introductions were requested.

The industry engagement continued until all identified stakeholders had an outreach attempt or communication. At this point, when additional contacts were requested the suggested people and companies had already been contacted. This was considered engagement saturation for this topic and occurred after approximately 55 outreach attempts and 45 engagements.

4. Findings

4.1 Hydrogen Source

Hydrogen options from Alberta were explored. The intention was to identify a complete set of logistics and associated costs to transport hydrogen to the Yukon. This included the use of transport trailers as temporary fueling stations for the dual fuel engines.

i. Hydrogen Fuel Estimate

Typical fuel consumption of a heavy-duty municipal vehicle is commonly reported to be around 120 L per day for single-shift vehicles. To estimate the hydrogen needed to run the pilot project we will assume the typical daily consumption of 120 L and 40% hydrogen off-set. This results in a hydrogen consumption rate of about 6 kg per day per vehicle. For a 6-month pilot project with 2 vehicles the hydrogen required would be around 2160 kg.

ii. Hydrogen Fuel – Transport Trailers

Hydrogen source options were determined through industry engagement and focus on availability in Alberta. Currently, the only sources of hydrogen available are grey and blue gaseous hydrogen. No hydrogen liquefaction facilities were identified. New hydrogen facilities have been announced near Edmonton that would add green hydrogen and liquified hydrogen into the supply. The proposed facilities have an estimated commissioning date in 2028.

Transport trailers are available with different maximum pressures depending on their construction and material type. A higher-pressure trailer is able to carry more hydrogen in a single trip. Transport trailers can be used for both on-site storage and refueling as a cascade filling system. A cascade filling system relies on the pressure and volume differences between the transport trailer and the vehicle cylinders to move gas from the trailer to the vehicle. A higher-pressure trailer enables more of the hydrogen to be used to refuel vehicles in the Yukon. There are high pressure transport trailers that meet these needs. A popular solution on the market enables the transport of 686 kg of hydrogen at 450 bar pressure. Approximately half of the capacity of the trailer would be usable in the converted engines. There are higher pressure trailers under development to carry hydrogen at 550 bar pressure. The supplier anticipated that these would become commercially available within the next year.

Compression equipment is required to fill the trailers with hydrogen. The hydrogen industry has traditionally been used for industrial applications and lower pressure tube trailers. The maximum compression that is currently available is 400 bar at the gas supply facilities. There are 450 bar filling stations that have been installed in BC and Alberta. These stations are designed to refuel vehicles directly and currently do not permit filling transport trailers. The Alternative Fuels Data Center with the

U.S. Department of Energy maps the locations for hydrogen refueling infrastructure. This resource indicates that the nearest high pressure refueling location would be in California. **The current industry characteristics make it infeasible to use transport trailers for a temporary fueling station to support the pilot project.**

iii. Hydrogen fuel – on-site generation

The analysis of on-site hydrogen generation is outside of the scope of this report. Since the hydrogen transport solutions currently are not viable, a different pathway for having hydrogen supply may need to be explored. Hydrogen can be produced from water and electricity using an electrolyzer. When the electricity used is generated from renewable sources the hydrogen produced is classified as green hydrogen. An on-site system would require purified water and electricity inputs into the electrolyzer. The electrolyzer would split the water into hydrogen and oxygen gases. The oxygen gas is commonly released to the atmosphere and the hydrogen is captured for use. A compressor would be needed to pressurize the hydrogen to 350 bar or greater and stored in a ground mount high pressure storage tank. A dispenser would also be needed to deliver the hydrogen from the storage tank into the fuel cylinders on the vehicle. **Investigation into the feasibility of green hydrogen production in the Yukon is recommended.**

4.2 End Use

The implementation of hydrogen dual fuel engines requires specialized engine conversions performed by industry technicians, appropriate shop facilities with hydrogen safety systems, and specific staff training to ensure proper operation and maintenance.

i. Engine Conversion

There are two commercially available options for converting diesel engines into dual fuel engines. The process of converting an engine would require industry technicians to come to Whitehorse and complete the engine conversion on-site. The conversion of a single engine reportedly takes 40 hours. During the conversion, the local technicians are trained in maintenance and can contact the supplier for ongoing support.

The engine types that can currently be converted to dual fuel are:

- Volvo D13
- Mack MP8
- Cummins ISL/L9
- Paccar MX13

These engines can commonly be found in long-haul trucks, delivery box trucks, dump trucks, waste collection trucks, equipment transporters, snow clearing trucks, buses and fuel delivery trucks.

