Pores, pipes and politics: The keys to blue hydrogen in Western Canada

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Introduction

Hydrogen holds significant promise as an alternative low-carbon energy source in a range of applications and sectors. Hydrogen is light, versatile, storable, transportable, and energy dense. At BLG we advise on the applications of hydrogen in high value sectors such as transportation, energy and utilities, technology, agribusiness and infrastructure. We also recognize that the hydrogen economy will develop uniquely in each industry sector and geographic region, with available feedstocks, energy inputs, existing infrastructure and geology influencing each industry and regional approach.

Blue hydrogen - hydrogen produced from natural gas, coupled with a carbon capture and storage (CCS) system - has an advantage in Western Canada, which boasts abundant natural gas reserves, close and symbiotic industry clusters, existing pipeline infrastructure, and ideal sequestration geology. Provinces such as Alberta also have favourable legislative regimes, sophisticated regulators, and experienced and innovative industry participants to support the emerging hydrogen economy. With government support, there will be extensive opportunities for new investment in hydrogen midstream infrastructure as the blue hydrogen economy emerges in Western Canada.

What you need to know:

- Western Canada's regional advantages favour blue hydrogen production
- Alberta has the natural geology, transferable experience and legislative framework to support CCS for blue hydrogen
- Existing hydrogen production and transportation infrastructure in Western Canada, along with blending opportunities, establishes a foundation for further dedicated hydrogen development, but government support and political will remain crucial.

Regional advantages

The federal government[1] and several provincial governments[2] have recently released hydrogen strategies analyzing the advantages and opportunities of transitioning toward a less carbon-intensive economy using hydrogen (see BLG's comments in our Hydrogen series).

Each Canadian region is likely to develop a distinct approach based on its available feedstocks (natural gas, electricity and water), energy inputs (natural gas, coal, nuclear or hydro-based electricity), existing infrastructure (pipelines, electric transmission) and geology. As the Federal Hydrogen Strategy recognized, "provincial regulations and policies, resource availability, geography and climate, infrastructure, and technology maturity will shape the timing and scale for hydrogen deployment across Canada."[3]

Western blue

In Western Canada, the natural advantage favours blue hydrogen.

While hydrogen can be produced from a variety of feedstocks,[4] currently the primary source of global hydrogen production is from natural gas, accounting for approximately 75 per cent of the annual global dedicated hydrogen production of approximately 70 millions tonnes (Mt).[5]

Canada ranks in the top 10 of global hydrogen producers and produces about 3 Mt of hydrogen annually (about 8,200 tonnes of hydrogen per day [6]), mainly for industrial use[7] - constituting approximately four per cent of the global total. Most hydrogen is currently produced in Western Canada (76 per cent).

Industrial hydrogen is mainly produced from Steam Methane Reforming, where methane from natural gas is heated with steam and a catalyst to produce a mixture of carbon monoxide and hydrogen[8].

Steam Methane Reforming is the most cost-efficient means of producing hydrogen.[9] It does, however, generate carbon emissions. To assist in achieving Canada's commitments to reduce green house gas (GHG) emissions by 30 per cent below 2005 levels by 2030,[10] and the federal government's target to achieve net zero emissions by 2050, Steam Methane Reforming production must be coupled with a CCS system. It is estimated that life-cycle emissions from hydrogen produced from natural gas with 90 per cent+ CCS ranges from 2 to 3 CO2e/kg Hydrogen,[11] compared to approximately 9 to 10.7 CO2e/kg Hydrogen without CCS[12].

CCS

a) Natural advantages

Having recognized the necessity of a CCS scheme to support blue hydrogen production, the location, feasibility and costs of carbon storage must be considered. Depleted oil and gas reservoirs and saline formations comprised of porous reservoir rocks saturated with brackish water or brine can be used for CO2 storage.[13] The geology of the Western Canadian Sedimentary Basin is the ideal location for this, and the geological characteristics of most depleted oil and gas reservoirs are well known and documented.

