Comments on the Canadian Federal Government's proposed Clean Hydrogen Investment Tax Credit and the definition of "Clean" Hydrogen

Submitted to the Department of Finance of the Government of Canada on January 6, 2023.

Johanne Whitmore, Senior Researcher, Chair in Energy Sector Management, HEC Montréal | (corresponding author: johanne.whitmore@hec.ca)

David Cebon, FREng, Professor of Mechanical Engineering and Director of the Centre for Sustainable Road Freight, University of Cambridge, UK; co-founder of the Hydrogen Science Coalition.

Paul Martin, Chemical Engineer and Process Development Expert, co-founder of the Hydrogen Science Coalition

Introduction

The term "clean hydrogen" is increasingly used in government and business communications and strategies to refer to "low carbon hydrogen". However, "clean hydrogen" is not guaranteed to reduce emissions. As noted by the Canadian Federal Government, "*there is no single definition of what constitutes "clean hydrogen", as there are a range of carbon intensities that may be associated with the production of hydrogen*[1]".

Climate science tells us we need to decarbonise the global economy by mid-century at the latest to avoid the worst climate impacts. If the objective of ramping up the production of "clean hydrogen" is to replace fossil fuels and avoid exacerbating the climate crisis, then the definition of clean hydrogen must be compatible with the *Intergovernmental Panel on Climate Change* (IPCC) and Paris Agreement's call for temperature rise to be limited to 1.5°C above pre-industrial levels[2].

The Federal Government published a *Hydrogen Strategy for Canada*, in December 2020, to accelerate the development of "clean" or "low carbon" hydrogen projects[3], despite the lack of adequate definition. It is now undergoing consultations to define "carbon intensity tiers for clean hydrogen" projects eligibility to receive clean

[1] Government of Canada, 2022. *Consultation on the Clean Hydrogen Investment Tax Credit*, web page accessed on Dec. 23, 2022, www.canada.ca/en/department-finance/programs/consultations/2022/consultation-on-the-investment-tax-credit-for-clean-hydrogen.html

[2] IPCC, 2022. *Climate Change 2022 – Mitigation of Climate Change*, AR6 WG III, https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf

[3] Government of Canada, 2020. *Hydrogen Strategy for Canada – Seizing the Opportunities for Hydrogen, A Call for Action*, December 2020, p.94, www.nrcan.gc.ca/sites/nrcan/files/environment/hydrogen/NRCan_Hydrogen-Strategy-Canada-na-en-v3.pdf

investment tax credits[4]. The proposed investment tax credit would be based on the lifecycle carbon intensity of hydrogen, like the carbon intensity tiers introduced in the *U.S. Inflation Reduction Act*[5] to guide the level of support to clean hydrogen projects. In this submission, the **Hydrogen Science Coalition[6] (HSC) proposes an objective, quantified and independent definition of "clean" hydrogen based on four key criteria to ensure it is compatible with the IPCC 1.5°C limit to global warming.**

The HSC is an independent group of academics, scientists and engineers who are working to bring an evidence-based viewpoint on the most effective use of hydrogen in the energy transition and to ensure that public investments in hydrogen reflect the most effective path forward towards net-zero goals by 2050. It uses its collective expertise to translate the potential role that hydrogen can play in the energy transition for politicians and investors. Time dedicated to the HSC is entirely voluntary and there are no public or private vested interests in its position.

SUMMARY DEFINITION: The HSC *Clean Hydrogen Definition* uses the same quantitative measure of GHG emissions as the *GH2 Green Hydrogen Standard*, but accounts for all GHG emissions in the production of fossil hydrogen and its supply chain, as follows:

For hydrogen to be defined a "clean" and compatible with the IPCC 1.5°C limit to global warming, total greenhouse gas (GHGs) emissions, across the entire supply chain, should be no more than 1 kg CO_2e per kg H_2 accounting for all 'scope 1' GHGs from hydrogen production, including methane reforming and carbon capture and storage (CCS), and all 'scope 2' GHGs from the methane supply chain and any on-site or purchased electricity.

