Ontario Low-Carbon Hydrogen Strategy

DISCUSSION PAPER

Ontario

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INTRODUCTION

Ontario is committed to promoting integrated, tangible environmental solutions that tackle climate change. The Made-in-Ontario Environment Plan, released in November 2018, commits the province to reducing greenhouse gas emissions to 30 per cent below 2005 levels by 2030, in line with Canada's 2030 target.

The impacts of the COVID-19 outbreak have been felt across Ontario, by families, workers, businesses and communities. This moment in time presents us with opportunities to encourage new industries that will help support a speedy economic recovery, while also helping reduce greenhouse gas emissions and moving us towards our 2030 greenhouse gas emissions reduction target and beyond.

The Environment Plan encourages collaboration with all levels of government, government agencies and the private sector to find the most effective and innovative ways to reduce greenhouse gas emissions.

The Environment Plan is evolving to address the environmental priorities of Ontarians as new information, ideas and innovations emerge. Although not a new idea, hydrogen has re-emerged as an exciting and potential long-term way to address climate change and air quality while creating opportunities for industry to grow.

This is especially important since about 80 per cent of Ontario's 2018 greenhouse gas emissions came from transportation, buildings and industry – all areas where hydrogen can be used.

Although some of these uses may occur in the longer term, certain actions are needed now to scale up technologies and bring down costs to support the province's hydrogen potential. Actions to support hydrogen can be leveraged to encourage other clean tech industries and to help support economic recovery from COVID-19.

Depending on how it is produced, hydrogen has the potential to be low-carbon, for example, hydrogen that is produced from Ontario's electricity grid. Together with other actions, hydrogen can help decarbonize our economy and reduce our reliance on fuels that have a larger carbon footprint like coal, natural gas, diesel and gasoline. Considering opportunities to support this sector could help Ontario's longer-term economic recovery in all regions of the province as businesses rethink how they operate and grow.

Clean technology and hydrogen

As part of the Ontario Jobs and Recovery Committee's work, the Ministry of the Environment, Conservation and Parks has consulted with the clean technology and hydrogen sectors to understand COVID-related disruptions and how government could support the sector to continue to grow and prosper beyond the immediate recovery.

We are evaluating ways to support the clean technology sector while respecting energy consumers and taxpayers. As part of these efforts, we are also working on a hydrogen strategy that would:

1. support the production of low-carbon hydrogen and related technologies,
2. build distribution infrastructure, and
3. enhance opportunities for end uses across the economy.

Our preliminary vision is to leverage our existing strengths to develop Ontario's hydrogen economy, creating local jobs and attracting regional investment while reducing greenhouse gas emissions.

Consultations and the discussion paper

Over the coming weeks, we will engage with stakeholders who would like to shape the development of Ontario's first ever low-carbon hydrogen strategy.

The purpose of this discussion paper is to begin a dialogue and to seek your input to:

- better understand the needs of the sector, including consumers
- better understand the challenges of supporting a complex hydrogen market
- consider ways to enable the private sector to expand adoption of hydrogen and support regional growth

Deploying hydrogen in Ontario provides both opportunities and challenges to overcome. It will require governments and stakeholders to work together. This is why we want to hear from you. We will consider the input we receive as we develop the strategy to help grow Ontario's hydrogen economy.

What is hydrogen?

Hydrogen is the first element on the periodic table. It is colourless and odourless, and makes up about 75 per cent of the known universe. Energy must be used to break the bond it has with other elements to release it from the materials where it is naturally found, for example in water, to create pure hydrogen gas (H2).

There are various ways to make hydrogen like using water, fossil fuels, renewable fuels, and biomass (for example forestry and crop residues). Depending on how it is produced, hydrogen has the potential to be a low-carbon fuel.

Hydrogen terminology

Hydrogen is often referred to as green, blue or grey:

- **Green hydrogen** is made using low-carbon sources like electricity from Ontario's grid or renewable organic material (i.e. biomass).
- **Blue hydrogen** is made from natural gas with carbon capture use and storage (CCUS).
- **Grey hydrogen** is made from natural gas.

Low-carbon hydrogen refers to the smaller carbon footprint of the hydrogen production method compared to other methods and includes blue and green hydrogen.