It has been estimated that for blue hydrogen to be the energy carrier for 27 per cent of Canada's primary energy demand in 2050, the CCS requirement would be approximately 203 Mt C02 per year[14] (although it is recognized that this is a theoretical upper bound since such hydrogen production would consume the equivalent of 72 per cent of Canada's current natural gas production). While there are a number of variables involved, it has been estimated that the practical CO_2 storage potential in all discovered oil and gas reservoirs in Western Canada ranges from 5 to 10 Gt CO_2.,[15] and theoretically as much as 4,000 Gt CO_2 in deep saline formations,[16] suggesting that the Western Canadian carbon storage capacity is more than sufficient to accommodate this theoretical upper bound of blue hydrogen production.

The challenge, however, will be to identify technically suitable and sufficiently depleted candidate reservoirs so that C02 storage can be staged with efficient oil and gas reservoir management and exploitation,[17] in locations that are proximate to hydrogen production sites, and that are not adversely competing or overlapping with other storage schemes. The candidate sites must also be "economically viable, technically feasible, safe, environmentally and socially sustainable and acceptable to the community.[18]" This C02 storage potential is the primary natural advantage for the production of blue hydrogen in Western Canada.[19]

b) Related experience

The development of the blue hydrogen economy in Western Canada will also be facilitated by its experience in similar projects. Many of the lessons and experiences from existing enhanced oil and gas recovery schemes and acid gas projects, and comparable operations such as natural gas storage, confirm that C02 can be safely injected and stored at appropriate locations. In addition, technology already used in the oil and gas industry in Western Canada (such as well drilling technology, liquid waste injection technology, computer simulation of storage reservoir dynamics and monitoring methods) can be adapted for long term CCS programmes.[20]

In Alberta, the Shell-operated Quest CCS facility has successfully demonstrated the capture and storage of 5 Mt of C02 over the past five years,[21] and the Alberta Carbon Trunk Line, with the capacity to transport 14.6 Mt per year, is demonstrating the successful transportation of captured C02 over a 240-kilometre pipeline. In Saskatchewan, the Weyburn and Midale C02 enhanced oil recovery projects, and the Aquistore transportation and storage projects provide opportunities to test, monitor and improve CCS schemes.

c) Existing legislative and regulatory regime

Alberta has already articulated a CCS legislative and regulatory framework which governs pore ownership, injection and long term stewardship, in addition to establishing detailed regulations for well construction, operation and abandonment for injection wells that will be applicable to C02 sequestration operations. This framework further supports and de-risks the development of the blue hydrogen economy.

According to the *Mines and Minerals Act*, [22] (the MMA) the pore space below the surface of all land in Alberta, other than land owned by the federal Crown, has been declared to be the property of the Crown in right of Alberta,[23] and the rights for use of the pore space are administered by Alberta Energy.

Indeed, the Carbon Sequestration Tenure Regulation[24] (the CS Tenure Regulation), specifically contemplates a storage domain for C02 sequestration consisting of pore space contained in, occupied by, or formerly occupied by, minerals or water within an underground formation deeper than 1,000 metres below the surface of the land (at which depth, depending on temperature, the C02 will be in a dense fluid state).

The CS Tenure Regulation contemplates the grant of evaluation permits to allow a person to test deep subsurface reservoirs and evaluate the geological or geophysical properties to determine its suitability for sequestration of captured C02. The MMA also contemplates the Minister entering into 'carbon sequestration leases,' granting a person the right to inject captured C02 into a subsurface reservoir for sequestration.[25] The carbon sequestration lease may grant the right to drill wells, conduct evaluation and testing, and inject captured C02 into the deep subsurface reservoirs for a 15-year term which term may be renewed, subject to appropriate monitoring, measurement and verification plans and closure plans.

Perhaps the most notable aspect of the MMA for the economic prospects of blue hydrogen in Alberta, however, is section 121, which provides that the Crown will assume long-term liability for projects involving the sequestration of captured C02, once abandonment obligations have been satisfied and a closure certificate has been granted. The effect is that the Crown becomes the owner of the injected C02, assumes the obligations as owner/licensee of the wells and facilities,[26] as the "person responsible" for the injected C02[27], as the operator of the lands[28] and as the user of the surface rights, and also releases the lessee from obligations to indemnify the Crown in relation to the use or drilling of the injection well[29].

