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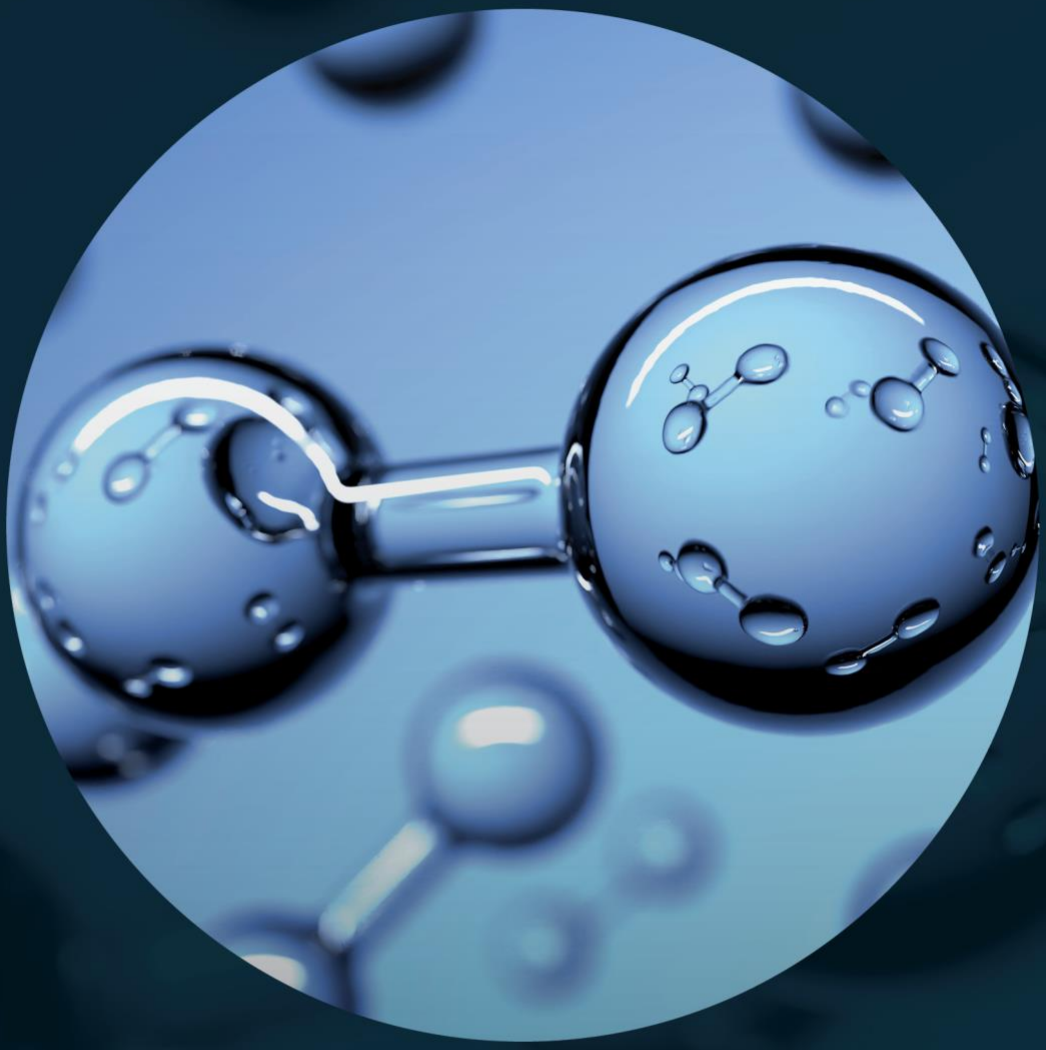

HYDROGEN:

A Viable Option for a Net-Zero Canada in 2050?

Report of the Standing Senate Committee on Energy, the Environment and Natural Resources

The Honourable Rosa Galvez, Chair

The Honourable Josée Verner, P.C., Deputy Chair

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THE COMMITTEE MEMBERSHIP

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The Honourable
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Membership of the Committee during this study which was held under the presidency of the Honourable Senator Paul J. Massicotte.

Ex-officio members of the committee:

The Honourable Senator Marc Gold, P.C., or Raymonde Gagné
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The Honourable Clément Gignac
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ORDER OF REFERENCE

Extract from the *Journals of the Senate* of Thursday, February 24, 2022:

The Honourable Senator Massicotte moved, seconded by the Honourable Senator Lankin, P.C.:

That the Standing Senate Committee on Energy, the Environment and Natural Resources be authorized to examine and report on emerging issues related to its mandate:

(a) The current state and future direction of production, distribution, consumption, trade, security and sustainability of Canada's energy resources;

(b) Environmental challenges facing Canadians including responses and adaptation to global climate change, pollution, biodiversity, and ecological integrity, and the cumulative environmental effects of energy and natural resource development;

(c) Sustainable development and management of renewable and non-renewable natural resources including but not limited to water, minerals, soils, flora and fauna;

(d) Pathways to net-zero greenhouse gas emissions and ways to address the human and environmental impacts of climate change and manage the transition to a low carbon economy;

(e) Opportunities and challenges for women, Indigenous Peoples, Black and racialized Canadians, newcomers, persons with disabilities, and LGBTQ2 Canadians, in the energy and natural resource sectors; and

(f) Canada's international treaty obligations affecting energy, the environment and natural resources and their influence on Canada's economic and social development; and

That the committee submit its final report no later than December 31, 2025 and that the committee retain all powers necessary to publicize its findings until 180 days after the tabling of the final report.

The question being put on the motion, it was adopted.

Interim Clerk of the Senate

Gérald Lafrenière

REQUEST FOR GOVERNMENT RESPONSE

Pursuant to rule 12-24(1), the Senate requests a complete and detailed response from the government to this report, with the Minister of Environment and Climate Change Canada being identified as minister responsible for responding to the report, in consultation with the Minister of Natural Resources, the Minister of Finance, the Minister of Innovation, Science and Industry, the Minister of Indigenous Services and the Minister of Crown-Indigenous Relations.

EXECUTIVE SUMMARY

Our committee launched a study titled *Hydrogen: A Viable Option for a Net-Zero Canada in 2050?*. We were concerned with solutions for climate change. We wanted to understand hydrogen's potential role in the energy transition for Canada to achieve its goal of net-zero greenhouse gas emissions by 2050 (NZE2050).

Achieving NZE2050 in Canada's energy system will depend, in part, on low-carbon intensity (CI) electricity and low-CI fuels, including hydrogen. Low-CI electricity will do most of the work of achieving NZE2050, but in the sectors and applications where electricity is not a good option, low-CI hydrogen can possibly replace high-CI fossil fuels. This would be something fundamentally new for Canada, requiring a transformational change to infrastructure and energy mixes over the coming few decades. If successful, new industries, products, and services could emerge with different regional benefits.

However, it does not make sense to consider hydrogen in isolation from the alternatives. To get to NZE2050 requires a systems perspective that looks at all the options for the energy system and optimizes for the outcomes we want. There are no low-CI options that are silver bullet solutions for the energy transition. The systems perspective makes transparent the tradeoffs between low-CI options and helps us understand their different social, environmental and economic values and costs. The perspective can help us protect current and future generations by identifying and considering their concerns in decision-making and energy planning today.

How hydrogen is made and whether it is made from methane or water is less important than what its life cycle carbon intensity is. NZE2050 demands that eventually Canada use only the lowest carbon intensity energy options in our economy. But the hydrogen Canada produces and consumes today is more than twice as carbon intensive as methane, so low-CI hydrogen supply and demand needs to grow from near-zero to play a role in achieving NZE2050.

While there are lots of potential pathways for producing and using low-CI hydrogen in Canada, some are more promising than others. The Government of Canada described many of these pathways in its national vision for the hydrogen sector, the *Hydrogen Strategy for Canada: Seizing the Opportunity*.

At the same time, the provinces and territories have their own hydrogen ambitions depending on their natural resources, energy supplies, policy environments,

economies, infrastructure, and other factors. What ends up determining the hydrogen pathway in each region may come down to the relative cost of methane, geological sequestration of greenhouse gases, and of low-CI electricity.

The Government of Canada has supported the hydrogen sector for many years, including through research and development, funding programs, tax incentives and regulations. But the domestic low-CI hydrogen sector is unlikely to develop on its own without further government supports – or at least it will not develop at the pace required by NZE2050. The domestic hydrogen sector is also at risk of investments going to other countries, such as the United States with its *Inflation Reduction Act of 2022*, that offer more generous incentives than Canada provides.

New Government of Canada policies have recently been announced to support the hydrogen sector. Our report, *Hydrogen: A Viable Option for a Net-Zero Canada in 2050?*, outlines our findings and provides our recommendations to the Government of Canada as it designs policies to help Canada achieve NZE2050.

RECOMMENDATIONS

Recommendation One

The Government of Canada must improve how it models the environmental, economic and social benefits and costs of its energy programs and policies by taking a system perspective and being more transparent about the tradeoffs between options.

Recommendation Two

The Government of Canada must make its energy models and related methodologies transparent and accessible to peer-review and public scrutiny and improve governance in this respect to enhance accountability and public trust.

Recommendation Three

The Government of Canada must quickly implement the recommendations of the Commissioner of the Environment and Sustainable Development (CESD) with respect to the CESD's hydrogen audit, including completing comprehensive modelling for the use of hydrogen, publishing a hydrogen market development roadmap, adopting a standard framework for estimating the emission reductions of government policies, and improving federal modelling assumptions.

Recommendation Four

The Government of Canada must present credible economic and energy transformation plans for achieving NZE2050 and any interim targets along the way, informed by the CESD's comments about factoring in the "environmental, economic and the social costs, the negative externalities that are not captured by carbon pricing and the negative temporal externalities that are borne by future generations."

Recommendation Five

Where possible, the Government of Canada must seek arrangements where it shares the funding, risk and rewards with hydrogen suppliers and investors in a pro-rated fashion, ensuring mutual benefit and risks.

Recommendation Six

The Government of Canada must take into account the dynamic of other countries' hydrogen subsidies on Canadian businesses as it develops incentives for the domestic hydrogen sector, so that, commensurate with its risks and investments, Canada claims its fair share of the results.

Recommendation Seven

The Government of Canada must apply its national carbon pricing framework more stringently across economic sectors and reduce any exemptions to the framework that may exist. It should take measures to increase certainty that the national carbon pricing framework will endure and that the carbon price will continue to rise.

Recommendation Eight

The Government of Canada's hydrogen and NZE2050 policies must define low-carbon intensity standards that are technology agnostic, and continually lower the allowed carbon intensity on track with credible NZE2050 pathways.

Recommendation Nine

The Government of Canada must focus on growing the domestic low-carbon intensity hydrogen supply and demand for the critical sectors and applications that will help achieve NZE2050; but it should invest strategically, in partnership with other levels of government and the private sector, and not take on too much risk with public funds.

Recommendation Ten

The Government of Canada must identify and invest in hydrogen hubs that will help achieve NZE2050 and work in partnership with provinces, territories and Indigenous Peoples to achieve regional hydrogen ambitions.

Recommendation Eleven

The Government of Canada, in the development and implementation of hydrogen as an energy source, must ensure that their relations with Indigenous Peoples and Indigenous Governments in Canada comply with Section 35 of the Constitution Act, 1982, the principle of the honour of the Crown, and the principles in Canada's treaty relationships, and its fiduciary obligations to the Indigenous Peoples of Canada.

Recommendation Twelve

The Government of Canada must ensure that hydrogen companies operating in Canada, or abroad, are in compliance with Canadian laws and regulations.

Recommendation Thirteen

Given that hydrogen energy is still nascent, the Government of Canada must periodically review its Hydrogen Strategy. If in the future hydrogen energy is no longer a cost-competitive or environmentally responsible path to net zero, the Government must revise its strategy and reevaluate its investment of public funds in this industry.

Recommendation Fourteen

The committee requests that the Government of Canada table a comprehensive response to this Report.

DEFINITIONS

[1]*Greenhouse gases*—Gases in the atmosphere that warm the earth by trapping infrared radiation. They include carbon dioxide, methane, and nitrous oxide.

Decarbonization—The process of reducing and removing carbon dioxide output from a country's economy.

Electrification—The process of using electricity to displace hydrocarbons in new economic sectors and applications.

Hydrogen—The simplest of the chemical elements.

Energy carrier—A substance that is used to store and transport energy from one place to another. Hydrogen is an energy carrier that stores energy in chemical form.