View full HSC Clean Hydrogen Definition: https://h2sciencecoalition.com/wp-content/uploads/2022/12/Clean-Hydrogen-Definition_final.pdf

*Definition prepared by **David Cebon**, Professor of Mechanical Engineering at the University of Cambridge, in collaboration with HSC members.*

Context

Hydrogen is not an energy source, but an energy carrier that can be produced from different energy sources (e.g., hydrocarbons, renewable or nuclear electricity, chemical by-product). In 2021, 99% of the world's hydrogen was produced from hydrocarbons, primarily natural gas and coal, which emit greenhouse gases (GHGs) in the process. There is no official classification of its carbon footprint, but hydrogen made from hydrocarbons is often classified as "grey hydrogen". This becomes "blue hydrogen" if the carbon is captured and sequestered. "Green hydrogen", which better

[4] Government of Canada, 2022. *Consultation on the Clean Hydrogen Investment Tax Credit*, web page consulted on January 4 2023, www.canada.ca/en/department-finance/programs/consultations/2022/consultation-on-the-investment-tax-credit-for-clean-hydrogen.html
[5] IRS, 2022. *U.S. Inflation Reduction Act of 2022*, www.irs.gov/inflation-reduction-act-of-2022
[6] Hydrogen Science Coalition, 2022. Website consulted on January 5 2023, https://h2sciencecoalition.com

aligns with climate goals, refers to hydrogen made by the electrolysis of water using renewable electricity. These alternative manufacturing processes avoid a large portion of emissions but represent less than 1% of current global hydrogen production. Producing it is expensive and energy intensive. Depending on the end-use of green hydrogen, electricity generation requirements can be 2 to 14 times higher than direct electrification solutions for the same effect[7].

In 2021, global carbon emissions associated with hydrogen production reached more than 900 Mt CO_2 – an increase of around 6% compared with 2020[8]. For scale, Canada emitted a total of 672 Mt CO_2e in 2020. Hydrogen is commercially used today for two main purposes: production of refined petroleum products and the production of ammonia (NH_3) based fertilizers for industrial agriculture. According to the 2022 IPCC report, decarbonized hydrogen will remain a relatively small portion of the global energy balance due to technical and economic barriers – at best 2% in 2050 and 5% in 2100[9].

Given the limited supply and techno-economic potential for decarbonizing the economy, studies emphasize the need to first focus on replacing existing grey hydrogen uses in the markets with green hydrogen, while new uses of hydrogen based fuels should focus on "no-regret" sectors[10] (i.e., those that do not lend themselves to direct use of electricity, such as industries that utilize the chemical (reducing) properties of hydrogen [e.g., steel, glass, cement]), as well as targeted strategies that promote local production and consumption of green hydrogen in industrial hubs – to minimize energy loss throughout the value chain (i.e., from production to end-use). Blending hydrogen in natural gas[11] for heating buildings[12] or for personal transportation, for example, are identified as wasteful applications of hydrogen due to high energy inefficiencies and because there are more cost-effective options to use electricity directly for decarbonizing those end-uses.

While the designation of "clean" hydrogen can include green hydrogen or hydrogen produced from nuclear electricity, it is more typically used by the fossil industry and governments to refer to hydrogen produced from fossil fuel coupled with carbon capture and storage (CCS). Without CCS, a technology that is unproven economically at large-scale, fossil-based (or grey) hydrogen is more polluting than using natural gas

---

[7] Ueckerdt, F., et al., 2021. "Potential and risks of hydrogen-based e-fuels in climate change mitigation", *Nature Climate Change*, Vol 11, pages 384–393, https://dx.doi.org/10.1038/s41558-021-01032-7

[8] IEA, 2022. *Hydrogen Supply – Subsector Overview*, Tracking report, September 2022, www.iea.org/reports/hydrogen-supply

[9] IPCC, 2022. *Climate Change 2022 – Mitigation of Climate Change*, AR6 WG III, Chapter 12, p.123, https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf

[10] Ueckerdt, F., et al., 2021.