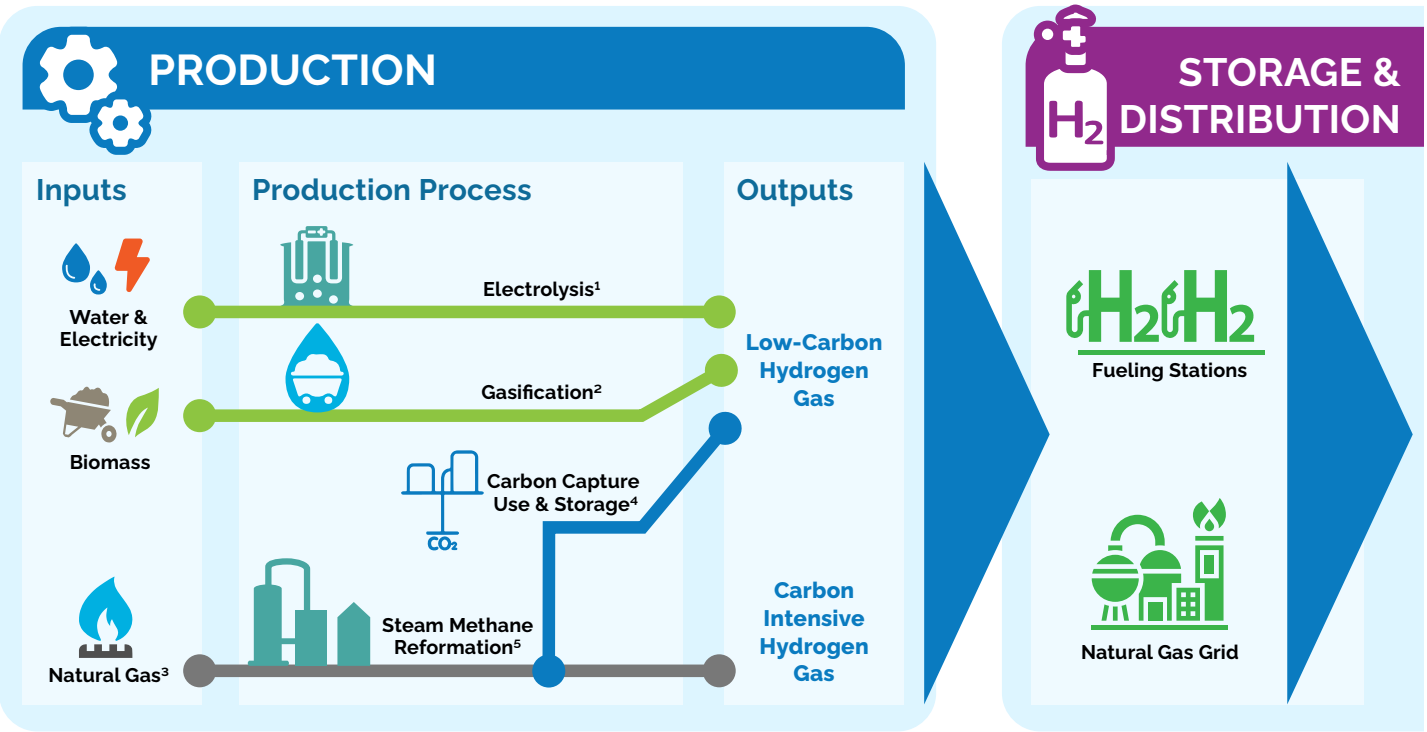
Hydrogen made from natural gas has a higher carbon footprint but could potentially be paired with carbon capture use and storage (CCUS) technology to keep most of the carbon dioxide from its production from entering the atmosphere. Hydrogen made from electricity or biomass results in zero or near-zero greenhouse gas emissions over its lifecycle, if the source of the electricity is low-carbon. This is relevant in Ontario since our electricity grid is largely carbon free.

Globally, most hydrogen is produced as higher-carbon hydrogen from natural gas (also known as grey hydrogen). This process, called steam methane reformation, is the cheapest way to make hydrogen. Low-carbon hydrogen (also known as green or blue hydrogen) is produced using other sources, and currently represents only 0.5 per cent of the global market share (Wood Mackenzie, 2020).

In Ontario, most hydrogen is made from natural gas and is distributed to end users via pipelines. There are a few projects that make smaller amounts of hydrogen from electricity, where it is generally used on-site.

According to IHS Markit (2020), globally, electricity-based hydrogen is expected to be cost-competitive with hydrogen made from natural gas by 2030 due to economies of scale and technological improvements. Currently, producing low-carbon hydrogen is costly in Ontario in part because of the cost difference between electricity and natural gas. Given that specific challenge, and the opportunity of promoting the production and use of low-carbon hydrogen, Ontario is interested in hearing about technologies and business models that can improve cost-competitiveness at producing low-carbon hydrogen.

Hydrogen production



[1] Electrolysis is performed by electrolyzers using electricity to split water into hydrogen and oxygen atoms. It is the reverse of the chemical reaction that takes place in a fuel cell.

[2] Biomass gasification uses a controlled process involving heat, steam, and oxygen to convert biomass to hydrogen and other products, without combustion.

[3] Increasing renewable natural gas in the natural gas system lowers the carbon of hydrogen from steam methane reformation.

[4] Carbon capture use and storage is a process that captures carbon dioxide emissions from sources like natural gas-fired electricity generation or fossil-fuel produced hydrogen and either uses or stores it so it will not enter the atmosphere.