Carbon intensity of hydrogen production—A method for comparing the end-to-end life cycle of greenhouse gas emissions of hydrogen as it moves from a primary energy source to a delivered energy commodity.

Hydrogen production pathway—Describes the hydrogen production process based on the different processes (for example, steam methane reforming or electrolysis) and feedstocks (for example, methane or water) used to produce it.

Steam methane reforming—A process in which methane from natural gas is heated using steam, usually with a catalyst, to produce a mixture of carbon monoxide and hydrogen.

Carbon capture, utilization and sequestration—The process of capturing carbon dioxide from facilities (including industrial or power applications), compressing it, and transporting it to be permanently stored in geological formations underground (for example, saline aquifers or oil reservoirs) or used to create products (for example, concrete and low-carbon synthetic fuels).

Electrolysis—The process of using electricity to decompose water into hydrogen and oxygen gas.

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[1] Definitions adapted from Commissioner of the Environment and Sustainable Development, *Report 3—Hydrogen's Potential to Reduce Greenhouse Gas Emissions*, 2022.

Grey hydrogen—Hydrogen that is produced from methane using steam methane reforming. Greenhouse gases from the process are released unabated to the atmosphere.

Blue hydrogen—Hydrogen that is produced from methane using steam methane reforming. Greenhouse gases from the process are captured and sequestered or used to create other products.

Green hydrogen—Hydrogen that is produced from water using electrolysis, emitting no greenhouse gases from the process.

1. HYDROGEN: A VIABLE OPTION FOR A NET-ZERO CANADA IN 2050?

1.1 Introduction

The Standing Senate Committee on Energy, the Environment and Natural Resources (we, us, or the committee) launched our study titled *Hydrogen Energy for Canada in a Net-zero 2050* in March 2022. Hydrogen atoms are the simplest and lightest of the chemical elements. The widespread use of *hydrogen* in the energy system would be something fundamentally new for Canada. Today, virtually all hydrogen in Canada and the rest of the world is used as a feedstock for chemicals, fertilizers and refining. Through this study, we have sought to understand what it could mean to develop the hydrogen energy opportunity for Canada and whether hydrogen energy will help Canada reduce its *greenhouse gas* ("GHG," *definition*) emissions to *net-zero emissions by 2050* (NZE2050).[2] While we don't yet have a clear understanding of the role hydrogen will play in our energy systems over the next three decades, we heard a range of opinions from those claiming that hydrogen must be deployed at scale for Canada to have a chance of achieving NZE2050 to those claiming that only non-emitting forms of hydrogen may earn a place in Canada's energy mix.

We heard from 33 witnesses over the course of 9 meetings held between March and November 2022.[3] The witnesses to our study discussed many policy tools and investments that the Government of Canada is making or could leverage to help the industry develop sustainably. They also highlighted many of the opportunities and challenges facing Canada's nascent hydrogen sector.

During our hearings, there were important developments that informed our inquiry. For example, these included the signing of a bilateral declaration of intent establishing the *Canada–Germany Hydrogen Alliance* for the export of hydrogen produced from renewable energy sources, and the enactment of the *Inflation Reduction Act of 2022* in the United States, which creates incentives for *low-carbon intensity* ("low-CI," *definition*) hydrogen supply and demand in that country.

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[2] *Net-zero emissions* is the national greenhouse gas target set for Canada in the *Canadian Net-zero Emissions Accountability Act, 2021* (CNZEAA, 2021) for the year 2050. According to CNZEAA, 2021, "net-zero emissions" means that "anthropogenic emissions of greenhouse gases into the atmosphere are balanced by anthropogenic removals of greenhouse gases from the atmosphere over a specified period."

[3] A list of the witnesses who appeared during our study is included in the Appendix.

This report sets out our findings and recommendations to the Government of Canada. In this first chapter, we look at the hydrogen opportunity in the context of Canada achieving NZE2050. We begin by considering the life cycle of hydrogen supply and demand from a systems perspective. We go on to consider the sectors and applications in the Canadian and global energy system where low-CI hydrogen could be important for driving the energy transition and clean growth. In the second chapter, we explore the different Government of Canada programs and policies that support the hydrogen sector. In the third chapter, we discuss other challenges and opportunities for the hydrogen sector that our witnesses raised, which are important for the Government of Canada to consider as it designs energy and climate policies to achieve NZE2050. Finally, the report concludes with our recommendations to the Government of Canada.

1.2 Consider Hydrogen from a Systems Perspective

> Hydrogen deployed at scale across Canada is needed for us to meet our decarbonization objectives and climate change commitments. We cannot get to net zero without hydrogen. – *Sabina Russell*[4]

Hydrogen is the simplest element. It is found first on the periodic table of elements. In nature, hydrogen is not found in its pure state, but it can be produced through different industrial processes by separating hydrogen from molecules of water or methane. When hydrogen is isolated this way, it is called an *energy carrier* (*definition*), meaning that it stores energy that is released when it is combusted, or when it is used in a device called a fuel cell, for instance.

The witnesses we interviewed could not say with certainty what the ultimate role of hydrogen will be in Canadian or global energy systems, or how hydrogen will contribute to the energy transition as we move towards NZE2050. We heard many questions about hydrogen's role in the energy system and economy that remain to be answered. Some witnesses were enthusiastic about hydrogen's potential while others expressed reservations.Yet, we frequently heard during our study that low-CI hydrogen will be a necessary complement to *electrification* (*definition*) and other

[4] Senate, Standing Committee on Energy, the Environment and Natural Resources (ENEV), *Evidence* (Sabina Russell, Principal and Co-founder, Zen Clean Energy Solutions), 31 March 2022.

decarbonization (*definition*) strategies, as part of a viable approach to achieving NZE2050.

The Government of Canada has outlined a vision of a transformational change in Canada's energy systems in its *Hydrogen Strategy for Canada: Seizing the Opportunity* that sees hydrogen delivering "up to 30% of Canada's end-use energy by 2050."[5] Aaron Hoskin of Natural Resources Canada (NRCan) told us that:

> For Canada to reach its commitment to net-zero emissions by 2050, the economy will need to be powered by two key energy sources: clean power and clean fuels, including hydrogen. […] Clean hydrogen can reduce our annual GHG emissions by between 22 and 45 million metric tonnes a year by 2030, and this number could be as much as 190 million metric tonnes by 2050, depending on actions taken and investments made across the economy. – *Aaron Hoskin*[6]

Many of the witnesses agreed generally that hydrogen will play multiple roles in Canada's energy systems as we transition to NZE2050, but hydrogen is likely not a panacea to the challenges of the energy transition. José Bermudez of the International Energy Agency told us, for example, that:

> We have to be clear that hydrogen is not a silver bullet or anything similar to that. It is just one more piece of this complex puzzle that we need to put together to achieve net-zero emissions by 2050, along with other key pillars of decarbonization of the energy system such as improved energy efficiency; deployment of renewables; direct electrification of end uses; carbon capture, utilization and storage; sustainable bioenergy and others. – *José Bermudez*[7]

Jerry DeMarco, Canada's Commissioner of the Environment and Sustainable Development (CESD, or Commissioner) also urged us to look beyond hydrogen in isolation and to consider the whole challenge of the social, environmental and

[5] Government of Canada, *Hydrogen Strategy for Canada: Seizing the Opportunity, A Call to Action*, December 2020.
[6] ENEV, *Evidence* (Aaron Hoskin, Senior Manager, Natural Resources Canada), 7 April 2022.
[7] ENEV, *Evidence* (José Miguel Bermudez, Energy Analyst, International Energy Agency), 6 October 2022.

economic sustainability of the economy and energy system and to plan for the outcomes we want to achieve:

> Although hearings like this look at a particular subject matter, we do need an economic and energy transformation plan that doesn't just pick a winner and then sets up a system to make sure that fuel is favoured over all the others. You have to look at it in a holistic way and factor in the environmental, economic and the social costs, the negative externalities that are not captured by carbon pricing and the negative temporal externalities that are borne by future generations. Once you put all that together, Canada should have a better sense of the role hydrogen will play.
> – *Jerry DeMarco*[8]

Professor Sean McCoy of the University of Calgary was one of several witnesses that explained that we need to adopt a *systems perspective* to understand hydrogen's potential role in society:

> To meet our climate goals in a cost-effective manner, we need to understand in which end uses hydrogen is competitive with other low-carbon energy vectors […] Answering this question requires a system perspective. Such a perspective will allow us to understand how the different fuels and energy vectors we have available to us will interact as we seek to transform the Canadian economy to meet our net-zero vision.
> – *Sean McCoy*[9]

So, while it may be tempting to treat low-CI hydrogen as a universal solution for the energy transition, it is important to ask, "hydrogen for what?" How do we decide whether or when to use hydrogen, or electrification, or renewables, or to deploy carbon capture, utilization and storage ("CCUS," *definition*), for instance? How do we weigh potential public investments in hydrogen compared to other alternatives? Which pathways to net-zero emissions should the Government of Canada prioritize

[8] ENEV, *Evidence* (Jerry DeMarco, Commissioner of the Environment and Sustainable Development, Office of the Auditor General of Canada), 20 October 2022.
[9] ENEV, *Evidence* (Sean McCoy, Transition Accelerator Fellow, Assistant Professor, University of Calgary, as an individual), 24 November 2022.

and which should it ignore? With the goal of achieving NZE2050 in mind, the systems perspective encourages us to model from the bottom-up, using accurate data about the equipment and energy assets that exist today, and to optimize for the outcomes we want.

The CESD also reminded our committee to consider the impact of current decisions on future generations and other vulnerable communities that are underrepresented in policy-making today.[10] We take the Commissioner's advice to heart as we consider what we learned during our study.

Recommendation One

The Government of Canada must improve how it models the environmental, economic and social benefits and costs of its energy programs and policies by taking a system perspective and being more transparent about the tradeoffs between options.

Recommendation Two

The Government of Canada must make its energy models and related methodologies transparent and accessible to peer-review and public scrutiny and improve governance in this respect to enhance accountability and public trust.

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[10] ENEV, *Evidence* (Jerry DeMarco), 20 October 2022.

1.3 The Hydrogen Life Cycle

There are various stages in the life cycle of hydrogen, including:

1) Producing hydrogen and hydrogen-derived products;
2) Storing, transporting and delivering hydrogen; and,
3) Using the hydrogen for its stored energy.

The carbon intensity of hydrogen is determined at all stages of its life cycle by the carbon intensity of the feedstocks and processes used to produce the hydrogen and how the hydrogen is stored, transported and transformed into other substances. We heard that hydrogen releases no harmful GHGs when it is eventually used, but we also heard that infrastructure and equipment are not always totally efficient, and that if leaked, hydrogen and its derivatives can be potent GHGs on their own.

We benefitted from our witnesses' explanations of how hydrogen can be produced, transported, and used as a low-CI energy carrier. Below, we summarize some of what we heard about this topic and discuss the different arguments that we heard about prioritizing particular types of hydrogen production and use.

1.31 Hydrogen Production

During our study, we heard about several colours of hydrogen that each correspond to a different *hydrogen production pathway* (*definition*). Each hydrogen production pathway uses different feedstocks and industrial processes to produce the hydrogen. While the colours of hydrogen are a useful shorthand for distinguishing between the different hydrogen production pathways, they can also be confusing because there are no standard definitions of the hydrogen colours, particularly with respect to their different carbon intensities.

Table 1 presents data shared with our committee by the CESD that summarizes the different hydrogen production pathways based on costs and carbon intensities in comparison with natural gas in 2020.

Table 1 – Hydrogen types by production costs and carbon intensity compared to natural gas, 2020

Type of gas	Production process (and % of carbon capture and sequestration)	Production costs ($ per gigajoule)	Emissions (carbon intensity)
Natural gas		$3.79	60 kilograms carbon dioxide equivalent per gigajoule
Grey hydrogen	Steam methane reforming (0%)	$16.70	2.2 times the natural gas emissions
Dark blue hydrogen	Steam methane reforming (53%)	$19.60	1.1 times the natural gas emissions
Light blue hydrogen	Steam methane reforming (89%)	$23.90	0.25 times the natural gas emissions
Green hydrogen	Electrolysis (solar)	$62.60	No emissions
	Electrolysis (wind)	$63.80	No emissions
	Electrolysis (hydro)	$22.00	No emissions

Notes: See *definitions* section for key terms.
A gigajoule is a standard unit of energy measurement.
Natural gas costs include capital, labour, and fuel for natural gas processes. Natural gas emissions are the sum of emissions from combustion and production.
Green hydrogen production processes do not require carbon capture and sequestration.