[11] Bard, J., et al., 2022. *The limitation of hydrogen blending in the European gas grid - A study on the use, limitations and cost of hydrogen blending in the European gas grid at the transport and distribution level*, Fraunhofer Institute for Energy Economics and Energy System Technology, prepared for the European Climate Foundation, www.iee.fraunhofer.de/content/dam/iee/energiesystemtechnik/en/documents/Studies-Reports/FINAL_FraunhoferIEE_ShortStudy_H2_Blending_EU_ECF_Jan22.pdf

[12] Rosenow, J., 2022. "Is heating homes with hydrogen all but a pipe dream? An evidence review", *Joules*, Vol 6, Issue 1, October 19 2022, www.sciencedirect.com/science/article/abs/pii/S2542435122004160

outright, on a life-cycle basis, and therefore cannot be considered "clean" by default. Canada's Shell Quest project, currently one of the few large-scale fossil hydrogen with CCS projects globally, has emission capture rates of less than 50%. That's far short of the 90% capture rate often promised by industry[13], and this is before factoring in emissions from energy used for CCS, harmful methane fugitive emissions[14], as well as hydrogen leaks whose global warming potential (GWP) are two to six times[15] higher than previously thought (see Figure 1, below).

The perceived advantage of hydrogen is its resemblance to natural gas – it exists as liquid or gas, flows through pipes, stores in tanks, and burns in engines. Switching one gas for the other seems logical. But the inherent challenges of hydrogen, as discussed above, has led many, including the International Energy Agency, to call for slashing gas demand as a priority. In the context of western Canada, many view repurposing natural gas infrastructure to hydrogen as a way of avoiding stranded assets[16] in the fossil fuel industry as we progress towards a net-zero economy. However, blue hydrogen production and export are not expected to be economically viable without huge public subsidies or very high carbon tax. Experts argue that shipping liquid hydrogen would be at least five times as expensive as liquid natural gas (LNG)[17]. As Europe's energy crisis intensifies demand for North American LNG imports, this will only lead to higher gas prices and costs to consumers. A future tight market means fossil hydrogen with CCS won't be a low-cost solution, even before the costs of scaling CCS and mitigating upstream fugitive emissions are accounted for[18]. By default, hydrogen will always be significantly more expensive than the energy used to produce it.

Hydrogen as a "clean" energy vector therefore has significant progress to make to be consistent with the net zero emissions pathway by 2050. These limits, supported by independent studies, has led the HSC to develop **five guiding principles**[19] to ensure an effective use of hydrogen in the energy transition which is compatible with the Paris Agreement:

---

[13] Meredith, S., 2022. *Shell's massive carbon capture facility in Canada emits far more than it captures, study says, CNBC*, article published on-line on January 24 2022, www.cnbc.com/2022/01/24/shell-ccs-facility-in-canada-emits-more-than-it-captures-study-says.html

[14] Longden, T. et al., 2022. "'Clean' hydrogen? – Comparing the emissions and costs of fossil fuel versus renewable electricity-based hydrogen", *Applied Energy*, vol 306, Part B, January 15 2022, https://doi.org/10.1016/j.apenergy.2021.118145

[15] Ocko, I., Hamburg, S., 2022. "Climate consequences of hydrogen emissions", *Atmospheric Chemistry and Physics*, 22, 9349-9368, https://acp.copernicus.org/articles/22/9349/2022/acp-22-9349-2022.pdf

[16] Semieniuk, G., et al., 2022. Stranded fossil-fuel assets translate to major losses for investors in advanced economies, *Nature Climate Change*, 12, 532-538, www.nature.com/articles/s41558-022-01356-y

[17] Barnard, M., 2021. Shipping Liquid Hydrogen Would Be At Least 5 Times As Expensive As LNG Per Unit Of Energy, *CleanTechnica*, article published on December 20 2021, https://cleantechnica.com/2021/12/20/shipping-liquid-hydrogen-would-be-at-least-5-times-as-expensive-as-lng-per-unit-of-energy/

[18] Collins, L., 2022. 'High risk of stranded assets' | Blue hydrogen 'does not make sense' in a gas price crisis: study, *RECHARGE*, article published on May 24 2022, www.rechargenews.com/energy-transition/high-risk-of-stranded-assets-blue-hydrogen-does-not-make-sense-in-a-gas-price-crisis-study/2-1-1224465

[19] Hydrogen Science Coalition, 2022. *Our Principles*, https://h2sciencecoalition.com/wp-content/uploads/2022/08/Hydrogen-Science-Coalition-Principles.pdf