[5] Steam Methane Reformation: The process for reacting methane, which is the main component of natural gas, with steam to produce hydrogen as a product.

Once produced, hydrogen can be moved, or distributed as a gas through dedicated pipelines, or as a liquid in ships or trucks to fuelling stations (much like filling up your car with gasoline).

A note on the history of hydrogen

Almost since its discovery, hydrogen has played an important part in contemporary visions of the future. Hydrogen was discovered as a flammable gas in the 18th century. It was used for street lighting before electricity became widespread and economical to use in public spaces.

Hydrogen gained importance as a fuel in the 1960s for space travel, and in the 1970s as an alternative energy concept during the oil price crises. Interest waned in the 1990s when energy prices were low. Renewed global interest in hydrogen has recently grown as decreasing hydrogen production costs make projects more economically feasible as a way to help lower greenhouse gas emissions.

Reducing our carbon footprint with hydrogen

Currently, the main uses for hydrogen in Ontario are in refineries and fertilizer production. But hydrogen is versatile and can be a clean fuel alternative or complement to fossil fuels like coal, natural gas, diesel and gasoline over the medium- to long-term (2030 to 2050).

Industry

In industrial processes, low-carbon hydrogen could replace the hydrogen made from natural gas that is currently used as a chemical input in fertilizer production and in oil refineries. By 2040, hydrogen is also expected to become a cost-competitive low-carbon solution in high temperature industrial applications globally, for example, in steel and cement production (International Energy Agency, 2019; Hydrogen Council, 2020).

Transport

Hydrogen can complement battery technology in replacing fossil fuels for vehicles, especially with commercial vehicles, buses, commuter trains, ferries and forklifts. For example, the International Energy Agency (2019) identifies hydrogen as a leading option to reduce greenhouse gas emissions from long-distance and long-haul road transport that could be cost-competitive by 2030 globally. The cost-competitiveness of hydrogen would depend on the cost of fuel cells, hydrogen and competing fuels, as well as the availability of fuelling stations. Several companies are currently using hydrogen forklifts in their warehouses because they are already cost-competitive when operated for 24 hours a day.

Electricity

Hydrogen production can be used to help balance electricity supply with customer demand by controlling when electricity is used, for example producing hydrogen using electrolyzers when there is more supply and not producing during periods of peak demand. Hydrogen can also be used as a form of electricity storage by using electricity to make hydrogen, storing the hydrogen, and, when needed, used in fuel cells or burned in generators to make electricity. In this case, hydrogen competes with other electricity storage technologies.

Hydrogen could also be considered a low-carbon source of electricity or combined heat and power for remote communities replacing diesel generators (for example in Northern Ontario).

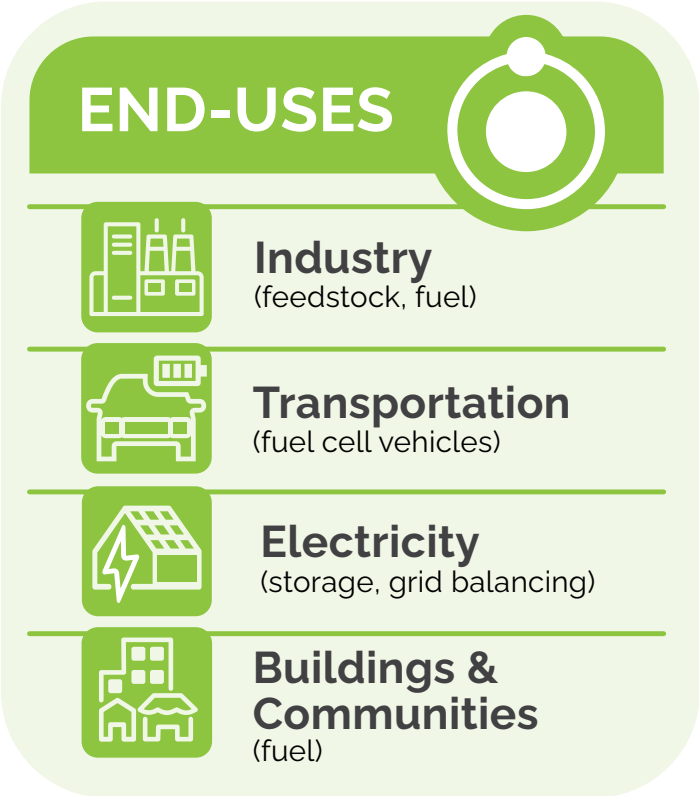
A note on hydrogen production and renewable electricity

Renewable electricity generation from

wind and solar sources fluctuates, at times creating more electricity than needed by consumers. Producing hydrogen from excess wind and solar electricity using electrolyzers presents an opportunity to store that energy over days, weeks or even months. This could help improve the reliability and affordability of Ontario's electricity system.