Source: Adapted from information provided by Commissioner of the Environment and Sustainable Development.

Grey hydrogen (*definition*) represents almost all the hydrogen made in Canada and the world today. According to the *Hydrogen Strategy for Canada*, Canada is estimated to produce about 3 million tonnes of hydrogen annually and is one of the top 10 hydrogen producers in the world.[11] Global hydrogen production in 2021 totalled 94 million tonnes of hydrogen with associated emissions of 900 million tonnes of GHGs.[12]

Grey hydrogen is made from methane or bio-methane as a feedstock, using an industrial process called *steam methane reforming* ("SMR," *definition*), which releases GHG emissions in the form of process emissions, energy-related emissions,

[11] Government of Canada, *Hydrogen Strategy for Canada: Seizing the Opportunity, A Call to Action*, December 2020.
[12] ENEV, *Evidence* (José Miguel Bermudez), 6 October 2022.

and through fugitive emissions of methane, which makes grey hydrogen a high-carbon intensity product compared to methane.[13]

Sean McCoy of the University of Calgary explained that the advantage of SMR is that it is a well-understood process, it is convenient, and it is less costly than the alternative hydrogen production pathways.[14] However, the price of methane-derived hydrogen depends largely on the price of methane, making hydrogen subject to price shocks and energy security concerns. Witnesses highlighted current European prices for grey hydrogen that are five to six times higher than usual, as an example of such risks.[15]

Blue hydrogen (*definition*) is produced in the same way as grey hydrogen, but differs by capturing the GHGs that are by-products of SMR, thereby preventing most of them from being emitted. The key technology for producing blue hydrogen, besides SMR, is CCUS. CCUS involves capturing and storing GHGs from the SMR process and sequestering them to prevent their release, hopefully permanently. In some cases, the GHGs are then used by companies to make other products like synthetic chemicals and fuels, for example.

Witnesses explained that the carbon intensity of blue hydrogen depends on the effectiveness of CCUS capture and storage rates, the life cycle carbon intensity of the methane feedstock, and the performance of the system with respect to minimizing fugitive methane leaks at all points of the system. For example, Table 1 above differentiates between “dark blue” and “light blue” hydrogen because of the different rate of carbon capture for each production pathway. We heard that installing and operating CCUS at hydrogen facilities could make the cost of producing blue hydrogen nearly double that of grey hydrogen.[16]

The *green hydrogen* (*definition*) production pathway is fundamentally different than making grey or blue hydrogen. Green hydrogen is made by splitting hydrogen from water using the *electrolysis* (*definition*) process through a device called an *electrolyzer*. The only by-products of electrolysis are hydrogen and oxygen. We heard

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[13] ENEV, Evidence (Robert W. Howarth, Professor David R. Atkinson Ecology and Environmental Biology, Cornell University, as an individual), 27 September 2022.
[14] ENEV, *Evidence* (Sean McCoy), 24 November 2022.
[15] ENEV, *Evidence* (Niall MacDowell, Professor, CCS Knowledge Centre), 20 October 2022; ENEV, *Evidence* (José Miguel Bermudez), 6 October 2022.
[16] ENEV, *Evidence* (Sean McCoy), 24 November 2022; ENEV, *Evidence* (José Miguel Bermudez), 6 October 2022; ENEV, *Evidence* (Christopher Bataille, Adjunct Research Fellow, Columbia Centre for Global Energy Policy, Adjunct Professor, Simon Fraser University, as an individual), 20 October 2022.

that electrolysis powered by low-CI electricity sources like hydro, wind, solar and nuclear will make the lowest-CI hydrogen. Some witnesses also noted that the price of electrolyzers is trending downwards as electrolyzer manufacturing increases, supply chains grow, and learning effects for hydrogen technology production take place.[17]

Because the price of electricity represents up to 70% of the cost of producing green hydrogen, it is the main lever for reducing green hydrogen costs.[18] Professor Chris Bataille of Simon Fraser University told us that in the Canadian context, where carbon prices are set to rise to $170 per tonne by 2030, green hydrogen would be cost-competitive with blue hydrogen in 2030 if the price of electricity is between $0.01 to $0.02 per kilowatt hour of electricity generated.[19]

1.32 Hydrogen Transport

We heard that hydrogen can be difficult to handle, store, transport and deliver. In part, this is because of the physical characteristics of hydrogen, which make it intrinsically difficult and expensive to handle. How hydrogen behaves in different states when interacting with different materials and equipment is still being studied and codes and standards are still being developed. Witnesses noted that handling hydrogen requires care. While not fundamentally different than handling other potentially toxic substances, hydrogen products can be dangerous to people, the environment and the climate and so they require regulation.[20] Kevin Larmer of the Canadian Gas Association worried that companies in the hydrogen and lower-CI fuels industry are moving faster than regulators are finalizing regulations and standards for the sector.[21]

There are many ways to transport hydrogen that depend largely on how far the hydrogen must go from its point of production to its point of consumption. In the local area around the hydrogen production facility, hydrogen pipelines can be practical for distribution. In Alberta today, there are about 80 kilometres of

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[17] ENEV, *Evidence* (José Miguel Bermudez), 6 October 2022; ENEV, *Evidence* (Bruno G. Pollet, Professor and Deputy Director, Institute for Hydrogen Research, University of Montreal, as an individual), 4 October 2022; ENEV, *Evidence* (Julia Levin, National Climate Program Manager, Environmental Defence Canada), 27 September 2022.
[18] ENEV, *Evidence* (José Miguel Bermudez), 6 October 2022.
[19] ENEV, *Evidence* (Christopher Bataille), 20 October 2022.
[20] ENEV, *Evidence* (Rachel Samson, Vice President, Research, Institute for Research on Public Policy), 24 November 2022; ENEV, *Evidence* (Mark Zacharias, Executive Director Clean Energy Canada), 29 September 2022.
[21] ENEV, *Evidence* (Kevin Larmer, Director of Innovation and Markets, Canadian Gas Association), 4 October 2022.

dedicated hydrogen pipelines.[22] Outside of the local hydrogen pipeline network, hydrogen can be liquefied and shipped by truck. For longer distances, hydrogen can be converted to other hydrogen-derived products like ammonia and methanol for reasons of cost, convenience, or to satisfy customer demand for these products. Some witnesses suggested that long-distance pipelines could eventually be used to transport hydrogen, but that further study is needed before that happens.[23]

Several witnesses recommended that the Government of Canada make targeted investments in dedicated hydrogen infrastructure that could lower the cost of local distribution, create new industries, and facilitate access to export markets. As we discuss in the third chapter, these include, *hydrogen hubs*, which simultaneously support the growth of supply and demand for hydrogen in regional hubs.

1.33 Hydrogen Use

Virtually all the hydrogen that is used in the world today is grey hydrogen. Consumption is dominated by three industrial sectors: oil refining (33%), chemicals (ammonia and methanol production, 27% and 11%, respectively), and iron and steel (3%).[24] Several witnesses told us that the most urgent use of low-CI hydrogen would be to replace current demand for grey hydrogen.[25]

Hydrogen's versatility as an energy carrier creates potential applications in other sectors that could become significant as technologies evolve.[26] We heard from many witnesses that to achieve NZE2050, low-CI hydrogen products could be most useful in the following sectors and applications, keeping in mind that the development pathways are still unclear and that hydrogen must be considered against other emission reduction options from a systems perspective:

- *Decarbonizing the existing supply of grey hydrogen*, such as by adding carbon capture and storage to facilities or by decommissioning these facilities and

[22] ENEV, *Evidence* (Kevin Larmer), 4 October 2022.
[23] ENEV, *Evidence* (Kevin Larmer), 4 October 2022; ENEV, *Evidence* (Mark Kirby, President and Chief Executive Officer, Canadian Hydrogen and Fuel Cell Association), 31 March 2022; ENEV, *Evidence* (Jean-Denis Charlebois, Chief Economist, Canada Energy Regulator), 29 September 2022.
[24] International Energy Agency, *The Future of Hydrogen*, 2019.
[25] ENEV, *Evidence* (Julia Levin), 27 September 2022; ENEV, *Evidence* (Mark Zacharias), 29 September 2022; ENEV, *Evidence* (José Miguel Bermudez), 6 October 2022.
[26] ENEV, *Evidence* (Judy Meltzer, Director General, Environment and Climate Change Canada), 7 April 2022; ENEV, *Evidence* (David Layzell, Energy Systems Architect, The Transition Accelerator, University of Calgary, as an individual), 31 March 2022; ENEV, *Evidence* (Aaron Hoskin), 7 April 2022.

building new low-carbon intensity hydrogen supply. This would lower the carbon intensity of upgraded oil products and fertilizers, for example.[27]

- To *replace coal in steel and iron making*. Witnesses noted how this option could open new export opportunities for low-carbon intensity iron ore, for example.[28]
- As a *fuel for long-distance transport*, including marine, aviation, heavy trucks and rail.[29]
- As a source of *high-grade heat for industrial processes* that operate above about 200 degrees Celsius.[30]
- As a *feedstock for chemical production*, including for fossil fuel replacements like renewable or synthetic natural gas or jet fuel.[31]

There was less certainty among our witnesses about the prospects of low-CI hydrogen in the following sectors, with some witnesses suggesting these applications could be useful and other witnesses disputing their potential:

- As a fuel for light-duty personal vehicles.
- As a *replacement for methane for space heating buildings*, such as by blending hydrogen with natural gas[32] or used in dedicated hydrogen pipelines and space heating equipment.
- As a *replacement for methane for generating electricity*, such as by blending hydrogen with natural gas and capturing the greenhouse gases with CCUS.

Taking a global view of future hydrogen demand, José Bermudez outlined an International Energy Agency scenario where by 2050, global demand for hydrogen could increase sixfold from current levels, including for new applications where hydrogen is used as an energy carrier.[33] In this scenario, hydrogen could represent more than 10% of total final energy consumption by 2050.

Bermudez explained that the demand that exists for grey hydrogen today is not necessarily the same type of demand that is emerging for low-CI hydrogen. We heard

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[27] ENEV, *Evidence* (Christopher Bataille), 20 October 2022.
[28] ENEV, *Evidence* (Christopher Bataille), 20 October 2022; ENEV, *Evidence* (Mark Zacharias), 29 September 2022; ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022; ENEV, *Evidence* (Rachel Samson), 24 November 2022.
[29] ENEV, *Evidence* (Mark Kirby), 31 March 2022; ENEV, *Evidence* (David Layzell), 31 March 2022; ENEV, *Evidence* (Aaron Hoskin), 7 April 2022.
[30] ENEV, *Evidence* (Christopher Bataille), 20 October 2022.
[31] ENEV, *Evidence* (Christopher Bataille), 20 October 2022.
[32] We heard that hydrogen-natural gas blends are being piloted in natural gas distribution systems in several Canadian cities.
[33] ENEV, *Evidence* (José Miguel Bermudez), 6 October 2022.

from some witnesses that because of this dynamic, low-CI hydrogen doesn't always need to compete on price with grey hydrogen because customers differentiate on carbon intensity and will pay more for lower-CI hydrogen, depending on the application.[34]

An alternative perspective on Canada's possible hydrogen demand in 2050, albeit in a scenario that does not align with NZE2050, was presented to us by Jean-Denis Charlebois of the Canada Energy Regulator (CER). Charlebois told us that CER models indicate that Canada's total hydrogen demand in 2050 could account for about 6% of total energy end use, which is five times less than envisaged in the *Hydrogen Strategy for Canada*.[35] We look forward to updated scenarios from the CER in 2023 that are aligned with NZE2050, so governments can make better-informed decisions about climate and energy policy.

1.4 Grey, Blue or Green or Everything In Between?

During our study, we heard divided opinions from our witnesses about whether blue hydrogen or green hydrogen was a better production pathway for Canada than grey hydrogen, or whether the Government of Canada should be agnostic on colour and focus on carbon intensity instead.

Mark Kirby of the Canadian Hydrogen and Fuel Cell Association, told us that in Canada, "we celebrate hydrogen diversity," and argued that:

[34] ENEV, *Evidence* (Rachel Samson), 24 November 2022; ENEV, *Evidence* (José Miguel Bermudez), 6 October 2022; ENEV, *Evidence* (Mark Zacharias), 29 September 2022; ENEV, *Evidence* (Niall MacDowell), 20 October 2022.
[35] ENEV, *Evidence* (Jean-Denis Charlebois), 29 September 2022.