1) Near zero emissions hydrogen is an opportunity for governments to advance the energy transition. However, the only near zero emissions hydrogen, on a life-cycle basis, is that made from renewable electricity.
2) Near zero emission hydrogen must be deployed for existing grey hydrogen uses and hard to decarbonize sectors.
3) Hydrogen shouldn't be used to delay deploying electrification and energy efficiency solutions.
4) Given how valuable near zero emissions hydrogen is, blending it into the existing natural gas grid does not make sense due to its limited impact on emissions savings.
5) Prioritize the production and consumption of locally produced renewable hydrogen to minimize energy loss and cost.

Clean Hydrogen Definition

Despite the substantial challenges described above, the Canadian government has committed to "clean" hydrogen, placing fossil hydrogen with CCS at the centre of its *Hydrogen Strategy for Canada*. There is concerns that if the Department of Finance defines carbon intensity tiers for clean hydrogen too leniently and consequently incompatible with the IPCC 1.5°C limit to global warming – notably for developing a blue hydrogen market[20] – this would risk locking Canada into a fossil-based economy and divert funds from real cost-effective mitigation measures that structurally decarbonize the Canadian economy, including energy efficiency, circular economy strategies, direct electrification applications and renewable hydrogen.

The HSC therefore recommends that the Department of Finance bases its carbon intensity tiers on an objective, quantified and independent definition of "clean" hydrogen that is compatible with the IPCC 1.5°C limit to global warming.

The following are excerpts from the *Clean Hydrogen Definition* published on the HSC website: https://h2sciencecoalition.com/wp-content/uploads/2022/12/Clean-Hydrogen-Definition_final.pdf

RECOMMENDATION 1. *To be defined as "clean" hydrogen, emissions intensity levels should be no greater than 1 kg CO_2e per kg H_2 taken as an average over a 12-month period.*

As mentioned, there are several methods for generating "clean" hydrogen. The HSC definition concentrates on the two methods most likely to dominate future production, namely green and blue.

HSC recommends that the Department of Finance uses as the starting point of its Clean Hydrogen Definition the same quantitative measure of GHGs as the *GH2 Green*

[20] Whitmore and Martin, 2022. "Repurposing LNG infrastructure for hydrogen exports is not realistic", *Globe and Mail*, Op-Ed published on August 8 2022, www.theglobeandmail.com/business/commentary/article-lng-infrastructure-clean-hydrogen-exports

Hydrogen Standard (1 kg CO2e per kg H2), but accounts for all GHG emissions in the production of fossil hydrogen and its supply chain. This will ensure:

- A **level playing field** in the hydrogen industry as all hydrogen will be required to meet the same emissions standards and satisfy rigorous net-zero emissions standards into the future.
- When clean hydrogen is used it will have **equally low GHG emissions**, whatever the source of the hydrogen.
- Anyone specifying systems that use clean hydrogen will be **confident of the level of embodied carbon**, without having to perform a detailed analysis of the pedigree of the hydrogen. This will simplify hydrogen trade by providing market alignment between countries.
- **Best available technology** will be used uniformly in hydrogen production.
- Any government subsidies applied to clean hydrogen manufacture will be applied **in the best interests of the environment**, rather than in the interests of one sector of the industry over another.

To guarantee that the GHG emissions of fossil-based hydrogen are no greater than for green hydrogen, the HSC recommends that the definition meet four components summarized in Table 1. Each of the components are further described in the on-line document (see p.4-5: https://h2sciencecoalition.com/wp-content/uploads/2022/12/Clean-Hydrogen-Definition_final.pdf).