It is recommended that staff who will be working on the hydrogen system take hydrogen training courses. Two options for hydrogen training are Swagelok and The Northern Alberta Institute of Technology (NAIT). The approximate training budget is $1000 - $2000 per employee.

ii. Shop requirements

The shop requirements to complete an engine conversion and maintenance are commonly found in a heavy-duty shop. Some of the specifications that are notable are:

- CVIP certified
- 4000 lb hoisting capability
- Hydrogen leak detection system

Shop specifications do not fully address the building assessment for safety. **It is important to have someone with experience in hydrogen codes review the building where maintenance will occur and indicate what modifications would be necessary for safe maintenance.**

iii. Data Monitoring

Data loggers will be installed on target engines for baseline performance monitoring for the first 6 months of the pilot. Ideally, this 6-month period will cover winter and summer seasons. The data logger will capture typical diesel consumption and GHG emissions to establish a comparative baseline for the vehicle that is converted. The data logger would remain in place post-conversion to capture fuel and emission data for the following 6-month period. Ideally, each 6-month period would include both summer and winter operation. This information will quantify the impact dual fuel engines can have on reducing GHG emissions in the Yukon.

iv. First responder safety

During the development of other pilot projects emergency responders were consulted to identify a way to inform them about the hydrogen gas on the vehicle. The solution was to complete a decal wrap on the converted vehicles to communicate there was hydrogen fuel onboard. This fulfilled the purpose of enabling first responders to deal with an emergency safely and also to promote the use of the alternative fuel.

4.3 Cost

The pilot project cost depends on the source of hydrogen that is secured. If it is possible to complete the pilot using high pressure transport trailers, the project would have a total estimated cost of about $1,000,000. If the hydrogen is produced on-site and a fueling station is set-up the estimated cost would be about $10,000,000.

4.4 Interim Findings from Other Pilots

News sources were used to identify hydrogen pilot projects and people involved in the projects. Reaching out to the pilot project leaders was part of the engagement strategy to learn from the experiences in other regions.

i. Most pilot projects were designed to run for 3-5 years.

The pilot project durations in other regions were longer than what was conceptualized for the Yukon pilot project. The most common duration of the pilots was to operate for 3-5 years.

Key reasons for the longer pilot durations included:

- Allowed for a larger data set to be collected over multiple seasons.
- The capital cost of establishing the projects was high so it was desirable to operate the equipment over a longer period of time.
- Allowed a time buffer for issues to occur and be fixed and still have sufficient data collected from the operating periods.

ii. Difficulty obtaining small volumes of hydrogen.

There were 2 projects that required purchasing hydrogen as an industrial gas. One project had assets that were refuelled directly at the production facility and the other used an on-site 400 bar trailer for refueling. Both projects reported difficulty in securing a contract for hydrogen due to the low volumes. When contracts were established, the supply was less consistent than expected. In the project that had a trailer for refueling, the operator reported that the vehicle fueling time was inconsistent and increased significantly each time the trailer was used to fill the vehicle. It was also reported that as the pressure decreased in the trailer, the measurement of the gas became inaccurate.

iii. Hydrogen production sites had higher than expected down time.

Projects that included operating a production facility reported various levels of success. Site visits of 6 different facilities by High Latitude and U.S. Department of Energy noted that none of them were operating on the day of the visits. Operators at all sites reported that the systems had previously produced hydrogen but overall, there was more downtime than they were expecting. Five of the systems were designed to produce hydrogen from electrolysis. The other system produced hydrogen from methane pyrolysis.

iv. Experience level of suppliers had significant impact on project success.

It was reported by all project owners how important it was to work with companies who had successfully delivered hydrogen projects. All of these stakeholders shared stories of working with new entrants to hydrogen projects and the escalating costs due to rework. In some cases, the pilot projects had key stakeholders who suddenly went out of business or stopped operating part way through the project. There were 2 pilot projects that were publicly announced and partially deployed but none of the stakeholders remained in operation. **The recommendation is to request a portfolio of previous projects and references prior to selecting suppliers.**

4.5 Risks

The commercial hydrogen ecosystem is still in an early stage of development. This increases the complexity of creating a project because of limitations in infrastructure, regulations and suppliers.

i. Suppliers not interested in fulfilling small orders or Yukon-based orders.

Hydrogen has been produced and used in industrial applications for over 50 years in Alberta. Suppliers were contacted to request pricing, pressure and logistics information to support the pilot project. No suppliers in Alberta were willing to provide information. The suppliers indicated they were not set up to deal with small volumes. They also did not want any of their assets traveling to the Yukon or remaining in the Yukon. The industry is currently best able to handle large volumes with industrial clients**. If transported hydrogen is explored in the future it is important to contact suppliers early on to assess if small volume purchase is available.**

ii. Insufficient infrastructure for refueling high pressure trailers.