Buildings and Communities

Low-carbon hydrogen can also be blended into natural gas and distributed through natural gas pipelines, making Ontario's natural gas cleaner. This also acts as an energy storage mechanism. The blended natural gas can then be used to heat space and water in our homes and businesses. Hydrogen can also be burned directly in a furnace. In this case, hydrogen complements other technologies like electric heat pumps and renewable natural gas.



Why hydrogen now

Ontario is not alone in its interest in hydrogen. There is growing support world-wide from governments, and rapid growth in private sector investment.

Low-carbon hydrogen production is ramping up and jurisdictions are committing resources to accelerate this process as they see this fuel as a key component of their long-term climate strategies.

In recent years, a number of countries and regions like Australia, the European Union, Germany, Japan, and Spain and sub-national jurisdictions like California and New South Wales in Australia have issued hydrogen strategies or plans. In most cases, they are part of long-term commitments to reduce greenhouse gas emissions and fight climate change. These jurisdictions use a variety of tools to support the use of hydrogen, including setting targets, technology pilots, subsidies and regulation to support production, distribution and use (for example zero- and low-emissions vehicle mandates for light-, medium-, and heavy-duty vehicles).

Some countries are attaching financial commitments to their strategies. Germany, for example, committed €9 billion (CAD$14 billion) over the next decade, while others, like Spain, will rely on investments from the private sector.

The Canadian government recognizes the important role that hydrogen could play in the future and is expected to release a hydrogen strategy for Canada in fall 2020. Following release of the national strategy, the federal government will work with provinces on developing regional hydrogen blueprints.

The proposed federal Clean Fuel Standard (CFS) supports demand for low-carbon fuels such as hydrogen. The draft CFS design proposes that hydrogen fuelling station operators create CFS compliance units by dispensing hydrogen to fuel cell vehicles. The compliance units are eligible for sale to fossil fuel suppliers who have obligations under the regulation. Supplying hydrogen to light, medium and heavy-duty fuel cell vehicles is therefore incented through this federal approach. The lifecycle carbon footprint of the hydrogen, and how much is supplied, is reported to determine how many CFS compliance units are generated.

Several provinces are considering how they might play a part in the global push to make low-carbon hydrogen a viable option. British Columbia and Quebec are working on their own hydrogen strategies. The Alberta Natural Gas Strategy, released in October 2020, commits the province to developing a hydrogen roadmap by 2023.

Private sector investment

While government support for hydrogen is growing, the private sector is also making significant low-carbon hydrogen investments globally. Recent investments to promote the use of hydrogen include:

- a joint venture between The Volvo Group and Daimler Truck AG, which has a fuel cell production facility in Vancouver (British Columbia), to develop fuel cells for heavy-duty trucking and other applications
- a project in Germany for over 40 regional trains powered by hydrogen using fuel cells developed by Cummins for Alstom Transport
- a power-to-gas facility built by Enbridge and Cummins in Markham (2.5 MW capacity with the option to expand to 5 MW) that converts low-carbon electricity from the provincial power grid to hydrogen, providing reliability services for the electricity grid. The hydrogen will be injected into the natural gas distribution system (an additional $5M investment). This utility-scale facility is the first of its kind in North America

According to the International Energy Agency (2019), the cost of producing low-carbon hydrogen and hydrogen end-use equipment is expected to continue to decrease as the international demand for hydrogen increases. This is, in part, due to the ongoing decline expected for the cost of renewable electricity that can be used to produce hydrogen (National Renewable Energy Laboratory 2019).

According to Bloomberg New Energy Finance estimates, annual global sales of hydrogen could reach US$700 billion (CAD$924 billion) by 2050 assuming that strong, supportive government policies are in place. This would require US$11 trillion (CAD$15 trillion) of investment in production, storage and transportation infrastructure globally, which would provide the basis for hydrogen to meet 24 per cent of the world's energy demand by 2050.

Ontario's advantages and opportunities

Ontario is well-positioned to drive growth in a low-carbon hydrogen economy given our main advantage: our low-carbon electricity supply supported by an extensive natural gas distribution system and a set of established global companies.

Low-carbon electricity supply

Ontario has a competitive advantage in adopting low-carbon hydrogen due to its low-carbon electricity supply. Ontario's low-emission electricity grid – a combination of hydroelectric, nuclear, natural gas and renewable generating capacity – has allowed the province to avoid up to 30 megatonnes of annual greenhouse gas emissions. In 2019, approximately 94 per cent of the electricity generated in Ontario was emissions-free due to the end of coal-fired electricity in the province.