The Crown also indemnifies the lessee from damages in a tort action brought by a third party if attributable to the lessee's exercise of rights under an agreement in relation to the injection of captured C02[30]. The MMA also establishes a post-closure Stewardship Fund, into which CCS operators must pay fees in accordance with the regulations,[31] which can be used for monitoring the injected C02, fulfilling any liability obligations assumed by the Crown and paying for suspension, abandonment and reclamation or remediation costs for orphan facilities. These regulatory and statutory assurances should improve the long term risk mitigation and storage costs associated with CCS, thus facilitating blue hydrogen production.

Hydrogen pipelines

Addressing the CCS problem is only one part of supporting the blue hydrogen economy. The next challenge is providing for the transportation, compression or liquefaction, storage and distribution infrastructure for the produced hydrogen. Gaseous hydrogen is commonly delivered in compressed tube trailers or cryogenic liquid tankers by truck, rail or barge. However, transportation by dedicated hydrogen pipelines offers a low cost, safe option for delivering large volumes of hydrogen.[32]

There are a number of technical challenges involved in large volume hydrogen transportation by pipeline, including the potential for hydrogen to embrittle the steel and welds in transmission pipelines,[33] aggravating leak and permeation issues, and the need to improve reliable hydrogen compression to accomplish the necessary compression ratio.[34] These can be addressed by regulation or by tariff.

There are also economic, regulatory and scale issues. Dedicated hydrogen pipelines require significant capital investments, supported by long-term user contracts, and a supportive regulatory environment, to ensure responsible linear project development and to promote safe construction, operation and abandonment. It may also be necessary for public investment into the early stages of greenfield pipeline construction or brownfield pipeline conversion projects to ensure the development of a backbone hydrogen transportation system which provides sufficient scale to be economically viable and which is openly accessible.

Hydrogen can also be transported in existing natural gas pipelines by blending it with the natural gas (between 5 and 20 per cent hydrogen by volume[35]). This can provide a lower carbon gas product to consumers, or, in conjunction with downstream separation and purification technologies, a means of delivering pure hydrogen to market. Pilot blending projects are ongoing in B.C., Alberta[36] and Ontario. However, because of the limits on blending and the continuing need for natural gas pipelines, it is expected that a combination of blending and dedicated hydrogen pipelines will be required to support the development of the full Western Canadian hydrogen economy.

Takeaways

There is considerable excitement about the role of hydrogen in reducing energy carbon intensity. Each region in Canada may develop its own strategy based on its natural advantages.

In Western Canada, the production of blue hydrogen is supported by an advantageous CCS environment, including the natural geological potential of depleted oil and gas reservoirs and saline formations, transferable technology and experience, and a well articulated legislative and regulatory framework. Existing pipelines which transport C02, hydrogen and blended hydrogen will further support a blue hydrogen economy, although additional public support may be required to ensure sufficient scale.

[1] “Hydrogen Strategy for Canada: Seizing the Opportunities for Hydrogen”, Dec. 16, 2020, (the Federal Hydrogen Strategy).

[2] British Columbia ; Alberta; Ontario and Ontario Low-Carbon.

[3] Federal Hydrogen Strategy page 74.

[4] Including water, electricity, fossil fuels, and biomass.

[5] IEA “the Future of Hydrogen: Seizing today’s opportunities, June 2019” (the IEA Report).

[6] Layzell DB; Young C; Lof J; Leary J; Sit, S. 2020. Towards Net-Zero Energy Systems in Canada: a Key role for Hydrogen. Transition Accelerator Reports: Vol. 2, Issue 3 (the Transition Accelerator Report).

[7] Such as fuel refining and nitrogen fertilizer production.

[8] It is also possible to produce hydrogen using auto thermal reforming (ATR), which combines SMR with partial oxidation in a single reactor, coupled with CCS to produce blue hydrogen.