> Canada has the great fortune to be rich in feedstocks to produce hydrogen. We have among the cleanest electricity supplies in the world. This clean power coupled with Canada's freshwater resources can be leveraged to produce hydrogen from electrolysis. Canada also has abundant fossil fuel reserves and leads in innovation and geological storage potential to enable carbon capture and storage. We will need both of these pathways — blue and green — along with new innovative ones to make enough hydrogen to meet both domestic demand and to serve the rapidly growing global market. – *Mark Kirby*[36]

Some witnesses were pragmatic about whether blue hydrogen or green hydrogen was a better production pathway, anticipating that in some cases either blue or green hydrogen would be a logical option based on different factors, including demand, resource availability, cost of inputs, time horizon and the policy environment, among other considerations. For example, Chris Bataille of Simon Fraser University explained that the relative cost of methane compared to electricity in different regions would likely determine how the hydrogen industry develops in Canada and around the world. Bataille argued that:

> Because of this dynamic, blue [hydrogen] will dominate in regions with cheap methane and [carbon capture and storage] geology, for example, in Alberta and Saskatchewan, until at least the mid-2030s and possibly the 2040s. Europe, China and Quebec will instead go straight to electrolysis-based hydrogen. – *Chris Bataille*[37]

Mark Zacharias of Clean Energy Canada held that a blue hydrogen industry in Canada would create economic and social benefits in the mid-term, but that green hydrogen was a more certain bet for achieving NZE2050 due to the climate impact of methane:

[36] ENEV, *Evidence* (Mark Kirby), 31 March 2022.
[37] ENEV, *Evidence* (Christopher Bataille), 20 October 2022.

> At Clean Energy Canada, our position is that blue hydrogen and investing in a blue hydrogen industry builds a workforce, builds the skills and builds the capacity to eventually transition Canada to a green hydrogen industry. […] blue hydrogen does still have methane; it does still have a carbon footprint. In the future, however, we believe green hydrogen will be the solution, but given our workforce, given our natural gas reserves and given the need to transition, there will be a period by which blue hydrogen will be important for the B.C. and Canadian economy. – *Mark Zacharias*[38]

Professor Bruno Pollet of the Université du Québec à Trois-Rivières argued that government policy should prioritize green hydrogen over blue hydrogen to hasten the energy transition and avoid expanding fossil fuel infrastructure:

> I honestly thought we should look at green hydrogen production directly. […] I think that pushing for green hydrogen and pushing for this independence from natural gas and oil is crucial. – *Bruno Pollet*[39]

Some witnesses told us that blue hydrogen is a production pathway that is incompatible with Canada's climate ambitions. When we asked Professor Robert Howarth of Cornell University if the Government of Canada should stop investing in blue hydrogen altogether, he responded:

[38] ENEV, *Evidence* (Mark Zacharias), 29 September 2022.
[39] ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022.

> Yes, absolutely I would. I have testified before the U.S. Congress saying specifically that in New York […] we will not allow blue hydrogen in our state. […] There are two aspects to it. Carbon capture is far from a perfect enterprise. There's always some leakage. [The second aspect is economic.] Blue hydrogen is going to get more and more expensive as natural gas prices go up in the future. Green hydrogen is going to get less and less expensive as the cost of renewable energy goes down and as electrolysis procedures become less expensive. So it's a complete distraction at best. – *Robert Howarth*[40]

Julia Levin of Environmental Defence Canada, argued that blue hydrogen is tantamount to "greenwashing":

> Oil and gas companies are using hydrogen as a way to delay a true clean energy transition and lock in more natural gas infrastructure, which is completely incompatible with ensuring a climate-safe future. Only renewable hydrogen aligns with a climate-safe future; so-called blue hydrogen is not a climate solution. […] Investing in fossil hydrogen, blue hydrogen, would lock Canada into a future of fossil fuel use and methane emission leakage. There is no room for blue hydrogen in a climate-safe future. – *Julia Levin*[41]

Several witnesses said that the "colour" of hydrogen is less important than the life cycle carbon intensity of the hydrogen being produced. Professor James Meadowcroft of Carleton University told us that:

[40] ENEV, *Evidence* (Robert W. Howarth), 27 September 2022.
[41] ENEV, *Evidence* (Julia Levin), 27 September 2022.

> We shouldn't obsess too much right now about where the hydrogen comes from, other than that it needs to be low carbon. I think the establishment of a progressive standard that decarbonizes, that makes sure — you know, carbon hydrogen is not 50% emissions. It's got to be low, and it's got to eventually get to zero. I personally don't mind where it comes from, as long as it's as cheap as we can make it and it's as low carbon as we can possibly make it. – *James Meadowcroft* [42]

2. GOVERNMENT OF CANADA SUPPORT FOR THE HYDROGEN SECTOR

Over the past several decades, the Government of Canada has used a variety of policies to help develop Canada's hydrogen sector, including funding research, development and demonstration of hydrogen technologies, investing in hydrogen infrastructure, and procuring hydrogen and hydrogen technologies. After publishing the *Hydrogen Strategy for Canada: Seizing the Opportunity* in December 2020, the Government of Canada added several new policies to accelerate the development of this sector.

This chapter examines a range of different Government of Canada policies and investments that support the hydrogen sector. Some of these policies directly support the hydrogen sector, while others indirectly help. Some policies are already implemented, while the details of others are still being worked out.

We begin by discussing the *Hydrogen Strategy for Canada*, which is the Government of Canada's vision for the hydrogen sector. Then we discuss a range of spending programs and tax measures that the Government of Canada uses to invest in the hydrogen sector and conclude by considering regulations that the Government of Canada uses to drive decarbonization across the economy, such as carbon pricing and the Clean Fuel Regulations.

[42] ENEV, *Evidence* (James Meadowcroft, Professor, School of Public Policy and Administration, Carleton University, as an individual), 31 March 2022.

2.1 Canada's National Hydrogen Strategy

Canada is one of over 80 countries that has developed a national hydrogen strategy since 2020.[43] All the provinces and territories are considering how hydrogen could fit into their own economies and energy systems, with Alberta, British Columbia, Ontario and Quebec each having already published their own provincial strategies for the hydrogen sector.

The Government of Canada's *Hydrogen Strategy for Canada* sets out the following transformative vision for hydrogen in Canada's economy by 2050:

- More than five million fuel cell electric vehicles.
- Hydrogen fueling networks across Canada.
- Annual domestic production of 20 million tonnes of hydrogen, satisfying 30% of energy demand in Canada's energy system.
- Greater than 50% hydrogen in Canada's natural gas pipelines and the construction of dedicated hydrogen pipelines.
- New industries enabled by low-cost hydrogen.
- Annual greenhouse gas reductions equivalent of up to 190 million tonnes of carbon dioxide.
- Large distributed domestic supply of low-carbon intensity hydrogen ranging between $1.50-3.50 per kilogram.
- Canadian hydrogen sector revenues of greater than $50 billion annually.
- Greater than 350,000 hydrogen sector jobs.
- One of top 3 global clean hydrogen producers.[44]

Several witnesses to our study, including government witnesses, discussed whether the vision set out in the *Hydrogen Strategy for Canada* contained specific, measurable, achievable and realistic targets.

Government witnesses from NRCan, the lead department on the *Hydrogen Strategy for Canada*, told us that there is not yet a clear plan for achieving the vision of the strategy. Sébastien Labelle of NRCan explained how he, "wouldn't say that [satisfying 30% of consumed energy by 2050] is a target for which we necessarily have all the answers and all the ingredients to achieve it. We're working on this with our

[43] ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022.
[44] Government of Canada, *Hydrogen Strategy for Canada: Seizing the Opportunity, A Call to Action*, December 2020.

partners, but we're not at the point right now where we have a plan that takes us to 30% of the economy."[45]

Government officials emphasized that the *Hydrogen Strategy for Canada* was a call to action, more than a detailed roadmap, and that the ongoing work of numerous working groups dedicated to different aspects of the strategy was critical to help develop those plans over time. They also explained that the Government of Canada will update the modelling in its hydrogen strategy every two years.[46]

Mark Kirby of Canadian Hydrogen and Fuel Cell Association and Sabina Russell of Zen Clean Energy Solutions, each gave the federal government a "C-plus" grade on the hydrogen strategy due to a lack of smart goals with defined metrics.[47] Some witnesses called for clearer targets to improve the hydrogen strategy, such as "30 hydrogen hubs by 2030,"[48] or price goals for hydrogen.[49]

Jeff Griffin of Canadian Nuclear Laboratories called the hydrogen strategy a "strong framework toward [realizing net-zero emissions by 2050]" more than a detailed plan for getting there.[50]

However, Julia Levin of Environmental Defence Canada warned that the hydrogen strategy exaggerates the role of hydrogen and leaves "too much room for fossil hydrogen."[51]

The CESD told us that the Commissioner's office audited the Government of Canada's claims about how much GHG emissions could be reduced by adopting hydrogen at the levels envisaged in the *Hydrogen Strategy for Canada*.[52] We were disappointed to learn that the CESD's audit found numerous methodological issues in both NRCan's and Environment and Climate Change Canada's (ECCC) modelling and raised larger issues with how the federal government models and projects the greenhouse gas emissions reductions of its programs and policies. The Commissioner

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[45] ENEV, Evidence (Sébastien Labelle, Director General, Natural Resources Canada), 7 April 2022.
[46] ENEV, Evidence (Aaron Hoskin, Senior Manager, Natural Resources Canada), 24 November 2022.
[47] ENEV, Evidence (Mark Kirby), 31 March 2022; ENEV, Evidence (Sabina Russell), 31 March 2022.
[48] ENEV, *Evidence* (David Layzell), 31 March 2022; ENEV, Evidence (Sabina Russell), 31 March 2022; ENEV, Evidence (Mark Kirby), 31 March 2022.
[49] ENEV, *Evidence* (Kevin Larmer), 4 October 2022.
[50] ENEV, *Evidence* (Jeff Griffin, Vice-President, Science and Technology, Canadian Nuclear Laboratories), 3 November 2022.
[51] ENEV, *Evidence* (Julia Levin), 27 September 2022.
[52] ENEV, *Evidence* (Jerry DeMarco), 20 October 2022.

explained that the two departments took fundamentally different, and flawed, approaches to their estimates for hydrogen:

> To assess the demand for hydrogen, Environment and Climate Change Canada assumed a blending mandate for hydrogen and natural gas that was not based on any existing policy at the provincial or federal levels. In addition, this approach was uneconomical based on the current trend of carbon pricing. For its part, Natural Resources Canada favoured a transformative scenario that assumed the adoption of aggressive and sometimes non-existent policies, along with an ambitious uptake of new technology. – *Jerry DeMarco*[53]

The Commissioner recommended that the Government of Canada conduct more comprehensive modelling looking at hydrogen's position relative to other low-CI energy vectors, and what the best uses are for each over time, considering the environmental, social and economic sustainability for current and future generations, constrained by realistic technology deployment scenarios based on existing infrastructure.[54] The Commissioner stated that:

> Once you put all that together, Canada should have a better sense of the role hydrogen will play. With the information that we uncovered in this report, I can say that I wasn't confident in their assumptions, but I'm not in a position to say that the right answer is X, Y, or Z at this stage. There is a lot of important work that needs to be done by the departments, hopefully, in a coordinated way this time to address that – *Jerry DeMarco*[55]

The Commissioner also told us that ECCC would benefit from a "stronger framework for peer review, public scrutiny, and quality assurance and control in its modelling

[53] ENEV, *Evidence* (Jerry DeMarco, Commissioner of the Environment and Sustainable Development, Office of the Auditor General of Canada), 20 October 2022.
[54] ENEV, *Evidence* (Jerry DeMarco), 20 October 2022.
[55] ENEV, *Evidence* (Jerry DeMarco, Commissioner of the Environment and Sustainable Development, Office of the Auditor General of Canada), 20 October 2022.

exercises to improve the quality and transparency of, and the trust in, the department's climate change modelling in future emission reduction plans."[56]

Recommendation Three

The Government of Canada must quickly implement the recommendations of the Commissioner of the Environment and Sustainable Development (CESD) with respect to the CESD's hydrogen audit, including completing comprehensive modelling for the use of hydrogen, publishing a hydrogen market development roadmap, adopting a standard framework for estimating the emission reductions of government policies, and improving federal modelling assumptions.

Recommendation Four

The Government of Canada must present credible economic and energy transformation plans for achieving NZE2050 and any interim targets along the way, informed by the CESD's comments about factoring in the "environmental, economic and the social costs, the negative externalities that are not captured by carbon pricing and the negative temporal externalities that are borne by future generations."