Existing manufacturers and users

Ontario has several hydrogen projects and businesses already established or in development including:

- Two of the few global hydrogen electrolyzer firms, Cummins and Next Hydrogen, have facilities in the province
- Fuel cell and fuel cell component makers with operations in Ontario include Dana and Cummins
- New Flyer, one of only two North American hydrogen bus manufacturers has operations in Ontario
- Canadian Tire and Walmart use hydrogen powered forklifts in distribution centres
- Enbridge is planning a pilot to inject hydrogen into natural gas pipelines in Markham
- Air Products makes hydrogen from fossil natural gas for sale to industry, such as petroleum refiners in Sarnia, and has the ability to deliver or produce on-site hydrogen from natural gas or electricity

A note on the potential of electrolyzers

The International Energy Agency (2020) identifies electrolyzers, which use electricity to break water into hydrogen and oxygen, as a key technology to reach 2050 net-zero emission targets. The IEA emphasizes that, much like other clean technologies, the cost of electrolyzers is quickly decreasing. This will make this technology and low-carbon hydrogen made from electricity more cost-competitive.

Regional opportunities

Ontario's location within the Great Lakes region is beneficial for trade with the United States which could include trading hydrogen and hydrogen technologies in the future. Certain regions in Ontario have particular opportunities to advance hydrogen, for example:

- **Bruce County** has the world's largest operating nuclear station that provides clean and reliable energy to the grid and is exploring the opportunity to store hydrogen using its underground salt caverns.

- **Windsor-Quebec corridor**, including the US border crossing, is one of the largest freight corridors in North America.
- **Sarnia** has refineries and chemical producers that could switch from using high- to low-carbon hydrogen.
- **Northern Ontario** (e.g. Hearst, Thunder Bay and Huron Northshore) has vast sustainably managed forests, a potential low-carbon source to produce hydrogen that could be used as a fuel to heat homes or for low-carbon electricity generation for communities that rely on diesel.
- **TransCanada pipeline compression stations** could be considered for hydrogen production opportunities from forest biomass.
- **Greater Toronto and Hamilton area** has a large density of potential end-users (for example, transit, local manufacturing, fleets and the natural gas grid) and internationally exported steel manufacturing.
- **Southern Ontario and Sault Ste Marie** has cement and iron and steel facilities that could transition to hydrogen as part of their long-term evolution.
- **Landfills as well as food and organic waste processing facilities across Ontario** could produce hydrogen from biogas.

Through a provincial hydrogen strategy, Ontario hopes to build on its existing strengths to reduce emissions, attract investment and create jobs in different regions of the province.

Policy landscape

Along with the province's greenhouse gas reduction target, the following supportive provincial policies and programs are currently in place and provide a foundation to grow the hydrogen market:

- **Electricity rates:** Ontario is committed to reducing electricity rates for all consumers which will benefit hydrogen production.. The Industrial Conservation Initiative (ICI), which reduces electricity costs for participating large electricity consumers, may increase the cost-competitiveness of converting Ontario's low-carbon electricity into hydrogen.
- **Certification for hydrogen technicians:** as one of the first provinces requiring certification through the Technical Standards and Safety Authority, Ontario has a skilled workforce.
- **Transit procurement:** through the Province's GO Rail Expansion Program, bidders on the On-Corridor Works project have the opportunity to propose innovative approaches to meet future GO Transit rail service levels, including opportunities for technology that could be used to electrify core segments of the GO rail network, such as an overhead electric wire system or hydrogen fuel cells.
- **Green Vehicle Licence Plate Program:** hydrogen fuel cell vehicles eligible for green licence plates have ongoing access to High Occupancy Vehicle (HOV) lanes and no-cost access to High Occupancy Toll (HOT) lanes on 400-series highways and the Queen Elizabeth Way (QEW), even if there is only one person in the car.
- **Hydrogen readiness:** prepare for anticipated uptake of low-carbon hydrogen production by considering compatibility of new infrastructure with hydrogen. For example, proposed updates to Guideline A-5 Atmospheric Emissions from Stationary Combustion Turbines to allow for hydrogen use.
- **Food and Organic Waste Policy Statement:** established under the Resource Recovery and Circular Economy Act, directs municipalities and businesses to meet targets of up to 70% reduction and diversion of food and organic waste from landfills by 2025, which could provide a source for hydrogen production.

Current and potential job and investment opportunities

For 2017, the Canadian hydrogen and fuel cell sector reported (MNP LLP, 2018):

- **Revenue:** $207 million. 12 per cent of revenue was generated from Ontario.
- **Employment:** 2,177 jobs. Ten per cent of these jobs were in Ontario. In comparison, 60 per cent were in British Columbia (BC).
- **Research, development, and demonstration expenditures:** $91 million. 4 per cent occurred in Ontario, behind BC (62 per cent), Germany (12 per cent), US (10 per cent) and Quebec (7 per cent).