[9] While there is much interest in “green” hydrogen, which produces hydrogen using renewable energy to electrolyse water, green energy does not have the production capacity or cost advantages of blue hydrogen in the near term. For example, the Transition Accelerator Report estimates that blue hydrogen can be produced for approximately $1.52/kg to $3.32/kg compared to approximately $2.24/kg to $5.36/kg for green hydrogen. Thus, blue hydrogen will retain an advantage until the scale and costs of green hydrogen permit it to take on a larger role. (See Transition Accelerator Report, page 44).

[10] Canada committed to reducing GHG emissions by 30 per cent below 2005 levels by 2030 as part of the Paris Agreement with a 2030 target of 511 Mt.

[11] See Transition Accelerator Report, page 9.

[12] See Transition Accelerator Report, page 31.

[13] Intergovernmental Panel on Climate Change, 2005: IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [Metz, B., O. Davidson, H. C. de Coninck, M. Loos, and L. A. Meyer (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 442 pp (the IPCC Report) - Chapter 5 “Underground geological storage”.

[14] Transition Accelerator Report, page 10.

[15] IPCC Report Chapter 5 “Underground geological storage” page 222.

[16] IPCC Report Chapter 5 “Underground geological storage” page 223.

[17] IPCC Report Chapter 5 “Underground geological storage” page 221. “There is uncertainty about when oil and gas fields will be depleted and become available for C02 storage. The depletion of oil and gas fields is most affected by economic rather than technical considerations, particularly oil and gas prices.” Note also that s.39(1.1) of the *Oil and Gas Conservation Act* RSA 200, c.O-6 provides that the Regulator shall not grant a C02 disposal scheme approval unless it is satisfied that the injection of the captured C02 will not interfere with (a) the recovery or conservation of oil or gas, or (b) an existing use of the underground formation for the storage of oil or gas.

[18] IPCC Report Chapter 5 “Underground geological storage”.

[19] The Federal Hydrogen Strategy notes that “The production of hydrogen from natural gas via steam methane forming with CCUS will be constrained by the availability and accessibility of carbon storage geology. Alberta, BC and Saskatchewan have both large natural gas reserves and CO2 storage potential making them favourable for this production pathway.” P. 25.

[20] IPCC Report p. 197

[21] Quest CCS facility captures and stores five million tonnes.

[22] RSA 2000, c M-17.

[23] Section 15.1(1) of the *Mines and Minerals Act* RSA 2000, c M-17 declares that: (1) "no grant from the Crown of any land, … or mines or minerals in any land in Alberta, has operated or will operate as a conveyance of the title to the pore space contained in, occupied by or formerly occupied by minerals or water below the surface of that land; (2) "the pore space below the surface of all land in Alberta is vested in and … remains the property of the Crown in right of Alberta," whether or not the MMA or an agreement issued under the MMA grants rights in respect of a subsurface reservoir (for example, storage rights) or minerals occupying a subsurface reservoir (for example, mineral rights), whether or not "minerals or water is produced, recovered or extracted from a subsurface reservoir"; and (3) Crown title to pore space "is deemed to be an exception contained in the original grant from the Crown for the purposes of section 61(1) of the *Land Titles Act*.

[24] Alta Reg 68/2011.

[25] S. 116 MMA.

[26] Under the *Oil and Gas Conservation Act*. RSA 2000, c O-6.

[27] Under the *Environmental Protection and Enhancement Act* RSA 2000, c E-12.

[28] Under the *Environmental Protection and Enhancement Act* (ibid).

[29] Section 56(2)(a) of the MMA.

[30] Section 121(2).

[31] Section 122 of the MMA.

[32] The Air Products 50 kilometre hydrogen pipeline from its 150 mmcf/d hydrogen facility in the Industrial Heartland of Alberta is an example.

[33] "Blending Hydrogen into Natural Gas Pipeline Networks: a Review of Key Issues." M.w. Melaina; O. Antionia; and M. Penev. National Renewable Energy Laboratory, March 2013. Page viii.

[34] U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy

[35] It is noted that the maximum hydrogen blend varies widely depending on industrial facilities, end user appliances, pipeline types and ages, and natural gas composition and is subject to numerous safety and material integrity issues.

[36] See for example the Atco Gas and Pipelines Fort Saskatchewan hydrogen blending project.

By

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