The traditional use of hydrogen in industrial applications also impacts the maximum filling pressures. Current facilities can compress to 400 bar or less. This level of compression is sufficient for industrial application but not for high pressure transportation. The high-pressure tube trailers require compression to 450 bar. The only filling sites identified that had higher compression were only for light-duty vehicles and it was not allowable to fill a trailer at these locations. There is currently a gap for filling high pressure trailers for transporting hydrogen.

iii. Gaps in codes and standards make projects challenging to navigate.

There are many gaps in codes and standards throughout Canada that may put the development of hydrogen projects at risk. Natural Resources Canada released a report in January 2025 titled, *Canadian Hydrogen Codes and Standards Roadmap*[5]. This report highlights the various sectors of the hydrogen industry and what gaps exist in the regulatory framework. The proposed pilot project will involve delivery, storage and end-use elements. Depending on the source of hydrogen that is selected, this project may involve hydrogen production elements also. Projects in other jurisdictions have leveraged the codes for natural gas or propane installations to progress hydrogen installations. **High priority codes and standards are expected to be adopted within a timeframe of 18 months - 3 years.** If the shorter timeframe is achieved, the regulatory space may have shifted between by the time the pilot project is initiated.

iv. Hydrogen industry has high complexity.

Navigating the hydrogen industry has high complexity. There is a risk of getting into project development and chosen suppliers going out of business. There is also a risk of chosen suppliers not having full competence in the project type that is selected. **One way to mitigate this risk is to hire a hydrogen consultant who can navigate the ecosystem as an owner-advisor.**

5. Recommendations and Next Steps

Recommendation #1: Delay targeted demonstration start date to 2030, re-visit state of hydrogen industry in 2028.

This recommendation is based on the following findings:

- Pilot projects currently underway in cold climate regions in Canada are expected to be complete and findings available in 2028.
- Hydrogen codes and standards are under development with the expected completion date of the majority in 2028.
- Proposed green hydrogen facility and liquefaction plant are planned to be complete in 2028. These additional sources of hydrogen may create new opportunities for purchasing small quantities of hydrogen to run the pilot project. This also creates an opportunity to explore liquified hydrogen as a possible alternative for hydrogen source.

Recommendation #2: Explore feasibility of on-site hydrogen production.

This recommendation is based on the following findings:

- Enable the hydrogen stock to be green
- Mitigate the risk that a viable hydrogen transportation solution does not emerge in the future
- On-site production is a more complex project, this exploration would help define the scope, budget and timelines for this project-type to support go/no go decision making
- Build understanding on the success of electrolyzer performance in cold climates

6. Conclusion

The Yukon Hydrogen Pilot Project was originally designed to convert two heavy-duty diesel engines to dual fuel systems capable of running on both diesel and hydrogen. This approach was selected over hydrogen fuel cell vehicles due to its cost-effectiveness, operational flexibility and ability to directly measure emissions reductions through comparative data logging. The pilot would include six months of baseline monitoring followed by six months of post-conversion monitoring. The hydrogen used was intended to be sourced from Western Canada and shipped to the Yukon in transport trailers that would also act as the storage and filling station.

Despite performing early industry engagement of the project design, the project faces significant implementation barriers that render it unfeasible in the current environment. The primary obstacle is hydrogen supply—suppliers in Alberta are unwilling to provide small volumes or send assets to the Yukon. The current compression capabilities of 400 bar are insufficient for high-pressure transportation trailers which carry hydrogen at 450 bar. On-site production would solve the supply issue but the high-level cost information provided suggests that this would be a $10,000,000 solution compared to $1,000,000 for the transport option. On-site generation would require more detailed investigation to determine if it is viable or not.

Additionally, the hydrogen industry's ecosystem remains underdeveloped, with regulatory gaps in codes and standards, limited proven commercial solutions and a shortage of experienced workforce for the new project types. Experience from other pilots reveals consistent challenges with hydrogen supply reliability and significant downtime for production facilities.

Based on these findings, two courses of action are recommended:

1. Delay targeted demonstration start date to 2030, re-visit state of hydrogen industry in 2028. This is when industry development will have progressed significantly through:
    - Completion of current pilots in similar cold climates

- ➢ Development of comprehensive hydrogen codes and standards
- ➢ New hydrogen production facilities in Alberta
- ➢ Greater industry maturity and more reliable supply options

2. Conduct a detailed exploration of on-site green hydrogen production to determine if this could be a viable path forward and explore the actual cost of a right-sized solution.

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