According to a report by the Green Ribbon Panel (2020), a group of Canadian nuclear and cleantech professionals chaired by Bruce Power, 23,000 hydrogen sector jobs could be created in Ontario based on a scenario of high hydrogen adoption (for example assumes 80 per cent of heavy-duty trucks use hydrogen fuel cells). The report also estimates that hydrogen could generate $2.5 billion of spending per year and improve Ontario's trade balance by $3.2 billion per year by displacing fossil fuel imports, such as natural gas, potentially making Ontario a leading technology exporter.

Adoption of low carbon hydrogen is still in the early stages – as a result, there is an opportunity to position Ontario as a leader in this space and demonstrate how the use of low-carbon hydrogen can help address climate change.

Vision for Ontario's Hydrogen Strategy

Leverage our existing strengths to develop Ontario's hydrogen economy, creating local jobs and attracting investment while reducing greenhouse gas emissions.

Key principles

To help us achieve this vision, the following draft principles will guide the development of Ontario's hydrogen strategy:

Reducing greenhouse gas emissions

Support the Environment Plan commitment to reduce greenhouse gas emissions by encouraging the use of low-carbon hydrogen.

Generating economic development and jobs

Build the hydrogen industry across Ontario to create jobs and facilitate longer-term economic recovery; and seek strategic partnerships and support innovation.

Promoting energy resilience

Consider the value of domestic hydrogen for Ontario's energy bills and evolving energy system.

Reducing barriers and enabling action

Attract investment and create a level playing field between technology options.

Using hydrogen where and when it makes sense

Focus on areas where hydrogen is most likely to become cost-competitive (for example end-uses where electrification and/or biofuels are not feasible greenhouse gas reduction opportunities).

We want to hear from you

Next steps

The ministry is seeking feedback on this discussion paper for 60 days. All comments will be considered and used to help develop Ontario's first hydrogen strategy. The goal is to support economic growth while helping the province reduce greenhouse gas emissions.

Discussion questions

Please consider the following questions when providing your feedback:

Vision

1. Do you support Ontario's efforts to create a hydrogen strategy?
2. How would you refine the vision statement?
3. What should be the key outcomes of Ontario's hydrogen strategy?
4. How should the hydrogen strategy define and measure success?

Reducing greenhouse gas emissions

5. What are Ontario's key technology, regulatory and business opportunities in developing low-carbon hydrogen?
6. What is the potential for hydrogen to contribute to Ontario's 2030 greenhouse gas emission reduction target?
7. What additional environmental benefits should be considered in the development of the strategy (for example during hydrogen production)?

Generating economic development and jobs

8. What role can hydrogen play in various regions and sectors?
9. What actions can Ontario take to help Ontario companies get ready to meet expected international demand (for example research and development, innovation, procurement)?
10. What are the training needs for the workforce to support the economy across Ontario?

Promoting energy resilience

11. How can hydrogen support a reliable and affordable energy system, including energy storage?
12. What are the barriers and opportunities for hydrogen in the energy system?

Reducing barriers and enabling action

13. How can the provincial government best support partnerships with the private sector, academia and other government / levels of government?
14. Are you aware of regulatory barriers that need to be addressed or regulatory enabling mechanisms that need to be put in place? Please explain.
15. What are the best opportunities to cost-effectively support hydrogen across Ontario while respecting tax payers?

Using hydrogen where and when it makes sense

16. What potential feedstocks and stages of the hydrogen supply chain (production, storage and distribution, and end-use) do you think Ontario is best-positioned to develop and lead in and which uses have the greatest potential for cost reduction?
17. What are the main risks of hydrogen use in Ontario and are there opportunities for the government to decrease these risks?
18. Considering that low-carbon hydrogen is expected to be more competitive over time, what should be the timeframe for Ontario's hydrogen strategy?

Ways to get involved

Please submit your comments on the Environmental Registry or email us at hydrogen@ontario.ca.
You may attach your submission as a PDF or Word document. You may also send a letter to the mailing address listed below. If applicable, include the name of your organization. Thank you for your participation.

Mailing address
Ministry of the Environment, Conservation and Parks
Climate Change Programs and Partnerships Branch
6th Flr, 135 St Clair Ave W, Toronto, ON M4V 1P5

Glossary

Biogas: Mixture of gases produced by the breakdown of organic matter.

Biomass: Organic matter (plant and animal material), for example forestry and crop residues, purpose-grown crops.

Biomass gasification: A controlled process involving heat, steam, and oxygen to convert biomass to hydrogen and other products, without combustion.

Carbon capture use and storage: Carbon capture use and storage is a process that captures carbon dioxide emissions when producing hydrogen that either uses or stores it so it will temporarily or permanently not enter the atmosphere.

Combustion: The burning fire produced by the combination of a fuel (see Fuel), heat, and oxygen.