Table 1. Four components of the proposed HSC definition of "clean" hydrogen

1 DEFINITION OF "CLEAN"	2 CLEAN ENERGY INPUTS
Total GHG emissions from the entire supply chain are consistent with the proposed *GH2 Green Hydrogen Standard*[21]: **1 kg CO_2e per kg H_2** (average over a 12-month period) • Incl. all scope 1 emissions from production, including methane reforming and CCS and scope 2 emissions from methane supply chain and any onsite or purchased electricity • GWP of all gases are calculated on a 100-year basis	• Require certificates of origin for all energy (gas and electricity) used in hydrogen production and CO_2 sequestration. • Guarantee that methane emissions throughout the gas supply chain complies with the *MIQ Standard*[22]: o Production, gathering and boosting o Processing and liquefaction o Transmissions: all pipes and vessels o Transportation, loading, unloading and storage
3 LOW PRODUCTION EMISSIONS	**4 INDEPENDENT PROCESS AUDIT**
• Guarantees of CO_2e emissions through the reforming process and downstream o CO_2 and other gases released during reforming and H_2 storage o CO_2 from CCS process energy o CO_2 leakage from compression, transmission, and sequestration • Guarantees of long-term storage fidelity (99% over 1,000 years), with provision for long-term monitoring of storage permanence and liability contract to cover cost of potential future leakage. o Measurements and calculations of CO_2 emissions according to standards by *ISO/TC 265 Carbon dioxide capture, transmissions, and geological storage*[23].	• Independent data-led verification by approved auditors, in accordance with the principles of *ISO 1416:2020 Environmental management – guidelines on the assurance of environmental reports*[24] • All emissions to be guaranteed during the design process, verified, and certified for the end-product.

[21] GH2, 2022. *The GH2 Green Hydrogen Standard*, web page consulted on January 5 2023, https://gh2.org/our-initiatives/gh2-green-hydrogen-standard

[22] MIQ, 2022. *The MIQ Standard*, web page consulted on January 5 2023, https://miq.org/

[23] ISO, 2022. *ISO/TC 265 Carbon dioxide capture, transmissions and geological storage,* https://www.iso.org/committee/648607.html

[24] ISO, 2020. *ISO 14016:2020 Environmental management. Guidelines on the assurance of environmental reports,* https://www.iso.org/obp/ui#iso:std:iso:14016:dis:ed-1:v1:en

RECOMMENDATION 2. *GHG emissions must be measured on a life cycle basis when quantifying the carbon intensity associated with the production of blue hydrogen.*

There are several sources of GHG emissions in the blue hydrogen manufacturing process (see Figure 1). These include:

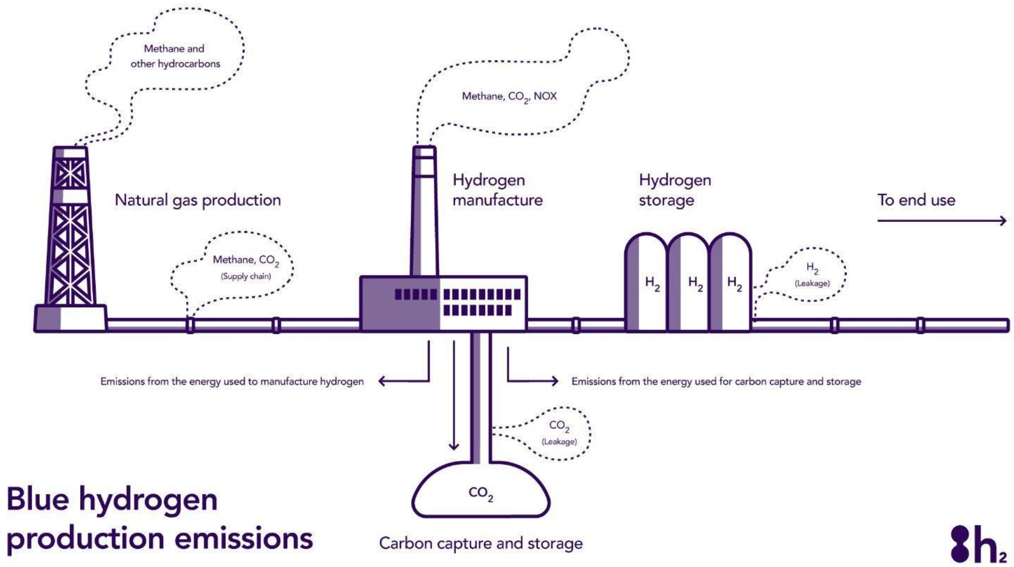
1) **Upstream fugitive emissions** of methane CH_4 and other hydrocarbons released from the input gas supply chain. These emissions can come from the gas well (flaring, venting or leaking) and leaks in the supply chain infrastructure (e.g., pipes, pumps, valves, vessels).
2) **Energy source**: The process requires considerable energy input which has associated CO_2e emissions that must be considered. Energy is required to pump methane, provide the water, heat the steam and run the process plant. A significant amount of energy is also needed to pump the output CO_2 into geological storage.
3) **Production emissions**: The reforming process can emit GHG including CH_4, CO_2 and N_2O, as well as other gases with a high global warming potential including NO_x and H_2. The largest sources are due to incomplete capture of CO_2 and any methane or hydrogen leaks from equipment.