2.2 Federal Funding for Hydrogen Production and Use

When we began our study in the spring of 2022, the Government of Canada was already funding the production and use of hydrogen and hydrogen technologies through several different programs. Witnesses told us early on in our study that these existing federal supports had helped the hydrogen sector grow, up to a point,

[56] ENEV, *Evidence* (Jerry DeMarco), 20 October 2022.

but that more federal funding was needed across the entire hydrogen value chain to drive the sector's growth.[57]

By the fall of 2022, when we resumed our study, our witnesses told us that the U.S. *Inflation Reduction Act of 2022* (IRA) puts pressure on the Government of Canada to increase public spending on hydrogen or risk potential private investments flowing to the U.S. instead.[58] The IRA is a new law in the United States containing upwards of US$400 billion in investments in the American clean economy over ten years – a level of public climate spending that one of our witnesses, Andrea Kent of Greenfield Global, called a "generational bonanza."[59]

The Government of Canada responded to the IRA in the 2022 Fall Economic Statement by announcing new policies and investments for the hydrogen sector, as well as for CCUS and other lower-carbon intensity technologies. As Miodrag Jovanovic of Finance Canada explained, the timing of the announcement and the design of the policies was, "mindful of the effect of the *Inflation Reduction Act of 2022* in the United States and the need for action."[60]

The main federal funding programs that support the hydrogen sector are discussed below. These funding programs include the *Clean Fuels Fund*, the *Net Zero Accelerator Initiative*, the *Energy Innovation Program*, the *Zero-Emission Vehicle Infrastructure Program* and the proposed *Canada Growth Fund*. They also include tax measures, including an accelerated capital cost allowance for hydrogen production and refuelling equipment, a reduced federal corporate tax rate for hydrogen technology manufacturers, and some newly proposed investment tax credits for hydrogen, CCUS, and lower-CI energy equipment.

2.21 Clean Fuels Fund

The *Clean Fuels Fund* (CFF), led by NRCan, represents a $1.5-billion investment over five years to build new or expand existing facilities for producing lower-carbon intensity fuels, including for producing hydrogen. Officials noted that through the CFF, the Government of Canada is targeting to invest in at least ten new hydrogen

[57] ENEV, *Evidence* (Mark Kirby), 31 March 2022; ENEV, *Evidence* (David Layzell), 31 March 2022; ENEV, *Evidence* (Sabina Russell), 31 March 2022.
[58] ENEV, *Evidence* (Gene Gebolys, Director, World Energy GH2), 6 October 2022; ENEV, *Evidence* (Mark Zacharias), 29 September 2022; ENEV, *Evidence* (Rachel Samson), 24 November 2022.
[59] ENEV, *Evidence* (Andrea Kent, Board Member at Renewable Industries Canada, Vice President Industry and Government Affairs at Greenfield Global), 3 November 2022.
[60] ENEV, *Evidence* (Miodrag Jovanovic, Assistant Deputy Minister, Department of Finance Canada), 24 November 2022.

production facilities in Canada. The CFF will offer 30% of the capital costs of a project, up to a maximum of $150 million.[61] Officials noted that the CFF includes a funding stream devoted for Indigenous-led projects, meaning that the project itself has to be more than 50% Indigenous-owned and operated to be eligible to receive funding.[62] The CFF also includes $50 million to support the development of codes and standards for hydrogen and other fuels.

Kevin Larmer of the Canadian Gas Association said his association is supportive of the CFF, but that "it remains smaller on a per capita basis in comparison to several other countries."[63]

2.22 Strategic Innovation Fund

The Strategic Innovation Fund's *Net Zero Accelerator Initiative* (NZAI), led by Industry, Science and Economic Development Canada is expected to provide up to $8 billion to support large-scale industrial decarbonization in Canada, including for hydrogen projects.

During our study, the federal government announced a $300-million investment made through the NZAI[64] in an Alberta-based facility led by one of our witnesses, Air Products. We were told that the facility will use methane produced in Alberta to produce hydrogen, with close to 95% reductions in emissions over conventional hydrogen.[65] We were also told about a $400 million investment through the NZAI in electric arc furnaces for a Hamilton steel production facility that will initially run on methane, but could one day run on hydrogen.[66] Bruno Pollet of the Université du Québec à Trois-Rivières said that programs like the NZAI are needed to help Canada overcome the challenge of turning its intellectual property into industrial supply chains capable of creating hydrogen equipment and products for export.[67]

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[61] ENEV, *Evidence* (Sébastien Labelle, Director General, Natural Resources Canada), 24 November 2022.
[62] ENEV, *Evidence* (Aaron Hoskin), 24 November 2022.
[63] ENEV, *Evidence* (Kevin Larmer), 4 October 2022.
[64] Government of Canada, "Government of Canada makes significant investment in Alberta's clean hydrogen sector and outlines next steps to help Canadian industry sectors cut pollution," 8 November 2022.
[65] ENEV, *Evidence* (Sébastien Labelle), 24 November 2022.
[66] ENEV, *Evidence* (Aaron Hoskin), 7 April 2022.
[67] ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022.

2.23 Zero-Emission Vehicle Infrastructure Program

The *Zero Emission Vehicle Infrastructure Program* (ZEVIP), led by Natural Resources Canada, supports the build-out of new chargers for electric vehicles as well as hydrogen refuelling stations in key metropolitan centres acroshs Canada. The ZEVIP represents an overall investment of $680 million and covers up to 50% of the total project costs of a hydrogen refuelling station, to a maximum of $1 million per site. Like the CFF, the ZEVIP includes a funding stream devoted to Indigenous-led projects, which are eligible for up to 75% funding, to a maximum of $1.5 million per site.[68]

While Mark Kirby of the Canadian Hydrogen and Fuels Cells Association recognized the importance of the ZEVIP and Government of Canada collaboration with the provinces at getting some early hydrogen refuelling infrastructure built, he noted that hydrogen deployment in transportation in Canada has lagged behind other countries.[69] Sabina Russell of Zen Clean Energy Solutions argued that the slow deployment of hydrogen fuel cell vehicles in Canada is a problem with Canadian policy and highlighted California's zero-emission bus and truck mandates as an example of "regulation that drives action," which Canada could emulate.[70] Several other witnesses also suggested vehicle emission standards as a policy tool that could provide a domestic market for home-grown fuel cells and hydrogen buses like those produced by British Columbia's Ballard Power Systems and Manitoba's New Flyer bus company.[71]

2.24 Energy Innovation Program

The *Energy Innovation Program*, led by Natural Resources Canada, is a funding mechanism that invests in energy research, development and deployment projects. This fund makes targeted calls for project proposals with streams that include lower-carbon intensity fuels and industrial fuel switching, as well as CCUS. Several witnesses lauded Canada's capacity for research and development, but as we have heard on this and other studies, Canada's innovation system is often criticized for failing to commercialize technologies and market products.[72]

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[68] Government of Canada, "Zero-Emission Vehicle Infrastructure Program - News and FAQ," 10 August 2022.
[69] ENEV, *Evidence* (Mark Kirby), 31 March 2022.
[70] ENEV, *Evidence* (Sabina Russell), 31 March 2022.
[71] ENEV, *Evidence* (Sabina Russell), 31 March 2022.
[72] ENEV, *Evidence* (Rachel Samson), 24 November 2022; ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022; ENEV, *Evidence* (Sabina Russell), 31 March 2022.

Bruno Pollet of the Université du Québec à Trois-Rivières argued that more funding is needed for hydrogen in large research and development programs to "validate the technology, to generate innovation, [intellectual property] and new industries, as well as investing in training programs to train the next generations of hydrogen engineers, scientists, technologists and economists."[73]

2.25 Canada Growth Fund

The *Canada Growth Fund* is a new program with an initial capitalization of $15 billion that was announced in the 2022 Fall Economic Statement. The Government of Canada is still working on the design of the Canada Growth Fund and we were told by Finance Canada officials that details would be available in Budget 2023.[74] A technical backgrounder that accompanied the 2022 Fall Economic Statement described how the Canada Growth Fund could adopt a range of innovative financing tools intended to provide hydrogen project developers with long-term certainty about future carbon prices.

The Canada Growth Fund includes several potential supports for hydrogen and other low-CI alternatives. As Sébastien Labelle of NRCan told us, the Canada Growth Fund is meant to help "ensure Canada's world-leading industry maintains its competitive advantages in the face of significant investments being made by other jurisdictions, like those made in the United States with the *Inflation Reduction Act of 2022* or the *European Union's European Green Deal*."[75] Miodrag Jovanovic told us that the purpose of the Canada Growth Fund is "to catalyze private investment to help Canada scale any technologies that will decarbonize our economy and create jobs."[76]

2.26 Tax Measures

Recent budgets have introduced several new federal tax measures to support Canada's hydrogen sector. For example, proposals in Budget 2021 expanded the accelerated capital cost allowance to include certain hydrogen equipment and related machinery, while also lowering the corporate tax rate for hydrogen equipment manufacturers in Canada. Greg Moffatt of the Chemistry Industry

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[73] ENEV, Evidence (Bruno G. Pollet), 4 October 2022.
[74] ENEV, *Evidence* (Miodrag Jovanovic), 24 November 2022.
[75] ENEV, *Evidence* (Sébastien Labelle), 24 November 2022
[76] ENEV, *Evidence* (Miodrag Jovanovic), 24 November 2022.

Association of Canada, requested that the changes to the capital cost allowances be extended until at least 2040, with no phase-out or wind-down until at least 2030.[77]

In Budget 2022, the Government of Canada proposed a new refundable investment tax credit specifically for CCUS equipment. The investment tax credit is not finalized and consultations on its design are ongoing.[78] Some witnesses to our study recommended that Canada implement a CCUS investment tax credit,[79] but Greg Moffatt noted that what the Government of Canada had proposed in Budget 2022 was not as generous as the United States' so-called "45Q" tax credit for CCUS investments.[80]

The 2022 Fall Economic Statement proposed two other new investment tax credits: one for "clean energy" equipment, including hydrogen refuelling equipment, and another for hydrogen production equipment. Miodrag Jovanovic of Finance Canada explained that the hydrogen investment tax credit proposed in the 2022 Fall Economic Statement is informed by the United States' credit design and is based on tiers of carbon intensity, with the lowest-carbon intensity hydrogen production receiving a refundable tax credit of at least 40%. Jovanovic noted that consultations with industry on the design of the hydrogen investment tax credit are ongoing, but that the objective is "to make sure we have a level playing field with the United States."[81]

Several witnesses recommended that Canada should adopt a hydrogen production investment tax credit like what the Government of Canada has proposed. Mark Zacharias of Clean Energy Canada, for example, told us that Canada's tax credit should be based on the carbon intensity of the hydrogen that is produced.[82] Greg Moffatt said that the incentives created by the tax credit should be "technology-agnostic and outcome-based, with clear eligibility criteria providing predictability and certainty."[83] Simon Moore of Air Products, was encouraged by the announcement of the hydrogen investment tax credit and urged the Government of Canada to finalize

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[77] ENEV, *Evidence* (Greg Moffatt, Vice President, Policy and Corporate Secretary, Chemistry Industry Association of Canada), 29 September 2022.
[78] Government of Canada, "Additional Design Features of the Investment Tax Credit for Carbon Capture, Utilization and Storage: Recovery Mechanism, Climate Risk Disclosure, and Knowledge Sharing," 9 August 2022.
[79] ENEV, *Evidence* (Mark Zacharias), 29 September 2022; ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022.
[80] ENEV, *Evidence* (Greg Moffatt), 29 September 2022.
[81] ENEV, *Evidence* (Miodrag Jovanovic), 24 November 2022.
[82] ENEV, *Evidence* (Mark Zacharias), 29 September 2022.
[83] ENEV, *Evidence* (Greg Moffatt), 29 September 2022.

its regulations quickly.[84] Similarly, Gene Gebolys of World Energy GH2 also stressed the urgency of implementing a hydrogen investment tax credit quickly, explaining that companies are rushing to get into global supply chain queues for needed equipment like electrolyzers.[85]

Recommendation Five

Where possible, the Government of Canada must seek arrangements where it shares the funding, risk and rewards with hydrogen suppliers and investors in a pro-rated fashion, ensuring mutual benefit and risks.

Recommendation Six

The Government of Canada must take into account the dynamic of other countries' hydrogen subsidies on Canadian businesses as it develops incentives for the domestic hydrogen sector, so that, commensurate with its risks and investments, Canada claims its fair share of the results.