Electrolysis: A process that is performed using electricity to split water into hydrogen and oxygen atoms. It is the reverse of the chemical reaction that takes place in a fuel cell.

Electrolyzer: A device that uses electricity to break water into hydrogen and oxygen.

Fuel: A material used to create heat or power through conversion in processes like combustion.

Fuel cell: A device that produces electricity through an electrochemical process, usually from hydrogen and oxygen.

Gasification: A technological process that can convert any carbon-based raw material such as coal or biomass into fuel gas

Greenhouse gas: A gas that contributes to the greenhouse effect (warming of the planet) by absorbing and emitting infrared radiation, for example carbon dioxide and methane.

Grid balancing services: A technique used by electricity grid operators to match the supply of electricity (from sources like nuclear, hydropower, natural gas, wind, solar, and biomass) to the demand (for example, usage from businesses and homes).

Low-carbon energy: A form of energy that emits few or no greenhouse gases (see Greenhouse Gas) when used or produced (for example nuclear energy).

Petajoule (PJ): A unit of energy; the heat generated, or energy expended.

Renewable energy: A form of energy that is never exhausted because it is renewed by nature (within short time scales; for example, wind, solar radiation, hydro power).

Steam methane reformation: The process for reacting natural gas with steam to produce hydrogen as a product.

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Appendix

Snapshot of select global hydrogen developments

Jurisdiction (hydrogen milestone)	Description
California (January 1999)	Since January 1999, the California Fuel Cell Partnership, a public-private partnership involving the state of California, has been promoting fuel cell electric vehicles (FCEVs) and hydrogen. In 2018, the partnership released a vision of having a million FCEVs (cars, buses and trucks) and one thousand hydrogen fuelling stations by 2030.
Japan (December 2017)	In December 2017, Japan released a Basic Hydrogen Strategy with the aim of becoming the first country in the world with a hydrogen-based society so that it can lead the world in using hydrogen. The strategy sets targets for 2030 with regards to hydrogen technologies in transportation and buildings. The strategy consists of increasing the use of hydrogen, developing international hydrogen supply chains (with Australia, for example), expanding renewable energy production in Japan, promoting hydrogen in selected sectors (transportation, buildings, electricity generation, and industry), using innovative technologies and promoting public understanding and regional cooperation.
France (June 2018)	In June 2018, France released a hydrogen long-term hydrogen use plan to scale up action on hydrogen and put into place an innovation and hydrogen use strategy with the goal of supporting the country's energy transition and help develop its existing industrial capacities in hydrogen. The plan sets out targets for 2028 with regards to hydrogen production (for example, 20-40 per cent of hydrogen used by industry to be green) and hydrogen use (for example, in transportation). The plan focuses actions in three key areas: • Hydrogen production via electrolysis for use in industry • Creating value for hydrogen in transportation, complementing the role of battery-electric vehicles • Helping to stabilize energy networks in the medium term, such as by injecting hydrogen into natural gas systems and using hydrogen to store electric energy.

South Korea (November 2018)	In November 2018, South Korea released Hydrogen Roadmap Korea to present a vision, roadmap and recommendations for the country's future hydrogen economy. Hydrogen Roadmap Korea has a vision where, by 2050, hydrogen would fuel 7 million fuel cell passenger cars and 1 million fuel cell trucks, and meet objectives with regards to providing energy for electricity, energy for industry and heat for residential and commercial buildings. Hydrogen Roadmap Korea includes the following recommendations to put the country on the path to a sustainable hydrogen economy: • Set concrete milestones for key applications • Support milestones through public-private partnerships • Develop the transport system into the leading global hydrogen and fuel cell mobility market • Strengthen the hydrogen and fuel cell industry • Build a long-term pathway for the decarbonization of the natural gas network • Build a sustainable and competitive hydrogen supply industry
British Columbia (Fall 2019)	BC Bioenergy Network (BCBN) has been working with the provincial government to develop a BC Hydrogen Roadmap. This follows a 2019 report, sponsored by British Columbia, BCBN and Fortis BC, that outlines a comprehensive list of instrument and policy recommendations to support the development of a hydrogen economy in BC. BC is in the process of finalizing its hydrogen strategy.
Quebec (October 2019)	In October 2019, Quebec established a four-year pilot project to study the performance of hydrogen fuel cell electric vehicles (FCEVs) in northern climates and to increase knowledge on this subject. This pilot project resulted in around fifty FCEVs being put on Québec roads and the construction of Quebec's first hydrogen fuelling station in Québec City. In August 2020, Quebec released a report on the potential of the hydrogen industry in the province. Quebec is in the process of finalizing its hydrogen roadmap (TBC).
Australia (November 2019)	In November 2019, Australia released a National Hydrogen Strategy that sets out a vision for the hydrogen industry enabling it to be a major global player by 2030. Efforts will focus on the use of hydrogen in industrial, regional or remote areas to help scale up hydrogen production and use. The hydrogen hubs will be supported by efforts to use hydrogen in transport, industry and gas distribution networks. The strategy also includes a set of nationally coordinated actions involving governments, industry and communities. The strategy highlights the hydrogen strategies and plans of all the Australian states and two of the three inner territories.