All these emissions must be measured and included when quantifying the GHG emissions associated with the manufacture of blue hydrogen.

It is important to note that chemical plants of the type used to produce fossil hydrogen typically have an operational life of 30 years, because of the high cost of capital which must be recovered over a long period of operation. Fossil hydrogen production cannot therefore be considered as a temporary or interim measure. Consequently, to be a sustainable solution, any new hydrogen manufacturing process must comply with rigorous net-zero emissions standards and adopt performance requirements equivalent to *GH2 Green Hydrogen Standard*[25].

[25] GH2, 2022. *The GH2 Green Hydrogen Standard*, webpage consulted on January 5 2023, https://gh2.org/our-initiatives/gh2-green-hydrogen-standard

Figure 1. GHG emissions generated in the process of blue hydrogen supply chain



RECOMMENDATION 3. *To be compatible with the IPCC 1.5°C limit to global warming, the carbon intensity tiers, and tax credit rates must also be compatible with the recommended definition for "clean" hydrogen (maximum of ≤ 1 kg CO_2e per kg H_2 taken as an average over a 12-month period).*

Below is a proposed revision of carbon intensity tiers and credit rates for Canadian investment tax credit compatible with a "clean" hydrogen, as defined by the HSC (≤1 kg CO_2e per kg H_2), and the IPCC 1.5°C limit to global warming. See Recommendations 1 and 2 above for full definition.

Carbon Intensity Tiers (CO_2e per kg of H_2 produced taken as an average over a 12-month period)	**Investment Tax Credit Rates***
<0.45 kg	40%
0.45 kg to <0.65 kg	30%
0.65 to **≤1 kg**	20%

Answers to key questions

The following section provides answers or references to answers to key questions on the design of the investment tax credit for clean hydrogen (See www.canada.ca/en/department-finance/programs/consultations/2022/consultation-on-the-investment-tax-credit-for-clean-hydrogen.html). HSC answers are provided in *italic*.

1. What clean hydrogen production pathways can be expected going forward? What are expectations for future hydrogen demand (e.g., by 2030)? What are potential hydrogen opportunities in Canada?

See Context chapter, above, p. 2-4: « In 2021, global carbon emissions associated with hydrogen production reached more than 900 Mt CO2 – an increase of around 6% compared with 2020. For scale, Canada emitted a total of 672 Mt CO2 eq in 2020. Hydrogen is commercially used today for two main purposes: production of refined petroleum products and the production of ammonia (NH3) based fertilizers for industrial agriculture. ***According to the 2022 Intergovernmental Panel on Climate Change (IPCC) report, decarbonized hydrogen will remain a relatively small portion of the global energy balance due to technical and economic barriers – at best 2% in 2050 and 5% in 2100.***

Opportunities*: Given the limited supply and techno economic potential for decarbonizing the economy, studies emphasize the need to first focus on* ***replacing existing grey hydrogen uses*** *in the markets with green hydrogen, while new uses of hydrogen based fuels should focus on* ***"no-regret" sectors*** *(i.e., those that do not lend themselves to direct use of electricity, such as industries that exploit the chemical characteristics of hydrogen [e.g., steel, glass, cement]), as well as* ***targeted strategies that promote local production and consumption of green hydrogen in industrial hubs*** *– to minimize energy loss throughout the value chain (i.e., from production to end-use). Blending hydrogen in natural gas for heating buildings or for personal transportation, for example, are identified as wasteful applications of hydrogen due to high energy inefficiencies and because there are more cost-effective options to use electricity directly for decarbonizing those end-uses.»*

See also:

- *Un appel à la réalité s'impose pour l'hydrogène vert, www.lapresse.ca/debats/opinions/2022-04-16/un-appel-a-la-realite-s-impose-pour-l-hydrogene-vert.php*
- *Repurposing LNG infrastructure for hydrogen exports is not realistic, www.theglobeandmail.com/business/commentary/article-lng-infrastructure-clean-hydrogen-exports*

2. What would constitute appropriate carbon intensity tiers in the Canadian context? What makes such tiers appropriate?

See Recommendation 5 and 1, above, p. 5-6.