2.3 Federal Regulations and Standards that Support Hydrogen

The climate regulations that the Government of Canada uses to drive decarbonization across the economy include carbon pricing, the Clean Fuel Regulations, and other standards that have the indirect effect of supporting hydrogen development in Canada. Below, we discuss our witnesses' views about how the Government of Canada should design and implement these policies to grow the hydrogen sector, so hydrogen can be one of those "puzzle pieces" that José Bermudez of the International Energy Agency suggested we would need for achieving NZE2050.

[84] ENEV, *Evidence* (Simon Moore, Vice President, Investor Relations, Corporate Relations and Sustainability, Air Products), 24 November 2022.
[85] ENEV, *Evidence* (Gene Gebolys), 6 October 2022.

2.31 Carbon Pricing

Carbon pricing is the main regulatory instrument that the Government of Canada is using to reduce GHGs across the entire economy. The carbon price in Canada is set to rise from $65 per tonne of GHGs on 1 April 2023 to $170 per tonne by 2030.[86] The legal framework for Canada's carbon price is established in the *Greenhouse Gas Pollution Pricing Act, 2018* (GGPPA) and regulations made under the GGPPA.

Many witnesses told us that the price signal set by Canada's carbon pricing system is critical to developing projects in Canada's hydrogen sector, and that without certainty about future carbon prices, some projects will not move forward.[87]

More importantly for the development of the hydrogen pathway overall, we heard, is that without sufficiently high carbon prices, certain low-carbon intensity hydrogen production methods or uses in new sectors and applications will not be economically competitive on their own compared to conventional hydrogen or other alternatives.[88] That could mean that the opportunity to develop and deploy certain hydrogen pathways could be delayed or even lost as energy infrastructure is built to serve other energy alternatives that occupy hydrogen's potential place.[89]

We heard that companies, utilities, and energy system operators in Canada are making significant infrastructure investments that are justified by Canada's carbon pricing system. For example, Michael Powell of Electricity Canada argued that Canada needs, "to make sure that price signals remain consistent and clear," noting that, "[Electricity Canada's] members are making substantial investments, and there needs to be certainty on pricing that that investment will be sound, particularly around issues such as carbon pricing."[90] Jeff Griffin of Canada Nuclear Laboratories argued that "a clear carbon policy with long enough timelines to support private

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[86] Government of Canada, *The federal carbon pollution pricing benchmark*.
[87] ENEV, *Evidence* (Jeff Griffin), 3 November 2022; ENEV, *Evidence* (Michael Powell, Vice President of Government Relations Electricity Canada), 29 September 2022; ENEV, *Evidence* (David Layzell), 31 March 2022; ENEV, *Evidence* (Greg Moffatt), 29 September 2022; ENEV, *Evidence* (Douglas Dias, Board Member at Renewable Industries Canada, Vice President Sales and Market Development at Greenfield Global), 3 November 2022; ENEV, *Evidence* (Andrea Kent), 3 November 2022.
[88] ENEV, *Evidence* (Christopher Bataille), 20 October 2022; ENEV, *Evidence* (David Layzell), 31 March 2022; ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022.
[89] ENEV, *Evidence* (José Miguel Bermudez), 6 October 2022; ENEV, *Evidence* (Niall MacDowell), 20 October 2022; ENEV, *Evidence* (Christopher Bataille), 20 October 2022; ENEV, *Evidence* (David Layzell), 31 March 2022; ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022; ENEV, *Evidence* (James Meadowcroft), 31 March 2022; ENEV, *Evidence* (Julia Levin), 27 September 2022.
[90] ENEV, *Evidence* (Michael Powell), 29 September 2022.

sector investment, decision making, technology development and adoption will support industry growth."[91]

We heard that carbon pricing drives supply and demand for low-CI hydrogen, and that carbon pricing increases the value of low-CI products compared to high-CI alternatives, especially as high-CI energy vectors are phased-out over time and as technologies evolve. For example, Douglas Dias of Greenfield Global, which is proposing a green methanol project at the Port of Montreal, explained to us that carbon pricing determines what Greenfield Global's customers will pay and what products to offer them:

> There is certainly a gap between the conventional hydrogen and conventional methanol pricing and the green hydrogen and green methanol pricing. We're still in a discovery process with potential customers in the Port of Montreal and in other industries, heavy industry, transport and so on, to see what price they would be willing to pay, which will be motivated by the carbon price in Canada and other reasons that they have to pursue the transition. – *Douglas Dias*[92]

Some witnesses explained that carbon pricing can accelerate the energy transition. For example, Professor David Layzell of the University of Calgary argued that governments could increase the stringency of their carbon pricing regulations to build capacity for low-CI fuel production and hasten fuel-switching:

> […] all of the emissions of the fossil fuel companies need to be exposed to carbon taxes. Then, the economic benefit that comes from the carbon taxes can be used to transition these sectors to the production of zero-emission fuels like hydrogen or ammonia and to move them off the production of the fuels that we know we need to replace, which are gasoline, diesel, jet fuel and natural gas. – *David Layzell*[93]

[91] ENEV, *Evidence* (Jeff Griffin), 3 November 2022.
[92] ENEV, *Evidence* (Douglas Dias), 3 November 2022.
[93] ENEV, *Evidence* (David Layzell), 31 March 2022.

However, we heard that carbon pricing is not the only policy solution needed to develop the hydrogen sector or to achieve NZE2050. For example, James Meadowcroft of Carleton University explained that:

> the carbon price will help a great deal and that it's very important, but the obstacles to the kinds of changes to the systems we're talking about are multiple. There are issues of regulation, and there are safety rules and raising capital. There are many obstacles. It's a great step forward, but more can still be done by governments at various levels to unlock the potential of hydrogen. – *James Meadowcroft*[94]

Recommendation Seven

The Government of Canada must apply its national carbon pricing framework more stringently across economic sectors and reduce any exemptions to the framework that may exist. It should take measures to increase certainty that the national carbon pricing framework will endure and that the carbon price will continue to rise.

2.32 Clean Fuel Regulations

Canada's *Clean Fuel Regulations*, made under the *Canadian Environmental Protection Act, 1999*, came into force on 21 June 2022. The *Clean Fuel Regulations* require that gasoline and diesel that are produced and sold for use in Canada must reduce their life cycle carbon intensity over time. Judy Meltzer of ECCC, explained that the *Clean Fuel Regulations* are designed to be technology neutral by setting a standard for the carbon intensity of liquid fuels and create market incentives that encourage private investment in lower-CI alternatives, including potentially hydrogen.[95]

Some witnesses pointed to the benefits that the *Clean Fuel Regulations* could have for the nascent hydrogen-transportation pathway. For example, Sabina Russell of Zen Clean Energy Solutions told us that federal regulations like the *Clean Fuel Regulations*

[94] ENEV, *Evidence* (James Meadowcroft), 31 March 2022
[95] ENEV, *Evidence* (Judy Meltzer), 7 April 2022.

and a possible federal mandate for zero-emission vehicles, "are important policy signals to drive the needed investment in the sector today."[96] Mark Kirby of the Canadian Hydrogen and Fuel Cell Association hoped that the *Clean Fuel Regulations* could eventually help hydrogen compete on costs against diesel and unlock a development pathway to use hydrogen for heavy-duty freight applications in Canada.[97] Kirby argued that to unlock other opportunities for hydrogen in the transportation sector, the *Clean Fuel Regulations*, "must be designed so as to support private-sector investment in hydrogen refuelling stations."[98]

Douglas Dias of Greenfield Global told us that for companies evaluating hydrogen projects around the world, the design of countries' low-CI fuel regulations matters.[99] Dias argued that Canada's *Clean Fuel Regulations* are narrowly restricted to on-road transportation fuels and highlighted the United States' IRA and the European Commission's Renewable Energy Directive III as more-broadly scoped with better incentives for private investment in the hydrogen sector.[100]

2.33 Clean Electricity Standard

The *Clean Electricity Standard* is a regulation that has been proposed by the Government of Canada. The proposed *Clean Electricity Standard* would set a goal to achieve net-zero emissions in the electricity sector by 2035. According to ECCC officials, consultation on the design of the proposed regulations is ongoing.[101] The design of the *Clean Electricity Standard* was described in a March 2022 discussion paper published by ECCC, calling the proposed regulations, "Canada-wide […] emissions performance standards for emitting electricity generators to ensure that the electricity sector transitions to [net-zero emissions by 2035]."[102]

We heard that the *Clean Electricity Standard*, which would decarbonize Canada's electricity supply, along with electrifying more of the economy, which would drive demand growth for low-CI electricity, would also create demand for low-CI hydrogen. Several of our witnesses explained that low-CI hydrogen and electricity are potentially complementary solutions for achieving NZE2050 because low-CI hydrogen

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[96] ENEV, *Evidence* (Sabina Russell), 31 March 2022.
[97] ENEV, *Evidence* (Mark Kirby), 31 March 2022.
[98] ENEV, *Evidence* (Mark Kirby), 31 March 2022.
[99] ENEV, *Evidence* (Douglas Dias), 3 November 2022.
[100] ENEV, *Evidence* (Douglas Dias), 3 November 2022.
[101] ENEV, *Evidence* (Judy Meltzer), 7 April 2022
[102] Government of Canada, "A clean electricity standard in support of a net-zero electricity sector: discussion paper," 16 March 2022.

can be used to generate electricity in a fuel cell, be blended with methane to generate electricity at a CCUS-equipped power plant, or can store the energy of low-CI electricity, for example.[103] As Michael Powell of Electricity Canada told us, hydrogen production with low-carbon intensity electricity is "electrification by another name."[104] These applications of low-CI hydrogen could be of lower-carbon intensity than the alternatives they replace, depending on the circumstances.

We heard that to achieve NZE2050, the electricity grid and generation will need to double or triple in size to meet the demand for electricity, including from new uses of electricity created by electrifying more of the economy.[105] Despite the low-cost of renewable generation in Canada and the relative ease of building new renewable assets, some provinces and utilities could face potential deficits in power production as early as 2026 to 2028 based on demand growth forecasts for electricity.[106] Michael Powell said that decarbonizing the electricity grid by 2035, as proposed in the *Clean Electricity Standard*, would be, "a big lift, especially while keeping the system reliable and affordable, particularly in provinces that rely more on emitting forms of electricity generation than others."[107]

3. FURTHER CONSIDERATIONS

Having surveyed the policy instruments that the Government of Canada is using to support the hydrogen sector, we now consider some of the other issues raised by our witnesses during our study. Michael Powell's comment about how building the electricity infrastructure of the future is a "big lift" echoes a theme that was raised by many of our witnesses, which is that achieving NZE2050 is an enormously big lift and we need to have a plan – many plans, actually – if we're to have a hope of accomplishing the goal.

If low-CI hydrogen is vital to achieving NZE2050, as we heard, then what are the challenges and opportunities to developing the sector sustainably? What problems are the Government of Canada trying to solve with its hydrogen-related policies and spending, and what are the policy gaps that remain? The discussion in this chapter

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[103] ENEV, *Evidence* (Judy Meltzer), 7 April 2022; ENEV, *Evidence* (Michael Powell), 29 September 2022; ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022.
[104] ENEV, *Evidence* (Michael Powell), 29 September 2022.
[105] ENEV, *Evidence* (Michael Powell), 29 September 2022.
[106] ENEV, *Evidence* (Mark Zacharias), 29 September 2022
[107] ENEV, *Evidence* (Michael Powell), 29 September 2022.

explores several of the challenges, opportunities and unanswered questions that our witnesses asked us and the Government of Canada to consider.

3.1 Growing Hydrogen Supply and Demand

We heard that in some ways, the Government of Canada, other levels of government and industry are trying to solve a "chicken-and-egg problem"[108] in trying to develop the hydrogen sector. In other words, for the sector to reach its potential, government programs must simultaneously grow hydrogen supply and demand. Without buyers lined up to offtake hydrogen supply, private capital is reluctant to invest in production facilities. But without the capacity, knowledge, workforce and infrastructure that comes from a developed domestic hydrogen supply chain, the potential applications of hydrogen are more limited and so domestic demand and infrastructure investments remain small.

Several witnesses drew a connection between Canada's hydrogen support policies, its climate policies, and its general industrial policy. Because Canada's hydrogen industry is still nascent, witnesses argued that it is important that governments get some framework policies in place for the industry to get established.