New South Wales, Australia (March 2020)	The New South Wales Net-Zero Plan Stage 1: 2020-2030 supports the Australian National Hydrogen Strategy by requiring 10 per cent of the state's gas to come from green hydrogen by 2030. In addition, the state commits to establishing a hydrogen program which would help the scale-up of hydrogen as an energy source and industrial input. The program would offer grants for demonstration, research and development and commercialization projects. It would provide $1.1 billion (CAD$1 billion) in funding over 10 years and would require co-investment from the private sector.
Netherlands (April 2020)	In April 2020, the Netherlands released a Government Strategy on Hydrogen. The strategy supports a vision of creating a low-carbon hydrogen supply chain with four pillars to guide action: • Legislation and regulation: government to guide the development of hydrogen infrastructure • Reducing green hydrogen costs and scaling up production • Sustainability markets for hydrogen: ensuring hydrogen can be competitive in some sectors of the economy • Work and coordinate with other policies and strategies, for example international strategy, regional policy, research and innovation • The Netherlands's National Climate Agreement from 2019 initiated the country's hydrogen program and has goals for 2030 such as 3-4 GW of installed electrolyzer capacity for green hydrogen production and meeting various vehicle and infrastructure targets in the transportation sector
Germany (June 2020)	In June 2020, Germany released The National Hydrogen Strategy to provide a framework for the generation, transport and use of hydrogen, aiming to encourage innovation and investment in hydrogen technologies. The strategy also identifies actions needed to meet its climate goals, stimulate the creation of new supply chains and encourage international energy policy cooperation. The German strategy includes the following goals: • Making hydrogen a competitive option • Developing a domestic market for hydrogen technology • Enhancing hydrogen transport and distribution infrastructure • Strengthening German industry and securing global market opportunities for German firms To help develop a domestic for hydrogen production, Germany aims to establish up to 5 GW of green hydrogen capacity by 2030. Germany is also supporting efforts to meet the goal of having 1.8 million FCEVs and one thousand hydrogen fuelling stations.

European Union (July 2020)	In July 2020, the European Union released A Hydrogen Strategy for a climate-neutral Europe, which aims to coordinate existing and new actions in EU countries on low-carbon hydrogen and create an environment that would enable the scaling up of low-carbon hydrogen to achieve climate goals. The strategy targets the supply chain for low-carbon hydrogen, from production to distribution and use, so that it can be a cost-competitive technology to decarbonize the economy. The strategy provides a roadmap to 2050 for a European hydrogen ecosystem: • 2020-2024: Scale up hydrogen production with green hydrogen as a priority, aiming to have 6 GW of capacity able to produce 140 PJ/y of green hydrogen by 2024; focus on hydrogen potential in some industrial processes and heavy-duty transport. • 2025-2030: Scale up hydrogen production even further, aiming to have 40 GW of capacity able to produce 1,400 PJ/y of green hydrogen; integrate hydrogen further into the energy system to help decarbonize various sectors. • 2031-2050: Achieve hydrogen technology maturity, with hydrogen use at a large enough scale to decarbonize high emission sectors that have few alternative options (for example iron and steel sector).
Spain (October 2020)	In October 2020, Spain released a Renewable Hydrogen Roadmap that identifies the challenges and opportunities in exploiting the full potential of green hydrogen in the country. It sees green hydrogen as a key component in achieving the country's goal of achieving net-zero greenhouse gas emissions by 2050 while developing a new industry. The roadmap aims to develop the country's hydrogen industry by creating technology hubs and pilot projects on a regional scale, promoting innovation in industry and decreasing the cost of producing renewable energy in order to make green hydrogen more competitive. By 2030, the country hopes to have 4 GW of electrolyzer capacity installed for green hydrogen production, achieve 25 per cent green hydrogen use in industry and meet various vehicle and infrastructure targets in the transportation sector. Spain estimates that €8.9 billion (CAD$14 billion) in investments will be needed over the next decade to achieve its hydrogen roadmap targets and expects that most of the investment will come from the private sector.

Alberta (October 2020)	In October 2020, Alberta released its Natural Gas Vision and Strategy which includes expanding the use of natural gas for new products, such as low-carbon hydrogen. The province plans to take steps to ensure that these new products can compete internationally and draw in major investments to the province. The strategy includes Alberta's commitment to develop a hydrogen roadmap by 2023, including short-, medium- and long-term actions to, by 2040, establish domestic and international export markets for blue hydrogen and hydrogen-derived products.