3. Under what carbon intensity tiers are the different clean hydrogen production pathways in Canada expected to be found?

All green hydrogen projects would be eligible as long as they are fed electricity with sufficiently low carbon intensity (i.e., the use of grid electricity would be discouraged in provinces such as Alberta, Saskatchewan, PEI, New Brunswick and Nova Scotia and even Ontario would make grid electricity use questionable) , but most blue hydrogen projects currently ongoing wouldn't, as their GHG intensities are still too high even if high percentage CO2 capture methodologies for hydrogen production are used (i.e., autothermal reforming). See reference to Canada's Shell Quest project on p.3 above. Fossil hydrogen as a "clean" energy vector still has significant progress to make to be consistent with the net zero emissions pathway by 2050.

4. What levels of support would be appropriate for each carbon intensity tier, including the proposed top rate of at least 40 percent?

See Recommendation 3, above, p.8.

5. What equipment is required at clean hydrogen production facilities? Is there equipment that is external to the facility that may be needed to support clean hydrogen production and how should the government consider eligibility for that equipment under the clean hydrogen investment tax credit or other investment tax credits?

The Canadian Government should remain technology neutral and instead set certified and internationally recognized emissions performance standards, to allow greater flexibility to industry. See proposed standards in Table 1, above, p.6

6. What are the most common methods used to prepare clean hydrogen for transportation, including the various forms that hydrogen could take (e.g., compressed gas, liquid, or intermediate "hydrogen carrying" products like ammonia or methanol)? What stationary infrastructure is required to prepare hydrogen for transportation, either domestically or internationally?

See Context chapter, above, p. 2-4. See also «Repurposing LNG infrastructure for hydrogen exports is not realistic», www.theglobeandmail.com/business/commentary/article-lng-infrastructure-clean-hydrogen-exports/

7. Life cycle carbon intensity calculation:

a. Are there any concerns with using the Government of Canada's Fuel Life Cycle Assessment Model for calculating the life cycle carbon intensity of clean hydrogen production?
b. What additional guidance or support could be provided to help with the calculation of life cycle carbon intensity of clean hydrogen production with this model?
c. What should be included in the scope of the life cycle carbon intensity calculation? How could this extend to clean hydrogen that is produced alongside co-products, or as a by-product of an industrial process?

See Recommendations 1 and 2, above, p. 5-7.

8. Once hydrogen is being produced, how much would the carbon intensity differ from the carbon intensity that was expected based on the design of the plant? Does this differ by production pathway? Is it possible to ensure that the carbon intensity of the clean hydrogen produced will be within a certain band and would this change over time? For the different clean hydrogen production pathways, what ongoing monitoring and calculations are done to measure carbon intensity once a clean hydrogen facility begins production?

This is why annual independent process audits and GH2, MQI and ISO standards should be required for clean hydrogen projects requesting tax credits. See Table 1, above.

9. How could life cycle carbon intensity calculations at the stage of plant design, and once a plant has actually started operations, be verified?

See our answer to question 8 above.

10. What is the typical service life of a clean hydrogen production facility and what are the risks that a project may not operate through to the end of its useful life?

Chemical plants of the type used to produce fossil hydrogen typically have an operational life of 30 years, because the high capital cost requires payback over an extended operating period. Fossil hydrogen production cannot therefore be considered as a temporary or interim measure. Consequently, to be a sustainable solution, any new hydrogen manufacturing process must comply with rigorous net-zero emissions standards and adopt performance requirements equivalent to GH2 Green Hydrogen Standard. See Recommendations 1 and 2, above.