Several witnesses recommended *accelerating the development of codes and standards* to define the hydrogen production pathways and their relative carbon intensities. Government officials told us that code- and standard-development for lower-CI fuels is well-funded and underway. But our other witnesses are likely aware of this work, since some of them are involved in working groups that implement the *Hydrogen Strategy of Canada*; yet, some still advised governments to speed the process up to drive industrial development and/or to protect people and the environment through regulation.[109]

Rachel Samson of the Institute for Research on Public Policy explained the link between carbon intensity standards and industrial development, arguing that:

[108] ENEV, *Evidence* (Michael Powell), 29 September 2022.
[109] ENEV, *Evidence* (Normand Mousseau, Professor of Physics and Scientific Director of the Institut de l'énergie Trottier, Université de Montréal, as an individual), 31 March 2022; ENEV, *Evidence* (Kevin Larmer), 4 October 2022; ENEV, *Evidence* (Sabina Russell), 31 March 2022; ENEV, *Evidence* (Mark Kirby), 31 March 2022; ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022.

> Part of the challenge now in this early stage of market development is to set the standards of what we know we don't want in terms of greenhouse gas emissions and air pollution, et cetera. Then we let the companies compete and see which ones — what type of hydrogen, what type of project — will be the most cost competitive in that market. So rather than governments determining the most likely successful companies or the most likely successful colour of hydrogen at this point, we can just set the standards and let the companies compete to meet them. – *Rachel Samson*[110]

James Meadowcroft of Carleton University argued that, "the energy world will be completely transformed over the next two, three or four decades. If we want Canada to have a prosperous and competitive place in that world, we need an orientation for a green industrial strategy or low-carbon industrial strategy."[111] Rebutting concerns about "picking winners," Meadowcroft told us that governments should lead on setting standards for carbon intensity and building out infrastructure.

Another framework condition that witnesses raised throughout our study was to *build strategic infrastructure* to support hydrogen development. We heard that government leadership to build early infrastructure is critical for growing supply and demand at the beginning of Canada's low-CI industries.

Our witnesses had many different opinions about which hydrogen infrastructure would constitute a good public investment. For example, Debbie Murray of the Association of Canadian Port Authorities argued that the Government of Canada should invest in *Canada's ports* because they represent strategic nodes where hydrogen infrastructure could open opportunities for new imports and exports, and around which new industries can grow.[112] Murray recommended that the Government of Canada make funding permanently available to Canada's port authorities to develop hydrogen-related infrastructure, and also to expand current funding programs for hydrogen to ports. NRCan officials noted that there is a working group on ports, in particular, under the *Hydrogen Strategy for Canada* to

[110] ENEV, *Evidence* (Rachel Samson), 24 November 2022.
[111] ENEV, Evidence (James Meadowcroft), 31 March 2022.
[112] ENEV, *Evidence* (Debbie Murray, Senior Director, Policy and Regulatory Affairs, Association of Canadian Port Authorities), 27 September 2022.

discuss exports and port equipment and how hydrogen can facilitate and support the energy transition in these facilities.[113]

Some witnesses argued that the Government of Canada should invest in *CCUS infrastructure* like carbon dioxide pipelines and storage because CCUS is required to make blue hydrogen.[114] Michael Powell of Electricity Canada argued that *electricity infrastructure* can also be hydrogen infrastructure, if "demand for electricity may also help serve as a market for hydrogen, helping create the demand to incentivize production. We can be the chicken and the egg at the same time."[115]

Bruno Pollet of the Université du Québec à Trois-Rivières argued for governments to adopt more proactive low-CI industrial policies to commercialize Canada's research and development, but was less specific about where to invest public funds, calling for greater spending on "constructing and implementing hydrogen infrastructure across the whole hydrogen value chain."[116]

José Bermudez of the International Energy Agency explained that while the global project pipeline for low-CI hydrogen is growing rapidly, only 4% of proposed hydrogen projects in the world have reached a final investment decision.[117] This signals a high-level of project risk for hydrogen facilities.

Rachel Samson of the Institute for Research on Public Policy discussed how the Government of Canada could avoid project risks by taking a carbon intensity standards approach and only supporting the most promising hydrogen projects that are secured by long-term contracts.[118] Samson argued that, with respect to hydrogen, governments should be minimalist and strategic in their low-CI industrial policies:

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[113] ENEV, *Evidence* (Sébastien Labelle), 24 November 2022.
[114] ENEV, *Evidence* (Niall MacDowell), 20 October 2022; ENEV, *Evidence* (Greg Moffatt), 29 September 2022; ENEV, *Evidence* (Normand Mousseau), 31 March 2022.
[115] ENEV, *Evidence* (Michael Powell), 29 September 2022.
[116] ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022.
[117] ENEV, *Evidence* (José Miguel Bermudez), 6 October 2022.
[118] ENEV, *Evidence* (Rachel Samson), 24 November 2022.

> [While] hydrogen is an important opportunity for Canada, and the sector needs additional policy support. However, we should not put all our eggs in one basket. With limited public resources, Canada will need to be strategic to capture the best opportunities for growth and jobs. – *Rachel Samson*[119]

Recommendation Eight

The Government of Canada's hydrogen and NZE2050 policies must define low-carbon intensity standards that are technology agnostic, and continually lower the allowed carbon intensity on track with credible NZE2050 pathways.

Recommendation Nine

The Government of Canada must focus on growing the domestic low-carbon intensity hydrogen supply and demand for the critical sectors and applications that will help achieve NZE2050; but it should invest strategically, in partnership with other levels of government and the private sector, and not take on too much risk with public funds.

3.2 Hydrogen Hubs

We heard that one potential solution to the chicken-and-egg problem is to build hydrogen hubs. These are regional areas where hydrogen infrastructure is built to coordinate the development of supply and demand and take advantage of regional differences in energy systems, resource availability, energy prices, skilled labour, and

[119] ENEV, *Evidence* (Rachel Samson), 24 November 2022.

other factors. Several witnesses told us that hydrogen hubs will help lower the cost of hydrogen production and distribution where they are established.

Mark Kirby of the Canadian Hydrogen and Fuel Association – who was one witness that called for Canada to build "30 hydrogen hubs by 2030" – told us about the benefits of hydrogen hubs and explained how they "don't just happen" without government support:

> Hubs de-risk investment, improve the economics and attract more investment, foster innovation, develop skills and lead to meaningful GHG reductions. But they don't just happen. Hubs must be supported with funding for foundation reports, economic analyses, professional management, stakeholder communication and key infrastructure investment. – *Mark Kirby*[120]

Bruno Pollet of the Université du Québec à Trois-Rivières argued that government-funded hydrogen hubs could leverage Canada's strong research and development capacity to drive innovation and create new industries, if hubs:

> Cluster several research institutions and government-funded initiatives to carry out industrial small to large pilot projects, technology demonstrations across the complete hydrogen value chain. These hubs would also attract light and heavy-duty transportation manufacturers, power to gas manufacturers, to name but a few. – *Bruno Pollet*[121]

Some hydrogen industry witnesses we interviewed also supported the concept of hydrogen hubs. For example, Douglas Dias of Greenfield Global told us that:

[120] ENEV, *Evidence* (Mark Kirby), 31 March 2022.
[121] EN, *Evidence* (Bruno G. Pollet), 4 October 2022.

> We love the idea of sustainability hubs. This is the concept where the supply and demand are neighbours and benefit from that symbiosis. This is the heart of our concept in Varennes, Quebec, where we already have an existing hub that involves bioethanol, renewable natural gas, industrial demand and demand in Montreal East with the oil terminals and oil refineries. It's a hub concept. It's very symbiotic. It ensures that a given project will have durability and will make sense in the present and for years to come because the partners in the project become interdependent and are growing together. It's not one person's vision or ambition that the whole structure is built upon, but it's partnerships of supply sources and demand sources. In my view, that's where we have seen the best economics, and therefore it's where we believe we can compete most favourably. – *Douglas Dias*[122]

Recommendation Ten

The Government of Canada must identify and invest in hydrogen hubs that will help achieve NZE2050 and work in partnership with provinces, territories and Indigenous Peoples to achieve regional hydrogen ambitions.

3.3 Understanding Regional Hydrogen Ambitions and Aligning Federal, Provincial and Territorial Policy

> Hydrogen can be a national unity play because it's something that can be developed in different ways using different resources in different parts of the country, and yet it's something that can all be built together. – *James Meadowcroft*[123]

[122] ENEV, *Evidence* (Douglas Dias), 3 November 2022.
[123] ENEV, *Evidence* (James Meadowcroft), 31 March 2022.

As Canada's provinces and territories develop and implement their own hydrogen strategies, we heard that it will be important for the Government of Canada to understand and recognize the differing resources, economies, policy environments and hydrogen opportunities in each region.

As Chris Bataille of Simon Fraser University, and others, explained, the potential hydrogen pathways in different regions are based on the starting conditions of their energy systems.[124] Normand Mousseau of the Institut de l'énergie Trottier explained that such price differences will determine the optimal role for hydrogen across Canada, arguing that:

> There also need to be regional strategies, because the current power grid is very different everywhere in Canada […] The roles will vary across Canada and that has to be taken into account. – *Normand Mousseau*[125]

David Layzell of the University of Calgary told us that as a first step, the Government of Canada should fund "foundation reports" for each region through its economic development agencies to assess "for the feasibility of that region actually supporting new fuel hydrogen value chains."[126] Officials from NRCan told us that the "first step" of developing regional hydrogen blueprints that reflect their differing resources was already underway.[127]

We heard that, in general, oil and gas-producing provinces with good CCUS potential will likely focus on blue hydrogen pathways. Provinces with low-CI electricity grids and low-cost pathways for growing the electricity grid will likely favour green hydrogen. Coastal access and assets like pipelines, and rail, aviation and refuelling infrastructure will also influence these patterns. There will likely be a mix of grey, blue and green hydrogen across Canada as the energy transition unfolds over several decades, but different regional pathways for hydrogen development based on feedstock and production processes are already emerging.

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[124] ENEV, *Evidence* (Christopher Bataille), 20 October 2022; ENEV, *Evidence* (David Layzell), 31 March 2022; ENEV, *Evidence* (Normand Mousseau), 31 March 2022.
[125] ENEV, *Evidence* (Normand Mousseau), 31 March 2022.
[126] ENEV, *Evidence* (David Layzell), 31 March 2022.
[127] ENEV, *Evidence* (Aaron Hoskin), 7 April 2022.

We heard that over time, the energy transition to NZE2050 will require phasing out high-CI energy sources that are commonly used today like gasoline, diesel and jet fuel. Some witnesses argued that low-CI hydrogen offers a potential path forward for regions with large fossil fuel sectors. James Meadowcroft of Carleton University, for instance, told us that low-CI hydrogen, "presents a potential future for the fossil fuel sector, to some extent, in a decarbonized energy future."[128]

Judy Meltzer of ECCC described how the Government of Canada sees this energy transition dynamic potentially playing out in Canada's oil- and gas-producing regions:

> Hydrogen does produce and provide that new market for our conventional energy resources, provided the carbon intensity of that product is driven toward zero over time. It should be part of our net-zero futures. We have the resources — and I think our minister has been very clear on this — to produce zero-emission hydrogen, and we can lever the investments that have gone into the conventional energy sector. – *Judy Meltzer*[129]

Other witnesses highlighted the green hydrogen opportunity for provinces with low-CI electricity. These include, for example, making green hydrogen from wind power in Newfoundland and Labrador, where a dozen projects have been proposed to take advantage of the region's "world-class wind resources."[130] Or, producing green hydrogen from hydroelectricity in Quebec to manufacture lower-carbon intensity steel, cement and aluminum.[131]

With respect to aligning federal hydrogen ambitions with regional ones, we heard that a large part of the challenge for the Government of Canada is that while the federal government has many policies to use in the hydrogen sector, a lot of the really effective ones are the jurisdiction of the provinces.

Douglas Dias of Greenfield Global explained how federal-provincial policy misalignment can affect the investment decisions of hydrogen companies:

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[128] ENEV, *Evidence* (James Meadowcroft), 31 March 2022.
[129] ENEV, *Evidence* (Judy Meltzer), 7 April 2022.
[130] ENEV, *Evidence* (Gene Gebolys), 6 October 2022.
[131] ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022; ENEV, *Evidence* (Christopher Bataille), 20 October 2022.

> We have power that is regulated by the provinces with provincially focused regulators. Therefore, the tariffs and availability of clean and green power is addressed by those regulators. We have a federal hydrogen policy and federal hydrogen ambitions, so we need alignment, somehow, between the provincial and federal policies to have something commercially operational. – *Douglas Dias*[132]

3.31 Northern and Remote Canada

We asked some of our witnesses to discuss the opportunities and challenges of using hydrogen in northern and remote communities and industrial sites in Canada. We heard that northern and remote communities face unique challenges when it comes to decarbonizing their energy systems while maintaining a secure supply of affordable energy. But we also heard that there are benefits to decarbonizing energy systems in the north beyond just lowering GHGs; in particular, *reducing black carbon emissions* from diesel engines, which are harmful to human health and cause environmental damage.[133]

James Meadowcroft of Carleton University told us that one potential opportunity is for remote communities that are not connected to the electricity grid to produce hydrogen for the community *as a storage for either small local hydro or wind*, for example. "In those contexts," Meadowcroft explained, "you might produce hydrogen there, and then it would serve as a storage vector, and perhaps for fuels and things like that."[134] Another opportunity mentioned by David Layzell of the University of Calgary is that in the Northwest Territories and Nunavut, ammonia could one day have potential as a low-CI energy carrier.[135]

NRCan officials told us that there are working groups that include territorial governments under the *Hydrogen Strategy for Canada* that look at opportunities for hydrogen in the North. Aaron Hoskin of NRCan told us that "hydrogen is seen *as a displacement of diesel*."[136] Hoskin also discussed the Raglan Mine in northern Quebec as an example of an operating *wind-to-hydrogen* facility that produces hydrogen

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[132] ENEV, *Evidence* (Douglas Dias), 3 November 2022.
[133] ENEV, *Evidence* (Aaron Hoskin), 7 April 2022.
[134] ENEV, *Evidence* (James Meadowcroft), 31 March 2022.
[135] ENEV, *Evidence* (David Layzell), 31 March 2022.
[136] ENEV, *Evidence* (Aaron Hoskin), 24 November 2022.

from surplus wind, which then displaces diesel in the local electricity grid; a practice that could be replicable in other remote areas.

Judy Meltzer of ECCC explained that federal climate regulations like carbon pricing and the *Clean Fuel Regulations* take account of the different challenges facing Canada's remote and northern communities by treating the territories differently.[137]

We regret not hearing directly from any First Nations, Métis or Inuit witnesses during our study. We strive not to let this happen again in our future studies. Nevertheless, we offer the following recommendation to the Government of Canada.

Recommendation Eleven

The Government of Canada, in the development and implementation of hydrogen as an energy source, must ensure that their relations with Indigenous Peoples and Indigenous Governments in Canada comply with Section 35 of the Constitution Act, 1982, the principle of the honour of the Crown, and the principles in Canada's treaty relationships, and its fiduciary obligations to the Indigenous Peoples of Canada.

Recommendation Twelve

The Government of Canada must ensure that hydrogen companies operating in Canada and/or abroad comply with Canadian laws and regulations in their operations.

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[137] ENEV, *Evidence* (Judy Meltzer), 7 April 2022.

3.4 The Potential to Export Hydrogen and Hydrogen Technologies

Our witnesses discussed how the greatest economic opportunity for Canada's hydrogen industry may be to develop an export-orientation.

The signing of the *Canada-Germany Hydrogen Alliance* in August 2022 emphasized the export opportunity. NRCan officials told us that signing the Canada-Germany agreement was essential for Canada because, "it opens the door for our private sector to start to export energy products into the European market — Germany first and then into the Netherlands and then further into the European Union."[138] Government officials suggested that by 2050, green hydrogen exports from Eastern Canada to Germany could total upwards of 25 million tonnes of hydrogen per year.[139]

Mark Kirby of the Canadian Hydrogen and Fuel Cell Association told us that over the past five years, the Association's members have experienced significant growth in revenue and employment by selling products and services to foreign markets.[140] Sabina Russell of Zen Clean Energy Solutions told us that a lot of foreign interest in Canada comes from developing large-scale green hydrogen projects to export as ammonia, but that Canadian products like fuel cells and hydrogen vehicles are also finding markets overseas.[141]

We heard that large public subsidies for hydrogen in the United States, Europe and other regions of the world are both an opportunity and a challenge for Canada's exports of hydrogen and hydrogen technology. The opportunity could be to access new markets and foreign capital for Canadian hydrogen and hydrogen-equipment manufacturing companies.

But the challenge is avoiding being, "relegated to the status of [an intellectual property or raw material] exporter rather than a product exporter," according to Bruno Pollet of the Université du Québec à Trois-Rivières.[142] Several witnesses expressed a concern that unless Canada levels the playing field with competitors' subsidies as countries race to implement their own hydrogen strategies, Canada will miss gaining a toehold in key export markets and sectors. Witnesses were also concerned that Canadian projects could get blocked out of international queues for

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[138] ENEV, *Evidence* (Aaron Hoskin), 24 November 2022.
[139] ENEV, *Evidence* (Aaron Hoskin), 7 April 2022.
[140] ENEV, *Evidence* (Mark Kirby), 31 March 2022.
[141] ENEV, *Evidence* (Sabina Russell), 31 March 2022.
[142] ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022.

critical hydrogen equipment if inventories get snapped up by other countries. We heard that the risk of these challenges occurring is exacerbated if Canada lacks hydrogen export-import infrastructure and a domestic supply chain.

Pollet described the potential for an end-to-end Canadian hydrogen supply chain:

> We have something here [in Canada] that is unique. If we wanted to, we could have a complete electrolyzer supply chain, from the extraction of our minerals, to the production of those electrolyzers, to the implementation of those giga-factories to export those big electrolyzer systems to different markets in the world. Likewise with fuel cells. – *Bruno Pollet*[143]

On the other hand, whether Canada is able to produce hydrogen at levels that would satisfy domestic demand while leaving surplus hydrogen available for export is also in question. As Jean-Denis Charlebois of the CER explained, "the potential exists, but it remains to be seen whether the economic dynamics, as well as the political and regulatory support, will essentially facilitate hydrogen production at the necessary level, not only to meet the demand here in Canada, but also for export."[144]

Nor is it a given that from a systems perspective, exporting hydrogen would be a good choice for Canada's NZE2050 goals. For example, we heard that it would often be better to directly electrify certain end-uses than to use low-CI hydrogen due to efficiency losses. It could also be less expensive to electrify directly. Julia Levin of Environmental Defence Canada told us, for example, that in Atlantic Canada where the immediate challenge is to stopping using coal-fired electricity, renewable power would be better used to decarbonize the regional electricity grid than to produce hydrogen to ship overseas.[145] Another example was given by Normand Mousseau and Robert Horwath who were both skeptical that Quebec could feasibly export green hydrogen at large-scale, since the province would need to add new electrical generating capacity at a cost that would be borne by Quebec ratepayers and taxpayers.[146] Michael Powell of Electricity Canada underlined the tradeoff that could

[143] ENEV, *Evidence* (Bruno G. Pollet), 4 October 2022.
[144] ENEV, *Evidence* (Jean-Denis Charlebois), 29 September 2022.
[145] ENEV, *Evidence* (Julia Levin), 27 September 2022.
[146] ENEV, *Evidence* (Normand Mousseau), 31 March 2022; ENEV, *Evidence* (Robert W. Howarth), 27 September 2022.

be faced by taxpayers and ratepayers in regions where electricity is used to produce green hydrogen for export markets:

> The broader issue of whether we will have the capacity to export green hydrogen to other parts of the world will rely on our ability to have power here that is surplus to our domestic needs — beyond lighting homes, running air conditioners and charging cars — in ways that are affordable and in sufficient quantities so that the investments people make in electrolyzers are able to run at a capacity that is there. – *Michael Powell*[147]

4. CONCLUSION

Canada's low-carbon intensity hydrogen industry is only just beginning to develop. Low-carbon intensity hydrogen may be a fuel of the future needed to achieve net-zero emissions by 2050 but it will have to prove its utility, cost and performance against other decarbonization solutions. Understanding how hydrogen fits into the energy system requires a systems perspective.

Governments should be aware that some investments in hydrogen enable high-carbon intensity production pathways that do not align with national climate plans. If the Government of Canada wants to convince the public about the validity of its hydrogen vision it should engage the public and Indigenous peoples, and present accurate, transparent and credible information about its emission reduction and energy transition plans.

There is a role for the Government of Canada to play in helping to grow the industry. Government policies establishing continually-lower carbon intensity standards across the economy could accelerate the growth of the low-CI hydrogen industry while enabling other decarbonization solutions.

[147] ENEV, *Evidence* (Michael Powell), 29 September 2022.

Recommendation Thirteen

Given that hydrogen energy is still nascent, the Government of Canada must periodically review its *Hydrogen Strategy for Canada*. If in the future hydrogen energy is no longer a cost-competitive or environmentally responsible path to net zero, the Government must revise its strategy and reevaluate its investment of public funds in this industry.

Recommendation Fourteen

The committee requests that the Government of Canada table a comprehensive response to this Report.

APPENDIX – Witnesses

Thursday, March 31, 2022

Mark Kirby, President and Chief Executive Officer, Canadian Hydrogen and Fuel Cell Association

David Layzell, Energy Systems Architect, The Transition Accelerator, University of Calgary, as an Individual

James Meadowcroft, Professor, School of Public Policy and Administration, Carleton University, as an Individual

Normand Mousseau, Professor of Physics and Scientific Director, Institut de l'énergie Trottier, Université de Montréal, as an Individual

Sabina Russell, Principal and Co-Founder, Zen Clean Energy Solutions

Thursday, April 7, 2022

Aaron Hoskin, Senior Manager, Intergovernmental Initiatives, Natural Resources Canada

Sébastien Labelle, Director General, Clean Fuels Branch, Natural Resources Canada

Judy Meltzer, Director General, Carbon Markets Bureau, Environmental Protection Branch, Environment and Climate Change Canada

Douglas Nevison, Assistant Deputy Minister, Climate Change Branch, Environment and Climate Change Canada

Tuesday, September 27, 2022

Robert W. Howarth, Professor David R. Atkinson Ecology and Environmental Biology, Cornell University, as an Individual

Julia Levin, Associate Director, National Climate, Environmental Defence Canada

Debbie Murray, Senior Director, Policy and Regulatory Affairs, Association of Canadian Port Authorities

Thursday, September 29, 2022

Jean-Denis Charlebois, Chief Economist, Canada Energy Regulator

Jim Fox, Vice-President, Regulatory Strategy and Cooperation, Canada Energy Regulator

Greg Moffatt, Vice President, Policy and Corporate Secretary, Chemistry Industry Association of Canada

Michael Powell, Vice President of Government Relations, Electricity Canada

Mark Zacharias, Executive Director, Clean Energy Canada

Tuesday, October 4, 2022

Kevin Larmer, Director of Innovation and Markets, Canadian Gas Association

Bruno G. Pollet, Professor and Deputy Director, Institute for Hydrogen Research

Thursday, October 6, 2022

José Miguel Bermudez, Energy Analyst, Hydrogen and Alternative Fuels, International Energy Agency

Gene Gebolys, Director, World Energy GH2

Thursday, October 20, 2022

Christopher Bataille, Adjunct Research Fellow, Columbia Centre for Global Energy Policy, Adjunct Professor, Simon Fraser University, as an Individual

Jerry V. DeMarco, Commissioner of the Environment and Sustainable Development, Office of the Auditor General of Canada

Mathieu Lequain, Director, Office of the Auditor General of Canada

Niall Mac Dowell, Professor, CCS Knowledge Centre

Thursday, November 3, 2022

Douglas Dias, Board Member, Vice President Sales and Market Development, Greenfield Global, Renewable Industries Canada

Jeff Griffin, Vice-President, Science and Technology, Canadian Nuclear Laboratories

Andrea Kent, Board Member, Vice President Industry and Government Affairs, Greenfield Global, Renewable Industries Canada

Thursday, November 24, 2022

Aaron Hoskin, Senior Manager, Intergovernmental Initiatives, Natural Resources Canada

Miodrag Jovanovic, Assistant Deputy Minister, Tax Policy Branch, Department of Finance Canada

Sébastien Labelle, Director General, Clean Fuels Branch, Natural Resources Canada

Marie-Josée Lambert, Acting Director General, Crown Investment and Asset Management, Department of Finance Canada

Sean McCoy, Assistant Professor, Transition Accelerator Fellow, Chemical and Petroleum Engineering, University of Calgary, as an Individual

Simon Moore, Vice President, Investor Relations, Corporate Relations and Sustainability, Air Products

Rachel Samson, Vice President, Research, Institute for Research on Public Policy

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